

Designing a motherboard for a MC3001 Motion Controller

Summary

FAULHABER provides motherboards for the plug-in Motion Controllers MC3001.

There is variety of motherboards with different connectors fitting the FAULHABER motor portfolio. Such a motherboard from the shelf, is all needed to get started with a MC3001.

For the final application you might want to design your own motherboard to exactly fit your construction space. This application note provides the guidelines for the motherboard design, including the hardware filters relevant for achieving EMC conformance.

- The footprints of the two MC3001 versions are explained on page 2 and 3.
The P version using conventional pin-headers allowing for a compact design and the B version using flat board to board connectors fitting in the most limited construction spaces.
- It is recommended to use at least a 4-layer PCB, with detailed layer descriptions on page 4.
- Explanations on EGROUND and shielding highlight their importance for EMC conformance and signal integrity and show how to realize them, see page 4.
- An EMC motor phase filter recommended to pass EMC conformance tests is described on page 6.
- DC-Motors with precious metal commutation require an additional filter, see page 8.
- Depending on the power supply, an optional EMC supply filter might have to be considered. (page 9)
- For network operation with MC3001 via the RS232 interface, an additional circuit is required, which is described on page 13.
- And finally, the part names of useful PCB connectors are provided.

For further information on the MC3001 pin description refer to the technical manual, for functionality description refer to the [drive functions manual](#).

For further guidelines on shielding, cable length and functional earth see [application note 187](#).

Applies To

Motion Controllers MC3001P and MC3001B

Description

The Footprint

The **MC3001 P** version uses pin-headers allowing for a compact design. It has an onboard micro-USB interface (X1) for convenient configuration in the application without using CAN or RS232 interface for this purpose.

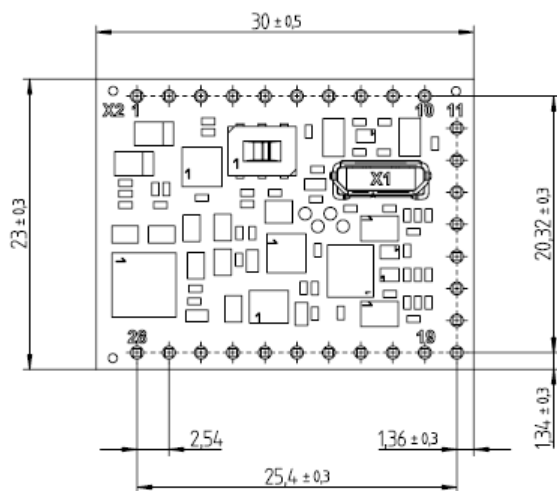


Figure 1: Top view of MC3001 P – in mm

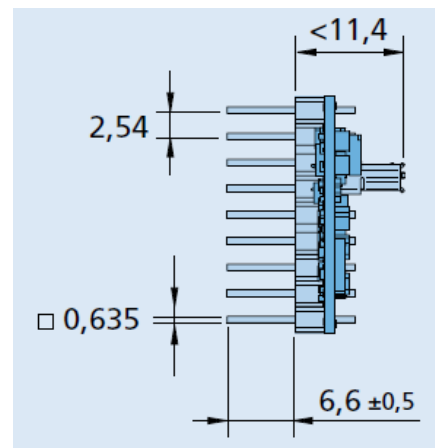


Figure 2: Side view of MC3001 P – in mm

To place a MC3001 P on a motherboard the following sockets are needed:

Quantity	Type	Manufacturer	Part name
2	10-pin, gold-plated socket	W+P	153-010-1-50-00
1	8-pin, gold-plated socket	W+P	153-008-1-50-00

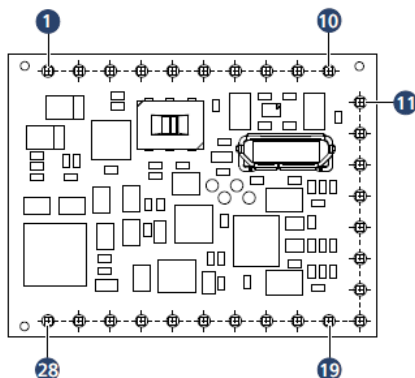


Figure 3: Pin numeration

The **MC3001 B** version is extremely compact using board-to-board connectors, fitting in the most limited construction spaces.

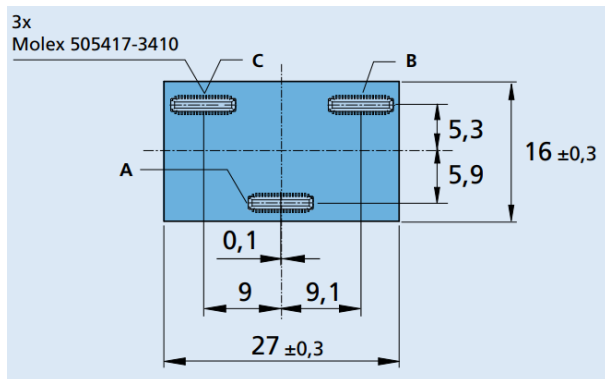


Figure 4: Bottom view of MC3001 B – in mm

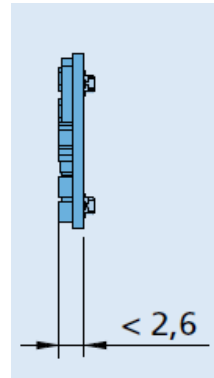


Figure 5: Side view of MC3001 B – in mm

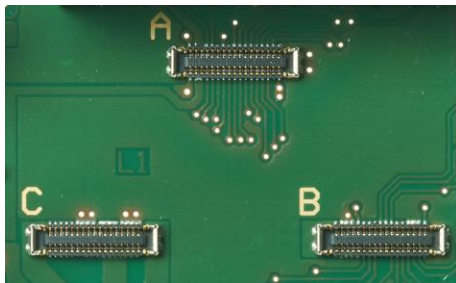


Figure 6: Footprint of MC3001 B

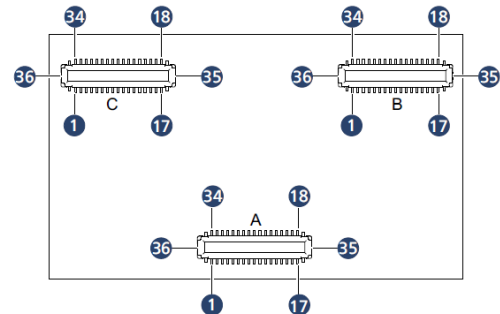


Figure 7: Bottom view with pin numeration



Please make sure to refer to the footprint in figure 6 for the layout of the motherboard to avoid a mirror-inverted non-functional design.

The dimensions 9 and 9.1 in Figure 4 refer to the vertical symmetry line. Connector A is offset by 0.1 mm from this line.

To place a MC3001 B on a motherboard the following sockets are needed:

Quantity	Type	Manufacturer	Part name
3	34 + 2-pin, gold-plated socket	Molex	505413-3410

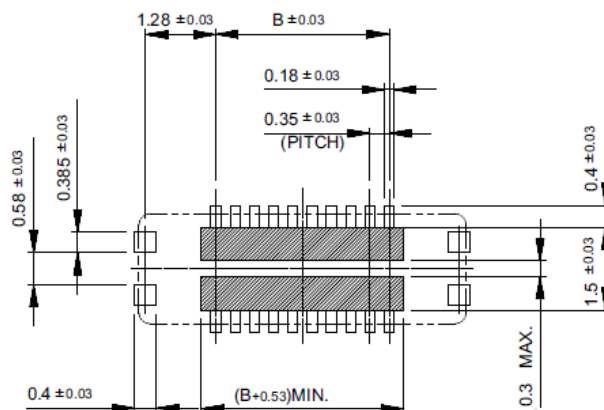


Figure 8: Footprint of the Molex connector; values in mm; B = 5.6 mm

General layout guidelines

Layer stackup

It is highly recommended to use at least a 4-layer PCB for the motherboard design.

- Reserve one layer for the power supply voltage and one layer for its return path (GND). Use the two middle layers for this purpose.
- The top and the bottom layers are to be used as EGND layers, sharing its layers with motor phases and signal traces.

Recommended layer stackup

Layer structure	Signals
Top Layer	EGND + motor phases and signal traces
Layer 2	GND (supply return path), only
Layer 3	U _{mot} (motor supply) + U _p (electronics supply), only
Bottom Layer	EGND + signal traces

EGND and shielding



EGND equals functional earth of the PCB.

A functional earth concept for the complete system combined with shielding of the motor phases is essential for passing EMC conformance tests. Depending on the cable length the encoder and sensor lines have to be shielded as well to achieve signal integrity.

Here are the guidelines to setup a robust system:

- Establish a metal base plate (functional earth).
- Insert PCB mounting holes in the motherboard design.
- Place gold-plated pads around the mounting holes as shown in figure 9, on the top and the bottom layer.



Figure 9: Motherboard 6500.01802 with mounting holes and EGND pads

- Make sure these pads are connected to the EGND layers.
- The EGND signal has to be connected to the supply via at least 2 x Y-Capacitors as shown below.

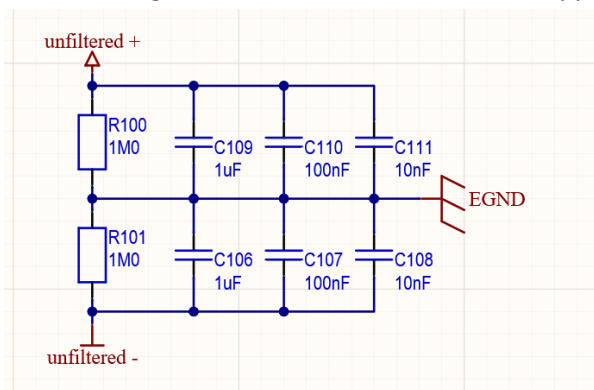


Figure 10: Defining EGND

- Connect EGND of the PCB with the metal base plate using screws, washers and spacers made of metal.
- For shielding ideally place a shield clamp next to the motor connector on the PCB and attach it to an additional gold-plated EGND pad via a screw.

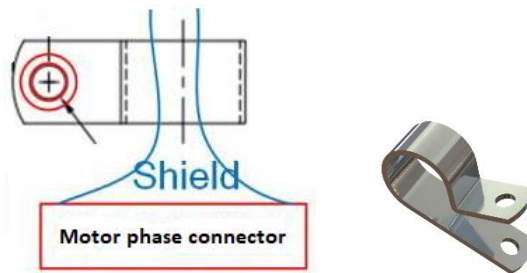


Figure 11: Shielding of motor phases, using a shield clamp connected to the PCB

- Instead of directly connecting the shield clamp to the PCB, it can be placed on the metal base plate next to the motherboard, too.



For the further system setup, please refer to [application note 187](#) for more details on shielding, applicable cable length, and the concept of functional earth. The application note 187 uses examples of larger machinery for demonstration, but all the principles also apply to the smallest embedded devices.

EMC Filter Design – recommended motor phase filter

The FAULHABER motherboards have 3 motor phase filters onboard which significantly reduce radiated EMI, which is essential for passing related EMC conformance tests. In addition, the filters increase robustness of the system, in terms of the signal integrity of the motor feedback sensor.



It is recommended to place motor phase filters on the motherboard to pass EMC conformance tests. The following section describes the motor phase filter, the component selection and highlights what to pay attention to when designing the layout.

The motor phase filters:

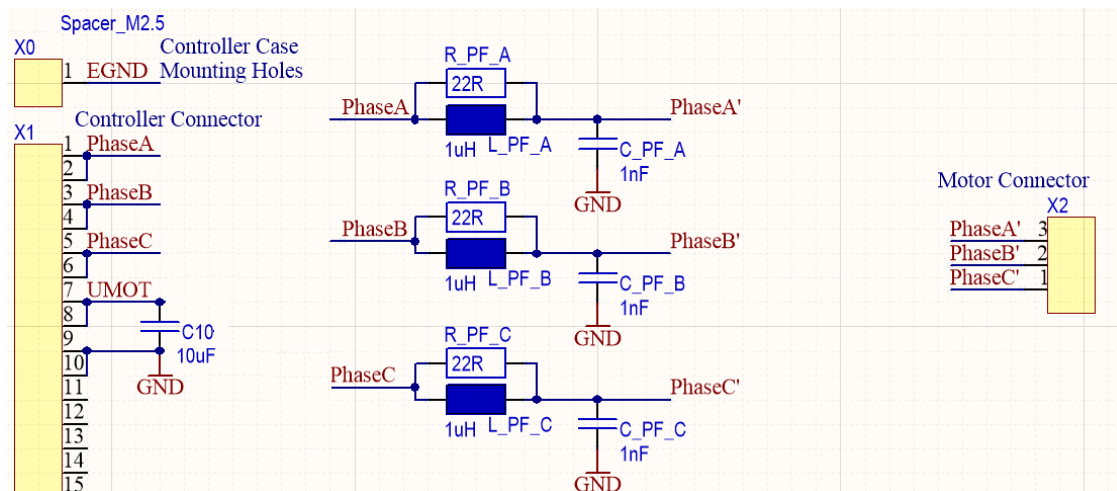


Figure 12: Three LCR motor phase filters

As shown in figure 11 each filter consists of three components L, C and R and is placed between the phase pin of the Motion Controller and the motor connector. Phase A is unfiltered, Phase A' is the filtered part of the circuit.

The selection of motor phase filter components:

Inductor	Quantity	Type	Manufacturer	Part name
L	3	1 uH	Bourns	SRP3020TA-1R0M

Resistor	Quantity	Type	Manufacturer	Part name
R	3	22 Ohm, 0603 or 0805	any	

Capacitor	Quantity	Type	Manufacturer	Part name
C	3	1 nF, 50V, X7R, 0402, Multilayer ceramic capacitor	Such as: TAYO YUDEN KEMET TDK	UMK105B7102MVHF C0402C102J5RACTU C1005X5R1H102K050BA

The layout of motor phase filters:

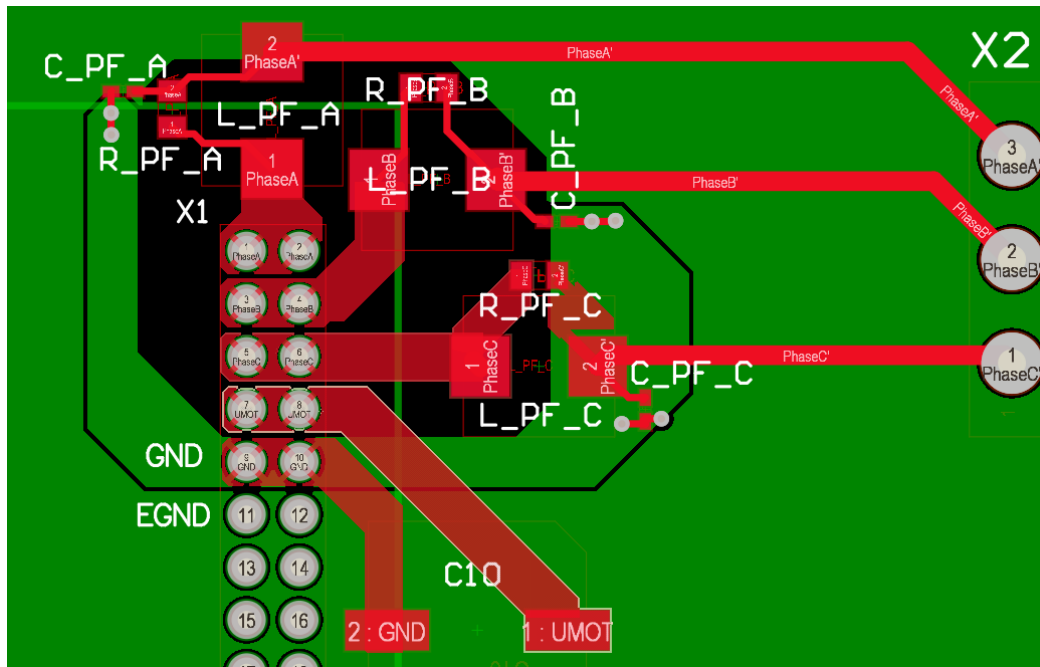


Figure 13: Layout of three LCR motor phase filters – showing the design principle, not the MC3001 specific parts

Here are the guidelines for the filter design. Please follow them strictly for the filter to be effective.

- Place the LCR filter as close as possible to the Motion Controller MC3001, not more than 3...4 mm away from the phase pins of the controller.
- The L and R need to be placed in parallel, close together.
- Connect the capacitor directly to the parallel circuit of inductor and resistor.
Add a short, low impedance GND connection back to the controller (GND, not EGND.) Here this is realized with two vias and wide GND tracks.
- Keep all layers underneath the unfiltered part (including one pad of the inductance and one pad of the resistor) at a distance of at least 1..2 mm.
This also means EGND has to be kept out of this area.

(For clear visibility EGND is shown in green in figure 12. Actually, EGND has to be placed on the top and bottom layers – see the recommended layer structure in the section “general layout guidelines”).

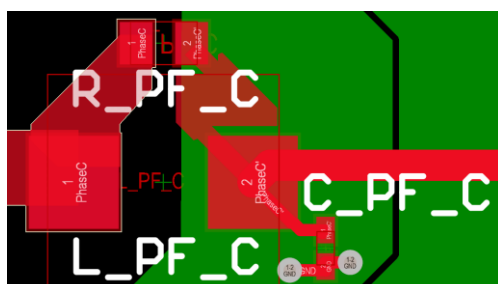


Figure 14: Zoomed in view of the phase filter C



Figure 15: Motor phase filters on motherboard 6500.01802

Motor phase filter for DC-Motors

Many of FAULHABER DC-Motors with precious metal commutation are equipped with an internal filter. The filter protects the commutator from excessive electrical erosion caused by the energy stored in the motor inductance during the transition from one commutation segment to the following one. In the end, this approach helps to increase the lifetime of the DC-motor.

However, this filter is only effective if the motor is operated with a DC-voltage. If the motor is operated with drive electronics using a PWM-voltage (E.g. a FAULHABER Motion Controller), additional measures must be taken into consideration. The PWM-voltage must be smoothed out by using an additional filter.

For designing a motherboard for an MC 3001, this means: If a FAULHABER DC-Motor with precious metal commutation is used, we strongly recommend to realize the following filter design on the motherboard:

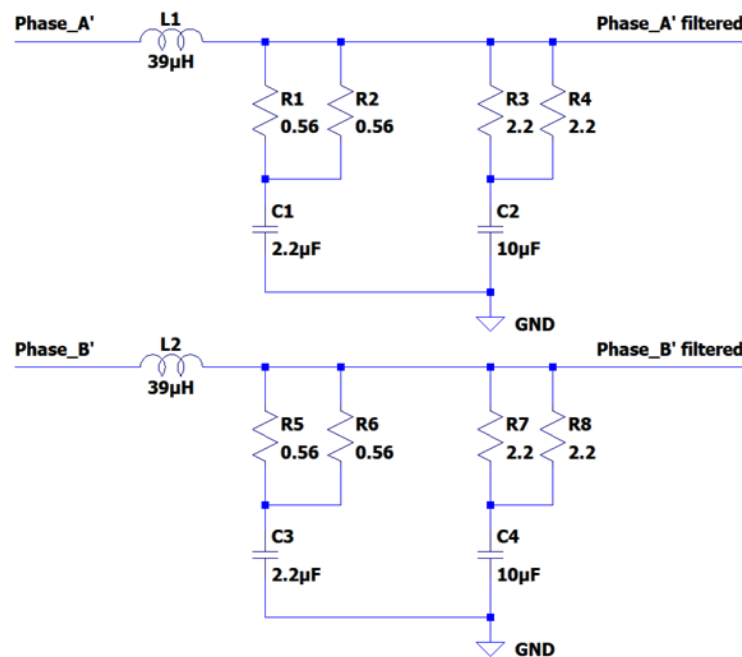


Figure 16: Filter design for DC-Motors with precious metal commutation

Phase_A' and Phase_B' are the output of the motor phase filter, which is described on page 6. Phase_A' filtered and Phase_B' filtered are supposed to be connected to the DC-Motor.

The following table includes suggestions for the selection of the filter components. Those components are dimensioned for a power supply of 24 V and a continuous current of 1 A. If a lower supply voltage (E.g. 12 V) is used or the motors' rated current is significantly less than 1 A, it is possible to select components with correspondingly lower ratings.

Inductors	Quantity	Type	Manufacturer	Part name
L1, L2	2	39 μ H	Bourns	SRR1206-390YL

Resistors	Quantity	Type	Manufacturer	Part name
R1, R2, R5, R6	4	0.56 Ω , Footprint: 0805, Power dissipation: 0.125 W	any	

Resistors	Quantity	Type	Manufacturer	Part name
R3, R4, R7, R8	4	2.2 Ω , Footprint: 0805, Power dissipation: 0.125 W	any	

Capacitors	Quantity	Type	Manufacturer	Part name
C1, C3	2	2.2 μ F, 50 V, X7R, Footprint: 0805, multilayer ceramic capacitor	TDK	C2012X7R1H225K125AC

Capacitors	Quantity	Type	Manufacturer	Part name
C2, C4	2	10 μ F, 50 V, X7R, Footprint: 1206, multilayer ceramic capacitor	TDK	C3216X7R1H106K160AC

EMC Filter Design – optional supply filter

The above motor phase filters are damping radiated EMI. When considering EMC, conducted EMI is a relevant aspect, too. Largely depending on the used power supply an optional additional supply filter might have to be considered to dampen conducted EMI.

When using a low-cost power supply, it is more likely that a supply filter is going to be necessary to pass any related EMC conformance tests. More expensive power supplies on the other hand usually already have filter components included which make additional filtering obsolete.



So, what to look for when selecting a power supply and aiming to avoid the use of an additional supply filter? Usually a good hint is the power supply's datasheet information about passing EMC tests related to conducted emission, without any restrictions.

The following section describes the optional supply filter, the component selection and highlights what to pay attention to when designing the layout.

The supply filter:

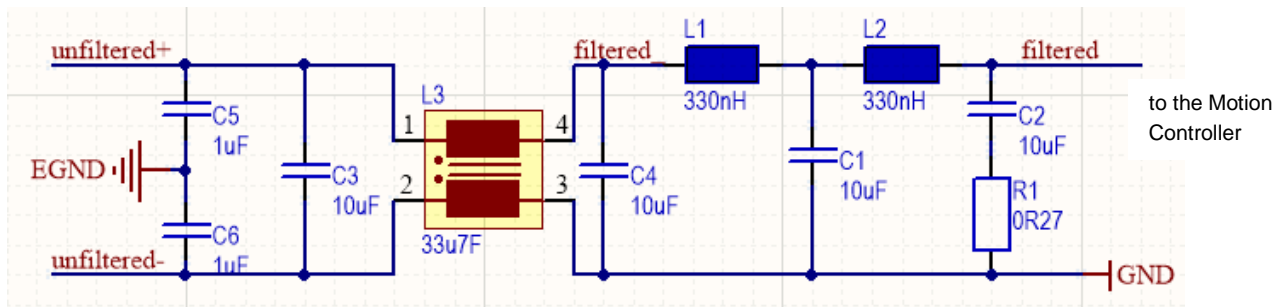


Figure 17 : Common mode filter

Differential mode filter

As shown in figure 15 the supply filter consists of two parts, a common mode filter and a differential mode filter. The input of the common mode part is connected to the DC supply voltage (unfiltered+, unfiltered-). The output of the differential mode filter part supplies the Motion Controller and is connected to the pins Umot + Up (motor and electronics supply) and GND.

The selection of the supply filter components:

Common mode choke	Quantity	Type	Manufacturer	Part name
L3	1	33 uH	TDK	ACM1211-102-2PL-TL01

Inductors	Quantity	Type	Manufacturer	Part name
L1, L2	2	0.33 uH	Sumida	0420CDMCCDS-R33MC

Capacitor	Quantity	Type	Manufacturer	Part name
C1, C2, C3, C4	4	10 uF, 50V, X7R, 1206, multilayer ceramic capacitor	Such as: TAYO YUDEN KEMET TDK	UMK316BBJ106ML-T C1210C106K5RACTU C3216X7R1H106K160AC

Capacitor	Quantity	Type	Manufacturer	Part name
C5, C6	3	1 uF, 50V, X7R, 1206, multilayer ceramic capacitor	Such as: TAYO YUDEN KEMET TDK WE	UMK107AB7105MA-T C1206C105J5REC7800 C3216X7R1H105K160AB 885012208093

Resistor	Quantity	Type	Manufacturer	Part name
R1	1	0.27 Ohm, 0603 or 0805	any	

The layout of the supply filter:

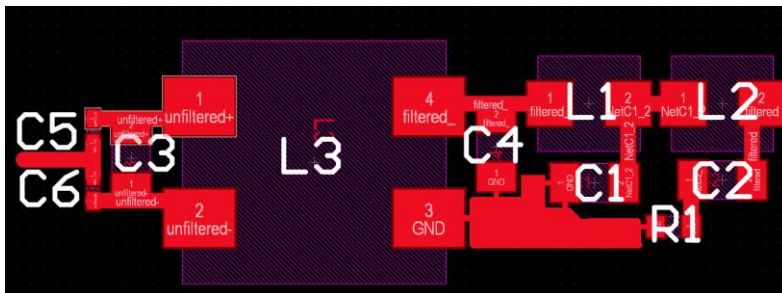
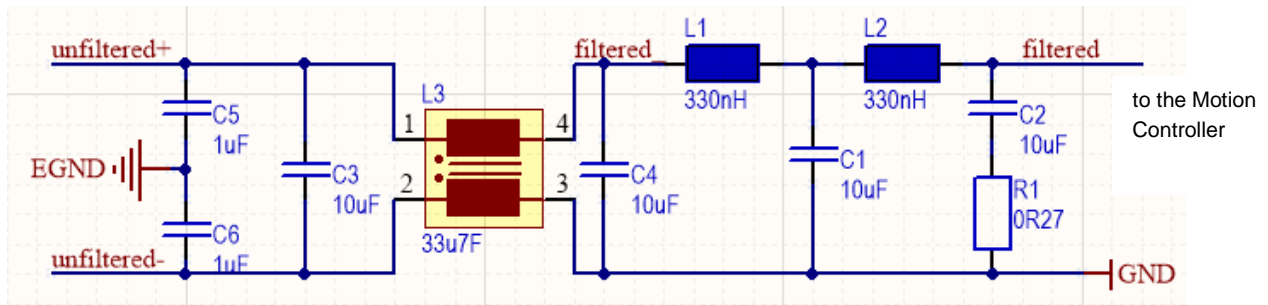


Figure 18: Layout and schematic of the supply filter

Here are the guidelines for the filter design. Please follow them strictly for the filter to be effective.

- Place the filter as close as possible to the Motion Controller.
- Arrange the components in a compact way, to avoid parasitic effects.
- Route tracks on one layer only.
- Make sure to connect the Y-capacitors C5 and C6 to EGND (not GND), which is essential for the effectiveness of the filter.

If size is relevant an even more compact design could look like this:

- Place the common mode choke L3 on the top side of the PCB
- Place the rest of the filter on the bottom side, directly opposite to the choke.

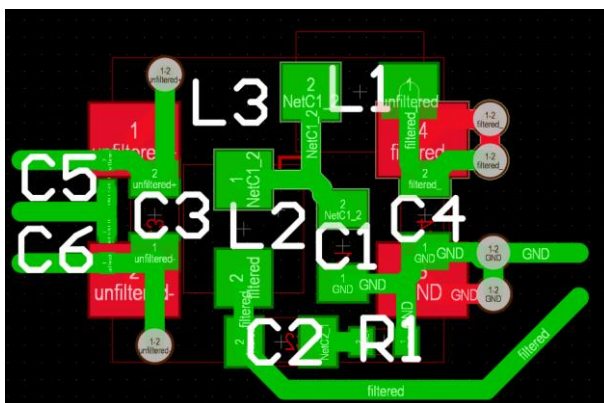


Figure 19: Layout of size-optimized supply filter

Network operation via RS232

Multiple MC 3001 B/P RS can be operated in a network with e.g. an embedded μ C or a PC as master controller. To achieve this functionality, an additional electronic circuit with diodes und multichannel RS232 transceivers must be integrated on the motherboard.

The following circuit diagram shows our recommended solution. Each multichannel RS232 transceiver can be connected to two MC 3001 B/P RS. If more than four MC 3001 B/P RS shall be operated in the network, the circuit in the orange box must be duplicated accordingly.

For the connection to the host, it must be differentiated between TTL voltage levels and RS232 voltage levels. A host with RS232 voltage levels requires an additional RS232 transceiver which is shown in the lower left corner.

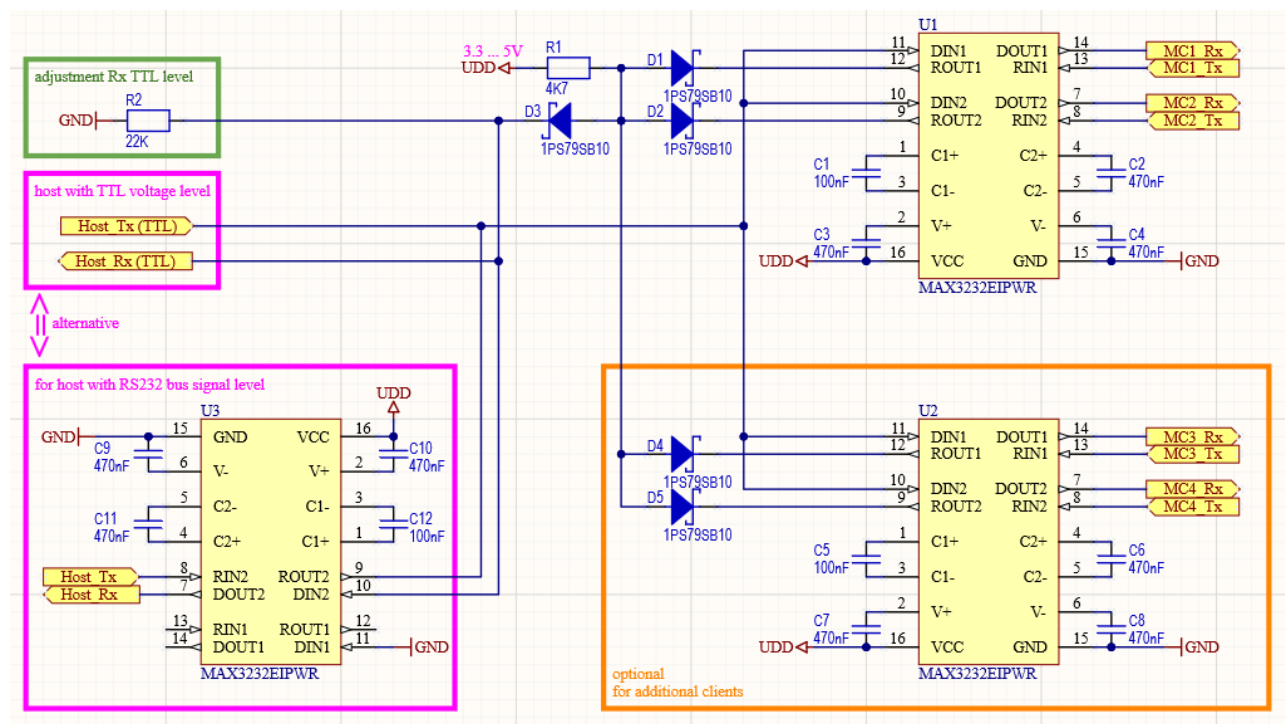


Figure 20: Electronic circuit diagram for network operation of MC 3001 B/P RS

The resistor R2 (green box) must be adapted according to the required voltage level at the Rx signal (TTL level) of the host:

Udd [V]	R2 [k Ω]	Rx high [V]	Rx low [V]
5	22	3,9	0,3
3,3	22	2,5	0,3
5	10	3,2	0,3
3,3	10	2,1	0,3
5	4,7	2,3	0,3
3,3	4,7	1,5	0,2

The selection of the components:

Transceiver	Type	Manufacturer	Part name
MAX3232	-	Such as: Texas Instruments	MAX3232EIPWR

Diode	Type	Manufacturer	Part name
D1, D2, D3, D4, D5	Schottky Diode	Such as: Nexperia USA Inc.	1PS79SB10

Capacitor	Type	Manufacturer	Part name
C1, C5, C12	100 nF	any	
C2, C3, C4, C6, C7, C8, C9, C10, C11	470 nF	any	

PCB Connectors

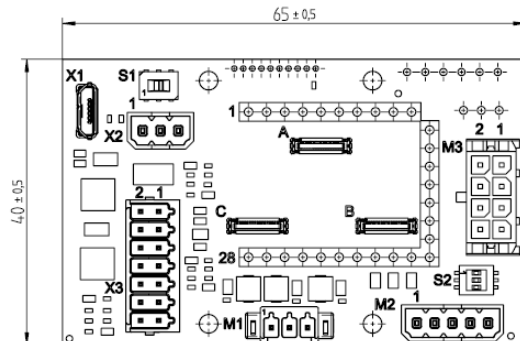


Figure 21: FAULHABER motherboard 6500.01802

Here is a summary of the connectors of the motherboard 6500.01802. If this motherboard was used for testing, some of its connectors might fit nicely into the new design as well:

	Manufacturer	Part name	Type
M1 – motor phases	Phoenix	1821407	MCV 0.5 / 3-G-2.54 P20 THR R24
M2 – hall sensors	Phoenix	1778586	PTSM 0.5/ 5-HV-2.5-THR R32
M3 – encoder	Molex	43045-0827	Micro-Fit 8 pol
X1 – USB (option for MC3001 B)	Molex	105133-0011	USB Micro B
X2 – CAN or RS232	Phoenix	1778560	PTSM 0.5 / 3-HV-2.5-THR R32
X3 – Power supply and I/O	Phoenix	1844921	DMCV 0.5 / 7-G1-2.54 P20THR R44

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