The Drive & Control Company

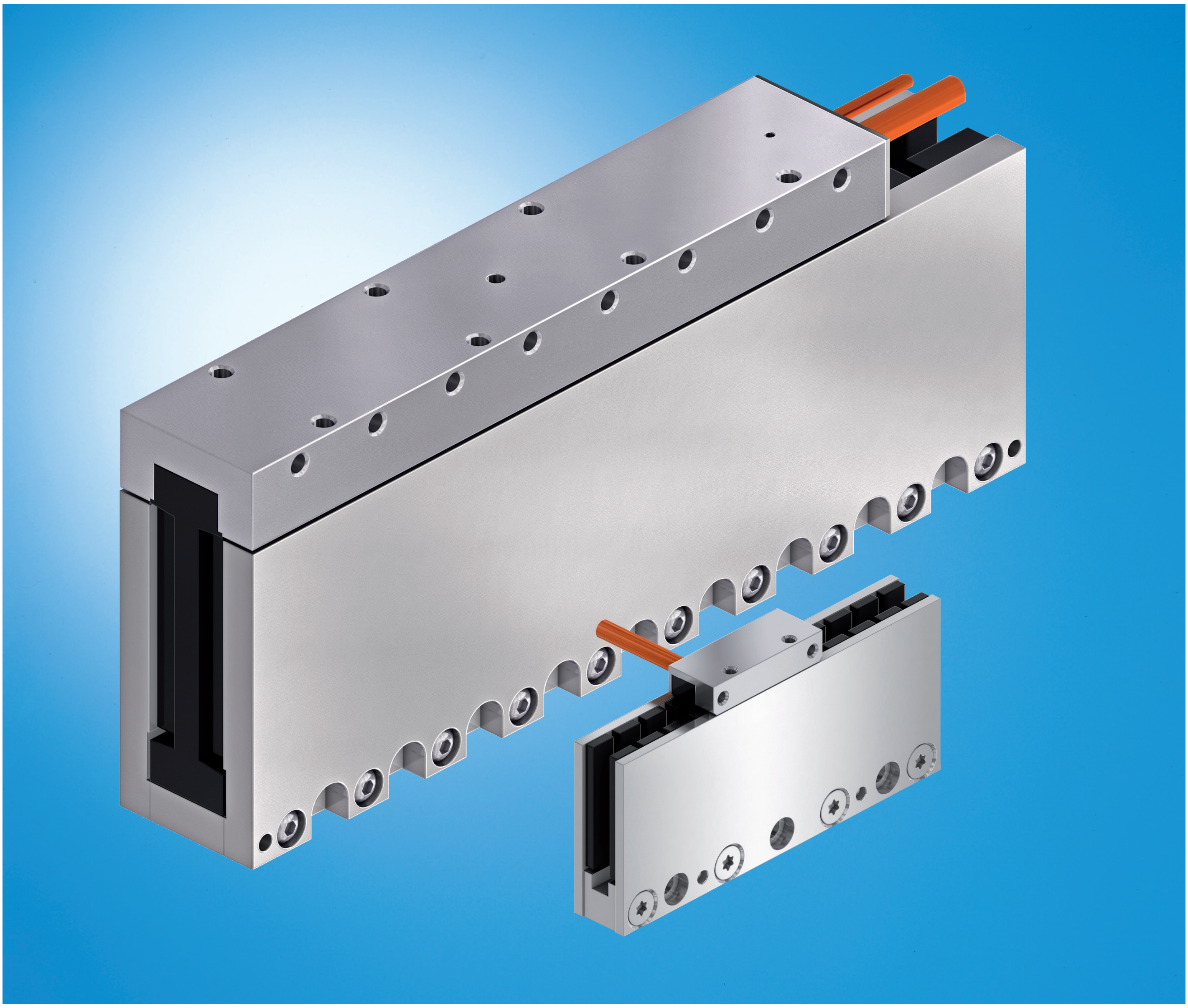
Rexroth
Bosch Group

Rexroth IndraDyn L

Ironless Linear Motors MCL

Project Planning Manual
R911330592

Edition 05



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

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1 Rexroth MCL - Product presentation

1.1 Fields of application ironless linear motors

Continuously increasing demands on 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, if only with high effort.

Ironless linear direct drive technique is an extension of the IndraDyn L product family with innovative product characteristics. 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
- Solid state technology (e.g. wafer-inspection and bonding)
- Medicine technology (e.g. transport of pipettes)
- Solar technology (e.g. for 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 srew, 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 families of Bosch Rexroth Electric Drives and Controls, please refer to the following link in our online product catalog: http://www.boschrexroth.com/indradyn.

1.2 Construction ironless linear motors

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 required.

The motor 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

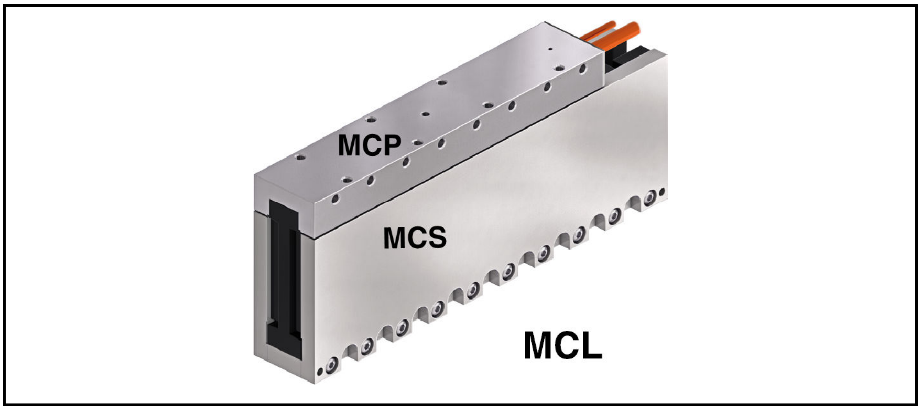

Fig. 1-1: Rexroth MCL example

1.3 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.

1.4 Power spectrum of MCL motors

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

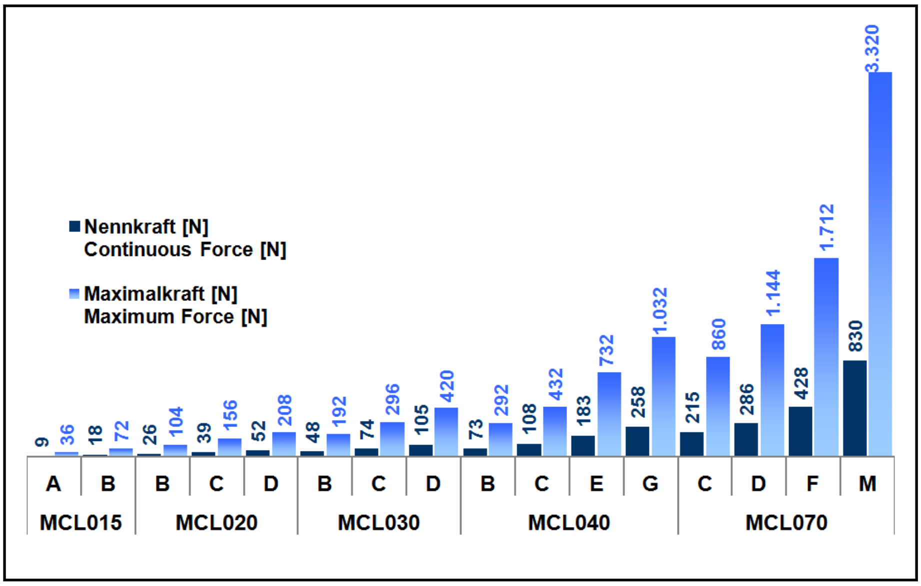

Fig. 1-2: Perfomance spectrum Rexroth MCL

1.5 About this documentation

1.5.1 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.

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<tr><th>Chapter</th><th>Title</th><th colspan="4">Content</th></tr>
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<tr><td>2</td><td>Important instructions on 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>
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Tab. 1-1: Chapter structure

1.5.2 Additional 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

1.5.3 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:

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1.5.4 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.

1.5.5 Your feedback

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

Please send your remarks to:

Bosch Rexroth AG

Dept. DC-IA/EDM3 (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 they are delivered, they are inspected to ensure that they operate safely.

The products may only be used as intended. If they are not used as intended, situations may arise which result in personal injuries and property damage.

☞ For damage caused by products not being used as intended, Bosch Rexroth gives no warranty, assumes no liability, and will not pay for any damages. Any risks resulting from the products not being used as intended are the sole responsibility of the user.

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

- Everyone who in any way whatsoever handles one of our products must read and understand the corresponding notes regarding safety and regarding the intended use.
- If the products are hardware, they must be kept in their original state, i.e., no constructional modifications may be made. Software products may not be decompiled, and their source codes may not be modified.
- Damaged or improperly working products may not be installed or put into operation.
- It must be ensured that the products are installed according to the regulations specified in the documentation.

2.1.2 Areas of use and application

Coreless linear motors MCL of the IndraDyn L series by Bosch Rexroth are determined to be used as linear servo drive motors.

There are drive controllers with different ratings, different DC bus voltages and different interfaces to allow application-specific use of the motors. To control and monitor the motors, additional sensors must be connected, e.g., length measuring systems.

☞
- The motors may only be used with the accessories specified in this documentation. Components that are not explicitly mentioned may neither be attached nor connected. The same is true for cables and lines.
- The motors may only be operated in the explicitly mentioned configurations and combinations of components and with the software and firmware specified in the corresponding functional description.

Any connected drive controller must be programmed before startup in order to ensure that the motor executes the functions specifically to the particular 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 the 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 to be "inappropriate use".

MCL motors may not be used if . . .

- they are exposed to operating conditions which do not comply with the ambient conditions described above; for example, operation under water, under extreme variations in temperature or extreme maximum temperatures is not permitted;
- the intended fields of application have not been expressly released for the motors by Bosch Rexroth.

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

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,

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

2) to be trained or instructed to maintain and use adequate safety equipment

3) to attend a course of instruction in first aid

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 Technolo-

gy". 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 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 mm^2 (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 mm^2 (16 AWG)	10 mm^2 (8 AWG)	2 × 1.5 mm^2 (16 AWG)
2.5 mm^2 (14 AWG)		2 × 2.5 mm^2 (14 AWG)
4 mm^2 (12 AWG)		2 × 4 mm^2 (12 AWG)
6 mm^2 (10 AWG)		2 × 6 mm^2 (10 AWG)
10 mm^2 (8 AWG)		-
16 mm^2 (6 AWG)	16 mm^2 (6 AWG)	-
25 mm^2 (4 AWG)		-
35 mm^2 (2 AWG)		-
50 mm^2 (1/0 AWG)	25 mm^2 (4 AWG)	-
70 mm^2 (2/0 AWG)	35 mm^2 (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, notebooks, display units) to these connections.

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

If extra-low voltage circuits of devices containing voltages and circuits of more than 50 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 equip-

ment 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 Magnetic and Electromagnetic Fields During Operation and Mounting

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

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

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

3.3.5 Protection against contact with hot parts

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 given on the following pages in terms of tables and characteristic curves. The following dependents are observed:

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

☞ All given data and characteristic curves are relating on the following conditions, if no others are specified:

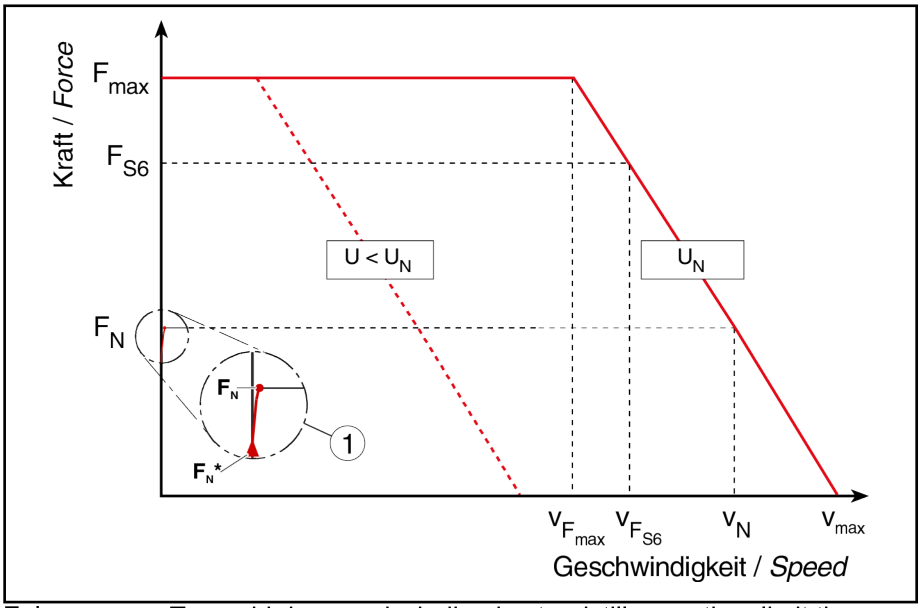
- Installation mode B acc. to fig. 11-29 " Motor force dependend from the thermal connection" on page 150
- Keeping installation tolerances acc. to chapter 5.1 "Installation tolerances" on page 47
- Keeping ambient temperatures acc. to chapter 9.3 "Setup elevation and ambient conditions" on page 100
- Motor winding temperature ≤110 °C

Specified values in the data sheet are effective values according to DIN EN 60034-1. Reference value is the maximum intermediate circuit voltage of 420 V_{DC} at MCP020 ... 070 or 48 V_{DC} at MCP015.

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.

Technical data



F_N*	To avoid damaged winding in standstill operation, limit the current or the operation duration.
①	When using the motor in this operating range, observe the notes under chapter 11.8 "Operation at or near motor standstill" on page 152

Fig. 4-1: Example motor characteristic curve

For deviating connection or intermediate circuit voltage, the specified characteristic curves - linear - can be converted according to the existing voltages.

The maximal force F_{max} is available up to speed v_{Fmax}. With increasing speed, the available intermediate circuit voltage by the speed-dependent reverse voltage. This leads to a reduced maximum feed force with increased speed.

The force F_{S6} is the maximum possible force at operating mode S6 acc. to DIN EN 60034-1. It is available up to speed $v_{F_{S6}}$. The characteristic curve is application-dependent and can be calculated via the duty factor (ED). Refer to "Relative duty factor" on page 28.

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.

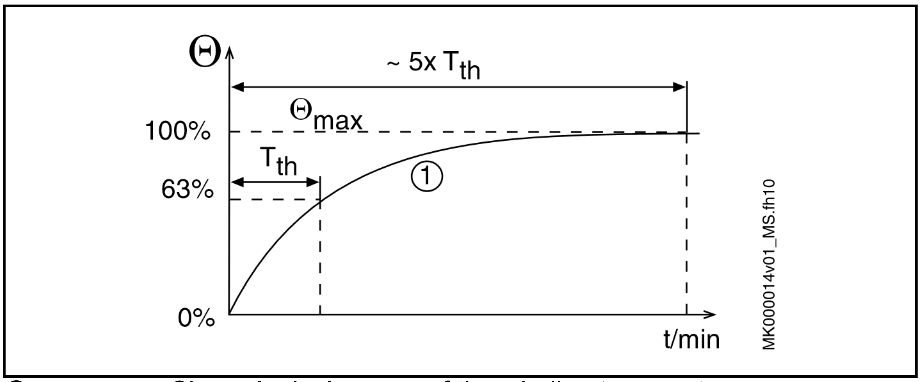
The reachable motor data are significantly dependent from the thermal coupling of the motor onto the machine (power loss dissipation) and from the used drive controller. The reference quantity for details of technical data and the presentation of the motor characteristic curves is an uncontrolled DC 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 11.7 "Thermal connection of MCL motors on the machine." on page 149.

Notes about standstill operation under chapter 11.8 "Operation at or near motor standstill" on page 152.

4.1.3 Description of specified sizes

Maximum force F_{max}	Maximum feed force of the motor at maximum current I_{max}. Unit [N].
Continuous nominal force F_N	Available continuous nominal force of the motor up to v_N at nominal current I_N. Unit [N].
Maximum current I_{max}	Maximum current of the motor at F_{max}. Unit [A].
Rated current I_N	Rated current of the motor at continuous nominal force F_N. Unit [A].
Reference voltage intermediate circuit U_{DC}	Reference voltage of intermediate circuit for determination of the winding velocity. Unit [V].
Maximum allowed intermediate circuit U_{DC_max}	Maximum allowed intermediate circuit. Unit [V].
Maximum velocity v_{Fmax}	Maximum velocity at maximum force F_{max}. Velocity, up to maximum feed force of the motor is available. Unit [m/min].
Nominal velocity v_N	Velocity, up to continuous nominal force F_N of the motor is available. Unit [m/min].
Force constant K_{FN}	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. Unit [N/A].
Voltage constant K_{EMK} bei 20 °C	Induced motor voltage depending from the travel velocity relating on velocity 1 m/s. Unit[Vs/m].
Winding resistance R_{12} at 20 °C	Measured winding resistance among two strands. Unit [Ω].
Winding inductivity L_{12}	Measured winding inductivity among strand 1 and 2. This details are typical values, which are determined with a measuring current of 1 mA at a measuring frequency of 1 kHz. Unit [mH].
Winding inductivity $L_{23/31}$	Measured winding inductivity among two strands (strand 2/3 or 3/1). Due to boundary effects, the specified measuring values are different to L_{12}. This details are typical values, which are determined with a measuring current of 1 mA at a measuring frequency of 1 kHz. Unit [mH].
Rated power loss P_{VN}	Power loss in operation mode S1 (continuous operation) at nominal velocity v_N. Unit [W].
Pole width t_P	Distance dimension of pole center to pole center of the magnets on the secondary part. Unit [mm].
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. 4-2: Thermal time constant

Technical data

Primary part mass m_P Mass of primary part Unit [kg].

Secondary part mass m_S Mass of secondary part Unit [kg].

Relative duty factor Relative duty factor $ED_{F_{S6}}$ in %, relating on the specified maximum and continuous nominal force. The relative duty factor ED_{F_S6} is calculated via:

$$ED_{F_{S6}} \approx \left(\frac{F_N}{F_{S6}} \right)^2 \cdot 100\%$$

F_{dN}	Continuous nominal force of the motor in N
F_{S6}	Force F_{S6} in N

Fig. 4-3: Calculation of possible duty factor relating on F_{S6}

A force F_{S6} higher than the continuous nominal force of the motor is only then available, if the continuous voltage of the drive-controller is higher than the continuous nominal voltage of the motor.

Allowed ambient temperature T_{UM} during operation Allowed ambient temperature Unit [°C].

Degree of protection Degree of protection according to DIN EN 60034-5

Temperature class Temperature class according to DIN EN 60034-1.

RoHS conformity RoHS conformity according to EC guidelines 2002/95/EG.

☞ 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.

4.2 General technical data

For the sake of clarity, the following table contains data which is applicable to all motor frame 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 (bleeder threshold)			420	
Ambient temperature in operation (See chapter 9.3 "Setup elevation and ambient conditions" on page 100)	T_{amb}	°C	0 ... +40	
Allowed transport temperature (See chapter 12.4.1 "Notes about transport" on page 156)	T_T	°C	-20 ... +80	
Allowed storage temperature (See chapter 12.4.2 "Notes about storage" on page 157)	T_L	°C	-20 ... +60	
Temperature class according to DIN EN 60034-1	-	-	130 (B)	/
Warning temperature (winding) (See chapter 9.10 "Motor temperature monitoring" on page 107)	T_{warn}	°C	110	/
Shutdown temperature (winding) (See 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	
RoHS conformity according to EC guidelines 2002/95/EG	-	-	RoHS conform	
Latest amendment: 2012-03-23				

Tab. 4-1: General technical data

4.3 Technical data - frame size MCL015

4.3.1 Data sheet MCP015

Technical data specified in Tab. 4-2 are only valid in combination with secondary parts MCS015-3S-____-NNNN.

Parameter	Symbol	Unit	MCP015	
Frame lengths			A	B
Winding			L040	L040
Maximum force	F_{max}	N	36.0	72.0
Continuous nominal force	F_N	N	9.0	18.0
Maximum current	$I_{max(eff)}$	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	K_{EMK}	Vs/m	3.6	3.2
Winding resistance at 20 °C	R_{12}	Ohm	5.3	2.7
Winding inductivity	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	t_p	mm	8.25	
Thermal time constant	T_{th}	min	0.6	
Primary part mass	m_P	kg	0.050	0.075
Latest amendment: 2014-08-19				

Tab. 4-2: MCP015 - Technical data

4.3.2 Data sheet MCS015

Designation	Symbol	Unit	MCS015-__-0066	MCS015-__-0099
Secondary part mass	m_S	kg	0.2	0.3
Latest amendment: 2012-06-21				

Tab. 4-3: MCS015 - Technical data

4.3.3 Motor characteristic curve frame size 015

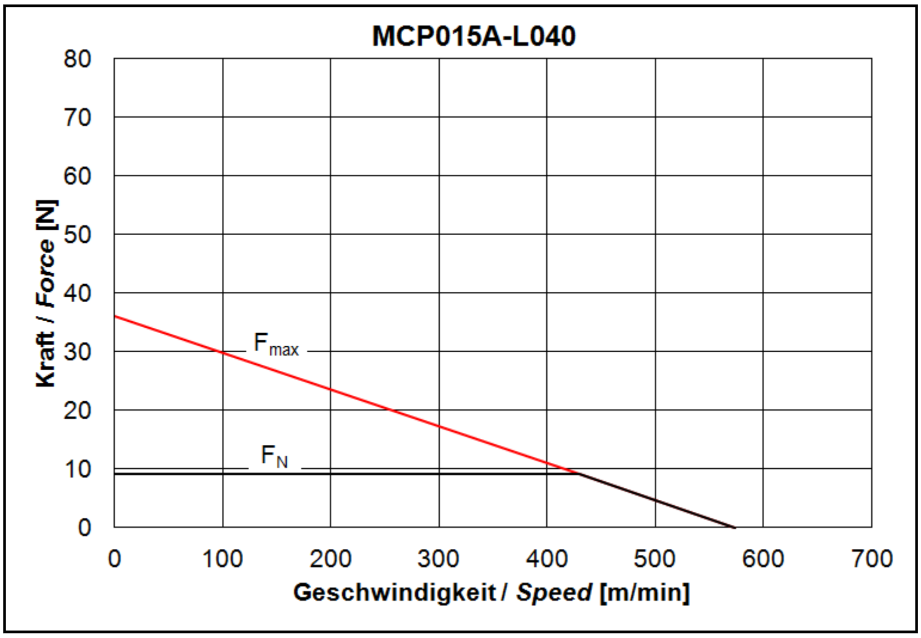


Fig. 4-4: Motor characteristic curve MCP015A-L040 at 48 V_{DC}

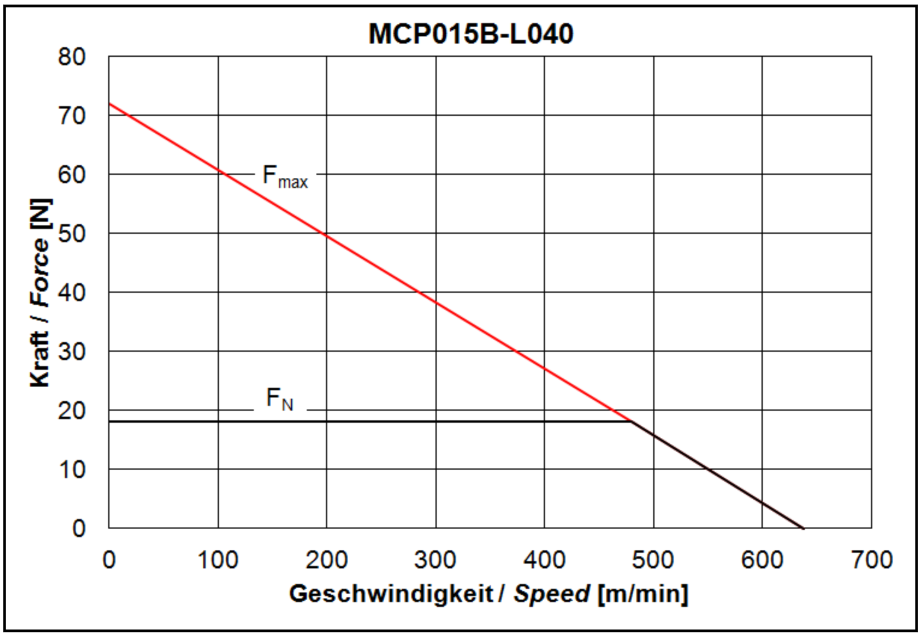


Fig. 4-5: Motor characteristic curve MCP015B-L040 at 48 V_{DC}

4.4 Technical data - frame size MCL020

4.4.1 Data sheet MCP020

☞ Technical data specified in Tab. 4-4 are only valid in combination with secondary parts MCS020-3S-____-NNNN.

Parameter	Symbol	Unit	MCP020					
Frame lengths			B		C		D	
Winding			V180	V720	V180	V720	V180	V720
Maximum force	F_{max}	N	104.0		156.0		208.0	
Continuous nominal force	F_N	N	26.0		39.0		52.0	
Maximum current	$I_{max(eff)}$	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	1,100	550	1,095	620	1,410
Force constant	K_{FN}	N/A	32.5	18.6	32.0	17.8	30.1	16.0
Voltage constant	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	t_p	mm	15.00					
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: 2014-02-25								

Tab. 4-4: MCP020 - Technical data

4.4.2 Data sheet MCS020

Designation	Symbol	Unit	MCS020-__-0120	MCS020-__-0180	MCS020-__-0300
Secondary part mass	m_S	kg	0.4	0.7	1.1
Latest amendment: 2012-03-29					

Tab. 4-5: MCS020 - Technical data

4.4.3 Motor characteristic curves frame size 020

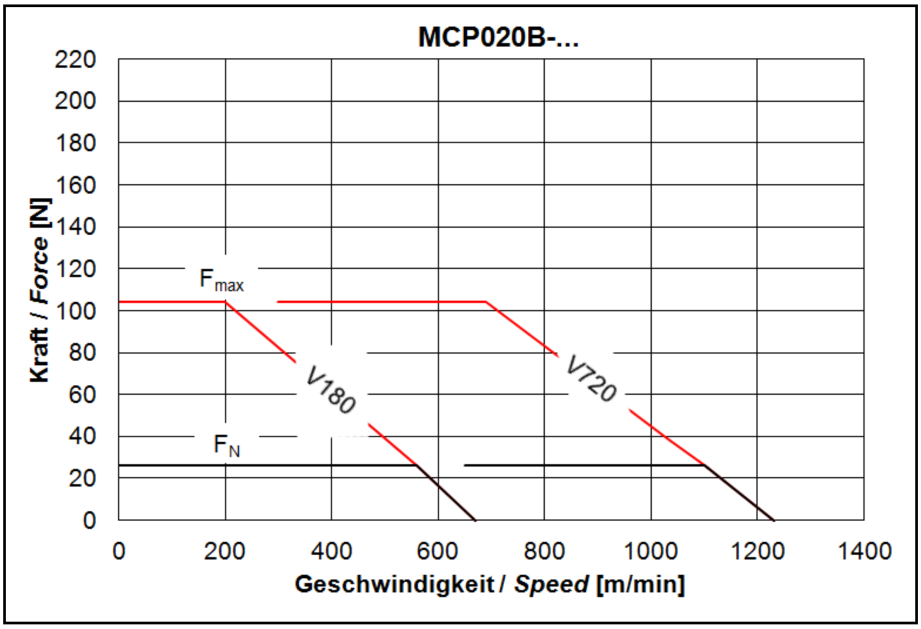


Fig. 4-6: Motor characteristic curves MCP020B at 300 V_{DC}

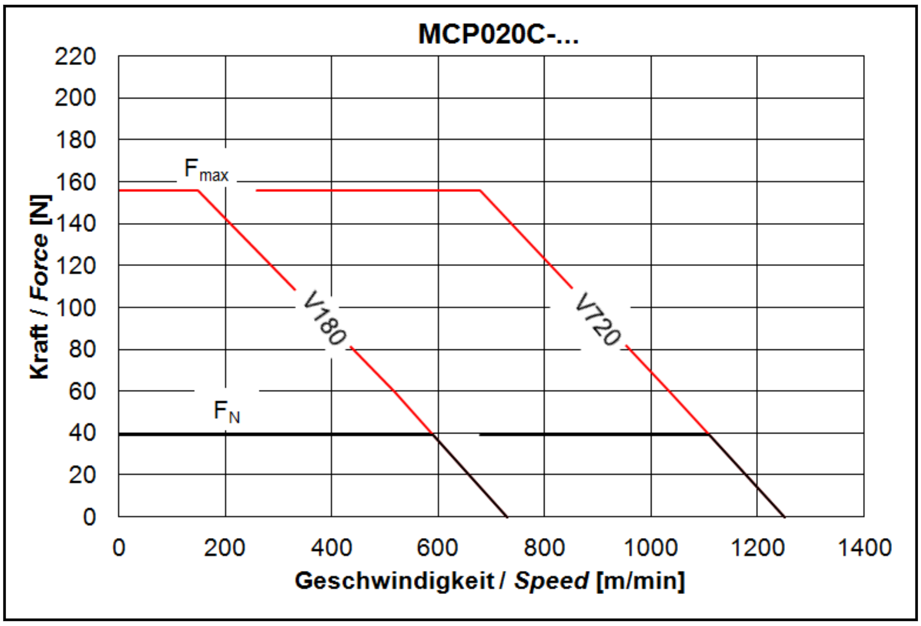


Fig. 4-7: Motor characteristic curves MCP020C at 300 V_{DC}

Technical data

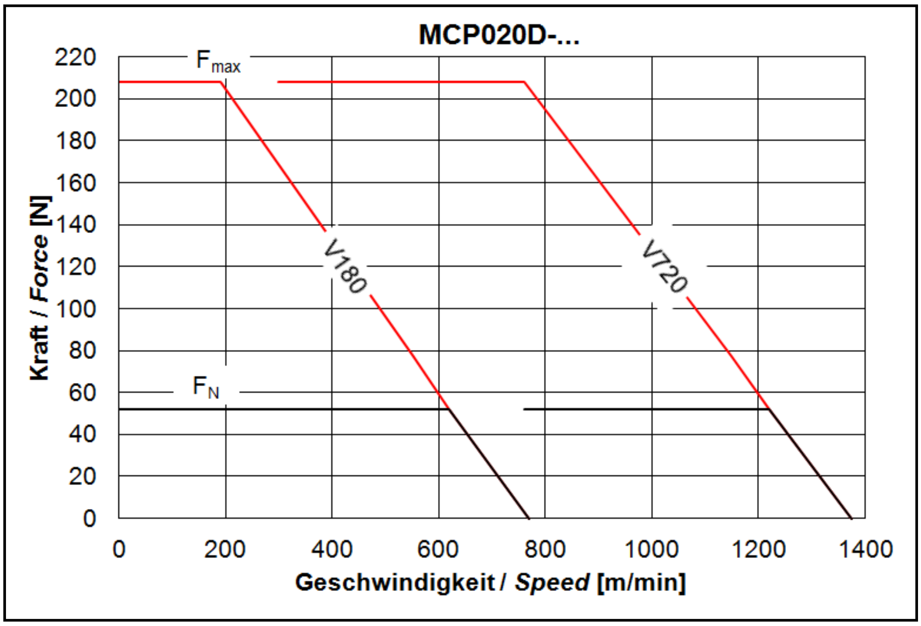


Fig. 4-8: Motor characteristic curves MCP020D at 300 V_{DC}

4.5 Technical Data - frame size MCL030

4.5.1 Data sheet MCP030

Technical data specified in Tab. 4-6 are only valid in combination with secondary parts MCS030-3S-____-NNNN.

Parameter	Symbol	Unit	MCP030					
Frame lengths			B		C		D	
Winding			V180	V390	V180	V390	V180	V390
Maximum force	F_{max}	N	192.0		296.0		420.0	
Continuous nominal force	F_N	N	48.0		74.0		105.0	
Maximum current	$I_{max(eff)}$	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	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	t_p	mm	30.00					
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: 2013-07-03								

Tab. 4-6: MCP030 - Technical data

4.5.2 Data sheet MCS030

Designation	Symbol	Unit	MCS030-__-0120	MCS030-__-0180	MCS030-__-0300
Secondary part mass	m_S	kg	0.7	1.0	1.6
Latest amendment: 2012-03-29					

Tab. 4-7: MCS030 - Technical data

4.5.3 Motor characteristic curve frame size 030

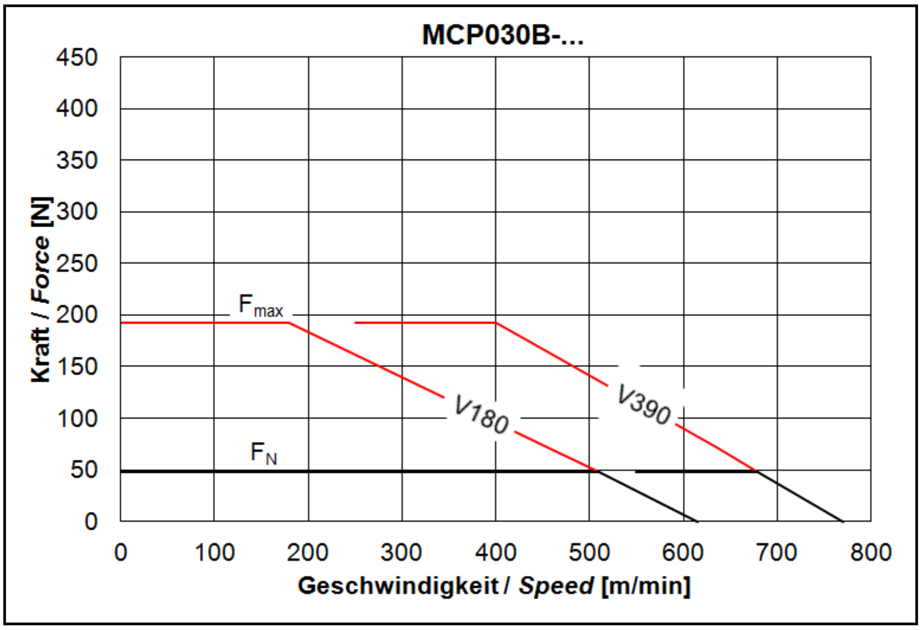


Fig. 4-9: Motor characteristic curve MCP030B at 300 V_{DC}

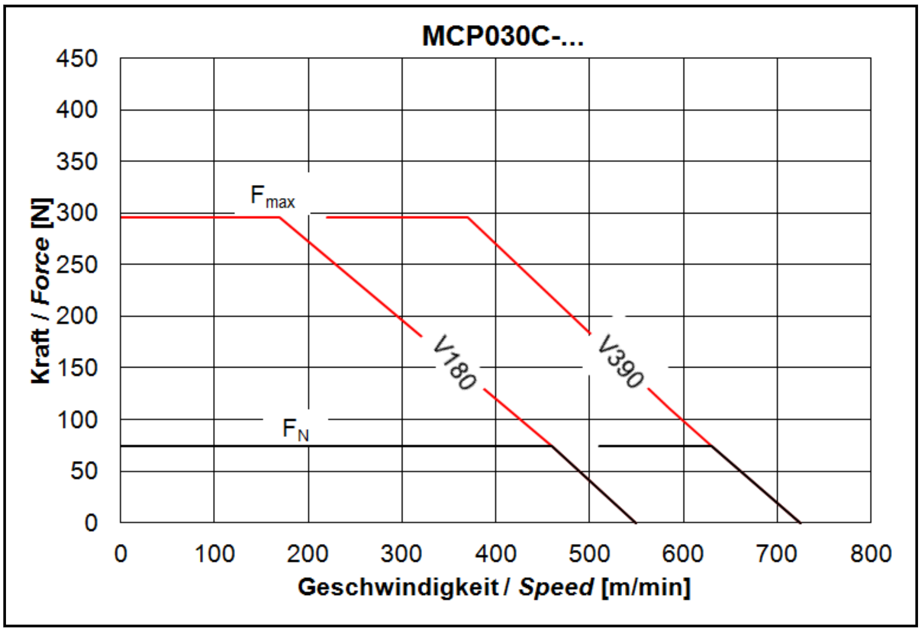


Fig. 4-10: Motor characteristic curve MCP030C at 300 V_{DC}

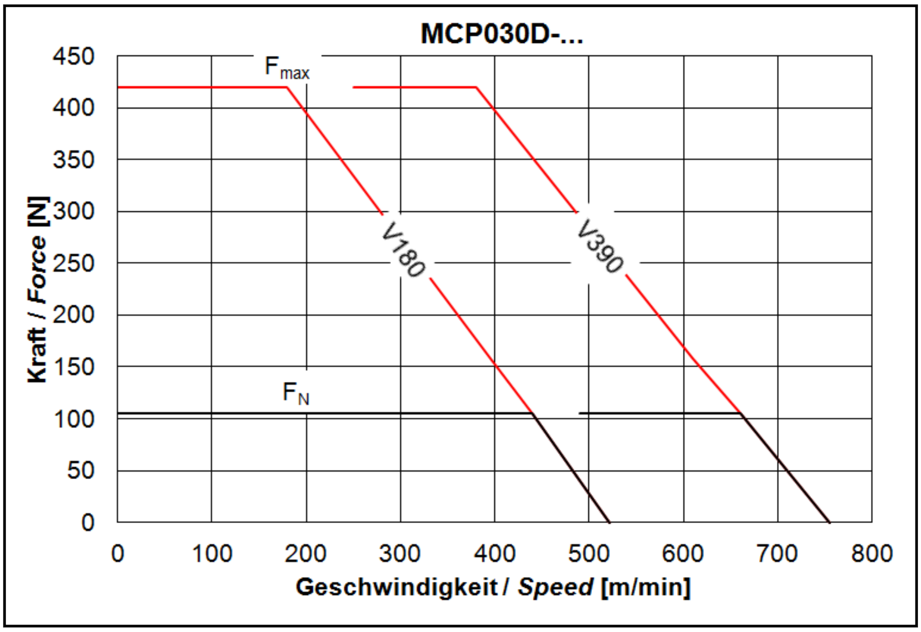


Fig. 4-11: Motor characteristic curve MCP030D at 300 V_{DC}

4.6 Technical data - frame size MCL040

4.6.1 Data sheet MCP040

☞ Technical data specified in Tab. 4-8 and Tab. 4-9are only valid in combination with secondary parts MCS040-3S-____-NNNN.

Parameter	Symbol	Unit	MCP040			
Frame lengths			B		C	
Winding			V070	V300	V070	V300
Maximum force	F_{max}	N	292.0		432.0	
Continuous nominal force	F_N	N	73.0		108.0	
Maximum current	$I_{max(eff)}$	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	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	t_p	mm	30.00			
Thermal time constant	T_{th}	min	2.3		2.4	
Primary part mass	m_P	kg	0.56		0.81	
Latest amendment: 2013-07-03						

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

Parameter	Symbol	Unit	MCP040			
Frame lengths			E		G	
Winding			V070	V300	V070	V300
Maximum force	F_{max}	N	732.0		1,032.0	
Continuous nominal force	F_N	N	183.0		258.0	
Maximum current	$I_{max(eff)}$	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			
Latest amendment: 2013-07-03						

Parameter	Symbol	Unit	MCP040			
Frame lengths			E		G	
Winding			V070	V300	V070	V300
Maximum velocity at F_{max}	v_{Fmax}	m/min	60	260	50	290
Nominal velocity	v_N	m/min	280	510	260	500
Force constant	K_{FN}	N/A	63.1	38.9	66.2	39.1
Voltage constant	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 inductivity	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	t_p	mm	30.00			
Thermal time constant	T_{th}	min	2.6		2.8	
Primary part mass	m_P	kg	1.26		1.71	
Latest amendment: 2013-07-03						

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

4.6.2 Data sheet MCS040

Designation	Symbol	Unit	MCS040-__-0120	MCS040-__-0180	MCS040-__-0300
Secondary part mass	m_S	kg	1.3	1.9	3.2
Latest amendment: 2012-03-29					

Tab. 4-10: MCS040 - Technical data

Technical data

4.6.3 Motor characteristic curves frame size 040

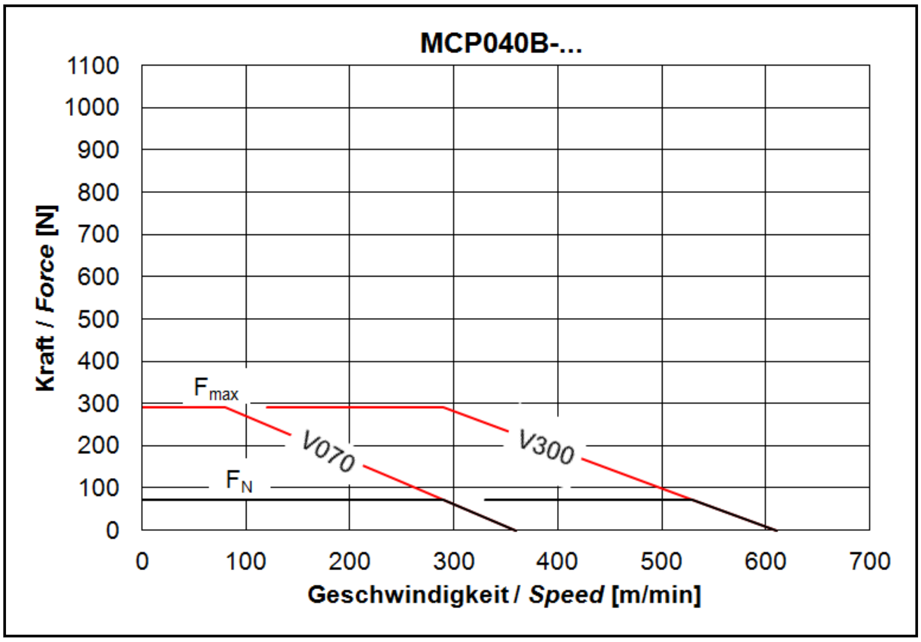


Fig. 4-12: Motor characteristic curve MCP040B at 300 V_{DC}

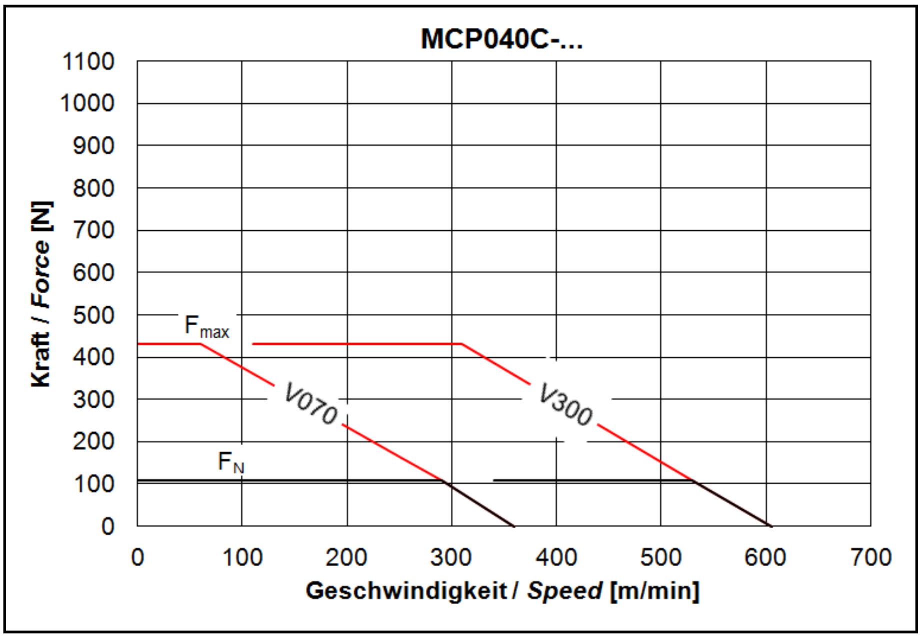


Fig. 4-13: Motor characteristic curve MCP040C at 300 V_{DC}

Technical data

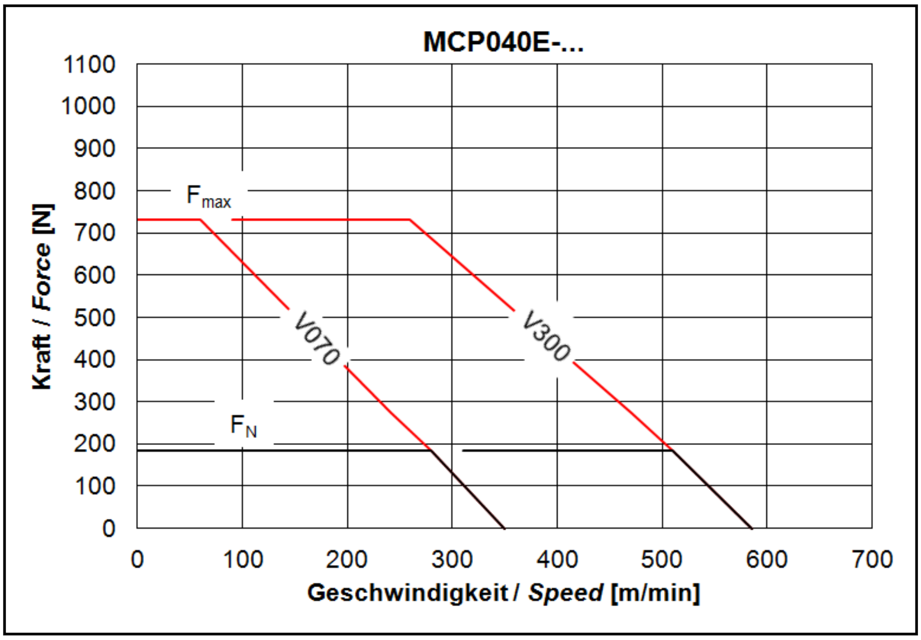


Fig. 4-14: Motor characteristic curve MCP040E at 300 V_{DC}

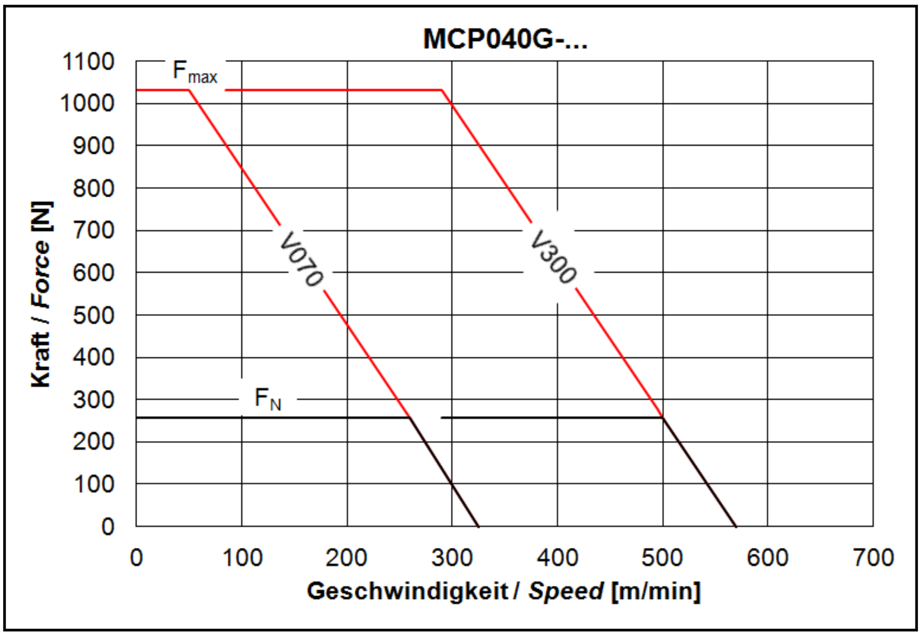


Fig. 4-15: Motor characteristic curve MCP040G at 300 V_{DC}

4.7 Technical data - frame size MCL070

4.7.1 Data sheet MCP070

Technical data specified in Tab. 4-11 and Tab. 4-12are only valid in combination with secondary parts MCS070-3S-____-NNNN.

Parameter	Symbol	Unit	MCP070			
Frame lengths			C		D	
Winding			V050	V300	V050	V300
Maximum force	F_{max}	N	860.0		1144.0	
Continuous nominal force	F_N	N	215.0		286.0	
Maximum current	$I_{max(eff)}$	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	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	t_p	mm	30.00			
Thermal time constant	T_{th}	min	3.0		4.0	
Primary part mass	m_P	kg	1.50		1.95	
Latest amendment: 2013-07-03						

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

Parameter	Symbol	Unit	MCP070			
Frame lengths			F		M	
Winding			V050	V300	V050	V230
Maximum force	F_{max}	N	1.712,0		3.320,0	
Continuous nominal force	F_N	N	428.0		830.0	
Maximum current	$I_{max(eff)}$	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			
Latest amendment: 2014-10-22						

Parameter	Symbol	Unit	MCP070			
Frame lengths			F		M	
Winding			V050	V300	V050	V230
Maximum velocity at F_{max}	v_{Fmax}	m/min	70	290	60	230
Nominal velocity	v_N	m/min	210	460	200	370
Force constant	K_{FN}	N/A	93.0	47.5	92.2	52.9
Voltage constant	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	t_p	mm	30.00			
Thermal time constant	T_{th}	min	5.0	3.1	3.3	
Primary part mass	m_P	kg	2.85		5.9	
Latest amendment: 2014-10-22						

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

4.7.2 Data sheet MCS070

Designation	Symbol	Unit	MCS070-__-0120	MCS070-__-0180	MCS070-__-0300
Secondary part mass	m_S	kg	3.0	4.5	7.4
Latest amendment: 2012-03-29					

Tab. 4-13: MCS070 - Technical data

4.7.3 Motor characteristic curve frame size 070

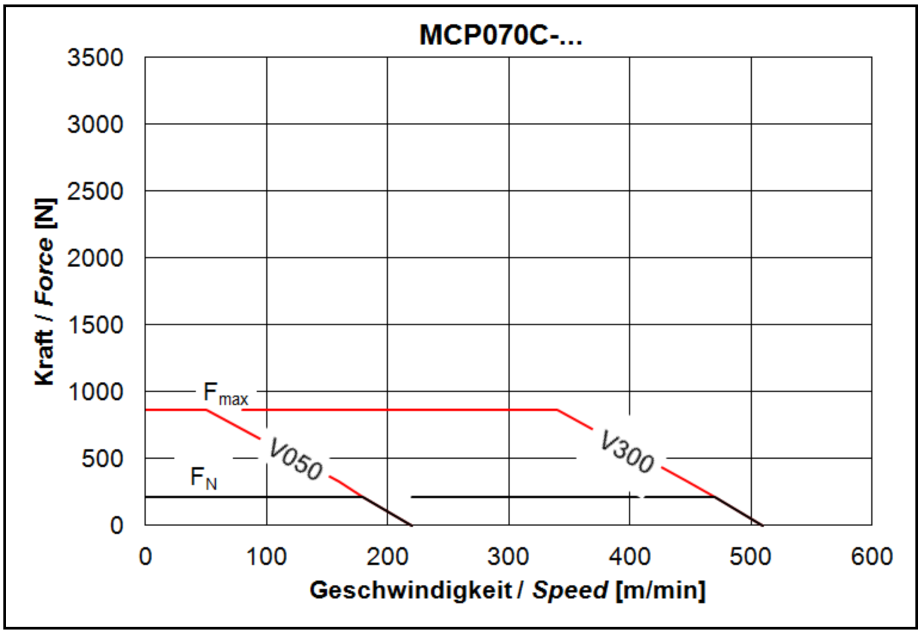


Fig. 4-16: Motor characteristic curve MCP070C at 300 V_{DC}

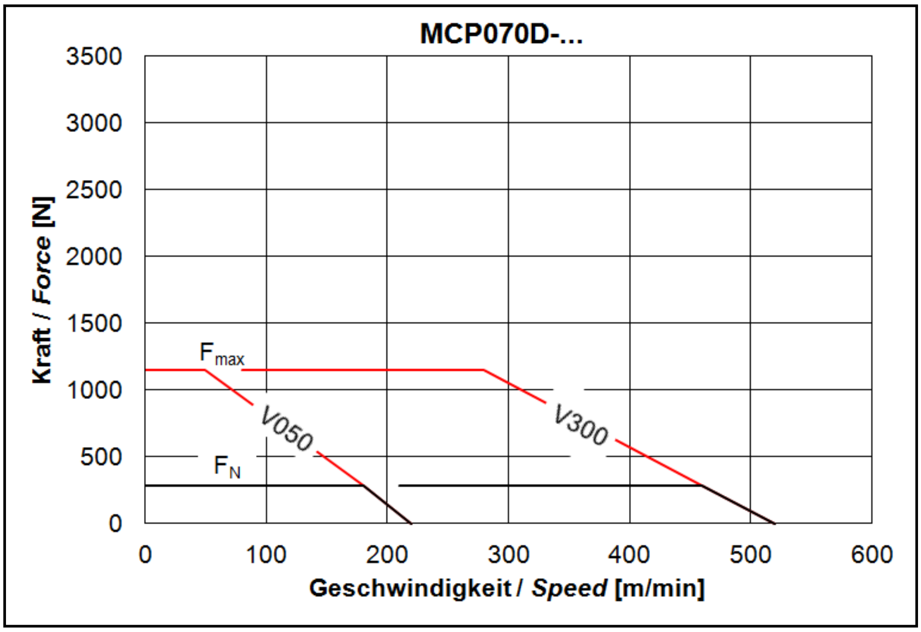


Fig. 4-17: Motor characteristic curve MCP070D at 300 V_{DC}

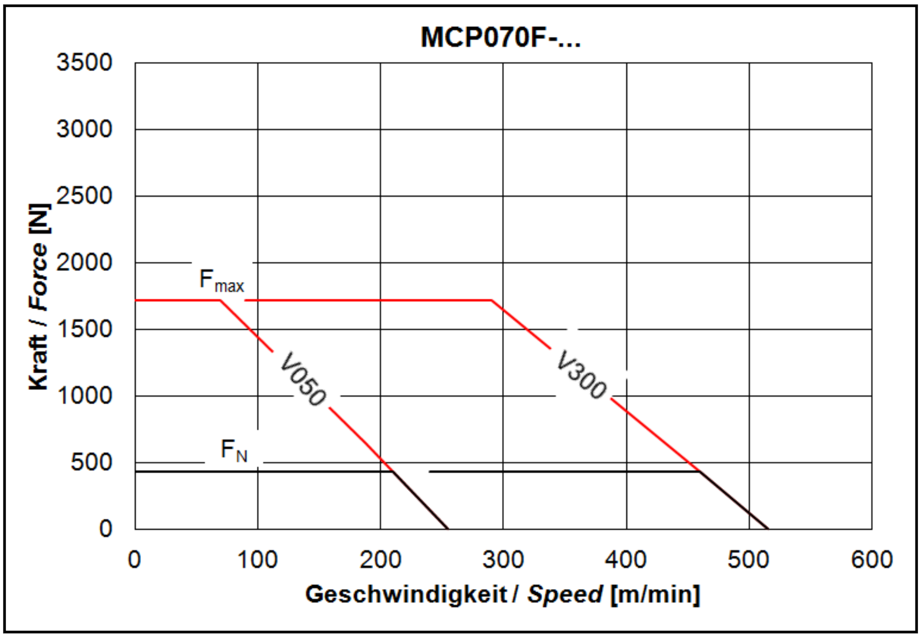


Fig. 4-18: Motor characteristic curve MCP070F at 300 V_{DC}

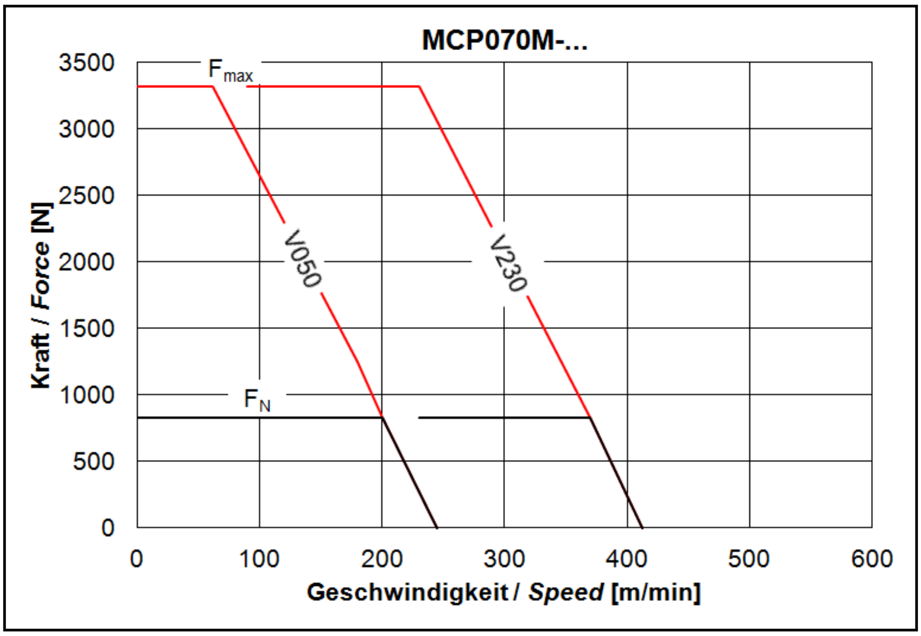


Fig. 4-19: Motor characteristic curve MCP070M at 300 V_{DC}

5 Dimension sheets

5.1 Installation tolerances

5.1.1 General information

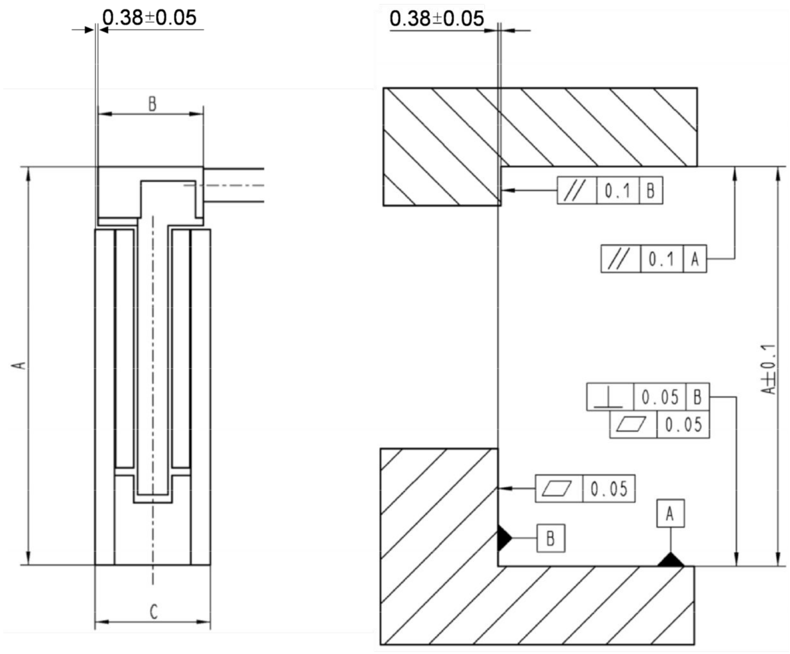
To ensure a safe operation and constant force over the total traversing range, an air gap between primary and secondary part must exist. Therefore, the single parts of the motor have the corresponding tolerances. The distance of the mounting surface, the parallelism and the symmetry of the primary and secondary part of the linear motor in the machine must be within a certain tolerance above the entire travel path. Any deformations that result from weight, attractive forces and process forces must be taken into account.

☞ The specified installation dimensions with the corresponding tolerances must be kept by the user over the complete travel path. Due to an undersized air gap, the primary part can have contact with the secondary part and can therewith damage or destroy motor components.

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

Dimension sheets

5.1.2 Frame size MCL015



Motor dimensions

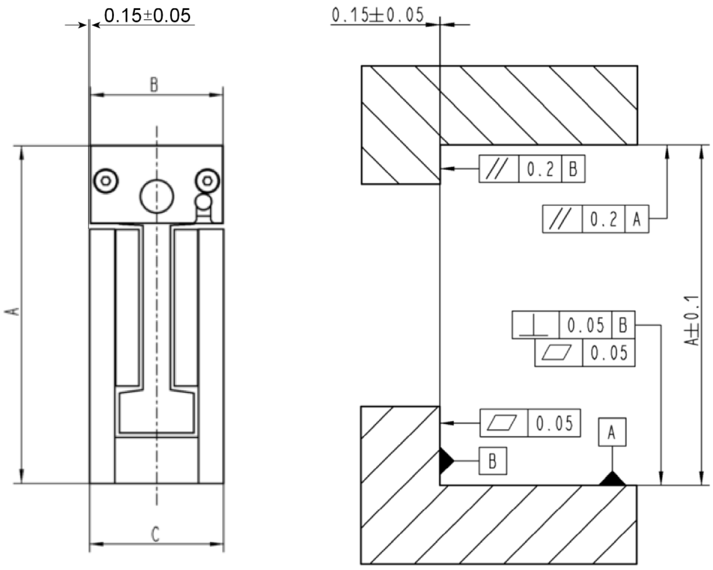
Motor installation space (by the customer)

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

*) Tolerance details see motor dimension sheet

Tab. 5-1: Mounting sizes and tolerances MCL0150

5.1.3 Frame size MCL020 ... 070



Motor dimensions

Motor installation room (by the customer)

Frame size	Motor height A	Motor width	
		MCP B*	MCS 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

*) Tolerance details see motor dimension sheet

Tab. 5-2: Mounting sizes and tolerances MCL020 ... 070

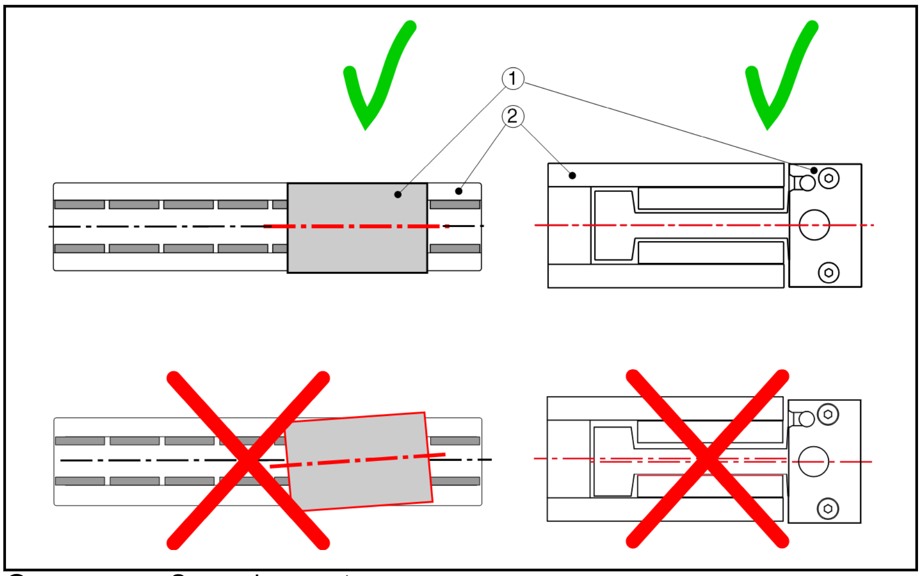
☞ The specified installation dimensions with the corresponding tolerances must be kept by the user over the complete travel path.

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 according to must be kept.

To keep the tolerances, it is necessary that the fastening holes and threads for the primary part and the secondary part in the machine are strictly done according to the dimensions of the particular dimension sheet. The alignment of the motor components must be done according to fig. 5-1 "Parallelism and symmetry between primary and secondary parts" on page 50.

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



① Secondary part
② Primary part

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

Dimension sheets

5.2 Dimension sheets MCL015

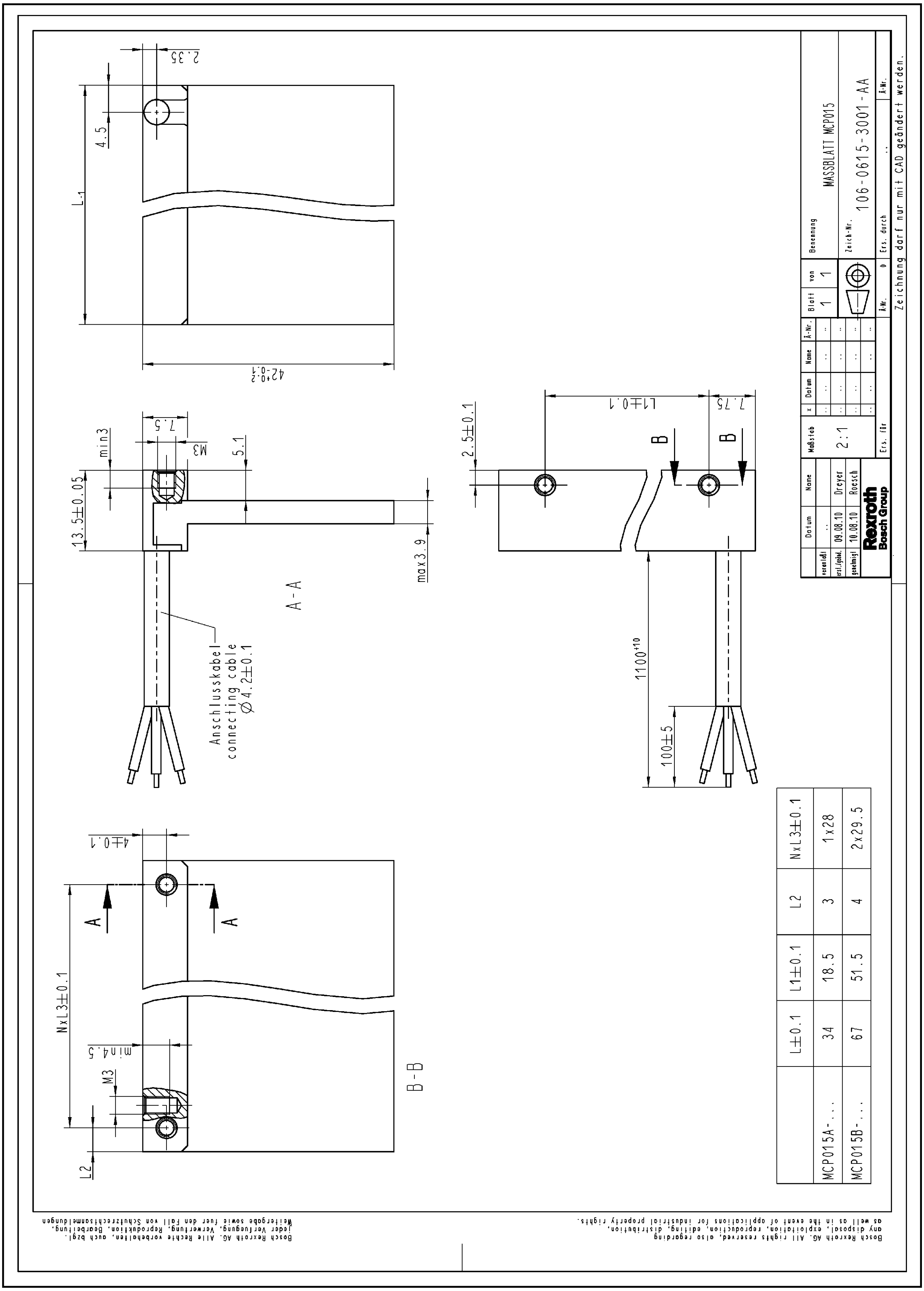


Fig. 5-2: Dimension sheet primary part MCP015

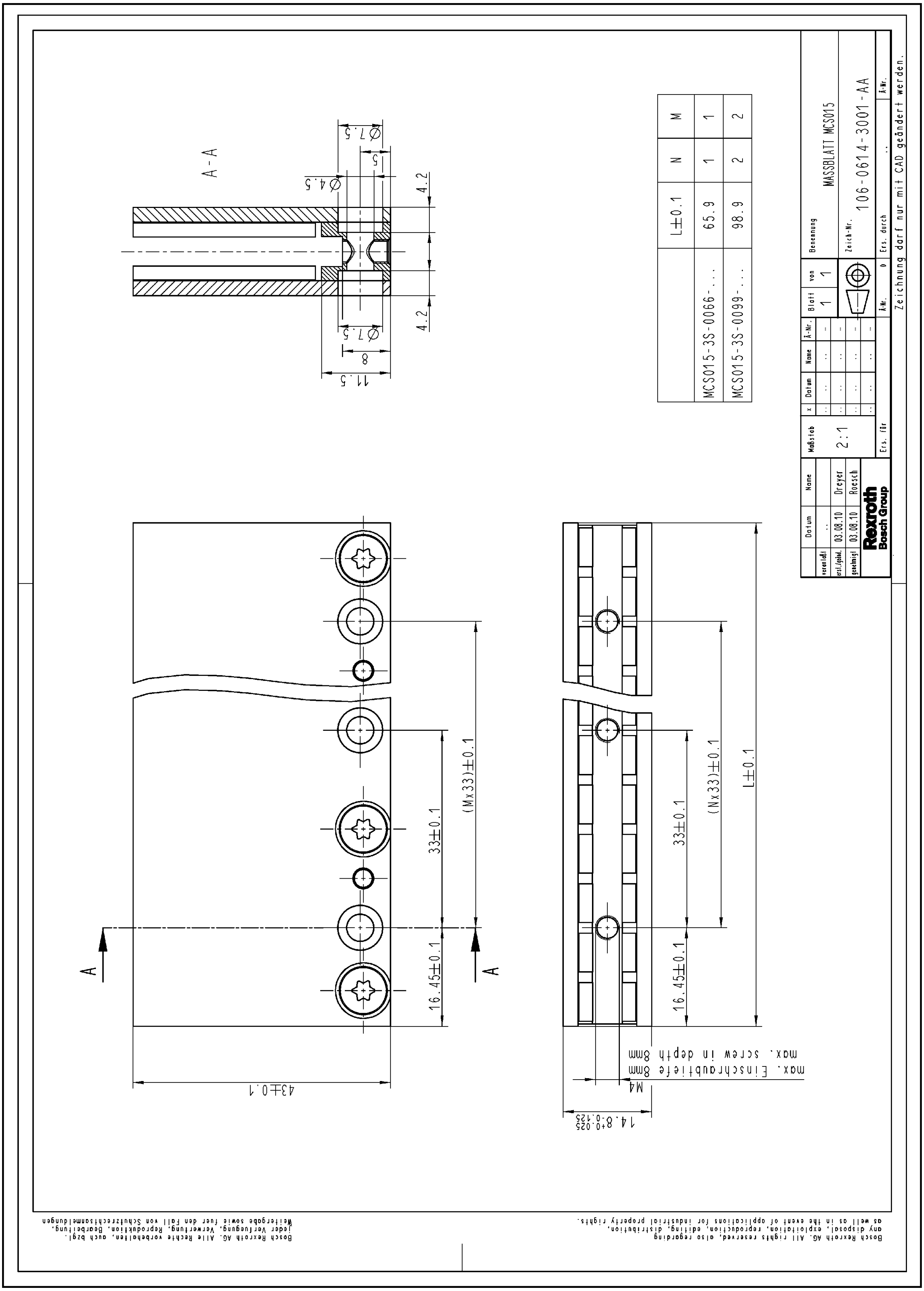
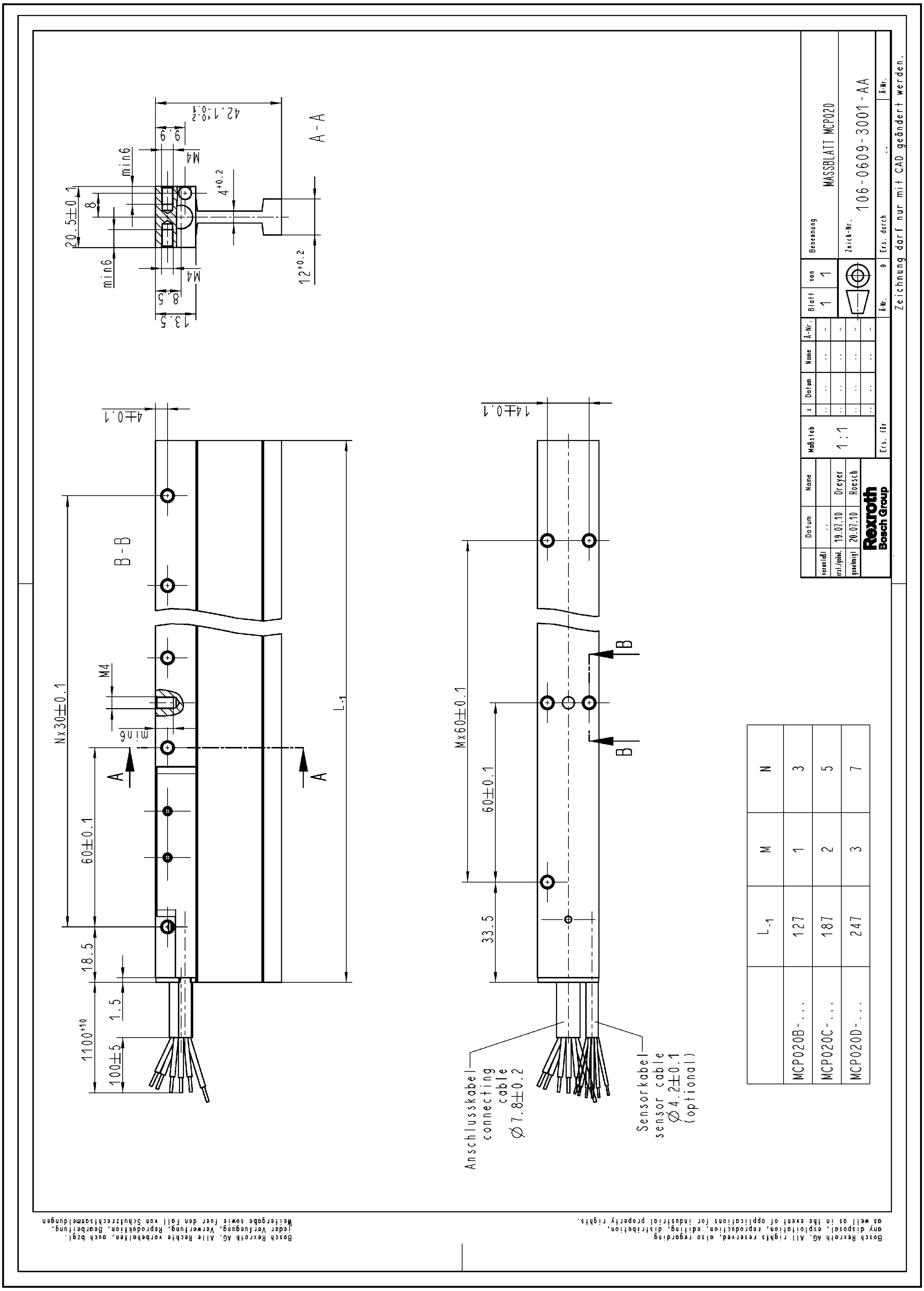


Fig. 5-3: Dimension sheet secondary part MCP015

Dimension sheets

5.3 Dimension sheets MCL020



	L_{-1}	M	N
MCP020B-...	127	1	3
MCP020C-...	187	2	5
MCP020D-...	247	3	7

Fig. 5-4: Dimension sheet primary part MCP020

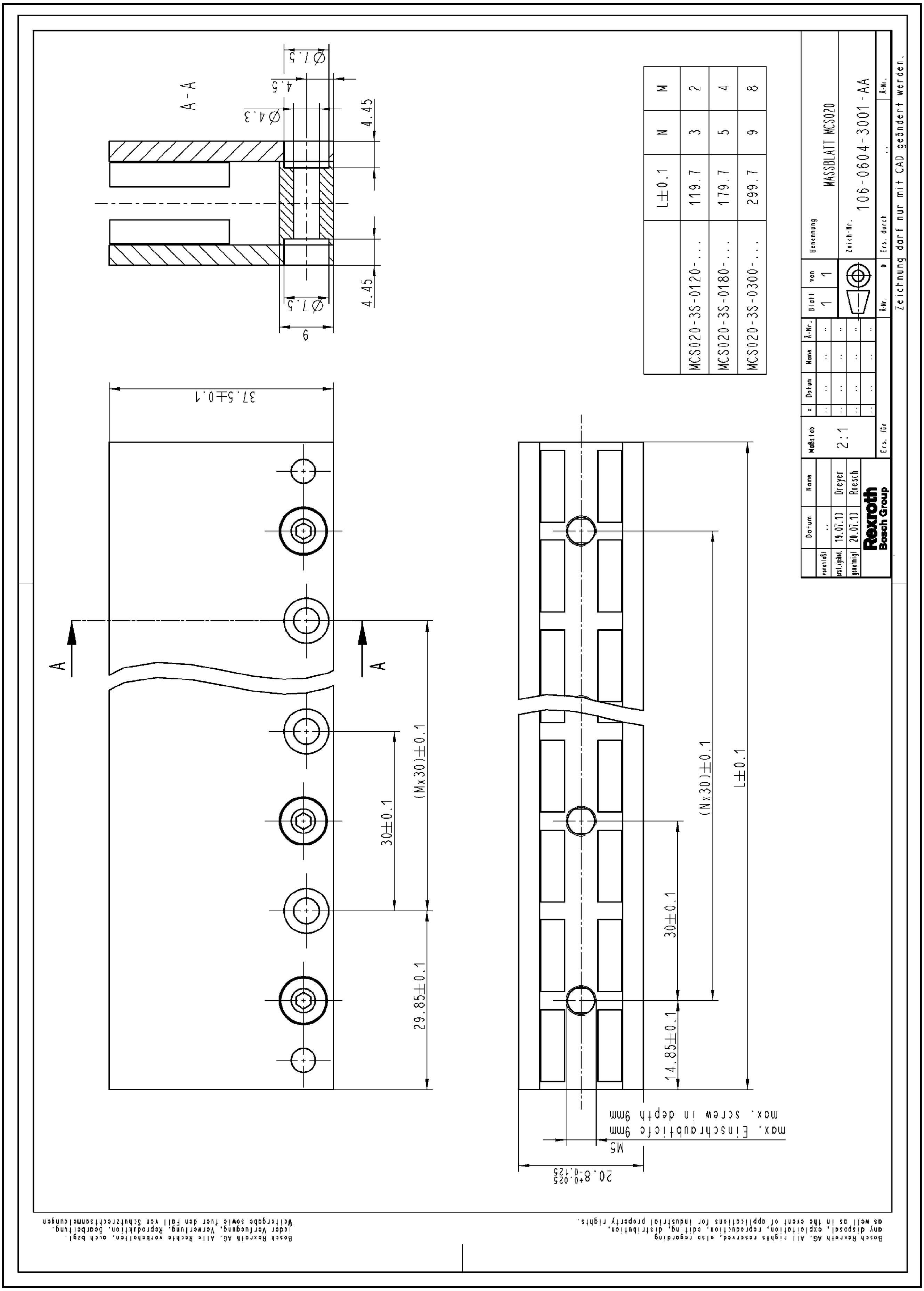


Fig. 5-5: Dimension sheet secondary part MCS020

5.4 Dimension sheets MCL030

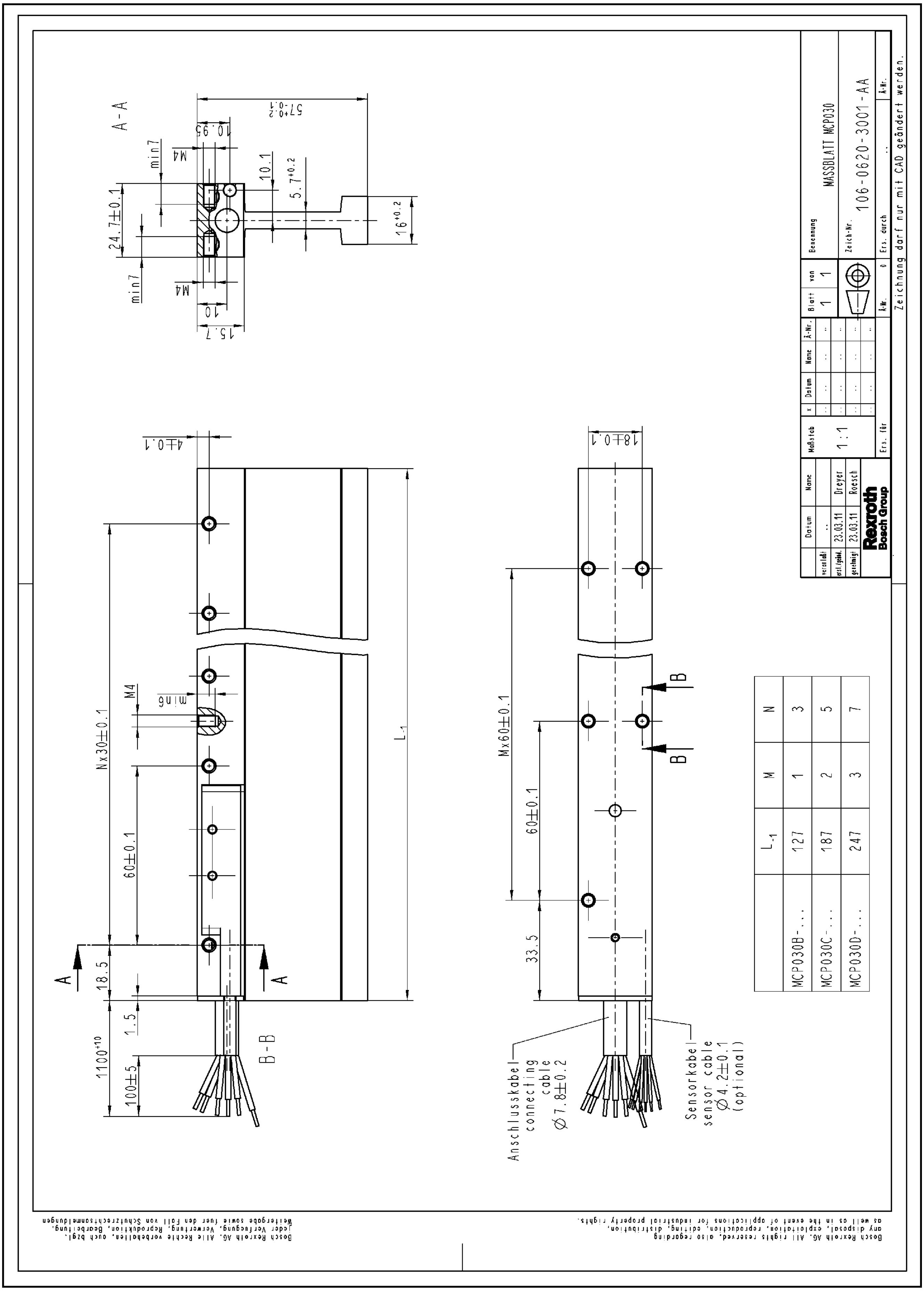


Fig. 5-6: Dimension sheet primary part MCP030

Dimension sheets

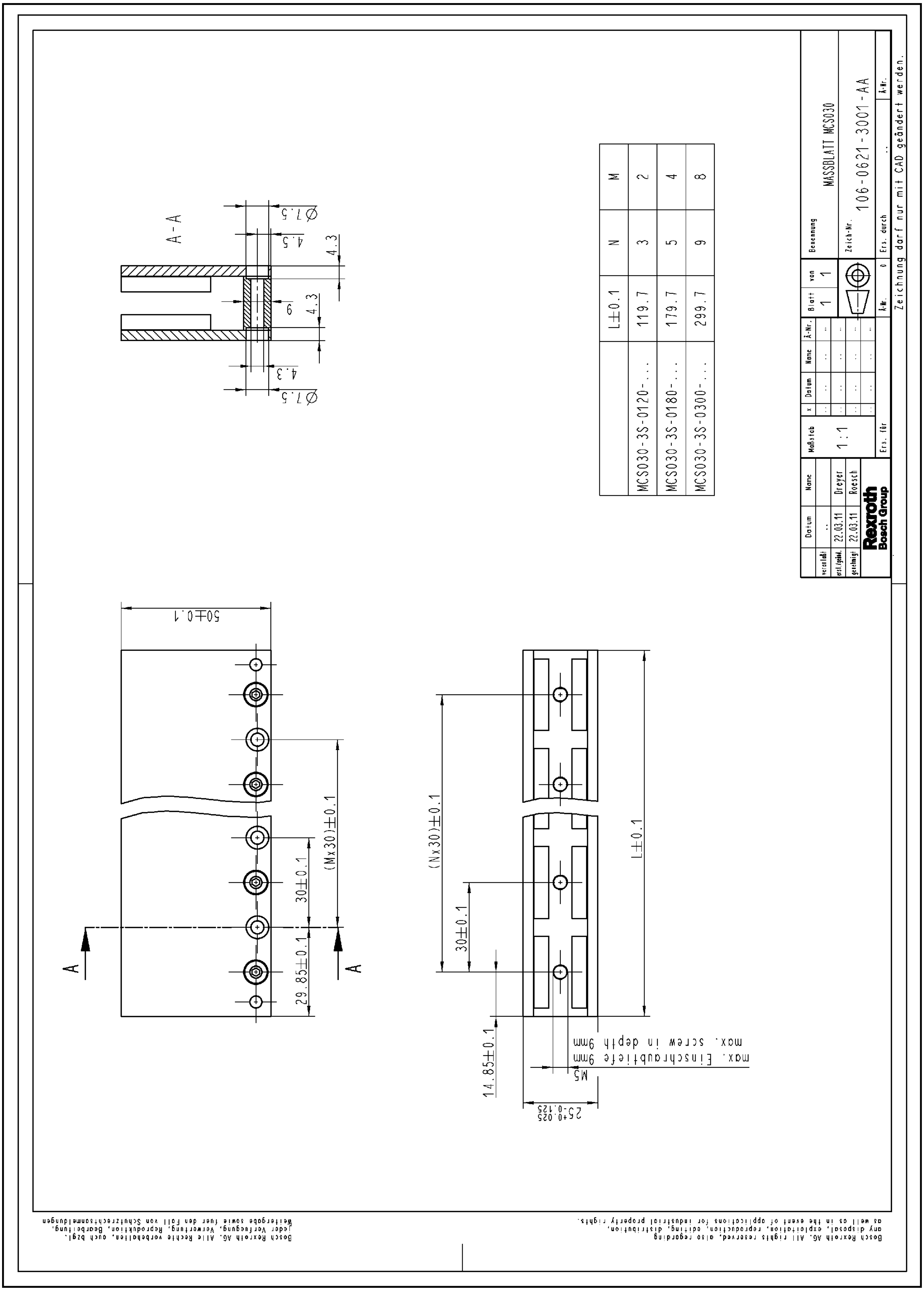


Fig. 5-7: Dimension sheet secondary part MCS030

Dimension sheets

5.5 Dimension sheets MCL040

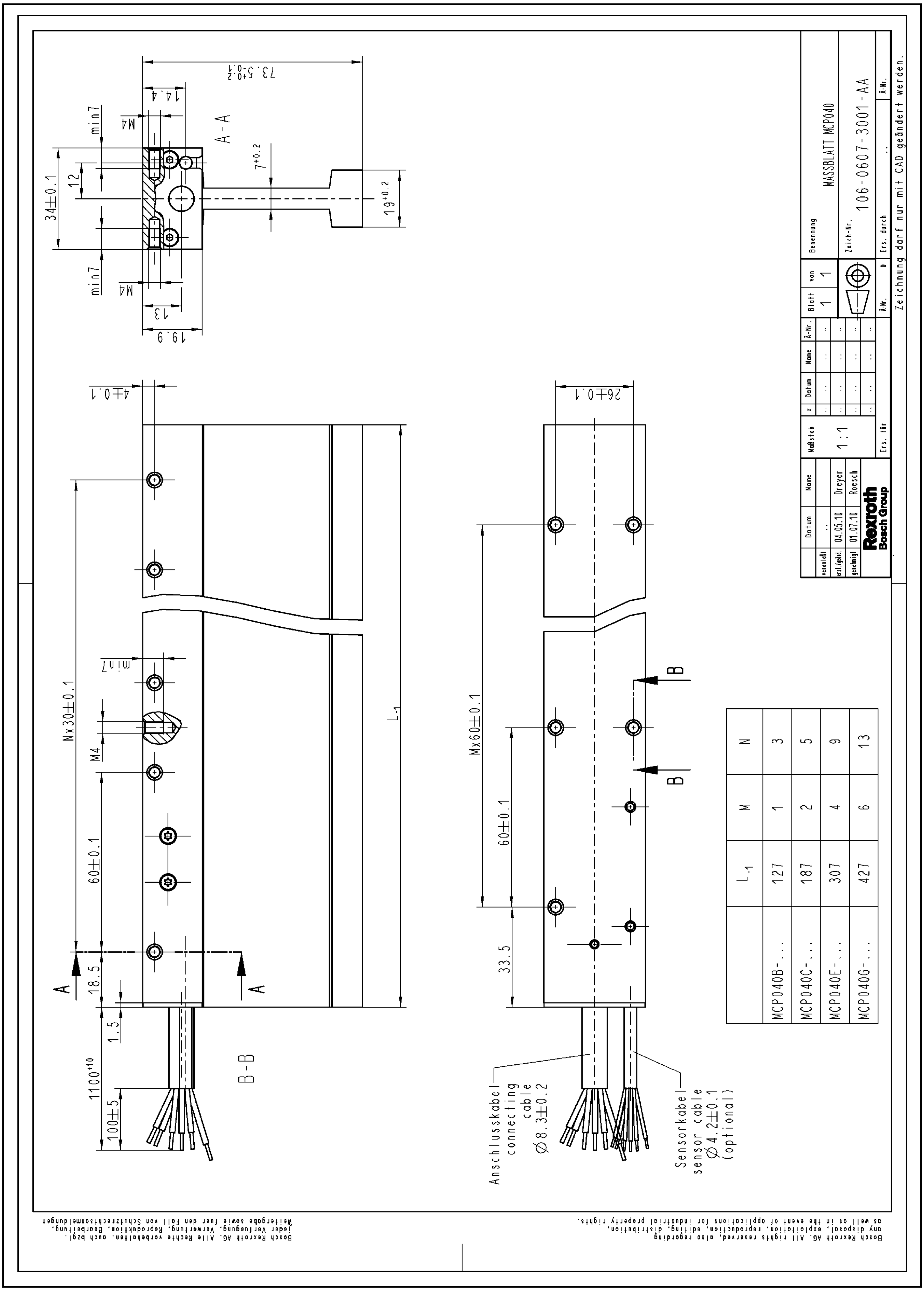


Fig. 5-8: Dimension sheet primary part MCP040

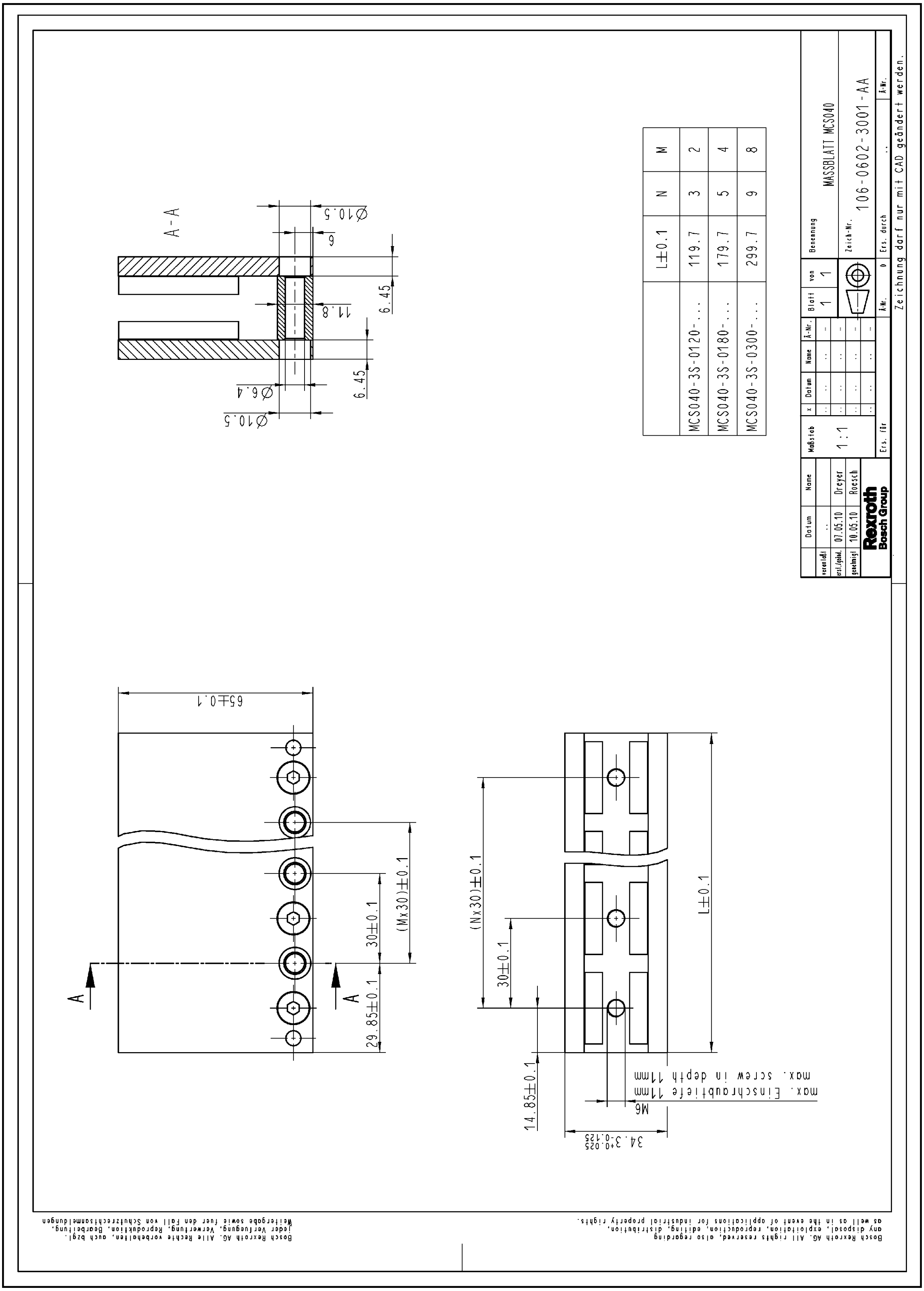


Fig. 5-9: Dimension sheet secondary part MCS040

5.6 Dimension sheets MCL070

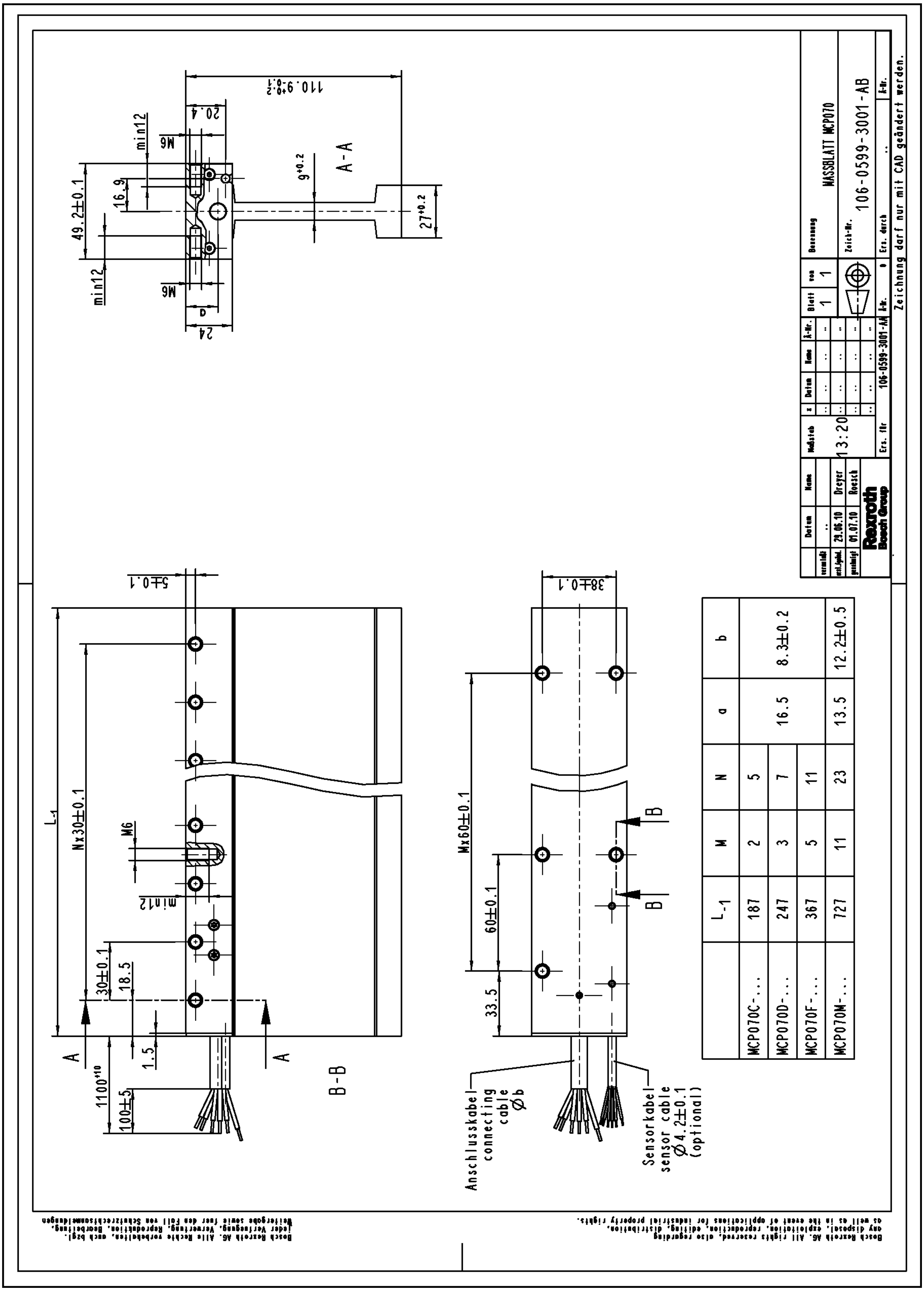
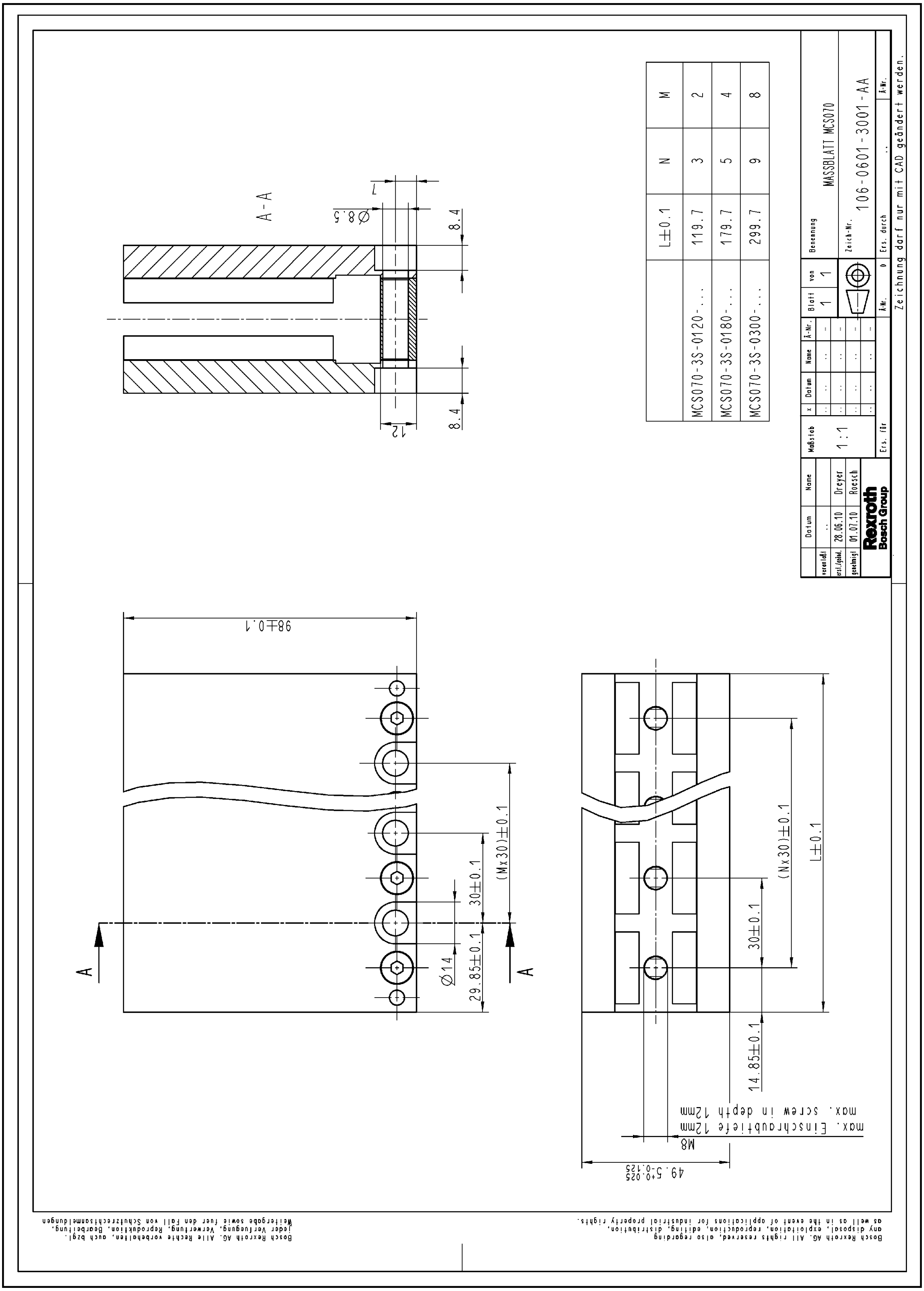


Fig. 5-10: Dimension sheet primary part MCP040

Dimension sheets



	L±0.1	N	M
MCS070-3S-0120-...	119.7	3	2
MCS070-3S-0180-...	179.7	5	4
MCS070-3S-0300-...	299.7	9	8

Fig. 5-11: Dimension sheet secondary part MCS070

6 Type codes

6.1 Type code structure and description

6.1.1 General information

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..

In the following, a type code example is given, where a stipulation of the single components (e.g. for orders) is made 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 the chapter "chapter 4 "Technical data" on page 25" and chapter "chapter 9 "Application and construction instructions" on page 97".

6.1.2 Type code primary part MCP

General information

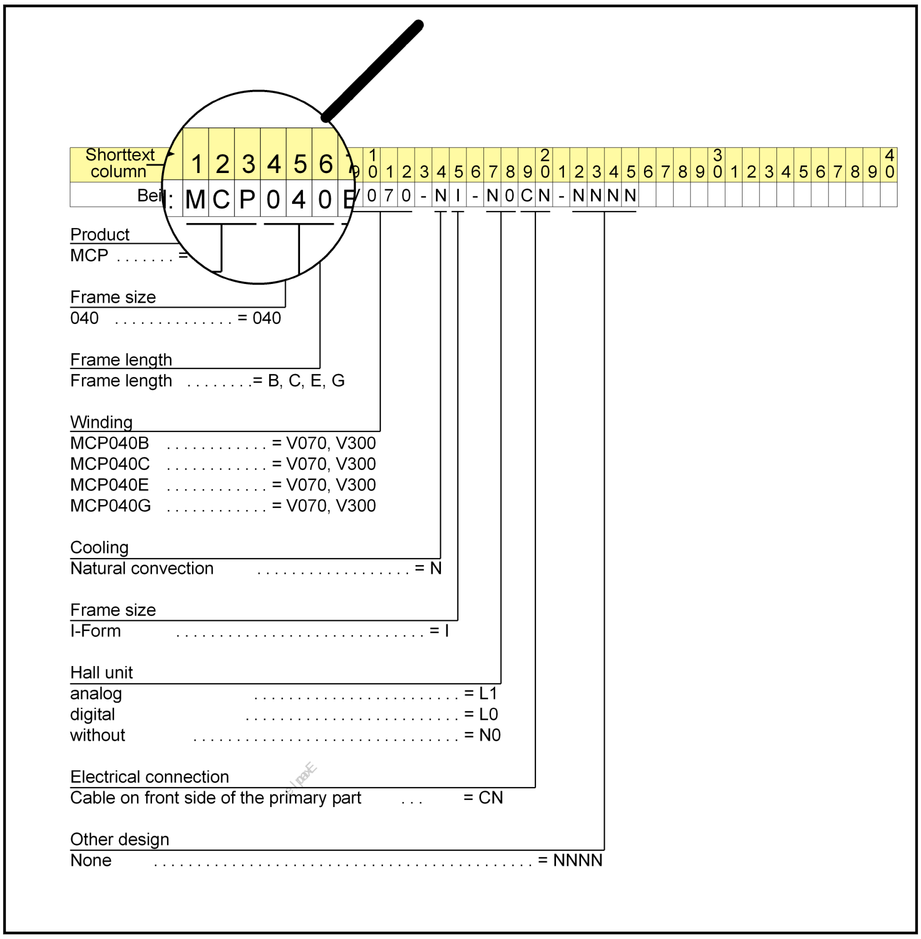


Fig. 6-1: Example of type code MCP040 primary part

Product

Short-text columns 123

MCP is the name of an ironless linear motor primary part product group.

Frame size

Short-text columns 456

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

Frame length

Short-text column 7

Within a series, the grading of increasing motor length is indicated by ID letters in alphabetic order.

Winding

Abbrev. column 9 10 11 12

The winding designation is made via the prefix "V" for a DC bus voltage of 300 V_{DC} or a prefix "L" for a DC bus voltage of 48 V_{DC}.

Cooling

Short-text column 14

MCP primary parts are only available with cooling mode natural convection.

Design

Short-text column 15

Depending from the frame size, two different frame sizes are available. The frame size derives from the cross section of the respective primary part and is described by the letters "T" and "I".

Hall unit

Short-text columns 1718

Primary parts of size 020 up to 070 can be optionally fitted with a Hall unit for position detection. Depending 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 performed 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 has to be provided and mounted by the machine manufacturer himself.

Electrical connection

Short-text columns 1920

All primary parts are provided with a flexible and shielded connection cable. The connection cable is firmly connected with the primary part and performed on the front side for MCP020 up to MCP070 and laterally for MCP015.

Other design

Abbrev. column 22 23 24 25

Those fields are not reserved.

6.1.3 Type code secondary part MCS

General Information

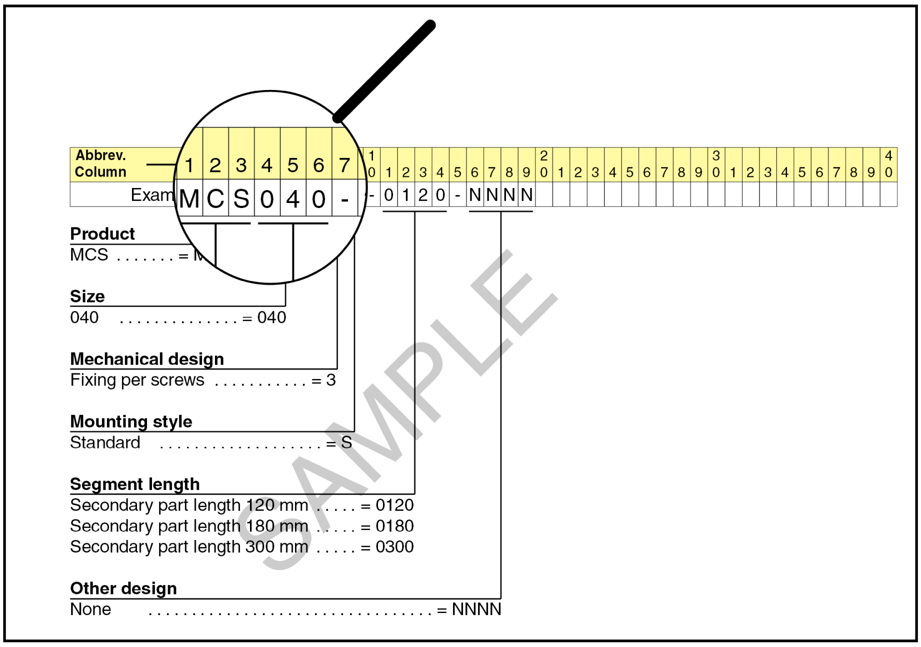


Fig. 6-2: Example of type code MCS040 secondary part

Product

Short-text columns 123

MCS is the name of an ironless linear motor secondary part product group.

Frame Size

Short-text columns 456

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

Mechanical Design

Short-text column 8

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

Mechanical Protection

Short-text column 9

To ensure the best possible operational reliability, the permanent magnets of the secondary part are protected against outer influences like corrosion by coating. Therefore, no additional cover for specified environmental conditions is necessary.

Segment Length

Abbrev. column 11 12 13 14

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

Other design

Abbrev. column 16 17 18 19

Those fields are not reserved.

6.2 Type code frame size 015

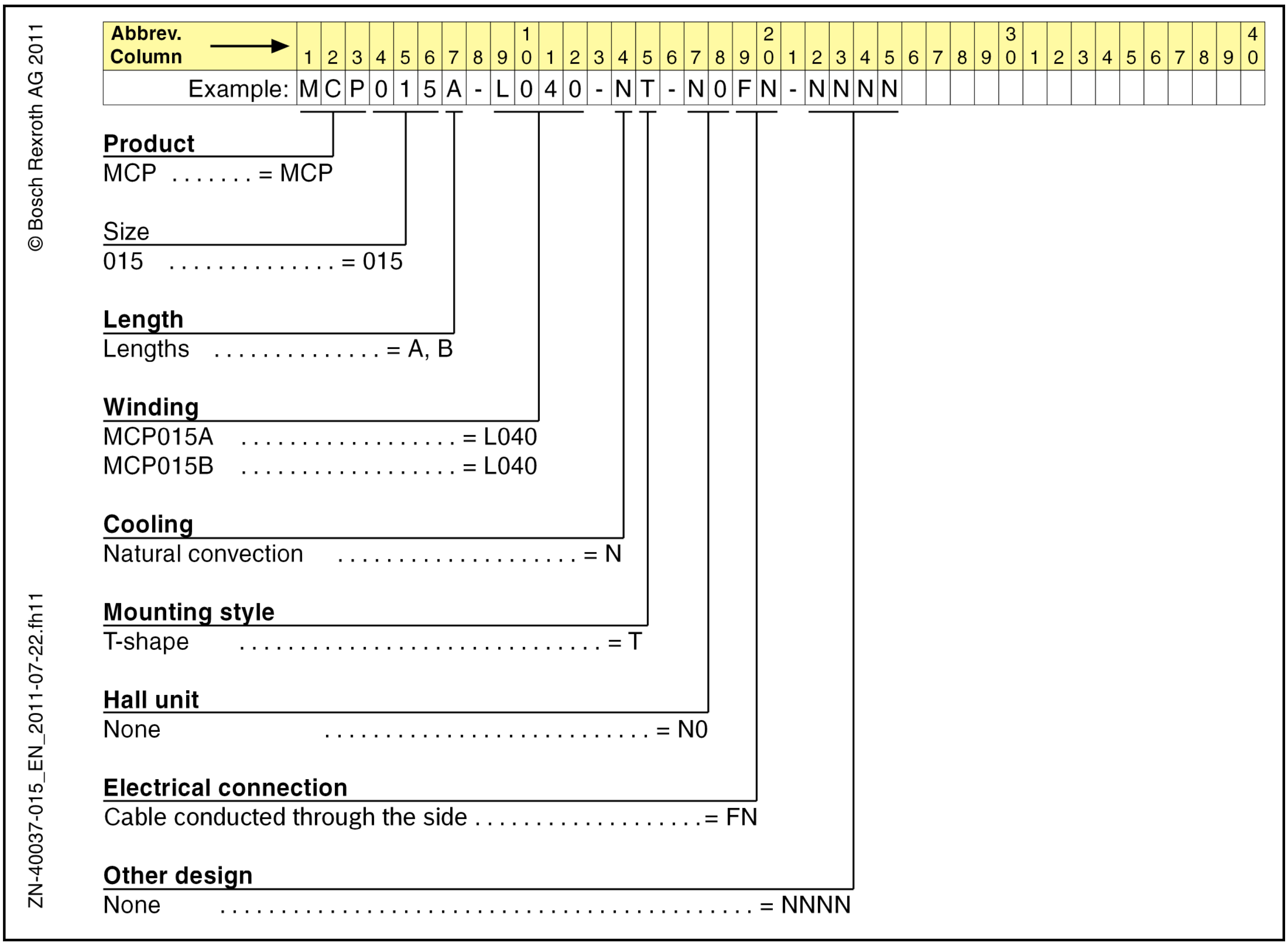


Fig. 6-3: Type code MCP015 primary part

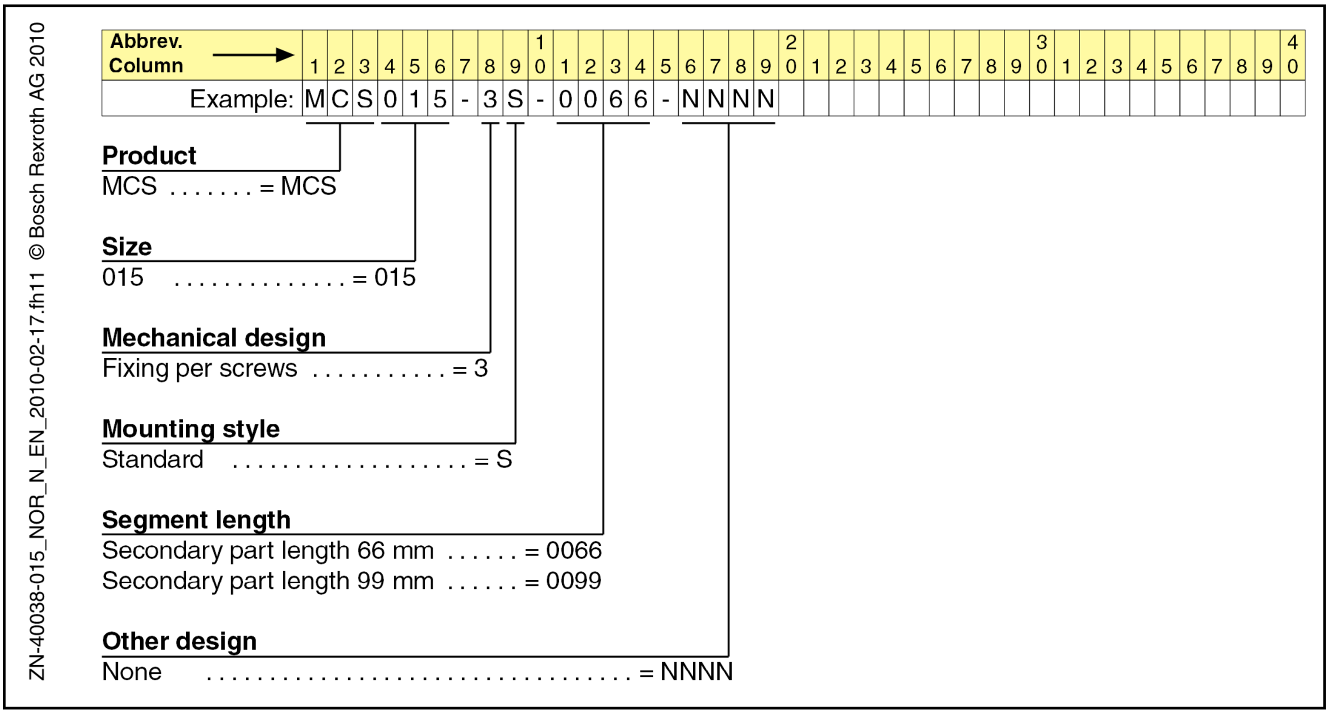


Fig. 6-4: Type code MCS015 secondary part

6.3 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 MCP020 primary part

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	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

ZN-40038-020_NOR_N_EN_2010-02-17.fh11

Fig. 6-6: Type code MCS020 secondary part

Type codes

6.4 Type code frame size 030

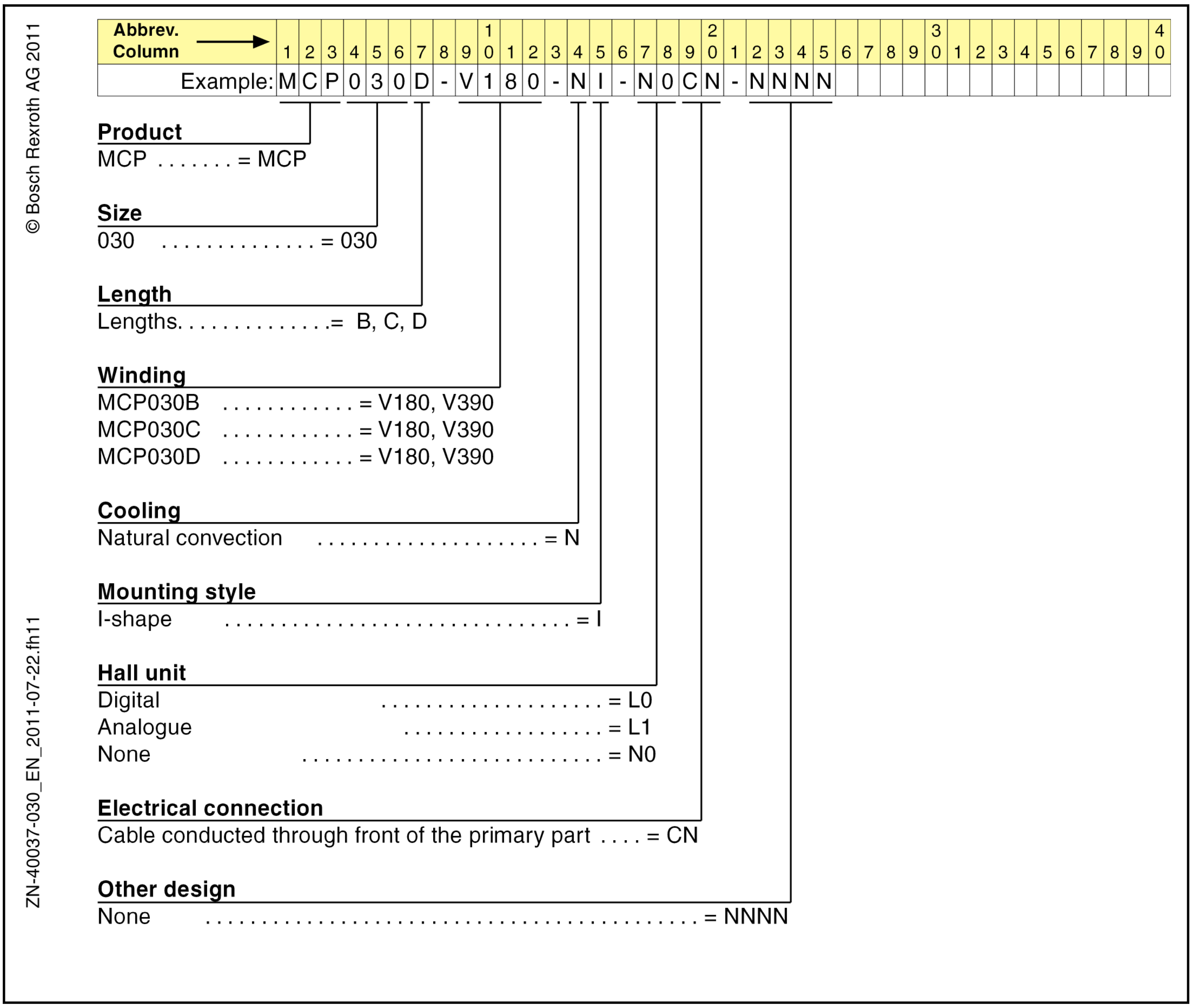


Fig. 6-7: Type code MCP030 primary part

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	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

Fig. 6-8: Type code MCS030 secondary part

6.5 Type code frame size 040

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 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 MCP040 primary part

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 MCS040 secondary part

6.6 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 MCP070 primary part

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

ZN-40038-070_NOR_N_EN_2010-02-17.fh11

Fig. 6-12: Type code MCS070 secondary part

7 Accessories and options

7.1 Hall unit

7.1.1 General information

To drive synchronous motors, an absolute position information regarding pole pair or pole pair width is necessary to recognize the position of the permanent magnets to the motor windings. Only in connection with an electric commutation offset angle, which must be determined at initial start-up, it is possible to impress the voltage with correct phase position to the magnetic field via the controller so that the motor can develop its force.

When using an incremental length measuring system, a commutation of the axes has to result from every step up of the phases of the drive device. This is done by a drive-internal procedure. After this, a force processing of the motor is possible.

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

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

- in Gantry arrangement,
- on vertical axes,
- in mechanical safe state,
- which are not allowed to be driven during the commutation process for safety reasons.

7.1.2 Hall unit functional princple

The Hall unit (analog or digital) serves for motionless commutation of ironless linear motors in connection with an incremental measuring system. On IndraDrive Cs, the motor is automatically commutated from phase switch into operating mode. Therefore, no power motion is necessary. The motor can be stalled, for example, or be at the travel length end (end stop).

Rexroth linear motors of MCL020 ... 070 series can be ordered with or without Hall unit (see chapter 6.1.2 "Type code primary part MCP" on page 63) according to the motor type code.

☞ Independend from the origin order design, the primary parts of 020 ... 070 series can be upgraded or modified with a Hall unit which can be ordered separately.

Accessories and options

Hall unit analog

Analog Hall units for MCL from Rexroth create two sinusoidal signals, which are phase-delayed by 120°. The output voltage is maximum 1 V_{SS} depend-end from the position of the Hall unit via the magnets of the secondary parts and is prepared on the lines according to Fig.7-1. The voltage supply is 7 ... 20 V. The voltage supply must ensure a current consumption of the Hall unit of minimum 40 mA.

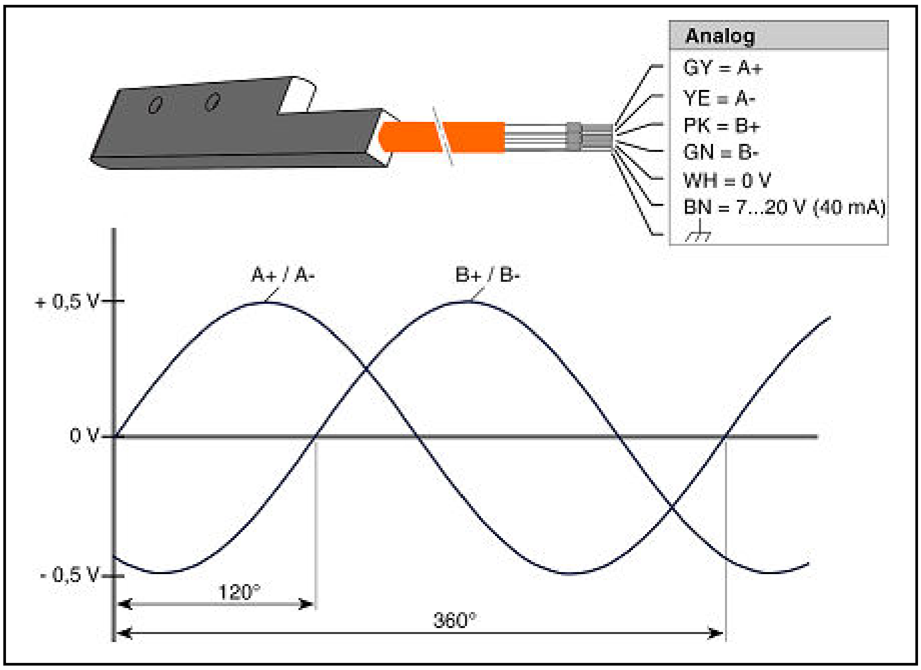


Fig. 7-1: Signal curve of an analog Hall unit

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

Hall unit digital

Digital Hall units for MCL from Rexroth create three rectangular signals, which are phase-delayed by 120°. The signals of an open-collector-switch are provided on the lines according to Fig. 7-2. The voltage supply is 3 ... 24 V. The voltage supply must ensure a current consumption of the Hall unit of minimum 40 mA.

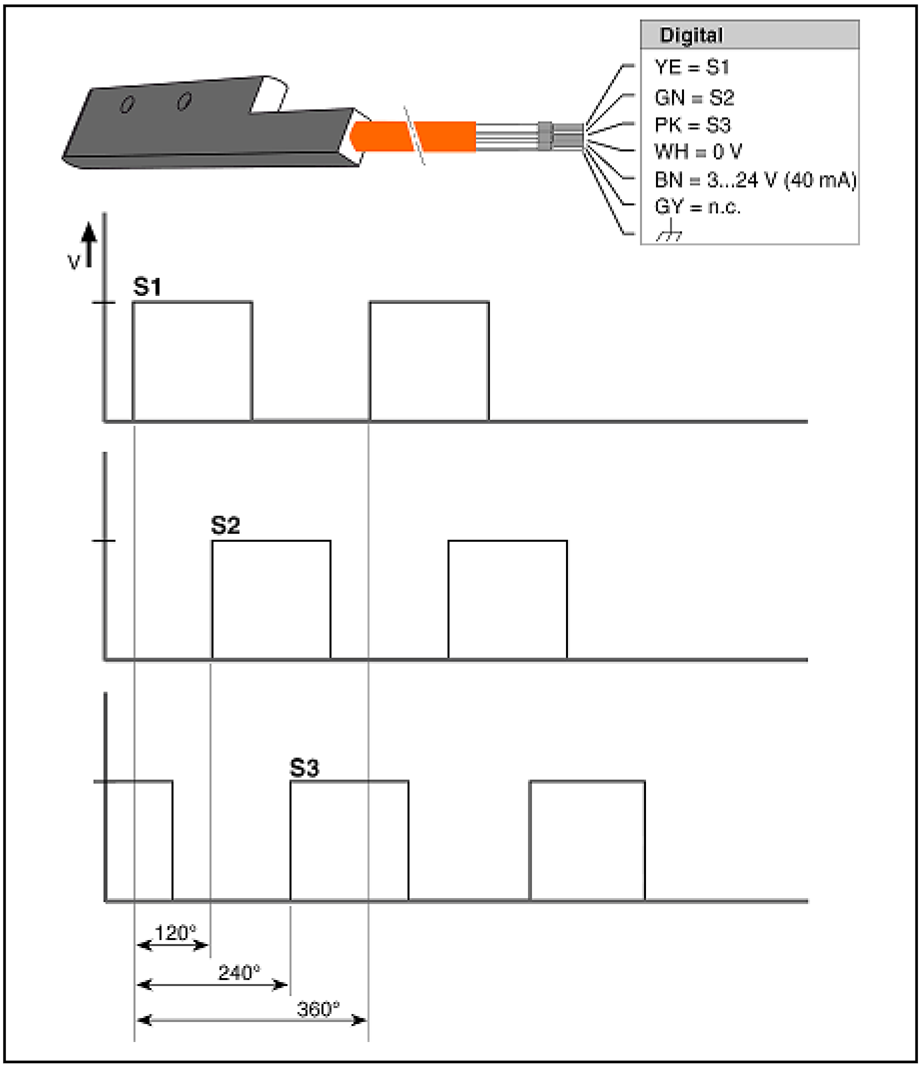


Fig. 7-2: Signal curve of a digital Hall unit

☞ The signal height of the digital Hall unit is depending on the voltage supply of open-collector-switch. Bosch Rexroth contoller use a voltage supply of 5 V.

7.1.3 Hall unit assembly/disassembly

☞ The Hall unit is an ESD sensitive device. Before connecting the Hall unit, take appropriate measures for ESD protection (ESD = electrostatic discharge).

If a Hall unit on the primary part must be retrofitted or exchanged, remove a dummy or the Hall unit to be changed from the installation space of the sensor. For easy press out of the dummy or the Hall unit, a small tool is provided with the accessory delivery. The existing fastening screws can be used for assembly of the new Hall unit. Observe the allowed tightening torque (see Fig. 7-1) not to be exceeded, when tightening the fastening screws. A too high tightening torque can damage the fastening thread of the Hall unit and can make it useless, then.

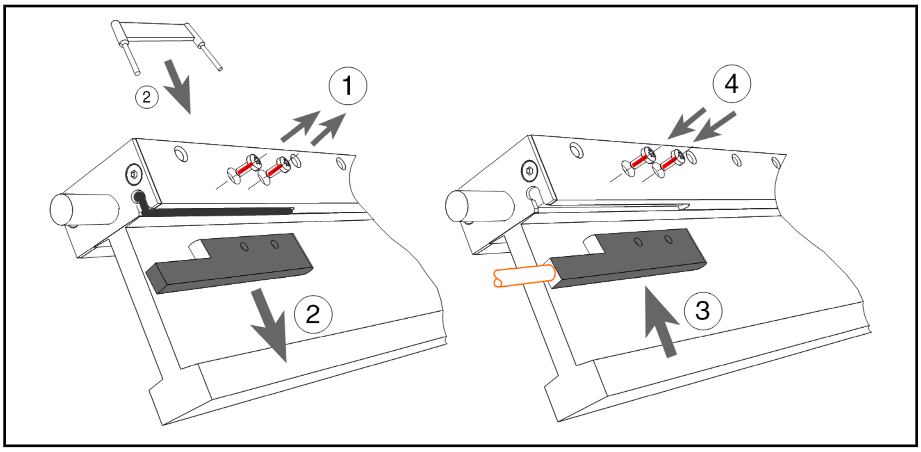


Fig. 7-3: Hall unit assembly / disassembly

1. Loosen both fastening screws. Store them until the new Hall unit must be fastened. When loosing the fastening screws, only use screws of the same design (see Fig. 7-1)!
2. Press the dummy or the Hall unit with the tool out of the installation space and remove it.
3. Assemble the new Hall unit.

Hall unit assembly - tightening torque of screws

Hall unit on	Bolt size- ISO-grade	Property 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 designation separate Hall unit

Primary part MCP ...	Ordering designation Hall unit	
	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: Ordering designation Hall unit

7.2 Hall unit adapter box SHL03.1

7.2.1 General functional principle

Are Rexroth linear motors of the MCL020 ... 070 series operated on the IndraDrive Cs, using a Hall unit adapter box SHL03.1 makes the use of a digital Hall unit and an incremental length measuring system possible at the same time. The SHL03.1 adapter box joins signals of both components and merges them with the provided interface on the IndraDrive Cs.

☞ A possible cabling with Rexroth cables is described under chapter 8.2.4 "Connect digital Hall unit" on page 93.

7.2.2 Order designation Hall unit adapter box

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

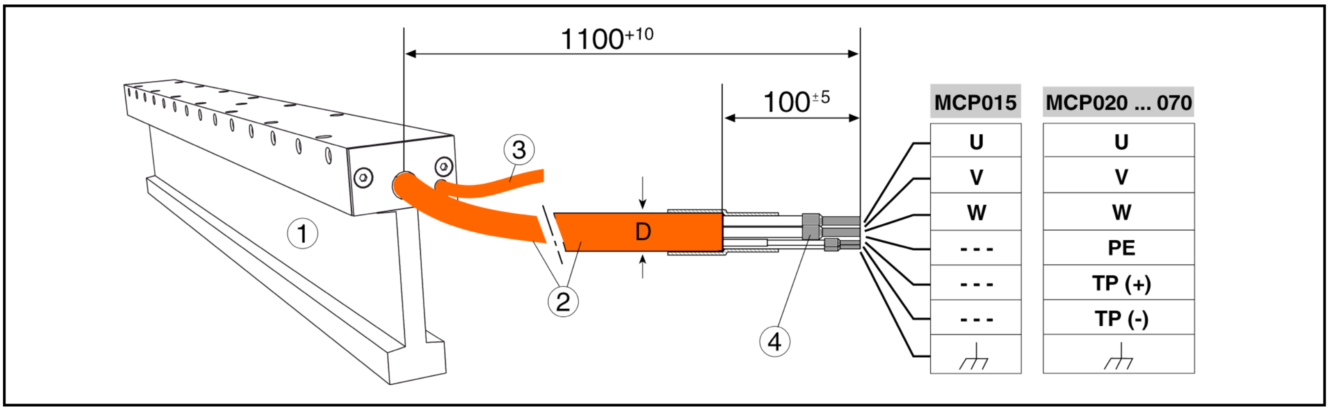
Tab. 7-3: Order desgination SHL03.1 adapter box

8 Connection technique

8.1 Power connection

8.1.1 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
①	Connection cable (Hall unit - optional bei MCP020 ... 070; see Fig.8-8)
①	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).

Technical data power connection cable

<table>
<tr><th>Frame size</th><th>Connection cable
(Bulk cable)</th><th>Diameter
[D in mm]</th><th>Cross section
Power wires
[mm²]</th><th>Cross section
Control wire
[mm²]</th><th>Allowed bending radius[R]*</th></tr>
<tr><td>MCP015</td><td>REL0010</td><td>4.2 ±0.1</td><td>3 x 0.14</td><td>- / -</td><td rowspan="6">- for fix installation 5 x D
- for flexible installation 7.5 x D</td></tr>
<tr><td>MCP020</td><td rowspan="2">REL0011</td><td rowspan="2">7.8 ±0.2</td><td rowspan="2">4 x 0.5</td><td rowspan="4">2 x 0.14</td></tr>
<tr><td>MCP030</td></tr>
<tr><td>MCP040</td><td rowspan="2">REL0012</td><td rowspan="2">8.3 ±0.2</td><td rowspan="2">4 x 0.75</td></tr>
<tr><td>MCP070C/D/F</td></tr>
<tr><td>MCP070M</td><td>INK0650</td><td>12.2 ±0.5</td><td>4 x 1.5</td><td>4 x 0.75
(only 2 wires are necessary and lead out from the temperature sensor)</td></tr>
<tr><td colspan="6">*) See notes regarding bending radius under Fig.8-2</td></tr>
</table>

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

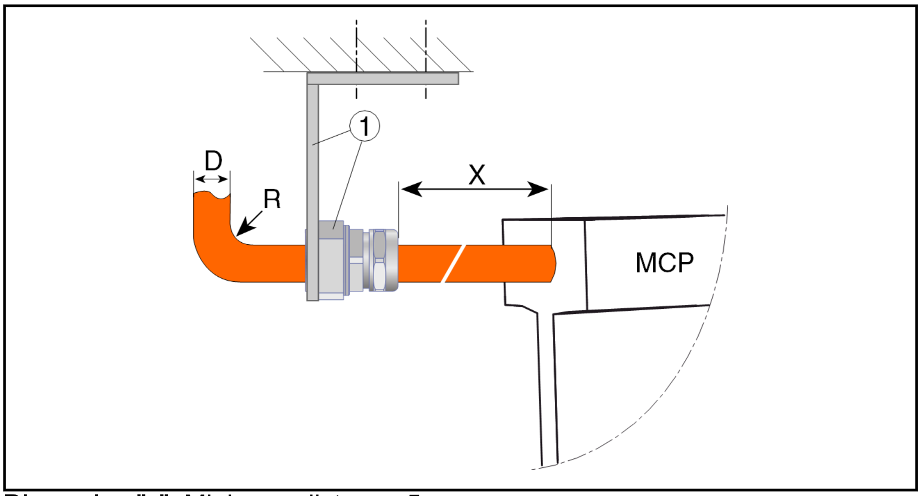
Installation of connection cable

The connection cable is moulded 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 allowed cable bending radius

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

Ground connection

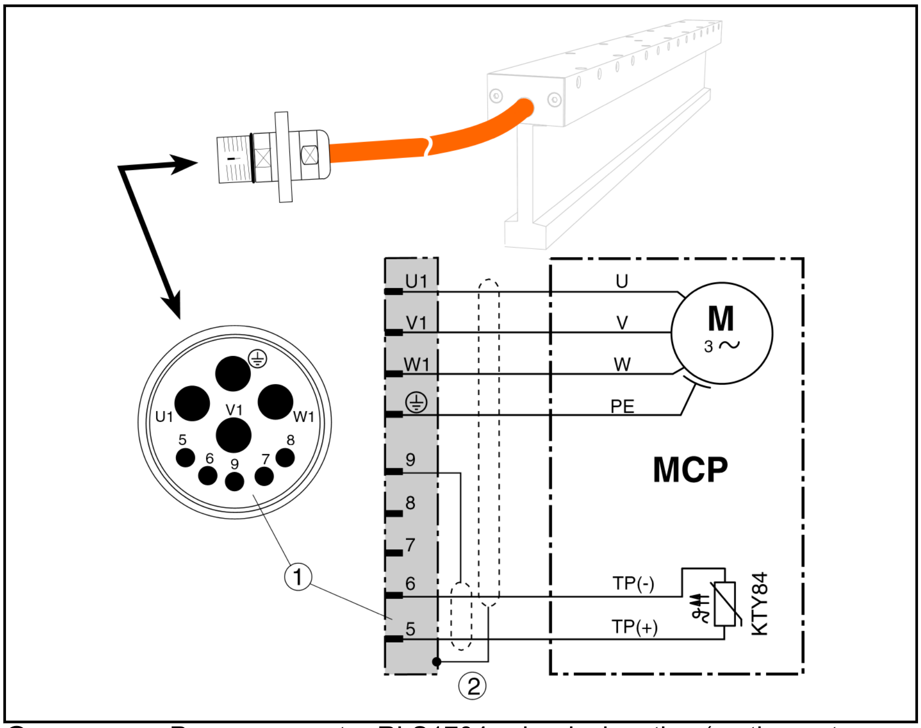
If the grounding of the secondary parts cannot be ensured with mounting into the customer`s machine construction, connect it according to DIN VDE 0100-410 with the potential of the protective conductor .

8.1.2 Assembly connection cable on primary part

Bosch Rexroth offers ready-made power cables to connect MCP primary part on Rexroth controllers. See also chapter 8.1.3 "Connection Power " on page 86.

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 table tab. 10-2 "Motor-controller-combinations with IndraDrive Cs" on page 130.



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.

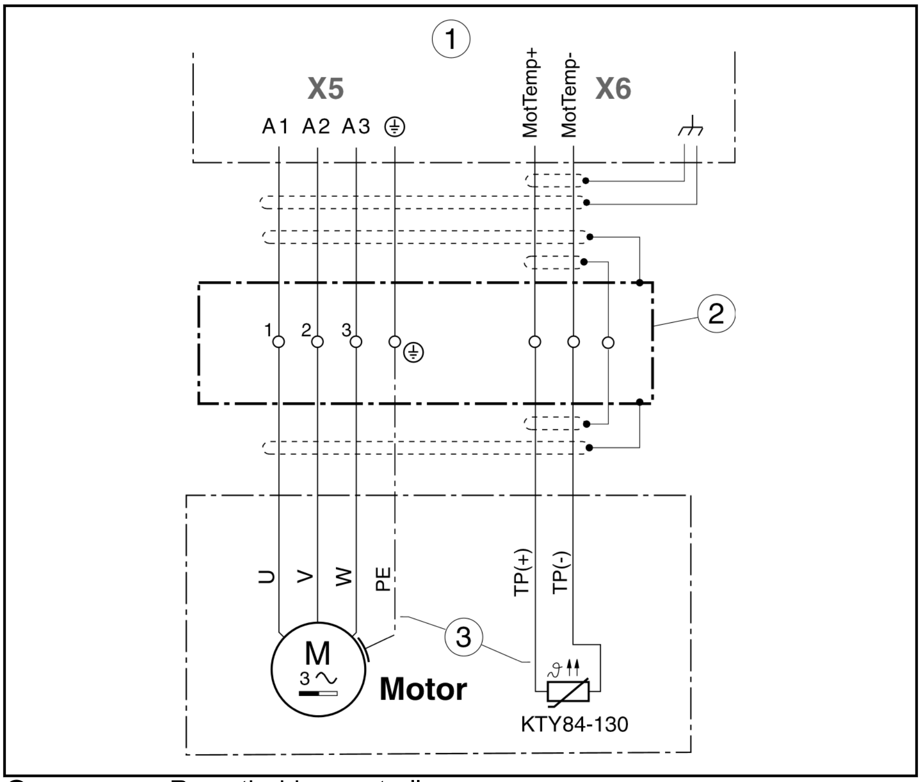
8.1.3 Connection Power

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)
① 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

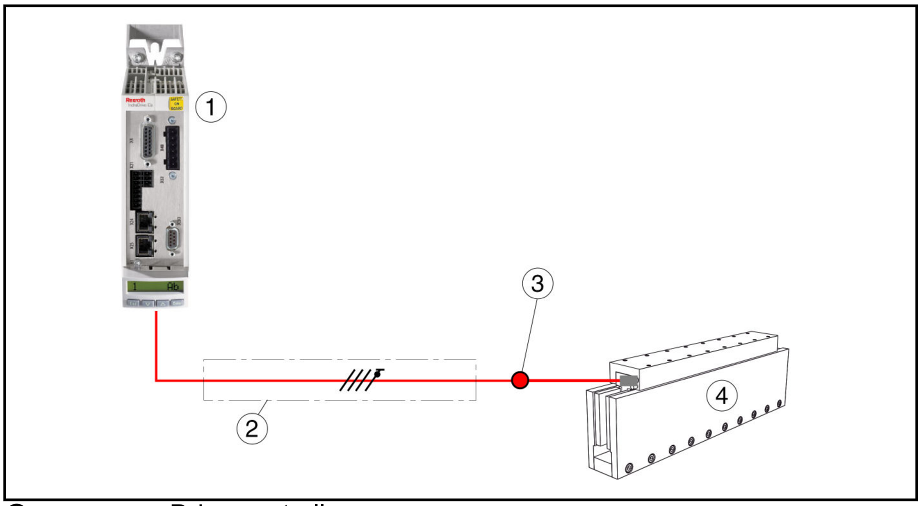
Connection power cable in dependence from primary part at parallel arrangement

At parallel arrangement of primary parts, the connection 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 under chapter "Parallel arrangement " on page 114.

Connection technique

8.1.4 Installation of power connection

Installation method for motor single arrangement



①	Drive controller
②	Energy chain
①	Junction (Connector or Terminal boxes)
①	Motor

Fig. 8-5: Motor single arrangement

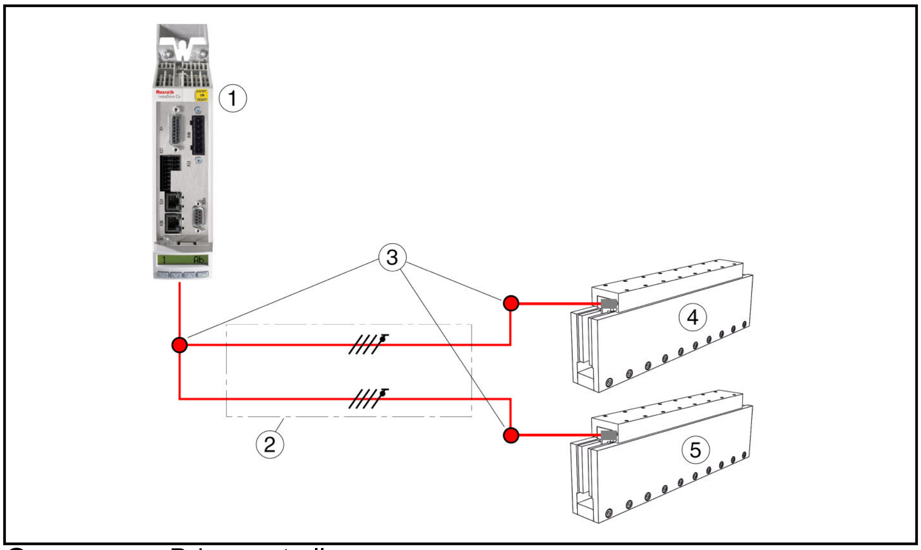
Parallel motor connection

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 power cables are described in the documentation "Rexroth Connection Cables", MNR R911322948 (DE) or R911322949 (EN). R911322948 (DE) or R911322949 (EN).

Parallel arrangement, installation method separate power cables

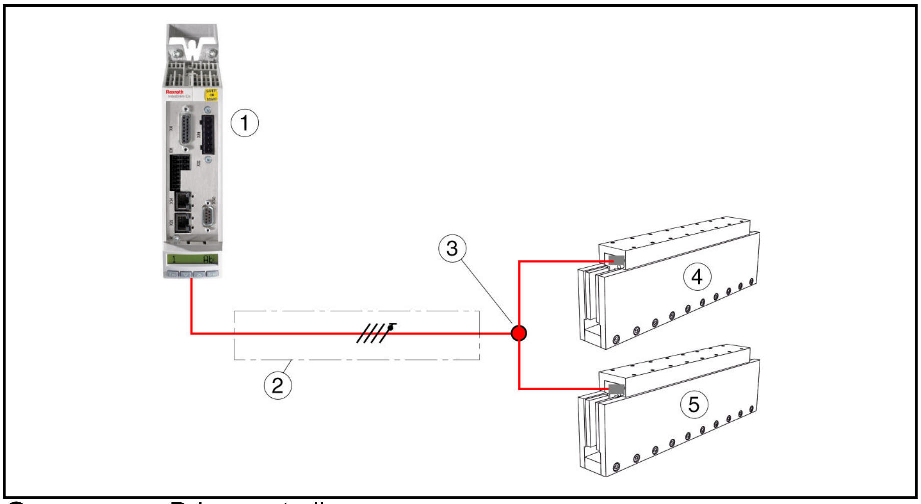


①	Drive controller
②	Energy chain
①	Junctions (Connector bzw. Terminal boxes)
①	Motor 1
①	Motor 2

Fig. 8-6: Parallel arrangement, separate power cable

Parallel arrangement, 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 nominal current of the motor when selecting the power cable



①	Drive controller
②	Energy chain
①	Junction (Terminal boxes)
①	Motor 1
①	Motor 2

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

8.2 Sensors

8.2.1 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.

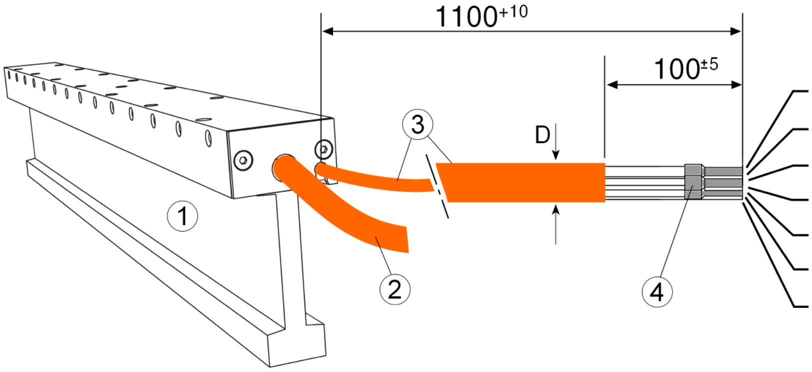
Heed the right polarity of the connection wires when connecting the KTY84-130 . The wire designation can be found under Fig. 8-1.

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.

8.2.2 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. 8.2.3 .



Analog	Digital
A+ (GY)	**S1** (YE)
A- (YE)	**S2** (GN)
B+ (PK)	**S3** (PK)
B- (GN)	**0V** (WH)
0V (WH)	**12V** (BN)
12V (BN)	n.c.
⏚	⏚

① Primary part MCP
② Connection cable power(see chapter 8.1.1 "Connection cable on primary part" on page 83)
① Connection cable (Hall unit - optional bei MCP020 ... 070
① 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 Abb.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!

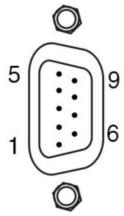
The connection cable of the Hall unit can be connected with the power cable via cable ties, if the power cable is provided with a strain relief. If a fixed installation is not possible, provide the connection cable of the Hall unit with a strain relief (for example see Fig. 8-2) to protect the cable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

☞ The Hall unit is a component that might 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.

8.2.3 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 of the connector depends on the Hall unit used (digital or analog).

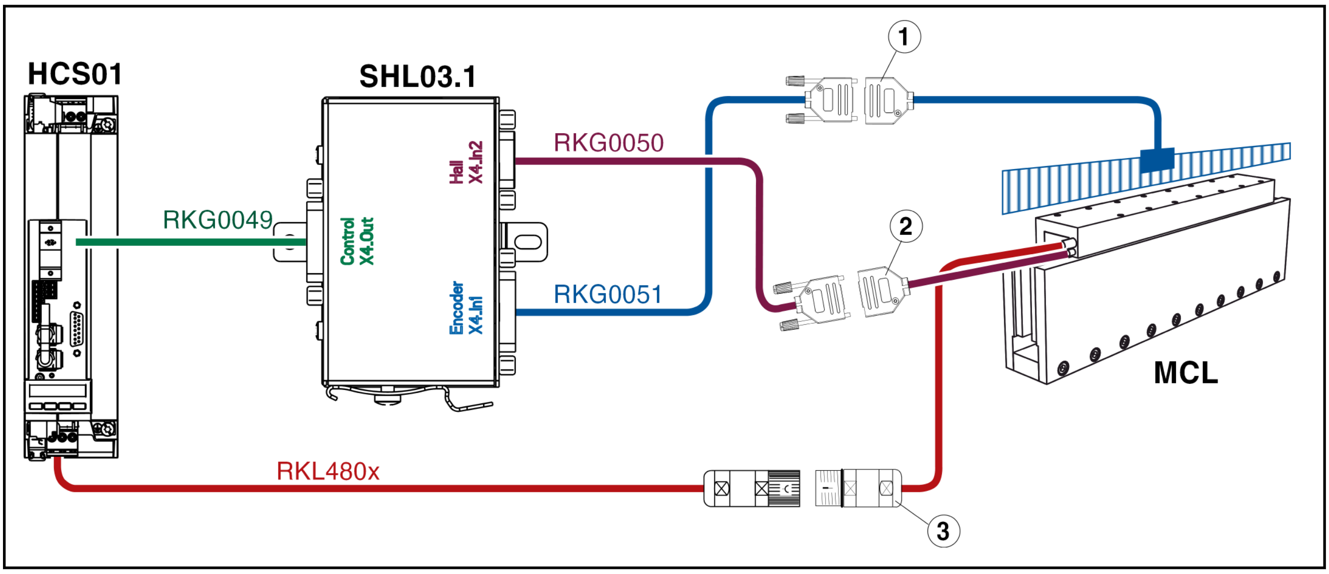
	Connection cable Hall unit	
	analog	digital
1	12 V (BN)	12 V (BN)
2	A+ (GY)	S1 (YE)
3	A- (YE)	/
4	0V (WH)	S2 (GN)
5	B+ (PK)	0V (WH)
6	B- (GN)	/
7	/	/
8	/	S3 (PK)
9	/	/
Connector housing	Outer shield	Outer shield

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

8.2.4 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)

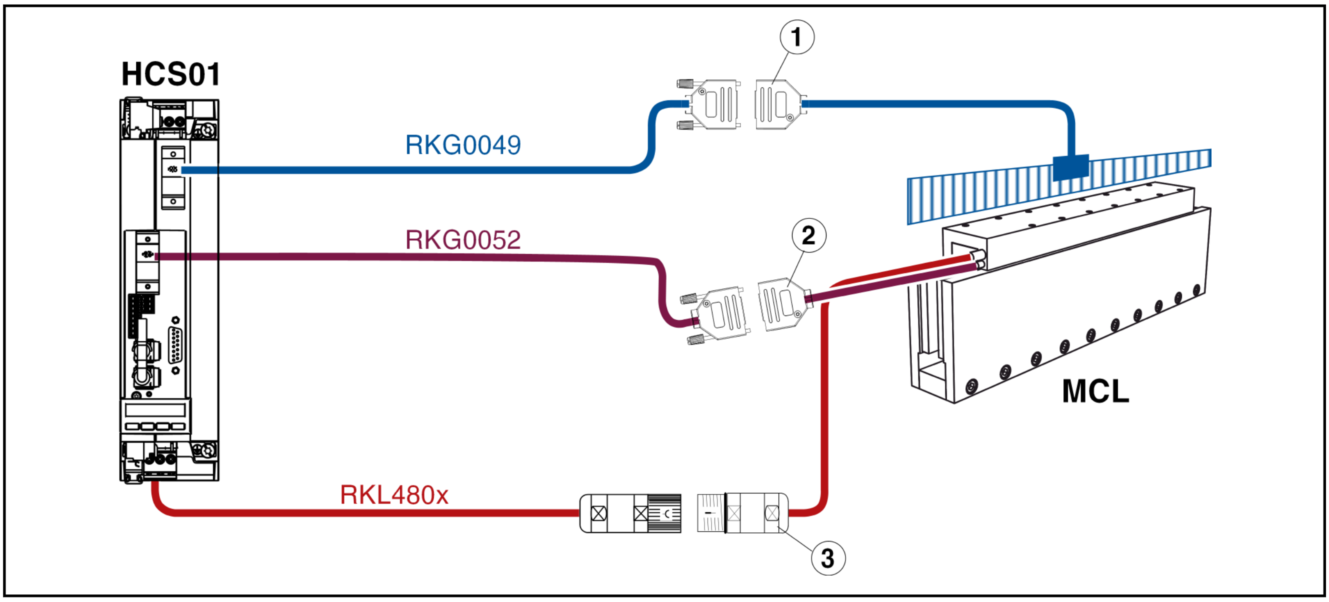
Fig. 8-9: Connection overview MCP with digital Hall unit

☞

- 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" on page 81.

8.2.5 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))
①	Flange socket RLS1704
RKL480x	Motor power cables (max. cable length 75 m)
RKG0049	Analog Hall unit ↔ encoder evaluation on drive controller (max. cable length 75 m)
RKG0051	Length measuring system ↔ adapter box (max. cable length 75 m)

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

☞
- The total distance between drive controller and the head of the length measuring system 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" on page 81.

8.3 Length measuring system

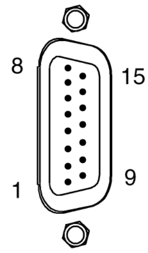
☞ The length measuring system is not in the scope of delivery of the motor and must be prepared and assembled by the maschine manufacturer (see chapter 9.14 "Length measuring system" on page 119).

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
- Linear scale
- Linear guide
- Energy flow
- Slide or machine construction

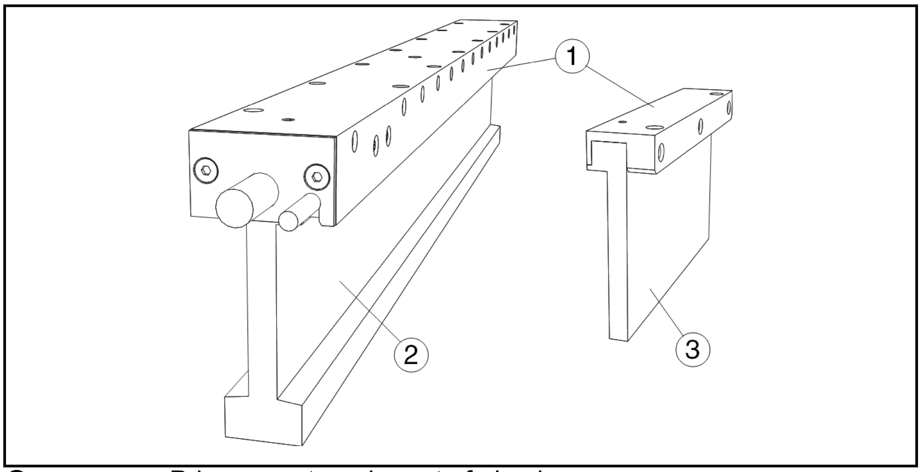
For force multiplication can be two or more primary parts mechanically coupled, arranged in-line. For further information see chapter 9.13.2 "Several motors per axis" on page 113.

☞ 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.



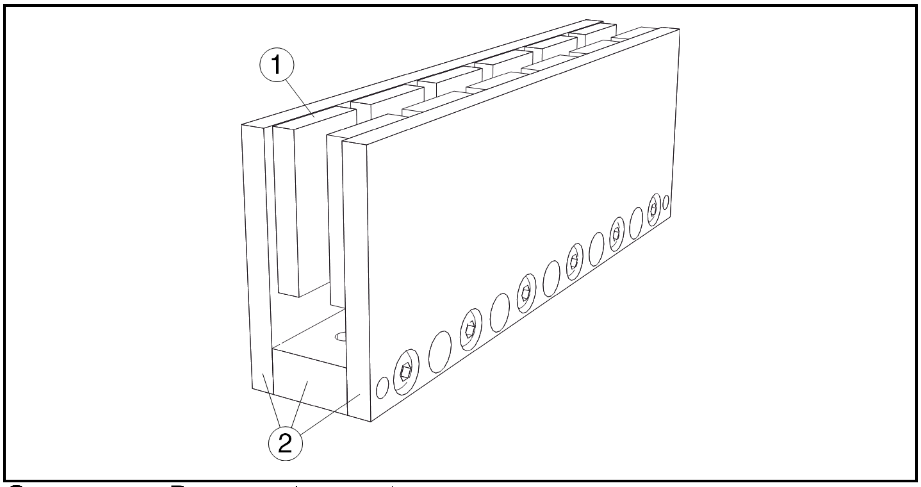
① Primary part carrier out of aluminum
② Form of molded motor winding in design **I-form** (MCP020 ... 070)
① Form of molded motor winding in design **T-form** (MCP015)

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 in the type code underchapter " Segment Length" on page 65.

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.

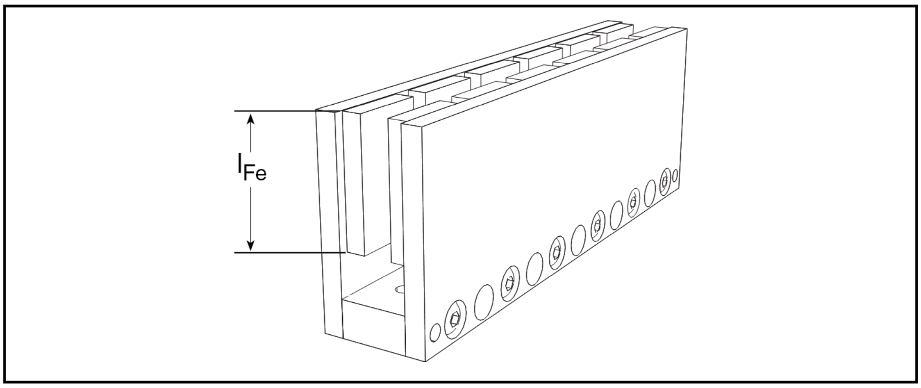


Fig. 9-4: l_{Fe} = Active magnet heigth

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 differnet 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.

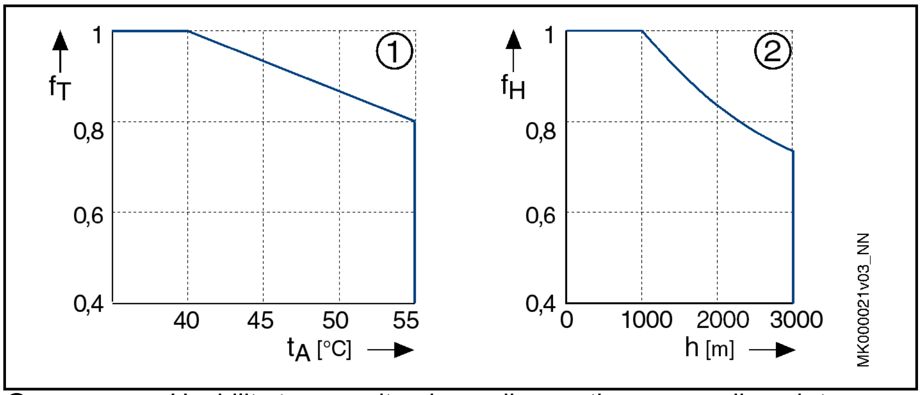
☞ For detailed information about available frame sizes and lengths refer to the type code of the motor in chapter 6 "Type codes" on page 63.

9.3 Setup elevation and ambient conditions

The motor performance data specified are applicable for

- Ambient temperature 0 ... +40 °C
- Setup elevation of 0 m 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

$M_{0\_red} = M_0 \times f_T$

Installation altitude > 1,000 m

$M_{0\_red} = M_0 \times f_H$

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

$M_{0\_red} = M_0 \times f_T \times f_H$

☞ 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 Ambient conditions

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 ambient conditions	3K2
Classification of biological ambient conditions	3B1
Classification of chemically active materials	3C2
Classification of mechanically active materials	3S2
Classification of mechanical ambient conditions	3M8

Tab. 9-1: Allowed classes of ambient 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 used 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	+5 ... +40 1)
Air humidity (relative)	%	5 ... 95
Air humidity (absolute)	g/m³	1 ... 29
Max. temperature change rate	°C/min	0.5
Occurrence of salt mist		Not permitted 2)
Sand in air		Not permitted 3)

1) Rexroth permits 0 °C as the lowest air temperature.
2) Deviating from class 3C2 of DIN EN 60721-3-3
3) Deviating from class 3S2 of DIN EN 60721-3-3

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 ambient factors.

9.5 Degree of protection

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

Motor component	Degree 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-Sign

Declaration of conformity

Certificate of conformity certifying the structure of and the compliance with the valid EN standards and EC guidelines are available for all MCL motors. If necessary, these declarations of conformity can be requested from the responsible sales office.

The CE mark is applied to the motor type label of the MCL motors.

Fig. 9-6: CE mark

9.6.2 RoHS conformity

We confirm in our manufacturer´s declaration TC 30806-1 (2013-06-03) that our products confirm with the RoHS directive 2011/65/EG "Restriction of the use of certain hazardous substances in electrical and electronic equipment".

9.7 Magnet fields

During operation of electro motors, electro-magnetic fields on live-parts and connection lines of these motors occur. The secondary parts of synchronous linear motors and rotors of synchronous kit motors equipped with permanent magnets are not shielded magnetically and create continuously a static magnetic field (constant field), even in non-activated condition. This is clearly signaled by a warning label, which is stuck on the outside of every package with open permanent-magnet parts.

Observing all regulations and safety measures, involves no risk of danger in the case of IndraDyn synchronous motors with open permanent magnet parts (rotor or secondary parts). Ferromagnetic chips are not attracted at a distance of approximately 100 mm from the surface of open permanent magnetic parts. Despite this, we recommend persons with implants to keep a safety distance of 1 meter (1,000 mm) minimum.

Depending from operation place, transport path and storage of the machine or its parts, regional regulations and laws are valid which must be observed during constructing, transporting or operating the machine.

⚠ WARNING **Electromagnetic / magnetic fields! Health risk for persons with pacemaker, metallic implants or hearing devices! Material damage.**

Danger due to magnetic and electromagnetic fields on live conductors or permanent magnets of electro motors.

Persons with active implanted medical devices or passive metallic implants must keep away from these motor parts.

Access to areas, in which such drive components are mounted and operated, is not allowed for the named persons. It is allowed after consulting a doctor, only.

Keep magnetic data carriers, credit cards, check cards and identity cards with magnetic strips and all ferromagnetic parts away from magnetic fields. It if forbidden to wear jewelry made of ferromagnetic material during on the job.

Safety measures for service personal

Within the European Union (EU), the guideline 2004/40/EG specifies the minimum requirements about protection of safety and health of employees from danger due to electromagnetic and magnetic fields. For valid regulations and guidance for machine manufacturers and users please refer to the following public documents:

- Standard EN 50499 (DE: DIN EN 50 499, DIN VDE 0808-499)
- Standard EN 50527 (DE: DIN VDE 0848-3)
- in Germany: acident prevention regulation BGV/GUV-V B11

This list does not lay claim to completeness. Machine manufacturers and machine users must decide which regional regulations are valid and which safety and occupational-safety measures for work within hazardous areas must be adopted. Essentially are not the electromagnetic features of single machine parts, but the effective overall exposures in electric, magnetic and electromagnetic fields in specific working area.

Construction notes

When constructing the machine, provide suitable covers and protective measures for safe machine operation.

- During machine construction, observe the with above-named standards specified regulations about labeling and access restrictions of hazardous areas.
- During operation, prevent admittance of operating staff into the moving area of the motors.
- Prevent penetrating of foreign bodies, chips and dirt within the moving area of the motors.

Notes for transport

For shipping of open, non-magnetic shieldes permanent magnetic parts as air freight, limit values (according to IATA953) for magnetic flow density in all room directions must be kept. All rotors of Bosch Rexroth synchronous motors belong to category I according to the following figure. Secondary parts of Bosch Rexroth linear motors belong to one of the three named categories, depending on their geometry and construction. Before shipping, define the category of the shipped item, first.

Category	Distance of edge of package	Flow density	Measure
I	2.1 m	≤ 0.525 µT ≤ 5.25 mG	Package can be sent without declaration and designation.
II	4.6 m	≤ 0.525 µT ≤ 5.25 mG	Declaration and designation as magnetic material necessary.
III	4.6 m	>0.525 µT > 5.25 mG	Shipping only with pre-approval of the responsible national authority of the state of departure and the state of the airline.

Tab. 9-4: Limit values of magnetic flow 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.

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

$$f_T = R_{12} \cdot (1 + \Delta T \cdot \alpha_{20})$$

P_V	Total loss in W
P_{Vl}	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. 9-7: Power loss of synchronous linear motors

☞ When you determine the power loss according to Fig. 9-7 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. 9-8) 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. 9-9 and Fig. 9-11 are used to define the operating modes, e.g. acc. to DIN EN 60034-1.

Application and construction instructions

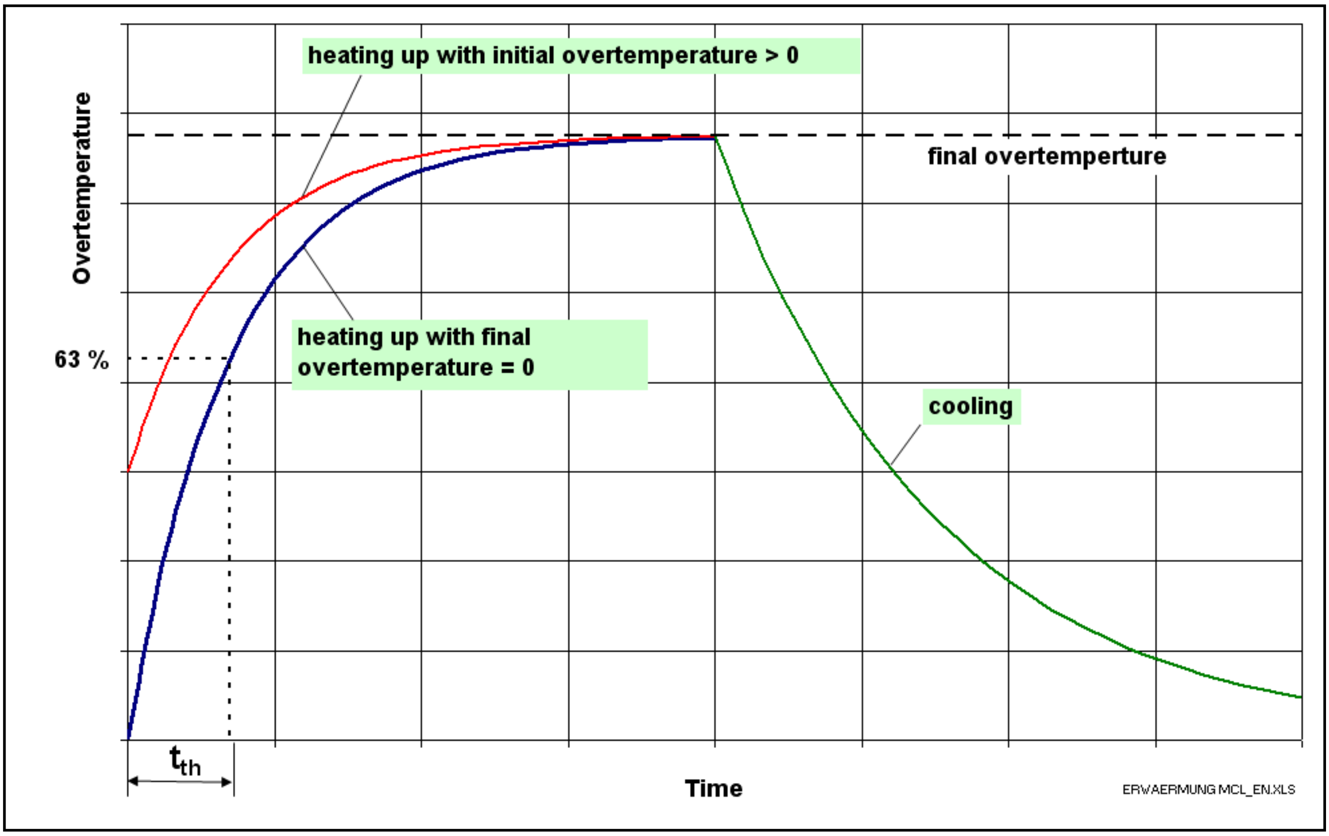


Fig. 9-8: Heating up and cooling down of an electrical machine

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

Fig. 9-9: Heating (overtemperature) 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 146)
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. 9-10: Expected final over temperature of the motor

Cooling down

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

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

Fig. 9-11: 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 nominal 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 nominal 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 further information, please refer to the functional description of IndraDrive control devices.

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

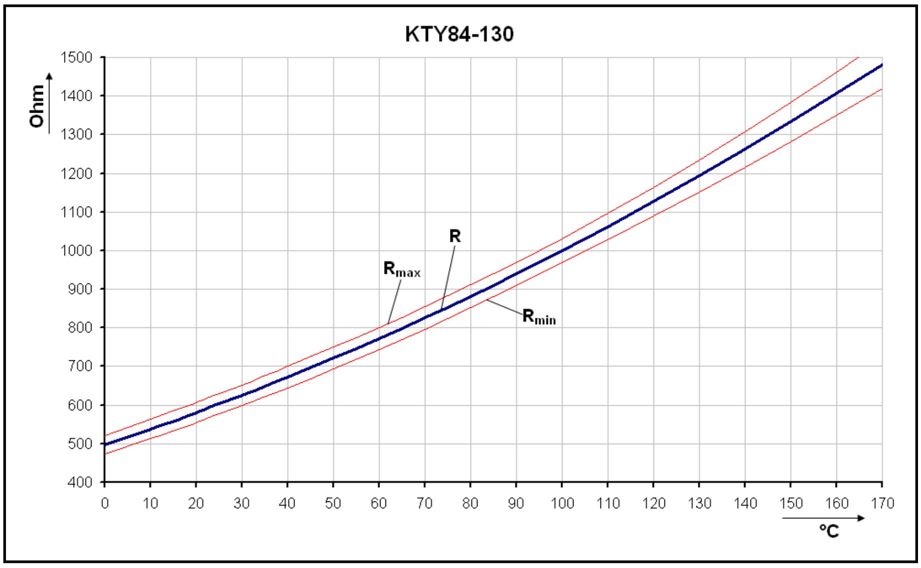


Fig. 9-12: Characteristic temperature sensor KTY84-130

Temperature sensor KTY84-130 is a component that might be 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 appropriate measures for ESD protection (ESD = electrostatic discharge).

To connect temperature sensors heed the details under chapter 8.2.1 "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 force is reduced linearly as a function of the reduced coverage area.

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

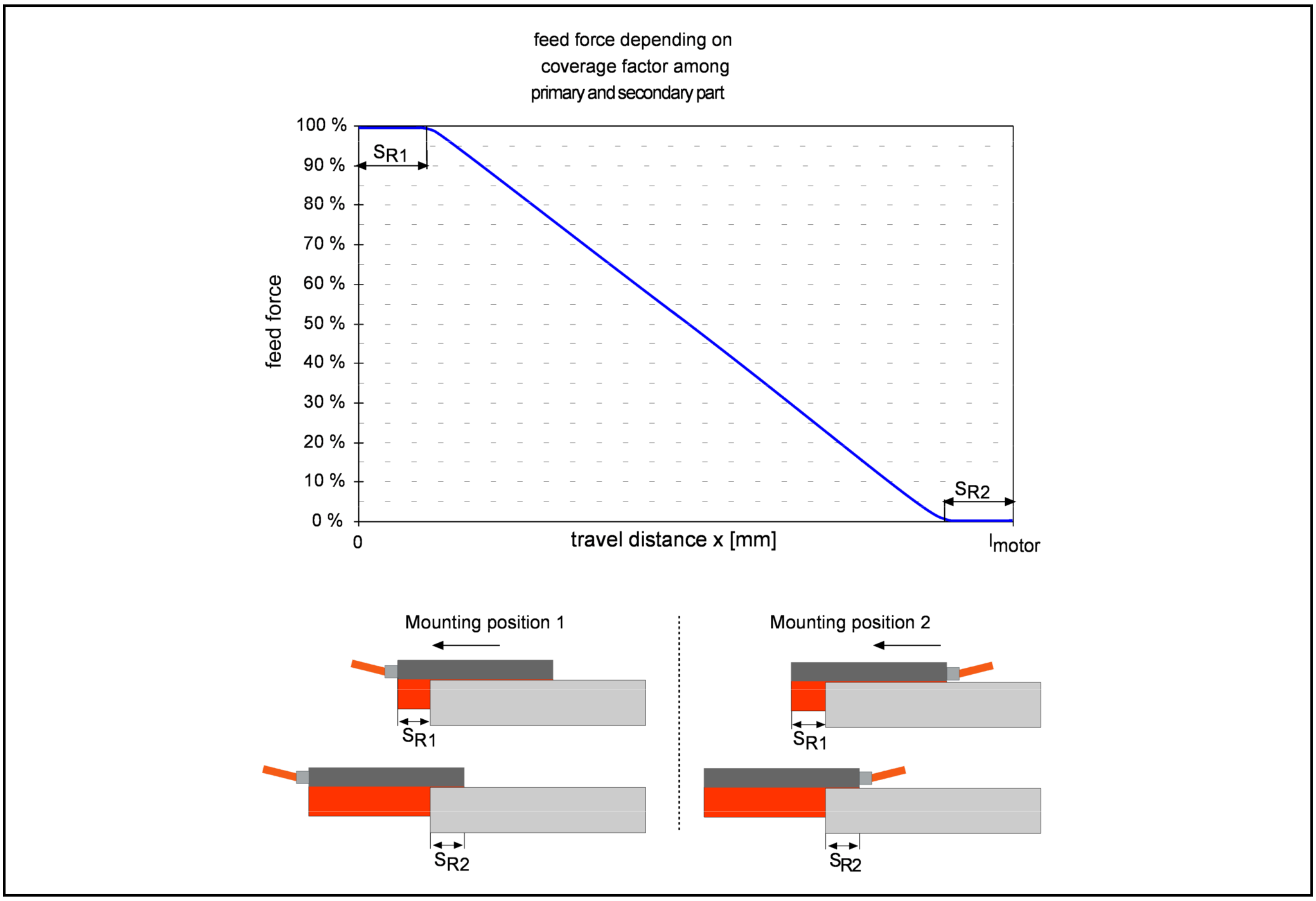


Fig. 9-13: Force reduction with partial coverage of primary and secondary part

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, the moved masses should be minimized whilst the rigidity is kept at a high level.

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. skeleton structures).

If highest acceleration is not required, even relative big mass can be moved. Precondition therefore is, a very rigid coupling of the motor to the weight.

9.12.3 Mechanical rigidity

In conjunction with the mass and the resulting resonant frequency, 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 with, as the mass increases. $f \approx \sqrt{1/m}$

Mechanically coupled axes

The elasticity´s of the axes (both, the mechanical and the control-engineering component) add up. This must be taken into account with respect to the rigidity of cinematically coupled axes.

If several axes must cinematically be coupled 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 it to vibrate.

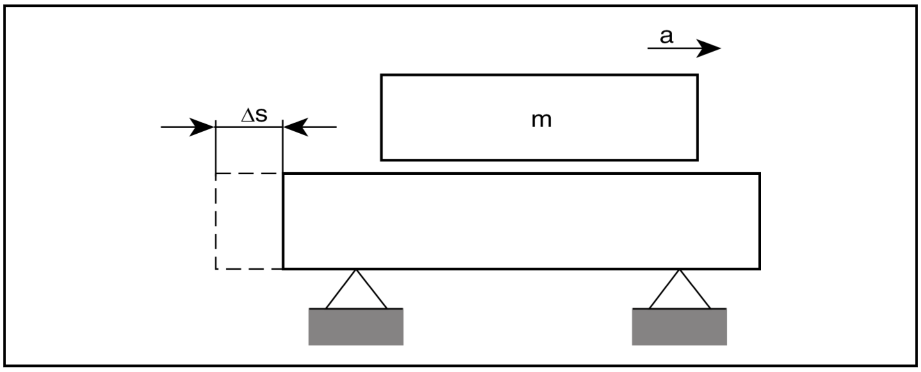


Fig. 9-14: Deformation of the machine base caused by the reactive force during the acceleration process

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

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

Fig. 9-15: Calculation example of the machine base 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 119.

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, swarfs, resirable 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 "Degree of protection" on page 102).

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

- an increased heat introduction due to friction between the motor components. Thereby, temperatures can arise, which can cause a motor damage.
- Grinding traces and /or scratch-formation on the motor components can lead, for example to destroying of casting compound on the primary part, to motor breakdown, due to high mechanical force effect.

Please observe that dirt can also be brought indirectly into via preasure 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.

9.12.5 Thermal motor connection

See information in chapter 11.7 "Thermal connection of MCL motors on the machine." on page 149.

9.13 Arrangement of motor components

9.13.1 Single arrangement

The single arrangement - independend operation of single primary parts - of the primary part is the most common arrangement. In such an arrangement, the length measuring system can also be equipped with two or more scanning heads.

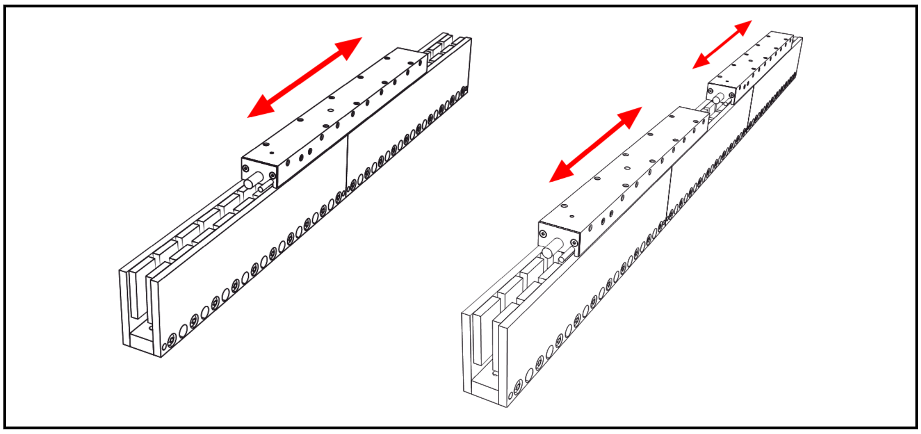
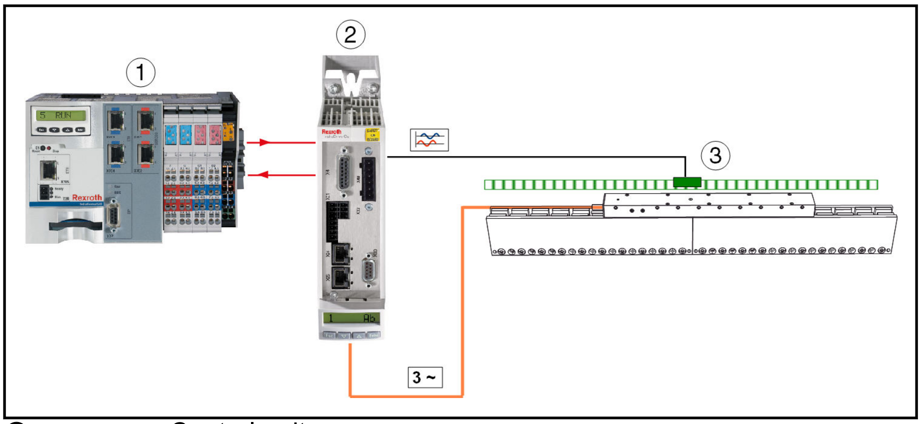


Fig. 9-16: Single axis arrangement of primary parts



① Control unit
② Controller
① Linear scale

Fig. 9-17: Controlling a linear motor with single arrangement of the motor components

9.13.2 Several motors per axis

General

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

- Multiplied feed forces
- Optimized utilization of available installation space

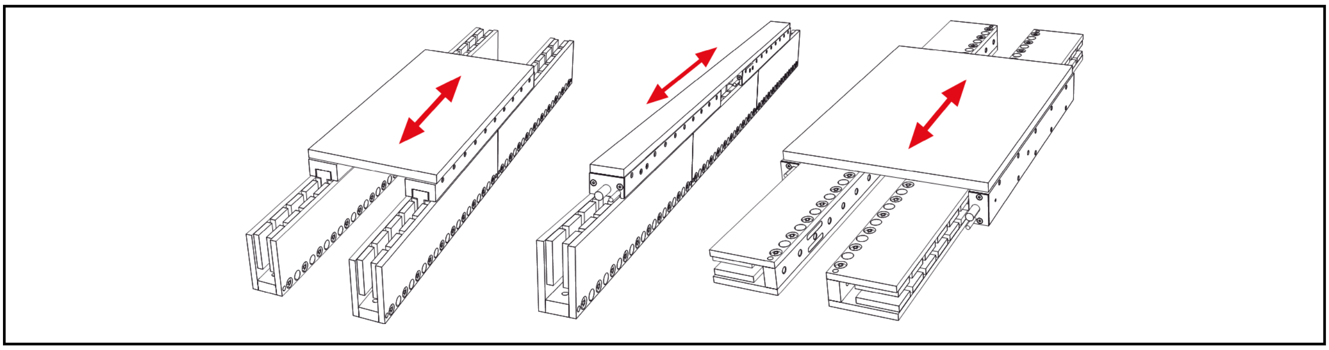


Fig. 9-18: Arrangement of several motors per axis

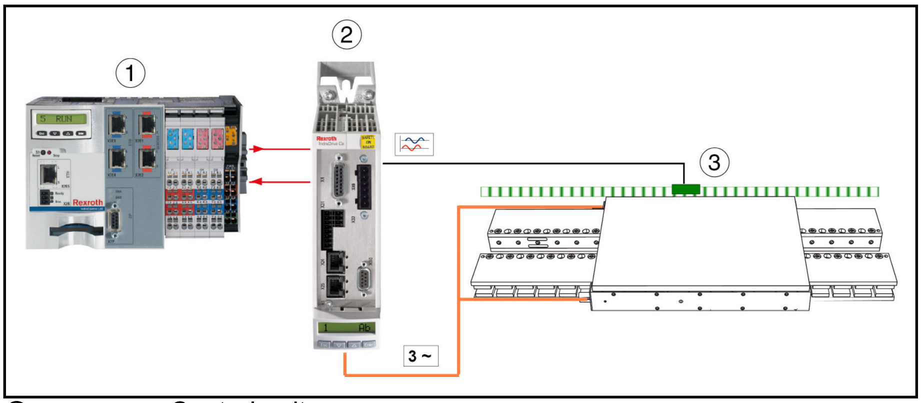
Depending on the application, the motors can be controlled in two different ways:

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

Application and construction instructions

Parallel arrangement

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
① Linear scale

Fig. 9-19: Parallel arrangement of two primary parts on one drive controller in conjunction with a length measuring system

To ensure successful operation, the primary parts must be arranged in a specific distance to each other and must fulfill the following conditions:

- 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 entry and the permissible bending radius of the power cable.

Cable outlet in the same direction

If the primary parts are arranged behind each other with the cable entries in the same direction acc. to Fig. 9-20, an integer multiple of twice the electrical pole pitch must be adhered to:

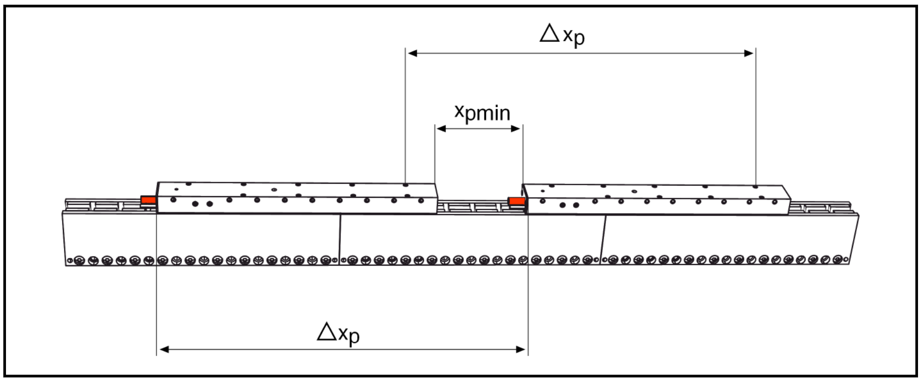


Fig. 9-20: Arrangement of the primary parts behind each other and cable entry in the same direction

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

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

☞ When you determine the correct primary part distance with cable entries in the same direction acc. to Fig. 9-20, you must always use the same reference point for both primary parts (e.g. the same fastening hole).

☞ Reference motor for determination of encoder polarity and commutation setting according toFig.9-20 is always primary part 1.

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

Δx_p Required grid spacing between the primary parts in mm
n Integer factor (depends on mounting distance)
τ_p Pole width see chapter 4 "Technical data" on page 25

Fig. 9-21: Determining the distance between the primary parts with cable entries in the same direction

Minimum distances between primary parts

According to Fig. 9-20 and Fig. 9-21 result size-related minimum distances between the primary parts at a motor arrangement with cable output into the same direction:

$$x_p = n \cdot 2 \cdot \tau_p + x_{p\min}$$

x_p Required grid spacing between the primary parts in mm
n Integer factor (depends on mounting distance)
τ_p Pole width see chapter 4 "Technical data" on page 25
x_{pmin} smallest allowed distance between the primary parts.

Fig. 9-22: Determining the distance between the primary parts with cable entries in the same direction

Cable output into the opposite direction (variant 1)

If the primary parts are arranged behind each other and with cable entries in opposite directions to Fig. 9-23, a defined distance must be kept between the primary parts according to Fig. 9-24:

Application and construction instructions

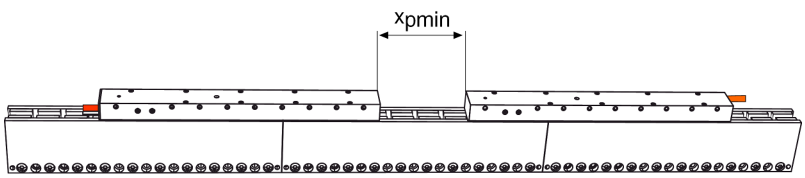


Fig. 9-23: Option 1: Arrangement of primary parts behind each other with cable entries in opposite directions

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

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

When you determine the correct primary part distance with cable entries in opposite directions according to Fig.9-23 you can only use the distance between the primary part end faces (x_{pmin}) as reference point.

The primary part 1 according to Fig. 9-23 is always the reference motor that is used for determining the encoder polarity and for commutation setting.

$$x_p = n \cdot 2 \cdot \tau_p + x_{pmin}$$

x_P Required disctance between the front faces of the primary parts in mm
n Integer factor (depends on mounting distance)
τ_P Pole width see chapter 4 "Technical data" on page 25
x_{pmin} Smallest allowed distance between the primary parts.

Fig. 9-24: Determining the grid distance between primary parts with cable entries in opposite directions

Cable output in opposite direction (option 2)

If the primary parts are arranged behind each other and with cable entries in opposite directions to Fig. 9-25, a defined distance must be kept between the primary parts according to Fig. 9-26:

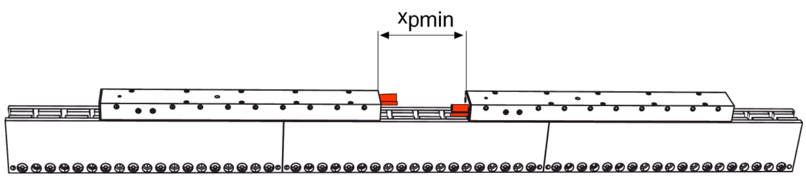


Fig. 9-25: Option 2: Arrangement of primary parts behind each other with cable entries in opposite directions

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 ... 070C/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

Tab. 9-9: Distance and phase sequence of arranged primary parts behind each other with cable entries in opposite directions (option 2)

☞ When you determine the correct primary part distance with cable entries in opposite directions according to Fig.9-25 you can only use the distance between the primary part end faces (x_{pmin}) as reference point.

☞ The primary part 1 according to Fig.9-25 is always the reference motor that is used for determining the sensor polarity and for commutation setting.

$$x_p = n \cdot 2 \cdot \tau_p + x_{pmin}$$

x_P Required grid spacing between the primary parts in mm
n Integer factor (depends on mounting distance)
τ_P Pole width see chapter 4 "Technical data" on page 25
x_{pmin} Smallest allowed distance between the primary parts.

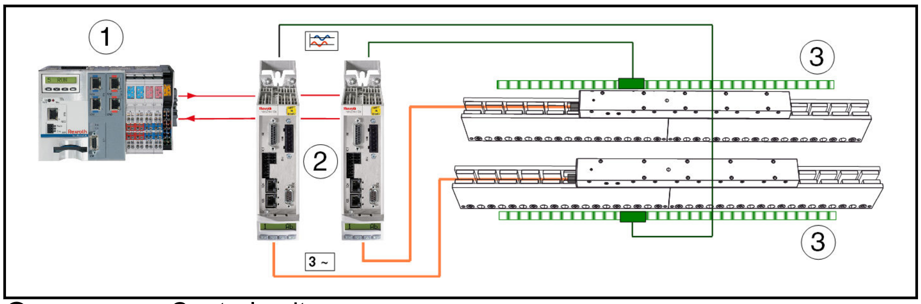
Fig. 9-26: Determining the grid distance between primary parts with cable entries in opposite directions

Gantry arrangement

Operation with two linear scales and drive controllers (Gantry arrangement) should be planned if there are load conditions that are different with respect to place and time, and sufficient rigidity between the motors cannot be ensured. This is frequently the case with axis in a Gantry structure, for example.

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.)
① Length measuring system (2 pcs.)

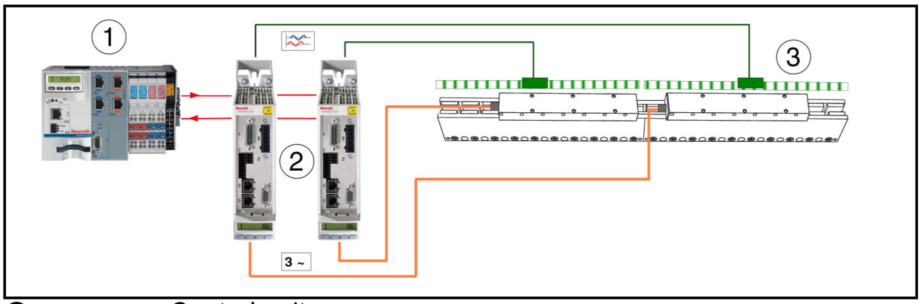
Fig. 9-27: Gantry arrangement (double comb)

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 bas load may lead to a generally higher stress than in 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 a drive-internal axis error compensation.

Arrangement of primary parts in a row (Gantry)

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



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

Fig. 9-28: 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 linear scale serves for high-resolution position sensing and to determine the current speed.

☞ 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 himself (tab. 9-10 "Manufacturers of length measuring systems" on page 120).

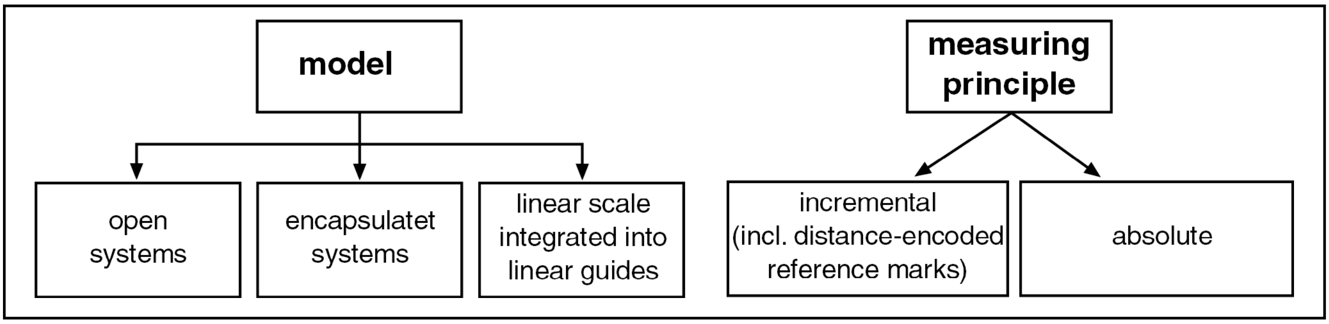


Fig. 9-29: Classification of linear scales

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 scales mainly depends on:

- the maximum feed rate (model, signal period)
- the maximum travel (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)
Renishaw GmbH	Karl-Benz Strasse 12 72124 Pliezhausen, Germany http://www.renishaw.de/
SIKO GmbH	Weihermattenweg 2 79256 Buchenbach, Germany info@siko.de http://www.siko.de/
NUMERIK JENA GmbH	Ilmstraße 4 07743 Jena, Deutschland applikation@numerikjena.de http://www.numerikjena.de/
SICK AG	Erwin-Sick-Straße 1 79183 Waldkirch, Germany http://www.sick.com/
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/

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 from the motor arrangement, are necessary due to feed forces and process forces and reachable velocity. 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

9.16 Manufacturers of linear guiding systems

☞ 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 responibility 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 9.22 "Position and velocity resolution" on page 127.

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

9.17 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 9.18 "End position shock absorber " on page 122 and chapter 9.21 "Deactivation upon EMERGENCY STOPand in the event of a malfunction " on page 124 as well as in the appropriate functional description of the drive controller.

9.18 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 this maximum deceleration is exceeded, this can lead to loosening the primary part and to damaging of motor components.

☞
- Using a suitable end stop shock absorber, the maximum permissible deceleration for moving against an end stop must be limited to **250 m/s²**.
- The necessary spring excursion of the shock absorbers must be taken into account when the end position shock absorber are integrated into the machine (in particular when the total travel path is determined).

9.19 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 contamination (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 – supportet by the corresponding specialized supplier.

9.20 Drive and control of IndraDyn L motors

9.20.1 General

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

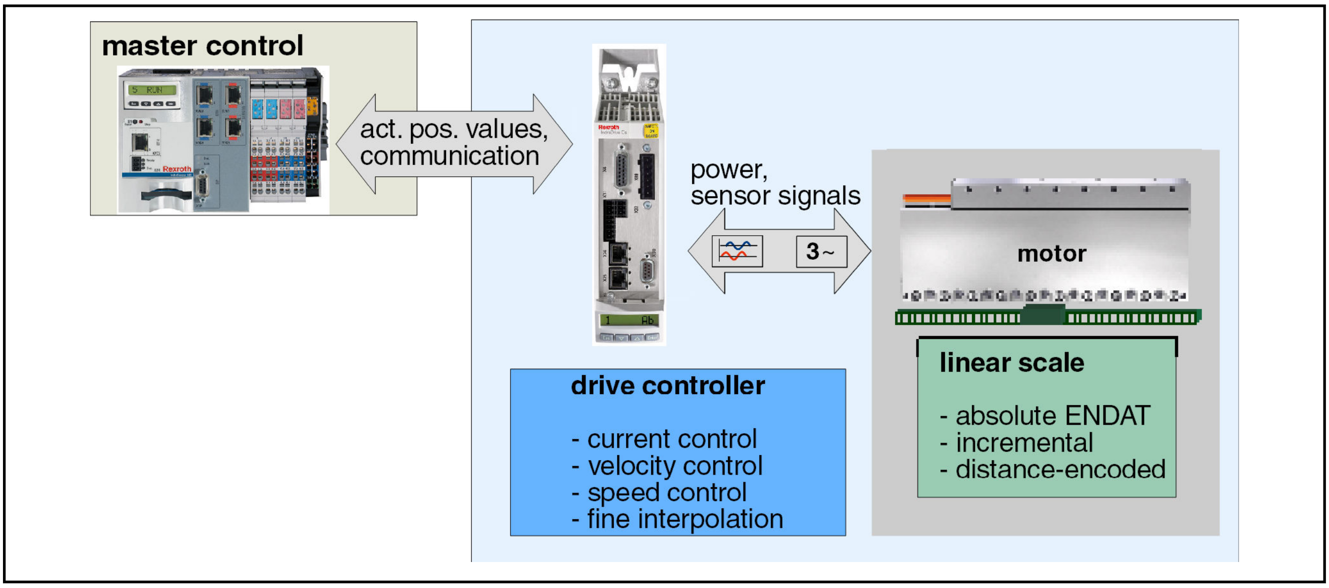


Fig. 9-30: Linear direct drive

9.20.2 Drive controllers

To control IndraDyn L motors, different digital drive controllers and power supply modules are available. (see chapter 10 "Motor-controller-combinations" on page 129)

9.20.3 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.

9.21 Deactivation upon EMERGENCY STOPand in the event of a malfunction

9.21.1 General

The deactivation of an axis, equipped with an IndraDyn L motor, can be initiated by

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

For the options of deactivation an IndraDyn L motor in the event of a malfunction, distinction must be made between

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

9.21.2 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.

9.21.3 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 deactivate 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 by the control shutdown

Deactivation by the master control 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.

9.21.4 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 contractor.

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.

9.21.5 Response to a mains

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

- either an uninterruptible 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 mains failure.

☞ 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:

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

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_{iF}	Motor constant (force constant) in N/A
R_{12}	Winding resistance at 20 °C
F_R	Frictional force in N

Fig. 9-31: 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.

9.21.6 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 the induction; thereby the motor phases are shorted. The reachable braking force is not very high and velocity-dependent. The DC bus short-circuit can therefore only be used to support existing mechanical braking devices.

9.22 Position and velocity resolution

9.22.1 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.9-33). 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 vertices (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. 9-32: Multiplication factor

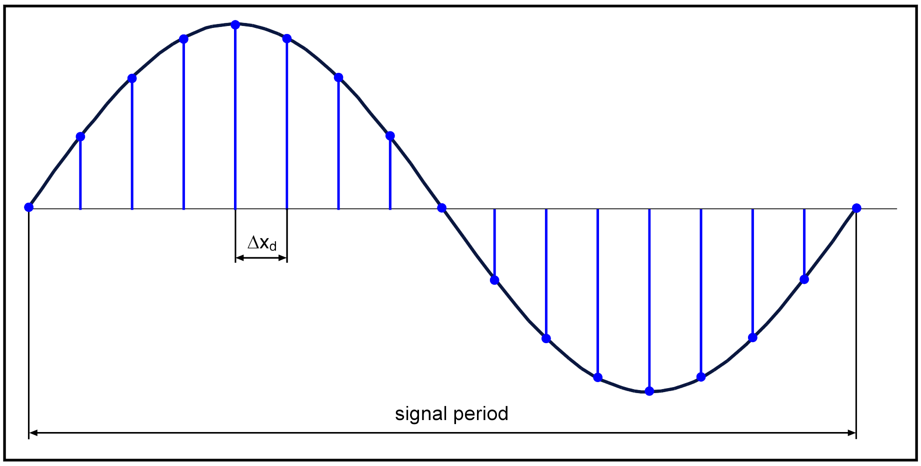


Fig. 9-33: Drive-internal multiplication and/or interpolation of the measuring system signals

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. 9-34: 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. 9-35: 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.

9.22.2 Velocity resolution

The resolution of the velocity is proportional to the position resolution (see fig. 9-34 "Drive-internal position resolution" on page 128) and inversely proportional to the sample time 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}	Sample time in s (IndraDrive: Basic Performance 250 µs / ADVANCED 125 µs)

Fig. 9-36: Velocity resolution

10 Motor-controller-combinations

10.1 General information

Technical data and figures of motor characteristic curves of the respective motors are shown in chapter chapter 4 "Technical data" on page 25.

☞ Dimensioning and selection for separate motors results from the Gantry-arrangement .

Maximum allowed DC bus voltage

For MCL motors are, depending on their size, maximum DC bus voltages defined. Please also observe the information provided in tab. 4-1 "General technical data" on page 29.

⚠ 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).

10.2 Motor-controller-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

■ Optimal combination
x Allowed combination - reduced velocity, as the DC bus voltage is reduced in opposite to the nominal voltage
\- Combination not allowed

Tab. 10-1: Motor-Controller-Combinations with NYCe 4000

10.3 Motor-controller-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

■ optimal combination
□ allowed combination
x allowed combination - but maximum force reduces, as controller is under-dimensioned.

Tab. 10-2: Motor-controller-combinations with IndraDrive Cs

11 Motor dimensioning

11.1 General procedure

The dimensioning and design of linear drives ist significantly defined by the application-related profiles of velocity, feed force and the thermal connection. The basic sequence of sizing linear drives is shown in the figure below.

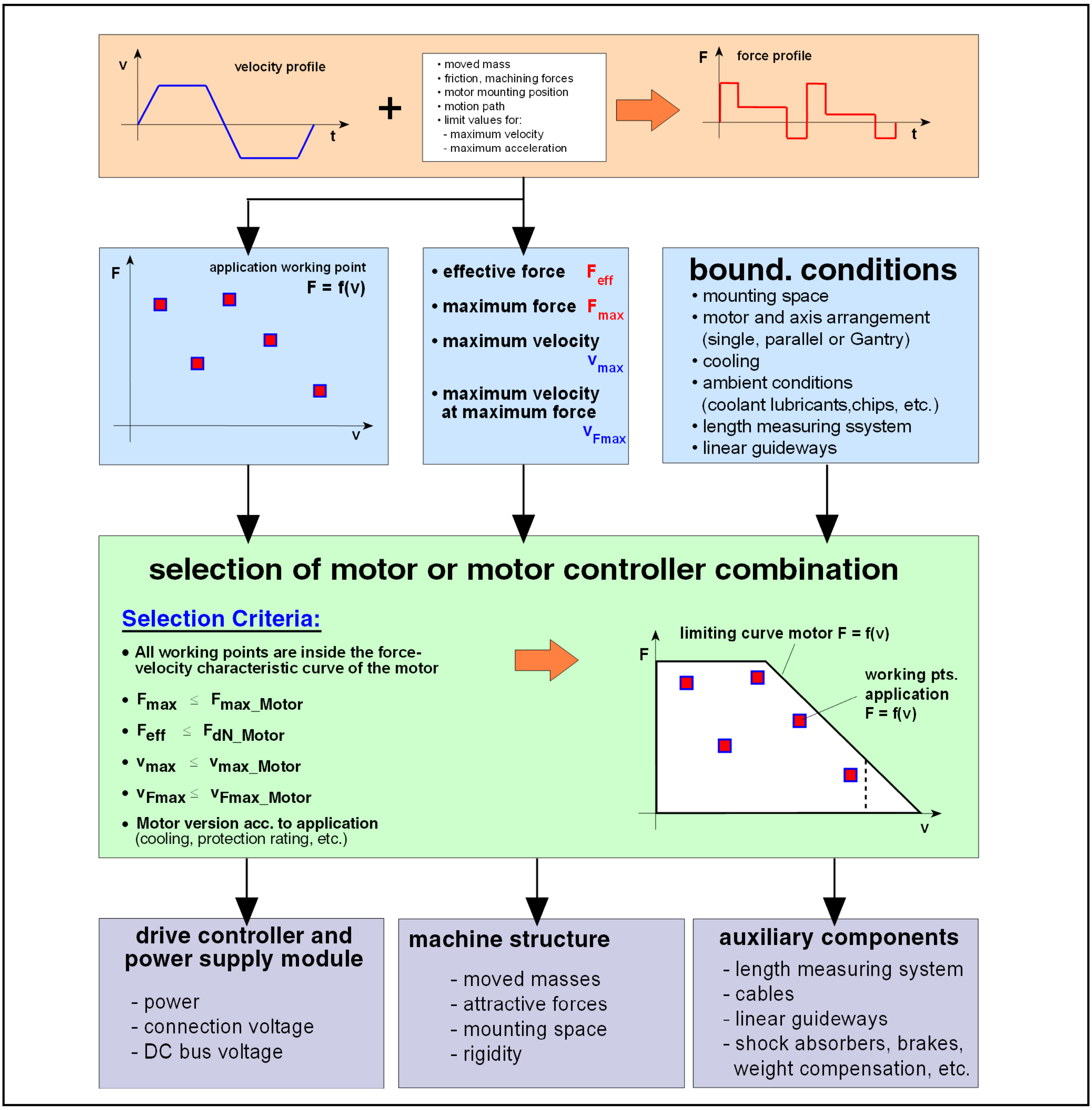


Fig. 11-1: Basic procedure of sizing linear drives

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.

☞ When linear direct drives are configured, the process-related feed forces and velocities are used directly and without conversion for selecting the drive.

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 vs. time in m/s
s(t)	Path profile vs. time in m
a(t)	Acceleration profile vs. time in m/s²
F(t)	Force profile vs. time in N
m	Moved mass in kg
F_0(t)	Base force and friction in N
F_P(t)	Process or machining 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). Using the preparatory function, velocity, acceleration and forces can be calculated. 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 velocity characteristics.

11.2.2 Feed forces

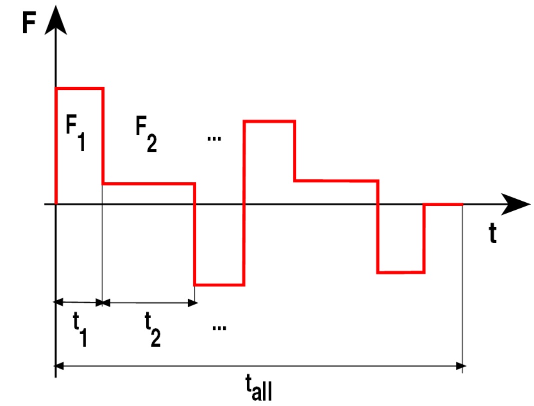


Fig. 11-3: Determining the feed forces

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

F_{ACC}	Acceleration force in N
F_W	Force due to weight in N
F_F	Frictional force in N
F_0	Additional frictional or base force in N (e.g. by seals of linear guides)
F_{MAX}	Maximum force in N
F_{EFF}	Effective force in N
F_P	Processing force in N
l	Acceleration in m/s²
m	Moved mass in kg
g	Gravitational acceleration (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 the feed forces

Motor dimensioning

☞ For sizing calculations of linear motor drives, the moved mass of the motor component must be taken into account (in particular, if the slide masses are relatively small). The moved mass is only noted after successfull motor selection. Thus, first make assumptions for these variables and verify these values after the motor has been selected.

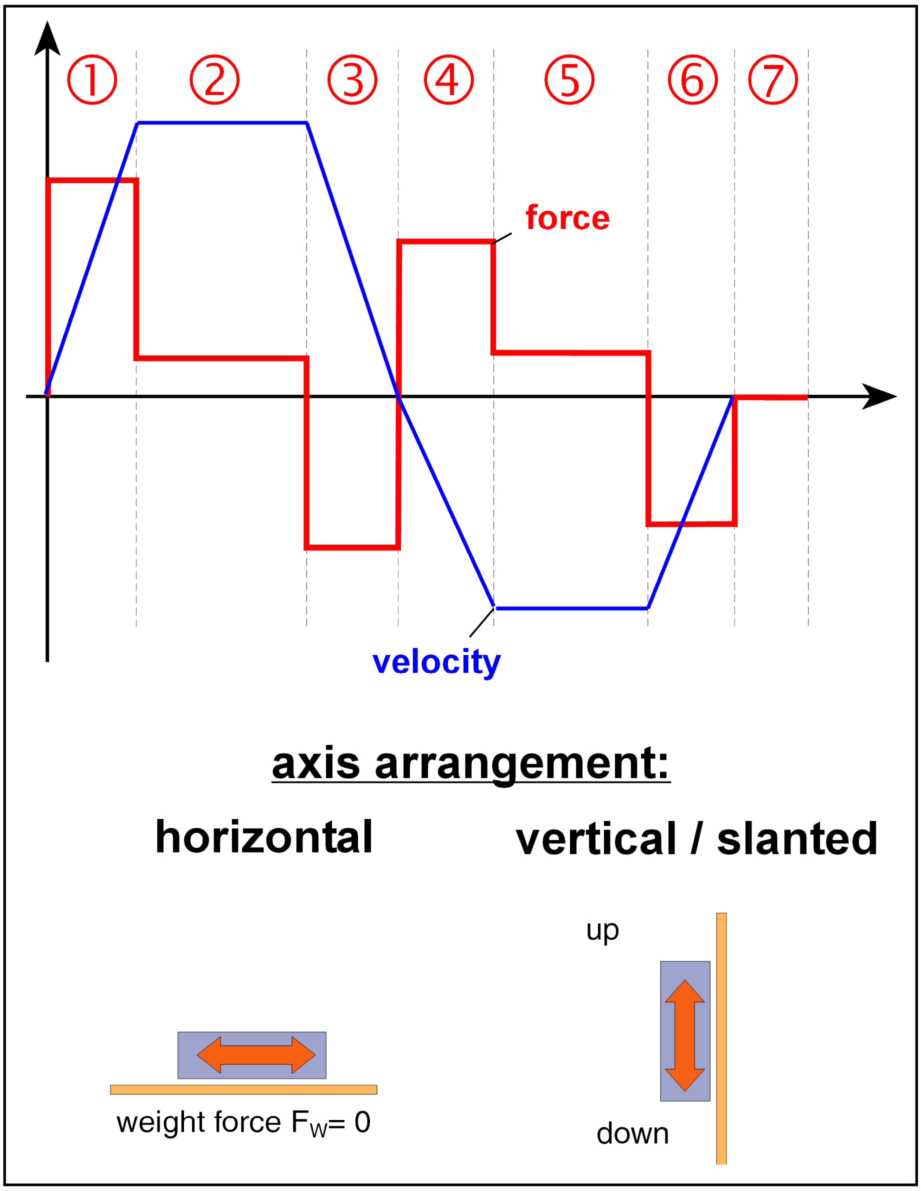


Fig. 11-5: Determining the resulting feed forces according to motion type and direction

(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 Force due to weight in N
F_F Frictional force in N

Fig. 11-6: Determining the resulting feed forces according to motion type and direction

☞ With horizontal axis arrangement, the weight is $F_W = 0$.

Further directional base and process forces must be taken into account.

11.2.3 Average velocity

The average velocity is required for determining the mechanical continuous output of the drive. fig. 11-2 "General equations of motion" on page 132 shows the general way of determining the average velocity. The following calculation can be used for a simple determination in trapezoidal or triangular velocity profiles:

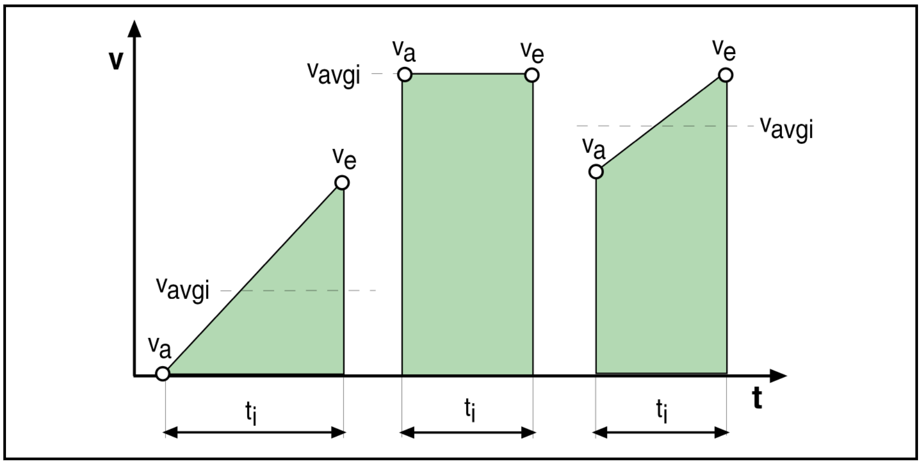


Fig. 11-7: Triangular or trapezoidal velocity profile

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

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

v_{avgi}	Average velocity for a velocity segment of the 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 duty cycle time in m/s
t_i	Duration of velocity segment in s
t_{all}	Total duty cycle time, including breaks and/or standstill time, in s

Fig. 11-8: Determining the average velocity with triangular or trapezoidal velocity profile

11.2.4 Trapezoidal velocity profile

General information

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

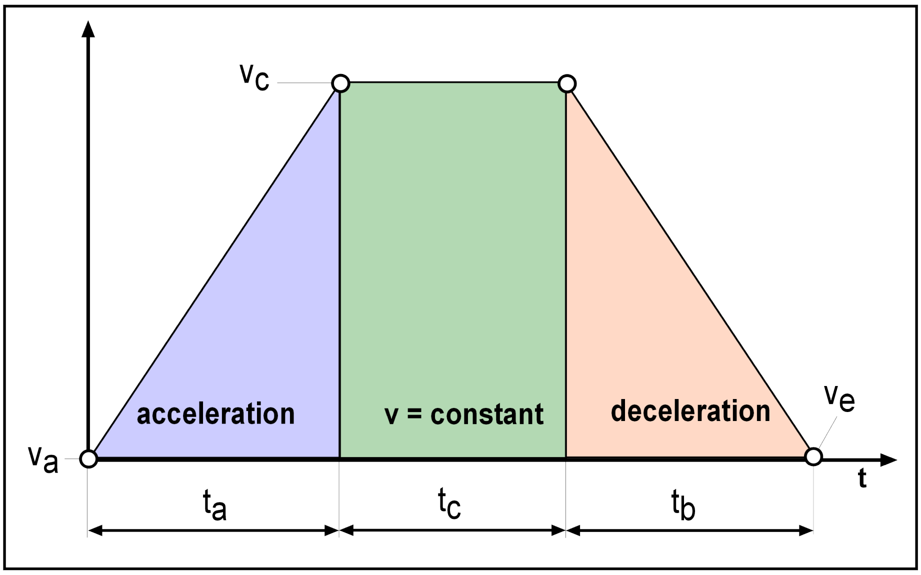


Fig. 11-9: Trapezoidal velocity profile

To determine the respective parameters acceleration a, velocity v, path s and time t for the trapezoidal drive, do a case differentiation regarding 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

Motor dimensioning

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

l	Acceleration in m/s²
v_c	Final velocity in m/s
t_a	Acceleration time in s
c	Travel covered during acceleration in m

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

Acceleration, initial velocity $v_a \neq 0$

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

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

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

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

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

l	Acceleration in m/s²
v_c	Final velocity in m/s
v_a	Initial velocity in m/s
t_a	Acceleration time in s
c	Travel covered during acceleration in m

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

Constant velocity

☞
- Velocity v = constant
- Acceleration a = 0

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

Travel: $$s_c = v_c \cdot t_c$$

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

v_c	Average velocity in m/s
t_c	Time during constant velocity in s
s_c	Travel covered constant velocity in m

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

Braking, final velocity v_e = 0

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

Motor dimensioning

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

l	Acceleration in m/s²
v_c	Final velocity in m/s
t_b	Braking time in s
c	Travel covered during acceleration in m

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

Braking, final velocity $v_e \neq 0$

☞
- Velocity v ≠ constant
- Final velocity $v_e \neq 0$
- 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:	$t_a = \frac{v_c - v_e}{a} = \frac{2 \cdot s}{v_c + v_e} = \frac{v_c - \sqrt{v_c^2 - 2 \cdot a \cdot s}}{a}$

l Acceleration in m/s²
v_c Initial velocity in m/s
v_e Final velocity in m/s
t_b Braking time in s
c Travel covered during acceleration in m

Fig. 11-14: Constantly accelerated movement, initial velocity $v_e \neq 0$ (for trapezoidal velocity profile)

11.2.5 Triangle-shaped velocity profile

In contrast to the trapezoidal characteristic, this velocity profile does not have a phase of constant velocity. The acceleration phase is immediately followed by the deceleration phase. This characteristic can frequently be found in conjunction with movements of short strokes.

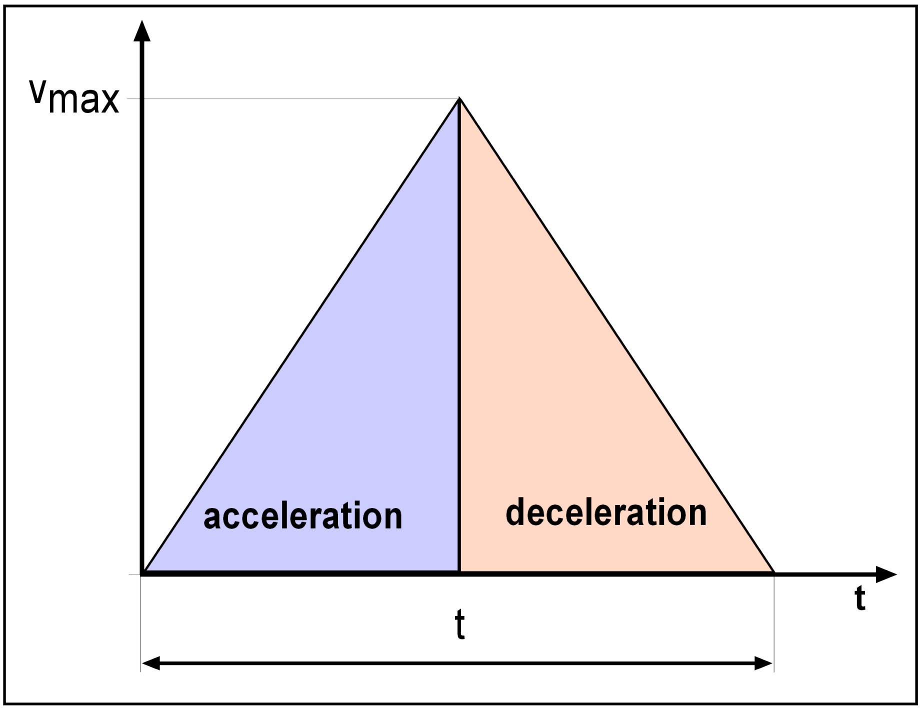


Fig. 11-15: Triangular velocity profile

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 velocity in m/s
I	Acceleration in m/s²
s_{all}	Total motion travel in m
t	Positioning time in s

Fig. 11-16: Determine triangular velocity profile

11.2.6 Sinusoidal velocity profile

This velocity profile results, for example, from the circular interplation of two axes (circular movement) or the oscillating movement of one axis (grinding, for example).

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

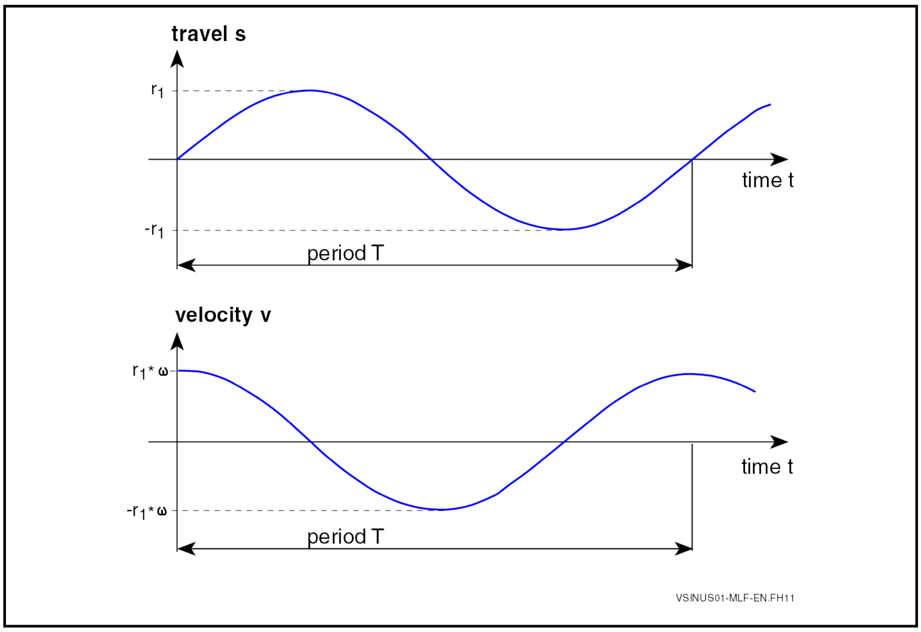


Fig. 11-17: Insert motion profiles of an axis at sinusoidal velocity.

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 development of the path
r_1	Radius
r(t)	Chronological path of velocity
t	Time
a(t)	Acceleration
ω	Circular frequency
T	Cycle duration
f	Frequence

Fig. 11-18: Calculation formula for motion profiles of an axis at sinusoidal velocity.

The following calculation bases on fig. 11-17 "Insert motion profiles of an axis at sinusoidal velocity." on page 142 and fig. 11-18 "Calculation formula for motion profiles of an axis at sinusoidal velocity." on page 143:

Motor dimensioning

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	Motion travel in one direction (or circle radius) in m
T	Period in s
m	Moved mass in kg
F_{ACC}	Acceleration force in N
F_{EFF}	Effective force in N
F_{EFFv}	Effektive force at vertical or inclined axis arrangement in N
F_0	Base force, e.g. frictional force in N
F_W	Force due to weight in N

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

☞ Further directional base and process forces must additionally be taken into account.

11.3 Duty cycle and feed force

11.3.1 General information

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. Capacity the motor with rated force is possible over the entire duty cycle time. The duty cycle must be reduced at $F > F_{dN}$ (see fig. 11-20 "Correlation between duty cycle and feed force" on page 145) in order to not thermally overload the motor at higher feed forces.

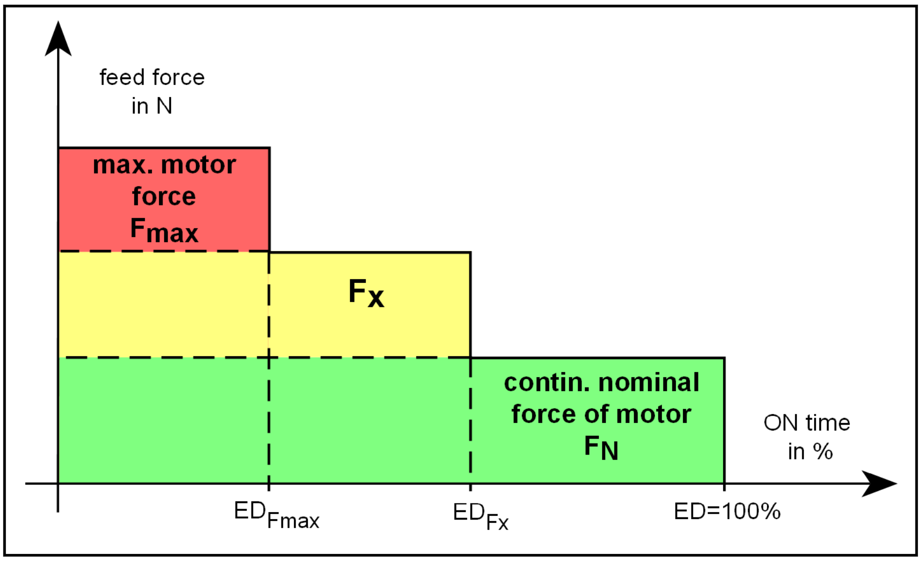


Fig. 11-20: Correlation between duty cycle and feed force

11.3.2 Determining the duty cycle

Due to the linear correlation of force and current, the detection of relative duty cycle ED_{ideal} happens 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 rated force in N
F_{MAX}	Maximum feed force

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

Use fig. 11-22 "Determining the duty cycle ED" on page 145 to determine the possible relative duty cycle.

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

ED_{real}	Possible relative duty cycle in %
P_{vN}	Maximum dissipated rated power loss 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 information

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 Rated output

The rated output 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	Rated power in W
P_{cm}	Mechanical rated output 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: Rated power of the linear motor

☞ The rated electrical output (see fig. 11-23 "Rated power of the linear motor" on page 146) is reduced when the rated force is reduced.

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.

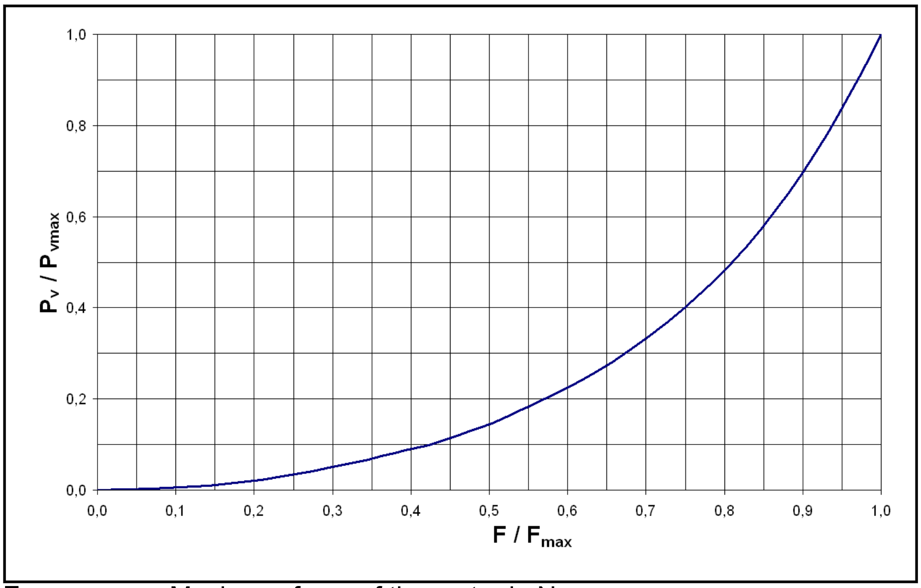
Total maximum power: $$P_{max} = P_{max\,m} + P_{max\,e}$$

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

☞ When the maximum feed force is reduced against the achievable maximum force of the motor, the electrical maximum output P_{maxe} is reduced, too. To determine the reduced electrical maximum output P_{maxe} use fig. 11-25 "Diagram used for determining the reduced electrical power loss" on page 147.



F_{max}	Maximum force of the motor in N
F	Maximum force application in N
P_{vmax}	Maximum power loss of the motor in W
P_V	Power loss of the 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 the electric continuous power loss of the motor.

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

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 servo motors, the energy of a linear motor during deceleration is lower. The translatory velocity of a linear motor is usually much lower than the circumferential speed of a rotary servo motor.

The regeneration energy of a synchronous linear drive results from the energy balance during the deceleration process. To size additional brake resistors or power supply units with feedback capability, it can be estimated as follows.

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

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

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

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

Fig. 11-27: Regeneration energy of the linear motor

Prerequisites: Velocity-independent friction

Constant deceleration

Final velocity = 0

☞ If the regeneration energy that is determined according to Fig. 11-27 is negative, energy is not fed back. This means that energy must be supplied to the motor during the deceleration process.

11.6 Efficiency

The efficiency of electrical machines is the ration between the motor output and the power fed to the motor. With linear motors, it is determined by the application-related traverse rates and forces, and the corresponding motor losses.

fig. 11-28 "Determining the efficiency of linear motors" on page 149 can be used for determining and/or estimating the motor efficiency.

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

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

Fig. 11-28: Determining the efficiency of linear motors

11.7 Thermal connection of MCL motors on the machine.

An effective power loss dissipation is precondition to reach the specified motor data. The height of the power loss in the motor is significantely defined by the utilization capacity of the motor. The motor performance depends from as good as or as fast as the power loss can be dissipated.

If the existing power loss of the motor cannot be sufficiently dissipated via the natural convection, the heat introduction via the screw on surfaces into the machine construction increases. A very good heat dissipation is reached, if the screw on surfaces of the primary part and the screw on surfaces of the secondary part are both connected with a heat-dissipating machine construction.

Please observe that an increased heat introduction into the machine construction reduced the reachable accuracy. The operating temperature of the motor winding has a vital importance when dimensioning the system with highest exactness.

With increasing winding temperature, the dissipated heat amount increases on the machine, too. If the temperature niveau of the machin must be constantly kept, the motor should be a little overdimensioned or a cooling prepared on the machine side.

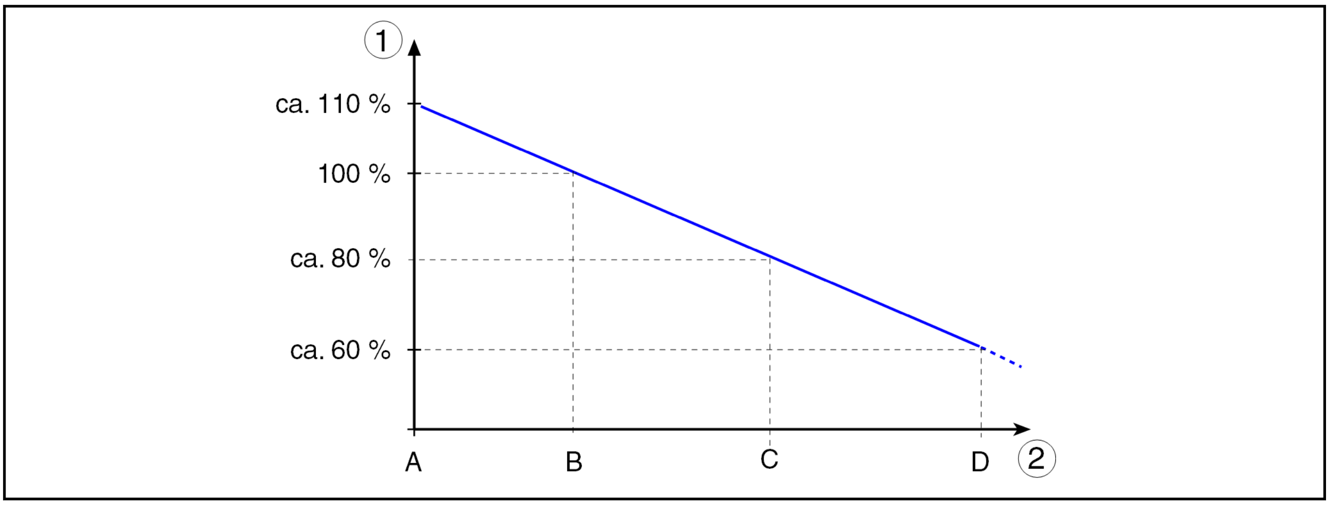
Motor dimensioning

☞ When the screw on surfaces of the motor components, especially the screw on surface of the primary part, is made of a badly heat-dissipating material (like plastics), it must be reckoned with a reduced power data of the motor.

As a general rule, the heat dissipation must increase proportional to size and length and thus the higher power loss of the motor, if the same motor utilization must be reached.

Please observe a optimal heat dissipation possibility of the motor components when dimensioning the machine . Only then, a power loss of the motor via adjacent machine parts can be guarenteed optimally.

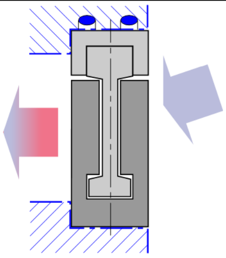
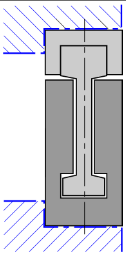
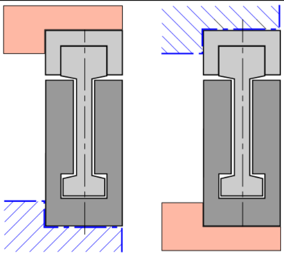
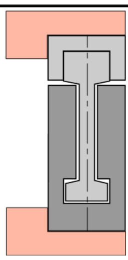
The following details should help to estimate the reachable motor power data in dependence of the thermal connection of the motor. The figured installation modes can be selected and observed at motor-controller-dimensioning in IndraSize and at commissioning in IndraWorks.



① Available motor force
② Mounting method

Fig. 11-29: Motor force dependend from the thermal connection

Explanation of installation modes

Mounting method	Schematic display	Description
A		**Installation mode A** requires a **good thermal connection** of the motor together **with an additional cooling**, e.g. by using a fan or by cooling the screw on surfaces. A metallic conducting surface is required as consistency of the screw on surfaces on the machine.
B		**Installation mode B (preferred solution)** requires a **good thermal connection**. A metallic conducting surface is required as consistency of the screw on surfaces on the machine. Technical data for this installation mode are specified in chapter 4 "Technical data" on page 25.
C		**Installation mode C** assumes that a motor component, either primary or secondary part, is thermally isolated and other components must be well-dissipating connected onto the machine. In this case, reckon with a reduced output of the motor, due to **moderate possibility of heat dissipation** of this motor component.
D		**Installation mode D** This kind of assembly is the **worst case** and you must reckon with a significant reduced output of the motor.

Tab. 11-1: Explanation of installation modes

11.8 Operation at or near motor standstill

In the case of motor operation within or near standstill observe special conditions. For means of simplification, this operation is indicated as standstill operation in the following. The 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 small frequency (f ≤ 0.1 Hz)

Due to the 3-phase system, in standstill operation always a result in one of the three phases instantaneous value of the current, which sum is higher than the permitted continuous current. Does the current flow continuously, the motor is overheated and 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 with

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

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

Fig. 11-30: Power loss coil

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

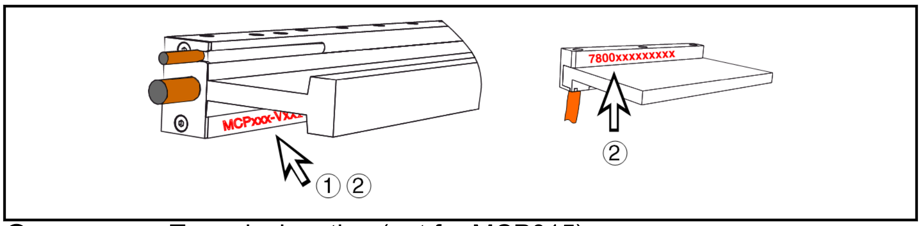
To avoid the winding to be damaged during standstill operation, limit the current or the operation duration . A possible form of an additional motor protection in standstill operation is to limit the motor current to 87% of the nominal current.

12 Handling, transport and storage

12.1 Identification of the motor components

12.1.1 Primary part

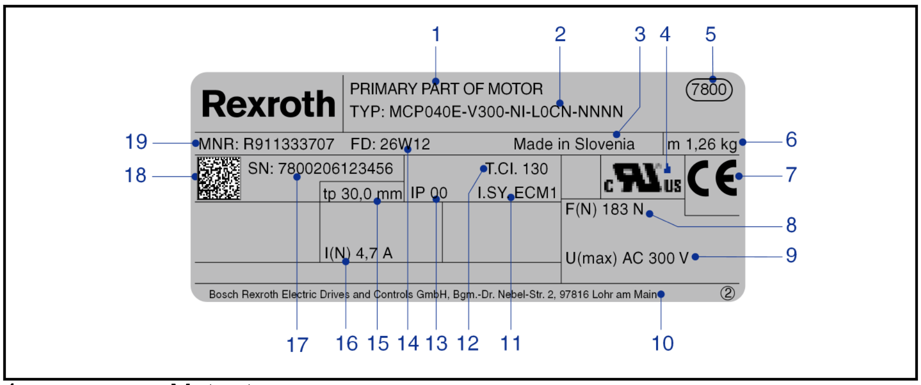
An engraved type designation is on the primary part.



①	Type designation (not for MCP015)
②	Serial number

Fig. 12-1: 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.



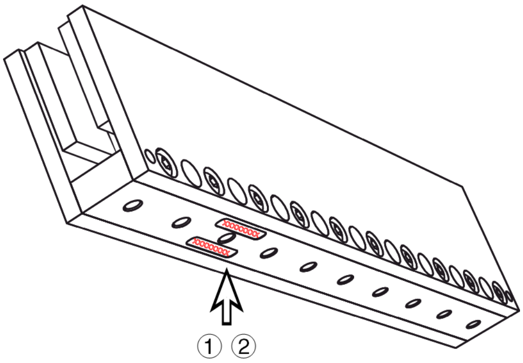
1	Motor type
2	Type designation
3	Designation of origin
4	UL sign
5	Factory number
6	Mass of primary part
7	CE sign
8	Rated power
9	Maximum input voltage
10	Company address
11	Insulation system
12	Thermal temperature class
13	Protection class by housing
14	Production date
15	Pole graduation
16	Rated current
17	Serial number
18	Rexroth bar code
19	Part number

Fig. 12-2: Type plate example of primary part

Handling, transport and storage

12.1.2 Secondary part

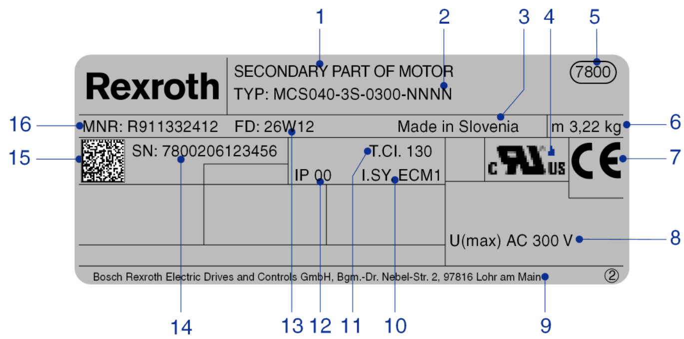
The type designation with serial number is at the bottom of the secondary part.



①	Type designation
②	Serial number

Fig. 12-3: 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	UL mark
5	Factory number
6	Secundary part mass
7	CE sign
8	Maximum input voltage
9	Company address
10	Insulation system
11	Thermal temperature class
12	Protection class by housing
13	Production date
14	Serial number
15	Rexroth bar code
16	Part number

Fig. 12-4: Example of a secondary part type plate

12.2 Delivery status and packaging

12.2.1 Primary parts

The primary parts are separately packed in a cardboard box. To identify the primary part, a type designation exist on the packaging.

12.2.2 Secondary parts

The secondary parts are separately packed in a cardboard box. To identify the secondary part, a type designation exist on the packaging.

Warnings on the packaging of the secondary parts

On the packaging of the secondary parts is a self-adhesive warning sign which indicates with the following warning notes to the dangers after opening the package and further handling of secondary parts.

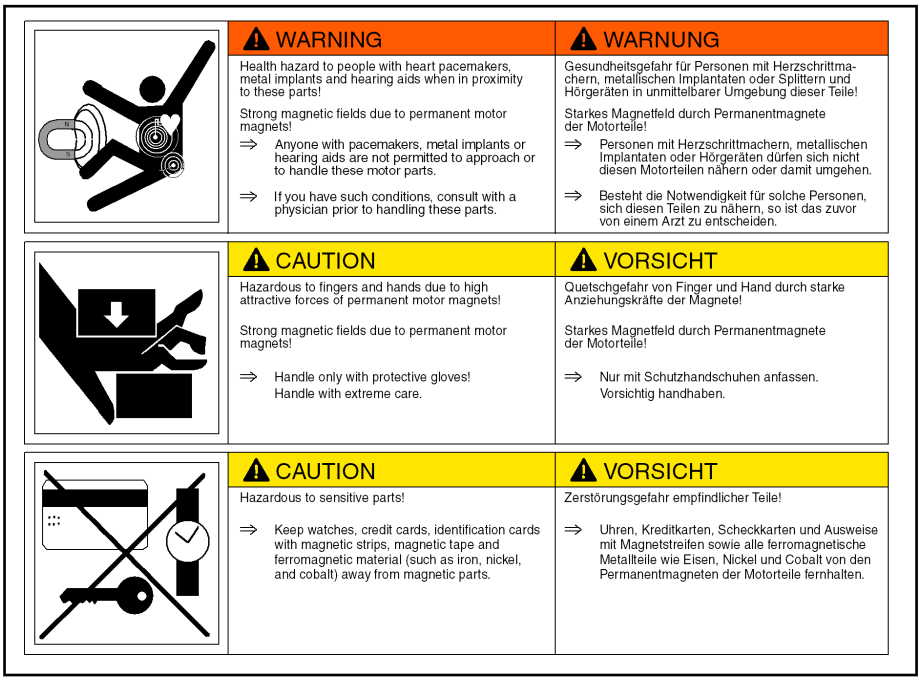


Fig. 12-5: Warning label on the packaging of secondary parts

☞ The self-sticking warning label (sizes approx. 110 mm x 150 mm) can be ordered from Rexroth (MNR R911278745).

12.3 Checking the motor components

12.3.1 Factory checks of the motor components

Electrical inspections

The Bosch Rexroth linear motors undergo the following electrical checks at the factory:

- HIgh voltage test according to DIN EN 60034-1
- Insulation resistance test acc. to DIN EN 60204-1
- Verification of the specified electrical characteristics

Mechanical inspections

The Bosch Rexroth linear motors undergo the following mechanical tests:

- Form and location tolerances acc. to ISO 1101
- Construction and fits acc. to DIN 7157
- Surface structure acc. to DIN ISO1302
- Thread test acc. to DIN 13, Part 20

☞ Each motor is accompanied by a corresponding test certificate.

⚠ CAUTION **Destruction of motor components due to improperly repeated high-voltage inspection! Invalidation of warranty!**

⇒ Avoid repeated tests.

⇒ Observe the guidelines of DIN EN 60034-1

EMV radia interference suppression

The linear motor components of Bosch Rexroth have been subjected to an EMV type test and have been certified as complying

EN 55011 Limit Class B, VDE 0875 Part 11

12.4 Transport and storage

12.4.1 Notes about transport

Transport our products only in their original package. Also observe specific ambient factors to protect the products from transport damage.

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

The inner side of the secondary parts is adhered with permanent magnets. Please observe, that no ferro-magnetic parts, like screws can fall into the air gap. Observe the warning notes on fig. 12-5 "Warning label on the packaging of secondary parts" on page 155, too.

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. Observe the detailed description of the classifications to take all of the factors which are specified in the particular class into account.

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

Classification type	Allowed class
Classification of climatic ambient conditions	2K2
Classification of biological ambient conditions	2B1
Classification of chemically active materials	2C2
Classification of mechanically active materials	2S2
Classification of mechanical ambient conditions	2M1

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

For the sake of clarity, a few essential environmental factors of the aforementioned classifications are presented below. 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 ambient factors.

Allowed transport conditions

Environmental factor	Symbol	Unit	Value
Temperature	T_T	°C	-20 ... +80 1)
Air humidity (relative air humidity, not combinable with quick temperature change)	φ	%	75 (at +30 °C)
Occurence of salt mist			Not permitted 1)

1) Differs from DIN EN 60721-3-2

Tab. 12-2: Allowed transport conditions

Air freight

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

⇒ Heed the packaging and transport instructions (IATA 953)

12.4.2 Notes about storage

Storage conditions

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

- In their original package
- At a dry and dustfree location
- At room temperature
- Free from vibrations
- Protected against light or direct insolation

On delivery, protective sleeves and covers may be attached to our motors. They must 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. Observe 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 transport acc. to DIN EN 60721-3-1

Classification type	Class
Classification of climatic ambient conditions	1K2
Classification of biological ambient conditions	1B1
Classification of chemically active materials	1C2
Classification of mechanically active materials	1S1
Classification of mechanical ambient conditions	1M2

Tab. 12-3: Allowed classes of ambient conditions during storage

For the sake of clarity, a few essential environmental factors of the aforementioned classifications are presented below. 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 ambient factors.

Allowed classes of ambient conditions during storage acc. to DIN EN 60721-3-1

Environmental factor	Symbol	Unit	Value
Air temperature	T_L	°C	-20 ... +60[1)]
Relative air humidity	φ	%	5 … 95
Absolute air humidity	ρw	g/m³	1 … 29
Condensation	- -	- -	Not allowed
Ice formation/freezing	- -	- -	Not allowed
Direct solar radiation	- -	- -	Not allowed [1)]
Occurence of salt mist	- -	- -	Not allowed [1)]

1) Differs from DIN EN 60721-3-1

Tab. 12-4: Allowed storage conditions

Storage times

Additional measures must be taken on commissioning to preserve proper functioning – irrespective of the storage time which may be longer than the warranty period of our products. However, this does not involve any additional warranty claims.

Motors

Storage time	Measures for commissioning
< 1 year	Visual inspection of all parts to be damage-free Check the electric contacts to verify that they are free from corrosion
1 ... 5 years	
> 5 years	

Tab. 12-5: Measures before commissioning motors that have been stored over a prolonged period of time

Cables and connectors

Storage time	Measures before 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, change it; otherwise check the electric contacts to verify that they are free from corrosion

Tab. 12-6: Measure before commissioning cables and connectors that have been stored over a prolonged period of time

13 Installation

13.1 Basic precondition

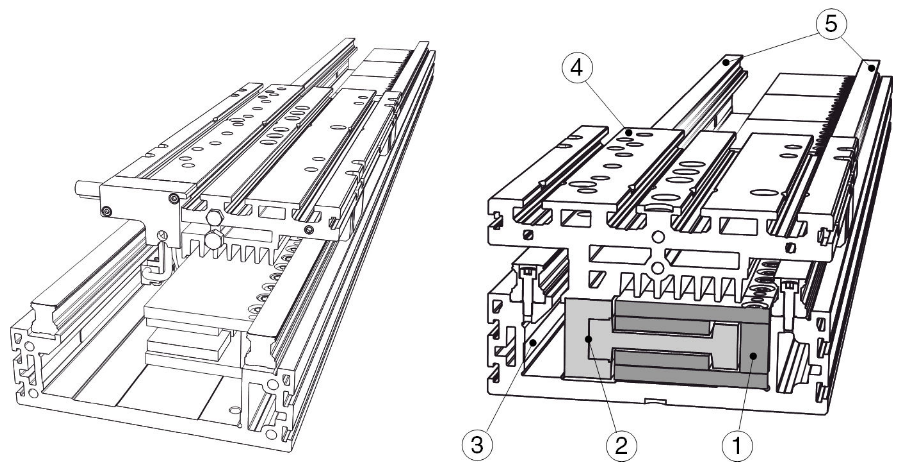
Before you begin with the assembly, you must observe or check the following points:

- Observation of the necessary installation sizes (see chapter 5.1 "Installation tolerances" on page 47)
- Machine construction fulfills the requests for mounting (stiffness, attractive force, feed force 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

When planning the machine observe and specify in which position the motor components are assembled into the machine. The stop or screw on surfaces must be prepared by the machine manufacturer for assembly of the motor components.

Basically, is no limitation regarding motor component arrangement. It can be an advantage to mount the secondary part sidewards (seefig. 13-1 "Arrangement of motor components in pre-finished compact module CKL of Rexroth" on page 159) or to the bottom that no dirt, procedding residues, a.s.o. can fall from above into the air gap between primary and secondary part. In this context, observe the notes under chapter 9.12.4 "Protection of the motor installation space" on page 112 on how to design the mounting space to protect the motor components optimally. The following figure shows a possibility how a motor can be mounted. Depending from the utilization, another arrangement can be preferred.



①	Secondary part MCS
②	Primary part MCP
③	Measuring system
④	Machine slide
⑤	Guides / profile rails

Fig. 13-1: Arrangement of motor components in pre-finished compact module CKL of Rexroth

13.3 Installation of motor components

The order of installation of motor components is depending from the machine construction or the available space in the machine. Thereby, the arrangement of the motor components play a significant role.

The following assembly examples always assume that the motors are assembled in single arrangement.

- Possibility A

  First, assemble the secondary parts. Then, slide the primary part from the side into the secondary parts and fasten it on the machine. The primary parts of the MCP015 can be inserted from above into the secondary part due to their construction (T-shape).
- Possibility B

  First, 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, assemble the remaining secondary parts.
- Possibility C

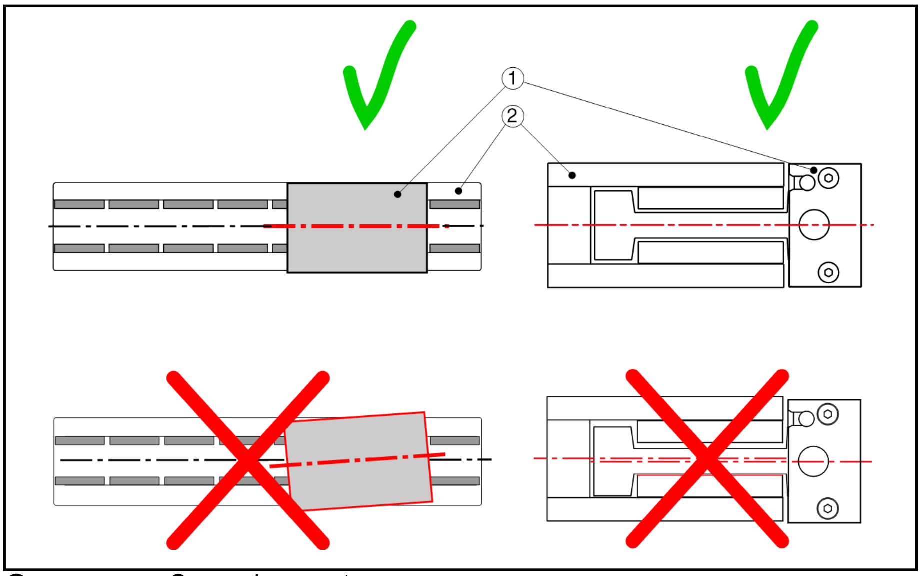
  First, assemble the primary part and then the secondary part(s).

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 (see).

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 the installation dimensions in tab. 5-1 "Mounting sizes and tolerances MCL0150" on page 48 and tab. 5-2 "Mounting sizes and tolerances MCL020 ... 070" on page 49 were kept, the correct arrangement of both motor components to each other result automaticylly.



① Secondary part
② Primary part

Fig. 13-2: Aligning the motor components

Air gap

NOTICE **Motor damage due to unsufficient air gap between primary and secondary part!**

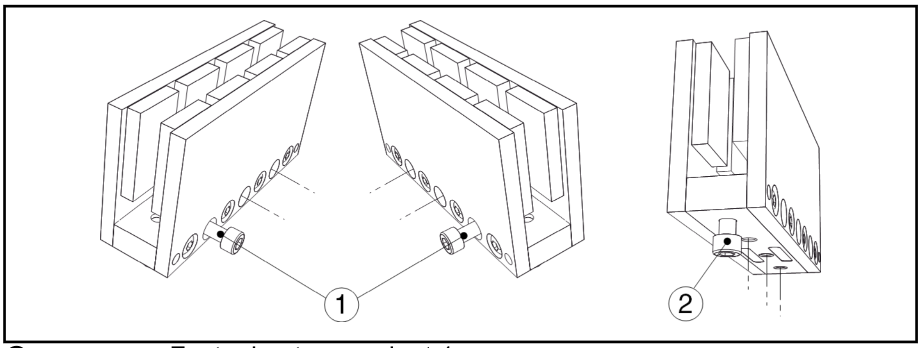
After assembly, check the free movement of the motor components to each other immediately. Therefore, move the versatile motor components by hand over the complete traverse path. The versatile motor components must be freely moveable at each position over the total traverse path - without any contact to fixed motor components. Furthermore, with this test you will detect a faulty assembly (e.g. due to dirt unter the mounting surface, faulty installation dimension, unsufficient machine rigidity etc.) in time.

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.
- All screws must be tightened with the specified tigthening torque after adjusting the secondary parts (see Chapter 13.4) Additionally secure the screw connection, e.g. 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 unsufficient 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 Variant 1	Bolt size-ISO-grade (DIN EN ISO 4762)	Property class	Tightening torque (+/-10 %)
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

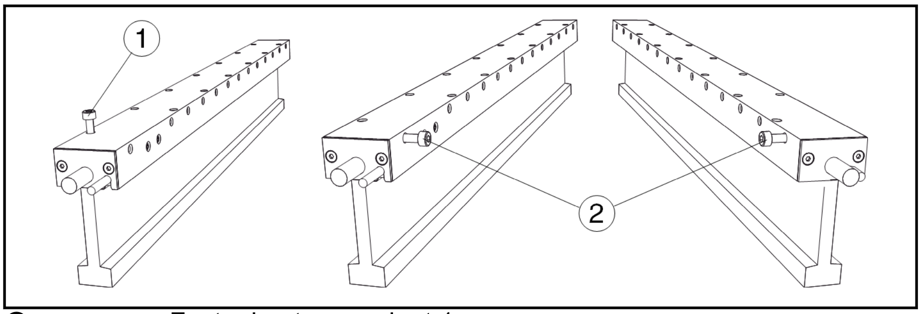
Secondary part MCS ...	Thread diameter within secondary part	Maximum screw-in depth Variant 2	Bolt size-ISO-grade (DIN EN ISO 4762)	Property class	Tightening torque (+/-10 %)
015	M4	9 mm	M4	8.8	3.1 Nm
020	M5	9 mm	M5		6.1 Nm
030	M5	9 mm	M5		6.1 Nm
040	M6	11 mm	M6		10.4 Nm
070	M8	12 mm	M8		25 Nm

Tab. 13-2: Fastening mode (variant 2) with tightening torques for MCS

The calculation of the screw connection to fasten the secondary parts is based on the presumption that both, the screw-on surfaces of the secondary part and on the machine are cleaned and the secondary part is directly screwed with the machine.

☞
- In certain cases, the secondary part cannot be screwed directly with the machine, because additional materials like distance plates, heat-conductive paste etc. are between the secondary part and the machine. Therefore, a sufficient property of the screw-connection must be ensured by the machine manufacturer.
- The effect of liquid screw locking is damaged due to loosening or re-tightening of the screws (e.g. due to torque check) and must be carried out again.
- To fasten the secondary parts, use all fastening points.

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 ...	Bolt size-ISO-grade (DIN EN ISO 4762)	Screw-in depth Variant 1	Screw-in depth Variant 2	Property class	Tightening torque (+/-10 %)
015	M3	see chapter chapter 5 "Dimension sheets" on page 47		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. Prepare threaded holes and screws for assembly.
2. Fasten the primary part with screws 1, 2, 3...x until the primary part lies on the slide.

   Fasten screws - from inside to outside - 1, 2, 3 ... x with nominal tightening torque:

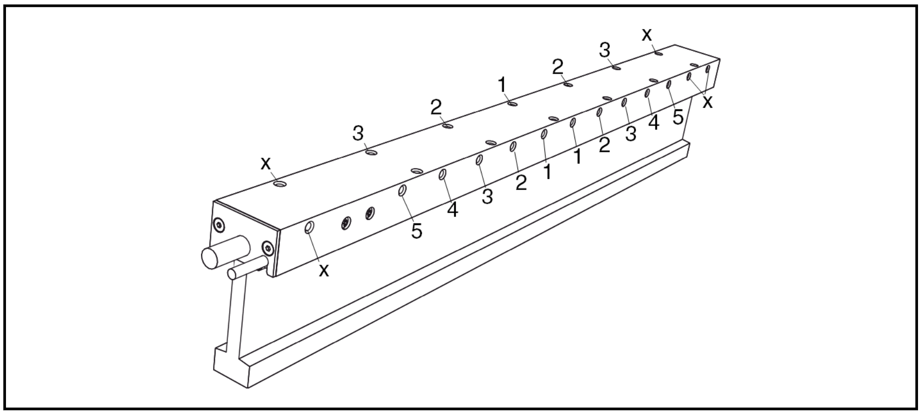


Fig. 13-5: Tightening row of screws

- To fasten the primary parts, use **all fastening points**.
- The effect of liquid screw locking Loctite 243 is damaged due to loosening or re-tightening of the screws (e.g. due to torque check) and must be carried out again.

13.7 Electrical connection

Connect the motor electrically according to the connection diagrams and the instructions in chapter 8 "Connection technique" on page 83. Observe 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. The drive components must be connected in the machine exclusively according to the machine manufacturer's system circuit diagrams.

14 Commissioning, operation and maintenance

14.1 General information for startup of ironless IndraDyn L motors

The startup of linear motors is different to the rotary servo motors. The following points have to be especially noticed when startup synchronous-linear motors.

Parameters

Synchronous-linear motors are kit motors whose single components are – completed by an encoder system – directly installed into the machine by the manufacturer. 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 start-up-program IndraWorks makes all motor parameters of Bosch Rexroth available.

Controller optimization

The procedure used for optimizing the control loops (current, velocity and position controllers) of linear direct drives corresponds to the one used for rotary servo drives. At linear drives are only the adjustment limits higher. At linear direct drives compared with rotary servo drives can be, for example, a 10-fold higher kv-factor adjusted. Precondition therefore is an appropriate machine construction (see chapter 9.12 "Requirements on the machine design" on page 110).

Moving masses

At controlled rotary servo drives are automatic-control engineering modifications at the rate of motor-moment of inertia to demand-moment of inertia. Such a modification is not available for direct drives with linear motors. The moved foreign mass is independent from the motor self-mass.

Encoder polarity

The polarity of the actual-speed (length measuring system) must agree with the force polarity of the motor. This connection has to be established before commutation-adjustment.

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. The commutation adjustment can be done after installation of the motor components and length measuring system. The way of doing the commutation adjustment complies with the measuring principle of the length measuring system.

14.2 General requirements

14.2.1 General information

The following requirements must 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
- Properly install the motor
- Properly establish the power connection of the motor
- Correct connection of the length measuring system
- Ensure proper function of existing safety limit switches, door switches, etc.
- Ensure proper function of the emergency stop circuit and emergency stop.
- Ensure proper and complete machine construction (mechanical installation)
- Availability and function of suitable end-of-stroke damper.
- Ensure proper connection and function of drive controller and control unit

14.2.3 Tools

Start-up software IndraWorks 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 When commissioning, IndraWorks requires a commercial Windows PC.

Commissioning via NC Commissioning via the NC control unit requires access to all drive parameters and functionalities.

Multimeter At troubleshooting and check of the components can be a multimeter with the possibility to voltage metering and resistor measuring helpful.

14.3 General start-up procedure

In the following flow-chart is the general start-up procedure at synchronous linear motors MCL shown. The individual items are explained in more detail in the chapters following thereafter.

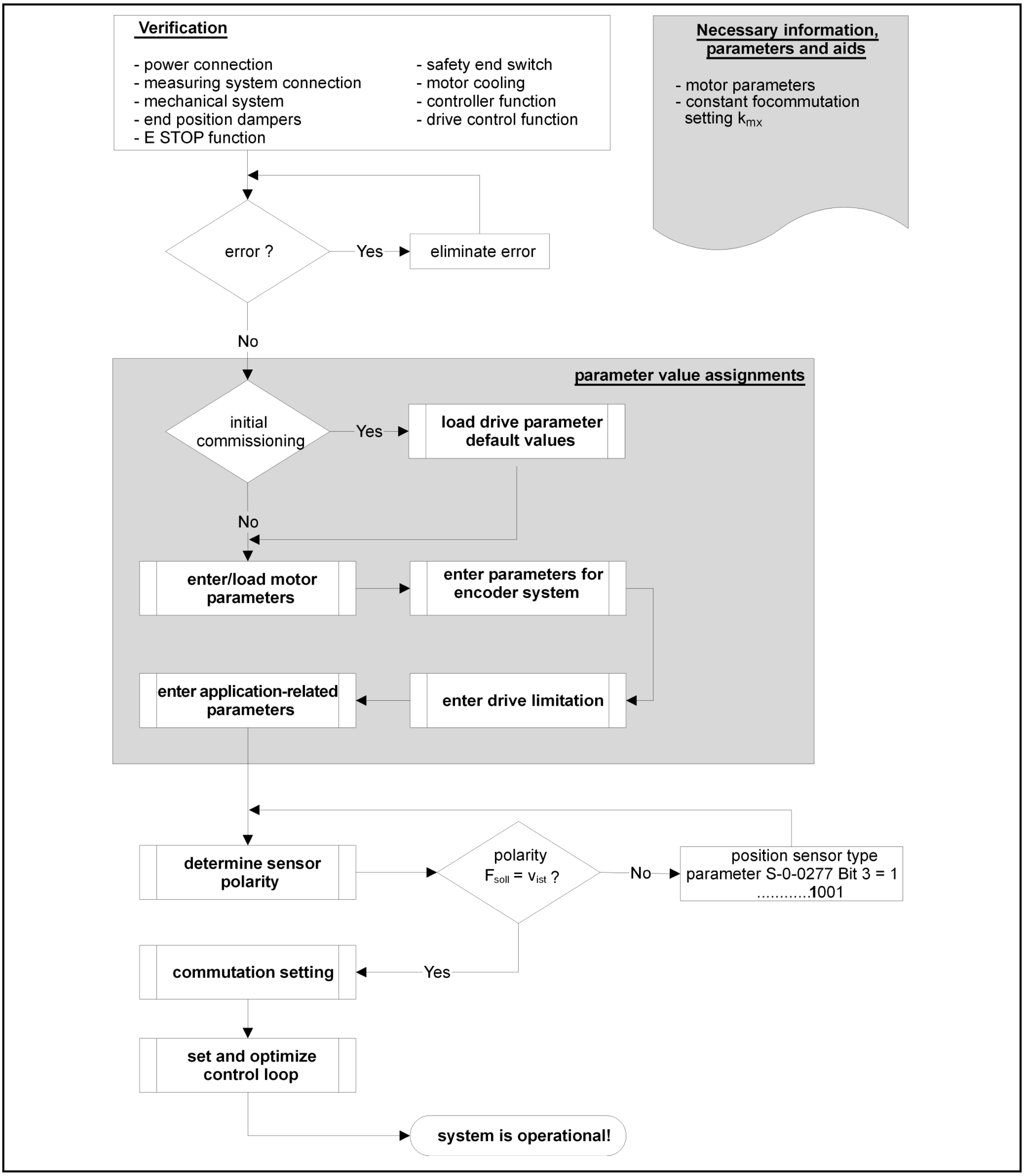


Fig. 14-1: General start-up procedure at synchronous linear motors

14.4 Parameterization

14.4.1 General information

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 may not be changed by the user. Commissioning is not possible, if these parameters are not available. 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 after the motor parameters have been entered!

⇒ Enter the parameters for the linear scale.

⇒ Check and adjust the measuring system polarity.

⇒ Adjust the commutation

The motor parameters can be entered in the following way:

- Use IndraWorks to load all the motor parameters.
- Enter the individual parameters manually via the controller.
- With series machines, load a complete parameter record via the controller or IndraWorks

14.4.3 Entering length measuring system parameter

Encoder type

The type of the linear scale must be defined. Therefore serves the parameter P-0-0074, Encoder type 1.

Encoder type	P-0-0074
Incremental measuring system	2
Absolute encoder with ENDAT interface	8
Incremental encoder with Hall sensor	14 or 15 (depending from the hardware configuration)

Tab. 14-1: Defining the encoder type

☞ Detailed information can be found in the project planning manual of the used drive controller and/or firmware

- Rexroth IndraDrive MPx-xx Parameter description, MNR R911328650
- Rexroth IndraDrive MPx-xx Parameter description, MNR R911297317
- Rexroth IndraDrive Firmware MPx-xx Funktionsbeschreibung, MNR R911328670
- Rexroth IndraDrive MPx-xx Parameter description, MNR R911326767

Signal period

Linear scale for linear motors generate and interpret **sinusoid signals**. The signal period must be entered in parameter S-0-0116, Resolution of feedback 1.

Please observe the details of the measuring system manufacturer regarding resolution of encoder signals.

14.4.4 Entering drive limitations and application-related parameters

Drive limitations

The possible selectable drive limitations 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 information can be found in the project planning manual of the used drive controller and/or firmware See also chapter 14.4.3 "Entering length measuring system parameter" on page 168.

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 linear scales must be the same.

⚠ WARNING

Different effective directions of motor force and count direction of linear scale cause uncontrolled movements of the motor upon power-up!

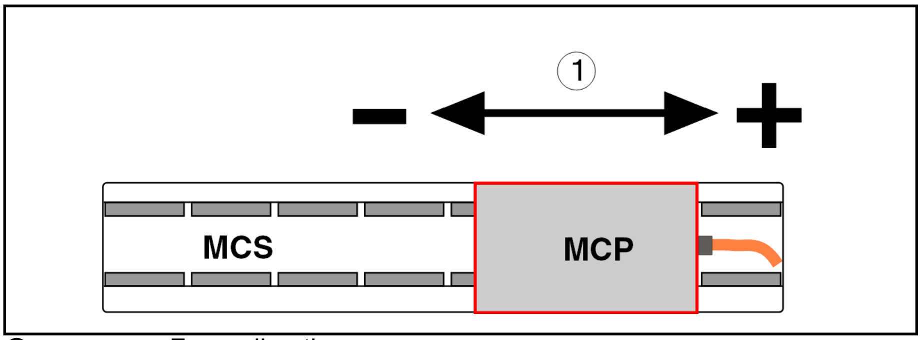
⇒ Secure the motor against uncontrolled movement

⇒ Adjust effective direction of motor force equal to linear scale count direction.

Effective direction of motor force

To set the correct sensor polarity:

The effective direction of the motor force is always positive in the direction of the cable connection of the primary part.

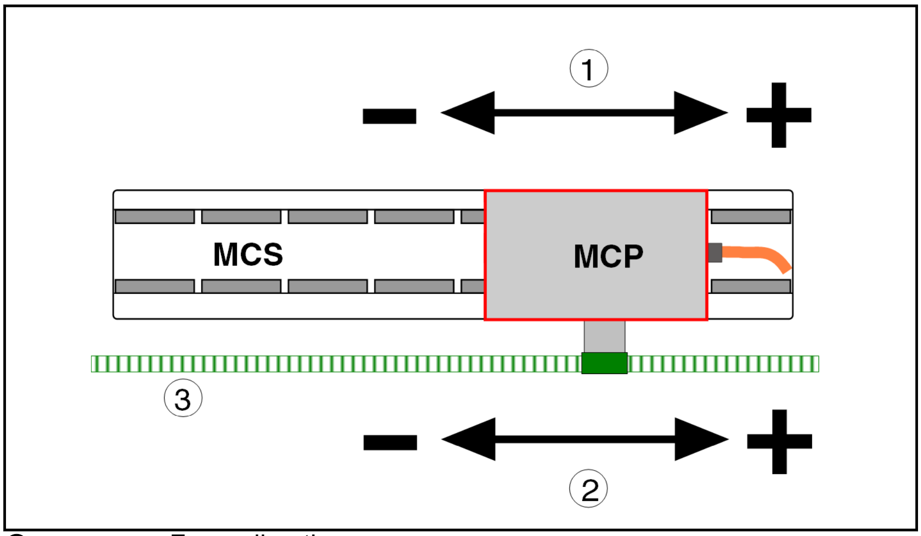


① Force direction

Fig. 14-2: Effective direction of motor force

Effective direction motor force = linear scale count direction

When the primary part is moved in the direction of the cable connection, the count direction of the linear scale must consequently be positive:



① Force direction
② Counting direction
③ linear scale

Fig. 14-3: Effective direction motor force = linear scale count direction

☞ The encoder polarity is selected via the primary part (cable connection). The installation direction or the pole sequence of the secondary part does not have any influence on the selection of the sensor polarity.

The encoder polarity is selected via the parameter

S-0-0277, position encoder type 1 (Bit 3)

Position, velocity and force data must not be inverted when the linear scale count direction is set:

S-0-0085, Torque/force polarity parameter 0000000000000000

S-0-0043, Velocity polarity parameter 0000000000000000

S-0-0055, Position polarities 0000000000000000

14.6 Commutation adjustment

14.6.1 General information

Setting the correct commutation angle is a prerequisite for maximum and constant force development of the synchronous linear motor.

☞ Commutation adjustment must always be performed in the following cases:

⇒ Initial start-up

⇒ After the mechanical attachment of the length measuring system has been modified

⇒ Replacement of the linear scale

⇒ 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 figure below shows the correlation between the employed linear scale and the method that is to be use.

Commissioning, operation and maintenance

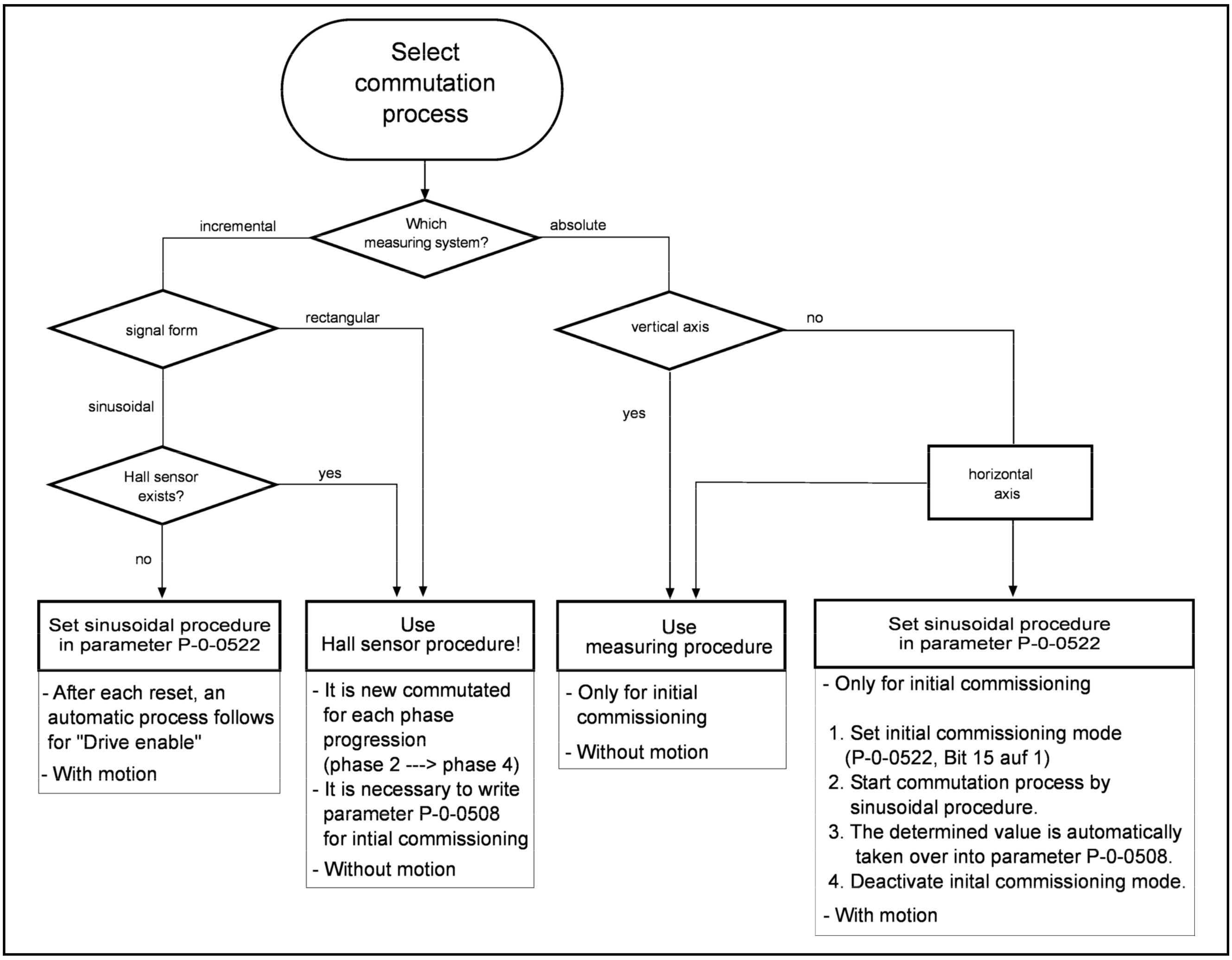


Fig. 14-4: Commutation adjustment method for ironless synchronous linear motors

☞ Observe the following requirements for commutation adjustment:

⇒ Effective direction motor force = linear scale count direction

⇒ Ensure correct motor and encoder parameterization

⇒ Follow the adjustment procedures described

⇒ Ensure reasonable parameterization of the current and velocity control loops

⇒ Correctly connect the motor power cable

⇒ Ensure protection against uncontrolled movements

⚠ DANGER

Errors in commutation adjustment may result in malfunctions and/or uncontrolled movements of the motor!

Do the commuation adjustment very carefully! Please observe the detailed notes about commutation in the documentation under chapter 14.4.3 "Entering length measuring system parameter" on page 168.

Motor connection

The individual phases of the motor power connection must be assigned correctly.

Parameter verification

To ensure a correct commutation adjustment, the following parameters should be checked again:

Identity number	Description	Description / function
S-0-0085	Torque/force polarity parameter	See parameter description • Rexroth IndraDrive MPx-xx, MNR R911328650 • Rexroth IndraDrive MPx-xx, MNR R911297317
S-0-0043	Velocity polarity parameter	
S-0-0055	Position polarities	
P-0-4014	Type of construction of motor	
P-0-0018	Number of pole pairs/pole pair distance	
S-0-0116	S-0-0016, Feedback 1 Resolution	
P-0-0522	Control word for commutation setting	
P-0-0074	Encoder type 1 (motor encoder)	

Tab. 14-2: Parameters that must be checked prior to commutation adjustment

14.6.2 Sinusoidal procedure

Limitations and detailed notes about sinusoidal procedure can be found in

- Rexroth IndraDrive Firmware MPx-xx Funktionsbeschreibung, MNR R911328670
- Rexroth IndraDrive MPx-xx Parameter description, MNR R911326767

14.6.3 Hall sensor procedure

The Hall sensor procedure is used when an incremental measuring system in connection with a Hall unit within the primary part is operated. Please also observe the information about the Hall unit provided in chapter 7.1 "Hall unit " on page 77.

Commutation via analog Hall unit

The following sercos parameter must be descripted before commissioning when a Rexroth IndraDrive Cs is operated.

Identity 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 dependend constant. It is not the real commutation offset. This is displayed after automatic calculation in parameter P-0-0521 "Effective commutation offset".

Tab. 14-3: Parameters that must be checked prior to commutation adjustment

With the aforementioned adjustments, the effective commutation offset (P-0-0521) is calculated automatically when switching into the operating mode. The drive is ready for power switch-on

☞ The procedure "Reference point - optimal commutation offset" cannot be used for analog Hall units, as the necessary parameter P-0-0508 is already used for the procedure "Commutation via analog Hall units".

Commutation via digital Hall unit

The following sercos parameter must be descripted before commissioning when a Rexroth IndraDrive Cs is operated:

Identity number	Description	Value
P-0-0509 (for MCP020)	Commutation - Offset, abrasive 1)	**946**
P-0-0509 (for MCP030 ... 070)	Commutation - Offset, abrasive 1)	**62**
P-0-0074	Encoder type 1 (motor encoder)	**23**

1) The parameter is used to enter the motor dependend constant. It is not the real commutation offset. This is displayed after automatic calculation in parameter P-0-0521 "Effective commutation offset".

Tab. 14-4: Parameters that must be checked prior to commutation adjustment

With the aforementioned adjustments, the effective commutation offset (P-0-0521) is calculated automatically when switching into the operating mode. By commutation via digital Hall unit, only an exactness of +/- 30° is electrically reached. Thereby, reckon with a maximum power loss of 14%.

The "Reference point - optimal commutation offset must be prepared that the maximum motor force is available.

Procedure on IndraDrive Cs:

1. Activate initial commissioning mode (P-0-0522, Bit 15)
2. Do the commutation adjustment via sinusoidal procedure.
3. Switch axis in "AF".
4. Start fine commutation.
5. Activate reference point drive.

   When the reference point is reached, the "Reference-point optimal commutation-offset" (P-0-0508) is stored.

6. Deactivate initial commissioning mode.

For every restart of the machine, the abrasive definition of the commutation offset (+/- 30°) is done by switching into the operating mode. The drive can drive to the reference point with reduced force, now. As soon as the reference point is reached or passed, the drive resumes the reference point- optimal commutation offset and the maximum force is available for the axis.

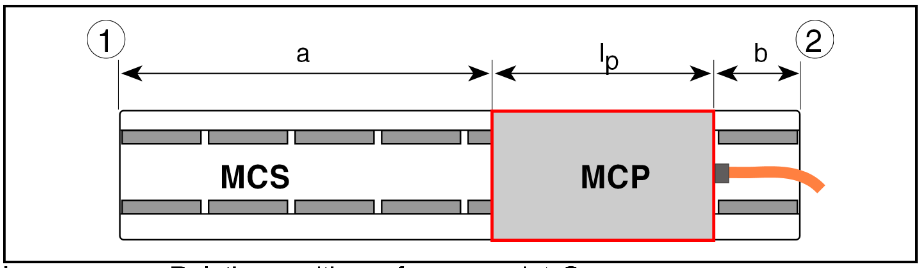
14.6.4 Measuring procedure: Measuring the reference between primary and secondary part

If this procedure is used for commutation adjustment, the relative position of the primary part with respect to the secondary part must be determined. The benefit of this procedure is that the commuation adjustment requires neither the power to be switched on nor the axes to be moved. Commutation adjustment need only be performed during the first-time commissioning.

This procedure requires an absolute length measuring system.

Measuring the relative position between primary and secondary part

Depending on the accessibility of primary and secondary part in the machine or system, the relative position between primary and secondary part can be measured in different ways.



l	Relative position reference point ①
b	Relative position reference point ②
l_P	Length primary part

Fig. 14-5: Measuring the relative position between primary and secondary part

From now on, the position of the primary part must not be changed until the commutation adjustment procedure is terminated!

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 relativce position of the primary part with respect to the secondary part (Fig. 14-5, distance d, e, f or g, depending on accessibility), and a motor-related constant k_{mx} (see Fig. 14-6 und Fig. 14-5).

$$\text{Reference point 1:}\quad P-0-0523 = a - k_{mx}$$

$$\text{Reference point 2:}\quad P-0-0523 = -b - l_p - k_{mx}$$

P-0-0523	Commutation adjustment measured value in mm
l	Relative position reference point ① in mm (Fig. 14-5)
b	Relative position reference point ② in mm (Abb. 14-5)
k_{mx}	Motor constant for commutation adjustment in mm
l_P	Length of primary part 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 be entered when the setup procedure is started.

Motor constant k_{mx} for commutation adjustment

Primary part	k_{mx} in mm
MCP020	24.1
MCP030 / 040 / 070	49.6

Tab. 14-5: Motor constant k_{mx} for commutation adjustment

Example on 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 on 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 the A0-13 state during the subsequent adjustment procedure (=ready for power connection).
2. The position of the primary part and/or the slide must not habe changed since the relative position of the primary part with respect to the secondary part has been measured.

Once the determined value P-0-0523, Commutation setting measured value, has been entered, the command P-0-0524 (D300 commutation setting command) must be started. The commutation offset is calculated in this step.

☞ If the drive is in command start "AB" (drive ready for operation), the commuation offset with the selected procedure (saturation or sinuisoidal procedure) is determined for automatic commutation.

The command must subsequently 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 of the controllers is active is defined by the operation mode.

☞ Defining the control loop settings requires the corresponding expertise.

The procedure used for optimizing the control loops (current, velocity and position controllers) of linear direct drives corresponds to the one used for rotary servo drives. At linear drives are only the adjustment limits higher.

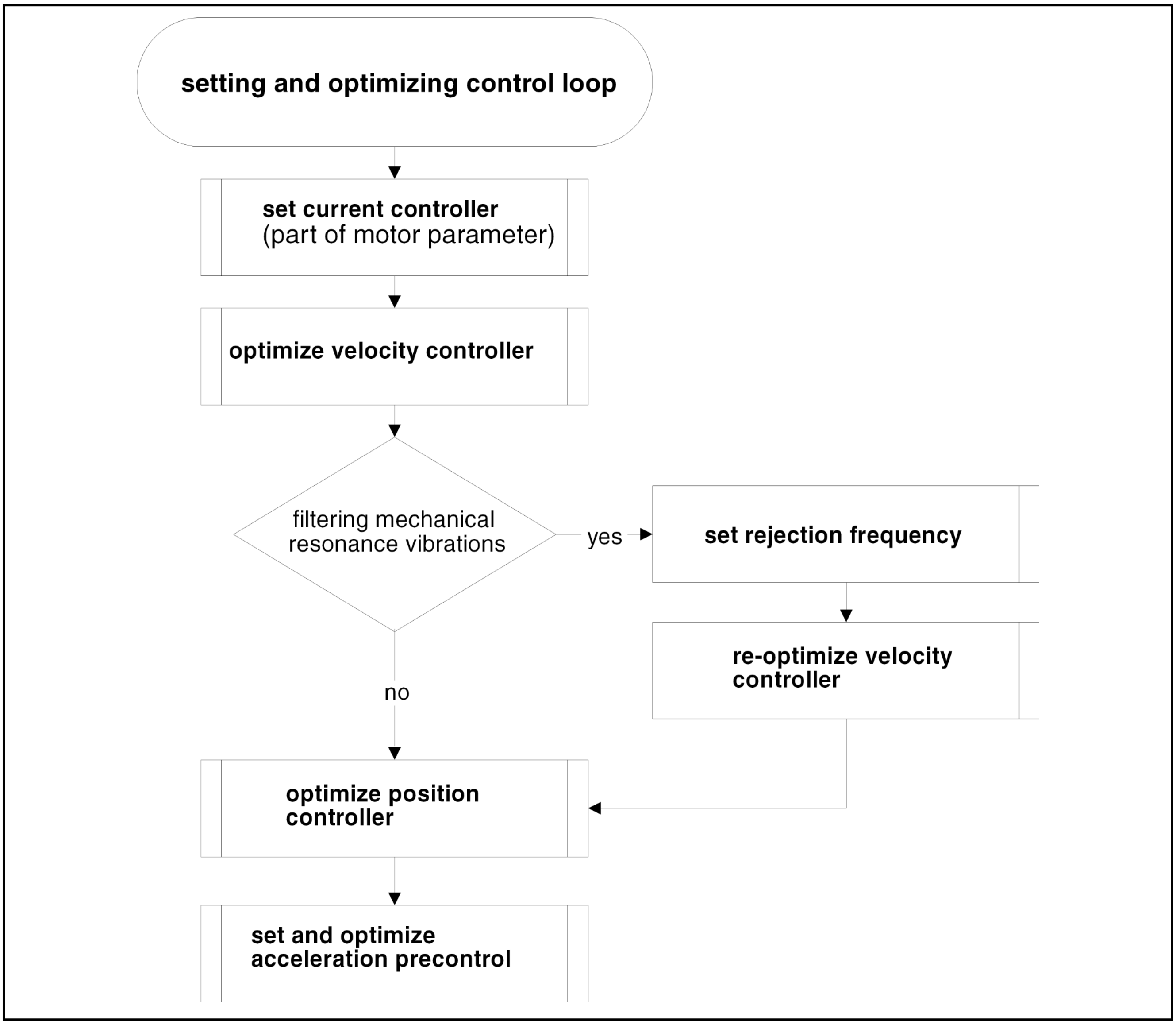


Fig. 14-7: Setting and optimizing the control loop of synchronous linear drives.

For more detailed information refer to

- Rexroth IndraDrive Firmware MPx-xx Funktionsbeschreibung, MNR R911328670
- Rexroth IndraDrive MPx-xx Parameter description, MNR R911326767

Automatic control loop setting

Rexroth drive controllers are able to perform automatic control loop adjustment.

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 position or velocity feedback in the closed control loop excites the mechanical system of the slide that is moved by the linear drive to perform mechanical vibrations. 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 highest attenuation takes effect on the rejection frequency. The bandwith defines the frequency range at which the attenuation is less than –3 dB. A higher bandwidth leads to less attenuation of the rejection frequency!

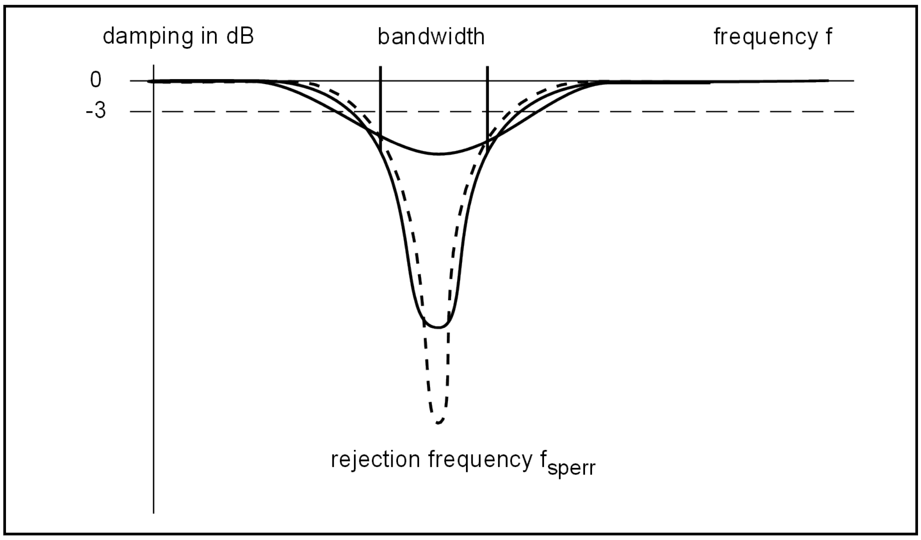


Fig. 14-8: Amplitude response of the rejection filter in relation to the bandwidth, qualitative

14.7.2 Parameterization and optimization of Gantry axes

General Information

Prerequisites:

- The parameter settings of the axes are identical
- Parallelism of the guides of the Gantry axes
- Parallelism of the linear scale
- In the controller, the axes are registered as individual axes

☞ Drive-internal axis error compensation procedures can be used for compensating the misalignments between two linear scales as or the mechanical system. Please refer to the corresponding description of functions of the drive controller for a description of the operational principle and the parameter settings.

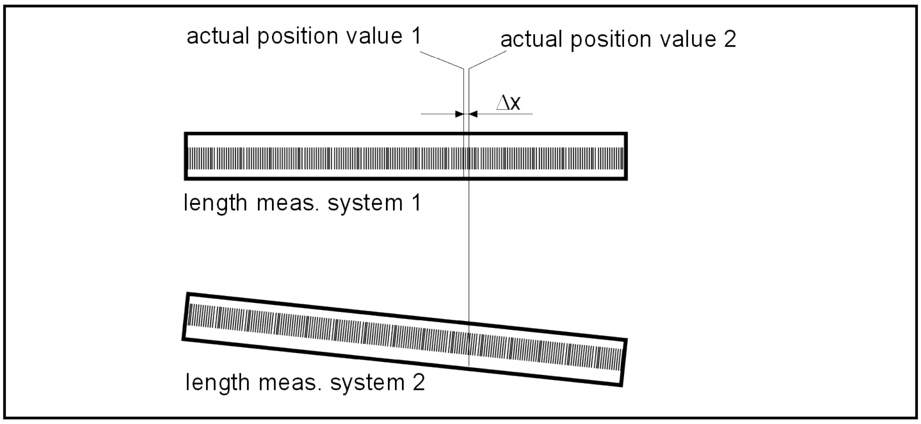


Fig. 14-9: Possible misalignment with the linear scale of a Gantry axes

Parameter settings

When using Gantry axes, your must ensure that the parameter settings of the following parameters are identical:

- Motor parameter
- Polarity parameters for force, velocity and position
- Control loop parameters

We have:

$$k_{v1} = k_{v2}$$

$$k_{p1} = k_{p2}$$

k_v Position controller kv-factor S-0-0104

k_p Velocity controller proportional gain S-0-0100

Fig. 14-10: Proportional gains in the position and velocity control loop of both axes.

Velocity controller integral time (integral part)

The following possibilities must be taken into account for the velocity controller integral time (integral part):

	Possibility 1	Possibility 2	Possibility 3	Possibility 4
Alignment of length linear scale and guides	ideal	not ideal	not ideal	not ideal
Integral Part	in both axes	in both axes	in one axis only	in no axis
Behaviour of the axes	Since both motors follow the position command value ideally, there will not be a distortion of the mechanical system	Both axes work against each other until there is an equalization via the mechanical coupling or until the maximum current of one or both drive controller(s) has been reached and a control effect is no longer possible.	The axis without integral-part permits a continuous position offset. The size of the position offset depends on the rigidity of the mechanical coupling of both axes and of the proportional gains in the position and velocity control loop.	Both axes permit a continuous position offset. The size of the position offset depends on the proportional gains in the position and velocity control loop.

Tab. 14-6: Parameterization of the velocity controller integral time S-0-0101 for Gantry-axes.

Optimization

The previously described procedure must be followed for optimizing the position and velocity loop.

☞ Any parameter modifications that are made during the optimization of Gantry axes must always be made in both axes simultaneously. If this is not possible, the parameter changes should be made during optimization in smaller subsequent steps in both axes.

14.7.3 Estimating the moved mass using a velocity ramp

Often, the exact moving mass of the machine slide is not known. Determining this mass can be made difficult by moving parts, additionally mounted parts, etc.

The procedure explained below permits the moving axes mass to be estimated on the basis of a recorded velocity ramp. This permits, for example, the acceleration capability of the axis to be estimated.

Preparation

This procedure requires the oscillographic recording of the following parameters:

- S-0-0040, actual velocity value
- S-0-0080, torque/force command value

You can either use an oscilloscope or the oscilloscope function of the drive in conjunction with IndraWorks or NC.

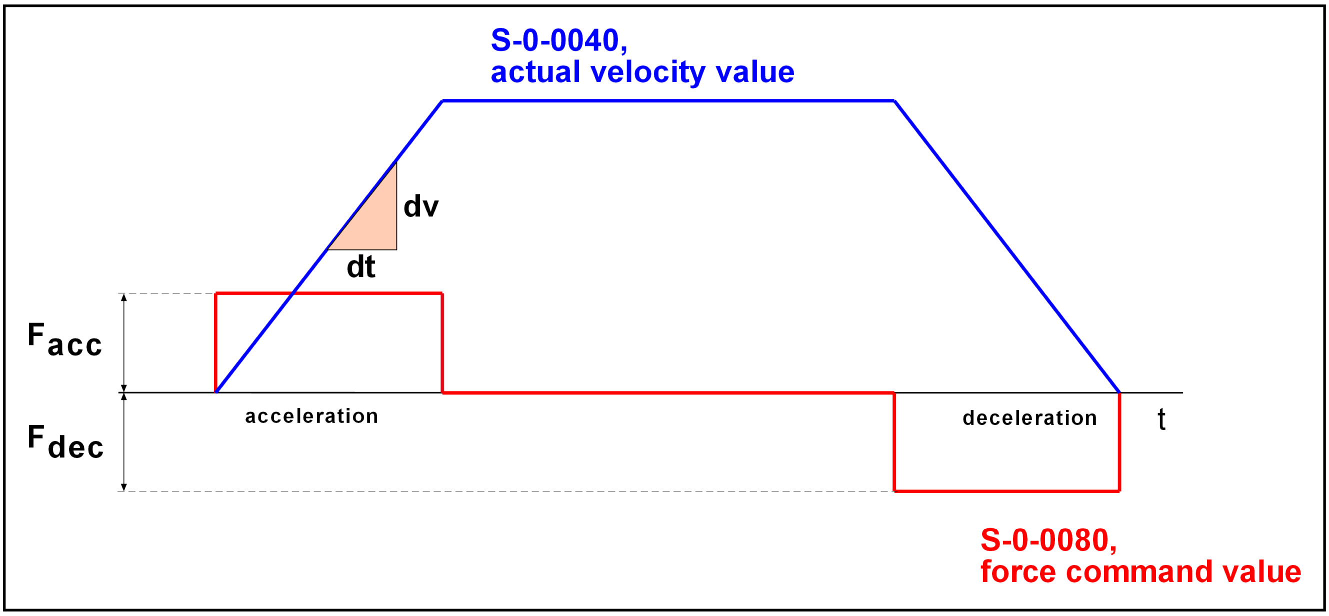


Fig. 14-11: Oscillogram of velocity and force

$$m = 30 \cdot F_N \cdot \left(\frac{F_{ACC} + F_{DEC}}{100\%} \right) \cdot \frac{\Delta t}{\Delta v}$$

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 braking in %
Δv	Velocity change during constant acceleration in m/min Acceleration in m/min
Δt	Time change during constant acceleration in s

Fig. 14-12: Determining the moved axis mass on the basis of a recorded 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. Do measuring with a motor force between F_N and F_{max}.

☞ Due to possible direction-related force variations, this procedure cannot or only conditionally be used for vertical axes.

14.8 Maintenance and check of motor components

14.8.1 General information

The motor components of IndraDyn L do not need any maintenance. Due to external influence, the motor components can be damaged during operation. There should be a preventive maintenance of the linear motor components within the service intervals of the machine or system.

14.8.2 Check of motor and auxiliary 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, swarfs, 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 linear scale (e.g. soiled)
- State of guides (e.g. deterioration of linear guides)

14.8.3 Electrical check of motor components

The electrical defect of a primary part can be checked by measuring 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 inductance

The measured values of resistance and inductance can be compared with 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.

Isolation resistance

The insulation resistance – measured between the motor connecting leads and ground – should be at least 1 MΩ (MegaOhm) The primary part must be replaced in this case.

☞ If there are and doubts during the electrical verification, please consult Rexroth Service.

14.9 Operation with third-party controllers

Rate of rise of voltage

The electrical insulation system 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.

☞ The final stages of IndraDrive converters keep this limits.

14.10 Environmental protection and disposal

14.10.1 Environmental protection

Production processes

The products are made with 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 the case of appropriate use. Normally, our products will not have any negativ influences on the environment.

Significant components

Basically, our products contain the following components:

Electronic devices
- steel
- aluminum
- copper
- synthetic materials
- electronic components and modules

Motors
- steel
- aluminum
- copper
- brass
- magnetic materials
- electronic components and modules

14.10.2 Disposal

Return of products

Our products can be returned to our premises free of charge for disposal. It is a precondition, however, that the products are free of oil, grease or other dirt.

Furthermore, the products returned for disposal must not contain any undue foreign material or foreign components.

Send 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

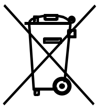
Packaging

The packaging materials consist of cardboard, wood and polystyrene. These materials 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.

The end user within the EU is legally obligated to return used batteries. Outside the validity of the EU Directive 2006/66/EC keep the stipulated directives.

Used batteries can contain hazardous substances, which can harm the environment or the people´s health when they are improper stored or disposed of.

After use, the batteries or accumulators contained in Rexroth products have to be properly disposed of according to the country-specific collection.

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 modules.

Metals contained in electric and electronic modules can also be recycled by means of special separation processes.

Products made of plastics can 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 valid legal requirements.

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)

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