FAULHABER

Technical Manual

22xx...BX4(S) SC

32xx...BX4 SC

32xx...BX4 SCDC

26xx...B SC

1525...BRC

1935...BRC

3153...BRC

2214...BXT H SC

3216...BXT H SC

4221...BXT H SC

Imprint

Version:
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Dr. Fritz Faulhaber GmbH & Co. KG cannot accept any liability for any errors in this document or for the consequences of such errors. Equally, no liability can be accepted for direct or consequential damages resulting from improper use of the equipment.

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

Content

1 About this document

1.1 Validity of this document

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

- 22xx...BX4(S) SC
- 32xx...BX4 SC
- 32xx...BX4 SCDC
- 26xx...B SC
- 1525...BRC
- 1935...BRC
- 3153...BRC
- 2214...BXT H SC
- 3216...BXT H SC
- 4221...BXT H SC

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

All data in this document relate to the standard versions of the series listed above. Changes relating to customer-specific versions can be found in the corresponding data sheet.

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
BRC	Brushless DC-motor with integrated Electronics
EMF	Back-induced electromotive force
EMC	Electromagnetic compatibility
ESD	Electrostatic discharge
PWM	Pulse Width Modulation
SC	Speed Controller
SCDC	Speed Controller in two-wire version
SCS	Speed Control Systems

1.5 Symbols and designations

CAUTION!
Hazards to persons. Disregard may lead to minor injuries.

- Measures for avoidance

CAUTION!
Hazards due to hot surfaces. Disregard may lead to burns.

- Measures for avoidance

NOTICE!
Risk of damage.

- Measures for avoidance

Instructions for understanding or optimising 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 motors described here are designed as drives for small machines and for speed-controlled applications. The following points must be observed to ensure that the motors are used as intended:

- Handle the motors in accordance with the ESD regulations.
- Do **not** use the motors in environments where it will come into contact with water, chemicals and/or dust, **nor** in explosion hazard areas.
- Always operate the motors within the limits specified in the data sheet.
- Please ask the manufacturer for information about individual use under special environmental conditions.

2.2 Safety instructions

NOTICE!
Electrostatic discharges can damage the electronics.

- Wear conductive work clothes.
- Wear an earthed wristband.

NOTICE!
Penetration of foreign objects can damage the electronics.

- Do not open the housing.

NOTICE!
Connection and disconnection of cables while the supply voltage is still being applied at the device can damage the electronics.

- Do not connect or disconnect cables while the supply voltage is still being applied at the device.

NOTICE!
Exposure of the motors to mechanical shock will damage the bearings and reduce the service life of the motor.

- Do not exceed the shock and vibrational loads defined in DIN EN 60068-2-27 and DIN EN 60068-2-6.

2.3 Environmental conditions

- Select the installation location so that clean dry air is available for cooling the motor.
- 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 motor.
- Select a power supply that is within the defined tolerance range.
- Protect the motor against heavy deposits of dust, in particular metal dust and chemical pollutants.
- Protect the motor against humidity and wet.

2.4 EC directives on product safety

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

Machinery Directive (2006/42/EC)
Because of their small size, no serious threats to life or physical condition can normally be expected from electric miniature drives. Therefore the Machinery Directive does not apply to our products. The products described here are not “incomplete machines”. Therefore installation instructions are not normally issued by FAULHABER.

Low Voltage Directive (2014/35/EU)
The Low Voltage Directive applies for all electrical equipment with a nominal voltage of 75 to 1500 V DC and 50 to 1000 V AC. The products described in this technical manual do not fall within the scope of this directive, since they are intended for lower voltages.

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.

3 Product description

3.1 General product description

FAULHABER Speed Control Systems are highly dynamic drive systems with controlled speed. The drive electronics are integrated in the brushless DC-Motors and matched to the respective motor.

The compact integration of the Speed Controller as well as the flexible connection possibilities enable applications in areas such as laboratory technology and equipment manufacturing, automation technology, pick-and-place machines and machine tools, or pumps.

The integration of the control electronics in space-optimised add-on systems reduces space requirements and simplifies installation and start-up.

The integrated electronics facilitate speed control by means of a PI controller with external setpoint input. The direction of rotation can be changed via a separate switching input; the speed signal can be read out via the frequency output. The motors can optionally be operated in voltage controller mode or in fixed speed mode.

Depending on the model series, the rotor position is detected by means of digital (optionally analogue) Hall sensors or sensorless by means of the induced countervoltage (EMF) of the motors (model series BRC). The resulting lower speed limits are 1000 min^{-1} (sensorless), 200 min^{-1} (digital Hall) and 50 min^{-1} (analogue Hall).

Depending on the model series, FAULHABER Speed Control Systems (SCS) can be adapted to the application via the FAULHABER Motion Manager software from version 5.x or 6.x. The following can be set:

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

The USB programming adapter for Speed Controllers is used for configuration, and a contacting board is used for connecting the cables. The two-wire versions (SCDC) are preconfigured at the factory and the parameters can only be changed by the manufacturer.

The following interfaces and discrete I/Os are available:

- Analogue input as set value input for setting the speed via PWM or analogue voltage value.
- Digital input as switching input for defining the direction of rotation of the motor
- Digital output, can be programmed either as frequency output or as error output

The following additional functions are available:

- Integrated current limitation to protect against thermal overload
- Short-time operation with up to double the continuous current
- Separate voltage supply for motor and electronics

3.2 Product information

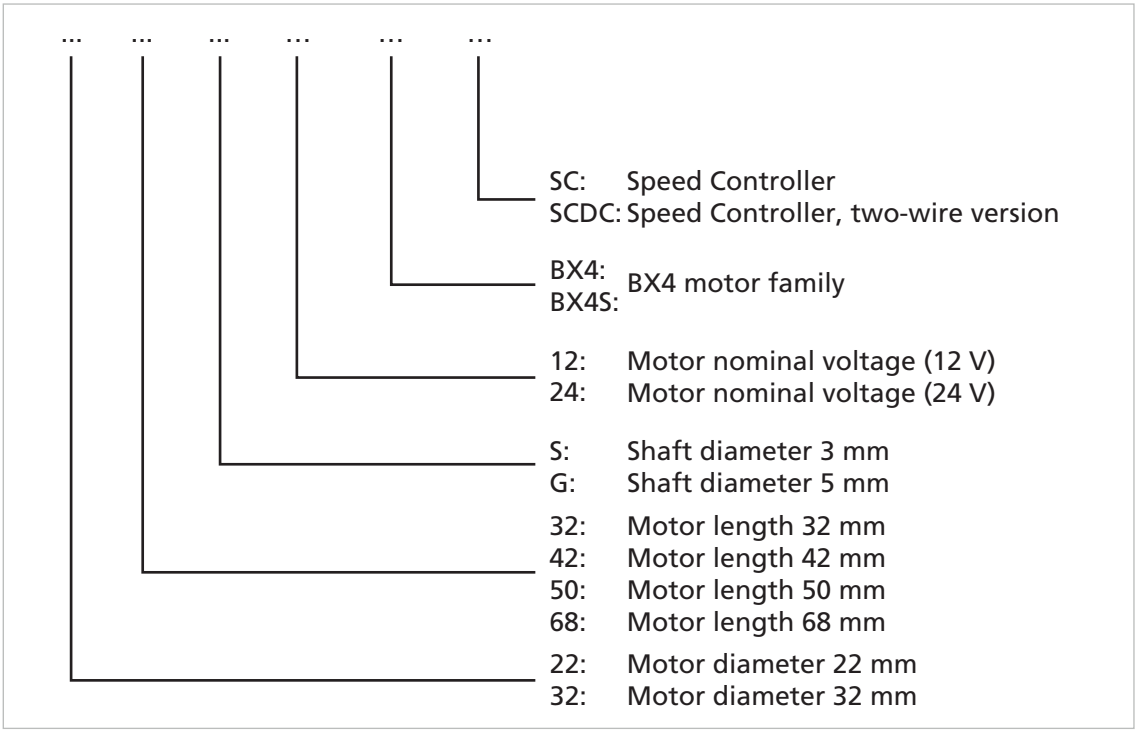


Fig. 1: Designation key for motor series 22xx and 32xx...BX4

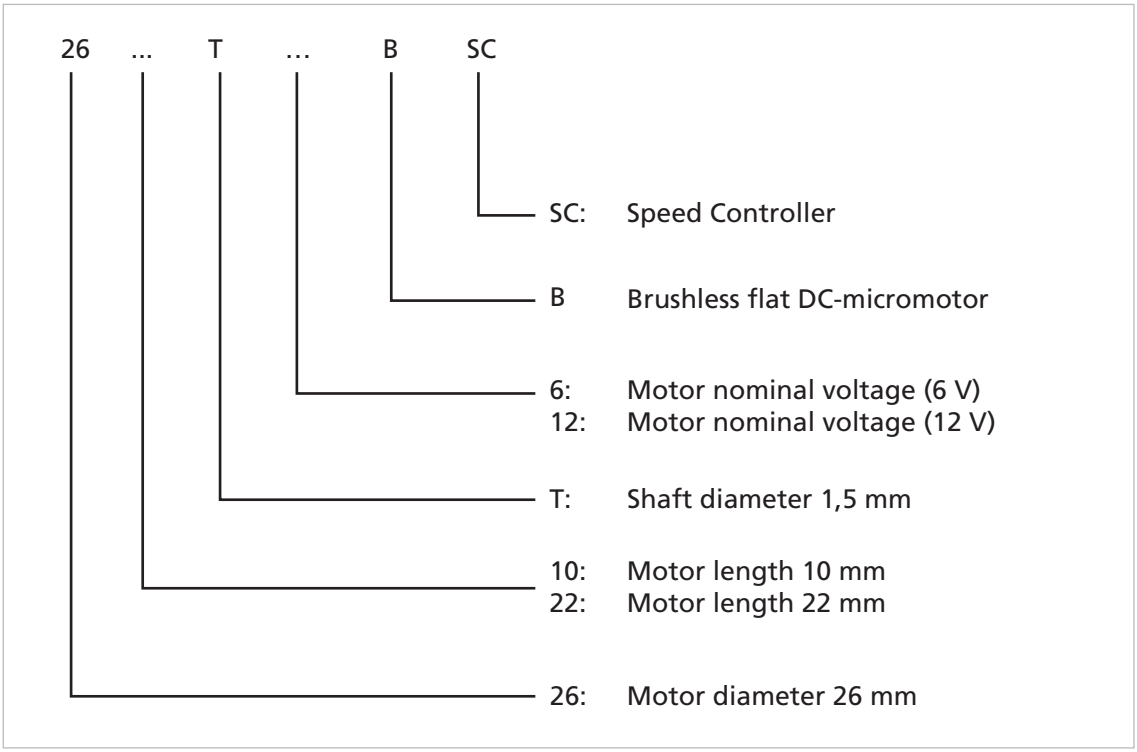


Fig. 2: Designation key for motor series 26xx...B

Product description

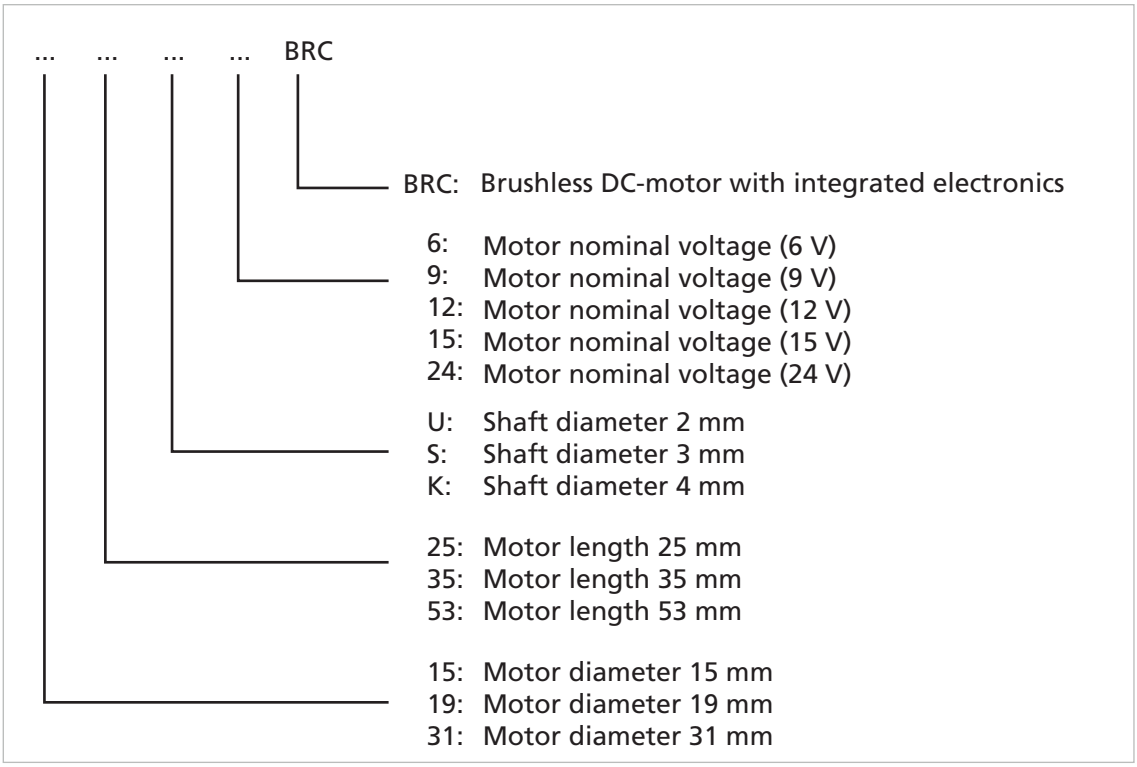


Fig. 3: Designation key for motor series 1525, 1935 and 3153...BRC

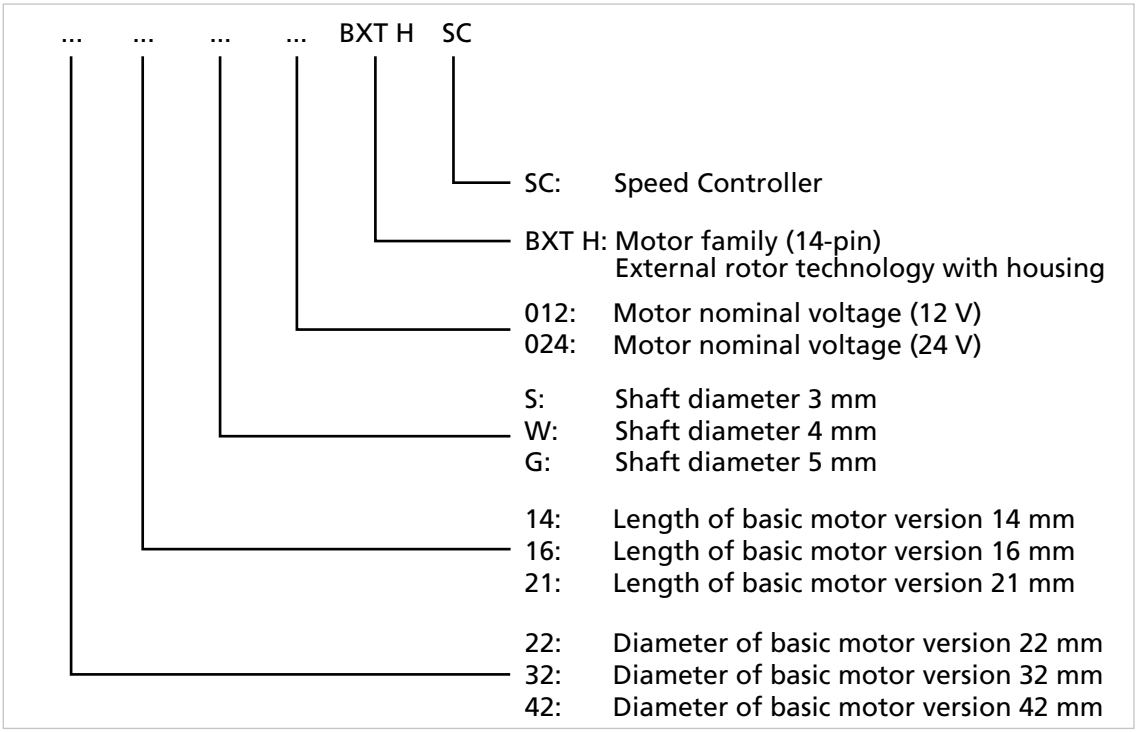


Fig. 4: Designation key for motor series 2214, 3216 and 4221...BXT H

3.3 Product variants

Tab. 1: Product variants – Speed Control Systems

Motor series	Sensors	Speed range [a]	Power supply of electronics/motor (V DC)	Rated torque (mNm) [b]
2232S012BX4S SC	Digital Hall	400…22 500 [c]	5…28 / 6…28	6
	Analogue Hall	50…22 500 [c]	5…28 / 6…28	6
2232S024BX4S SC	Digital Hall	400…17 000	5…28 / 6…28	7
	Analogue Hall	50…17 000	5…28 / 6…28	7
2232S012BX4 SC	Digital Hall	400…14 000	5…28 / 6…28	17
	Analogue Hall	50…14 000	5…28 / 6…28	17
2232S024BX4 SC	Digital Hall	400…8 500	5…28 / 6…28	17.5
	Analogue Hall	50…8 500	5…28 / 6…28	17.5
2250S024BX4S SC [d]	Digital Hall	400…13 500	5…28 / 6…28	13.3
2250S024BX4 SC	Digital Hall	400…7 300	5…28 / 6…28	25
	Analogue Hall	50…7 300	5…28 / 6…28	25
3242G012BX4 SC	Digital Hall	400…14 000 [c]	6.5…30 / 6.5…30	50
	Analogue Hall	50…14 000 [c]	6.5…30 / 6.5…30	50
3242G024BX4 SC	Digital Hall	400…7 000	6.5…30 / 6.5…30	60
	Analogue Hall	50…7 000	6.5…30 / 6.5…30	60
3242G012BX4 SCDC [d]	Digital Hall	400…12 000 [c]	6.5…30 / 6.5…30	39
3242G024BX4 SCDC [d]	Digital Hall	400…11 200	6.5…30 / 6.5…30	45
3268G024BX4 SC	Digital Hall	400…6 500	6.5…30 / 6.5…30	99
	Analogue Hall	50…6 500	6.5…30 / 6.5…30	99
3268G024BX4 SCDC [d]	Digital Hall	400…7 000	6.5…30 / 6.5…30	60
1525U009BRC	Sensorless	1 000…25 000	4…18 / 1.7…18	1.9
1525U012BRC	Sensorless	1 000…25 000	4…18 / 1.7…18	1.9
1525U015BRC	Sensorless	1 000…18 900	4…18 / 1.7…18	1.9
1935S006BRC	Sensorless	1 000…17 400	4…18 / 1.7…18	3.3
1935S009BRC	Sensorless	1 500…17 500	4…18 / 1.7…18	3.6
1935S012BRC	Sensorless	1 000…12 300	4…18 / 1.7…18	3.1
3153K009BRC	Sensorless	1 000…10 500	5…30 / 0…18	34.5
3153K012BRC	Sensorless	1 000…10 500	5…30 / 0…24	33.5
3153K024BRC	Sensorless	1 000…6 500	5…30 / 0…30	36.5
2610T006B SC	Digital Hall	400…13 300	4…18 / 1.7…18	3.25
2610T012B SC	Digital Hall	400…10 000	4…18 / 1.7…18	3.12
2622S006B SC [e]	Digital Hall	400…5 000	4…18 / 1.7…18	max. 100
2622S012B SC [e]	Digital Hall	400…5 000	4…18 / 1.7…18	max. 100
2214S012 BXT H SC [d]	Digital Hall	200…10 000	5…28 / 6…28	10
2214S024 BXT H SC [d]	Digital Hall	200…10 000	5…28 / 6…28	10
3216W012 BXT H SC [d]	Digital Hall	200…10 000	6.5…30 / 6.5…30	33.5

Product description

Motor series	Sensors	Speed range [a]	Power supply of electronics/motor (V DC)	Rated torque (mNm) [b]
3216W024 BXT H SC [d]	Digital Hall	200…10 000	6.5…30 / 6.5…30	35
4221G024 BXT H SC [d]	Digital Hall	200…8 000	6.5…30 / 6.5…30	92

a) The speed range depends on the maximum motor supply voltage.

b) At metal flange.

c) The drive must be reconfigured in order to reach the maximum speed.

d) Option of analogue Hall sensors is not available in this version.

e) Integrated gearhead; for details, see the product data sheet.

4 Installation

- This description must be carefully read and observed before commissioning.
- Observe the environmental conditions (see chap. 2.3, p. 8).

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

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

4.1 Mounting

4.1.1 Mounting instructions

CAUTION!
The motor can become very hot during operation.

- Place a guard against contact and warning notice in the immediate proximity of the motor.
- Ensure that adequate heat dissipation is provided.

NOTICE!
Installation and connection of the motor when the power supply is applied can damage the device.

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

NOTICE!
The motor can be damaged if mounted incorrectly.

- Observe the maximum screw-in depth of the fastening screws (see Tab. 2).

NOTICE!
Excessive loads on the motor shaft can cause irreparable damage to the motor.

- When attaching parts to the motor shaft, observe the maximum permissible load values (see the product data sheet) of the shaft.

NOTICE!
Excessive radial loads on the servomotor or excessively tightened fastening screws can cause irreparable damage to the mounting flange.

- Observe the maximum permissible radial load on the motor (see Tab. 2).
- Make sure that the screws are tightened in accordance with Tab. 2.

4.1.2 Mounting the motor

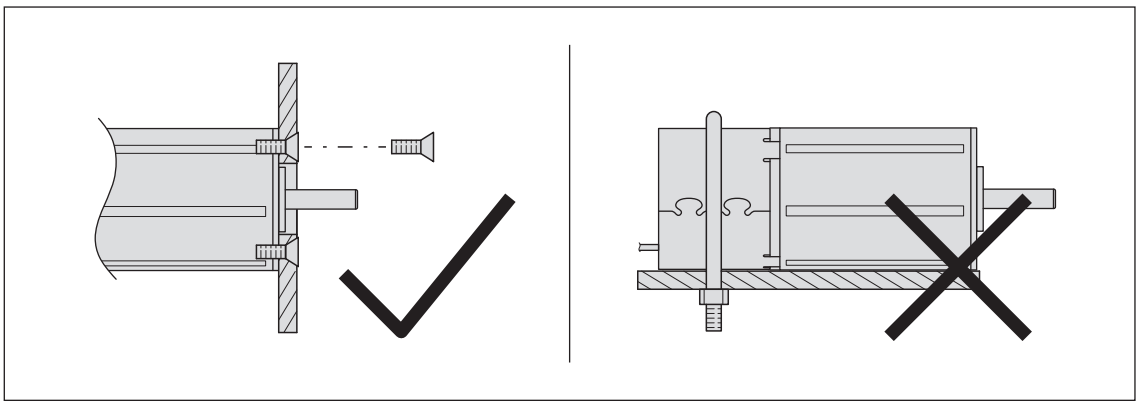


Fig. 5: Mounting example – 22xxBX4 SC series

1. Secure the front flange of the motor to a suitable surface using fastening screws (for the screw size and torque, see Tab. 2).
2. Protect the fastening screws to prevent displacement due to the effect of heat.
3. If necessary, attach parts to the motor shaft.

Information on the used flange can be found in the product data sheet.

Tab. 2: Attachment specifications

Motor series	Screw type	Thread depth (mm)	Max. tightening torque (Ncm)	Radial motor load, max. (N)
22xx…BX4(S) SC	M2	3.0	50	30
32xx…BX4 SC / SCDC	M3	4.0	120	60
2622…B SC [a)]	M2	3.5	40	20
1525…BRC	M1.6	2.0	40	10
1935…BRC	M2	3.0	40	15
3153…BRC	M3	4.0	40	20
2214…BXT H SC	M2	2.5	40	20
3216…BXT H SC	M2	3.0	40	30
4221…BXT H SC	M3	3.0	40	40

a) Motors of model series 2610…B SC are mounted at fastening points outside the motor diameter using a quadratic flange.

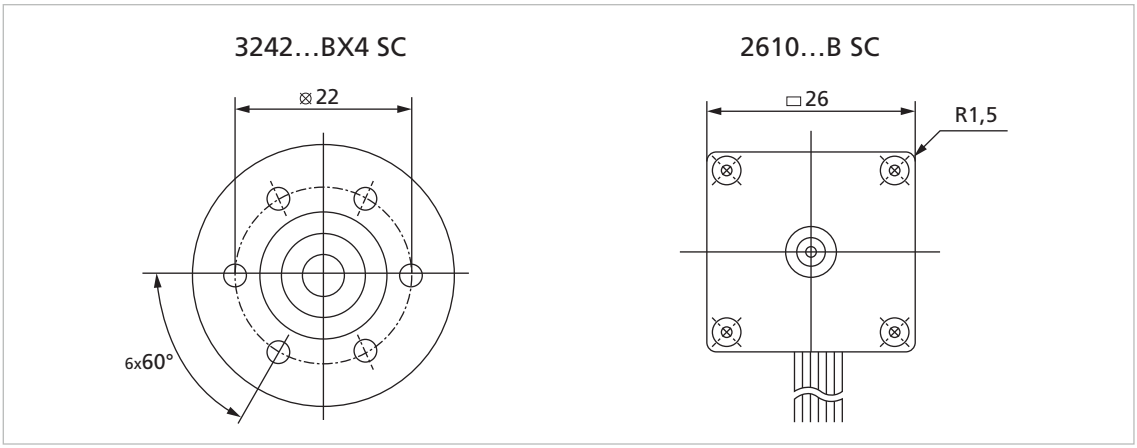


Fig. 6: Comparison of round flange and quadratic flange

4.2 Electrical connection

4.2.1 Notes on the electrical connection

NOTICE!
Electrostatic discharges to the motor connections can damage the electronic components

- Observe the ESD protective measures.
- Carry out work only at ESD-protected workstations.
- Connect the connections as per the pin assignment (see chap. 4.2.2.3, p. 19)

NOTICE!
Extreme static or dynamic loads on the ribbon cable can cause the cable to be damaged.

- Make sure that the ribbon cable is not subjected to abrasion, crushing or excessively tight bending radii during installation and operation.
- With frequent bending, the bending radius must not be less than 10 mm. The possible number of bending cycles increases as the bending radius increases.
- Do not bend the cable at temperatures < –10 °C.
- Comply with permissible loads (see Tab. 3).

Tab. 3: Permissible loads of the ribbon cables

Motor series	Contact spacing	Permissible loads
22xx…BX4(S) SC	1.27 AWG28	Tensile load: <30 N Continuous tensile load: <17 N Bending radius with one-off installation: >1.2 mm
32xx…BX4 SC / SCDC	2.54 AWG24	Tensile load: <60 N Continuous tensile load: <20 N Bending radius with one-off installation: >1.8 mm
26xx…B SC	1.00 AWG28	Tensile load: < 20 N Continuous tensile load: < 11 N Bending radius with one-off installation: >1.2 mm
1525…BRC / 1935…BRC	1.00 AWG28	Tensile load: < 20 N Continuous tensile load: < 11 N Bending radius with one-off installation: >1.2 mm
3153…BRC	1.27 AWG26	Tensile load: < 20 N Continuous tensile load: < 17 N Bending radius with one-off installation: >1.2 mm
2214…BXT H SC	1.27 AWG28	Tensile load: <30 N Continuous tensile load: <17 N Bending radius with one-off installation: >1.2 mm
3216…BXT H SC	2.54 AWG24	Tensile load: <60 N Continuous tensile load: <20 N Bending radius with one-off installation: >1.8 mm
4221…BXT H SC	2.54 AWG24	Tensile load: <60 N Continuous tensile load: <20 N Bending radius with one-off installation: >1.8 mm

4.2.2 Electrical connection of motor

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.
- Observe the EMC protective measures described here.

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).

4.2.2.2 EMC suppressor circuit

Suppressor circuit 1

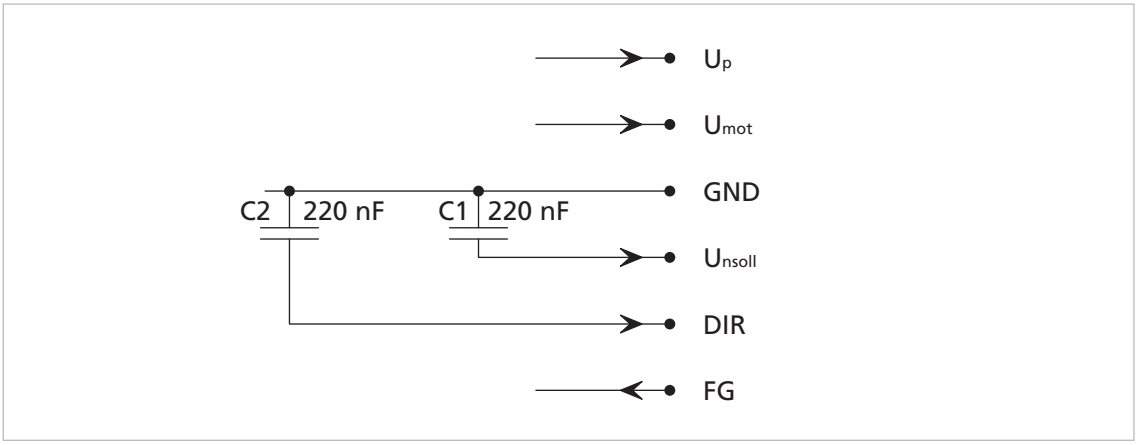


Fig. 7: EMC suppressor circuit with ceramic capacitors

- 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.

Suppressor circuit 2

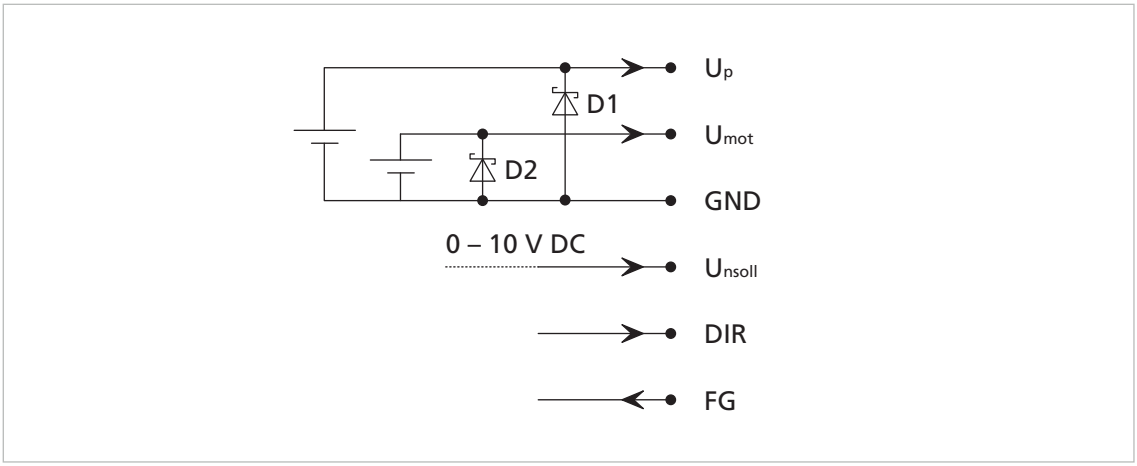


Fig. 8: EMC suppressor circuit with suppressor diodes

- Separated suppressor diodes (D1 and D2, e.g. P6KE33A von STMicroelectronics) for U_P and U_{mot} in case of separated supply voltages.
- If only one power supply is used (jumper between U_P and U_{mot}), one suppressor diode (D1) is sufficient.

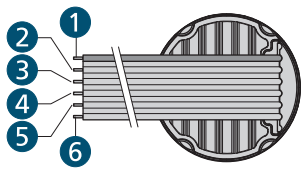
4.2.2.3 Pin assignment

NOTICE!
Incorrect polarity can cause irreparable damage to the electronics

- Connect the motor in accordance with the pin assignment.

Motors with integrated SC have a 6-wire cable. Wire 1 is highlighted in red for all product variants.

Tab. 4: Pin assignment of ribbon cable (SC)



Wire	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. 28)
5	DIR	Switching input for the rotation direction of the motor
6	FG	Digital output with open collector and integrated pull-up resistor (22 kΩ) The digital output can be configured for various tasks (see chap. 5.3, p. 31)

Tab. 5: Electrical data – motor connections on motor series 22xx BX4(S) SC

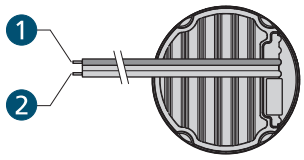
Wire	Designation	Value
1 (U_p)	Electronics supply	5…28 V DC
2 (U_{mot})	Coil supply	6…28 V DC
3 (GND)	Ground	–
4 (U_{nsoll}) Analogue input	Input voltage	U_{in} = 0…10 V U_{in} > 10 V…U_p ➞ speed set value not defined
	Input resistance	R_{in}≥ 8.9 kΩ
	Speed set value	pro 1 V, 1 000 min^{-1} (2 000 min^{-1} (S)) 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 22 kΩ pull-up resistor 6 lines per revolution

Tab. 6: Electrical data – motor connections on motor series 32xx BX4 SC

Wire	Designation	Value
1 (U_p)	Electronics supply	6.5…30 V DC
2 (U_{mot})	Coil supply	6.5…30 V DC
3 (GND)	Ground	–
4 (U_{nsoll}) Analogue 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	pro 1 V, 1 000 min^{-1} 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 22 kΩ pull-up resistor 6 lines per revolution

Motors in the version with SCDC have a 2-wire cable. In this operating mode, the servomotor is connected in the same way as a conventional DC motor. The rotation direction of the motor is determined by the polarity of the connection wires.

Tab. 7: Pin assignment of ribbon cable (SCDC)



Wire	Designation	Meaning
1 (red)	Mot +	Positive connection of the power supply
2	Mot –	Negative connection of the power supply

Tab. 8: Electrical data – motor connection (SCDC)

Wire (designation)	Value	Voltage
1 (Mot +)	▪ Clockwise rotation with homopolar connection ▪ Anticlockwise rotation with oppositely poled connection	6.5…30 V
2 (Mot –)		

Tab. 9: Electrical data – motor connections on motor series 26xx B SC

Wire	Designation	Value
1 (U_p)	Electronics supply	4…18 V DC
2 (U_{mot})	Coil supply	1.7…18 V DC
3 (GND)	Ground	–
4 (U_{nsoll}) Analogue 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	pro 1 V, 1 000 min^{-1}
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 22 kΩ pull-up resistor 6 lines per revolution

Tab. 10: Electrical data – motor connections on motor series BRC

Wire	Designation	Value
1 (U_p)	Electronics supply	1525…BRC: 4…18 V DC 1935…BRC: 4…18 V DC 3153…BRC: 5…30 V DC
2 (U_{mot})	Coil supply	1525…BRC: 1.7…18 V DC 1935…BRC: 1.7…18 V DC 3153…BRC: 0…30 V DC
3 (GND)	Ground	–
4 (U_{nsoll}) Analogue 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	1525…BRC: pro 1 V, 2 000 min^{-1} 1935…BRC: pro 1 V, 2 000 min^{-1} 3153…BRC: pro 1 V, 1 000 min^{-1} 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 22 kΩ pull-up resistor 3 lines per revolution

Tab. 11: Electrical data – motor connections on motor series 2214 BXT H SC

Wire	Designation	Value
1 (U_p)	Electronics supply	5…28 V DC
2 (U_{mot})	Coil supply	5…28 V DC
3 (GND)	Ground	–
4 (U_{nsoll}) Analogue 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	pro 1 V, 1 000 min^{-1} (2 000 min^{-1} (S)) 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 22 kΩ pull-up resistor 21 lines per revolution

Tab. 12: Electrical data – motor connections on motor series 3216 and 4221 BXT H SC

Wire	Designation	Value
1 (U_p)	Electronics supply	6.5…30 V DC
2 (U_{mot})	Coil supply	6.5…30 V DC
3 (GND)	Ground	–
4 (U_{nsoll}) Analogue 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	pro 1 V, 1 000 min^{-1} 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 22 kΩ pull-up resistor 21 lines per revolution

4.2.2.4 Connection examples

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})

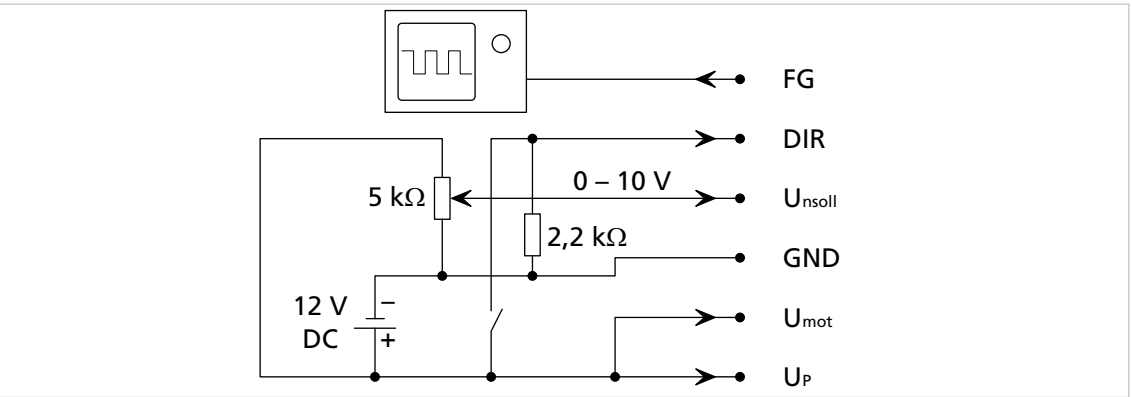


Fig. 9: Normal operation (speed set value specification by U_{nsoll})

- 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. 31), the speed signal can be measured at the digital output.

Motor clockwise (SCDC)

Fig. 10: Clockwise rotating motor

- Mot + is connected to the positive pole.
- Mot – is connected to the negative pole.

The motor rotates clockwise at a load-dependent speed.

Motor anticlockwise (SCDC)

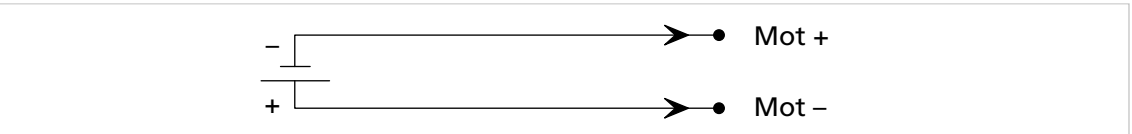


Fig. 11: Anticlockwise rotating motor

- Mot – is connected to the positive pole.
- Mot + is connected to the negative pole.

The motor rotates anticlockwise at a load-dependent speed.

5 Description of functions

5.1 Operating modes

5.1.1 Speed-controlled operation

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 commutation type.

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

5.1.1.1 BL motors with digital Hall sensors

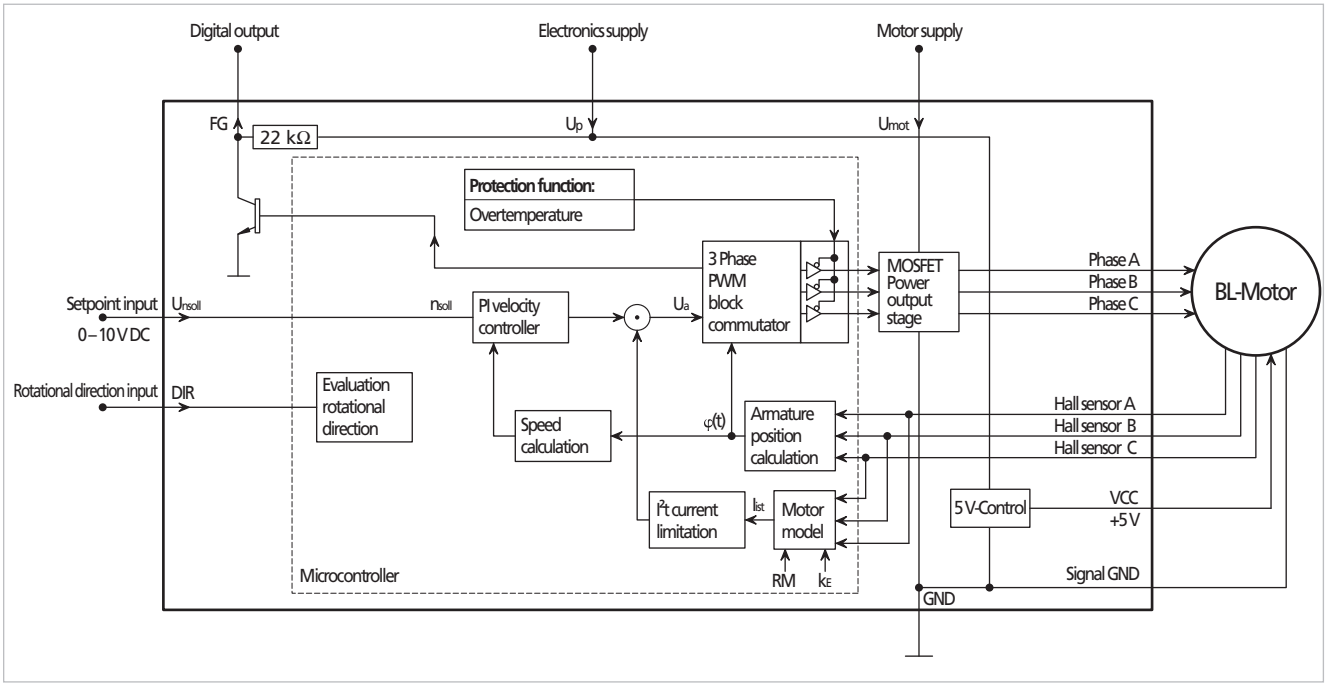


Fig. 12: Block diagram of a BL motor with digital Hall sensors

The resolution of the digital Hall sensors means that stable control of the following mechanical speeds is possible:

- BXT H series: from approx. 200 min^{-1}
- All other series: from 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 value specification	Analogue
Digital output	Frequency output
Operating mode	Speed-controlled
2-quadrant operation with brake function	The speed is reduced by short-circuiting the motor
Speed filter	Active

The following settings can be made by the user:

Designation	Explanation
Set value specification	The following set value specifications can be set (see chap. 5.2, p. 28): ▪ Fixed speed mode ▪ Speed set value specification via analogue 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. Possible values are 2 and 6 lines per revolution. ▪ Fault output (see chap. 5.3, p. 31).
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

5.1.1.2 BL motors with analogue Hall sensors

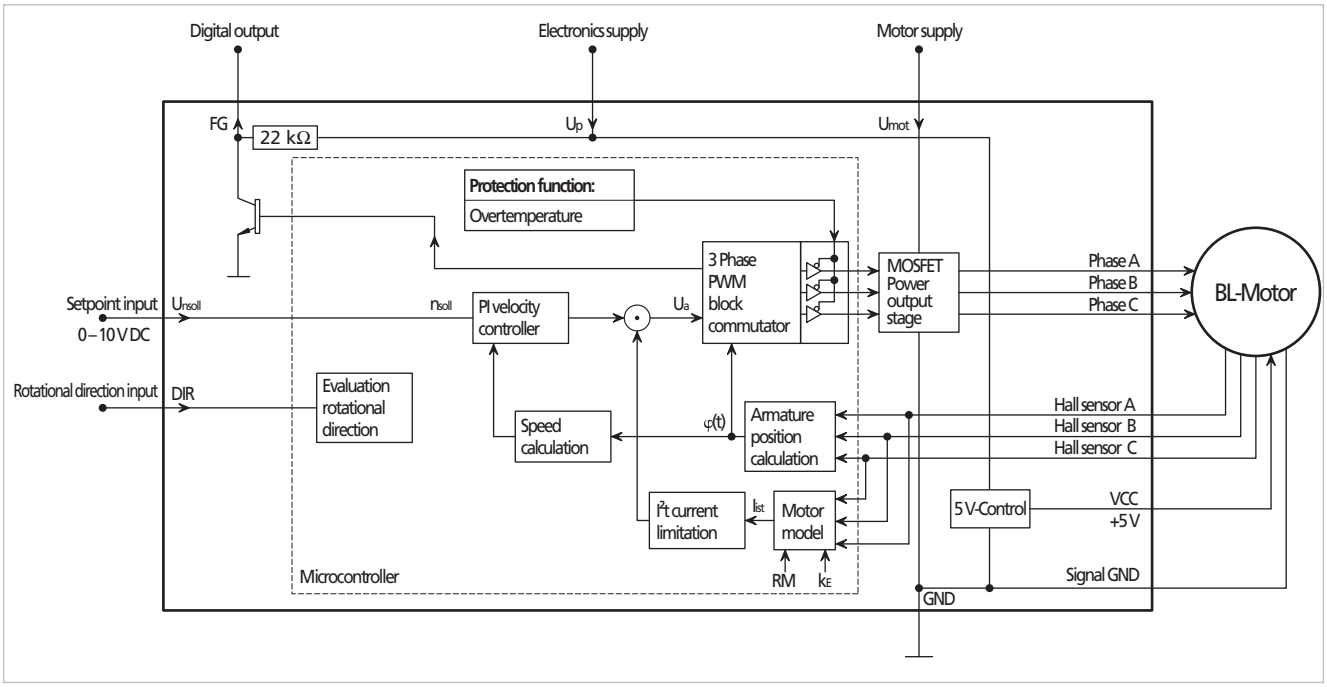


Fig. 13: Block diagram of a BL motor with analogue Hall sensors

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

In this configuration, the commutation signal is determined via the analogue Hall sensors. The position information from the analogue 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 value specification	Analogue
Digital output	Frequency output
Operating mode	Speed-controlled
Speed filter	Active

The following settings can be made by the user:

Designation	Explanation
Set value specification	The following set value specifications can be set (see chap. 5.2, p. 28): ▪ Fixed speed mode ▪ Speed set value specification via analogue 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. Possible values are 2 and 6 lines per revolution. ▪ Fault output (see chap. 5.3, p. 31).
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

5.1.1.3 BL motors without Hall sensors (BRC motors)

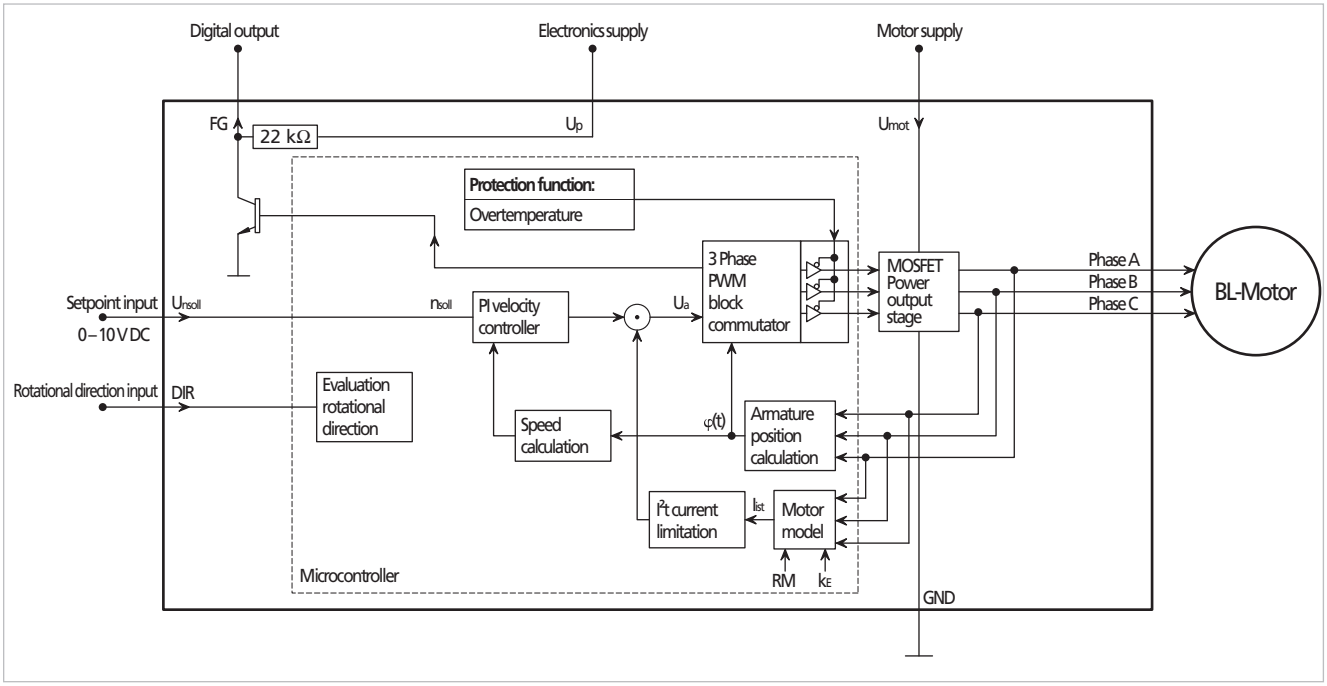


Fig. 14: Block diagram of a BL motor without Hall sensors

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

BRC motors do not have any 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 value specification	Analogue
Digital output	Frequency output (cannot be changed)
Operating mode	Speed-controlled

The following settings can be made by the user:

Designation	Explanation
Set value specification	The following set value specifications can be set (see chap. 5.2, p. 28): ▪ Fixed speed mode ▪ Speed set value specification via analogue 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. Possible values are 2 and 6 lines per revolution.
Operating mode	▪ Speed-controlled ▪ Voltage controller

5.1.2 Operation as voltage controller

The integrated 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 for commutation.

5.2 Set-point specification

The following setting options for set value specification are possible:

- Fixed speed specification
- Analogue 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. 32).

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 Analogue set value specification

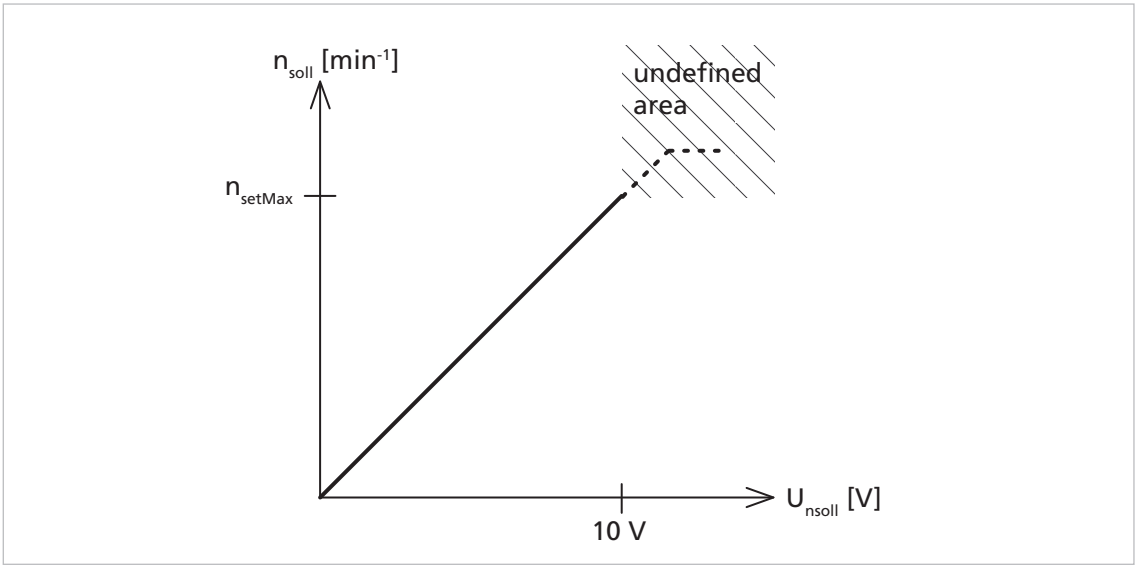


Fig. 15: Set value determination for speed controller

- The analogue input can process voltages from 0 V to 10 V.
- An analogue 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 $n_{set-Max}$ cannot be reached. In this case, the motor rotates at the maximum speed which can be reached at the given voltage (see Tab. 1).

5.2.3 PWM set value specification

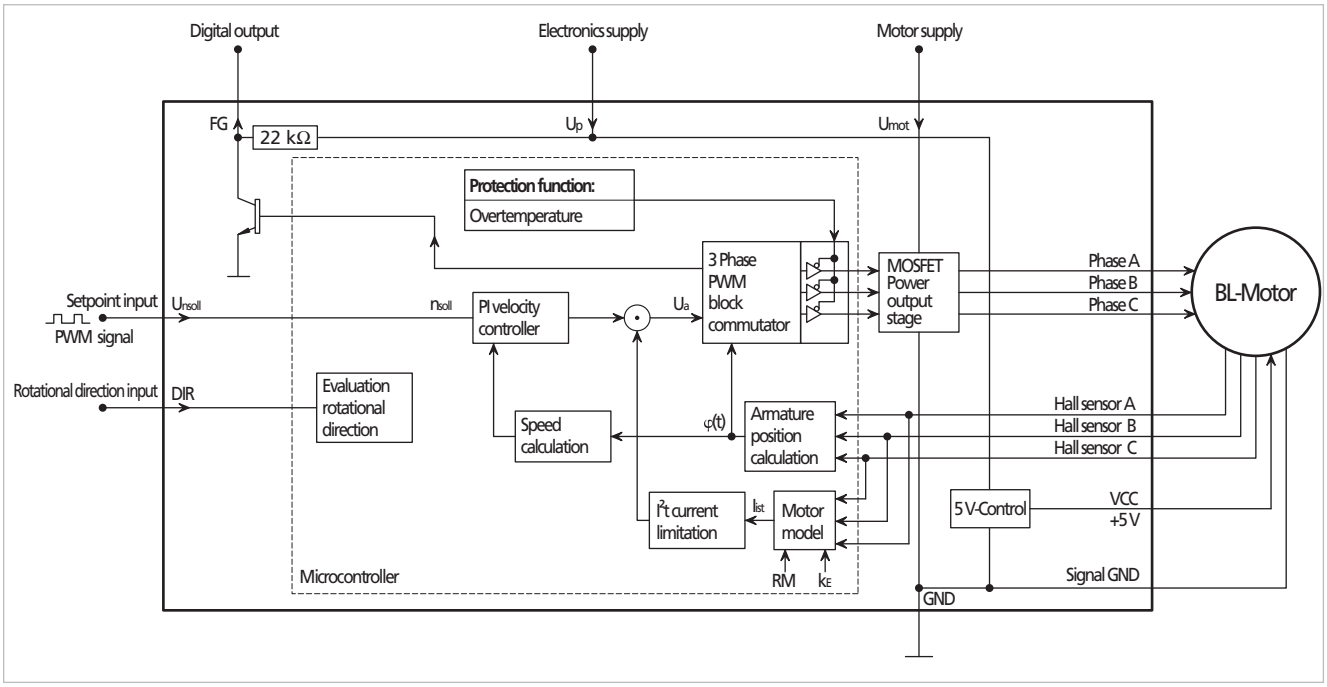


Fig. 16: Block diagram of a motor with integrated SC in PWM mode

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. 13: 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 available for 1525 and 1935 BRC motors

5.3 Configuration of the digital output

The digital output can be configured for the following tasks:

Fault output [1]

- 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

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

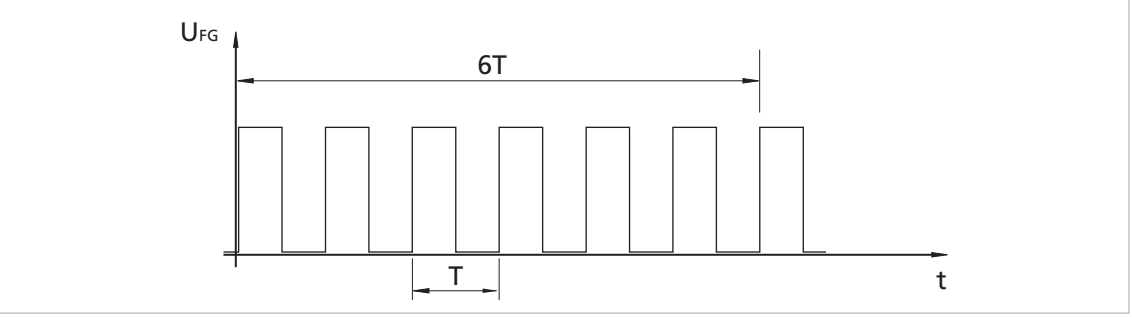


Fig. 17: Signal structure of frequency output

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 kΩ) between FG and the supply voltage 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.

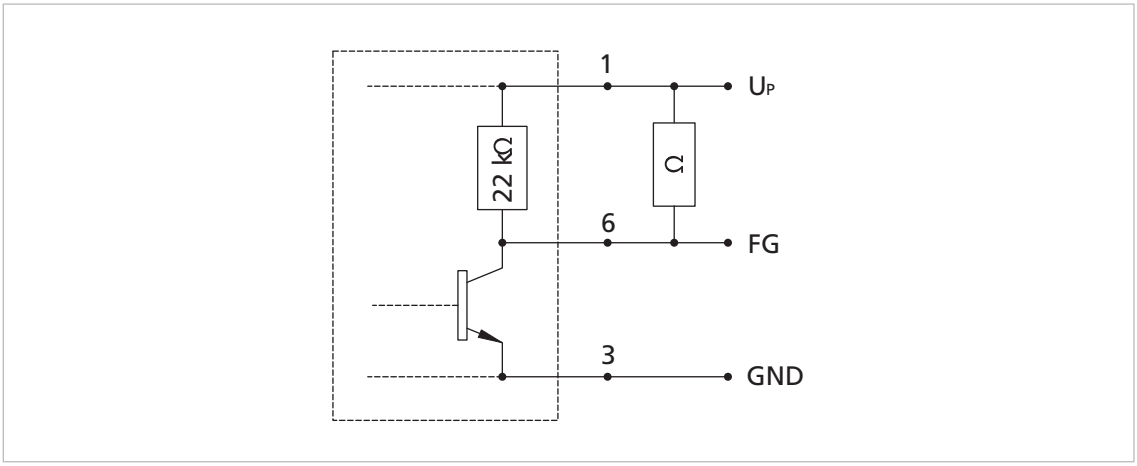


Fig. 18: Connection of an additional pull-up resistor

1 Not available for BRC motors

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 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. 36). The permissible values must be observed.

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

Tab. 14: Motor-specific values for motor continuous current (I_{cont}) and peak current (I_{max})

Motor series	Motor continuous current (I_{cont}) [a]	Peak current (I_{max}) [a]	Unit
2232S012BX4(S) SC	1 000	2000	mA
2232S024BX4(S) SC	500	1 000	mA
2250…BX4(S) SCC	900	1800	mA
3242G012BX4 SC	2000	4000	mA
3242G024BX4 SC	1 000	2000	mA
3242G012BX4 SCDC [b]	1900	3800	mA
3242G024BX4 SCDC [b]	1700	3400	mA
3268…BX4 SC	1600	3200	mA
3268…BX4 SCDC	1900	3800	mA
1525U009BRC	640	1280	mA
1525U012BRC	500	1 000	mA
1525U015BRC	390	780	mA
1935S006BRC	500	1 000	mA
1935S009BRC	400	800	mA
1935S012BRC	330	660	mA
3153K009BRC	2000	3500	mA
3153K012BRC	1600	3200	mA
3153K024BRC	850	1700	mA
2610/2622…006B SC	470	950	mA
2610/2622…012B SC	230	470	mA
2214S012 BXT H SC	650	1300	mA
2214S024 BXT H SC	350	700	mA
3216W012 BXT H SC	1950	3900	mA

Motor series	Motor continuous current (I_{cont}) a)	Peak current (I_{max}) a)	Unit
3216W024 BXT H SC	1 000	2000	mA
4221G024 BXT H SC	2580	5160	mA

a) Depending on the cooling factor, operating point and ambient temperature, the current limitation parameter can be adapted using the FAULHABER Motion Manager. The specified values apply in the case of 22 °C ambient temperature and the nominal voltage for motor and electronics.

b) Parameters can only be changed at the factory.

5.4.2 Fixed speed

In fixed speed mode, the speed set value is preset via a configurable parameter (see chap. 5.2.1, p. 28).

Parameter	Meaning	Maximum value	Unit
Fixed speed (N_{setFix})	Speed set value in fixed speed mode	65 535	rpm

5.4.3 Lines per motor revolution

The digital output (FG) can be configured as a frequency output (see chap. 5.3, p. 31). 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. 15: Number of lines per revolution depending on sensor system

Encoder type	Possible values	Unit
Digital Hall sensors, 4-pin motors	2, 6	1/revolution
Digital Hall sensors, 14-pin motors	7, 21	1/revolution
Analogue Hall sensors, 4-pin motors	2, 4, 6, 8, 16, 32	1/revolution
Sensorless operation, 2-pin motors	1, 3, 6	1/revolution

5.4.4 Maximum speed

If a speed set value is specified by means of an analogue 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-specific	min^{-1}

Tab. 16: Motor-specific values n_{setMax}

Motor series	Sensors	Maximum speed value (n_{setMax}) [a]	Unit
2232…BX4(S) SC	Digital Hall Analogue Hall	20000 20000	min^{-1}
2250…BX4S SC [b]	Digital Hall	20000	min^{-1}
2250…BX4 SC	Digital Hall Analogue Hall	10000 20000	min^{-1}
3242…BX4 SC	Digital Hall Analogue Hall	20000 20000	min^{-1}
3268…BX4 SC	Digital Hall Analogue Hall	10000 10000	min^{-1}
1525…BRC	Sensorless	20000	min^{-1}
1935…BRC	Sensorless	20000	min^{-1}
3153…BRC	Sensorless	10000	min^{-1}
2610…B SC	Digital Hall	10000	min^{-1}
2622…B SC [c]	Digital Hall	10000	min^{-1}
2214…BXT H SC [b]	Digital Hall	10000	min^{-1}
3216…BXT H SC [b]	Digital Hall	10000	min^{-1}
4221…BXT H SC [b]	Digital Hall	10000	min^{-1}

a) Delivery state. The speed range depends on the maximum motor supply voltage.

b) Option of analogue Hall sensors is not available in this version.

c) Integrated gearhead; for details, see the product data sheet.

5.4.5 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	65 535	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.

5.4.6 Start time (in sensorless mode only)

In sensorless mode, the 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

5.4.7 Minimum speed (in sensorless mode only)

Stable operation of the motor in sensorless mode 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	rpm

5.4.8 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. 31). 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.

Functionality of the I^2t current limitation

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

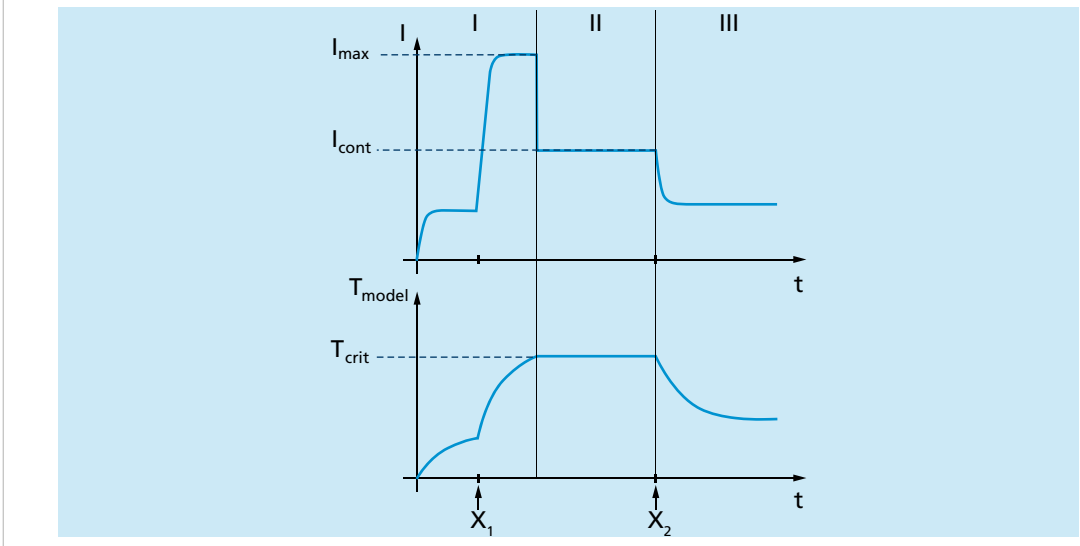


Fig. 19: Example of I^2t current limitation

Area I:

- When the motor is started, the peak current is preset as the set value 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 a motor with 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 BRC, 32…BXT H and 42…BXT H motors). 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.

A reduction in efficiency at the motor causes a reduction in the maximum permissible current. The maximum torque also decreases as a result.

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.

6 Commissioning

CAUTION!
Hazards due to hot surfaces.

Depending on the load and ambient temperature, the motor can overheat.

- Allow the motor to cool down after operation.
- Be sure to wear protective gloves when touching the motor shortly after operation.

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 optimised for specific applications. In this case, the digital controller operates at a sampling rate of 500 µs. Controller optimisation performed when commissioning the motor is described below.

✓ Motor is mounted as per the specifications (see chap. 4, p. 14).

✓ Motor is electrically connected as per the specifications (see chap. 4.2.2, p. 18).

✓ 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 behaviour.
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.
Contact adapter	6501.00112
Programming adapter USB	6501.00096

Details on configuration can be found in the Motion Manager manual (see chap. 1.2, p. 5).

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

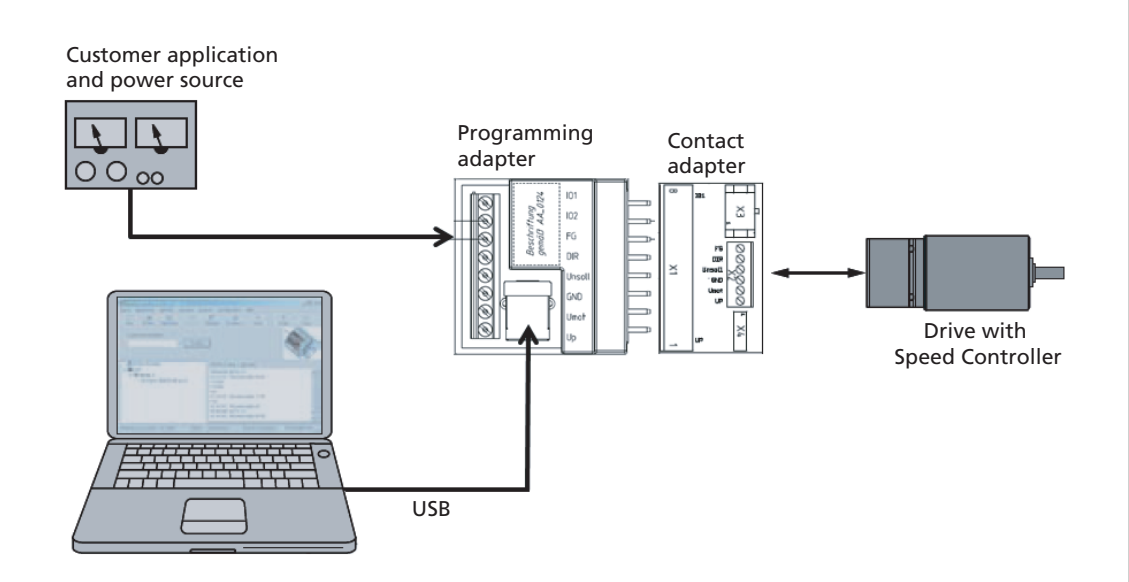


Fig. 20: Setup with programming adapter and contact adapter

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

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.

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