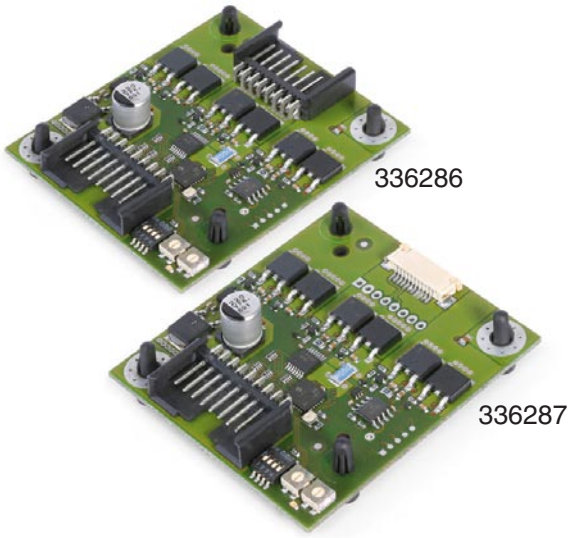
maxon motor control 1-Q-EC Amplifier DEC 24/3

Order number 336286, 336287

Operating Instructions May 2010 Edition

The DEC 24/3 (**D**igital **E**C **C**ontroller) is a small 1-quadrant digital controller for the control of brushless DC motors (**E**lectronic **C**ommutated motors) up to 72 W.
The used EC motor must be equipped with digital Hall sensors.



- Digital speed control
- Maximum speed 120‘000 rpm (motor with 1 pole pair)
- Operates as speed control or as open loop speed control
- Brake, Direction and Enable input
- Status indication with green LED
- Set value input through built-in potentiometer (several speed ranges can be selected) or through analogue set value input (0 ... +5 V)
- Maximum current limit adjustable
- Current limit permits temporary twice the continuous current
- Blockage protection (current limit for blocked motor)
- Two amplifier versions with different motor connector types allow a direct connection of various maxon EC-motors or maxon flat motors
- Speed can be monitored through the speed monitor output

Table of Contents

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 number 336286 or 336287.

1. Safety Instructions

Skilled Personnel

Installation and starting of the equipment shall only be performed by experienced, skilled personnel.

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 primary operation the motor should be free running, i.e. with the load disconnected.

Additional safety equipment

Any electronic apparatus 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 be made by authorised personnel only or by the manufacturer. Improper repairs can result in substantial dangers for the user.

Danger

Do ensure that during the installation of the DEC 24/3 no apparatus is connected to the electrical supply. 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 wrong polarity will destroy the unit.

Short circuit and earth fault

The DEC 24/3 amplifier is not protected against winding short circuits against ground safety earth and/or GND!

Electrostatic sensitive device (ESD)

2 Performance Data

2.1 Electrical data

Nominal supply voltage $+V_{CC}$ ..... 5...24 VDC
Absolute minimum supply voltage $+V_{cc\ min}$ ..... 4.5 VDC
Absolute maximum supply voltage $+V_{cc\ max}$ ..... 28 VDC
Max. output voltage ..... V_{CC} - 1.5 V
Continuous output current I_{cont} ..... 3 A
Max. output current I_{max} ..... 6 A
Switching frequency ..... 39 kHz
Max. speed (motor with 1 pole pair) ..... 120'000 rpm

2.2 Inputs

«Set value speed» ..... Analogue input (0...5 V); Resolution: 1024 steps
«Enable» ..... +2.4...+24 VDC, (R_i = 47 kΩ), or switch against «+5 VDC OUT»
«Direction» ..... +2.4...+24 VDC, (R_i = 47 kΩ), or switch against «+5 VDC OUT»
«Brake» ..... +2.4...+24 VDC, (R_i = 47 kΩ), or switch against «+5 VDC OUT»
Hall sensor signals ..... «Hall sensor 1», «Hall sensor 2», «Hall sensor 3»

2.3 Outputs

«Monitor n» ..... Digital output signal (+5 VDC / R_O = 1 kΩ)

2.4 Voltage outputs

Hall sensors supply voltage «V_{CC} Hall» ..... 5 VDC, max. 30 mA
Auxiliary voltage «+5 VDC OUT» ..... 5 VDC, max. 10 mA

2.5 Motor connections

«Motor winding 1», «Motor winding 2», «Motor winding 3»

2.6 Trim potentiometers

Speed, I_{cont}

2.7 LED indicator

Operating and fault display ..... green LED

2.8 Ambient temperature / humidity range

Operating ..... -10...+45° C
Storage ..... -40...+85° C
Non condensating ..... 20...80%

2.9 Protective functions

Blockage protection ..... Motor current restriction if motor shaft is blocked for longer than 1.5 s
Dynamical current limitation ..... $I_{max} = 2 \cdot I_{cont}$ is limited to I_{cont} after 1 s
Undervoltage shutdown ..... shutdown if $V_{CC} < 4.5$ VDC

2.10 Mechanical data

Weight ..... approx. 28 g
Dimensions (LxWxH) ..... see dimension drawing, chapter 11
Mounting ..... 4 hexagonal M3 distance pins with inner winding
Mounting hole separation ..... see dimension drawing, chapter 11

2.11 Terminals

Power / Signal

Male header ..... single row, 9 poles, pitch 2.5 mm
Suitable plug (included) ..... STOCKO, MKF 13269-6-0-909 **or** Lumberg, 2.5 MBX 09
Suitable for wire cross section ..... 0.22... 0.25 mm² (AWG 24)

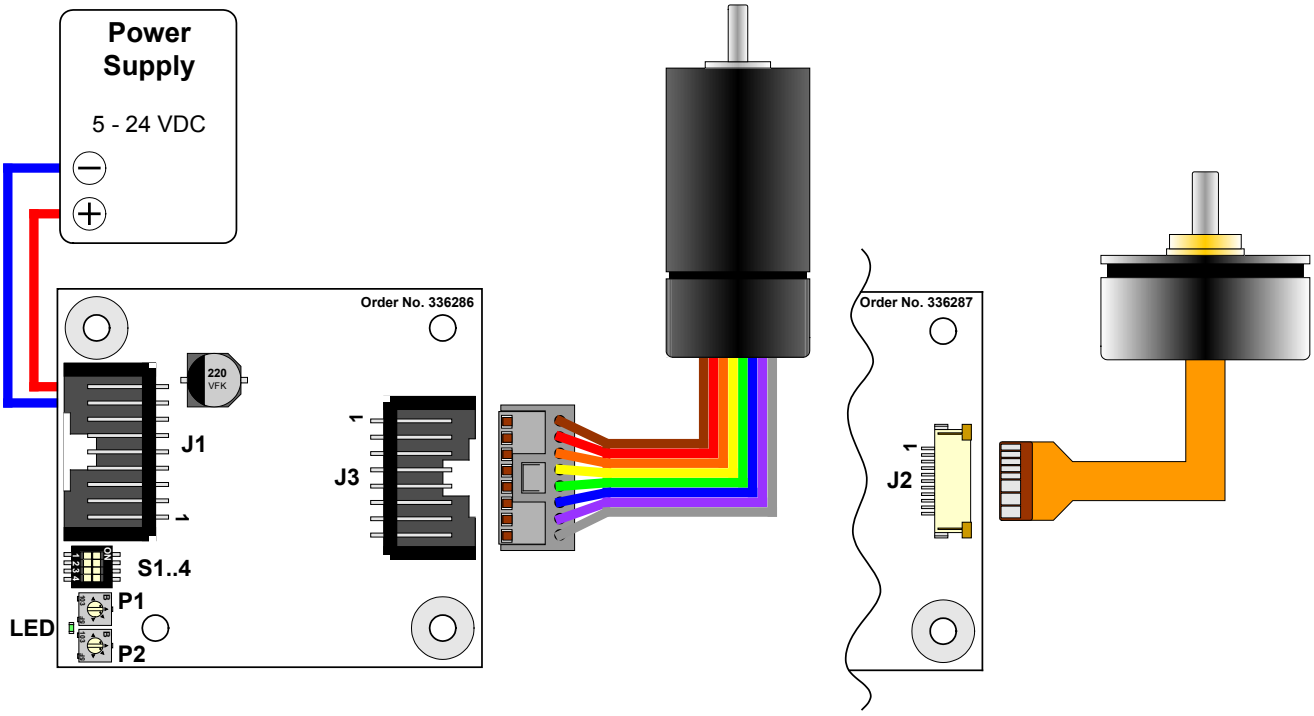
Motor and Hall sensors

Order number DEC 24/3 (SL) 336286
Male header ..... single row, 8 poles, pitch 2.5 mm
Suitable plug (not included) ..... STOCKO, MKF 13268-6-0-808 **or** Lumberg, 2.5 MBX 09
Suitable for wire cross section ..... 0.22... 0.25 mm² (AWG 24)
or
Order number DEC 24/3 (FPC) 336287
FPC-FFC flat flexible cable connector, top contact style ..... 11 poles
Pitch ..... 1 mm

3. Minimum External Wiring

3.1. Operating mode

3.1.1. Speed control



Pin assignment J1:

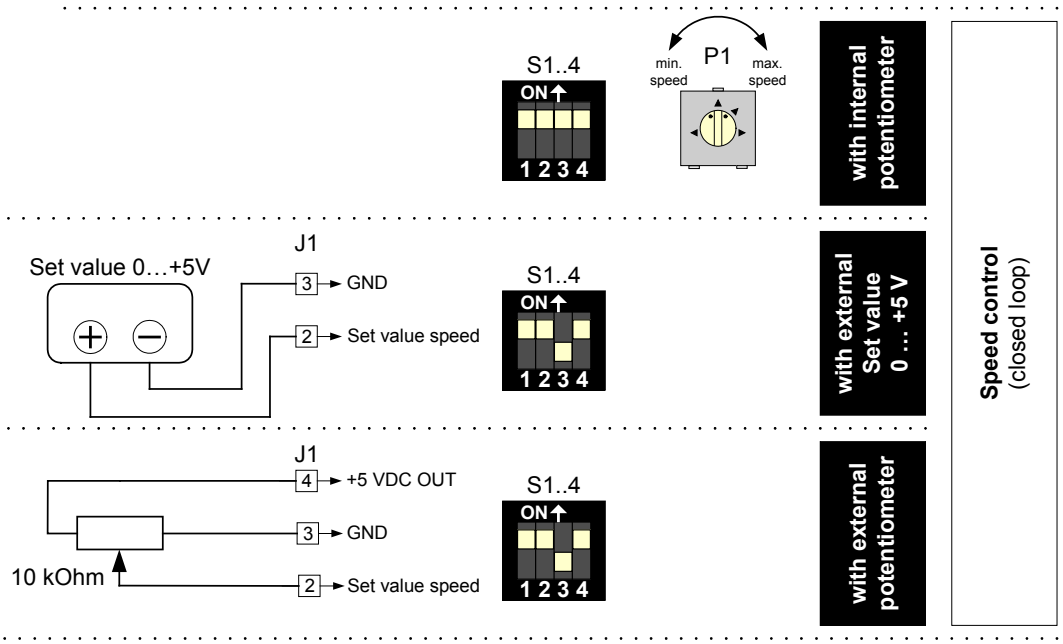
9	$+V_{CC}$ 5...24 VDC
8	Power GND
7	Enable
6	Direction
5	Brake
4	+5 VDC OUT
3	GND
2	Set value speed
1	Monitor n

Pin assignment J3:

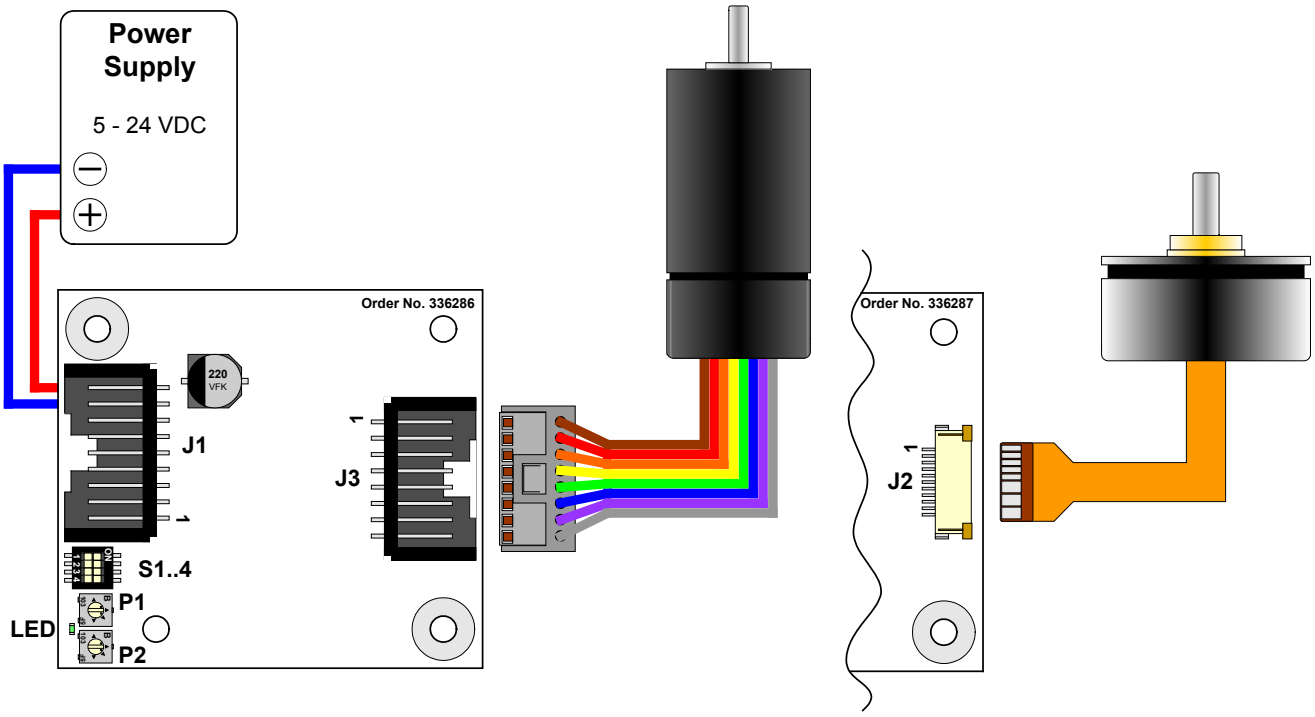
1	Motor winding 1
2	Motor winding 2
3	Motor winding 3
4	V_{CC}Hall
5	GND
6	Hall sensor 1
7	Hall sensor 2
8	Hall sensor 3

Pin assignment J2:

1	V_{CC}Hall
2	Hall sensor 3
3	Hall sensor 1
4	Hall sensor 2
5	GND
6 + 7	Motor winding 3
8 + 9	Motor winding 2
10 + 11	Motor winding 1



3.1.2. Open loop speed control



Pin assignment J1:

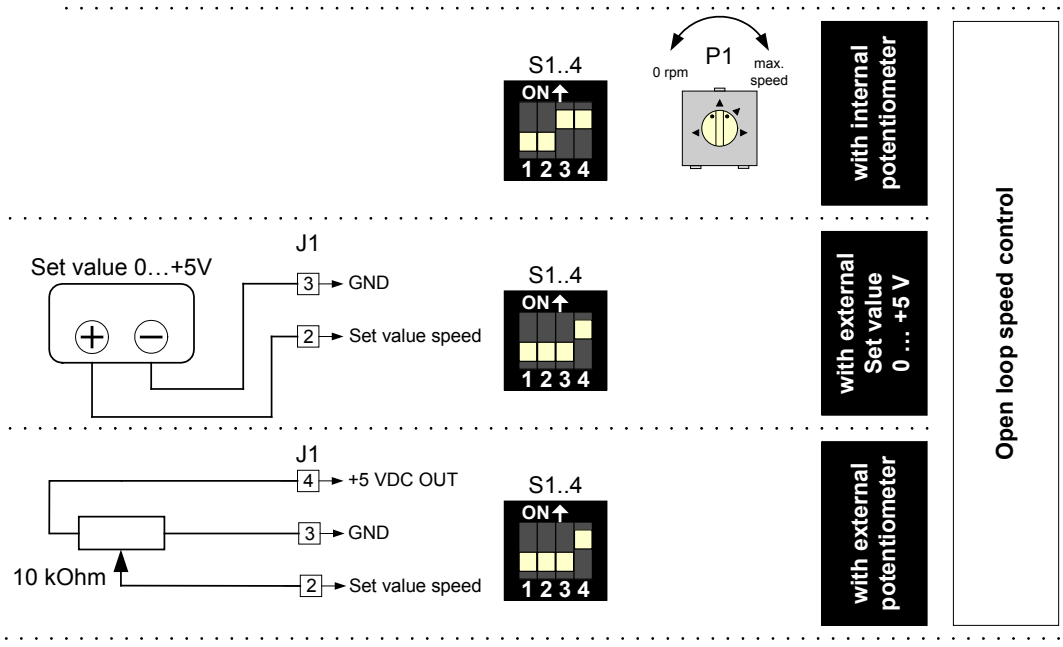
9	+V_{CC} 5...24 VDC
8	Power GND
7	Enable
6	Direction
5	Brake
4	+5 VDC OUT
3	GND
2	Set value speed
1	Monitor n

Pin assignment J3:

1	Motor winding 1
2	Motor winding 2
3	Motor winding 3
4	V_{CC}Hall
5	GND
6	Hall sensor 1
7	Hall sensor 2
8	Hall sensor 3

Pin assignment J2:

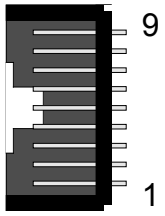
1	V_{CC}Hall
2	Hall sensor 3
3	Hall sensor 1
4	Hall sensor 2
5	GND
6 + 7	Motor winding 3
8 + 9	Motor winding 2
10 + 11	Motor winding 1



3.2. Pin assignment

3.2.1. Power and signal

Connector J1

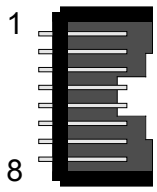


Angular pin header 9-poles

Pin-No.	Signal	Description
1	Monitor n	Speed monitor
2	Set value speed	Set value speed
3	GND	Digital ground
4	+5 VDC OUT	Auxiliary voltage output 5 VDC / 10 mA
5	Brake	Brake input
6	Direction	Direction input
7	Enable	Enable input
8	Power GND	Ground for power supply
9	$+V_{CC}$	Supply voltage 5...24 VDC

3.2.2. Connector for maxon EC motors (Order number 336286)

Connector J3

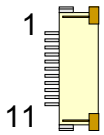


Angular pin header 8-poles

Pin-No.	Signal	Description
1	Motor winding 1	Motor winding 1
2	Motor winding 2	Motor winding 2
3	Motor winding 3	Motor winding 3
4	V_{CC}Hall	Hall sensor voltage 4.5...5 VDC / 30 mA
5	GND	Digital ground
6	Hall sensor 1	Hall sensor 1
7	Hall sensor 2	Hall sensor 2
8	Hall sensor 3	Hall sensor 3

3.2.3. Connector for maxon flat motors with flex print (Order number 336287)

Connector J2



FPC-FFC flex print connector
11-poles

Pin-No.	Signal	Description
1	V_{CC}Hall	Hall sensor voltage 4.5...5 VDC / 30 mA
2	Hall sensor 3	Hall sensor 3
3	Hall sensor 1	Hall sensor 1
4	Hall sensor 2	Hall sensor 2
5	GND	Digital ground
6	Motor winding 3	Hall sensor 2
7		
8	Motor winding 2	Motor winding 2
9		
10	Motor winding 1	Motor winding 1
11		

4. Operating Instructions

4.1. Power supply layout

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

Power supply requirements	
Output voltage	5 VDC < V_{CC} < 24 VDC
Output current	depending on load, continuous max. 3 A acceleration, short-time max. 6 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 the 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 power stage.

What speed do I reach with my power supply:

$$n_B = \left[(V_{CC} - 1.5\,V) \cdot \frac{n_0}{U_N} \right] - \left[\frac{\Delta n}{\Delta M} \cdot M_B \right]$$

Note:

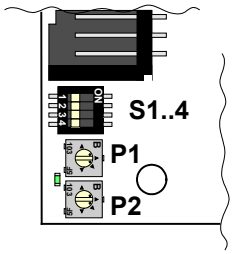
- ⇨ The undervoltage protection switch the DEC 24/3 off, as soon as the supply voltage V_{CC} goes below 4.5 V. Therefore, at low supply voltage V_{CC} you have to pay attention to the voltage drop over the supplying cables.

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_{cont}	50%



Note

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

4.2.2. Adjustment

Digital speed control

1. Selected the desired motor speed range with DIP switch **S1** and **S2**.

	Motor type		
DIP switches S1 and S2	**1 pole pair**	**4 pole pairs**	**8 pole pairs**
	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

2. Depending on set value mode selected, apply set value at the «Set value speed» input or with potentiometer **P1** so that required speed is reached.
Note:
At 0 V set value, the speed is **NOT** 0 rpm. It depends on the pole pair number of the connected motor (see table under point 1).

3. Adjust potentiometer **P2 I_{cont}** to required limiting value.
With potentiometer **P2**, the motor nominal current (max. continuous current) can be adjusted in a range of 0.1…3 A.
Note:
The limiting value I_{cont} should be below the max. continuous current as shown on the motor data sheet (corresponds to line 6 in maxon catalogue).

Digital open loop speed control

1. Set DIP switch **S1** and **S2** to “OFF” position.

DIP switches S1 and S2	
	Operation as open loop speed control 0...100 % is equivalent to motor voltage range of 0...V_{CC}

2. Depending on set value mode selected, apply set value at the «Set value speed» input or with potentiometer **P1** so that required speed is reached.
Note:
At 0 V set value, the speed is 0 rpm.

3. Adjust potentiometer **P2 I_{cont}** to required limiting value.
With potentiometer **P2**, the motor nominal current (max. continuous current) can be adjusted in a range of 0.1…3 A.
Note:
The limiting value I_{cont} should be below the max. continuous current as shown on the motor data sheet (corresponds to line 6 in maxon catalogue).

5. Inputs and Outputs

5.1. Inputs

5.1.1. Set value «Set value speed»

The analogue set value is predetermined at the «Set value speed» input.
The «Set value 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 «Set value speed» input, DIP switch S3 have to be switched OFF.

5.1.2. «Enable»

Enables or disables the power stage.

If a voltage higher than 2.4 V is applied to the «Enable» input, the amplifier is activated (Enable).

Input voltage > 2.4 V	Motor running (Enable)

If a voltage lower than 0.8 V or ground potential is applied to the «Enable» input, the power stage is high impedant and the motor shaft freewheels and slows down (Disable).

Set input to Gnd or input voltage < 0.8 V	Power stage switched off (Disable)

The «Enable» input is protected against overvoltage.

Input voltage range	0...+5 V
Input impedance	47 kΩ pull-down resistor to Gnd
Continuous overvoltage protection	-24...+24 V
Delay time	max. 30 ms

Note

⇨ If the settings of DIP switch **S1**, **S2** or **S3** was changed, the new settings are adopted through a disable-enable procedure.

⇨ If the «Enable» input is not connected, the DIP switch **S4** is deciding on enabling (**S4** = ON) or disabling (**S4** = OFF) of the power stage (see chapter 6.3.).

5.1.3. «Direction»

When the level changes, the motor shaft slows down in an uncontrolled fashion to a standstill by short-circuiting the motor windings, (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	47 kΩ pull-down resistor to Gnd
Continuous overvoltage protection	-24...+24 V
Delay time	max. 30 ms

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

The motor shaft slows down in an uncontrolled fashion to a standstill by short-circuiting the motor windings.

If a voltage lower than 0.8 V or ground potential is applied to the «Enable» input, the «Brake» function is inactive.

Brake function not active (motor windings not short-circuited)	Input open, set to Gnd or input voltage < 0.8 V

If a voltage higher than 2.4 V is applied to the «Brake» input, the function is active.

Brake function active (motor windings short-circuited)	Input voltage > 2.4 V

The «Brake» input is protected against overvoltage.

Input voltage range	0...+5 V
Input impedance	47 kΩ pull-down resistor to Gnd
Continuous overvoltage protection	-24...+24 V
Max. brake current	22 A
Delay time	max. 30 ms

Note:

⇨ The motor windings remained short-circuited until the brake function is deactivated again.

⇨ The brake function will be executed even if the power stage is disabled.

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

⇨ I <= 18 A (max. allowed brake current)

⇨ W_k = 20 Ws (max. allowed kinetic energy)

The values can be calculated as follows:

max. permitted brake speed limited by brake current (I = 18 A)

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

$$n_{max} = 18A \cdot k_n \cdot (R_{Ph-Ph} + 0.08\Omega) \qquad [rpm]$$

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 [gcm²]
J_L = load inertia [gcm²]

5.1.5. «Hall sensor 1», «Hall sensor 2», «Hall sensor 3»

Hall sensors are needed for detecting rotor position and actual speed.

«Hall sensor» inputs are protected against overvoltage.

Input voltage range	0...+5 V
Input impedance	10 kΩ pull-up resistor to +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. Hall sensor voltage «V_{cc}Hall»

An internal voltage of +5 VDC is provided for powering the Hall sensors.

Output voltage	5 VDC	± 5%	($V_{CC} \geq$ 5.5 VDC)
		-10%+5%	(V_{CC} < 5.5 VDC)
Max. output current	30 mA (short-circuit protected)		

Note
When using long thin lines, the voltage drop can become so large, that the supply voltage for the Hall sensors fall below the minimal value.
The maximum cable length for the Hall sensors supply voltage between motor and controller is approx. 10 m. The minimum cross-section is AWG 26.

5.2.2. Auxiliary voltage «+5 VDC OUT»

An internal auxiliary voltage of +5 VDC is provided.
Used as reference voltage:

⇨ For external set value potentiometers (recommended value: 10 kΩ)

⇨ Gating the signals: «Enable», «Direction» and «Brake»

Output voltage	5 VDC	± 5%	($V_{CC} \geq 5.5$ VDC)
		-10%+5%	($V_{CC} < 5.5$ VDC)
Max. output current	10 mA (short-circuit protected)		

5.2.3. «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 of 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

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

n = Speed [rpm]
z_{Pol} = Number of pole pairs

Sought values: Motor shaft speed

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

$f_{Monitor\ n}$ = 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.

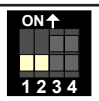
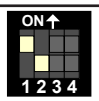
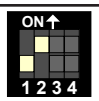
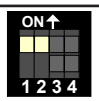
⇨ The «Monitor n» output also functions in disable mode.

6. Functional Description of DIP Switches

Operating modes are adjusted using four DIP switches:

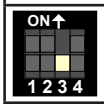
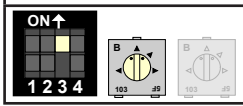
6.1. Setting mode / speed range

S1 and **S2** are used to predetermine the operating mode (speed control or open loop speed control) as well as the speed range in speed control mode).

	Motor type		
DIP switches S1 and S2	**1 pole pair**	**4 pole pairs**	**8 pole pairs**
	Operation as open loop speed control 0...100 % is equivalent to motor voltage range of 0...V_{CC}		
	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

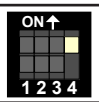
S3 is used to select the type of set value input (external set value input or with internal potentiometer **P1**).

DIP switch S3	**Set value input**
	With external set value 0...+5 V
	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.)

6.3. Setting Enable

At open «Enable» input, the DIP switch **S4** is deciding on enabling of the power stage.
If the «Enable» input is wired, the functional description in chapter 5.1.2. «Enable» is valid, independent of DIP switch **S4**.

DIP switch S4	**Power stage condition (in case of open «Enable» input)**
	Power stage switched off (preadjustment)
	Power stage activated

7. Potentiometers

7.1. Potentiometer P1 «Speed»

If DIP switch **S3** is switched on, the set speed value is adjusted at potentiometer **P1** «Speed».

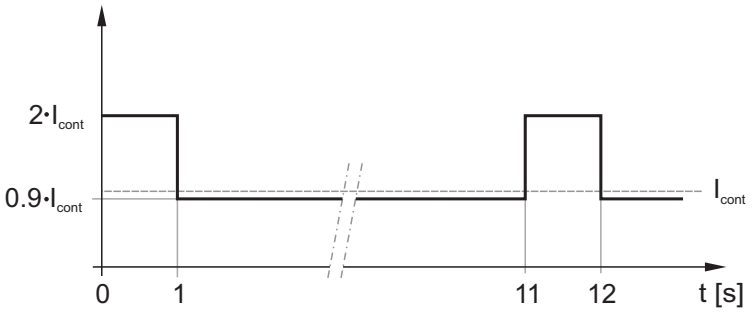
Note	
Left end stop of potentiometers:	Minimal value (see chapter 6.1.)
Right end stop of potentiometers:	Maximum value (see chapter 6.1.)

7.2. Potentiometer P2 «I_{cont}»

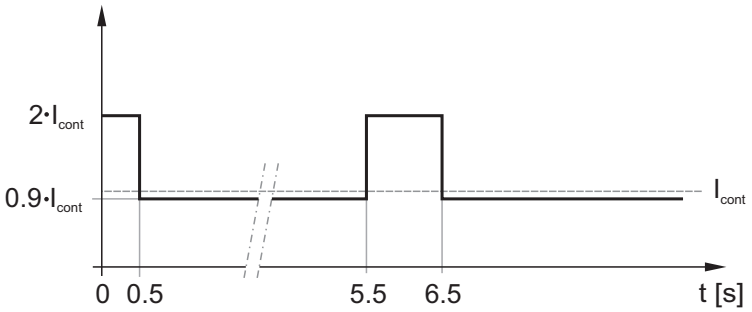
Adjusting the max. continuous current in the 0.1…3 A range.

The current adjusted on the potentiometer is available for an unlimited period. For a short period of time the amplifier is able to provide $I_{max} = 2 \cdot I_{cont}$. The duration is dependent on the load before the increased current draw and the value of the current draw.
After that time, it is limited to the max. continuous current I_{cont}.

Example 1
If the current is at less than 90 % of the max. continuous current for more than 10 s, I_{max} is permitted for another second.
If the motor is operated long term with the max. continuous current I_{cont}, no higher current is 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 show the operating status and the error condition.

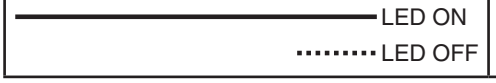
Definition


8.1. No green LED

Reason:

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

8.2. Green LED constantly on

Blink pattern (green LED)	Operating status
	Amplifier enabled

8.3. Green LED flashes every second

Blink pattern (green LED)	Operating status
	Amplifier disabled

8.4. Green LED flickers or flashes intermittently

Reason:

- 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:

Blink pattern (green LED)	Operating status
	• Motor shaft is blocked • Load too great • I_{cont} setting too low • Missing 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 shaft does not turn when in “Enable” mode, the “motor shaft is blocked” error message will always appear.

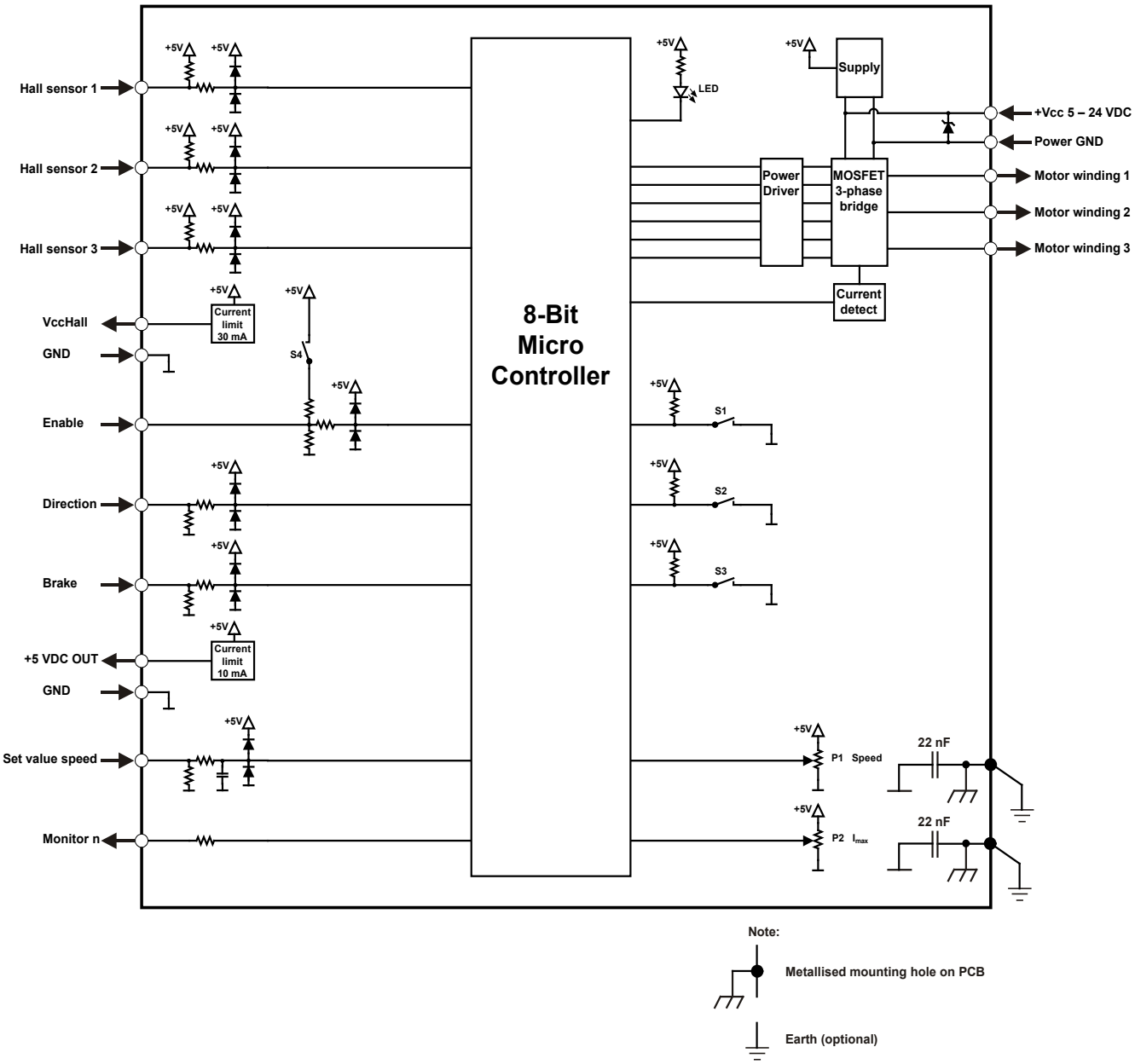
⇨ Errors are not stored. The amplifier will be ready as soon as the error is removed (no confirmation through Disable/Enable necessary).

9. Protection

9.1. Blockage protection

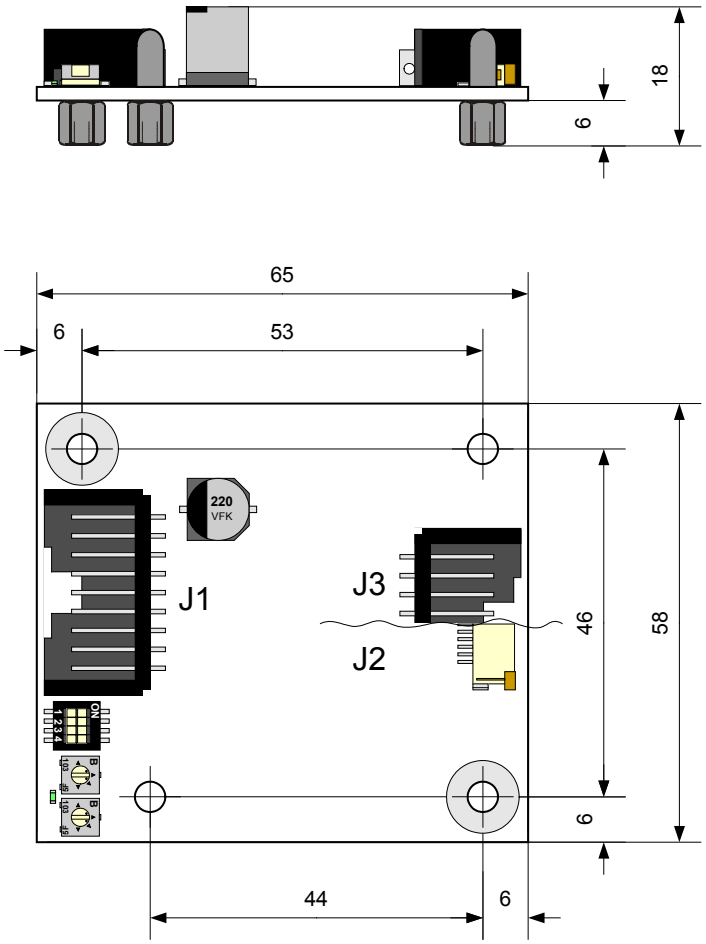
If the motor shaft is blocked for longer than 1.5 s, the current limit is set at 2 A, provided the current limit was not set lower via I_{cont} potentiometer.

10. Block Diagram



11. Dimension Drawing

Dimensions in [mm]



12. Spare Parts List

maxon motor order number	Designation
341661	9 pole single row plug pitch 2.5 mm (suitable to J1)
203209	8 pole single row plug pitch 2.5 mm (suitable to J3)