High Power DC Motor Speed Controller - Part 2

Design by JOHN CLARKE

Continuing on from last month, here are the construction and setup details. We split the circuit into two sections/PCBs because it is such a high power design.

One PCB accommodates the control section, mainly involving the PIC16F88 microcontroller IC1 and the high-side driver, IC2.

The second is the switching or power side of the circuit, involving two or three (optional) MOSFETs and all the linking options to take care of high-side or low-side switching. In fact, this second board can be thought of as a single high-power MOSFET which can be wired for high or low-side switching.

Construction

Assembly simply involves building the two PCBs and connecting them together inside the compact diecast aluminium box which measures 119 × 94 × 57mm.

The control PCB is coded 11112161 and measures 107 × 82mm and it is installed on the bottom of the diecast case.

The power PCB is coded 11112162, and measures 111 × 85mm. It is installed on the lid of the diecast case and the two boards are connected together with five wires. Both of the PCBs are available from the *EPE PCB Service*. No heavy currents flow between the two PCBs so we don't need heavy-duty wiring for the interconnections.

Nor is there any heavy duty wiring between the power PCB and the various terminals for the DC supply and motor.

Instead, all the heavy duty currents flow in the tracks of the PCB which is manufactured using '2-ounce' copper, twice as thick as normally used. In addition, the four 50A-rated terminals are mounted directly on the PCB, with substantial tin-plated 'lands' to provide low resistance connections.

Furthermore, since six of the 'links' on the power PCB also carry heavy currents, they each have four paralleled tinned copper wire links, ie, LK1, LK2 and LK3 for high-side switching or LK4, LK5 and LK6 for low-side switching.

The component overlays for the two PCBs are shown in Fig.4 – power board at top and the control board below.

Start by assembling the control board and install IC2 first, as it is the only surface-mount component used in this project. Align the IC onto the pads and solder one corner lead to the PCB. Check that the IC is aligned correctly before soldering the remaining pins. You can re-align the IC easily by melting the solder joint and readjusting the position. Check that none of the IC leads are shorted with solder. Any excess solder can be removed with solder wick.

Next, you can install the resistors. We recommend that you use a digital multimeter to check the values of each resistor, as you install them. Note that the values for R1 and R2 are dependent upon the battery supply, as shown in Table 1, which is slightly modified from that in last month's issue.

Diodes D2 and D3, and ZD2 and ZD3 can be installed next. These need to be inserted with the correct polarity, with the striped end (cathode, k) oriented as shown in the overlay diagram.

Zener diode ZD4 is only used when the battery voltage is higher than 12V; Table 1 shows the required zener for 24V, 36V or 48V batteries. Note that for a 12V battery, when ZD4 is not required, JP1 is installed instead. Only if you are using low-side switching, install JP2 at the same time, otherwise it must be omitted.

There are five test points, at TP1, TP2, TP GND, TPS and TPV. To make them easy to use, we suggest that you install a PC stake at each point. Next, install the 18-pin DIL socket for IC1. Ensure it is oriented correctly.

Then you can install the capacitors, noting that the electrolytic types must be installed with the polarity shown on the overlay diagram. Note that the 10µF capacitor located just to the left of REG1 has a 63V rating, as shown on the diagram.

REG1 and REG2 mount horizontally on the PCB with their leads bent at 90° to allow them to be inserted into the holes. The metal tab is secured to the PCB using an M3 x 6mm screw and M3 nut. Secure each tab before soldering the leads.

Trimpots VR1 to VR7 come next. VR1 to VR6 are 10kΩ and may be marked as 103. VR7 is 50kΩ and may be marked as 503. Switch S2 is installed directly onto the PCB.

Terminal strips and LEDs

Terminal strips CON7 and CON8 are made by first dove-tailing two sections together. CON7 comprises a 3-way terminal with a 2-way section secured on each side. Similarly, CON8 is made by dovetailing a 3-way and 2-way terminal.

Orient these with the wire entry side adjacent to the edge of the PCB.

LED1-LED4 need to have their leads bent so they can protrude through the side of the diecast box. Each LED is mounted so the inside of the top lead is 15mm above the PCB.

Drilling the case

Now insert the control PCB inside the case. Mark the mounting hole positions and drill the required four 3mm holes.

Final PCB preparation involves attaching an M3 tapped × 9mm standoff to each corner mounting position.

The other holes in the side and lid of the case are shown in the diagram of Fig.5 on page 67. The required holes for the LEDs are 5mm in diameter and 25mm up from the outside base of the case. Do not forget to drill the hole at the CON7 end of the box for the cable gland. Drill this hole 25mm down from the top edge.

Mount the PCB onto the spacers with the M3 × 6mm screws. If using countersunk screws on the base, countersink the holes first. Secure to the base of the box with the M3 screws.

Power PCB assemby

Assembly of the PCBs can begin by installing the 4.7Ω gate resistors for MOSFETs Q1 and Q2, and 15V zener diode ZD1.

As already noted, the high-current links for low or high-side switching each consist of four sections of tinned copper wire. And we now repeat: only install LK1, LK2, LK3 and LK7 for high-side switching (HSS) or LK4, LK5, LK6 and LK8 for low-side switching (LSS). These links are shown in red for HSS and blue for LSS. **Do not install both sets otherwise you will provide a complete short circuit which will vaporise the fuse!**

Note that each set of HSS ***or*** LSS links must be soldered on both the top and bottom of the PCB.

Q1 and Q2 are mounted directly on the PCB and secured with M3 screws and nuts. Bend the leads to insert into the MOSFET holes on the PCB and solder the leads to the top and bottom of the PCB.

Diode D1 is mounted in the same manner. Note that it was installed differently on our prototype, but this has now been fixed.

Fuse and fuse clips

Now some notes about the fuse clips and fuse. The fuse holder clips are rated for a continuous current of up to 30A, although it is possible to fit a 40A fuse.

If the motor you intend to use with this controller is rated for a continuous current up to 30A, then there is no problem. Solder the fuse clips on both sides of the PCB.

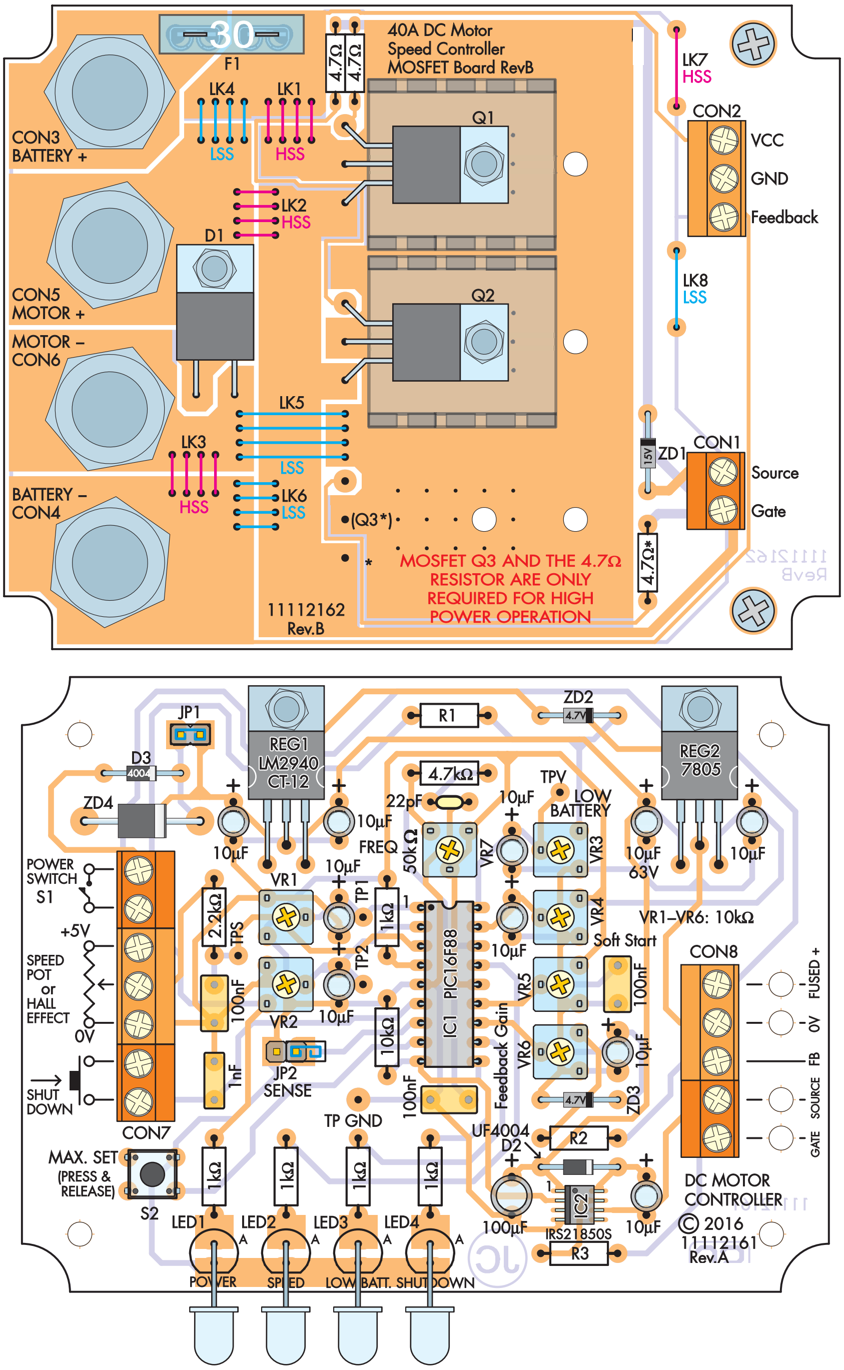

Fig.4: component overlays for the two PCBs – the power board at top and the control board at bottom. Again, we must reiterate that only one set of links (LK1-LK6) for either high-side switching (pink) or low-side switching (blue) can be fitted, otherwise the life-span of the fuse can be measured in milliseconds!

On the other hand, if your motor has a continuous current of up to 40A or more, the PCB-mount fuse clips will not be adequate.

In this case, the correct approach is to fit an in-line 5AG fuseholder in place of the 30A blade fuseholder (eg, Jaycar SZ-2065) together with a 40A 5AG fuse. The holes in the PCB which housed the 30A fuseholder may need to be enlarged slightly to fit heavy-current wires for the 5AG fuseholder.

Terminals CON1 and CON2 are mounted with the wire entry toward the outside of the PCB.

Install the two 12mm spacers on the underside of the PCB using two M3 screws.

The banana connectors/binding posts are unscrewed and the insulating bush arrangement fitted on top and the underside of the lid, then the nut is attached. The second nut goes on after the PCB is attached to the terminals. Use red for the Motor+ and Battery+ and black for the Motor– and Battery– terminals. Fig.6 shows the wiring connections between the two PCBs.

Make sure there is sufficient length for each wire so the terminal side of the 'power' PCB can sit over the CON8 terminals. The wires are secured with cable ties.

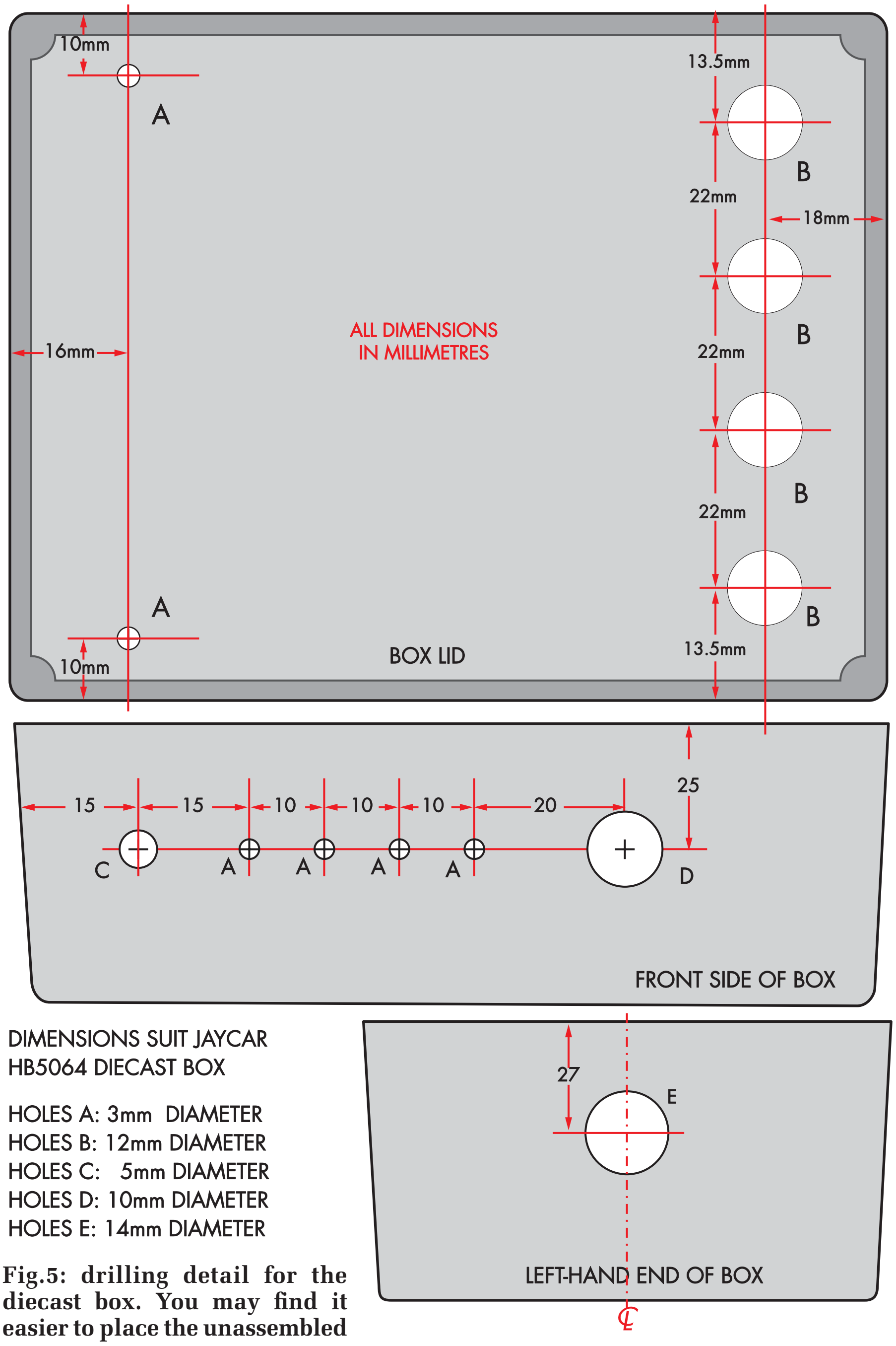

Fig.5: drilling detail for the diecast box. You may find it easier to place the unassembled 'power' PCB on the lid (underside) and use it as a template to mark out the lid holes – they're the only ones that are really critical.

Nominal supply voltage	R1	R2	JP1 Inserted?	ZD4
12V	22kΩ	10kΩ	Yes	None
24V	56kΩ	27kΩ	No	10V 1W
36V	82kΩ	47kΩ	No	20V 1W
48V	91kΩ	68kΩ	No	30V 3W

Table 1: resistor, zener and jumper settings for various battery voltages.

For the main control PCB, there are holes available on the PCB in front of the screw terminals that allow cable ties to secure the wiring to the PCB for strain relief.

For our prototype, we installed the power switch on the side of the box adjacent to the Power LED and wired it to CON7. Similarly, the throttle can be installed in the box.

However, the switch and throttle would generally be used separate to the box, with the wires passing through the cable gland from CON8 and to a potentiometer or throttle. The emergency shut-down switch wiring would also pass through this gland.

Wiring to a motor

Unless the motor is to run at a full 30A load current continuously, 25A-rated wire could be used to make the battery and motor connections. Typically, this wire comprises 41 strands of 0.3mm tinned copper wire. These wires will fit through the binding post wire hole.

For higher current, use 56A wire (7 × 95 × 0.12mm wire). This wire won't fit through the post wire hole. However, you can crimp the wires first to 8mm ID crimp eyelets and secure these to the terminals.

Testing

With IC1 out of its socket, apply power between the Battery+ and Battery– terminals. Check that there is approximately 12V at the output of REG1 and 5V at the REG2 output. Rotate VR2 and VR3 fully clockwise and VR1, VR4, VR5 and VR6 fully anti-clockwise. Set VR5 mid way.

If you are using a Hall effect throttle, monitor the voltage at TP1 as the throttle is rotated from minimum to maximum. Take note of the minimum and maximum voltage. Then set VR1 to the minimum voltage and VR2 to the maximum voltage.

Check that these settings are within the allowable range. See the specifications published in *Part 1* last month for the reference voltage settings. Now turn the power off and insert IC1.

Shut down

You can use the shut-down feature in one of two modes. Mode 1 is where normal motor speed control operation is restored once the throttle is returned to zero.

The second mode is where motor speed control operation is only restored when power is switched off and on again. Emergency shut down is indicated by LED4.

At every power up, this LED also lights up momentarily to indicate which mode is set. For the first mode, the LED blinks once and it blinks twice for the second mode.

To change the mode, press and hold the limit switch (S2) at power up. (Note that it is not the shut-down switch that is pressed at power up).

The mode will then change from one to the other. The shut-down LED will also flash once if it is the first mode that's selected, or twice for the second mode. The selected mode is stored in IC1 to be used subsequently.

Throttle limit

Press S2 and adjust the throttle for the maximum speed required from the motor. Release the switch at this speed.

In use, bringing the throttle beyond the speed limit will be indicated by the shut-down/limit LED lighting.

Low-battery threshold

The low-battery threshold is set by adjusting VR3 and measuring the voltage at test point TPV.

To make the adjustment, first decide on the low-battery cutout voltage required; typically 11.5V for a 12V lead-acid battery. Then measure the voltage at the switch S1 terminals or at the CON7 switch terminals when

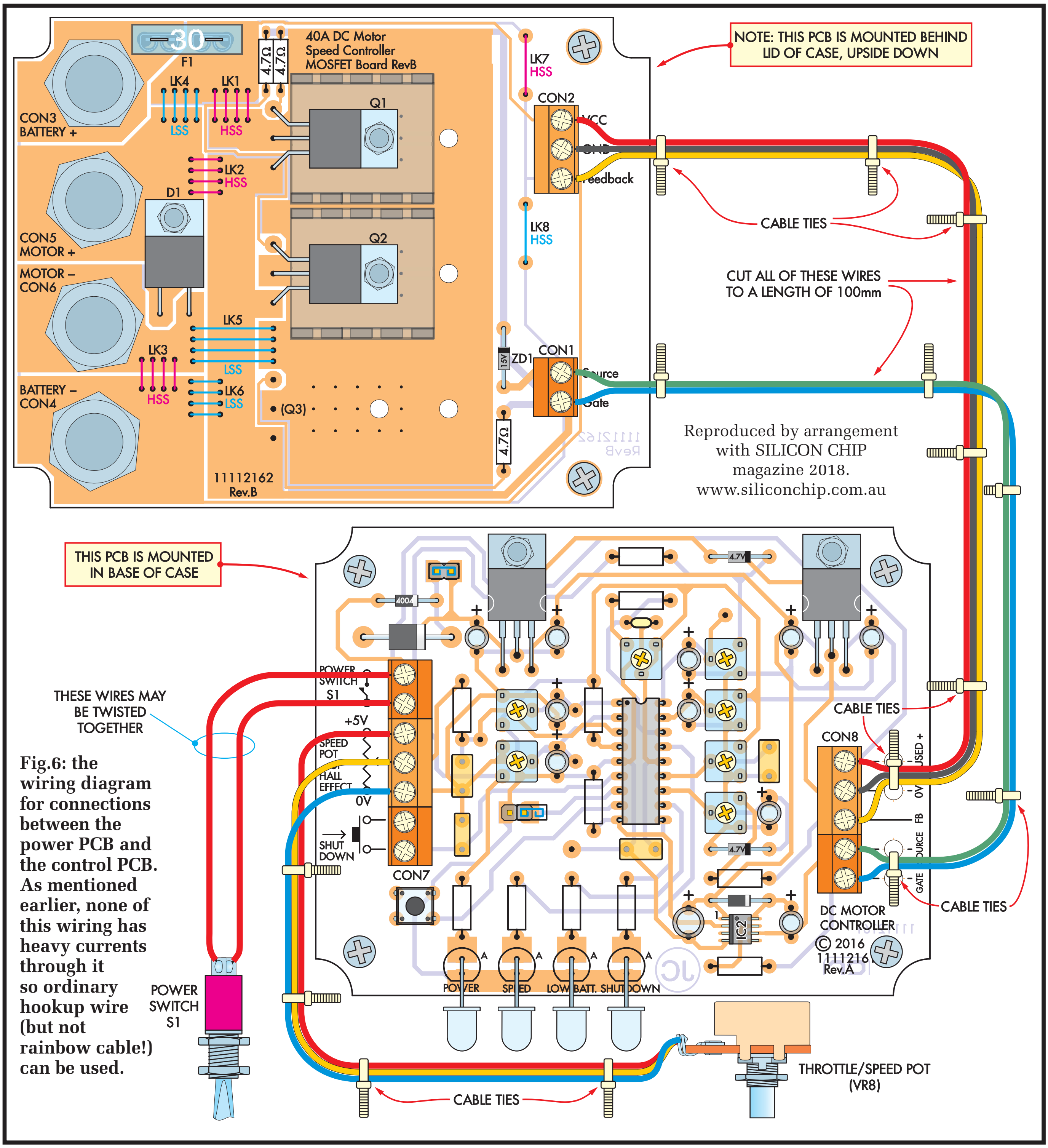

Fig.6: the wiring diagram for connections between the power PCB and the control PCB. As mentioned earlier, none of this wiring has heavy currents through it so ordinary hookup wire (but not rainbow cable!) can be used.

the switch is on and note it. Finally, measure the actual 5V supply (at the out terminal of REG2 – while the regulator has a nominal 5V output, it could be anywhere from 4.95V to 5.05V out).

Divide the voltage measured at S1 by the required low-voltage threshold value. Then multiply the result by one half of the actual 5V supply.

The formula is TPV = (voltage at S1 ÷ low-battery voltage value) x (the actual 5V supply ÷ 2).

Say, for example, the measured voltage at S1 is 13V and the required low battery shut-down voltage is 11.5V. Now divide 13V by 11.5V. The result of the calculation is 1.13. If the actual 5V supply is 4.95V, then half its value is 2.475V. Multiplying this by 1.13 gives a result of 2.80V.

Note that if you decide to change the low-battery threshold, the voltage at S1 needs to be re-measured and the TPV voltage recalculated and reset.

Adjusting feedback

Rotate the gain trimpot fully anticlockwise if you don't want motor speed feedback.

Otherwise, set the feedback control VR6 fully clockwise for high-side operaton (and fully anti-clockwise for low-side operation) and the gain control VR5 about one-third back from its fully anticlockwise position.

Then, with the motor running, rotate the feedback control anticlockwise (clockwise for low-side operation) until the motor just starts to increase in speed. Rotate slightly clockwise (anticlockwise for low-side operation), until the motor speed slows again. The gain control is then adjusted for the required amount of speed regulation when the motor is under load.

You can adjust the soft-start control VR4 and the frequency control VR7 to suit your particular motor and application.