FAULHABER

Technical Manual

SC 1801

SC 2402

SC 2804

SC 5004

SC 5008

WE CREATE MOTION

EN

Imprint

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The relevant regulations regarding safety engineering and interference suppression as well as the requirements specified in this document are to be noted and followed when using the software.

Subject to change without notice.

The respective current version of this technical manual is available on FAULHABER's internet site:
www.faulhaber.com

Content

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1 About this document

1.1 Validity of this document

This document describes the installation and use of the following series:

- SC 1801
- SC 2402
- SC 2804
- SC 5004
- SC 5008

This document is intended for use by trained experts authorized to perform installation and electrical connection of the product.

All data in this document relate to the standard versions of the series listed above.

1.2 Associated documents

For certain actions during commissioning and operation of FAULHABER products additional information from the following manuals is useful:

Manual	Description
Motion Manager 6	Operating instructions for FAULHABER Motion Manager PC software

1.3 Using this document

- Read the document carefully before undertaking configuration, in particular chapter “Safety”.
- Retain the document throughout the entire working life of the product.
- Keep the document accessible to the operating and, if necessary, maintenance personnel at all times.
- Pass the document on to any subsequent owner or user of the product.

1.4 List of abbreviations

Abbreviation	Meaning
AES	Absolute encoder
BL	Brushless
DC	Direct Current
EMF	Back-induced electromotive force
EMC	Electromagnetic compatibility
ESD	Electrostatic discharge
FFC	Flat Flexible Cable
FPC	Flexible Printed Circuit
GND	Ground
LIF	Low Insertion Force
PWM	Pulse Width Modulation
SC	Speed Controller
TTL	Transistor Transistor Logic

1.5 Symbols and designations

⚠ DANGER!

Danger with high level of risk: if not avoided, death or serious injury will result.

- Measures for avoidance

⚠ WARNING!

Danger with medium level of risk: if not avoided, death or serious injury may result.

- Measures for avoidance

⚠ CAUTION!

Danger with low level of risk: if not avoided, minor or moderate injury may result.

- Measures for avoidance

NOTICE!

Risk of damage.

- Measures for avoidance

Instructions for understanding or optimizing the operational procedures

✓ Pre-requirement for a requested action

1. First step for a requested action
   ↳ Result of a step
2. Second step of a requested action

↳ Result of an action

- Request for a single-step action

2 Safety

2.1 Intended use

The Speed Controllers described here are designed for the activation and speed control of DC and BL motors in the low (SC 1801), medium (SC 2402 / SC 2804) and higher power range (SC 5004 / SC 5008). The following points must be observed to ensure that the motors are used as intended:

- The Speed Controller contains electronic components and should be handled in accordance with the ESD regulations.
- Do **not** use the Speed Controller in environments where it will come into contact with water, chemicals and/or dust, **nor** in explosion hazard areas.
- The Speed Controller is **not** suitable for backdriving.
- The housings of the SC 1801 S and SC 1801 F Speed Controllers are not solvent-resistant and must not come into contact with certain solvents (see chap. 2.2, p. 10) or substances containing solvents.
- The Speed Controller should be operated only within the limits specified in this Technical Manual.
- Please ask the manufacturer for information about use under individual special environmental conditions.

The following motor types can be operated with the Speed Controllers:

- DC motors with incremental encoder
- DC motors without encoder (not SC 5004 / SC 5008)
- BL motors with digital Hall sensors
- BL motors without Hall sensors (sensorless operation) (not SC 5004 / SC 5008)
- BL motors with absolute encoder (e.g., AES-4096)
- BL motors with analog Hall sensors
- BL motors with digital Hall sensors and encoder

2.2 Safety instructions

In addition to the safety risks described in this technical manual, machine-specific dangers could arise that cannot be foreseen by the manufacturer of the Speed Controller (e.g., risk of injury from driven components). The manufacturer of the machine in which the Speed Controller is installed must perform a risk analysis in accordance with the regulations applicable to the machine and inform the end user of the residual risks.

2.2.1 Dangers in the event of damages and changes

Damage to the Speed Controller can impair its functions. A damaged Speed Controller can unexpectedly start, stop or jam. This can result in damage to other components and materials.

- Do **not** start up a drive system with a defective or damaged Speed Controller.
- Appropriately mark a defective or damaged Speed Controller.
- Do **not** replace defective or damaged components of the Speed Controller.
- Make no changes (modifications, repairs) to the Speed Controller.
- Have loose or defective connections immediately replaced by an electrician.
- After replacing a defective or damaged Speed Controller, test and document the correct function.

2.2.2 Correct installation and commissioning

Errors during the installation and commissioning of the Speed Controller could impair its function. An incorrectly installed Speed Controller can unexpectedly start, stop or jam. This can result in damage to other components and materials.

- Follow the instructions for installation and commissioning given in these installation instructions exactly.
- Only have work on electrical operating equipment performed by an electrician.
- During all work on the electrical equipment, observe the 5 safety rules:
  a) Disconnect from power
  b) Secure against being switched on again
  c) Check that no voltage is present
  d) Ground and short-circuit
  e) Cover or block-off adjacent parts that are under voltage

Electrostatic discharges can damage the electronics.

- Store and transport the Speed Controller in suitable ESD packaging.
- Handle the Speed Controller in compliance with the ESD handling regulations (e.g. wear an ESD wristband, ground surrounding components).
- During installation, ensure that components in the surroundings cannot be electrostatically discharged.

Soiling, foreign bodies, humidity and mechanical influences can damage the electronics.

- Keep foreign objects away from the electronics.
- Install the Speed Controller in a housing that protects it from mechanical influences and is adapted to the ambient conditions (protection class determination).

Installation and connection work whilst supply voltage is applied at the device can damage the electronics.

- Do **not** insert or withdraw connectors whilst supply voltage is applied at the Speed Controller.
- During all aspects of installation and connection work on the Speed Controller, switch off the power supply.

Incorrect connection of the pins can damage the electronic components.

- Connect the wires as shown in the connection assignment.

2.2.3 Sensitivity to solvents

The housings of the SC 1801 S and SC 1801 F Speed Controllers have only limited resistance to solvents, such as alcohols and acetone.

- Protect the housings against contact with solvents or substances containing solvents.

2.2.4 Heat development

Active components may cause the Speed Controller to heat up. If touched, there is a risk of burning.

- Protect the Speed Controller against being touched and cool sufficiently.
- If necessary, affix a suitable warning sign in the immediate vicinity of the controller.

Fig. 1: Suitable warning sign acc. to DIN EN ISO 7010

2.3 Environmental conditions

- Select the installation location so that clean dry air is available for cooling the Speed Controller.
- Select the installation location so that the air has unobstructed access to flow around the drive.
- When installed within housings and cabinets take particular care to ensure adequate cooling of the Speed Controller.
- Select a power supply that is within the defined tolerance range.
- Protect the Speed Controller against heavy deposits of dust, in particular metal dust and chemical pollutants.
- Protect the Speed Controller against humidity and wet.

2.4 EC directives on product safety

- The following EC directives on product safety must be observed.
- If the Motion Controller is being used outside the EU, international, national and regional directives must be also observed.

Machinery Directive (2006/42/EC)
The controllers with attached motor described in this technical manual may be drive systems according to the Machinery Directive. They are therefore to be considered incomplete machines according to the Machinery Directive. Compliance is documented by the Declaration of Incorporation for the product and by the EC Declaration of the Conformity.

EMC Directive (2014/30/EU)
The directive concerning electromagnetic compatibility (EMC) applies to all electrical and electronic devices, installations and systems sold to an end user. In addition, CE marking can be undertaken for built-in components according to the EMC Directive. Conformity with the directive is documented in the Declaration of Conformity.

Applied standards
Various harmonized standards were applied to the products described in this technical manual; these standards are documented in the EC Declaration of Conformity. You can find the Declaration of Incorporation for the product and the EC Declaration of Conformity in chap. 10, p. 74.

WEEE Directive (2012/19/EU)
The directive on the disposal of electrical and electronic devices prescribes the separate collection of old electrical and electronic devices. The products described in this technical manual fall within the scope of this directive.

3 Product description

3.1 General product description

FAULHABER Speed Controllers are based on an integrated microcontroller and are used for speed control in the motor models listed in chap. 2.1, p. 9.

The Speed Controllers are equipped with the following functions for controlling the motors:

- Speed control through setpoint specification via an analog voltage
- Speed control through setpoint specification via a PWM signal
- Operation with fixed speed
- Operation as voltage controller
- Current limitation
- Direction of rotation changeover via switching input
- Digital output, configurable as fault output or frequency output
- Change configuration and parameters through firmware download

Depending on the product variant, BL motors or DC motors can be operated in a controlled manner.

- For BL motors, the rotor position can be detected via digital or analog Hall sensors or without sensors. Alternatively, motors with AES absolute encoders can be connected.
- For DC motors, the speed is determined via a 2-channel incremental encoder or without sensors from the motor current.

FAULHABER Speed Controller (SC) can be adapted to the application via the FAULHABER Motion Manager software from version 5.x. The following can be set:

- Type and scaling of the set value specification
- Operating mode
- Controller parameters

The programming adapter for Speed Controllers is used for configuration (see chap. 8, p. 72).

Thanks to their compact design, the Speed Controllers can be used in a wide variety of applications and require only basic wiring. The flexible connection possibilities open a wide range of applications in all areas, such as in:

- decentral systems in automation technology,
- pick-and-place machines and machine tools,
- pump drives.

3.2 Product information

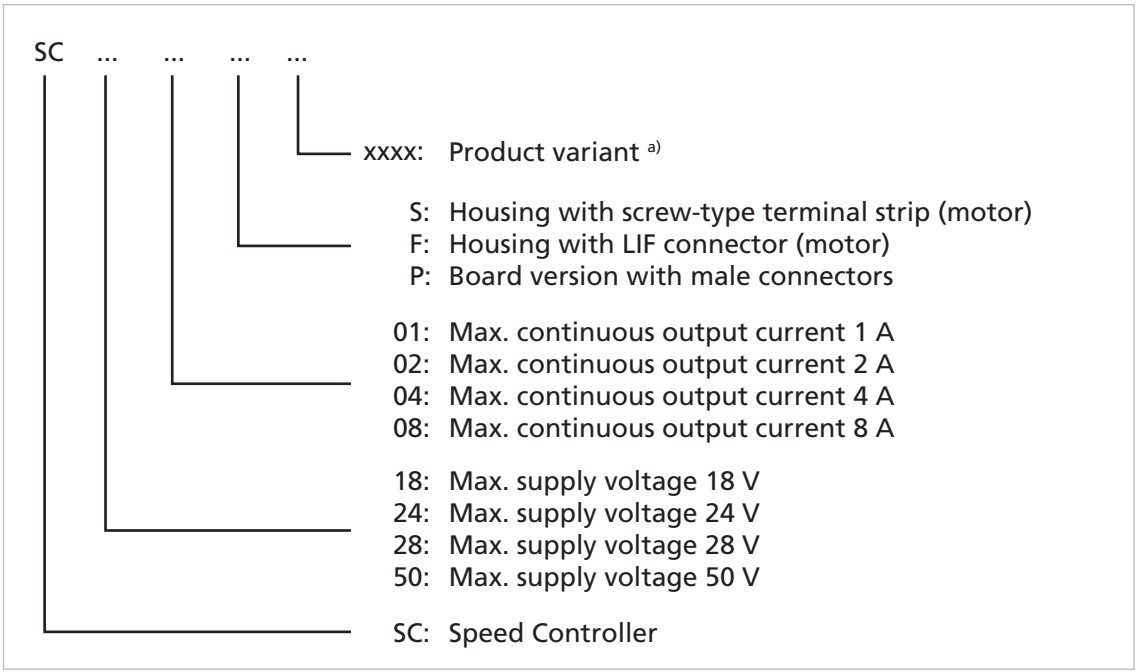


Fig. 2: Designation key

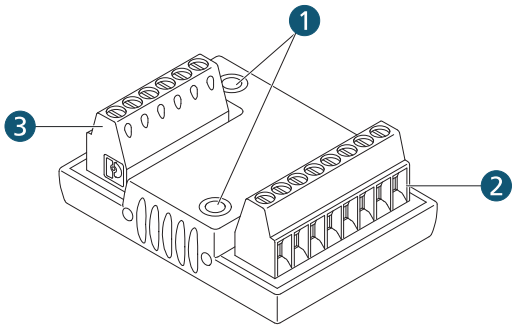
a) For details, see chap. 3.3, p. 15

3.3 Product variants

3.3.1 Speed Controllers for motors in the lower power range

3.3.1.1 SC 1801 S

Speed Controller with housing and screw terminals on the supply and motor side.



1 Assembly sleeves
2 Screw terminal block on the motor side
3 Screw terminal block on the supply side

Tab. 1: Product variants of the SC 1801 S series

Variant	Standard configuration	Speed range [min^{-1}] a)	Power supply of electronics/motor (V DC)	Optional configurations b)
3530	BL + Hall sensors (digital, 2-pole)	500…100 000	4.0…18 / 1.8…18	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
6339	BL + Hall sensors (digital, 4-pole)	400…50 000	4.0…18 / 1.8…18	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
6340	BL + Hall sensors (digital, 14-pole)	400…14 000	4.0…18 / 1.8…18	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
3531	DC + incremental encoder c)	100…30 000	4.0…18 / 1.8…18	▪ BL + Hall sensors (digital) ▪ BL sensorless (normal / high speed) ▪ DC sensorless
3980/ 4763	BL + AES absolute encoder (4-pole/2-pole)	50…10 000	4.0…18 / 1.8…18	▪ BL + Hall sensors (analog) ▪ BL + absolute encoder (4096) ▪ DC sensorless
4289/ 4764	BL + Hall sensors (analog, 2-pole/4-pole) d)	50…60 000	4.0…18 / 1.8…18	▪ BL + absolute encoder (4096) ▪ DC sensorless

a) The speed range depends on the maximum motor supply voltage.
To reach the maximum speed, it may be necessary to reprogram the controller.

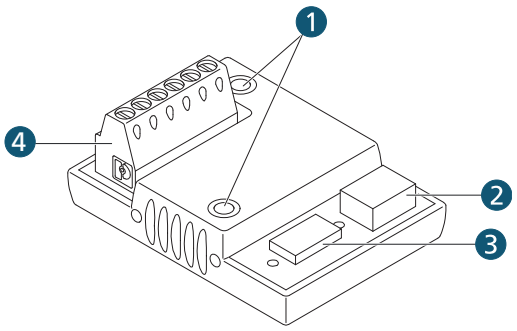
b) Reconfiguration with Motion Manager and programming adapter

c) Preset to 512 pulses

d) The maximum speed refers to 2-pole motors. For motors with more poles, the maximum speed decreases accordingly.

3.3.1.2 SC 1801 F

Speed Controller with housing and screw terminals on the supply side and with flexboard connection on the motor side.



1 Assembly sleeves
2 LIF plug connector on the motor side for FFC and FPC, 3-pole
3 LIF plug connector on the motor side for FFC and FPC, 8-pole
4 Screw terminal block on the supply side

Tab. 2: Product variants of the SC 1801 F series

Variant	Standard configuration	Speed range [min^{-1}] a)	Power supply of electronics/motor (V DC)	Optional configurations b)
3530	BL + Hall sensors (digital, 2-pole)	500…100 000	4.0…18 / 1.8…18	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
3533	BL sensorless (high speed) c)	1000…65 000	4.0…18 / 1.8…18	▪ BL + Hall sensors (digital) ▪ BL sensorless (normal) ▪ DC + incremental encoder ▪ DC sensorless
3980/ 4763	BL + AES absolute encoder (4-pole/2-pole)	50…10 000	4.0…18 / 1.8…18	▪ BL + Hall sensors (analog) ▪ BL + absolute encoder (4096) ▪ DC sensorless
4289/ 4764	BL + Hall sensors (analog, 2-pole/4-pole) c)	50…60 000	4.0…18 / 1.8…18	▪ BL + absolute encoder (4096) ▪ DC sensorless

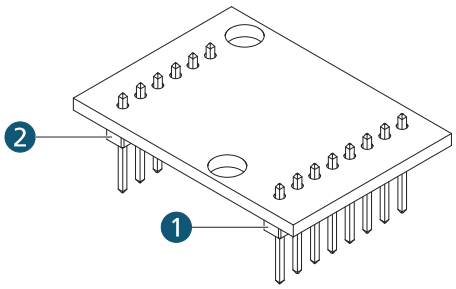
a) The speed range depends on the maximum motor supply voltage.
To reach the maximum speed, it may be necessary to reprogram the controller.

b) Reconfiguration with Motion Manager and programming adapter

c) The maximum speed refers to 2-pole motors. For motors with more poles, the maximum speed decreases accordingly.

3.3.1.3 SC 1801 P

Speed Controller without housing (board version) with plug connectors on the supply and motor side.



1 Plug connector on the motor side
2 Plug connector on the supply side

Tab. 3: Product variants of the SC 1801 P series

Variant	Standard configuration	Speed range [min^{-1}] a)	Power supply of electronics/motor (V DC)	Optional configurations b)
3530	BL + Hall sensors (digital, 2-pole)	500…100 000	4.0…18 / 1.8…18	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
6339	BL + Hall sensors (digital, 4-pole)	400…50 000	4.0…18 / 1.8…18	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
6340	BL + Hall sensors (digital, 14-pole)	400…14 000	4.0…18 / 1.8…18	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
3531	DC + incremental encoder c)	100…30 000	4.0…18 / 1.8…18	▪ BL + Hall sensors (digital) ▪ BL sensorless (normal / high speed) ▪ DC sensorless
3980/ 4763	BL + AES absolute encoder (4-pole/2-pole)	50…10 000	4.0…18 / 1.8…18	▪ BL Hall sensors (analog) ▪ BL absolute encoder (4096) ▪ DC sensorless
4289/ 4764	BL + Hall sensors (analog, 2-pole/4-pole) d)	50…60 000	4.0…18 / 1.8…18	▪ BL absolute encoder (4096) ▪ DC sensorless

a) The speed range depends on the maximum motor supply voltage.
To reach the maximum speed, it may be necessary to reprogram the controller.

b) Reconfiguration with Motion Manager and programming adapter

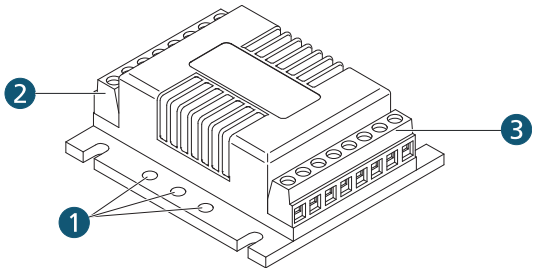
c) Preset to 512 pulses

d) The maximum speed refers to 2-pole motors. For motors with more poles, the maximum speed decreases accordingly.

3.3.2 Speed Controllers for motors in the medium power range

3.3.2.1 SC 2804 S

Speed Controller with metal housing and screw terminals on the supply and motor side.



1 Mounting holes
2 Screw terminal block on the supply side
3 Screw terminal block on the motor side

Tab. 4: Product variants of the SC 2804 S series

Variant	Standard configuration	Speed range [min^{-1}] [a]	Power supply of electronics/motor (V DC)	Optional configurations [b]
3530	BL + Hall sensors (digital, 2-pole)	500…100 000	5.0…28 / 0…28	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
6339	BL + Hall sensors (digital, 4-pole)	400…50 000	5.0…28 / 0…28	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
6340	BL + Hall sensors (digital, 14-pole)	400…14 000	5.0…28 / 0…28	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
3531	DC + incremental encoder [c]	100…30 000	5.0…28 / 0…28	▪ BL + Hall sensors (digital) ▪ BL sensorless (normal / high speed) ▪ DC sensorless
4475	BL + Hall sensors (digital) + encoder [d]	100…30 000	5.0…28 / 0…28	▪ BL + Hall sensors (digital) ▪ BL + digital Hall + enable ▪ DC + incremental encoder
4476	BL + Hall sensors (digital) + Brake/Enable [b] [e]	500…100 000	5.0…28 / 0…28	▪ BL + Hall sensors (digital) ▪ BL digital Hall + incremental encoder ▪ DC + incremental encoder
3980/ 4763	BL + AES absolute encoder (4-pole/2-pole)	50…10 000	5.0…28 / 0…28	▪ BL + Hall sensors (analog) ▪ BL + absolute encoder (4096) ▪ DC sensorless
4289/ 4764	BL + Hall sensors (analog, 2-pole/4-pole) [e]	50…60 000	5.0…28 / 0…28	▪ BL + absolute encoder (4096) ▪ DC sensorless

a) The speed range depends on the maximum motor supply voltage.
To reach the maximum speed, it may be necessary to reprogram the controller.

b) Reconfiguration with Motion Manager and programming adapter

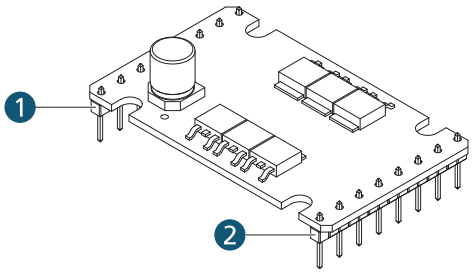
c) Preset to 512 pulses

d) Preset to 256 pulses

e) The maximum speed refers to 2-pole motors. For motors with more poles, the maximum speed decreases accordingly.

3.3.2.2 SC 2402 P

Speed Controller without housing (board version) with plug connectors on the supply and motor side.



1 Plug connector on the supply side
2 Plug connector on the motor side

Tab. 5: Product variants of the SC 2402 P series

Variant	Standard configuration	Speed range [min^{-1}] [a]	Power supply of electronics/motor (V DC)	Optional configurations [b]
3530	BL + Hall sensors (digital, 2-pole)	500…100 000	5.0…24 / 0…24	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
6339	BL + Hall sensors (digital, 4-pole)	400…50 000	5.0…24 / 0…24	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
6340	BL + Hall sensors (digital, 14-pole)	400…14 000	5.0…24 / 0…24	▪ BL sensorless (normal / high speed) ▪ DC + incremental encoder ▪ DC sensorless
3531	DC + incremental encoder [c]	100…30 000	5.0…24 / 0…24	▪ BL + Hall sensors (digital) ▪ BL sensorless (normal / high speed) ▪ DC sensorless
4475	BL + Hall sensors (digital) + encoder [d]	100…30 000	5.0…24 / 0…24	▪ BL + Hall sensors (digital) ▪ BL + digital Hall + enable ▪ DC + incremental encoder
4476	BL + Hall sensors (digital) + Brake/Enable [b] [e]	500…100 000	5.0…24 / 0…24	▪ BL + Hall sensors (digital) ▪ BL digital Hall + incremental encoder ▪ DC + incremental encoder
3980/ 4763	BL + AES absolute encoder (4-pole/2-pole)	50…10 000	5.0…24 / 0…24	▪ BL + Hall sensors (analog) ▪ BL + absolute encoder (4096) ▪ DC sensorless
4289/ 4764	BL + Hall sensors (analog, 2-pole/4-pole) [e]	50…60 000	5.0…24 / 0…24	▪ BL + absolute encoder (4096) ▪ DC sensorless

a) The speed range depends on the maximum motor supply voltage.
To reach the maximum speed, it may be necessary to reprogram the controller.

b) Reconfiguration with Motion Manager and programming adapter

c) Preset to 512 pulses

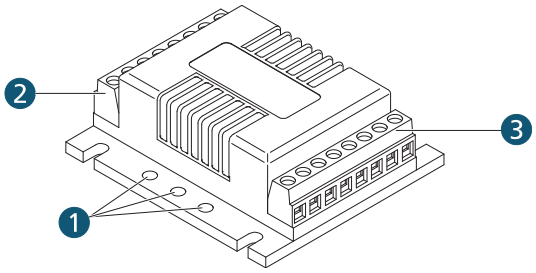
d) Preset to 256 pulses

e) The maximum speed refers to 2-pole motors. For motors with more poles, the maximum speed decreases accordingly.

3.3.3 Speed Controllers for motors in the higher power range

3.3.3.1 SC 5008 S

Speed Controller with metal housing and screw terminals on the supply and motor side.



1 Mounting holes
2 Screw terminal block on the supply side
3 Screw terminal block on the motor side

Tab. 6: Product variants of the SC 5008 S series

Variant	Standard configuration	Speed range [min^{-1}] a)	Power supply of electronics/motor (V DC)	Optional configurations b)
3530	BL + Hall sensors (digital, 2-pole)	500…100 000	6.0…50 / 0…50	▪ BL + Hall sensors (analog) ▪ DC + incremental encoder
6339	BL + Hall sensors (digital, 4-pole)	400…50 000	6.0…50 / 0…50	▪ BL + Hall sensors (analog) ▪ DC + incremental encoder
6340	BL + Hall sensors (digital, 14-pole)	400…14 000	6.0…50 / 0…50	▪ BL + Hall sensors (analog) ▪ DC + incremental encoder
3531	DC + incremental encoder c)	100…30 000	6.0…50 / 0…50	▪ BL + Hall sensors (digital/analog)
4475	BL + Hall sensors (digital) + encoder d)	100…30 000	6.0…50 / 0…50	▪ BL + Hall sensors (digital) ▪ BL digital Hall + enable ▪ DC + incremental encoder
4476	BL + Hall sensors (digital) + Brake/Enable b) e)	500…100 000	6.0…50 / 0…50	▪ BL + Hall sensors (digital) ▪ BL digital Hall + incremental encoder ▪ DC + incremental encoder
3980/ 4763	BL + AES absolute encoder (4-pole/2-pole)	50…10 000	6.0…50 / 0…50	▪ BL + absolute encoder (4096)
4289/ 4764	BL + Hall sensors (analog, 2-pole/4-pole) e)	50…60 000	6.0…50 / 0…50	▪ BL + Hall sensors (digital) ▪ DC + incremental encoder

a) The speed range depends on the maximum motor supply voltage.
To reach the maximum speed, it may be necessary to reprogram the controller.

b) Reconfiguration with Motion Manager and programming adapter

c) Preset to 512 pulses

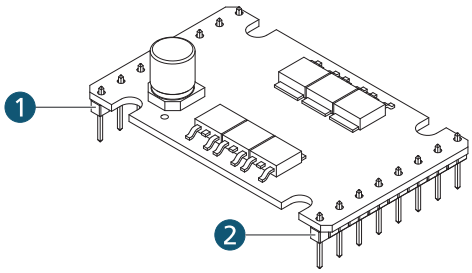
d) Preset to 256 pulses

e) The maximum speed refers to 2-pole motors. For motors with more poles, the maximum speed decreases accordingly.

It is essential to adapt the controller to the motor using the programming adapter.

3.3.3.2 SC 5004 P

Speed Controller without housing (board version) with plug connectors on the supply and motor side.



1 Plug connector on the supply side
2 Plug connector on the motor side

Tab. 7: Product variants of the SC 5004 P series

Variant	Standard configuration	Speed range [min^{-1}] [a]	Power supply of electronics/motor (V DC)	Optional configurations [b]
3530	BL + Hall sensors (digital, 2-pole)	500…100 000	6.0…50 / 0…50	▪ BL + Hall sensors (analog) ▪ DC + incremental encoder
6339	BL + Hall sensors (digital, 4-pole)	400…50 000	6.0…50 / 0…50	▪ BL + Hall sensors (analog) ▪ DC + incremental encoder
6340	BL + Hall sensors (digital, 14-pole)	400…14 000	6.0…50 / 0…50	▪ BL + Hall sensors (analog) ▪ DC + incremental encoder
3531	DC + incremental encoder [c]	100…30 000	6.0…50 / 0…50	▪ BL + Hall sensors (digital/analog)
4475	BL + Hall sensors (digital) + encoder [d]	100…30 000	6.0…50 / 0…50	▪ BL + Hall sensors (digital) ▪ BL digital Hall + enable ▪ DC + incremental encoder
4476	BL + Hall sensors (digital) + Brake/Enable [b] [e]	500…100 000	6.0…50 / 0…50	▪ BL + Hall sensors (digital) ▪ BL digital Hall + incremental encoder ▪ DC + incremental encoder
3980/ 4763	BL + AES absolute encoder (4-pole/2-pole)	50…10 000	6.0…50 / 0…50	▪ BL + absolute encoder (4096)
4289/ 4764	BL + Hall sensors (analog, 2-pole/4-pole) [e]	50…60 000	6.0…50 / 0…50	▪ BL + Hall sensors (digital) ▪ DC + incremental encoder

a) The speed range depends on the maximum motor supply voltage.
To reach the maximum speed, it may be necessary to reprogram the controller.

b) Reconfiguration with Motion Manager and programming adapter

c) Preset to 512 pulses

d) Preset to 256 pulses

e) The maximum speed refers to 2-pole motors. For motors with more poles, the maximum speed decreases accordingly.

It is essential to adapt the controller to the motor using the programming adapter.

4 Installation

Only trained experts and instructed persons with knowledge of the following fields may install and commission the Motion Controller:

- Automation technology
- Standards and regulations (such as the EMC Directive)
- Low Voltage Directive
- Machinery Directive
- VDE regulations (DIN VDE 0100)
- Accident prevention regulations

This description must be carefully read and observed before commissioning.

Also comply with the supplementary instructions for installation (see chap. 2.3, p. 12).

4.1 Mounting

4.1.1 Mounting instructions

⚠ CAUTION!

The Speed Controller can become very hot during operation.

- Place a guard against contact and warning notice in the immediate proximity of the controller.

NOTICE!

Improper installation or installation using unsuitable attachment materials can damage the Speed Controller.

- Comply with the installation instructions.

NOTICE!

Installation and connection of the Speed Controller when the power supply is applied can damage the device.

- Prior to all aspects of installation and connection work on the Speed Controller, switch off the power supply.

4.1.2 Install Speed Controller with housing

NOTICE!

Pressing out of the assembly sleeves.

On a soft or uneven surface, the assembly sleeves can be pushed out while screwing on the Speed Controller.

- Select a smooth and hard surface that supports the assembly sleeves against the screwing forces.

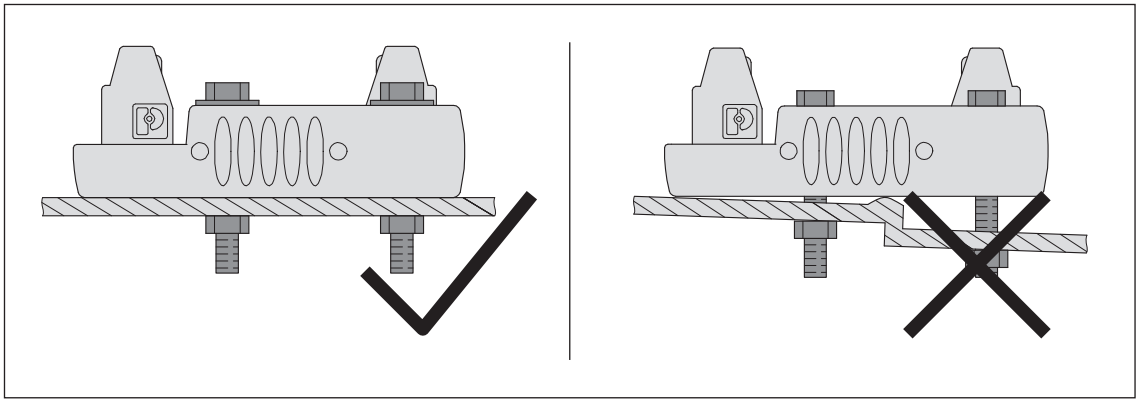


Fig. 3: Mounting (example)

1. Secure the Speed Controller at the assembly sleeves or mounting holes with fastening screws on a flat and hard surface (for torque, see Tab. 8).
2. Protect the fastening screws to prevent displacement due to the effect of heat.

Tab. 8: Attachment specifications

Speed Controller	Min. tightening torque (Ncm)	Max. tightening torque (Ncm)
SC 1801 S/F	12	15
SC 2804 S	50	60
SC 5008 S	50	60

4.2 Electrical connection

4.2.1 Notes on the electrical connection

NOTICE!

Electrostatic discharges to the Speed Controller connections can damage the electronic components

- Observe the ESD protective measures.

NOTICE!

Incorrect connection of the wires can damage the electronic components.

- Connect the wires as shown in the connection assignment.

NOTICE!

Excessive force can damage the motor-side flexboard (SC 1801 F only).

- Do not press in the plug connectors by force.
- Use a suitable tool (tweezers, flat-nose pliers) if necessary.
- Do not pinch the flexboard.

NOTICE!

A short-term voltage peak during braking can damage the power supply or other connected devices.

- Dimension power supply units and any other peripheral components accordingly.
- For applications with high load inertia, the FAULHABER Braking Chopper of the BC 5004 series can be used to limit overvoltages and thereby protect the power supply. For more detailed information see the data sheet for the Braking Chopper.

4.2.2 Electrical connection of the Speed Controller

4.2.2.1 EMC-compliant installation

NOTICE!

Signal interference may be caused if the connection cables are too long.

- Do not exceed a cable length of 3 m on the supply side.
- Observe the EMC protective measures described here and in chap. 4.3, p. 35.

4.2.2.2 EMC protective measures

The devices are intended only for use in industrial applications. If the devices are used in the home, in business, in commerce or in a small business, appropriate measures must be taken to ensure that the emitted interference is below the permissible limit value.

Tab. 9 shows which additional EMC measures can be implemented to optimize the behavior of the equipment in the intended environment with regard to transient emission and interference resistance.

Tab. 9: EMC measures

Motion Controller	Operational environment	Interference type	Action
SC 1801	Industrial area	Transient emission	EMC suppressor circuit 1 + 2
SC 2804 / SC 5008	Industrial area	Transient emission	EMC filter
SC 2804 / SC 5008	Industrial area	Interference resistance	EMC suppressor circuit 3

EMC filter

- Each electronics and motor supply cable must be installed directly at the unit with two windings through a suitable ferrite sleeve (e.g. Würth Elektronik No.: 74270090).
- For DC motors with encoders, the signal cables must be installed directly at the device on both connection sides with one turn through one Star-TEC each (e.g., Würth Elektronik No.: 74271132).

EMC suppressor circuit 1 (SC 1801)

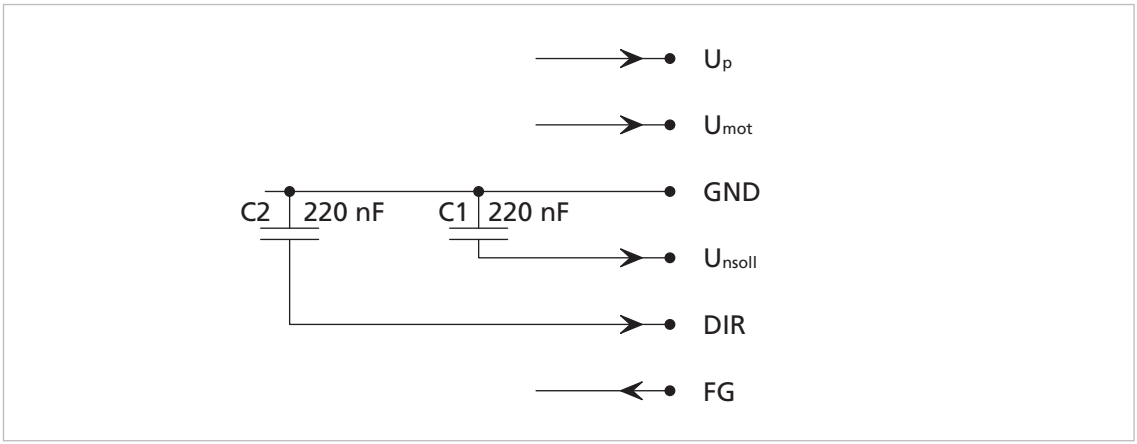


Fig. 4: EMC suppressor circuit with ceramic capacitors

- If a ceramic capacitor (C1) is used in the PWM_{nsoll} operating mode: To avoid faults, use a signal source with a low internal resistance.
- To update the firmware using the Motion Manager software, remove capacitor C2.

EMC suppressor circuit 2 (SC 1801)

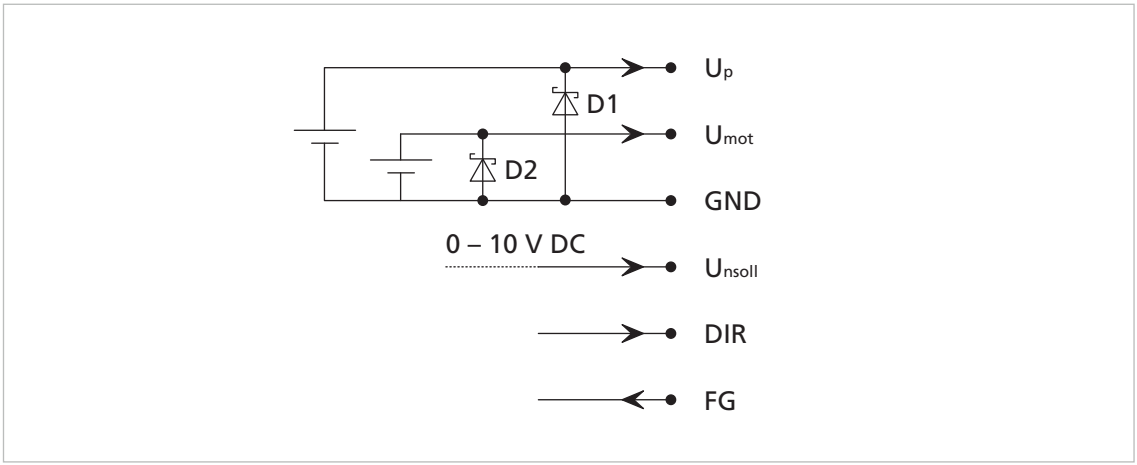


Fig. 5: EMC suppressor circuit for SC 1801 with suppressor diodes

- Separate suppressor diodes (D1 and D2, e.g., P6KE18 from STMicroelectronics) for U_P and U_{mot} with separate power supplies.
- If only one power supply is used (jumper between U_P and U_{mot}), one suppressor diode (D1) is sufficient.

EMC suppressor circuit 3 (SC 2804 / SC 5008)

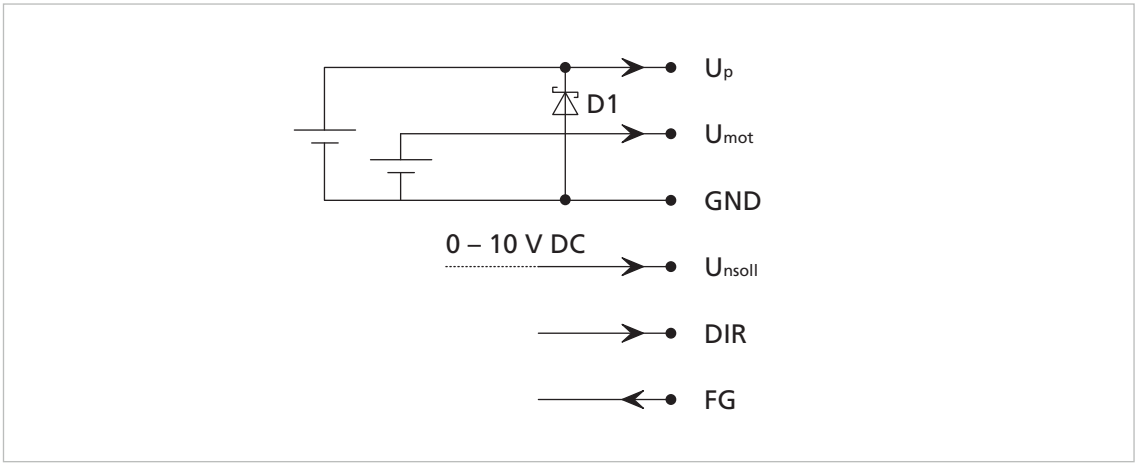


Fig. 6: EMC suppressor circuit for SC 2804 and SC 5008 with suppressor diodes

- Suppressor diode D2 at U_{mot} is integrated in the controller. If only one power supply is used (bridge between U_P and U_{mot}), this is sufficient.
- If separate power supplies are used, an additional external suppressor diode D1 at U_p is recommended, e.g., :
  - U_p = 24 V: D1 = P6KE33A from STMicroelectronics
  - U_p = 48 V: D1 = P6KE56A from STMicroelectronics

4.2.2.3 Pin assignment

NOTICE!

Incorrect connection of the wires can destroy the electronics.

- Connect the motor in accordance with the pin assignment.

NOTICE!

Electrostatic discharges to the Speed Controller connections can cause irreparable damage to the electronics.

- Take the appropriate ESD protective measures.

Pin assignment on the supply side

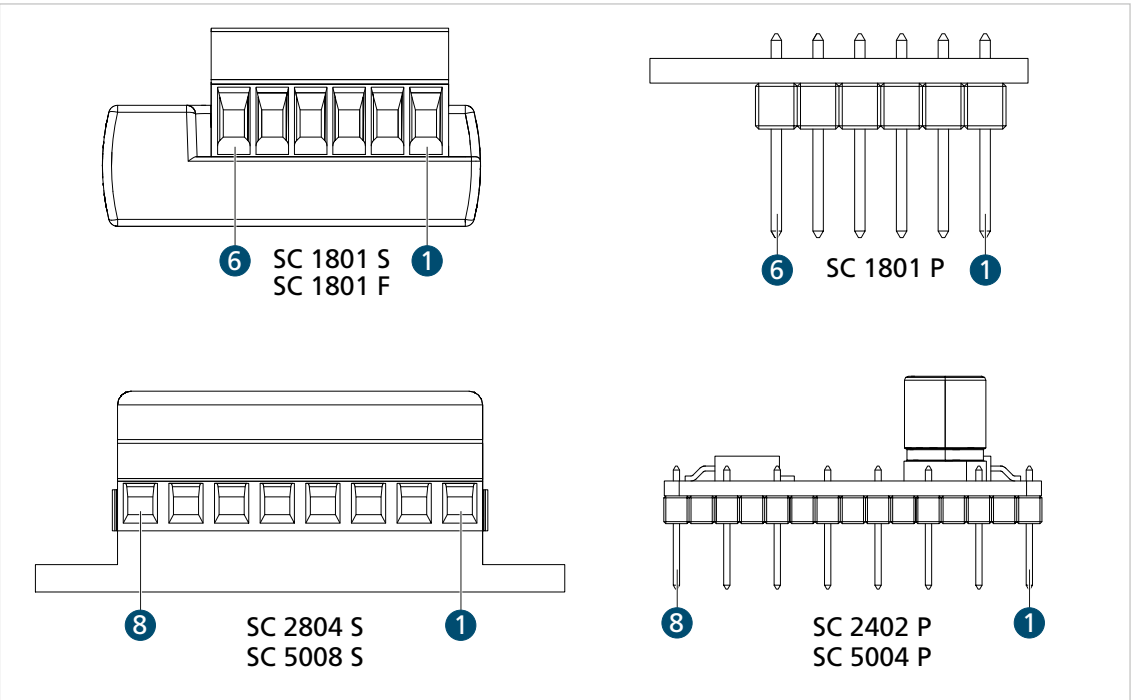


Fig. 7: Connections on the supply side

Tab. 10: Pin assignment on the supply side

Pin	Designation	Meaning
1	U_p	Electronics supply
2	U_{mot}	Power supply of the motor
3	GND	Common ground
4	U_{nsoll}	Control voltage for the set speed (see chap. 5.2, p. 58)
5	DIR	Switching input for the rotation direction of the motor
6	FG	Digital output with open collector and integrated pull-up resistor The digital output can be configured for various tasks (see chap. 5.3, p. 60)
7	IO2	Encoder or enable (only with corresponding hardware, not SC 1801)
8	IO1	Encoder or brake (only with corresponding hardware, not SC 1801)

Tab. 11: Electrical data – supply side

Wire	Designation	Value
1 (U_p)	Electronics supply	▪ SC 1801: 4…18 V DC ▪ SC 2402: 5…24 V DC ▪ SC 2804: 5…28 V DC ▪ SC 5004: 6…50 V DC ▪ SC 5008: 6…50 V DC
2 (U_{mot})	Coil supply	▪ SC 1801: 1.8…18 V DC ▪ SC 2402: 0…24 V DC ▪ SC 2804: 0…28 V DC ▪ SC 5004: 0…50 V DC ▪ SC 5008: 0…50 V DC
3 (GND)	Ground	–
4 (U_{nsoll}) Analog input	Input voltage	U_{in} = 0…10 V U_{in} > 10 V…U_p ➞ speed set value not defined
	Input resistance	R_{in}≥ 8.9 kΩ
	Speed set value	Speed set value per 1 V see Tab. 20 U_{in}< 0.15 V ➞ motor stops U_{in} > 0.3 V ➞ motor runs
5 (DIR) Digital input	Rotation direction input	To ground or U < 0.5 V: anticlockwise U > 3 V: clockwise
	Input resistance	R_{in}≥ 10 kΩ
6 (FG) Digital output	Frequency output	Max. U_p, I_{max} = 15 mA Open collector with pull-up resistor: ▪ SC 1801, SC 2402, SC 2804: 22 kΩ ▪ SC 5004, SC 5008: 47 kΩ Lines per revolution are dependent on configuration and sensor system (see Tab. 19)
7 (IO2) (only for option 4475)	TTL signal level	Encoder channel B
7 (IO2) (only for option 4476) Digital input	TTL signal level	U_{in} = 2.8 V…U_p: high ➞ motor activated U_{in} = 0…0.5 V: low ➞ motor deactivated
8 (IO1) (only for option 4475)	TTL signal level	Encoder channel A
8 (IO1) (only for option 4476) Digital input	TTL signal level	U_{in} = 2.8 V…U_p: high ➞ motor is braked / stopped U_{in} = 0…0.5 V: low ➞ motor turns

Pin assignment on the motor side

The maximum length of the cable between the Speed Controller and motor depends on the sensor system used and the electrical and magnetic fields in the environment.

Tab. 12: Guide values for the cable length

Encoder type	Unshielded length	Shielded length [a]
Digital Hall sensors	0.5 m	2–5 m
Analog Hall sensors	0.5 m	2–5 m
Incremental encoders	0.5 m	2–5 m
Absolute encoder	0.3 m	0.5 m

a) applies to cables separately shielded from the motor phase power cables.

Longer connection cables are generally permissible, but must be validated for the target installation.

Optimization of the behavior in respect of transient emission and interference resistance may require additional EMC measures (see chap. 4.2.2.2, p. 25).

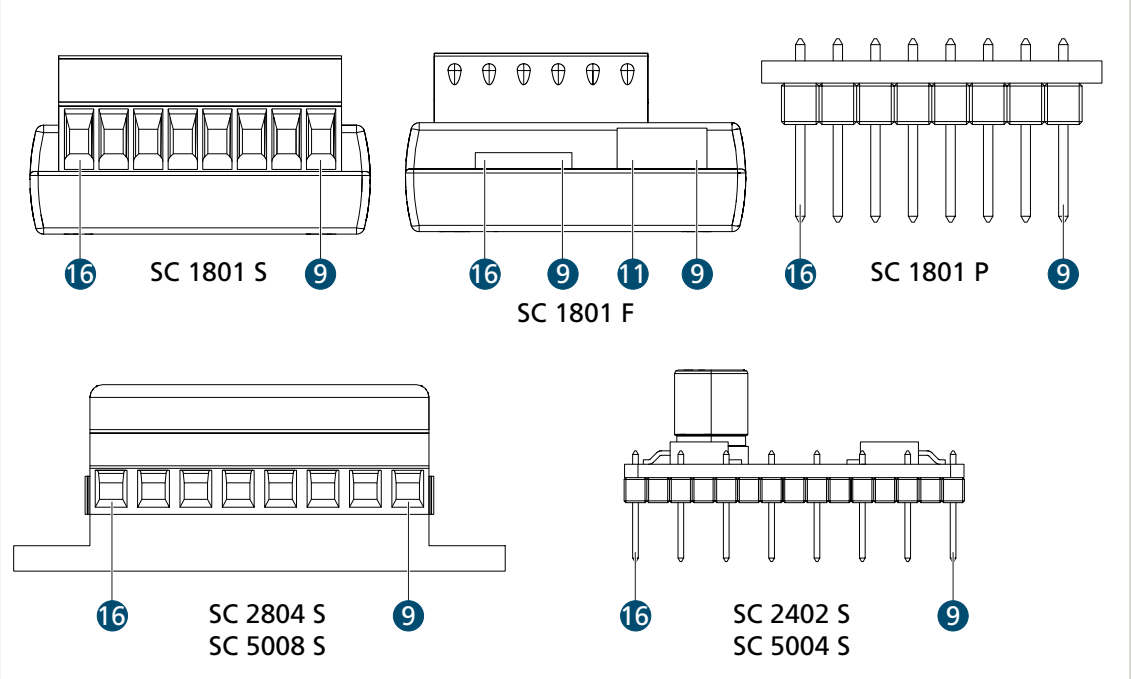


Fig. 8: Connections on the motor side

Tab. 13: Pin assignment on the motor side

Pin	Designation	Meaning
9	Mot C	Power supply of the motor C
10	Mot B	Power supply of the motor B
11	Mot A	Power supply of the motor A
12	SGND	Ground connection of the signal
13	V_{CC}	Power supply for external consumer loads
14	Sens C	Sensor input C
15	Sens B	Sensor input B
16	Sens A	Sensor input A

Tab. 14: Electrical data – motor connection

Pin	DC motors	BL motors
9 (Mot C)	not used	Phase C
10 (Mot B)	Mot –	Phase B
11 (Mot A)	Mot +	Phase A
	▪ Clockwise rotation with homopolar connection ▪ Anticlockwise rotation with oppositely poled connection	

Tab. 15: Electrical data – power supply for external consumer loads

Pin	Designation	SC 1801	SC 2402	SC 2804	SC 5004	SC 5008
13 (V_{CC})	Output voltage	5 V DC				
	Max. output current	25 mA	20 mA	30 mA	100 mA	100 mA

Tab. 16: Electrical data – sensor inputs

Pin	DC motors	BL motors with Hall sensors	BL motors with absolute encoder
14 (Sens C)	Encoder channel B	Hall sensor C	CLK
15 (Sens B)	Encoder channel A	Hall sensor B	not used
16 (Sens A)	not used	Hall sensor A	DATA

4.2.3 Connection examples

4.2.3.1 Connection examples for the supply side

NOTICE!

Damage to the electronics caused by excessive power supply.

- Observe the minimum and maximum power supply.

Normal operation (speed set value specification by U_{nsoll})

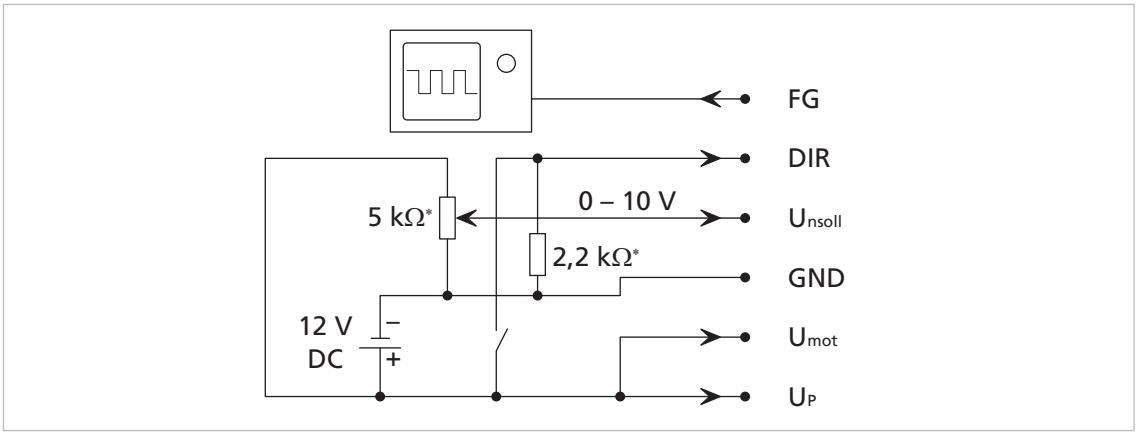


Fig. 9: Normal operation (speed set value specification by U_{nsoll})

* The specified resistance values are to be understood as suggestions

- With the switch open, the connected motor rotates anticlockwise at a controlled speed; with the switch closed, it rotates clockwise.
- The speed is preset by U_{nsoll} and depends on the set maximum speed where U_{nsoll}= 10 V.
- If the digital output is configured as the frequency output (see chap. 5.3, p. 60), the speed signal can be measured at the digital output.

Full modulation (motor speed is determined by U_{mot})

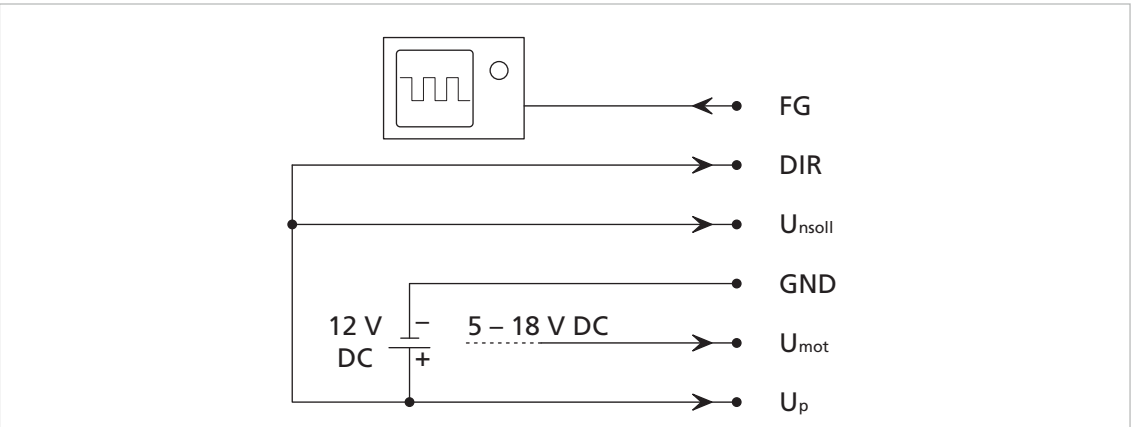


Fig. 10: Full modulation (motor speed is determined by U_{mot})

- The connected motor rotates clockwise at a load-dependent speed.
- The speed can be adapted by changing U_{mot}.
- If the digital output is configured as the frequency output (see chap. 5.3, p. 60), the speed signal can be measured at the digital output.

4.2.3.2 Connection examples for the motor side

DC motor without encoder (not SC 5004 and SC 5008)

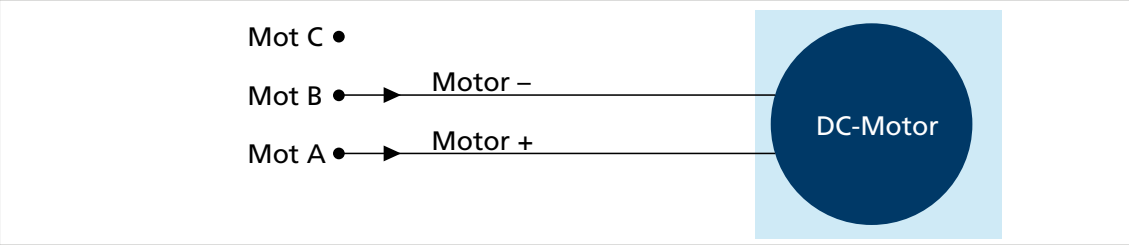


Fig. 11: DC motor without encoder (not SC 5004 and SC 5008)

DC motor with encoder

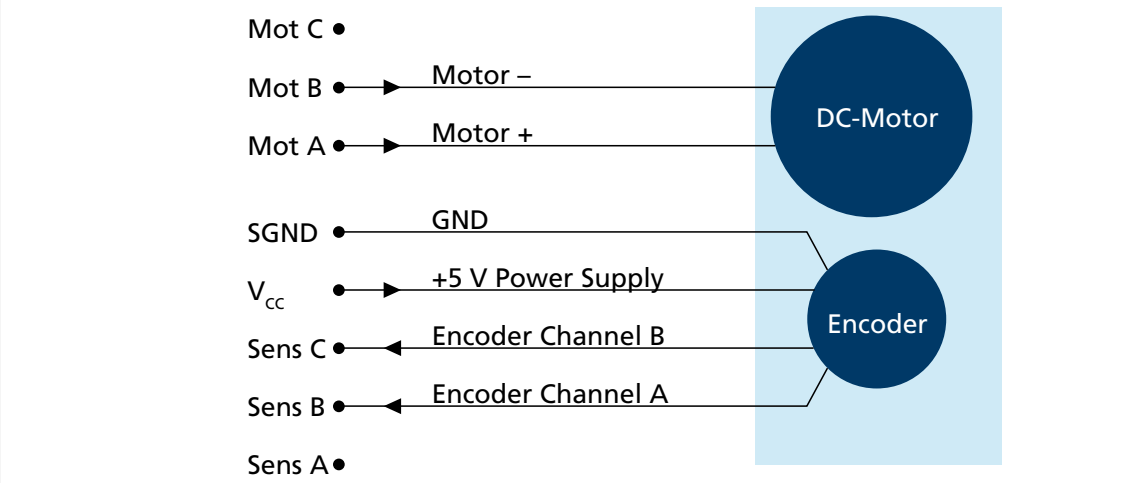


Fig. 12: DC motor with encoder

BL motor without Hall sensors (not SC 5004 and SC 5008)

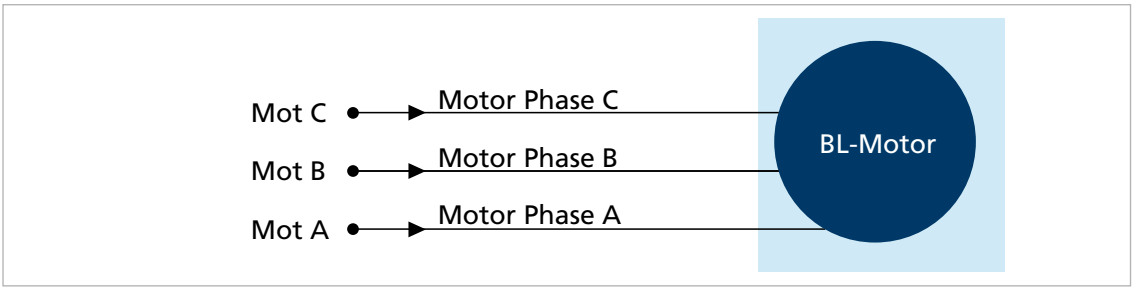


Fig. 13: BL motor without Hall sensors (not SC 5004 and SC 5008)

BL motors with digital/analog Hall sensors

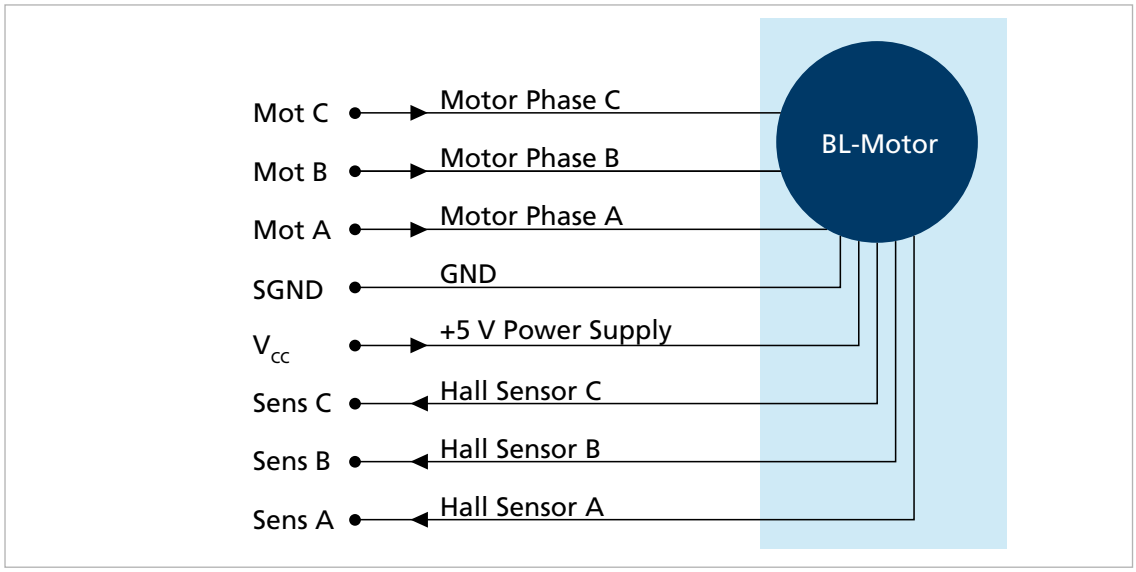


Fig. 14: BL motors with Hall sensors

BL motor with absolute encoders

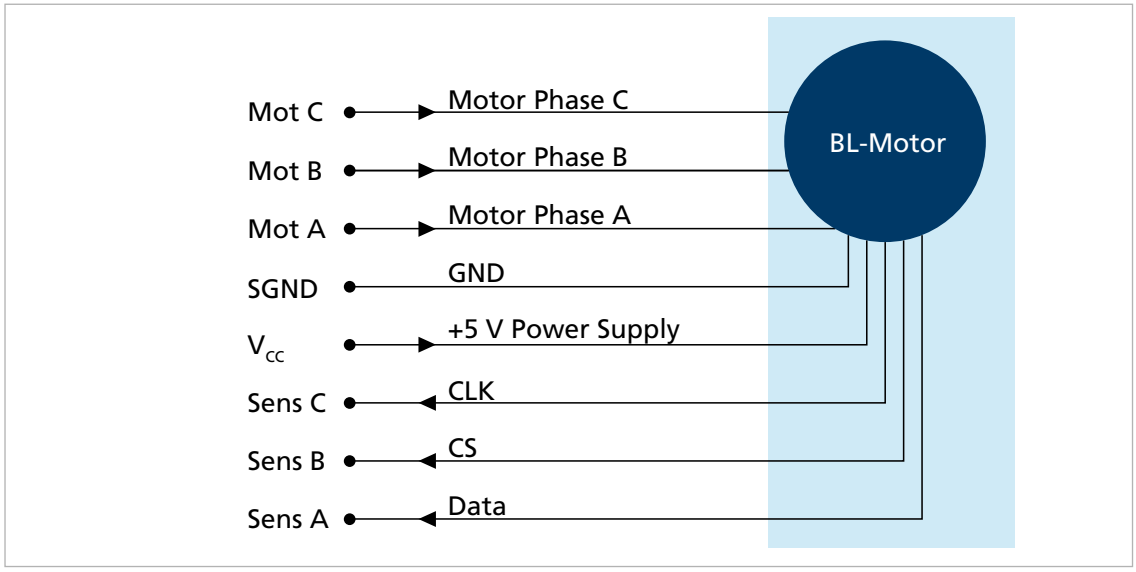


Fig. 15: BL motor with absolute encoders

BL motor with digital Hall sensors and incremental encoders (only option 4475)

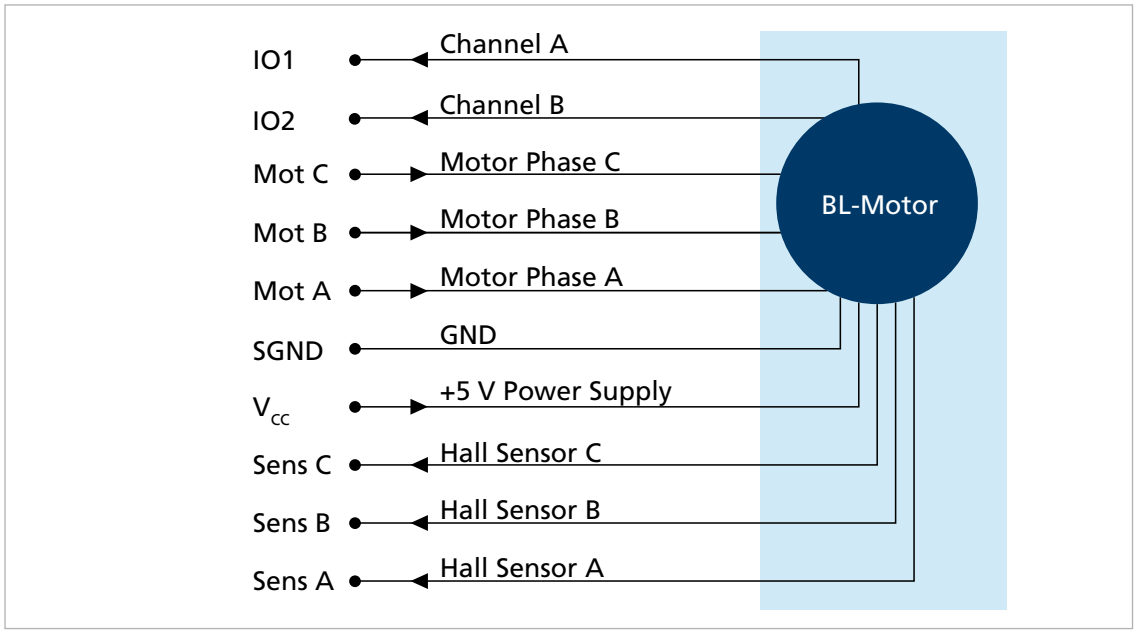


Fig. 16: BL motor with digital Hall sensors and incremental encoders (only option 4475)

BL motor with digital Hall sensors and brake/enable (only option 4476)

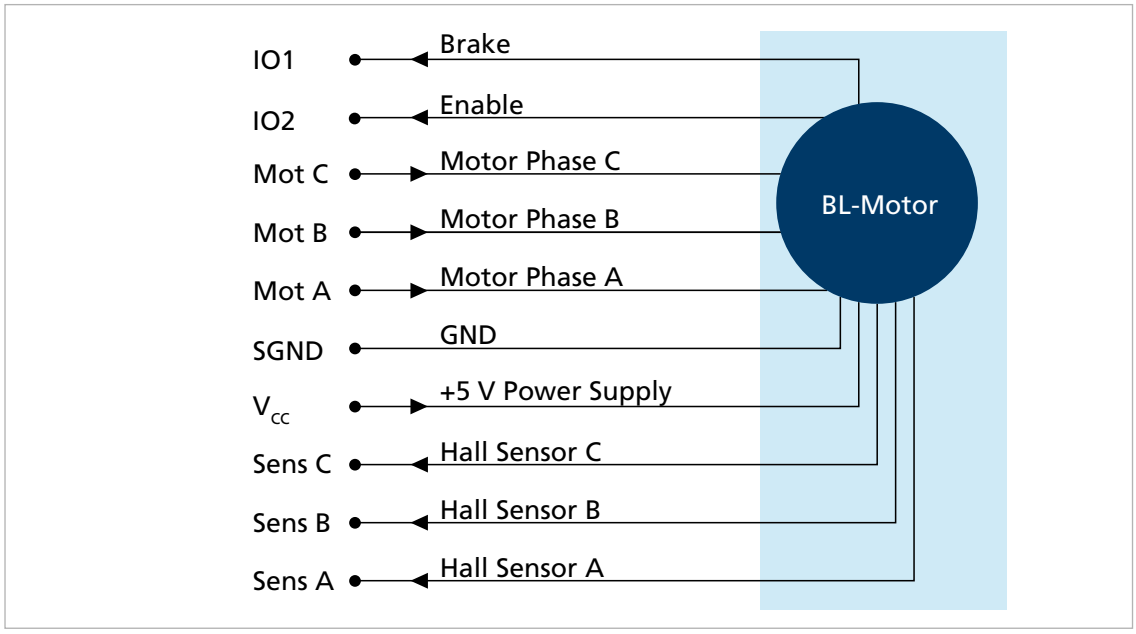


Fig. 17: BL motor with digital Hall sensors and brake/enable (only option 4476)

4.3 Electromagnetic compatibility (EMC)

- Follow the instructions in the following chapters to perform an EMC-compliant installation.

⚠ WARNING!

The Motion Controller can cause high-frequency interference which can affect the function of electronic implants and other electronic devices.

- Take appropriate interference suppression measures, particularly during use in residential environments.
- Observe the notices for EMC-compliant setup.

NOTICE!

Drive electronics with qualified limit values in accordance with EN-61800-3: Category C2 can cause radio interference in residential areas.

- For these drive electronics, take additional measures to limit the spread of radio interference.

4.3.1 Functional earthing

⚠ DANGER!

Danger to life through ground leakage currents ≥3.5 mA

- Check the grounding of the devices for proper installation.

The grounding system is essential for discharging parasitic current and for a potential distribution in the system that is as uniform as possible. The most efficient systems have a star or mesh shape. A star-shaped connection is easier to implement.

- Ensure an adequate cross section and a very good electrical ground connection so that the contact resistances are low not only for the low-frequency currents.

  The ground connection can be improved, e.g., by removing the oxide layers from the ends of conductors with fine sandpaper.

For electrical safety:

- Ground in accordance with current standards and guidelines.
- Use separate protective conductors (PE) for all necessary parts (e.g., mains supply, motor, controller).
- Keep grounding cable as short as possible.

For functional earthing:

- Use a braided shield that is meshed as tightly as possible.
- Direct contact with the grounding plate is to be preferred.

  Therefore, avoid contact with the controller and then with the grounding plate.
- Connections made over a large surface area are to be preferred.

4.3.2 Cable routing

⚠ WARNING!

Voltages >25 V AC are generated and transmitted in the drive system.

- Set up the wiring of the drive system in a touch-proof manner.
- Only operate the drive system on an SELV or PELV power supply network.

The cable routing depends on various factors, such as:

- Is the cable shielded, twisted?
- Were interference-reducing measures taken?
- What material and what cable routing are used in the cable duct?
- Over what surface is the cable routed?

Observe the following when laying the cables:

- Use a full-surface, u-shaped and, if possible, metal cable duct.
- Lay the cables near the corners of the cable duct.
- Separate the cables by function where possible.
- Maintain distances when laying the cables.

  The distances may vary depending on the zone in the switching cabinet.
- If possible, all cables should be twisted pairs or twisted and shielded in function groups (e.g., motor phases together, Hall sensors and supply together).

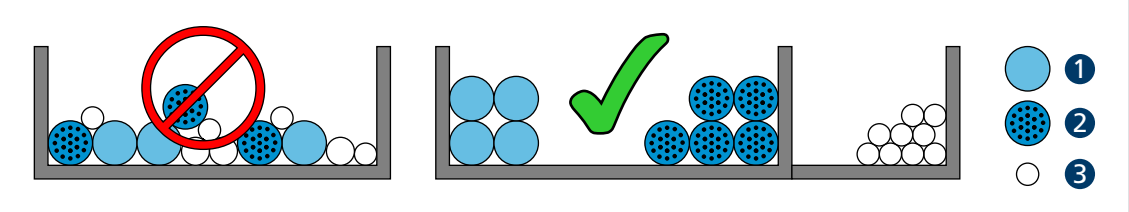


Fig. 18: Laying in the cable duct

1 High-current cable
2 Digital cable
3 Sensor cable

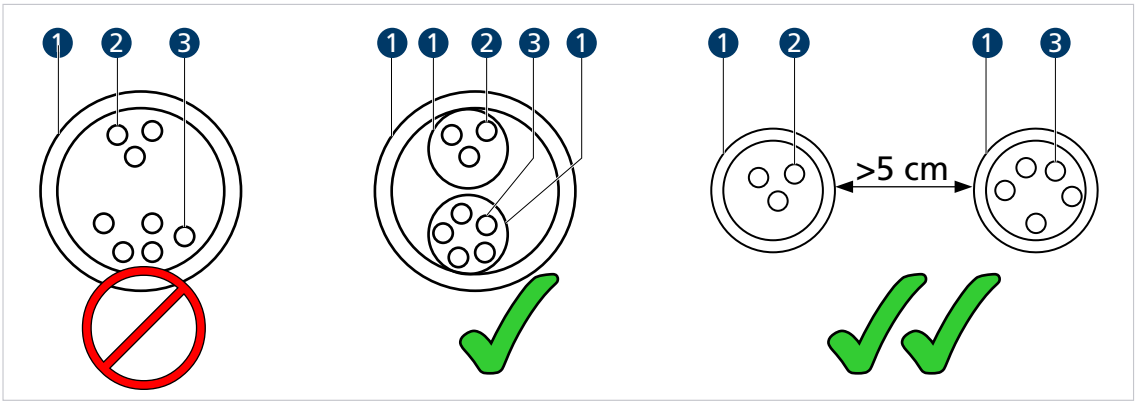


Fig. 19: Grouping and shielding of the cables

1 Shielding
2 Motor phase
3 Hall sensor

4.3.3 Shielding

- Shield cables in all cases.

  Shield cables that are longer than 3 m with tightly meshed copper braiding.

- Shield all supply lines according to current guidelines/standards (e.g., IPC-A-620B) and connect using (round) shield clamp.

  In special cases (e.g., with pigtail) or after qualification, the shield can be omitted for the following cables:

  - Cables with length <50 cm
  - Cables with low power supplies (e.g., <20 V)
  - Sensor cables

- Connect shield clamps to a low-impedance (<0.3 Ω) grounding bar or grounding plate.

  A connection to the controller housing should only be made if no grounding bar is available.

- Establish a star-point ground connection.

- Lay the motor phases in a shield, separate from the sensor or encoder signals, and connect on at least the motor side (see 1 or 2 in Fig. 20).

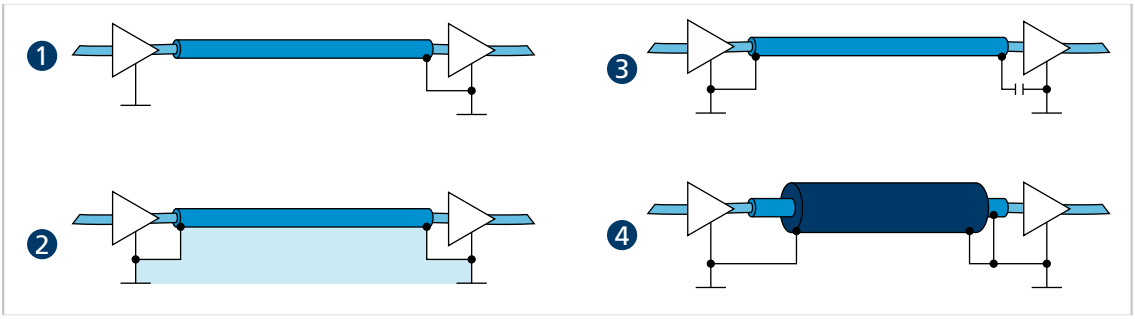


Fig. 20: Various possibilities for the shield connection

1 Suppressing electrical fields
2 Alternating magnetic field
3 Interruption of the ground loop for direct currents or low-frequency currents
4 Discharging parasitic currents to the reference potential

The sensor signals can optionally be laid with the motor phases in a shared cable/insulation hose using another outer braided shield. This outer braided shield must be connected at both ends (e.g., 4 in Fig. 20). A solution such as 2 in Fig. 20 is not functional in every case for this configuration. If this is not possible by means of a ground offset, establish the RF connection via specially suited capacitors (e.g., safety capacitors such as Y1/Y2/X1/X2, see 3 in Fig. 20). In this case, do not connect the shield multiple times except at the motor connection and controller side.

4.3.3.1 Establishing the shield connection

The best results when establishing a shield connection on the cable are achieved in the following way:

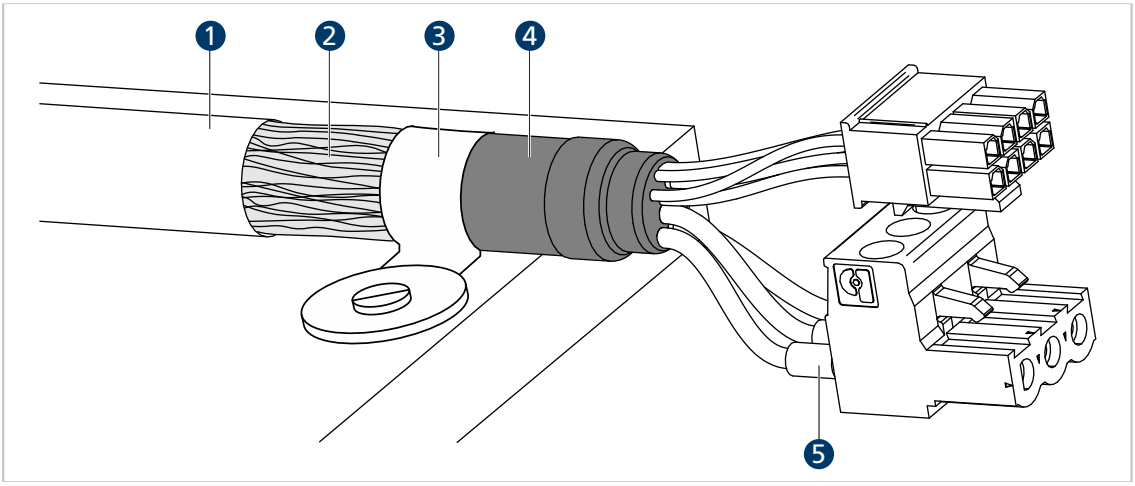


Fig. 21: Motor cable shield connection

1 Outer cable shield
2 Braided shield
3 Shield clamp
4 Heat-shrink tubing
5 Crimp-sleeve

1. Remove approx. 50-100 mm from the outer cable shield (1). Make certain that none of the fibers of the braided shield (2) are destroyed.
2. Either push back the shield or roll it up and fasten with heat-shrink tubing (4).
3. Optionally fit crimp-sleeves on the cable ends (5) and attach to the plug connectors.
4. Fasten the shield and the fixed end of the heat-shrink tubing with a cable tie (3).

4.3.3.2 Establishing shield connection with cable lug

A shield connection with cable lug should be avoided whenever possible. If it is necessary, however, the connection should be established as follows.

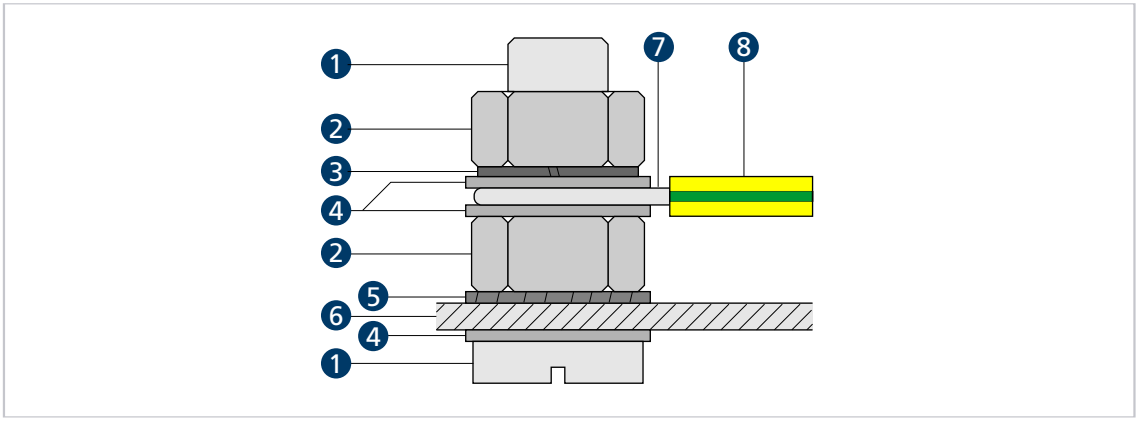


Fig. 22: Shield connection with cable lug

1	*Screw*	*5*	*Lock washer*
2	*Nut*	*6*	*Wall*
3	*Spring washer*	*7*	*Wire eyelet*
4	*Washer*	*8*	*Protective conductor*

1. Scrape the surface around the hole to remove as much of the oxide layer as possible.
2. Guide screw with washers through the cable lug.
3. Place lock washer on the screw.

   Depending on the screw length, also position the lock washer against the roughened surface.
4. Fix screw with nut on the bottom side or screw into the thread.

4.3.4 Sensor and encoder interfaces

The sensor systems used at FAULHABER for angle determination should be divided according to their useful frequency range. Depending on the frequency range, various filter measures are suitable.

- Analog Hall sensors (very low frequency)
- Digital Hall sensors and quadrature interfaces
- Absolute encoder

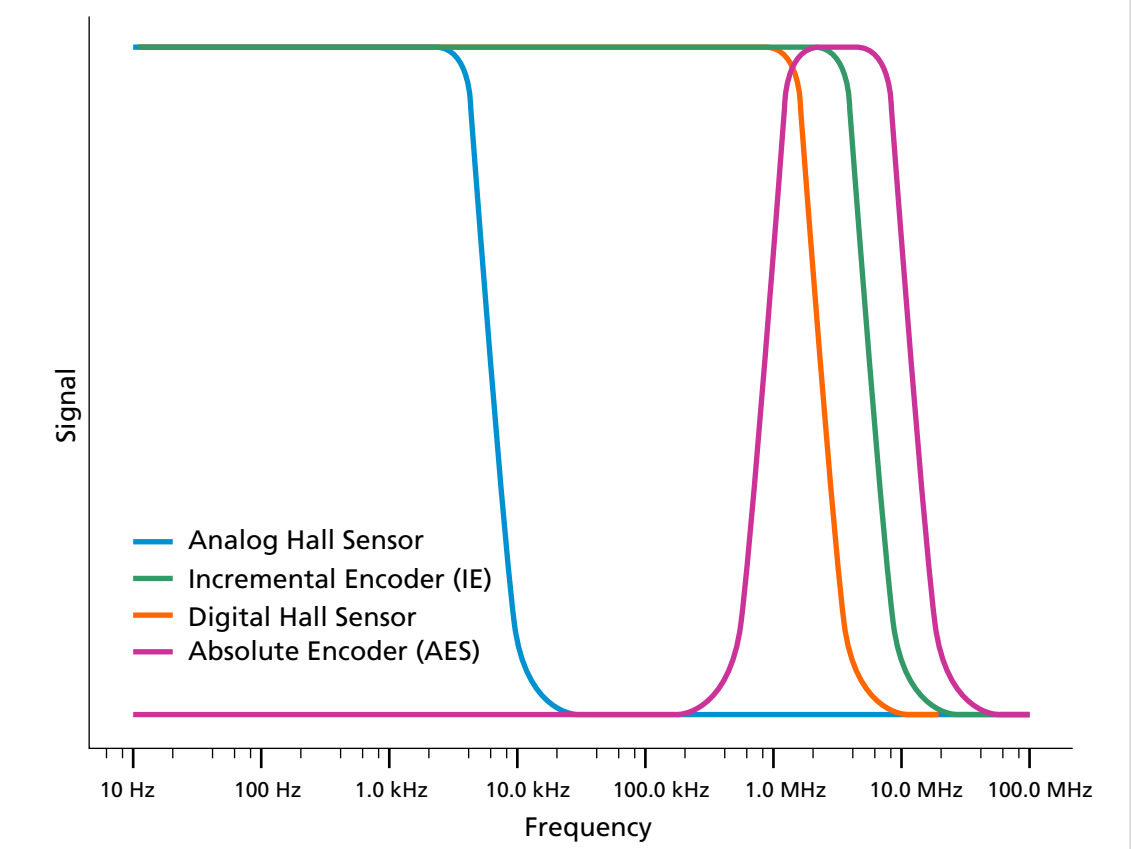


Fig. 23: Useful frequency ranges of the encoders

- To evaluate the interference on the signal (transmission quality), measure the signals.
- Make certain that no parasitic effects are measured. Select the reference potential correctly and measure directly on the controller if possible.

The following statement applies to all mentioned sensor systems: Differential signal transmission with line driver is an effective measure for increasing the interference immunity for longer cable lengths.

Additional measures for the various sensor systems can be found in the following sections.

4.3.4.1 Analog sensors and analog Hall sensors

- Where possible, shield analog sensor cables and lay them apart from (shielded) motor cables.
- Connect the shield on one end, ideally on the motor side.

4.3.4.2 Incremental encoders / Digital Hall sensors / Digital sensors

Due to the increased signal hysteresis, digital Hall sensors are more robust than analog Hall sensors.

Incremental encoders are robust due to a four-edge evaluation in the controller.

4.3.5 Using filters

The filters are divided into various function and current ranges.

Filter types:

- Input-side filters: filters on the power supply side
- Motor-side filters: filters that are connected between controller and motor in the motor phases

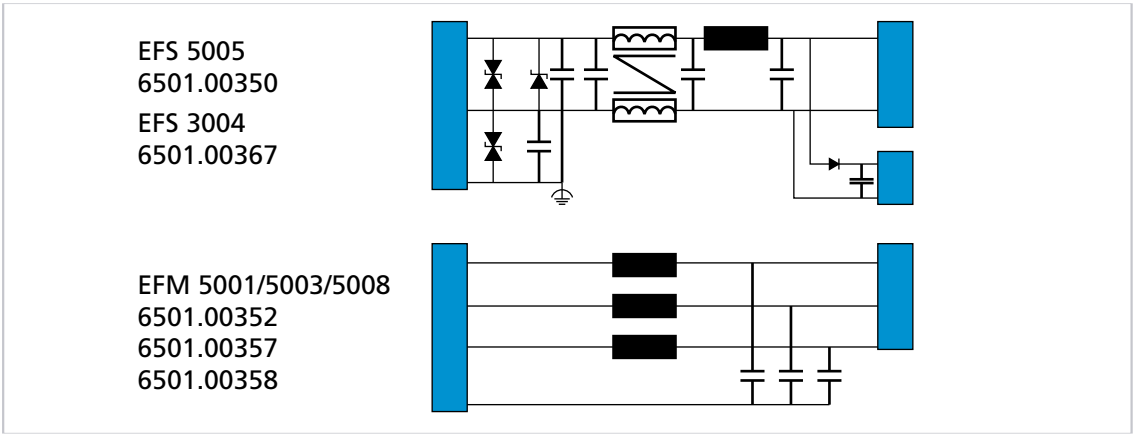


Fig. 24:

4.3.5.1 Input-side filters

These filters are for applications that either cannot use the motor filter (e.g., integrated controllers) or in which the filtering by the motor filters is not sufficient. In this case, two filtering measures are used:

- Measure comparable to large capacitors (approx. >100 µF) as close as possible to the controller and, where possible, low-ESR capacitances
- Discharge of common-mode interference with a common-mode choke, a low-pass filter and capacitors between functional earth and DC power supply

4.3.5.2 PWM filter (motor-side)

The PWM filters are designed for the maximum motor supply voltage with a nominal value of 50 V (+10%) and allow a nominal motor current of 1, 3 or 8 ampere. With DC-motors, the supply line RMS value can be used. A peak current of 3 s can be assumed.

The motor filters are only suitable for the PWM frequency of 100 kHz. Lower PWM frequencies must be explicitly tested, as the power losses increase at lower PWM frequency.

For the proper filter effect, all PWM filters require a 0 V connection, which should be connected as short as possible to the 0 V voltage (GND) of the motor supply (connection X5 of the supply side).

4.3.5.3 Insulation resistance

The filters from FAULHABER are not intended for an insulation resistance test. Discharging of the common-mode interference with capacitors prevents a meaningful result from an insulation resistance test.

4.3.5.4 Coiling ferrite ring

Ideally, ferrites made of manganese-zinc material are used that are active in the 1…10 MHz range. Typical diameters are between 25 and 35 mm onto which two to three windings with all 3 motor phases are wound simultaneously.

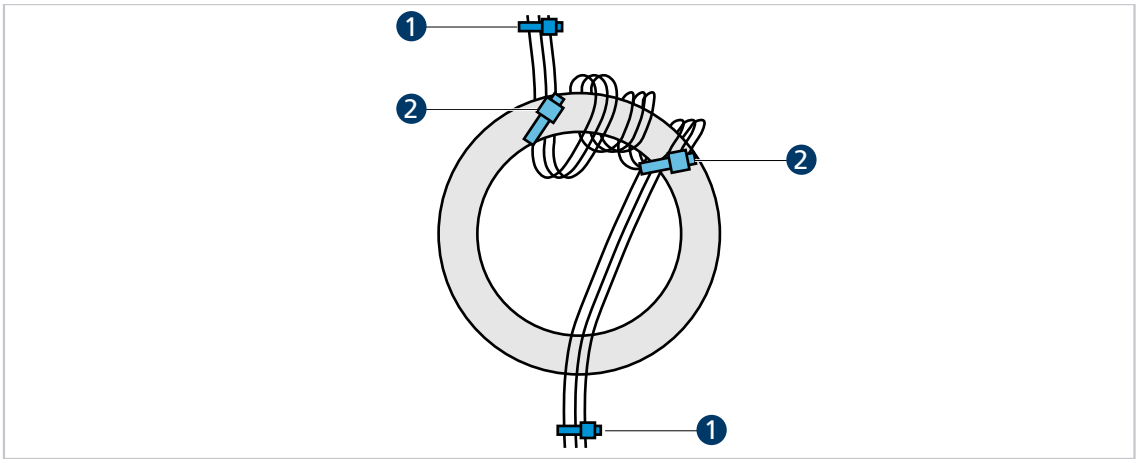


Fig. 25:

1 Fastening the motor phase cables *2 Fastening on the ferrite ring (optional)*

1. Fasten motor phase cables, e.g., with cable ties (1), so that the motor side end of the cable points away from the user and the plug end of the cable points toward the user.
2. Simultaneously guide all three phases through the ferrite ring from below.
3. Guide the wound stranded wires back through the ring clockwise next to the first stranded wires so that a winding is created.
4. Wrap 2 further windings directly next to the existing windings in the same way.
   ↳ There are 9 stranded wires in the ferrite ring.
5. Again secure the motor phase cables, e.g., with cable ties (2), on the ferrite ring.

4.3.6 Error avoidance and troubleshooting

1. Can the problem clearly be traced back to the FAULHABER drive system?
   a) Switch the output stage off and on.

      The voltage controller mode is suitable here.

   b) Unplug controller supply voltages or operate controller via a separate external power supply used solely for this purpose.

   c) If present, switch off unnecessary system components.

2. Have the measures shown in chap. 4.3.1, p. 35 been performed and tested?
   a) Can a uniform ground potential be ensured, e.g., by using large cable cross sections?

   b) Is the RF quality of the connections ensured?

      - Establish connection through metal-to-metal connection elements.
      - Remove paints or other insulating materials. Check that the shield connection is correct.

3. Were the recommended cables used?
   a) Select motor cables in the accessory catalog.

   b) Motor cables must be shielded as they otherwise act as an antenna.

      Unshielded cables could cause interference in the surrounding area. If uncertain, the shield can be doubled; for further information, see FAULHABER accessories catalog and chap. 4.3.3, p. 37.

4. Are the contacts correctly screwed down or properly plugged in?
5. Are the cables laid in accordance with the standards/directives (e.g., IPC-A-620B-2013)?
   a) Sensor cables and encoders are to be laid at least 10 cm from the motor phases.

   b) Lay sensor cables at least 10 cm from all other signal cables that are not also sensor cables. Alternatively, use absolute encoders and/or line drivers.

   c) Keep cables away from high-voltage current and mains cables.

   d) Only cross cables at an angle of 90°.

6. Is it necessary to use filters?
   a) Use filters in the case of poor signal quality or if interference occurs/is to be expected.

   b) Note the product listing in chap. 4.3.5, p. 41.

Conformity measurements

The following points must be observed during the conformity measurement:

Conducted interference voltage measurement	Radiated interference voltage measurement
▪ When laying cables, remove all loops. ▪ Lay the cables with a meandering shape.	▪ Where possible, lay cables over a grounding plate.
▪ Connect the shield of the motor cable on the motor side and as close as possible on the controller side. ▪ The shield is to be connected over a large area, ideally with a round connection.	▪ The connection of the motor cable shield is to be as short as possible ▪ Keep the motor cable as short as possible.
▪ Use an input filter. When selecting, pay attention to the difference of filter attenuation between 50 Ω and realistic values 1/100 Ω or 100/1 Ω measurement.	▪ Use a motor filter and keep the connection as short as possible.
▪ If possible, secure cable with shield clamps or with adhesive tape.	

5 Description of functions

5.1 Operating modes

5.1.1 Speed-controlled operation of the DC motors

The actual speed value for the speed controller can be determined in different ways. The configurations described below differ in this regard.

The digital output is permanently programmed as fault output.

5.1.1.1 DC motors with encoder

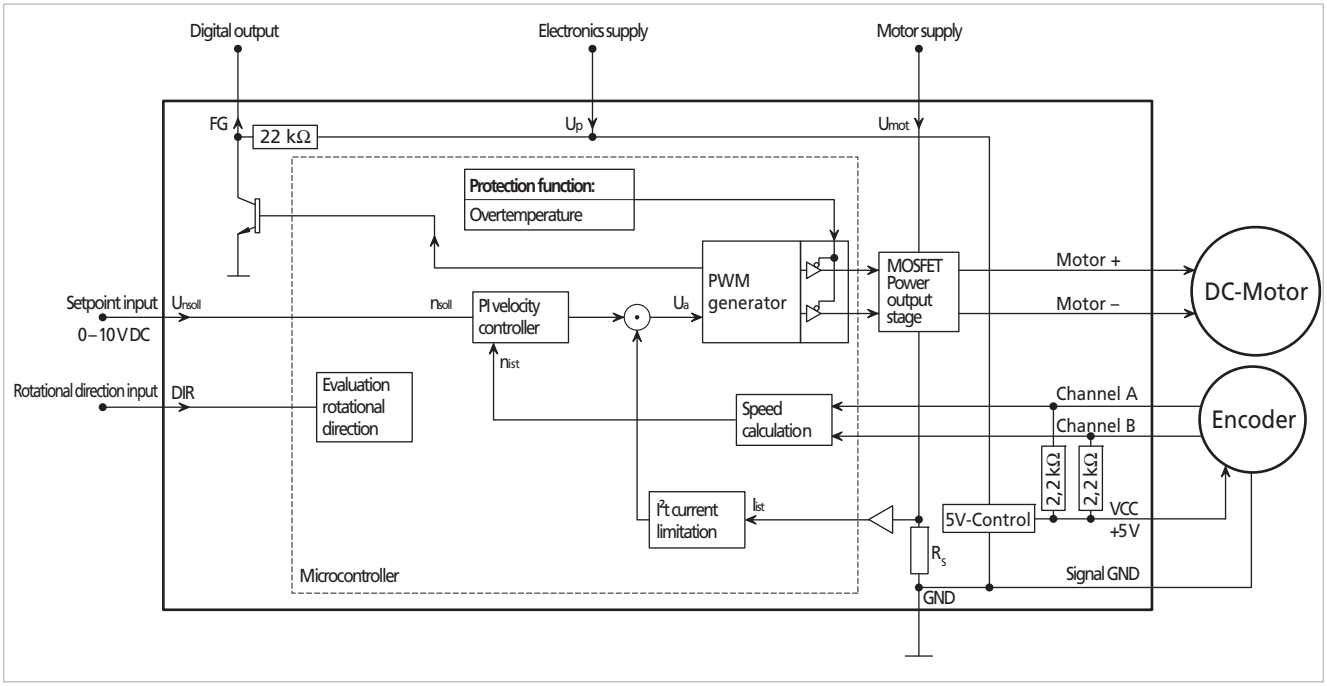


Fig. 26: Block diagram of a DC motors with encoder

Stable speed control is possible at speeds above approx. 100 min^{-1}.

In this configuration, an incremental encoder is used as speed actual value encoder. In this configuration, the incremental encoder must be attached to or integrated in the motor. Limited 4-quadrant operation is possible in this configuration.

Actual speed value and direction of rotation are determined using different signals:

Designation	Explanation
Actual speed value	Determined via the quadrature signals of the incremental encoder. Two-edge evaluation without detection of the direction of rotation.
Direction of rotation	Determined via direction of rotation input.

The following basic parameters are preset in this configuration:

Designation	Explanation
Set-point specification	Analog
Digital output	Fault output (cannot be changed)
Operating mode	Speed-controlled
2-quadrant operation with brake function	The speed is reduced by short-circuiting the motor. When using the SC 5004 / SC 5008 controller, the fastest possible braking operation is performed taking into account the permissible motor current.

Due to the sampling rate of the controller, sound may be generated in braking operation.

The following settings can be made by the user:

Designation	Explanation
Set-point specification	The following set value specifications can be set (see chap. 5.2, p. 58): ▪ Fixed speed mode ▪ Speed set value specification via analog signal ▪ Speed set value specification via PWM signal at speed set value input
Operating mode	▪ Speed-controlled ▪ Voltage controller
Speed filter	Can be activated/deactivated Especially for encoders with low to medium resolution, it is possible to activate filtering. This reduces any possible noises and increases controller stability. Whether or not filtering is advantageous for operation depends on the given application.
Limited 4-quadrant operation for low speeds	Speed control on load change by applying the opposite voltage (braking operation).

5.1.1.2 DC motors without encoder (not SC 5004 and SC 5008)

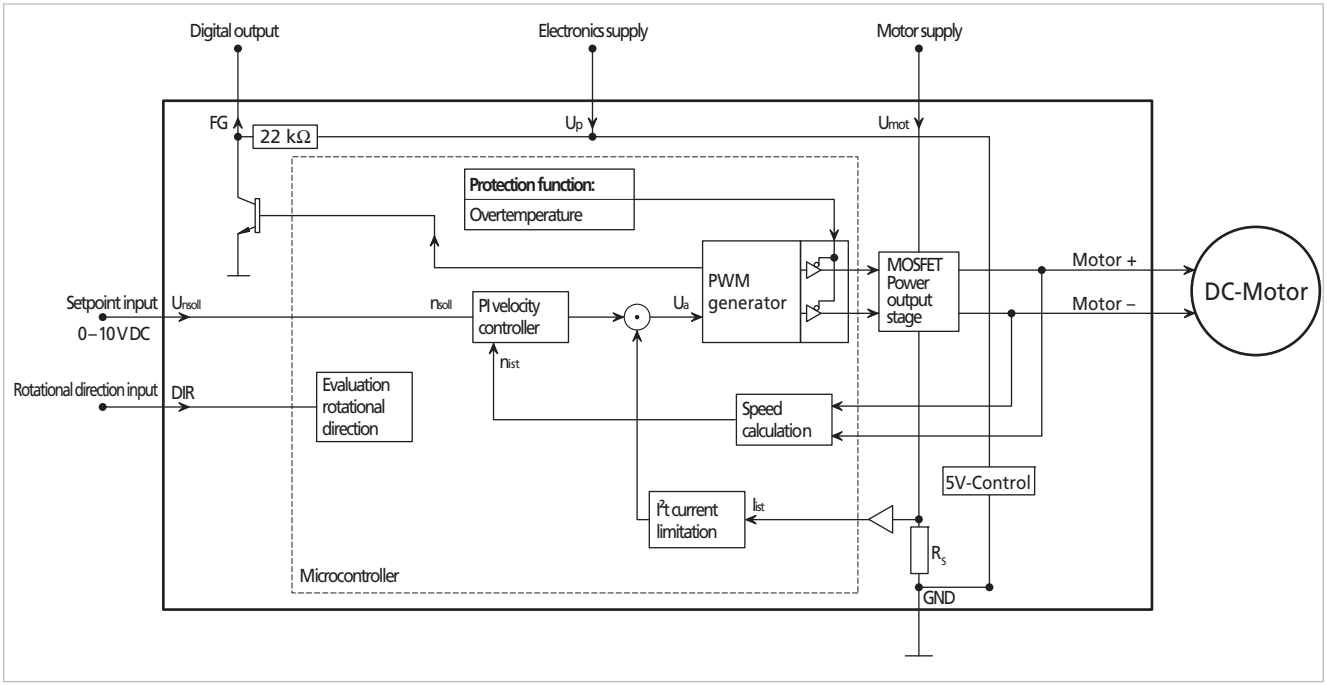


Fig. 27: Block diagram of a DC motor without encoder

Stable speed control is possible at speeds above approx. 100 min^{-1}.

Stable operation is dependent mainly on the following factors and cannot generally be predicted:

- Motor type
- U_{mot} compared to the nominal voltage of the motor U_N
- Characteristics of the load caused by the application
- Operating point of the motor (low or high load for the respective motor)

The suitability of the motor must be determined on a case-by-case basis through appropriate tests.

The actual speed value is determined using sensorless methods:

Designation	Explanation
Back-EMF (back induced voltage)	At low load or low modulation of the output PWM, the back-EMF of the motor is evaluated in the off state of the PWM. To do this, the generator voltage constant k_E must be set on the connected motor.
IxR compensation	Method for speed determination at higher load or higher modulation. The motor speed is determined here via an internal motor model. For this purpose, the appropriate generator voltage constant k_E and connection resistance R must be set for the connected motor.

There may be functional limitations in the transition range from back-EMF to IxR speed determination. Faultless function in all conceivable operating states must be checked before final use.

The following basic parameters are preset in this configuration:

Designation	Explanation
Set-point specification	Analog
Digital output	Fault output (cannot be changed)
Operating mode	Speed-controlled
2-quadrant operation with brake function	The speed is reduced by short-circuiting the motor

The following settings can be made by the user:

Designation	Explanation
Set-point specification	The following set value specifications can be set (see chap. 5.2, p. 58): ▪ Fixed speed mode ▪ Speed set value specification via analog signal ▪ Speed set value specification via PWM signal at speed set value input
Operating mode	▪ Speed-controlled ▪ Voltage controller

5.1.2 Speed-controlled operation of the BL motors

The actual value for speed used for speed control can be determined by means of the signals used for commutation. The configurations described below differ with regard to the used sensor systems.

The digital output is factory-configured as the frequency output.

5.1.2.1 BL motors with digital Hall sensors

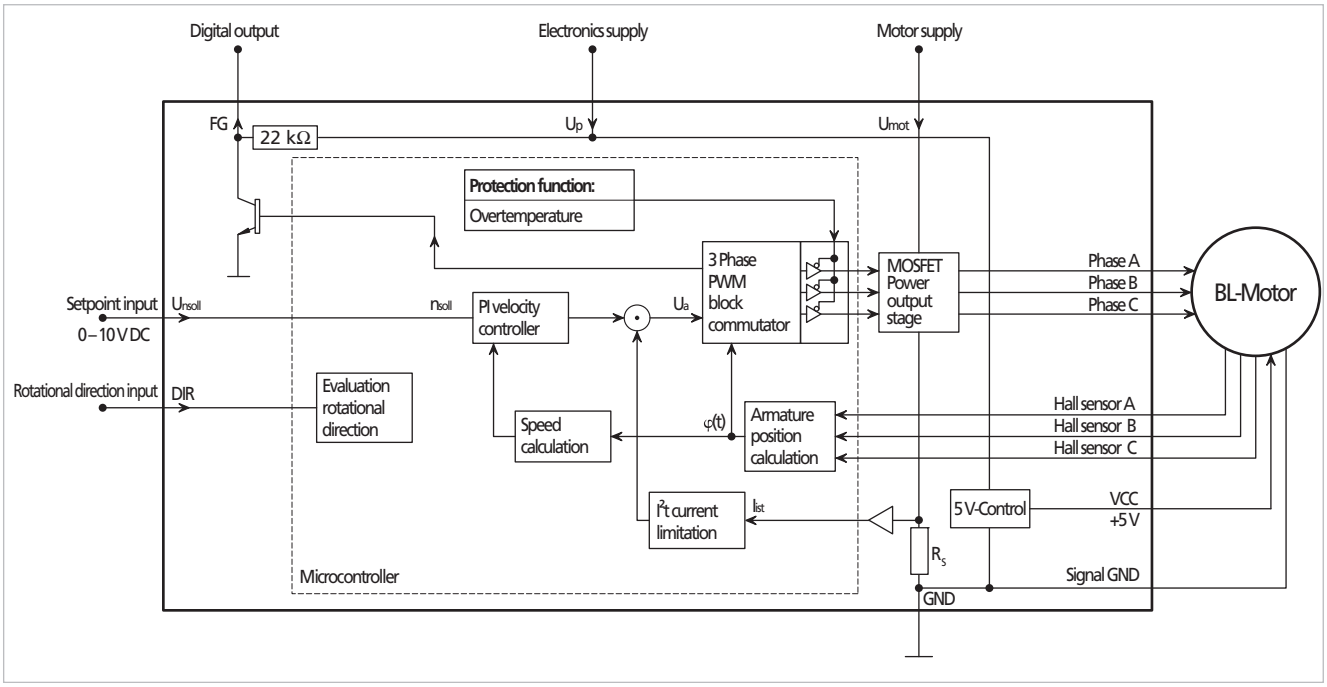


Fig. 28: Block diagram of a BL motor with digital Hall sensors

The resolution of the digital Hall sensors means that stable speed control is possible above approx. 500 min^{-1}. With 4-pole and 14-pole motors, stable control is possible above approx. 400 min^{-1}.

In this configuration, the commutation signal is determined via the digital Hall sensors. The actual value for speed is determined using the time interval between the edges of the Hall sensor signals.

The following basic parameters are preset in this configuration:

Designation	Explanation
Set-point specification	Analog
Digital output	Frequency output
Operating mode	Speed-controlled
2-quadrant operation with brake function	The speed is reduced by short-circuiting the motor. When using the SC 5004 / SC 5008 controller, the fastest possible braking operation is performed taking into account the permissible motor current.

The following settings can be made by the user:

Designation	Explanation
Set-point specification	The following set value specifications can be set (see chap. 5.2, p. 58): ▪ Fixed speed mode ▪ Speed set value specification via analog signal ▪ Speed set value specification via PWM signal at speed set value input
Digital output	▪ Frequency output: The number of lines per revolution which is output at the frequency output can be set. For possible values, see Tab. 19. ▪ Fault output (see chap. 5.3, p. 60).
Operating mode	▪ Speed-controlled ▪ Voltage controller
2-quadrant operation with brake function	The speed is reduced by short-circuiting the motor. Brake function can be activated/deactivated.
Speed filter	Can be activated/deactivated

5.1.2.2 BL motors with analog Hall sensors

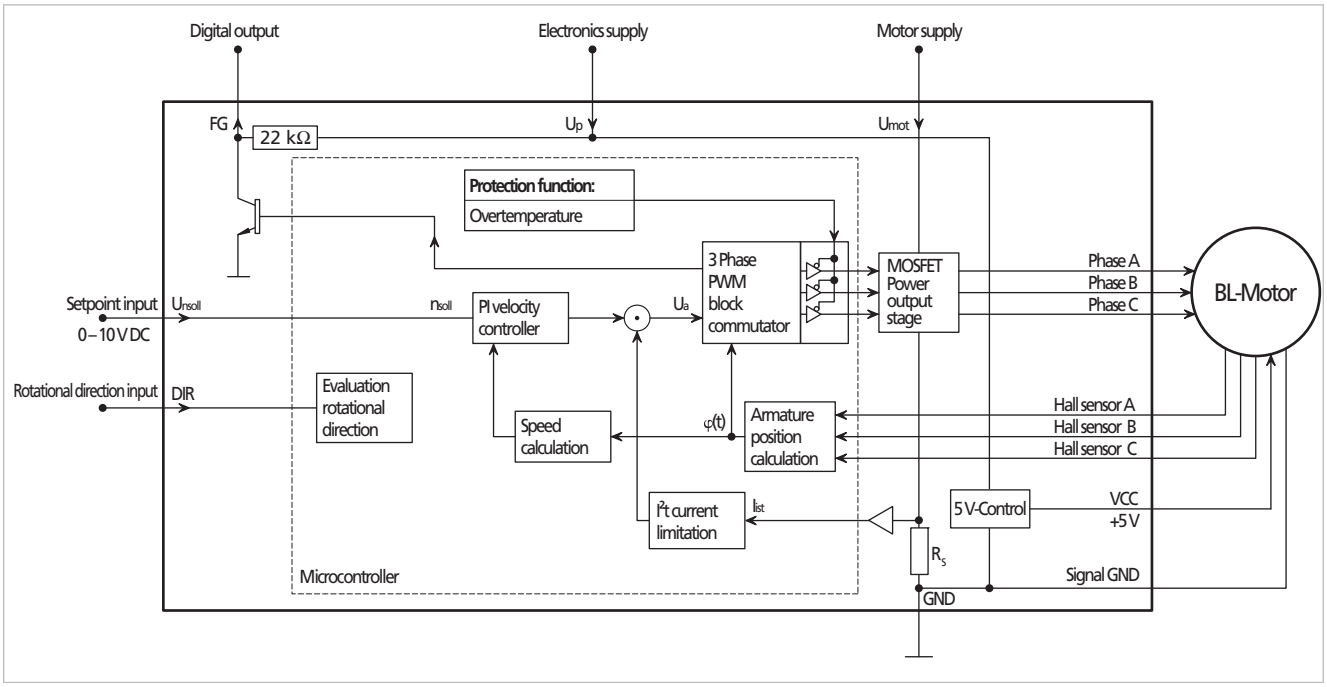


Fig. 29: Block diagram of a BL motor with analog Hall sensors

The resolution of the analog Hall sensors means that stable speed control is possible from approx. 50 min^{-1}.

In this configuration, the commutation signal is determined via the analog Hall sensors. The position information from the analog Hall sensors is used for commutation of the motor and for speed determination. 4-quadrant operation is possible in this configuration.

The following basic parameters are preset in this configuration:

Designation	Explanation
Set-point specification	Analog
Digital output	Frequency output
Operating mode	Speed-controlled
4-quadrant operation with brake function	Active acceleration and braking of the motor. Brake function can be activated/deactivated.

The following settings can be made by the user:

Designation	Explanation
Set-point specification	The following set value specifications can be set (see chap. 5.2, p. 58): ▪ Fixed speed mode ▪ Speed set value specification via analog signal ▪ Speed set value specification via PWM signal at speed set value input
Digital output	▪ Frequency output: The number of lines per revolution which is output at the frequency output can be set. For possible values, see Tab. 19. ▪ Fault output (see chap. 5.3, p. 60).
Operating mode	▪ Speed-controlled ▪ Voltage controller
Speed filter	Can be activated/deactivated

5.1.2.3 BL motors without Hall sensors (sensorless operation, not SC 5004 and SC 5008)

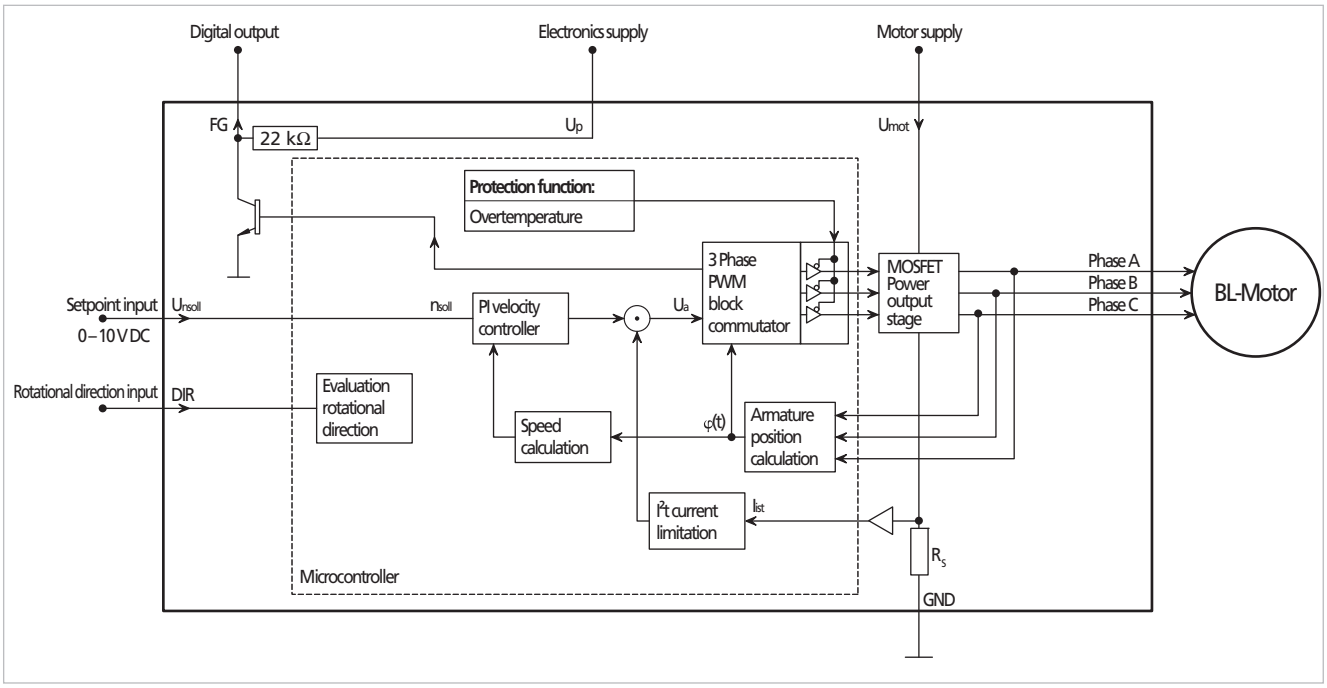


Fig. 30: Block diagram of a BL motor without Hall sensors

Depending on the motor, stable speed control is possible in this configuration from approx. 1 000 min^{-1}.

With BL motors without Hall sensors, the commutation signal is generated using the back-EMF (back-induced voltage). In sensorless operation, the actual value for speed is determined using the time interval between the commutation switching points.

Sensorless operation differs from operation with sensors with regard to the following points:

Designation	Explanation
Motor start	The motor start uses algorithms which also enable the motor to start from stationary when the position of the rotor is unknown. As a result, when the motor starts, it can briefly (less than half a revolution) rotate in the wrong direction. The motor start time is greater compared to operation with Hall sensors.
Operation with low load	With low load and low speed values, the speed is set by specifying a rotating field. In this case, changing the speed set value specification or changing the load causes a transition between rotating field mode and speed-controlled mode. In order to ensure constant speeds even in the case of changes in load, the operating range should be outside of this transition range. A suitable operating point can usually be found by reducing the motor power supply.

The following basic parameters are preset in this configuration:

Designation	Explanation
Set-point specification	Analog
Digital output	Frequency output (cannot be changed)
Operating mode	Speed-controlled
2-quadrant operation	No active brake function

The following settings can be made by the user:

Designation	Explanation
Set-point specification	The following set value specifications can be set (see chap. 5.2, p. 58): ▪ Fixed speed mode ▪ Speed set value specification via analog signal ▪ Speed set value specification via PWM signal at speed set value input
Digital output	Frequency output: The number of lines per revolution which is output at the frequency output can be set. For possible values, see Tab. 19.
Operating mode	▪ Speed-controlled ▪ Voltage controller

5.1.2.4 BL motors with absolute encoder (AES-4096)

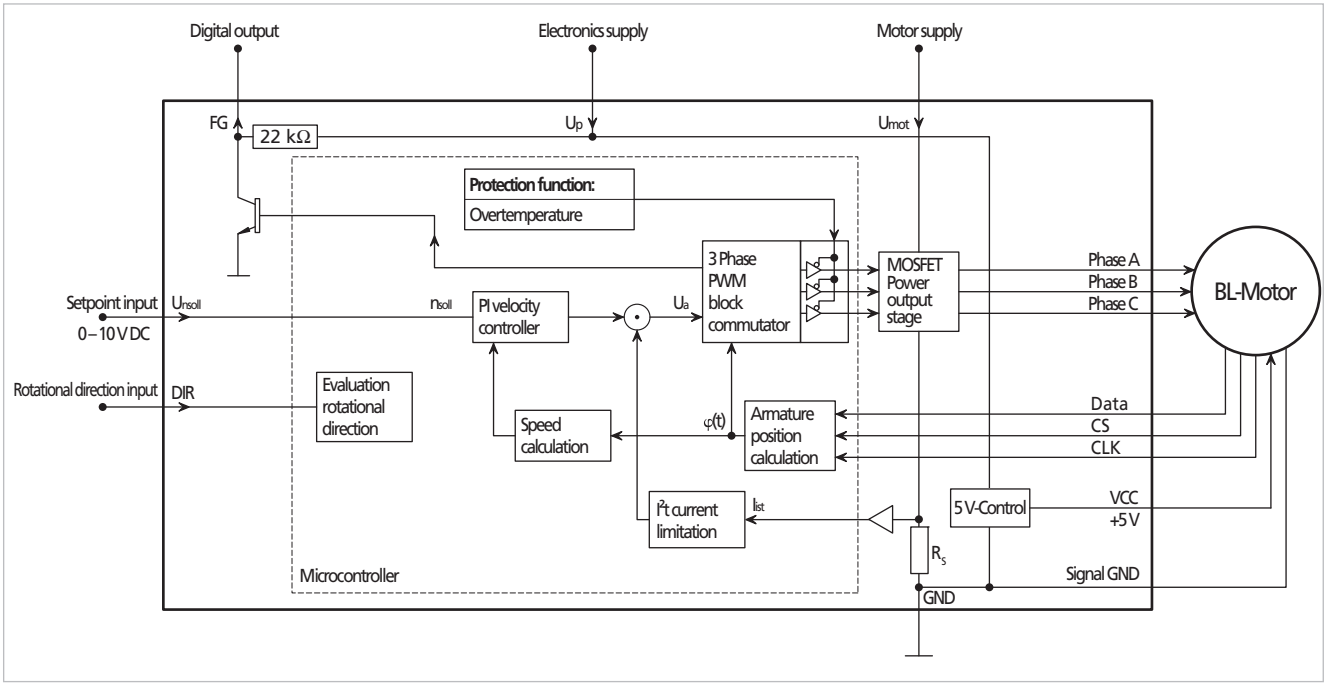


Fig. 31: Block diagram of a BL motor with absolute encoder

The resolution of the absolute encoder means that stable speed control is possible above approx. 50 min^{-1} (AES-4096).

In this configuration, the commutation signal is determined via the absolute encoder. The position information of the absolute encoder is used for commutation of the motor and for speed determination. 4-quadrant operation is possible in this configuration.

The following basic parameters are preset in this configuration:

Designation	Explanation
Set-point specification	Analog
Digital output	Frequency output
Operating mode	Speed-controlled
Speed filter	Active
4-quadrant operation with brake function	Active acceleration and braking of the motor. Brake function can be activated/deactivated.

The following settings can be made by the user:

Designation	Explanation
Set-point specification	The following set value specifications can be set (see chap. 5.2, p. 58): ▪ Fixed speed mode ▪ Speed set value specification via analog signal ▪ Speed set value specification via PWM signal at speed set value input
Digital output	▪ Frequency output: The number of lines per revolution which is output at the frequency output can be set. For possible values, see Tab. 19. ▪ Fault output (see chap. 5.3, p. 60).
Operating mode	▪ Speed-controlled ▪ Voltage controller

5.1.2.5 BL motors with digital Hall sensors and incremental encoders (option 4475)

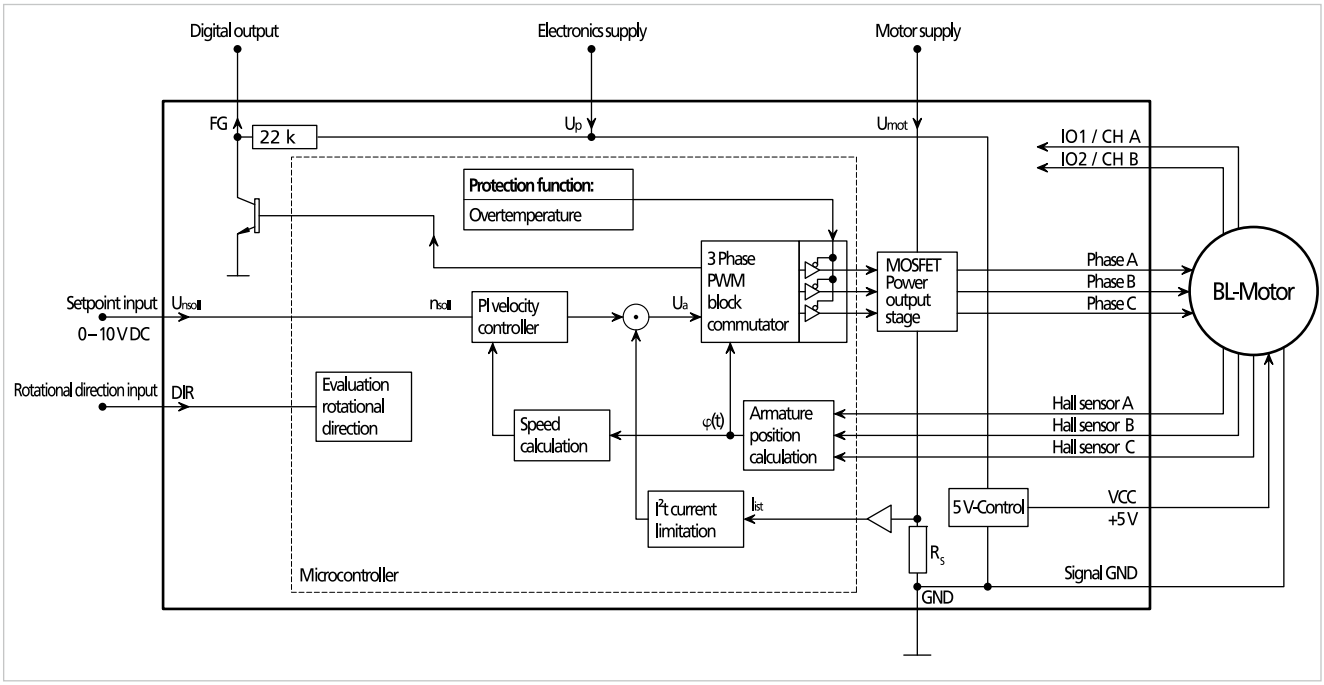


Fig. 32: Block diagram of a BL motor with digital Hall sensors and incremental encoders

The resolution of the incremental encoder means that stable speed control is possible above approx. 100 min^{-1}.

The position information of the digital Hall sensors is used for commutation of the motor and the incremental encoder information for speed determination. 4-quadrant operation is possible in this configuration.

The following basic parameters are preset in this configuration:

Designation	Explanation
Set-point specification	Analog
Digital output	Frequency output
Operating mode	Speed-controlled
2-quadrant operation with brake function	Active acceleration and braking of the motor. Brake function can be activated/deactivated. When using the SC 5004 / SC 5008 controller, the fastest possible braking operation is performed taking into account the permissible motor current.

The following settings can be made by the user:

Designation	Explanation
Set-point specification	The following set value specifications can be set (see chap. 5.2, p. 58): ▪ Fixed speed mode ▪ Speed set value specification via analog signal ▪ Speed set value specification via PWM signal at speed set value input
Digital output	▪ Frequency output: The number of lines per revolution which is output at the frequency output can be set. For possible values, see Tab. 19. ▪ Fault output (see chap. 5.3, p. 60).
Operating mode	▪ Speed-controlled ▪ Voltage controller
Speed filter	Filtering (averaging) of the speed signal can be activated/deactivated.

5.1.2.6 BL motors with digital Hall sensors and brake/enable (option 4476)

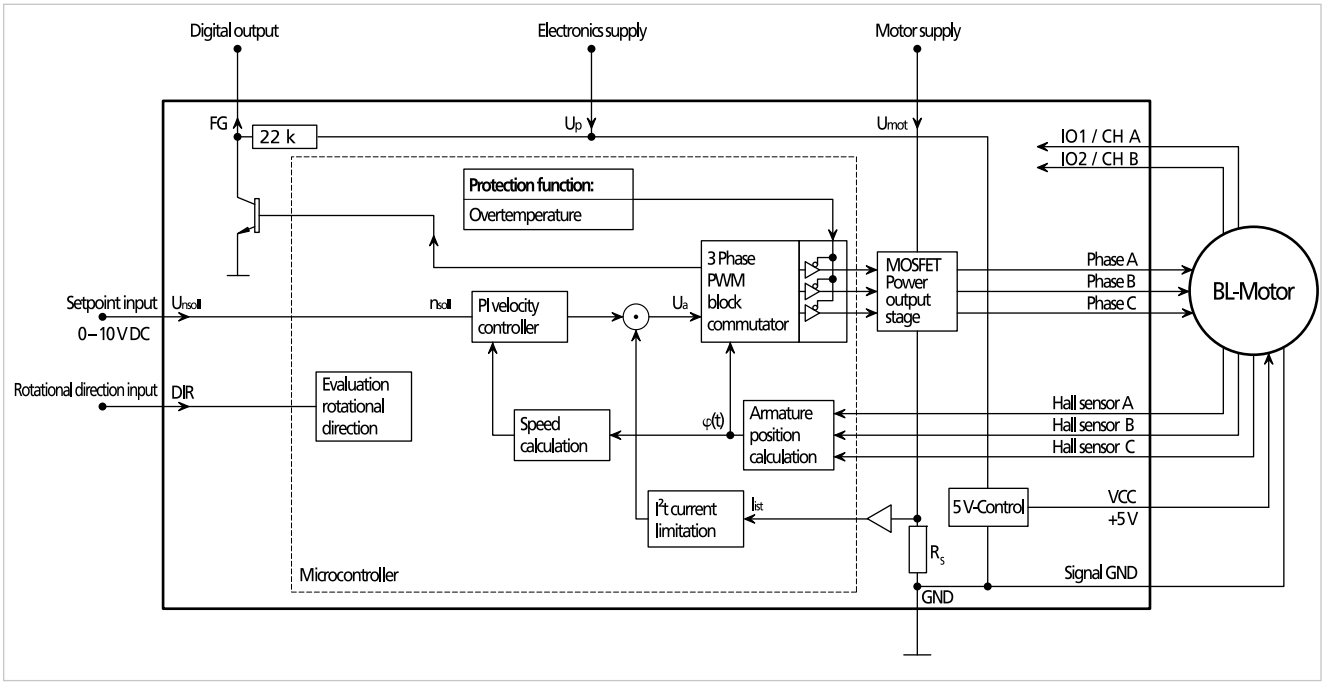


Fig. 33: Block diagram of a BL motor with digital Hall sensors and brake/enable

The resolution of the digital Hall sensors means that stable speed control is possible above approx. 500 min^{-1}. With 4-pole and 14-pole motors, stable control is possible above approx. 400 min^{-1}.

In this configuration, the commutation signal is determined via the digital Hall sensors. The actual value for speed is determined using the time interval between the edges of the Hall sensor signals.

IO1 and IO2 are used as digital inputs:

- IO1: brake/standstill or turn the motor (high: brake, low: turn)
- IO2: activate/deactivate the motor (high: activated, low: deactivated)

The following basic parameters are preset in this configuration:

Designation	Explanation
Set-point specification	Analog
Digital output	Frequency output
Operating mode	Speed-controlled
2-quadrant operation with brake function	The speed is reduced by short-circuiting the motor. When using the SC 5004 / SC 5008 controller, the fastest possible braking operation is performed taking into account the permissible motor current.

The following settings can be made by the user:

Designation	Explanation
Set-point specification	The following set value specifications can be set (see chap. 5.2, p. 58): ▪ Fixed speed mode ▪ Speed set value specification via analog signal ▪ Speed set value specification via PWM signal at speed set value input
Digital output	▪ Frequency output: The number of lines per revolution which is output at the frequency output can be set. For possible values, see Tab. 19. ▪ Fault output (see chap. 5.3, p. 60).
Operating mode	▪ Speed-controlled ▪ Voltage controller
2-quadrant operation with brake function	The speed is reduced by short-circuiting the motor. Brake function can be activated/deactivated.
Speed filter	Can be activated/deactivated

5.1.3 Operation as voltage controller

The Speed Controller can be configured as a voltage controller. The motor voltage is output in proportion to the voltage at the speed set value input U_{nsoll}. Current limitation remains active.

A supervisory controller can be used in Voltage controller mode. The Speed Controller then acts as a power amplifier. With BL motors, it is also used for commutation.

5.2 Set-point specification

The following setting options for set value specification are possible:

- Fixed speed specification
- Analog set value specification
- PWM set value specification

5.2.1 Fixed speed specification

In fixed speed mode, the motor is operated at a certain speed. In this case, the set speed to be set is fixed using a parameter (see chap. 5.4, p. 61).

The following settings for the speed set value input U_{nsoll} are possible:

- Quick-stop input (low level)
  - Motor stop with $U_{nsoll} < 0.15$ V
  - Motor stop with open connection
  - Motor start with $U_{nsoll} > 0.3$ V (0.5 V with BL motors in sensorless operation)
- Quick-stop input inverted (high level)
  - Motor start with $U_{nsoll} < 2$ V
  - Motor runs with open connection
  - Motor stop with $U_{nsoll} > 2.4$ V
- No function
  - Motor always runs

5.2.2 Analog set value specification

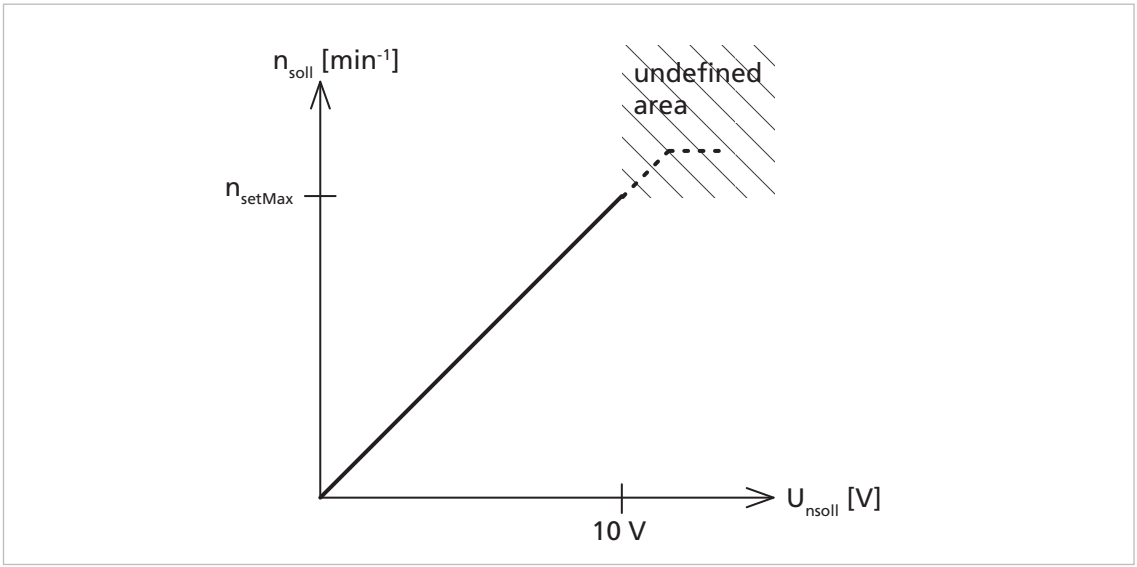


Fig. 34: Set value determination for Speed controller

- The analog input can process voltages from 0 V to 10 V.
- An analog set value specification of 10 V corresponds to the value specified in the parameter n_{setMax}.
- A linear conversion is performed between 0 V and 10 V:
  - Speed-controlled operation: $n_{soll} = n_{setMax} * (U_{nsoll} / 10\ V)$
  - Voltage controller: $U = U_{mot} * (U_{nsoll} / 10\ V)$

Depending on the motor type and the applied voltage, the set value specified in n_{setMax} cannot be reached. In this case, the motor rotates at the maximum speed which can be reached at the given voltage.

5.2.3 PWM set value specification

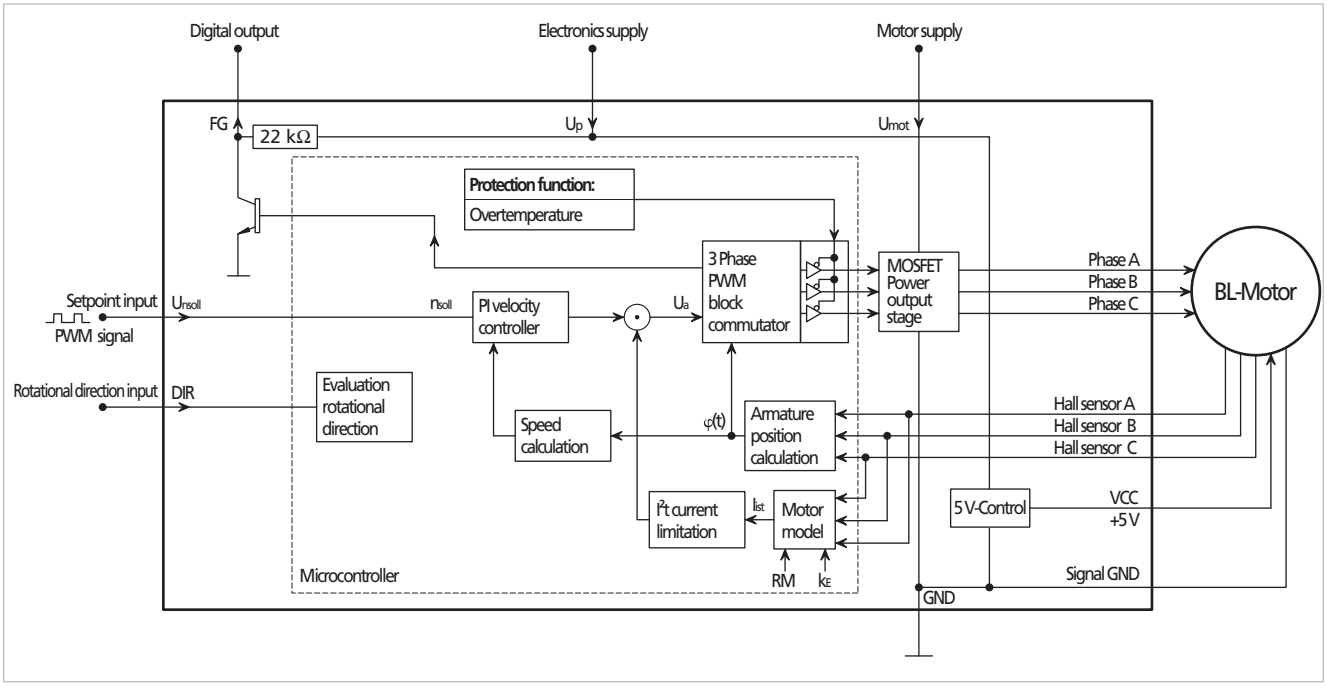


Fig. 35: Block diagram of a motor in PWM mode

The speed set value is proportional to the duty cycle.

- Motor stop with duty cycle: <2.0 %
- Motor start with duty cycle: >3.0 %
- 100% duty cycle corresponds to a set value specification of n_{setMax}

The PWM signal must have a fixed frequency in the range 500 Hz to 18 kHz.

TTL and PLC levels can be configured as switching levels:

Tab. 17: TTL and PLC level values

Mode	High level	Low level
TTL [a)]	>3.0 V DC	<0.5 V DC
PLC	>7.5 V DC	<2.0 V DC

a) not SC 5004 and SC 5008

5.3 Configuration of the digital output

The digital output can be configured for the following tasks:

Fault output (not with BL motors in sensorless operation)

- When current limitation is activated, the output switches to high level. The delay between activation of current limitation and setting of the output can be adjusted.
- When current limitation is deactivated, the output switches to low level.

Frequency output (not with DC motors)

- The frequency output can be used to determine the actual motor speed. In this example, a signal contains 6 lines per motor revolution.

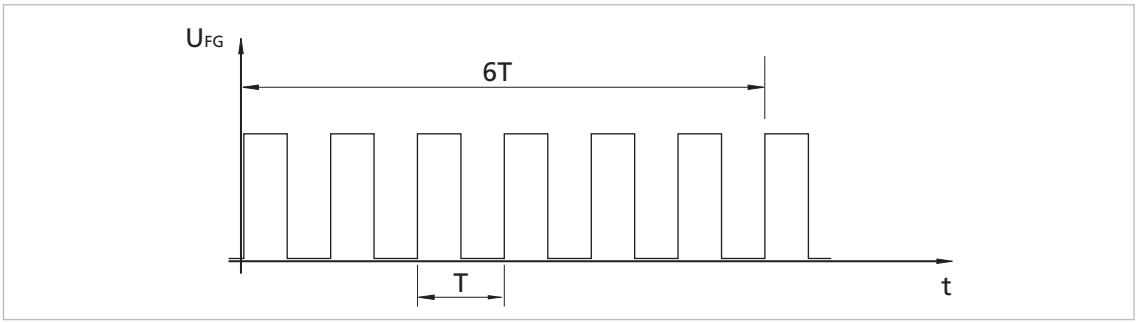


Fig. 36: Signal structure of frequency output

T Pulse duration

In order to increase the edge steepness at the digital output, an additional external pull-up resistor can be connected.

Observe the maximum load capacity of the digital output.

By connecting the internal pull-up resistor (22 or 47 kΩ) between FG and the power supply U_P, cable-based electromagnetic RF interference can impair the frequency signal. This RF interference does not have a negative effect on the speed and rotation direction of the motor.

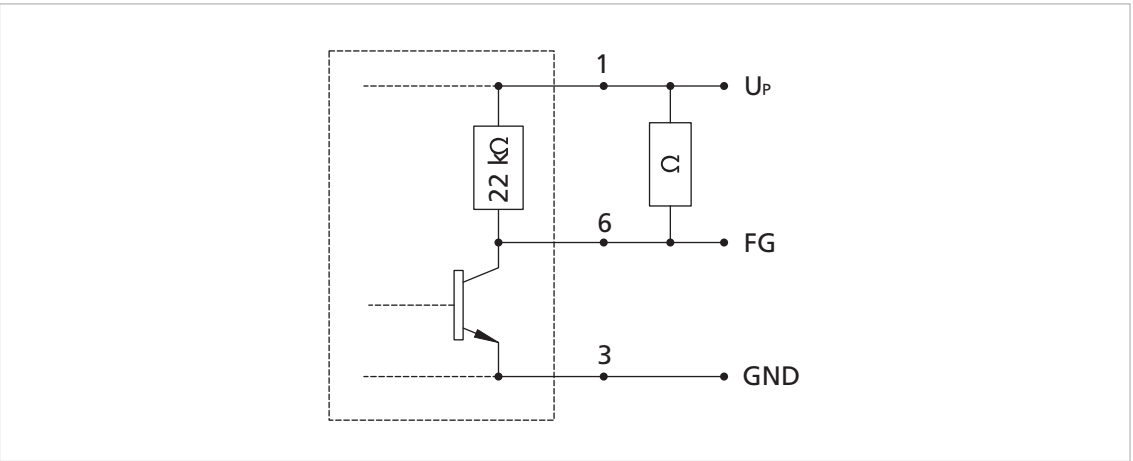


Fig. 37: Connection of an additional pull-up resistor

5.4 Parameter settings

The parameters listed below can be used to adjust the Speed Controller to the respective application. A number of the parameters listed here are only effective in certain configurations or with certain settings.

5.4.1 Motor constants

The motor constants must be configured for the following applications to enable smooth operation:

- DC motor in sensorless operation
- Speed-controlled operation with SC 5004 or SC 5008

Parameter	Meaning	Maximum value	Unit
Generator voltage constant (k_E)	Voltage that the motor produces in generator operation as a function of the speed	0…327	mV/min^{-1}
Connection resistance (R_M)	Connection resistance of the connected motor	0…327	Ω

5.4.2 Current limitation values

For I^2t current limitation, it is possible to set the peak current (I_{max}) and the motor continuous current (I_{cont}) (see chap. 5.5, p. 66). The permissible motor and controller values are to be observed.

Parameter	Meaning	Maximum value	Unit
Peak current (I_{max})	Value for the briefly permitted maximum current	Device-specific	A
Motor continuous current (I_{cont})	Value for the continuous current to which the motor is limited	Device-specific	A

Tab. 18: Device-specific values for motor continuous current (I_{cont}) and peak current (I_{max})

Device type	Motor continuous current (I_{cont}) [a]	Peak current (I_{max}) [a]	Unit
SC 1801	1	2	A
SC 2402	2	4	A
SC 2804	4	8	A
SC 5004	4	8	A
SC 5008	8	16	A

a) delivery state

5.4.3 Fixed speed

In fixed speed mode, the speed set value is preset via a configurable parameter (see chap. 5.2.1, p. 58).

Parameter	Meaning	Maximum value	Unit
Fixed speed (N_{setFix})	Speed set value in fixed speed mode	Up to 120 000 [a]	min^{-1}

a) depending on the option

5.4.4 Lines per motor revolution

With BL motors, the digital output (FG) can be configured as a frequency output (see chap. 5.3, p. 60). The number of lines per revolution can be set.

Parameter	Meaning	Maximum value	Unit
Lines per revolution (pulses)	Number of lines per revolution at the digital output	Depends on encoder type	1/revolution

Tab. 19: Number of lines per revolution depending on sensor system

Encoder type	Possible values [a]	Unit
Digital Hall sensors	1, 3	1/revolution
Analog Hall sensors	1, 2, 3, 4 [b], 8 [b], 16 [b]	1/revolution
Sensorless operation	1, 3, 6	1/revolution
AES-4096	1, 2, 3, 4 [b], 8 [b], 16 [b]	1/revolution
Incremental encoders	1, 2, 3, 4 [b], 8 [b], 16 [b]	1/revolution

a) Values apply for 2-pole motors. With 4-pole motors, the specified values are doubled, with 14-pole motors, the values increase sevenfold (not for AES).

b) More than 3 lines per revolution could lead to errors in the signal at the frequency output at high speeds.

5.4.5 Maximum speed

If a speed set value is specified by means of an analog voltage or PWM signal, it is then possible to adjust the speed value which is to be set at 10 V DC and at a duty cycle of 100%. In this way, the maximum speed is adapted to the application.

Different resolutions of the maximum speed value and different maximum values are possible depending on the operating mode and motor type.

Parameter	Meaning	Maximum value	Unit
Maximum speed value (n_{setMax})	Maximum speed set value with 10 V and 100 % duty cycle at the speed set value input U_{nsoll}	Motor and operating-mode specific	min^{-1}

Tab. 20: Motor- and operating mode-specific values for the maximum speed (n_{setMax})

Operating mode	Option [a]	Controller type	Value (n_{setMax})	Speed per 1 V
BL motors (2-pole) with digital Hall sensors	3530	SC 1801	30 000 min^{-1}	3 000 min^{-1}
		SC 2402	20 000 min^{-1}	2 000 min^{-1}
		SC 2804	20 000 min^{-1}	2 000 min^{-1}
		SC 5004	20 000 min^{-1}	2 000 min^{-1}
		SC 5008	20 000 min^{-1}	2 000 min^{-1}
BL motors (4-pole) with digital Hall sensors	6339	SC 1801	20 000 min^{-1}	2 000 min^{-1}
		SC 2402	20 000 min^{-1}	2 000 min^{-1}
		SC 2804	20 000 min^{-1}	2 000 min^{-1}
		SC 5004	20 000 min^{-1}	2 000 min^{-1}
		SC 5008	20 000 min^{-1}	2 000 min^{-1}

Operating mode	Option [a]	Controller type	Value (n_{setMax})	Speed per 1 V
BL motors (14-pole) with digital Hall sensors	6340	SC 1801	10 000 min^{-1}	1 000 min^{-1}
		SC 2402	10 000 min^{-1}	1 000 min^{-1}
		SC 2804	10 000 min^{-1}	1 000 min^{-1}
		SC 5004	10 000 min^{-1}	1 000 min^{-1}
		SC 5008	10 000 min^{-1}	1 000 min^{-1}
BL motors (2-pole) with analog Hall sensors	4289	SC 1801	40 000 min^{-1}	4 000 min^{-1}
		SC 2402	20 000 min^{-1}	2 000 min^{-1}
		SC 2804	20 000 min^{-1}	2 000 min^{-1}
		SC 5004	20 000 min^{-1}	2 000 min^{-1}
		SC 5008	20 000 min^{-1}	2 000 min^{-1}
BL motors (4-pole) with analog Hall sensors	4764	SC 1801	10 000 min^{-1}	1 000 min^{-1}
		SC 2402	10 000 min^{-1}	1 000 min^{-1}
		SC 2804	10 000 min^{-1}	1 000 min^{-1}
		SC 5004	10 000 min^{-1}	1 000 min^{-1}
		SC 5008	10 000 min^{-1}	1 000 min^{-1}
BL motors (2-pole) with AES-4096 absolute encoder	4763	SC 1801	30 000 min^{-1}	3 000 min^{-1}
		SC 2402	30 000 min^{-1}	3 000 min^{-1}
		SC 2804	30 000 min^{-1}	3 000 min^{-1}
		SC 5004	30 000 min^{-1}	3 000 min^{-1}
		SC 5008	30 000 min^{-1}	3 000 min^{-1}
BL motors (4-pole) with AES-4096 absolute encoder	3980	SC 1801	30 000 min^{-1}	3 000 min^{-1}
		SC 2402	20 000 min^{-1}	2 000 min^{-1}
		SC 2804	20 000 min^{-1}	2 000 min^{-1}
		SC 5004	20 000 min^{-1}	2 000 min^{-1}
		SC 5008	20 000 min^{-1}	2 000 min^{-1}
BL motors in sensorless operation [b]	3533	SC 1801	40 000 min^{-1}	4 000 min^{-1}
BL motors with digital Hall sensors and incremental encoders [c]	4475	SC 2402	20 000 min^{-1}	2 000 min^{-1}
		SC 2804	20 000 min^{-1}	2 000 min^{-1}
		SC 5004	20 000 min^{-1}	2 000 min^{-1}
		SC 5008	20 000 min^{-1}	2 000 min^{-1}
BL motors with digital Hall sensors and brake/enable [b]	4476	SC 2402	20 000 min^{-1}	2 000 min^{-1}
		SC 2804	20 000 min^{-1}	2 000 min^{-1}
		SC 5004	20 000 min^{-1}	2 000 min^{-1}
		SC 5008	20 000 min^{-1}	2 000 min^{-1}

Operating mode	Option [a]	Controller type	Value (n_{setMax})	Speed per 1 V
DC motors with incremental encoder [d]	3531	SC 1801	10 000 min^{-1}	1 000 min^{-1}
		SC 2402	10 000 min^{-1}	1 000 min^{-1}
		SC 2804	10 000 min^{-1}	1 000 min^{-1}
		SC 5004	10 000 min^{-1}	1 000 min^{-1}
		SC 5008	10 000 min^{-1}	1 000 min^{-1}

a) The use of a programming adapter is necessary for making changes to the factory setting.

b) Preconfigured for 2-pole motors (delivery state). When operated with 4-pole motors, the Speed Controller must be reconfigured with the FAULHABER Motion Manager software.

c) Preset to 256 pulses

d) Preset to 512 pulses.

5.4.6 Controller parameters

The controller parameters are preset at the factory. They can be adapted for special applications.

The following requirements with respect to the control system can be identified:

- Control rigidity
- Uniformity of the speed within one revolution
- Permitted control deviation
- Permitted overshoot
- Required stability reserves

The proportional component and the integral component of the PI speed controller can be adjusted.

Parameter	Meaning	Maximum value	Unit
V	Proportional component	32767	Digit
VI	Proportional component multiplied by integral component	65535	Digit

If parameter V is increased while parameter VI remains unchanged, the I-component of the controller will decrease. If the I-component is to remain unchanged, parameter VI must be multiplied by the same factor as parameter V.

5.4.7 Encoder resolution

The resolution of the connected incremental encoder must be set correctly as the drive would otherwise regulate to the wrong speed values.

The parameter specifies the resolution in such a way that a 4-edge evaluation would give an equivalent distance per revolution. The parameter *Impulszahl* from the data sheet of the encoder is thus multiplied by 4.

Parameter	Meaning	Maximum value	Unit
Encoder resolution (Encres)	4x pulse number of the encoder per revolution	65535	Digit

5.4.8 Start time (only BL motors in sensorless operation)

In sensorless operation, the BL motor starts via a synchronous drive. The time between switchover from one commutation state (phase) to the next commutation state can be set to the connected motor.

Parameter	Meaning	Maximum value	Unit
Start time	Switchover time between the phases at start-up	2739	ms

5.4.9 Minimum speed (only BL motors in sensorless operation)

Stable operation of the BL motor in sensorless operation is only possible from a certain speed. It is therefore recommended to define a minimum set speed. This value is used even if other parameters or speed set value specifications would result in a lower speed.

Parameter	Meaning	Minimum value	Unit
Minimum speed (n_{setMin})	Minimum speed set value specification	1	min^{-1}

5.4.10 Delayed Current Error (only error output)

This parameter is only effective if the digital output has been set as a fault output (see chap. 5.3, p. 60). Activation of the output may be delayed in this case. The output is not activated until the time preset by DCE has expired, even if the current is already being limited. As a result, brief exceedance of the limit current can be ignored.

Parameter	Meaning	Maximum value	Unit
Delayed Current Error (DCE)	Delay in activation of the fault output	5100	ms

5.5 Protective functions

5.5.1 I^2t current limitation

I^2t current limitation protects the motor against overheating. A thermal current model which calculates the motor temperature is created for this purpose. The motor current is influenced depending on the calculated temperature. The following values are relevant for I^2t current limitation:

- Peak current (I_{max}):
  The current is limited to the peak current for as long as the thermal current model calculates a non-critical temperature.
- Continuous current (I_{cont}):
  The current is limited to the continuous current if the thermal model calculates a critical temperature.

In order to provide protection against overheating, the controller must be adapted to the respective motor using the programming adapter.

Functionality of the I^2t current limitation

The functionality of I^2t current limitation is explained below with the aid of an example.

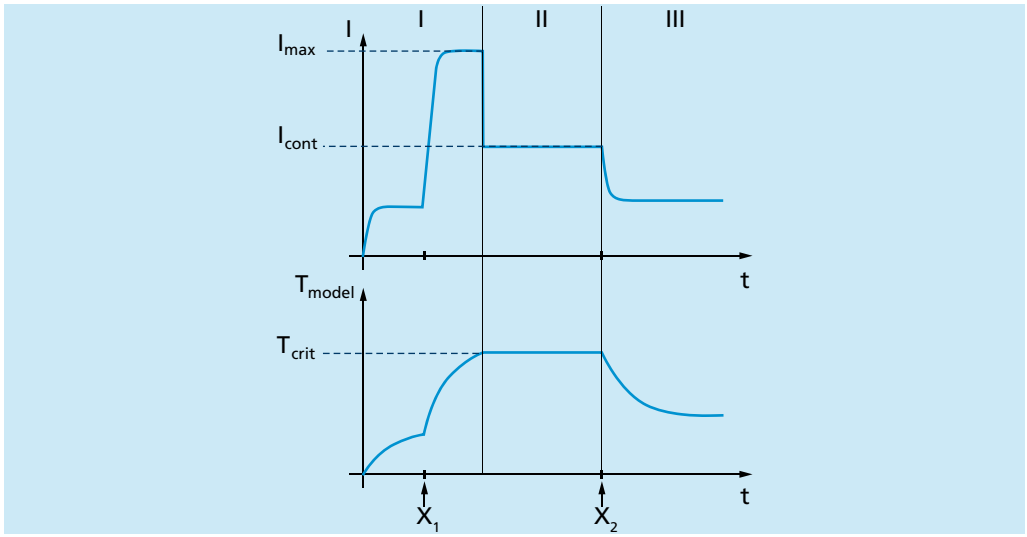


Fig. 38: Example of I^2t current limitation

Area I:

- When the motor is started, the peak current is preset as the set-point at the current controller.
- As the load (X_1) increases, the current in the motor becomes higher and higher until the peak current (I_{max}) is reached.

- The current controller comes into effect and limits the motor current to the peak current (I_{max}). At the same time, the flowing current is used to calculate a model temperature in a thermal current model.
- If the calculated model temperature reaches a critical value (T_{crit}), the current controller comes into effect and limits the motor current to the continuous current (I_{cont}).

Area II:

- As in this area the calculated model temperature reaches the critical temperature (T_{crit}) as a result of the change in load (X_1), the current controller adjusts the motor current to the continuous current (I_{cont}).

Area III:

- The current in the motor becomes less and less as a result of the change in load (X_2). The calculated model temperature is below the critical temperature (T_{crit}) so that the current controller no longer needs to intervene.

5.5.2 Overtemperature shutdown

If the temperature of the electronics exceeds 100 °C, the motor is deactivated.

⚠ CAUTION!

Risk of injury caused by automatic starting of the motor.

As soon as the electronics temperature drops below approx. 95°C, the motor is activated again automatically.

- Attach suitable guards.

5.6 Voltage output at motor

The power stage of the Speed Controller uses pulse width modulation (PWM). In the case of a fixed PWM frequency, the duty cycle between the switch-on time and switch-off time is set according to the controller output value. Since in the case of pulse width modulation the inductance of the motor acts as a current filter, a high PWM frequency is selected (96 kHz and 24 kHz with motors in sensorless operation). This method is extremely energy-efficient. A comparatively low amount of heat is generated.

With a small PWM duty cycle and a large motor load, a high current flow is briefly generated. This results in higher losses, i.e. a large amount of heat is generated.

- At the operating point, set a duty cycle as large as possible. When doing so, observe the required control reserve. This may require the motor supply voltage to be reduced.

If the permissible maximum housing temperature is observed in PWM mode, the maximum possible continuous torque may be less than with full modulation. In this case, the maximum thermally permissible continuous current drops.

Example

- Motor: 2232U012SR
- Connection resistance R = 4.09 Ω
- Terminal inductance L = 180 µH
- Operating point n = 4 000 min^{-1}
- Motor power supply U_{mot} = 18 V DC
- Efficiency during operation with true DC voltage: η_{gl} = 74.7%

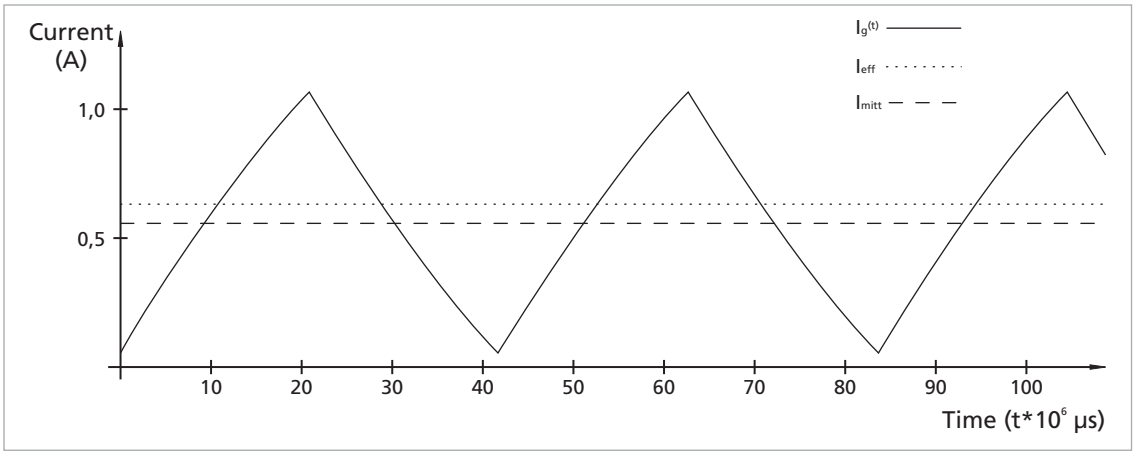


Fig. 39: PWM frequency = 24 kHz

- Efficiency during operation with PWM (24 kHz): η_{PWM} = 69.6%

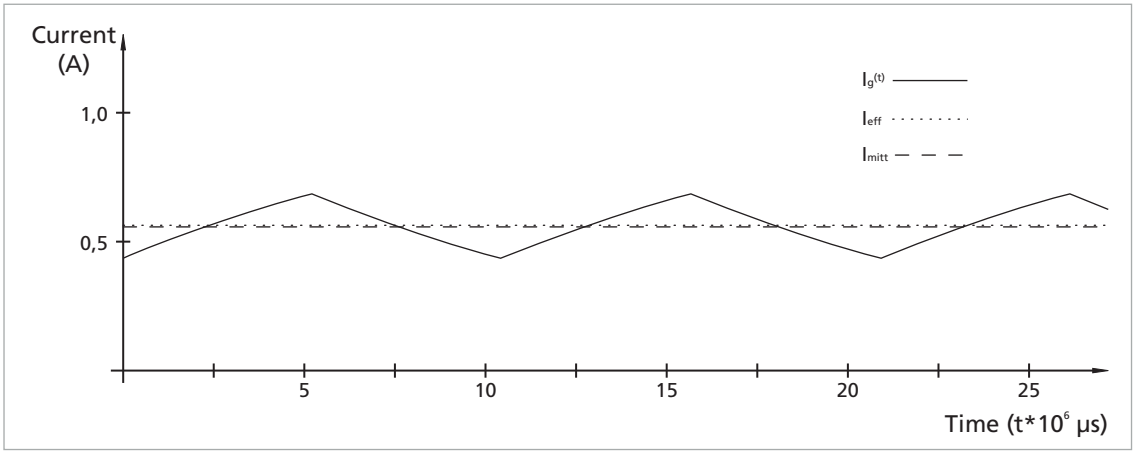


Fig. 40: PWM frequency = 96 kHz

- Efficiency during operation with PWM (96 kHz): η_{PWM} = 74.3%

At a higher PWM frequency, a better motor efficiency is achievable and the current has a lower ripple.

Alternatively, an additional inductance in series with the motor can improve the motor efficiency.

In this example, there is little difference at 96 kHz between DC voltage and PWM operation. An additional inductance is, therefore, not necessary here.

If the Speed Controller is operated at full or near-full modulation, the efficiency of the motor is likewise improved.

A low PWM duty cycle can result in a lower efficiency in the Speed Controller and in the motor connected to it.

6 Commissioning

⚠ CAUTION!

Risk of injury caused by protruding, rotating or moving parts of the driven mechanical units.

- Attach suitable guards.

NOTICE!

Damage to the motor and/or Speed Controller as a result of incorrectly set control parameters.

- Before commissioning, check and if necessary adjust the configured parameters.

NOTICE!

Rapid, repeated switching of the motor's direction of rotation (reversing operation) can damage the electronics.

- Do not use the Speed Controller for reversing operation.

The connections U_P and U_{mot} can be supplied with power from the same power supply unit.

Make sure that the output of the power supply unit is sufficient for supplying power to the Speed Controller and the connected motor.

Controller parameters are preset at the factory. The controller can optionally be optimized for specific applications. In this case, the digital controller operates at a sampling rate of 500 µs. Controller optimization performed when commissioning the motor is described below.

✓ Speed Controller is mounted as per the specifications (see chap. 4, p. 22).

✓ Speed Controller is electrically connected as per the specifications (see chap. 4.2.2, p. 25).

✓ Connected mechanical components are mounted in such a way that they cannot become jammed.

✓ Shaft load (axial, radial, torque) is within the specified values.

1. Set the initial configuration.
2. Increase the controller gain (proportional component V).
3. Increase the speed jump from 1/3 of the maximum speed to 2/3 speed.
4. Set the speed jump from 2/3 of the maximum speed to 1/3 and monitor the motor's behavior.
5. Repeat steps 2. to 4. until the controller becomes unstable.
6. Reduce the controller gain until the system is stable again.
7. Repeat steps 2. to 6. for the proportional-integral component (VI).

↳ The motor is ready for operation.

7 Maintenance

7.1 Maintenance tasks

The motor is generally maintenance-free. Where the device is mounted in a cabinet, depending on the deposition of dust the air filter should be regularly checked and cleaned if necessary.

7.2 Troubleshooting

If unexpected malfunctions occur during operation according to the intended use, please contact your support partner.

8 Accessories

The following accessories are available:

Article	Article no.
Programming adapter USB	6501.00096 a)
Programming adapter USB	6501.00097 a)

a) Use is dependent on the size of the Speed Controller

Details on configuration can be found in the Motion Manager manual (see chap. 1.2, p. 6).

Details on the connection sequence can be found in the product data sheet of the programming adapter.

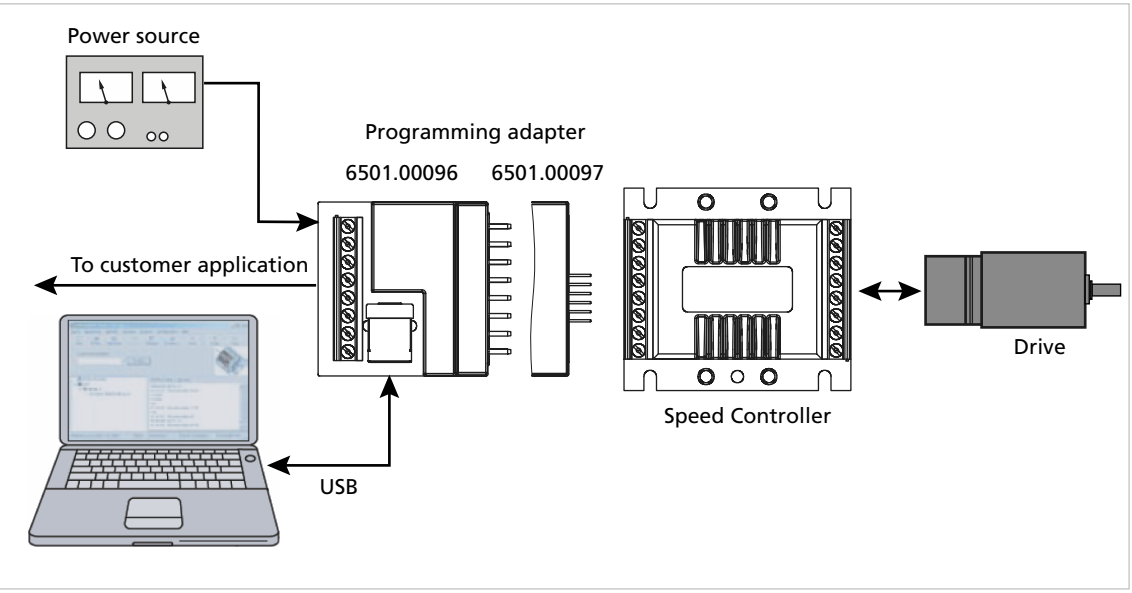


Fig. 41: Setup with programming adapter

Information on other accessories can be found in the main catalog.

9 Warranty

Products of the company Dr. Fritz Faulhaber GmbH & Co. KG are produced using the most modern production methods and are subject to strict quality inspections. All sales and deliveries are performed exclusively on the basis of our General Conditions of Sale and Delivery which can be viewed on the FAULHABER home page www.faulhaber.com/gtc and downloaded from it.

10 Additional documents

10.1 Declaration of Conformity SC 1801 S/F/P

EG–Konformitätserklärung
EC Declaration of Conformity

Dokument-Nr./Monat.Jahr: *Document-No./Month.Year:*	EG-00036-001 / 07.2021
Der Hersteller: *The manufacturer:*	**Dr. Fritz Faulhaber GmbH & Co. KG** Daimlerstr. 23/25 D-71101 Schönaich Germany

erklärt hiermit, dass das folgende Produkt
declares that the following product

Produktbezeichnung: *Product designation*:	**SC 1801 F, SC 1801 P, SC 1801 S**
Produkttyp: *Product type:*	**Motorcontroller** ***Motor controller***

den wesentlichen Schutzanforderungen entspricht, die in der/den nachfolgenden Richtline(n) festgelegt sind:
fulfills the essential protection requirements defined within the following directive:

EMV-Richtlinie 2014/30/EU
EMC-Directive 2014/30/EU

Die Einhaltung dieser Richtlinie(n) setzt die Umsetzung aller in der technischen Dokumentation genannten Maßnahmen voraus.
The measures indicated in all technical documents must be fulfilled in order to meet the requirements of this directive.

Diese Erklärung gilt für alle Exemplare, die in verschiedenen Leistungsdaten in dieser Serie hergestellt werden.
This statement should be valid for all derivates produced according to the related construction drawings and electrical drawings, which are part of the technical documentation.

Die Konformität wird in Bezug auf folgende angewandte harmonisierte Normen erklärt:
The declared conformity relates to the following harmonized standards

- Anhang A / „Dokumentidentifikation“
- *Annex A / Document identification*

Die Anlage ist Bestandteil dieser Erklärung.
The annex is a component of this declaration.

Schönaich,	12.07.21 (Datum) *(date)*	Dr. Thomas Bertolini, Geschäftsführung *(Name, Chairman)*	T. Bertolini (Unterschrift) *(signature)*

Anhang A zur Konformitätserklärung
Annex A to Declaration of Conformity

Dokument-Nr./Monat.Jahr: *Document-No./Month.Year:*	EG-00036-001 / 07.2021

Die Übereinstimmung mit den genannten EG-Richtlinien wurde durch Überprüfung gemäß nach folgender Fachgrundnorm nachgewiesen:
The conformity with the EC guidelines was proven according to the following standards:

Fundstelle *Document*	Ausgabedatum *Date of issue*	Richtlinienbezug *Related to directive*
EN 61800-3	2018	EMV Richtlinie EMC directive

10.2 Declaration of Incorporation SC 1801 S/F/P

Einbauerklärung nach Anhang II B, EG-Maschinenrichtlinie 2006/42/EG

Installation Declaration according to Appendix II B, EC Machinery Directive 2006/42/EC

Dokument-Nr./Monat.Jahr: *Document No./Month.Year:*	EG-00037-001 / 07.2021
Der Hersteller: *The manufacturer:*	**Dr. Fritz Faulhaber GmbH & Co. KG** Daimlerstr. 23/25 D-71101 Schönaich Germany

erklärt hiermit, dass es sich beim nachfolgend bezeichneten Produkt um eine Einbaukomponente (siehe unten) handelt und diese zum Einbau in eine Maschine bestimmt ist. Die Inbetriebnahme dieser unvollständigen Maschine ist solange untersagt, bis festgestellt wurde, dass die Gesamtmaschine, in die diese Komponente eingebaut werden soll, den grundlegenden Schutzanforderungen der hier genannten EG-Maschinenrichtlinie 2006/42/EG entspricht.
herewith declares that the product designated below is an installable component (see below), and that it is intended for installation in a machine. It is prohibited to bring this incomplete machine into service until it has been proven that the machine as a whole in which this component is to be installed meets the basic safety requirements of the here mentioned EC Machinery Directive 2006/42/EC.

Einbaukomponente: *Installable component::*	**SC 1801 F, SC 1801 P, SC 1801 S**
Produkttyp: *Product type:*	**Speed Controller** (mit angeschlossenem Antrieb) ***Speed Controller*** (with attached electrical drive)

Gemäß Anhang VII Teil B der EG-Maschinenrichtlinie 2006/42/EG wurden spezielle technischen Unterlagen für diese unvollständige Maschine erstellt. Durch begründetes Verlangen einzelstaatlicher Stellen können diese in elektronischer Form übermittelt werden.
Pursuant to Appendix VII, Part B of the EC Machinery Directive 2006/42/EC, specific technical documents have been created for this incomplete machine. On reasoned request by national authorities these documents may be transmitted in machine-readable format.

Der Bevollmächtigte für die Zusammenstellung und Übermittlung der relevanten technischen Unterlagen ist:
The person responsible for the compilation and transmission of the relevant technical documents is:

Dr. Andreas Wagener, Dr. Fritz Faulhaber GmbH & Co. KG, Daimlerstr. 23/25, 71101 Schönaich, Germany.

Schönaich,	12.07.21 (Datum) *(Date)*	Dr. Thomas Bertolini, Geschäftsführung *(Name, Chairman)*	T. Bertolini (Unterschrift) *(Signature)*

10.3 Declaration of Conformity SC 2402 P and SC 2804 S

EG–Konformitätserklärung
EC Declaration of Conformity

Dokument-Nr./Monat.Jahr: *Document-No./Month.Year:*	EG-00038-001 / 07.2021
Der Hersteller: *The manufacturer:*	**Dr. Fritz Faulhaber GmbH & Co. KG** Daimlerstr. 23/25 D-71101 Schönaich Germany

erklärt hiermit, dass das folgende Produkt
declares that the following product

Produktbezeichnung: *Product designation*:	**SC 2402 P, SC 2804 S**
Produkttyp: *Product type:*	**Motorcontroller** ***Motor controller***

den wesentlichen Schutzanforderungen entspricht, die in der/den nachfolgenden Richtline(n) festgelegt sind:
fulfills the essential protection requirements defined within the following directive:

EMV-Richtlinie 2014/30/EU
EMC-Directive 2014/30/EU

Die Einhaltung dieser Richtlinie(n) setzt die Umsetzung aller in der technischen Dokumentation genannten Maßnahmen voraus.
The measures indicated in all technical documents must be fulfilled in order to meet the requirements of this directive.

Diese Erklärung gilt für alle Exemplare, die in verschiedenen Leistungsdaten in dieser Serie hergestellt werden.
This statement should be valid for all derivates produced according to the related construction drawings and electrical drawings, which are part of the technical documentation.

Die Konformität wird in Bezug auf folgende angewandte harmonisierte Normen erklärt:
The declared conformity relates to the following harmonized standards

- Anhang A / „Dokumentidentifikation“
- *Annex A / Document identification*

Die Anlage ist Bestandteil dieser Erklärung.
The annex is a component of this declaration.

Schönaich, 12.07.21	Dr. Thomas Bertolini,	T. Bertolini	
(Datum) *(date)*	Geschäftsführung *(Name, Chairman)*	(Unterschrift) *(signature)*	

Anhang A zur Konformitätserklärung
Annex A to Declaration of Conformity

Dokument-Nr./Monat.Jahr: *Document-No./Month.Year:*	EG-00038-001 / 07.2021

Die Übereinstimmung mit den genannten EG-Richtlinien wurde durch Überprüfung gemäß nach folgender Fachgrundnorm nachgewiesen:
The conformity with the EC guidelines was proven according to the following standards:

Fundstelle *Document*	Ausgabedatum *Date of issue*	Richtlinienbezug *Related to directive*
EN 61800-3	2018	EMV Richtlinie EMC directive

10.4 Declaration of Incorporation SC 2402 P and SC 2804 S

Einbauerklärung nach Anhang II B, EG-Maschinenrichtlinie 2006/42/EG

Installation Declaration according to Appendix II B, EC Machinery Directive 2006/42/EC

Dokument-Nr./Monat.Jahr: *Document No./Month.Year:*	EG-00039-001 / 07.2021
Der Hersteller: *The manufacturer:*	**Dr. Fritz Faulhaber GmbH & Co. KG** Daimlerstr. 23/25 D-71101 Schönaich Germany

erklärt hiermit, dass es sich beim nachfolgend bezeichneten Produkt um eine Einbaukomponente (siehe unten) handelt und diese zum Einbau in eine Maschine bestimmt ist. Die Inbetriebnahme dieser unvollständigen Maschine ist solange untersagt, bis festgestellt wurde, dass die Gesamtmaschine, in die diese Komponente eingebaut werden soll, den grundlegenden Schutzanforderungen der hier genannten EG-Maschinenrichtlinie 2006/42/EG entspricht.
herewith declares that the product designated below is an installable component (see below), and that it is intended for installation in a machine. It is prohibited to bring this incomplete machine into service until it has been proven that the machine as a whole in which this component is to be installed meets the basic safety requirements of the here mentioned EC Machinery Directive 2006/42/EC.

Einbaukomponente: *Installable component::*	**SC 2402 P, SC 2804 S**
Produkttyp: *Product type:*	**Speed Controller** (mit angeschlossenem Antrieb) ***Speed Controller*** (with attached electrical drive)

Gemäß Anhang VII Teil B der EG-Maschinenrichtlinie 2006/42/EG wurden spezielle technischen Unterlagen für diese unvollständige Maschine erstellt. Durch begründetes Verlangen einzelstaatlicher Stellen können diese in elektronischer Form übermittelt werden.
Pursuant to Appendix VII, Part B of the EC Machinery Directive 2006/42/EC, specific technical documents have been created for this incomplete machine. On reasoned request by national authorities these documents may be transmitted in machine-readable format.

Der Bevollmächtigte für die Zusammenstellung und Übermittlung der relevanten technischen Unterlagen ist:
The person responsible for the compilation and transmission of the relevant technical documents is:

Dr. Andreas Wagener, Dr. Fritz Faulhaber GmbH & Co. KG, Daimlerstr. 23/25, 71101 Schönaich, Germany.

Schönaich,	12.07.21 (Datum) *(Date)*	Dr. Thomas Bertolini, Geschäftsführung *(Name, Chairman)*	T. Bertolini (Unterschrift) *(Signature)*

10.5 Declaration of Conformity SC 5004 P and SC 5008 S

EG–Konformitätserklärung
EC Declaration of Conformity

Dokument-Nr./Monat.Jahr: *Document-No./Month.Year:*	EG-00040-001 / 07.2021
Der Hersteller: *The manufacturer:*	**Dr. Fritz Faulhaber GmbH & Co. KG** Daimlerstr. 23/25 D-71101 Schönaich Germany

erklärt hiermit, dass das folgende Produkt
declares that the following product

Produktbezeichnung: *Product designation*:	**SC 5004 P, SC 5008 S**
Produkttyp: *Product type:*	**Motorcontroller** ***Motor controller***

den wesentlichen Schutzanforderungen entspricht, die in der/den nachfolgenden Richtline(n) festgelegt sind:
fulfills the essential protection requirements defined within the following directive:

EMV-Richtlinie 2014/30/EU
EMC-Directive 2014/30/EU

Die Einhaltung dieser Richtlinie(n) setzt die Umsetzung aller in der technischen Dokumentation genannten Maßnahmen voraus.
The measures indicated in all technical documents must be fulfilled in order to meet the requirements of this directive.

Diese Erklärung gilt für alle Exemplare, die in verschiedenen Leistungsdaten in dieser Serie hergestellt werden.
This statement should be valid for all derivates produced according to the related construction drawings and electrical drawings, which are part of the technical documentation.

Die Konformität wird in Bezug auf folgende angewandte harmonisierte Normen erklärt:
The declared conformity relates to the following harmonized standards

- Anhang A / „Dokumentidentifikation“
- *Annex A / Document identification*

Die Anlage ist Bestandteil dieser Erklärung.
The annex is a component of this declaration.

Schönaich, 12.07.21	Dr. Thomas Bertolini,	T. Bertolini	
(Datum) *(date)*	Geschäftsführung *(Name, Chairman)*	(Unterschrift) *(signature)*	

Anhang A zur Konformitätserklärung
Annex A to Declaration of Conformity

Dokument-Nr./Monat.Jahr: *Document-No./Month.Year:*	EG-00040-001 / 07.2021

Die Übereinstimmung mit den genannten EG-Richtlinien wurde durch Überprüfung gemäß nach folgender Fachgrundnorm nachgewiesen:
The conformity with the EC guidelines was proven according to the following standards:

Fundstelle *Document*	Ausgabedatum *Date of issue*	Richtlinienbezug *Related to directive*
EN 61800-3	2018	EMV Richtlinie EMC directive

10.6 Declaration of Incorporation SC 5004 P and SC 5008 S

Einbauerklärung nach Anhang II B, EG-Maschinenrichtlinie 2006/42/EG

Installation Declaration according to Appendix II B, EC Machinery Directive 2006/42/EC

Dokument-Nr./Monat.Jahr: *Document No./Month.Year:*	EG-00041-001 / 07.2021
Der Hersteller: *The manufacturer:*	**Dr. Fritz Faulhaber GmbH & Co. KG** Daimlerstr. 23/25 D-71101 Schönaich Germany

erklärt hiermit, dass es sich beim nachfolgend bezeichneten Produkt um eine Einbaukomponente (siehe unten) handelt und diese zum Einbau in eine Maschine bestimmt ist. Die Inbetriebnahme dieser unvollständigen Maschine ist solange untersagt, bis festgestellt wurde, dass die Gesamtmaschine, in die diese Komponente eingebaut werden soll, den grundlegenden Schutzanforderungen der hier genannten EG-Maschinenrichtlinie 2006/42/EG entspricht.
herewith declares that the product designated below is an installable component (see below), and that it is intended for installation in a machine. It is prohibited to bring this incomplete machine into service until it has been proven that the machine as a whole in which this component is to be installed meets the basic safety requirements of the here mentioned EC Machinery Directive 2006/42/EC.

Einbaukomponente: *Installable component::*	**SC 5004 P, SC 5008 S**
Produkttyp: *Product type:*	**Speed Controller** (mit angeschlossenem Antrieb) ***Speed Controller*** (with attached electrical drive)

Gemäß Anhang VII Teil B der EG-Maschinenrichtlinie 2006/42/EG wurden spezielle technischen Unterlagen für diese unvollständige Maschine erstellt. Durch begründetes Verlangen einzelstaatlicher Stellen können diese in elektronischer Form übermittelt werden.
Pursuant to Appendix VII, Part B of the EC Machinery Directive 2006/42/EC, specific technical documents have been created for this incomplete machine. On reasoned request by national authorities these documents may be transmitted in machine-readable format.

Der Bevollmächtigte für die Zusammenstellung und Übermittlung der relevanten technischen Unterlagen ist:
The person responsible for the compilation and transmission of the relevant technical documents is:

Dr. Andreas Wagener, Dr. Fritz Faulhaber GmbH & Co. KG, Daimlerstr. 23/25, 71101 Schönaich, Germany.

Schönaich,	12.07.21 (Datum) *(Date)*	Dr. Thomas Bertolini, Geschäftsführung *(Name, Chairman)*	F. Bertolini (Unterschrift) *(Signature)*

FAULHABER

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