maxon motor

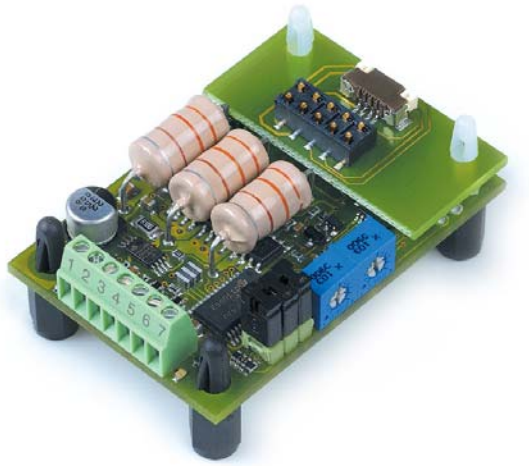
maxon motor control 1-Q-EC Amplifier DEC 24/1

Order numbers 249630, 249631, 249632, 318305, 381510

Operating Instructions September 2009 edition

The DEC (**D**igital **E**C **C**ontroller) is a 1-quadrant amplifier for controlling electronically commutated (brushless) DC motors with Hall sensors with a maximum output of 24 W.

- Digital speed control
- Maximum speed: 120 000 rpm (Motor with 1 pole pair)
- Operation as speed controller or open loop speed control
- /Brake, Direction and /Disable input
- Status indicator with green LED
- Set value input through built-in potentiometer (several speed ranges can be selected) or analogue set value input (0 … 5 V)
- Adjustable maximum current limit
- Integrated chokes for very low-impedant motors to operate at low loss
- Current limit permits temporary twice the continuous current
- Attachable adapter boards enable all kinds of maxon micromotors to be used
- Speed can be monitored through the speed monitor output



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The latest edition of these operating instructions may be downloaded from the internet as a PDF-file under www.maxonmotor.com, category «Service & Downloads», order numbers 249630, 249631, 249632, 318305, 381510 or in the e-shop http://shop.maxonmotor.com.

1. Safety Instructions

Skilled personnel
Only skilled, experienced personnel should install and start the equipment.

Statutory regulations
The user must ensure that the amplifier and the components belonging to it are assembled and connected according to local statutory regulations.

Load disconnected
For initial operation, the motor should be free running, i.e. with the load disconnected.

Additional safety equipment
Any electronic equipment is, in principle, not fail-safe. Machines and apparatus must therefore be fitted with independent monitoring and safety equipment. If the equipment breaks down, if it is operated incorrectly, if the control unit breaks down or if the cables break etc., it must be ensured that the drive or the complete apparatus is kept in a safe operating mode.

Repairs
Repairs may only be carried out by authorised personnel or the manufacturer. It is dangerous for the user to open the unit or carry out any repairs.

Danger
Ensure that no apparatus is connected to the electrical supply during installation of the DEC 24/1! After switching on, do not touch any live parts!

Max. supply voltage
Make sure that the supply voltage is between 5 and 24 VDC. Voltages higher than 28 VDC or of the wrong polarity will destroy the unit.

Short circuit and earth fault
The amplifier is not protected against winding short circuits against ground safety earth and/or Gnd!

Electrostatic sensitive device (ESD)

2. Technical Data

2.1. Electrical data

Supply voltage V_{CC} (ripple< 2 %) ..... 5…24 VDC
Max. output voltage at max output current ..... V_{CC} - 1.5 V
Continuous output current I_{cont} ..... 1 A
Max. output current I_{max} ..... 2 A
Switching frequency of end stage ..... 39 kHz
Max. speed (2-pole motor) ..... 120 000 rpm
Internal motor chokes per phase ..... 150 µH, 1 A, 0.39 Ω

2.2. Input

Speed ..... Analogue input (0 … 5 V)
Resolution: 1024 steps
/Disable ..... TTL, CMOS (5 V) or switch to Gnd
Direction ..... TTL, CMOS (5 V) or switch to Gnd
/Brake ..... TTL, CMOS (5 V) or switch to Gnd
Hall Sensor 1, 2, 3

2.3. Output

Speed monitor ..... Digital output signal (+5 VDC / 1 kΩ)

2.4. Voltage output

Hall sensors supply voltage "V_{cc} Hall" ..... 4.5...5 VDC, max. 30 mA

2.5. Motor connections

"Motor winding 1", "Motor winding 2", "Motor winding 3"

2.6. Trim potentiometers

Speed, I_{max}

2.7. LED indicator

Operating and fault display: green LED

2.8. Ambient temperature/humidity range

Operation ..... -10…+45°C
Storage ..... -40…+85°C
No condensation ..... 20…80 %

2.9. Protective functions

Blockage protection ..... Motor current limit if minimum speed is not maintained for 1.5 s

2.10. Mechanical data

Weight ..... approx. 20 g
Dimensions (L x B x H) ..... see dimension drawing, chapter 11
Mounting ..... 4 hexagonal M3 distance pins with inner winding
Mounting hole separation ..... 49 x 28 mm

2.11. Terminals

Power / Signal

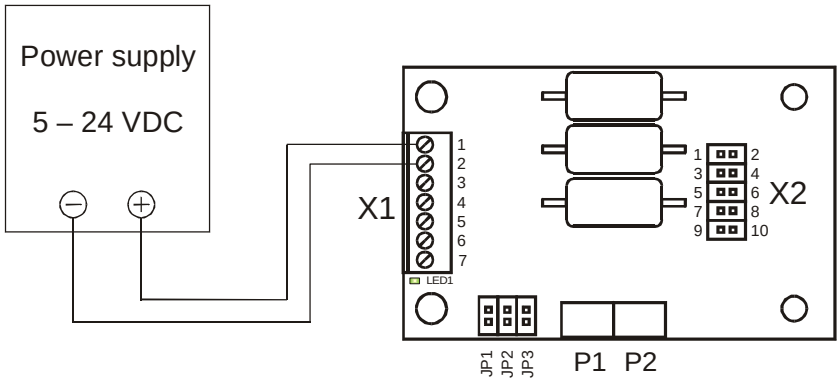
Screw terminal 7-pole
Pitch ..... 2.54 mm
suitable for wire cross-section ..... 0.14 ... 0.5 mm^2 (AWG 26-20)

Motor and Hall sensors

Flat flexible cable connector, top contact style 8-pole
Pitch ..... 0.5 mm
or
Flat flexible cable connector, top contact style 11-pole
Pitch ..... 1 mm
or
Pin connector with snap-in locking device 8-pole
Pitch ..... 2.5 mm
or
Screw terminal 8-pole
Pitch ..... 2.54 mm
suitable for wire cross-section ..... 0.14 ... 0.5 mm^2 (AWG 26-20)

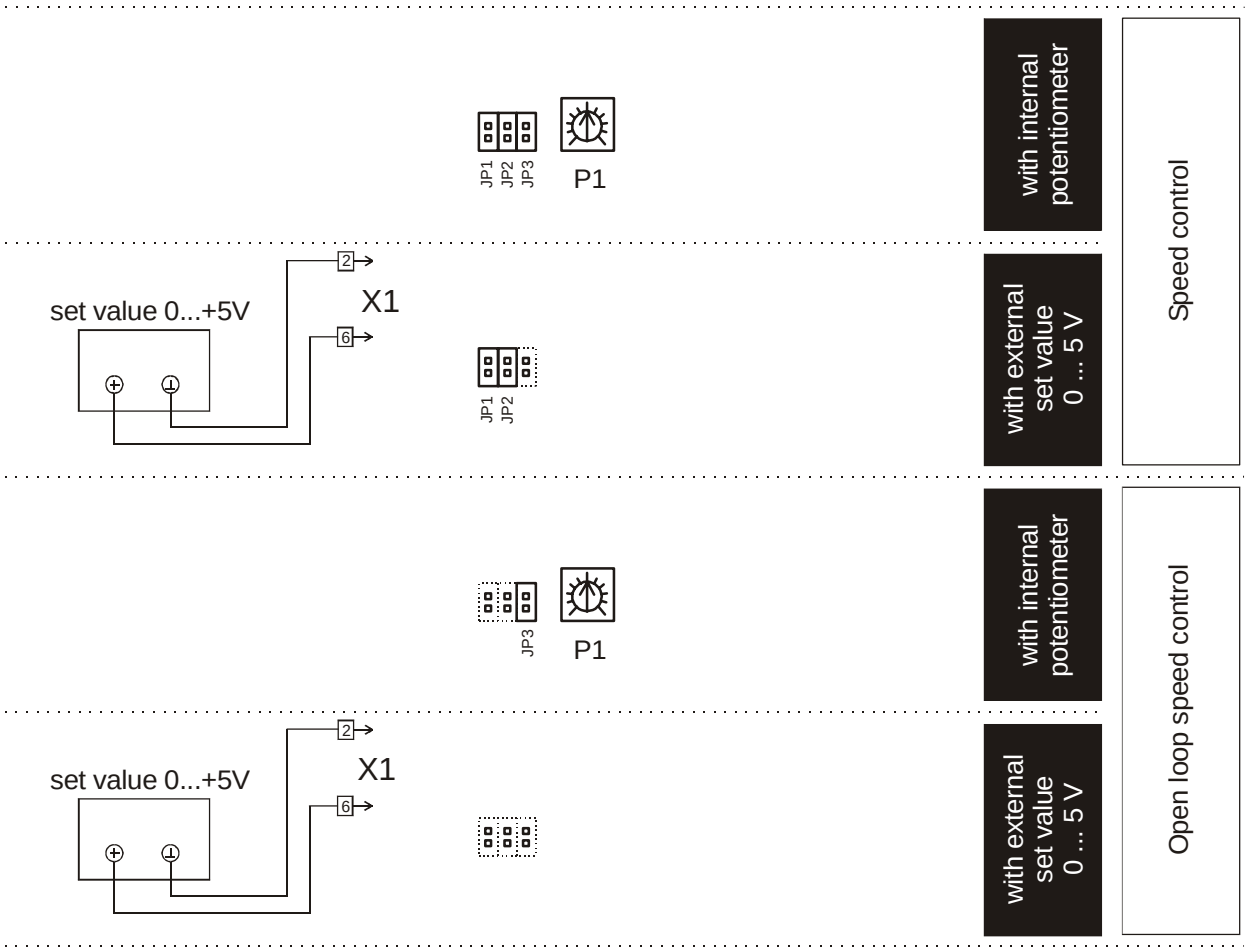
3. Minimum Wiring

3.1. Operating mode



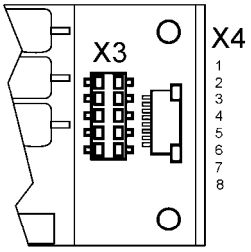
Pin assignment X1:
1 $+V_{CC}$ 5 – 24 VDC
2 Gnd
3 Direction
4 /Disable
5 /Brake
6 Speed
7 Monitor n

Pin assignment X2:
1 Motor winding 1
2 Motor winding 2
3 Motor winding 3
4 V_{Hall} 4.5 ... 5 VDC
5 Gnd
6 Hall sensor 1
7 Hall sensor 2
8 Hall sensor 3
9 n.c.
10 n.c.



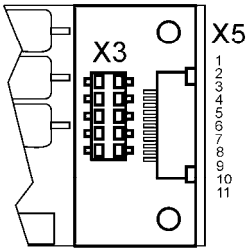
3.2. Pin assignment

Pin assignment X4 (Order number 318305)



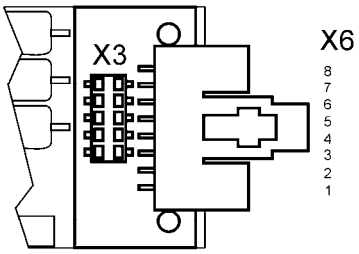
1 Motor winding 3
2 Motor winding 2
3 Hall sensor 3
4 V_{Hall} 4.5 ... 5 VDC
5 Gnd
6 Hall sensor 1
7 Hall sensor 2
8 Motor winding 1

Pin assignment X5 (Order number 249630)



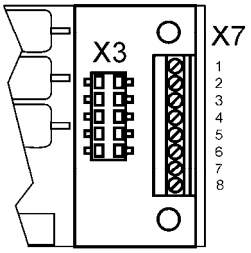
1 V_{Hall} 4.5 ... 5 VDC
2 Hall sensor 3
3 Hall sensor 1
4 Hall sensor 2
5 Gnd
6 Motor winding 3
7 Motor winding 3
8 Motor winding 2
9 Motor winding 2
10 Motor winding 1
11 Motor winding 1

Pin assignment X6 (Order number 249631)



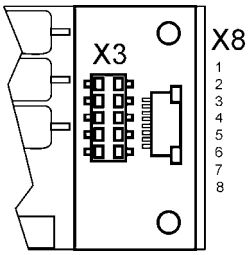
1 Motor winding 1
2 Motor winding 2
3 Motor winding 3
4 V_{Hall} 4.5 ... 5 VDC
5 Gnd
6 Hall sensor 1
7 Hall sensor 2
8 Hall sensor 3

Pin assignment X7 (Order number 249632)



1 Motor winding 1
2 Motor winding 2
3 Motor winding 3
4 V_{Hall} 4.5 ... 5 VDC
5 Gnd
6 Hall sensor 1
7 Hall sensor 2
8 Hall sensor 3

Pin assignment X8 (Order number 381510)



1 Motor winding 1
2 Motor winding 2
3 Motor winding 3
4 V_{Hall} 4.5 ... 5 VDC
5 Gnd
6 Hall sensor 1
7 Hall sensor 2
8 Hall sensor 3

4. Operating Instruction

4.1. Power supply layout

Any available power supply can be used as long as it meets the minimum requirements set out below.
During set-up and adjustment phases, we recommend separating the motor mechanically from the machine to prevent damage from uncontrolled motion.

Power supply requirements	
Output voltage	V_{CC} min. 5 VDC; V_{CC} max. 24 VDC
Ripple	< 2%
Output current	depending on load, continuous max 1 A acceleration, short-time max. 2 A

The required voltage can be calculated as follows:

Known values
- ⇨ Operating torque M_B [mNm]
- ⇨ Operating speed n_B [rpm]
- ⇨ Nominal motor voltage U_N [V]
- ⇨ Motor no-load speed at U_N, n_0 [rpm]
- ⇨ Speed/torque gradient of motor $\Delta n/\Delta M$ [rpm/mNm]

Sought values
- ⇨ Supply voltage V_{CC} [V]

Solution

$$V_{CC} = \frac{U_N}{n_0} \cdot (n_B + \frac{\Delta n}{\Delta M} \cdot M_B) + 1.5V$$

Choose a power supply capable of supplying this calculated voltage under load. The formula takes into account a 1.5 V maximum voltage drop (at nominal current) at the power stage.

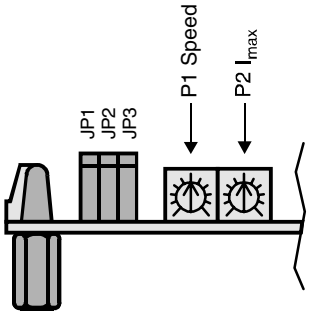
Note
Please note chapter 5.1.4, “/Brake” function when using the “/Brake“ input!

4.2. Adjusting the potentiometers

4.2.1. Pre-adjustment

With pre-adjustment, the potentiometers are set in a preferred position.
Units in the original packing are already pre-set.

Pre-adjustment of potentiometers		
P1	Speed	50 %
P2	I_{max}	50 %



Note

Left end stop of potentiometers:	Minimum value
Right end stop of potentiometers:	Maximum value

4.2.2. Adjustment

Digital speed control

1. Depending on operating mode selected, apply set value at the “Speed” input or with potentiometer **P1** so that required speed is reached. If necessary, adjust maximum speed with built-in jumper **JP1** and **JP2**. At 0 set value, the speed is NOT 0 rpm. It depends on the pole pair number of the connected motor (see chapter 6.1).
2. Adjust potentiometer **P2 I_{max}** to required limiting value. With potentiometer **P2**, continuous current can be adjusted in a range of 0.1…1 A.

Digital open loop speed control

1. Depending on operating mode selected, apply set value at the “Speed” input or with potentiometer **P1** so that required speed is reached. At 0 set value, the speed is 0 rpm.
2. Adjust potentiometer **P2 I_{max}** to required limiting value. With potentiometer **P2**, the maximum current can be adjusted in a range of 0.1…1 A.

5. Inputs and Outputs

5.1. Inputs

5.1.1. Set value “Speed”

The analogue set value is predetermined at the “Speed” input.
The “Speed” input is protected against overvoltage.

Input voltage range	0...+5 V (ref: Gnd)
Input impedance	> 1 MΩ (in range 0...+5 V)
Continuous overvoltage protection	-24...+24 V

Note
If the set value is applied using the “Speed” input, jumper **JP3** must not be plugged in.

5.1.2. “/Disable”

Enabling or disabling the power stage.

If the “/Disable” connection is not wired up or a voltage set higher than 2.4 V, the amplifier is activated (Enable).

Release enable (motor running)	Input open or input voltage > 2.4 V

If the “/Disable” connection is connected to Gnd Potential or at a voltage lower than 0.8 V, the power stage is high impedant and the motor shaft freewheels and slows down (Disable).

Block disable (power stage switched off)	Set input to Gnd or input voltage < 0.8 V.

The “/Disable” input is protected against overvoltage.

Input voltage range	0 ... +5 V
Input impedance	33 kΩ pull-up resistor at +5 V
Continuous overvoltage protection	-24 ... +24 V
Delay time	approx. 20 ms

Note
If the jumper setting was changed, the new settings are adopted through a disable-enable procedure.

5.1.3. "Direction"

When the level changes, the motor slows down in an uncontrolled fashion (as windings are short-circuited, see also chapter 5.1.4, "/Brake") and accelerates in the opposite direction, until the nominal speed is reached again.
The "Direction" input is protected against overvoltage.

Input voltage range	0...+5 V
Input impedance	33 kΩ pull-up resistor at +5 V
Continuous overvoltage protection	-24...+24 V
Delay time	approx. 20 ms

Clockwise (CW)	Input open or input voltage > 2.4 V
Counter-clockwise (CCW)	Set input to Gnd or input voltage < 0.8 V.

If the direction is changed with a rotating motor shaft, the limitations described in chapter 5.1.4, "/Brake" must be observed, or the amplifier may be damaged.

5.1.4. "/Brake" function

If the connection is not wired up or the voltage set higher than 2.4 V, the brake function is inactive.

Brake function not active (motor windings not short-circuited)	Input open or input voltage > 2.4 V

If the connection is placed at Gnd potential or the voltage is lower than 0.8 V, the /brake function is active and the motor shaft slows down to a standstill, short-circuiting the motor windings. The motor windings remained short-circuited until the /brake function is deactivated again.

Brake function active (motor windings short-circuited)	Set input to Gnd or input voltage < 0.8 V.

The brake function will be executed even if the power stage is disabled.
The "/Brake" input is protected against overvoltage.

Input voltage range	0...+5 V
Input impedance	33 kΩ pull-up resistor at +5 V
Continuous overvoltage protection	-24...+24 V
Max. brake current	10 A
Delay time	approx. 20 ms

The maximum permitted brake speed is limited through the maximum permitted short-circuit current and maximum kinetic energy:

- I <= 10 A
- W_k = 20 Ws

The values can be calculated as follows:

max. permitted brake speed limited by brake current. (I = 10 A)

The maximum permitted brake speed can be calculated from the motor data:

$$n_{\max} = 10\,A \cdot k_n \cdot \left(R_{Ph-Ph} + 1\Omega\right) \qquad [rpm]$$

k_n = speed constant [rpm/V]

R_{Ph-Ph} = terminal resistance phase-phase [Ω]

max. permitted brake speed limited by kinetic energy (W_k = 20 Ws)

With the given moment of inertia, the maximum speed can be determined using the following formula:

$$n_{\max} = \sqrt{\frac{365}{J_R + J_L}} \cdot 10\,000\,[rpm]$$

J_R = rotor inertia [gcm^2]

J_L = load inertia [gcm^2]

5.1.5. "Hall sensor 1", "Hall sensor 2", "Hall sensor 3"

Hall sensors are needed for detecting rotor position.
"Hall sensor" inputs are protected against overvoltage.

Input voltage range	0...+5 V
Input impedance	10 kΩ pull-up resistor at +5 V
Voltage value "low"	max. 0.8 V
Voltage value "high"	min. 2.4 V
Continuous overvoltage protection	-24...+24 V

Suitable for Hall effect sensors IC using Schmitt trigger and open collector output.

5.2. Outputs

5.2.1. "V_{CC} Hall"

Powering the Hall sensors.

Output voltage	4.5...5 VDC
Max. output current	30 mA

Note
When using long thin lines, the voltage drop can be so great via the lines that the supply voltage falls below the minimum for Hall sensors.
The maximum cable length for the Hall sensors' supply voltage between motor and controller is 10 m. The minimum cross-section is AWG 26.

5.2.2. "Monitor n"

The actual speed of the motor shaft is monitored at the "Monitor n" output of the electronics. The actual speed is available as a digital signal (high/low) and is equivalent to a third the commutation frequency.

Output voltage range	0...+5 V
Output resistance	1 kΩ
low level	max. 0.6 V
high level	min. 4.2 V

Sought values: Frequency at "Monitor n" output

$$f_{Monitor\ n} = \frac{n_{ist} \cdot z_{Pol}}{20} \qquad [Hz]$$

n_{ist} = speed [rpm]
z_{Pol} = Number of pole pairs

Sought values: Motor shaft speed

$$n_{ist} = \frac{f_{Monitor\ n} \cdot 20}{z_{Pol}} \qquad [rpm]$$

$f_{Monitor\ n}$ = Frequency at "Monitor n" output [Hz]
z_{Pol} = Number of pole pairs

Note

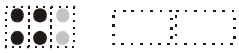
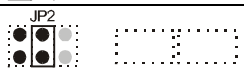
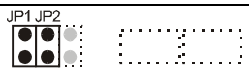
- Interference couplings into the "Monitor n" output (such as through long lines) should be avoided.
- The "Monitor n" output also functions in disable mode.

6. Built-in Jumpers

Operating modes are adjusted using 3 jumpers:

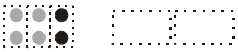
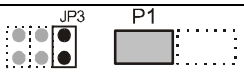
6.1. Setting mode / speed range

JP1 and **JP2** are used to predetermine the operating mode (speed control or open loop speed control) as well as the speed range.

	Motor type		
Jumpers **JP1** and **JP2**	1 pole pair	4 pole pairs	8 pole pairs
	Operation as open loop speed control 0...100 %		
	500...120 000 rpm	125...30 000 rpm	63...15 000 rpm
	500 ... 40 000 rpm	125 ... 10 000 rpm	63...5 000 rpm
	500...10 000 rpm	125...2 500 rpm	63...1 250 rpm

6.2. Setting set value input

JP3 is used to select the type of set value input (external set value input or with potentiometer **P1**).

Jumper **JP3**	Set value input
	Externally with “Speed” value input
	Internally with potentiometer **P1**

Note
If the jumper setting was changed, the new settings are adopted through a disable-enable procedure (see chapter 5.1.2)

7. Potentiometers

7.1. Potentiometer P1 “Speed”

If jumper **JP3** is plugged in, the set speed value is adjusted at potentiometer **P1** “Speed”.

Note

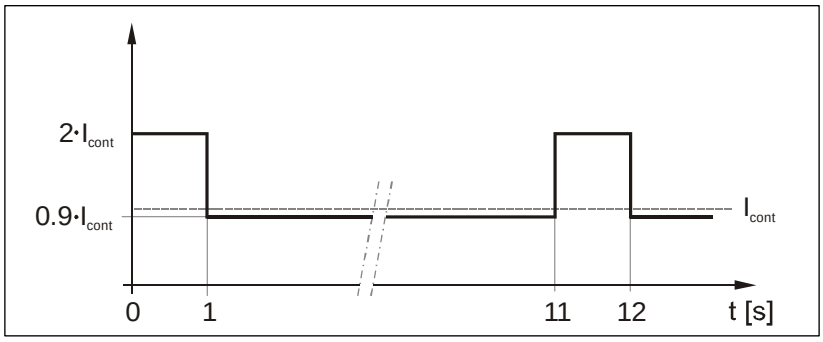
Left end stop of potentiometers:	Minimum value (see chapter 6.1)
Right end stop of potentiometers:	Maximum value (see chapter 6.1)

7.2. Potentiometer P2 “I_{max}”

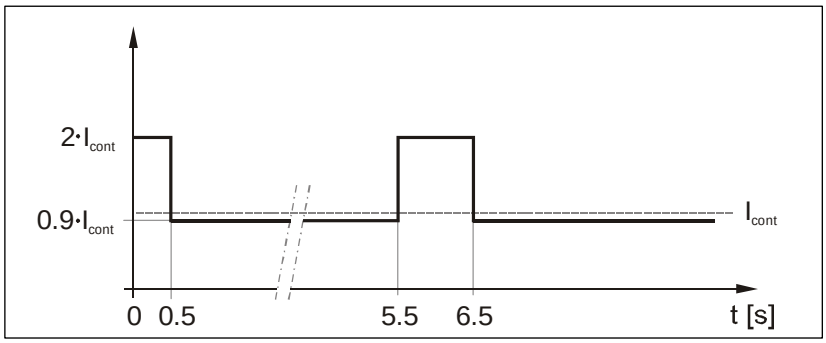
Adjusting the continuous current limit in the 0.1…1 A range.

The current adjusted on the potentiometer is available for an unlimited period. In the short-term (max. 1 s), a higher current is permitted ($I_{max} = 2 \cdot I_{cont}$), in which case the time depends on the current pattern’s background. After that time, it is limited to the continuous current I_{cont}.

Example 1
If the current is at less than 90 % of the continuous current for more than 10 s, I_{max} is permitted for another second.
If the motor is loaded for a long time in continuous current operation I_{cont}, a higher current level is not permitted.

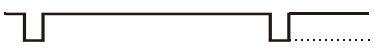


Example 2
If the maximum current is required for less than 1 s, the recovery time is shortened proportionately.



8. Operating Status Display

The green LED shows the operating status.

Definition
 LED on / LED off

8.1. No green LED

Cause:

- No supply voltage
- Wrong polarity of supply voltage
- Hall sensors' supply voltage V_{CC} Hall is short-circuited.

8.2. Green LED constantly lit up

Flashing type (green LED)	Operating status
 LED on / LED off	Amplifier activated, everything OK.

8.3. Green LED flashes every second

Flashing type (green LED)	Operating status
	Amplifier in "Disable" status.

8.4. Green LED flickers or flashes intermittently

The controller recognises invalid conditions in the Hall sensor inputs.

Cause:

- Hall sensors not connected or incorrectly connected
- Intermittent Hall sensor supply lines
- Excessive interference to Hall sensor supply lines
  (Solution: change supply line feeds, use shielded cable)
- Faulty Hall sensors in motor

8.5. Green LED flashes regularly

The following error messages can be distinguished depending on flashing type:

Flashing type (green LED)	Error message
	• Motor shaft is blocked • Load too great • I_{max} setting too low • No winding connection
	When switched on, the controller recognises invalid conditions in the Hall sensor inputs => check Hall sensor wiring and Hall sensor signals.

Note

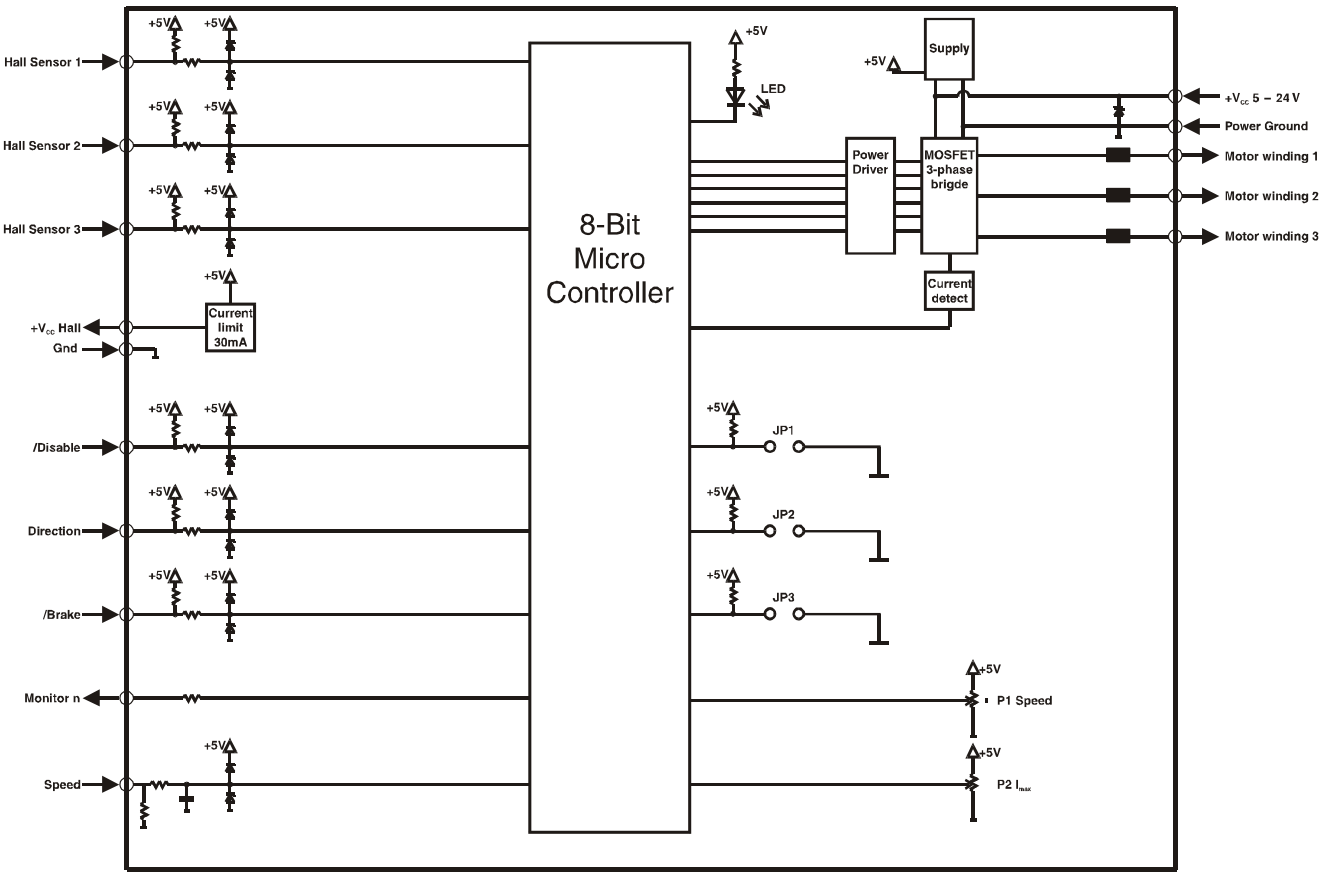
- If the motor does not turn when in "Enable" mode, the "motor shaft is blocked" error message will always appear.
- Errors and error displays are temporary and do not have to be confirmed through Disable/Enable.

9. Protection

9.1. Blockage protection

If the motor shaft is blocked for longer than 1.5 s, the current limit is set at 0.8 A, provided the current limit was not set lower via I_{max} potentiometer.

10. Block Diagram



11. Dimensional Drawings

Dimension in [mm]