

Operating Instructions

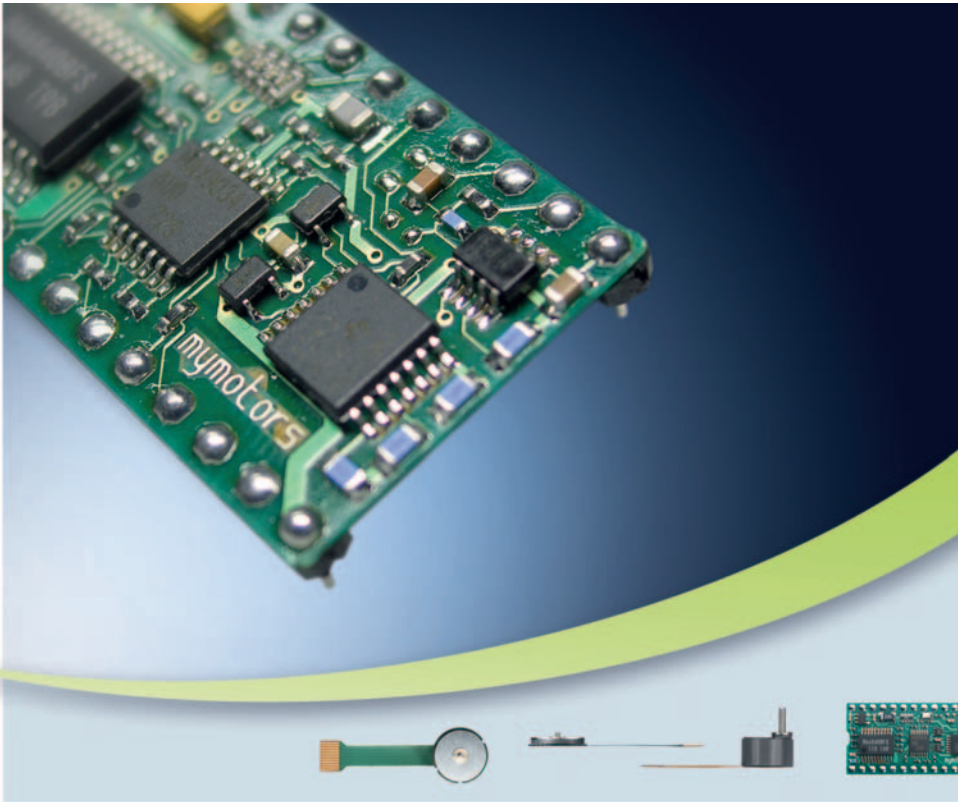


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1 Description

1.1 General

The BLD 1501 H is an electronic control for penny motors with analog Hall sensors for operation as a brushless DC motor.

The following main functions are available:

- Either a speed-controlled or a torque-controlled mode can be used.
- Speed controller with either 2 or 4 quadrants (Chap. 4 **Speed-controlled mode**).
- The output signals of the Hall elements are emitted in digital form for position detection. The resolution is 24 edges per revolution (Chap. 7 **Encoder outputs**).
- The power consumption can be reduced to around 1 μA in quiescent state (Chap. 3.3 **Power supply – quiescent state**).
- The circuit is designed as an easily integrated, plug-in hybrid module.

1.2 Speed-controlled mode

In speed-controlled mode, the actual speed of the motor is determined with the help of the signals from the Hall elements and regulated to the set value with an integrated controller. Depending on the configuration, the controller has active braking in addition to the acceleration function. This function is used when the actual speed exceeds the set speed. The torque and thus also the power consumption are constantly optimally adapted to the load.

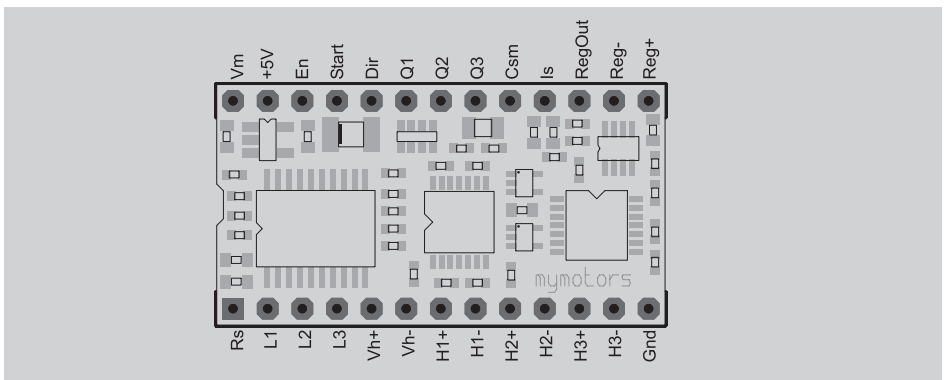
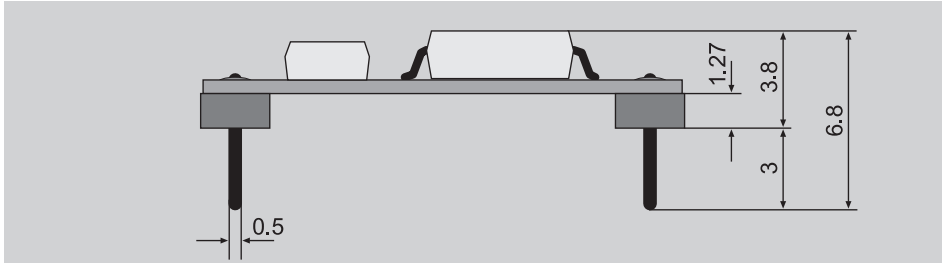
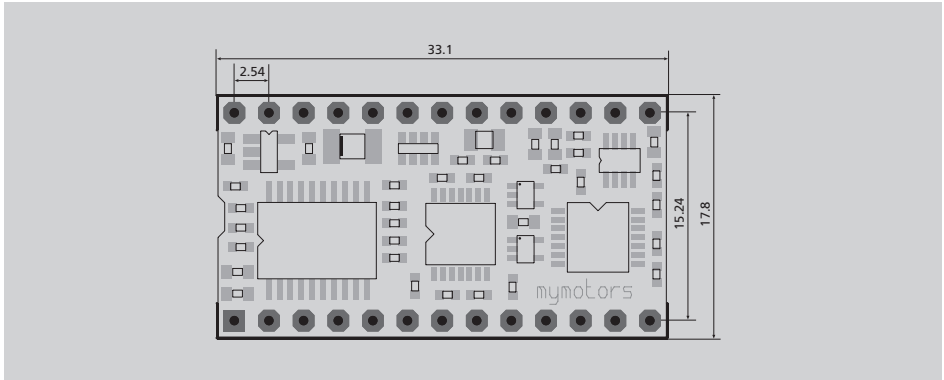
The controller characteristics can be adjusted through an external passive network.

1.3 Torque-controlled mode

In torque-controlled mode, the motor is operated with impressed phase currents of constant amplitudes. The generated torque is proportional to the motor current and therefore largely independent of speed and load.

During operation, the motor accelerates until the speed-dependent counter-torque, formed by bearing friction and load, is equal to the driving torque. The self-adapting speed is therefore heavily load-dependent.

2 Dimensions and pin assignment



2 Dimensions and pin assignment

Pin	Description
Rs	Connection of an optional resistance to increase the maximum permissible motor current
L1, L2, L3	Motor connection: connections for the three phases of the penny-motor
Vh+, Vh-	Motor connection: supply voltage outputs for the Hall elements
H1+, H1-, H2+, H2-, H3+, H3-	Motor connection: analog Hall voltage inputs
GND	Ground
Reg+	Speed controller: positive input; internally configured with the measured actual speed n_{act}
Reg-	Speed controller: negative input n_{nom}
RegOut	Speed controller: output
Is	Set-point input for motor current and torque
Csm	Connection of an optional capacitor for limitation of the maximum settable speed in speedcontrolled mode
Q1, Q2, Q3	Digital encoder outputs with 24 increments per revolution; 4 pulses per revolution at each output, both edges analysable, signal phases displaced by 120° (Chap. 7 Encoder outputs)
Dir	Digital input for inverting the direction of rotation and switching between 2 or 4 quadrants (Chap. 4 Speed-controlled operation)
Start	Digital input for switching on the motor currents (Hall elements are not switched); should be connected with +5 V for continuous operation
En	Digital input for activating the entire circuit (end of quiescent state); should be connected with Vm for continuous operation
+5V	Stabilised voltage output 5 V/5 mA max.; is switched off in quiescent state
Vm	Supply voltage: +5 V to +15 V

3 Power supply

3.1 Operating voltage

- Operating voltage range: 4.5 V to 15 V stabilised, no polarity reversal protection
- Power consumption with motor switched off and active Hall elements: around 20 mA
- Power consumption in quiescent state: around 1 μ A
- Maximum permissible output current: 1 A

3.2 Motor current

3.2.1 Speed-controlled

The controller endeavours to operate the motor at a constant speed, irrespective of the load. The motor current and thus the entire current consumption are heavily load-dependent in this operating mode.

The maximum motor current is limited to around 150 mA, to protect against overloading. This value can be increased by means of an optional resistance at pin "Rs" for increased dynamics (Chap. 4.4 *Increasing the maximum torque*).

3.2.2 Torque-controlled

The motor current can be set to a constant value via a control voltage. As the motor current is impressed, the motor develops a torque that is largely independent of the speed.

Depending on the motor and the operating voltage, the torque can drop out at high speeds.

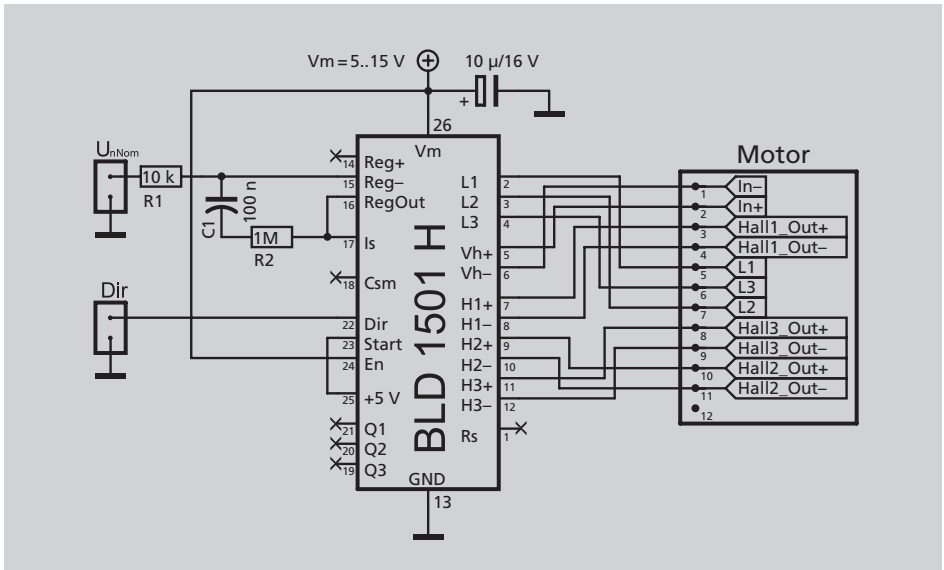
The maximum settable motor current is around 150 mA. This value can be increased by means of an optional resistance at pin "Rs" (Chap. 4.4 *Increasing the maximum torque*).

3.3 Quiescent state

A low level at input "En" sets the circuit to around 1 μ A in quiescent state, to reduce the power consumption. The stabilised 5 V output is switched off in quiescent state, and the outputs of the Hall sensors do not provide any signals.

Note: It is not possible to connect the "En" input to the "+5V" output for continuous operation, as this output is switched off in quiescent state. Pin "En" should be connected to pin "Vm" for continuous operation.

4 Speed-controlled mode



In order to use the speed controller, the controller output “RegOut” must be connected to the torque input “Is”.

The optimal controller characteristics for the application are defined by just a few external components, whose values are determined by the customer and which he then connects. Once the values are established, the relevant mymotors components can be optionally integrated into the controller.

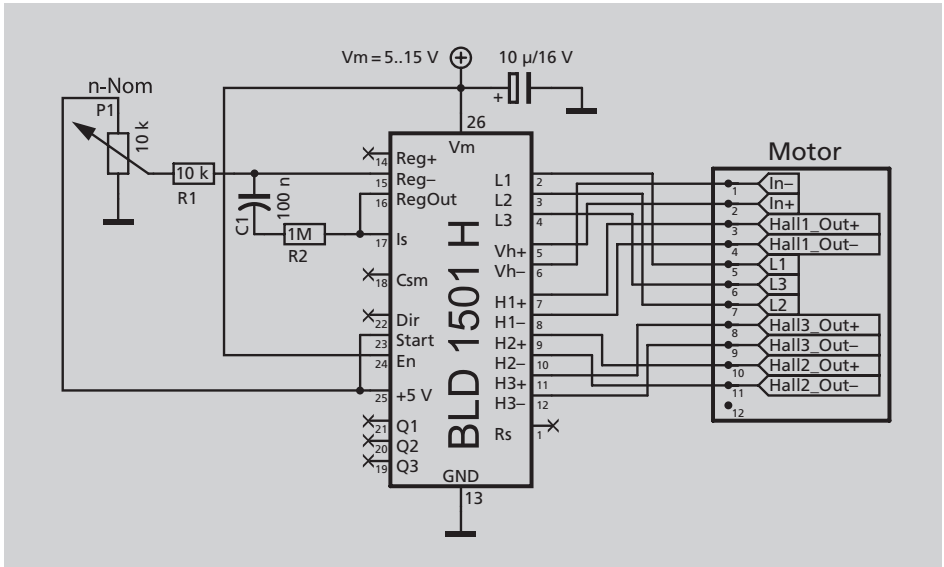
The digital input “Dir” has a dual function: it can be used to reverse the direction of rotation or to switch the controller from four quadrants to two quadrants.

Dir	Mode	U_{nNom}	Direction
High	2 quadrant	< 2.5 V	Clockwise
High	2 quadrant	> 2.5 V	Zero
Low	4 quadrant	< 2.5 V	Counterclockwise
Low	4 quadrant	> 2.5 V	Clockwise

- If the direction of rotation for a fixed speed is to be digitally switched with the “Dir” signal, a control voltage $U_{nNom} < 2.5$ V must be applied. The permissible voltage range of U_{nNom} extends from 0 V to 5 V; the speed is zero at 2.5 V.
- For a bi-directional analog speed presetting via an analog control voltage U_{nNom} , “Dir” must be set to digital low level.

4 Speed-controlled mode

4.1 PI speed controller for high speeds

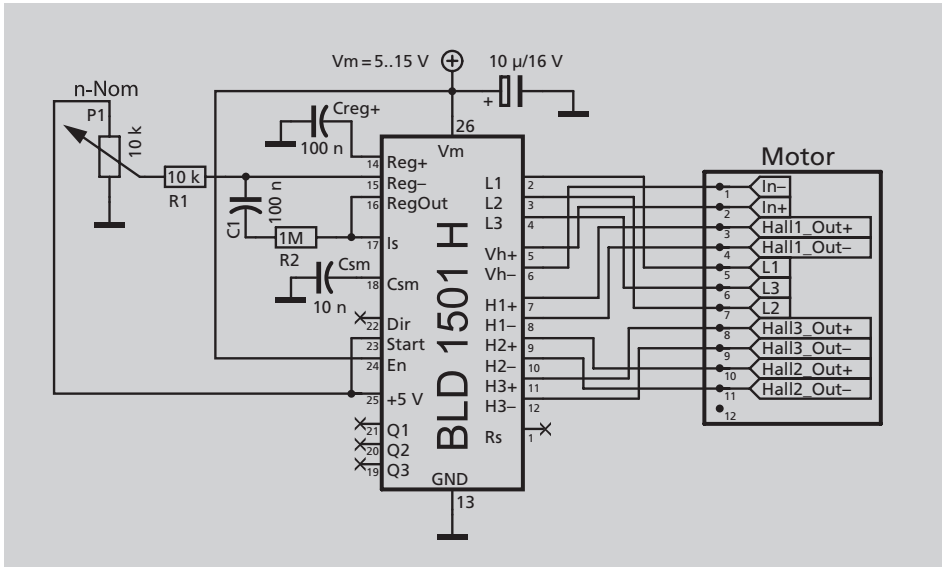


The PI speed controller implemented in this circuit is optimised for no-load operation of the penny-motor with a bi-directional speed range of between around 300 min^{-1} and $60,000 \text{ min}^{-1}$. A circuit with this type of configuration is provided by "Adapter board BLD 1501 H" and is included with the starter kit.

- Potentiometer P1 presets the nominal speed bi-directionally.
- The passive components R1, R2 and C1 influence the controller characteristics.
 - The ratio of R2 to R1 determines the amplification of the proportional component.
 - C1 determines the integral component.

4 Speed-controlled mode

4.2 PI speed controller for low speeds



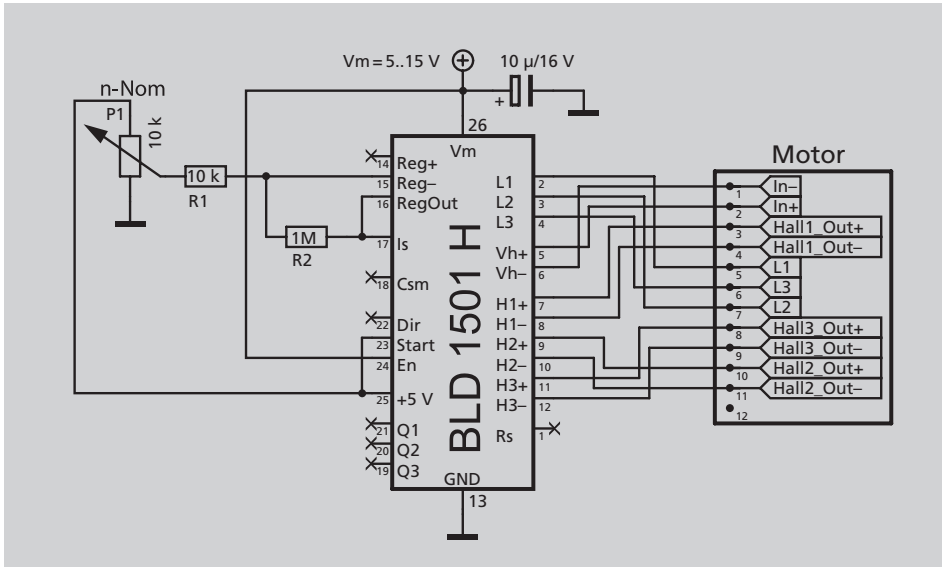
For low-speed applications, the speed range of the controller can be scaled using a C_{sm} capacitor. This increases the amplification in the speed measurement, allowing a lower speed to be adjusted with the same input voltage. Consequently, the controller operates with increased precision.

C_{sm}	n_{max}
/	$\pm 60,000 \text{ min}^{-1}$
1 nF	$\pm 30,000 \text{ min}^{-1}$
2.2 nF	$\pm 20,000 \text{ min}^{-1}$
4.7 nF	$\pm 12,000 \text{ min}^{-1}$
10 nF	$\pm 5,800 \text{ min}^{-1}$

The optional capacitor C_{reg+} smoothes the signal of the measured actual speed, so as to reduce torque fluctuations within a motor revolution. The permissible value range of C_{reg+} depends on the load and cannot be universally determined. A higher rotational inertia of the load reduces the dynamics of the drive, allowing increased smoothing.

4 Speed-controlled mode

4.3 P speed controller

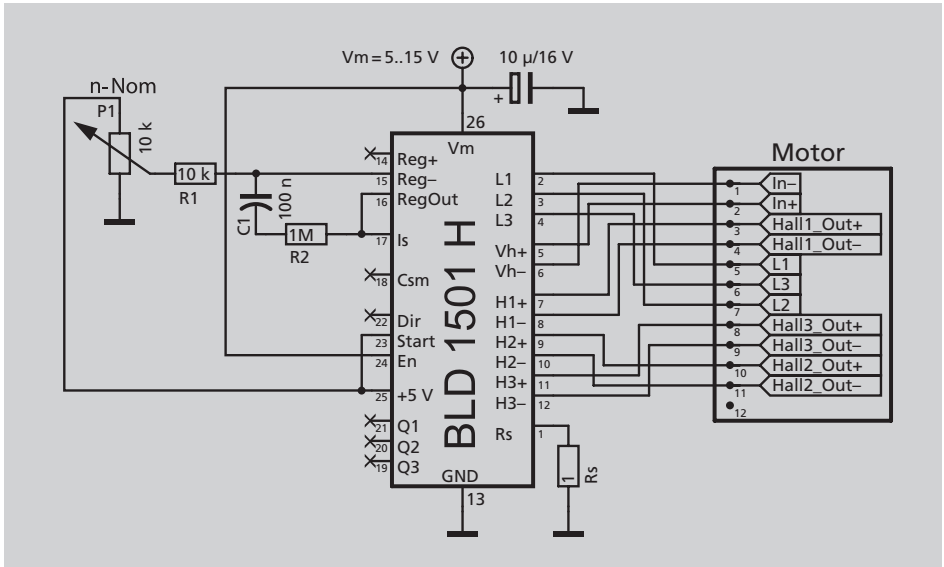


An integrating component in the controller can have a disruptive effect, particularly at very low speeds. It is not practically possible to set zero speed with an analog PI controller.

A P controller without an integrating component is achieved through a capacitance-free negative feedback in the controller. The occurring load-dependent deviation is determined through the amplification defined with R1 and R2.

4 Speed-controlled mode

4.4 Increasing the maximum torque



If a higher torque is required for increased dynamics, the maximum motor current can be increased through a resistance R_s . The motor is then supplied with higher currents during the acceleration phases and reaches the set speed more quickly.

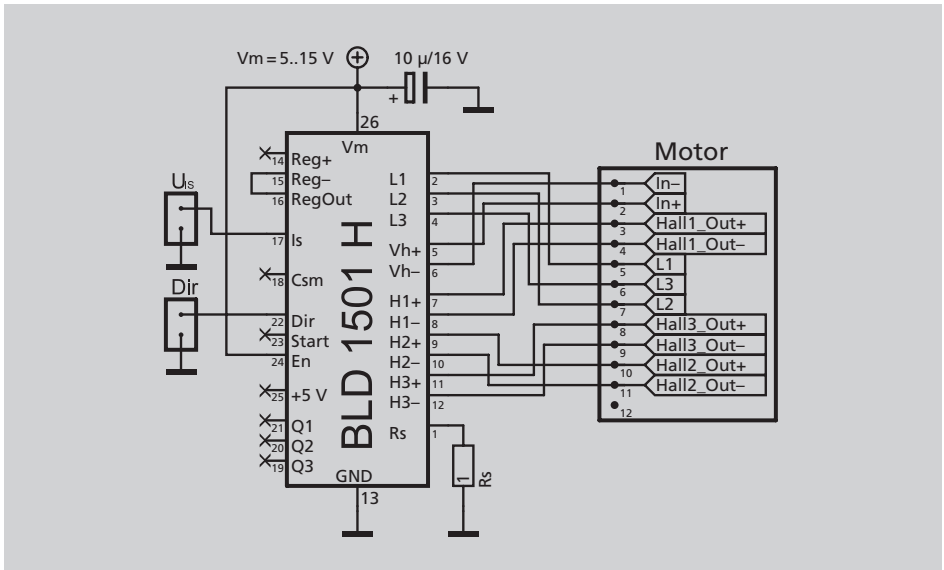
The power consumption is not influenced when the controller is in steady state. However, it must be ensured that the load-dependent continuous current does not exceed the nominal motor current, in order to prevent overheating of the motor.

Notes: Increasing the current amplification factor influences the design of the controller, as this means a proportional amplification in the control loop.

The maximum permissible current values of the motor as specified in the motor data sheet must not be exceeded.

R_s	I_{max}
/	150 mA
2.2 Ω	250 mA
1.5 Ω	300 mA
1 Ω	375 mA

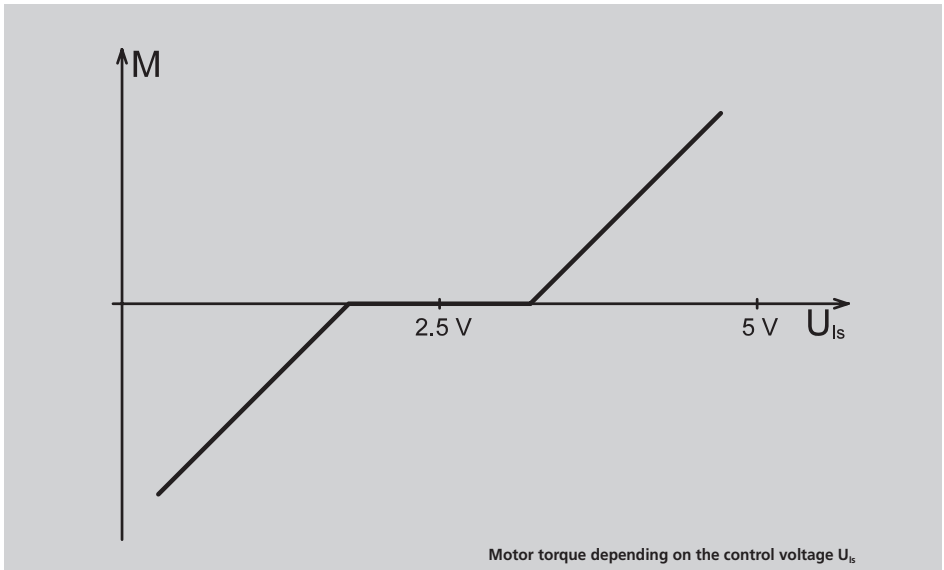
5 Torque-controlled mode



In torque-controlled mode, the speed controller is deactivated by connecting "RegOut" to "Reg". The signal for the sign-dependent nominal torque is applied at "Is". The input voltage range of U_{Is} extends from 0 V to 5 V,

with zero torque at an input voltage of 2.5 V. In order to safely guarantee the zero "torque adjustability", a dead band must be provided in this range.

5 Torque-controlled mode



The digital input “Dir” has a dual function: it can be used to reverse the direction of rotation or to switch the controller from four quadrants to two quadrants.

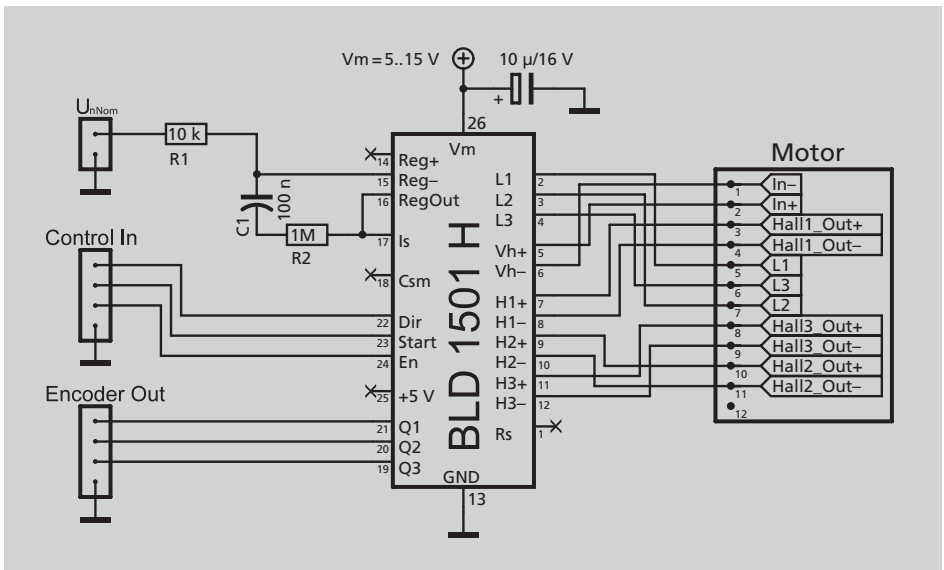
Dir	Mode	U_{Is}	Direction
High	2 quadrant	< 2.5 V	Zero
High	2 quadrant	> 2.5 V	Clockwise
Low	4 quadrant	< 2.5 V	Clockwise
Low	4 quadrant	> 2.5 V	Counterclockwise

The maximum motor current I_{max} and thus the maximum torque M_{max} can be increased through the optional resistance R_s .

R_s	I_{max}
/	150 mA
2.2 Ω	250 mA
1.5 Ω	300 mA
1 Ω	375 mA

6 Control using a microcontroller

The nominal value can be preset through an analog control voltage instead of a potentiometer in all operating modes, for example from an analog or filtered PWM output of a microcontroller.

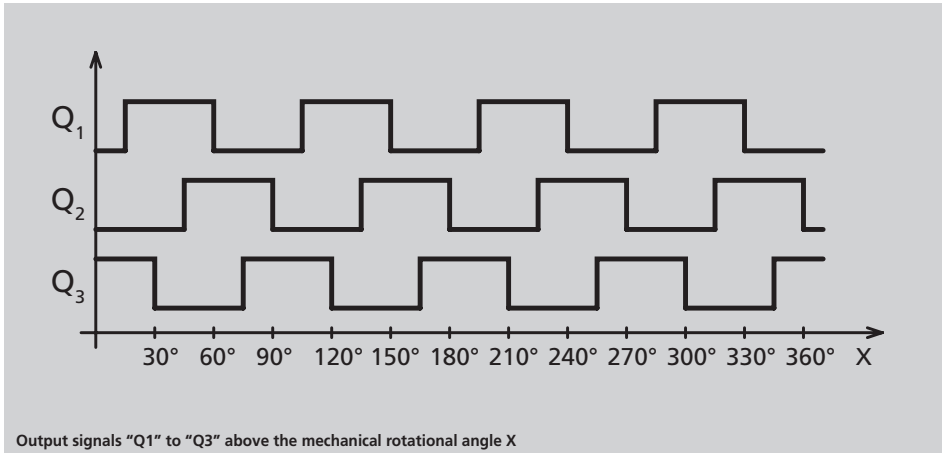


The digital encoder outputs “Q1” to “Q3” can be used to detect the position of the rotor. They provide three digital signals phase-displaced by 120° with a period length of a quarter of a revolution. The useful resolution is 24 edges per revolution.

A digital low level at the “start” pin switches the motor currents off; all other functions are maintained.

A digital low level at “En” sets the circuit to quiescent state. The outputs “Q1” to “Q3” and the stabilised 5 V voltage are also deactivated.

7 Encoder outputs



The digitized states of the analog Hall sensors integrated into the penny-motor are output at outputs "Q1" to "Q3". Each of the three signals (electrically) displaced by 120° passes through four periods per motor revolution, so that a

maximum resolution of 24 edges per revolution (15° mechanical) can be evaluated. The outputs are CMOS outputs with 5 V signal level and 1 kΩ output resistance.

8 Equivalent circuit diagrams of switching connections

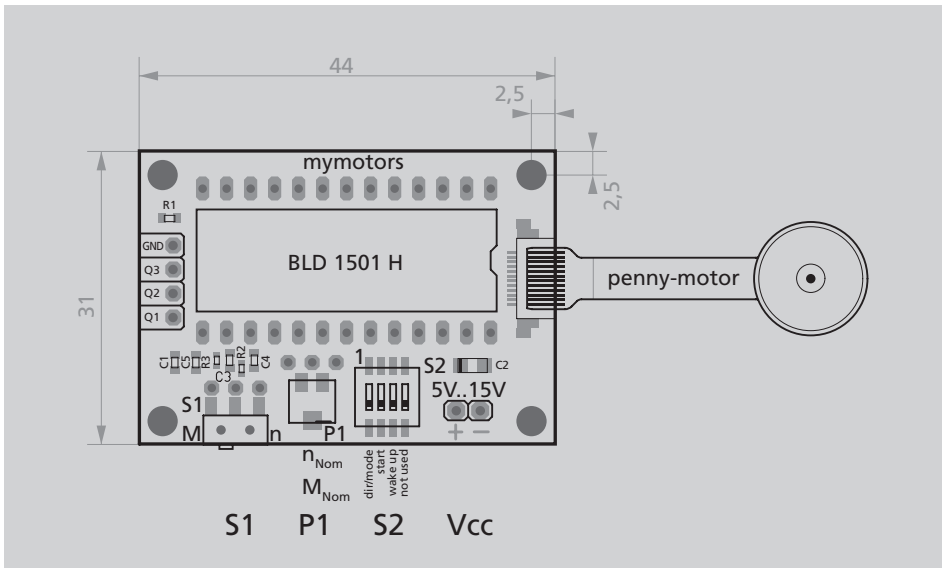
Pin	Equivalent circuit	Voltage range
Rs, L1, L2, L3		Output voltage Lx: 0 V..Vm
Vh+, Vh-		Voltage range: 0 V..5 V
H1+, H1- H2+, H2- H3+, H3-		Common-mode range: 1.5 V..4 V
Reg+, Reg- RegOut		Input current Reg-: $\pm 2 \mu\text{A}$ Output voltage Reg+: 0 V..5 V Output voltage RegOut: 0 V..5 V

8 Equivalent circuit diagrams of switching connections

Pin	Equivalent circuit	Voltage range
Is		Voltage range: 0 V..5 V
Csm		Voltage range: 0 V..5 V
Q1, Q2, Q3		Output voltage: 0 V..5 V
Dir		High: 3.5 V..5 V Low: 0 V..0.8 V
Start		High: 3.5 V..5 V Low: 0 V..0.8 V
En		High: 2 V..Vm Low: 0 V..0.8 V

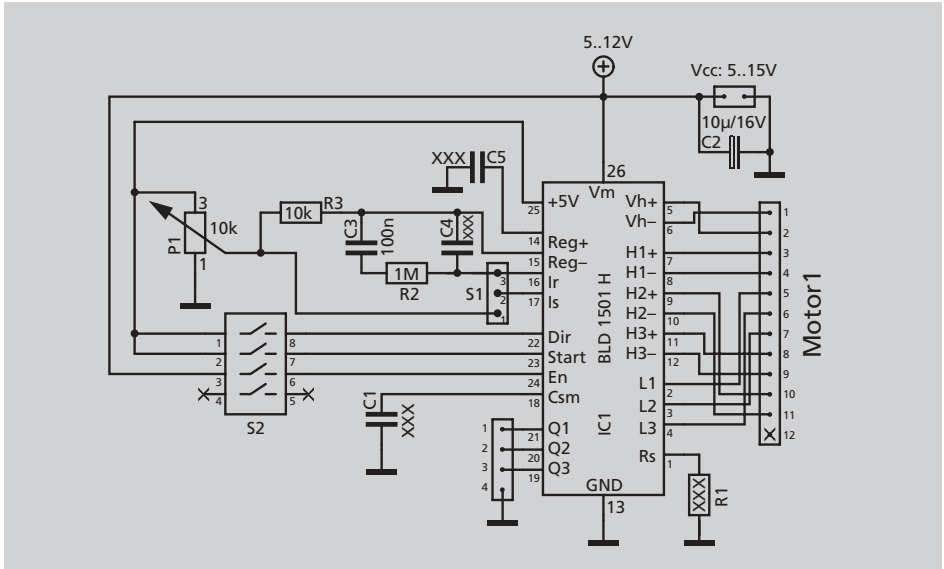
9 BLD 1501 H adapter board

The “BLD 1501 H” adapter board enables simple operation of a standard penny-motor in combination with a BLD 1501 H. The BLD 1501 H is plugged into the socket provided on the adapter board with the notch in the direction of the motor connector.



- The slide switch S1 allows you to switch between speed-controlled (right switch position) and torque-controlled (left switch position) mode.
 - The nominal value is preset bi-directionally with the multiple potentiometer P1 (lateral adjusting screw). The middle position corresponds to the nominal value zero.
 - The controller can be switched from four to two quadrants and the direction of rotation inverted with DIP switch S2.1.
 - The motor current can be switched on with DIP switch S2.2.
 - The circuit can be activated from quiescent state with DIP switch S2.3.
 - The encoder outputs Q1...Q3 can be accessed via soldering eyelets.
- Note:** For normal operation, DIP switch S2.1 should be switched off (switched in the direction of the board edge), and S2.2 and S2.3 switched on (switched in the direction of the BLD 1501 H). S2.4 has no function.

9 BLD 1501 H adapter board



All components necessary for the controller configuration are soldered onto the adapter board. As standard, the speed controller is designed as PI controller for load-free operation of the penny-motor from 300 min^{-1} to 60,000 min^{-1} , and the maximum motor current is limited to around 150 mA.

Components with the value "xxx" are unpopulated.

A more detailed description of the controller circuit can be found in Chapters 4 and 5.

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