ZEVA MC600C / MC1000C

Motor Controller Assembly Manual

Written by Ian Hooper, October 2021

Introduction

This document describes the assembly process for the ZEVA MC600C and MC1000C motor controllers for Series DC and PMDC motors. It should also be useful for disassembling any controllers that need repairs. Pictures shown are of an MC1000C. The MC600C is a similar design, but with a shorter power stage (fewer components) - the differences should be intuitive during assembly if you are making an MC600C.

Hopefully this manual will have sufficient detail for the assembly to go smoothly, but it is fairly complicated so take your time, and it is best to read this entire manual before getting started so you know what to expect.

Bill of Materials

This BoM covers parts needed for assembly, but not the individual components for each circuit board used. For PCB assemblies, please refer to their individual BoMs provided. You will also need the usual assortment of electronics tools such as soldering iron(s), pliers, side-cutters, screwdrivers, multimeter, variable power supply, and preferably an oscilloscope for testing.

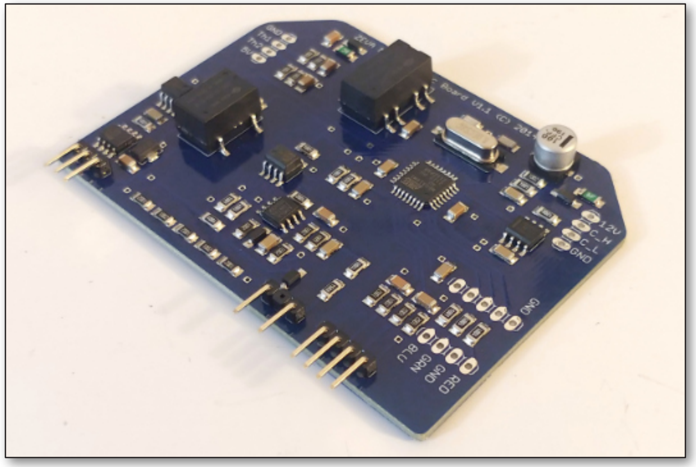
The motor controller has two microcontrollers that will need to be programmed using an AVRISP type programmer (USBASP is a common and inexpensive option), and using software such as AVR/Microchip Studio or AVR Dude to set the fuses (for clock speed etc) and transferring the firmware. The main microcontroller can be programmed in-system after assembly. The smaller microcontroller will need to be programmed before PCB assembly, which can be set up using a SOIC8 to DIP8 adapter and some breadboard.

Description / Part Number	MC600C	MC1000C
Logic board	1	1
Interface board	1	1
Capacitor boards *(4oz copper essential)*	5	8
Power boards *(4oz copper essential)*	5	8
Central heat block (162mm or 258mm long)	1	1
Thermal sheet, TG-A486S-320-320-0.23-0	1	1
M4x6 machine screws	10	16
IRFP4668 transistors	10	16
STTH6002 diodes	10	16
M3x12 countersunk machine screw	2	2
M3x35 machine screw	10	16
M3 Nyloc nut	12	18
Set of 3 busbars	1	1
Plastic tubing, 6mm OD, 4mm ID	60mm+	100mm+
M4x16 socket head machine screw	30	48
M4 spring washer	30	48
M4 nut	30	48
Thermistor (Altronics R4112)	1	1
M3x6 machine screw	1	1
M3 spring washer	1	1
5mm RGB LED	1	1
4-pin plug + socket (Altronics P0950, P0955)	1	1
5-pin plug + socket (Altronics P0951, P0956)	1	1
Hookup wire, ~AWG24, assorted colours	0.5m	0.5m
5mm RGB LED (common cathode)	1	1
M6x20 bolts (countersunk, if using ZEVA housing)	2	3

Logic board

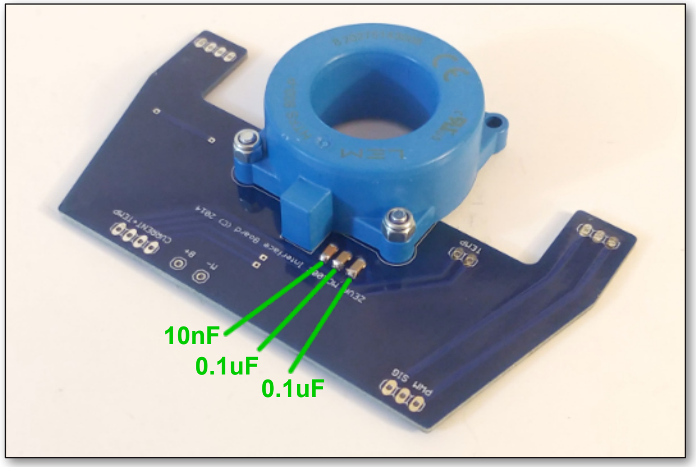
The logic board should be assembled as per provided files. All components are surface mount apart from the 90-degree 0.1" pin headers for attaching it to the interface board.

There is an Attiny13A "helper" microcontroller which will need to be programmed before the PCB is assembled, since there is no in-system programming port for it. The main Atmega16m1 microcontroller does have a programming port on the PCB.



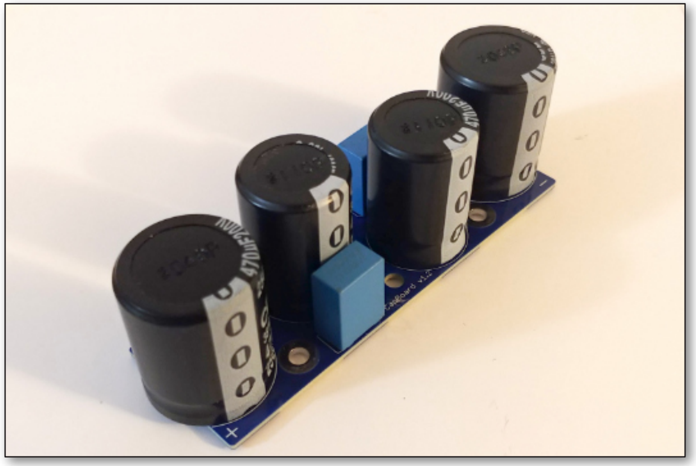
Interface board

The interface board fits between the logic board and power stage, and also has the current sensor and connection for temperature sensor. Current sensor should be LEM HTFS 800P, fastened to the PCB using two M3x12 countersunk screws and 2x M3 nyloc nuts. There are also three 1206-sized surface mount capacitors (25V X7R or similar).



Capacitor boards

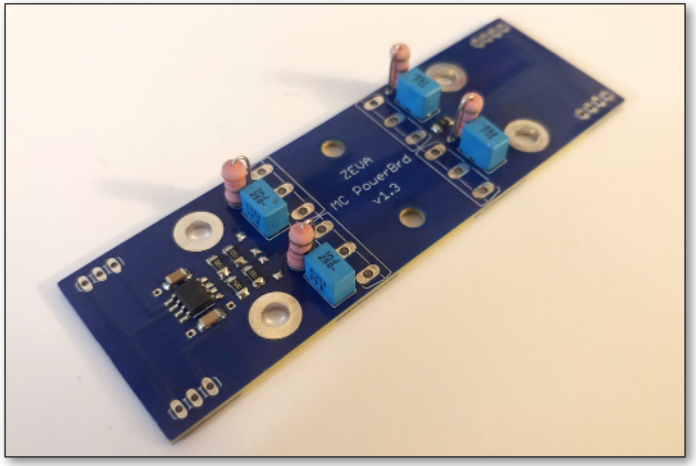
The MC600C has 5x modular PCBs for capacitors, and the MC1000C has 8x. There are two film capacitors which are non-polarised, and 4x electrolytic capacitors which are polarised - be careful to fit them the right way around.



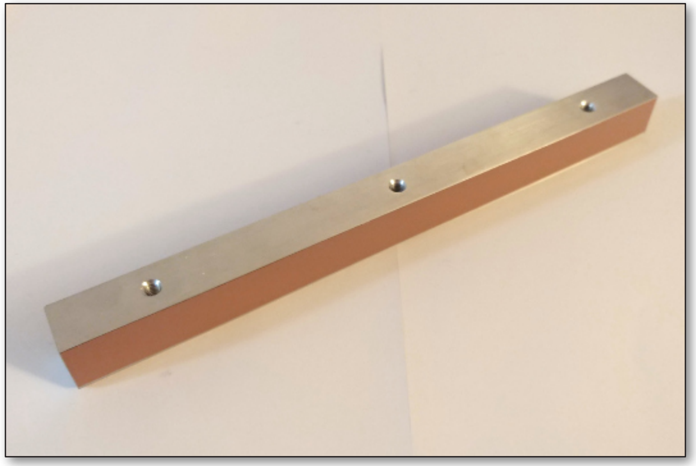
Power stage

The power stage uses a number of modular PCBs, 5x for the MC600C and 8x for the MC1000C. The small SOD123 diodes should be omitted (design change), and don't fit the power transistors or diodes yet. The boards should look something like below.

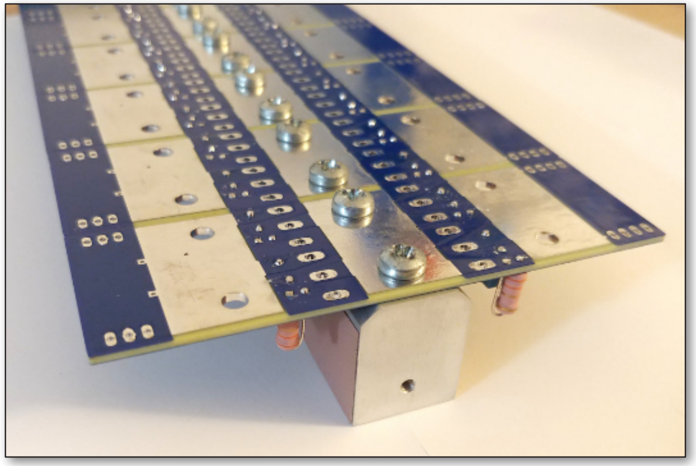
Tip: Hang on to the leg offcuts from the through-hole resistors, they'll used later.



• Cut two strips of thermal sheet, 160x20mm for MC600C or 256x20mm for MC1000C, and attach to either side of the heat block, about 1mm down from the top and 1mm in from each end.



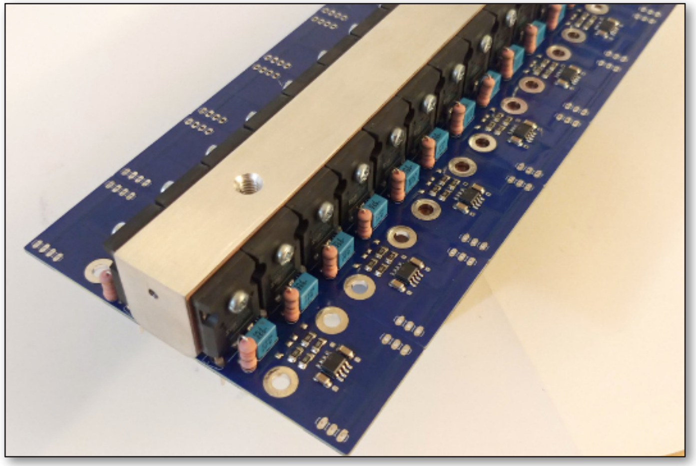
• Attach power boards to heat block with M4x6 screws, ensuring orientation matches the picture below with respect to hole for temperature sensor.



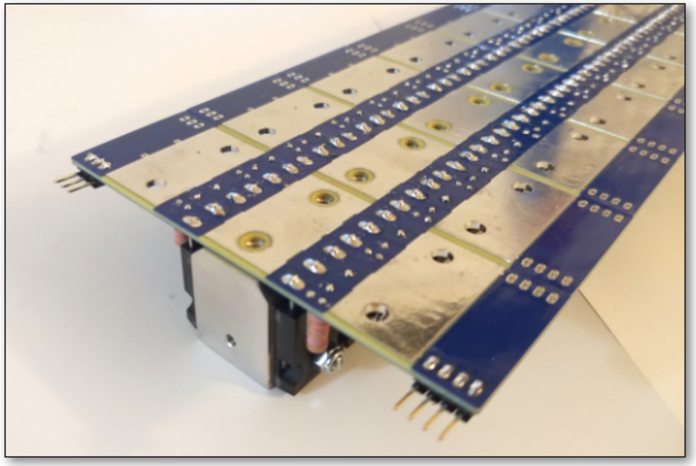
• Insert IRFP4668 transistors on the side with the gate drivers and STTH6002 diodes on the other side. Do a visual confirmation of part numbers as you go - fitting an incorrect part would be troublesome.

• Hold transistors and diodes against the heat block while puncturing the thermal sheet through the mounting holes using a small scribe or similar small pointy tool. This is so the screws that will clamp the transistors and diodes to the heat block can pass through the thermal sheet.

• Fasten the transistors and diodes to the heat block using M3x35 screws and nyloc nuts. Hold the transistors and diodes to the thermal sheet while inserting the screws to avoid lifting the thermal sheet.

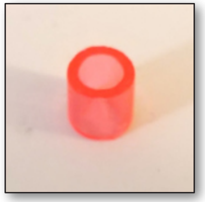


• Solder the legs of the power transitors and diodes to the power boards. A high power soldering iron (60W+) with a large chisel tip will be needed, and it is most effective to apply the iron on the side with the PCB track going to the busbars (which varies for different legs). Do a visual inspection of solder joints to verify they are tidy, then trim legs off with sidecutters (nice and short as per picture below). Remove M4x6 screws. Solder 3- and 4-way right-angle pin headers to the power board at the end with the temperature sensor hole.



• The busbars will usually need some preparation. It is best to slightly chamfer all holes to remove any burrs from machining, give all contact surfaces a light sanding, and apply a very thin layer of contact grease such as Noalox. A rotary wire brush in a drill works well for cleaning the larger power terminals.

Tech note: The busbars are made from aluminium, which is a good conductor of electricity, but quickly builds up an oxide layer which is not a good conductor. So it helps to remove the oxide then seal the surface from reoxidising using Noalox. When the busbars are screwed to the circuit boards, the screw pressure forces the grease to the edges, to allow conduction under the screws while also being sealed against future oxidation.



• The central busbar needs to be insulated from the screws using plastic inserts, 5-6mm lengths cut from 6mm OD, 4mm ID tubing. This is a common size for pneumatic tubing, which can be purchased from places like Farnell / Element14 / Newark. Make sure none are over 6mm long or they could prevent the busbar from making good contact with the circuit boards - better to be a bit under 6mm than a bit over.

• Give the large exposed tracks on the power boards and cap boards a wipe to get rid of any solder flux / grime, then assemble the power stage: Start with the heat block with power boards attached, place longest busbar on B+ side, slide interface board onto header pins, slide middle busbar through current sensor, place shortest busbar on B- side, then place capacitor boards (noting polarity).

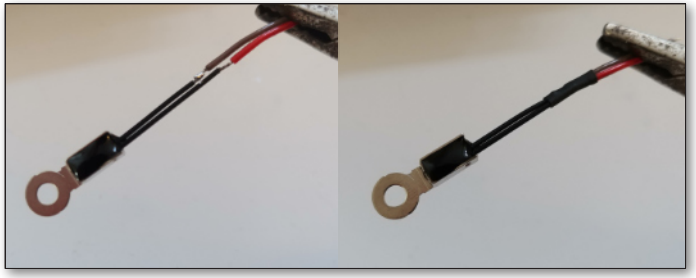
• Insert M4x16 socket head machine screws through all the holes in the capacitor boards (30 screws for MC600C, 48 screws for MC1000C). Fasten the middle row tightly into the heat block - about as tight as you can comfortably go using a screwdriver, or something like 1Nm.

• Tilt the assembly onto its side, support with a block of wood or similar, then add M4 spring washers and nuts to each of the screws protruding through the power boards. Hold each nut using a socket wrench and tighten its associated screw, again to about 1Nm torque. Repeat for other side (i.e screws through both B+ and B- busbars).

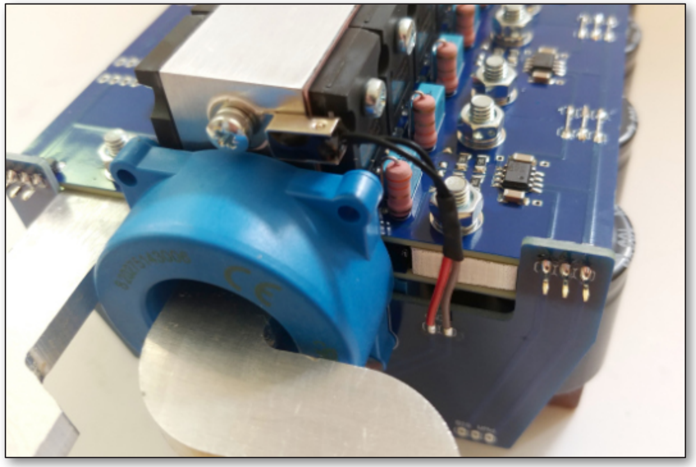
• Solder the pin headers connecting the interface board to the power boards, with a 90 degree angle between the boards.

• The gate drive signal that passes along the power boards needs to be connected electrically by bridging the groups of three pin headers. The resistor leg offcuts can be used to make 8-10mm wire jumpers to join the boards as shown in the picture. Inspect the solder joints with a loupe to ensure they are neat and tidy, as a bad solder joint could be fatal for the motor controller.

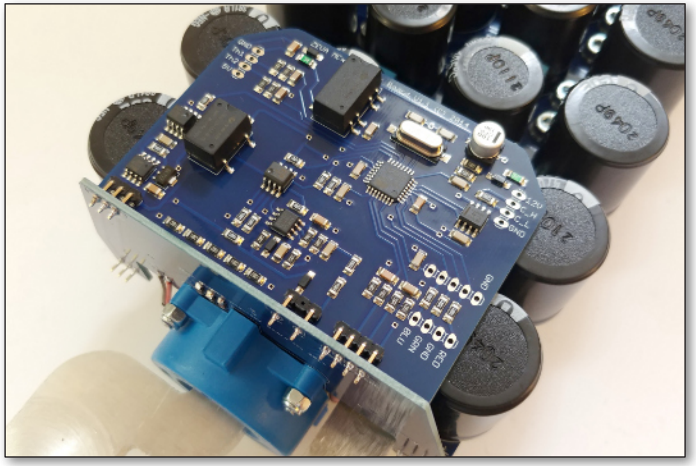
• The thermistor (temperature sensor) comes with short fly leads which need to be extended by about 20mm - something like the picture below.



• Add a little thermal paste to the thermistor's eyelet then it fasten to the heat block in horizontal orientation using an M3x6 machine screw with M3 washer under the screw head. The two wires can then be soldered to the location labelled TEMP on the interface board.

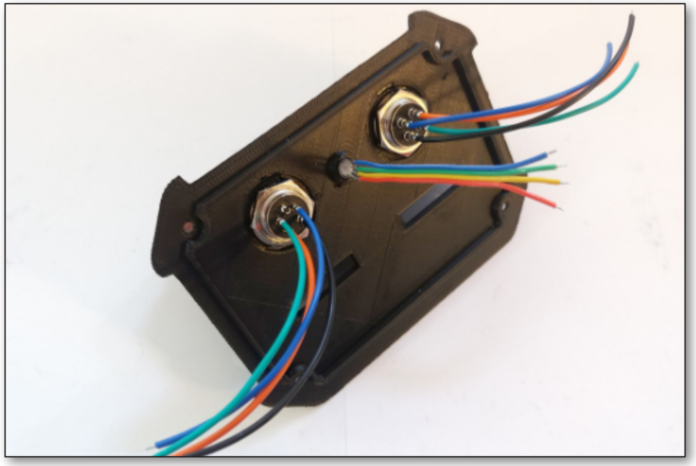


• Attach a 40mm piece of double-sided foam tape to the underside of the logic board, along the side opposite the pin headers. Fit the logic board pins into the interface board, press down to stick the foam tape to the capacitors below, then solder the pin headers to the logic board.

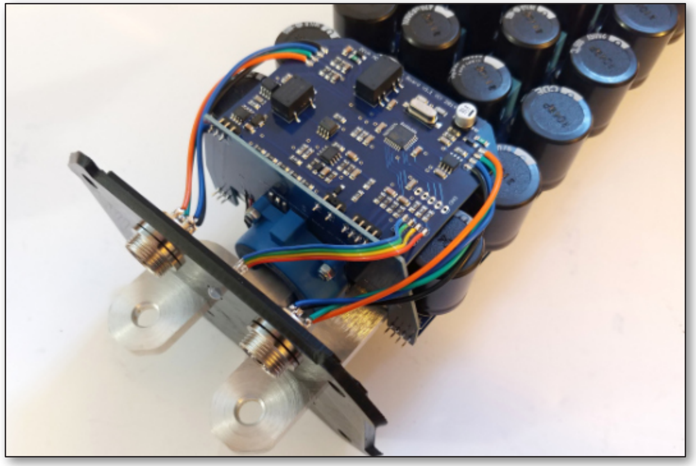


• The power input, CAN bus and throttle connections are wired to a 4- and 5-pin connector on the motor-end panel. Fit the two connectors to the end panel, ensuring you include the spring washer to prevent them loosening, and optionally add a drop of thin superglue to the washer/nut. Looking at the front of the panel, the 5-pin connector should be on the right. You will need 8 wires, 95mm in length, preferably four different colours. About AWG24 is recommended, but it's not too important (current requirement is very small).

• There is also a 5mm RGB LED for showing status. Trim the LED's legs off at about 6mm length, splay the legs out a little to make soldering easier, and attach a 70mm length of rainbow wire (or similar) to the legs. The pin order should be the same on the LED as the logic board, but you'll need to verify which end is which on the LED using a multimeter set to diode test mode. A picture of the panel with connectors and wires is shown below. (Note: *Your end panel may be different of course if you are making your own custom enclosure.)*

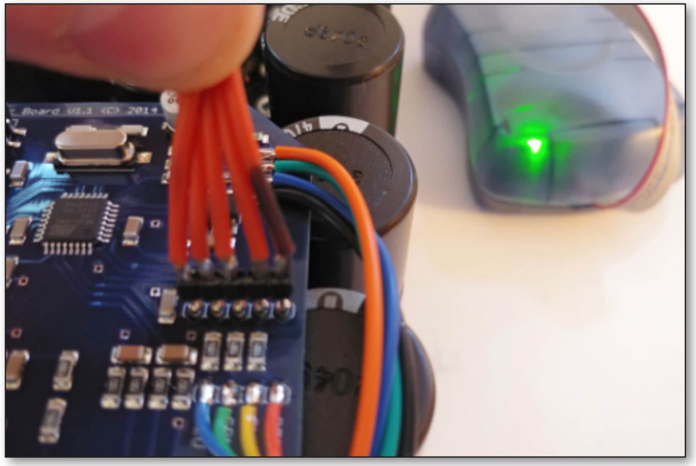


• Fit the end panel over the busbars then solder all wires to the logic board. Ideally twist the two CAN bus wires around each other a couple of times on the way (helps with noise immunity).



Programming

• Wire up the power/CAN connector with 12V and Ground wires, and apply 12V using a current limited power supply. The programming port on the logic board is a different pin layout to normal AVRISP header, having a single row of 5 pins ordered GND, MOSI, MISO, SCK, RESET, so you will need to make an adapter from your programmer. Fuses should be set to 4.2V brownout, CKDIV8 off, and external 8Mhz crystal with 0ms startup time. AVR/Microchip Studio or AVR Dude may be used to set the fuses and transfer the firmware.



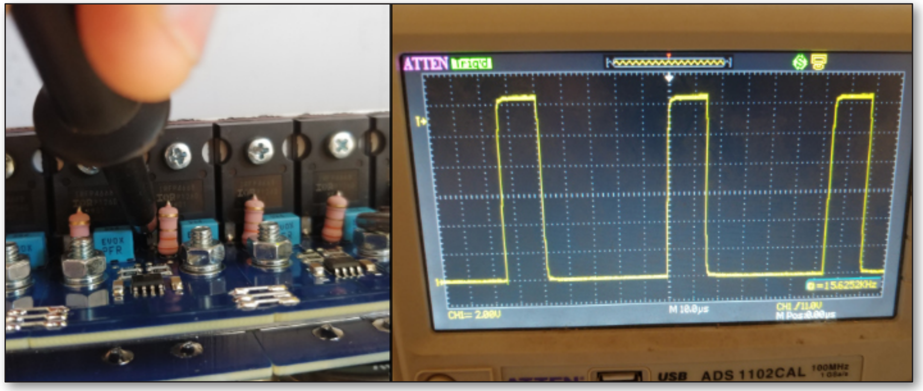
Congratulations, your motor controller should now be ready to run!
(But let's do some testing before you put it in a vehicle.)

Testing

• Apply 12V to the power/CAN connector from a current limited variable power supply, and the status LED should light up blue. Apply 12V to the B+ and B- power terminals and the LED should turn green.

• Check the current sensor level from the interface board (it should be 2.5V) and the temperature sensor level should also be about 2.5V (a bit more if hot, a bit less if cold).

• Fit the 4-pin throttle connector to a suitable 0-5V 3-wire + enable throttle. A 5kohm potentiometer can be used, with Enable wired permanently to 5V. Set the throttle to about 20%, then use an oscilloscope to check that every transistor gate has a 12V square wave. The oscilloscope ground lead can be clipped to one of the screws along the B- busbar.



• Disconnect the 12V wires from the power terminals. Ideally now test with a 12V-150V battery attached to the B-/B+ terminals and a motor attached to the M-/M+ terminals, but note that you will need to precharger the controller (e.g using a 50ohm 10W resistor in series) before attaching the battery terminals, and make sure you have a suitable fuse between the battery and controller. Alternatively, at this point you may wish to carefully test it in the vehicle. For initial testing, a fuse of about 50A and an unloaded motor is recommended.

Boxing up the controller

• This may vary depending on what sort of housing you are using, but in general you will need to apply a thin layer of thermal paste to the top of the heat block before fastening it to your heatsink or housing with 2 or 3 M6x20 countersunk machine screws. If using an original ZEVA extruded housing, the end plates attach to the housing using 4x M3x10 countersunk machine screws each.

• Application of Noalox or other contact grease is recommended on the power terminals to prevent oxidation which increases contact resistance and causes heating.