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, combined with a set of mating connectors, 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 EGND 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.
- Depending on the power supply, an optional EMC supply filter might have to be considered.
- 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.

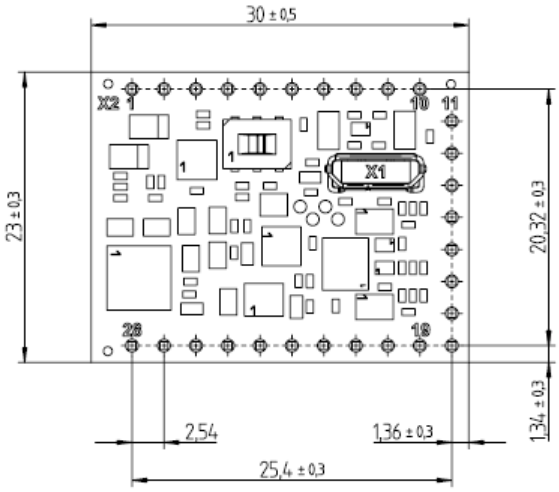

Figure 1: Top view of MC3001 P – in mm

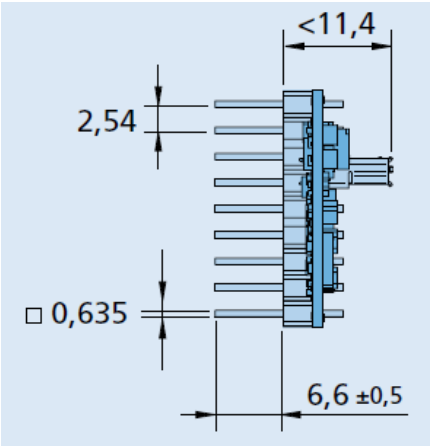

Figure 2: Side view of MC3001 P – in mm

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

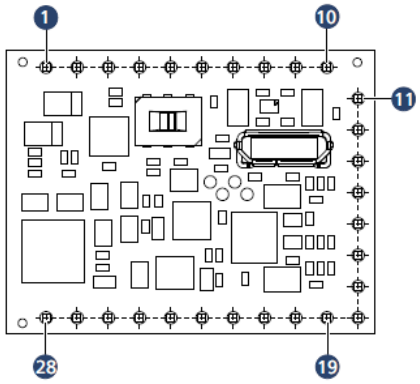

Figure 3: Pin numeration

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

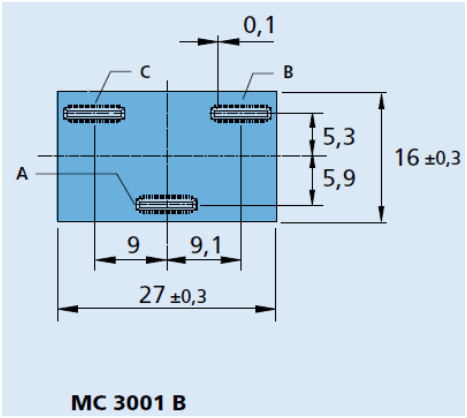

Figure 4: Bottom view of MC3001 B – in mm

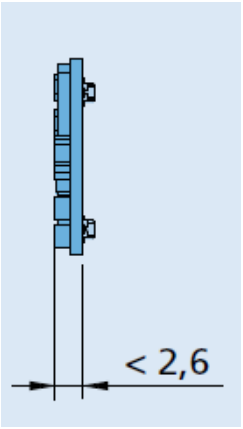

Figure 5: Side view of MC3001 B – in mm

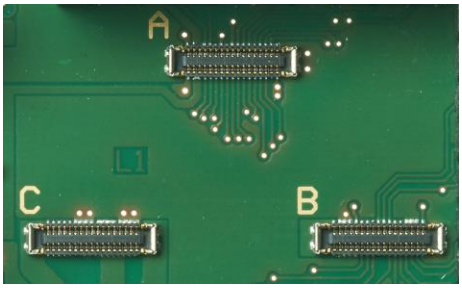

Figure 6: Footprint of MC3001 B

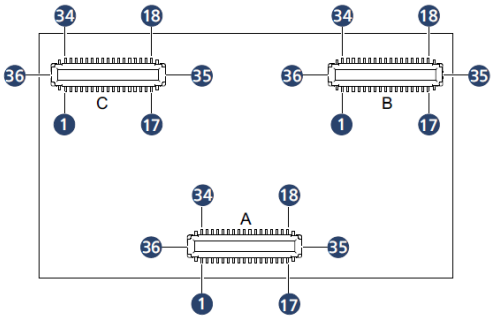

Figure 7: Bottom view with pin numeration

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.

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

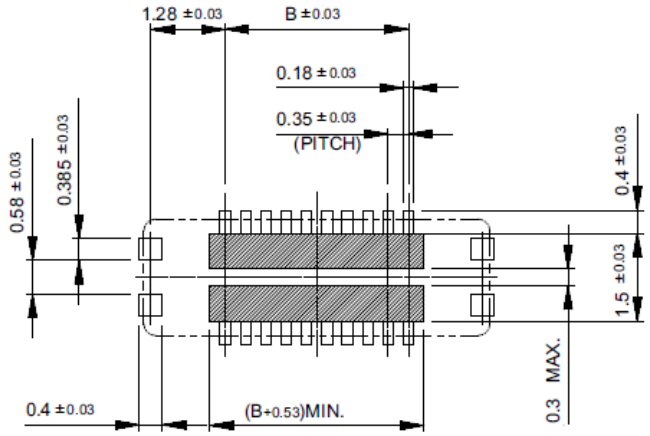

Figure 8: Footprint of the Molex connector; values in mm; B = 5.6 mm

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	Umot (motor supply) + Up (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.
- Make sure these pads are connected to the EGND layers.

Figure 9: Motherboard 6500.01802 with mounting holes and EGND pads

- 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.

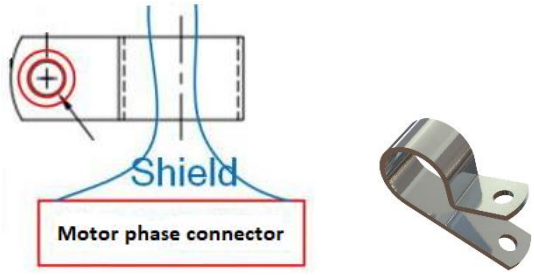

Figure 10: Shielding of motor phases, using a shield clamp connected to the PCB

- 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:

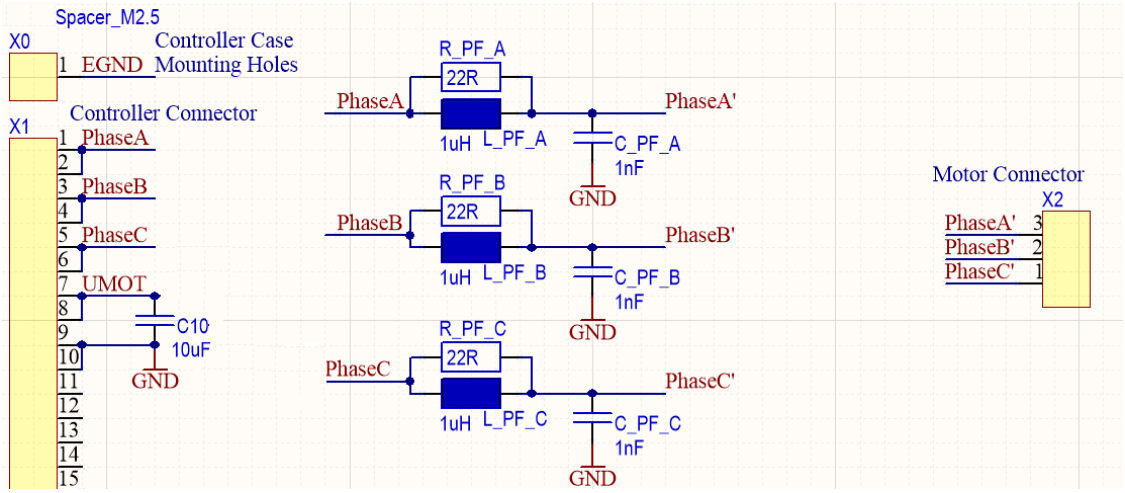

Figure 11: Three LCR motor phase filters

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:

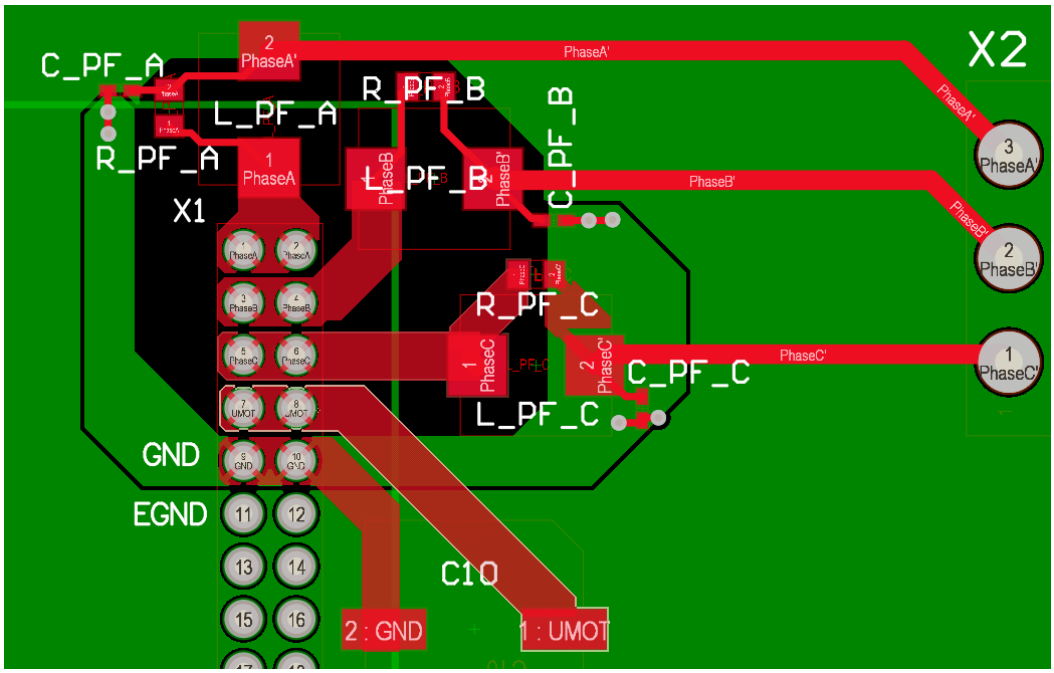

Figure 12: Layout of three LCR motor phase filters – showing the design principle, not the MC3001 specific parts

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”).

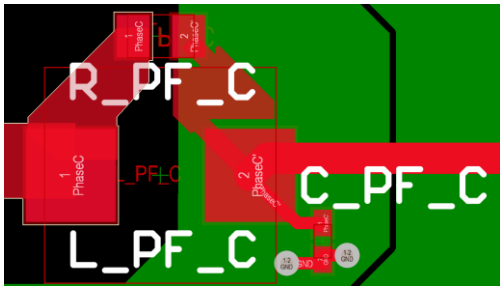

Figure 13: Zoomed in view of the phase filter C

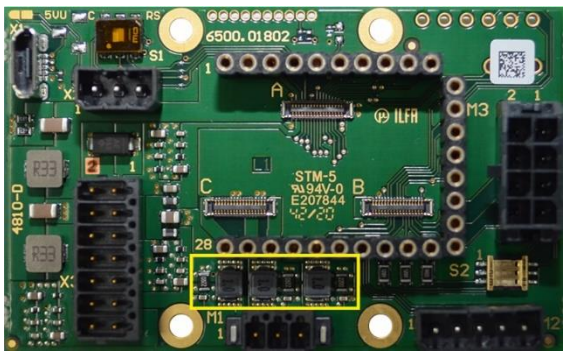

Figure 14: Motor phase filters on motherboard 6500.01802

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:

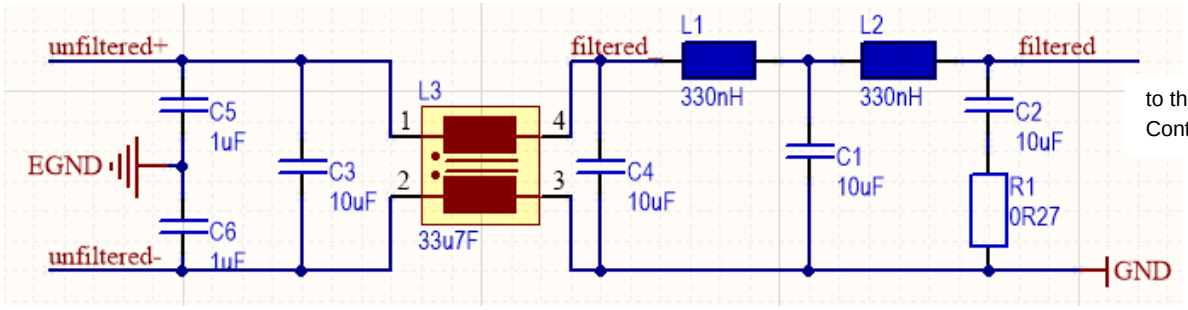

Figure 15 : Common mode filter Differential mode filter

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	0.027 Ohm, 0603 or 0805	any	

The layout of the supply filter:

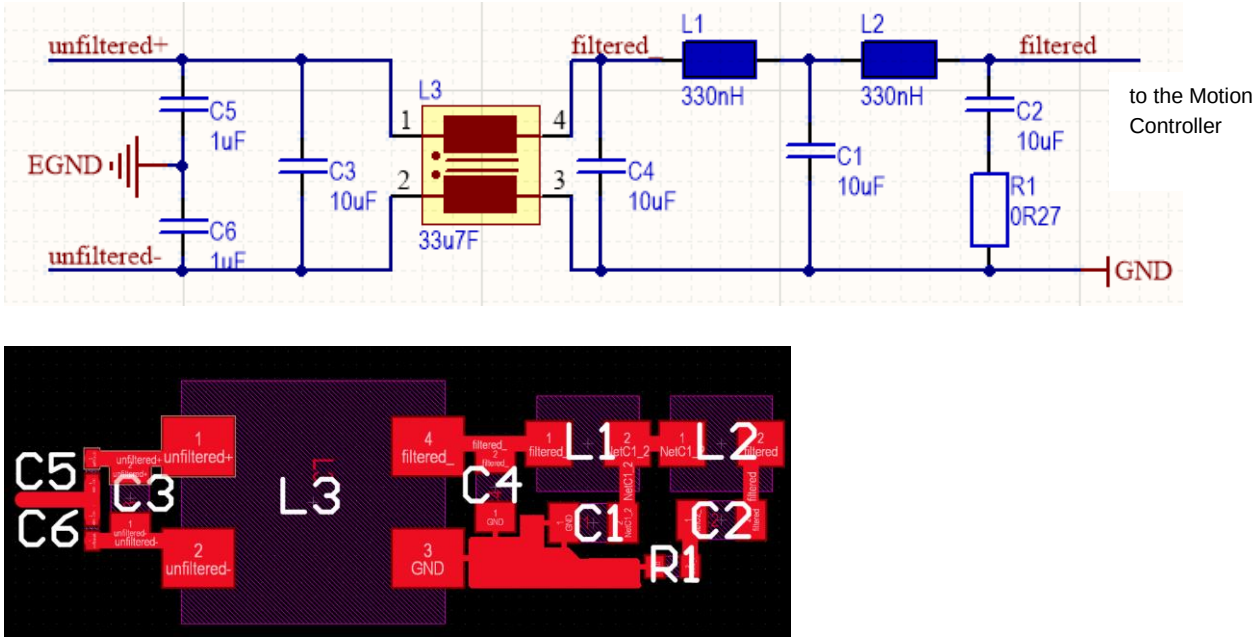

Figure 16: Layout and schematic of the supply filter

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.

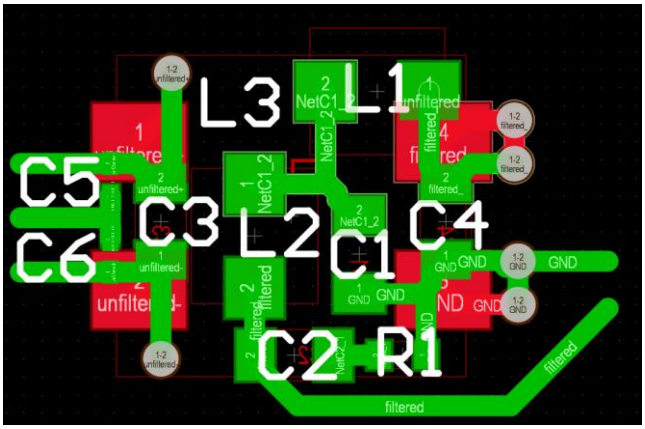

Figure 17: Layout of size-optimized supply filter

PCB Connectors

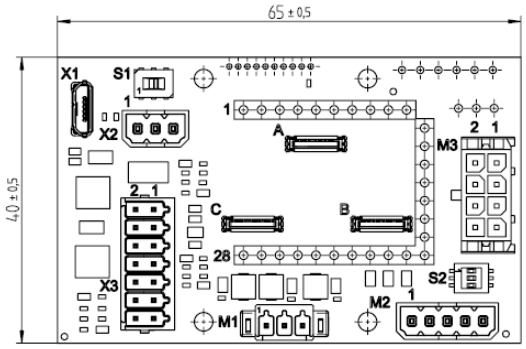

Figure 18: FAULHABER motherboard 6500.01802

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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