MLF

Water-Cooled Linear Motors

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See tab. 1-2 "Record of revisions" on page 5.

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1 MLF Synchronous linear motors

1.1 Fields of application

Very high requirements in terms of acceleration, speed, rigidity and accuracy can often not be realized with conventional drive technology, consisting of a rotary electric motor and subsequent mechanical transmission elements such as gearbox, belt transmissions, ball-type linear drive or gear rack pinion, or only with very high effort.

Linear direct drive technology is an optimal alternative in many cases and offers decisive advantages:

- High velocity and acceleration
- Excellent control quality and positioning behavior
- High static and dynamic load rigidity – no mechanical transmission elements like ball screw, toothed belt, gear rack, etc.
- Maintenance-free drive (no wearing parts at the motor)
- Simplified machine structure

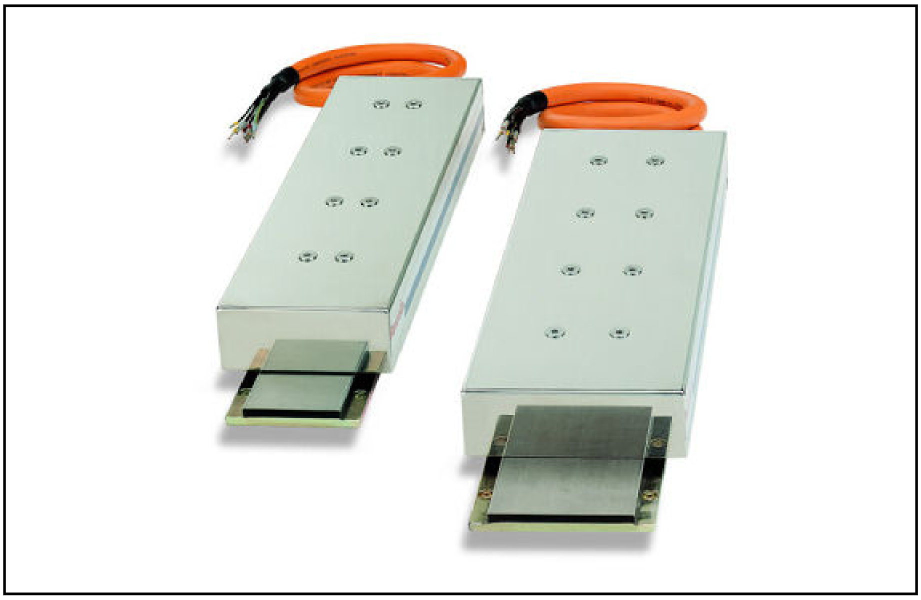


Fig. 1-1: Example of a MLFxx0 motor

Due to direct installation into the machine, wearing mechanical components are eliminated and the absence of these mechanical elements provides a backlash-free drive train with minimal or no hysteresis error. Thus, very high control qualities with gain factors in the position control loop can be achieved.

Positioning tasks with high travel speeds or rapid successive short-stroke movements with high accelerations, lead with conventional electromechanical systems to premature wear of the mechanical components and thus to failures associated with considerable costs. Linear direct drives offer decisive advantages in such applications.

Based on the above-mentioned advantages, typical applications result for linear synchronous direct drives, for example in:

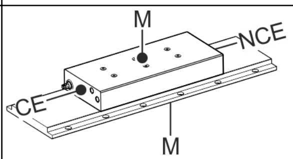
- High-speed cutting in transfer lines and machining centers
- Grinding machining, such as crankshaft and camshaft machining
- Laser machining
- Precision and ultra-precision machining

- Sheet-metal working,
- Handling, textile and packaging machines
- Free form surface machining
- Wood machining,
- Printed circuit board machining,

Linear direct drive technology offers new solutions with significantly increased performance data through a practice-oriented combination of motor technology with digital intelligent drive control units.

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 Basic features

Product	3~ PM motor
Type	MLF consists of MLP and MLS
Ambient temperature during operation	0 … 40 °C
Type of protection	IP65 (EN 60034-5)
Cooling mode	IC3W7, water cooling (EN 60034-6)
Installation altitude	0 ... 1000 m above MSL (without derating)
Thermal class	155 (F) (EN 60034-1)
Encoder system	Optional Hall sensor box
Electrical connection	Connection cable with open cable ends Shielded cable (3x power + 1x PE, 2x KTY, 2x PTC)
Mechanical protection	Stainless steel cover plate over the magnets of the secondary parts Stainless steel encapsulation of the primary parts
Thermal decoupling	Optional thermal encapsulation of primary parts
Motor ends	 **CE** Cable End, *Kabelabgangsseite* **NCE** Non Cable End, *Nicht-Kabelabgangsseite* **M** Mounting face, *Montagefläche*

1.3 Setup

Water-cooled linear motors of MLF series consist of the components primary and secondary part The primary part is the electrically active part of the linear motor. The plated iron pack carries the three-phase winding as well as the water cooling system and is encapsulated in a stainless steel housing with a plastic. The winding contains two temperature sensors. There are fastening threads for assembly into a machine at the mounting surface of the primary part.

The secondary part consists of a ferromagnetic base plate with permanent magnets. The magnets are covered with a stainless steel sheet for mechanical protection, the sealing of which complies with IP65 (water and dust). In most cases, the distance is arranged by means of serial secondary parts (short stator principle). The reverse principle is also possible (long stator principle).

A so called Hall sensor box is available.

The designation of the motor components is as follows:

- MLF: Motor linear liquid cooling (water)
- MLP: Motor linear primary part
- MLS: Motor linear secondary part

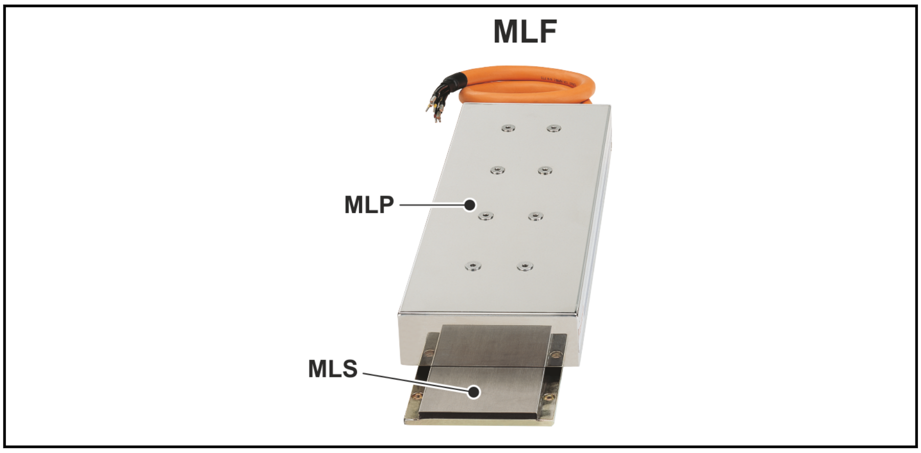


Fig. 1-2: MLF motor components

1.4 Power spectrum

The MLF water-cooled, iron-core linear direct drive technology offers new solutions through a powerful combination of motor technology with digital intelligent drive controllers. The spectrum of MLF linear drive technique of Bosch Rexroth realized drives with feed forces of 250 N up to 21,500 N, acceleration up to 250 m/s² and maximum velocity up to 600 m/min.

The following diagram gives an overview of the performance spectrum Performance spectrum:

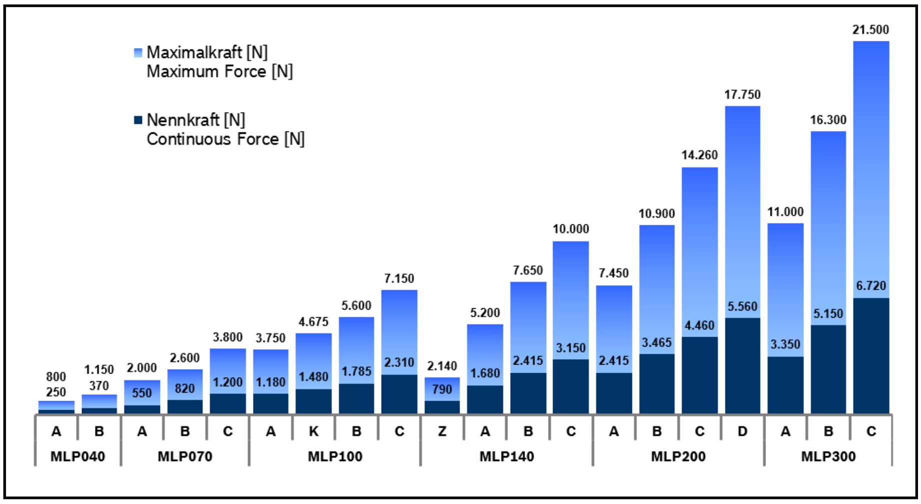


Fig. 1-3: MLFxx0 Power spectrum

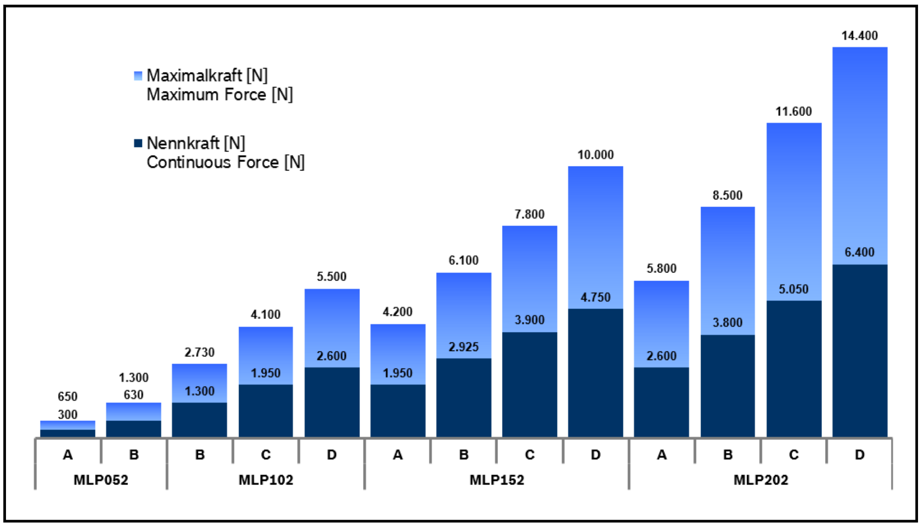


Fig. 1-4: MLFxx2 Power spectrum

MLFxx0 Features

MLFxx0 Motors are characterized by a high continuous force and a high maximum force. They have a comparatively large pole pitch of 37.5 mm. Thus, high speed can be achieved with correspondingly small frequencies. Especially the bigger frame sizes have a very high force density and thus power density. If there are no special requirements for thermal decoupling, the MLFxx0 motor can be used with primary parts in standard encapsulation This results in a reduction in overall height and reduces costs and weight both in the motor and in the machine design.

MLFxx2 Features

MLFxx2 Motors are optimized regarding synchronization characteristics. They have a force ripple that is about a factor of 3 lower than that of the MLFxx0. The magnetic circuit was changed to achieve this. The pole pitch is slightly smaller at 30.0 mm and this results in lower continuous and maximum forces for the same size. These motors can be especially used for grinding applications, for example. Here, the requirements regarding thermal decoupling are very high. Therefore, the MLPxx2 with integrated second cooling circuit are offered exclusively with thermal encapsulation.

☞ Using Bosch Rexroth drive controllers, a comparable synchronization quality can be achieved with both MLFxx0 and MLFxx2, e.g. by activating the so-called "cogging torque compensation”.

MLFxx0	MLFxx2
high continuous / maximum force	highest synchronization quality
highest power density with standard encapsulation	Integrated optimized thermal encapsulation results in lowest heat input into the machine

Tab. 1-1: Significant features of MLFxx0 and MLFxx2

1.5 About this documentation

1.5.1 Editions of this documentation

Edition	Release date	Notes
01	2004-01	First edition
02	2006-05	Revision / supplement
03	2008-05	Revision / supplement
04	2012-09	Revision / supplement
05	2016-06	Revision / supplement
06	2021-09	Revision / supplement; MLFxx2 added
07	2021-10	EAC label removed; fixing screws for secondary part adjusted

Tab. 1-2: Record of revisions

1.5.2 Document structure

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

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

Tab. 1-3: Chapter structure

1.5.3 Information presentation

Safety instructions

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

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

⚠ DANGER

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

⚠ WARNING

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

⚠ CAUTION

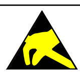
Non-compliance with this safety instructions **can** result in moderate or minor personal injury.

NOTICE

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

Safety symbols

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

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

Tab. 1-4: Meaning of safety signs

Markup

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


Reference to supplementary documentation

☞ This note gives important information, which must be observed.

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

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

1.5.4 Further documentation

To plan the drive-systems with MLF motors, additional documentation referring to the used devices may be required. 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

1.5.5 Standards

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

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

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

E-Mail:postmaster@beuth.de

1.5.6 Additional components

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

For references to manufacturers, please refer to chapter 14 "Appendix" on page 311.

1.5.7 Your feedback

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

Please send your feedback to:

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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. The products are tested prior to delivery to ensure operational safety and reliability.

⚠ WARNING **Improper product handling may result in personal injury and property damage!**

Only use the products as intended. If they are not used as intended, situations may arise resulting in personal injuries and property damage.

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

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

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

2.1.2 Areas of use and application

Synchronous linear motors of the MLF series of Bosch Rexroth are determined to be used as linear servo drive motors.

For application-specific use of the motors, drive controller types with different drive power and different interfaces are available.

For regulation and controlling of motors, additional sensors like length measuring systems must be connected.

☞

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

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

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

2.2 Inappropriate use

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

MLF motors may not be used, if

- they are exposed to operating conditions that do not meet the specified ambient conditions. For example, they may not be operated under water, under extreme temperature fluctuations or extreme maximum temperatures;
- the intended application range is not explicitly approved for Bosch Rexroth motors. Therefore, please carefully follow the specifications outlined in the general safety instructions!

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

Trademark right third parties

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

3 Safety notes for electric drives and controls

3.1 Term definition

System 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.

Electrical 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.

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

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

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

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

Manufacturer The manufacturer is 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.

Components 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.

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.

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 personnel 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

Control system

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

3.2 General information

3.2.1 Using the Safety instructions and passing them on to others

Do not 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 Danger-related notes

3.3.1 Protection against touch of electric parts and housings

☞ This section concerns components of electric drive and control systems with a voltage **over 50 volt.**

In the case of touching parts with a voltage higher than 50 volt, this can be dangerous for personnell and can lead to electric shock. During operation of components of electric drive and control systems, certain parts of these components are inevitably under dangerous voltage.

High electrical voltage! Danger of life, risk of injury due to electric shock or heavy bodily harm.

- Operation, maintenance and/or repair of components of electric drive and control systems may only be done by qualified personnel.
- Observe the general construction and safety instructions about work on high voltage systems.
- Before switching on, establish the fixed connection of the protective conductor to all electric components according to the interconnection diagram.
- Operation, even for short-term measuring and testing purposes, is only permitted with the protective conductor securely connected to the component points provided.
- Disconnect electric components from the mains or from the power supply, before you have contact with electric parts with a voltage higher than 50 V. Secure the electric components against restarting.
- Observe for electrical components:

  Please, always wait **30 minutes**, after switch-off, so live capacitors discharge before they have access to electric components. To exclude any danger due to any contact, measure electric voltage of live parts before working.
- Before switch-on install the provided covers and protective devices for the touch guard.
- Do not touch any electric junctions of live components.
- Do not disconnect or connect connectors under voltage.

High housing voltage and high discharge current! Danger! Risk of injury due to electric shock!

- Before switch-on and start-up, ground or connect the components of the drive and control system with the protective conductors on the grounding points.
- Connect the protective conductors of the electric drive and control systems always fix and continuously with the external supply network.
- Do a protective conductor connection with a minimum cross section according to the following table.

Cross-sectional area A of the live wires	Minimum cross-sectional area A_{PE} of the protective conductor
A ≤ 16 mm²	A
25 mm² < A ≤ 50 mm²	25 mm²
50 mm² < A	A / 2

Tab. 3-1: Minimum cross-section of protective conductor connection for motors

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

3.3.4 Protection against magnetic and electromagnetic fields

Magnetic and electromagnetic fields are created in the direct environment of live conductors or permanent magnets of electro motors and are a serious danger for certain persons. The machine operator must sufficiently protect personnel working in these areas from possibly occurring damage by suitable measures (e.g. warning notes, protective clothes, designation of the danger zone). Observe the safety instructionschapter 3.3.6 "Protection during handling and assembly" on page 20.

Observe the country-specific regulations. For Germany, please observe the specifications of the occupational insurance association BGV B11 and BGR B11 regarding “electromagnetic fields”.

Electro magnetic and magnetic fields!

Danger for persons with active body aids or passive metallic implants and for pregnant women.

- For persons with active body aids (like heart pacemakers), passive metallic implants (like hip prosthesis) and pregnant women possible hazards exist due to electro magnetic or magnetic fields in direct environment of electric drive and control components and the corresponding live conductors.

  Access into these areas can be dangerous for these persons:

  – Areas, in which components of electrical drive and control systems and corresponding live conductors are mounted, activated or operated.

  – Areas in which motor parts with permanent magnets are stored, repaired or assembled.

- Above mentioned persons must contact their attending physician before entering these areas.
- Please observe the valid industrial safety regulations for plants which are fitted with components of electrical drive and control systems and corresponding live conductors.

Risk of destruction of sensitive parts! Data loss!

- Keep watches, credit cards, check cards and identity cards and all ferromagnetic metal parts, such as iron, nickel and cobalt away from permanent magnets.

Crushing hazard of fingers and hand due to heavy attractive forces of the magnets!

The attractive force of the permanent magnets have an effect on all magnetic materials. Especially in an area < 100 mm, the attractive forces rise. Loose or not fastened components made of magnetizable materials can abruptly and inadvertently attracted with the permanent magnets.

- Extreme caution during handling of motor components with permanent magnets. Do never underestimate strong attractive forces.
- Never work alone.
- Use personal safety equipment (e.g. protective gloves, protective glasses).
- Do not unpack several motor components with permanent magnets or directly place them side by side at your working space.

- Unpack single motor components with permanent magnets immediately prior mounting and mount them immediately.
- Do not bring magnetized or magnetizable materials in the area of permanent magnets. If using magnetizable tools cannot be avoided, hold on the tool very tight, move carefully and observe the attractive force effect of the permanent magnets.

Behavior in the case of accidents with permanent magnets

During work with permanent magnets, the following emergency tools must be ready to use in the case of an accident to release impacted body parts (like fingers, hands, arms a.s.o.):

- Hammer (3-5kg) made of non-magnetized material like brass
- Minimum 2 wedges with approx. 10 - 15 ° lip angles made of non-magnetized material like brass, wood or similar to impact driving into the cutting slit.

In the case of an accident:

- Keep calm!
- If the machine is under load, de-energize immediately (emergency stop).
- Give first aid or request appropriate help (e.g. emergency doctor).
- Separate inherent parts via emergency tools to loose clamped body parts, like fingers, hand, foot, for example.
  – Therefore, beat the wedges with a hammer into the cutting slit to free the caught body parts.

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 assembly

Motor components with permanent magnets (e.g. secondary parts of a synchronous linear motor or rotor of a synchronous kit motor) create very strong attractive forces from ferromagnetic parts like further motor components with permanent magnets or parts of iron, nickel or cobalt.

Please observe the safety notes about strong attractive forces of permanent magnets under chapter 3.3.4 "Protection against magnetic and electromagnetic fields" on page 18.

The attractive forces of the permanent magnets influence all magnetizable materials. Especially in an area < 100 mm, the attractive forces rise. Surrounding components can abruptly and inadvertently be attracted by the permanent magnets.

Use the origin package of the motor components for transport and storage only. The origin package of Rexroth is constructed in such a way that the motor components with the permanent magnets are positioned within the package with suitable distance, providing that the package is correctly used.

Observe the following instructions during unpacking and handling.

- Instruct the personal with regard to the danger.
- Use personal safety equipment (e.g. protective gloves, protective glasses).
- Store all components in its origin package until assembly and for transport.
- Do only work on clean working spaces in which no ferromagnetic parts exist.
- If possible, use non-magnetic tools, e.g. made from aluminum or brass.
- Remove only one motor component from the package and secure it on your working space against slipping, rolling away.

Instruct all participating persons about the dangers and if necessary, expand the preliminary instructions.

Store the original package of the motor components with permanent magnets

Store the original package for later use.

In the case of reuse, ensure a good readability of the safety notes on the package. They must not be paste over!

Risk of injuries due to improper handling! Bodily injury due to crushing, scissors, cutting, punching!

- Observe the instructions on the package.
- Store the motor components with permanent magnets in the original package, only.
- Do not internally store or transport the motor components unpacked.
- Observe the accident prevention regulations.
- Use suitable assembly and transport equipment.

- Prevent clamping and squeezing by means of suitable measures.
- Use suitable tools, if necessary use special tools.
- Properly use lifting devices and tools.
- Use suitable safety equipment (like protective helmets, protective glasses, safety shoes, protective gloves).
- Never walk under hanging loads.
- Immediately remove spill on the ground, otherwise 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 General

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

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

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

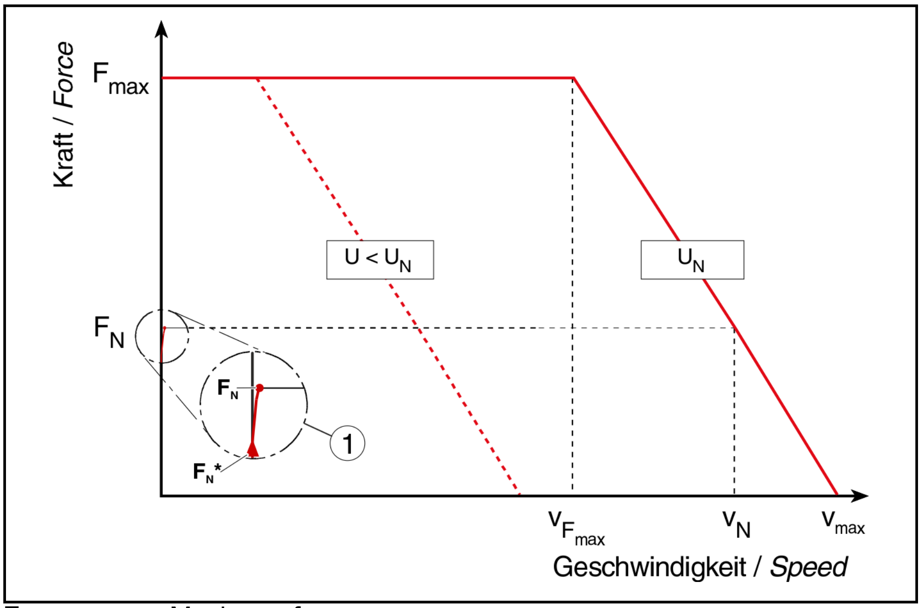
- Motor-winding temperature 135 °C
- Nominal air gap (see Dimensions and tolerances)
- Cooling method water, supply temperature 30 °C

☞
- Resulting data from certain motor-controller combinations can differ from the given data.
- All relationships and data described in the following sections may only apply if exclusively primary and secondary parts of the same size are combined (e.g. MLP040 with MLS040).

4.1.2 Operating behavior

The characteristic curve “maximum force over speed” (F_{max}) 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 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 (see chapter 4.1.3 "IndraSize" on page 26).

Furthermore, a rated force constant is specified. For the sake of simplicity, this is shown as constant over the speed, since with the short stator principle, heating of the MLS secondary parts and thus of the magnets as a function of the speed is generally not to be expected.



F_{max}	Maximum force
F_N	Continuous nominal force
F_{N^*}	To avoid damaged winding in standstill operation, limit the current or the operation duration.
①	When using these motors in this operating range, observe information specified in chapter 9.15 .
v_{Fmax}	Maximum velocity at maximum force
v_N	Nominal velocity
v_{max}	Maximum velocity
U_N	DC bus voltage 540 V_{DC}

Fig. 4-1: Example motor characteristic curve

☞ The reachable motor force depends on the drive control device used. The reference value for the technical data and the figured characteristic curves of the motor, is an DC bus voltage of 540 V_{DC}.

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

☞ If the supply or DC link voltages deviate, the specified characteristic curves can be converted - symplifying - according to the existing voltages.(see Fig. 4-2).

For supply modules with unregulated DC bus voltage, possible voltage dips due to simultaneous acceleration of several axes must be taken into account.

Example:

$$v_{(U_x)} = \frac{U_x}{540V(=U_N)} \times v_N$$

$v_{(Ux)}$	Speed due to adjusted DC bus voltage
v_N	Nominal velocity at 540 V
U_x	DC bus voltage deviating from 540 V

Fig. 4-2: Conversion formula

Parallel operation of two primary parts on a drive controller

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

In the following is spoken of “identical” primary parts.

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

The following interrelations exist for the parallel connection of two identical primary parts at one drive controller (see Fig. 4-3):

- Doublication of the feed force of the axis in the case of same current in each primary part (it not limited by the drive controller).

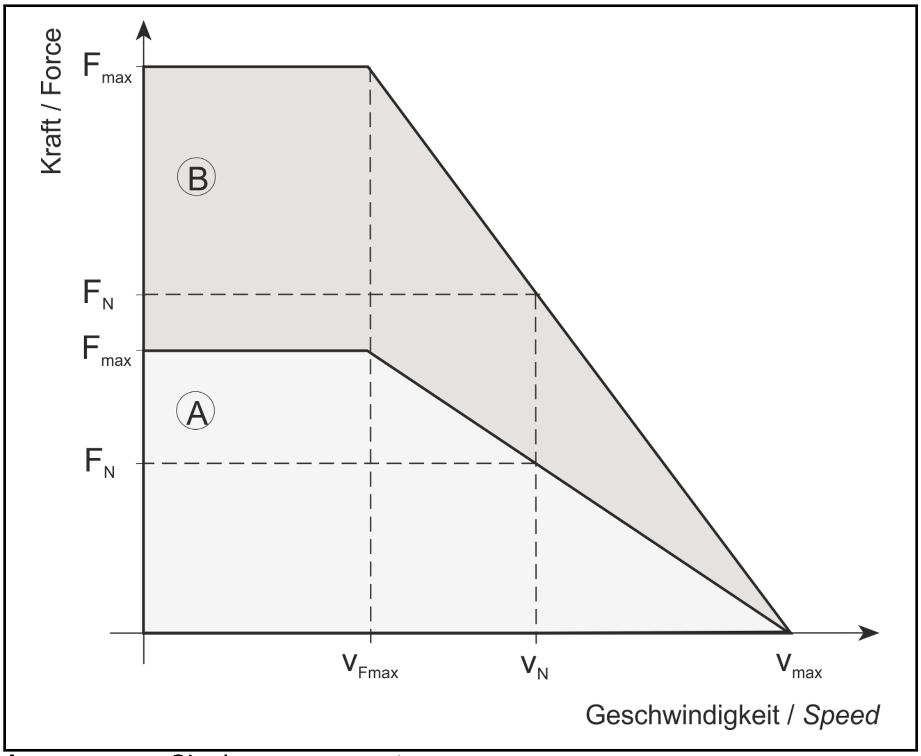
  $F_{total} = 2 \times F_{Motor}$
- Doublication of the voltage within the drive controller (if not limited by it)

  $I_{Inverter} = 2 \times I_{Motor}$
- Velocity v_{Fmax}, v_{nenn} and v_{max} as for single arrangement

  $v_{Fmax,total} = v_{Fmax,Motor}$ / $v_{nenn,total} = v_{nenn,Motor}$ / $v_{max,total} = v_{max,Motor}$
- Same motor and voltage constant (K_{FN}, K_{EMF})

  $K_{FN,total} = K_{FN,Motor}$ / $K_{EMK,total} = K_{EMK,Motor}$
- Total motor resistance and inductivity halved

  $R_{12,total} = 1/2 \times R_{12,Motor}$ / $L_{12,total} = 1/2 \times L_{12,Motor}$



A	Single arrangement
B	Parallel arrangement

Fig. 4-3: Characteristics force over velocity at single or parallel arrangment of two primary parts on one controller

For parallel connection of two primary parts at one drive controller, relevant motor parameters for start-up are specified in this documentation (see chapter 13 "Commissioning, operation and maintenance" on page 289).

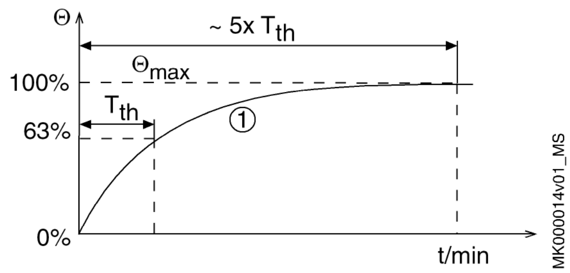
4.1.3 IndraSize

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

4.1.4 MLP Characteristics

Unless otherwise specified, the values specified in the data sheets are r.m.s. values according to DIN EN 60034-1. Reference value 540 V_{DC} DC bus voltage.

Technical data for MLP primary parts

Designation	Symbol	Unit	Toler-ance	Description
Maximum force	F_{max}	N	± 5 %	Available maximum force at maximum current I_{max}. The reachable force depends on the drive control device used.
Continuous nominal force	F_N	N	± 5 %	Available continuous force in operating mode S1 (continuous operation).
Maximum current	I_{max}	A		Maximum current (root-mean-square) of the motor at F_{max}.
Rated current	I_N	A		Phase current (effective value) of the motor at v_N and load with F_N.
Maximum velocity with maximum force	v_{Fmax}	m/min		Maximum speed with maximum force F_{max} specified by the manufacturer. The velocity reached depends on the DC bus voltage of the used drive control device.
Nominal celocity	v_N	m/min		Reachable nominal velocity at continuous nominal force F_N. The velocity reached depends on the DC bus voltage of the used drive control device.
Force constant	K_{FN}	N/A	± 5 %	Relation of force increase to increase of force-creating current. Applicable up to the rated current I_N.
Voltage constant at 20 °C	K_{EMF}	Vs/m	± 5 %	Electromagnetic force. Induced motor voltage (effective value) dependent on the feed rate regarding the velocity 1 m/s.
Winding resistance at 20 °C	R_{12}	Ohm		Measured winding resistance among two strands.
Winding inductance	L_{12}	mH		Measured winding inductivity between two strands. The defined measuring values are fluctuating due to boundary effects. These details are typical values, which are determined with a measuring current of 1 mA at a measuring frequency of 1 kHz.
Power wire cross section	A	mm²		Rated according to DIN VDE 0298-4 and laying type B2 according to DIN IEC 60204-1 with conversion factor for Rexroth cables at 40 °C ambient temperature. The power wire cross section that is specified in the data sheets can vary depending on the selected type of connection - plug or terminal box. When selecting the appropriate power cable, therefore please observe the information given in Chapter 8 Connection technique.
Pole width	T_p	mm		Distance dimension of pole center to pole center of the magnets on the secondary part.
Attractive force	F_{ATT}	N	± 5 %	Maximum attractive force among primary and secondary part at nominal air gap δ and currentless primary part. See information in Chapter 9.14 Feed and attractive forces ..
Thermal time constant	T_{th}	min		Duration of the temperature rise to 63% of the final temperature of the winding at motor load with permissible S1 continuous torque. The thermal time constant is determined by the cooling type used.  ①: chronological profile of the winding temperature Θmax: max. winding temperature T_{th}: Thermal time constant

Designation	Symbol	Unit	Toler-ance	Description
Mass standard encapsulation	m_{PS}	kg		Mass primary part with standard encapsulation
Mass thermal encapsulation	m_{PT}	kg		Mass primary part with thermo encapsulation
Power loss to be dissipated	P_V	W		Power loss in operation mode S1 (continuous operation) at nominal velocity v_N.
Coolant inlet temperature	T_{in}	°C		Allowed coolant supply temperatures. Unit [°C]. The coolant inlet temperature should be maximum 5°C lower than the existing ambient temperature T_{um}. In case of a higher temperature difference, danger of condensation! Also refer to the instructions in Chapter9.10 on page 191 about coolant inlet temperature.
Allowed coolant temperature rise at P_V	ΔT_{max}	K		Temperature difference between coolant inlet and outlet temperature during operation with liquid cooling (coolant water) and rated power loss P_V.
Required coolant flow for P_V	Q_{min}	l/min		Necessary coolant flow be keeping the specified continuous feed force. Please, observe the notes in Chapter 9.10.6 on page 200 about calculation of flow rate.
Pressure drop at Q_{min}	Δp	bar		Pressure drop within the internal coolant circuit of the motor Q_{min}. Please refer to the notes in Chapter 9.10.6 on page 200 about calculation of the pressure drop.
Constant for determining pressure drop	$K_{\Delta p}$	-		Constant for calculating the pressure drop in the motor-internal cooling system with water as the cooling medium. Please, observe the notes in Chapter 9.10.6 on page 200 about calculation of flow rate.
Volume of coolant duct standard encapsulation	$V_{cool,S}$	l		Coolant volume of the motor.
Volume of coolant duct thermal encapsulation	$V_{cool,T}$	l		
Maximum allowed inlet pressure	p_{max}	bar		Maximum permitted inlet pressure of the liquid cooling on the motor with coolant water.

4.1.5 MLS Characteristics

Technical data for secondary parts MLS

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

4.2 General technical data

For the sake of clarity, the following table contains data which is applicable to all motor frame sizes. However, refer to the information on the individual aspects in the respective chapter.

Designation	Symbol	Unit	MLPxxx	MLSxxx
Ambient temperature in operation (see also chapter 9.3 "Environmental conditions during operation" on page 185)	T_{um}	°C	0 ... +40	
Allowed transport temperature (see also chapter 11.2.2 "Transport instructions" on page 271)	T_T	°C	-25 ... +70	
Allowed storage temperature (see also chapter 11.2.3 "Storage instructions" on page 275)	T_L	°C	-25 ... +55	
Allowed coolant supply temperature (see also chapter "Coolant temperature " on page 199)	T_{in}	°C	+5 ... +40	
Maximum allowed coolant input pressure	p_{max}	bar	10	
Max. permitted secondary part temperature in operation	T_{Smax}	°C	/	70 °C
Thermal class acc. to DIN EN 60034-1	-	-	155	/
Warning temperature (winding)	T_{warn}	°C	145	/
Shutdown temperature (winding)	T_{abst}	°C	155	/
Degree of protection according to DIN EN 60034-5	-	-	IP65	
E-file number	-	-	E341734	
RoHS conformity	-	-	2011/65/EU	
Latest amendment: 2019-11-07				

Tab. 4-1: General technical data

4.3 Frame size 040

4.3.1 Data MLP040

Parameter	Symbol	Unit	MLP040			
Frame lengths			A	B		
Winding			0300	0150	0250	0300
Maximum force	F_{max}	N	800	1150		
Continuous nominal force	F_N	N	250	370		
Maximum current	I_{max}	A	18.0	18.7	28.3	36.9
Rated current	I_N	A	3.8	3.9	5.6	6.3
Maximum velocity at F_{max}	v_{Fmax}	m/min	300	150	250	300
Nominal velocity	v_N	m/min	500	300	400	500
Force constant	K_{FN}	N/A	66.1	94.4	66.8	58.6
Voltage constant	K_{EMK}	Vs/m	38.1	54.4	38.5	33.8
Winding resistance at 20 °C	R_{12}	Ohm	8.6	12.8	6.3	5.0
Winding inductance	L_{12}	mH	51.5	78.8	37.6	28.9
Power wire cross-section	A	mm^2	1.0			
Pole width	τ_p	mm	37.5			
Attractive force	F_{ATT}	N	1,200	1,700		
Thermal time constant	T_{th}	min	2.4			
Mass standard encapsulation	m_{PS}	kg	4.7	6.1		
Mass thermal encapsulation	m_{PT}	kg	6.1	8.1		
Data liquid cooling						
Heat loss to be dissipated	P_V	W	400	550		
Required coolant flow for P_V	Q_{min}	l/min	0.6	0.8		
Pressure drop at Q_{min}	Δp	bar	0.06	0.11		
Constant for determining pressure drop	$K_{\Delta p}$	-	0.16	0.166		
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.027	0.034		
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.043	0.05		
Latest amendment: 2019-02-07						

Tab. 4-2: MLP040 - Technical data

4.3.2 Motor characteristic curves MLP040

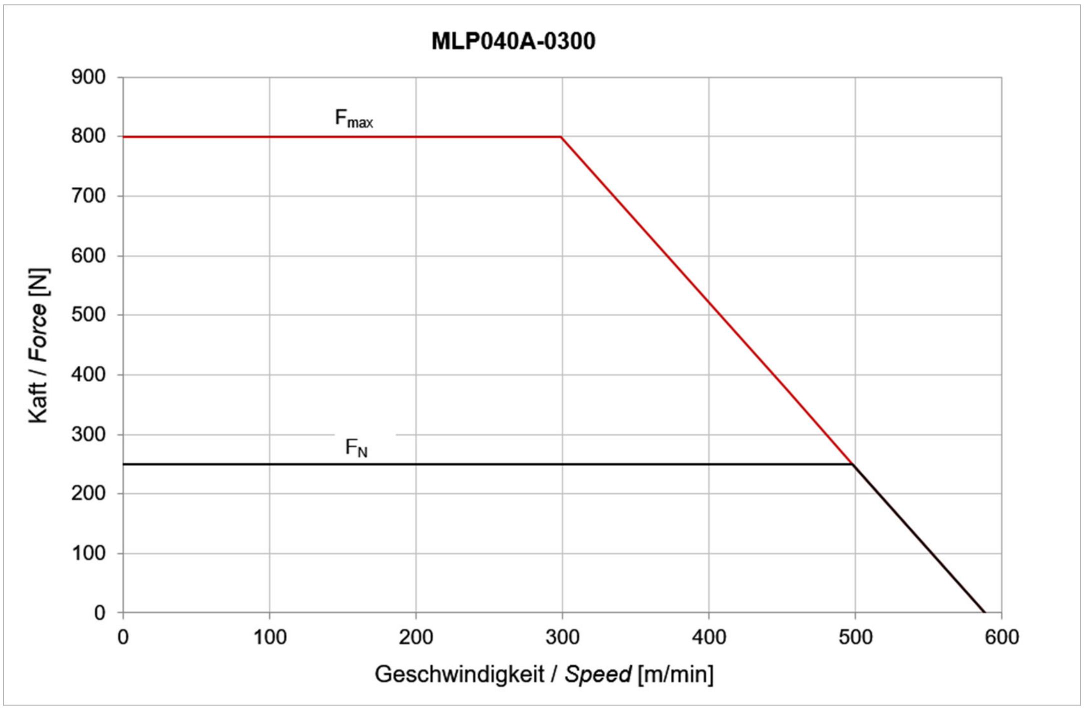


Fig. 4-4: Motor characteristic curve MLP040A-0300

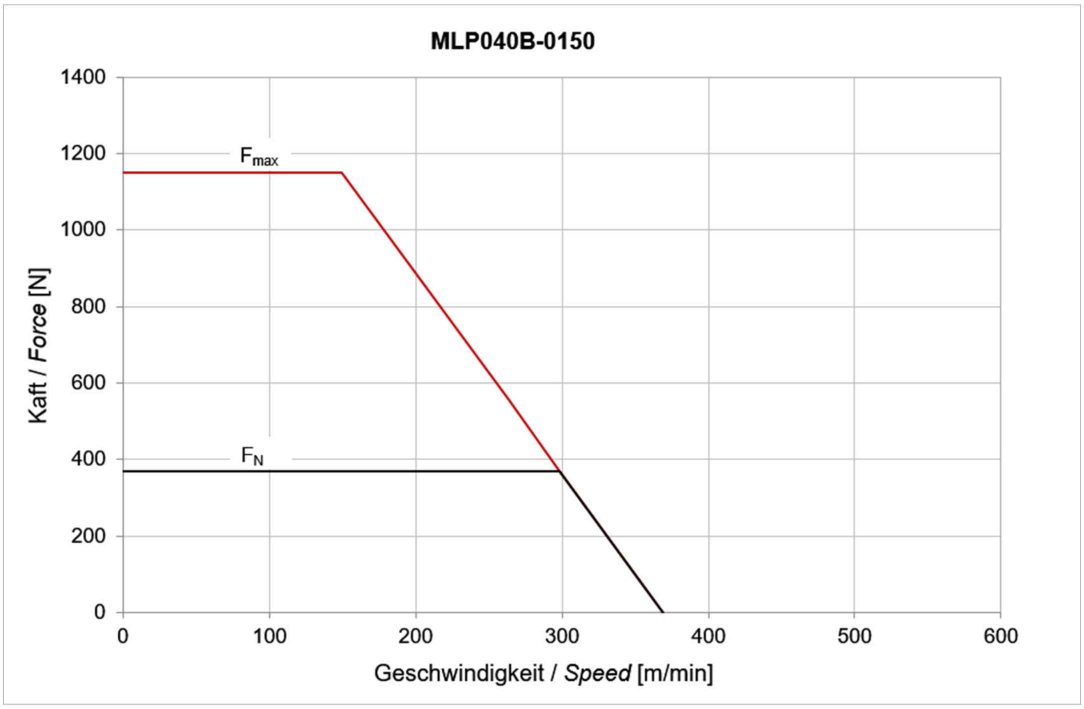


Fig. 4-5: Motor characteristic curve MLP040B-0150

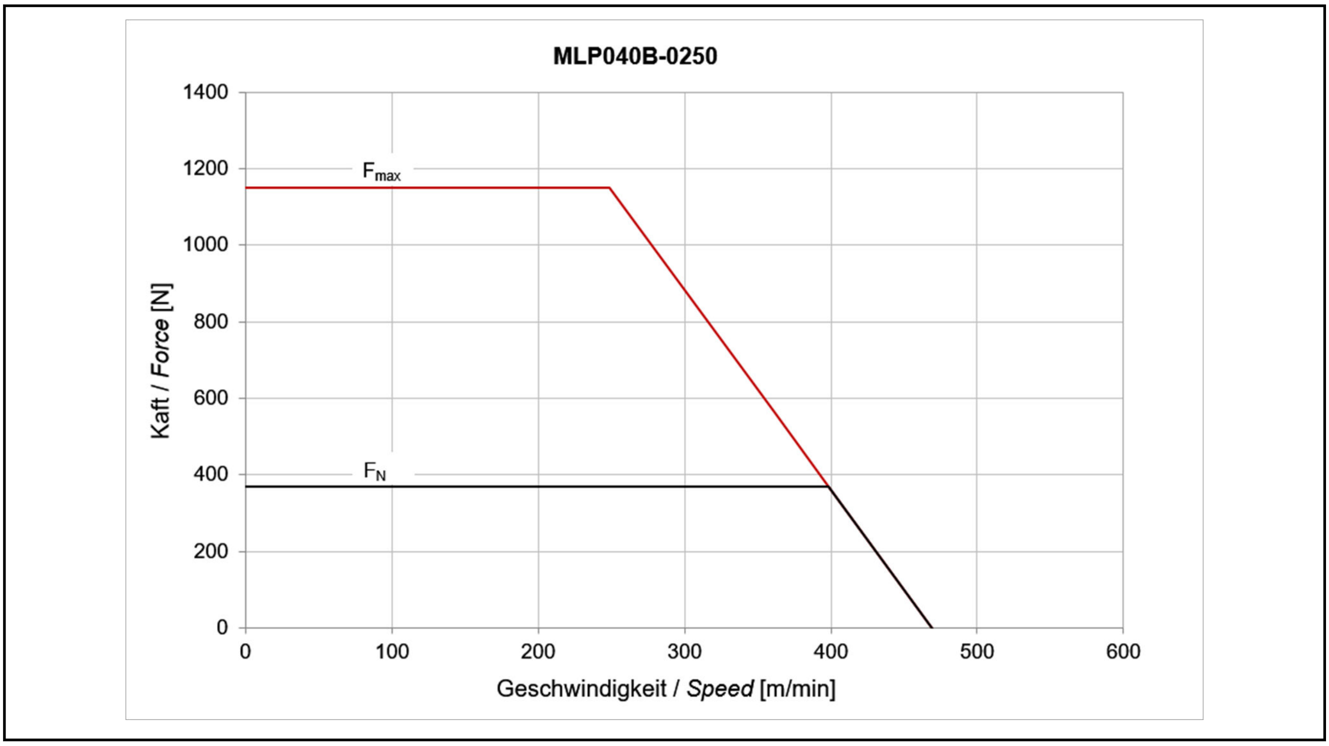


Fig. 4-6: Motor characteristic curve MLP040B-0250

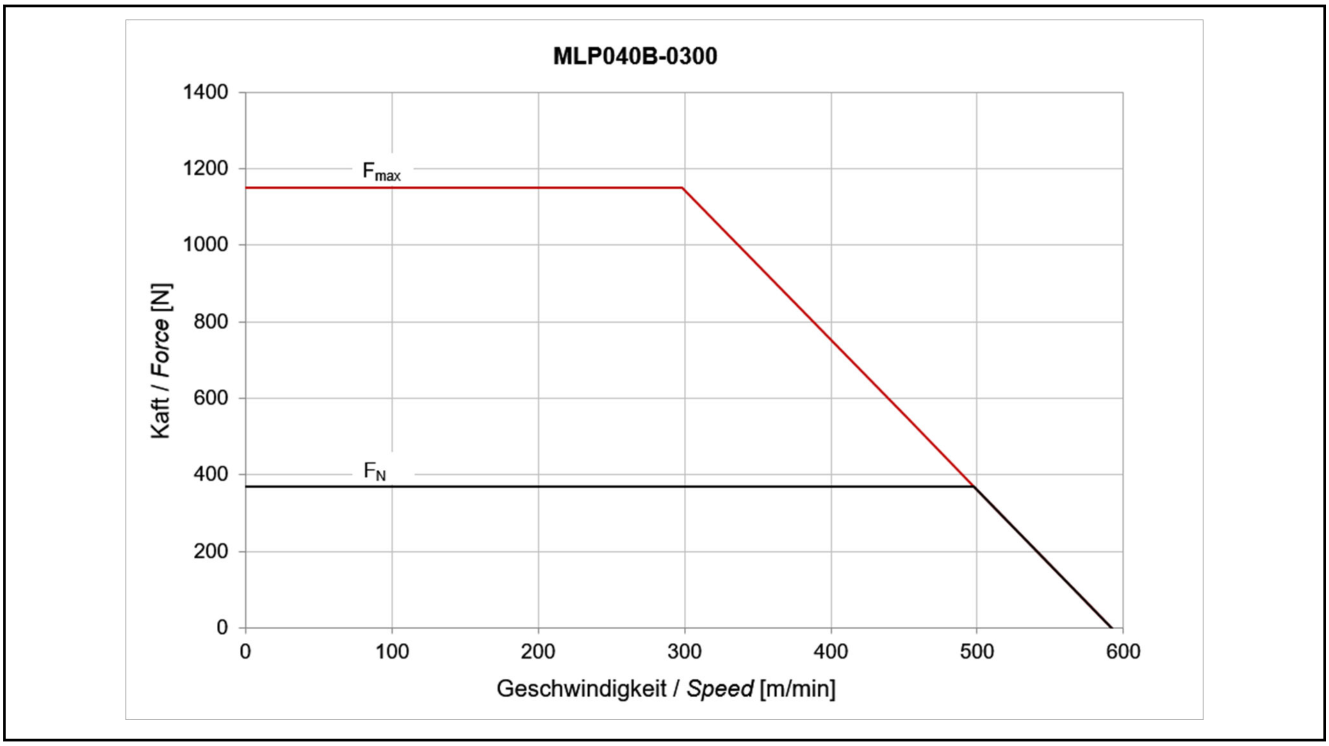


Fig. 4-7: Motor characteristic curve MLP040B-0300

4.3.3 Data MLS040

Designation	Symbol	Unit	MLS040_-_A-0150-NNNN	MLS040_-_A-0450-NNNN	MLS040_-_A-0600-NNNN
Mass secondary part	m_S	kg	0.8	2.4	3.2
Mass secondary part, relative	m_{S_rel}	kg/m	5.4		
Latest amendment: 2019-07-22					

Tab. 4-3: MLS040 - Technical data

4.4 Frame size 052

4.4.1 Data MLP052

Parameter	Symbol	Unit	MLP052	
Frame length			A	B
Winding			0300	0300
Maximum force	F_{max}	N	650	1,300
Continuous nominal force	F_N	N	300	630
Maximum current	I_{max}	A	13.8	28.0
Rated current	I_N	A	5.0	10.6
Maximum velocity at F_{max}	v_{Fmax}	m/min	300	
Nominal velocity	v_N	m/min	350	450
Force constant	K_{FN}	N/A	60.0	59.4
Voltage constant	K_{EMK}	Vs/m	37.6	39.3
Winding resistance at 20 °C	R_{12}	Ohm	5.0	2.67
Winding inductance	L_{12}	mH	56.0	34.0
Power wire cross-section	A	mm^2	1.0	
Pole width	τ_p	mm	30.0	
Attractive force	F_{ATT}	N	1,300	2600
Thermal time constant	T_{th}	min	3.7	4.2
Mass thermal encapsulation	m_{PT}	kg	5.0	8.5
Data liquid cooling				
Heat loss to be dissipated	P_V	W	300	600
Required coolant flow for P_V	Q_{min}	l/min	1.0	
Pressure drop at Q_{min}	Δp	bar	0.9	
Constant for determining pressure drop	$K_{\Delta p}$	-	0.9	
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.04	0.069
Latest amendment: 2019-02-07				

Tab. 4-4: MLP052 - Technical data

4.4.2 Motor characteristic curves MLP052

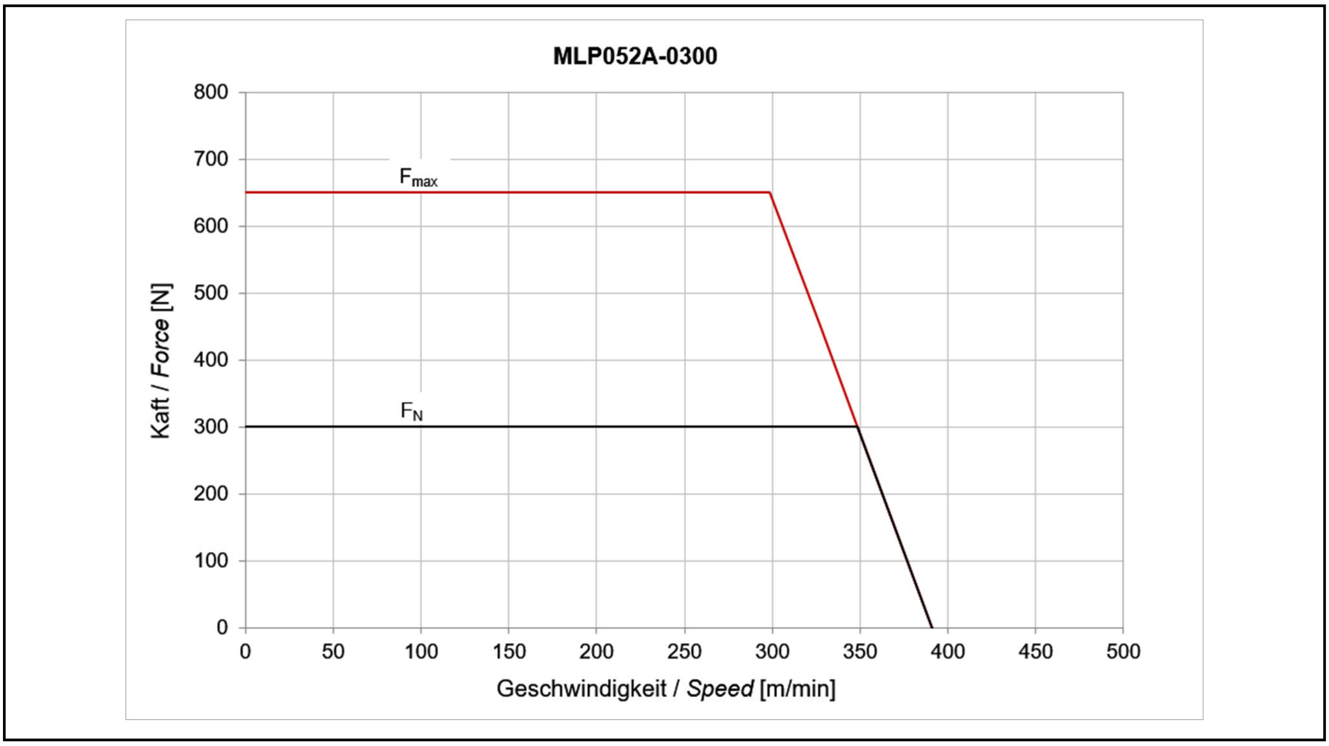


Fig. 4-8: Motor characteristic curve MLP052A-0300-...

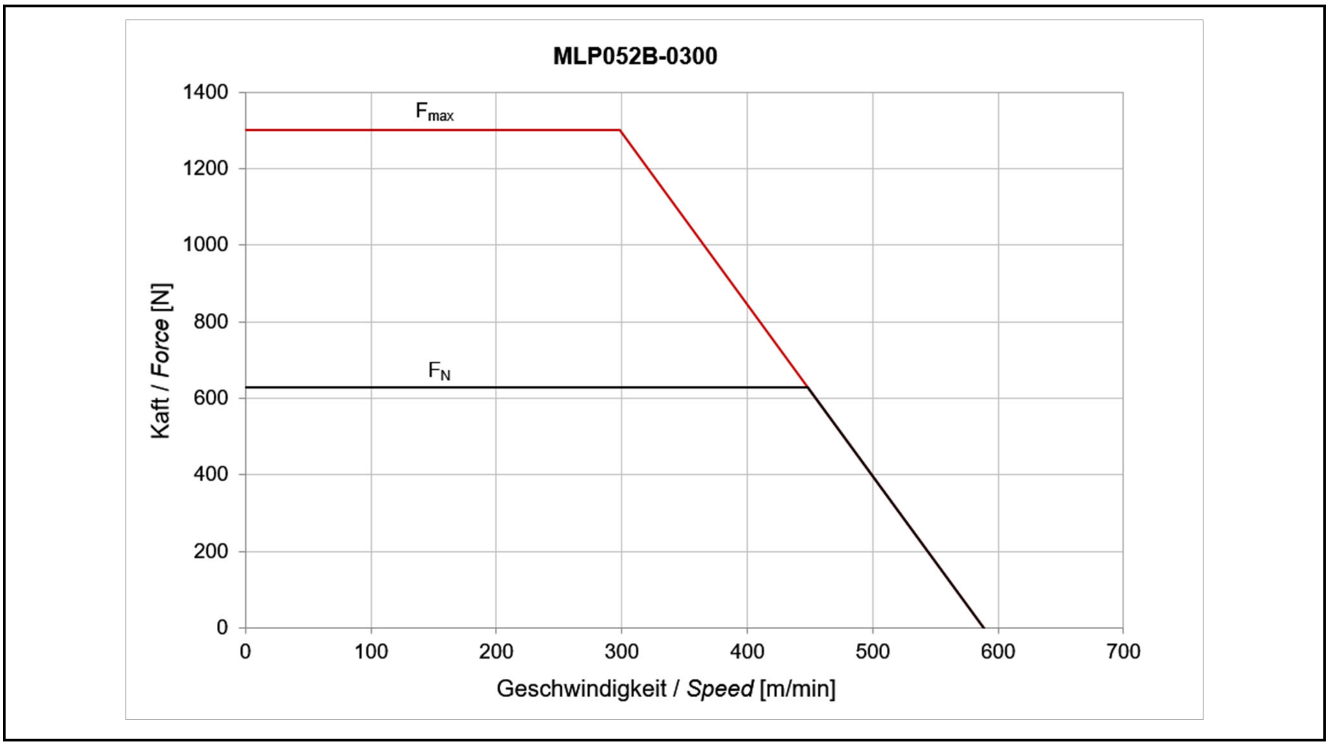


Fig. 4-9: Motor characteristic curve MLP052B-0300-...

4.4.3 Data MLS052

Designation	Symbol	Unit	MLS052_-_A-0180-NNNN
Mass secondary part	m_S	kg	1.5
Mass secondary part, relative	m_{S_rel}	kg/m	8.5
			Latest amendment: 2019-07-22

Tab. 4-5: MLS052 - Technical data

4.5 Frame size 070

4.5.1 Data MLP070A

Parameter	Symbol	Unit	MLP070		
Frame lengths			A		
Winding			0150	0220	0300
Maximum force	F_{max}	N	2,000		
Continuous nominal force	F_N	N	550		
Maximum current	I_{max}	A	29.6	40.5	42.0
Rated current	I_N	A	4.5	6.1	8.0
Maximum velocity at F_{max}	v_{Fmax}	m/min	150	220	300
Nominal velocity	v_N	m/min	200	360	450
Force constant	K_{FN}	N/A	121.7	90.7	68.7
Voltage constant	K_{EMK}	Vs/m	70.2	52.3	39.6
Winding resistance at 20 °C	R_{12}	Ohm	9.0	4.7	2.9
Winding inductance	L_{12}	mH	47.9	26.9	17.1
Power wire cross-section	A	mm^2	1.0		
Pole width	τ_p	mm	37.5		
Attractive force	F_{ATT}	N	2,900		
Thermal time constant	T_{th}	min	2.4		
Mass standard encapsulation	m_{PS}	kg	8.4		
Mass thermal encapsulation	m_{PT}	kg	10.9		
Data liquid cooling					
Heat loss to be dissipated	P_V	W	780		
Required coolant flow for P_V	Q_{min}	l/min	1.1		
Pressure drop at Q_{min}	Δp	bar	0.2		
Constant for determining pressure drop	$K_{\Delta p}$	-	0.18		
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.042		
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.06		
Latest amendment: 2019-02-07					

Tab. 4-6: MLP070A - Technical data

4.5.2 Motor characteristic curves MLP070A

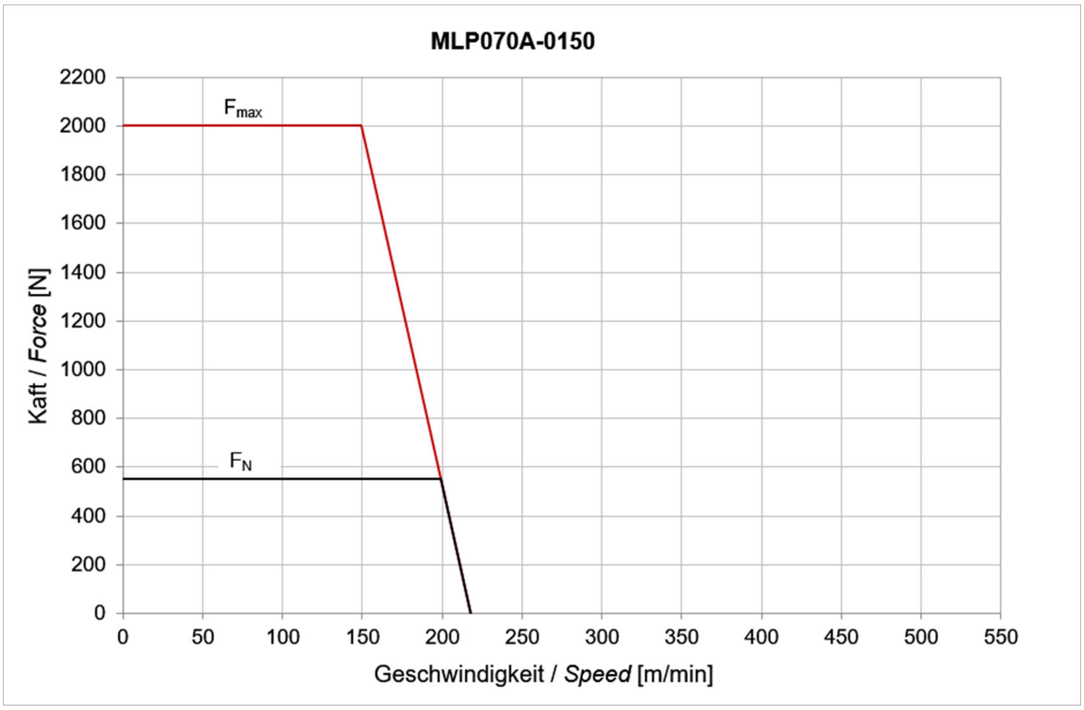


Fig. 4-10: Motor characteristic curves MLP070A-0150

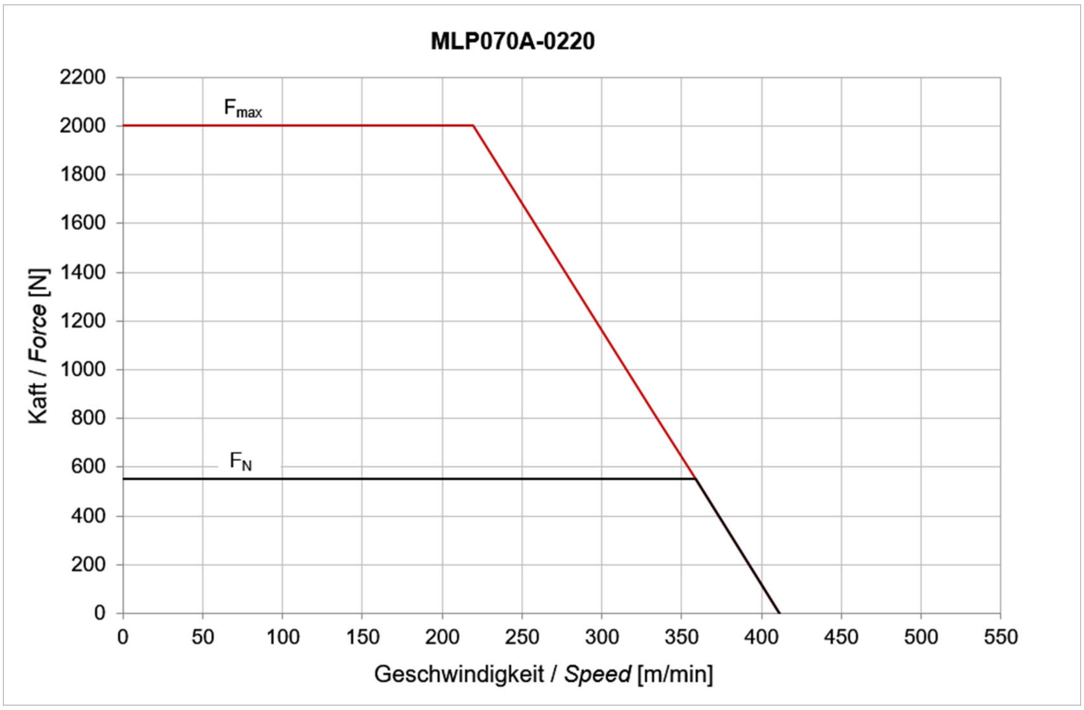


Fig. 4-11: Motor characteristic curves MLP070A-0220

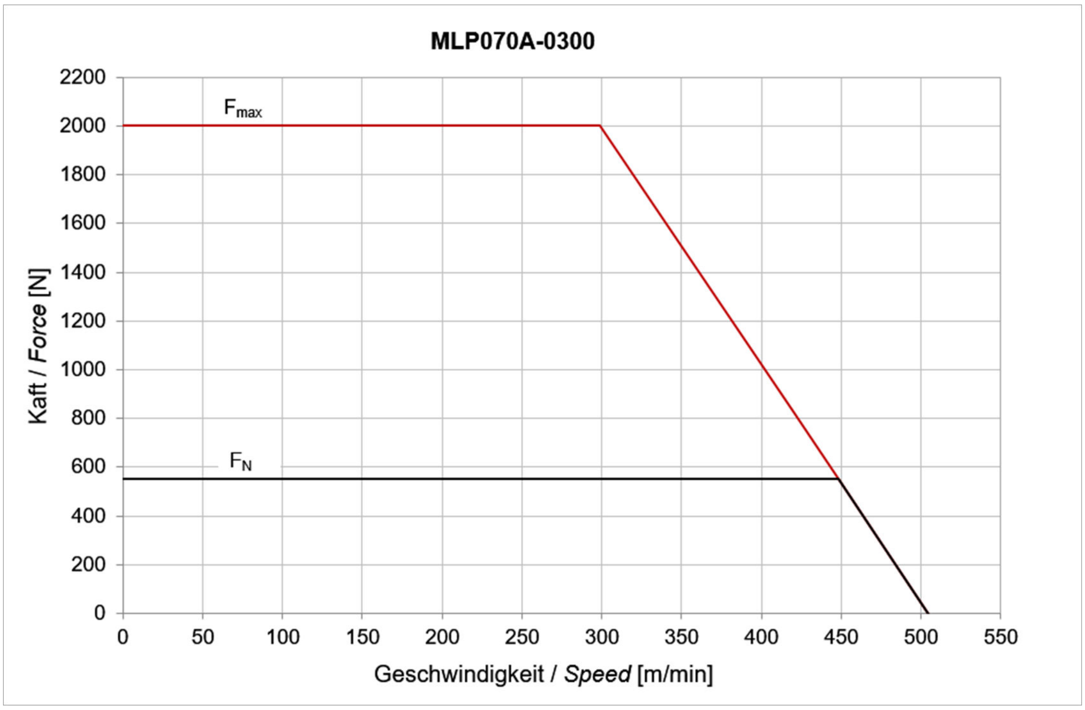


Fig. 4-12: Motor characteristic curves MLP070A-0300

4.5.3 Data MLP070B

Parameter	Symbol	Unit	MLP070				
Frame lengths			B				
Winding			0100	0120	0150	0250	0300
Maximum force	F_{max}	N	2600				
Continuous nominal force	F_N	N	820				
Maximum current	I_{max}	A	23.6	42.8	56.8	57.1	67.7
Rated current	I_N	A	4.6	5.9	7.3	10.4	11.6
Maximum velocity at F_{max}	v_{Fmax}	m/min	100	120	150	250	300
Nominal velocity	v_N	m/min	200	220	260	400	450
Force constant	K_{FN}	N/A	176.7	138.8	111.9	79.1	70.7
Voltage constant	K_{EMK}	Vs/m	101.9	80.1	64.6	45.6	40.8
Winding resistance at 20 °C	R_{12}	Ohm	14.9	9.2	6.1	3.0	5.7
Winding inductance	L_{12}	mH	89.0	47.558	30.1	17.0	36.2
Power wire cross-section	A	mm^2	1.0				
Pole width	τ_p	mm	37.5				
Attractive force	F_{ATT}	N	3750				
Thermal time constant	T_{th}	min	2.4				
Mass standard encapsulation	m_{PS}	kg	10.4				
Mass thermal encapsulation	m_{PT}	kg	13.4				
Data liquid cooling							
Heat loss to be dissipated	P_V	W	900				
Required coolant flow for P_V	Q_{min}	l/min	1.3				
Pressure drop at Q_{min}	Δp	bar	0.3				
Constant for determining pressure drop	$K_{\Delta p}$	-	0.186				
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.059				
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.082				
Latest amendment: 2019-02-07							

Tab. 4-7: MLP070B - Technical data

4.5.4 Motor characteristic curves MLP070B

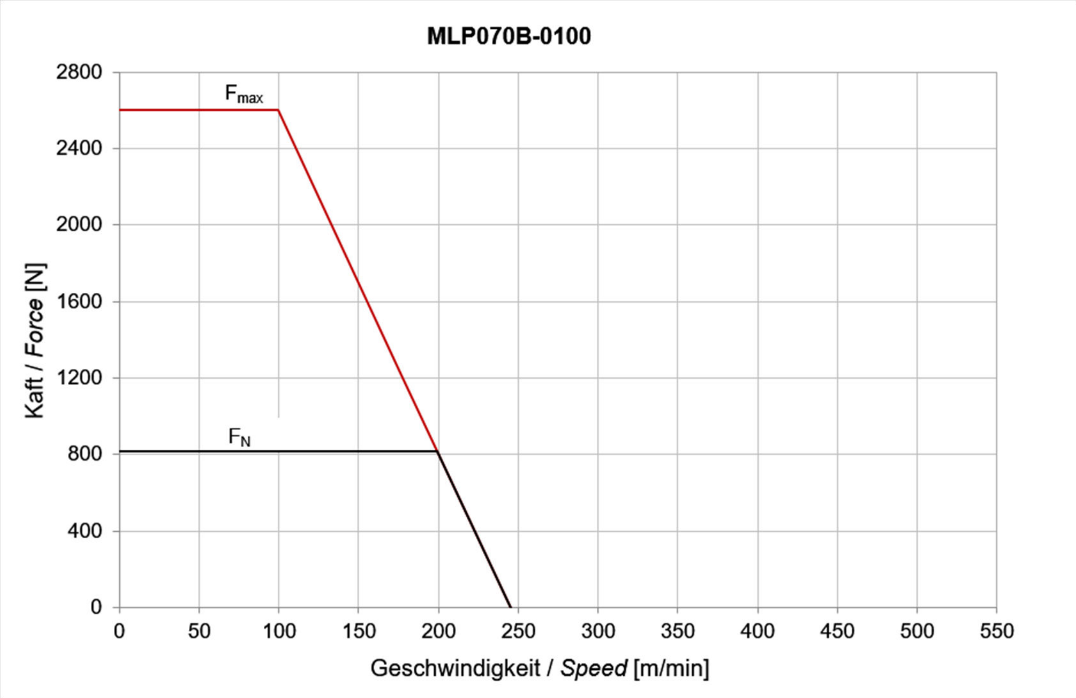


Fig. 4-13: Motor characteristic curve MLP070B-0100

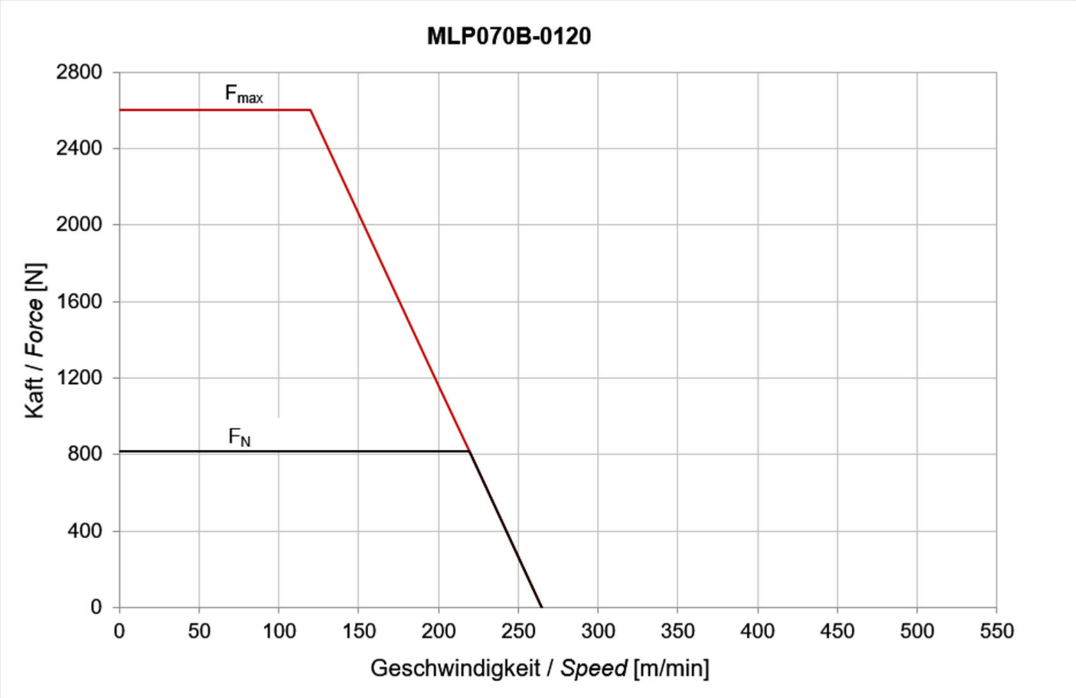


Fig. 4-14: Motor characteristic curves MLP070B-0120

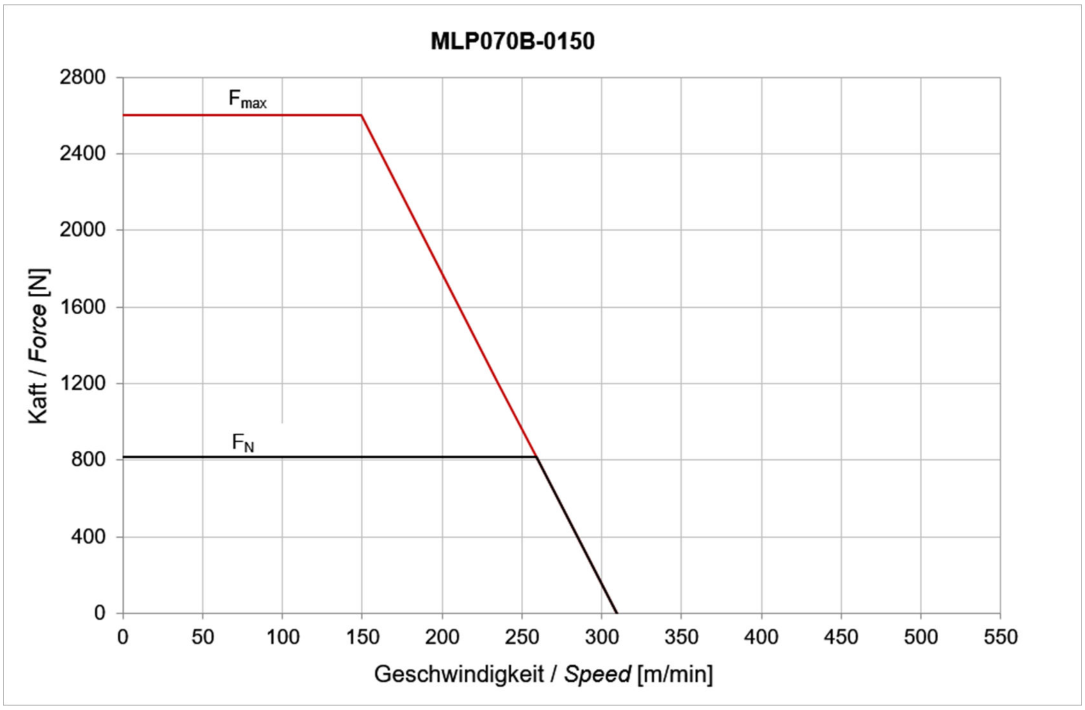


Fig. 4-15: Motor characteristic curves MLP070B-0150

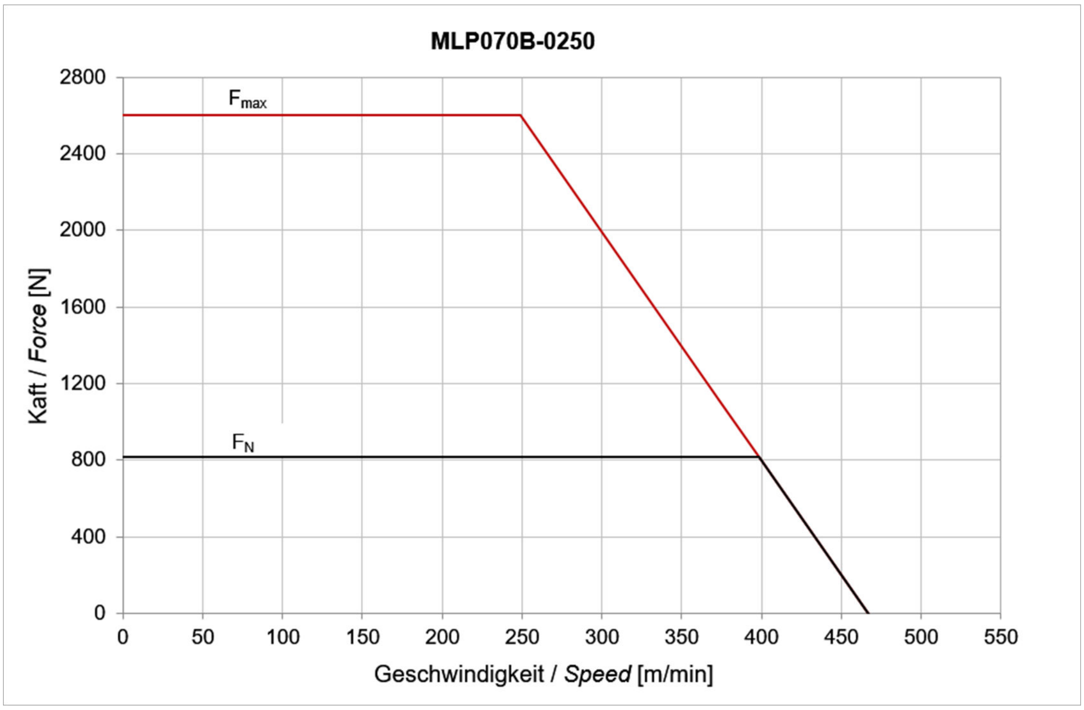


Fig. 4-16: Motor characteristic curves MLP070B-0250

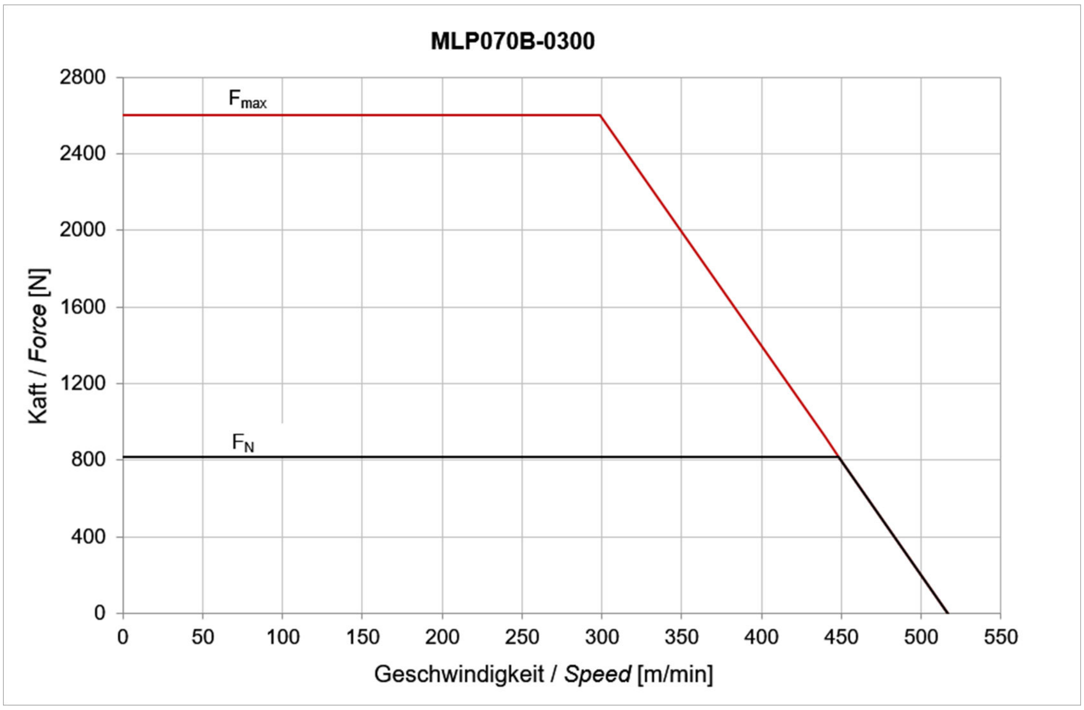


Fig. 4-17: Motor characteristic curves MLP070B-0300

4.5.5 Data MLP070C

Parameter	Symbol	Unit	MLP070				
Frame lengths			C				
Winding			0030	0120	0150	0240	0300
Maximum force	F_{max}	N	1900	3800			
Continuous nominal force	F_N	N	1,200				
Maximum current	I_{max}	A	6.5	56.9	65.9	107.9	106.7
Rated current	I_N	A	3.7	9.2	11.0	15.6	18.4
Maximum velocity at F_{max}	v_{Fmax}	m/min	30	120	150	240	300
Nominal velocity	v_N	m/min	70	180	250	350	450
Force constant	K_{FN}	N/A	326.1	130.4	109.1	77.1	65.2
Voltage constant	K_{EMK}	Vs/m	188.7	75.2	62.9	44.5	37.6
Winding resistance at 20 °C	R_{12}	Ohm	38.6	5.7	4.05	2.0	1.46
Winding inductance	L_{12}	mH	22.6	31.132	21.07	11.6	10.2
Power wire cross-section	A	mm^2	1.0				2.5
Pole width	τ_p	mm	37.5				
Attractive force	F_{ATT}	N	5,500				
Thermal time constant	T_{th}	min	2.4				
Mass standard encapsulation	m_{PS}	kg	14.3				
Mass thermal encapsulation	m_{PT}	kg	18.4				
Data liquid cooling							
Heat loss to be dissipated	P_V	W	1100				
Required coolant flow for P_V	Q_{min}	l/min	1.6				
Pressure drop at Q_{min}	Δp	bar	0.4				
Constant for determining pressure drop	$K_{\Delta p}$	-	0.193				
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.078				
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.111				
Latest amendment: 2019-02-07							

Tab. 4-8: MLP070C - Technical data

4.5.6 Motor characteristic curves MLP070C

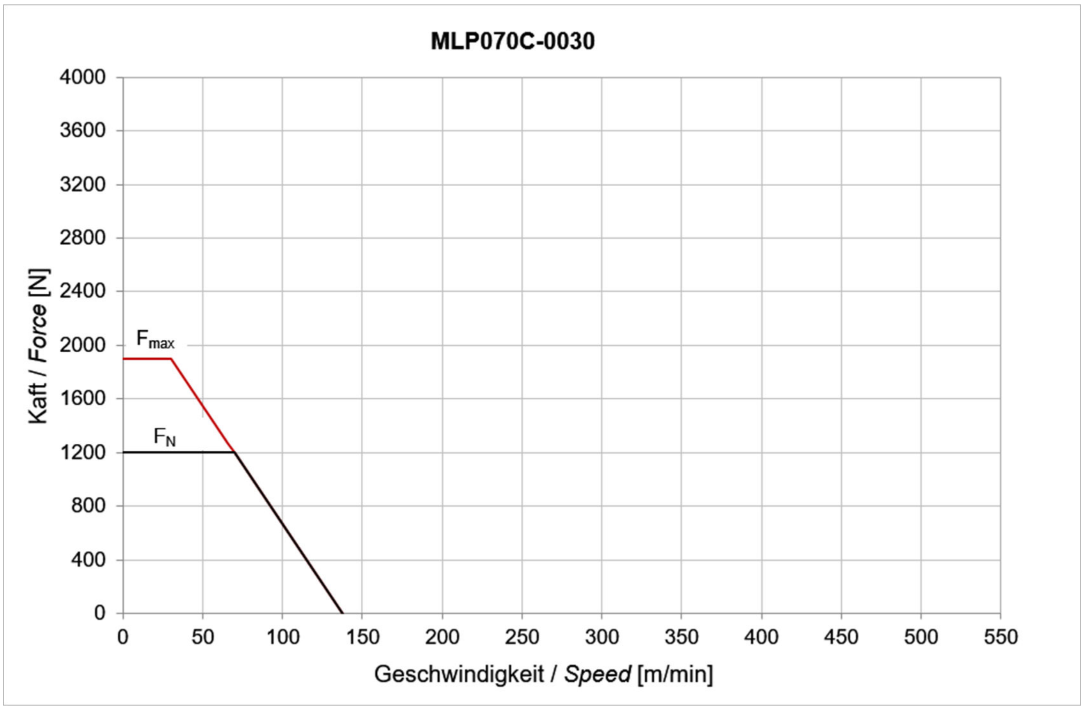


Fig. 4-18: Motor characteristic curve MLP070C-0030

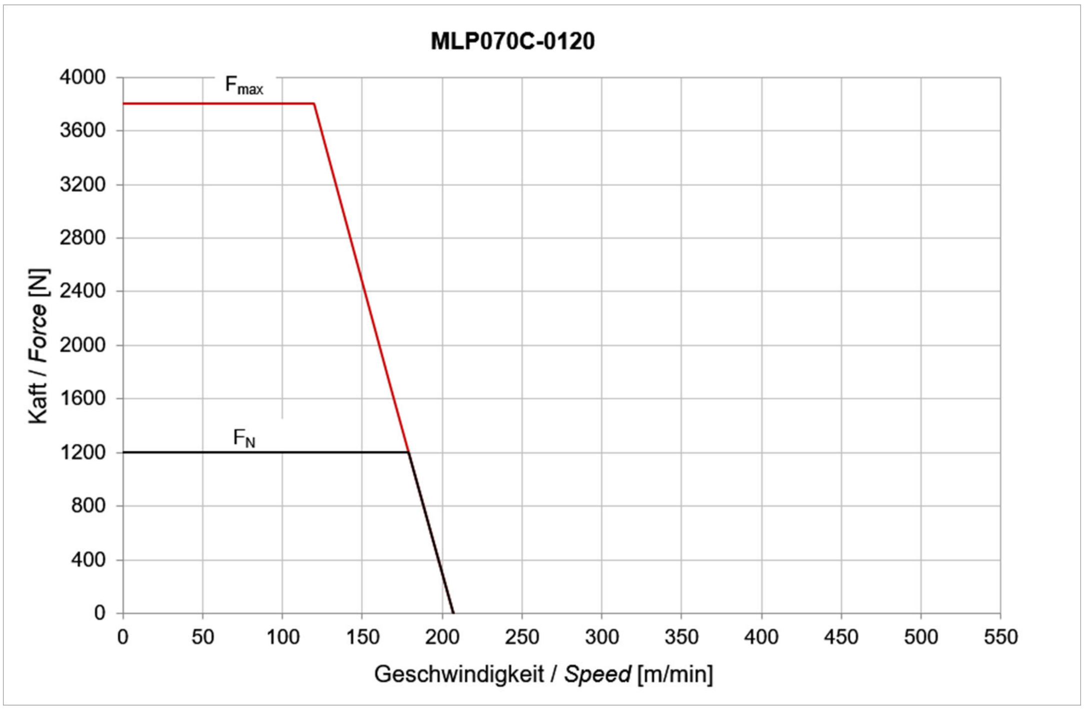


Fig. 4-19: Motor characteristic curves MLP070C-0120

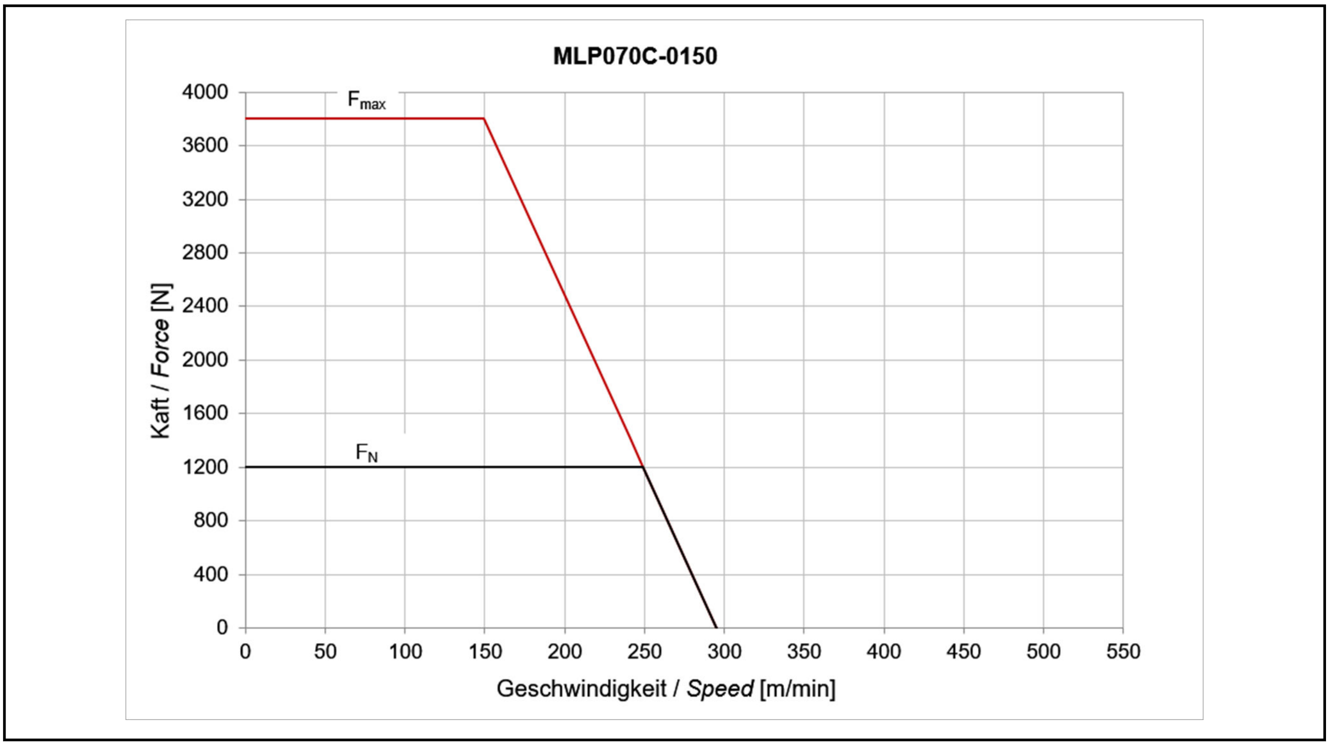


Fig. 4-20: Motor characteristic curves MLP070C-0150

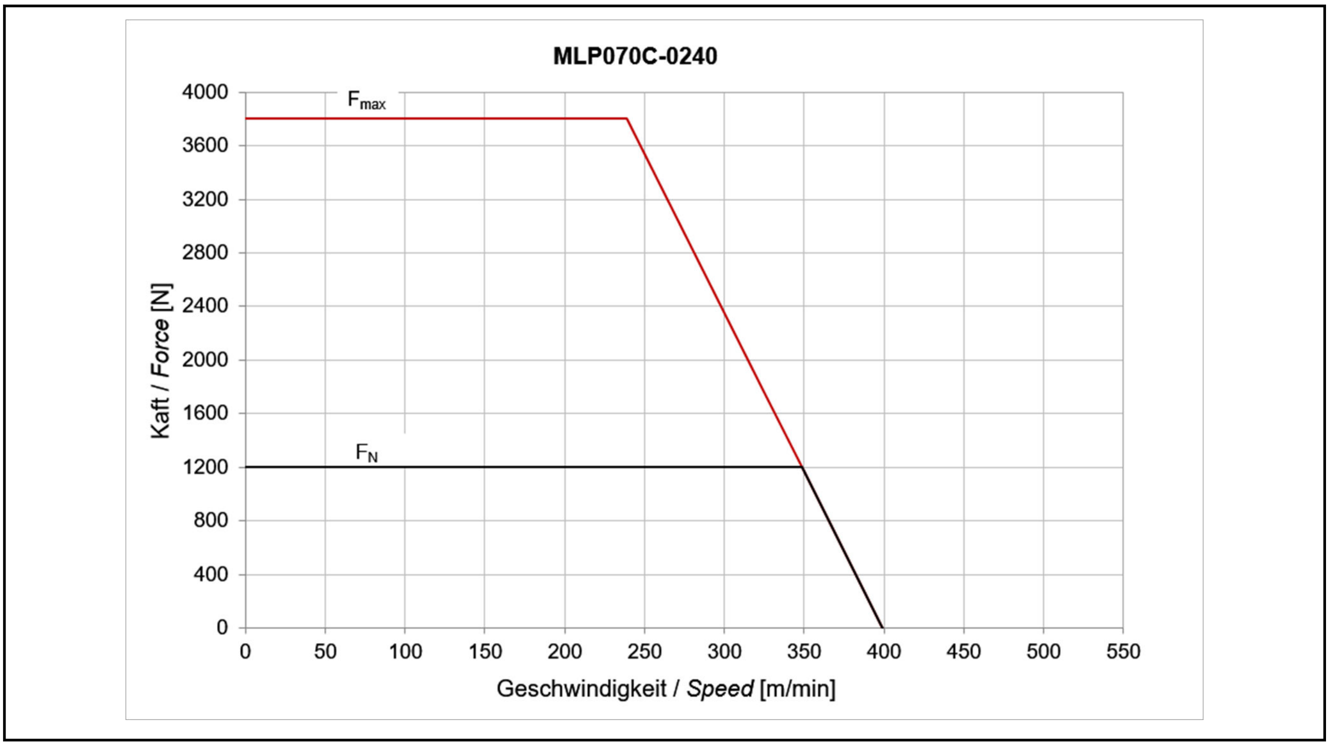


Fig. 4-21: Motor characteristic curves MLP070C-0240

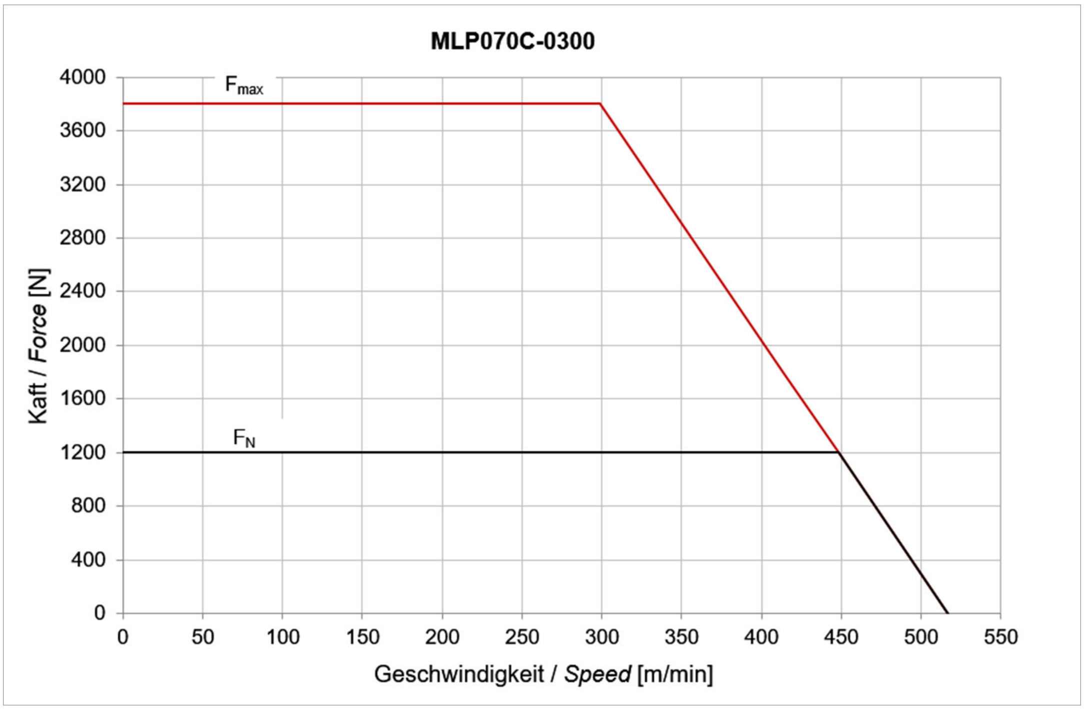


Fig. 4-22: Motor characteristic curves MLP070C-0300

4.5.7 Data MLS070

Designation	Symbol	Unit	MLS070_-_A-0150-NNNN	MLS070_-_A-0450-NNNN	MLS070_-_A-0600-NNNN
Mass secondary part	m_S	kg	1.4	4.2	5.6
Mass secondary part, relative	m_{S_rel}	kg/m	9.4		
Latest amendment: 2019-07-22					

Tab. 4-9: MLS070 - Technical data

4.6 Frame size 100

4.6.1 Data MLP100A

Parameter	Symbol	Unit	MLP100			
Frame lengths			A			
Winding			0090	0120	0150	0190
Maximum force	F_{max}	N	3750			
Continuous nominal force	F_N	N	1180			
Maximum current	I_{max}	A	34.2	40.5	50.8	69.2
Rated current	I_N	A	5.9	7.4	9.2	11.9
Maximum velocity at F_{max}	v_{Fmax}	m/min	90	120	150	190
Nominal velocity	v_N	m/min	150	190	220	290
Force constant	K_{FN}	N/A	198.9	160.4	127.8	99.5
Voltage constant	K_{EMK}	Vs/m	114.80	92.5	73.8	57.4
Winding resistance at 20 °C	R_{12}	Ohm	12.0	7.9	4.9	3.0
Winding inductance	L_{12}	mH	66.9	43.8	27.3	16.5
Power wire cross-section	A	mm^2	1.0			
Pole width	τ_p	mm	37.5			
Attractive force	F_{ATT}	N	5400			
Thermal time constant	T_{th}	min	2.4			
Mass standard encapsulation	m_{PS}	kg	13.5			
Mass thermal encapsulation	m_{PT}	kg	17.0			
Data liquid cooling						
Heat loss to be dissipated	P_V	W	900			
Required coolant flow for P_V	Q_{min}	l/min	1.2			
Pressure drop at Q_{min}	Δp	bar	0.3			
Constant for determining pressure drop	$K_{\Delta p}$	-	0.089			
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.071			
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.114			
Latest amendment: 2019-02-07						

Tab. 4-10: MLP100A - Technical data

4.6.2 Motor characteristic curves MLP100A

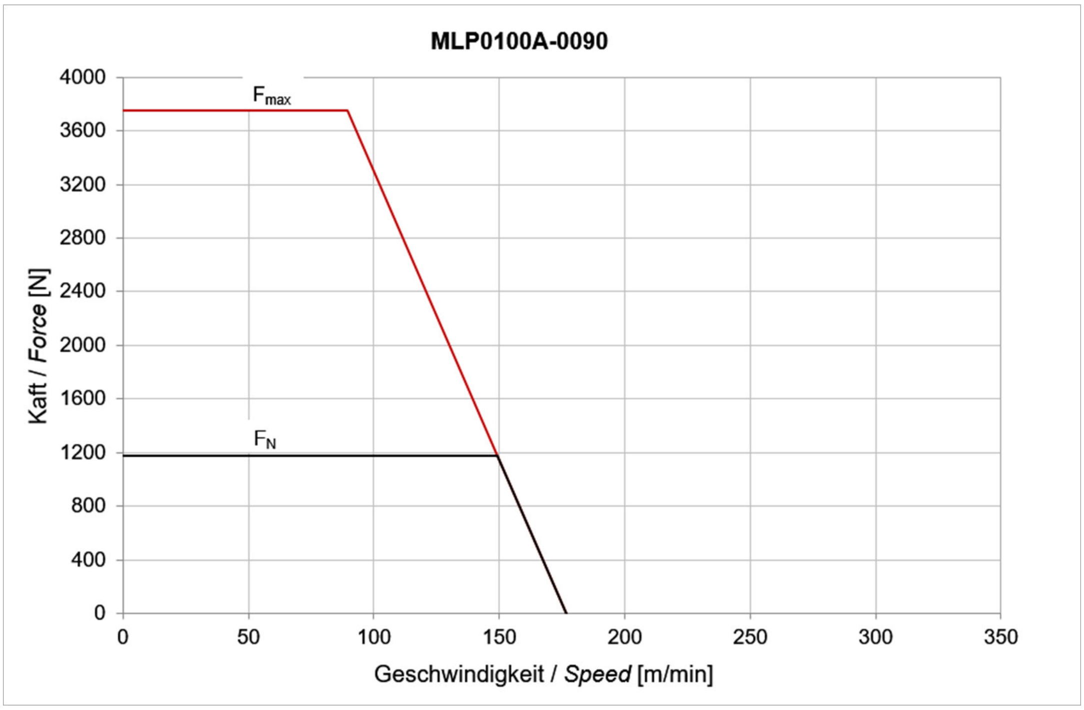


Fig. 4-23: Motor characteristic curve MLP100A-0090

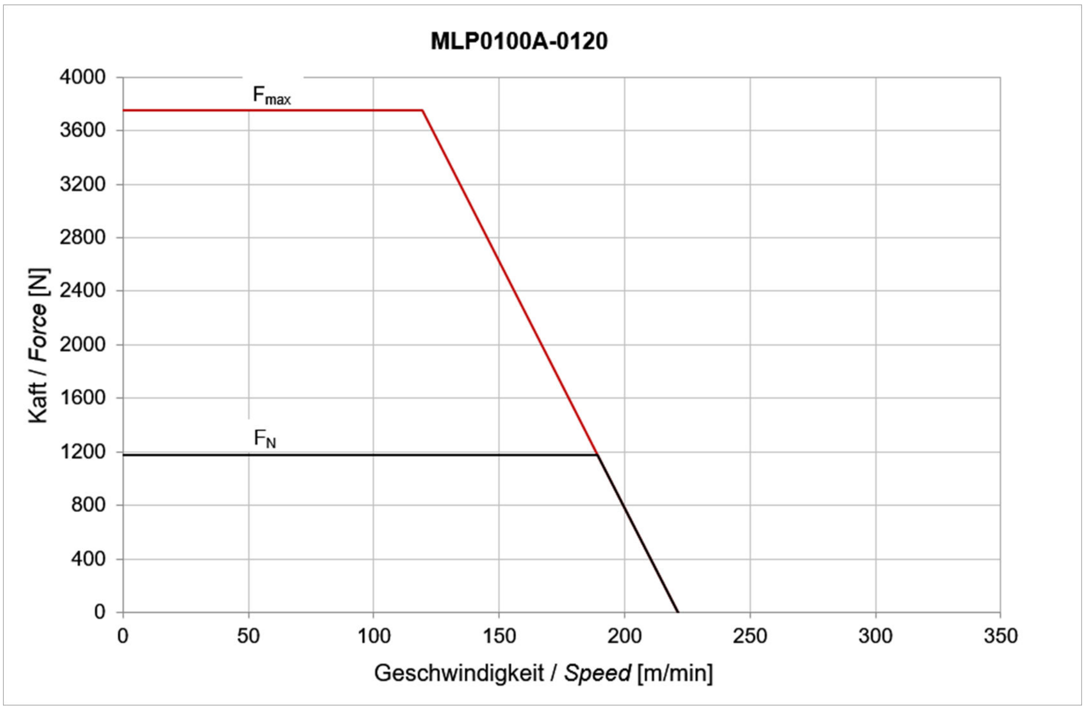


Fig. 4-24: Motor characteristic curves MLP100A-0120

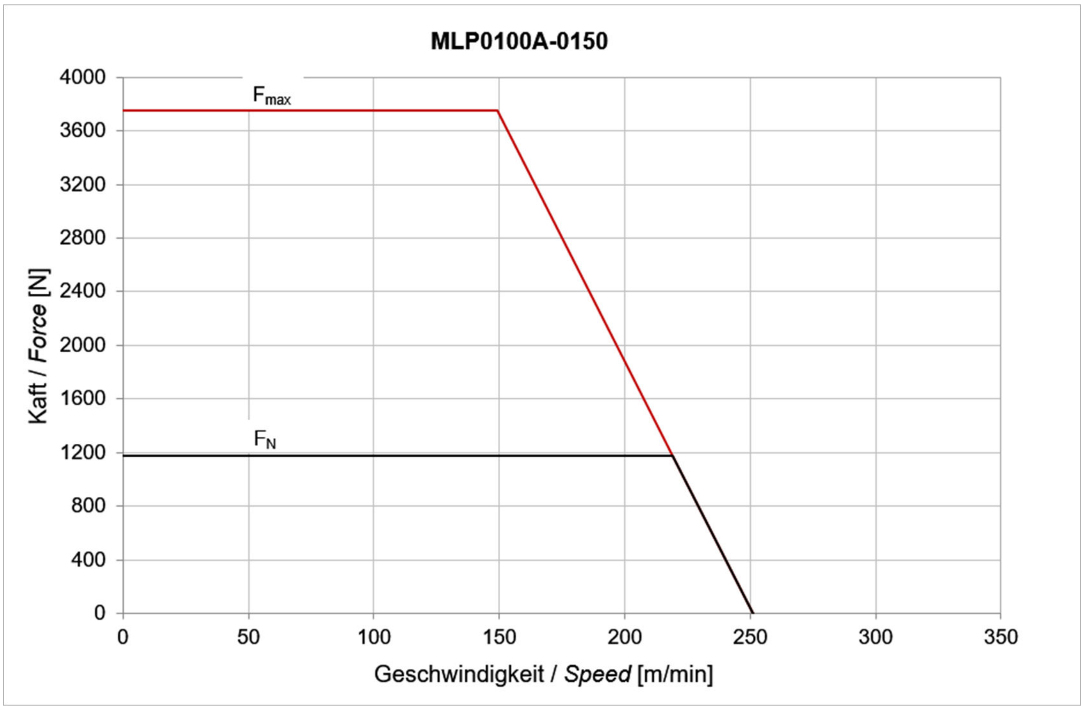


Fig. 4-25: Motor characteristic curves MLP100A-0150

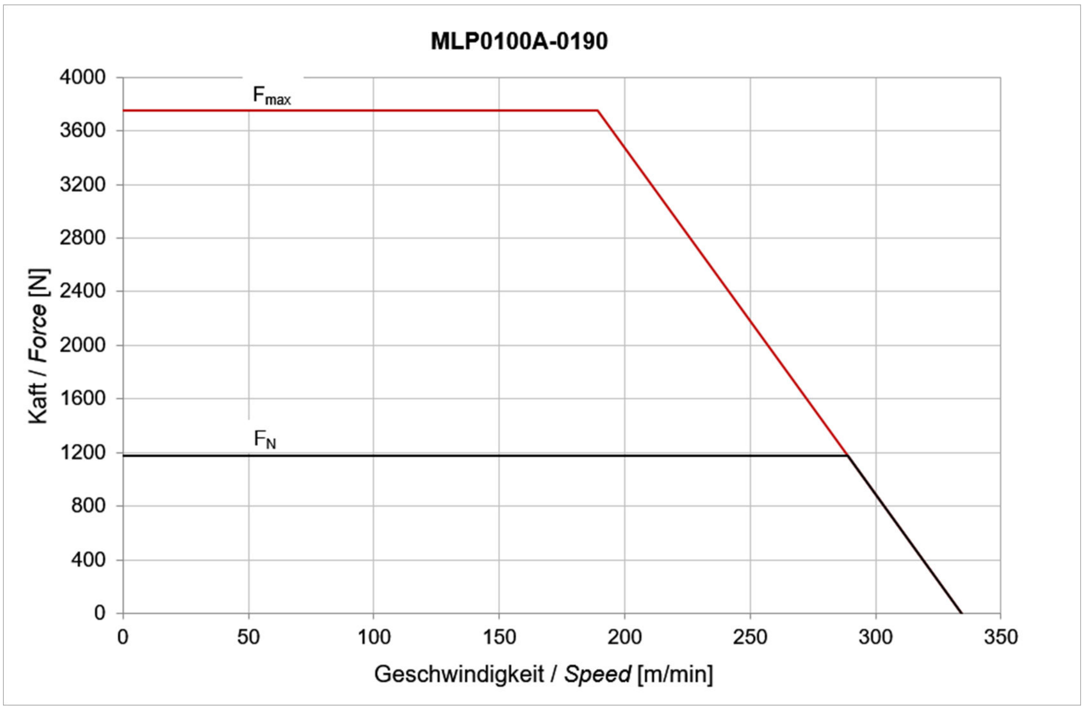


Fig. 4-26: Motor characteristic curves MLP100A-0190

4.6.3 Data MLP100K

Parameter	Symbol	Unit	MLP100
Frame length			K
Winding			0040
Maximum force	F_{max}	N	4675
Continuous nominal force	F_N	N	1480
Maximum current	I_{max}	A	33.6
Rated current	I_N	A	6.3
Maximum velocity at F_{max}	v_{Fmax}	m/min	40
Nominal velocity	v_N	m/min	135
Force constant	K_{FN}	N/A	235.0
Voltage constant	K_{EMK}	Vs/m	136.0
Winding resistance at 20 °C	R_{12}	Ohm	12.1
Winding inductance	L_{12}	mH	63.6
Power wire cross-section	A	mm^2	1.0
Pole width	τ_p	mm	37.5
Attractive force	F_{ATT}	N	6413
Thermal time constant	T_{th}	min	2.4
Mass standard encapsulation	m_{PS}	kg	17.1
Mass thermal encapsulation	m_{PT}	kg	20.3
Data liquid cooling			
Heat loss to be dissipated	P_V	W	1150
Required coolant flow for P_V	Q_{min}	l/min	1.6
Pressure drop at Q_{min}	Δp	bar	0.42
Constant for determining pressure drop	$K_{\Delta p}$	-	0.135
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.086
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.138
			Latest amendment: 2019-07-18

Tab. 4-11: MLP100K - Technical data

4.6.4 Motor characteristic curve MLP100K

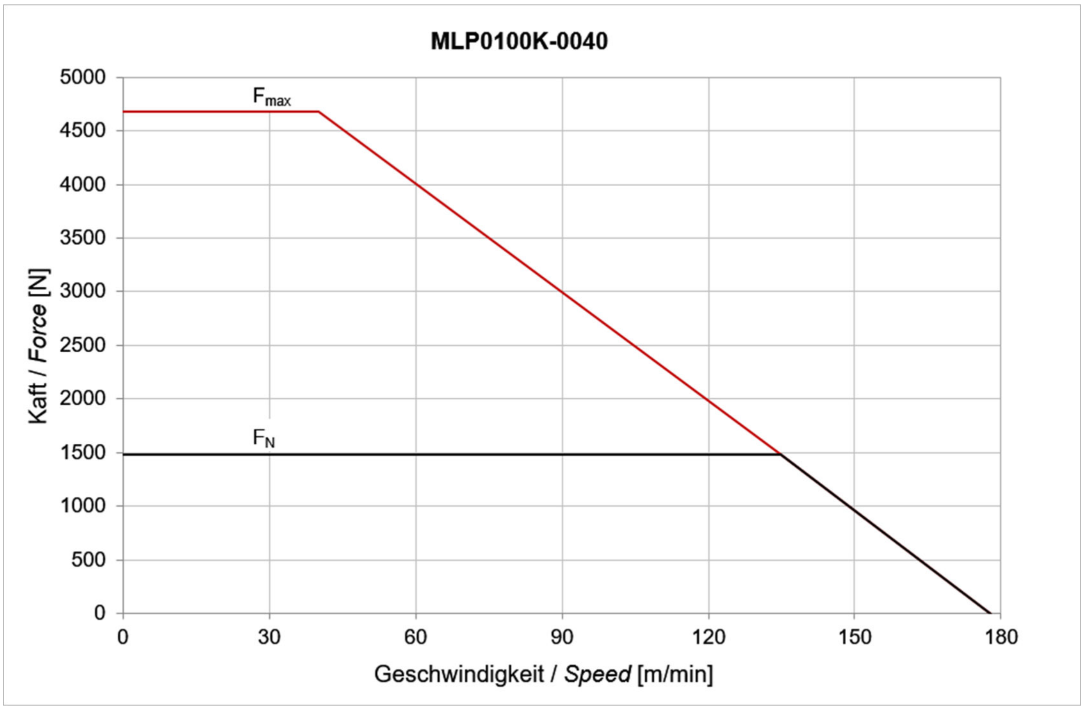


Fig. 4-27: Motor characteristic curve MLP100K-0040

4.6.5 Data MLP100B

Parameter	Symbol	Unit	MLP100		
Frame lengths			B		
Winding			0030	0120	0250
Maximum force	F_{max}	N	3000	5600	
Continuous nominal force	F_N	N	1785		
Maximum current	I_{max}	A	9.7	71.2	142.6
Rated current	I_N	A	5.1	12.2	24.1
Maximum velocity at F_{max}	v_{Fmax}	m/min	30	120	250
Nominal velocity	v_N	m/min	70	190	350
Force constant	K_{FN}	N/A	352.4	146.3	74.1
Voltage constant	K_{EMK}	Vs/m	203.4	84.4	42.7
Winding resistance at 20 °C	R_{12}	Ohm	26.4	4.5	1.2
Winding inductance	L_{12}	mH	137.0	25.6	6.5
Power wire cross-section	A	mm^2	1.0		2.5
Pole width	τ_p	mm	37.5		
Attractive force	F_{ATT}	N	8,000		
Thermal time constant	T_{th}	min	2.4		
Mass standard encapsulation	m_{PS}	kg	18.7		
Mass thermal encapsulation	m_{PT}	kg	23.3		
Data liquid cooling					
Heat loss to be dissipated	P_V	W	1,300		
Required coolant flow for P_V	Q_{min}	l/min	1.9		
Pressure drop at Q_{min}	Δp	bar	0.5		
Constant for determining pressure drop	$K_{\Delta p}$	-	0.181		
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.1		
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.164		
Latest amendment: 2019-02-07					

Tab. 4-12: MLP100B - Technical data

4.6.6 Motor characteristic curves MLP100B

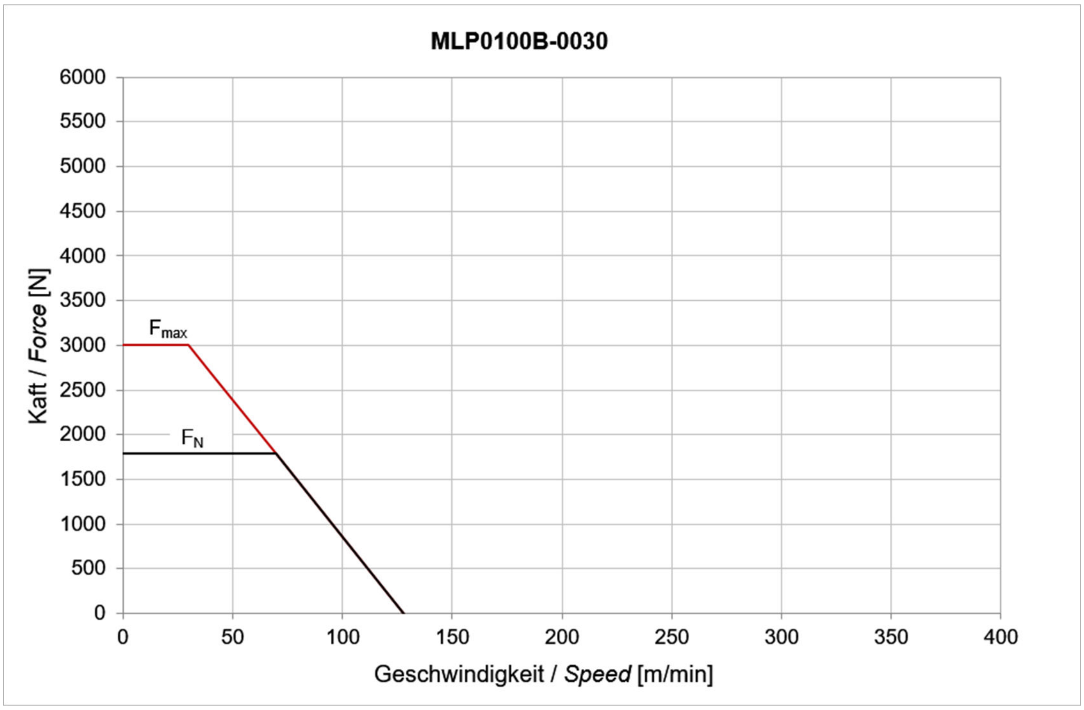


Fig. 4-28: Motor characteristic curve MLP100B-0030

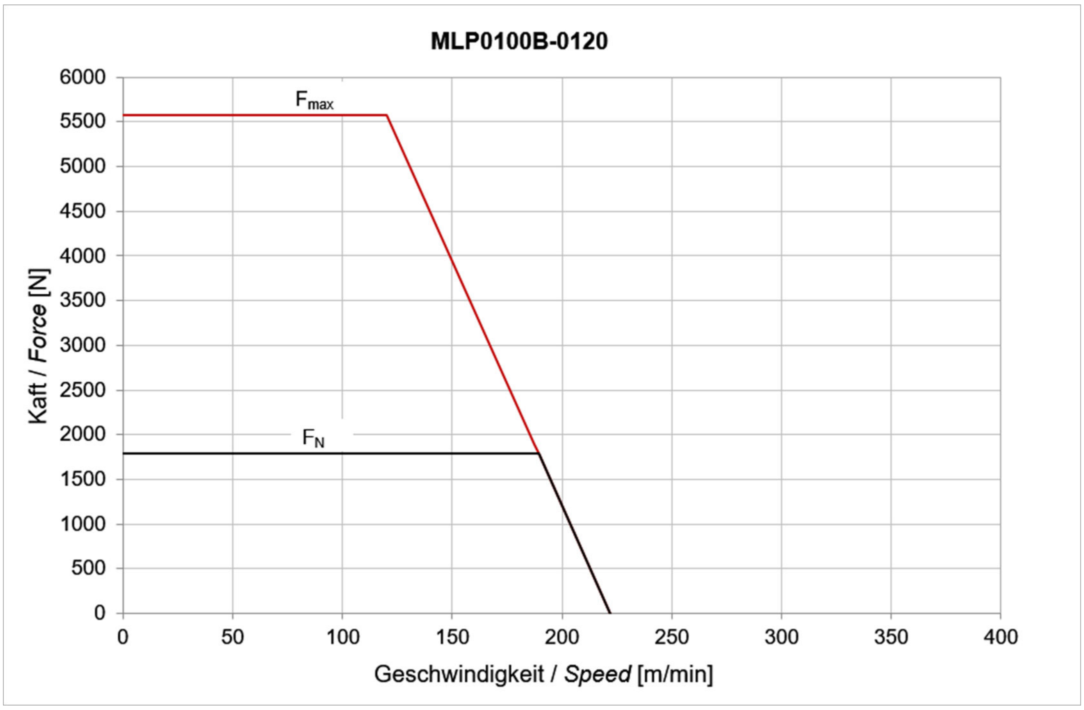


Fig. 4-29: Motor characteristic curves MLP100B-0120

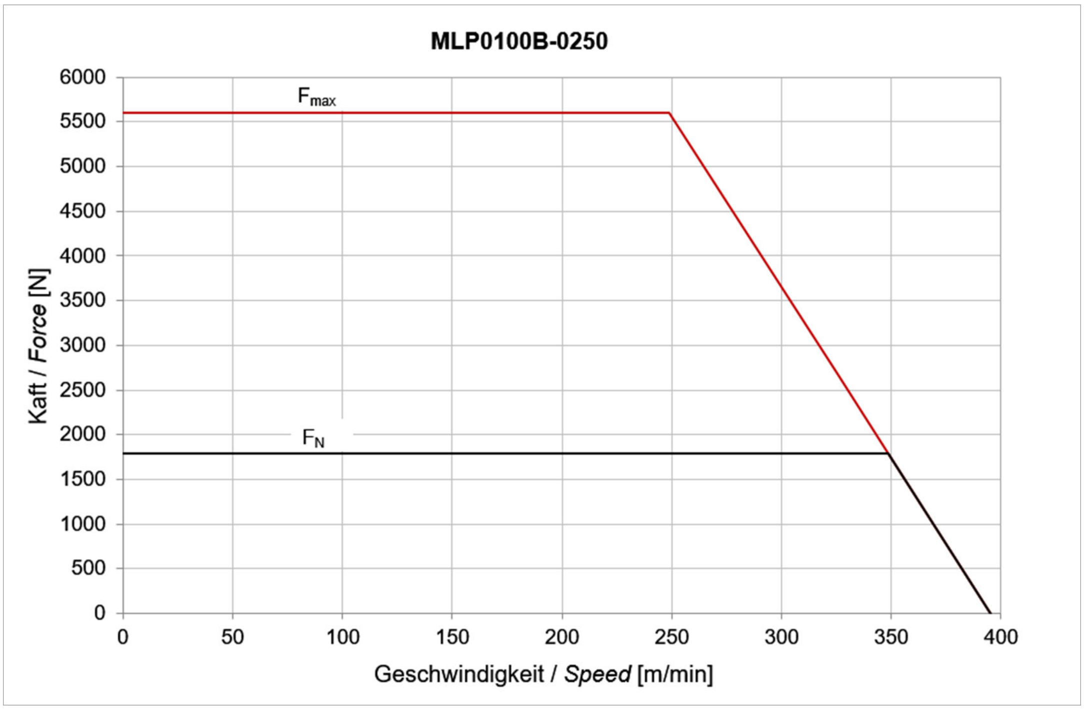


Fig. 4-30: Motor characteristic curves MLP100B-0250

4.6.7 Data MLP100C

Parameter	Symbol	Unit	MLP100		
Frame length			C		
Winding			0090	0120	0190
Maximum force	F_{max}	N	7150		
Continuous nominal force	F_N	N	2310		
Maximum current	I_{max}	A	83.6	84.9	147.1
Rated current	I_N	A	12.1	15.0	24.2
Maximum velocity at F_{max}	v_{Fmax}	m/min	90	120	190
Nominal velocity	v_N	m/min	170	190	290
Force constant	K_{FN}	N/A	191.3	154.2	95.7
Voltage constant	K_{EMK}	Vs/m	110.4	89.0	55.2
Winding resistance at 20 °C	R_{12}	Ohm	6.0	4.0	1.5
Winding inductance	L_{12}	mH	30.358	19.436	8.5
Power wire cross-section	A	mm^2	1.0	1.5	4.0
Pole width	τ_p	mm	37.5		
Attractive force	F_{ATT}	N	10400		
Thermal time constant	T_{th}	min	2.4		
Mass standard encapsulation	m_{PS}	kg	24.0		
Mass thermal encapsulation	m_{PT}	kg	29.7		
Data liquid cooling					
Heat loss to be dissipated	P_V	W	1,600		
Required coolant flow for P_V	Q_{min}	l/min	2.3		
Pressure drop at Q_{min}	Δp	bar	0.8		
Constant for determining pressure drop	$K_{\Delta p}$	-	0.191		
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.13		
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.212		
Latest amendment: 2019-02-07					

Tab. 4-13: MLP100C - Technical data

4.6.8 Motor characteristic curves MLP100C

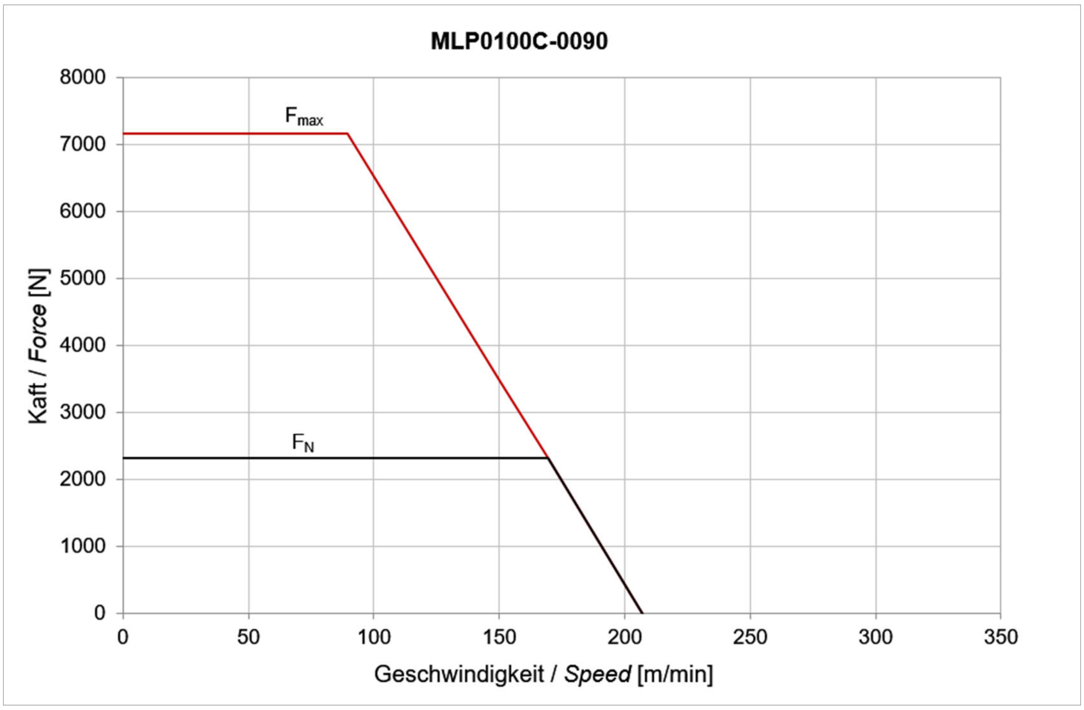


Fig. 4-31: Motor characteristic curve MLP100C-0090

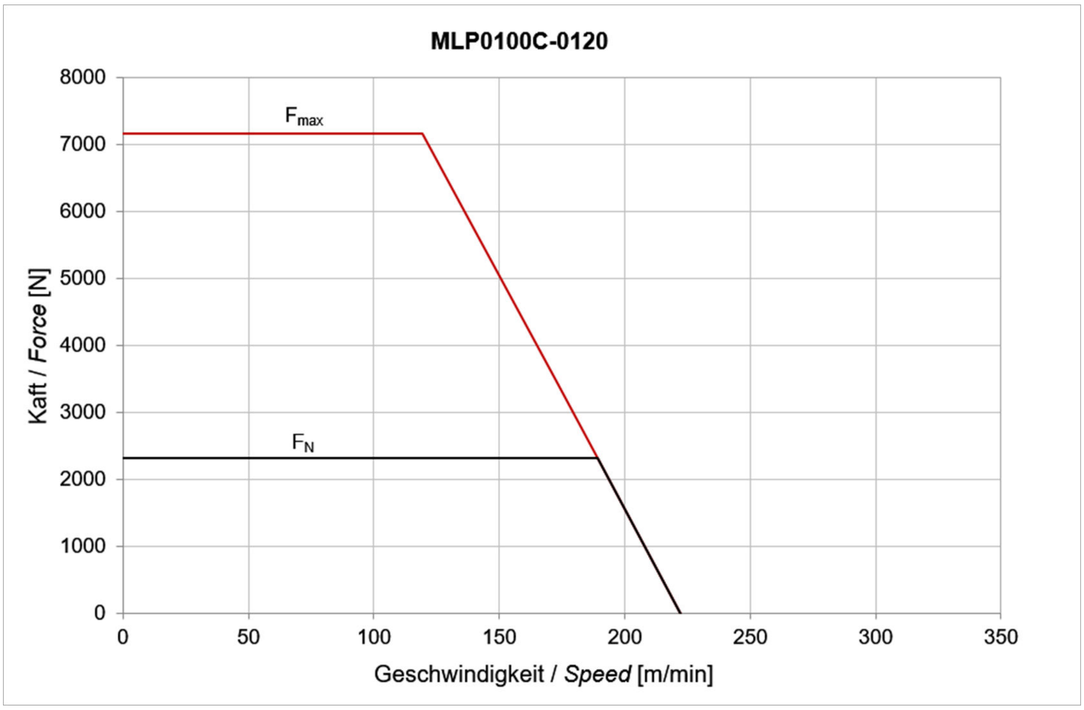


Fig. 4-32: Motor characteristic curves MLP100C-0120

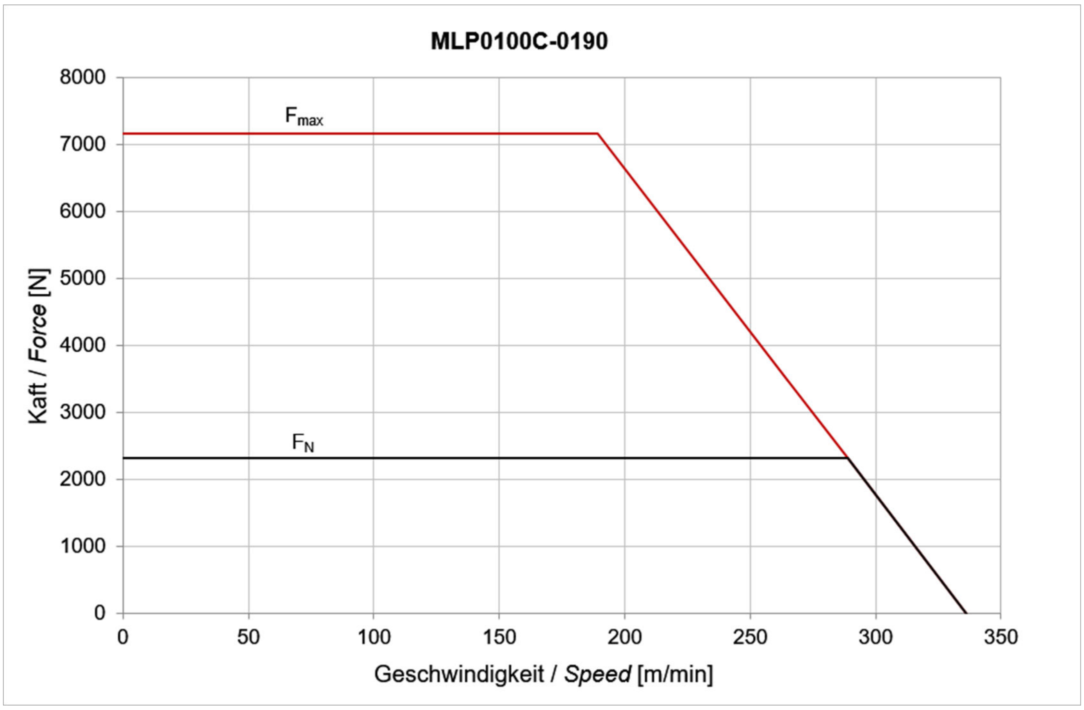


Fig. 4-33: Motor characteristic curves MLP100C-0190

4.6.9 Data MLS100

Designation	Symbol	Unit	MLS100_-_A-0150-NNNN	MLS100_-_A-0450-NNNN	MLS100_-_A-0600-NNNN
Mass secondary part	m_S	kg	2.0	6.0	8.0
Mass secondary part, relative	m_{S_rel}	kg/m	13.4		
Latest amendment: 2019-07-22					

Tab. 4-14: MLS100 - Technical data

4.7 Frame size 102

4.7.1 Data MLP102

Parameter	Symbol	Unit	MLP102		
Frame length			B	C	D
Winding			0060	0060	0060
Maximum force	F_{max}	N	2,730	4,100	5,500
Continuous nominal force	F_N	N	1,300	1,950	2600
Maximum current	I_{max}	A	19.0	29.0	38.5
Rated current	I_N	A	6.5	10.0	14.0
Maximum velocity at F_{max}	v_{Fmax}	m/min	60		
Nominal velocity	v_N	m/min	125	150	140
Force constant	K_{FN}	N/A	203.0	208.7	185.7
Voltage constant	K_{EMK}	Vs/m	117.2	122.8	108.8
Winding resistance at 20 °C	R_{12}	Ohm	10.5	6.4	4.9
Winding inductivity	L_{12}	mH	147.0	93.0	69.0
Power wire cross-section	A	mm^2	1.0		1.5
Pole width	τ_p	mm	30.0		
Attractive force	F_{ATT}	N	5,100	7,600	10,200
Thermal time constant	T_{th}	min	2.9	4.4	
Mass thermal encapsulation	m_{PT}	kg	16.0	20.5	25.0
Data liquid cooling					
Heat loss to be dissipated	P_V	W	1,050	1,300	1550
Required coolant flow for P_V	Q_{min}	l/min	2.1		
Pressure drop at Q_{min}	Δp	bar	1.13	1.7	2.2
Constant for determining pressure drop	$K_{\Delta p}$	-	0.308	0.464	0.601
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.085	0.122	0.158
					Latest amendment: 2019-02-07

Tab. 4-15: MLP102 - Technical data

4.7.2 Motor characteristic curves MLP102

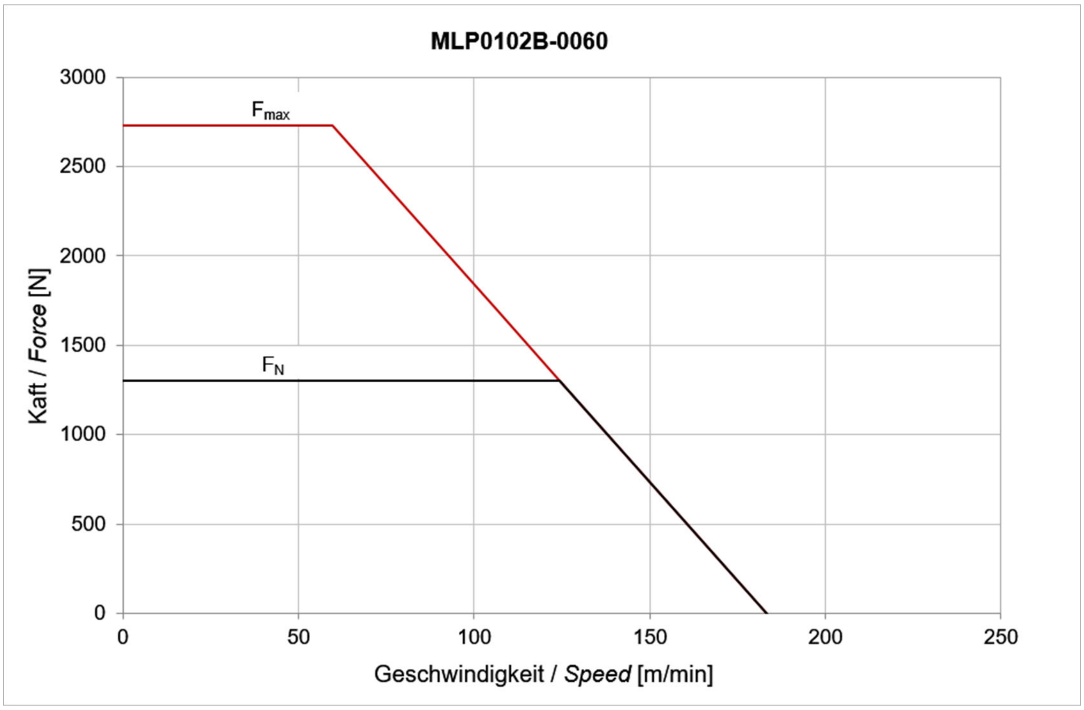


Fig. 4-34: Motor characteristic curve MLP102B-0060-...

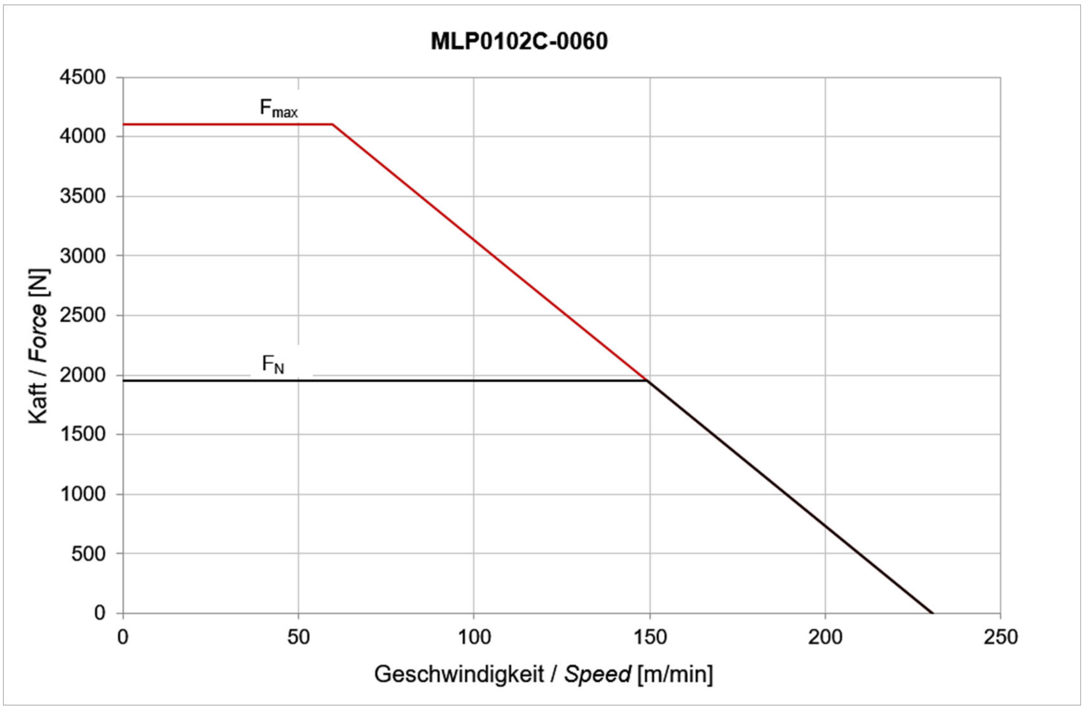


Fig. 4-35: Motor characteristic curve MLP102C-0060-...

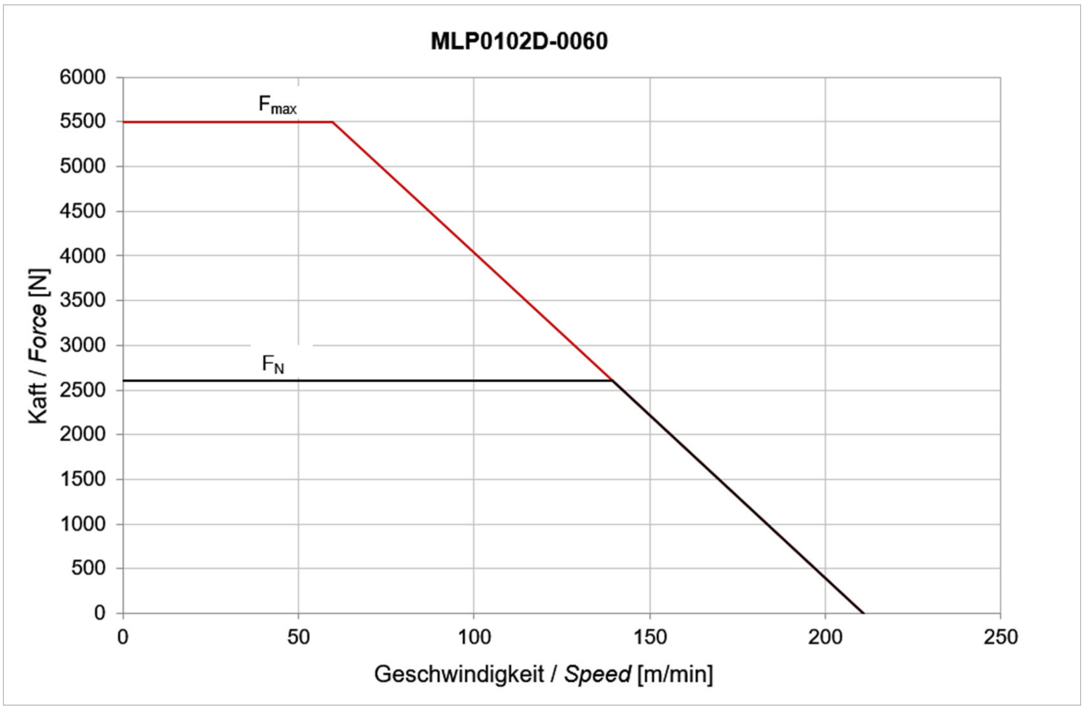


Fig. 4-36: Motor characteristic curve MLP102D-0060-...

4.7.3 Data MLS102

Designation	Symbol	Unit	MLS102_-_A-0180-NNNN
Mass secondary part	m_S	kg	2.6
Mass secondary part, relative	m_{S_rel}	kg/m	14.2
			Latest amendment: 2019-07-22

Tab. 4-16: MLS102 - Technical data

4.8 Frame size 140

4.8.1 Data MLP140Z

Parameter	Symbol	Unit	MLP140
Frame length			Z
Winding			0060
Maximum force	F_{max}	N	2140
Continuous nominal force	F_N	N	790
Maximum current	I_{max}	A	25.3
Rated current	I_N	A	4.2
Maximum velocity at F_{max}	v_{Fmax}	m/min	60
Nominal velocity	v_N	m/min	120
Force constant	K_{FN}	N/A	186.2
Voltage constant at 20 °C	K_{EMK}	Vs/m	107.5
Winding resistance at 20 °C	R_{12}	Ohm	13.6
Winding inductance	L_{12}	mH	75.4
Power wire cross-section	A	mm^2	1.0
Pole width	τ_p	mm	37.5
Attractive force	F_{ATT}	N	3750
Thermal time constant	T_{th}	min	2.4
Mass primary part with standard encapsulation	m_{PS}	kg	8.9
Data liquid cooling			
Power dissipation	P_V	W	550
Required coolant flow for P_V	Q_{min}	l/min	1.2
Pressure drop at Q_{min}	Δp	bar	0.4
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	8.9
Maximum allowed inlet pressure	p_{max}	bar	10.0
			Latest amendment: 2020-01-20

Tab. 4-17: MLP140Z - Technical data

4.8.2 Motor characteristic curve MLP140Z

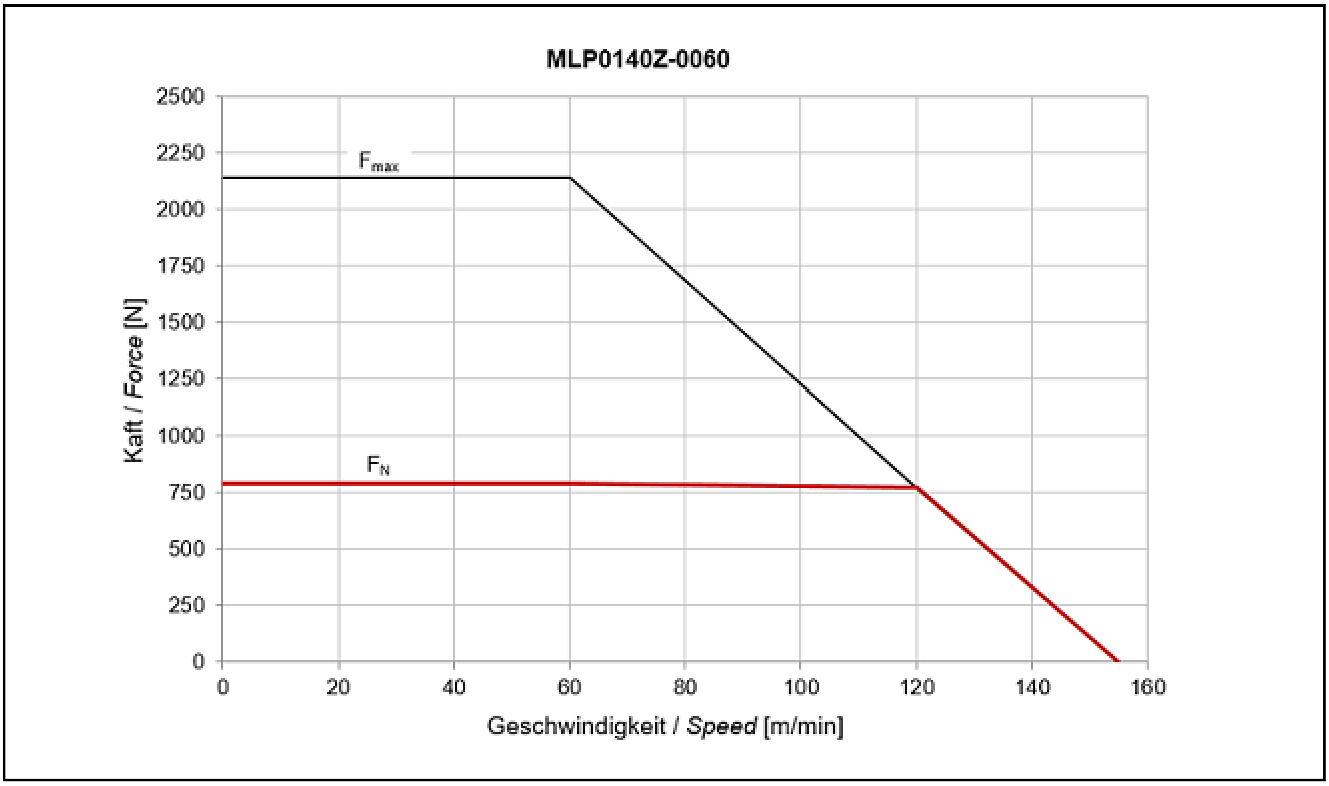


Fig. 4-37: Motor characteristic curve MLP140Z-0060

4.8.3 Data MLP140A

Parameter	Symbol	Unit	MLP140	
Frame lengths			A	
Winding			0030	0120
Maximum force	F_{max}	N	3000	5200
Continuous nominal force	F_N	N	1680	
Maximum current	I_{max}	A	10.5	70.8
Rated current	I_N	A	5.0	12.1
Maximum velocity at F_{max}	v_{Fmax}	m/min	30	120
Nominal velocity	v_N	m/min	75	190
Force constant	K_{FN}	N/A	337.6	138.5
Voltage constant	K_{EMK}	Vs/m	194.9	79.9
Winding resistance at 20 °C	R_{12}	Ohm	3.6	
Winding inductance	L_{12}	mH	20.2	
Power wire cross-section	A	mm^2	1.0	
Pole width	τ_p	mm	37.5	
Attractive force	F_{ATT}	N	7,500	
Thermal time constant	T_{th}	min	2.4	
Mass standard encapsulation	m_{PS}	kg	17.0	
Mass thermal encapsulation	m_{PT}	kg	21.2	
Data liquid cooling				
Heat loss to be dissipated	P_V	W	1,300	
Required coolant flow for P_V	Q_{min}	l/min	1.9	
Pressure drop at Q_{min}	Δp	bar	0.6	
Constant for determining pressure drop	$K_{\Delta p}$	-	0.187	
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.087	
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.145	
Latest amendment: 2019-02-07				

Tab. 4-18: MLP140 - Technical data

4.8.4 Motor characteristic curves MLP140A

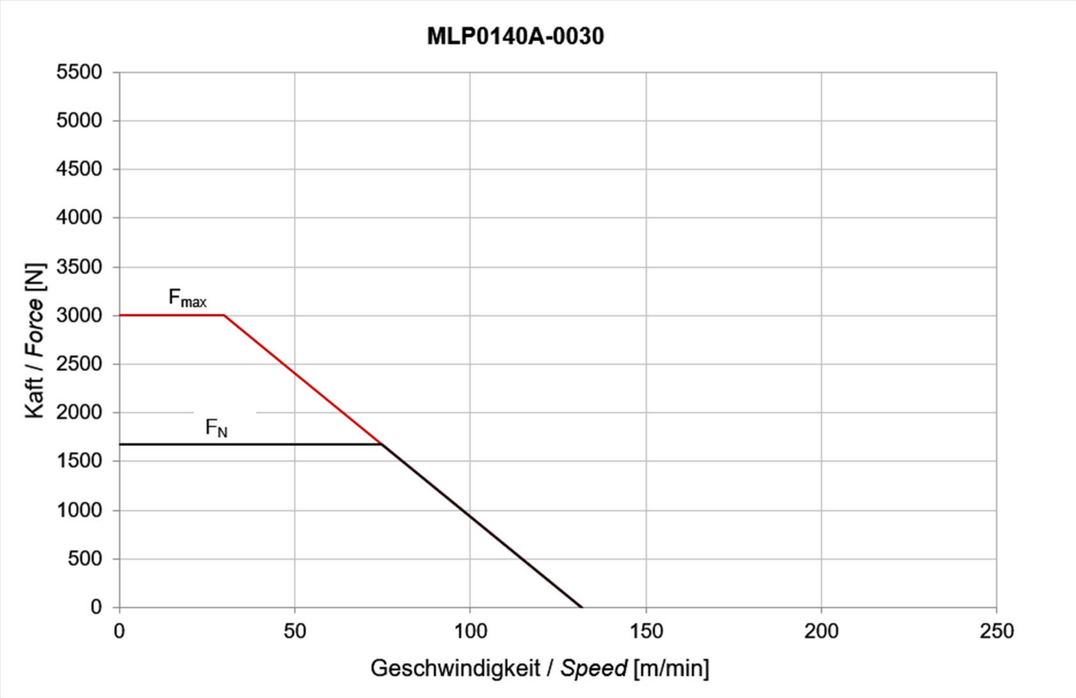


Fig. 4-38: Motor characteristic curve MLP140A-0030

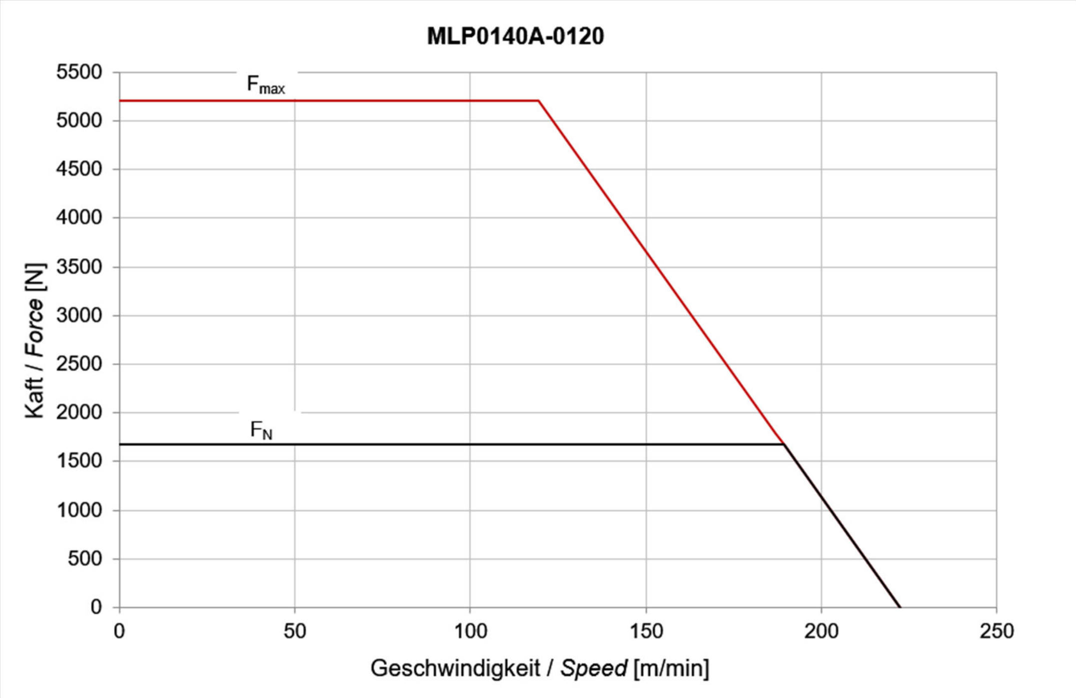


Fig. 4-39: Motor characteristic curves MLP140A-0120

4.8.5 Data MLP140B

Parameter	Symbol	Unit	MLP140		
Frame length			B		
Winding			0035	0090	0120
Maximum force	F_{max}	N	7650		
Continuous nominal force	F_N	N	2415		
Maximum current	I_{max}	A	41.3	79.3	103.8
Rated current	I_N	A	7.7	14.0	17.8
Maximum velocity at F_{max}	v_{Fmax}	m/min	35	90	120
Nominal velocity	v_N	m/min	85	160	190
Force constant	K_{FN}	N/A	313.6	172.8	135.8
Voltage constant	K_{EMK}	Vs/m	66.5	99.7	78.3
Winding resistance at 20 °C	R_{12}	Ohm	15.9	4.3	2.6
Winding inductance	L_{12}	mH	80.0	23.1	14.2
Power wire cross-section	A	mm^2	1.0		2.5
Pole width	τ_p	mm	37.5		
Attractive force	F_{ATT}	N	11,000		
Thermal time constant	T_{th}	min	2.4		
Mass standard encapsulation	m_{PS}	kg	24.5		
Mass thermal encapsulation	m_{PT}	kg	30.1		
Data liquid cooling					
Heat loss to be dissipated	P_V	W	2,512		
Required coolant flow for P_V	Q_{min}	l/min	3.6		
Pressure drop at Q_{min}	Δp	bar	0.9		
Constant for determining pressure drop	$K_{\Delta p}$	-	0.095		
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.123		
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.214		
Latest amendment: 2019-02-07					

Tab. 4-19: MLP140B - Technical data

4.8.6 Motor characteristic curves MLP140B

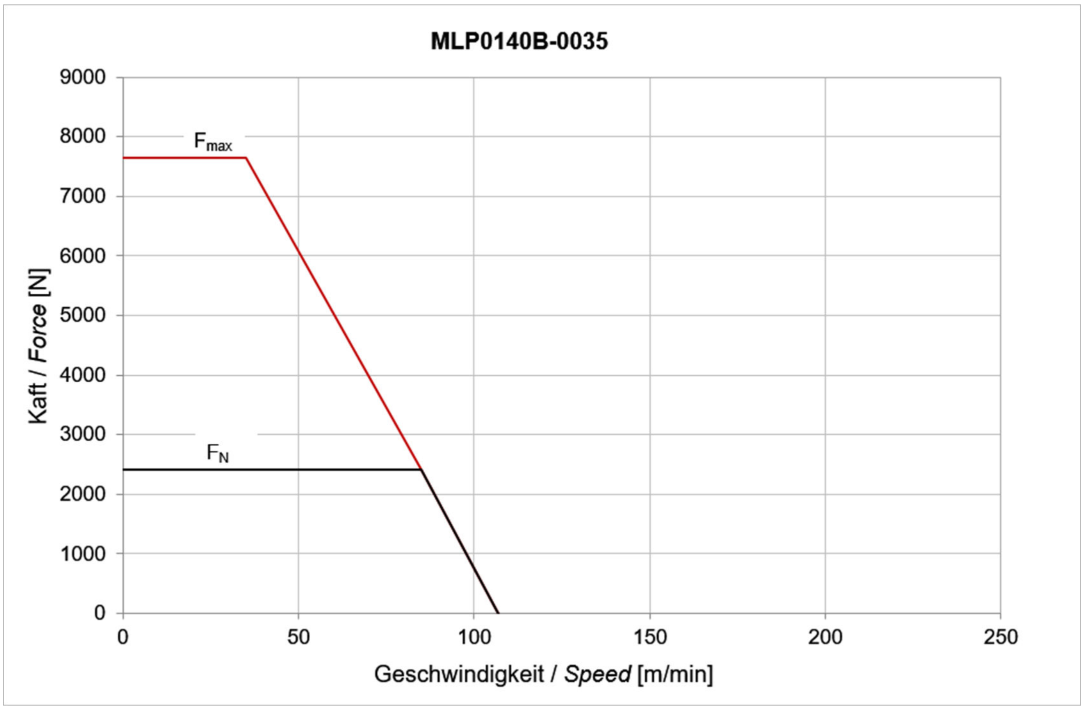


Fig. 4-40: Motor characteristic curves MLP140B-0035

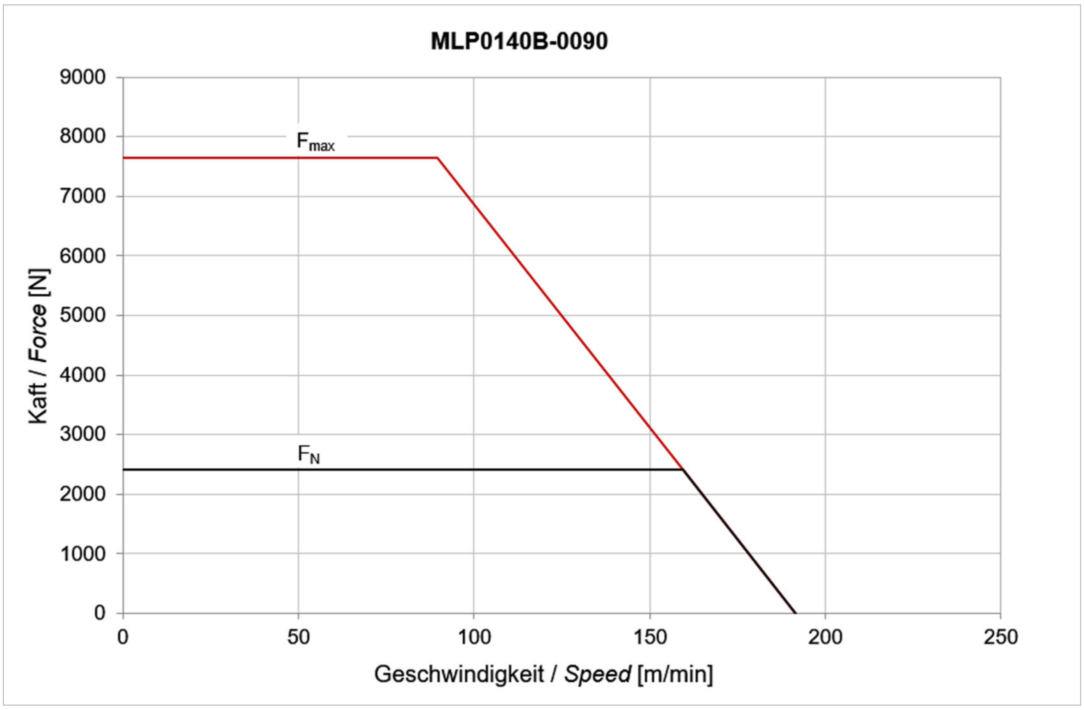


Fig. 4-41: Motor characteristic curve MLP140B-0090

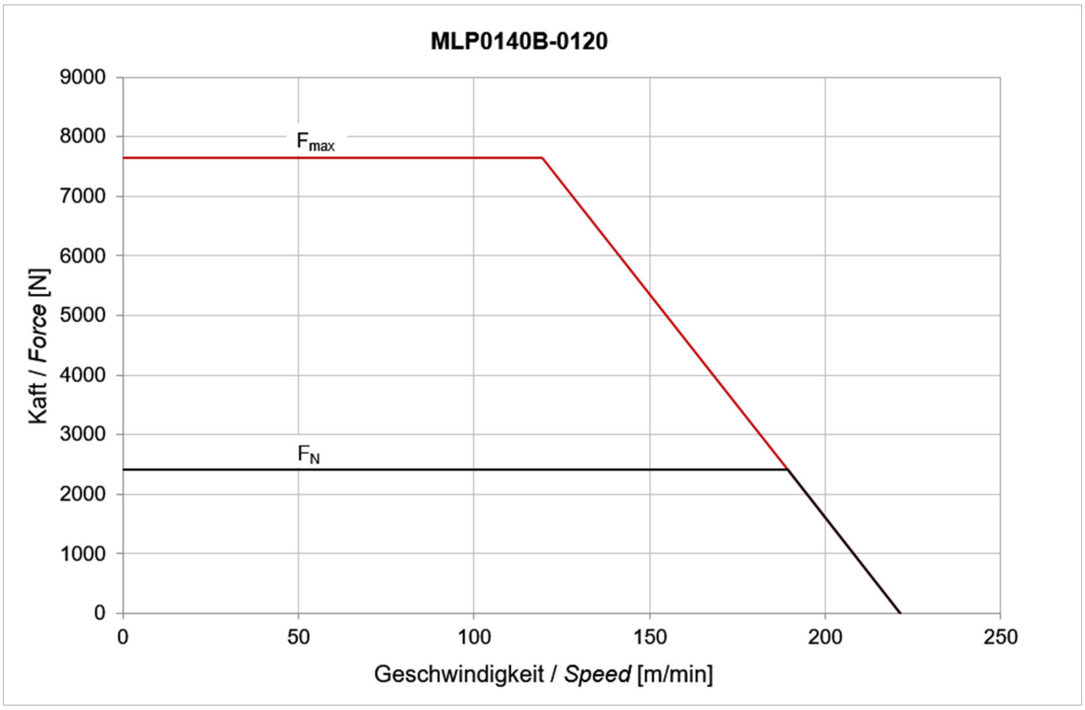


Fig. 4-42: Motor characteristic curves MLP140B-0120

4.8.7 Data MLP140C

Parameter	Symbol	Unit	MLP140			
Frame lengths			C			
Winding			0050	0120	0170	0350
Maximum force	F_{max}	N	10,000			
Continuous nominal force	F_N	N	3150			
Maximum current	I_{max}	A	78.6	122.9	137.8	231.1
Rated current	I_N	A	14.6	20.7	28.5	47.1
Maximum velocity at F_{max}	v_{Fmax}	m/min	50	120	170	350
Nominal velocity	v_N	m/min	110	190	250	400
Force constant	K_{FN}	N/A	215.9	152.6	110.4	66.9
Voltage constant	K_{EMK}	Vs/m	124.6	88.1	63.7	38.6
Winding resistance at 20 °C	R_{12}	Ohm	5.2	2.55	1.34	0.49
Winding inductance	L_{12}	mH	28.5	14.3	7.48	2.6
Power wire cross-section	A	mm^2	1.0	2.5	4.0	10.0
Pole width	τ_p	mm	37.5			
Attractive force	F_{ATT}	N	14,400			
Thermal time constant	T_{th}	min	2.4			
Mass standard encapsulation	m_{PS}	kg	32.0			
Mass thermal encapsulation	m_{PT}	kg	38.9			
Data liquid cooling						
Heat loss to be dissipated	P_V	W	2,000			
Required coolant flow for P_V	Q_{min}	l/min	2.9			
Pressure drop at Q_{min}	Δp	bar	1.2			
Constant for determining pressure drop	$K_{\Delta p}$	-	0.186			
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.159			
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.277			
			Latest amendment: 2019-02-07			

Tab. 4-20: MLP140C - Technical data

4.8.8 Motor characteristic curves MLP140C

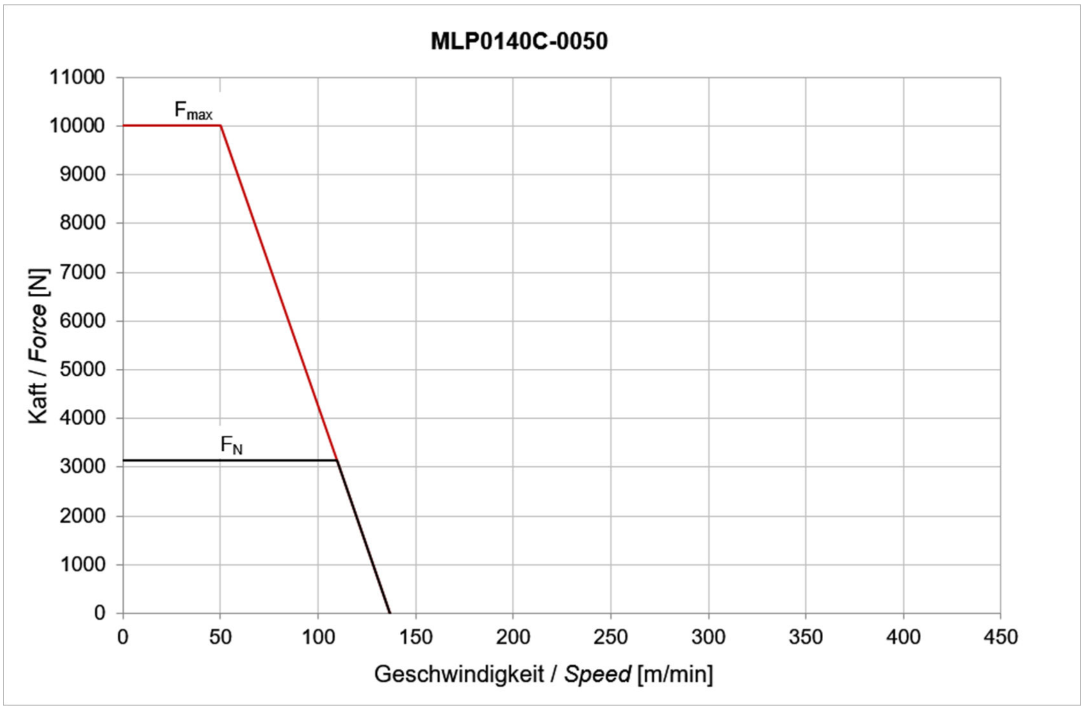


Fig. 4-43: Motor characteristic curve MLP140C-0050

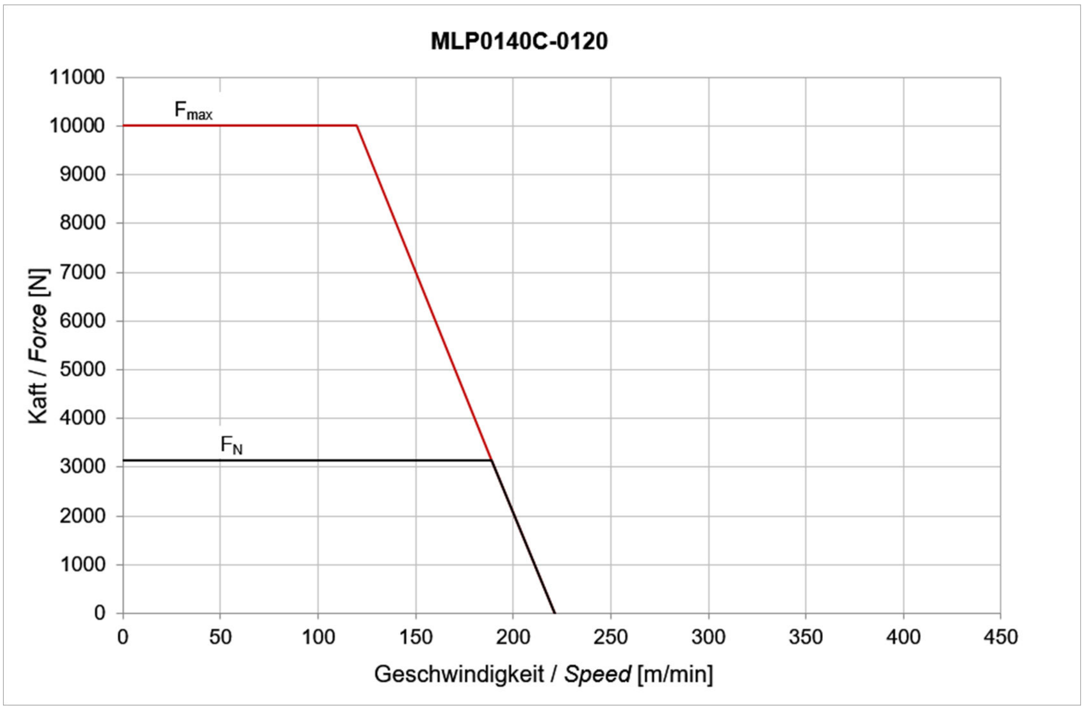


Fig. 4-44: Motor characteristic curves MLP140C-0120

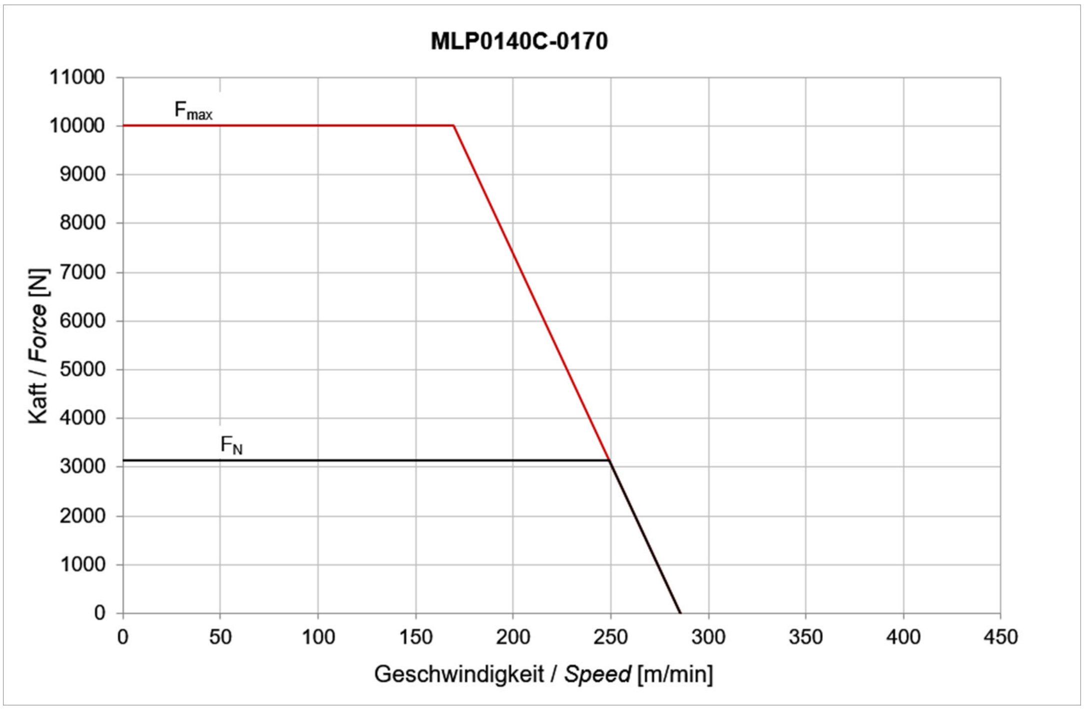


Fig. 4-45: Motor characteristic curves MLP140C-0170

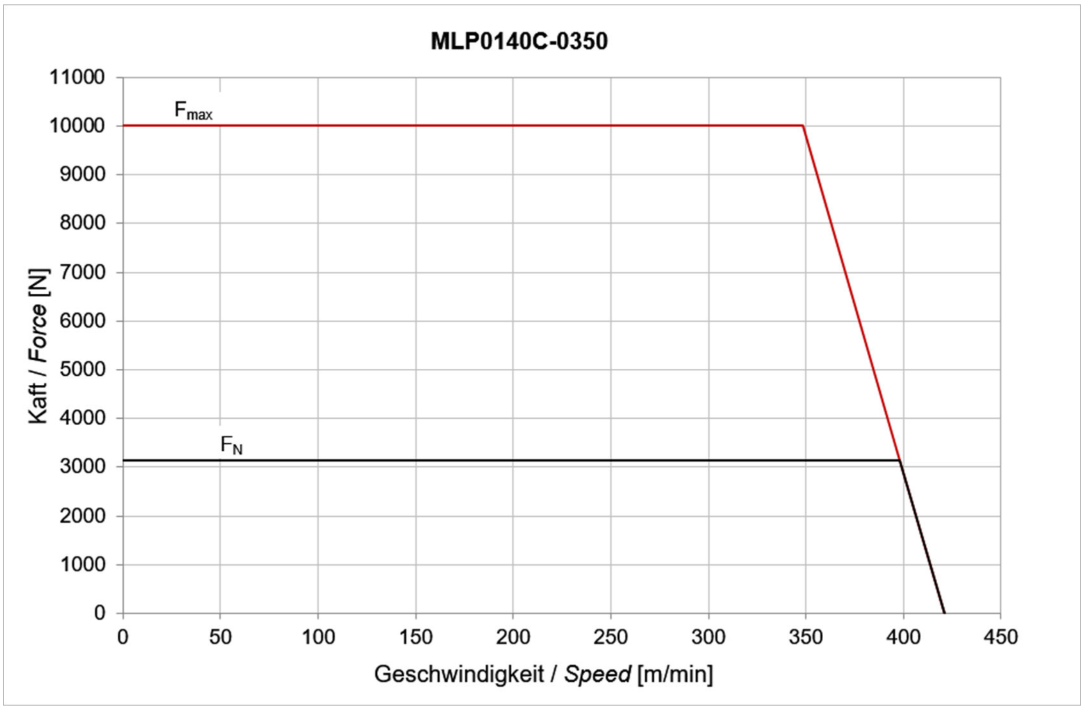


Fig. 4-46: Motor characteristic curves MLP140C-0350

4.8.9 Data MLS140

Designation	Symbol	Unit	MLS140_-_A-0150-NNNN	MLS140_-_A-0450-NNNN	MLS140_-_A-0600-NNNN
Mass secondary part	m_S	kg	2.5	7.6	10.1
Mass secondary part, relative	m_{S_rel}	kg/m	18.8		
Latest amendment: 2019-07-22					

Tab. 4-21: MLS140 - Technical data

4.9 Frame size 152

4.9.1 Data MLP152

Parameter	Symbol	Unit	MLP152			
Frame length			A	B	C	D
Winding			0060	0060	0060	0060
Maximum force	F_{max}	N	4200	6100	7800	10,000
Continuous nominal force	F_N	N	1,950	2925	3,900	4750
Maximum current	I_{max}	A	30.0	44.5	58.3	93.2
Rated current	I_N	A	11.0	16.3	22.0	28.0
Maximum velocity at F_{max}	v_{Fmax}	m/min	60			
Nominal velocity	v_N	m/min	150	140	150	
Force constant	K_{FN}	N/A	177.3	177.9	213.1	200.4
Voltage constant	K_{EMK}	Vs/m	122.8			115.6
Winding resistance at 20 °C	R_{12}	Ohm	5.5	3.7	2.8	2.24
Winding inductance	L_{12}	mH	82.0	55.0	42.1	34.0
Power wire cross-section	A	mm^2	1.0	2.5		4.0
Pole width	τ_p	mm	30.0			
Attractive force	F_{ATT}	N	6300	9500	15,200	19000
Thermal time constant	T_{th}	min	2.6			
Mass thermal encapsulation	m_{PT}	kg	17.0	24.0	31.0	38.0
Data liquid cooling						
Heat loss to be dissipated	P_V	W	940	1,660	2,480	3,100
Required coolant flow for P_V	Q_{min}	l/min	3.4			4.4
Pressure drop at Q_{min}	Δp	bar	0.87	1.24	1.6	1.9
Constant for determining pressure drop	$K_{\Delta p}$	-	0.102	0.146	0.188	0.142
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.078	0.111	0.143	0.176
Latest amendment: 2019-02-07						

Tab. 4-22: MLP152 - Technical data

4.9.2 Motor characteristic curves MLP152

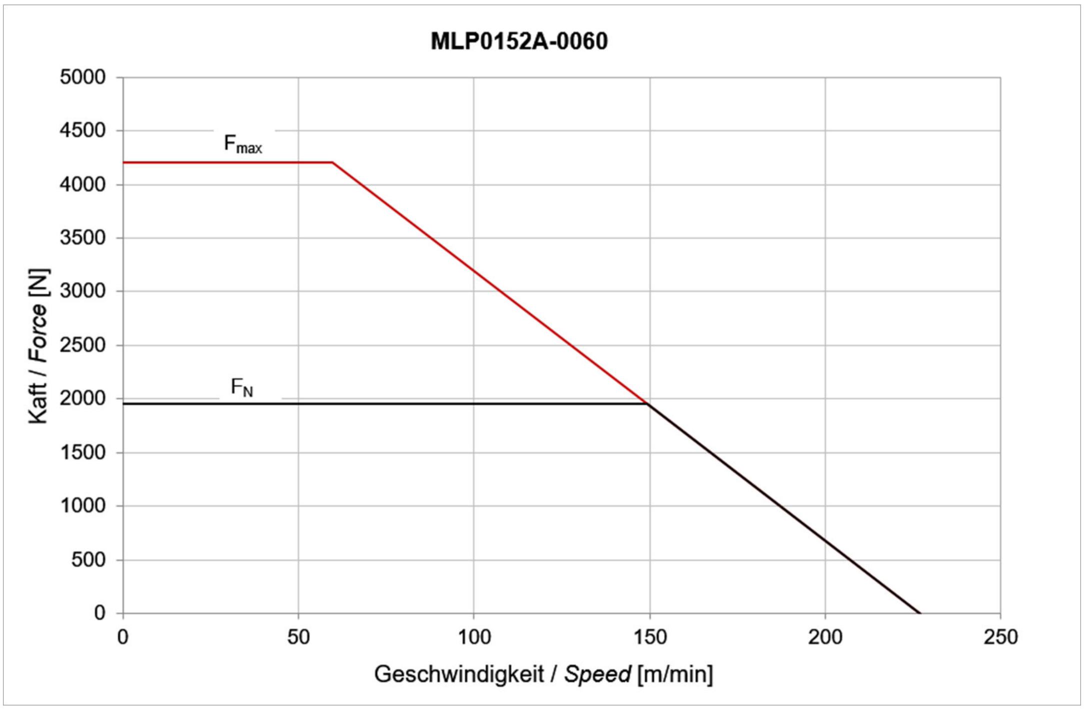


Fig. 4-47: Motor characteristic curves MLP152A-0060

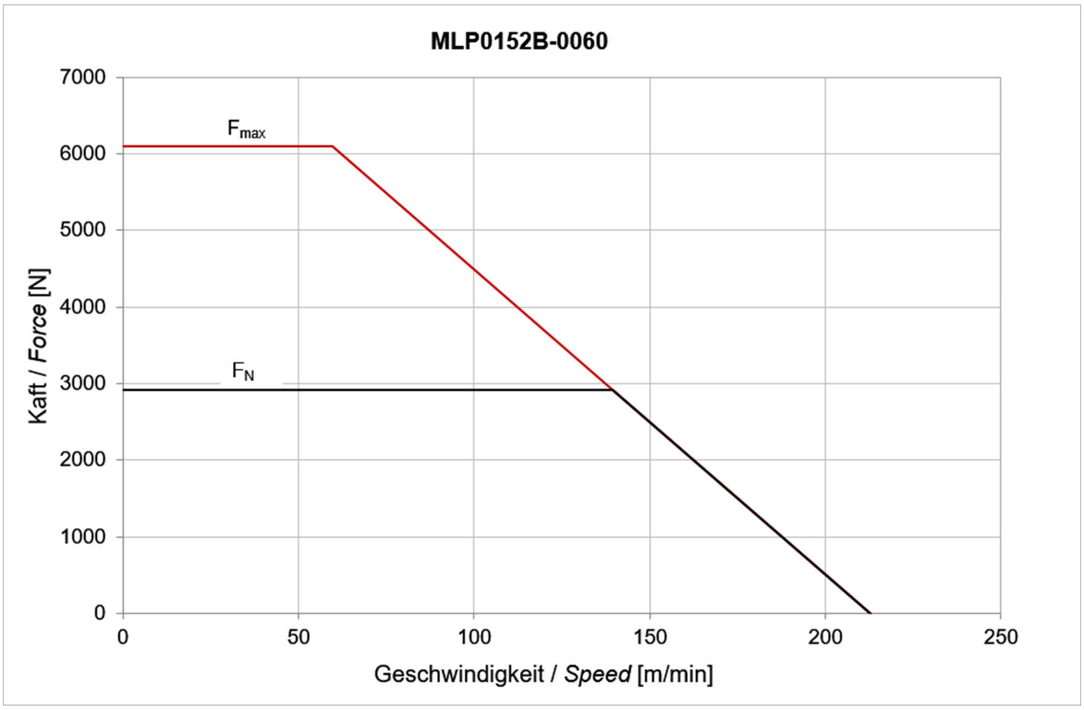


Fig. 4-48: Motor characteristic curves MLP152B-0060

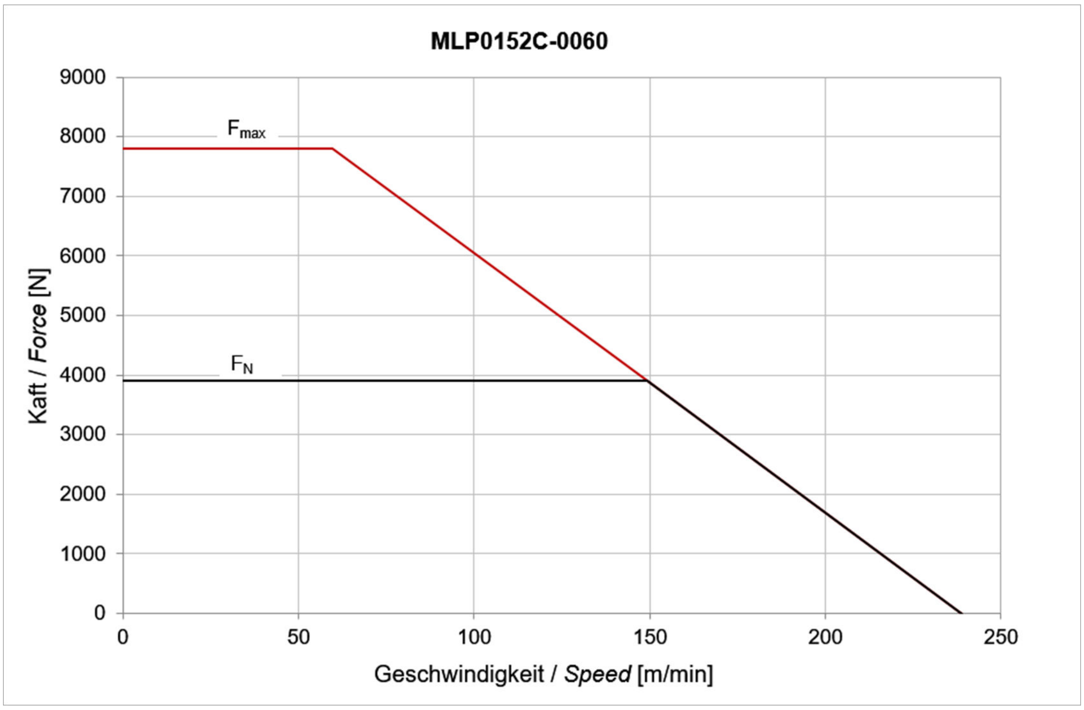


Fig. 4-49: Motor characteristic curve MLP152C-0060

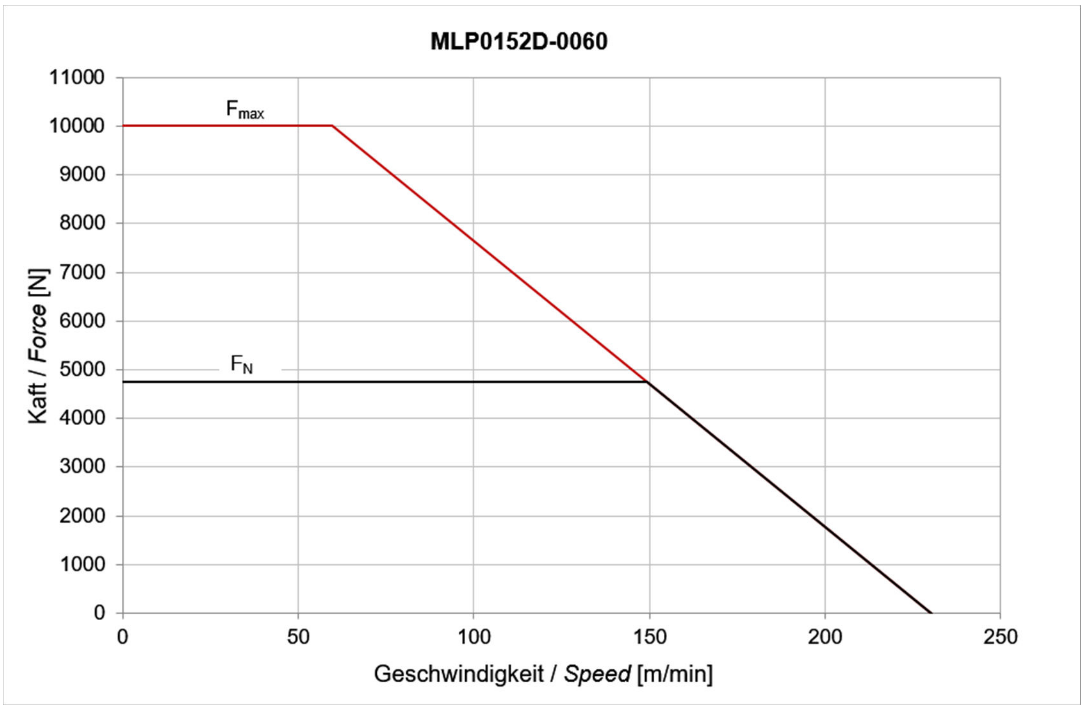


Fig. 4-50: Motor characteristic curve MLP152D-0060

4.9.3 Data MLS152

Designation	Symbol	Unit	MLS152_-_A-0180-NNNN
Mass secondary part	m_S	kg	3.6
Mass secondary part, relative	m_{S_rel}	kg/m	20.0
			Latest amendment: 2019-07-22

Tab. 4-23: MLS152 - Technical data

4.10 Frame size 200

4.10.1 Frame size MLP200A, MLP200B

Parameter	Symbol	Unit	MLP200			
Frame lengths			A		B	
Winding			0090	0120	0040	0120
Maximum force	F_{max}	N	7450		10900	
Continuous nominal force	F_N	N	2415		3465	
Maximum current	I_{max}	A	69.6	81.3	74.2	128.6
Rated current	I_N	A	12.9	14.8	13.8	21.8
Maximum velocity at F_{max}	v_{Fmax}	m/min	90	120	40	120
Nominal velocity	v_N	m/min	170	190	100	190
Force constant	K_{FN}	N/A	186.7	163.5	251.4	159.3
Voltage constant	K_{EMK}	Vs/m	107.8	94.3	145.1	91.9
Winding resistance at 20 °C	R_{12}	Ohm	4.5	2.3	5.7	2.34
Winding inductance	L_{12}	mH	22.7	14.0	29.7	12.1
Power wire cross-section	A	mm^2	1.0	2.5	1.0	2.5
Pole width	τ_p	mm	37.5			
Attractive force	F_{ATT}	N	10700		15,600	
Thermal time constant	T_{th}	min	2.4			
Mass standard encapsulation	m_{PS}	kg	23.0		33.0	
Mass thermal encapsulation	m_{PT}	kg	28.3		40.0	
Data liquid cooling						
Heat loss to be dissipated	P_V	W	1,700		2,200	
Required coolant flow for P_V	Q_{min}	l/min	2.4		3.2	
Pressure drop at Q_{min}	Δp	bar	0.9		1.4	
Constant for determining pressure drop	$K_{\Delta p}$	-	0.189		0.188	
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.11		0.157	
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.185		0.277	
Latest amendment: 2019-02-07						

Tab. 4-24: MLP200 - Technical data

4.10.2 Motor characteristic curves MLP200A

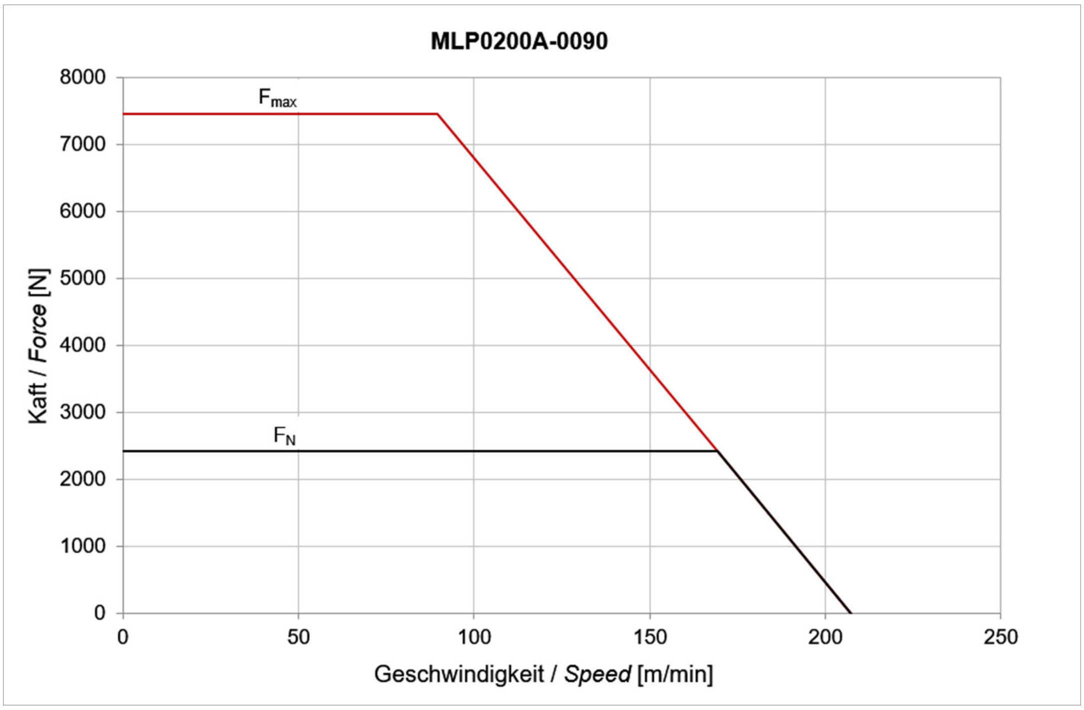


Fig. 4-51: Motor characteristic curve MLP200A-0090

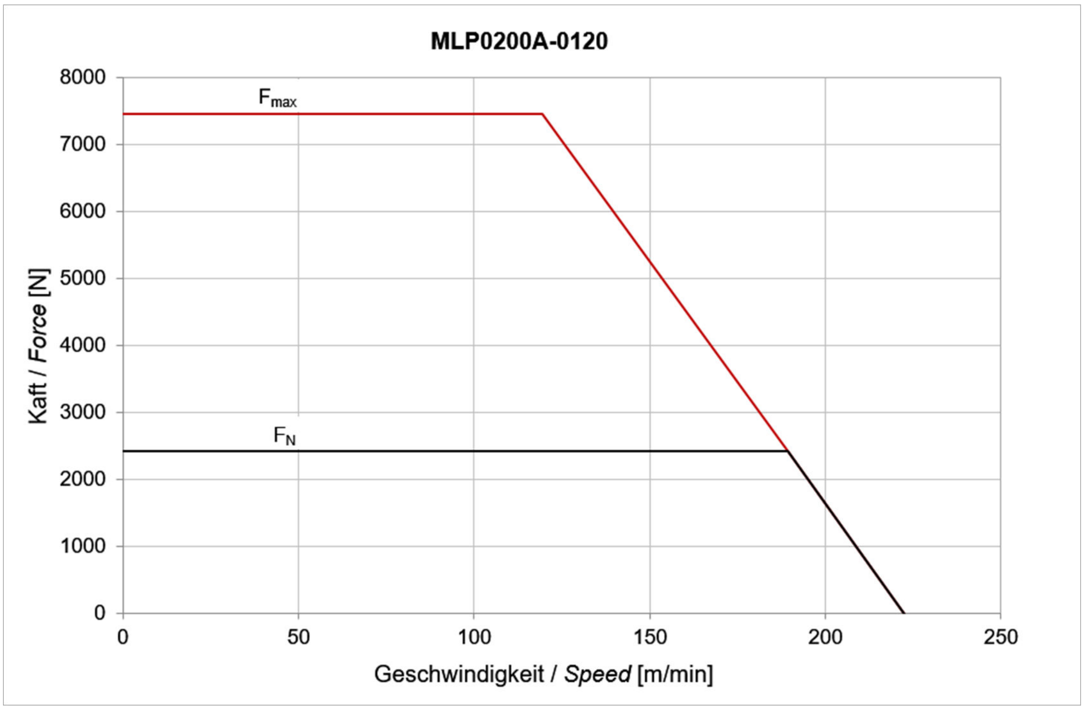


Fig. 4-52: Motor characteristic curves MLP200A-0120

4.10.3 Motor characteristic curves MLP200B

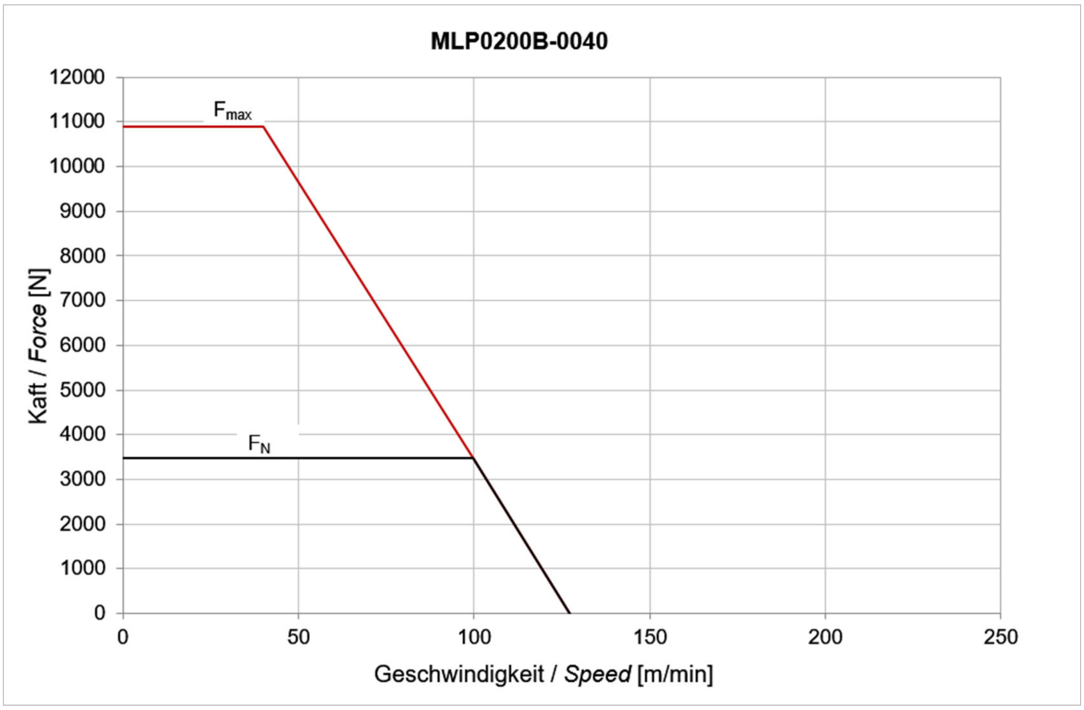


Fig. 4-53: Motor characteristic curve MLP200B-0040

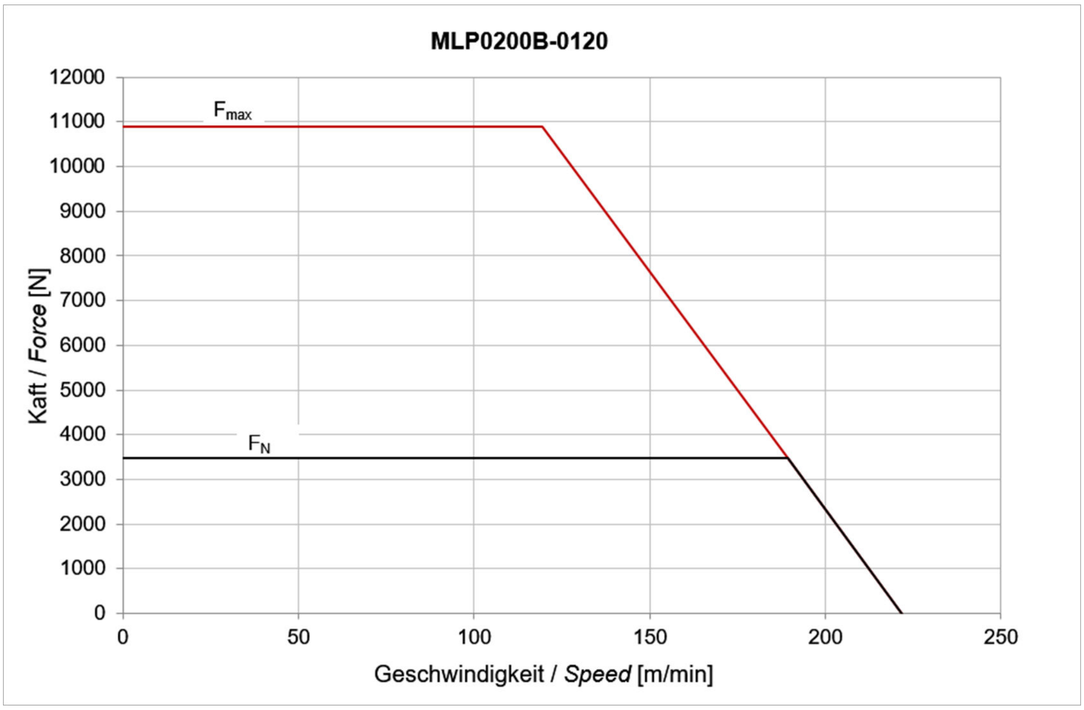


Fig. 4-54: Motor characteristic curves MLP200B-0120

4.10.4 Data MLP200C

Parameter	Symbol	Unit	MLP200		
Frame lengths			C		
Winding			0090	0120	0170
Maximum force	F_{max}	N	14250		
Continuous nominal force	F_N	N	4460		
Maximum current	I_{max}	A	117.9	146.2	162.6
Rated current	I_N	A	22.9	28.4	35.6
Maximum velocity at F_{max}	v_{Fmax}	m/min	90	120	140
Nominal velocity	v_N	m/min	170	190	220
Force constant	K_{FN}	N/A	194.1	157.2	125.3
Voltage constant	K_{EMK}	Vs/m	112.5	90.7	72.3
Winding resistance at 20 °C	R_{12}	Ohm	2.64	1.76	1.08
Winding inductance	L_{12}	mH	13.6	9.0	5.7
Power wire cross-section	A	mm^2	4.0	6.0	10.0
Pole width	τ_p	mm	37.5		
Attractive force	F_{ATT}	N	20500		
Thermal time constant	T_{th}	min	2.4		
Mass standard encapsulation	m_{PS}	kg	42.0		
Mass thermal encapsulation	m_{PT}	kg	50.7		
Data liquid cooling					
Heat loss to be dissipated	P_V	W	2,900		
Required coolant flow for P_V	Q_{min}	l/min	4.2		
Pressure drop at Q_{min}	Δp	bar	1.6		
Constant for determining pressure drop	$K_{\Delta p}$	-	0.13		
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.203		
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.358		
Latest amendment: 2019-02-07					

Tab. 4-25: MLP200C - Technical data

4.10.5 Motor characteristic curves MLP200C

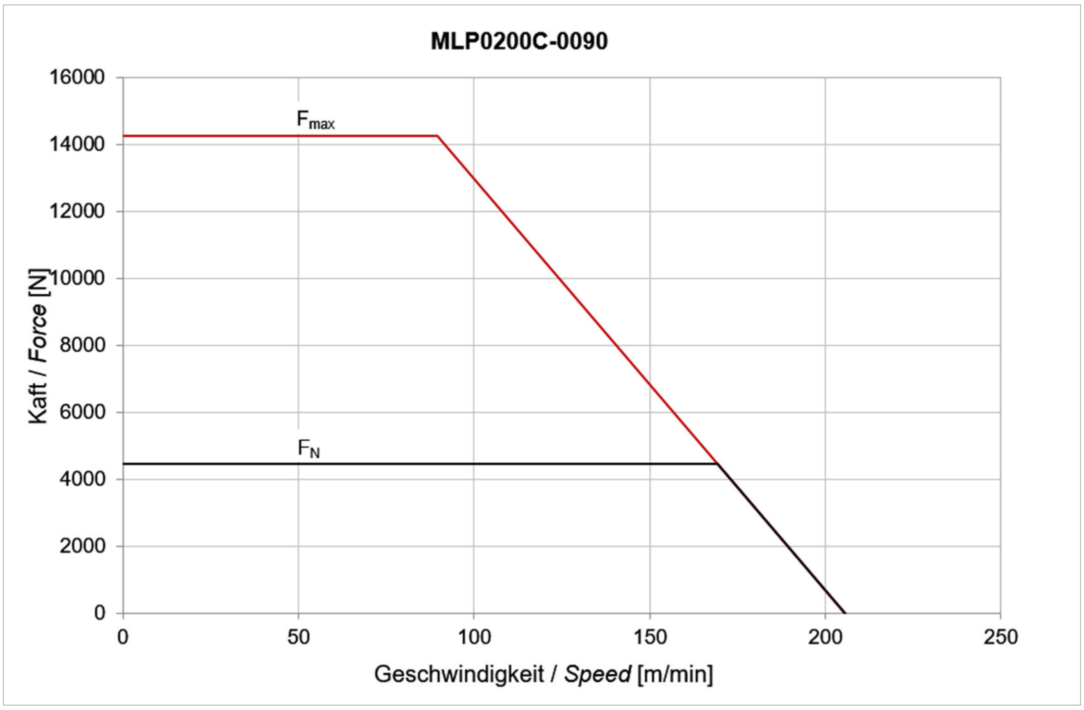


Fig. 4-55: Motor characteristic curve MLP200C-0090

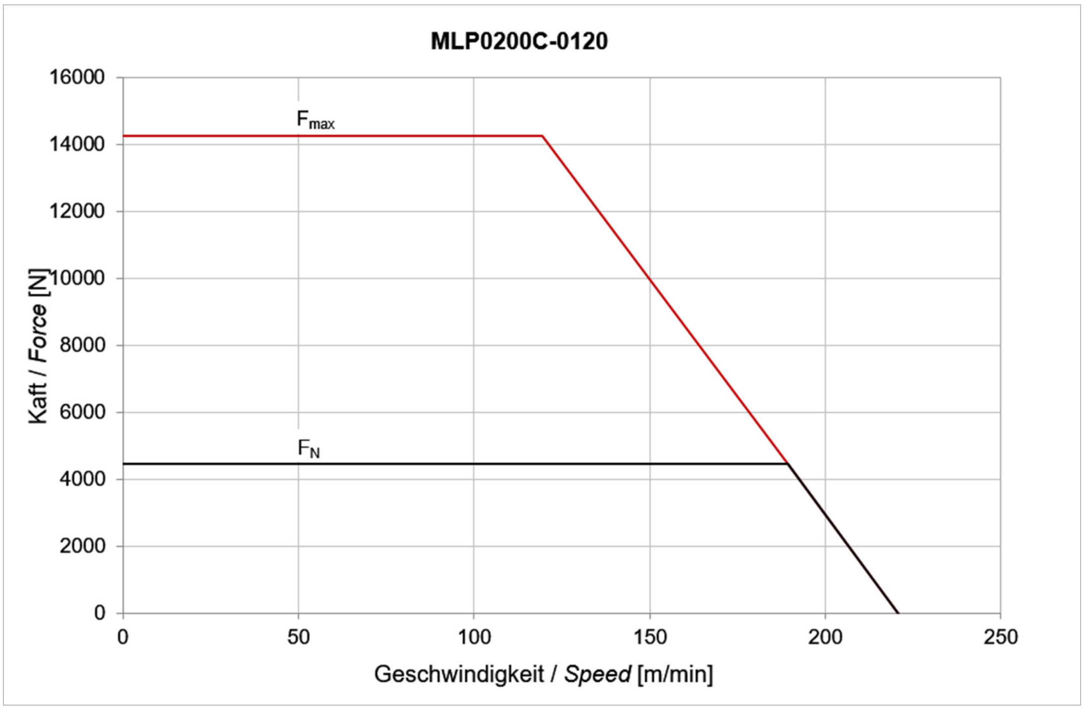


Fig. 4-56: Motor characteristic curves MLP200C-0120

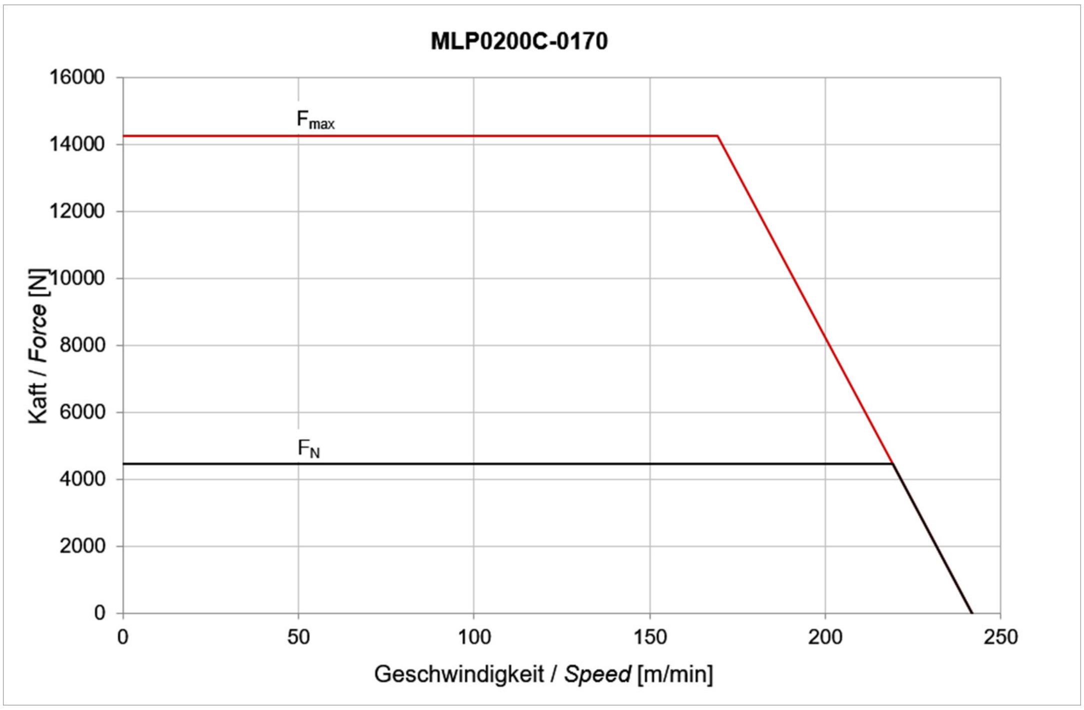


Fig. 4-57: Motor characteristic curves MLP200C-0170

4.10.6 Data MLP200D

Parameter	Symbol	Unit	MLP200			
Frame lengths			D			
Winding			0035	0060	0100	0120
Maximum force	F_{max}	N	16500	17750		
Continuous nominal force	F_N	N	5560			
Maximum current	I_{max}	A	90.0	126.2	204.4	201.5
Rated current	I_N	A	20.2	25.2	44.8	47.5
Maximum velocity at F_{max}	v_{Fmax}	m/min	35	60	100	120
Nominal velocity	v_N	m/min	105	140	180	190
Force constant	K_{FN}	N/A	275.4	220.4	124.3	117.3
Voltage constant	K_{EMK}	Vs/m	159.0	127.2	71.7	67.6
Winding resistance at 20 °C	R_{12}	Ohm	4.0	2.74	0.88	0.74
Winding inductance	L_{12}	mH	23.9	15.07	4.5	4.1
Power wire cross-section	A	mm^2	4.0		10.0	
Pole width	τ_p	mm	37.5			
Attractive force	F_{ATT}	N	25400			
Thermal time constant	T_{th}	min	2.4			
Mass standard encapsulation	m_{PS}	kg	51.0			
Mass thermal encapsulation	m_{PT}	kg	61.3			
Data liquid cooling						
Heat loss to be dissipated	P_V	W	3,700			
Required coolant flow for P_V	Q_{min}	l/min	5.2			
Pressure drop at Q_{min}	Δp	bar	2.45			
Constant for determining pressure drop	$K_{\Delta p}$	-	0.137			
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.25			
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.45			
Latest amendment: 2019-02-07						

Tab. 4-26: MLP200D - Technical data

4.10.7 Motor characteristic curves MLP200D

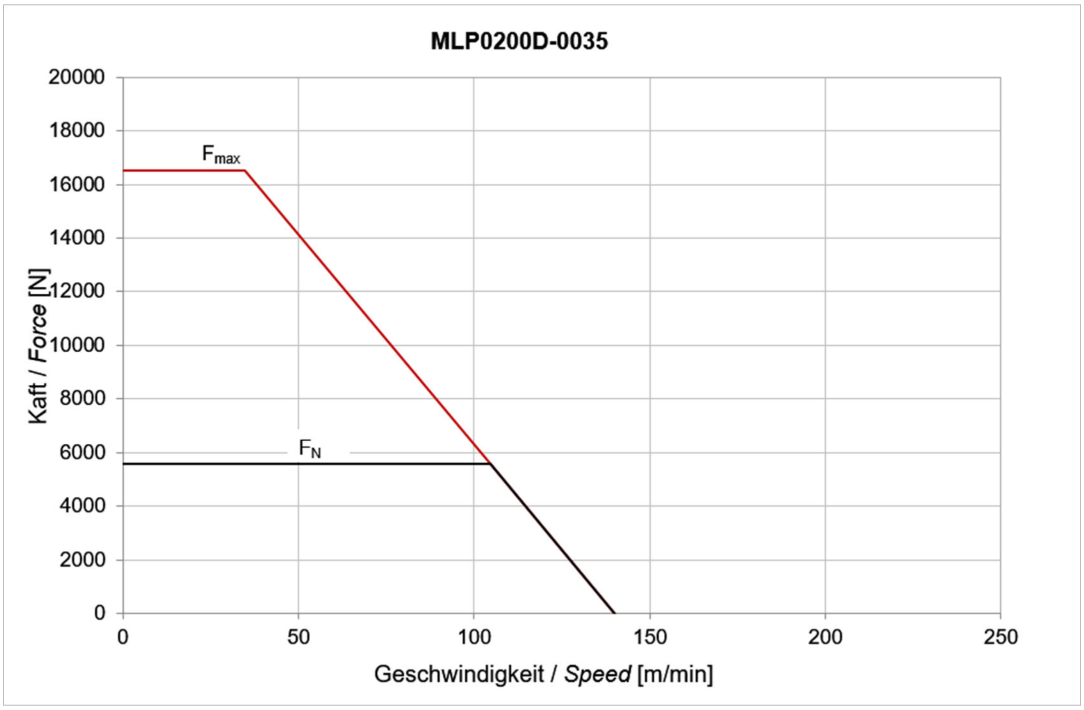


Fig. 4-58: Motor characteristic curve MLP200D-0035

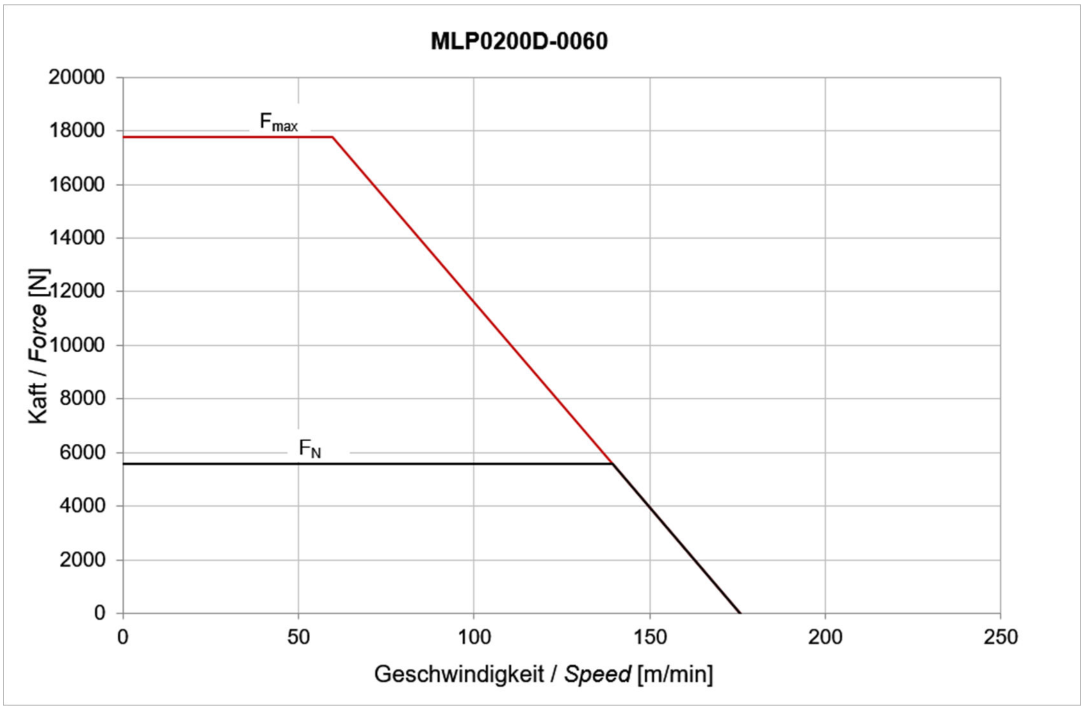


Fig. 4-59: Motor characteristic curves MLP200D-0060

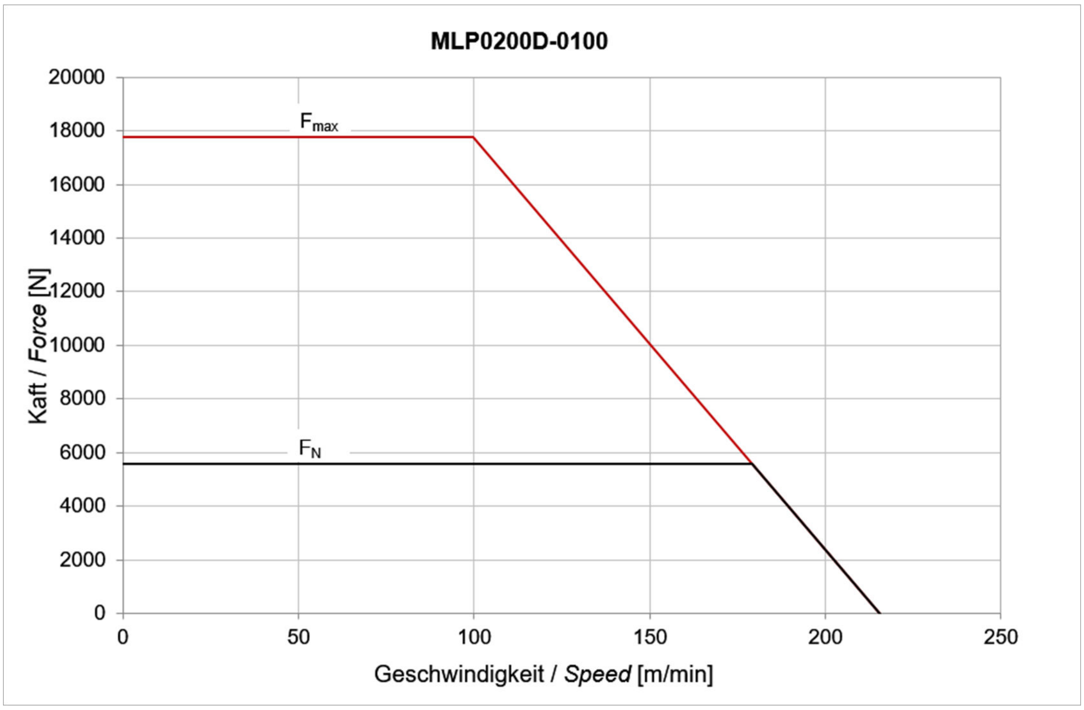


Fig. 4-60: Motor characteristic curves MLP200D-0100

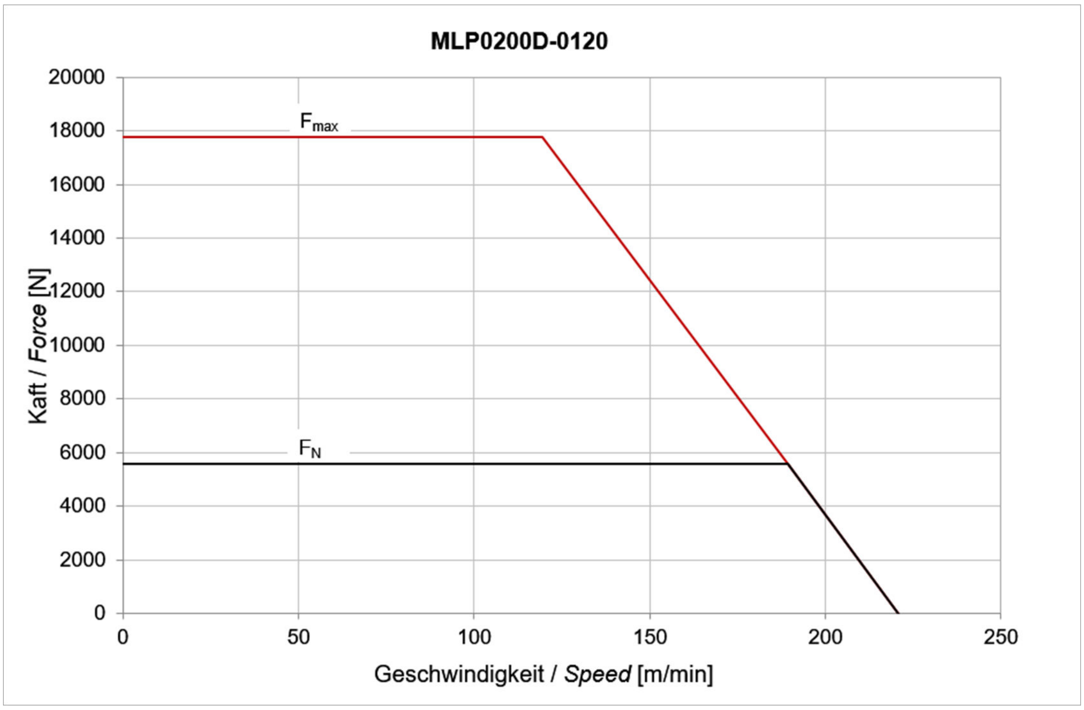


Fig. 4-61: Motor characteristic curves MLP200D-0120

4.10.8 Data MLS200

Designation	Symbol	Unit	MLS200_-_A-0150-NNNN	MLS200_-_A-0450-NNNN	MLS200_-_A-0600-NNNN
Mass secondary part	m_S	kg	4.0	12.1	16.1
Mass secondary part, relative	m_{S_rel}	kg/m	26.9		
Latest amendment: 2019-07-22					

Tab. 4-27: MLS200 - Technical data

4.11 Frame size 202

4.11.1 Data MLP202

Parameter	Symbol	Unit	MLP202			
Frame length			A	B	C	D
Winding			0060	0060	0060	0060
Maximum force	F_{max}	N	5800	8,500	11600	14,400
Continuous nominal force	F_N	N	2600	3800	5050	6400
Maximum current	I_{max}	A	40.7	62.9	93.4	117.0
Rated current	I_N	A	13.8	20.0	26.0	33.0
Maximum velocity at F_{max}	v_{Fmax}	m/min	60			
Nominal velocity	v_N	m/min	150		140	150
Force constant	K_{FN}	N/A	188.4	211.5	194.2	194.0
Voltage constant	K_{EMK}	Vs/m	107.4	121.9	111.4	112.0
Winding resistance at 20 °C	R_{12}	Ohm	4.4	2.9	2.2	1.7
Winding inductance	L_{12}	mH	62.0	44.5	33.2	26.2
Power wire cross-section	A	mm^2	1.5	2.5	4.0	
Pole width	τ_p	mm	30.0			
Attractive force	F_{ATT}	N	10,200	15,200	19,760	22,350
Thermal time constant	T_{th}	min	3.4			
Mass thermal encapsulation	m_{PT}	kg	30.4	35.0	39.7	44.3
Data liquid cooling						
Heat loss to be dissipated	P_V	W	1,410	2,500	3,720	4,650
Required coolant flow for P_V	Q_{min}	l/min	3.7			6.9
Pressure drop at Q_{min}	Δp	bar	2.8	4.0	5.2	6.4
Constant for determining pressure drop	$K_{\Delta p}$	-	0.284	0.405	0.527	0.218
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.095	0.135	0.177	0.219
Latest amendment: 2019-07-18						

Tab. 4-28: MLP202 - Technical data

4.11.2 Motor characteristic curves MLP202

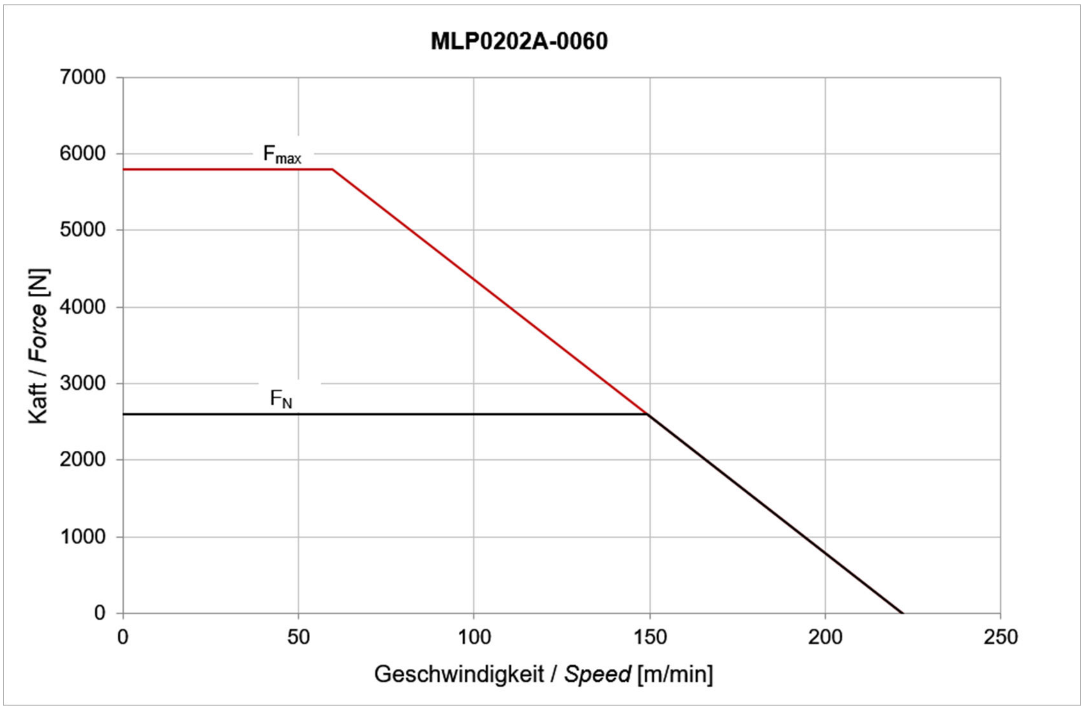


Fig. 4-62: Motor characteristic curves MLP202A-0060

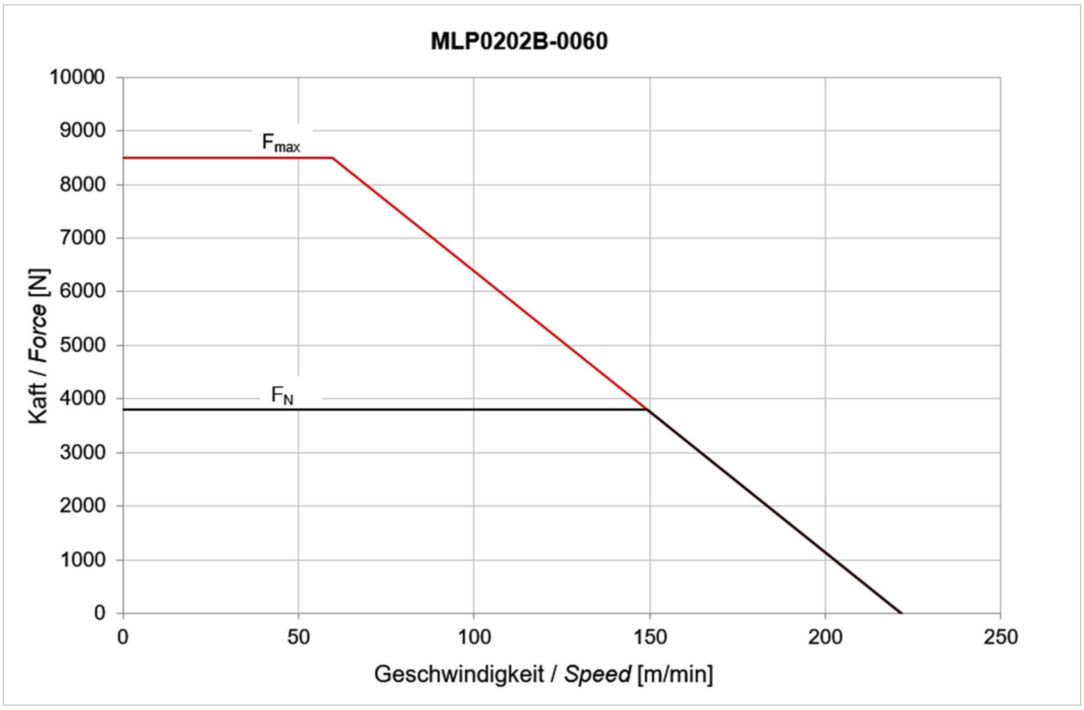


Fig. 4-63: Motor characteristic curve MLP202B-0060

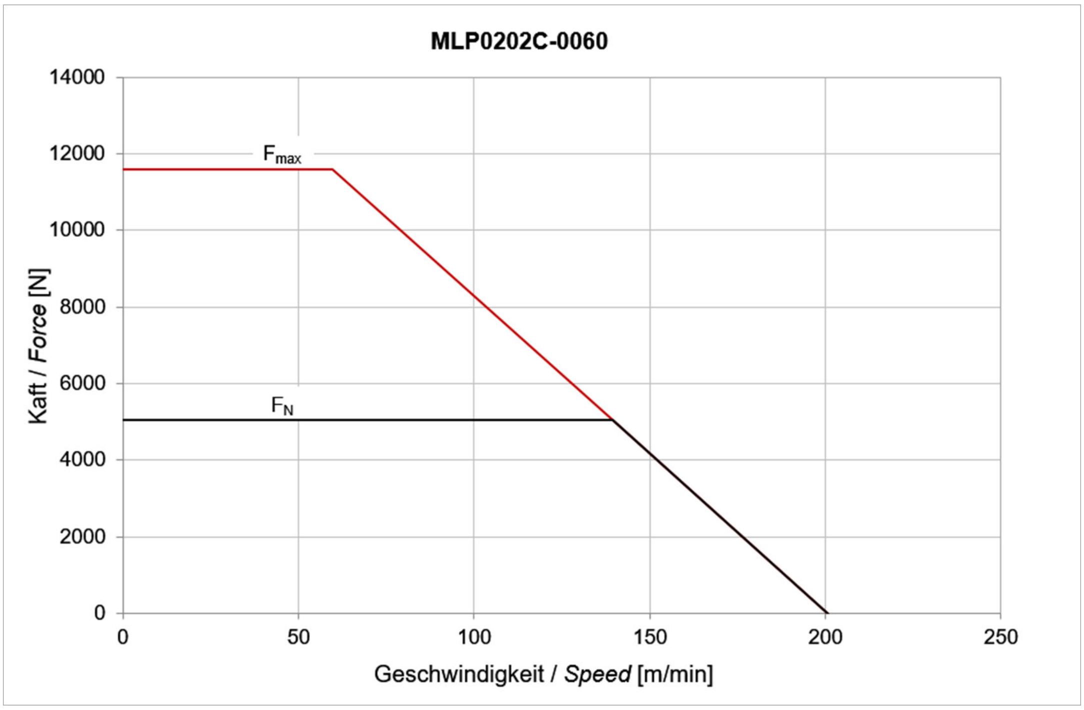


Fig. 4-64: Motor characteristic curve MLP202C-0060

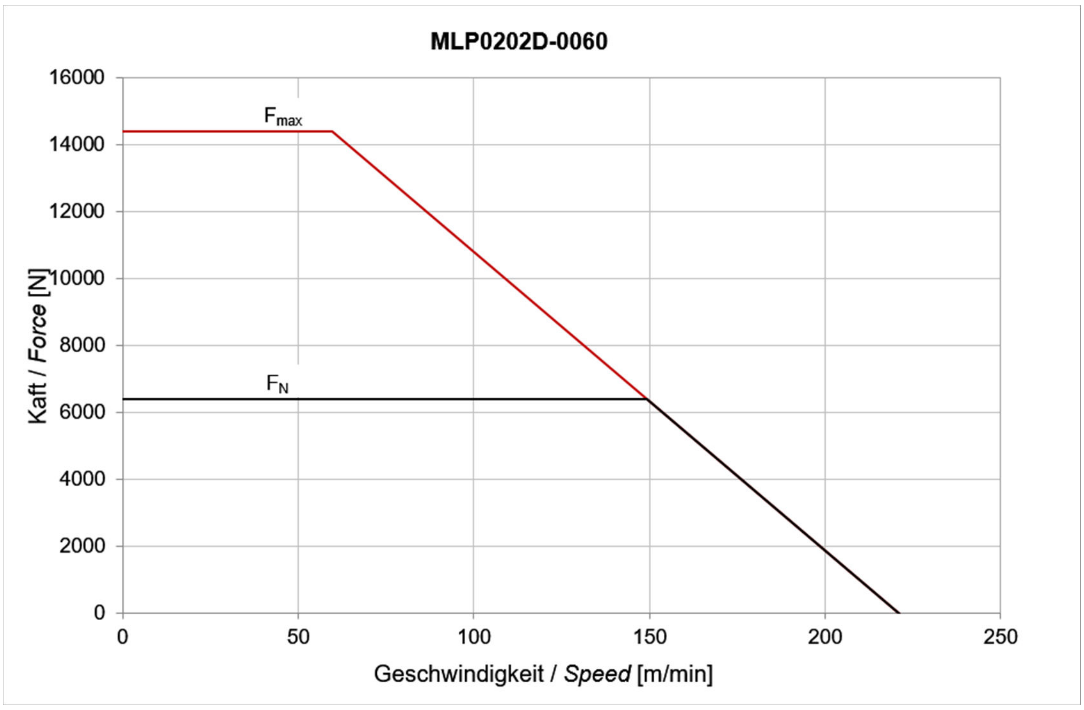


Fig. 4-65: Motor characteristic curve MLP202D-0060

4.11.3 Data MLS202

Designation	Symbol	Unit	MLS202_-_A-0180-NNNN	MLS202_-_A-0540-NNNN
Mass secondary part	m_S	kg	5.8	17.4
Mass secondary part, relative	m_{S_rel}	kg/m	32.3	
Latest amendment: 2019-07-22				

Tab. 4-29: MLS202 - Technical data

4.12 Frame size 300

4.12.1 Data MLP300A /-B

Parameter	Symbol	Unit	MLP300			
Frame lengths			A		B	
Winding			0090	0120	0070	0120
Maximum force	F_{max}	N	11,000		16300	
Continuous nominal force	F_N	N	3350		5150	
Maximum current	I_{max}	A	99.3	129.9	141.9	223.5
Rated current	I_N	A	17.2	21.6	28.4	38.2
Maximum velocity at F_{max}	v_{Fmax}	m/min	90	120	70	120
Nominal velocity	v_N	m/min	160	190	140	190
Force constant	K_{FN}	N/A	195.4	154.9	181.6	134.1
Voltage constant	K_{EMK}	Vs/m	112.8	89.4	104.8	77.9
Winding resistance at 20 °C	R_{12}	Ohm	3.05	2.0	2.2	1.3
Winding inductance	L_{12}	mH	14.9	9.3	12.0	6.7
Power wire cross-section	A	mm^2	2.5	4.0		6.0
Pole width	τ_p	mm	37.5			
Attractive force	F_{ATT}	N	16,000		23400	
Thermal time constant	T_{th}	min	2.4			
Mass standard encapsulation	m_{PS}	kg	33.0		48.0	
Mass thermal encapsulation	m_{PT}	kg	40.8		58.3	
Data liquid cooling						
Heat loss to be dissipated	P_V	W	2,200		2,900	
Required coolant flow for P_V	Q_{min}	l/min	3.2		4.2	
Pressure drop at Q_{min}	Δp	bar	1.4		2.3	
Constant for determining pressure drop	$K_{\Delta p}$	-	0.19			
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.15		/	
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.245		0.364	
Latest amendment: 2019-07-18						

Tab. 4-30: MLP300A /-B - Technical data

4.12.2 Motor characteristic curves MLP300A / -B

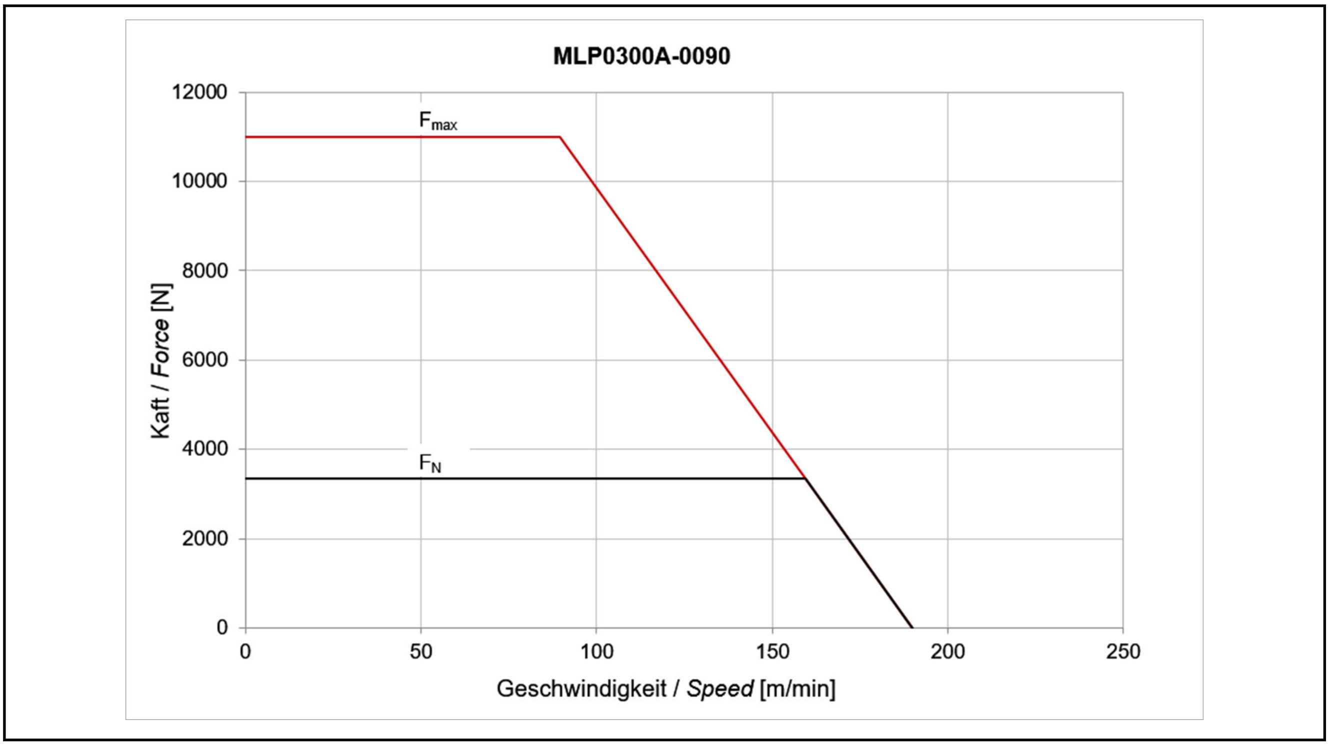


Fig. 4-66: Motor characteristic curve MLP300A-0090

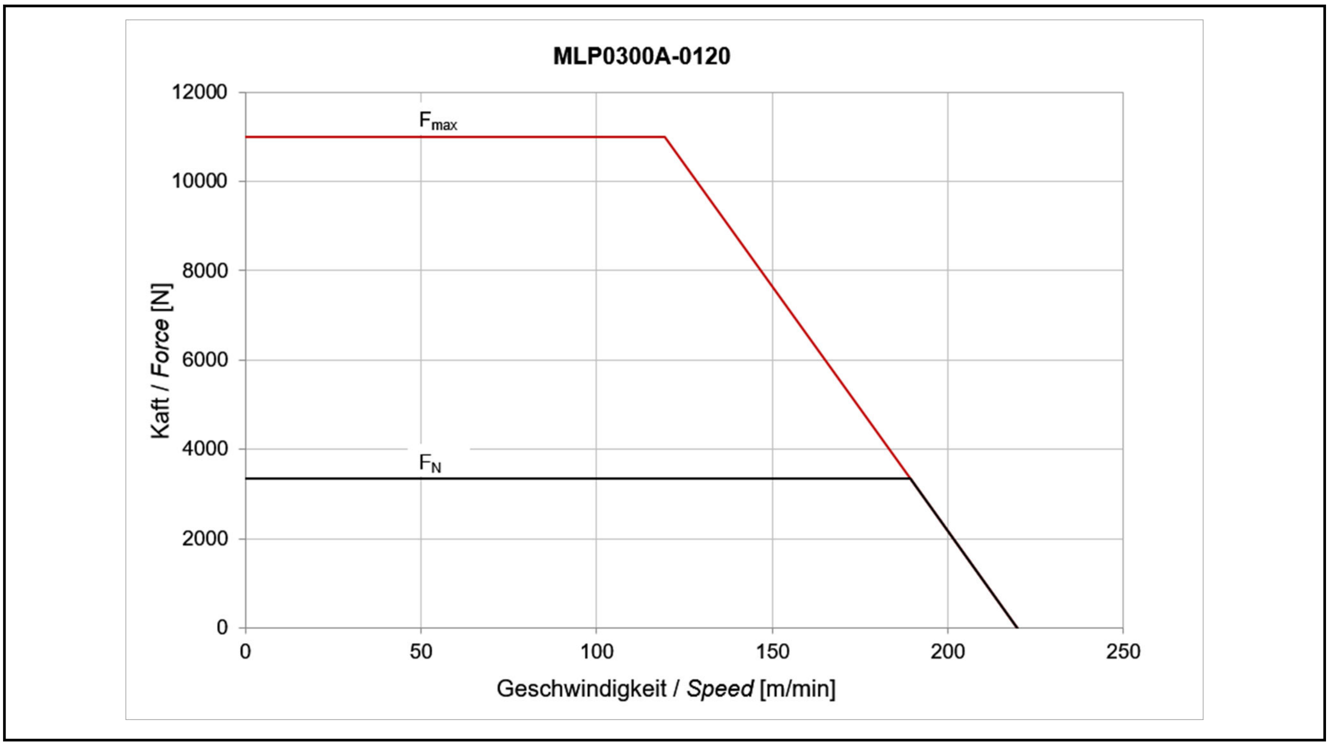


Fig. 4-67: Motor characteristic curves MLP300A-0120

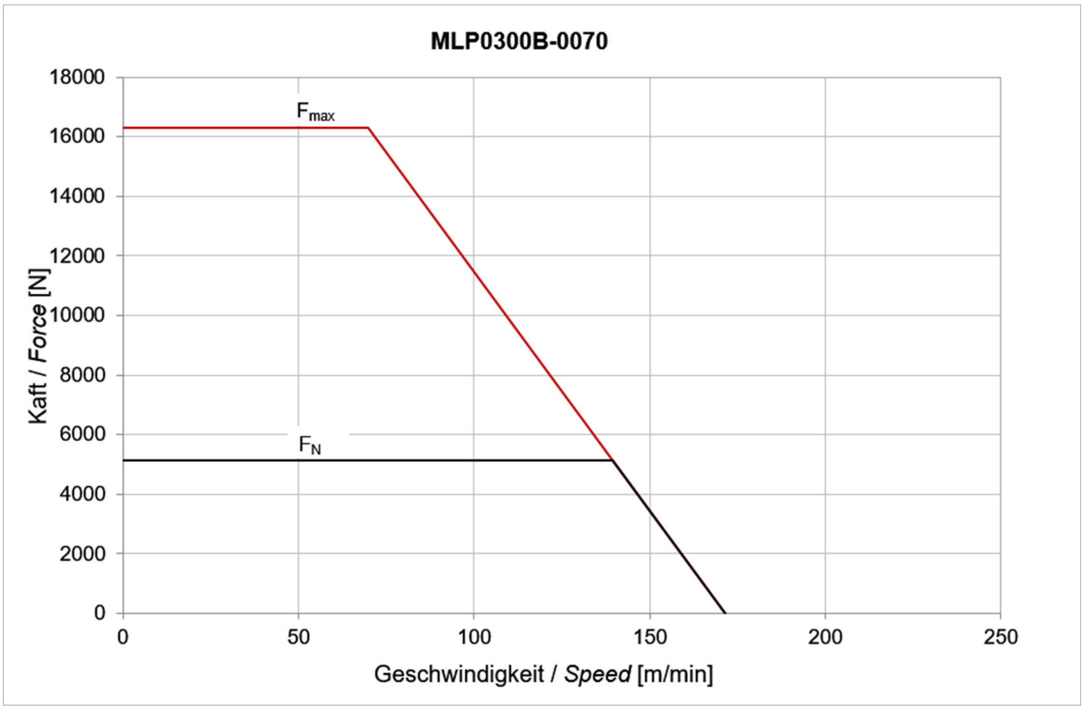


Fig. 4-68: Motor characteristic curve MLP300B-0070

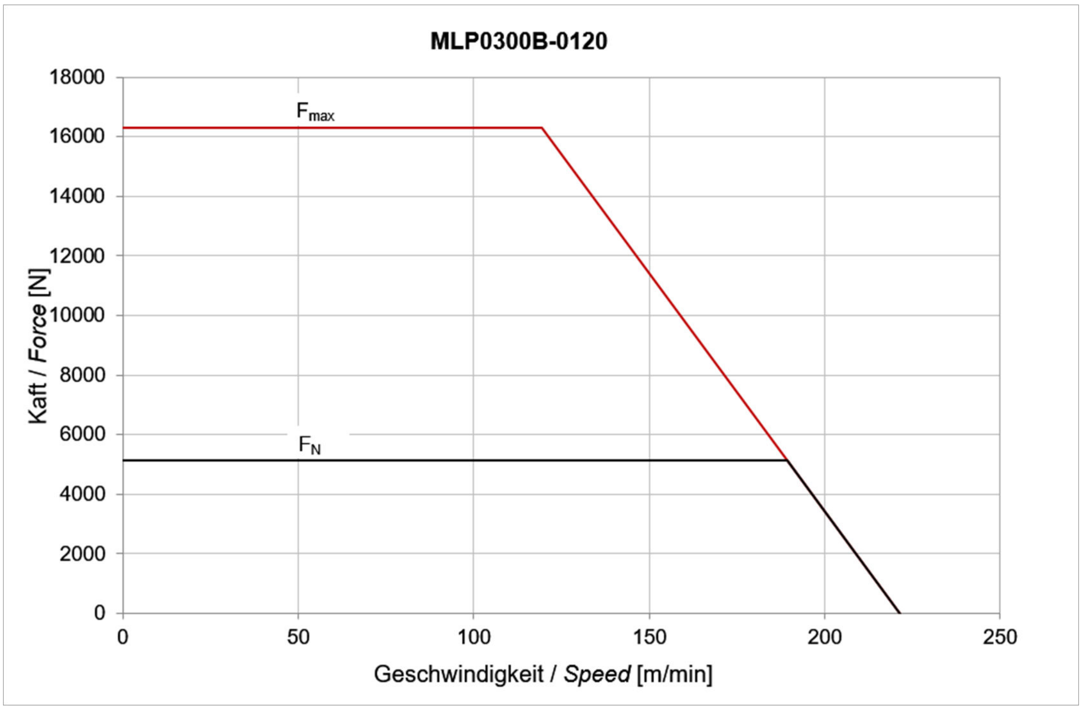


Fig. 4-69: Motor characteristic curves MLP300B-0120

4.12.3 Data MLP300C

Parameter	Symbol	Unit	MLP300		
Frame lengths			C		
Winding			0060	0090	0120
Maximum force	F_{max}	N	21500		
Continuous nominal force	F_N	N	6720		
Maximum current	I_{max}	A	143.1	205.0	300.0
Rated current	I_N	A	29.6	35.8	45.2
Maximum velocity at F_{max}	v_{Fmax}	m/min	60	90	120
Nominal velocity	v_N	m/min	110	150	180
Force constant	K_{FN}	N/A	226.9	187.9	148.9
Voltage constant	K_{EMK}	Vs/m	130.9	108.4	85.9
Winding resistance at 20 °C	R_{12}	Ohm	2.4	1.56	1.02
Winding inductance	L_{12}	mH	11.4	7.6	4.9
Power wire cross-section	A	mm^2	4.0	6.0	10.0
Pole width	τ_p	mm	37.5		
Attractive force	F_{ATT}	N	30700		
Thermal time constant	T_{th}	min	2.4		
Mass standard encapsulation	m_{PS}	kg	62.0		
Mass thermal encapsulation	m_{PT}	kg	74.9		
Data liquid cooling					
Heat loss to be dissipated	P_V	W	3,200		
Required coolant flow for P_V	Q_{min}	l/min	4.6		
Pressure drop at Q_{min}	Δp	bar	2.8		
Constant for determining pressure drop	$K_{\Delta p}$	-	0.19		
Coolant channel volume Standard encapsulation	V_{cool_S}	l	0.277		
Coolant channel volume Thermal encapsulation	V_{cool_T}	l	0.471		
Latest amendment: 2019-07-18					

Tab. 4-31: MLP300C - Technical data

4.12.4 Motor characteristic curves MLP300C

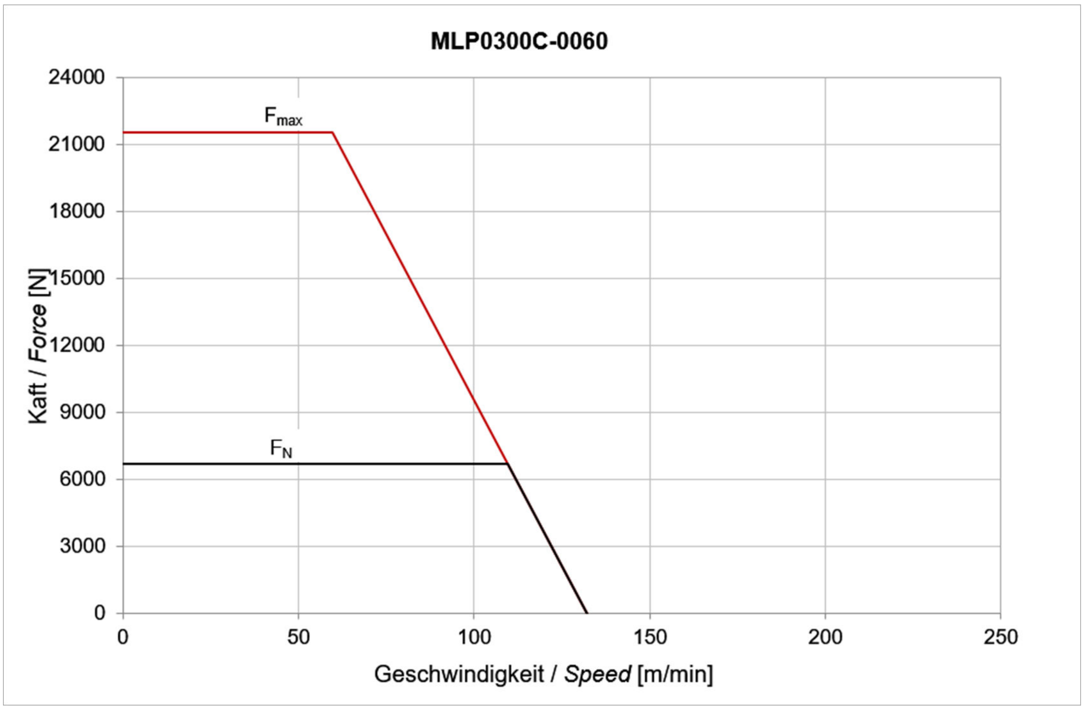


Fig. 4-70: Motor characteristic curve MLP300C-0060

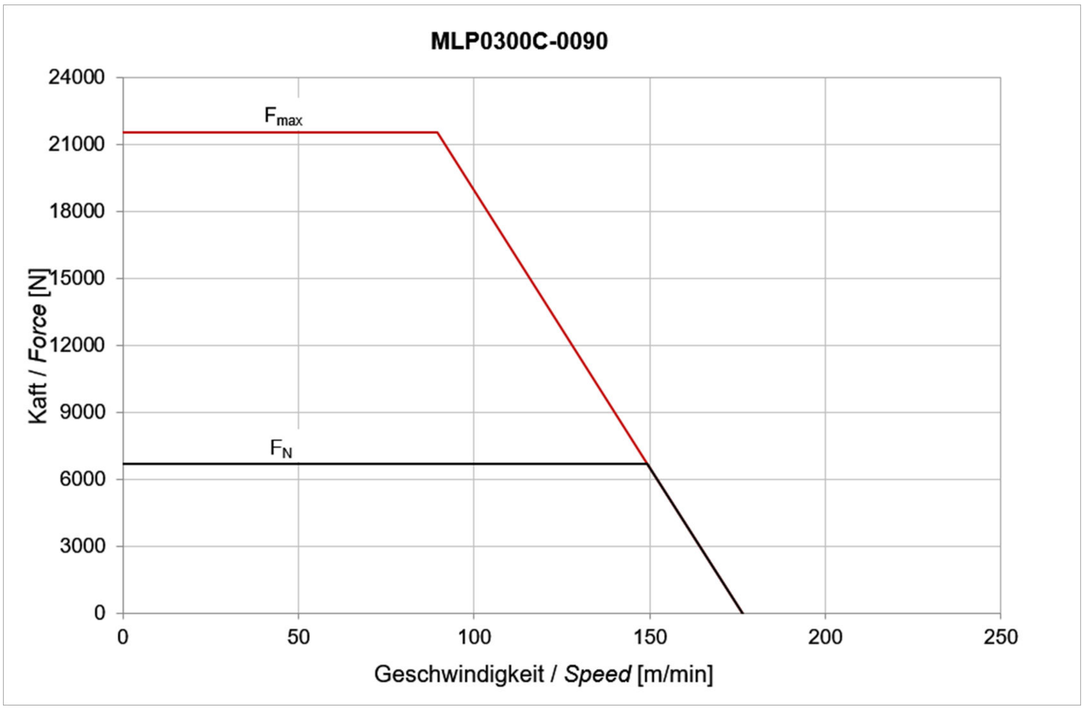


Fig. 4-71: Motor characteristic curves MLP300C-0090

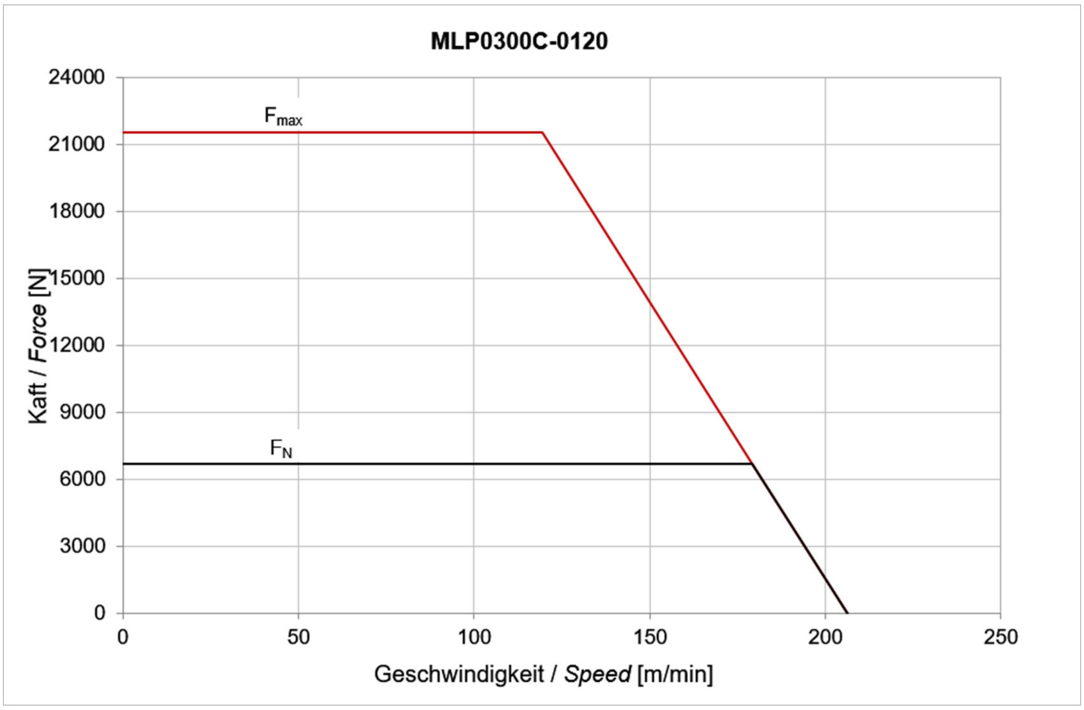


Fig. 4-72: Motor characteristic curves MLP300C-0120

4.12.5 Data MLS300

Designation	Symbol	Unit	MLS300_-_A-0150-HNNN	MLS300_-_A-0450-HNNN	MLS300_-_A-0600-HNNN
Mass secondary part	m_S	kg	10.5	31.5	42.0
Mass secondary part, relative	m_{S_rel}	kg/m	70.0		
Latest amendment: 2019-07-22					

Tab. 4-32: MLS300 - Technical data

5 Dimensions, installation dimension and - tolerances

5.1 General notes

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

5.2 Specifications

5.2.1 Dimensions and tolerances

In order to ensure a constant force along the entire travel length, a defined air gap height must be guaranteed. For this purpose, the individual parts of the motor (primary and secondary part) are tolerated accordingly. The distance of the mounting surface, the parallelism and the symmetry of the primary and secondary part of the linear motor in the machine must be within a certain tolerance above the entire travel length. Any deformations that result from weight, attractive forces and process forces must be taken into account.

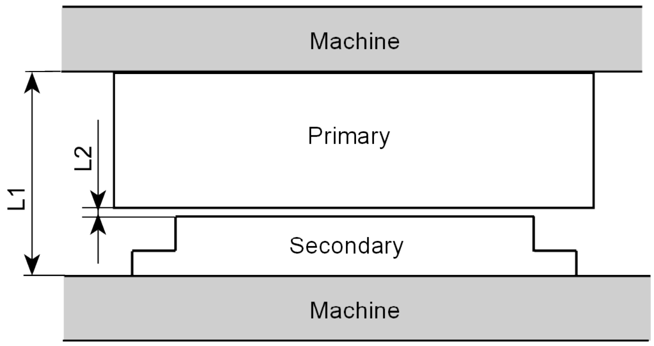
☞ Deviating specified nominal air gap lead to a reduction or modification of the specified performance data.

⚠ CAUTION **Air gap to small! Possible contact among primary and secondary part!**

In the case of a too small air gap among primary and secondary part, contact with the motor components can occur and this could damage or destroy them. Therefore the specified air gap height must be kept.

After installing or replacing the linear motor (MLP and MLS), the installation height L1 defined in Tab. 5-1 must be maintained.

☞
- Absolutely keep and check the specified installation height in the respective tolerances. Accordingly, possible deflection of the machine structure due to weight, attraction and process forces must be taken into account.
- After installation of the linear motor, the air gap should be checked by means of measurement. Test dimensions are given in Tab. 5-1 (measurable air gap L2).
- Long distances can make is necessary that the contact surfaces of the motor components must be directly processed from the mounted slide.



Frame size Primary part	Design Primary part	Design Secondary part	Installation height L1 [1)]	Measurable Air gap L2 [2)]
040 ... 200	Standard encapsulation	MLSxxxS-*	$61,4^{+0,1}$	$1,0^{+0,55}_{-0,4}$
300	Standard encapsulation		$72,5^{+0,1}$	$1,2^{+0,55}_{-0,4}$
040 ... 200	Thermal encapsulation		$73,9^{+0,1}$	$1,0^{+0,55}_{-0,4}$
202	Thermal encapsulation		$77.4^{+0.1}$	$1,0^{+0,55}_{-0,4}$
300	Thermal encapsulation		$87,0^{+0,1}$	$1,2^{+0,55}_{-0,4}$

1) The installation height of +0.1 mm is tolerated in such a way that there is no significant influence on the operating behavior of the motor. It may be helpful to provide for a larger positive tolerance. In this case, for example, a reduction in the tightening and feed force must be expected (see section 9.14). Alternatively, the air gap can also be adjusted (see chap. 12.6).

2) After installation of the motor components, the air gap L2 is set due to the component tolerances. To specifically dimension the air gap, please refer to Chap. 12.6.

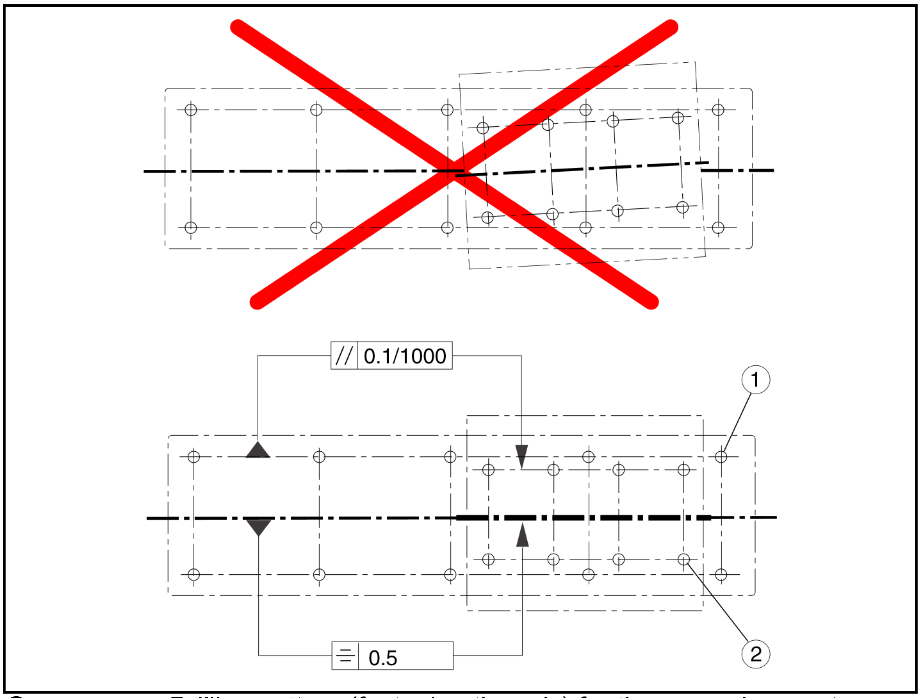
Tab. 5-1: Installation dimensions and tolerances

5.2.2 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 Fig. 5-1must be kept.

To keep the tolerances, it is necessary that the fastening holes for the primary part and the threaded holes for the secondary part in the machine are strictly done according to the dimensions of the particular dimension sheets.

If this is done correctly, the center lines of the fastening of threaded holes can serve as referance for aligning the parts.



① Drilling pattern (fastening threads) for the secondary part
② Drilling pattern (fastening holes) for primary part

Fig. 5-1: Parallelism and symmetry between the fastening holes for the primary part and the fastening threads for the secondary part

When moving primary and secondary parts, the stated tolerances regarding parallelism and symmetry must be kept during the total moving process.

You will find further notes regarding assembly of primary and secondary parts in chapter 12 "Assembly" on page 277.

5.3 Frame size 040

5.3.1 Primary part MLP040 with standard encapsulation

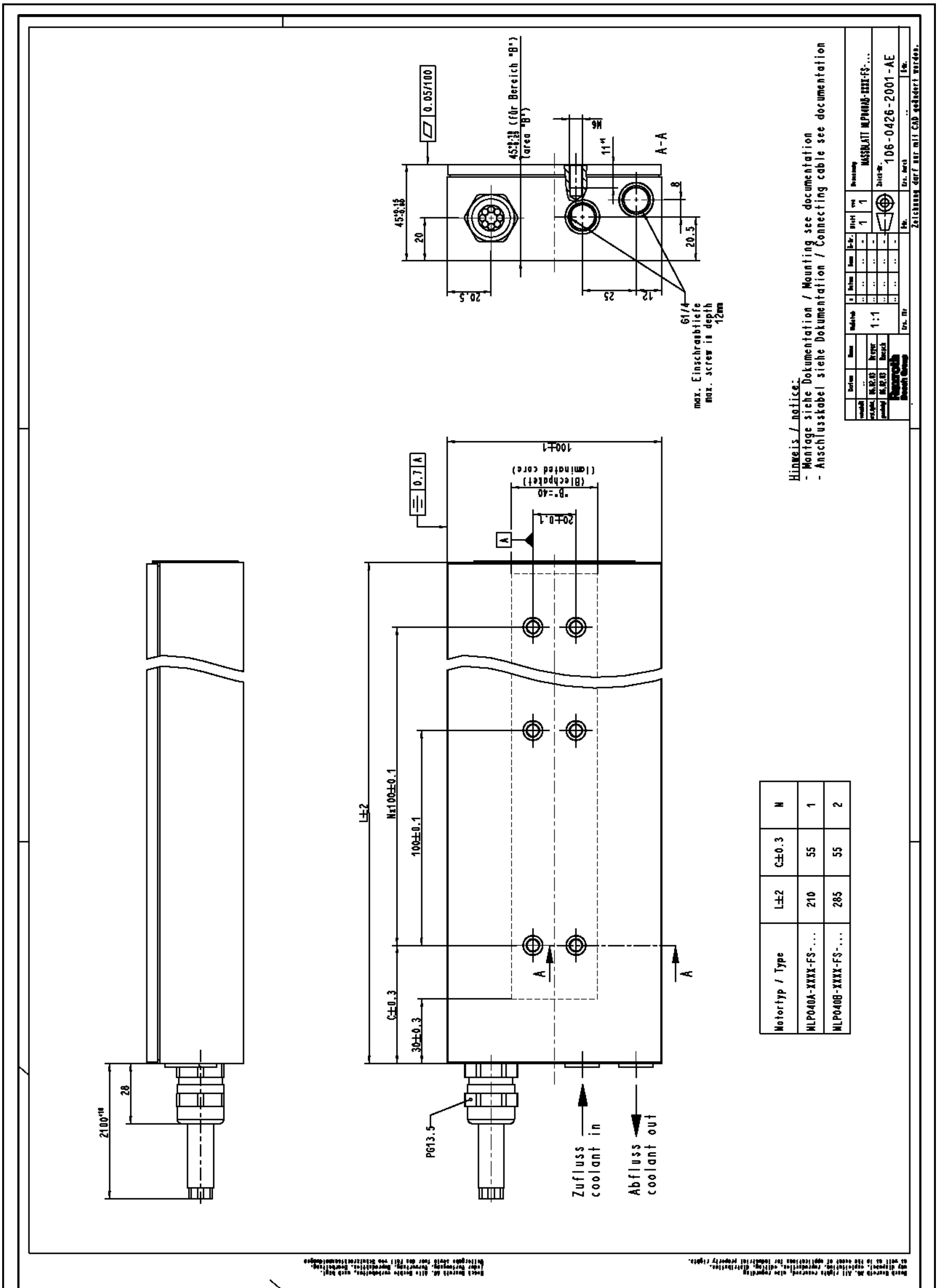


Fig. 5-2: Primary part MLP040 with standard encapsulation

5.3.2 Primary part MLP040 with thermo encapsulation

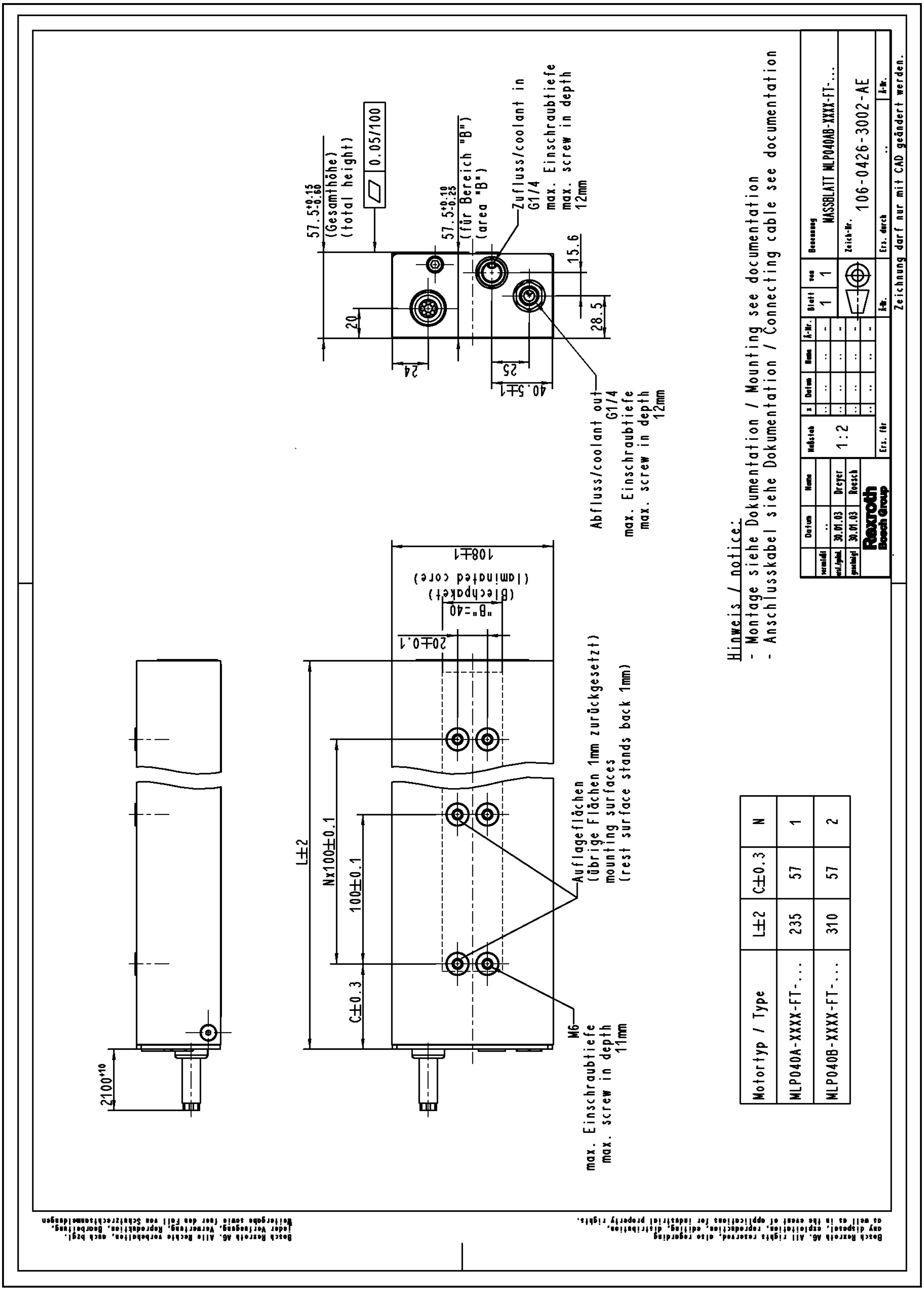


Fig. 5-3: Primary part MLP040 with thermo encapsulation

5.3.3 Secondary part MLS040

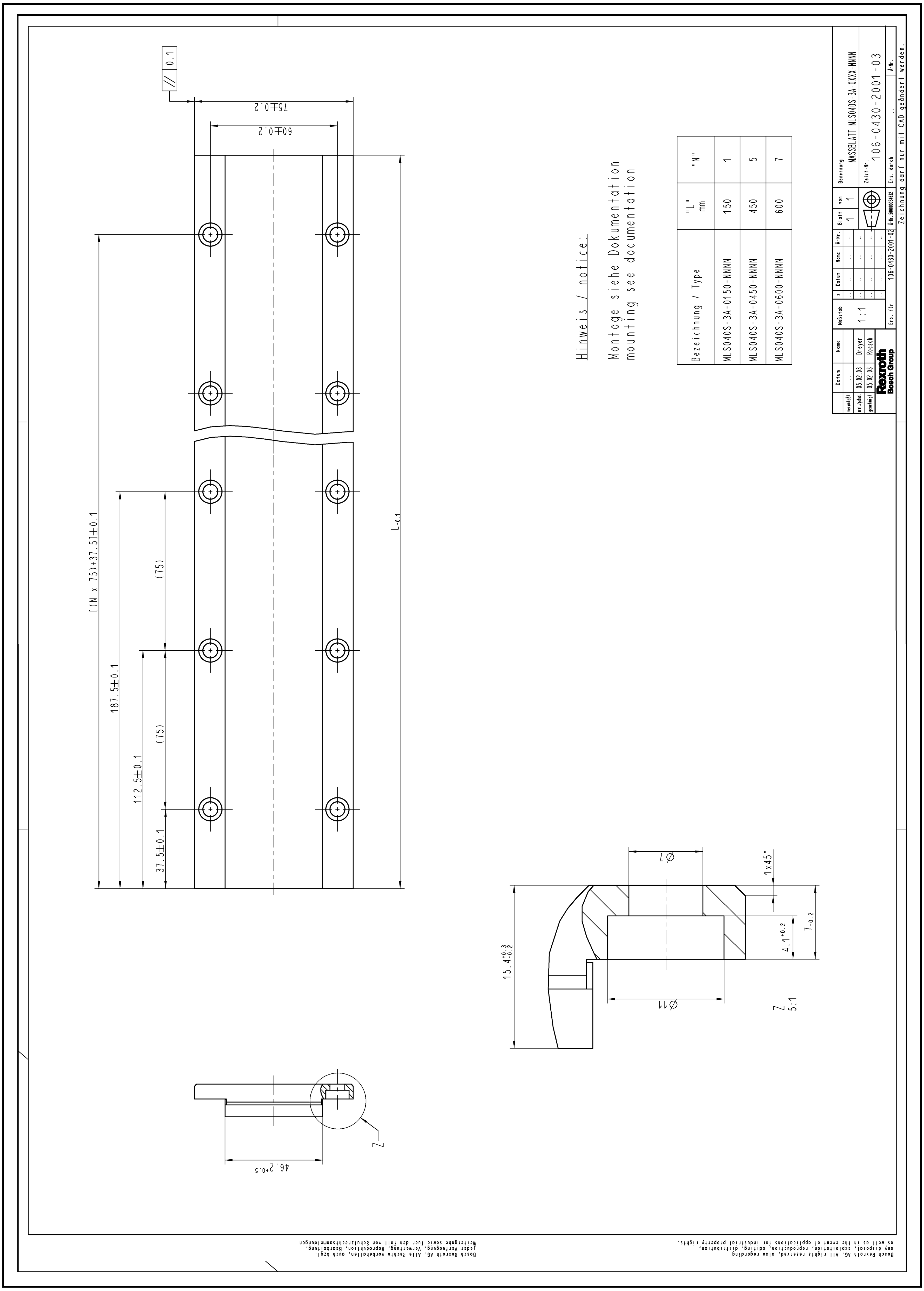


Fig. 5-4: Secondary part MLS040

5.4 Frame size 052

5.4.1 Primary part MLP052 with thermo encapsulation

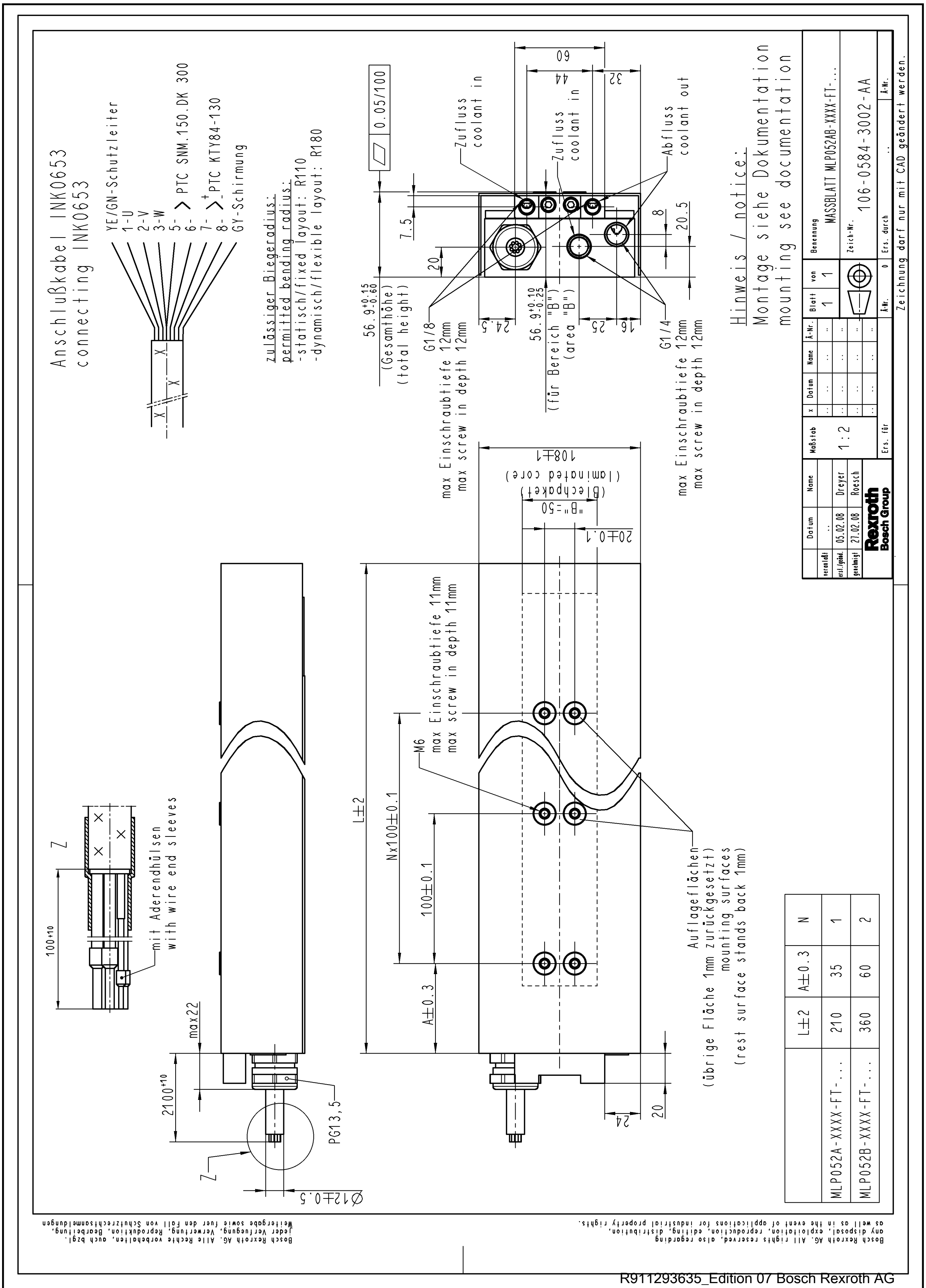


Fig. 5-5: Primary part MLP052 with thermo encapsulation

5.4.2 Secondary part MLS052

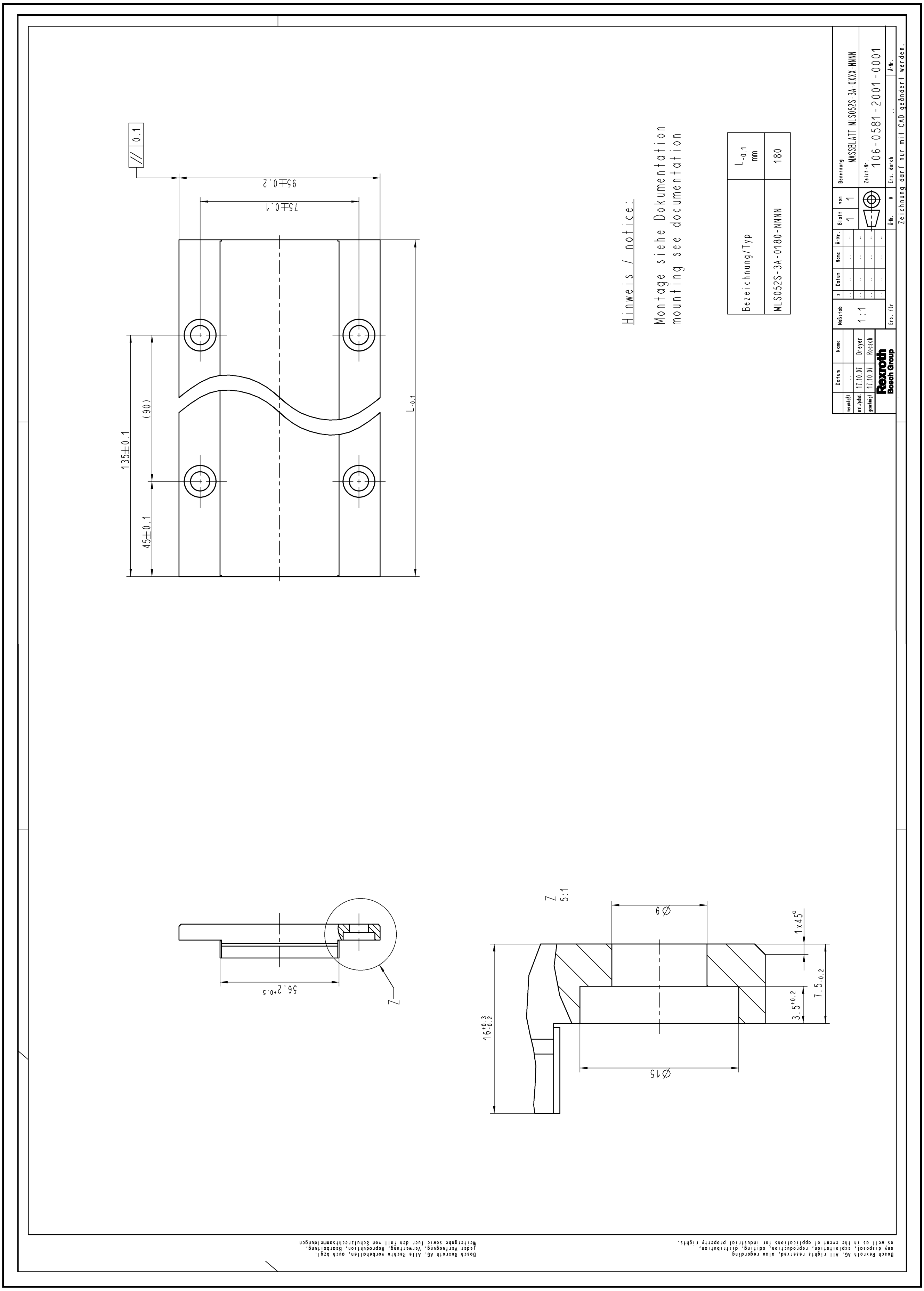


Fig. 5-6: Secondary part MLS052

5.5 Frame size 070

5.5.1 Primary part MLP070 with standard encapsulation

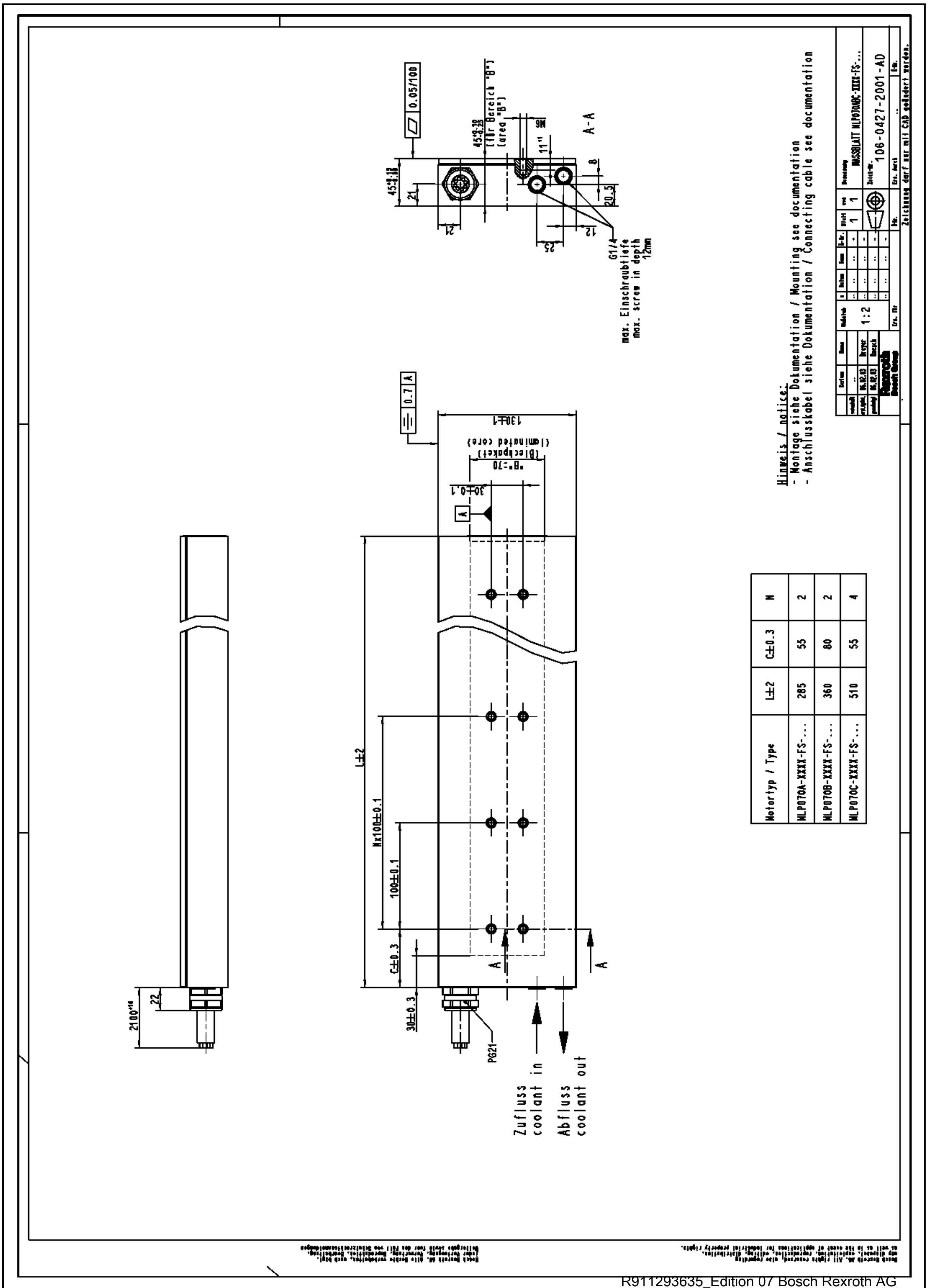
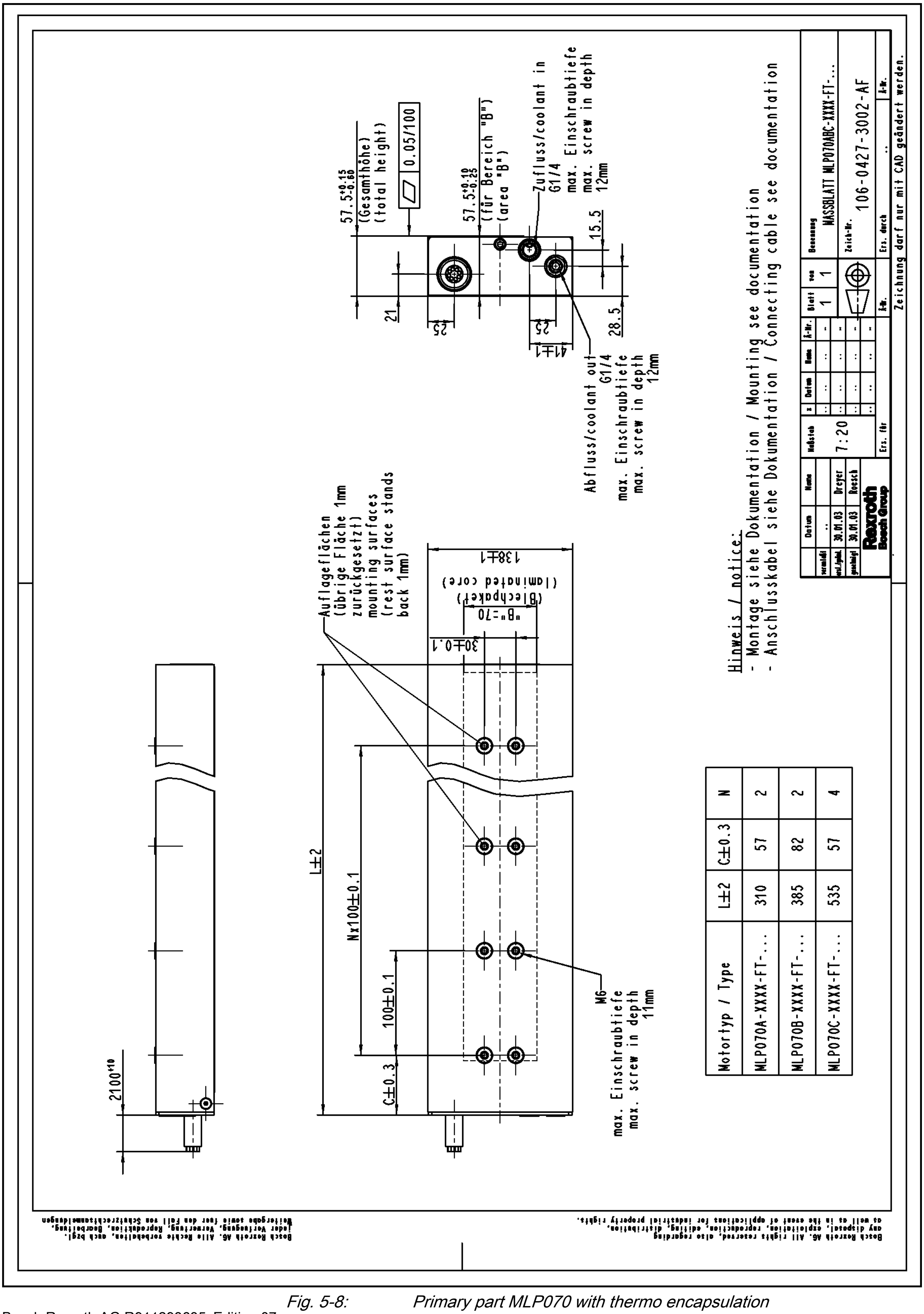


Fig. 5-7: Primary part MLP070 with standard encapsulation

Motortyp / Type	L±2	C±0.3	N
MLP070A-XXXX-FS-...	285	55	2
MLP070B-XXXX-FS-...	360	80	2
MLP070C-XXXX-FS-...	510	55	4

5.5.2 Primary part MLP070 with thermo encapsulation



Motortyp / Type	L±2	C±0.3	N
MLP070A-XXXX-FT-...	310	57	2
MLP070B-XXXX-FT-...	385	82	2
MLP070C-XXXX-FT-...	535	57	4

Fig. 5-8: Primary part MLP070 with thermo encapsulation

5.5.3 Secondary part MLS070

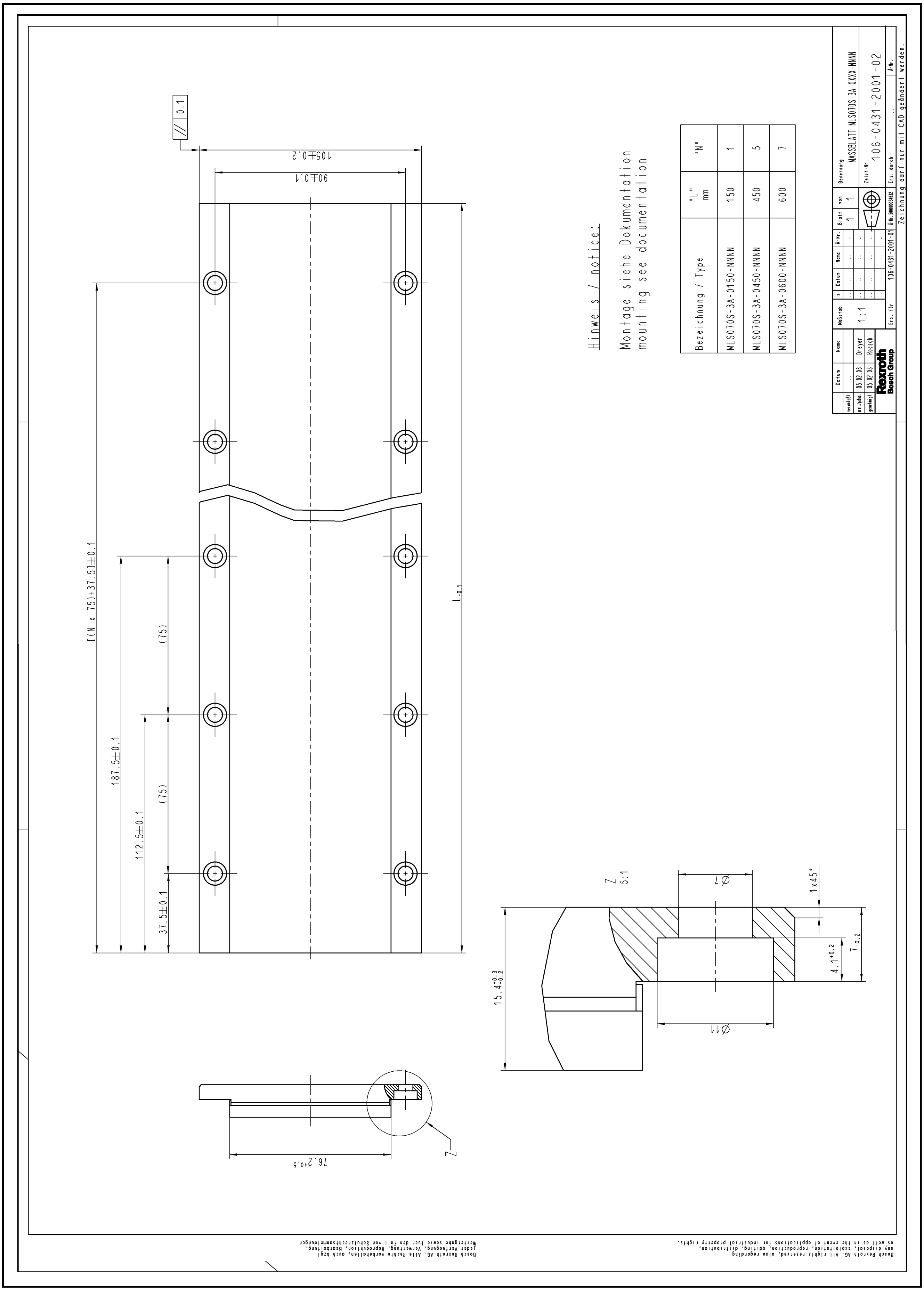
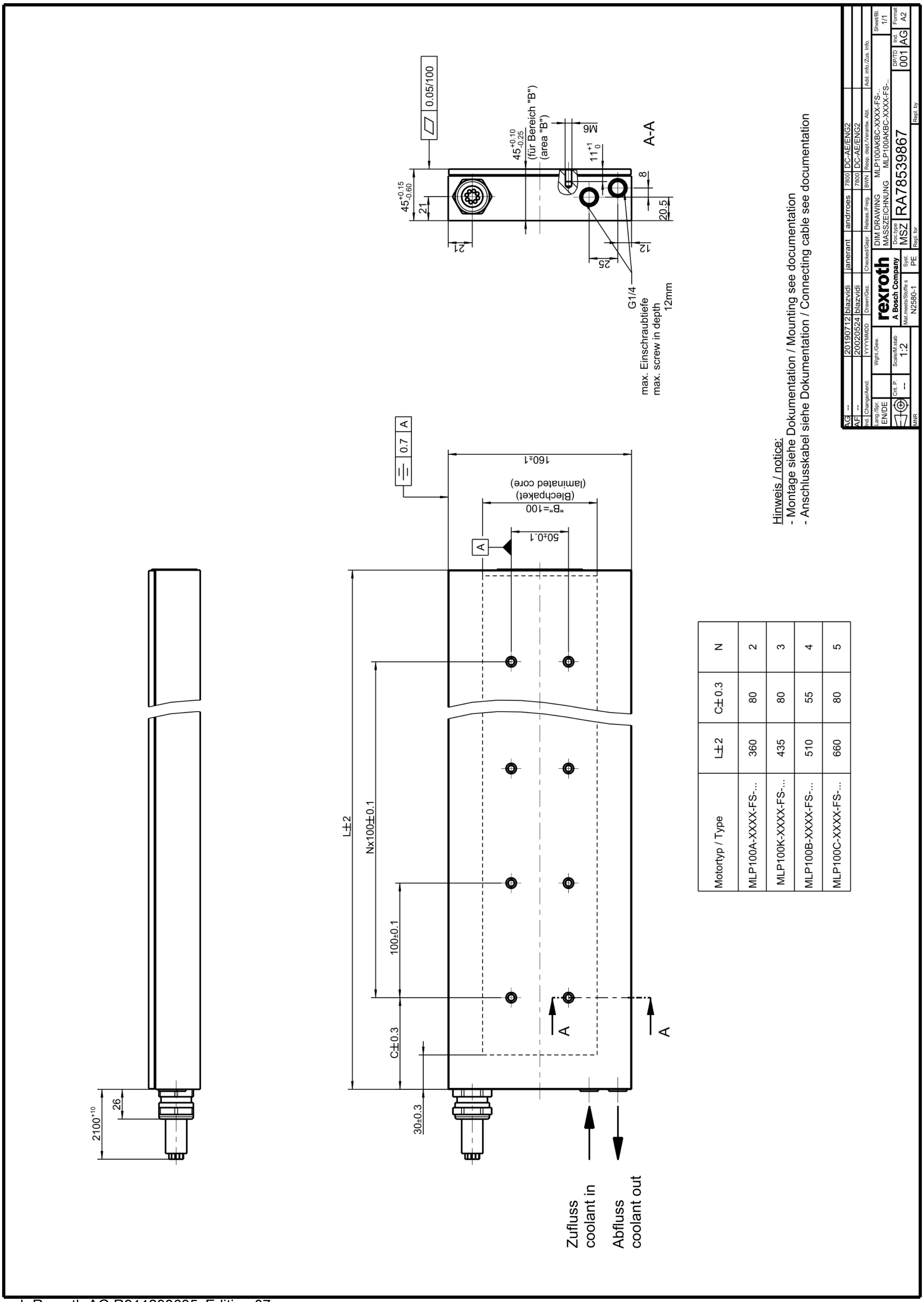


Fig. 5-9: Secondary part MLS070

5.6 Frame size 100

5.6.1 Primary part MLP100 with standard encapsulation



Motortyp / Type	L±2	C±0.3	N
MLP100A-XXXX-FS-...	360	80	2
MLP100K-XXXX-FS-...	435	80	3
MLP100B-XXXX-FS-...	510	55	4
MLP100C-XXXX-FS-...	660	80	5

Fig. 5-42 Primary part MLP100 with standard encapsulation

5.6.2 Primary part MLP100 with thermo encapsulation

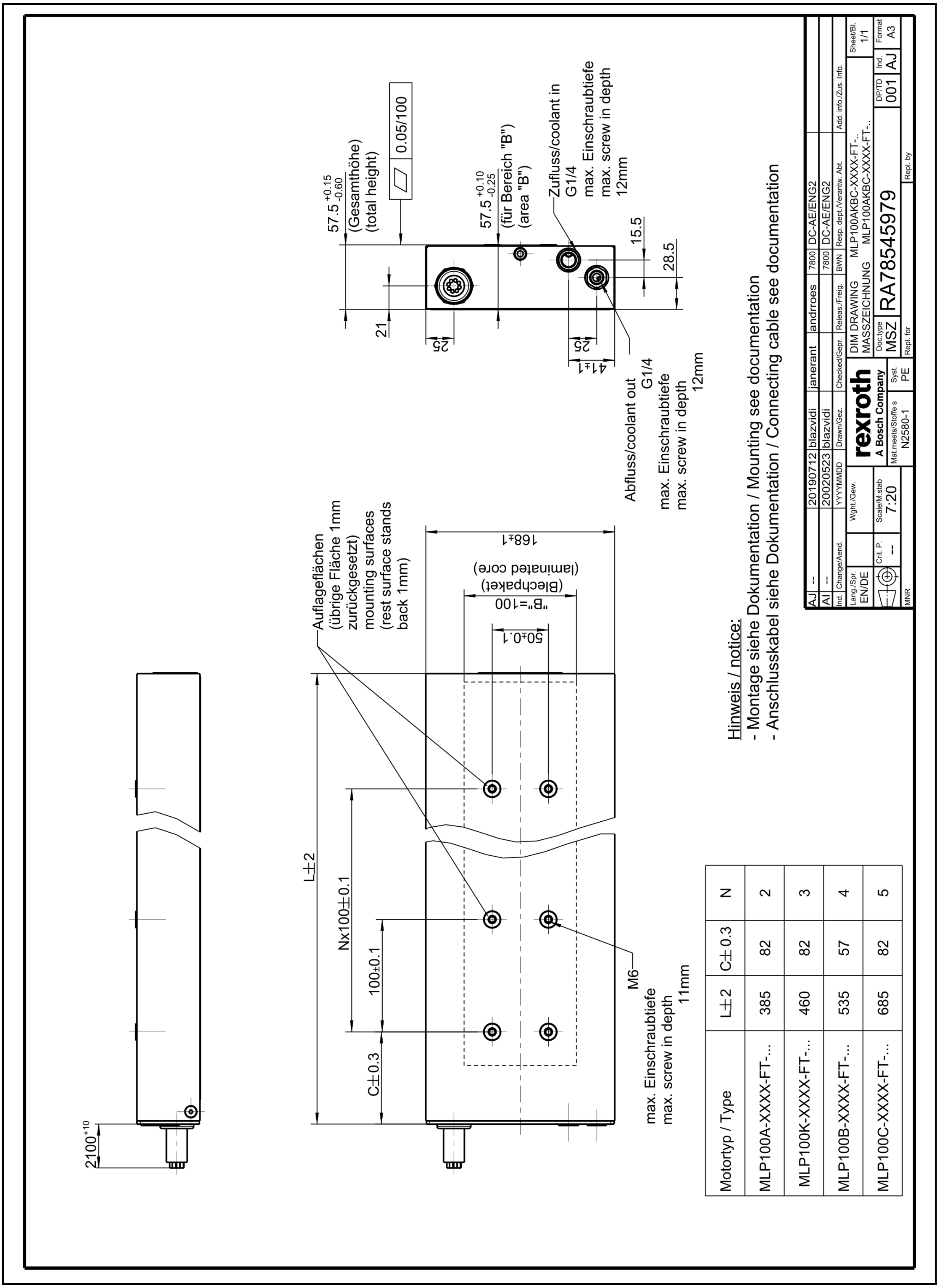


Fig. 5-11: Primary part MLP100 with thermo encapsulation

5.6.3 Secondary part MLS100

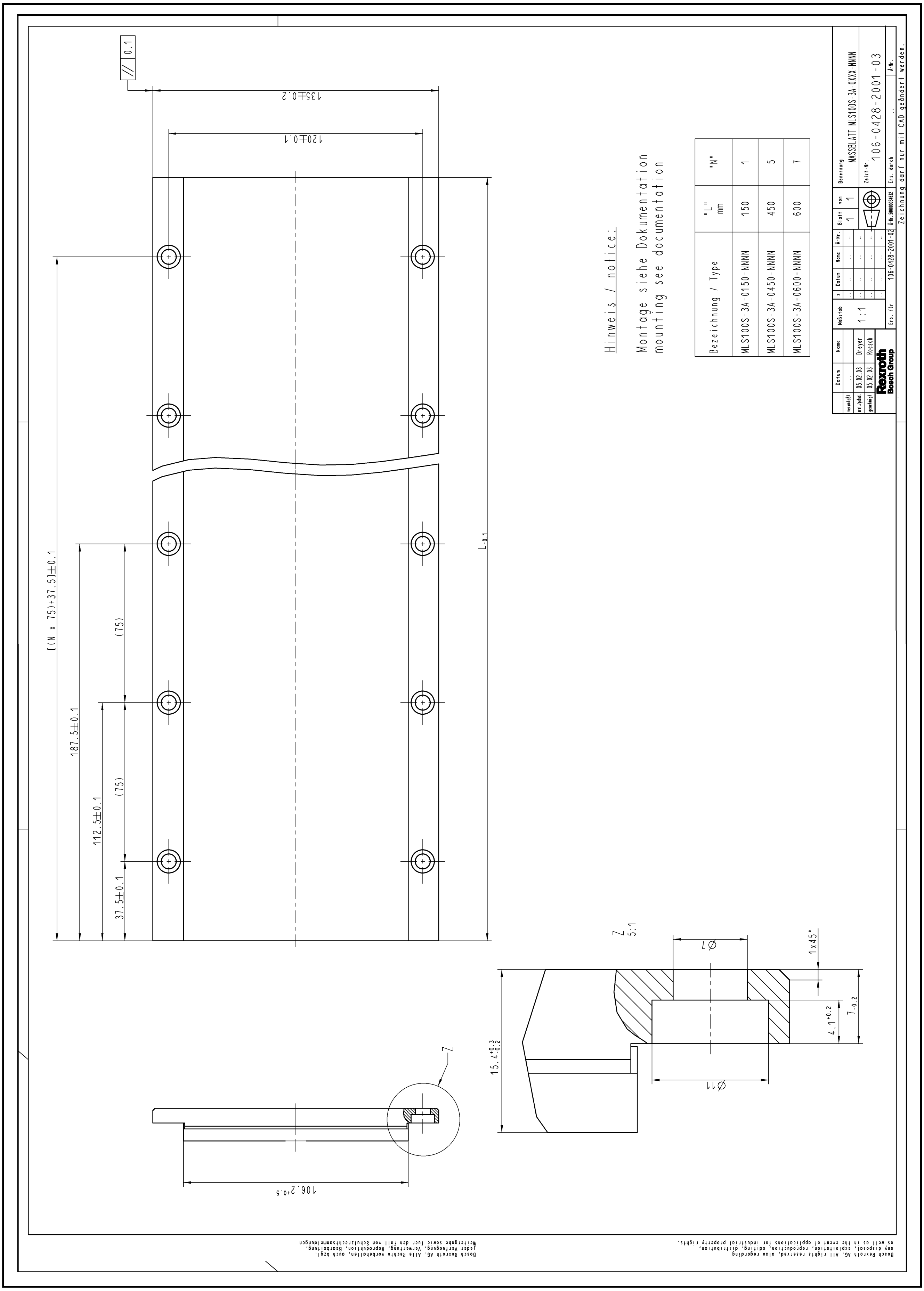


Fig. 5-12: Secondary part MLS100

5.7 Frame size 102

5.7.1 Primary part MLP102 with thermo encapsulation

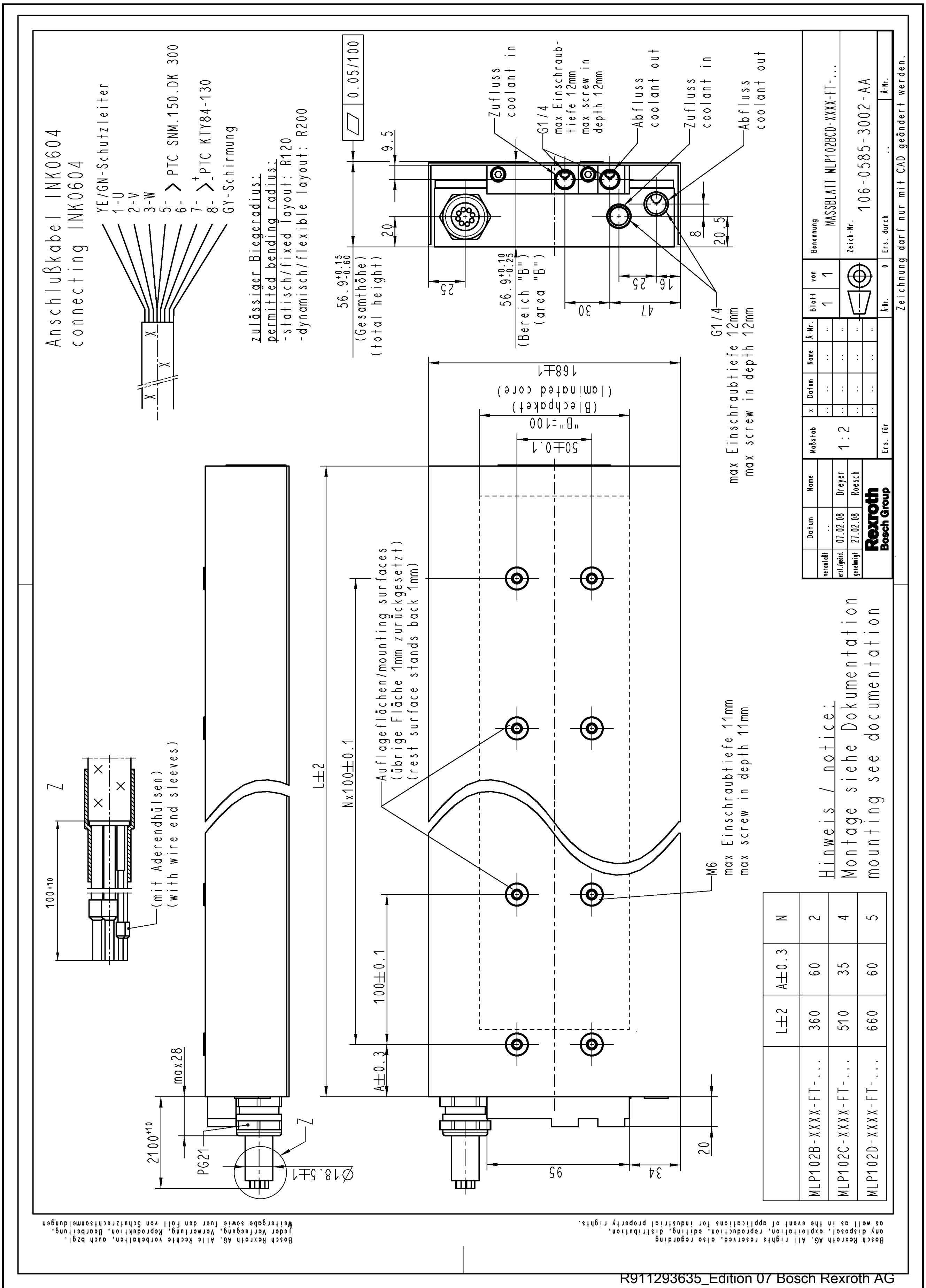


Fig. 5-13: Primary part MLP102 with thermo encapsulation

5.7.2 Secondary part MLS102

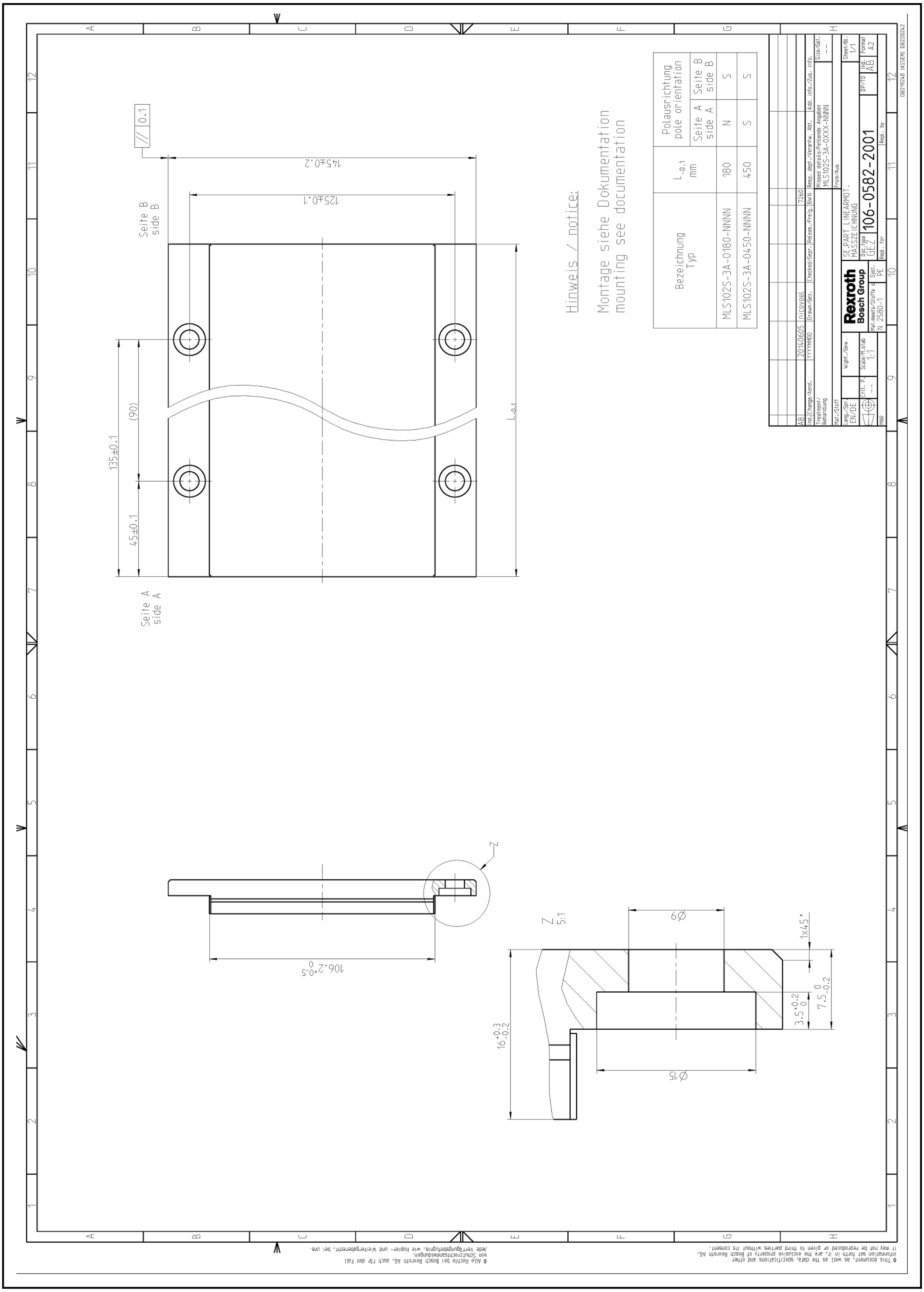


Fig. 5-14: Secondary part MLS102

5.8 Frame size 140

5.8.1 Size of cable thread

For cables with a power wire cross-section of 10 mm² (INK0605 and REL0110), a bigger cable gland (M32) is required. All other cables, with the exception of the cable at MLP140Z, are equipped with a smaller cable gland (PG21). In all cases, the screw connections are completely covered in the thermo encapsulation. Thus, only the standard encapsulation is affected by the of the interference contour of the screw connections. In tab. 8-1 "Connection cables on MLP primary part" on page 164, the affected motor designs are listed (refer to column "Connection cables" under REL0110 (INK0605)).

☞ Please note, for motors with cables with a power wire cross-section of 10 mm² (INK0605 and REL0110), a bigger cable gland (M32) is used.

5.8.2 Primary part MLP140Z with standard encapsulation

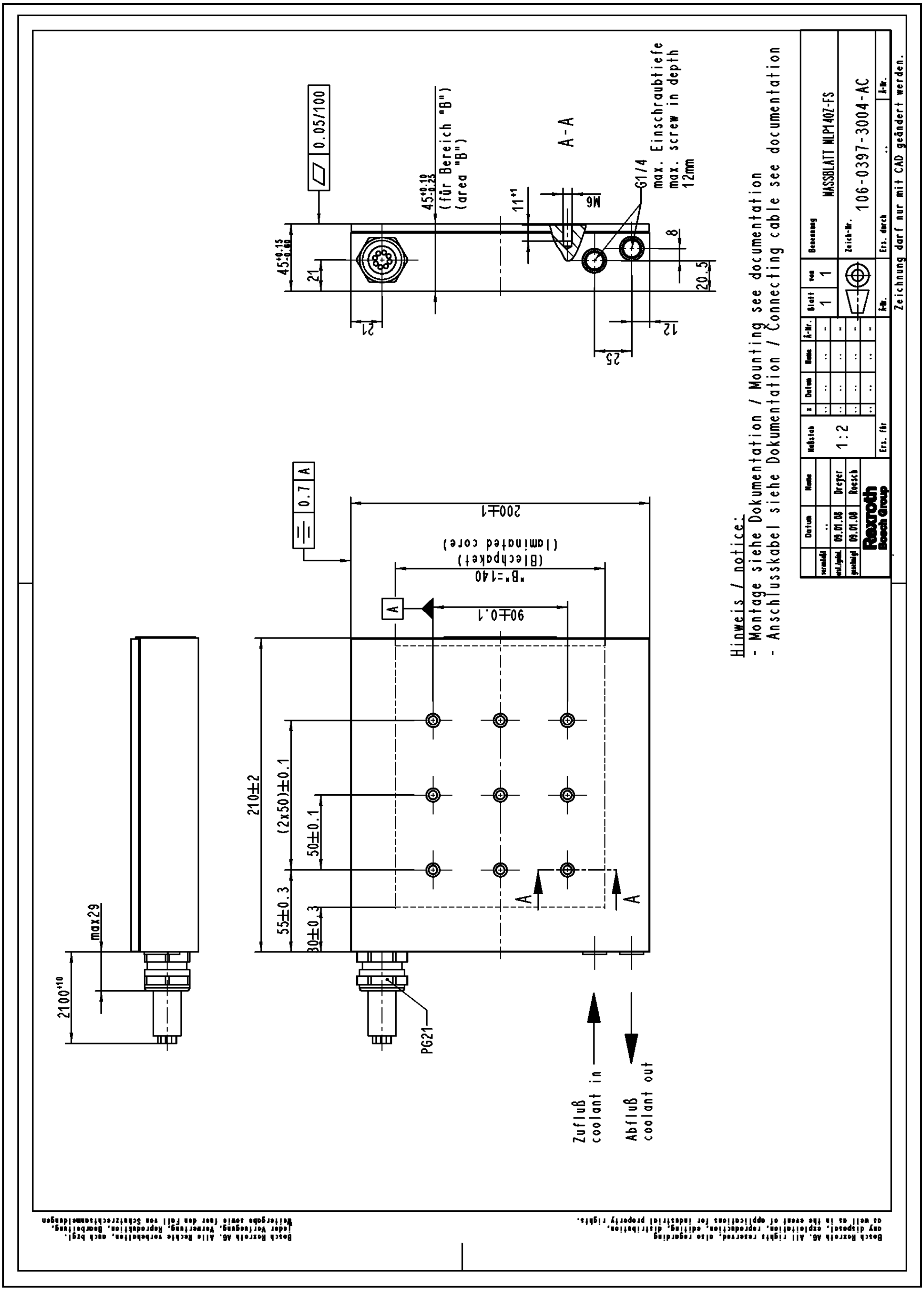
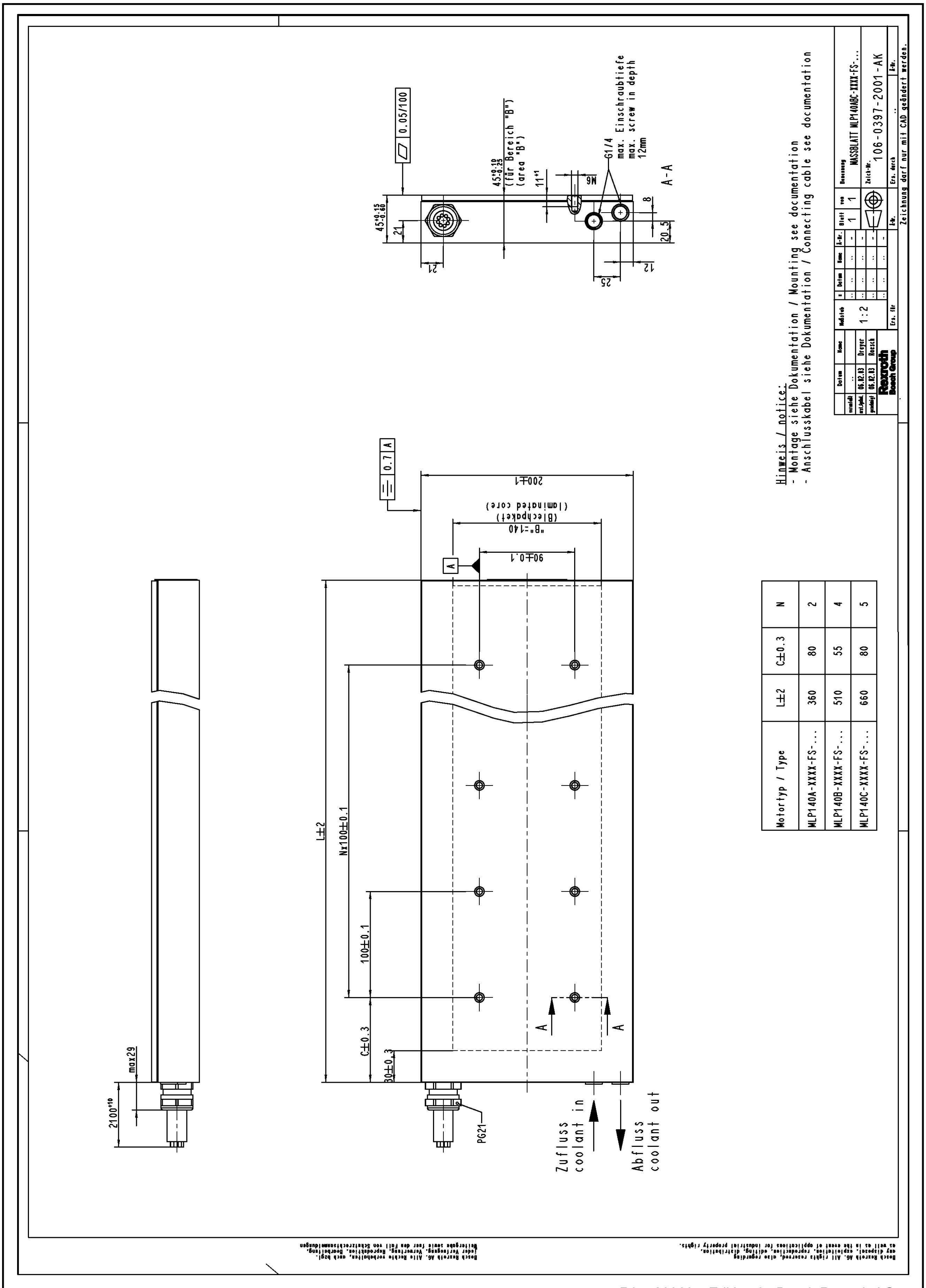


Fig. 5-15: Primary part MLP140Z with standard encapsulation

5.8.3 Primary part MLP140A/B/C, standard encapsulation, cable with power wire cross-section < 10 mm²



Motortyp / Type	L±2	C±0.3	N
MLP140A-XXXX-FS-...	360	80	2
MLP140B-XXXX-FS-...	510	55	4
MLP140C-XXXX-FS-...	660	80	5

Fig. 5-16: MLP140A/B/C, standard encapsulation, wire cross-section < 10 mm²

5.8.4 Primary part MLP140A/B/C, standard encapsulation, cable with power wire cross-section = 10 mm²

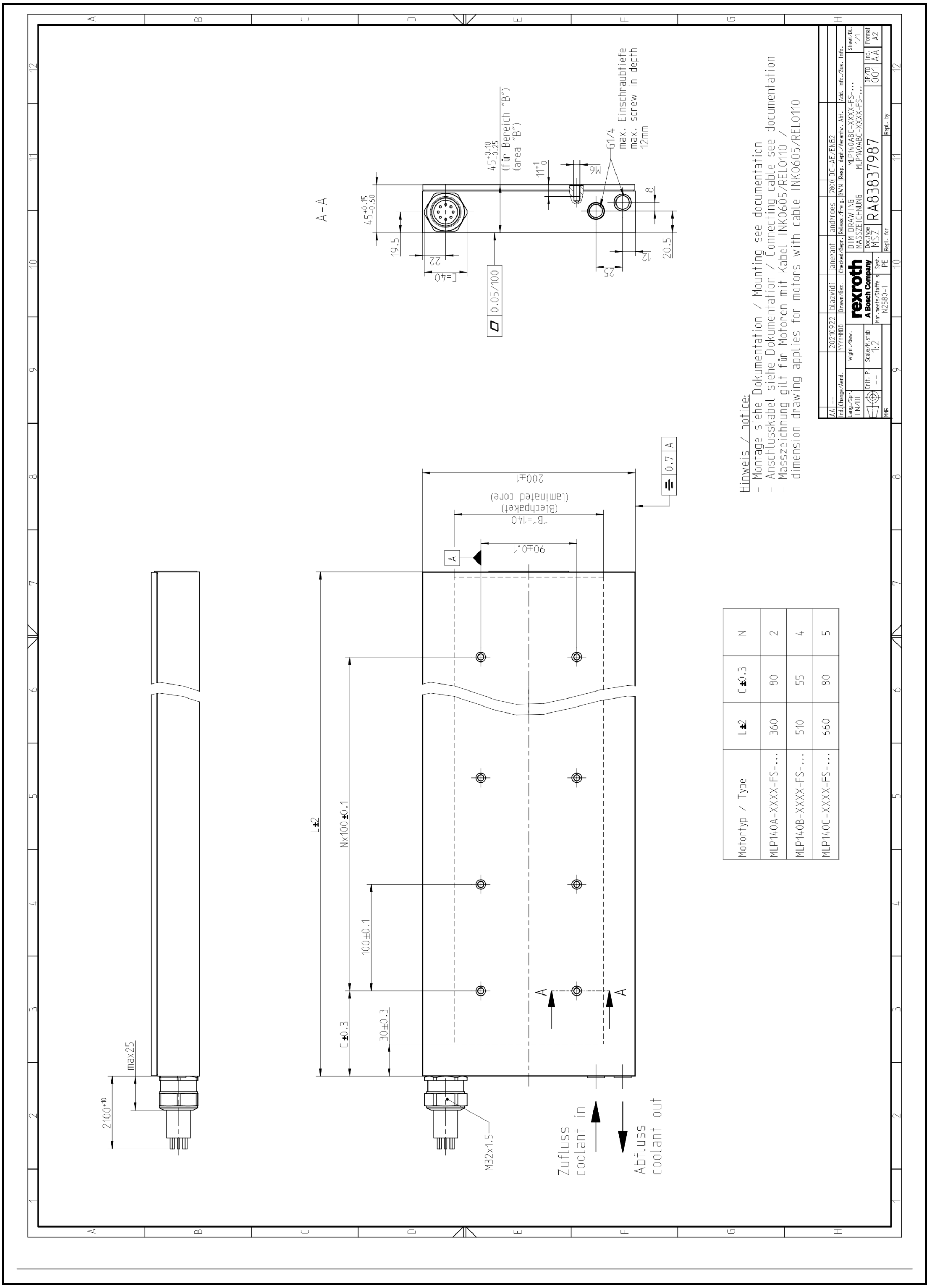


Fig. 5-17: MLP140A/B/C, standard encapsulation, wire cross section = 10 mm²

5.8.5 Primary part MLP140A/B/C with thermo encapsulation

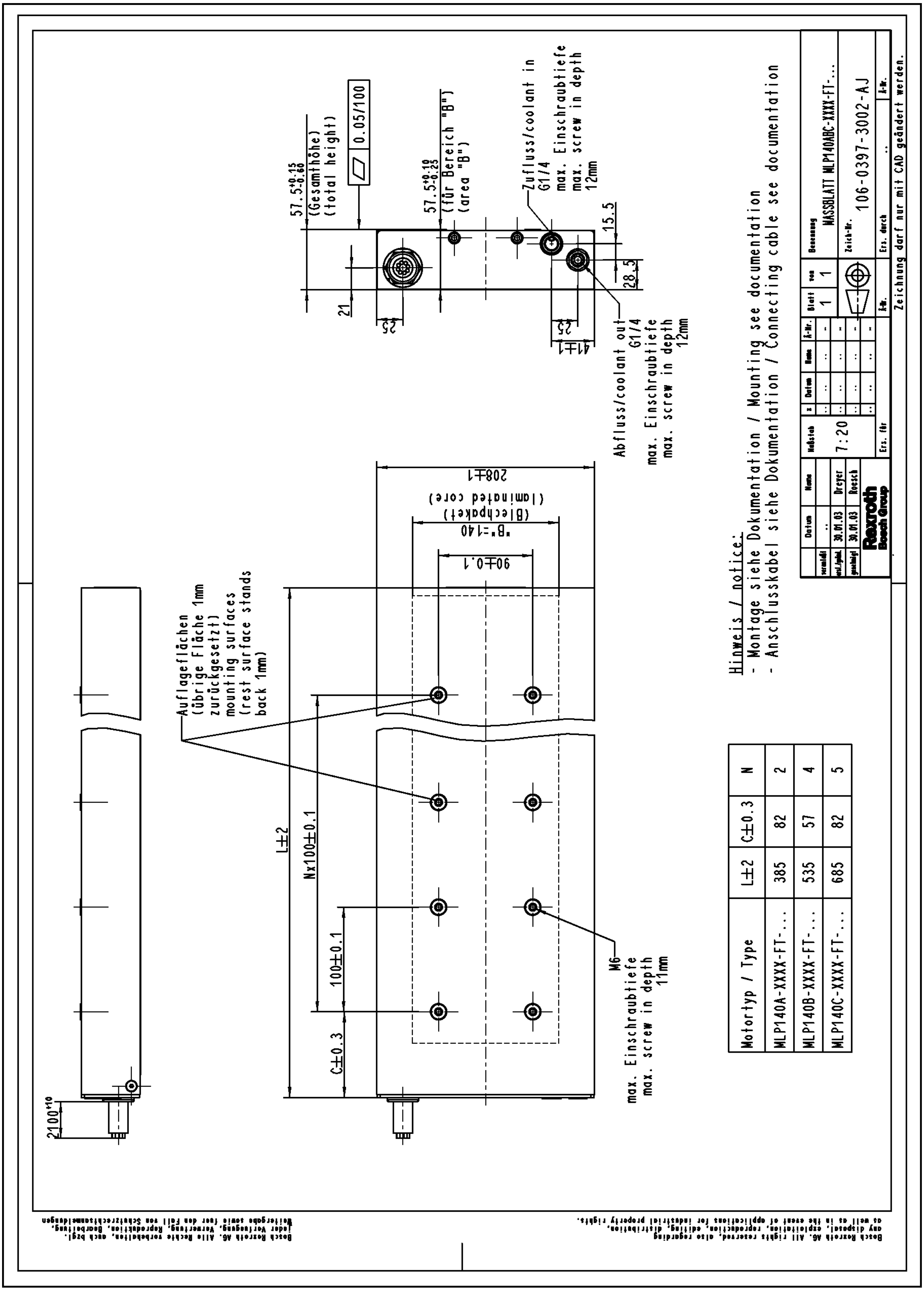


Fig. 5-18: Primary part MLP140A/B/C with thermo encapsulation

5.8.6 Secondary part MLS140

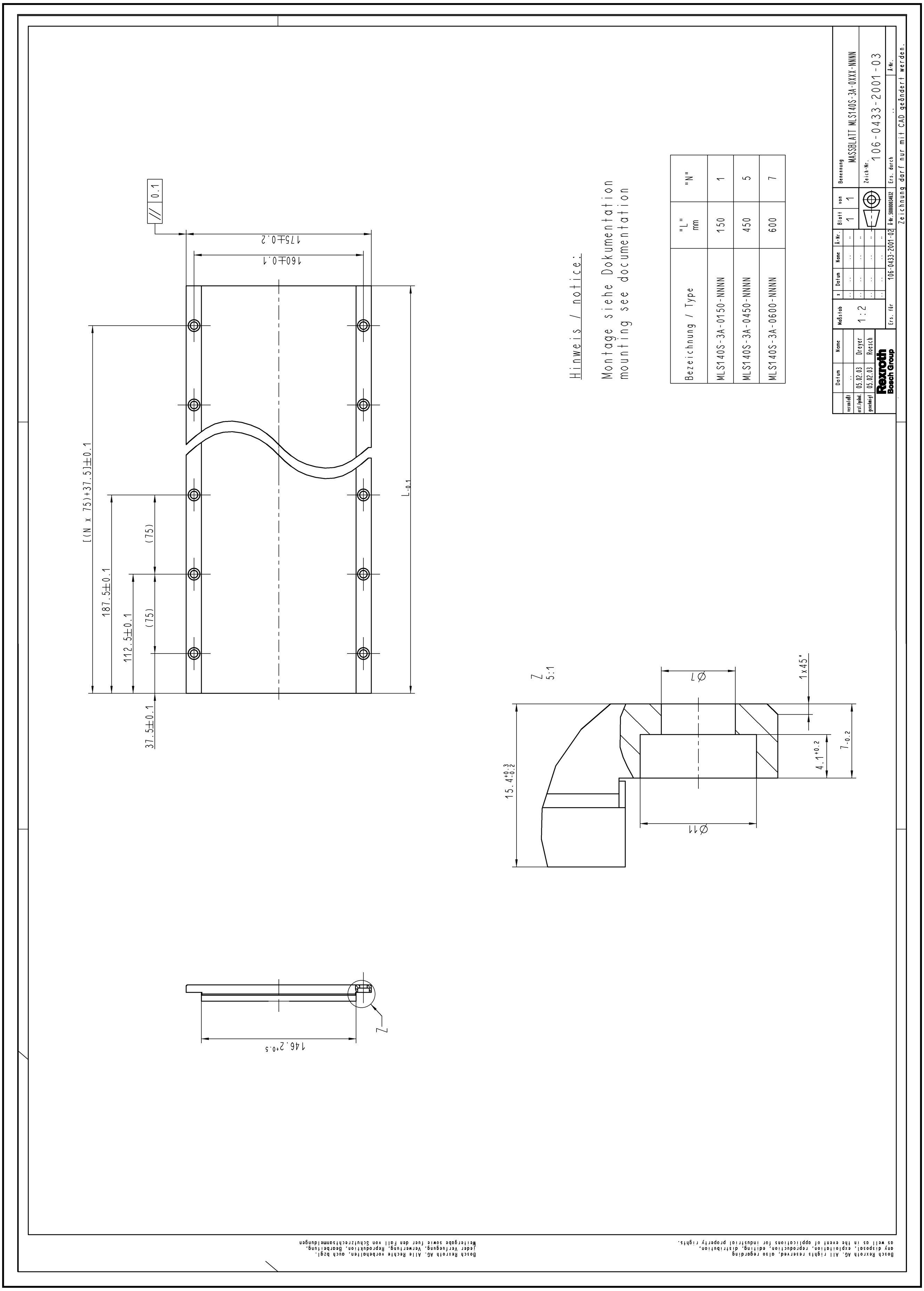


Fig. 5-19: Secondary part MLS140

5.9 Frame size 152

5.9.1 Primary part MLP152 with thermo encapsulation

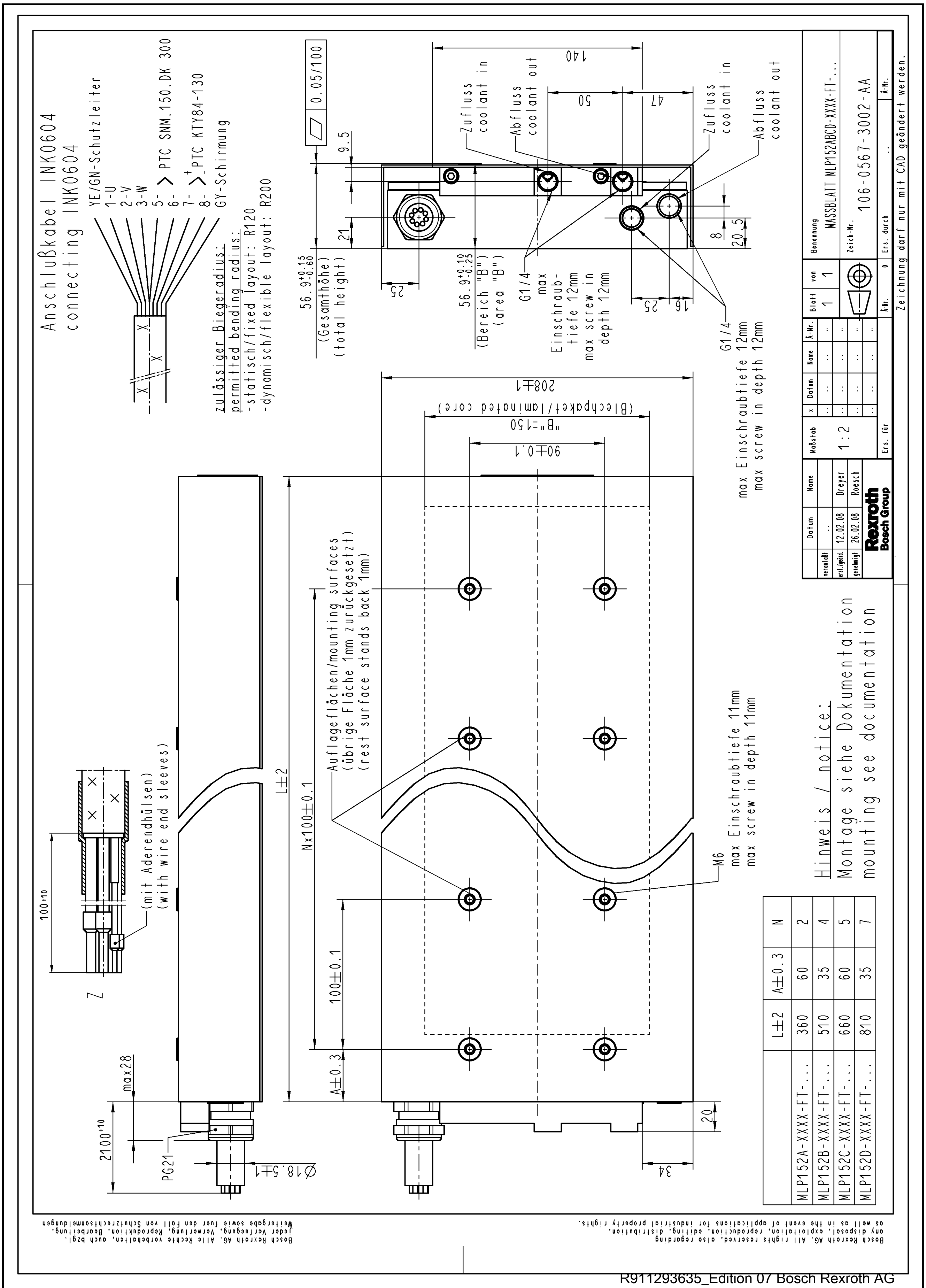


Fig. 5-20: Primary part MLP152 with thermo encapsulation

5.9.2 Secondary part MLS152

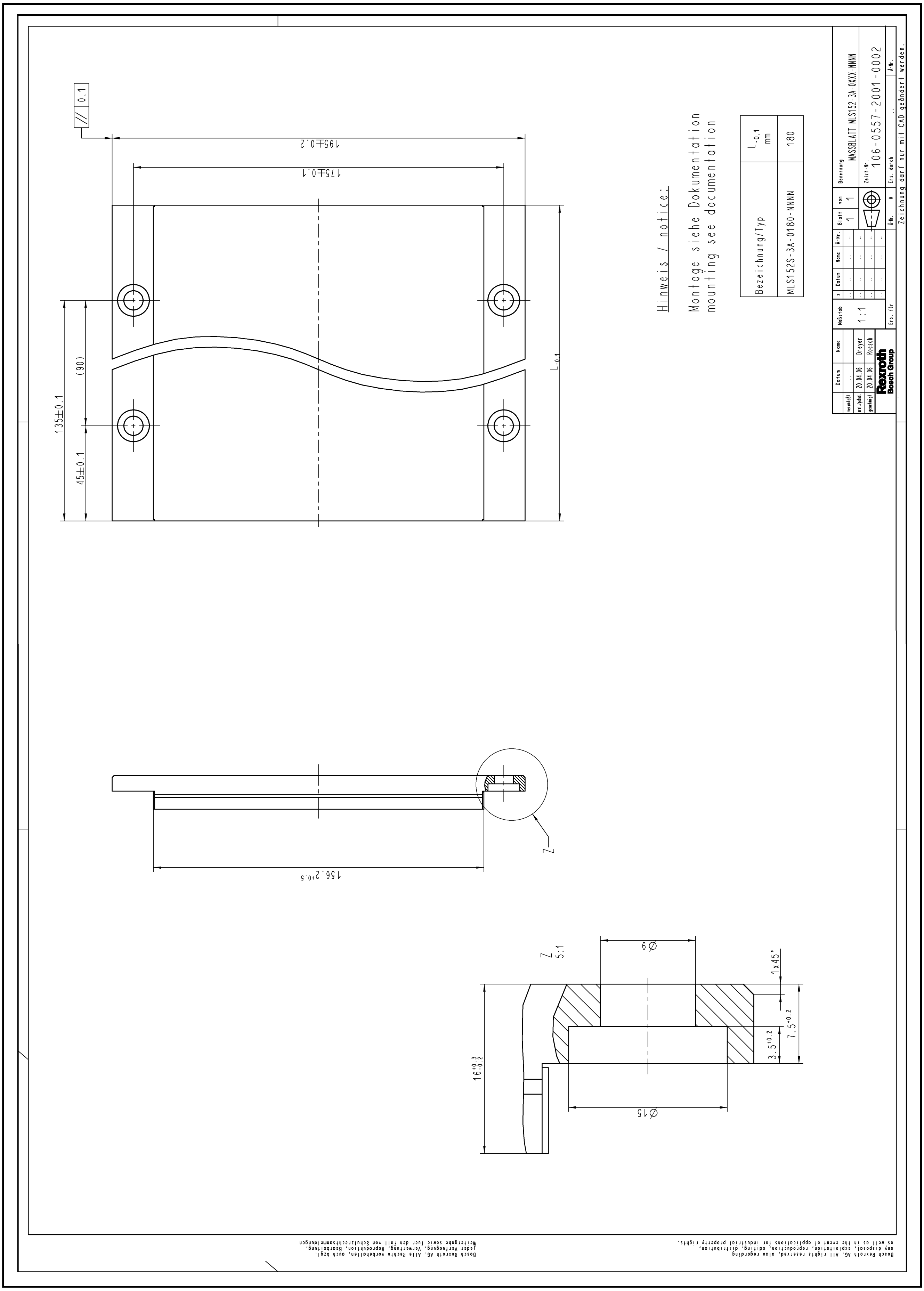


Fig. 5-21: Secondary part MLS152

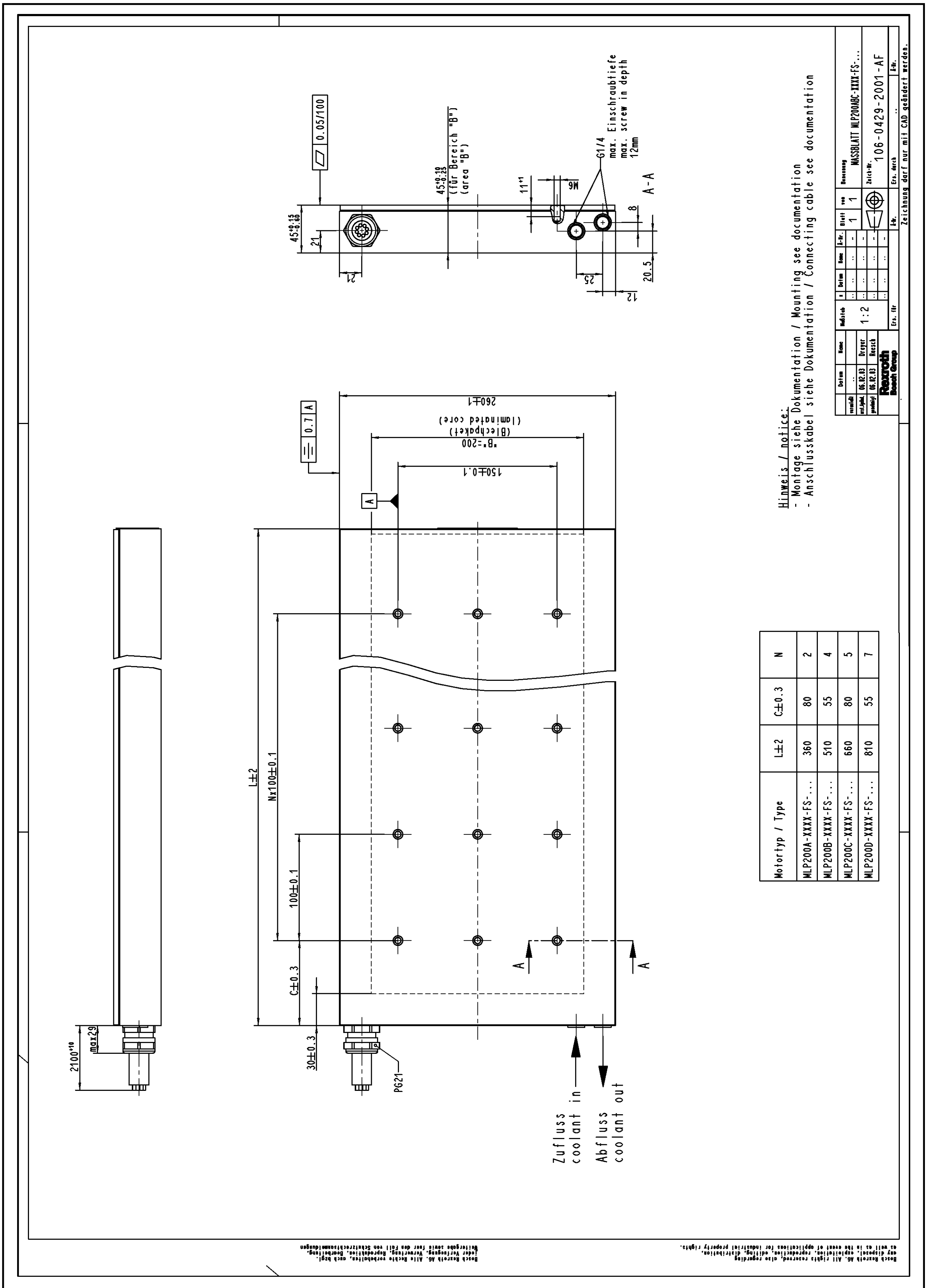
5.10 Frame size 200

5.10.1 Size of cable thread

For cables with a power wire cross-section of 10 mm² (INK0605 and REL0110), a bigger cable gland (M32) is required. All other cables are equipped with a smaller cable gland (PG21). In all cases, the screw connections are completely covered in the thermo encapsulation. Thus, only the standard encapsulation is affected by the of the interference contour of the screw connections. In tab. 8-1 "Connection cables on MLP primary part" on page 164, the affected motor designs are listed (refer to column "Connection cables" under REL0110 (INK0605)).

☞ Please note, for motors with cables with a power wire cross-section of 10 mm² (INK0605 and REL0110), a bigger cable gland (M32) is used.

5.10.2 Primary part MLP200, standard encapsulation, cable with power wire cross-section < 10 mm²



Motortyp / Type	L±2	C±0.3	N
MLP200A-XXXX-FS-...	360	80	2
MLP200B-XXXX-FS-...	510	55	4
MLP200C-XXXX-FS-...	660	80	5
MLP200D-XXXX-FS-...	810	55	7

Fig. 5-22: MLP200, standard encapsulation, wire cross-section < 10 mm²

5.10.3 Primary part MLP200, standard encapsulation, cable with power wire cross-section = 10 mm²

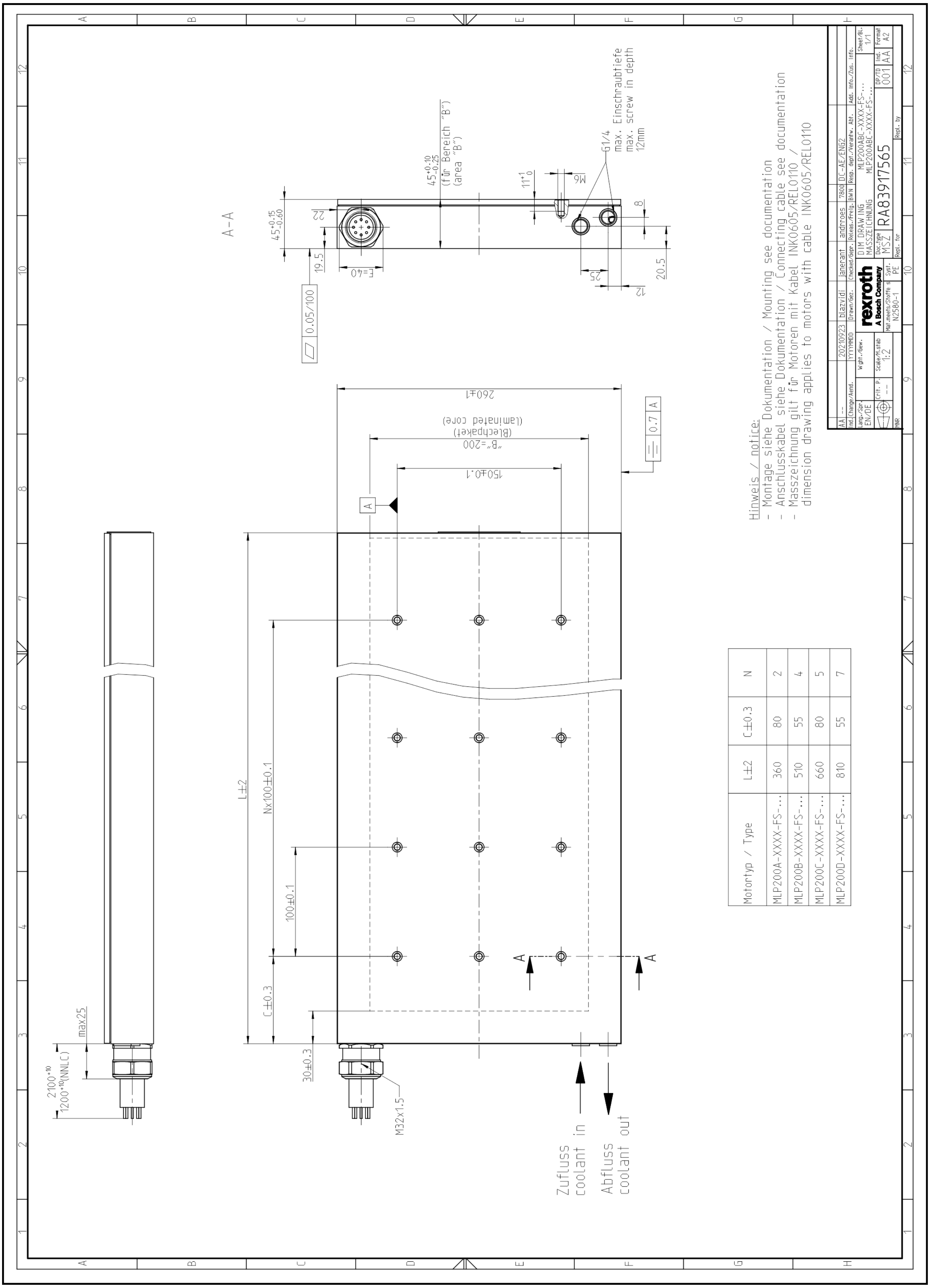
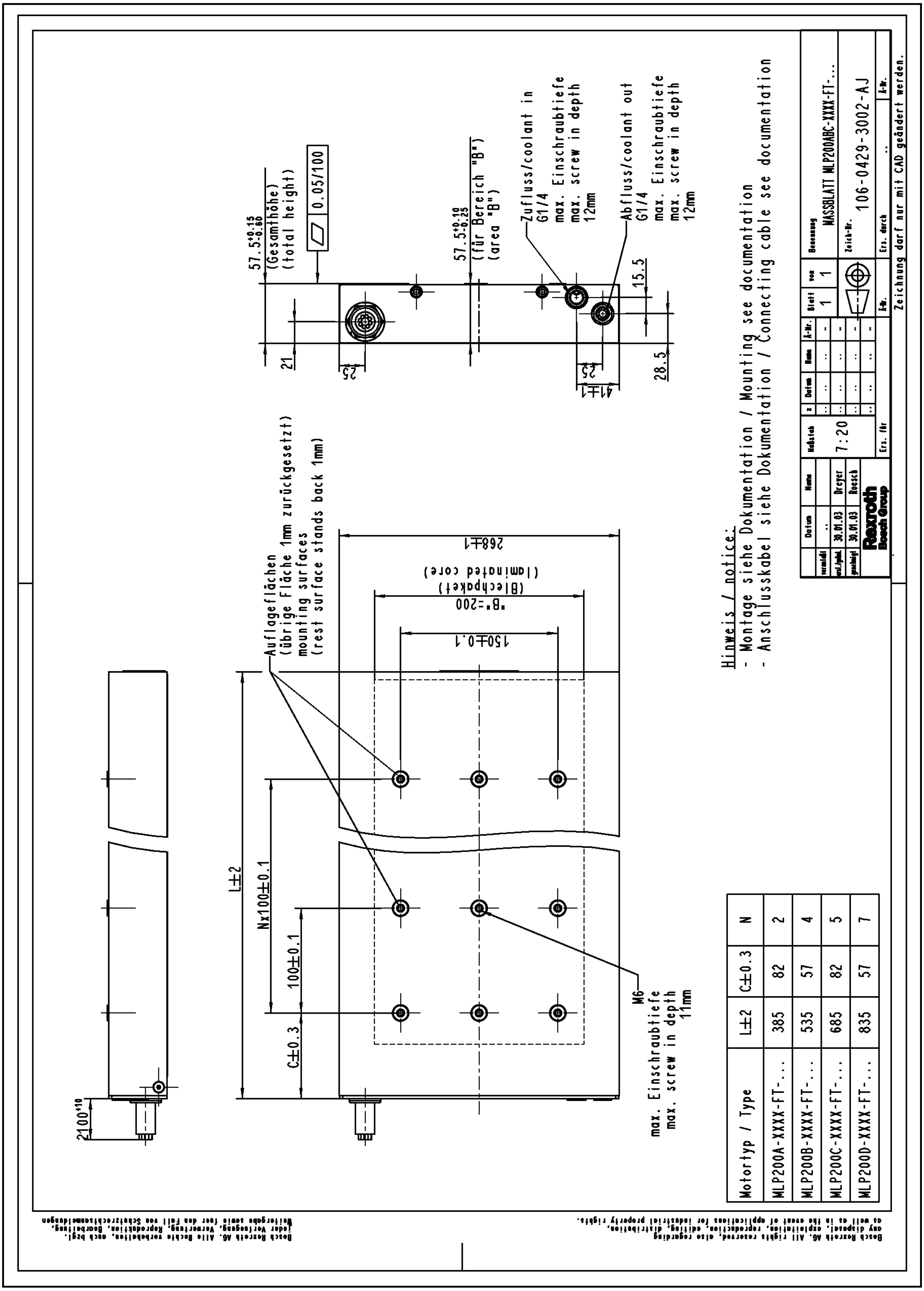


Fig. 5-23: MLP200, standard encapsulation, wire cross-section = 10 mm²

5.10.4 Primary part MLP200 with thermo encapsulation



Motortyp / Type	L±2	C±0.3	N
MLP200A-XXXX-FT-...	385	82	2
MLP200B-XXXX-FT-...	535	57	4
MLP200C-XXXX-FT-...	685	82	5
MLP200D-XXXX-FT-...	835	57	7

Fig. 5-24: Primary part MLP200 with thermo encapsulation

5.10.5 Secondary part MLS200

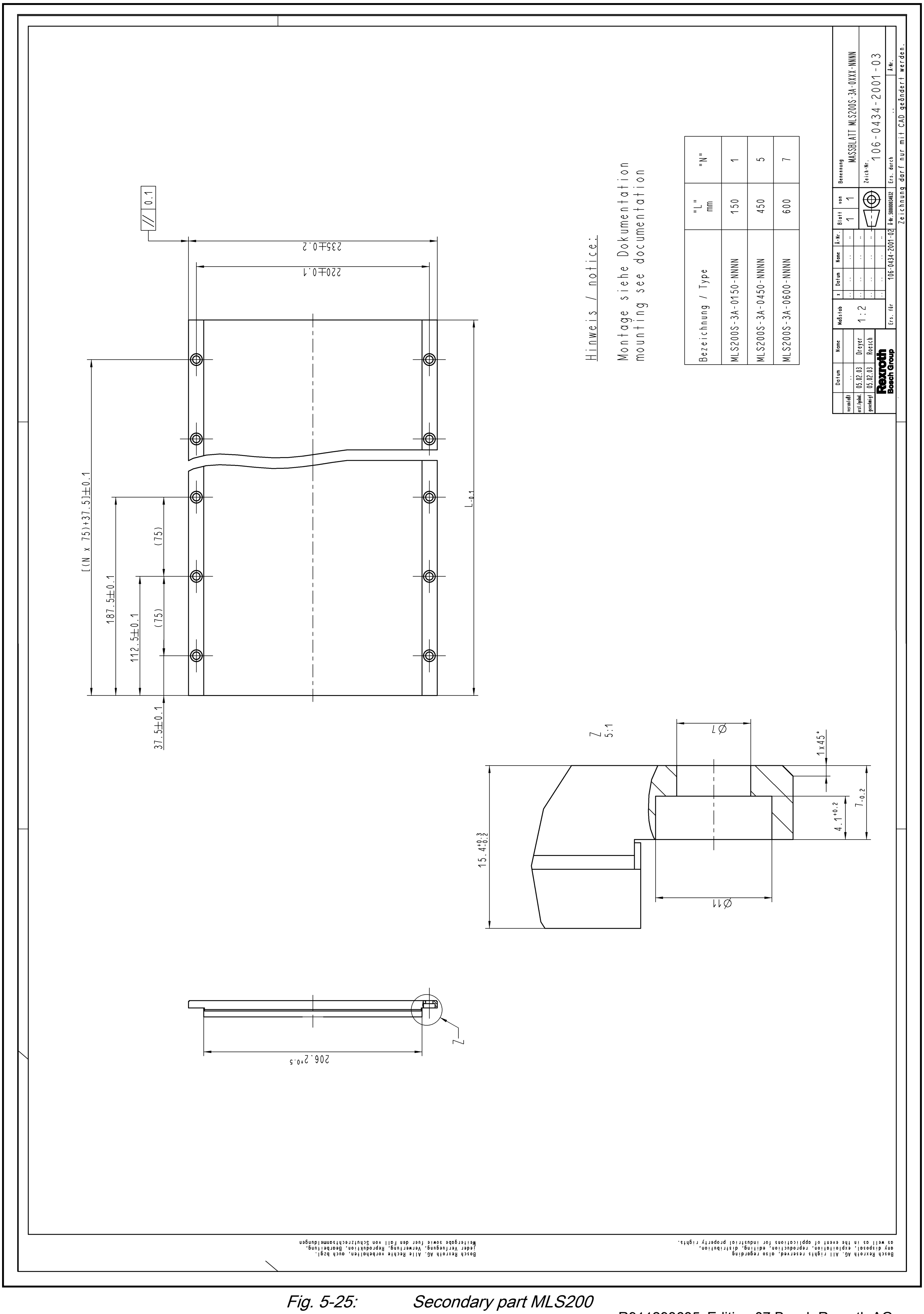


Fig. 5-25: Secondary part MLS200

5.11 Frame size 202

5.11.1 Primary part MLP202 with thermo encapsulation

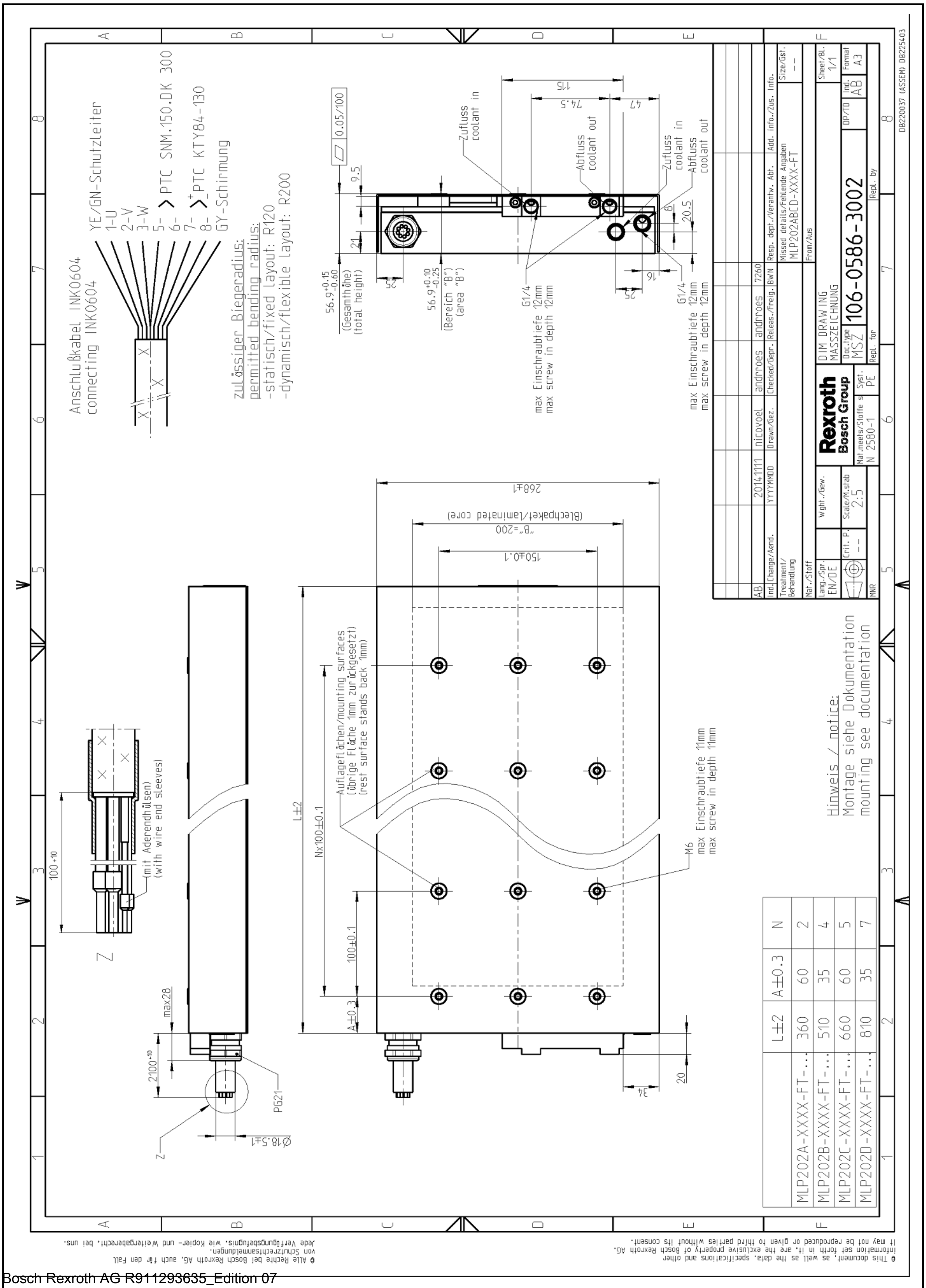


Fig. 5-26: Primary part MLP202 with thermo encapsulation

5.11.2 Secondary part MLS202

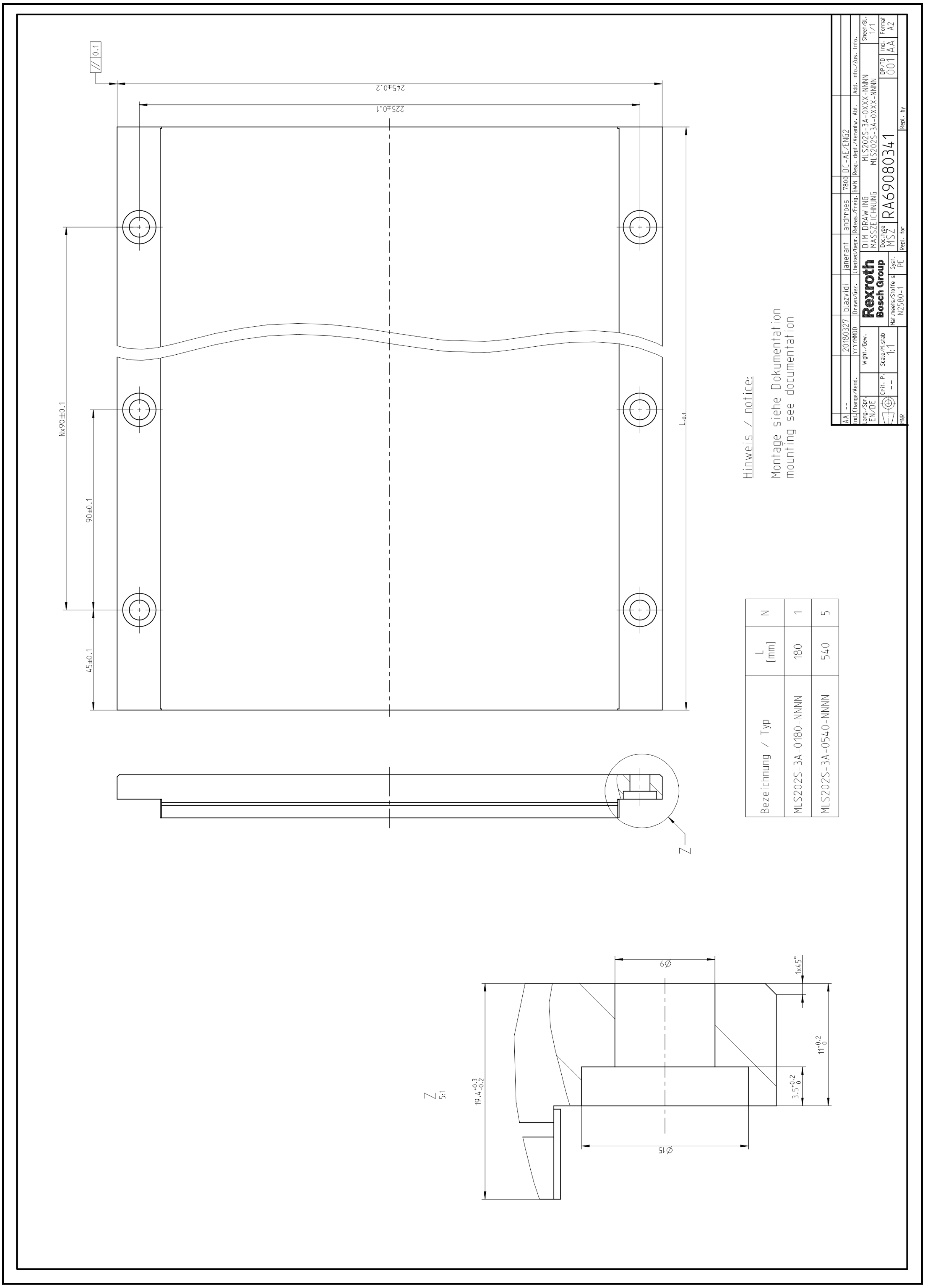


Fig. 5-27: Secondary part MLS202

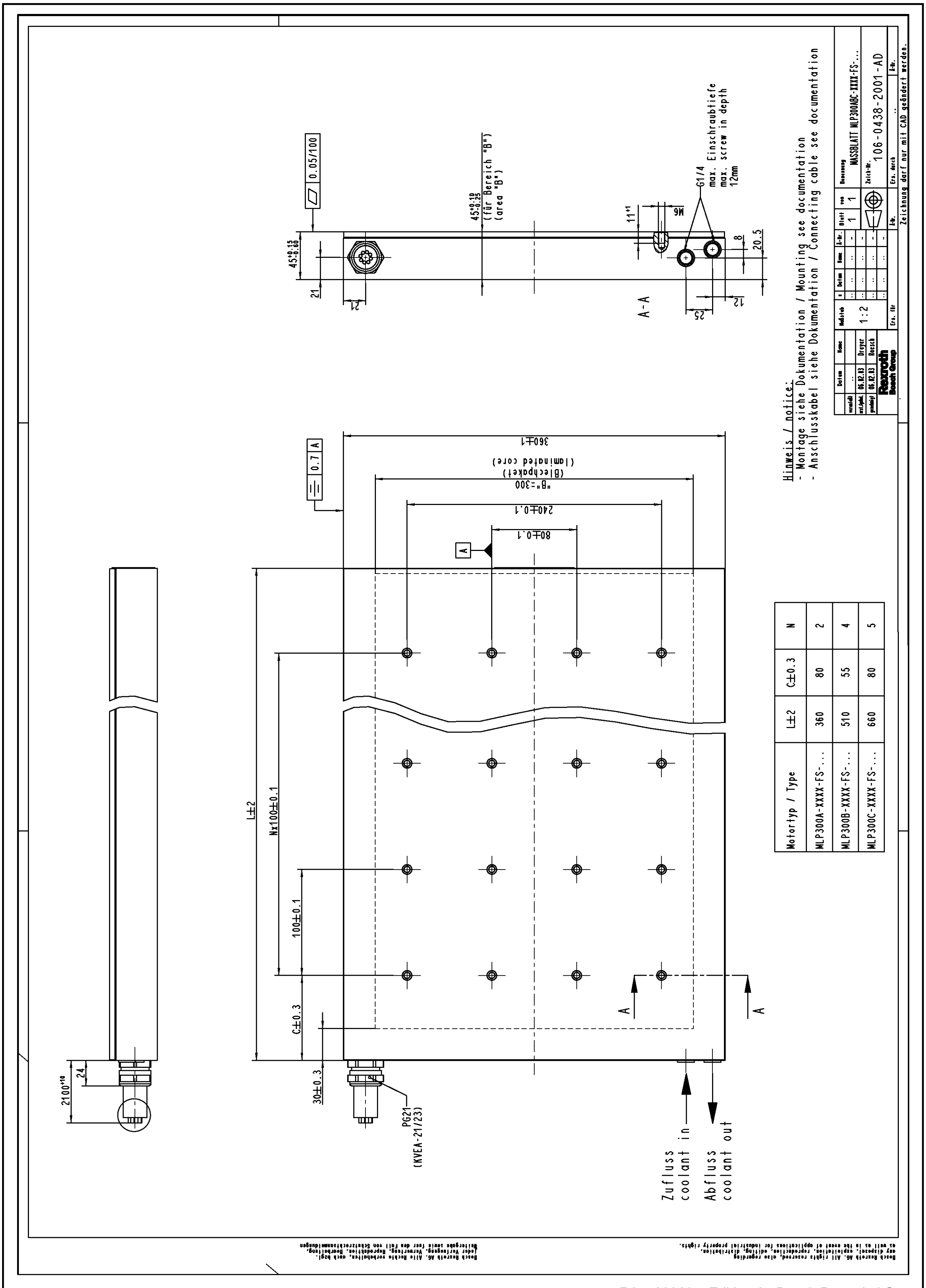
5.12 Frame size 300

5.12.1 Size of cable thread

For cables with a power wire cross-section of 10 mm² (INK0605 and REL0110), a bigger cable gland (M32) is required. All other cables are equipped with a smaller cable gland (PG21). In all cases, the screw connections are completely covered in the thermo encapsulation. Thus, only the standard encapsulation is affected by the of the interference contour of the screw connections. In tab. 8-1 "Connection cables on MLP primary part" on page 164, the affected motor designs are listed (refer to column "Connection cables" under REL0110 (INK0605)).

☞ Please note, for motors with cables with a power wire cross-section of 10 mm² (INK0605 and REL0110), a bigger cable gland (M32) is used.

5.12.2 Primary part MLP300, standard encapsulation, cable with power wire cross-section < 10 mm²



Motortyp / Type	L±2	C±0.3	N
MLP300A-XXXX-FS-...	360	80	2
MLP300B-XXXX-FS-...	510	55	4
MLP300C-XXXX-FS-...	660	80	5

Fig. 5-28: MLP300, standard encapsulation, wire cross-section < 10 mm²

5.12.3 Primary part MLP300, standard encapsulation, cable with power wire cross-section = 10 mm²

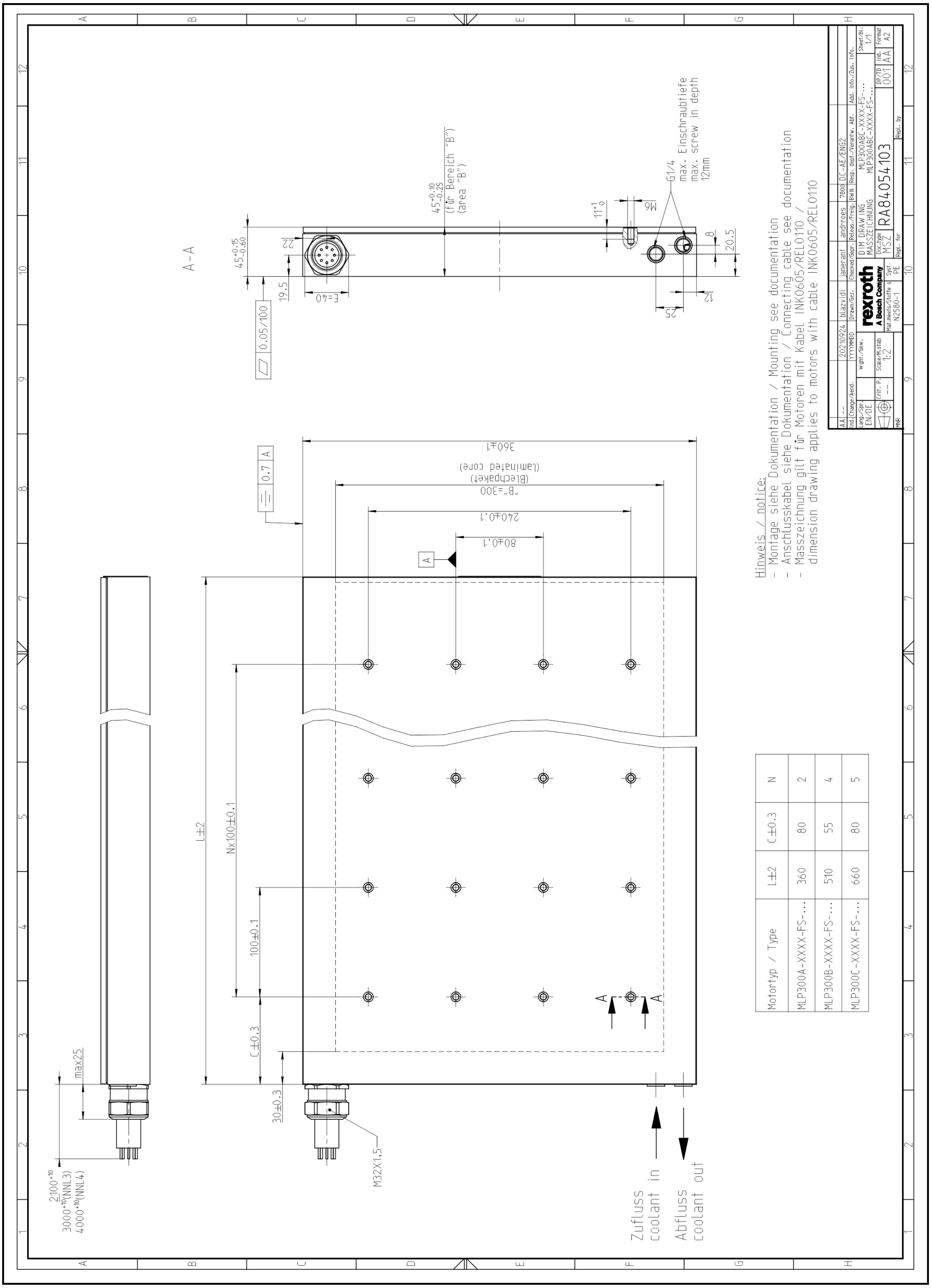


Fig. 5-29: MLP300, standard encapsulation, wire cross section = 10 mm²

5.12.4 Primary part MLP300 with thermo encapsulation

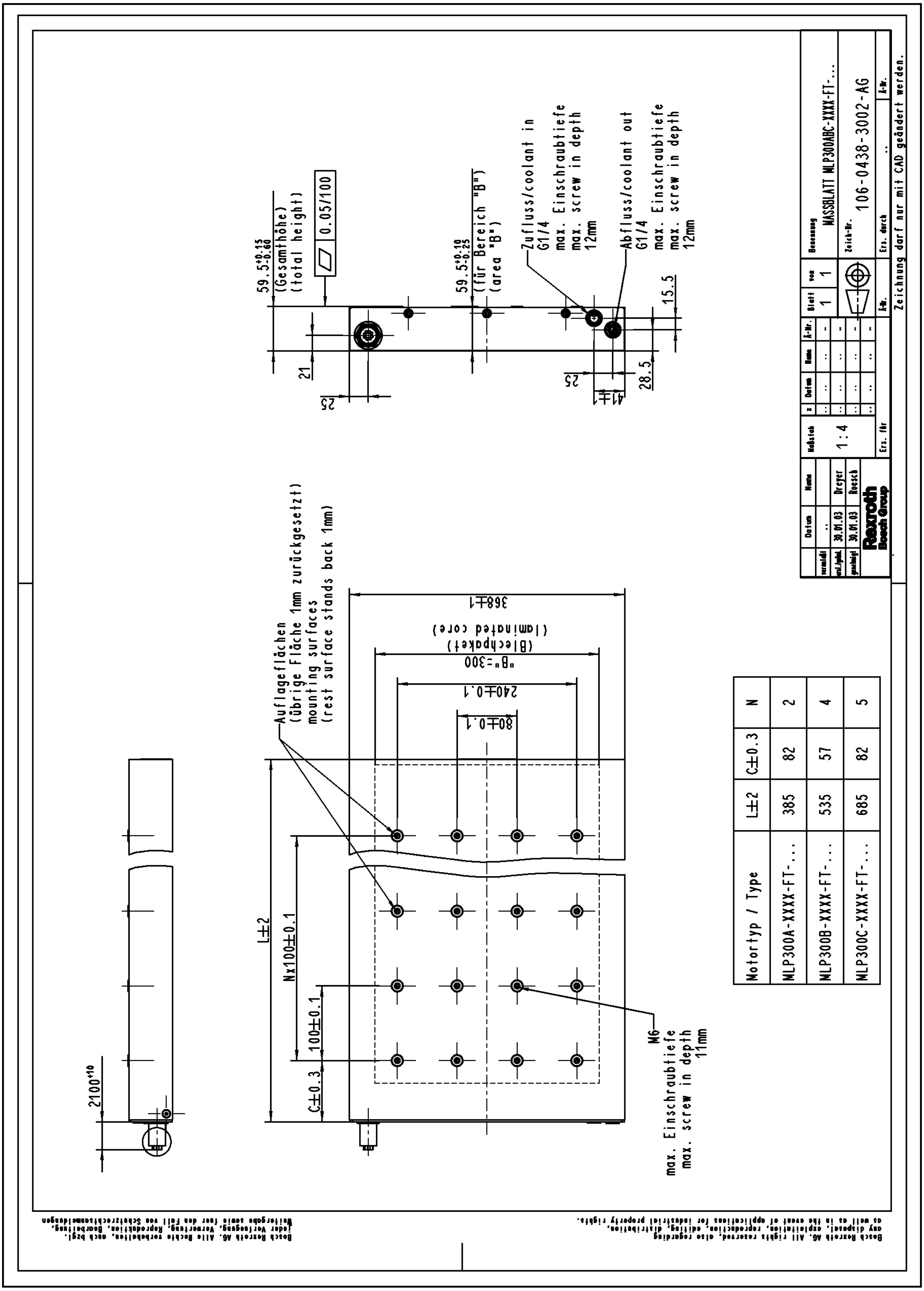


Fig. 5-30: Primary part MLP300 with thermo encapsulation

5.12.5 Secondary part MLS300

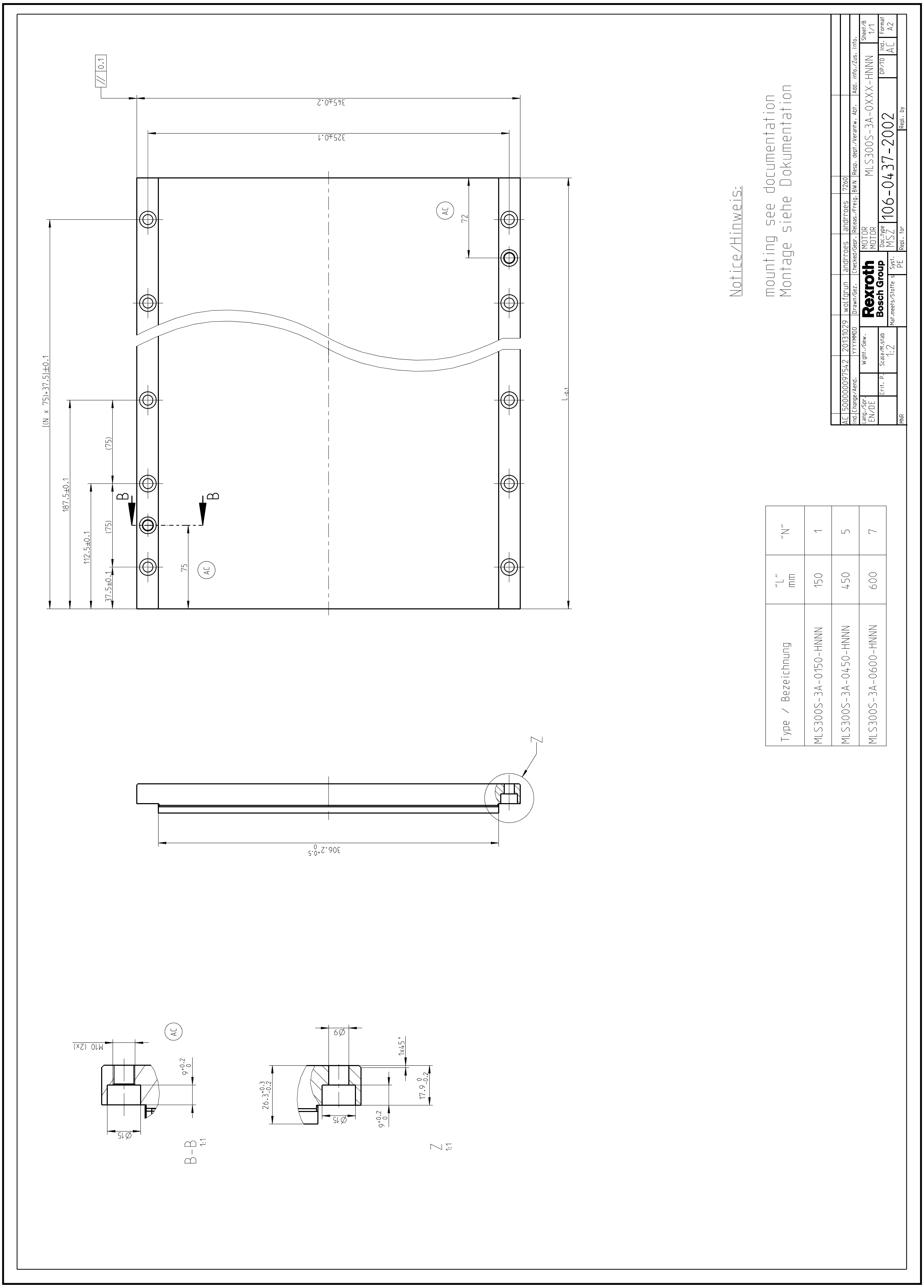


Fig. 5-31: Secondary part MLS300

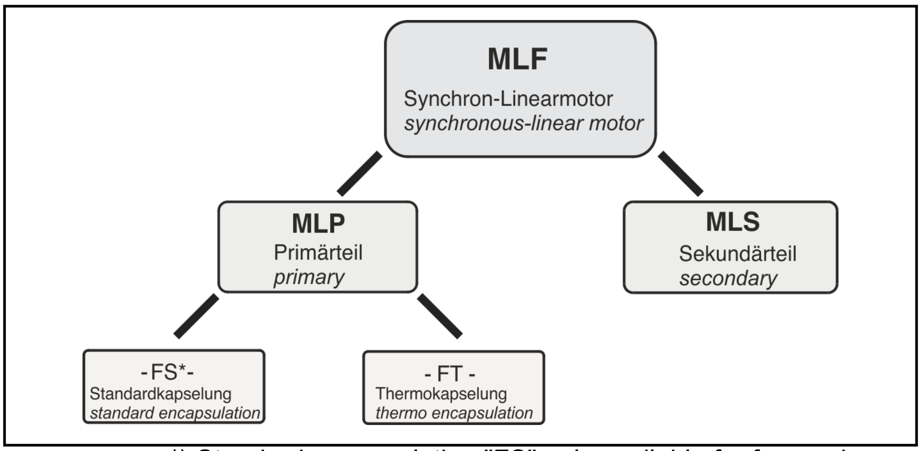
6 Product information

6.1 Type codes

6.1.1 General

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

The overall product designation MLF stands for synchronous linear motors. This designation describes the total system which consists of a primary and a secondary part. As linear motors are kit motors, the primary and secondary part have an additional, defined short term:



*) Standard encapsulation "FS" only available for frame size xx0

Fig. 6-1: MLF short name

The following figures give an example of a motor type code for primary and secondary parts, by which an exact specification of the single parts (e.g. for orders) is possible.

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

6.1.2 Type code primary part MLP

General

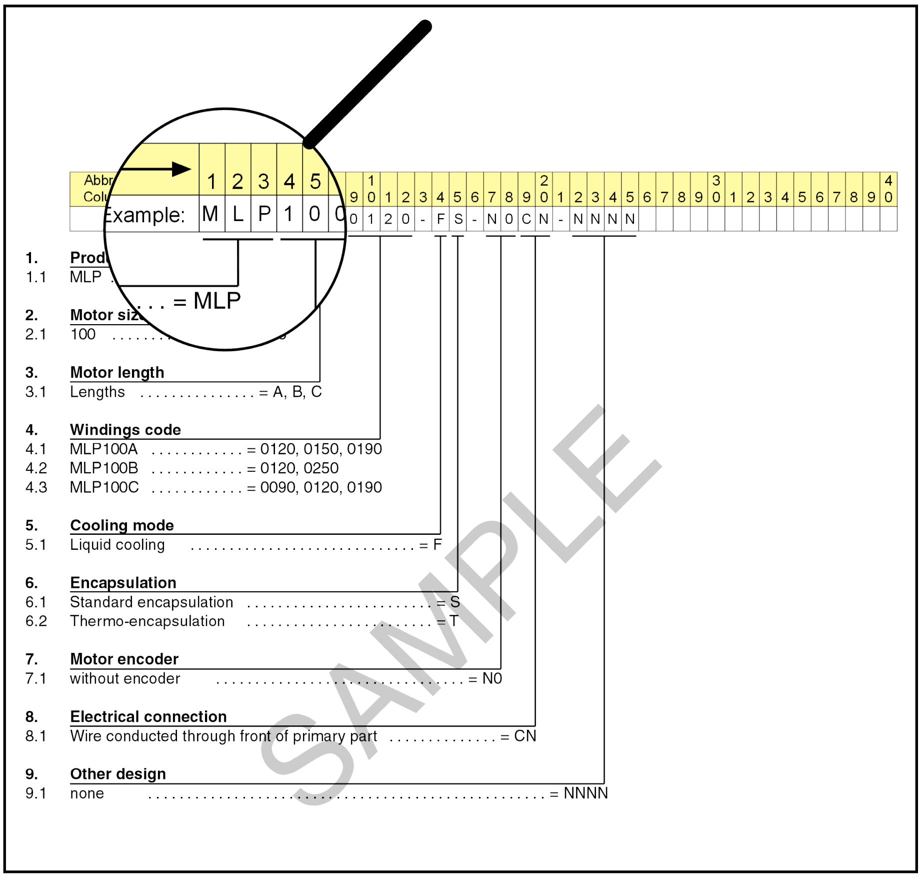


Fig. 6-2: Example - type code primary part MLP100

Component MLP

Abbrev. column 1 2 3

MLP is the designation of the primary part of an MLF motor.

Motor frame size

Short-text column 4 5 6

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

Motor length

Abbrev. column 7

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

Frame lengths are, for example, **A**, **B** or **C**. etc.

Winding code

Short-text column 9 10 11 12

The numbers of the winding code do also describe the reachable maximum speed F_{max} in m/min.

Cooling

Abbrev. column 14

In general, the primary parts of the MLF motors are provided with **liquid cooling** for operation and thus only available with liquid cooling.

Casing

Abbrev. column 15

- **"S" = Standard encapsulation.** Stainless steel encapsulation with liquid cooling integrated in the motor back to dissipate the heat loss
- **T = thermal encapsulation:** Stainless steel encapsulation with an additional liquid cooling on the back of the motor and heat conductive plates for optimum thermal decoupling to the machine construction.

Motor encoder

Abbrev. column 17 18

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 column 19 20

Primary parts of synchronous linear motors MLF are fitted with a high-flexible and shielded cable. The connection cable is brought out of the front of the primary part and is fixed with it.

Other designs

Abbrev. column 22 23 24 25

Those fields are not reserved.

6.1.3 Type code secondary part MLS

General

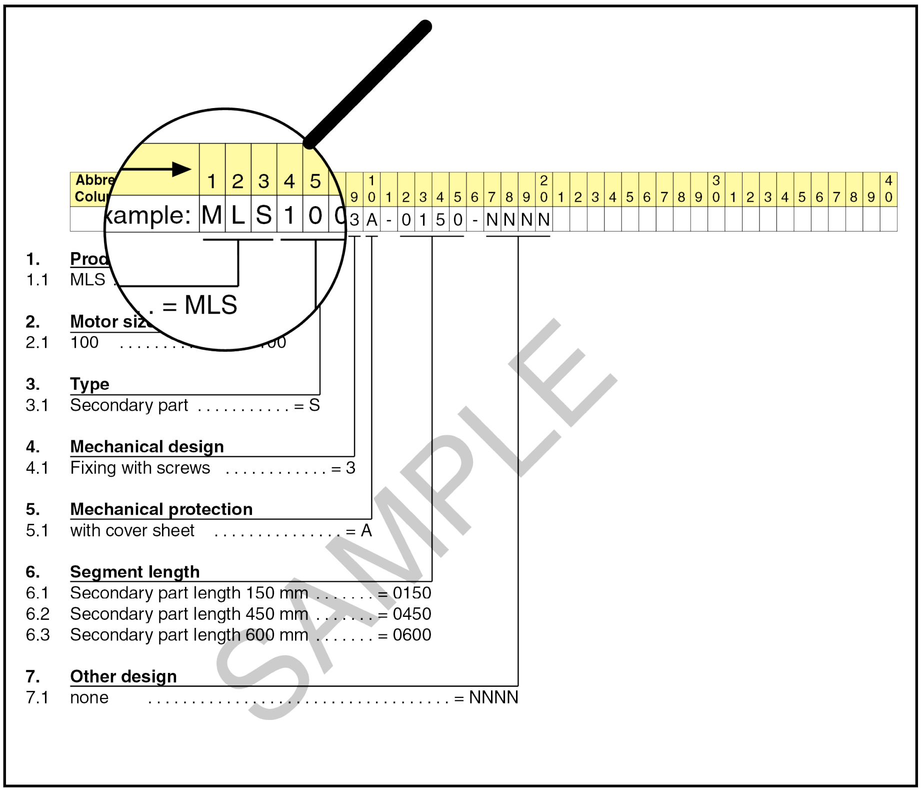


Fig. 6-3: Example - type code secondary part MLS100

Component MLS

Abbrev. column 1 2 3

MLS is the designation of the secondary part of an MLF motor.

Motor frame size

Short-text column 4 5 6

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

Type

Abbrev. column 7

S = secondary part

Mechanical design

Short-text column 9

The number **3** stands for the fastening of the secondary part with screws by fixing holes along the outer edge.

Mechanical protection

Short-text column 10

To ensure the utmost operation reliability, the permanent magnets of the secondary part are always protected against corrosion, action of outer influences (e.g. water and dust) and against mechanical damage, due to an integrated rustless cover plate.

Segment length

Abbrev. column 12 13 14 15

The length of the secondary parts is specified in mm as a 4-digit number with leading "0", e.g. "0150" --> 150 mm.

Other design

Abbrev. column 17 18 19 20	NNNN = Those fields are not reserved.
	HNNN = Reinforced basic carrier (only for MLS300)

6.1.4 Frame size 040

MLP040

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	L	P	0	4	0	A	-	0	3	0	0	-	F	S	-	N	0	C	N	-	N	N	N	N															

1. Product
1.1 MLP. . . . . = MLP

2. Motor size
2.1 040 . . . . = 040

3. Motor length
3.1 Lengths . . . . = A, B

4. Windings code
4.1 MLP040A. . . . . = 0300
4.2 MLP040B. . . . . = 0150, 0250, 0300

5. Cooling mode
5.1 Liquid cooling . . . . = F

6. Encapsulation
6.1 Standard encapsulation . . . . = S
6.2 Thermo-encpsulation . . . . = T

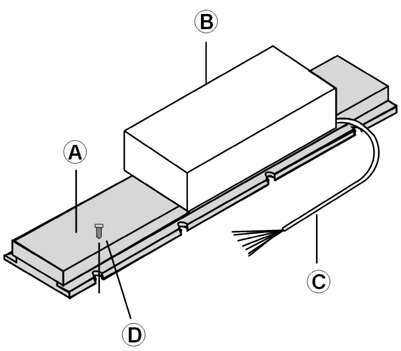
7. Motor encoder
7.1 without encoder. . . . . = N0

8. Electrical connection
8.1 Wire conducted through front of primary part . . . . = CN

9. Other design
9.1 none . . . . = NNNN

RNC-41430-401_NOR_N_D0_2003-08-06.fh11

Illustration example: MLP040



(A) Secondary part MLS
(B) Primary part MLP (Standard encapsulation or Thermo-encapsulation)
(C) Electrical connection
(D) Screw mounting (from above)

Fig. 6-4: Type code primary part MLP040

MLS040

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	L	S	0	4	0	S	-	3	A	-	0	1	5	0	-	N	N	N	N																				

1. Product
1.1 MLS . . . . = MLS

2. Motor size
2.1 040 . . . . = 040

3. Type
3.1 Secondary part . . . . = S

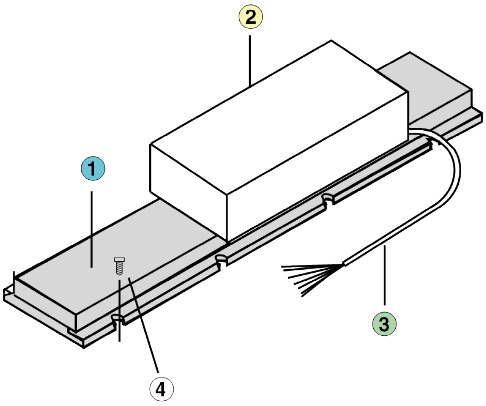
4. Mechanical design
4.1 Fixing with screws . . . . = 3

5. Mechanical protection
5.1 with cover sheet . . . . = A

6. Segment length
6.1 Secondary part length 150 mm . . . . = 0150
6.2 Secondary part length 450 mm . . . . = 0450
6.3 Secondary part length 600 mm . . . . = 0600

7. Other design
7.1 none . . . . = NNNN

Illustration example: MLS040



1 Secondary part MLS
2 Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3 Power connection
4 Screw mounting (from above)

Fig. 6-5: Type code secondary part MLS040

6.1.5 Frame size 052

MLP052

Short text 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	L	P	0	5	2	B	-	0	3	0	0	-	F	T	-	N	0	C	N	-	N	N	N	N															

01 **Product**
MLP.................. = MLP

02 **Frame size**
052 ....= 052

03 **Frame lengths**
Frame length.......................... = A
Frame length.......................... = B

04 **Windings**
MLP052A...................................... = 0300
MLP052B .... = 0300

05 **Cooling**
Liquid cooling .... = F

06 **Encapsulation**
Thermal encapsulation .... = T

07 **Encoder**
Without encoder .... = N0

08 **Electrical connection**
Line lead out at front side of the primary part .... = CN

09 **Other design**
None .... = NNNN

DCCS-40017-052_TCO_N_DE_2008-05-19

Fig. 6-6: Type code primary part MLP052

MLS052

Short text 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	L	S	0	5	2	S	-	3	A	-	0	1	8	0	-	N	N	N	N																				

01 **Product**
MLS.................. = MLS

02 **Frame size**
052 ....= 052

03 **Type**
Secondary part .... = S

04 **Mechanical design**
Screw fastening .... = 3

05 **Mechanical protection**
With cover plate .... = A

06 **Segment lengths**
180 mm ....= 0180
540 mm ....= 0540

07 **Other design**
Keine ....= NNNN

DCCS-40016-052_TCO_N_DE_2018-08-10

Fig. 6-7: Type code secondary part MLS052

6.1.6 Frame size 070

MLP070

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	L	P	0	7	0	A	-	0	3	0	0	-	F	T	-	N	0	C	N	-	N	N	N	N															

1. Product
1.1 MLP . . . . = MLP

2. Motor frame size
2.1 070 . . . . = 070

3. Motor frame lengths
3.1 Frame lengths. . . . .= A, B, C

4. Winding designation
4.1 MLP070A = 0150, 0220, 0300
4.2 MLP070B = 0100, 0120, 0150, 0250, 0300
4.3 MLP070C = 0030, 0120, 0150, 0240, 0300

5. Cooling
5.1 Liquid cooling . . . . = F

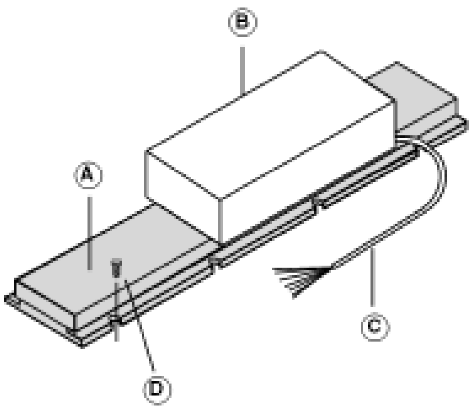
6. Encapsulation
6.1 Standard encapsulation. . . . . = S
6.2 Thermal encapsulation. . . . .= T

7. Motor encoder
7.1 Without encoder . . . . = N0

8. Electrical connection
8.1 Cable lead out from front side of the primary part . . . . = CN

9. Other design
9.1 None . . . . = NNNN

Example: MLP070



Ⓐ Secondary part MLS
Ⓑ Primary part MLP (depending from design - Standard encapsulation or thermal encapsulation)
Ⓒ Electrical connection
Ⓓ Screw fastening (from top)

Fig. 6-8: Type code primary part MLP070

MLS070

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	L	S	0	7	0	S	-	3	A	-	0	1	5	0	-	N	N	N	N																				

1. Product
1.1 MLS . . . . = MLS

2. Motor size
2.1 070 . . . . = 070

3. Type
3.1 Secondary part . . . . = S

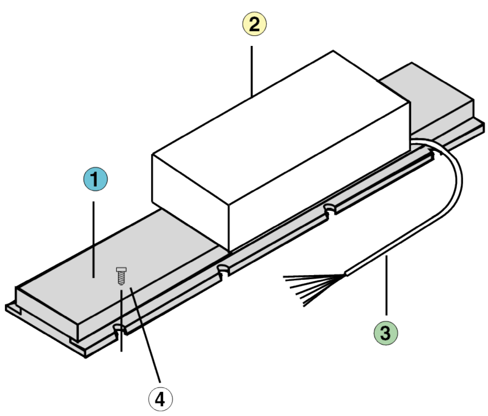
4. Mechanical design
4.1 Fixing with screws . . . . = 3

5. Mechanical protection
5.1 with cover sheet . . . . = A

6. Segment length
6.1 Secondary part length 150 mm . . . . = 0150
6.2 Secondary part length 450 mm . . . . = 0450
6.3 Secondary part length 600 mm . . . . = 0600

7. Other design
7.1 none . . . . = NNNN

Illustration example: MLS070



1. Secondary part MLS
2. Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3. Power connection
4. Screw mounting (from above)

Fig. 6-9: Type code secondary part MLS070

6.1.7 Frame size 100

MLP100

Type short description	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	L	P	1	0	0	A	-	0	1	2	0	-	F	S	-	N	0	C	N	-	N	N	N	N															

01 Product
MLP .... = MLP

02 Size
100................................ = 100

03 Length
Lengths........................= A, K, B, C

04 Winding
MLP100A.......... = 0090, 0120, 0150, 0190
MLP100K.......... = 0040
MLP100B.......... = 0030, 0120, 0250
MLP100C.......... = 0090, 0120, 0190

05 Cooling mode
Liquid cooling...= F

06 Encapsulation
Standard encapsulation..= S
Thermo encapsulation..= T

07 Encoder
Without encoder .... = N0

08 Electrical connection
Wire conducted through front of primary part........................= CN

09 Other design
None .... = NNNN

Fig. 6-10: Type code primary part MLP100

MLS100

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	L	S	1	0	0	S	-	3	A	-	0	1	5	0	-	N	N	N	N																				

1. Product
1.1 MLS . . . . = MLS

2. Motor size
2.1 100 . . . . = 100

3. Type
3.1 Secondary part . . . . = S

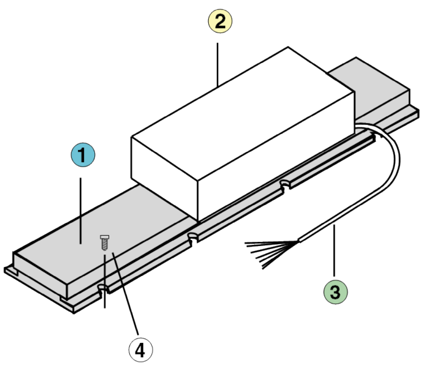
4. Mechanical design
4.1 Fixing with screws . . . . = 3

5. Mechanical protection
5.1 with cover sheet . . . . = A

6. Segment length
6.1 Secondary part length 150 mm . . . . = 0150
6.2 Secondary part length 450 mm . . . . = 0450
6.3 Secondary part length 600 mm . . . . = 0600

7. Other design
7.1 none . . . . = NNNN

Illustration example: MLS100



1 Secondary part MLS
2 Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3 Power connection
4 Screw mounting (from above)

Fig. 6-11: Type code secondary part MLS100

6.1.8 Frame size 102

MLP102

Short text 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	L	P	1	0	2	C	-	0	0	6	0	-	F	T	-	N	0	C	N	-	N	N	N	N															

01 Product

MLP.................. = MLP

02 Frame size

102 .... = 102

03 Frame lengths

Frame length .... = B

Frame length .... = C

Frame length .... = D

04 Windings

MLP102B...................................... = 0060

MLP102C .... = 0060

MLP102D .... = 0060

05 Cooling

Liquid cooling .... = F

06 Encapsulation

Thermal encapsulation .... = T

07 Encoder

Without encoder .... = N0

08 Electrical connection

Line is lead out of the front side of the primary part .... = CN

09 Other design

None .... = NNNN

DCCS-40017-102_TCO_N_DE_2018-07-09

Fig. 6-12: Type code primary part MLP102

MLS102

Short text 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	L	S	1	0	2	S	-	3	A	-	0	1	8	0	-	N	N	N	N																				

01 **Product**
MLS .... = MLS

02 **Frame size**
102 .... = 102

03 **Type**
Secondary part .... = S

04 **Mechanical design**
Screw fastening .... = 3

05 **Mechanical protection**
With cover plate .... = A

06 **Segment lengths**
180 mm .... = 0180
540 mm .... = 0540

07 **Other design**
None .... = NNNN

DCCS-40016-102_TCO_N_DE_2018-07-09

Fig. 6-13: Type code secondary part MLS102

6.1.9 Frame size 140

MLP140

Typkurzbezeichnung	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
Beispiel:	M	L	P	1	4	0	C	-	0	0	5	0	-	F	T	-	N	0	C	N	-	N	N	N	N															

01 Product
MLP .... = MLP

02 Size
140 .... = 140

03 Length
Lengths .... = Z, A, B, C

04 Winding
MLP140Z .... = 0060 [a)]
MLP140A .... = 0030, 0120
MLP140B .... = 0035, 0090, 0120
MLP140C .... = 0050, 0120, 0170, 0350

05 Cooling mode
Liquid cooling .... = F

06 encapsulation
Standard encapsulation .... = S
Thermo encapsulation.. = T

07 Encoder
Whithout encoder.. = N0

08 Electrical connection
Wire conducted through front of primary part .... = CN

09 Other design
None .... = NNNN

Note:
a) Length „Z“ and Winding „0060“ only available in following motor variant:
MLP140Z-0060-FS-N0CN-NNNN

DCCS-40017-140_TCO_N_EN_2020-01-15

Fig. 6-14: Type code primary part MLP140

MLS140

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	L	S	1	4	0	S	-	3	A	-	0	1	5	0	-	N	N	N	N																				

1. Product
1.1 MLS . . . . = MLS

2. Motor size
2.1 140 . . . . = 140

3. Type
3.1 Secondary part . . . . = S

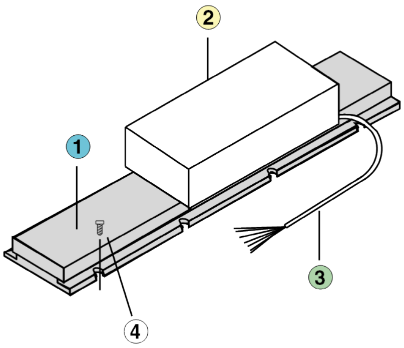
4. Mechanical design
4.1 Fixing with screws . . . . = 3

5. Mechanical protection
5.1 with cover sheet . . . . = A

6. Segment length
6.1 Secondary part length 150 mm . . . . = 0150
6.2 Secondary part length 450 mm . . . . = 0450
6.3 Secondary part length 600 mm . . . . = 0600

7. Other design
7.1 none . . . . = NNNN

Illustration example: MLS140



1 Secondary part MLS
2 Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3 Power connection
4 Screw mounting (from above)

Fig. 6-15: Type code secondary part MLS140

6.1.10 Frame size 152

MLP152

Short text 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	L	P	1	5	2	C	-	0	0	6	0	-	F	T	-	N	0	C	N	-	N	N	N	N															

01 Product
MLP.................... = MLP

02 Frame size
152 .... = 152

03 Frame lengths
Frame lenghts .... = A, B, C, D

04 Winding
MLP152A....................................... = 0060
MLP152B....................................... = 0060
MLP152C....................................... = 0060
MLP152D....................................... = 0060

05 Cooling
Liquid cooling .... = F

06 Encapsulation
Thermal encapsulation .... = T

07 Encoder
Without encoder .... = N0

08 Electrical connection
Line lead out at front side of the primary part .... = CN

09 Other design
None... = NNNN

DCCS-40017-152_TCO_N_DE_2018-07-05

Fig. 6-16: Type code primary part MLP152

MLS152

Short text 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	L	S	1	5	2	S	-	3	A	-	0	1	8	0	-	N	N	N	N																				

01 **Product**
MLS.................. = MLS

02 **Frame size**
152 ....= 152

03 **Type**
Secundary part ....= S

04 **Mechanical design**
Screw fastening ....= 3

05 **Mechanical protection**
With cover plate .... = A

06 **Segment length**
180 mm ....= 0180

07 **Other design**
None ....= NNNN

DCCS-40016-152_TCO_N_DE_2018-08-10

Fig. 6-17: Type code secondary part MLS152

6.1.11 Frame size 200

MLP200

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	L	P	2	0	0	A	-	0	1	2	0	-	F	S	-	N	0	C	N	-	N	N	N	N															

1. Product
1.1 MLP .... = MLP

2. Motor frame size
2.1 200 .... = 200

3. Motor frame lengths
3.1 Frame lengths .... = A, B, C, D

4. Winding designation
4.1 MLP200A .... = 0090, 0120
4.2 MLP200B .... = 0040, 0120
4.3 MLP200C .... = 0090, 0120, 0170
4.4 MLP200D .... = 0035, 0060, 0100, 0120

5. Cooling
5.1 Liquid cooling .... = F

6. Encapsulation
6.1 Standard encapsulation......................... = S
6.2 Thermal encapsulation.......................... = T

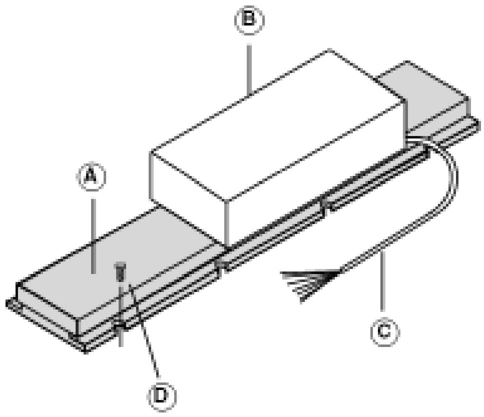
7. Motor encoder
7.1 Without encoder.................................. = N0

8. Electrical connection
8.1 Cable lead out from front side of primary part .... = CN

9. Other design
9.1 None .... = NNNN

ZN-40017-200_NOR_N_DE_2011-12-22

Example: MLP200



Ⓐ Secondary part MLS
Ⓑ Primary part MLP (depending from design - standard encapsulation or thermal encapsulation)
Ⓒ Electrical connection
Ⓓ Screw fastening (from top)

Fig. 6-18: Type code primary part MLP200

MLS200

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	L	S	2	0	0	S	-	3	A	-	0	1	5	0	-	N	N	N	N																				

1. Product
1.1 MLS . . . . = MLS

2. Motor size
2.1 200 . . . . = 200

3. Type
3.1 Secondary part . . . . = S

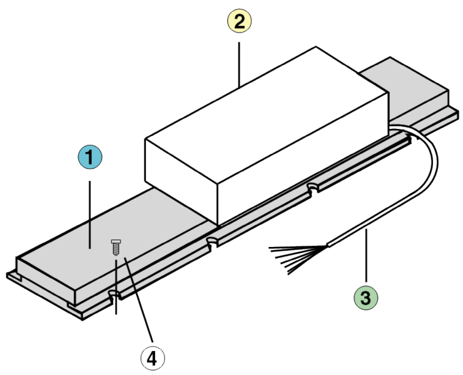
4. Mechanical design
4.1 Fixing with screws . . . . = 3

5. Mechanical protection
5.1 with cover sheet . . . . = A

6. Segment length
6.1 Secondary part length 150 mm . . . . = 0150
6.2 Secondary part length 450 mm . . . . = 0450
6.3 Secondary part length 600 mm . . . . = 0600

7. Other design
7.1 none . . . . = NNNN

Illustration example: MLS200



1 Secondary part MLS
2 Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3 Power connection
4 Screw mounting (from above)

Fig. 6-19: Type code secondary part MLS200

6.1.12 Frame size 202

MLP202

Short text 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	L	P	2	0	2	B	-	0	0	6	0	-	F	T	-	N	0	C	N	-	N	N	N	N															

01 Product
MLP.................. = MLP

02 Frame size
202 .... = 202

03 Frame lengths
Frame length.......................... = B
Frame length.......................... = C
Frame length.......................... = D

04 Winding
MLP202B...................................... = 0060
MLP202C .... = 0060
MLP202D .... = 0060

05 Cooling
Liquid cooling ....= F

06 Encapsulation
Thermal encapsulation .... = T

07 Encoder
Without encoder .... = N0

08 Electrical connection
Line lead out at front side of the primary part .... = CN

09 Other design
None ....= NNNN

DCCS-40017-202_TCO_N_DE_2017-06-20

Fig. 6-20: Type code primary part MLP202

MLS202

Short text 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	L	S	2	0	2	S	-	3	A	-	0	1	8	0	-	N	N	N	N																				

01 **Product**

MLS................. = MLS

02 **Frame size**

202 .... = 202

03 **Type**

Secondary part .... = S

04 **Mechanical design**

Screw fastening .... = 3

05 **Mechanical protection**

With cover plate .... = A

06 **Segment lengths**

180 mm .... = 0180

540 mm .... = 0540

07 **Other design**

None .... = NNNN

Increased resistance .... = S002

DCCS-40016-202_TCO_N_DE_2018-07-06

Fig. 6-21: Type code secondary part MLS202

6.1.13 Frame size 300

MLP300

Type short description	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	L	P	3	0	0	B	-	0	1	2	0	-	F	T	-	N	0	C	N	-	N	N	N	N															

01 **Product**
MLP.................... = MLP

02 **Size**
300 .... = 300

03 **Length**
Length ....= A, B, C

04 **Winding**
MLP300A................... = 0090, 0120
MLP300B................... = 0070, 0120
MLP300C................... = 0060, 0090, 0120

05 **Cooling mode**
Liquid cooling.. = F

06 **Encapsluation**
Standard encapsulation... = S
Thermo encapsulation .... = T

07 **Encoder**
Without encoder .... = N0

08 **Electrical connection**
Wire conducted through front of primary part......................= CN

09 **Other design**
None.. = NNNN

DCCS-40017-300_TCO_N_EN_2018-02-21

Fig. 6-22: Type code primary part MLP300

MLS300

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	L	S	3	0	0	S	-	3	A	-	0	1	5	0	-	H	N	N	N																				

Product
MLS. . . . . = MLS

Size
300 . . . . = 300

Type
Secondary part . . . . = S

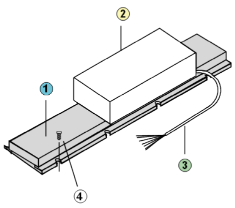
Mechanical design
Fixing per screws . . . . = 3

Mechanical protection
With cover sheet . . . . = A

Segment length
Secondary part length 150 mm . . . . = 0150
Secondary part length 450 mm . . . . = 0450
Secondary part length 600 mm . . . . = 0600

Other design
Reinforced basic carrier . . . . = HNNN

Illustration example: MLS300



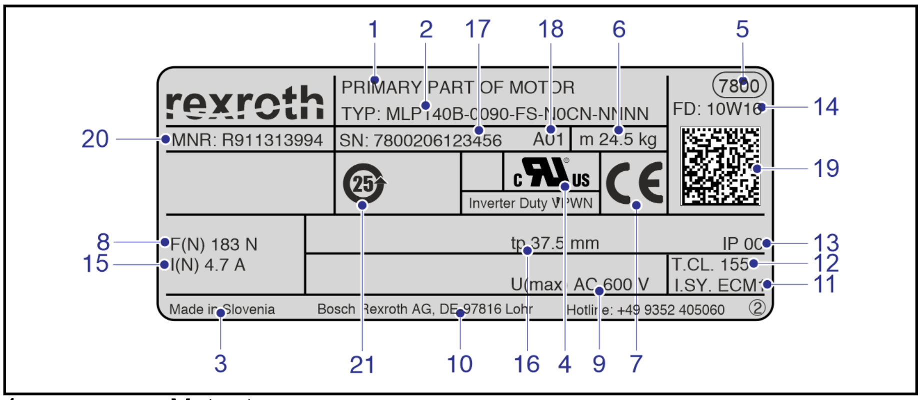
1. Secondary part MLS
2. Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3. Power connection
4. Screw mounting (from above)

Fig. 6-23: Type code secondary part MLS300

6.2 Product labeling

6.2.1 Type plate primary part

On the front of the primary part (NCE), a type plate is fixed. The type plate is for a precise identification of the primary part. A second type plate is enclosed. This can be adjusted on the machine or used ulterior by the user. The type plate of the primary part contains the following data



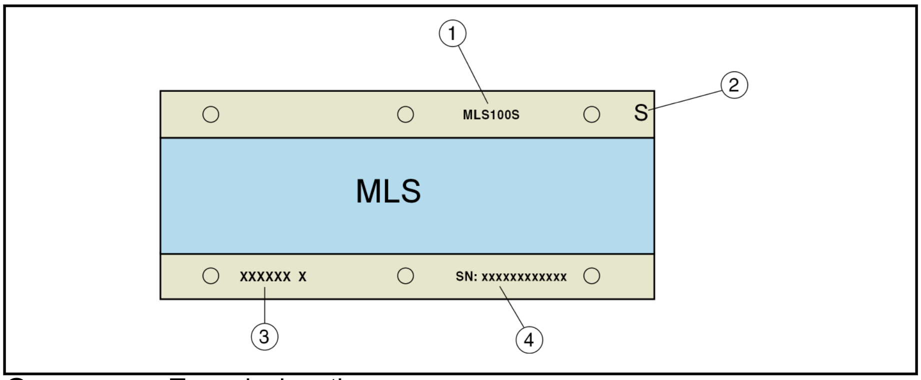
1	Motor type
2	Type designation
3	Designation of origin
4	UL-label
5	Factory number
6	Mass of primary part
7	EC declaration of conformity
8	Rated power
9	Maximum input voltage
10	Company address
11	Insulation system
12	Thermal class
13	Degree of protection by housing
14	Manufacturing date
15	Rated current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

Fig. 6-24: Type plate primary part

☞ Observe the information on the mark of conformity under chapter 9.6 "Acceptances and approvals" on page 188.

6.2.2 Type plate secondary part

Due to lack of space, a type plate cannot be fixed on the secondary part. Two identical type plates are enclosed to the secondary part, whereby the UL-label is specified on the first plate only. To ensure a safe and continuous identification of the type, the type designation and the serial number are additionally on the secondary part (see Fig. 6-25).



① Type designation
② Pole designation “S” (for South Pole)
① Internal labeling
① Serial number

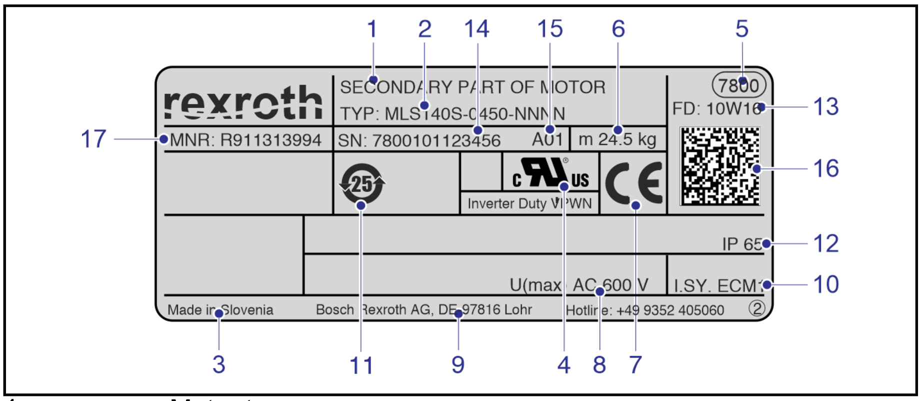
Fig. 6-25: Position of type designation and serial number of the secondary part

---

☞ Each secondary part has a magnetic north pole on one front face and a magnetic south pole on the opposite front face, regardless of length. The secondary parts are signed with ”S” (south pole) on one front

---

The type plate of the secondary part contains the following data



1	Motor type
2	Type designation
3	Designation of origin
4	UL sign
5	Factory number
6	Secondary part mass
7	EC declaration of conformity
8	Maximum input voltage
9	Company address
10	Insulation system
11	China RoHS conformity mark
12	Degree of protection by housing
13	Manufacturing date
14	Serial number
15	Revision state
16	Rexroth barcode
17	Material number

Fig. 6-26: Type plate secondary part

☞ Observe the information on the mark of conformity under chapter 9.6 "Acceptances and approvals" on page 188.

7 Accessories and options

7.1 Hall sensor box

7.1.1 General

The hall sensor box SHL02.1 (SHL box) is an optional component for drive controllers with incremental measuring systems and MLF motors of Bosch Rexroth.

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

☞ The commutation is determined automatically during the phase step up by the SHL-Box. Therefore, no power switch-on is necessary.

Possible applications are for example

- Commutation of motors on vertical axes,
- Commutation of motors which should not move for safety reasons during the commutation process .
- Gantry arrangement of motors.

The supply of the SHL box as an accessory is optionally.

- ex works, as accessory of an MLF motor,
- as part for retrofitting of existing machines with IndraDyn drive controllers and MLF motors.

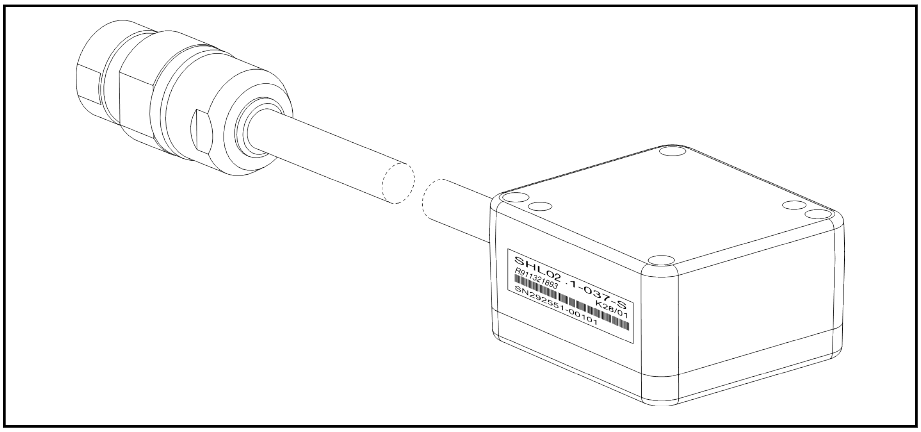


Fig. 7-1: Accessory Hall sensor box SHL02.1

7.1.2 Mode of functioning

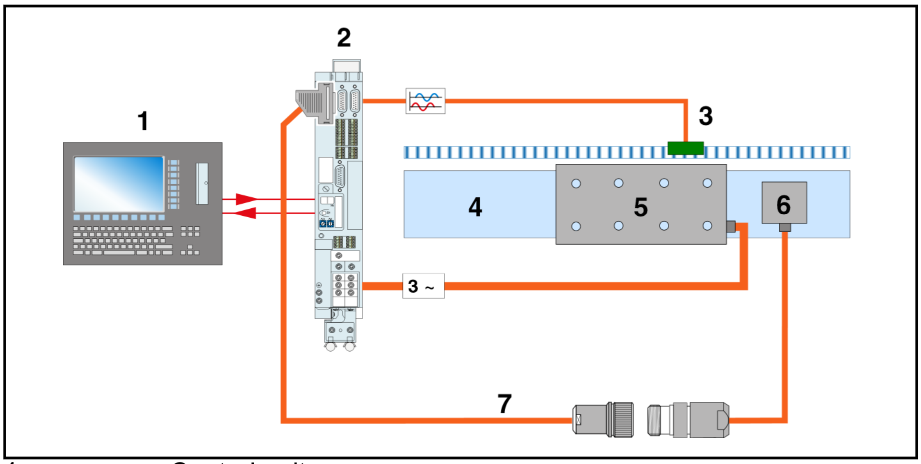
The Hall sensor box serves for motionless commutation of a linear motor in connection with an incremental measuring system. At the Rexroth controller, the motor commutation is performed automatically on phase switching to operating mode. For this, motion is not required. The motor may also be in a fixed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

7.1.3 Connection diagram

The connection scheme for using a SHL02.1 Hall sensor box is displayed inFig. 7-2. Operation of a MLF motor with incremental measuring system and a Hall sensor box requires a Bosch Rexroth controller, which has two position encoder inputs. The primary part is usually connected with the Bosch Rexroth controller. The Hall sensor box is arranged in the area of one of the frontal sides of the primary part above the secondary parts. For exact position please refer to the Functional description of the "Hall sensor box SHL". As well as the incremental measuring system as the Hall sensor box are connected with both encoder interfaces of the controller.

☞ Observe the notes in the Functional description when mounting the "Hall sensor box".

- MNR R911306588 (DE)
- MNR R911292537 (EN)



1 Control unit
2 Controller
3 Linear scale
4 Secondary part
5 Primary part
6 Hall sensor box with cables

Fig. 7-2: Schematic setup MLF with a Hall sensor box

7.1.4 Ordering designation

Series	Short name of box	Material number
MLFxx0	SHL02.1-037-S-120	R911321893
MLFxx2	SHL02.1-030-S-120	On request

Tab. 7-1: Ordering designation Hall sensor box SHL

8 Connection technique

8.1 General

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

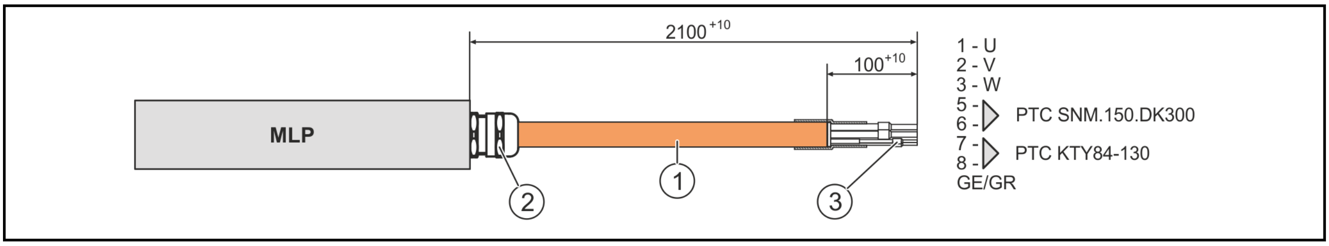
MLF motors can only be operated with suitable drive controllers with variable output voltage and frequency (converter mode) as specified by Rexroth.

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

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

8.2 Connection cable on primary part

All primary parts are fitted with a flexible and shielded connection cable. This 2 m long connection cable is connected with the primary part.



① Connection cables
② Cable gland
① Wire end ferrules

Fig. 8-1: Design of connection cable on the primary part MLP

The following overview gives the technical data of the connection cables for every single motor size.

<table>
<tr><th rowspan="2">Frame size</th><th rowspan="2">Connection cables</th><th colspan="2">Cross section [mm²]</th><th rowspan="2">Ø D
[mm]</th><th rowspan="2">Bending radius
static [mm]</th></tr>
<tr><th>Power wired (4x)</th><th>Sensors (2x2)</th></tr>
<tr><td>MLP040x-xxxx</td><td rowspan="2">REL0105
(INK0653)</td><td rowspan="2">1.0</td><td rowspan="2">0.75</td><td rowspan="2">12 ± 0.5</td><td rowspan="13">5 x D</td></tr>
<tr><td>MLP052x-xxxx</td></tr>
<tr><td>MLP070x-xxxx</td><td>REL0108
(INK0603)</td><td>4.0</td><td>1.0</td><td>17 ± 0,5</td></tr>
<tr><td>MLP100K-0040</td><td>REL0105
(INK0653)</td><td>1.0</td><td>0.75</td><td>12 ± 0.5</td></tr>
<tr><td>MLP100A-xxxx
MLP100B-xxxx
MLP100C-xxxx</td><td rowspan="6">REL0109
(INK0604)</td><td rowspan="6">6.0</td><td rowspan="9">1.0
+
1.5</td><td rowspan="6">18.2 ± 0.6</td></tr>
<tr><td>MLP102x-xxxx</td></tr>
<tr><td>MLP140Z-0060
MLP140A-xxxx
MLP140B-xxxx
MLP140C-0050
MLP140C-0120
MLP140C-0170</td></tr>
<tr><td>MLP152x-xxxx</td></tr>
<tr><td>MLP200A-xxxx
MLP200B-xxxx
MLP200C-0090
MLP200D-0035
MLP200D-0060</td></tr>
<tr><td>MLP202x-xxxx</td></tr>
<tr><td>MLP140C-0350</td><td rowspan="3">REL0110
(INK0605)</td><td rowspan="3">10.0</td><td rowspan="3">22.2 ± 1</td></tr>
<tr><td>MLP200C-0120
MLP200C-0170
MLP200D-0100
MLP200D-0120</td></tr>
<tr><td>MLP300x-xxxx</td></tr>
</table>

Tab. 8-1: Connection cables on MLP primary part

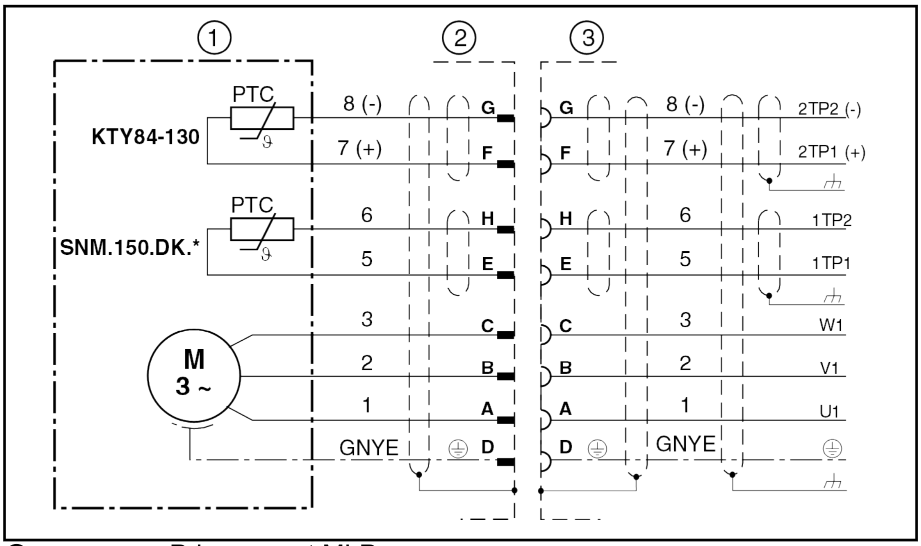
8.3 Electrical connection

8.3.1 Connection primary part

General

Additional description of the power cables for the following connection possibilities of primary parts, is done in the documentation "Rexroth Connection Cables", MNR R911322948 (DE) or R911322949 (EN).

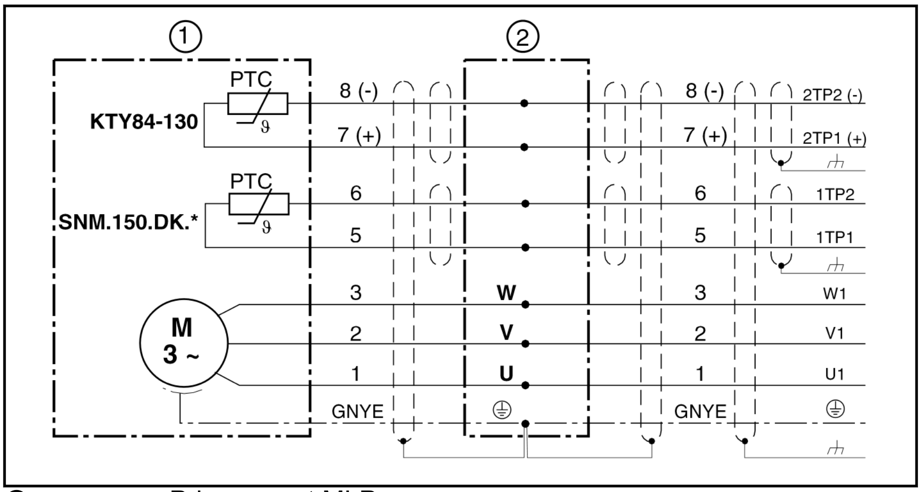
Connection via device connector and coupling



① Primary part MLP
② Coupling (e.g. INS0482 at power wire cross-secion 1.5 ... 10 mm²)
① Device connector (e.g. INS0481 for power wire cross-section 1.5 ... 10 mm²)

Fig. 8-2: Connection example with device connector and coupling

Connection via terminal boxes



① Primary part MLP
② Terminal boxes

Fig. 8-3: Connection example with terminal boxes

Connection power cable in dependence from primary part at parallel arrangement

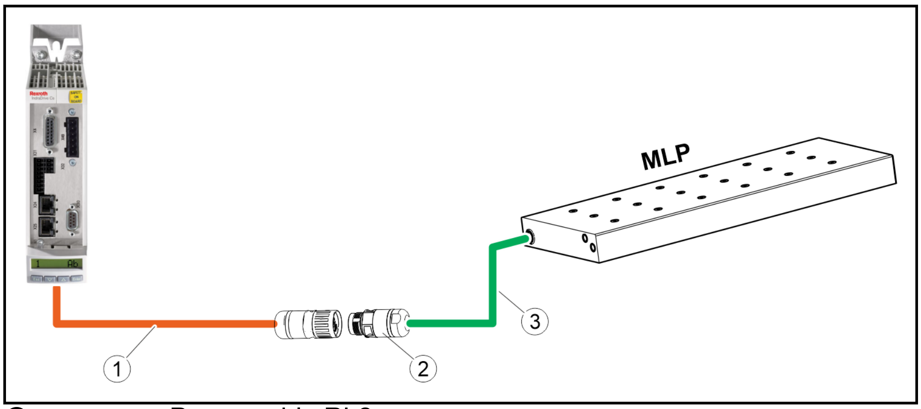
The connection of the power wires of the power cable on the drive controller (see Fig. 8-10) at parallel arrangement of primary parts with cable output in the opposite direction is dependent from the direction of the outgoing cable.

Connection at arrangement according to Fig. 9-42 on page 217 Cable outlet in the same direction			
Drive controller X5	A1	A2	A3
Primary part 1	A1	A2	A3
Primary part 2	A1	A2	A3
Connection at arrangement according toFig. 9-45 and Fig. 9-47 on page 219 Cable outlet in the opposite direction			
Drive controller X5	A1	A2	A3
Primary part 1	A1	A2	A3
Primary part 2	A1	A3	A2

Tab. 8-2: Connection of the power wires in case of parallel connection of primary parts on a drive controller

8.3.2 Connector set for connecting cables

A coordinated range of connector sets and ready-made RL2 power cables is available for connecting the motors to our Rexroth controllers. In order to be able to connect RL2 power cables to the motor, the motor connection cable must first be assembled by the customer, taking into account the installation situation.



① Power cable RL2...
② Connector (for order designation of connector sets refer to Tab. 8-3)
① Motor connection cable at the primary part (see Tab. 8-1 and Tab. 8-5)

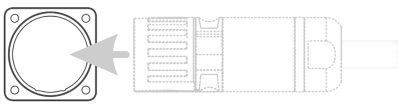
Fig. 8-4: Motor connection with device connector

Connection cables at the stator	Connector size	Connector set	Power and Power extenstion cable	Mounting flange for Connector gland (Optional)
REL0105 (INK0653)	M17	RLS1712/CM01 R911410540	see product information “Motor cables and connectors” R911401938	Z-SONS**-FLANGE M17 R911410540
	M23	RLS2309/CM03 R911381143		Z-SONS**-FLANGE M23 R911403772
REL0108 (INK0603)	M40	RLS4012/CM04 R911388432		Z-SONS**-FLANGE M40 R911388659
REL0109 (INK0604)	M40	RLS4012/CM06 R911388433		
REL0110 (INK0605)	M40	On request		
	M58	RLS5822/CM10 R911383999		Z-SONS**-FLANGE M58 R911410541

Tab. 8-3: Ordering designation connector sets for connecting on RL2 power cables

Mounting flange for connector gland

To feed the connector through to the machine, the connectors listed in Tab. 8-3 can be fitted with a flange. The flange can be ordered as an accessory.

Mounting flange for Connector gland	Designation
	see Tab. 8-3 “Mounting flange connector gland”

Tab. 8-4: Mounting flange for connector gland

8.3.3 Installation of connection cables

The connection cable, which is fixed at the primary part, ends with open wire ends provided with wire end ferrules and must not be subject to dynamic bending loads (see Fig. 8-1) Do not install connection cable of the primary part in a moving energy chain.

We recommend to install the connection cable to

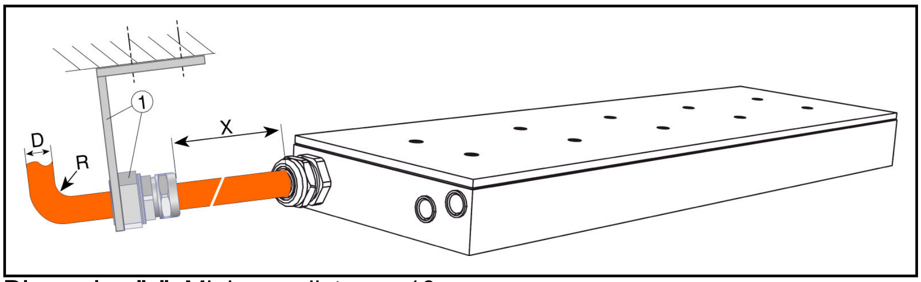
- a device connector,
- a coupling or
- a terminal box (not in the scope of delivery of Bosch Rexroth)

. From this junction, the power supply with a continuing power cable can then be laid through the energy chain or the machine structure. Also refer toFig. 8-6. Respective power cables are ready-made available by Rexroth.

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!

Do not install the connection cable in a moving energy chain. If a fixed installation is not possible, provide the connection cable with a strain relief (see Fig. 8-5) to protect the cable and the primary part from any damage (e.g. cable break).



Dimension "x"	Minimum distance 10 mm
①	Strain relief of the connection cable on MLP primary part
D	Diameter connection cable - see Fig. 8-1
R	Allowed bending radius - seeFig. 8-1

Fig. 8-5: Example for strain relief of connection cable

☞ The connection cable is designed for the highest type current of a frame size. The cross section of a continuative power cable can be designed smaller, if necessary.

Parallel motor connection

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

- Installation of a collective power cables with higher cross section (Fig. 8-8)
- Installation of two separate parallel power cables (Fig. 8-7)

The last possibility offers the benefit of smaller bending radii. The whole cross section of parallel installed cables must be according to the increased cross section for parallel motor connections.

Power connection for single arrangement

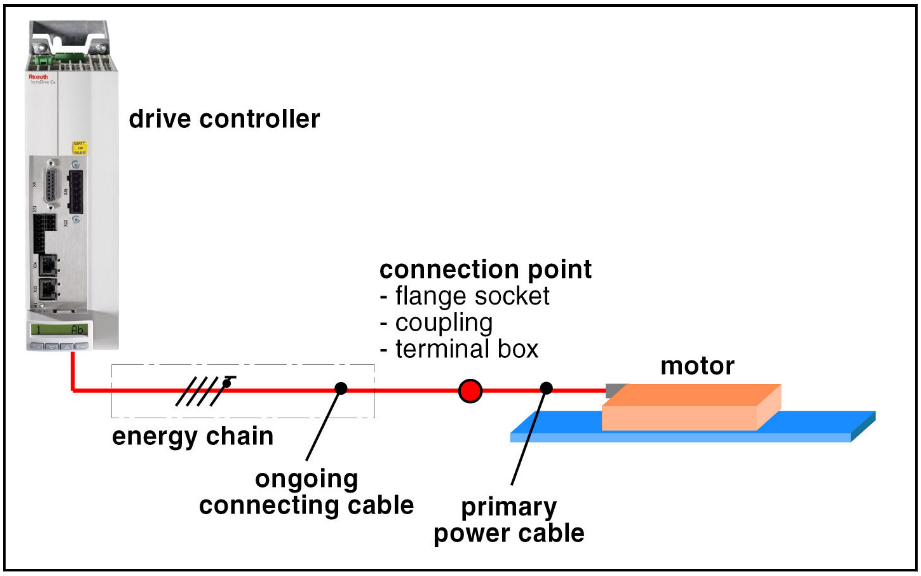


Fig. 8-6: Power connection for single arrangement

Power connection for parallel arrangement, separate connection cable

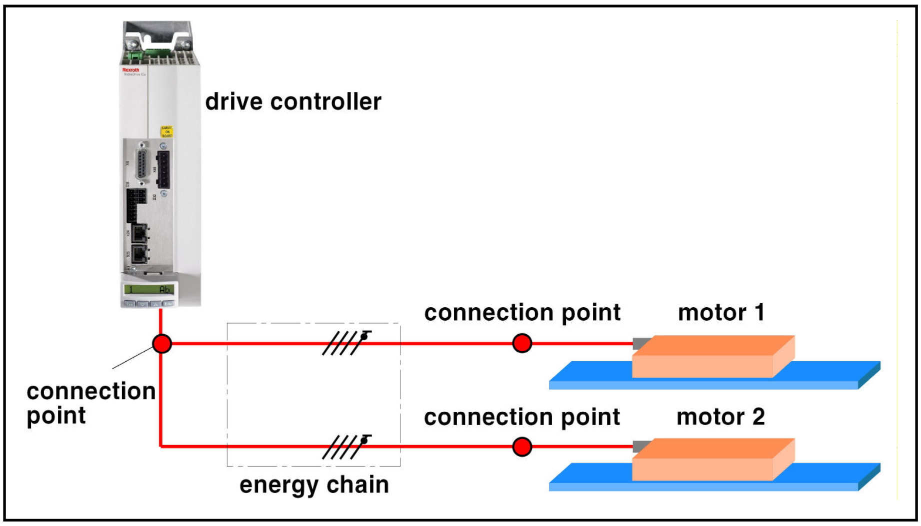


Fig. 8-7: Parallel arrangement, separate power cables

Power connection at parallel arrangement, collective connection cable with higher cross section

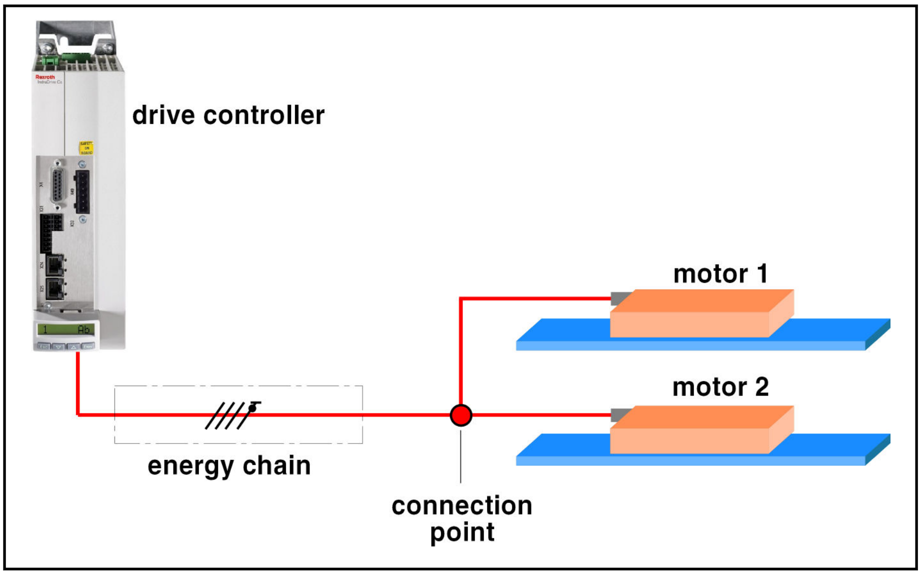


Fig. 8-8: Parallel arrangement, collective power cable

Selecting power cables

The selection of the necessary cable cross-section depends on the rated current of the primary part (see chapter Technical data) and on the installation method of the power cable. This must be done with regard to the following table.

<table>
<tr><th>Primary part MLP...</th><th>Power cables at single arrangement or parallel arrangement with separate power cables</th><th>Power cables at parallel arrangement with common power cable</th></tr>
<tr><td>040A-0300</td><td rowspan="6">1.0 mm²
REL0105 (INK0653)</td><td rowspan="5">1.0 mm²
REL0105 (INK0653)</td></tr>
<tr><td>040B-0150</td></tr>
<tr><td>040B-0250</td></tr>
<tr><td>040B-0300</td></tr>
<tr><td>052A-0300</td></tr>
<tr><td>052B-0300</td><td>2.5 mm²
REL0107 (INK0602)</td></tr>
<tr><td>070A-0150</td><td rowspan="11">1.0 mm²
REL0105 (INK0653)</td><td rowspan="2">1.0 mm²
REL0105 (INK0653)</td></tr>
<tr><td>070A-0220</td></tr>
<tr><td>070A-0300</td><td>2.5 mm²
REL0107 (INK0602)</td></tr>
<tr><td>070B-0100</td><td rowspan="2">1.0 mm²
REL0105 (INK0653)</td></tr>
<tr><td>070B-0120</td></tr>
<tr><td>070B-0150</td><td>1.5 mm²
REL0106 (INK0650)</td></tr>
<tr><td>070B-0250</td><td>2.5 mm²
REL0107 (INK0602)</td></tr>
<tr><td>070B-0300</td><td>4.0 mm²
REL0108 (INK0603)</td></tr>
<tr><td>070C-0030</td><td>1.0 mm²
REL0105 (INK0653)</td></tr>
<tr><td>070C-0120</td><td rowspan="2">2.5 mm²
REL0107 (INK0602)</td></tr>
<tr><td>070C-0150</td></tr>
<tr><td>070C-0240</td><td>1.5 mm²
REL0106 (INK0650)</td><td rowspan="2">6.0 mm²
REL0109 (INK0604)</td></tr>
<tr><td>070C-0300</td><td>2.5 mm²
REL0107 (INK0602)</td></tr>
</table>

<table>
<tr><th>Primary part MLP...</th><th>Power cables at single arrangement or parallel arrangement with separate power cables</th><th>Power cables at parallel arrangement with common power cable</th></tr>
<tr><td>100A-0090</td><td rowspan="7">1.0 mm^2
REL0105 (INK0653)</td><td>1.5 mm^2
REL0106 (INK0650)</td></tr>
<tr><td>100A-0120</td><td rowspan="2">2.5 mm^2
REL0107 (INK0602)</td></tr>
<tr><td>100A-0150</td></tr>
<tr><td>100A-0190</td><td>4.0 mm^2
REL0108 (INK0603)</td></tr>
<tr><td>100K-0040</td><td>1.0 mm^2
REL0105 (INK0653)</td></tr>
<tr><td>100B-0030</td><td rowspan="2">4.0 mm^2
REL0108 (INK0603)</td></tr>
<tr><td>100B-0120</td></tr>
<tr><td>100B-0250</td><td>4.0 mm^2
REL0108 (INK0603)</td><td>10.0 mm^2
REL0110 (INK0605)</td></tr>
<tr><td>100C-0090</td><td>1.0 mm^2
REL0105 (INK0653)</td><td>4.0 mm^2
REL0108 (INK0603)</td></tr>
<tr><td>100C-0120</td><td>1.5 mm^2
REL0106 (INK0650)</td><td>6.0 mm^2
REL0109 (INK0604)</td></tr>
<tr><td>100C-0190</td><td>4.0 mm^2
REL0108 (INK0603)</td><td>10.0 mm^2
REL0110 (INK0605)</td></tr>
<tr><td>102B-0060</td><td rowspan="2">1.0 mm^2
REL0105 (INK0653)</td><td>1.0 mm^2
REL0105 (INK0653)</td></tr>
<tr><td>102C-0060</td><td>2.5 mm^2
REL0107 (INK0602)</td></tr>
<tr><td>102D-0060</td><td>1.5 mm^2
REL0106 (INK0650)</td><td>4.0 mm^2
REL0108 (INK0603)</td></tr>
<tr><td>140Z-0060</td><td>1.0 mm^2
REL0105 (INK0653)</td><td>2.5 mm^2
REL0107 (INK0602)</td></tr>
<tr><td>140A-0030</td><td rowspan="3">1.0 mm^2
REL0105 (INK0653)</td><td>1.0 mm^2
REL0105 (INK0653)</td></tr>
<tr><td>140A-0120</td><td rowspan="3">4.0 mm^2
REL0108 (INK0603)</td></tr>
<tr><td>140B-0035</td></tr>
<tr><td>140B-0090</td><td>1.5 mm^2
REL0106 (INK0650)</td></tr>
<tr><td>140B-0120</td><td>2.5 mm^2
REL0107 (INK0602)</td><td>6.0 mm^2
REL0109 (INK0604)</td></tr>
<tr><td>140C-0050</td><td>1.5 mm^2
REL0106 (INK0650)</td><td>4.0 mm^2
REL0108 (INK0603)</td></tr>
</table>

<table>
<tr><th>Primary part MLP...</th><th>Power cables at single arrangement or parallel arrangement with separate power cables</th><th>Power cables at parallel arrangement with common power cable</th></tr>
<tr><td>140C-0120</td><td>2.5 mm²
REL0107 (INK0602)</td><td>10.0 mm²
REL0110 (INK0605)</td></tr>
<tr><td>140C-0170</td><td>4.0 mm²
REL0108 (INK0603)</td><td>16.0 mm²
REL0111 (INK0606)</td></tr>
<tr><td>140C-0350</td><td>10.0 mm²
REL0110 (INK0605)</td><td>25.0 mm²
REL0112 (INK0607)</td></tr>
<tr><td>152A-0060</td><td>1.0 mm²
REL0105 (INK0653)</td><td>2.5 mm²
REL0107 (INK0602)</td></tr>
<tr><td>152B-0060</td><td rowspan="2">2.5 mm²
REL0107 (INK0602)</td><td>6.0 mm²
REL0109 (INK0604)</td></tr>
<tr><td>152C-0060</td><td>10.0 mm²
REL0110 (INK0605)</td></tr>
<tr><td>152D-0060</td><td>4.0 mm²
REL0108 (INK0603)</td><td>16.0 mm²
REL0111 (INK0606)</td></tr>
<tr><td>200A-0090</td><td>1.0 mm²
REL0105 (INK0653)</td><td>4.0 mm²
REL0108 (INK0603)</td></tr>
<tr><td>200A-0120</td><td rowspan="2">1.5 mm²
REL0106 (INK0650)</td><td>6.0 mm²
REL0109 (INK0604)</td></tr>
<tr><td>200B-0040</td><td>4.0 mm²
REL0108 (INK0603)</td></tr>
<tr><td>200B-0120</td><td>2.5 mm²
REL0107 (INK0602)</td><td rowspan="2">10.0 mm²
REL0110 (INK0605)</td></tr>
<tr><td>200C-0090</td><td rowspan="2">4.0 mm²
REL0108 (INK0603)</td></tr>
<tr><td>200C-0120</td><td rowspan="2">16.0 mm²
REL0111 (INK0606)</td></tr>
<tr><td>200C-0170</td><td>6.0 mm²
REL0109 (INK0604)</td></tr>
<tr><td>200D-0035</td><td>2.5 mm²
REL0107 (INK0602)</td><td>10.0 mm²
REL0110 (INK0605)</td></tr>
<tr><td>200D-0060</td><td>4.0 mm²
REL0108 (INK0603)</td><td>10.0 mm²
REL0110 (INK0605)</td></tr>
<tr><td>200D-0100</td><td rowspan="2">10.0 mm²
REL0110 (INK0605)</td><td rowspan="2">25.0 mm²
REL0112 (INK0607)</td></tr>
<tr><td>200D-0120</td></tr>
<tr><td>202A-0060</td><td>1.5 mm²
REL0106 (INK0650)</td><td>4.0 mm²
REL0108 (INK0603)</td></tr>
</table>

Primary part MLP...	Power cables at single arrangement or parallel arrangement with separate power cables	Power cables at parallel arrangement with common power cable
202B-0060	2.5 mm² REL0107 (INK0602)	10.0 mm² REL0110 (INK0605)
202C-0060	4.0 mm² REL0108 (INK0603)	
202D-0060	6.0 mm² REL0109 (INK0604)	16.0 mm² REL0111 (INK0606)
300A-0090	2.5 mm² REL0107 (INK0602)	6.0 mm² REL0109 (INK0604)
300A-0120		10.0 mm² REL0110 (INK0605)
300B-0070	4.0 mm² REL0108 (INK0603)	16.0 mm² REL0111 (INK0606)
300B-0120	6.0 mm² REL0109 (INK0604)	25.0 mm² REL0112 (INK0607)
300C-0060		16.0 mm² REL0111 (INK0606)
300C-0090		25.0 mm² REL0112 (INK0607)
300C-0120	10.0 mm² REL0110 (INK0605)	

Tab. 8-5: Necessary cross-section of the power wires depend on the motor type, arrangement and connection type

8.3.4 Connection designations at Rexroth controller

Connection at single arrangement

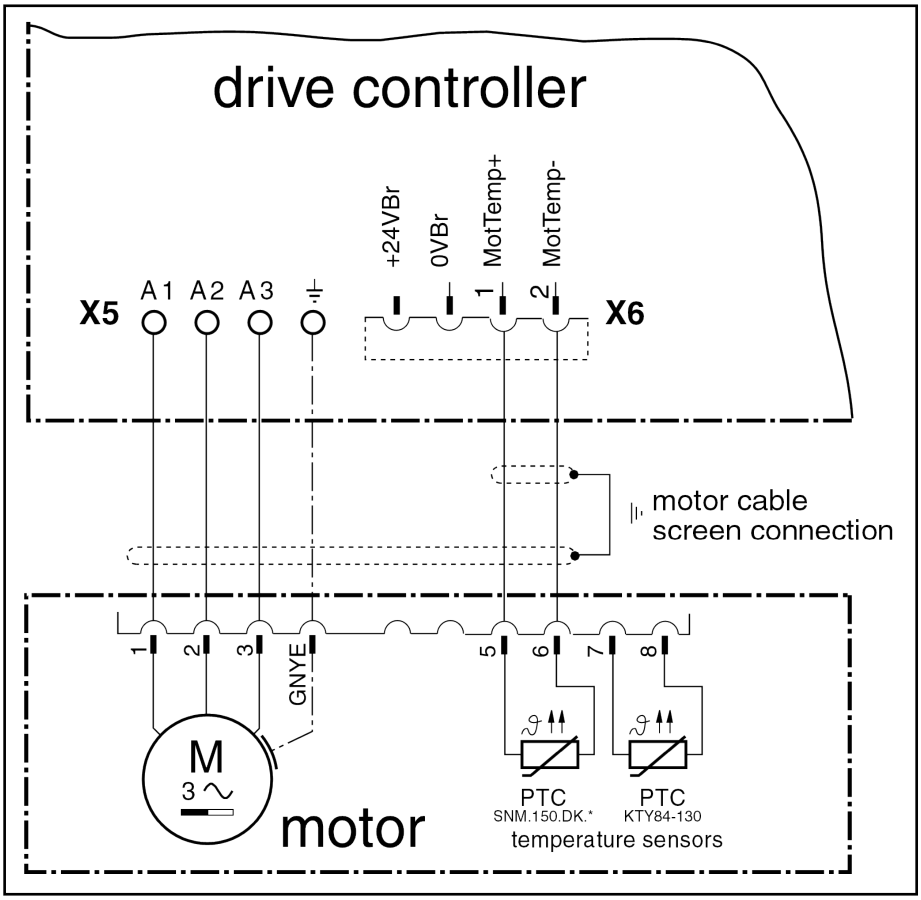


Fig. 8-9: Connection on drive controller - single arrangement primary part

Connection at parallel arrangement

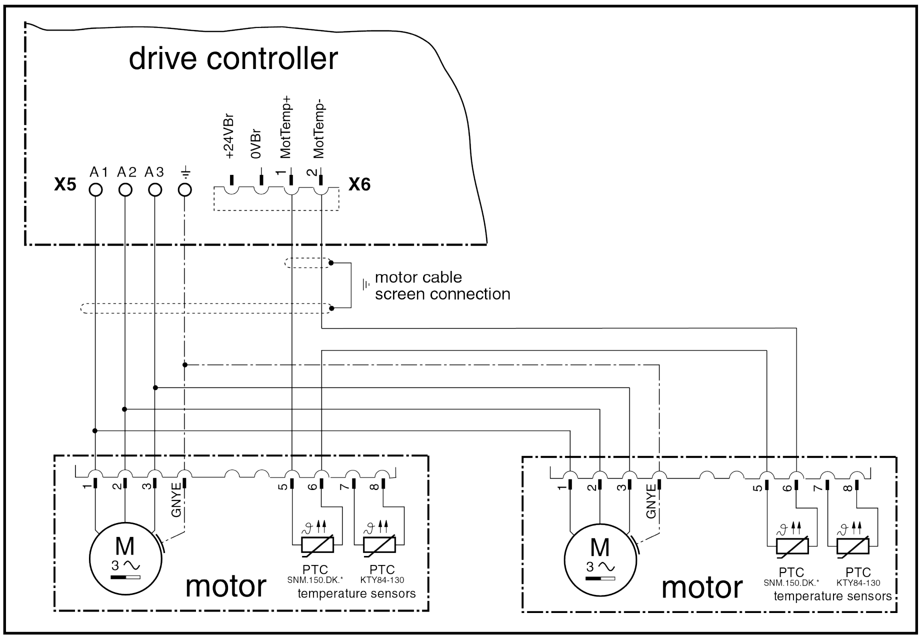


Fig. 8-10: Connection on drive controller - parallel connection primary part

8.4 Sensors

8.4.1 Temperature sensors

To ensure safe motor protectionagainst thermal overload, temperature sensor SNM.150.DK should be connected to the drive controller. The temperature sensor KTY84-130 can be used for external temperature measurement. Comply with the respective connection diagram for the selected connection type (device connector or terminal box) when connecting the temperature sensors. You will find additional information about temperature sensors inchapter 9.11 "Motor temperature monitoring" on page 208.

☞

- The SNM.150.DK is a drilling sensor. Therewith, all three phases of a motor are thermically monitored. The KTY84-130 is only in one phase active.
- KTY84-130 is an ESD sensitive device! For this reason, the stranded 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).
- Ensure correct polarity when using a KTY84-130.
- The used temperature sensors are equipped with double or reinforced insulation according to DIN EN 50178, so separation exists according to DIN EN 61800-5-1.

8.4.2 Connection linear scale

The connection of the linear scale on a Rexroth controller is done via a ready-made cable.

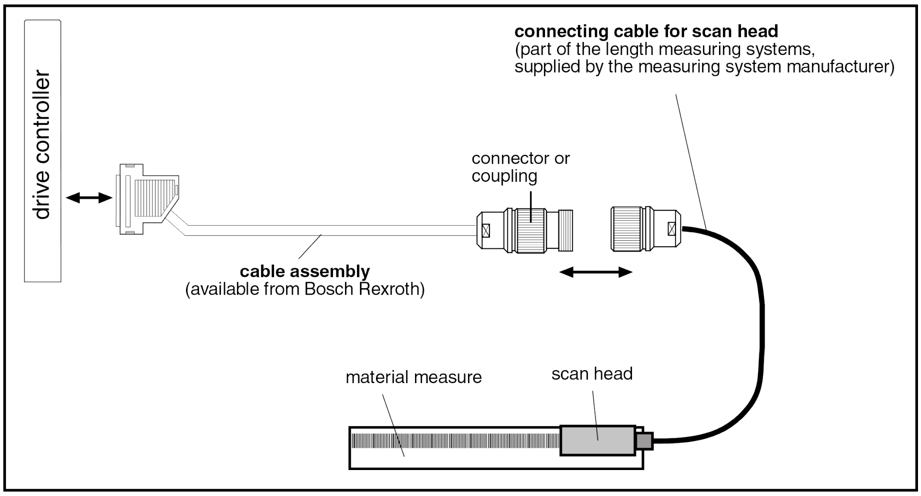


Fig. 8-11: Connection example linear scale

For an overview about ready-made cables to connect the length measuring system refer to the following table.

Measurement system type	Absolute, ENDAT	Incremental
Output variable	Voltage	Voltage
Signal shape	Sinus	Sinus
Signal amplitude	1 VSS	1 VSS

Measurement system type	Absolute, ENDAT	Incremental
Position interface	DAG	DLF
Depending from the connection mode (connector or coupling) of the length measuring system, Rexroth offers two different ready-made connection cables for connecting controller and measuring systems:		
DIAX04 <--> Connector DKCxx.3 <--> Connector IndraDrive <--> Connector	IKS 4142 IKS 4001 IKS 4038	IKS 4384 IKS 4002 IKS 4041
DIAX04 <--> Coupling DKCxx.3 <--> Coupling IndraDrive <--> Coupling	--- --- ---	IKS 4383 IKS 4389 IKS 4040

Tab. 8-6: Connection components linear scale

8.5 Motor cooling

8.5.1 General

For details about dimension, form and position of coolant connection refer to the specific dimension sheet.

When connecting the coolant ducts, please observe the assignment of inlet and outlet.

Install systems in the cooling circuit for monitoring flow, pressure and temperature.

You need other installation materials like couplings, tubes and fastening clips (not in the scope of delivery) to supply motors with a coolant.

The machine manufacturer is responsible for ensuring that the coolant connection is tight and for verifying and accepting the tightness after the motor has been installed.

Additional, regular inspections to ensure proper condition of the coolant connection should be logged in the maintenance schedule of the machine.

Tightening torque

The height of the specified tightening torque of the threaded connection on the motor sideFig. 8-7 may not be exceeded.

Please note, depending from the selected connection thread, the specified value cannot be exhausted, but must be reduced to do not damage the connection thread.

Therefore observe the information of the manufacturer of the selected connection thread, especially the details about permissible tightening torque.

The cooling connections on the motor side are provided for coolant connection threads with axial sealing.

Bosch Rexroth recommends to use threaded connections which contain an O-ring for axial sealing of the screw connections.

For example, seals consisting of hemp, teflon tape or cone-shaped screw connections are not considered to be suitable, since this type of seal may stress the connection thread at the motor to an unreasonably high extent and/or damage it permanently.

☞ The tightness of the coolant connection is the responsibility of the machine manufacturer and must be checked and approved by him after the motor has been installed.

Additional, regular inspections to ensure proper condition of the coolant connection should be logged in the maintenance schedule of the machine.

The following connection data must be kept. If the tightening torque or screw-in depth is exceeded, the motor may be damaged irreversibly.

Primary part with ...	Screwed connection on the motor		
	Pipe thread ISO228-...	Tightening torque	Screw-in depths
Standard encapsulation	G1/4	max. 30 Nm	max. 12 mm
Thermal encapsulation			

Tab. 8-7: Connection liquid cooling

8.5.2 Design and sealing of coolant connection

To seal the coolant connection thread, Bosch Rexroth therefore recommends to use screw connections which already contain an O-ring for sealing the screw connection in axial direction.

Not suited are sealings made of hamp, teflon-tape or with conical thread, as this mode of sealing can permanently damage the connection thread or lead to excessively overload due to unprofessional execution.

There are the following possibilities to connect liquid cooling, for example:

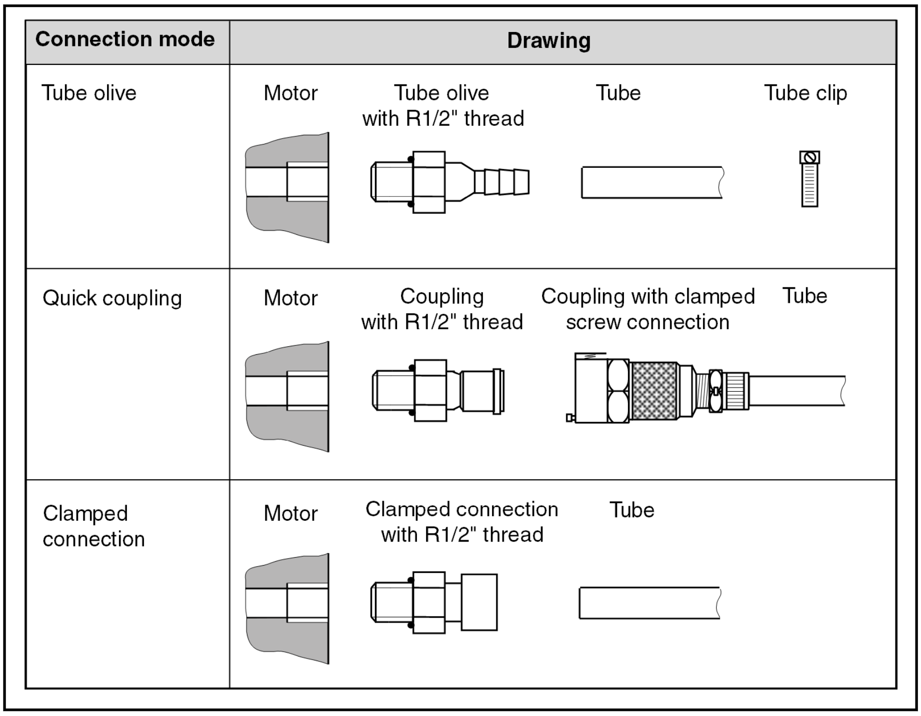


Fig. 8-12: Connection examples of liquid cooling

8.5.3 Operating pressure

The maximum system pressure over the internal coolant circuit of the motor is 10 bar for all motor designs.

Pressure fluctuations in the cooling circuit must not exceed ± 1 bar during engine operation.

⚠ WARNING **Motor destruction!**

- Comply with the permissible inlet pressure of the coolant.
- Eliminate impermissible pressure fluctuations and pressure peaks by design measures.

9 Application and construction instructions

9.1 Mode of functioning

The following figure shows the basic construction of a MLF motor.

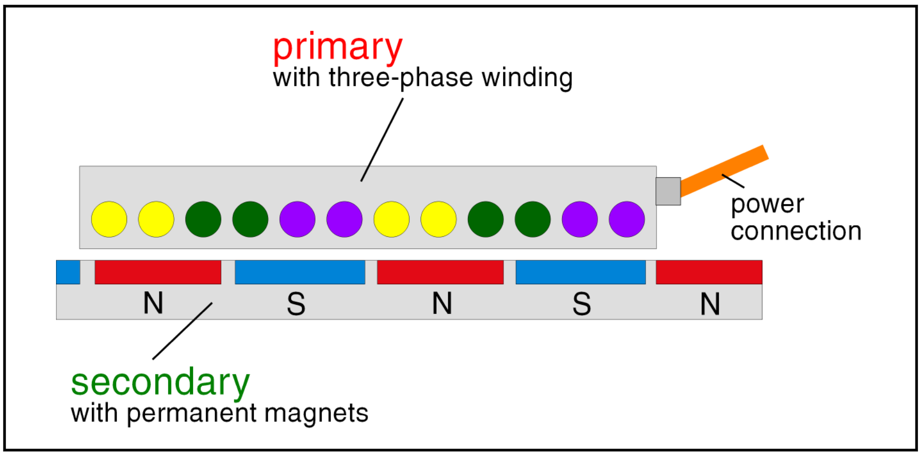


Fig. 9-1: Basic construction of a MLF motor

The force generation at synchronous linear motors corresponds to the torque generation at rotary synchronous motors. The primary part (active part) has a three-phase 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 length can be done by stringing together several secondary parts.

Axis construction

MLF is a kit motor. The components primary and secondary part(s) are delivered separately and completed by the user by linear guide and the linear measuring system.

The construction of an axis fitted with an MLF motor normally consists of

- Primary part with three-phase winding
- one or more secondary parts with permanent magnets
- Length measuring system
- Linear guides
- Energy supply
- Slide or machine construction

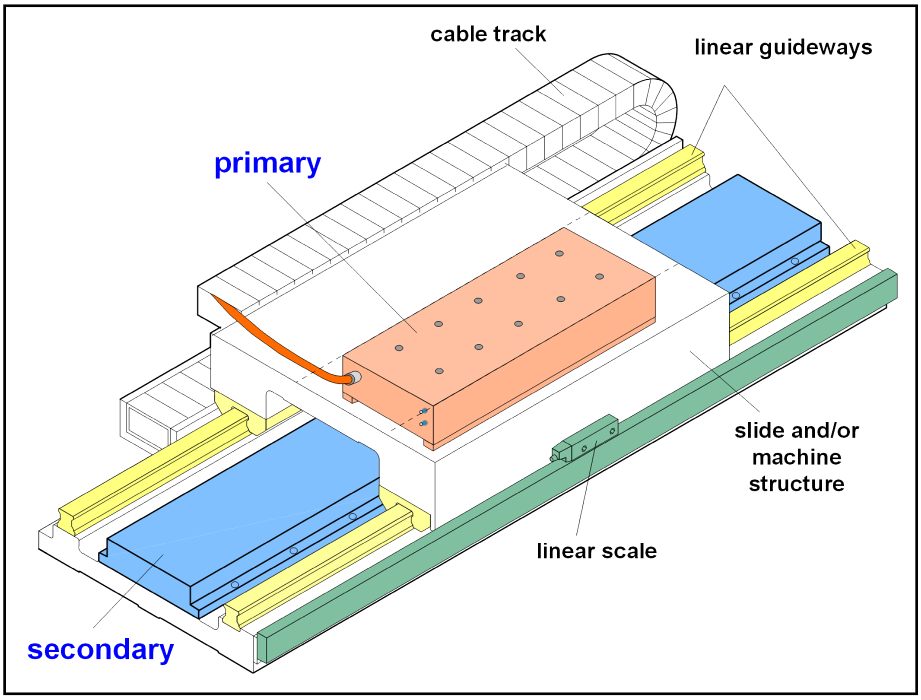


Fig. 9-2: Basic construction with an axis fitted with a MLF

For force multiplication can be two or more primary parts mechanically coupled. For further information see chapter 9.13.2 "Several motors per axis" on page 215.

Only the primary and the secondary part(s) belong to the scope of delivery of the motor.

Linear guides and length measuring system as well as further additional components have to be made available by the user. For recommendations on tested additional components, refer to chapter 14.1 "Recommended suppliers of additional components " on page 311.

9.2 Motor design

9.2.1 General

MLF motors of Bosch Rexroth are tested drive components. They have the following features:

- Modular system with different motor sizes and lengths for feed forces up to 21.500 N per motor and speeds over 600 m/min
- Different winding designs for each motor size for optimum adaptation to different speed requirements.
- All motor components are completely encapsulated.
- Different designs regarding cooling and encapsulation of the primary part (see below: standard and thermo encapsulation)
- Protection class IP65 (all motor components)
- DC bus voltages up to 750 V
- No mechanical wear

- Protection of motor winding against thermal overload by integrated temperature sensors
- Highly flexible, shielded and strain-reliefed power cable supply

Design of cooling and encapsulation

In order to be able to provide the optimum motor for a wide range of applications in terms of technical requirements and costs, primary parts are available in different designs with regard to cooling and encapsulation:

- **Standard encapsulation:** Stainless steel encapsulation with liquid cooling integrated in the motor back to dissipate the heat loss
- **Thermo encapsulation:** Stainless steel encapsulation with an additional liquid cooling on the back of the motor and heat conductive plates for optimum thermal decoupling to the machine construction.

9.2.2 Primary part standard encapsulation

☞ Standard encapsulation is only available for MLPxx0 primary parts.

For applications with less thermal demands on the machine accuracy, primary parts in standard encapsulation are an economic solution. Primary parts with standard encapsulation are mainly used in the general automation sector. The electrical motor components are protected by stainless steel encapsulation. For this motor design, the cooling system is integrated in the motor. It is used to dissipate the heat loss or to maintain the specified continuous feed forces, but does not provide any additional thermal decoupling to the machine on the motor side.

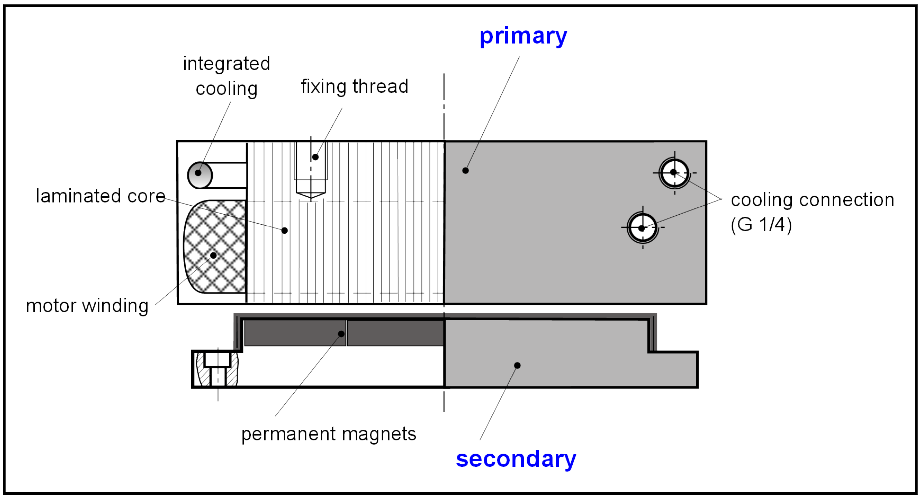


Fig. 9-3: Primary part (only MLPxx0) with standard encapsulation.

☞ For further notes regarding liquid cooling refer to chapter 9.10 "Motor cooling" on page 191.

Main application areas

The main fields of application of these primary part design are found in the

- General automation
- Handling

9.2.3 Primary part thermal encapsulation

☞ Thermal encapsulation is available for both series - MLPxx0 and MLPxx2.

Additional liquid cooling integrated into the encapsulation for thermal decoupling from the machine structure ensures high temperature constancy at the mounting surface for primary parts in thermal encapsulation. With the ”Thermal encapsulation” design, a maximum temperature rise at the screw-on surface opposite to the coolant inlet temperature of 2 K is reached.

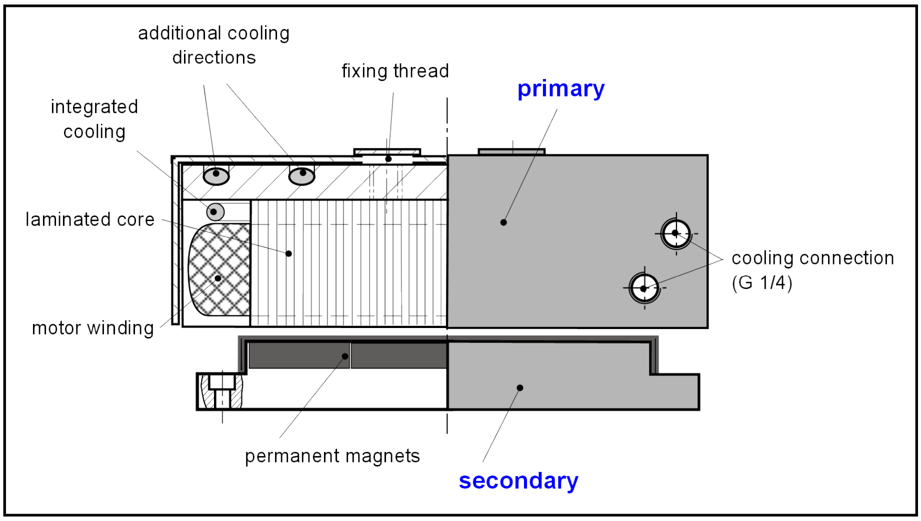


Fig. 9-4: Primary part with thermal encapsulation (figure shows MLPxx0)

The primary part is not completely connected to the machine-side mounting surface, but rests on raised support points. This offers the following advantages:

- Additional thermal decoupling and therewith further minimization of possible heat input into the machine.
- Simplification of the machining of the machine-side screw-on surface to comply with the necessary installation tolerances

☞ For further notes regarding liquid cooling refer to chapter 9.10 "Motor cooling" on page 191.

Main application areas

Main fields of application of these primary parts are, for example

- Machine tools
- Precision applicatiions

9.2.4 Secondary part design

The secondary part or a secondary part segment consists of a steel carrier with applied permanent magnets. The fastening threads are located on the outer edge along the secondary part.

To ensure the utmost operation reliability, the permanent magnets of the secondary part are protected against corrosion, action of outer influences (e.g. humidity) and against mechanical damage, due to an integrated rustless cover plate.

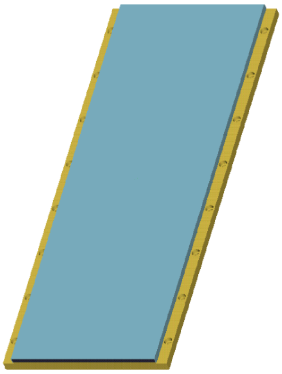


Fig. 9-5: MLS Secondary part

Available lengths secondary parts

Secondary parts or secondary part segments are available in the following lengths (see also chapter 6 "Product information" on page 133).

	MLSxx0	MLSxx2
Segment lengths	150 mm	180 mm
	450 mm	540 mm (only applicable to MLS202 motors)
	600 mm	

Tab. 9-1: Available segment lengths

Required length of the secondary parts

The necessary total lengths of secondary parts for a single arrangement of a primary part can be specified als follows:

$$L_{MLS} \geq L_V + L_{MLP,Fe}$$

L_{MLS}	Total lengths of all secondary parts in a row.
L_V	Lengths of the path or distance of the axis
$L_{MLP,Fe}$	Active iron length of the primary part (seeTab. 9-19)

Fig. 9-6: Defining the required length of the secondary part

9.3 Environmental conditions during operation

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

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

Allowed classes of environmental conditions during operation according to DIN EN 60721-3-3.

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

Tab. 9-2: Allowed classes of environmental conditions during operation

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

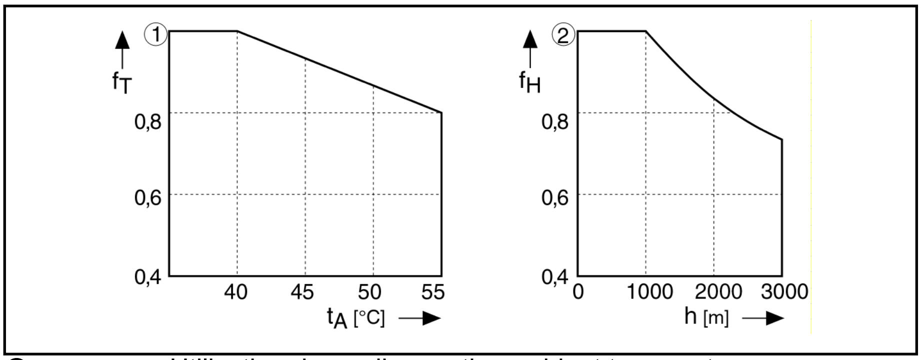
Permissible ambient conditions deviating from DIN EN 60721-3-3

Environmental factor	Unit	Value
Temperature	°C	0 ... +40[1)]
Relative air humidity	%	5 ... 95[1)]
Absolute air humidity	g/m³	1 ... 29[1)]
Installation altitude	m	up to 1,000 m above sea level

1) Differs from DIN EN 60721-3-3

Tab. 9-3: Deviating permissible ambient conditions

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



① Utilization depending on the ambient temperature
② Utilization 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. 9-7: Utilization factors

If **either** the ambient temperature **or** the installation altitude is above the nominal data:

1. Multiply the motor data specified in the selection data by the determined utilization factor.

2. Ensure that the reduced torque data are not exceeded by your application.

If **both** the ambient temperature **and** the installation altitude exceed the nominal data:

1. Multiply the determined utilization factors f_T and f_H.
2. Multiply the resulting value by the motor data specified in the selection data.

Ensure that your application does not exceed the reduced motor data.

9.4 Degree of protection

The design of MLF motors corresponds to the degree of protection according to DIN EN 60034-5:

Motor components	Degree of protection
Primary part with standard encapsulation Primary part with thermal encapsulation Secondary part	IP65

Tab. 9-4: Degree of protection

The degree of protection is defined by the IP (International Protection) abbreviation and two reference numbers specifying the degree of protection.

The **first code number** stands for the degree of protection against contact and ingress of foreign bodies. The **second reference number** defines the degree of protection against water.

First code number	Degree of protection
6	Protection against penetration of dust (dust-proof); complete contact protection
Second code number	Degree of protection
5	Protection against a jet of water from a nozzle which is directed against the housing from all directions (jet water)

Tab. 9-5: Degrees of protection IP

☞ The tests for the second reference number are carried out with untreated tap water. Cleaning processes with high pressure and / or the use of cleaning agents, solvents, cooling lubricants or the like do not correspond to the standard test conditions for the degree of protection. Therefore, we cannot assume any warranty for the chemical resistance of the sealing devices to these media.

⚠ WARNING **Personal injury, damage or destruction of the motor components!**

Using MLF motors is only allowed in environments for which the specified degree of protection is sufficient.

9.5 Housing surface

The design of the housing surface in the delivery condition is shown in the table below.

Motor component	Housing surface
Standard encapsulation primary part	Stainless steel V4A
Thermal encapsulation primary part	Stainless steel V4A
Secondary part segments	Stainless steel V4A cover plate Magnet basic carrier C45, chromated

Tab. 9-6: Housing surface design

☞ It is permitted to provide the surfaces of the motor components with paint with a maximum coat thickness of 40 µm. Before painting the surfaces, check the adhesiveness and resistance of the paint.

9.6 Acceptances and approvals

9.6.1 CE

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

9.6.2 UR/cUR

MLF motors were presented to “Underwriters Laboratories Inc.®” and have been approved by this UL authority. The E-file number issued is E341734. The appropriate identification of the motors is specified on the motor type plate.

9.6.3 RoHS

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

9.6.4 China RoHS 2

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

9.7 Compatibility test

All Rexroth controls and drives are developed and tested according to the latest state-of-the-art of technology.

As it is not possible to follow the continuing development of all materials (e. g. lubricants in machine tools) which may interact with our controls and drives, it cannot be completely ruled out that any reactions with the materials used by Bosch Rexroth might occur.

For this reason, before using the respective material a compatibility test has to be carried out for new materials (e. g. lubricants and cleaning agents) and our housing or our housing materials.

9.8 Magnetic fields

The permanent magnets of the secondary parts of synchronous linear motors are magnetically not shielded.

Personal protection

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

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

Persons with heart pacemakers and metal implants must keep clear from these motor components.

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

Keep watches, credit cards, check cards and identity cards with magnetic strips and all ferromagnetic parts away from magnetic fields.

When using secondary parts, please observe the safety notes under chapter 3.3.4 "Protection against magnetic and electromagnetic fields" on page 18 and chapter 3.3.6 "Protection during handling and assembly" on page 20.

Worldwide, there is no consistent and binding standard, regulation or directive containing explicit instructions or specifications for somebody with active medical implants or pregnant women in areas of exposure with electric, magnetic or electromagnetic fields. There are regional directives, guidelines and standards (e.g. BGV B11 of the German trade association, DIN EN 50527, DIN VDE 0848, etc.) or recommendations of non-proprietary organizations (e.g. ICNIRP).

In the European Community (EU), directive 2004/40/EC specifies minimum requirements for physical impacts on health and safety that are based on the maximum exposure limit values of the ICNIRP directives for occupational exposure. In addition, the European directive 2004/40/EC binds the employer to analyze, while performing the risk evaluation, indirect effects such as the interference (disturbance) with medical electronic or electric equipment and devices (including heart pacemakers and other implanted devices). For this purpose, the specific properties of active medical implants available in each individual case have to be taken into account (e.g. device type, different noise immunity classes), as well as the electric and magnetic fields effectively active at the machine. Depending on the desing of the machine, as well as the type, number, arrangement and mode of operation of the installed devices emitting electromagnetic fields, these fields may differ in each individual case and can only be determined at the respective machine.

Bosch Rexroth is unable to make a general statement on the admissibility or suitability of heart pacemakers or other active medical implants or hazards for pregnant women in these areas of exposure, and health hazards cannot be generally excluded. Bosch Rexroth strictly supports the principle not to allow staff members with active medical implants, such as heart pacemakers, defibrillators, etc., as well as pregnant women to work in such areas of exposure. This is clearly signaled by a warning label, which is stuck on the outside of every package with open permanent-magnet parts.

☞ The secondary parts generate a static magnetic field (DC field). The machine manufacturer (OEM) and user have to determine and decide themselves which guidelines and directives are to be used for the machine design and the instructions of use for the machine, and to which degree occupational health and safety measures have to be implemented at the machine.

Chip attraction

At a distance of approx. 100 mm and more to the surface of the secondary part, there is practically no attraction of ferromagnetic chips.

☞ Make sure that the secondary part is not in the chipping zone of the machine. Provide appropriate covers.

Air freight (IATA953)

For shipping secondary parts MLS as air freight, limit values (according to IATA953) for magnetic flow density in all room directions must be kept:

Distance to the edge of the package	Flux density	Measure
2.1 m	≤ 0.525 µT	Package does not require declaration and marking for shipping.
4.6 m	≤ 0.525 µT	Declaration and marking as magnetic material is required.
4.6 m	≥ 0.526 µT	Shipping requires prior approval of responsible national authorities in the country of dispatch and the state of the air freight carrier.

Tab. 9-7: Limit values of magnetic flux density for air freight

9.9 Noise emission

The noise emission of synchronous linear drives can be compared with conventional converter-operated feed drives.

According to experience, the noise development mainly depends on

- the linear guides used (velocity-related running noises),
- the mechanical configuration (rotating covers, etc.) and
- the settings of drive and controller (e.g. switching frequency)

and thus cannot be generally specified.

9.10 Motor cooling

9.10.1 General

The MLP primary parts have a cooling circuit closed in the motor. The motor power loss P_V transformed into heat is dissipated via this cooling circuit. The machine manufacturer has to size the cooling system in such a way that all requirements regarding flow, pressure, cleanliness, temperature gradient, etc. are complied with in every operating state.

⚠ CAUTION **Impairment or failure of motor, machine or cooling system!**

- Observe the manufacturer's instructions when designing and operating cooling systems.
- Do not use any cooling lubricants or cutting materials from machining processes.
- Avoid contamination of the cooling medium as well as modifications of chemical composition and pH.
- Observe the information and restrictions on operation of motors without liquid cooling under chapter 9.10.5 "Operating synchronous linear motors MLF without liquid cooling" on page 199.

Materials used

In the primary part, the coolant gets in contact with the following materials:

Size MLP...	Coolant ducts	Screw connections
040 ... 300	Copper (Cu-DHP-R200) [1)]	Brass (CuZn39Pb2)

1) according to DIN EN 12735-1

Tab. 9-8: Materials coming into contact with the coolant

For dimensioning and operation of the cooling system, the machine manufacturer has to ensure that the components of the motor do not get into contact with materials with chemical or electro-chemical impact leading to corrosion or disintegration.

9.10.2 Thermal behavior of linear motors

Power loss

The continuous feed force a synchronous linear motor can reach 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 maximum winding temperature of MLF motors is 155 °C. This corresponds to insulation class F.

Due to the low relative velocities between primary part and secondary part, the total loss of synchronous linear motors is almost exclusively determined by the short-circuit loss of the primary part.

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

P_V	Total loss in W
P_{VI}	Short-circuit loss in W
I	Current in motor cable in A
R_{12}	Electrical resistance of the motor at 20 °C in ohm
f_T	Factor temperature-related resistance rise

Fig. 9-8: Power loss of synchronous linear motors

☞ When you determine the power loss according to Fig. 9-8 you must take the temperature-related rise of the electrical resistance into account. At a temperature rise of 115 K (from 20 °C up to 135 °C), for example, the electrical resistance goes up by the factor f_T = 1.45.

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 9-9 shows a typical heating and cooling process of an electrical machine. The thermal time constant is the period within which 63% of the final excess temperature is reached. In the case of liquid cooling, the cooling time constant corresponds to the heating time constant. Therefore, both the heating process and the cooling process can be specified with the given thermal time constant (heating time constant) of the motor.

Together with the duty cycle, the relationships according to Fig. 9-10 and Fig. 9-12 are used to define the operation modes, e.g. acc. to DIN EN 60034-1.

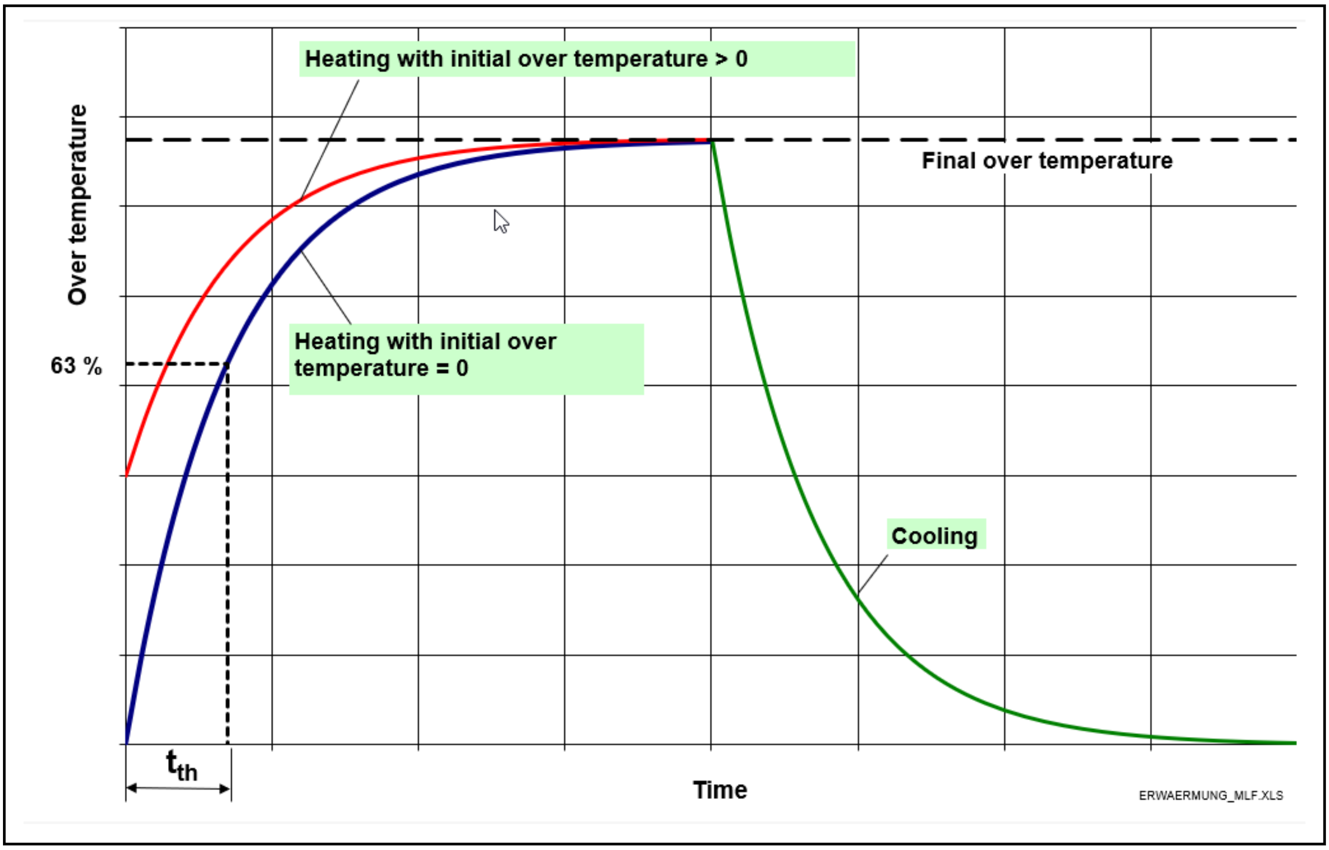


Fig. 9-9: Heating up and cooling down of an electrical machine

Heating up

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

ϑ_e	Final excess temperature in K
ϑ_a	Initial excess temperature in K
t	Time in min
t_{th}	Thermal time constant in min

Fig. 9-10: Heating (excess temperature) of an electric machine opposite the cooling medium

Final excess temperature

Since the final excess temperature is proportional to the power loss, the expected final excess temperature ϑ_e can be estimated according to Fig. 9-11:

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

P_{ce}	Continuous power loss or average power loss over cycle duration in W (see chap. 11.4 Determining the drive power)
P_{vN}	Nominal power loss of the motor in W
ϑ_{emax}	Maximum final excess temperature of the motor in K
F_{eff}	Effective force in N (from application)
F_{dn}	Continuous nominal force of the motor in N
t_{th}	Thermal time constant in min

Fig. 9-11: Expected final excess temperature of the motor

Cooling down

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

ϑ_e	Final excess temperature or shutdown temperature in K
t	Time in min
t_{th}	Thermal time constant in min

Fig. 9-12: Cooling down of an electrical machine

9.10.3 Cooling concept

The demand of highest feed forces with minimum mounting volume generally requires liquid cooling for linear motors. The liquid cooling provides for

- the dissipation of the power loss and thus the compliance with the specified continuous feed forces
- the maintenance of a certain temperature level at the machine

The cooling and encapsulation concept of MLF motors implies two different solutions:

Standard encapsulation

Primary parts with standard encapsulation are mainly used in the general automation sector. The liquid colling system of this motor design is only used to dissipate the heat loss or to maintain the specified continuous feed forces and does not provide any additional thermal decoupling to the machine on the motor side. The maximum temperature of the contact surface can locally be more than 60 °C. These maximum temperature gradients can occur independent of the coolant inlet temperature.

Thermal encapsulation

For optimum thermal decoupling from the machine structure, primary parts with thermal encapsulation have additional liquid cooling on the back of the motor, as well as the longitudinal sides and fronts. Due to the temperature constancy that is very well to reach, as well as the lowest possible heat introduction into the machine, primary parts with thermal encapsulation are preferably suited for use in machine tools and other precision applications. The internal cooling circuit for power loss dissipation and the cooling ducts of thermal encapsulation are already connected in the best possible way motor-internally so that this motor design only has two coolant connections.

The primary part is not completely connected to the machine-side contact surface, but only rests on raised support points. Thereby, additional thermal decoupling, for example, and thus further minimization of the possible heat introduction into the machine is achieved (see Fig. 9-13).

☞ Using the thermal encapsulation does not change the performance data, e.g.the continuous feed force. The performance data remain identical in both designs.

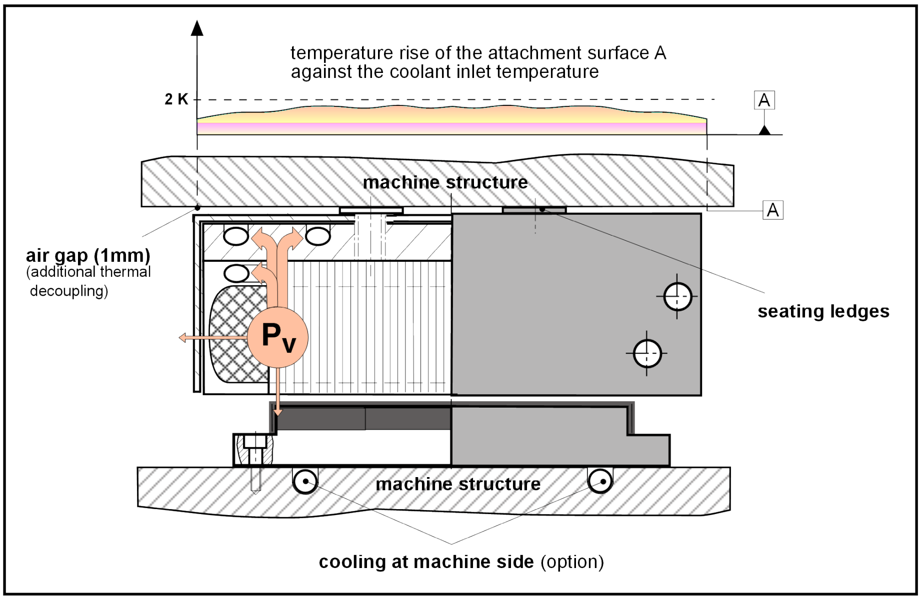


Fig. 9-13: Cooling concept with thermal encapsulation

Secondary parts

The secondary part design is identical for all primary part designs. The secondary part develops a negligible power loss. However, in the case of unfavorable conditions (long times of standstill or low primary part velocity with simultaneously high continuous force), heat introduction by the primary part through radiation and convection is possible.

The heat introduction depends on the ambient temperature and the mounting conditions in the machine.

To keep the temperature level of the machine constant, machine-side cooling can be used in these cases - e.g. via two cooling pipes (see Fig. 9-13).

9.10.4 Cooling medium

General

The specified motor data and the characteristic of the motor cooling system (e.g., continuous feed forces, pressure drops and characteristic flow curves), as well as all other data in this chapter, refer to liquid cooling, water as the cooling medium. Most of the cooling units also use water.

☞ The specified motor data and the characteristic of the motor cooling system (e.g., continuous feed forces, pressure drops and characteristic flow curves), as well as all other data in this chapter, refer to liquid cooling, water as the cooling medium.

If cooling media with other substance values are used, these data are no longer valid or usable and have to be recalculated or determined through experiments by the user.

Possibly, the impairment of thermal decoupling also has to be taken into account.

⚠ WARNING **Impairment of the cooling effect or damage to the cooling system!**

- Adjust cooling medium and flow to the required motor performance data
- For water as the cooling medium, use corrosion protection and comply with specified mixing ratio as well as pH value
- Only use allowed corrosion inhibitors
- Do not use any cooling lubricants from the machining process
- Filter the cooling medium
- No not use any running water
- Use a closed cooling circuit
- Comply with specified supply temperatures
- Comply with maximum pressure
- Motor operation not without liquid cooling, if possible

Cooling with running water from the public supply network is not allowed. Hard water may cause precipitations or corrosion and damage both motor and cooling system. Water which is to be used as cooling water must comply with certain criteria and treated accordingly if necessary. For detailed information, please contact your manufacturer of coolant additives.

☞ **Danger of damage due to insufficient water quality in the coolant circuit!**

Precipitations in the cooling system may deteriorate the coolant flow and thus reduce the performance of the cooling system over time.

Make sure the water used has the followng properties:

- pH value: 7 ... 8.5
- Hardness: 10° dH
- Chloride: max. 20 mg / l
- Nitrate: max. 10 mg / l
- Sulfate: max. 100 mg / l
- Insoluble substances: max. 250 mg / l

Usually, tap water complies with these requirements.

Observe the notes below on the suitable composition of the coolant.

pH value Apart from the mixing ratio, the pH value of the coolant used also has to be checked in adequate intervals. The coolant should be chemically neutral. Larger deviations can lead to changes in the stability of the emulsion, the behavior towards sealant, and the corrosion protection capability.

Corrosion protection To ensure corrosion protection and chemical stabilization, an additive which is suitable for mixed installations with materials such as steel or iron, aluminum, copper and brass must be admixed to the cooling water.

If the coolants, additives or cooling lubricants used are too aggressive, the motors may be damaged to an irreparable degree.

- Use systems with a closed circuit and a fine filter ≤ 100 µm.
- Refer to the environmental protection and waste disposal instructions at the place of installation when selecting the coolant.

Cleaning the coolant circuit

Inspect and clean (purge) the cooling system at regular intervals as specified in the machine and cooling system manufacturer's maintenance schedule.

Note that the utilization of unsuitable cleaning agents may cause irreversible damage to the motor cooling system. This type of damage does not lie within the responsibility of Bosch Rexroth.

⚠ CAUTION **Risk of damage to the motor cooling system by improper cleaning agents! Loss of warranty!**

- The only liquids or materials allowed for cleaning and motor cooling are liquids which do not corrode the motor cooling system and do not react aggressively to the materials used in Bosch Rexroth motors.
- Refer to the instructions of the manufacturers of the cleaning agent and the cooling system.

☞ After the motor was operated, e.g. in case it is put in storage or returned, the coolant has to be completely removed from the motor for reasons of environmental protection and motor protection.

Coolant additives

☞ Bosch Rexroth does not make any general statement and does not conduct any surveys regarding the suitability of device-specific cooling media, additives or operating conditions and does not assume any warranty for third-party products.

The performance test for the used cooling media and the design of the liquid cooling system is the responsibility of the machine manufacturer. The selected coolant additives have to comply with the materials within the cooling system.

Comply with the environmental protection and waste disposal instructions at the place of installation when selecting the coolant additives.

The proper chemical treatment of the closed water systems is precondition to prevent corrosion, to maintain thermal transmission, and to minimize the growth of bacteria in all parts of the system.

Bosch Rexroth recommends using coolant additives of NALCO Deutschland GmbH.

Depending on the size of the cooling system, the user may use different additives in form of “ready-to-use cooling water” and “water treatment kits”.

☞
- Use of the following chemicals is designed for closed cooling systems and the following metallurgy: Stainless steel, aluminum, copper and non-ferrous metal.
- The container size and its ingredients of a water treatment kit are adjusted for the specified system volume and can be poured into the coolant tank without regard to other mixture ratios.

Ready-to-use cooling water (Company NALCO)

System volume in liters	Order code	Additives NALCO...
0.5 ... 50	Nalco CCL100.11R	CCL100

Tab. 9-9: Ready-to-use cooling water (Company NALCO)

Cooling water NALCO CCL100

Nalco CCL100 is a ready-to-use, preserved cooling water for the use in closed cooling water systems. It is supplied directly to the closed systems and contains all reagents in the proper treatment concentration.

Nalco CCL100 contains a corrosion inhibitor protecting ferrous metal, copper, copper alloys and aluminum against corrosion. Nalco CCL100 is free of nitrite and minimizes the micro-biological growth.

Water Treatment Kits (Fa. NALCO)

System volume in liters	Order code	Additives NALCO...
50 ... 99	480-BR100-100.88	TRAC100 7330 73199
100 ... 199	480-BR100-200.88	
200 ... 349	480-BR100-350.88	
350 ... 500	480-BR100-500.88	

Tab. 9-10: Water treatment kits (company NALCO)

Coolant additive NALCO TRAC100

Nalco TRAC100 is a liquid corrosion and film inhibitor for the use in closed cooling systems. Optionally with TRASAR technology: it monitors, shows and dosages the product automatically to its target concentration and continuously protects the system. Nalco TRAC100 is a complete inhibitor protecting ferrous metal, copper alloys and aluminum against corrosion. Nalco TRAC100 is free of nitrite and minimizes the requirements for micro-biological control.

Coolant additive NALCO 7330

Nalco 7330 is a non-oxidizing broad band biocide and suitable for application in closed cooling circuit systems.

Coolant additive NALCO 73199

Nalco 73199 is an organic corrosion inhibitor supporting a fast own protection layer and covering protection layer for non-ferrous metals.

The above additives are part of the preventive water treatment program by Nalco. It comprises not only the chemicals but also test methods, service and equipment. All these are made available to the user of the products.

Water quality of additional water

Conductivity	< 20 µS/cm (e.g. purified water, osmosis water, a.s.o.)
Total hardness	< 0.5 °dH bzw. < 10 mg/l $CaCO_3$
Microbiology	< 100 KBE/ml (CFU/ml)
Iron / copper	< 0.1 mg/l
Turbidity	free from turbidity substances

Tab. 9-11: Water quality of additional water

The water treatment program is a specification for the user and describes the necessary minimum.

Additional equipment, tests and service must be coordinated with Nalco to reach optimum performance and system protection for the cooling system.

For further information or ordering please contact

NALCO Deutschland GmbH

http://www.nalco.com

Recommended manufacturers of coolant additives

Coolant additives can be purchased from the following manufacturers, too.

Manufacturer of chemical additives	
FUCHS PETROLUB AG	http://www.fuchs-oil.com
Clariant Produkte (Germany) GmbH	http://www.antifrogen.de
hebro chemie GmbH	http://www.hebro-chemie.de
TYFOROP Chemie GmbH	http://www.tyfo.de
Schweizer-Chemie GmbH	http://www.schweitzer-chemie.de

Coolant temperature

Coolant inlet temperature

Allowed coolant inlet temperature range is +5 ... +40 °C. The coolant inlet temperature to be set must be selected depending on the actual ambient temperature present and must not be more than 5 K below the measured ambient temperature.

Exceeding the recommended temperature range causes the continuous feed force to be reduced to a higher degree (see chap. 9.3 , Environmental conditions).

☞ The coolant inlet temperature may be max. 5°C lower than the actually existing ambient temperature to avoid condensation.

⚠ WARNING **Reduction of the continuous feed force or destruction of the motor!**

Observe the allowed temperature range of the coolant

Continuous feed force vs. coolant temperature

The specification of the rated feed force in the technical motor specifications is related to a coolant inlet temperature of 30 °C.

If the inlet temperature is different, there is a minor change of the continuous feed force according to Fig. 9-14:

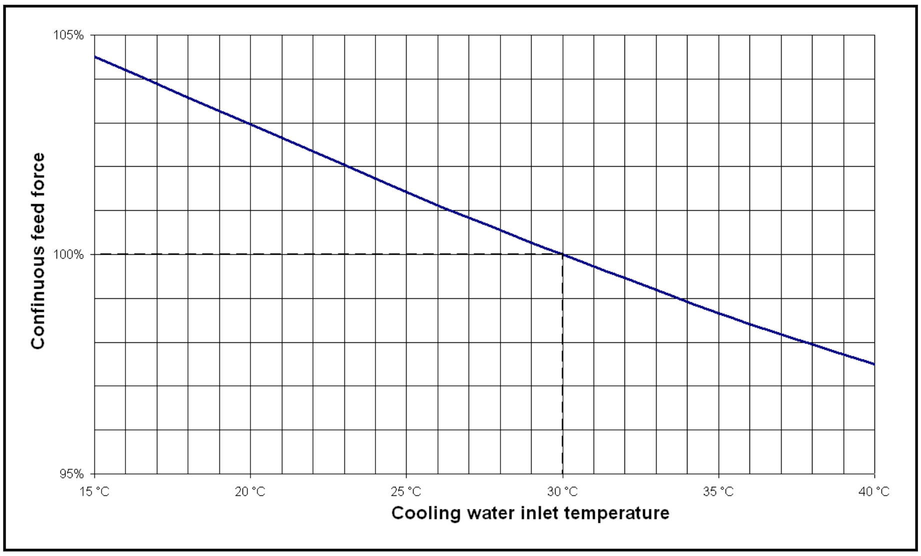


Fig. 9-14: Continuous feed force vs. coolant inlet temperature

9.10.5 Operating synchronous linear motors MLF without liquid cooling

Theoretically, operating MLF motors without liquid cooling is possible.

For this purpose, observe the following notes and restrictions:

- Without liquid cooling, the **performance data available are clearly reduced**, they are not contained in this documentation.
- The stated values in the data sheets regarding rated force and rated current of the motors must be lowered depending on the coupling of the motors to **~40 %** of the stated value.
- A higher temperature load of the machine can be expected. This results in an extension of the nominal air gap, which is stated in the particular data sheets of the motors. It must be extended by at least 0.2 mm.

This does not reduce the available maximum force of the motors.

Depending on the load, the temperature at the contact surface of the primary part may rise up to 140 °C without liquid cooling. The power loss of the motors in this case is dissipated via the contact surface and the customer's machine structure.

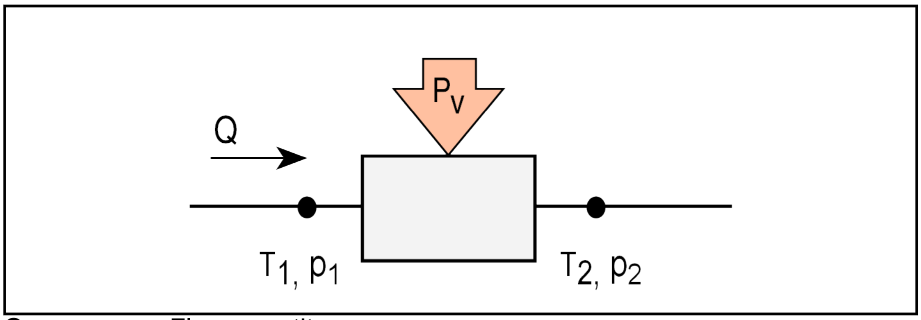
⚠ WARNING **Continuous feed force dramatically reduced and machine structure strongly heated up and under tension when synchronous linear motors operated without liquid cooling!**

- Provide liquid cooling
- For axes operated without liquid cooling, the continuous nominal force reduction and the heating of the machine structure (tensioning by expansion) has to be taken into account for dimensioning and design.
- Reduce the current via parameter S-0-0111 at the non-water cooled motor when starting up! If the rated current is not reduced, the motor heats up so fast that not in any case can the thermal contacts switch off the motor on time. This would cause the winding to overheat. Overheating of the winding will weaken or in extreme cases destroy the winding insulation.

☞ Therefore, note the details on parameterization inchapter 13.4 "Parameterization " on page 292 about operating MLF synchronous linear motors without liquid cooling.

9.10.6 Dimensioning the cooling circuit

General



Q	Flow quantity
T_1	Coolant inlet temperature
T_2	Coolant outlet temperature
p_1	Inlet pressure
p_2	Outlet pressure

Fig. 9-15: Liquid-cooled component

Coolant temperature rise

$$\Delta T = T_2 - T_1$$

T_1	Coolant inlet temperature in K
T_2	Coolant outlet temperature in K
ΔT	Coolant temperature rise in K

Fig. 9-16: Coolant temperature rise in K

Pressure drop

$$\Delta p = p_1 - p_2$$

p_1	Inlet pressure
p_2	Outlet pressure
Δp	Pressure drop

Fig. 9-17: Pressure drop via flown through component

Design criteria

When dimensioning the cooling circuit of synchronous linear motors, two basic requirements - in relation to the motor - have to be distinguished depending on the application:

1. Liquid cooling is only required to dissipate the power loss and thus to comply with the specified continuous nominal forces, e.g. in the motor design standard encapsulation
2. Liquid cooling is to simultaneously ensure defined temperature level at the contact surface, e.g. in the motor design thermal encapsulation

Coolant flow

Rexroth recommends to dimension the coolant flow for motors up to size 070 with ~ 5l/min, for size 100 and higher with ~ 6l/min. Please also observe the information in the respective motor data sheet in chapter Technical data.

The minimum coolant flow required to maintain the rated continuous feed force is specified in chapter "Technical Data".

For this value, a temperature increase of 10 K in the coolant is applied.

The required coolant flow at deviating temperature increase and/or non-water coolants is determined according to Fig. 9-18 and Fig. 9-12.

$$Q = \frac{P_{co} \cdot 60000}{c \cdot \rho \cdot \Delta T}$$

Q	Rated coolant flow in l/min
P_{co}	Amount of power to be dissipated in W
c	Specific heat capacity of the coolant in J / kg · K
ρ	Density of the coolant in kg/m³
ΔT	Coolant temperature rise in K

Fig. 9-18: Coolant flow required for removing power loss.

Coolants	Specific heat capacity of the coolant in J / kg · K	Density ρ in kg/m³
Water	4,183	998.3

Tab. 9-12: Substance values of coolant water at 20°C

Compliance with constant temperature level in the case of thermal encapsulation

If a defined temperature level is to be ensured at the contact surface of the primary part in the motor design thermal encapsulation, the coolant flow required to comply with a maximum temperature rise of the coolant is to be determined in accordance with Fig. 9-19. It is taken into account that only a part of the power loss to be dissipated has to be dissipated via the thermal encapsulation. ΔT_m is the temperature at the contact surface of the primary part.

Complying with a defined temperature level at the contact surface is only possible with the motor design thermal encapsulation.

$$Q = \frac{P_{\infty} \cdot 25200}{c \cdot \rho \cdot \Delta T_m}$$

Q	Rated coolant flow in l/min
P_{co}	Amount of power to be dissipated in W
c	Specific heat capacity of the coolant in J / kg · K
ρ	Density of the coolant in kg/m³
ΔT_m	Temperature rise at contact surface in K

Fig. 9-19: Coolant flow required to comply with a constant temperature level at the motor contact surface in the case of thermal encapsulation

Prerequisite: $Q \geq Q_{min}$

Pressure drop

The flow resistance at the pipe walls, deflections and changes in cross section lead to a pressure drop in the flown through component (Fig. 9-15).

The pressure drop Δp is increased with an increase in flow rate (Fig. 9-20).

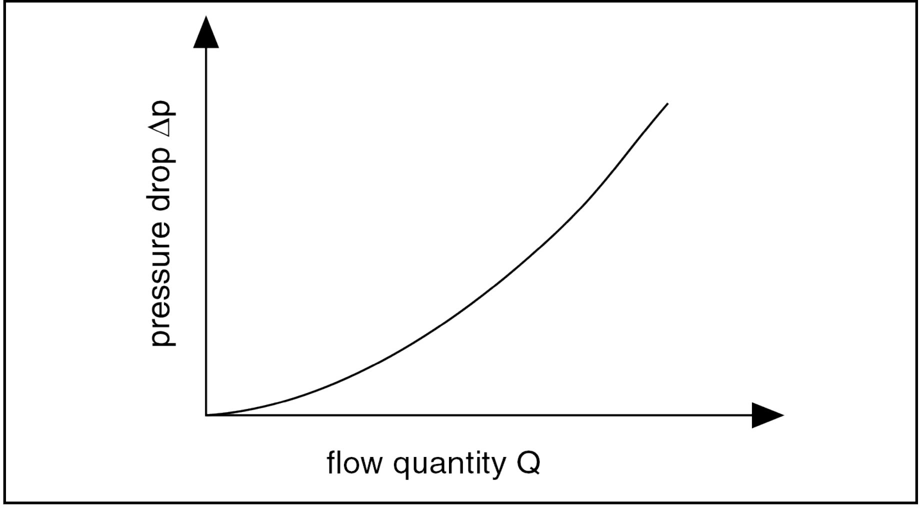


Fig. 9-20: Pressure drop depending on the flow rate; general representation

On the basis of the constant for determining the pressure drop k_{dp} that is explained in chapter "Technical Data", the pressure drop across the internal motor cooling circuit can be determined as follows:

$$\Delta p_m = k_{dp} \cdot Q^{1.75}$$

Δp_m	Pressure drop across internal motor cooling circuit in bar
Q	Flow rate in l/min
k_{dp}	Constant for determining pressure drop

Fig. 9-21: Determining the pressure drop depending on the flow rate

The pressure drop across the total system is determined by the sum of multiple partial pressure drops (Fig. 9-22). The pressure drop across the internal motor cooling system generally is relatively low.

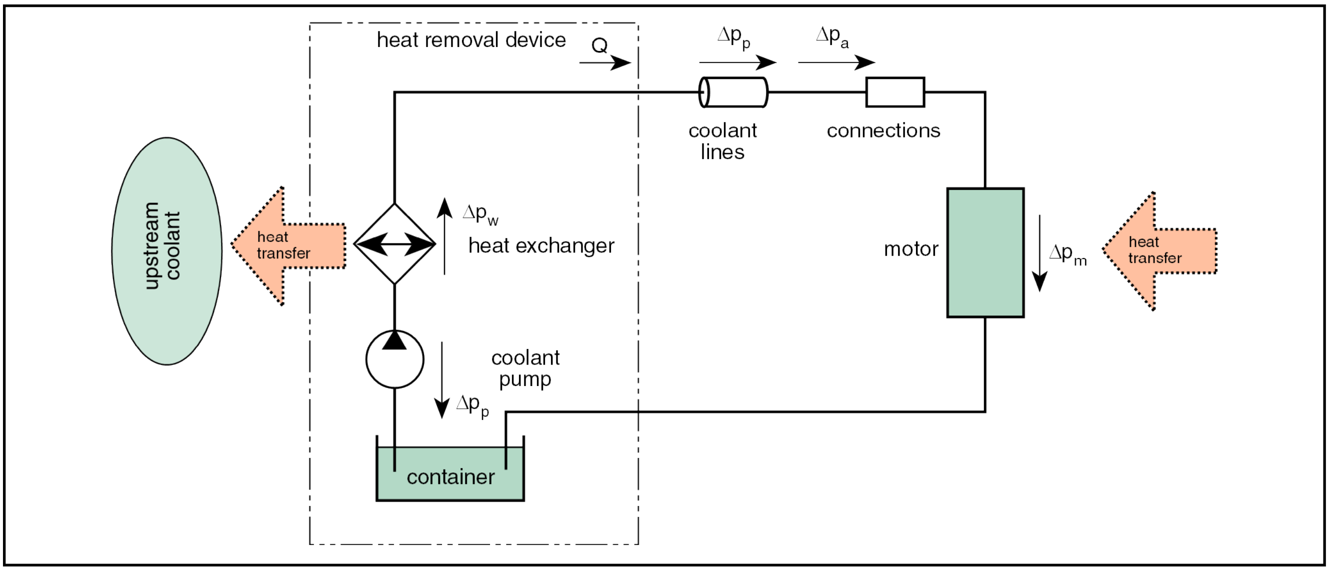


Fig. 9-22: General arrangement of a liquid cooled motor with heat removal facility

☞ The overall pressure drop of the cooling system is determined by various partial pressure drops (motor, feeders, connectors, etc.). This has to be taken into account by using manufacturer-specific data when the cooling circuit is sized.

9.10.7 Liquid cooling system

General

Machines and systems can require liquid cooling for one or more drive components. If several liquid-cooled drive components exist, they are connected to the heat removal device via a distribution unit.

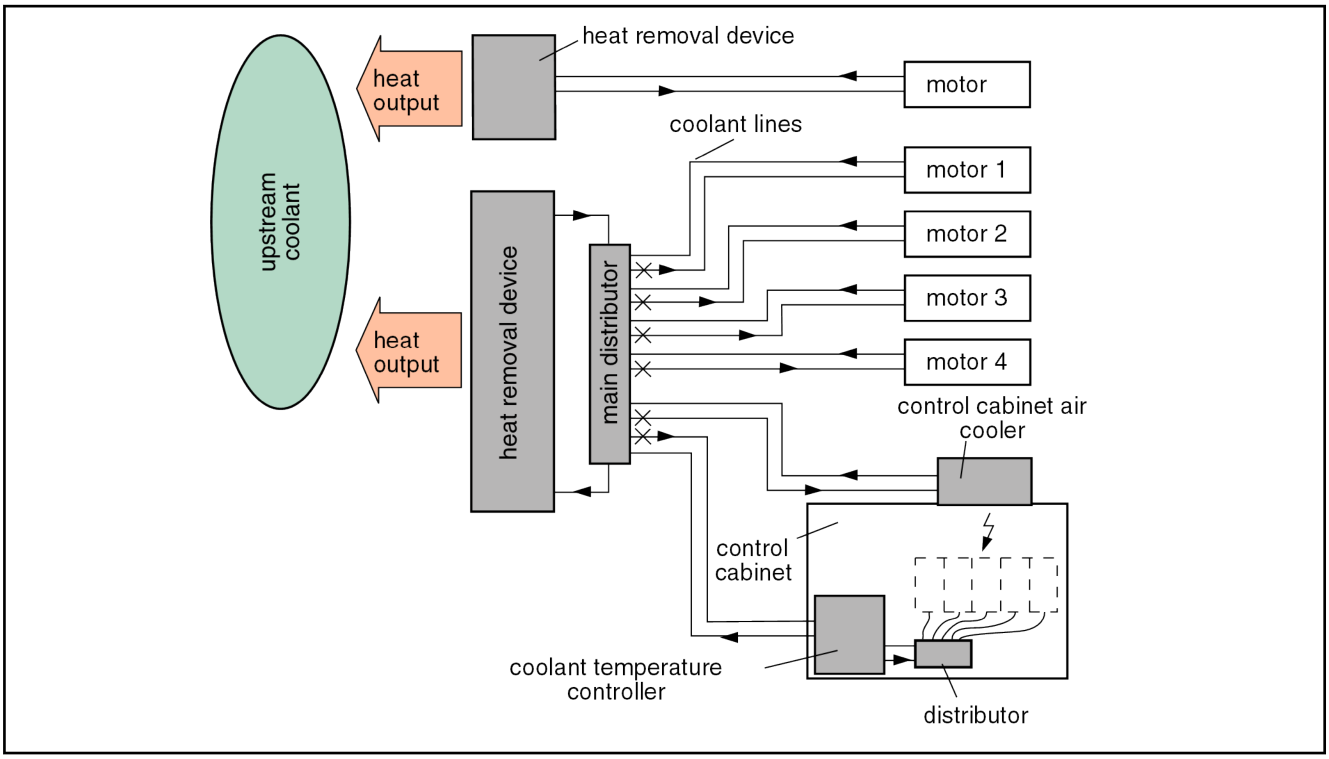


Fig. 9-23: General arrangement of cooling systems with one and more drive components

Heat removal device

The heat removal device dissipates the total heat that was fed into the liquid into a superordinate coolant. It provides a temperature-controlled coolant and thus maintains a required temperature level at the components that are to be cooled.

A heat removal device includes a heat exchanger, a coolant pump and a coolant container.

There are three different types of heat removal devices. They are identified by the type of the heat exchanger between the different media:

1. Air-to-liquid cooling unit
2. Liquid-to-liquid cooling unit
3. Cooling unit

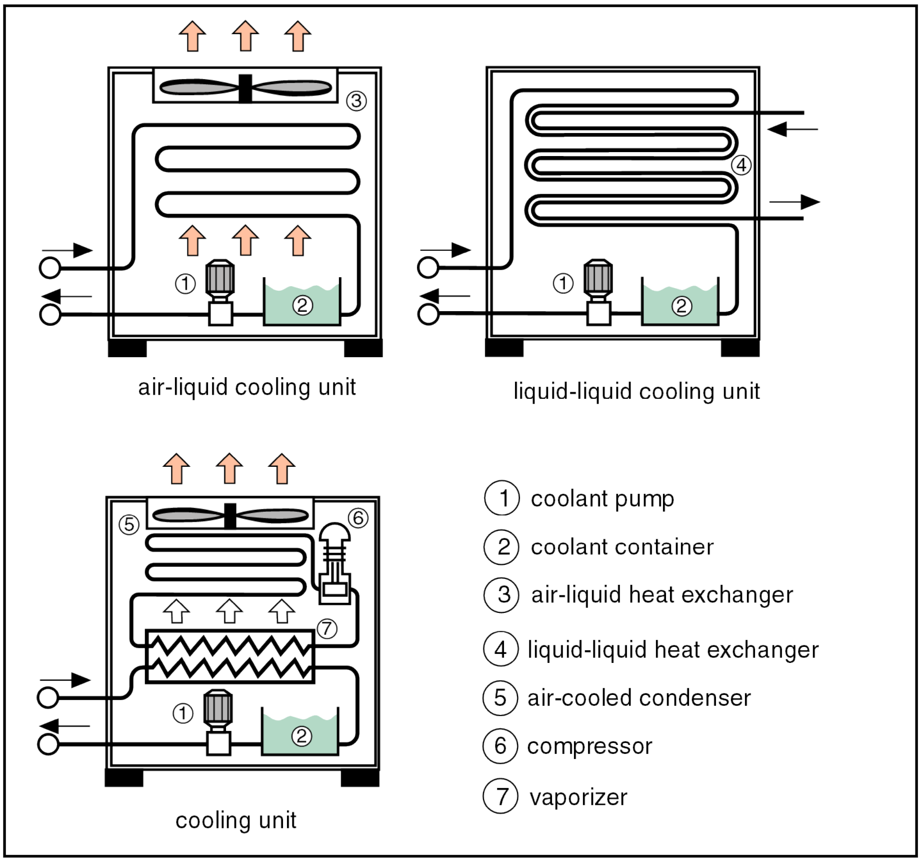


Fig. 9-24: Heat removal devices

	Air-to-liquid Cooling unit	Liquid-to-liquid Cooling unit	Cooling unit
Coolant temperature control accuracy	Low (±5 K)	Low (±5 K)	Good (±1 K)
Superordinate coolant circuit required	No	Yes	No
Heating of ambient air	Yes	No	Yes
Power loss recovery	No	Yes	No
Size of the cooling unit	Small	Small	Large
Depending on ambient temperature	Yes	No	No
Environment-damaging coolant	No	No	Yes
Notes on operational criteria	Particularly suitable for stand-alone machines that do not have a superordinate coolant circuit and which do not have to fulfill high requirements on the stability of the coolant temperature.	This cooling type is particularly suitable for systems with existing central feedback cooler. It does not fulfill high requirements on the stability of the coolant temperature.	Particularly suitable for high requirements on the thermal stability e.g. for high-precision applications.

Tab. 9-13: Overview of the heat removal devices according to utilization criteria

Coolant lines

The coolant lines are a major part of the cooling system. They have a great influence on the operational safety and pressure drop of the system. The lines can be made up as hoses or pipes.

Installing flexible coolant lines within the energy chain

For linear motor drives with a moving primary part, the coolant lines have to be installed within a flexible energy chain.

The continuous bending strain of the coolant lines always has to be taken into account when they are sized and selected.

Further optional components

- Distributions
- Coolant temperature controller
- Flow indicator

  A message is output when the flow drops below a minimum flow quantity.
- Level monitor

  Chiefly minimum-maximum level monitor to check the coolant level in the coolant container.
- Overflow valve
- Safety valve

  Opens a connection between the coolant inlet and tank when a certain pressure is reached
- Coolant filter (100 µm)
- Coolant heating

  To provide coolant at a correct temperature, in particular for coolant temperature control
- Choke and shut-off valves

Circuit types

The two possible ways of connecting hydraulic components (series/parallel connection) show significant differences with respect to:

- Pressure drop of the entire cooling system
- Capacity of the coolant pump
- Temperature level and controllability of the individual components that are to be cooled

Parallel connection

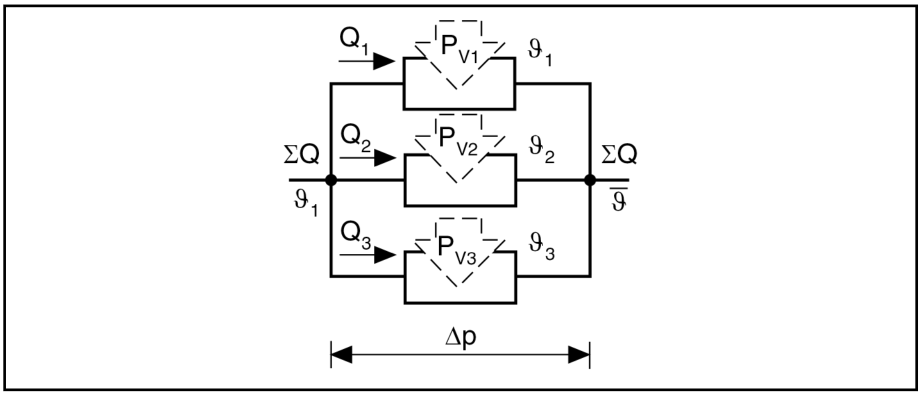


Fig. 9-25: Parallel connection of liquid-cooled drive components

The parallel connection is characterized by nodes in the hydraulic system. The sum of the coolant streams flowing into a node is equal to the sum of the coolant streams flowing out of this node. Between two nodes, the pressure difference (pressure drop) is the same for all intermediate cooling system branches.

$$Q = Q_1 + Q_2 \quad \ldots + Q_n$$

$$\Delta p = \Delta p_1 = \Delta p_2 = \Delta p_n$$

Δp	Pressure drop
Q	Flow rate

Fig. 9-26: Pressure drop and flow rate in the parallel connection of hydraulic components

When several drive components are cooled, parallel connection is advantageous for the following reasons:

- The individual components that are to be cooled can be cooled using the individual required flow rate. This means a high thermal operational reliability.
- Same temperature level at the coolant entry of all components (uniform machine heating)
- Same pressure difference between coolant entry and outlet of all components (no high overall pressure required)

Series connection

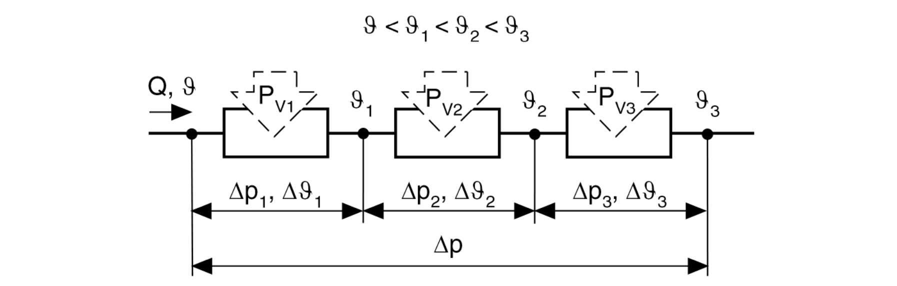


Fig. 9-27: Series connection of liquid-cooled drive components

In series connection, the same coolant stream flows through all components that are to be cooled. Each component has a pressure drop between coolant inlet and coolant outlet. The individual pressure drops add up to the overall pressure drop of the drive components.

Series connection does not permit any individual selection of the flow quantity required for the individual components to be made. It is only recommended if the individual components that are to be cooled need approximately the same flow rate and only cause a small pressure drop or if they are installed very far away from the heat removal device.

$$Q = Q_1 = Q_2 = Q_n$$

$$\Delta p = \Delta p_1 + \Delta p_2 \quad \ldots \quad + \Delta p_n$$

Δp Pressure drop
Q Flow rate

Fig. 9-28: Pressure drop and flow rate in the parallel connection of hydraulic components

The following disadvantages of series connection must always be taken into account:

- The required system pressure corresponds to the sum of all pressure drops of the individual components. This means a reduced hydraulic operational safety due to a high system pressure.
- The temperature level of the coolant incresaes from one component to the next. Each heat dissipation in the coolant rises its temperature (unsymmetrical machine heating)
- Some components may not be cooled as required since the flow rate cannot be selected individually.

Combination of series and parallel connection

Combining series and parallel connections of the drive components that are to be cooled permits the benefits of both connection types to be used.

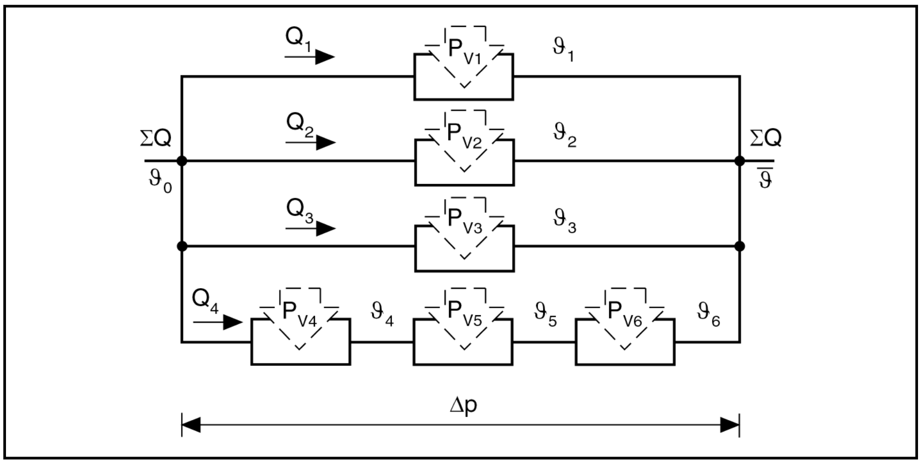


Fig. 9-29: Combination of series and parallel connection

9.11 Motor temperature monitoring

⚠ CAUTION **Failure in the machine or damage by improper use of the sensors!**

- The PTC sensors are no safety devices and are not intended for integration into safety systems to protect persons or machines.
- The PTC sensors are neither designed nor intended for measuring the temperatures of the housing, rotor or motor bearing. Additional temperature control requirements have to be realized by the machine manufacturer.
- To ensure safe motor protection against thermal overload, the temperature sensor SNM.150.DK has to be connected to the drive controller, and an appropriate thermal model has to be used in the controller.

In their standard configuration, primary parts of MLF motors are equipped with integrated temperature sensors for motor protection. Each motor phase contains one of three ceramic PTCs connected in series to enable reliable thermal monitoring of the motor in every phase of operation. These temperature sensors (referred to as Motor protection temperature sensor below) have a switching characteristic (Fig. 9-38) and are evaluated at all Rexroth drive controllers.

Furthermore all primary parts feature an additional temperature sensor for temperature measurement. This sensor (referred to as Temperature measurement sensor below) has an approximately linear characteristic curve (Fig. 9-32).

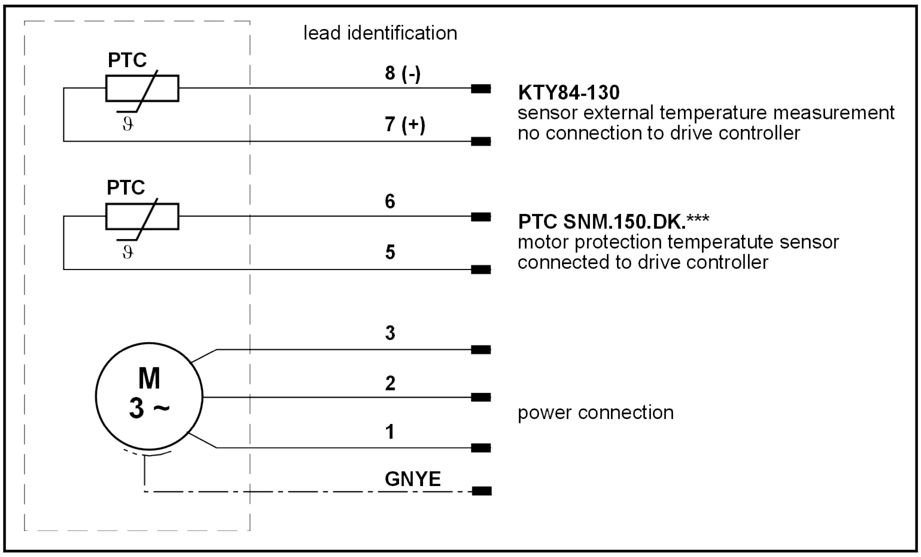


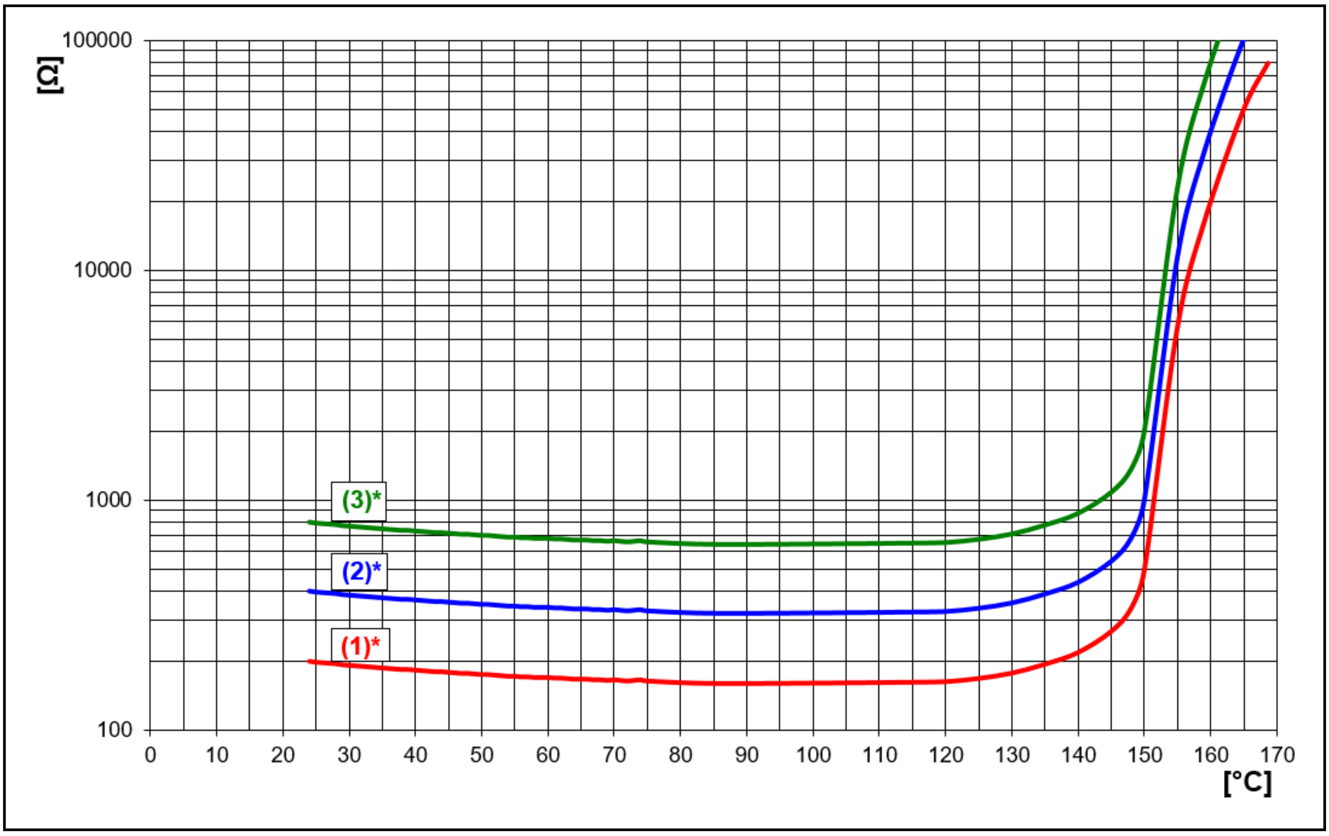
Fig. 9-30: Arrangement temperature sensors for MLF motors

Motor protection temperature sensor

Type	PTC SNM.150.DK.***
Rated response temperature ϑ_{NAT}	150 °C
Resistance at 25 °C	≈ 100 ... 250 Ohm

Tab. 9-14: Motor protection temperature sensor

☞ In the case of parallel connection of two or more primary parts, the motor protection temperature sensors of all primary parts are connected in series.



1	1x SNM.150.DK at 1x MLP
2	2x SNM.150.DK at 2x MLP
(3)	4x SNM.150.DK at 4x MLP

Fig. 9-31: Characteristic of temperature sensors for motor protection (SNM150.DK)

External temperature measurement sensor

Type	PTC KTY84-130
Resistance at 25 °C	577 ohm
Resistance at 100 °C	1000 ohm
Continuous current at 100 °C	2 mA

Tab. 9-15: External temperature measurement sensor

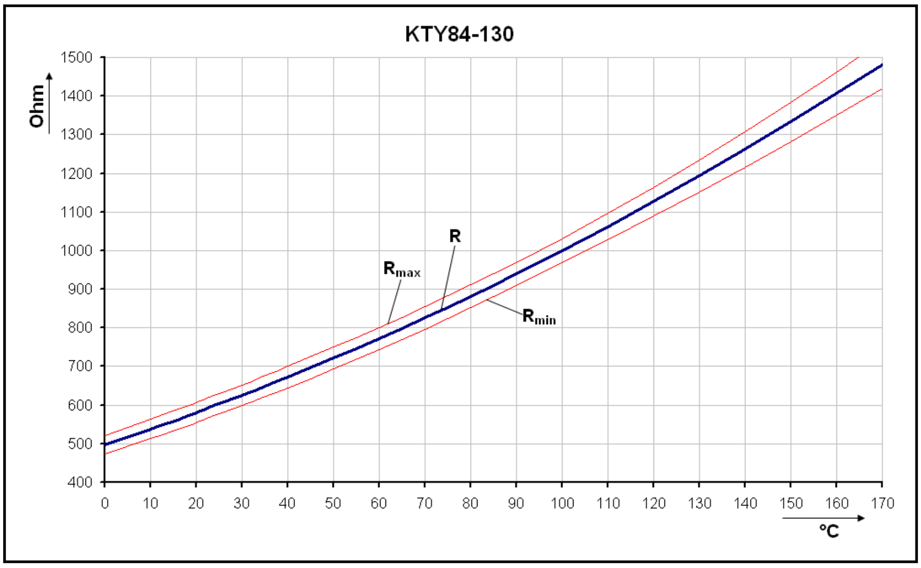


Fig. 9-32: Characteristic of temperature measurement sensor KTY84-130 (PTC)

A 3rd order polynomial is sufficiently precise for describing the resistance characteristic of the sensor used for temperature measurement (KTY84-130). It is specified below for determining a temperature at a known resistance and vice-versa.

Temperature in relation to the resistance

$$T_W = A \cdot R_{KTY}^{\ 3} + B \cdot R_{KTY}^{\ 2} + C \cdot R_{KTY} + D$$

T_W Winding temperature of the motor in °C
R_{KTY} Resistance of the temperature sensor in ohm
$A = 3.039 \cdot 10^{-8}$
$B = -1.44 \cdot 10^{-4}$
$C = 0.358$
$D = -143.78$

Fig. 9-33: Polynomial used for determining the temperature with a known sensor resistance (KTY84)

Resistance in relation to the temperature

$$R_{KTY} = A \cdot T_W^{\ 3} + B \cdot T_W^{\ 2} + C \cdot T_W + D$$

T_W Winding temperature of the motor in °C
R_{KTY} Resistance of the temperature sensor in ohm
$A = 1.065 \cdot 10^{-6}$
$B = 0.011$
$C = 3.93$
$D = 492.78$

Fig. 9-34: Polynomial used for determining the sensor resistance (KTY84) with a known temperature

☞
- Ensure correct polarity when using the sensor for temperature measurement.
- Before connecting the sensor, take appropriate measures for ESD protection (ESD = electrostatic discharge).
- The used temperature sensors are equipped with double or reinforced insulation according to DIN EN 50178, so separation exists according to DIN EN 61800-5-1.

For information on the connection of temperature sensors please refer to chapter chapter 8.4.1 "Temperature sensors" on page 176.

Standstill operation

If the motor is to be operated at standstill or near standstill, special conditions apply. Please also observe the notes in chapter 9.15 .

9.12 Requirements on the machine design

9.12.1 General

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

9.12.2 Mass reduction

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

If there are no requirements for the highest acceleration, even masses up to several tons can be moved without any problem. In this case, there is no control-related interrelation between moved slide mass and motor mass, like it is the case for rotary drives.

A very rigid connection of the motor to the load is a precondiiton.

9.12.3 Mechanical rigidity

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

Natural frequencies

The increased control bandwidth of linear direct drives requires 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 within the axis should not be less than an absolute value of approximately 200 Hz. The natural frequencies of axes with masses that are not constantly moving (e.g. due to work pieces that must be machined differently) change, so that the natural frequency is reduced as the mass increases. $f \approx \sqrt{1/m}$

Mechanically coupled axes

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

If several axes must be coupled kinematically 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, kinematic 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 may cause the stationary machine base to vibrate or deform it.

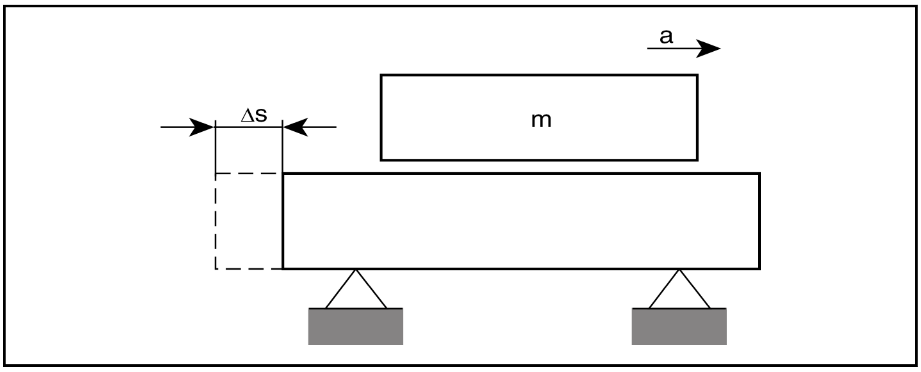


Fig. 9-35: Deformation of the machine base caused by the reactive force during the acceleration process

$$\Delta s = \frac{m \cdot a}{c} = \frac{500\ \text{kg} \cdot 10\ \text{m/s}^2}{1000\ \text{N}/\mu\text{m}} = 5\ \mu\text{m}$$

Δs	Deformation or 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. 9-36: Calculation example of the machine base deformation

Connecting the length measuring system

The rigidity of the length measuring system connection is particularly important. For explanations refer to chapter 9.16 "Length measuring system " on page 229.

9.12.4 Protection of the motor installation space

To avoid contamination of the motor during operation (e.g. residues, shavings, abrasive dust, grease of the guides, etc.) within the air gap between the primary and secondary part, you should especially pay attention to the protection of the motor installation space.

When designing the machine construction, observe appropriate protection measures, such as

- Self-made covers
- Bellows covers

If dirt penetrates between the motor components due to insufficient protection measures, during operation this can lead to ...

- increased heat introduction due to friction between the motor components. This can cause temperatures that may lead to motor failure.
- grinding traces and/or scratch-formation at the motor components which due to the high mechanical force effect may lead to motor failure.

Please observe that dirt can also be brought in via residues in the coolant, compressed air or other machine parts (e.g. grease of the guides). This must be prevented.

In addition, make sure by regular maintenance of the safety measures taken that their function is permanently fulfilled and the motor components are not damaged.

9.13 Arrangement of motor components

9.13.1 Single arrangement

The single arrangement of the primary part is the most common type of arrangement.

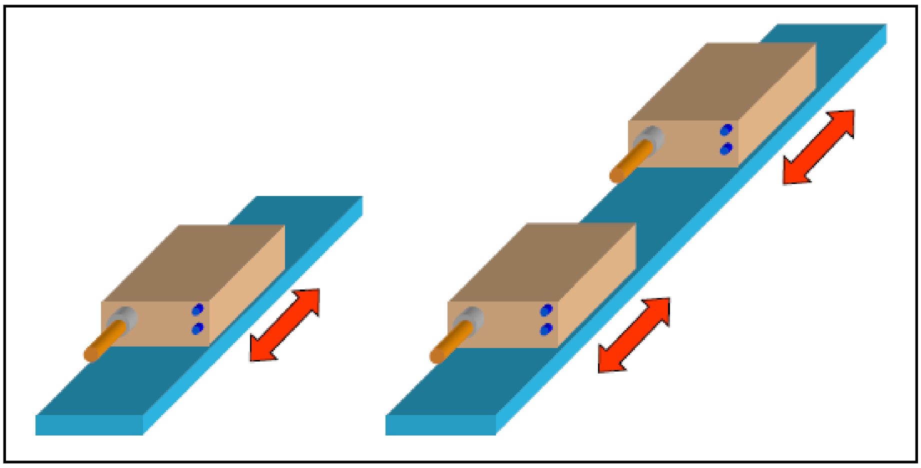


Fig. 9-37: Single arrangement of primary parts

It is also possible to independently operate two or more primary parts on a secondary part track (Fig. 9-37, to the right). In such an arrangement, the length measuring system can also be equipped with two or more scanning heads.

> In encapsulated length measuring systems, the number of scanning heads is usually limited to two due to the higher sealing lip friction. For more detailed information please contact the respective manufacturer.

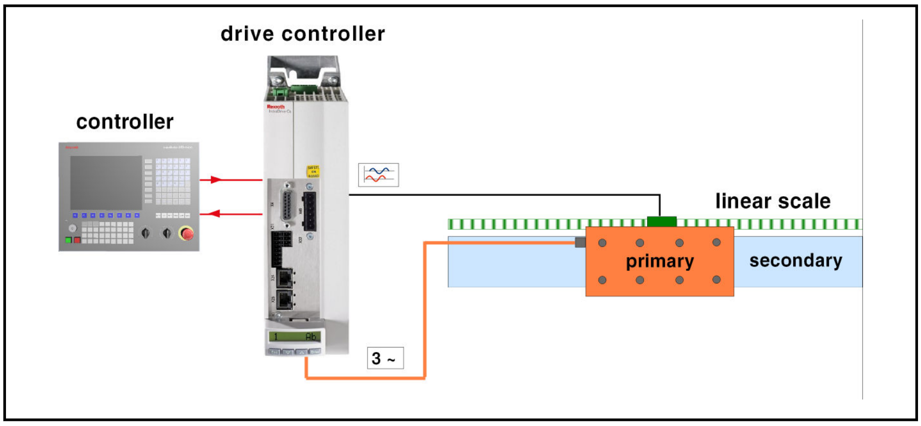


Fig. 9-38: Controlling a linear motor with single arrangement of the motor components

9.13.2 Several motors per axis

General

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

- Multiplied feed forces
- With corresponding arrangement, compensation of the attractive forces "outwards"

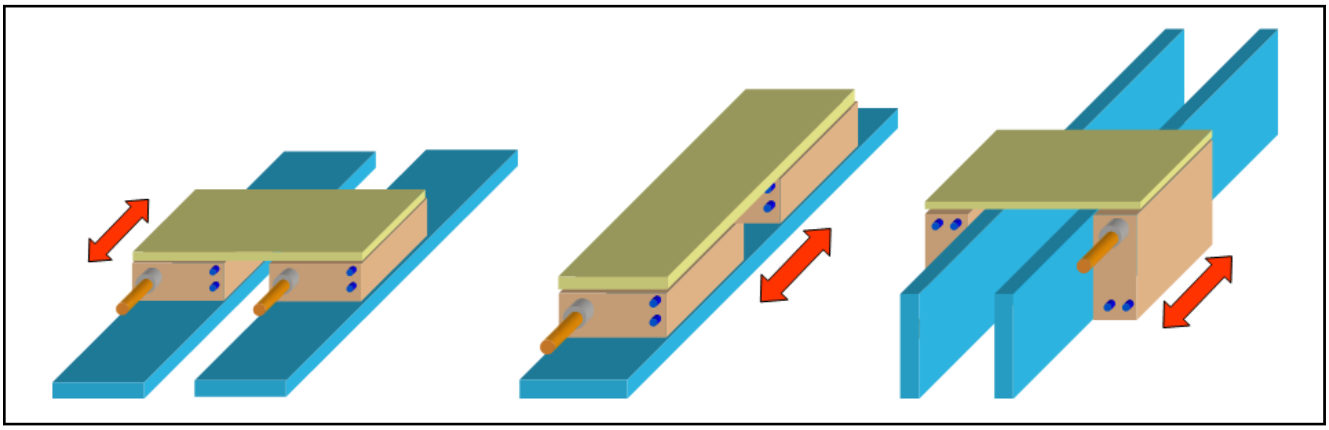


Fig. 9-39: Arrangement of several motors per axis

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

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

Parallel connection: Several primary parts in parallel

The arrangement of two or more primary parts at one drive controller in conjunction with a length measuring system is known as parallel connection. Parallel connection is possible if the coupling between the two motors is very rigid.

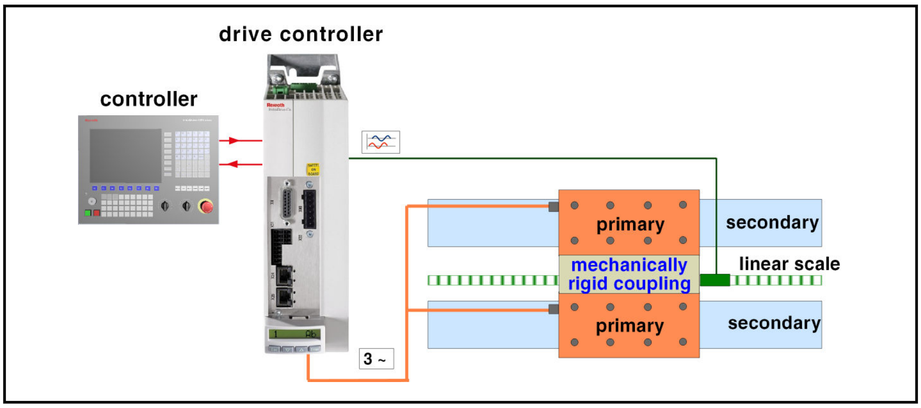


Fig. 9-40: Parallel connection of two primary parts at one drive controller in conjunction with a length measuring system

The following requirements must have been fulfilled:

- Identical primary and secondary parts
- Very rigid 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
- The same pole sequence of the secondary parts to each other
- If possible, load stationary and arranged symmetrically with respect to the motors

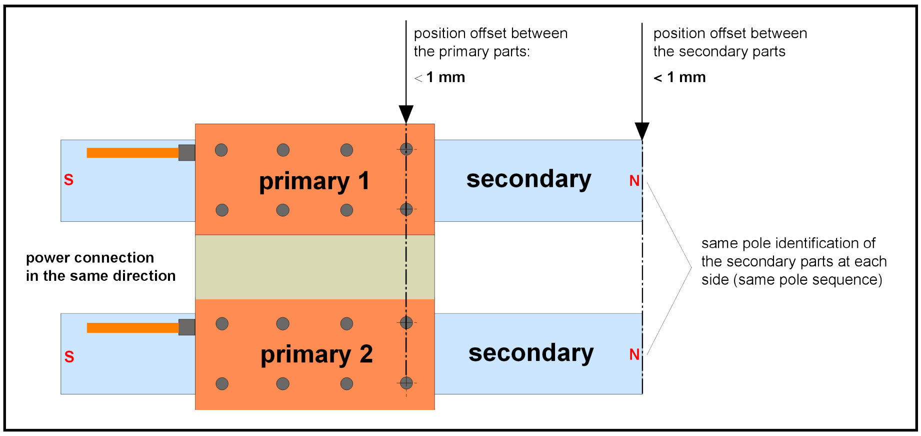


Fig. 9-41: Aligning the motor components in parallel connection

> ☞ To define the correct position of the motors in parallel connection, the mounting holes of the primary parts are used. In this case, always use the same hole in the pattern of both primary parts (see Fig. 9-41). An offset of the hole pattern between the primary parts is only allowed in accordance with Fig. 9-44 or Fig. 9-16.

If it is not possible to use the mounting holes as position reference, the front ends of the primary parts can also be used. The motor parts have been accordingly tolerated for this purpose.

Parallel connection: Double comb arrangement

In the case of parallel connection, the primary parts in feed direction can be mechanically coupled and arranged in the form of a so-called double comb arrangement (see on the right). Apart from force multiplication, the attractive forces between primary part and secondary part are compensated outwards. With the appropriate arrangement, the linear guides are not additionally stressed and possibly can be sized smaller. These requirements also apply:

- Identical primary and secondary parts
- Very rigid 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
- The same pole sequence of the secondary parts to each other
- If possible, load stationary and arranged symmetrically with respect to the motors

> ☞ In the case of double comb arrangement (according to Fig. 9-39, to the right), it is **not** necessary to maintain a minimum distance between the two secondary part contact surfaces.

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

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

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

Cable outlet in the same direction

If the primary parts are arranged behind each other and with cable outlets into the same directions to Fig. 9-42 a distance x_P must be kept.

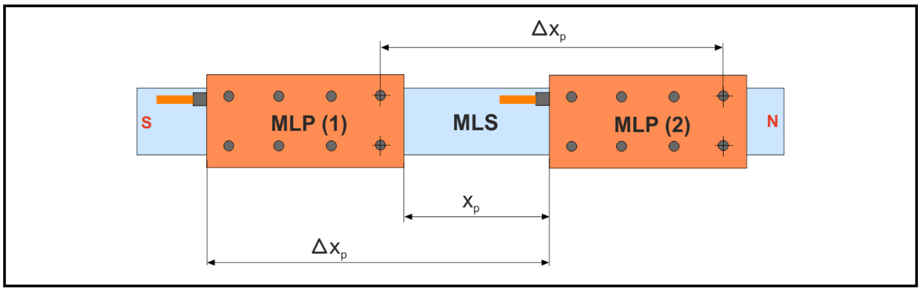


Fig. 9-42: Arrangement of the primary parts behind each other and cable outlets in the same direction

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

$$x_p > R$$

x_P	Distance between the front faces of the primary parts in mm
n	Freely selectable integer factor
τ_p	Pole width (see Chapter Technical data)
x_{Pmin}	Smallest allowed distance between the primary parts (see Tab. 9-16)
R	Allowed bending radius of the connection cable (see Tab. 8-1)

Fig. 9-43: Determining the distance x_P between the primary parts with cable outlets in the same direction

The grid dimension Δx_P acc. to Fig. 9-42 must be an integer multiple of the double pole width. Always use the same reference point for both primary parts (e.g. the same fastening hole or the same primary part front face).

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

Δx_p	Required grid dimension between the primary parts in mm
x_P	Distance between the front faces of the primary parts in mm
n	Freely selectable integer factor
τ_p	Pole width (see Chapter Technical data)

Fig. 9-44: Determining the grid dimension between the primary parts with cable outlets in the same direction

The distance x_P between the primary parts according to Fig. 9-42 may not be less than the following minimum distances x_{Pmin}:

Motor version		X_{Pmin}	Phase sequence L1 / L2 / L3	
			Primary part 1*)	Primary part 2
Standard encapsulation (only for MLFxx0)		15 mm	U-V-W	U-V-W
Thermal encapsulation	MLFxx0	65 mm		
	MLP052A MLP102C MLP152B/D MLP202B/D	30 mm		
	MLP052B MLP102B/D MLP152A/C MLP202A/C	60 mm		

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

Tab. 9-16: Minimum distance x_{Pmin} to be observed between the two primary parts with cable outlets in the same direction

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

If the primary parts are arranged behind each other and with cable outlets in opposite directions to Fig. 9-45, a defined distance x_P must be kept between the primary parts.

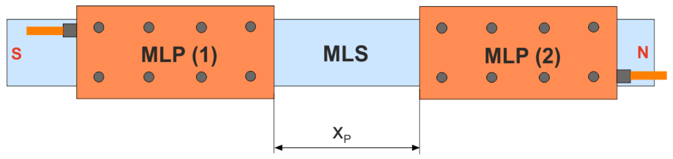


Fig. 9-45: Variant 1: Arrangement of primary parts behind each other with cable outlets in opposite directions

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

x_P Distance between the front faces of the primary parts in mm

n Freely selectable integer factor

τ_p Pole width (see Chapter Technical data)

x_{Pmin} Smallest allowed distance between the primary parts (see Tab. 9-17)

Fig. 9-46: Determining the distance between primary parts with cable outlets in opposite directions

When determining the correct primary part distance according to Fig.9-45, only the distance between the primary part front faces can be used as reference point.

Motor version		X_{Pmin}	Phase sequence L1 / L2 / L3	
			Primary part 1*)	Primary part 2
Standard encapsulation (only for MLFxx0)	MLPxx0	65 mm	U-V-W	U-W-V
Thermal encapsulation	MLPxx0	59 mm	U-V-W	U-W-V
	MLPxx2	5 mm	U-V-W	V-U-W

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

Tab. 9-17: Minimum distance to be observed between the two primary parts with cable outlets in opposite directions

Cable connection in opposite direction (variant 2: cables facing each other)

If the primary parts are arranged behind each other and with cable outlets in opposite directions according to Fig. 9-47, a defined distance x_P must be observed between the front faces of the primary parts.

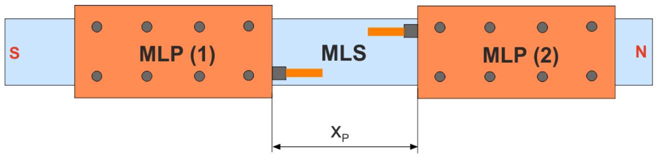


Fig. 9-47: Variant 2: Arrangement of primary parts behind each other with cable outlets in opposite directions

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

$$x_P > R$$

x_P Distance between the front faces of the primary parts in mm
n Freely selectable integer factor
τ_p Pole width (see Chapter Technical data)
x_{Pmin} Smallest allowed distance between the primary parts (see Tab. 9-18)
R Allowed bending radius of the connection cable (see Tab. 8-1)

Fig. 9-48: Determining the distance x_P between the primary parts with cable outlets in the same direction

☞ When determining the correct primary part distance according to Fig.9-47, only the distance between the primary part front faces can be used as reference point.

Motor version		X_{Pmin}	Phase sequence L1 / L2 / L3	
			Primary part 1*)	Primary part 2
Standard encapsulation (only for MLFxx0)	MLPxx0	40 mm	U-V-W	U-W-V
Thermal encapsulation	MLPxx0	71 mm	U-V-W	U-W-V
	MLPxx2	55 mm	U-V-W	V-U-W

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

Tab. 9-18: Minimum distance between the two primary parts with cable outlets in opposite directions

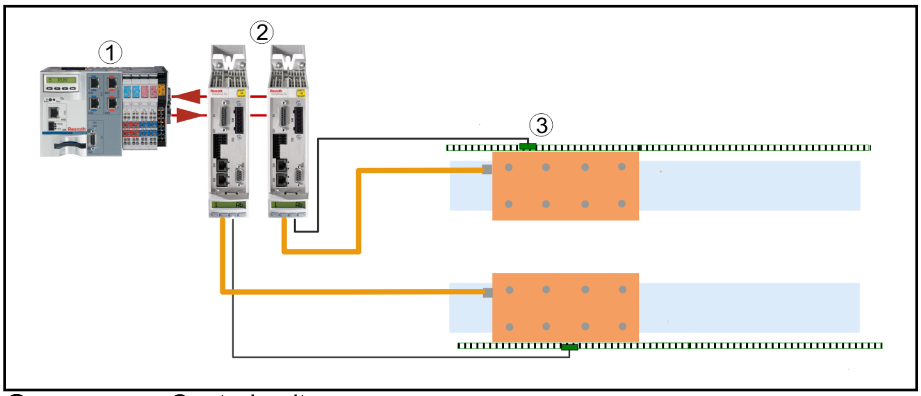
Gantry arrangement

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

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

Double comb arrangement (Gantry)

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



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

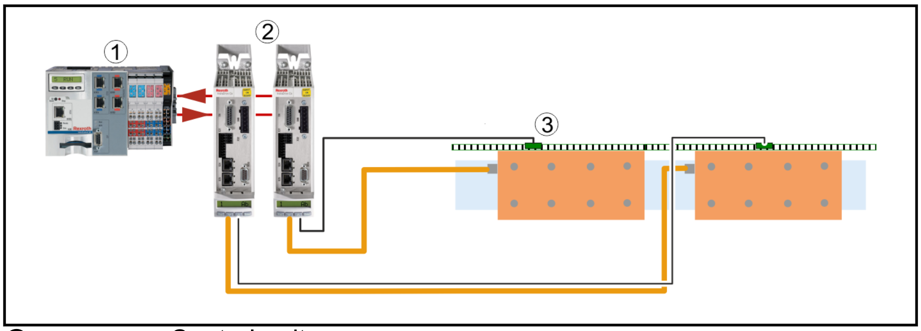
Fig. 9-49: Gantry arrangement

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

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

Arrangement of primary parts in a row (Gantry)

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



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

Fig. 9-50: Gantry arrangement (primary parts in a row)

9.13.3 Vertical axes

⚠ WARNING **Uncontrolled movement**

When using linear motors in vertical axes, keep in mind that the motor is not self-locking when power is switched off. Sinking of the axis can only be ensured by an appropriate holding brake (see also chapter 9.18 "Braking systems and holding devices" on page 235).

To keep the axis from sinking after power has been switched off, suitable holding devices have to be used. Appropriate holding devices have usually been integrated in weight compensation systems available today. These holding devices can be operated electrically, pneumatically or hydraulically.

☞

- At vertical axes, using an absolute measuring system is recommended.
- Incremental measuring systems can only be used, if, beside the holding device,
  - a Hall sensor box (see chapter 7 "Accessories and options" on page 161) is used.
  - the saturation method can be used for commutation adjustment, that is to say the controller makes available the maximum current of the motor.

    See also chapter 9.16.2 "Selection criteria for length measuring system " on page 229.

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 Feed and attractive forces

9.14.1 Attractive forces between primary and secondary part

In the assembled state, synchronous linear motors due to their operating principle have a permanently acting attractive force between primary and secondary part. In synchronous linear motors, this attractive force is also present while the motors have been switched off.

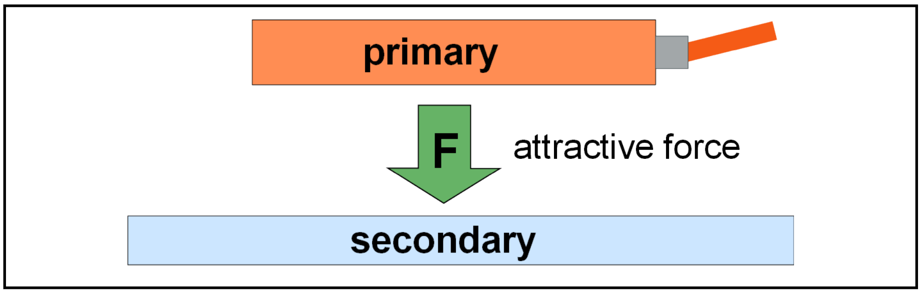


Fig. 9-51: Attractive force between primary and secondary part

These attractive forces strictly have to be taken into account for the mechanical design of the system. Due to the attractive forces, deformations (deflections) in the machine structure, as well as impermissible transverse loads of the linear guides, may occur if the motors have been inappropriately arranged. Therefore, the following points should be observed when designing the integration of the motors in the machine:

- Arrangement of linear guides as near as possible to the motor
- To compensate the attractive forces you can use the parallel arrangement shown at the right hand side in Fig. 9-39.

⚠ CAUTION

Possible motor damage due to insufficiently rigid design of the machine caused by constant and strong attractive forces between primary and secondary part!

Depending on the motor arrangement, the attractive forces have to be absorbed by the linear guides and the slide and machine structure.

☞

- After the linear motor has been installed and while it is operated, the installation height may not be less than the installation height L1 (see Tab. 5-1). Also refer to the instructions in chapter 5.2 .
- The attractive forces at nominal air gap are given in the data sheet of the respective motor in chapter 4 "Technical data" on page 23.

9.14.2 Attractive forces depending on the air gap

The attractive force increases as the distance between primary and secondary part is reduced. As soon as the primary part is lowered onto the secondary part, the attractive forces will increase as a result of the reduced air gap. The diagram below shows the curve of the attractive force depending on the air gap.

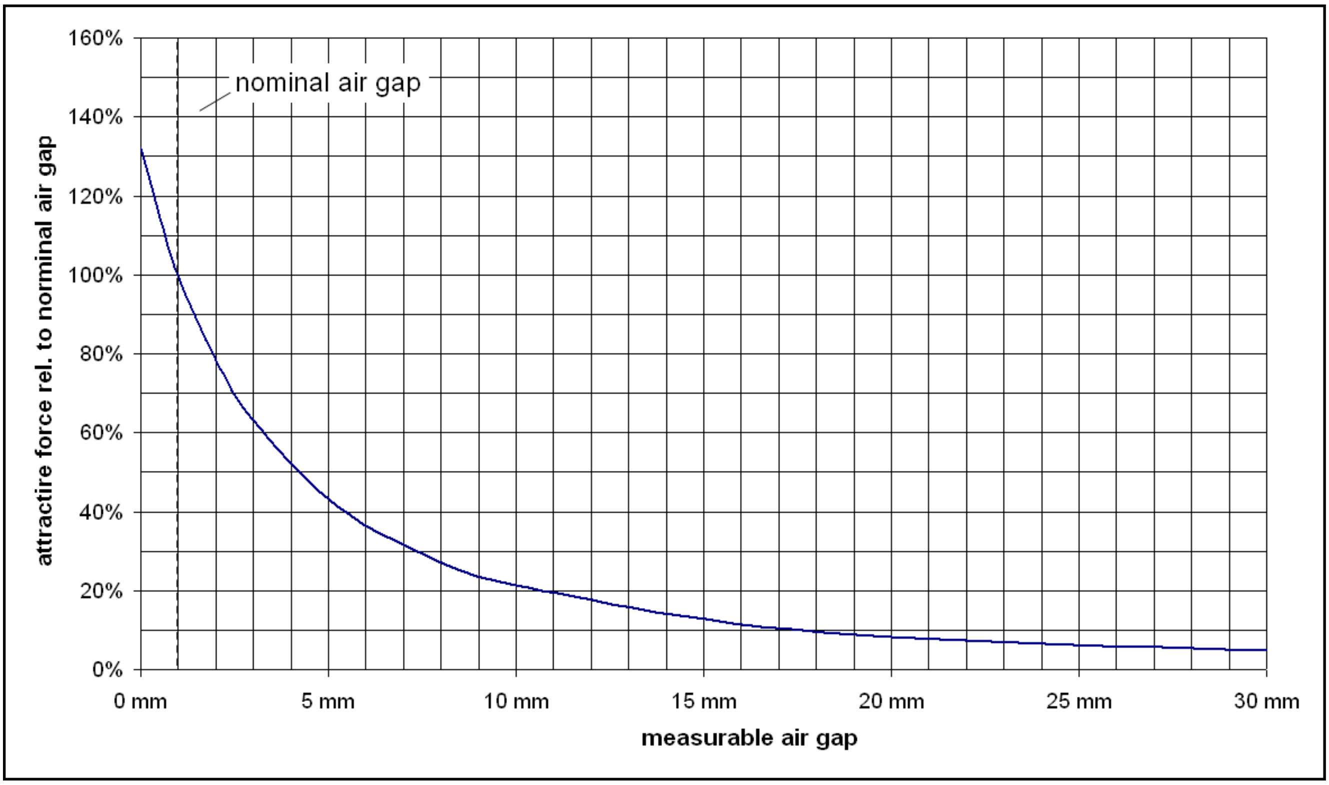
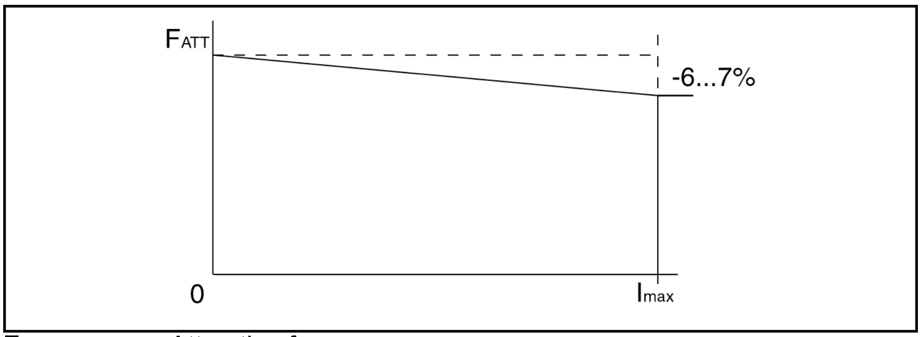


Fig. 9-52: Air-gap-related attractive forces between primary and secondary part

9.14.3 Attractive forces depending on the current supply

The attractive force is reduced as the current supply of the primary part increases. The diagram below shows the curve of the attractive force depending on the current supply.



F_{ATT} Attractive force

I_{max} Maximum current

Fig. 9-53: Attractive force depending on the current supply

9.14.4 Air-gap-related feed force

Air gap tolerances

The feed forces specified in the technical data refer to the indicated nominal air gap. The allowed tolerances for the measurable air gap have an effect on the feed forces that can be reached. The figure below shows this mutual dependence:

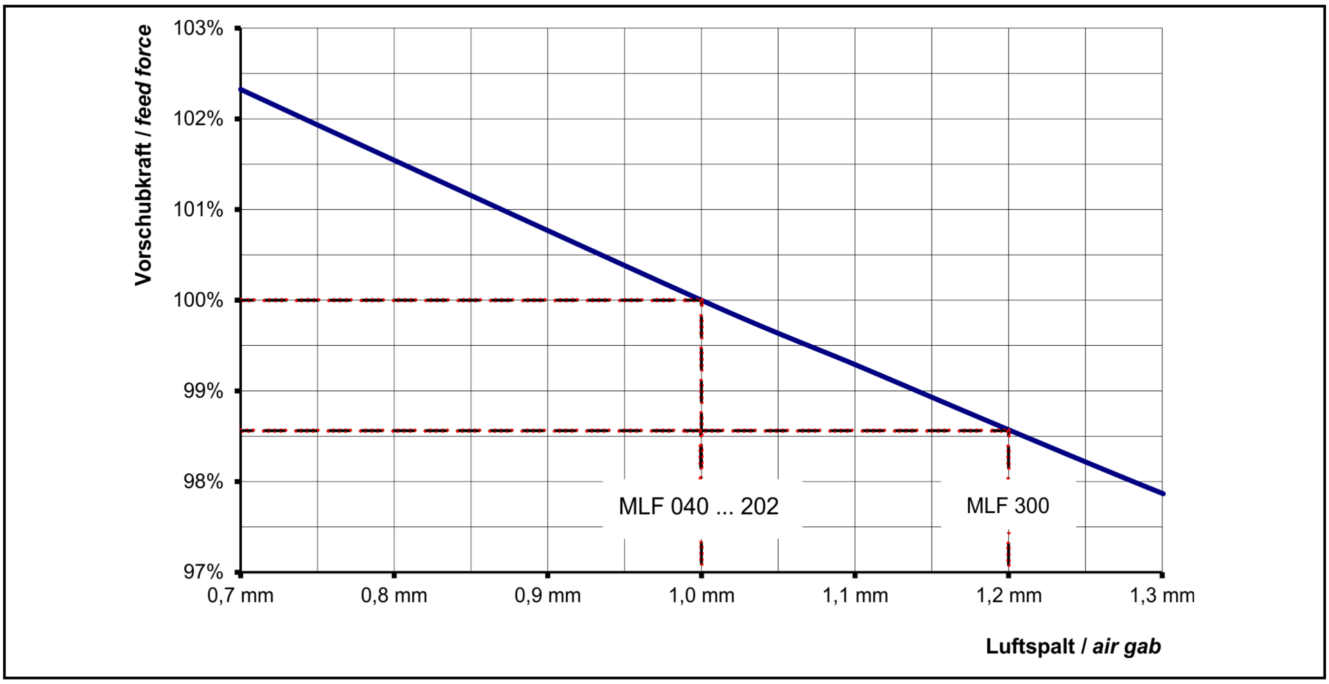


Fig. 9-54: Feed force within the air gap tolerance of synchronous linear motors MLF

9.14.5 Reduced coverage between primary and secondary part

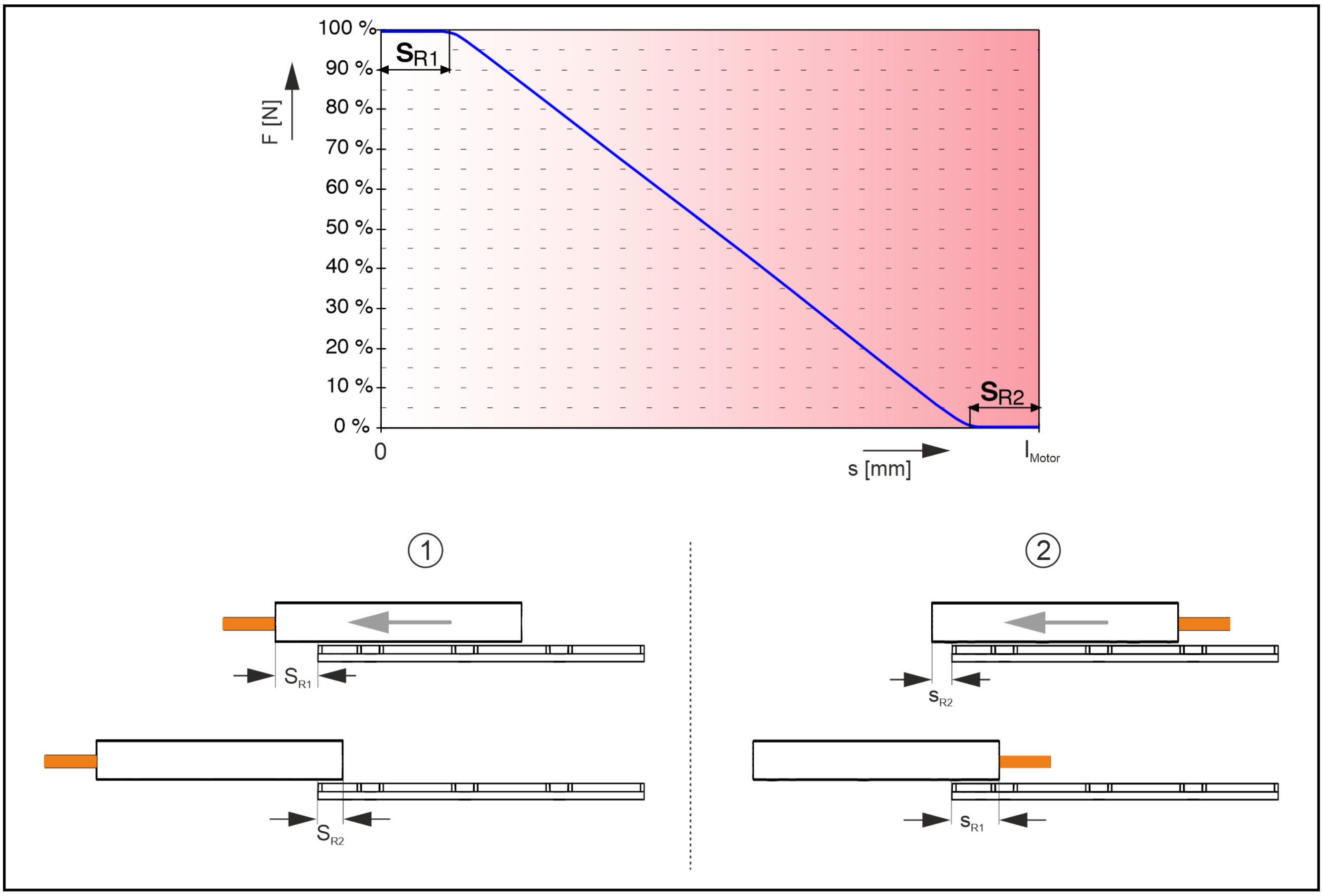
When moving in the end position range of an axis, it can be necessary that the primary part moves beyond the end of the secondary part. This results in a partial coverage between primary and secondary part.

If primary and secondary part are only partially covered, this inevitably results in a reduction of the feed forces.

☞ The partial coverage of the active range of the primary part with the secondary part 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.

Start of force reduction

Outside the beginning and end areas (s_{R1} or s_{R2}), the reduction of the force is linear with the reduced overlap area. The following diagram illustrates the correlation between the coverage of primary to secondary part and the resulting force reduction.



① Variant 1 - Overrun distance in direction of cable outlet side

② Variant 2 - Overrun distance in direction against cable outlet side

Fig. 9-55: Force reduction with partial coverage of primary and secondary part

Design MLP...		Active length	Overrun distance	
		$L_{MLP,Fe}$ [mm]	S_{R1} [mm]	S_{R2} [mm]
040	A-__-FS-...	175	30	5
	A-__-FT-...		52	8
	B-__-FS-...	250	30	5
	B-__-FT-...		52	8
052	A-__-FT-...	145	45	20
	B-__-FT-...	295		
070	A-__-FS-...	250	30	5
	A-__-FT-...		52	8
	B-__-FS-...	325	30	5
	B-__-FT-...		52	8
	C-__-FS-...	475	30	5
	C-__-FT-...		52	8

<table>
<tr><th colspan="2">Design MLP...</th><th>Active length</th><th colspan="2">Overrun distance</th></tr>
<tr><td rowspan="8">100</td><td>A-__-FS-...</td><td rowspan="2">325</td><td>30</td><td>5</td></tr>
<tr><td>A-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td>B-__-FS-...</td><td rowspan="2">475</td><td>30</td><td>5</td></tr>
<tr><td>B-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td>C-__-FS-...</td><td rowspan="2">625</td><td>30</td><td>5</td></tr>
<tr><td>C-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td>K-__-FS-...</td><td rowspan="2">400</td><td>30</td><td>5</td></tr>
<tr><td>K-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td rowspan="3">102</td><td>B-__-FT-...</td><td>295</td><td rowspan="3">45</td><td rowspan="3">20</td></tr>
<tr><td>C-__-FT-...</td><td>115</td></tr>
<tr><td>D-__-FT-...</td><td>115</td></tr>
<tr><td rowspan="6">140</td><td>A-__-FS-...</td><td rowspan="2">325</td><td>30</td><td>5</td></tr>
<tr><td>A-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td>B-__-FS-...</td><td rowspan="2">475</td><td>30</td><td>5</td></tr>
<tr><td>B-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td>C-__-FS-...</td><td rowspan="2">625</td><td>30</td><td>5</td></tr>
<tr><td>C-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td rowspan="4">152</td><td>A-__-FT-...</td><td>295</td><td rowspan="4">45</td><td rowspan="4">20</td></tr>
<tr><td>B-__-FT-...</td><td>115</td></tr>
<tr><td>C-__-FT-...</td><td>115</td></tr>
<tr><td>D-__-FT-...</td><td>115</td></tr>
<tr><td rowspan="8">200</td><td>A-__-FS-...</td><td rowspan="2">325</td><td>30</td><td>5</td></tr>
<tr><td>A-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td>B-__-FS-...</td><td rowspan="2">475</td><td>30</td><td>5</td></tr>
<tr><td>B-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td>C-__-FS-...</td><td rowspan="2">625</td><td>30</td><td>5</td></tr>
<tr><td>C-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td>D-__-FS-...</td><td rowspan="2">115</td><td>30</td><td>5</td></tr>
<tr><td>D-__-FT-...</td><td>52</td><td>8</td></tr>
<tr><td rowspan="4">202</td><td>A-__-FT-...</td><td>295</td><td rowspan="4">45</td><td rowspan="4">20</td></tr>
<tr><td>B-__-FT-...</td><td>115</td></tr>
<tr><td>C-__-FT-...</td><td>115</td></tr>
<tr><td>D-__-FT-...</td><td>115</td></tr>
</table>

Design MLP...		Active length	Overrun distance	
300	A-__-FS-...	325	30	5
	A-__-FT-...		52	8
	B-__-FS-...	475	30	5
	B-__-FT-...		52	8
	C-__-FS-...	625	30	5
	C-__-FT-...		52	8

Tab. 9-19: Partial coverage between primary and secondary part

⚠ WARNING **Malfunction and uncontrolled motor motion by partial coverage of primary and secondary part!**

- Partial coverage of primary and secondary part only when moving to the end position in the case of drive error
- Minimum coverage factor 75 %

When doing the project planning of the machine, first of all please get in touch with your Bosch Rexroth contact person and ask for application support in this regard.

9.15 Operation at or near motor standstill

If the motor is to be operated at standstill or near standstill, special conditions apply. For means of simplification, this operation is indicated as standstill operation in the following. The standstill operation is marked by one of 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 (≤ 2 * T_p).
- Motor moves only at very low frequency (f ≤ 0.1 Hz)

Due to the 3-phase system, during standstill operation in one of the three phases there is always an instantaneous value of the current, the amount of which is higher than the permissible continuous current. If the current flows continuously, the motor will overheat and be thermally damaged. Also refer to chapter 9.11 "Motor temperature monitoring" on page 208).

The peak value of the instantaneous current is equal with the amplitude of the sinusoidal assumed phase current. Its value is higher by root 2 than the effective value of the continuous current (I_N). The power loss P_V, created in the coil, is calculated using

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

$\Delta\vartheta$ Temperature difference between operation temperature and 20 °C

α_{Cu} Temperature coefficient 0.0039 1/K

Fig. 9-56: Power loss coil

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

Protection from thermal overload during standstill operation

Differentiate the following cases:

1. **Using the temperature sensor SNM.150.DK**

   If the tripple sensor SNM.150.DK used to monitor the winding temperature, all three phases are monitored (see Chapter 9.11 , Motor temperature monitoring). The motor winding is protected.

2. **Using the temperature sensor KTY84-130**

   The KTY84-130 is mounted in one phase only. Due to the utilization of the KTY84-130, the other phases cannot be protected from thermal overload at standstill operation. Therefore the current in standstill operation must be reduced according to the following table.

Primary part MLP	Reducing the nominal current I_N at standstill operation to
040 ... 300	**87 %**

Tab. 9-20: Necessary current reduction within standstill operation

☞ At currents > I_N the winding can overheat and thus be damaged despite the use of the SNM.150.DK. To avoid this, a suitable thermal model must be implemented in the controller. This is the case for Rexroth controllers.

9.16 Length measuring system

9.16.1 General

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

☞ The necessary length measuring system is not in the scope of delivery of Bosch Rexroth and has to be provided and mounted from the machine manufacturer themselves.

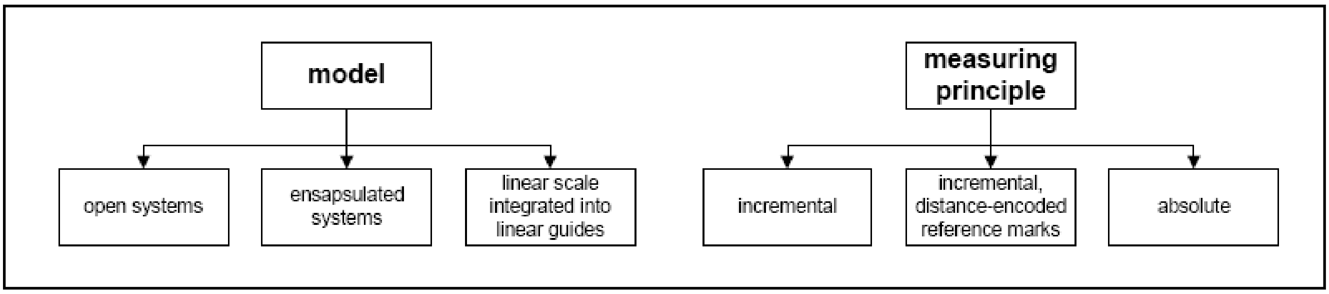


Fig. 9-57: Classification of linear scales

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.

9.16.2 Selection criteria for length measuring system

General

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

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

Frame sizes

Open construction form	Encapsulated frame size	Measuring system, integrated in rail guides
Advantages:		
- High feed rate - High exactness - No friction - Incremental and absolute measuring available	- Easy assembly - High degree of protection - Incremental and absolute measuring available	- Leading and measuring combined - No additional assembly effort - Highest degree of protection - High feed rate - Less required space

Open construction form	Encapsulated frame size	Measuring system, integrated in rail guides
Disadvantage:		
- Low degree of protection - Expensive mounting and alignment	Limitation of maximum velocity	- None or less absolute measuring systems available

Tab. 9-21: Advantages and disadvantages of different types of construction of length measuring systems

Open construction form

If there is no contamination, chips, etc. in a machine or system and the use of cooling lubricants can be ruled out, the use of open length measuring systems is recommended. Open length measuring systems are therefore frequently used on handling axes, precision and measuring machines, and in the semiconductor industry.

Encapsulated frame size

If chips are used and/or cooling lubricants are used, encapsulated systems must be used. To ensure maximum operational reliability, enclosed systems can be pressurized with sealing air. Encapsulated length measuring systems are mainly used on metal cutting machine tools.

Measuring system, integrated in rail guides

Ball and roller rail systems from Rexroth are available with an integrated inductive length measuring system. The system consists of a separate scanning unit (read head) and a measuring scale integrated into the rail. The measuring scale is mounted in a groove of the guide rail and is protected by a stainless steel strip which is tightly welded. The read head is mounted directly on the carriage.

The system is insensitive to contamination (e.g. dust, chips, coolant, etc.) and magnetic fields. The compact and robust unit (measuring system and guide) enables simplified designs due to the small space requirement compared to externally mounted measuring systems. Any costs for material and mounting of external systems are not applied.

Measuring principle

Absolute scales

The advantages of an absolute length measuring system result from the fact that a high availability and operational reliability of the motion axis and thus of the entire system is guaranteed:

Advantages:

- Monitoring and diagnostic functions of the electronic drive system are possible without any additional wiring
- A travel range limit switches is not necessary
- the maximum available motor power is available immediately after switching on at any point of the travel range
- No referencing required
- easy commissioning of horizontal and vertical axes
- Pole position detection necessary for initial commissioning only

Disadvantage:

- Higher acquisition costs than for incremental measuring systems

Using an absolute linear scales makes it possible that the pole position recognition of the motor need only be performed once for initial commissioning. This internal drive procedure is possible without power connection, i.e. without moving the axis. This offers special advantages when commissioning vertical axes.

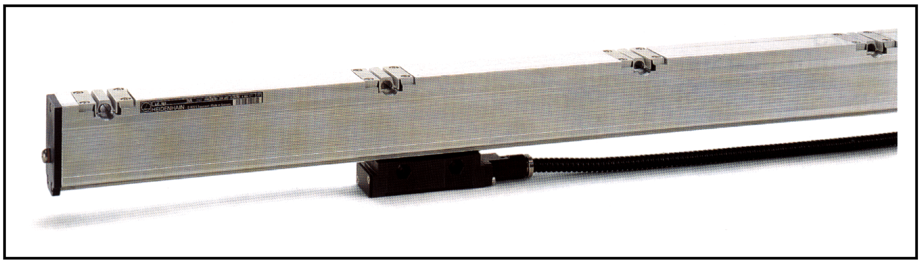


Fig. 9-58: Absolute encapsulated length measuring system

Incremental measuring systems

When using an incremental linear encoder in conjunction with synchronous linear motors, the position of the pole must be recorded each time the motor is switched on. This is done by means of an internal drive procedure, which must run after each switching-on of the axis. Subsequently, the motor power can develop.

☞ The drive-internal procedure for detection of pole position (commutation setting) must be performed for incremental linear encoders after each switch-on.

Depending on the selected control device, in connection with an incremental measuring system, two different methods for pollage detection can be used.

- **Sine-wave method** in connection with controllers with smaller type current than the motor maximum current.

  Here, an axis movement takes place during commutation.
- **Saturation method** in connection with controllers with the same or higher type current as motor maximum current.

  Here, no axis movement is required during commutation (axis can be firmly braked)

For detailed description of commutation methods see firmware description of controller and chapter 13.6 "Commutation adjustment " on page 296.

Advantages:

- Travel distance depending on design up to 30 m or unlimited possible
- High feed rate possible
- Different signal periods and thus different position resolutions possible

Disadvantages

- Acquisition of the pole position necessary after each switch-on
- Movement of the primary part required for detection of pole position (only with sinusoidal method)
- Pole position detection for vertical axes only possible with saturation method
- Pole position detection for axes with fixed brakes or axes at the fixed stop only possible with the saturation method
- Pole position detection for Gantry axis maybe problematically
- Reference mark evaluation and reference switch necessary
- Safety limit switch necessary

Incremental length measuring systems with distance-coded reference marks

Incremental length measuring systems with distance-coded reference marks, offer the advantage of a simplified and above all shortened reference run.

Depending on the design, only a range of a few centimeters has to be moved during reference travel with such a system.

☞ Distance-coded measuring systems do not measure absolutely. The pole position recognition must also occur at each switching-on, as with non-distance-coded incremental systems.

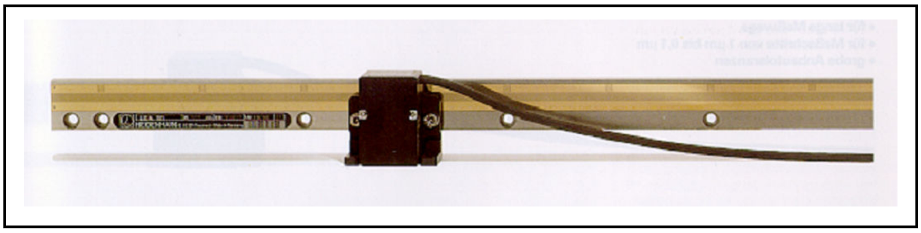


Fig. 9-59: Open incremental length measuring system with distance-coded reference marks

Maximum allowed velocity and acceleration

Maximum allowed travel velocity

The maximum permissible traversing speed of a linear encoder is limited by the sealing lips and the guide of the scanning carriage on the scale when the system is encapsulated.

On the other hand, there is a limitation by the limit frequency of the output signals (manufacturer's specifications) or the maximum permissible input frequency of the subsequent electronics (drive control unit).

$$v_{max} = f_{max} \cdot \text{Signal period} \cdot 60$$

v_{max} Maximum travel velocity in m/min

Signal period Signal period length measuring system in mm

f_{max} Maximum input frequency evaluation electronics

Fig. 9-60: Maximum travel velocity length measuring system with regard to the maximum input frequency evaluation electronics

Maximum allowed acceleration in measuring direction

With open length measuring systems, very high maximum accelerations in the measuring direction are permissible due to the very rigid internal structure. To allow relatively high mounting tolerances, the scanning carriage cannot be rigidly connected to the mounting base on sealed length measuring system. Encapsulated length measuring systems for linear motors are comparatively stiff, however.

☞ For detailed and updated information, use the documentation provided by the relevant manufacturers.

Position resolution and position accuracy

To achieve a high resolution of the length measuring system, an interpolation of the sinusoidal input signal of the length measuring system is performed in the drive controller. Depending on the maximum travel range and the signal period, a drive-internal position resolution of less than 1 nm is possible.

☞ The drive-internal position resolution does not correspond to the positioning accuracy! The absolute position accuracy depends on the total drive system including mechanics.

Measuring system cables

For the electrical connection between the output of the length measuring system and the input of the evaluation electronics, Rexroth provides appropriate ready-made cables. To ensure maximum transmission and scale interference safety, you should preferably use these ready-made cables.

Recommended length measuring systems for linear motors

Bosch Rexroth recommends the following manufacturers for suitable lengths measuring systems in connection with our linear motors:

Bosch Rexroth Linear and assembly technique (Integrated measuring system for profiled rail guide)	Maria-Theresien-Str. 23 97816 Lohr am Main, Germany info@boschrexroth.de http://www.boschrexroth.com/business_units/brl/de/
Renishaw GmbH	Karl-Benz Straße 12 72124 Pliezhausen, Germany http://www.renishaw.de/
DR. JOHANNES HEIDENHAIN GmbH	Postfach 1260 83292 Traunreut, Germany info@heidenhain.de http://www.heidenhain.de/

Tab. 9-22: Recommended 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.

9.16.3 Mounting the length measuring systems

Misalignment of coupling onto the machine

The coupling of the measuring system to the machine can cause a limitation of the bandwidth of the position control loop in linear drives. For the design, this means that the coupling of the scanning unit and the scale in open length measuring systems, or of the scale housing in encapsulated length measuring systems, to the machine must be designed with a natural frequency significantly higher than that of the length measuring system.

Furthermore, it must be ensured that the length measuring system is not attached to vibrating machine parts. In particular, avoid mounting near vibration maxima.

Installation mode

To minimize the moving masses and to obtain the highest stiffness in the measuring direction, the scanning unit should always be moved, if possible.

Open length measuring systems

When using an open length measuring system despite adverse environmental conditions (chips, dust, etc.), provide user-side encapsulation. It should also be noted that the scanning head must be adjusted when installing the open length measuring system. Appropriate adjustment possibilities must be provided for in the design (observe the instructions of the manufacturer).

Encapsulated length measuring systems

In order to achieve comparatively high mounting tolerances, the scanning carriage of encapsulated length measuring system is connected to the mounting base via a coupling that is very rigid in the measuring direction and can move slightly perpendicular to the measuring direction. If the stiffness of this coupling in the measuring direction is too low, low natural frequencies result in the feedback for the position and velocity control loop, which can limit the bandwidth. The natural frequency of the length measuring system in the measuring direction can thus be neglected compared to mechanical natural frequencies of the machine.

Parallel connection Several motors on a lengths measuring system

If several motors per axis are operated via only one linear encoder, the motors must be mounted as symmetrically as possible with respect to their position.

Gantry axes

In the case of a gantry axis in which a motor or pair of motors is assigned to one linear encoder each, care must be taken to keep the distance between the motor and linear encoder as small as possible. Furthermore, the accuracy of the length measuring systems within themselves and to each other must be less than 5 µm/m. Drive-internal axis error corrections can minimize remaining misalignments between the measuring systems.

9.17 Linear guides

Depending on the motor arrangement, the attractive, feed and process forces and the velocities of more than 600 m/min that can be reached today stress the linear guides. The used linear guiding systems must

- attractive force between primary and secondary part and
- the machining and acceleration forces

.

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

Manufacturers of linear guiding systems

In combination with our motors, we recommend using products from our linear and assembly technology range.

Bosch Rexroth Linear and assembly technique	Maria-Theresien-Str. 23 97816 Lohr am Main, Germany info@boschrexroth.de http://www.boschrexroth.com/business_units/brl/de/

Tab. 9-23: Manufacturers of linear guiding systems

9.18 Braking systems and holding devices

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

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

(See also chapter 14.1 "Recommended suppliers of additional components " on page 311).

Further designs about stand-still of linear motors are given in chapter 9.19 "End position shock absorber " on page 235 and chapter 9.23 "Deactivation upon EMERGENCY STOPand in the event of a malfunction " on page 238 as well as in the appropriate functional description of the drive controller.

9.19 End position shock absorber

In the case of linear drives with mostly high travel speeds and accelerations, uncontrolled movements - for example, run-out of the drive in the event of a power failure - cannot be ruled out with certainty.

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

⚠ 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

The necessary spring excursion of the shock absorbers must be taken into account when the end position shock absorbers are integrated into the machine (in particular when the total travel length is determined).

Maximum deceleration during positive stop drive procedure

Specifying the type of mounting and primary part (number of fastening screws, tightening force, mass, etc.), the maximum deceleration when driving to an end stop is obtained. If the maximum deceleration is exceeded, this can cause the primary part to come loose and damage the engine components.

☞ When moving against a fixed stop, the maximum permissible deceleration must be limited to **300 m/s²** by a suitable energy-absorbing end position damper.

Braking distance to be maintained when driving against a hard stop

With the known maximum deceleration and the maximum possible velocity, the minimum spring excursion can be calculated as follows:

$$s_{min} = \frac{v_{max}^2}{2158}$$

s_{min}	Minimum breaking distance in mm
v_{max}	Maximum possible velocity in m/min

Fig. 9-61: Braking distance to be maintained when driving against a hard stop

9.20 Axis cover systems

It is generally possible, to use a wiper for removing chips directly on the secondary part, if the measures to protect the motor installation space or to protect the air gap between primary and secondary part cannot be optimally implemented (see chapter 9.12.4 "Protection of the motor installation space" on page 213). Depending on the application, design, operational principle and features of synchronous linear motors, the following requirements on axis cover systems apply:

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

The following axis cover systems can be used:

- Bellows covers
- Telescopic covers
- Roller covers

A suitable axis cover system should be configured, if possible, during the early development process of the machine or system – supported by the corresponding specialized supplier (see chapter 14.1 "Recommended suppliers of additional components " on page 311).

9.21 Wipers

It is generally possible, to use a wiper for removing chips directly on the secondary part, if the measures to protect the motor installation space or to protect the air gap between primary and secondary part cannot be optimally implemented (see chapter 9.12.4 "Protection of the motor installation space" on page 213).

A significant disadvantage of this measure is, however, if magnet dirt (foreign bodies, chips, swarf, etc.) exists on the secondary part, this is difficult to remove and is afflicted with a high rate of wear because of the powerful attractive forces of the secondary part. The wiper and the motor components should therefore be checked for wear or damage at correspondingly short intervals.

⚠ WARNING **Possible damage of the motor components! Machine breakdown!**

Regularly using a wiper to remove foreign chips (even non-magnetic or non-metallic) can lead to mechanical damage of the secondary or primary part and therewith to a machine breakdown.

Any damage of the motor components due to wipers, does not lie in the responsibility of Bosch Rexroth and does not underlie the seller`s warranties.

The following must be taken into account when selecting and using a suitable wiper system:

Secondary part segments

If possible, a wiper should only be used on integral secondary part segments. If several secondary part segments are used, impacts between the secondary part segments must be taken into account (damage to the scraper or the secondary part segments). In these cases, a defined distance - smaller than the air gap between the primary and secondary part- between the wiper and the secondary part or a wiper in the form of a hard brush can provide a remedy.

☞ If the abutment consists of secondary parts arranged in a row and if machining residues, cooling lubricants, greases, etc. enter the installation space of the motor during operation, the following must also be observed:

- The wiper wores with subject to technical reasons. Dirt, machining residues, etc. are no longer reliably removed with increasing wear.
- Check the pollution degree of the secondary part and the condition of the wiper in regular and specified intervals. Remove any residue that may have accumulated on the surface of the secondary part.

Ferromagnetic foreign bodies

The secondary part attracts ferromagnetic bodies (e.g. chips) at a distance of approx. 100 mm. These attractive forces must be taken into account when ferromagnetic chips are removed.

Temperature development by friction

If the utilization of the wiper causes a significant rise of the temperature on the secondary part surface, it must be ensured that this temperature does not exceed the limit of 70 °C.

Fastening of the wiper

The wiper should be mounted to the superordinate machine construction. It is not permissible to fasten the wiper directly to the primary part by means of additional holes.

⚠ WARNING Damage to or destruction of the motor components due to improper use of a wiper on the secondary part!

- If possible, use only on integral secondary part segments
- Allowance for minor height differences of the secondary part segments
- Observe temperature development by friction
- Consider possible surface damage due to friction
- Direct fastening on the primary part by means of additional bores is not allowed.

9.22 Drive and control of MLF motors

9.22.1 General

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

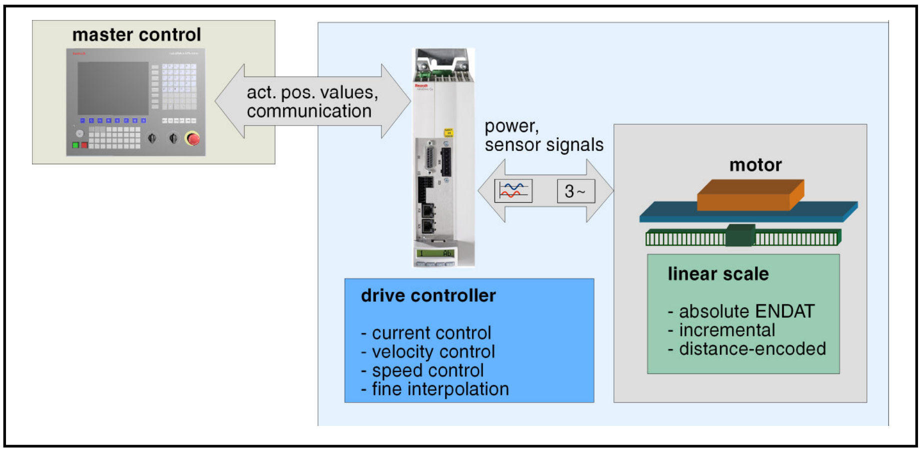


Fig. 9-62: Linear direct drive

9.22.2 Drive controllers and supply modules

For motor control, different digital drive controllers and power supply modules are available. These drive controllers are configurable and modular or compact in design.

☞ The same drive controllers and firmware are used for MLF motors as for Bosch Rexroth rotary drives.

9.22.3 Control systems

A master control is required for generating defined movements. Depending on the functionality of the overall system and the drive interface used, Bosch Rexroth offers different control systems.

9.23 Deactivation upon EMERGENCY STOPand in the event of a malfunction

9.23.1 General

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

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

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

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

☞ In the following, different cases of drive technology of Bosch Rexroth are described.

9.23.2 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.

9.23.3 Deactivation by a master control

Deactivation by control functions

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

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

Drive initiated via the control shutdown

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

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

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

9.23.4 Deactivation via mechanical braking device

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

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

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

- Fault reaction ”0”, ”1” and ”3”.

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

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

9.23.5 Response to a mains failure

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

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

must be provided.

Determining the required additional DC bus capacitor

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

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

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

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

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

Fig. 9-63: 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.

9.23.6 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; thereby the motor phases are short-circuited. However, the achievable braking force is not very high and also depends on the velocity. The DC bus short-circuit can therefore only be used to support existing mechanical braking devices.

9.24 Maximum acceleration changes (Jerk limitation)

Current and force rise rate

The maximum rate of current or force rise is determined by the available DC link voltage and the motor inductance. According to Fig. 9-64 the requirement for the highest possible DC link voltage and low motor inductance arises for highly dynamic movements and short strokes.

$$\frac{di}{dt} = \frac{U_{DC}}{L_{12}}$$

$$\frac{dF}{dt} = \frac{U_{DC}}{L_{12}} \cdot k_{FN}$$

di / dt	Speed of change of the current in A/s
U_{DC}	DC bus voltages in V
L_{12}	Winding inductivity in H
k_{FN}	Motor constant (force constant) in N/A
i	Current in A
t	Time in s

Fig. 9-64: Maximum rate of current and force rise

The change in acceleration per time (derivative of acceleration) is called jerk(Fig. 9-65).

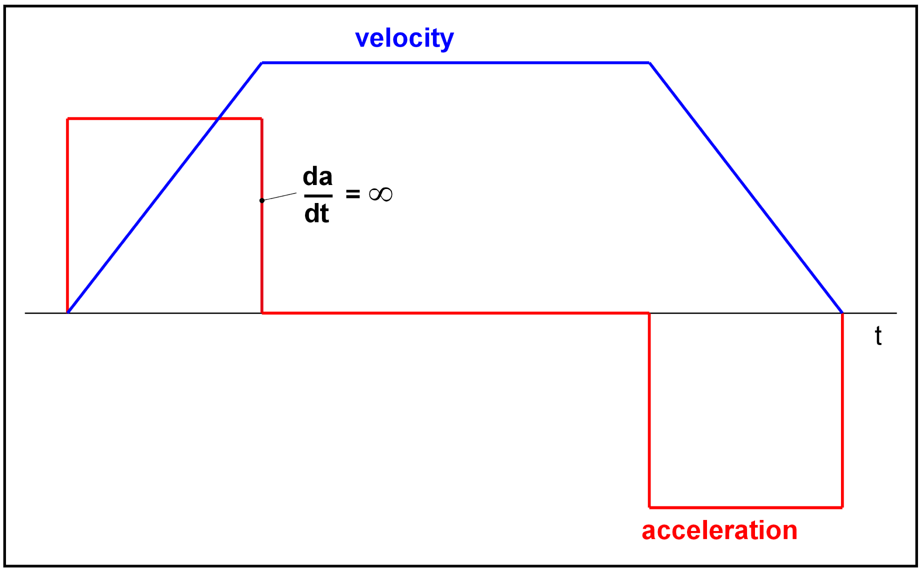


Fig. 9-65: Acceleration and speed without jerk limitation

☞ The drive controller or the master control must delimit the maximum jerk when direct drives are employed (acceleration ramp with da/dt ≠ ∞Abb. 9-66).

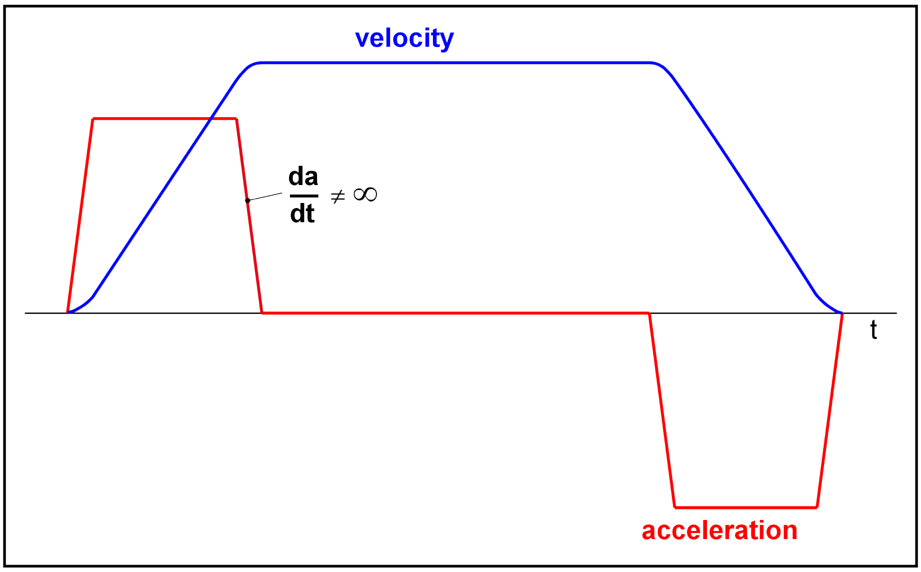


Fig. 9-66: Acceleration and speed with jerk limitation

Maximum jerk

The maximum jerk is determined by the maximum rate of current rise and by the moving mass and motor constant:

$$r_{\max} = \frac{da}{dt} = \frac{U_{DC} \cdot k_{FN}}{L_{12} \cdot m}$$

r_{max}	Maximum jerk in m/s³
m	Moved mass in kg
U_{DC}	DC bus voltage in V
k_{FN}	Motor constant (force constant) in N/A
L_{12}	Winding inductivity in H
a	Acceleration in m/s²
t	Time in s

Fig. 9-67: Maximum jerk (acceleration changes)

9.25 Position and velocity resolution

9.25.1 Drive internal position resolution and position accuracy

In linear direct drives, a linear scale is used for measuring the position. Length measuring systems for linear motors generally provide 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. 9-69). The drive-internal amplification also depends on the maximum travel area and the signal period of the length measuring system. It always employs 2^n grid points (e.g. 2048 or 4096).

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

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. 9-68: Multiplication factor

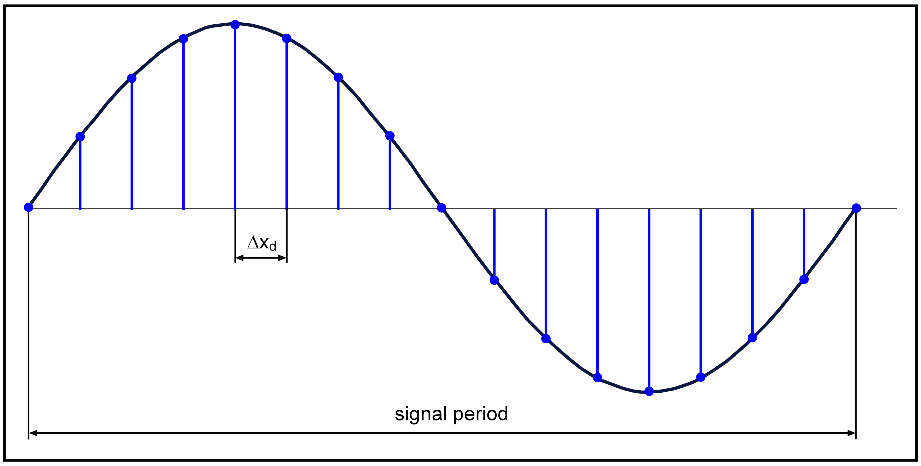


Fig. 9-69: Drive-internal multiplication and/or interpolation of the measuring system signals

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. 9-70: 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_{abs} Position accuracy

Δx_d Drive-internal position resolution

Fig. 9-71: 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.

9.25.2 Velocity resolution

The resolution of the velocity (velocity-quantization) is proportional to the position resolution and inversely proportional to the cycle rate t_{AD} from:

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

Δv_d	Velocity resolution in m/s
Δx_d	Drive-internal position resolution
t_{AD}	Scanning time in s (ECODRIVE03: 500 µs; IndraDrive: Standard Performance 250µs / High Performance 125µs)

Fig. 9-72: Velocity resolution

9.26 Load rigidity

9.26.1 General

The elastic deformation resistance of a structure to an external force is called stiffness and is often expressed in N/µm. The reciprocal of stiffness is called compliance.

When disturbance forces are applied to a controlled electric actuator, the term load stiffness is used. A distinction is made between **static** and **dynamic** load rigidity.

9.26.2 Static load rigidity

The static load stiffness of a linear direct drive depends only on the maximum motor force and the drive-internal position resolution:

$$c_{stat} = \frac{F_{max}}{\Delta x_D}$$

c_{stat}	Static load rigidity in N/µm
F_{max}	Maximum force motor in N
Δx_d	Drive-internal position resolution in µm

Fig. 9-73: Static load rigidity of linear direct drive

☞ When assessing the static load stiffness of a linear direct drive, the stiffness of the machine structure must be taken into account.

$$d_{stat} = \frac{\Delta x_D}{F_{max}}$$

d_{stat}	Static misalignment in µm/N
F_{max}	Maximum force motor in N
Δx_d	Drive-internal position resolution in µm

Fig. 9-74: Static misalignment on linear direct drive

9.26.3 Dynamic load rigidity

The dynamic load stiffness or compliance is a frequency-dependent quantity. The dynamic load rigidity of a linear direct drive only depends on the controller settings (current, velocity and position controller) and on the moved masses (). The maximum compliance or lowest load stiffness is in the range of the natural frequency of the control loop.

The following figure shows a simplified example of a compliance frequency response.

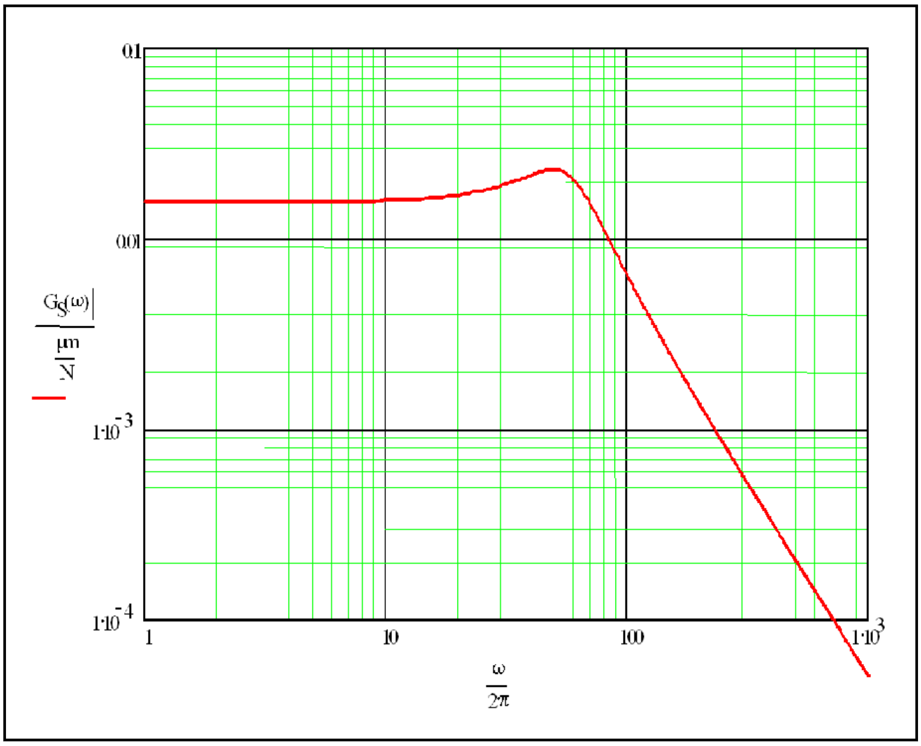


Fig. 9-75: Example misalignment frequency response of a linear direct drive

Estimating of dynamic load rigidity

Despite the frequency dependence, a sufficiently accurate estimate of the dynamic stiffness can be made for the range below the natural frequency of the control loop:

$$c_{dyn} = \frac{0.06 \cdot k_p \cdot k_{FN} \cdot \left(1 + 0.0167 \cdot k_v \cdot T_n\right)}{T_n \cdot \left(1 + \frac{e^{-D \cdot \frac{\pi}{\sqrt{1-D^2}}}}{\sqrt{1-D^2}}\right)}$$

mit / with

$$D = \frac{1}{2} \cdot \sqrt{\frac{0.06 \cdot k_p \cdot k_{FN} \cdot T_n}{m \cdot \left(1 + 0.0167 \cdot k_v \cdot T_n\right)}}$$

c_{dyn}	Dynamic load rigidity in N/μm
k_p	Proportional gain of velocity controller in A • min/m
k_{FN}	Motor constant (force constant) in N/A
k_v	Proportional gain of position controller (Kv-factor) in m/ min • mm
T_n	Integral action time velocity controller in ms
D	Damping
m	Moved total mass in kg

Fig. 9-76: Estimating of dynamic load rigidity

$$d_{dyn} = \frac{1}{c_{dyn}}$$

d_{dyn}	Dynamic compliance in μm/N
c_{dyn}	Dynamic load rigidity in N/μm

Fig. 9-77: Determining of dynamic compliance.

$$\omega_0 = \frac{1}{2 \cdot \pi} \cdot \sqrt{\frac{1000 \cdot k_p \cdot k_{FN} \cdot \left(60 + k_v \cdot T_n\right)}{m \cdot T_n}}$$

ω_0	Natural frequency in Hz
k_p	Proportional gain of velocity controller in A • min/m
k_{FN}	Motor constant (force constant) in N/A
k_v	Proportional gain of position controller (Kv-factor) in m/ min • mm
T_n	Integral action time velocity controller in ms
m	Moved total mass in kg

Fig. 9-78: Determining of natural frequency of controller

10 Motor dimensioning

10.1 General procedure

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

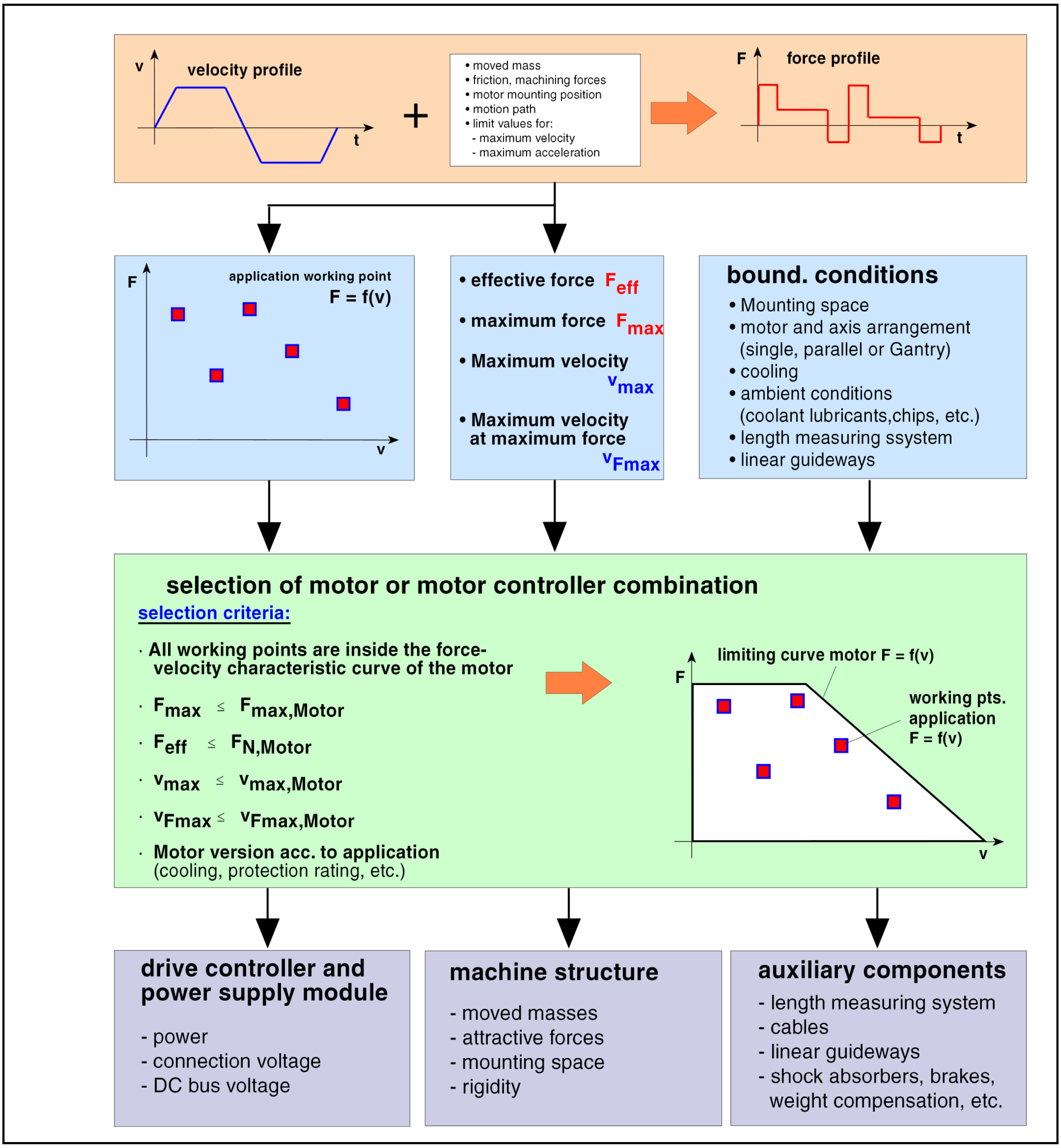


Fig. 10-1: General procedure of linear drives dimension

10.2 Basic formulae

10.2.1 General movement equations

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

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

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

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

Fig. 10-2: General equations of motion

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

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

For sizing, use the Bosch Rexroth application tool IndraSize (see Chapter 4.1.3 on page 26).

10.2.2 Feed forces

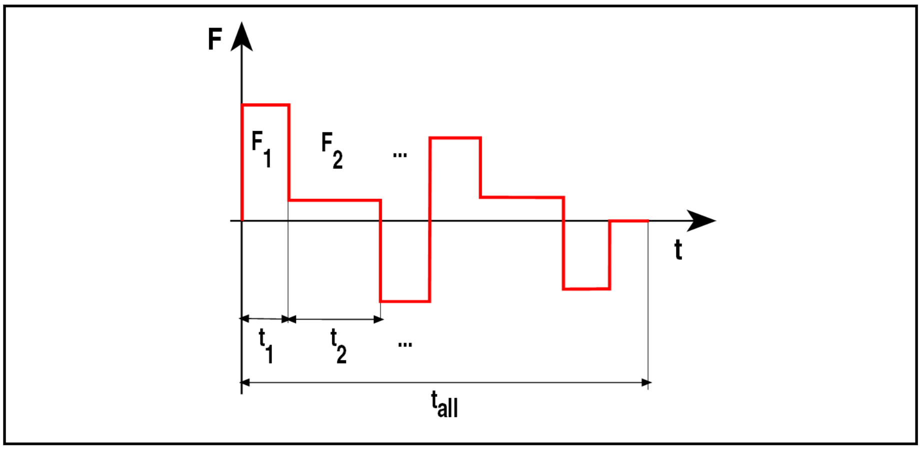


Fig. 10-3: Determining feed forces

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

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

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

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

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

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

Fig. 10-4: Determining feed forces

☞ For dimensioning of linear motor drives, take the moving mass of the motor components into consideration (in particular in case of low load inertia). However, the moving mass and the attractive force among primary and secondary part are only known after the motor has been selected. Thus, first make assumptions for these variables and verify these values after the motor has been selected.

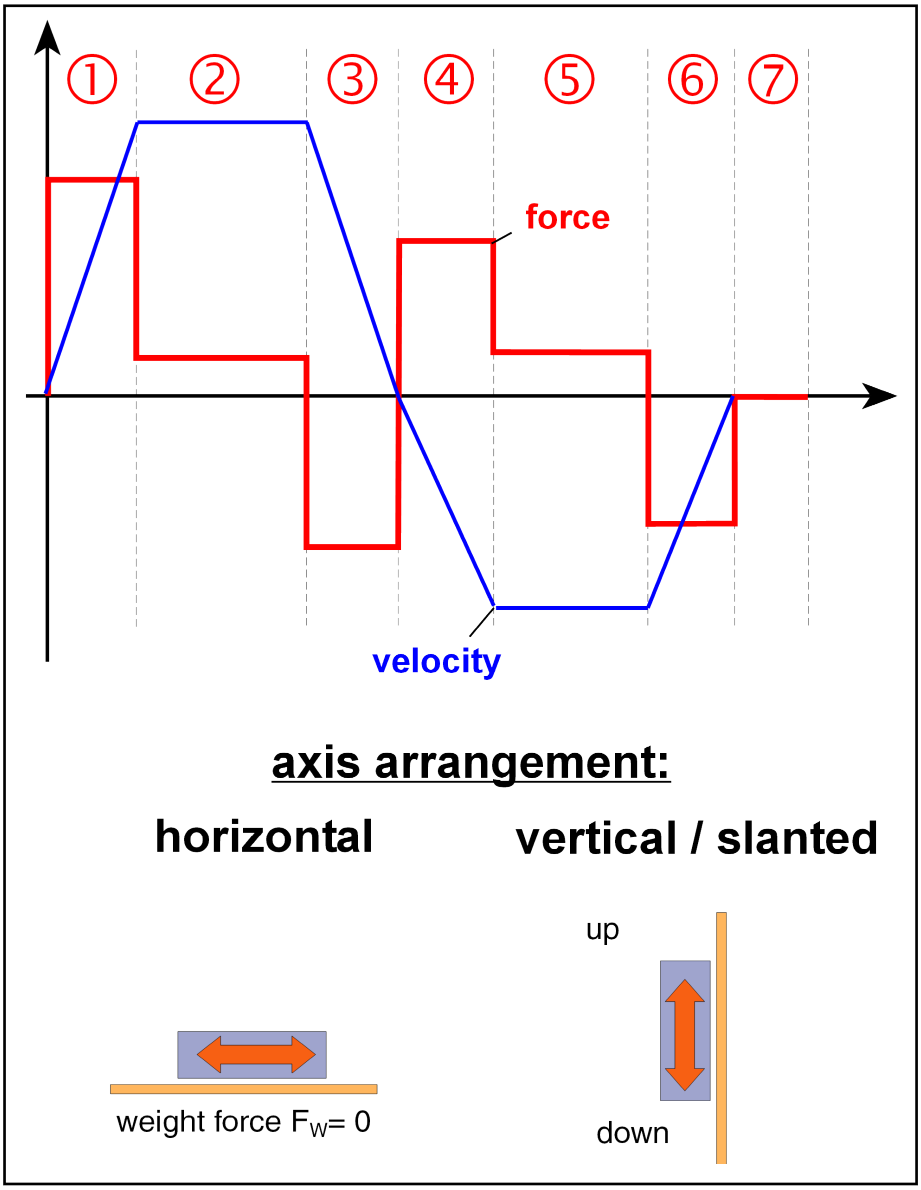


Fig. 10-5: Determining resulting feed forces, dependend from the mode of motion and direction.

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

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

Fig. 10-6: Determining resulting feed forces, dependend from the mode of motion and direction.

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

10.2.3 Average velocity

The mean velocity is required to determine the mechanic continuous power of the drive. The generally valid determination of the average velocity is specified in Fig. 10-2. The following calculation can be used for a user-friendly determination of trapezoidal or triangular speed profiles:

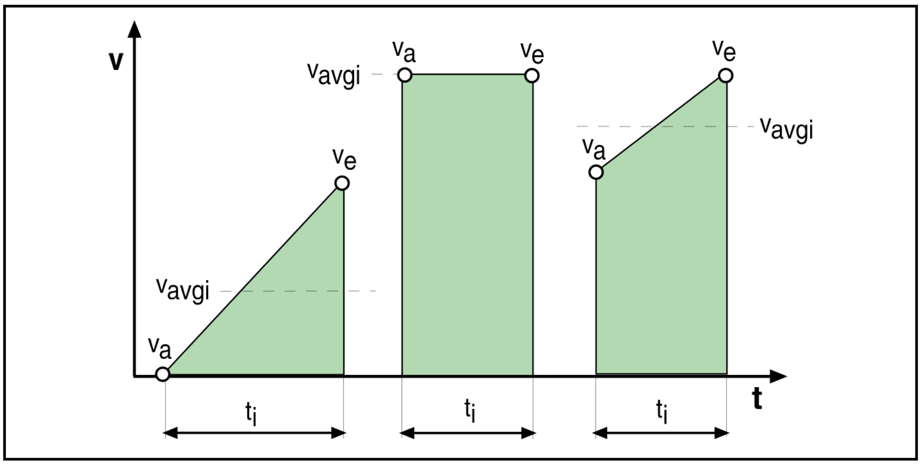


Fig. 10-7: Triangular or trapezoidal velocity profile

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

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

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

Fig. 10-8: Determining the mean velocity of triangular or trapezoidal speed profiles

10.2.4 Trapezoidal velocity

General

This mode of operation is characteristic for the most applications. The acceleration phase is followed by movement at constant speed until the deceleration phase.

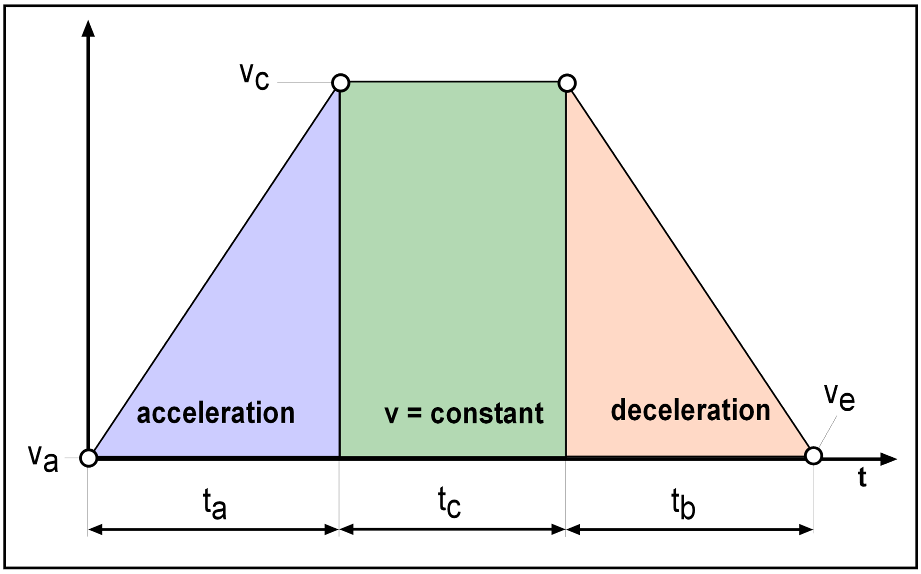


Fig. 10-9: Trapezoidal velocity profile

Acceleration, initial velocity = 0

☞

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

Acceleration:

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

Final velocity:

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

Travel:

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

Time:

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

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

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

Acceleration, initial velocity ≠ 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: $$t_a = \frac{v_c - v_a}{a} = \frac{2 \cdot s}{v_c + v_a} = \frac{\sqrt{2 \cdot a \cdot s + v_a^2} - v_a}{a}$$

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

Fig. 10-11: Constantly accelerated movement, initial velocity ≠ 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	Constant velocity in m/s
t_c	Time during constant velocity in s
s_c	Distance during constant velocity in m

Fig. 10-12: Constant velocity (for trapezoidal velocity profile)

Brakes, final velocity = 0

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

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

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

Fig. 10-13: Constantly decelerated movement, final velocity = 0 (for trapezoidal velocity profile)

Brakes, final velocity ≠ 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: $$t_a = \frac{v_c - v_e}{a} = \frac{2 \cdot s}{v_c + v_e} = \frac{v_c - \sqrt{v_c^2 - 2 \cdot a \cdot s}}{a}$$

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

Fig. 10-14: Constantly accelerated movement, initial velocity ≠ 0 (for trapezoidal velocity profile)

10.2.5 Triangular velocity

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

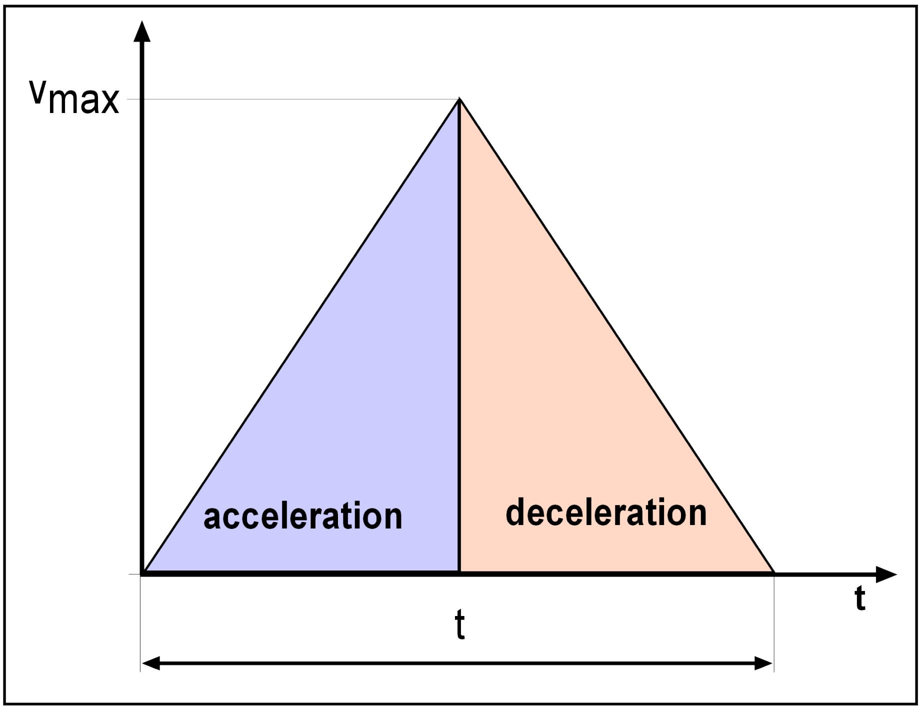


Fig. 10-15: Trapezoidal velocity profile.

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

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

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

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

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

Fig. 10-16: Calculation of triangular velocity profile

10.2.6 Sinusoidal velocity

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

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

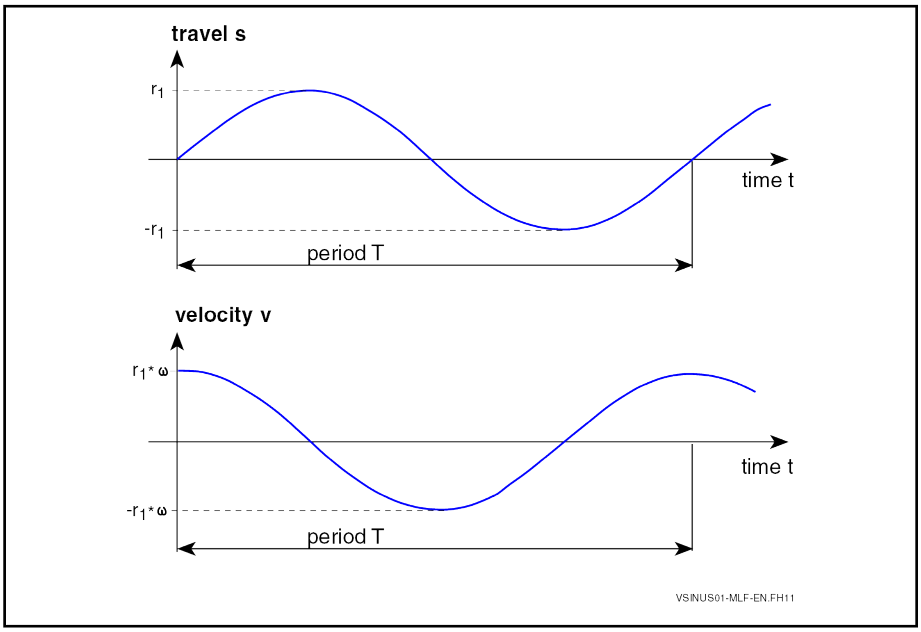


Fig. 10-17: Insert distance and velocity of an axis at sinusoidal velocity

Travel profile:	$s(t) = r_1 \cdot \sin\ (\omega \cdot t)$
Velocity profile:	$v(t) = r_1 \cdot \cos\ (\omega \cdot t) \cdot \omega$
Acceleration profile:	$a(t) = -r_1 \cdot \sin(\omega t) \cdot \omega^2$
Jerk profile:	$r(t) = -r_1 \cdot \cos(\omega t) \cdot \omega^3$
	$\omega = \frac{2 \cdot \pi}{T} = 2 \cdot \pi \cdot f$

Fig. 10-18: Calculation formular for distance and velocity of an axis for sinusoidal velocity

By means of Fig. 10-17 and Fig. 10-18 results in the following calculation base:

Maximum accerlation: $a_{max} = r \cdot \left(\frac{2 \cdot \pi}{T}\right)^2$

Maximum velocity: $v_{max} = r \cdot \frac{2 \cdot \pi}{T}$

Average velocity: $v_{avg} = \frac{2 \cdot v_{max}}{\pi} = \frac{4 \cdot r}{T}$

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

Effective force: $F_{EFF} = \sqrt{\frac{F_{acc}{}^2}{2} + F_0^2}$

Vertical axis arrangement:

$$F_{EFFv} = \sqrt{\frac{F_{acc}^2 + F_{0\,up}^2 + F_{0\,down}^2}{2}}$$

Base force up movement: $F_{0\,up} = F_0 + F_w$

Base force down movement: $F_{0\,down} = F_0 - F_w$

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

Fig. 10-19: Calculation formula for sinusoidal velocity profile

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

10.3 Duty cycle and feed force

10.3.1 General

The relative duty cycle ED specifies the duty cycle percentage of the load with respect to a total duty cycle time, including idle time. The thermal load capacity of the motor limits the duty cycle. Loading the motor with a continuous nominal force is possible during the entire duty cycle time. To avoid thermal overload at motors with higher feed forces reduce the duty cycle at F > F_{dN} (see Fig. 10-20).

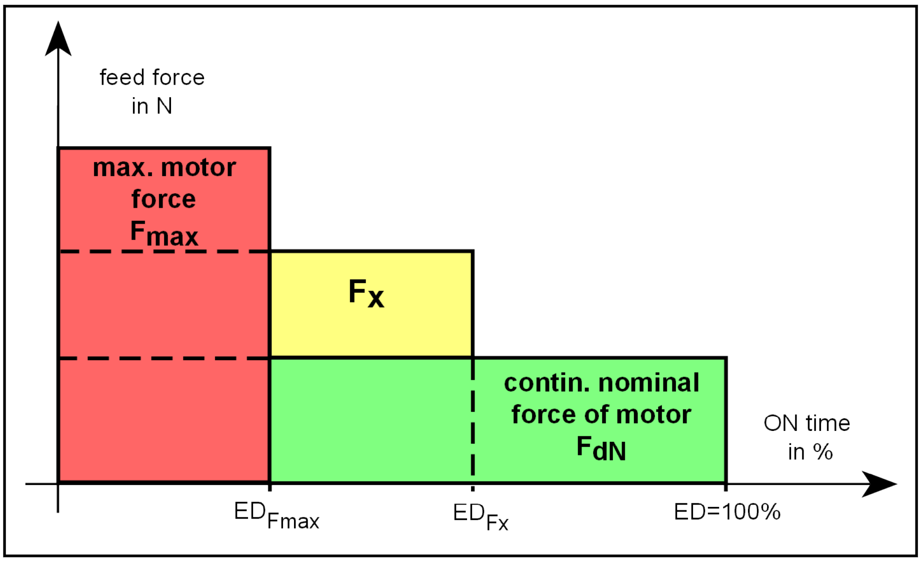


Fig. 10-20: Correlation between duty cycle and feed force.

10.3.2 Determining the duty cycle

The approximate determination of the relative duty cycle ED_{ideal} is performed via the correlation:

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

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

Fig. 10-21: Approximate determination of duty cycle ED

Prerequisites: Linear correlation between feed force and current.

For MLF motors acc. to Fig. 10-21, only an approximate duty cycle calculation is possible since there is a non-linear correlation between torque and current.

This calculation is valid for a rough determination of possible duty cycle at short-time duty forces with $F_{KB} \leq 1.5\ F_{dN}$.

☞ For an exact determination of the relative duty cycle of the MLF synchronous torque motors, use Fig. 10-22 or Fig. 10-23.

The non-linearity of the characteristic curve force via current of synchronous linear motors lead to an increased rise of power loss at higher torque forces. This increased power loss leads – in particular at a high percentage of acceleration and deceleration processes – to a possible duty cycle that is reduced with respect to Fig. 10-21.

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

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

Fig. 10-22: Determining the duty cycle ED

Prerequisites: Duty cycle time ≤ Thermal time constant of motor

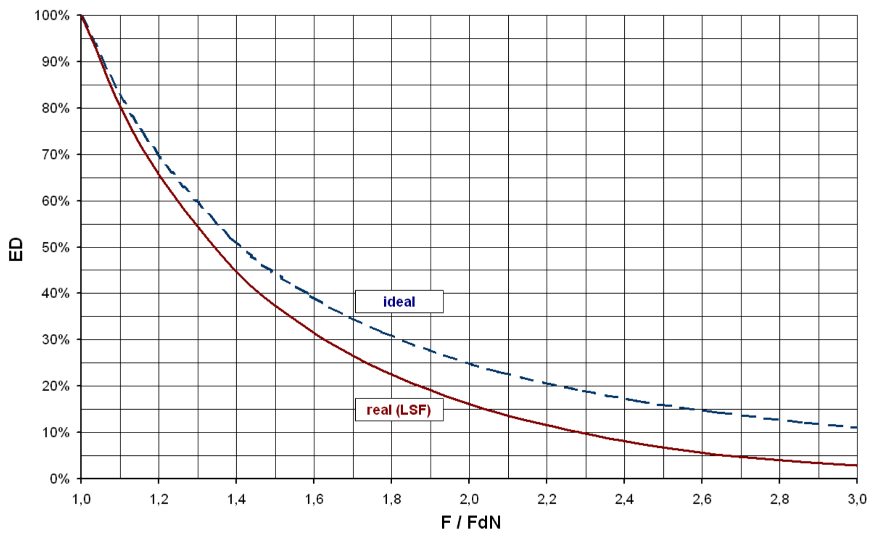


Fig. 10-23: Duty cycle via force for MLF synchronous linear motors

☞ In standstill operation, there is an uneven distribution of losses in the motor. Therefore, this must be consideres separately. Please observe the information in Chapter 9.15 on page 228.

10.4 Determining the drive power

10.4.1 General

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

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

10.4.2 Continuous power

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

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

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

Rated electrical output: $P_{ce} = \left(\frac{F_{eff}}{F_{dn}}\right)^2 \cdot P_{vn} \quad with \quad F_{eff} \leq F_{dn}$

P_c	Continuous power in W
P_{cm}	Mechanical continuous power in W
P_{ce}	Electrical continuous power loss of motor in W
F_{eff}	Effective force in N (from application)
v_{avg}	Average velocity in m/s
F_{dn}	Nominal force of the motor in N
P_{vn}	Nominal power loss of the motor in W

Fig. 10-24: Continuous power of the linear motor

☞ When reducing the continuous nominal force, the electric continuous power is also reduced (seeFig. 10-24).

10.4.3 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.

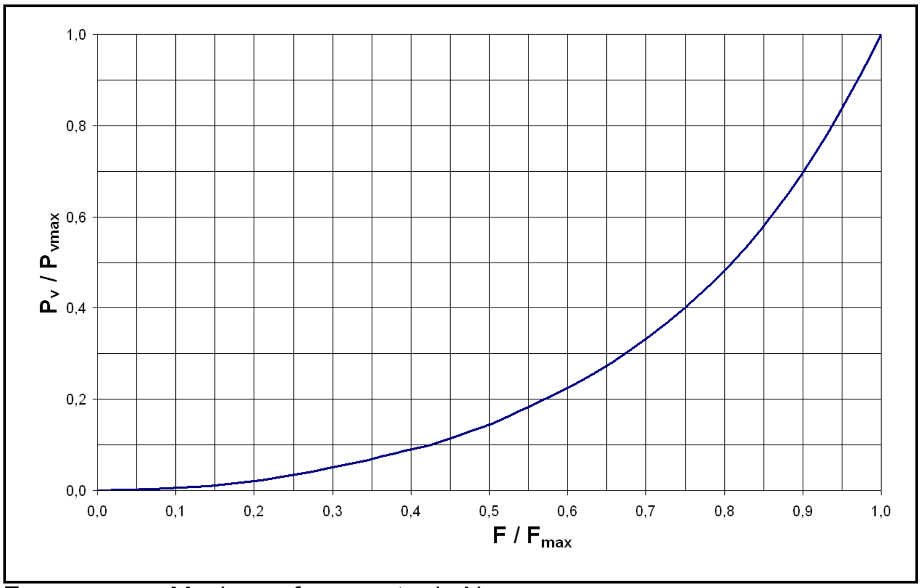
Total maximum power: $P_{max} = P_{max\,m} + P_{max\,e}$

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 Fig. 10-26)
F_{max}	Maximum feed force in N
v_{Fmax}	Maximum velocity with F_{max} in N

Fig. 10-25: Maximum power of the linear motor

☞ If the maximum feed force is reduced in relation to the achievable maximum force of the motor, the maximum electrical power is also reduced P_{maxe}. To determine the reduced electrical maximum output P_{maxe}, use Fig. 10-26.



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

Fig. 10-26: Diagram used for determining the reduced electrical power loss

10.4.4 Cooling capacity

The necessary cooling capacity corresponds the electric continuous power loss of the motor.

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

P_{co}	Required cooling capacity in W
P_{ce}	Electrical power loss of motor in W
F_{eff}	Effective force in N
F_{dn}	Nominal force of the motor in N
P_{vn}	Nominal power loss of the motor in W

Fig. 10-27: Required cooling capacity of the linear motor

10.4.5 Energy regeneration

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

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

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

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

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

P_R	Energy regeneration during a braking phase in W
P_{Ravg}	Average energy regeneration over total cycle duration in W
m	Moved mass in kg
v	Maximum velocity in m/s
t_b	Braking time in s
F_R	Friction force in N
R_{12}	Winding resistance of the motor at 20°C in ohms
$R_{12, warm}$	Winding resistance of the motor at operational temperature
$\Delta\vartheta$	Temperature difference between operation temperature and 20 °C
α_{Cu}	Temperature coefficient 0.0039 1/K
a_{max}	Brake retardation (negative acceleration) in m/s²
k_{iFN}	Motor constant in N/A
t_{all}	Total cycle duration in s

Fig. 10-28: Energy regeneration of linear motor

Prerequisites: Velocity-independent friction

Constant deceleration

Final velocity = 0

☞ If the determined regenerative power according to Fig. 10-28 is negative, no energy is fed back, i.e. energy must be supplied to the motor during braking.

10.5 Efficiency

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

The motor efficiency can be determined or estimated with the help of Fig. 10-29 and Fig. 10-30.

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

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

Fig. 10-29: Efficiency determination for linear motors

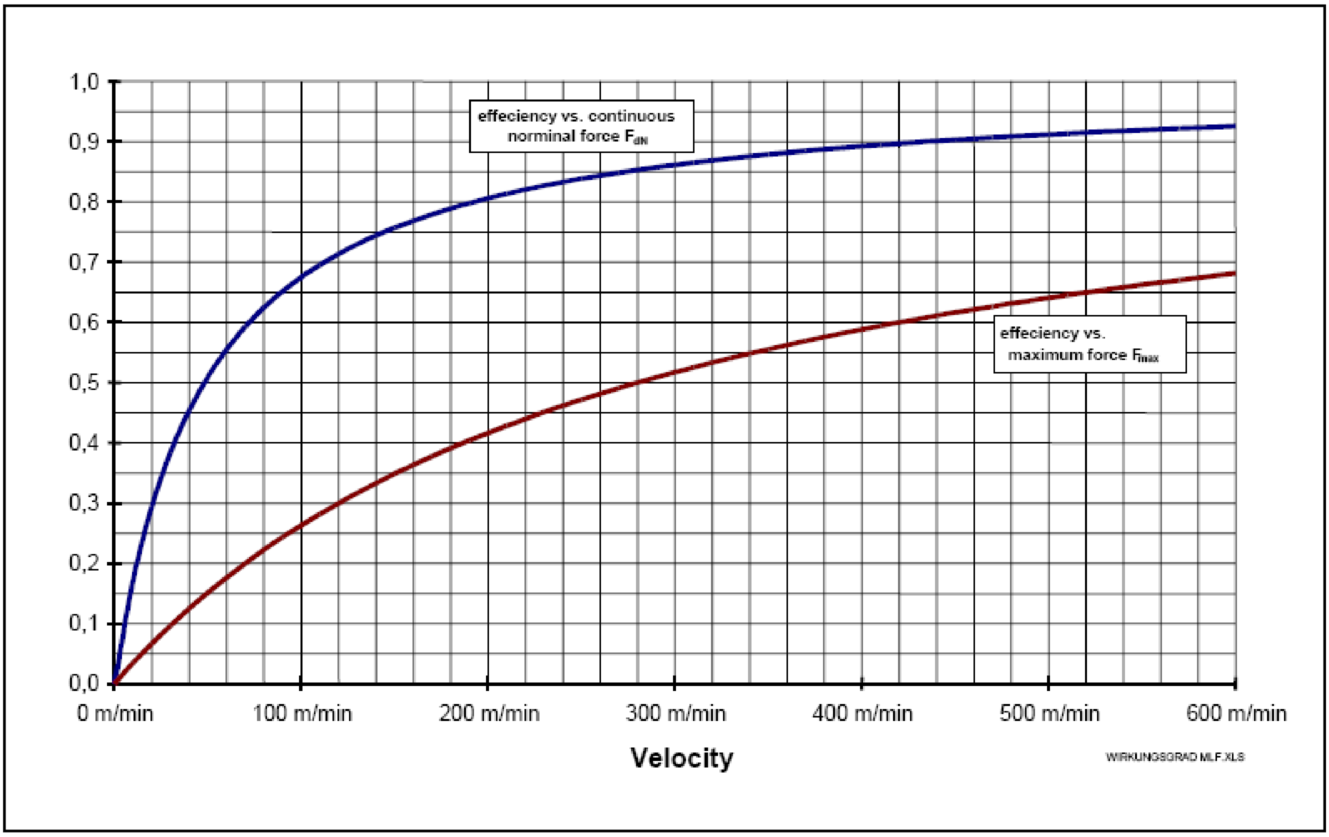


Fig. 10-30: Efficiency via velocity for MLF synchronous linear motors

☞ In standstill operation, there is an uneven distribution of losses in the motor. Therefore, this must be consideres separately. Please observe the information inChapter 9.15 .

11 Handling, transport and storage

11.1 Delivery status and packaging

11.1.1 Packaging

☞ Preferably use the original package for storage, transport and when using the motor components. In particular, keep the packaging of the secondary part for later use for reasons of work and transport safety.

The original package of the secondary parts offers a reliably protects from heavy magnetic forces of the affixed permanent magnets. In the case of re-use, ensure a good readability of the safety notes on the package. They must not be paste over! Additionally observe the supplementary notes about packaging and handling of secondary parts under chapter 3.3.6 "Protection during handling and assembly" on page 20.

11.1.2 Primary parts

Depending from their frame size, primary parts are separately packed in a cardboard box or a wooden crate. For identification, the package is marked with a label with the type designation of the primary part.

11.1.3 Secondary parts

Depending from their frame size, secondary parts are separately or more packed in a cardboard box or a wooden crate. For identification, the package is marked with a label with the type designation of the secondary part.

Warning notes on the package of the secondary parts

On the packaging of the secondary parts, a self-adhesive warning label with the following warnings:

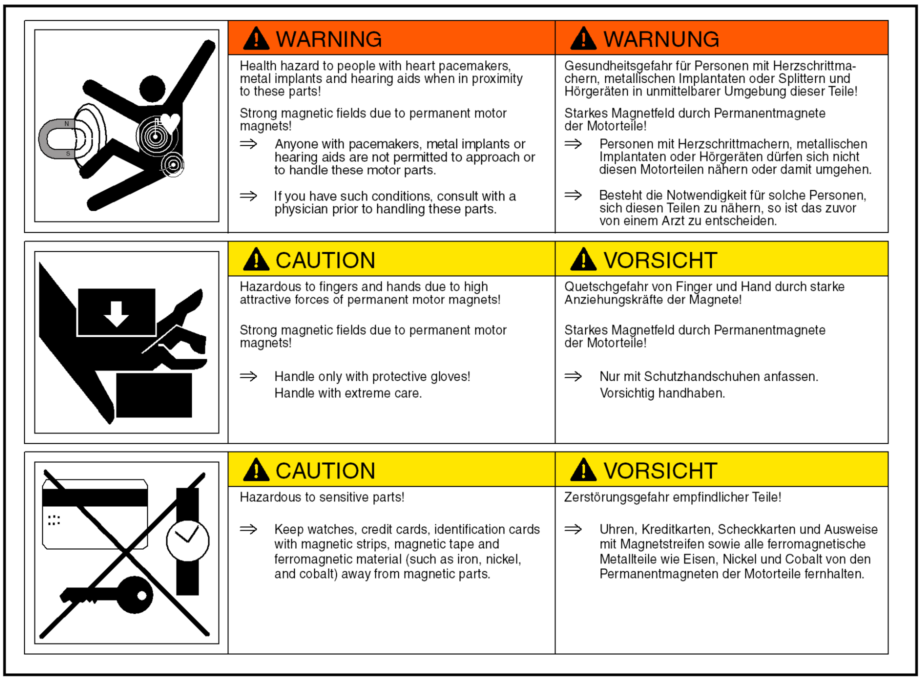


Fig. 11-1: Warning label on the package of MLS secondary parts

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

Additionally observe the supplementary notes about packaging and handling of secondary parts under chapter 3.3.6 "Protection during handling and assembly" on page 20.

11.1.4 Factory checks of the motor components

Electrical testing

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

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

Mechanical testing

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

- Shape and position tolerance according to DIN ISO 1101
- Construction and fitting according to DIN 7157
- Surface structure according to DIN ISO1302
- Thread testing DIN 13 part 20
- Leakage test of the cooling circuit

EMC radio interference suppression

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

EN 55011 Limit Class B, VDE 0875 Part 11

11.1.5 Customer test

Since all motors undergo a standardized test procedure, high-voltage tests on the customer side are not required. Motors and components could be damaged if they are subjected to repeated high-voltage tests.

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

- Avoid repeated inspections.
- Observe the guidelines of DIN EN 60034-1.

11.1.6 Scope of delivery

The total scope of delivery can be seen from the delivery note or the accompanying document. The content, however, can be delivered in several packages. Each package can be identified by a forwarding label.

☞ Compare the ordered and delivered types after receipt of the goods. Reclaim deviations immediately.

11.2 Transport and storage

11.2.1 General

Also refer to the notes regarding storage and transport on the package and accompanying papers.

⚠ WARNING **Strong attractive forces due to permanent magnets on the secondary part! Risk of injury and danger of crushing body parts by magnetic forces!**

When using secondary parts, please observe the safety notes under chapter 3.3.4 "Protection against magnetic and electromagnetic fields" on page 18 and chapter 3.3.6 "Protection during handling and assembly" on page 20.

⚠ CAUTION **Damage or injuries and loss of the warranty due to improper handling! Heavy weight!**

- Protect the products against moisture and corrosion .
- Avoid mechanical loads, strokes, throwing, tilting or dropping of the products.
- Use only suitable lifting gear.
- Do not lift the motor at its connectors, cables or connection fittings.
- Use suitable protective equipment and protective clothing during transport.

11.2.2 Transport instructions

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

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

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

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

Tab. 11-1: Allowed classes of environmental conditions during transport

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

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

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

1) Differs from DIN EN 60721-3-2

Tab. 11-2: Deviating permissible storage conditions

To lift the motor out of the transport crate or to install the motor into the machine, use the transport or lifting eyebolts at the motor.

The lifting eyebolts at least must meet the requirements of DIN 580. Before each transport, ensure that the lifting eyebolts have been screwed down fully to the contact surface and that your selected lifting equipment and lifting method does not overstress the lifting eyebolts.

☞ Please comply with DIN 580 on the transport of motors. Non-observance of the information in this standard can cause overstress to the lifting eyebolts and result in personal injury and/or product damage.

☞ Before transport, empty the liquid coolant from the liquid-cooled motors to avoid damage.

Transport primary part

Depending from size and weight of the primary part it is no longer possible to transport it by hand. In this case, use suitable lifting tools.

To move the primary part in horizontal position, transport it by ring screws, for example. Therefore, please observe the thread dimensions in the dimension sheet of the primary part.

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

- For example, use the two or four of the outermost diagonally opposite threaded holes on the mounting side of the MLP (see Fig. 11-2).
- Manually screw the ring screws into the fastening thread as far as possible or the base of head of the ring screw lies on the primary part. Do not exceed the permitted thread depths.
- Use 4 lifting belts of equal lengths to reach a uniform load of the threaded holes and to prevent tilting of the primary parts during transport.

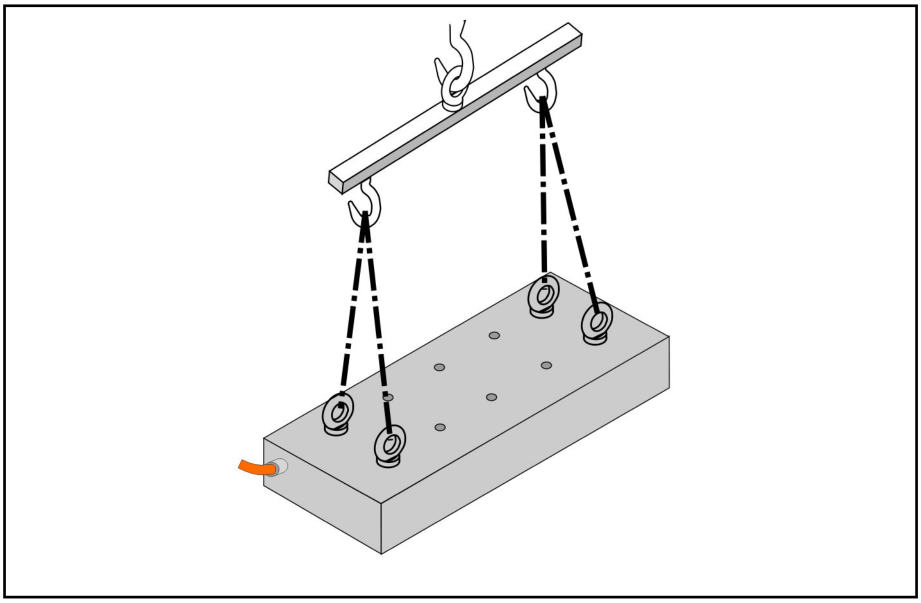


Fig. 11-2: Transport primary part (example)

Transport secondary part

⚠ WARNING **Strong attractive forces on the permanent magnets on the secondary part! Risk of injury and danger of crushing body parts by magnetic forces!**

- When using secondary parts, please observe the safety notes under chapter 3.3.4 "Protection against magnetic and electromagnetic fields" on page 18 and chapter 3.3.6 "Protection during handling and assembly" on page 20.
- Remove styrofoam which is stuck on the cover plate only when or after mounting into the machine (see Fig. 11-3).

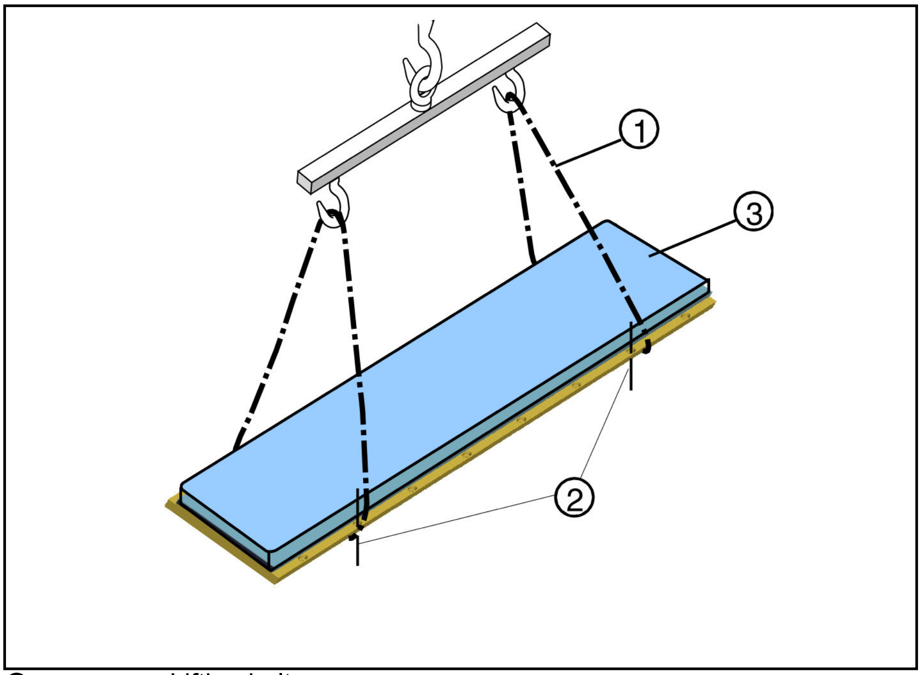
Depending from size and weight of the secondary part it is no longer possible to transport it by hand. Due to heavy magnetic fields near the secondary part, use antimagnetic lifting devices.

Safety during transport on lifting belt.

To prevent slipping lifting belts during transport, secure it. Therefore, two fastening screws for the secondary part can be connected into the appropriate holes on the secondary part (see Fig. 11-3). Ensure sufficient protrusion of the securing underneath the secondary part.

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

Use an antimagnetic securing with lifting belts during transport of secondary parts. The securing prevents from sliding of lifting belts during transport.



① Lifting belts
② Safety against sliding lifting belts. To transport MLS300 use the two ring screws.
③ Affixed styrofoam plate

Fig. 11-3: Transport secondary part (example)

☞ Due to their size and weight, secondary parts of size 300 have two additional threaded holes (M10) to fix the ring screws for transport. For exact position of the threaded holes, refer to the dimension sheet of MLS300 Fig.5-31.

Further features about transport of secondary parts

The permanent magnets of the secondary parts of synchronous linear motors are magnetically not shielded. Please observe the safety notes (fig. 11-1 "Warning label on the package of MLS secondary parts" on page 269) and the specified safety notes when handling the secondary part.

Instructions on transport by air

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

If rmotor components are not forwarded in the unopened Rexroth original packaging, applicable packaging and transport regulations must be observed (IATA 953).

This involves, for example:

- Secondary parts of synchronous linear motors
- Rotors of synchronous kit motors
- Rotors of synchronous housing motors (if these are dispatched as motor component, i.e. separate from the stator or motor housing, in service cases)

Please also observe the information provided under "Air freight (IATA953)" on page 190. For details on the maximum allowed magnetic field strengths as well as information on measurement methods for these magnetic field strengths, please refer to the current IATA DGR.

11.2.3 Storage instructions

Storage of primary and secondary parts

Preferably use the original package to store the parts. If this is not possible, the components, i.e. primary and secondary parts, of synchronous linear motors must be supported over their entire surface when stored on a flat base. This must also be ensured in the case of brief discarding.

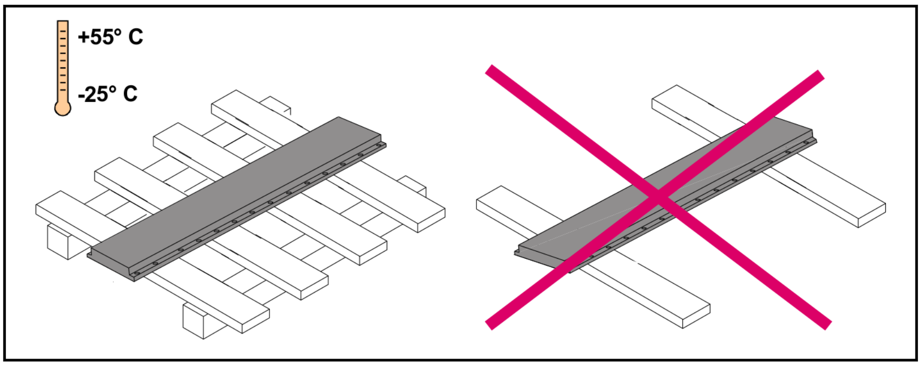


Fig. 11-4: Storage of linear motor components

⚠ CAUTION **Damage or destruction of motor components due to improperly handling during storage and transport!**

- Use the original packaging for permanent storage.
- Observe the ambient conditions for storage and transport.
- Short-term storage during installation acc. to Fig. 11-4
- Do not throw parts
- Remove the transport or assembly protection only when or after mounting into the machine

On delivery, protective sleeves and covers may be attached to our motors. They have to remain on the motor for transport and storage. Do not remove these parts until shortly before assembly.

Based on DIN EN 60721-3-1, the tables below specify classifications and limit values which are allowed for our products while they are stored. Refer to the detailed description of the classifications to take all of the factors which are specified in the particular classification into account.

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

Classification type	Class
Classification of climatic environmental conditions	1K21
Classification of biological environmental conditions	1B1
Classification of chemically active materials	1C1
Classification of mechanically active materials	1S10
Classification of mechanical environmental conditions	1M11

Tab. 11-3: Allowed classes of environmental conditions during storage

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

Deviating from DIN EN 60721-3-1 permissible ambient conditions

Environmental factor	Unit	Value [1)]
Air temperature	°C	-25 ... +55
Relative air humidity	%	5 ... 75
Absolute air humidity	g/m³	1 ... 29
Insolation	-/-	Not permitted

1) Differs from DIN EN 60721-3-1

Tab. 11-4: Deviating permissible storage conditions

☞ Before re-storage, empty the liquid coolant from the liquid-cooled motors to avoid damage.

Storage times motors

Irrespective of the storage duration - which can exceed the warranty period of our products - the function is retained provided additional measures are taken into account and carried out during commissioning. However, this does not entail any additional warranty claims.

Storage time	Measures prior to commissioning
< 1 year	Visual inspection of all parts to be damage-free
1 ... > 5 years	Visual inspection of all parts to be damage-free Check the electric contacts to verify that they are free from corrosion Measure insulation resistance. Dry the winding at a value of < 1kOhm per volt rated voltage. Visually inspect the cable jacket. Do not use the cable if you detect any abnormalities (squeezed or kinked spots, color deviations, ...).

Tab. 11-5: Measures before commissioning motors that have been stored over a prolonged period of time

12 Assembly

12.1 General notes

To keep the following points is the basic prerequisite for installation of MLF components

- Observation of the necessary installation sizes (see chapter 5.2.1 "Dimensions and tolerances" on page 97)
- Machine construction fulfills the requirements for mounting (stiffness, attractive force, feed and acceleration force, etc.)
- Machine construction is prepared for installation of all components.
- Clean screw-on surfaces between machine and motor components
- The installation is performed by skilled personnel.
- Compliance of danger and safety notes is guaranteed.

12.2 General safety instructions

⚠ WARNING **Strong attractive forces on the permanent magnets on the secondary part! Risk of injury and danger of crushing body parts by magnetic forces!**

When using secondary parts, please observe the safety notes under chapter 3.3.4 "Protection against magnetic and electromagnetic fields" on page 18 and chapter 3.3.6 "Protection during handling and assembly" on page 20.

⚠ WARNING **Injuries caused by live parts! Lifting of heavy loads! Risk of damage!**

- Carry out all work steps with particular care. This minimizes the risk of accidents and damage.
- Use suitable lifting equipment and protective equipment and wear protective clothing during transport.
- Do not lift or move the motor at the cable strand.
- Install the motors only when they are de-energized and not connected electrically.

The volume and order of the steps described can be affected by special features of the machine construction and deviate from the schematic procedure. The following description only serves for orientation. The machine manufacturer's mounting instructions are the only binding guidelines.

Work space, handling and transport

Sufficiently mark your work space with notes according to Fig.11-1 and observe the handling and transport instructions under chapter 11.2 "Transport and storage" on page 271.

Accident prevention

The accident prevention “Electrical plant and apparatus” (VBG 4) has to be complied with:

Prior to working on shock-hazardous parts of electrical systems, ensure that these parts are de-energized and remain de-energized during the duration of the work. The electrical plant and apparatus has to be checked before initial startup by an electrician to ensure that they are in proper condition.

The user is responsible for proper grounding of the complete plant. To prevent accidents due to touching of live parts, protective measures against direct and indirect touch are necessary. For notes, refer to DIN VDE 0100, Part 410.

12.3 Screw lock

All screwed connections have to be secured against potential impacts and vibrations during operation of the machine. A suitable and field-tested screw lock for all metal thread connections is, e.g., Loctite 243.

Loctite 243 is a liquid screw lock (medium-hard) and is applied to the parts to be mounted immediately prior to assembly. For detailed information on correct handling and processing, please refer to the manufacturer's data sheets under http://www.loctite.de. The manufacturer's homepage also provides information on hardening accelerators or other screw locks.

12.4 Assembly of secondary parts

12.4.1 General

The installation of the motor in the machine design depends on the type of secondary part arrangement and can therefore also be carried out in different ways:

- Installation at a path with several secondary parts
- Installation at a path with one secondary part

☞ The described procedures are only suggestions and can be proceed in another way with regard to a specific application.

⚠ WARNING **Damage of motor components!**

Remove the transport and installation protection of the secondary part only after mounting of the secondary parts.

☞ To fasten the secondary parts, it is only allowed to use new, unused screws.

All screws have to be tightened with the specified tightening torque (seeFig. 12-1 on page 279) and provided with screw lock.

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. It must be expected that certain influences continuously occur during motor operation, contact of secondary part with coolant lubricants, grinding emulsion, and others, for example. This can reduce the kinetic friction among the screwed parts during the machine lifetime. In this case, we recommend to use screws with a higher fastening class, like 10.9, to realize a higher tightening torque.

The tightening torques of the fastening screws is specified in the following table:

Frame size secondary part	Screw size	Fastening class	Tightening torque (+/- 10%)
040, 070, 100, 140, 200	M6 (DIN 7984, flat head) M6 (DIN EN ISO 4762)	8.8	10 Nm
		10.9	15 Nm
052, 102, 152, 202	M8 (DIN 7984, flat head) M8 (DIN EN ISO 4762)	10.9	37 Nm
300	M8 (DIN EN ISO 4762)	10.9	37 Nm

Tab. 12-1: Fastening screws with tightening torques for MLS secondary parts

By using screws with a flat head according to DIN 7984, the excess length of the screw heads over the rail fastening at the side is reduced.

The calculation of screw connection for fastening the secondary part are based on the assumption that the screwing surface of the secondary part and the screwing surface of the machine is clean and the secondary part is screwed in direct contact with the machine (see Fig. 9-13 on page 195).

- In certain cases, it is not possible to screw the secondary part in direct contact with the machine as additional materials like distance plates, thermal grease and so on, are between the secondary part and the machine. Then a sufficient fastening of the screw connection must be ensured by the machine manufacturer.
- The effect of liquid screw lock is damaged by loosening or re-tightening of screws (e.g. due to torque tests) and must be renewed.

12.4.2 Installation at a path with several secondary parts

⚠ WARNING **Malfunction and / or uncontrolled movement of the motor and therewith danger of material damage or risk of injuries!**

Correct concatenation of secondary part segments

If several secondary part segments are used over the whole traverse path, keep the poles and the flush direction at concatenation according to the following figure.

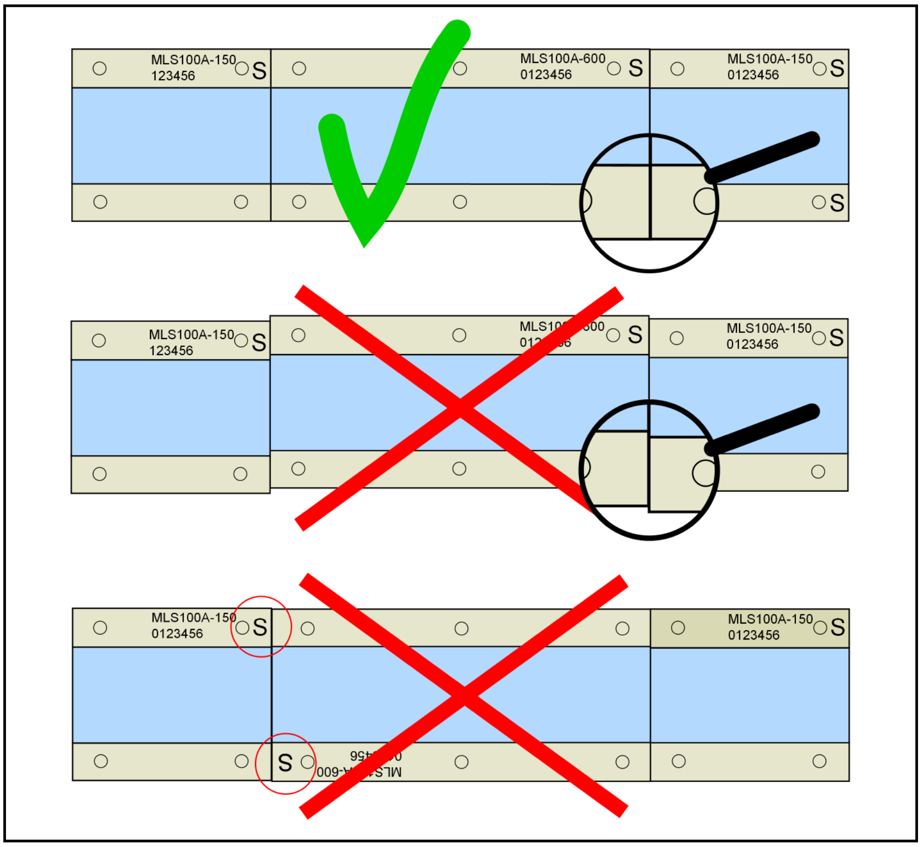


Fig. 12-1: Concatenation of several secondary part segments

⚠ WARNING **Risk of injuries or material damage due to attractive or repulsive force at concatenation of secondary part segments!**

- Secure against uncontrolled movement
- Remove the transport or assembly protection only when or after mounting into the machine

The attractive or repulsive force when arranging the secondary part segments can be up to 300 N depending from their frame size.

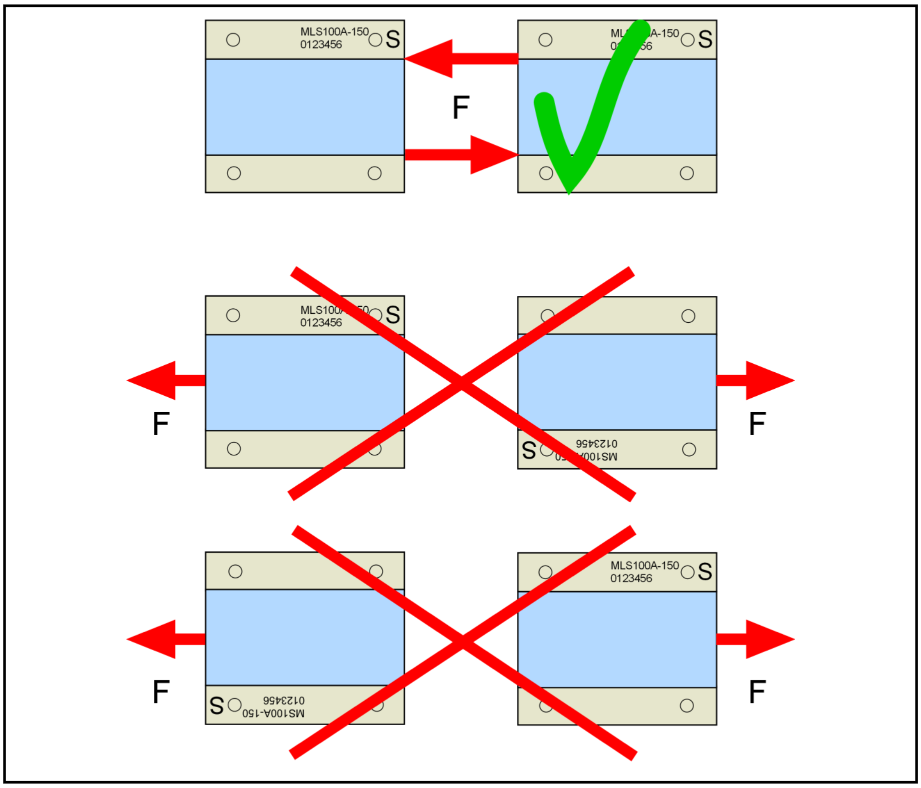


Fig. 12-2: *Attractive or repulsive force when arranging the secondary part segments*

In the case of a path consisting of several secondary parts, the assembly can be made as followsFig. 12-3 Here, only one part of the secondary parts is initially installed so that the primary part can be placed on the machine bed during its assembly.

⚠ WARNING **Do not deposit the primary part directly onto the secondary part!**

Lifting the primary part from the secondary part is very difficult due to the high attraction forces (fixture required). In addition, there is a risk of mechanical damage to the secondary and/or primary part during placement.

After that, the primary part can be assembled in the already installed slide. The slide with the primary part installed can then be slid over the previously installed secondary parts. Then, assemble the remaining secondary parts.

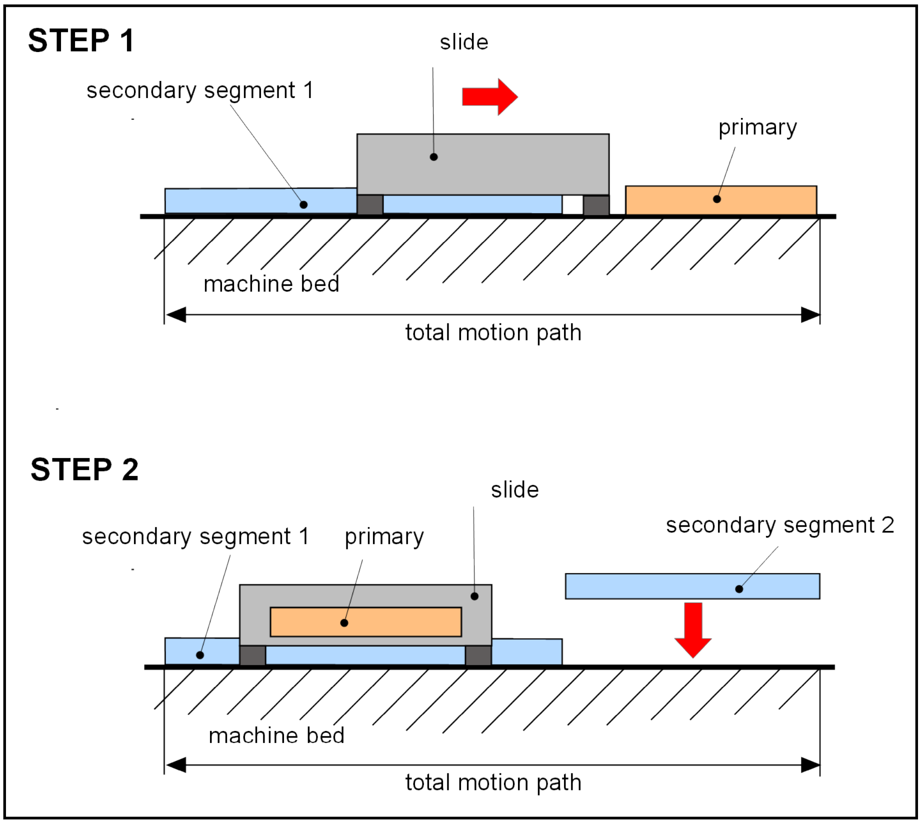


Fig. 12-3: Installation of linear motor components at a path with several secondary parts

⚠ CAUTION **Uncontrolled movement of the slide! Crushing hazard or risk of injury!**

Secure the slide against uncontrolled movement due to partial overlapped primary and secondary parts (force in traverse direction).

12.4.3 Installation at a path with one secondary part

In the case of a path consisting of one secondary part only, the primary part can be preassembled on the slide that has not yet been installed. After the secondary part has been installed, the slide with preassembled primary part can be lowered onto the machine bed by means of a suitable device.

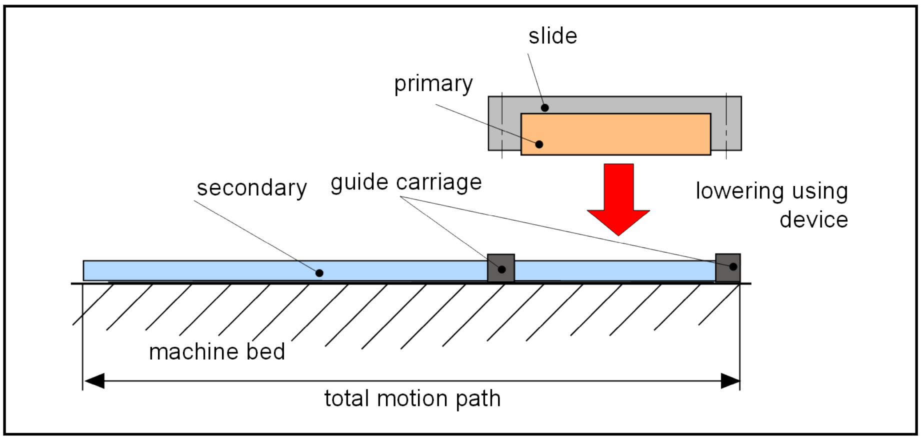


Fig. 12-4: Installation of linear motor components at a path consisting of one single secondary part.

☞ A fixture to lower the primary part or the slide is not in the scope of delivery of Bosch Rexroth.

⚠ CAUTION **As soon as the primary part is lowered onto the secondary part, the attractive forces will increase as a result of the reduced air gap.**

- Heed the specifications in Chapter 9.14 on page 221.
- Do not put down the primary part onto the secondary part by a crane (elasticity / attractive force).

Another option is to place the primary part on the installed secondary part - also using a suitable device - and then screw it into the slide using the fastening screws. In this case, a non-ferromagnetic distance plate (plastic, wood, etc.) must be inserted between the primary and secondary parts so that the primary part does not directly contact the secondary part. The thickness of the distance plate must be dimensioned in such a way that it is possible to move the slide after the primary part has been screwed to it. The thickness of the distance plate must be dimensioned in such a way that the primary part with the fastening screws must not be lifted or only slightly.

Example: Measurable air gap: 1.0 mm

Thickness of distance plate: 0.95 mm

The tightening of the fastening screws for the primary part has to be made as described in chapterChapter 12.5 on page 285.

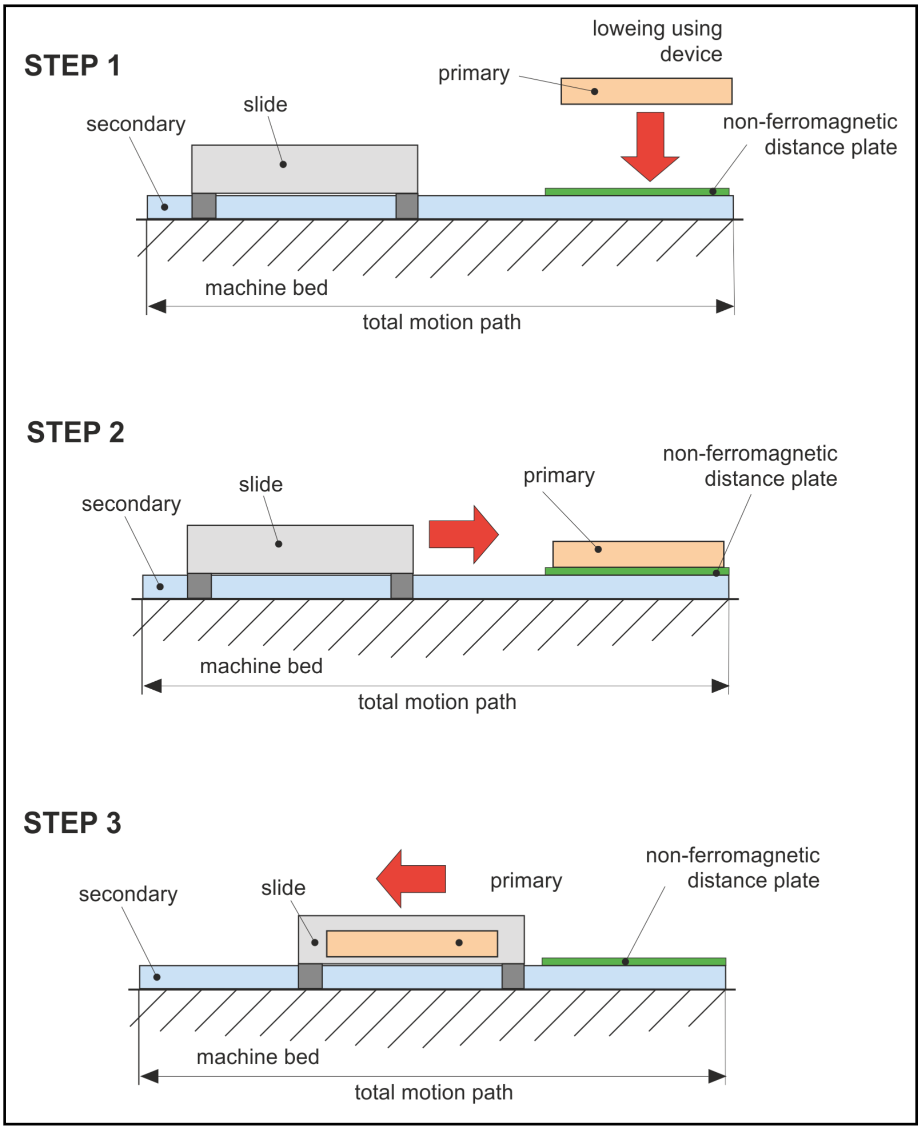


Fig. 12-5: Installation of linear motor components at a complete secondary part via the total path.

12.5 Assembly of primary parts

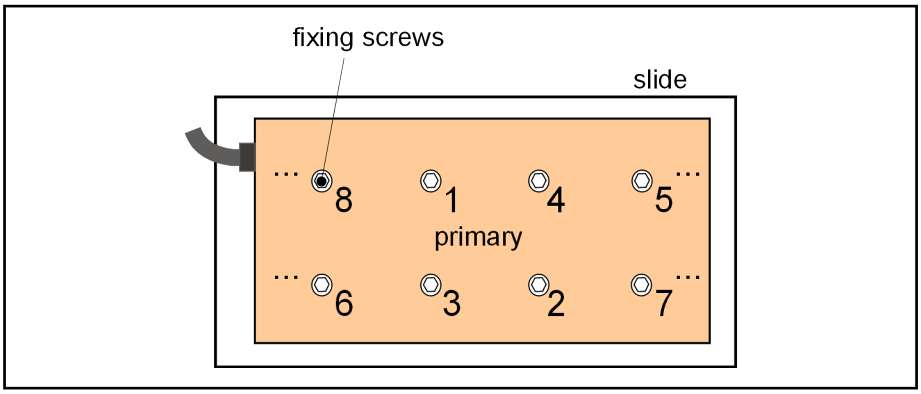


Fig. 12-6: Tightening sequence fastening screws of primary part

The screw-on surfaces must be cleaned and be free of grease before the primary parts can be screwed on the machine construction. If it can be expected, that certain influences are continuously occurring during motor operation, like contact of the primary part with coolant lubricant, grinding emulsion a.s.o., the kinetic friction among the screwed parts can be reduced during the machine lifetime. In this case, we recommend to use screws with a higher fastening class, like 10.9, to realize a higher tightening torque.

Mounting instructions:

1. Clean or prepare threaded holes and screws.
2. Secure all screwed connections with screw connection, e.g. Loctite 243.
3. Fasten the primary part with screws 1, 2, 3...n until the primary part lies on the slide (see Fig. 12-6).
4. Fasten screws - from inside to outside - 1, 2, 3 ... x with nominal tightening torque:

Frame size Primary part	Screw size	Strength class	Tightening torque (+/-10%)
040 ... 300	M6 (DIN EN ISO 4762)	8.8	10 Nm
		10.9	15 Nm

Tab. 12-2: Tightening torque for the fastening screws of the primary parts

☞ The effect of liquid screw lock is damaged by loosening or re-tightening of screws (e.g. due to torque tests) and must be renewed. Observe the notes of the lubricant manufacturer.

12.6 Air-gap, parallelism and symmetry among the motor components

Air gap

After assembly of the motor components, we recommend to check the minimum air gap between primary and secondary part.

For this reason, insert a test strip made of non-magnetic material (copper, plastics, etc.) with a thickness of

- **0.5 ... 0.55 mm** (at frame size 040 ... 202)
- **0.7 ... 0.75 mm** (at frame size 300)

into the air gap between primary and secondary part. The test strip must be free moving on each point within the whole traverse path of the air gap.

With this measure, you ensure the minimum necessary air gap between the motor components.

Furthermore, with this test you will detect a faulty assembly (e.g. due to dirt under the mounting surface, faulty installation dimension, insufficient machine rigidity etc.) in time.

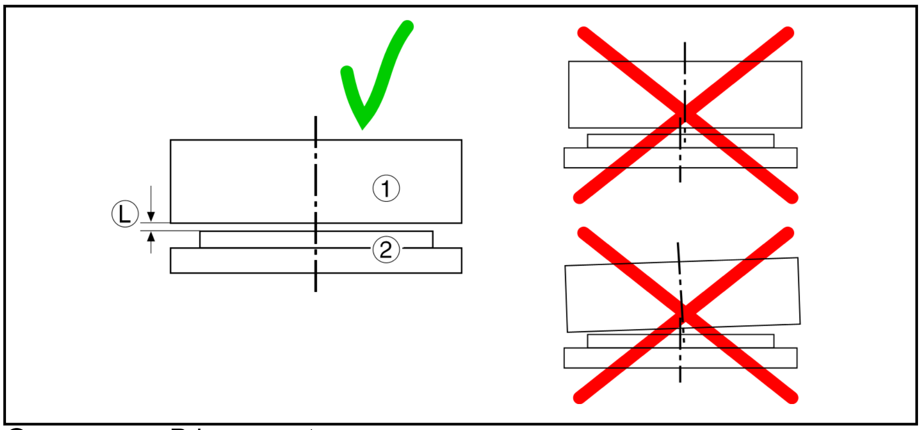
⚠ CAUTION **Motor damage due to insufficient air gap between primary and secondary part!**

With aforementioned measures check the necessary minimum air gap between primary and secondary part immediately after assembly of both motor components.

Parallelism and symmetry

When mounting primary and secondary parts, their position is specified inChapter Parallelism and symmetry of machine parts by the holes or threads within the machine slide and within the machine bed.

Before finally tighten the screws, the motor components must be centered and adjusted correctly according to Fig. 12-1 and Fig. 12-7.



① Primary part
② Secondary part
(L) Air gap

Fig. 12-7: Aligning the motor components

12.7 Connection liquid cooling

The connection of the liquid cooling is done via standard thread directly on the primary part (see Chapter 5 , specifications).

☞
- Connection threads and coolant tubes are not in the scope of delivery of the motors.
- Connect the motor according to the connection diagrams and the instructions in chapter 8.5 "Motor cooling" on page 177.

12.8 Electrical connection

Connect the motor electrically according to the connection diagrams and the instructions in chapter 8 "Connection technique" on page 163. Refer to the references to supplementary documentation.

☞
- When using self-manufactured cables, ensure EMC-compliant design and installation.
- Where applicable, ensure that connectors and lines are fastened for strain relief purposes.
- The connection diagrams of the product documentation serve to create system circuit diagrams. Only the machine manufacturer's system wiring diagrams are relevant for the connection of the drive components in the machine.

13 Commissioning, operation and maintenance

13.1 General information for startup

In some points, commissioning of linear motors is different in comparison to rotary servo motors. These points are addressed in this chapter.

☞ Further detailed information on commissioning is given in the parameter or application description of the drive controller used.

Example:

- Rexroth IndraDrive MPx-16 to MPx-21 and PSB Parameter description, MNR 911328651
- Rexroth IndraDrive MPx-16 Application description, MNR R911326767
- Rexroth IndraDrive MPx-17 Functions, MNR R911331236
- Rexroth IndraDrive MPx-18 Functions, MNR R911338673
- Rexroth IndraDrive MPx-20 Functions, MNR R911345606
- Rexroth IndraDrive MPx-21 Application description, MNR R911385759 (DE)

Parameters

Synchronous linear motors are kit motors whose single components are directly installed into the machine by the manufacturer – completed by an encoder system. Kit motors therefore do not have their own data memory with electronic nameplate. When using Bosch Rexroth controllers, the data can be transmitted and transferred digitally. In other cases, the parameterization is done manually.

Controller optimization

The procedure for controller optimization (current, velocity and position controller) at linear direct drives corresponds to the procedure for rotary servo drives. Only the setting limits of linear drives are higher. For example, this enables setting up to 10 times higher proportional amplifier factors at linear direct drives in comparison to rotary servo drives. However, this requires a respective machine construction (see Chapter 9.12 on page 212).

Encoder polarity

The polarity of the actual speed (length measuring system) must match the force polarity of the motor, i.e. the polarity of the direction of movement is the same as the direction of force. Before commutation adjustment, this relation must be established (see Chapter 13.5).

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 (pole position recognition or commutation adjustment). Commutation adjustment can only be made after installation of motor components and the length measuring system. The way of commutation adjustment depends on the measuring principle of the length measuring system and the direction of movement of the linear axis (horizontal or vertical).

13.2 General requirements

13.2.1 General

The following requirements have to be met to ensure successful commissioning:

- Compliance with safety-related guidelines and instructions
- Check of electrical and mechanical components for reliable functioning
- Availability and provision of required tools
- Adherence to the commissioning procedure described below

13.2.2 Checking all electrical and mechanical components

Check all electrical and mechanical components prior to commissioning and pay particular attention to the following issues:

☞

- Ensure safety for man and machine
- Correctly install the motor
- Correct power connection of the motor
- Connect connection of the length measuring system
- Ensure proper function of existing safety limit switches, door switches, etc.
- Ensure correct function of the emergency stop circuit and emergency stop.
- Ensure proper and complete machine construction (mechanical installation)
- Availability and function of suitable end position dampers
- Ensure a correct connection and function of the motor cooling system
- Ensure correct connection and function of drive controller and control unit

13.2.3 Tools

IndraWorks commissioning software The motors can be commissioned either directly via an NC terminal or via special commissioning software. The IndraWorks commissioning software allows menu-driven, custom-designed and motor-specific parameterization and optimization.

PC For commissioning by means of IndraWorks, a conventional Windows PC is required.

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

Oscilloscope An oscilloscope can be used for drive optimization. Alternatively, IndraWorks provides an individual drive-internal oscilloscope. This oscilloscope serves to display the signals which can be output via the adjustable analog outputs of the drive controller. Viewable signals include nominal and actual values of the speed, position or voltage, position lag, intermediate circuit, etc.

Multimeter Troubleshooting and component checks can be facilitated by a multimeter allowing the measurement of voltage, current and resistance values.

13.3 General commissioning procedure

In the following flow diagram, the commissioning sequence for synchronous linear motors is explained. The individual items are explained in more detail in the following chapters.

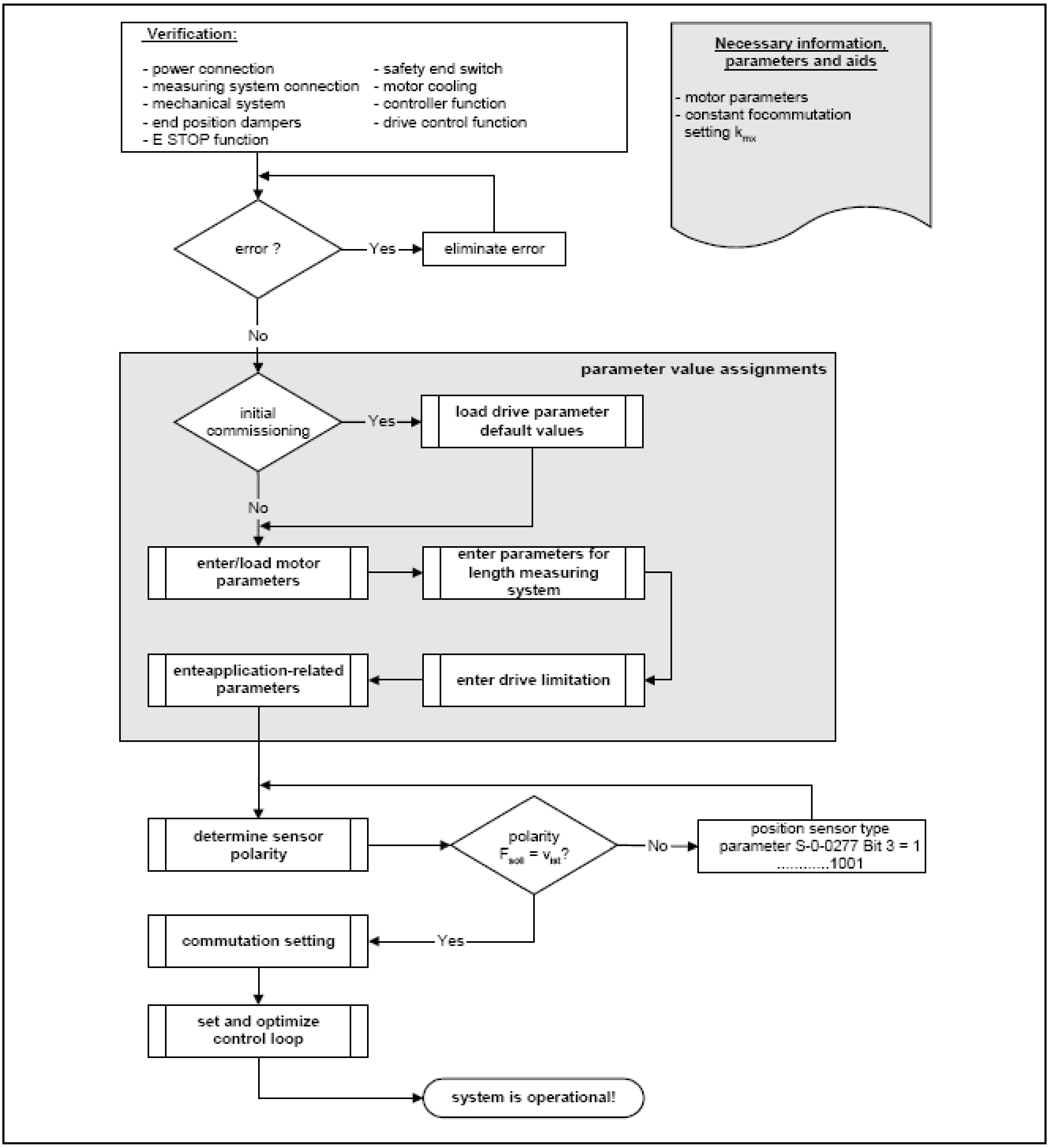


Fig. 13-1: General commissioning procedure for synchronous linear drives

13.4 Parameterization

13.4.1 General

IndraWorks allows entering or editing certain parameters and executing commands during commissioning by means of menu-driven dialogs and list representations or, optionally, via the control terminal.

☞ Further detailed information on commissioning is given in the parameter or application description of the drive controller used.

Example:

- Rexroth IndraDrive MPx-16 to MPx-21 and PSB Parameter description, MNR 911328651
- Rexroth IndraDrive MPx-16 Application description, MNR R911326767
- Rexroth IndraDrive MPx-17 Functions, MNR R911331236
- Rexroth IndraDrive MPx-18 Functions, MNR R911338673
- Rexroth IndraDrive MPx-20 Functions, MNR R911345606
- Rexroth IndraDrive MPx-21 Application description, MNR R911385759 (DE)

13.4.2 Entering motor parameters

☞ Motor parameters are specified by Rexroth and cannot be changed by the user. If these parameters are not available, commissioning is not possible! In this case, please contact your Rexroth Sales and Service Facility.

⚠ WARNING **Activation of the motor immediately after motor parameter input may result in injury and mechanical damage! The motor is not yet ready for operation simply by entering the motor parameters!**

- Enter parameters for length measuring system
- Check and adjust the measuring system polarity
- Configure the commutation settings

The motor parameters can be entered as follows:

- Use IndraWorks to load all motor parameters.
- Enter the individual parameters manually via the controller
- Load a complete parameter set at serial machines via the controller or IndraWorks

13.4.3 Motor parameter at parallal arrangement

Are two linear motors operated in a control device, the following parameters have to be adjusted when commissioning:

Parameter	Designation	Adjustment factor
P-0-4016	Direct-axis inductance of motor	x 0.5
P-0-4017	Quadrature-axis inductance of motor	x 0.5
P-0-4048	Motor winding resistance	x 0.5
S-0-0106	Current loop proportional gain 1	x 0.5
S-0-0109	Motor peak current	x 2
S-0-0111	Motor current at standstill	x 2

Tab. 13-1: Parameter adjustment at parallel arrangement

☞ A smaller controller can be used, if the maximum possible continuous nominal force or the maximum possible peak force of the motor is not required. In this case, re-adjust the configured currents to the selected controller. Therefore, use Rexroth IndraSize (see Chapter 4.1.3).

13.4.4 Operation without liquid cooling

⚠ WARNING **Motor damage! Overheating of the winding!**

If the permissible continuous current at the non-water-cooled motor is not limited accordingly, an impermissible rapid heating of the winding can already occur at currents < I_N. The temperature indicated by the thermal sensors is lagging and is too low to ensure safe shutdown of the motor. Overheating of the winding will weaken or even destroy the winding insulation.

Without liquid cooling, however, the performance data available is reduced considerably, which is not specified in this documentation.

The stated values in the data sheets regarding rated force and rated current of the motors must be lowered depending on the coupling of the motors to ~40% of the stated value.

Parameters for Rexroth - controller

If this current reduction is not entered in parameter S-0-0111 (motor standstill current), the control allows a short-term overload current of 2.2 times the value of the rated current with water cooling. This value is by factor 2.5 too high for a motor without water cooling.

Example:

Rated current for **water-cooled motors** = 10 A

S-0-0111 = 10 A

Possible short-time overload current = 2.2 x 10 A = **22 A**

Rated current for same motor design, but **not water cooled**:

S-0-0111 = 10 A x 0.4 = 4 A

Possible current = 2.2 x 4 A = **8.8 A**

☞ Please also observe the information provided in Chapter 9.10.5 on page 199 about operation of MLF motors without liquid cooling.

13.4.5 Entering length measuring system parameter

Encoder type

The type of the length measuring system has to be defined. The following parameters are used:

Encoder type	from firmware MPx20 S-0-0602.x.1	up to firmware MPx18 P-0-0074
Incremental measuring system	2	
Absolute encoder with EN-DAT2.1 interface	6	8
Absolute encoder with EN-DAT2.2 interface	106	-
Incremental encoder with Hall sensor	14 or 15 (depending from Hardware configuration)	

Tab. 13-2: Defining the encoder type

Signal period

Linear scale for linear motors generate and interpret **sinusoid signals**. Please also observe the information provided by the measuring system manufacturer for resolution of encoder signals. The sine signal period has to be entered in the relevant parameter.

For more information about entering parameters, refer to firmware descriptions.

13.4.6 Entering drive limitations and application-related parameters

Drive limitations

The drive limitations that can be set, include:

- Current limitation
- Force limitation
- Velocity limitations
- Travel range limitations

Application-related parameters

Application-dependent drive parameters include, for example, drive fault responses.

☞ Detailed descriptions can be found in the firmware or parameter description of the drive controller used.

13.5 Determining the polarity of the linear scale

In order to avoid direct feedback in the velocity control loop, the effective direction of the motor force and the count direction of the length measuring system must be identical.

⚠ WARNING

Different effective directions of motor force and count direction of the encoder system cause uncontrolled movements of the motor upon switch-on!

- Secure against uncontrolled movement
- Setting of the effective direction of the motor force identically to the counting direction of the length measuring system

Effective direction of motor force

The following applies for setting of the correct encoder polarity:

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

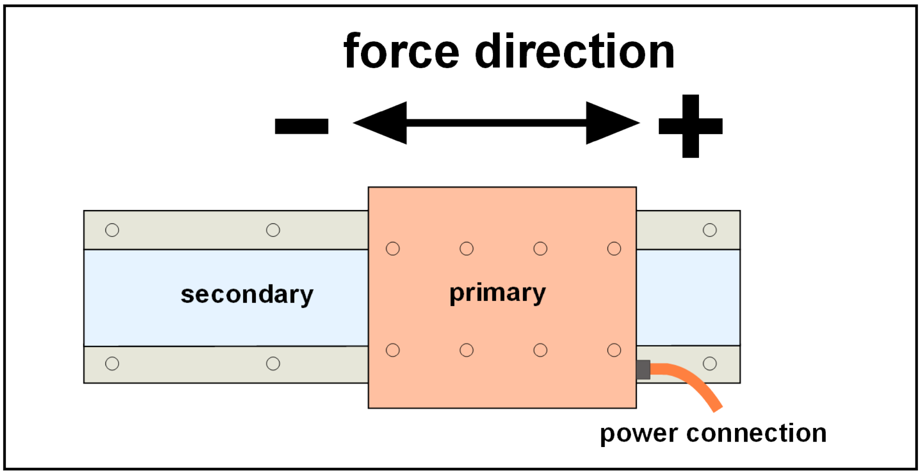


Fig. 13-2: Effective direction of motor force

Effective direction of the motor force = Counting direction of the length measuring system

In case of motion of the primary part in the direction of the cable connection, the counting direction of the length measuring system must also be positive:

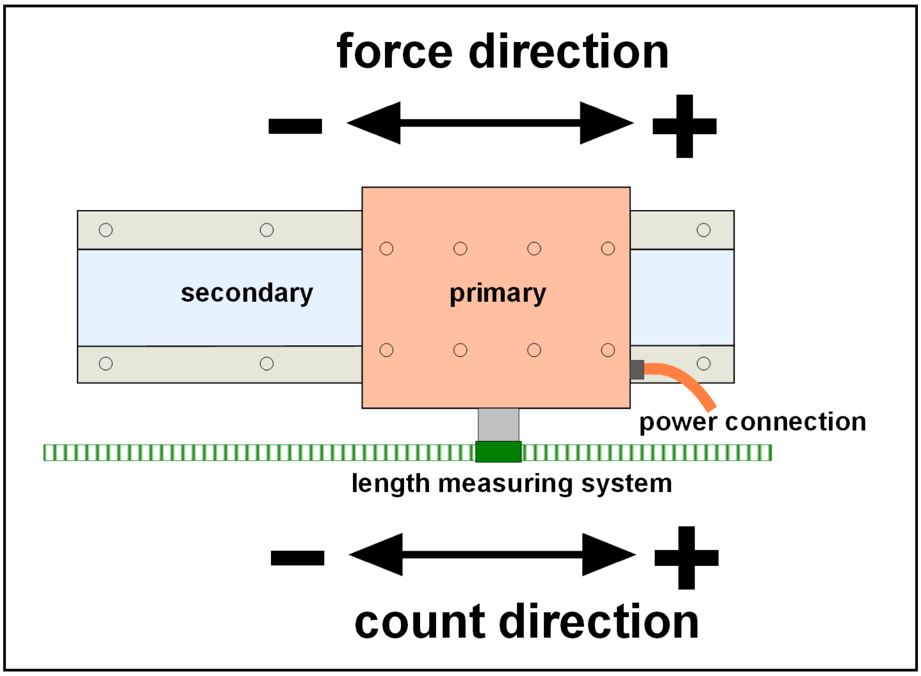


Fig. 13-3: Effective direction of the motor force = Counting direction of the length measuring system

☞ The encoder polarity is always set in regard to the primary part (cable connection). The installation direction or pole sequence of the secondary part does not have any impact on the encoder polarity setting.

The encoder polarity is set via parameters

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

Position, velocity and force data must not be inverted when the length measuring system count direction is set:

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

S-0-0043, Velocity polarity parameter 0000000000000000

S-0-0055, Position polarity 0000000000000000

If required, the process-related axis counting direction is set **after** the encoder polarity and commutation have been set.

13.6 Commutation adjustment

13.6.1 General

The force of the synchronous linear motor can only develop to a maximum and constant degree, if the commutation angle or the pole position is set correctly.

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°. In this state, the motor supplies the maximum possible force.

⚠ DANGER **Errors in commutation adjustment can result in malfunctions and/or uncontrolled movements of the motor!**

Take care when carrying out the commutation adjustment. In addition, observe the notes on commutation setting in the application description of the firmware used.

☞ Further detailed information on commissioning is given in the parameter or application description of the drive controller used.

Example:

- Rexroth IndraDrive MPx-16 to MPx-21 and PSB Parameter description, MNR 911328651
- Rexroth IndraDrive MPx-16 Application description, MNR R911326767
- Rexroth IndraDrive MPx-17 Functions, MNR R911331236
- Rexroth IndraDrive MPx-18 Functions, MNR R911338673
- Rexroth IndraDrive MPx-20 Functions, MNR R911345606
- Rexroth IndraDrive MPx-21 Application description, MNR R911385759 (DE)

Adjustment procedure

Different commutation adjustment procedures have been implemented in the firmware. The following figure shows the connection between the length measuring system used and the procedure to be applied.

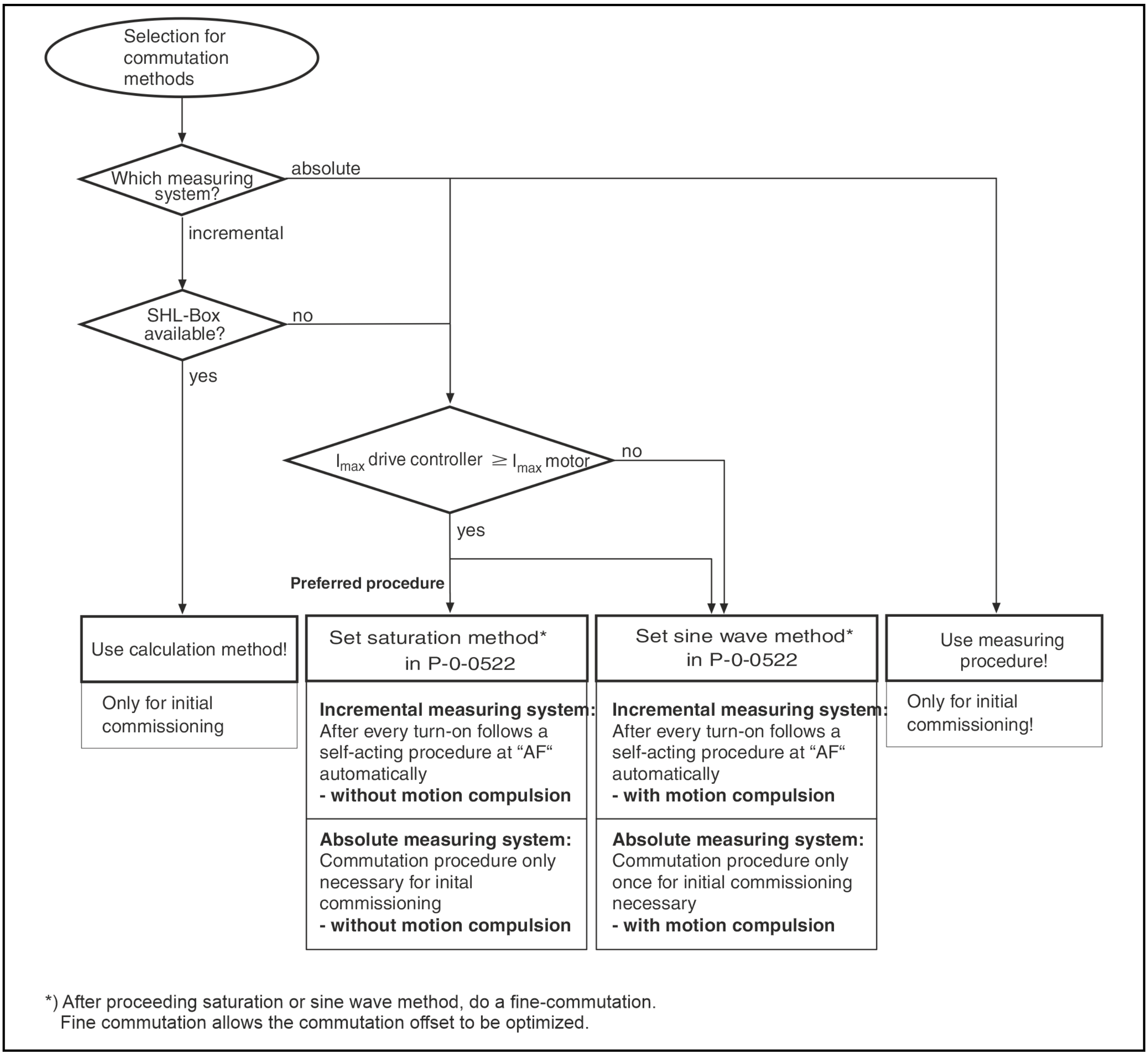


Fig. 13-4: Procedure for commutation adjustment for synchronous linear motors

☞ Commutation adjustment always has to be performed in the following cases:

- Initial commissioning
- Modification of the mechanical attachment of the linear scale
- Length measuring system replacement
- Modification of the mechanical attachment of the primary and/or secondary part

☞ Observe the following requirements for commutation adjustment:

- Effective direction of the motor force = Counting direction of the length measuring system
- Correct motor and encoder parameterization
- Complying with the described setting procedures
- Current or velocity control circuits must be reasonably parameterized
- Correct connection of motor power cable
- Protection against uncontrolled movements

Motor connection The individual phases of the motor power connection have to be assigned correctly. Also refer to Chapter 8 on page 163.

Parameter checking To ensure proper commutation adjustment, the following parameters should be checked before commutation:

Ident number		Description	Designation/ function
up to MPx18	from MPx20		
S-0-0085		Torque/force polarity parameter	See Parameter Description Rexroth Drive Controller
S-0-0043		Velocity polarity parameter	
S-0-0055		Position polarity	
P-0-4014		Type of motor	
P-0-0018		Number of pole pairs/pole pair distance	
S-0-0116	-	Encoder 1 resolution	
-	S-0-0602.x.21	Phys. encoder resolution (analog)	
P-0-0522		Commutation adjustment control word	

Tab. 13-3: Parameters to be checked before commutation adjustment

13.6.2 Saturation procedure (preferred procedure for commutation of synchronous linear motors)

The saturation procedure is the preferred procedure for commutation of synchronous linear motors.

For detailed information about saturation factor refer to chapter “Commutation settings” in the Rexroth MPx application manual (seeChapter 13.6.1).

13.6.3 Sinusoidal procedure

This method is used when the saturation method cannot be applied.

For detailed information about sinusoidal procedure refer to chapter “Commutation settings” in the Rexroth MPx application manual (seeChapter 13.6.1).

13.6.4 Note on the possibility of post-optimization of the commutation offset

The post-tuning method can be applied to the sinusoidal method as well as to the saturation method. The prerequisite for this is that the axis is not firmly braked but can move freely.

It is recommended to re-optimize the determined value for the commutation offset. This can be done automatically by activating "C5600 Command Commutation Offset Reoptimization".

For detailed information about subsequent optimization refer to chapter “Commutation settings” in the Rexroth MPx application manual (seeChapter 13.6.1).

13.6.5 Calculation method in connection with SHL Hall sensor box.

Calculation procedure is used for incremental measuring systems and use of Hall sensor box (distance measure, currentless → only possible for Rexroth linear kit motors). Also observe the functional description of the SHL02.1 Hall sensor box(DOK-SUPPL*-SHL********-FK) with MNR R911292537.

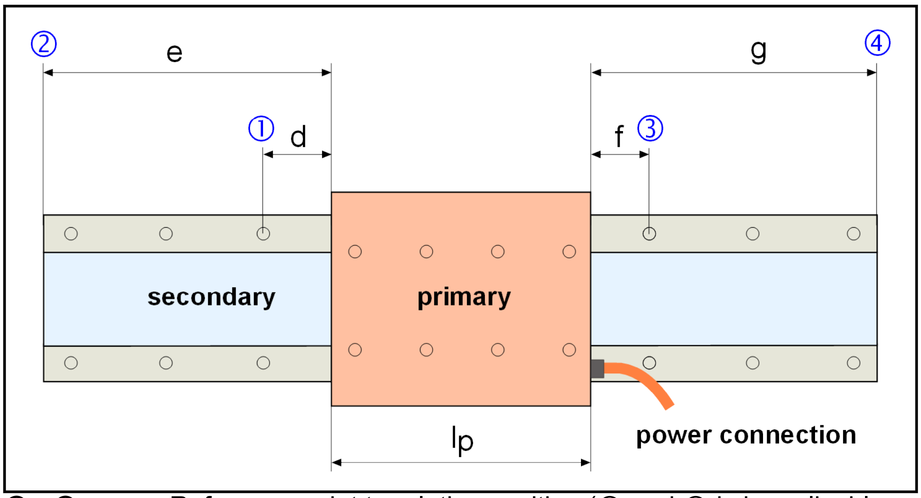
For detailed information on the computational procedure, refer to chapter "Commutation settings" of the Rexroth MPx application manual (seeChapter 13.6.1).

13.6.6 Measuring procedure: Measuring of the relation between primary and secondary part

☞ This method requires an absolute length measuring system with ENDAT interface.

Measuring of the relative position of the primary to the secondary part

Depending on the accessibility of the primary and secondary part in the machine or system, the relative position of the primary to the secondary part may be calculated in different ways:



①...④ Reference point to relative position (① and ③ is inapplicable for series xx2).

Fig. 13-5: Measuring of the relative position of the primary to the secondary part

☞

- Reference point ① and ③ cannot be applied to primary parts of xx2 series because the screw spacing of the secondary parts does not correspond to the pole width of MLPxx2.
- The position of the primary part must not be changed during the commutation setting procedure!

Calculation of P-0-0523, Commutation adjustment measured value

The input value for P-0-0523 that is required for calculating the commutation offset, is determined from the measured relative position of the primary part with respect to the secondary part (Fig. 13-5, distance d, e, f or g, depending on accessibility), and a motor-related constant k_{mx} (Fig. 13-6 and Fig. 13-4).

$$d \rightarrow \quad P-0-0523 = d - k_{mx}$$

$$e \rightarrow \quad P-0-0523 = e - k_{mx} - \tau_P$$

$$f \rightarrow \quad P-0-0523 = -f - l_p - k_{mx}$$

$$g \rightarrow \quad P-0-0523 = \tau_P - g - l_p - k_{mx}$$

P-0-0523	Commutation adjustment measured value in mm
d	Relative position reference point 1 in mm (Fig. 13-5)
e	Relative position reference point 2 in mm (Fig. 13-5)
f	Relative position reference point 3 in mm (Fig. 13-5)
g	Relative position reference point 4 in mm (Fig. 13-5)
k_{mx}	Motor constant for commutation adjustment in mm
τ_P	Pole width MLPxx0 = 37.5 mm; MLPxx2 = 30 mm
l_p	Primary part length in mm

Fig. 13-6: Calculation of P-0-0523, Commutation adjustment measured value

☞ Ensure that the sign is correct when you determine P-0-0523, Commutation adjustment measured value. If P-0-0523 is determined with a negative sign, this must also be entered in the beginning of the setting procedure.

Motor constant for commutation adjustment k_{mx}

The motor constants for setting the commutation offset k_{mx} depend on the alignment of the primary and secondary:

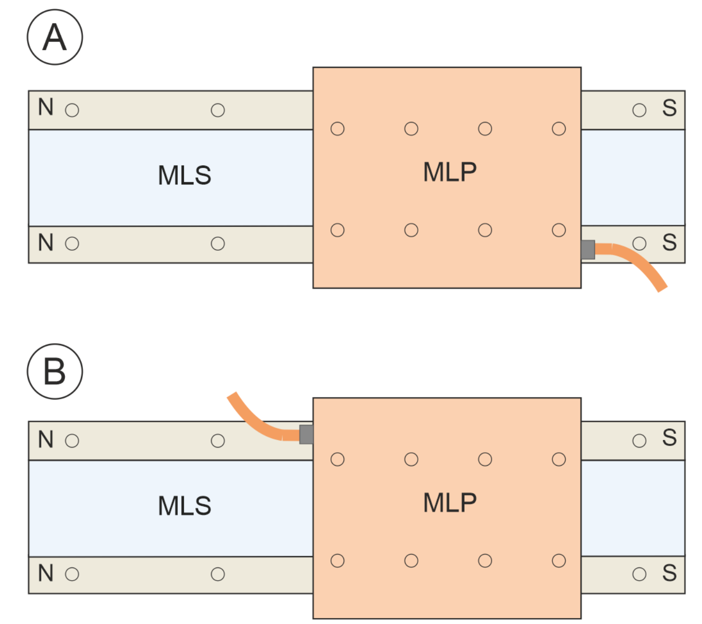


Fig. 13-7: Arrangement options primary to secondary part

	Arrangement Ⓐ k_{mx} in mm	Arrangement Ⓑ k_{mx} in mm
Standard encapsulation MLFxx0 frame sizes 040 ... 300	68	105.5
Thermal encapsulation MLFxx0 frame sizes 040 ... 300	65	102.5
Thermal encapsulation MLFxx2 frame sizes 052 ... 202	52.2	22.2

Tab. 13-4: Motor constant for commutation adjustment k_{mx}

Command for commutation setting

Prerequisite:

1. The drive must be in status A0-13 during the following adjustment procedure (= ready for power switching).
2. The position of the primary part or the slide must not have changed after measuring of the relative position of the primary to the secondary part.

After the determined value P-0-0523 (Commutation adjustment measured value) is entered, command P-0-0524 (D300 Commutation adjustment command) has to be started. In this process, the commutation offset is calculated.

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

Afterwards, the command is to be cleared.

13.7 Setting and optimizing the control loop

13.7.1 General procedure

The control loop settings in a digital drive controller have an essential importance for the properties of the servo axis. The control loop structure consists of a cascaded position, velocity and current controller. Which controller is active is defined by the operation mode.

☞ Defining the control loop settings requires the corresponding expertise.

The procedure for control loop optimization (current, velocity and position controller) at linear direct drives corresponds to the procedure for rotary servo drives. Only the setting limits of linear drives are higher.

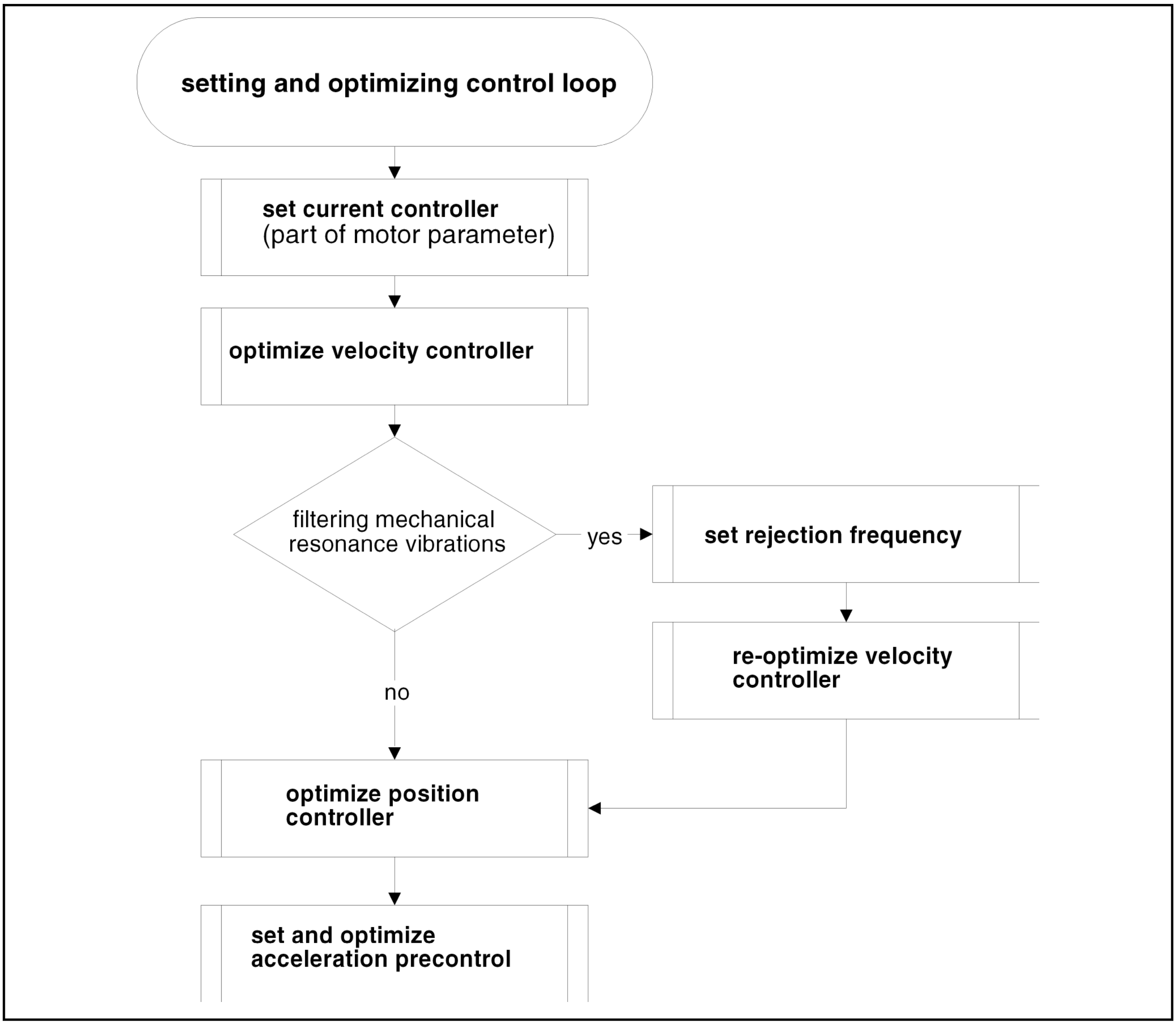


Fig. 13-8: Setting and optimizing the control loop of synchronous linear motors

☞ Refer to the functional description of the drive controller for more detailed information.

Filtering mechanical resonance vibrations

Digital drives from Rexroth are able to provide a narrow-band suppression of vibrations that are produced due to the power train between motor and mechanical axis system. This results in increased drive dynamics with good stability.

The mechanical system of the slide that is moved by the linear drive is stimulated to vibrate mechanically due to the position and/or velocity return within the closed control loop. This behavior, known as "Two-mass vibrational system", is mainly in the frequency range from 400 to 800 Hz. It depends on the rigidity of the mechanical system and the spatial expansion of the system.

In most cases, this "Two-mass vibrational system" has a clear resonant frequency that can be selectively suppressed by a rejection filter installed in the drive.

When the mechanical resonant frequency is suppressed, the dynamic properties of the velocity control loop and of the position control loop may, under certain circumstances, be improved as compared with closed-loop operation without rejection filter.

This leads to an increased profile accuracy and shorter cycle times for positioning processes at a sufficient distance to the stability limit.

Rejection frequency and bandwidth of the filter can be selected. The rejection frequency is the frequency with the highest attenuation. The bandwidth defines the frequency range in which the attenuation is less than –3 dB. A higher bandwidth leads to less attenuation of the rejection frequency!

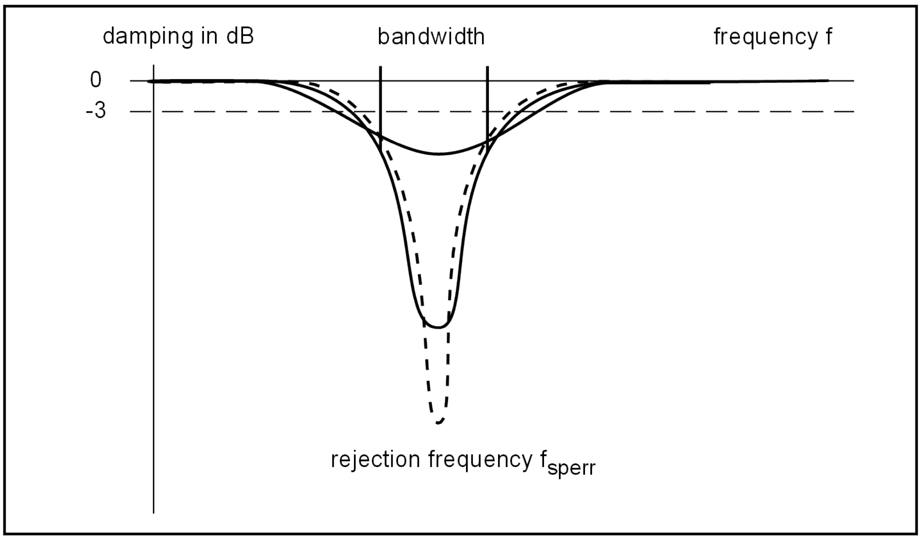


Fig. 13-9: Amplitude response of the rejection filter in relation to the bandwidth, qualitative

13.7.2 Parameter value assignments and optimization of Gantry axes

General

Prerequisites:

- Parametrization or axes is realized identically
- Parallelism of guides of Gantry axes
- Parallelism of length measuring systems
- The axes are registered as individual axes in the control unit

☞ For compensation of alignment errors between two length measuring systems or the mechanical system, drive-internal axis error correction procedures can be applied. Please refer to the corresponding description of functions of the drive controller for a description of the operational principle and the parameter settings.

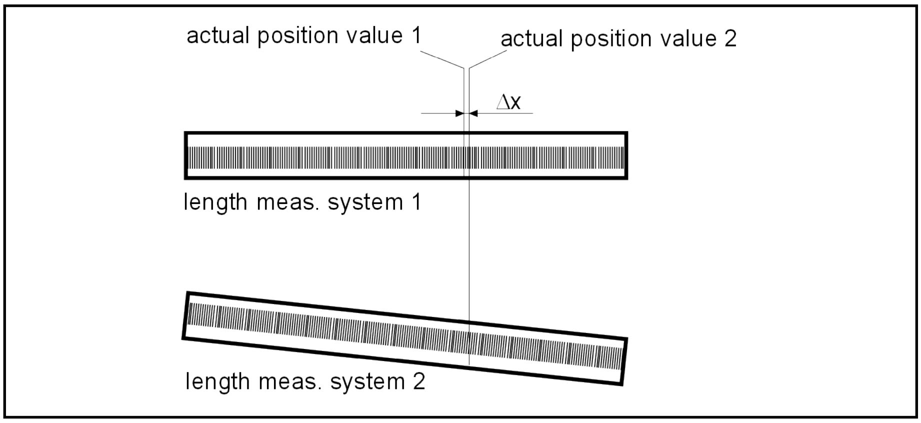


Fig. 13-10: Possible alignment errors at length measuring systems of Gantry axes

Parametrization

For operation of Gantry axes, identical parameterization of the following parameters must be ensured:

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

We have:

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

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

k_v	Position controller proportional gain S-0-0104
k_p	Velocity loop proportional gain S-0-0100

Fig. 13-11: Proportional gain in position and velocity control loop of both axes

Velocity loop integral action time (integral part)

For velocity loop integral action time (integral part), the following possibilities must be taken into consideration:

	Possibility 1	Possibility 2	Possibility 3	Possibility 4
Alignment of length measuring systems and guides	ideal	not ideal	not ideal	not ideal
Integral part	in both axes	in both axes	in one axis only	in no axis
Behavior of the axes	Tensioning of the mechanical system is not realized as both motors ideally follow the position command value	Both axes work against each other until compensation via the mechanical coupling or until the maximum current is reached at one or both drive controllers and no more control effect can be achieved	The axis without integral part allow continuous position offset. The position offset depends on the stiffness of the mechanical coupling of both axes as well as the proportional gains in the position and velocity control loop	Both axes allow continuous position offset. The position offset depends on the proportional gains in the position and velocity control loop

Tab. 13-5: Parametrization of the velocity loop integral action time S-0-0101 at Gantry axes.

Optimization

For optimization of velocity and position control loop, the above-described procedure must be observed.

☞ Parameter changes during optimization of Gantry axes must always be carried out at both axes. If this is not possible, the parameter changes during optimization should be carried out subsequently in small steps at both axes.

13.7.3 Estimating the moved mass using a velocity ramp

The moving weight of a machine slide is often not precisely known. This may be obstructed by subsequently installed attachments, moving components, etc.

The procedure described below enables estimation of the moved axis mass according to recording of a velocity ramp. For example, this enables estimation of the acceleration capacity of the axis.

Preparation

Precondition for positioning is oscillographical representation of the following parameters:

- S-0-0040, Velocity actual value
- S-0-0080, Torque/force command value

For this purpose, an oscilloscope or the oscilloscope function of the drive can be used in combination with IndraWorks or NC.

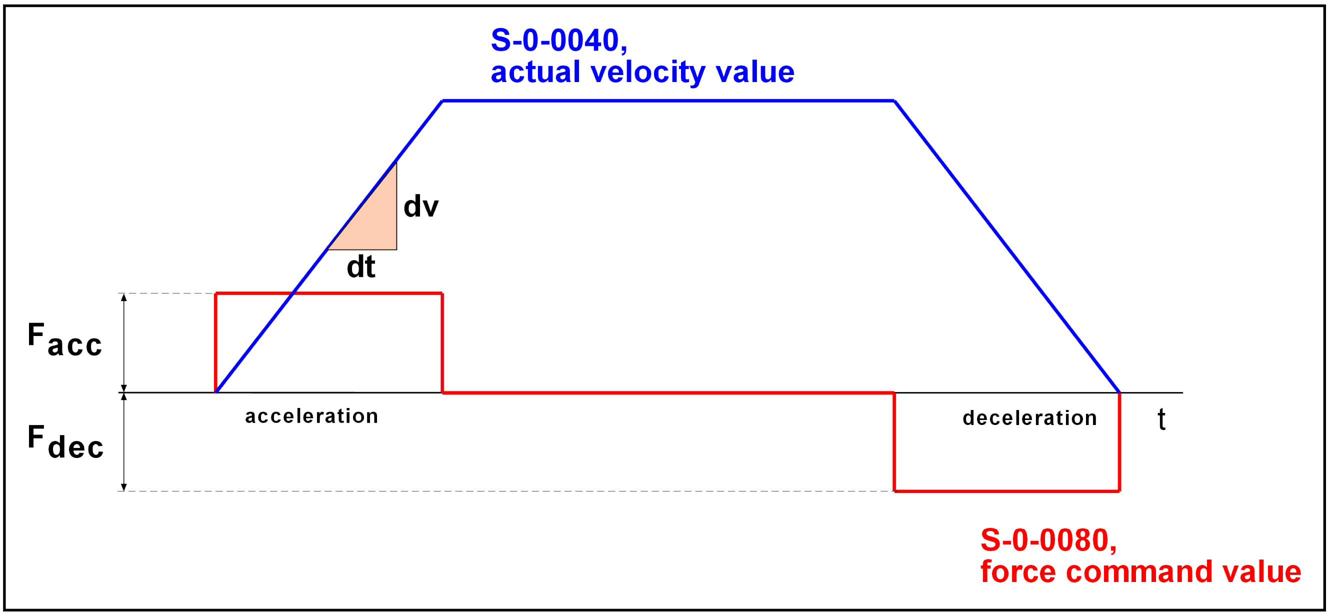


Fig. 13-12: Oscillogram of velocity and force

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

m	Moved axis mass in kg
F_N	Continuous nominal force of the motor in N
F_{ACC}	Force command value during acceleration in %
F_{DEC}	Force command value during deceleration in %
Δv	Velocity change during const. acceleration in m/min
Δt	Time change during const. Acceleration in s

Fig. 13-13: Determination of the moved axis mass according to recording of a velocity ramp

Prerequisites:

1. Correct parameter settings of the rated motor current (basis of representation S-0-0080)
2. Frictional force not directional
3. Recording of Δv and Δt at constant acceleration
4. Do not perform at maximum motor force to avoid non-linearity

☞ The procedure is not suitable or suitable only to a limited extend for vertical axes due to potential direction-depending force changes.

13.8 Maintenance

13.8.1 General

MLF synchronous motors operate maintenance-free within the specified operating conditions and service life. Operation under unfavorable conditions can, however, lead to restrictions in availability.

- Increase availability with regular preventive maintenance measures. Comply with the machine manufacturer's instructions in the machine maintenance plan and the maintenance measures described below.
- Record all maintenance measures in the machine maintenance plan.

13.8.2 Measures

⚠ DANGER **Risk of injury due to moving elements! Risk of injury due to hot surfaces!**

- Do not carry out any maintenance measures while the machine is running.
- While carrying out maintenance work, secure the machine such that it cannot restart or be used by unauthorized persons.
- Do not work on hot surfaces.

Bosch Rexroth recommends the following maintenance measures, based on the maintenance plan of the machine manufacturer:

Measure	Interval
Check the cooling system for proper functioning.	According to the specifications in the machine maintenance plan, but at least every 1000 operating hours.
Check the mechanical and electrical connections.	According to the specifications in the machine maintenance plan, but at least every 1000 operating hours.
Check the machine for smooth running, vibrations and bearing noise.	According to the specifications in the machine maintenance plan, but at least every 1000 operating hours.
Remove dust, chips and other dirt from the motor housing, cooling fins and the connections.	Depending on the degree of soiling, but after one operating year at the latest.

Tab. 13-6: Maintenance measures

The following points should be observed and if necessary restored during the preventive check of motor and auxiliary components:

- Noticeable sound during operation
- Scratches on primary and secondary part
- Dirt (e.g. shavings, dust, grease by guides etc.) within the air gap between primary and secondary part

  Check function of protective measures and replace if necessary! Also refer to Chapter 9.12.4 on page 213.
- Tightness of liquid cooling, hoses and connections
- State of power and encoder cables in a drag chain.

- State of length measuring system (e.g. contamination)
- State of guides (e.g. deterioration of linear guides)

13.8.3 Electrical check of motor components

Electrical defects at a primary part are can be indicated in advance by measuring the electrical characteristics. The following variables are relevant:

- Resistance between motor connecting wires 1-2, 2-3 and 1-3
- Inductance between motor connecting wires 1-2, 2-3 and 1-3
- Insulation resistance between motor connecting wired and guides

Resistance and inductivity

The measured values of resistance and inductance can be compared with the values specified in Chapter 4 ”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. If so, the primary part must be exchanged.

Insulation resistance

The insulation resistance measured between the motor connection wires and ground should be at least 1 MΩ (MegaOhm). If this value is fallen below, replacement of the primary part is recommended.

☞ If necessary, please contact the Bosch Rexroth customer service for inspection of the electrical system.

13.9 Operation with third-party controllers

Rate of rise of voltage

The 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):2018-12 (picture 40, 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 Appendix

14.1 Recommended suppliers of additional components

14.1.1 Length measuring system

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

DR. JOHANNES HEIDENHAIN GmbH
Dr.-Johannes-Heidenhain-Straße 5
83301 Traunreut, Germany
Internet: http://www.heidenhain.de

Renishaw GmbH
Karl-Benz Strasse 12
72124 Pliezhausen, Germany
Internet: http://www.renishaw.com

14.1.2 Linear scales

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

14.1.3 Energy chains

igus GmbH
Spicher Straße 1a
51147 Cologne, Germany
Internet: http://www.igus.de

KABELSCHLEPP GMBH
Marienborner Straße 75
57074 Siegen, Germany
Internet: http://www.kabelschlepp.de

14.1.4 Cooling aggregate

SCHWÄMMLE GmbH & Co KG
Dieselstraße 12-14
71546 Aspach, Germany
Internet: http://www.schwaemmle-gmbh.de

Universal Hydraulik GmbH
Siemensstraße 33
61267 Neu-Anspach, Germany
Internet: http://www.universalhydraulik.com

14.1.5 Coolant additives

NALCO Deutschland GmbH
Plankstr. 26
71691 Freiberg/Neckar, Germany
Fax +49(0)7141-703-239
e-mail: slund@nalco.com

14.1.6 Coolant hose

Polyflex AG
Dorfstaße 49
5430 Wettingen, Switzerland
Internet: http://www.polyflex.ch

igus GmbH
Spicher Straße 1a
51147 Cologne, Germany
Internet: http://www.igus.de

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

14.1.7 Axis cover systems

Möller Werke GmbH
Kupferhammer
33649 Bielefeld, Germany
Internet: http://www.moellerflex.de

HCR-Heinrich Cremer GmbH
Oppelner Str. 37
41169 Moenchengladbach, Germany
Internet: http://hcr.connection-net.de/deutsch/index.html

Gebr. HENNIG GmbH
P. O. Box 1137
85729 Ismaning, Germany
Internet: http://www.hennig-gmbh.de

14.1.8 End position cushioning

ACE Stoßdämpfer GmbH
P. O. Box 1510
40740 Langenfeld, Germany
Internet: http://www.ace-ace.de

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

Metal Braid Shock Absorbers

Rhodius GmbH
Treuchlinger Str. 23
91781 Weißenburg, Germany
Internet: http://www.rhodius.com

14.1.9 Clamping elements for linear scales

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

14.1.10 External mechanical brakes

Kendrion Binder Magnete GmbH
Mönchweilerstr. 1
78048 Villingen-Schwenningen, Germany
Internet: http://www.kendrion-electromagnetic.com

Ortlinghaus-Werke GmbH
Kenkhauser Str. 125
42929 Wermelskirchen, Germany
Internet: http://www.ortlinghaus.com

14.1.11 Weight compensation systems

Pneumatic

Ross Europa GmbH
Robert-Bosch-Str. 2
63225 Langen, Germany
Internet: http://www.rosseuropa.com

Hydraulic

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

14.1.12 Wiper

Hunger DFE GmbH Dichtungs- und Führungselemente
Alfred-Nobel Str. 26
97080 Würzburg. Germany
Internet: http://www.hunger-dichtungen.de

HME Dichtungssysteme
Richthofenstr. 31
86343 Königsbrunn, Germany
Internet: http://www.hme-seals.de

15 Environmental protection and disposal

Production method

The products are manufactured in energy- and resource-optimized production processes which allow re-using and recycling the resulting waste. We regularly try to replace pollutant-loaded raw materials and supplies by more environment-friendly alternatives.

No release of hazardous substances

Our products do not contain any hazardous substances which may be released in case of appropriate use. Normally, our products will not have any negative influences on the environment.

Basic components

Basically, our motors consist of the following components: Steel, aluminum, copper, brass, permanent magnets (rare earth metal), electrotechnical components.

Return of products

Our products can be returned to us for disposal free of charge. However, this requires that the products be free from oil, grease or other dirt.

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

Deliver the products "free domicile" to the following address:

Bosch Rexroth AG
Electric Drives and Controls
Buergermeister-Dr.-Nebel-Straße 2
97816 Lohr am Main, Germany

Permanent magnets

⚠ WARNING **Danger due to permanent magnets!**

- Health hazard for persons with heart pacemakers, metallic implants and hearing aids in direct environment of permanent magnets.

- Crushing hazard of fingers and hand due to heavy attractive forces of the magnets.

- Risk of destruction of sensitive parts such as watches, credit cards, ...

Permanent magnets present a serious danger during disposal. Prior to disposal, permanent magnets attached to the motor components (e.g. synchronous motor rotors, secondary parts of linear motors) have to be demagnetized using thermal treatment. The disposal of demagnetized permanent magnets is prohibited.

Demagnetize magnets

The demagnetization of the permanent magnets is reached via special thermal treatment. The handling duration is influenced by the frame of the motor component. The motor component has to remain in the oven for a minimum of 30 minutes, starting at the time, the magnetic surface has reached 300 °C.

Please also refer to the safety instructions regarding protection from magnetic fields, handling and assembly in the chapter “Safety Notes for Electric Drives and Controls” when using permanent magnets.

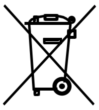
Packaging

Packaging materials consist of cardboard, wood and polystyrene. They can be recycled anywhere without any problem.

For ecological reasons, please refrain from returning the empty packages to us.

Batteries and accumulators

Batteries and accumulators can be labeled with this symbol.



The symbol indicating "separate collection" for all batteries and accumulators is the crossed-out wheeled bin.

End users in the EU are legally bound to return used batteries. Outside the validity of the EU Directive 2006/66/EC, the particularly applicable regulations must be followed.

Used batteries can contain hazardous substances which can harm the environment or people's health when improperly stored or disposed of.

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

Recycling

Most of the products can be recycled due to their high content of metal. In order to recycle the metal in the best possible way, the products must be disassembled into individual assemblies.

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

Plastic parts of the products may contain flame retardants. These plastic parts are labeled according to EN ISO 1043. They have to be recycled separately or disposed of according to the applicable legal provisions.

16 Service and support

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

Service Germany

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

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

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

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

Service worldwide

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

Preparing information

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

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

Index

Notes

rexroth
A Bosch Company

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Fax +49 9352 18 8400
www.boschrexroth.com/electrics

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