# Enhanced 'Mk2' VK Powermaster

Here's a new and improved version of one of the most popular 13.8V power supply designs we've ever published. It now features an output current meter, a reset switch for the overload reset circuit, a powder-finished steel case and provision for an optional cooling fan to extend the continuous current rating to 15 amps (25A intermittent).

**by JIM ROWE**

Power supply designs have been always been very popular — especially those to provide 13.8V DC for operation of mobile radio equipment from the mains. Back in May 1978 we described a 13.8V/5A supply called the VK Powermate, which has been so popular that we've had to update it twice now: in December 1983 and more recently as the VK Powermate Mk2 in October 1988.

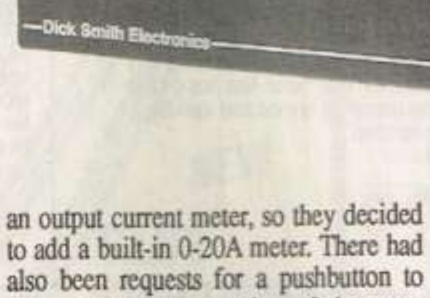
But while the VK Powermate design is capable of powering the majority of mobile radio transceivers, its 5A power rating has made it unsuitable for use with higher-powered equipment such as linear amplifiers. For these a somewhat 'huskier' supply is needed, and it was to fill this further need that we presented the design for a bigger brother of the Powermate, in the March 1984 issue: the VK Powermaster.

Designed by Rex Callaghan of the R&D Department at Dick Smith Electronics, the original VK Powermaster offered an excellent performance/cost ratio and has also been extremely popular. With a continuous current rating well over double that of the Powermate, and a peak current rating of 25A, it was capable of running all but the very highest-powered mobile gear. (And in January 1990 we described the VK Powermate 25, to cope with these too.)

But recently Rex Callaghan and his R&D colleagues at DSE decided that good though it was, the VK Powermaster design could still be improved. The original aluminium case was a bit light and spartan, for example, so they elected to replace it with a more professional powder-finished steel case, pre-punched and silk screened.

Over the years there had been quite a few requests for information on adding


an output current meter, so they decided to add a built-in 0-20A meter. There had also been requests for a pushbutton to allow convenient resetting of the over-



*Each of the four power transistors is mounted on its own finned heatsink. The correct mains fuse must be used.*

current protection circuit, so this was added as well.

Experiments had shown that the continuous current rating of the supply could also be increased to a comfortable 15A, if desired, by using a larger transformer and adding a cooling fan and a heatsink radiator for the rectifier bridge. So these were also provided for in the new design, along with some improvements to the basic design to enhance its transient overload tolerance and noise performance characteristics.

So that's the story behind this new, better than ever Mk2 version of the VK Powermaster design. Copyright for the front panel, case and PCB pattern for the new design is held by DSE, by the way, so in the form shown it can not be marketed by other firms. But DSE will be selling it as a basic kit, plus the various options needed to build it in any of three forms — with performance ratings as shown in Table 1. The basic kit has the DSE catalog number K-3400, and is priced at $189.00 — not including the power transformer and bridge rectifier, or the optional additional heatsink, fan and filter components.

## Circuit description

The circuit is very similar to that for the original VK Powermaster, which used a slightly unconventional approach in order to simplify the over-current protection system. The main rectifier section is quite standard, with an 18V secondary on the power transformer feeding a PB40 rectifier bridge followed by a parallel combination of four 10,000uF (10mF) reservoir capacitors. This provides the basic 'raw' DC output.

The regulator section uses discrete components, with a configuration which may seem 'upside down' because it has the series-pass transistors in the negative, rather than the positive rail. Although this is just as valid as the more usual arrangement, it may make it a little harder to follow its operation. The basic circuit is therefore shown in Fig.1, but with all of the polarities reversed so that you may find it easier to recognise.

As you can see, transistors Q2 and Q3 form a complementary- Darlington pair, acting as a series-pass emitter follower. Q1 acts as a comparator, comparing a preset fraction of the output voltage (applied to its base) with a regulated reference voltage at its emitter, established by the 220Ω resistor and 6.2V zener diode. In turn Q1 controls the base voltage and current of Q2, to provide a high degree of negative feedback and regulation of the output voltage, at a point where the voltage at Q1's base is just one Vbe drop (0.6V) above that at its emitter — i.e., at around 6.8V.

If the output voltage attempts to rise, the voltage at the base of Q1 will rise above this level; as a result Q1 will conduct more and this reduces the drive to Q2 and Q3, correcting the situation. Similarly if the output voltage tends to fall, the voltage at Q1's base will fall below 6.8V and Q1 will conduct less, increasing the drive to Q2 and Q3 to again correct the situation.

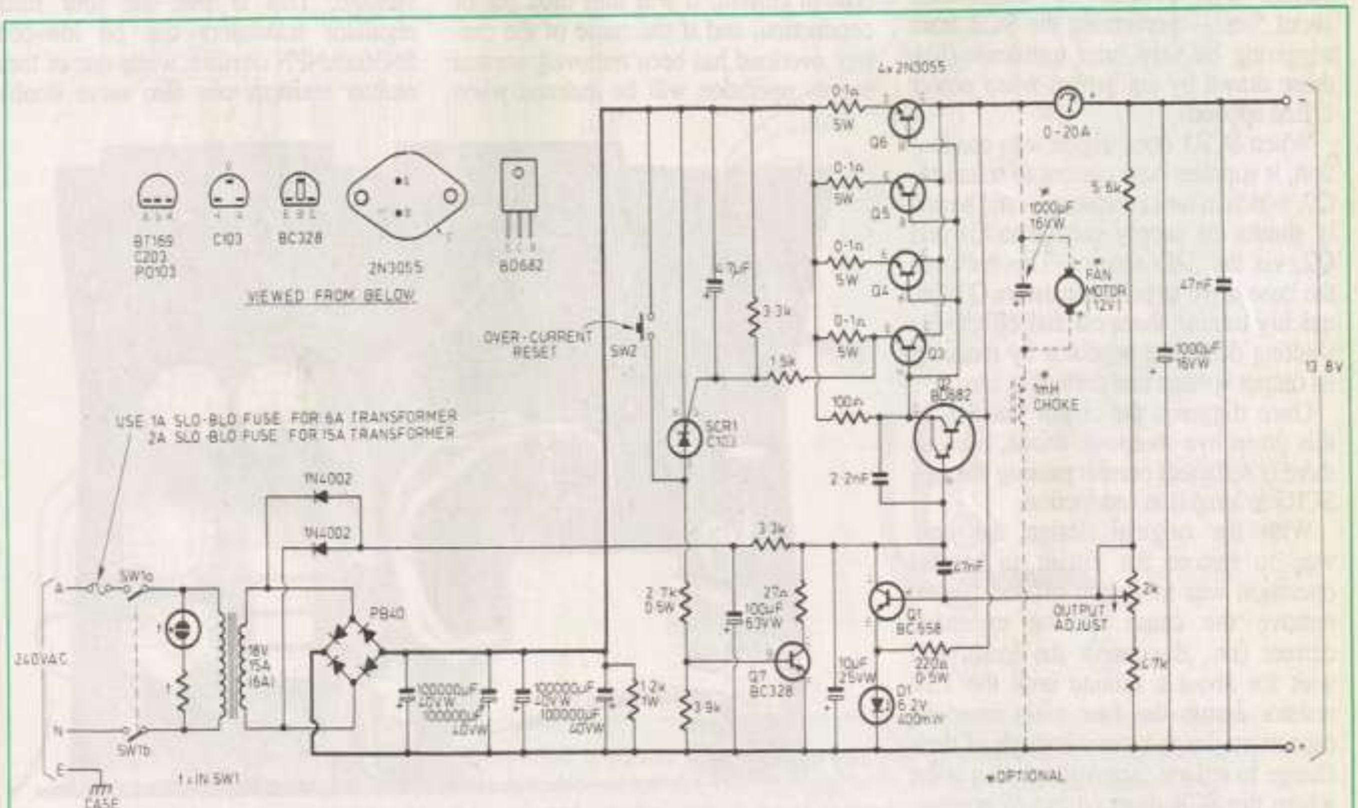
The preset pot in the base circuit of Q1 allows adjustment of the exact proportion of the output voltage fed back to the base, hence varying the output voltage level which corresponds to the circuit's stable operating point where Q1's base is at 6.8V. Another way of visualising the pot is as a control over the feedback loop's overall DC voltage gain. Either way, the bottom line is that the pot acts as an adjustment for the circuit's regulated DC output voltage, allowing it to be set to exactly 13.8V.

Note that with this kind of regulator configuration the supply current for Q1 and the base of Q2 is best fed from a separately derived and filtered voltage source, to ensure optimum regulation at high currents. As we'll see in a moment, this also allows use of a relatively simple circuit for over-current protection.

Hopefully with this understanding of basic circuit operation based on Fig.1, you'll now be able to make sense of the full schematic — despite the reversed polarities. Comparator transistor Q1 is now a BC558 PNP transistor, with its emitter connected to a reference voltage of -6.2V provided by zener diode D1.

Transistor Q2 is now itself a BD682 PNP Darlington device, to provide sufficient current gain and output drive capability, while Q3 of Fig.1 has now become four 2N3055 NPN power transistors, connected in parallel and all mounted on finned heatsinks to provide the required high current rating. The four 0.1Ω/5W emitter resistors are used to ensure that they share the output current equally.

Note that the optional 0-20A ammeter, if used, is connected in the output line *before* the voltage divider feeding the base of Q1, so that it is 'inside' the regulator's feedback loop. This means that the meter's voltage drop is compensated by the regulator, and doesn't degrade the supply's regulation.




***As you can see from the schematic, the Powermaster uses a fairly standard regulator configuration, except that it uses complementary devices to those often used — and hence may look 'upside down'.***

The supply voltage for Q1 and the base of Q2 (now negative) is derived from the 18V transformer secondary using a pair of 1N4004 diodes, feeding a 100uF/63VW reservoir electro and a filter circuit using the 3.3k series resistor and 10uF/25VW electro.

Note also that both Q1 and Q2 have small capacitors connected between collector and base, to reduce their gain at high frequencies and hence reduce any likelihood of instability in the regulator's feedback loop.

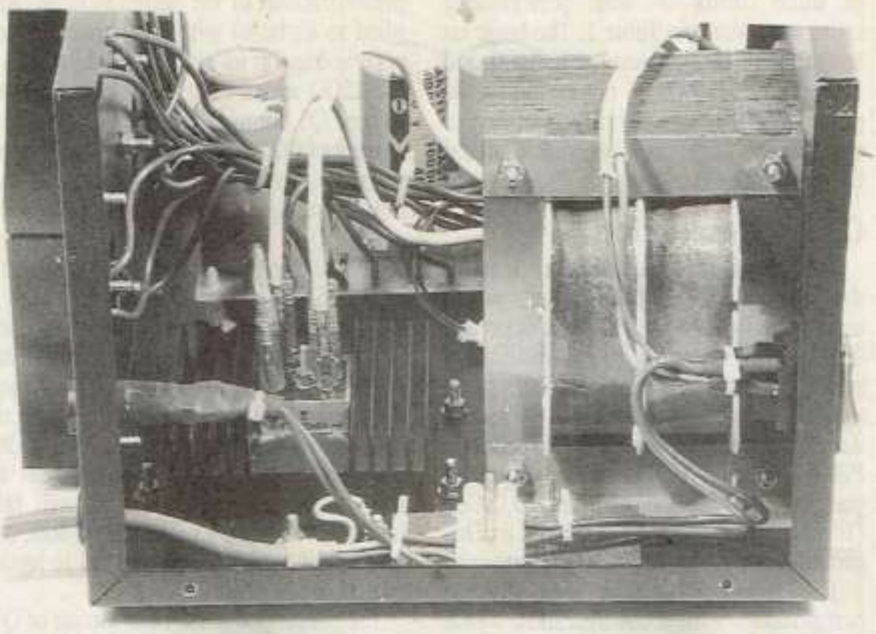
Now let's look at the circuit's over-current protection, based around SCR1 and Q7. The basic idea here is that SCR1 monitors the voltage drop across the emitter resistor of Q3; since this resistor carries 25% of the total load current, its voltage drop is thus directly proportional to load current (100mV for each 4A of total load current).

The gate-cathode circuit of SCR1 is effectively connected across this resistor, via the resistive divider formed by the 1.5k and 3.3k resistors. This means that when the total output current from the supply rises above about 27A, the gate-cathode voltage of SCR1 exceeds 0.65V and the SCR is triggered into conduction. The 4.7uF capacitor between gate and cathode is used to ensure that this only happens when the excessive load current level persists for longer than about 5ms — preventing the SCR from triggering on very brief transients (like those drawn by equipment when power is first applied).

When SCR1 does trigger into conduction, it supplies base current to transistor Q7, which in turn conducts — and heavily shunts the supply voltage to Q1 and Q2, via the 27Ω resistor. This removes the base drive to pass transistors Q3-Q6, quickly turning them off and effectively shutting down the regulator by reducing its output voltage and current to zero.

Once triggered the circuit 'latches' in this protective shutdown mode, because there is sufficient current passing through SCR1 to keep it in conduction.

With the original design the only way to restore the circuit to normal operation was to switch off the power, remove the cause of the excessive current (i.e., disconnect the load), and wait for about a minute until the 1.2k resistor across the four main reservoir capacitors drained away enough of their charge to reduce their voltage to a point where the SCR dropped out of conduction. Then the power could be switched back on, and the supply would return to normal operation.

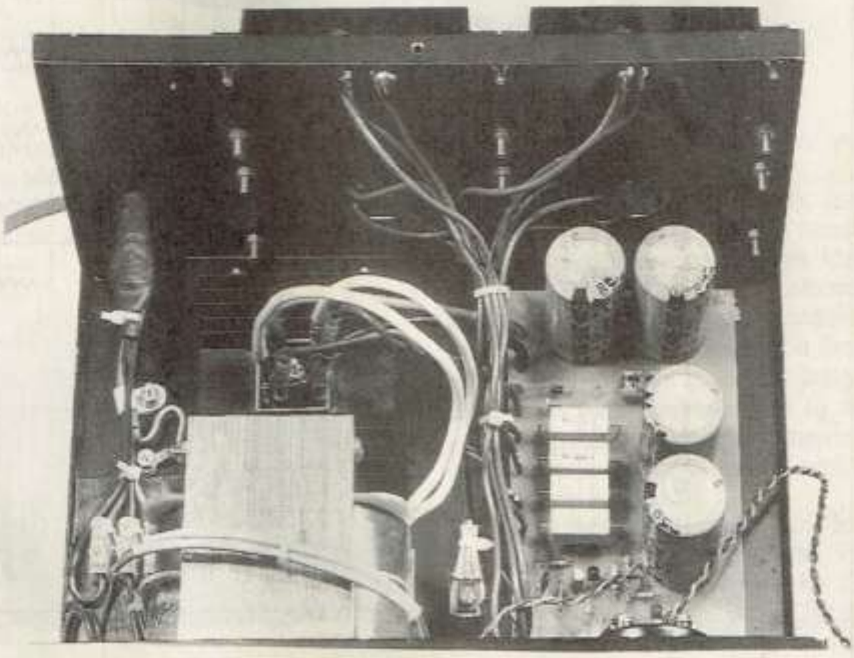


***A view inside the left-hand end of the case, showing the mains wiring and also the rectifier bridge on its optional heatsink. As explained in the text, insulating sleeves should be fitted over all terminations of the mains wiring.***

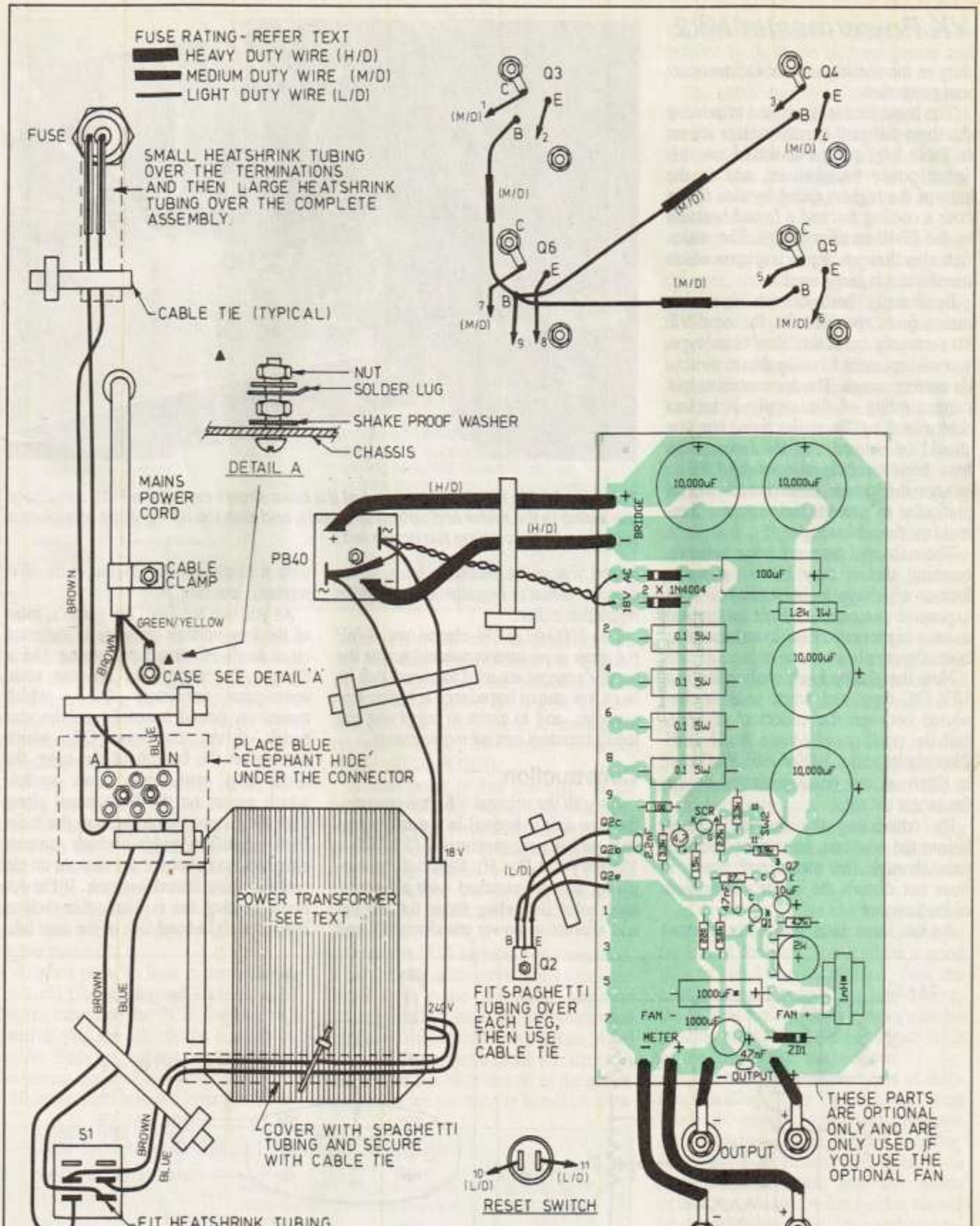
The addition of pushbutton SW2 to the design has made resetting more convenient. All you have to do now is disconnect the load (if the overload is due to a load fault), and press the button.

This places a temporary short between the SCR's anode and cathode, reducing its current to zero and hence removing its hold-in current. It will thus drop out of conduction, and if the cause of the current overload has been removed, normal supply operation will be restored when SW2 is released. Of course if the fault causing the overload is still present, the SCR will trigger on again and the circuit will latch off once more...

So that's the basic operation of the VK Powermaster circuit. Note that the final circuit configuration, 'upside down' compared with Fig.1, has one big advantage. This is that the four main regulator transistors can be low-cost 2N3055 NPN devices, while one of their emitter resistors can also serve double



***A general view inside the supply's case, showing the positions of most of the major items. Note that the rectifier bridge is shown mounted on the optional finned heatsink (see text).***




***We've combined the usual PCB overlay diagram with a complete wiring diagram, to help you in assembling the new VK Powermaster. Note that the two components on the PCB marked with an asterisk are only required if the optional cooling fan is used to increase the supply's continuous current rating.***

duty as the sensing resistor for over-current protection.

The basic circuit is adapted to achieve the three different current ratings shown in Table 1 by using a choice of two different power transformers, and in the case of the highest rating by also fitting both a cooling fan and a finned heatsink to the PB40 rectifier bridge. The mains fuse also changes, depending upon which transformer is being used.

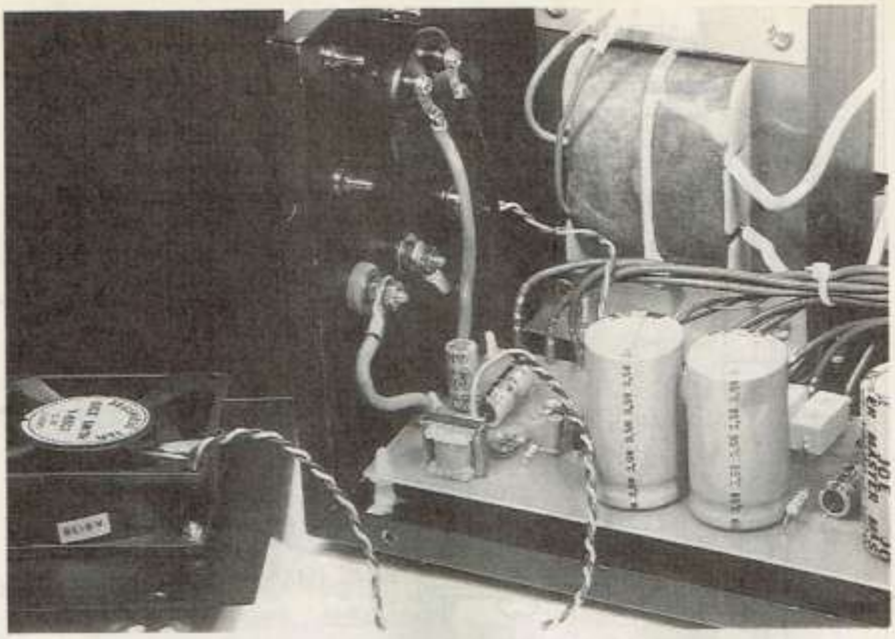
Incidentally both of the alternative mains fuses specified for the new VK Powermaster are of the 'slow blow' type, to avoid spurious blowing due to switch-on current surges. The continuous output current rating of the supply is in fact determined by the mains fuse, but you should be warned that the fuse ratings have been carefully selected by DSE to protect the power transformers and in particular to prevent their internal thermal fuse from blowing.

These thermal fuses are non-resettable, meaning that if they blow, the transformer will have to be replaced — an expensive exercise. So don't be tempted to use a higher rated fuse, in an attempt to boost the supply's current rating...

Note that the optional cooling fan is a 12V DC type, and when used is connected between the collectors of Q3-6 and the positive rail, via a small 1mH filter choke and a 1000uF/16VW electro to filter out any noise generated by the fan motor circuit.

By connecting the fan into circuit before the ammeter, its current does not pass through the meter and hence it does not disturb the meter's indication of load current.

At the same time the motor is connected within the feedback loop, so its current doesn't degrade the supply's regulation either.



*This view inside the right-hand end of the case shows part of the PCB assembly, the wiring to the meter and output terminals, and also the wiring and components for the optional cooling fan (lower left).*

The 1000uF/16VW electro and 47nF polyester capacitors connected across the supply's output are used to ensure that its has a low output impedance at higher frequencies, and to assist in supplying the load's transient current requirements.

## Construction

As with the original VK Powermaster, the new unit is housed in a sturdy metal case which now measures 275 x 220 x 155mm (W x D x H). DSE will be supplying this pre-punched with all necessary holes (including those for the fan and alternative power transformers), and with a black powder coating with silk-screened lettering.

As you can see from the photo's, most of the low voltage circuitry is mounted on a small PC board measuring 185 x 88mm. The exceptions are the main series-pass transistors Q3-6, which mount on finned heatsinks on the rear panel; driver transistor Q2, which mounts on the bottom of the case; the meter and over-current reset switch, which mount on the front panel along with the output terminals; and the main PB40 rectifier bridge, which mounts either on the bottom of the case, or on the optional extra finned heatsink. If the optional cooling fan is fitted, this mounts inside the right-hand side of the case lid.

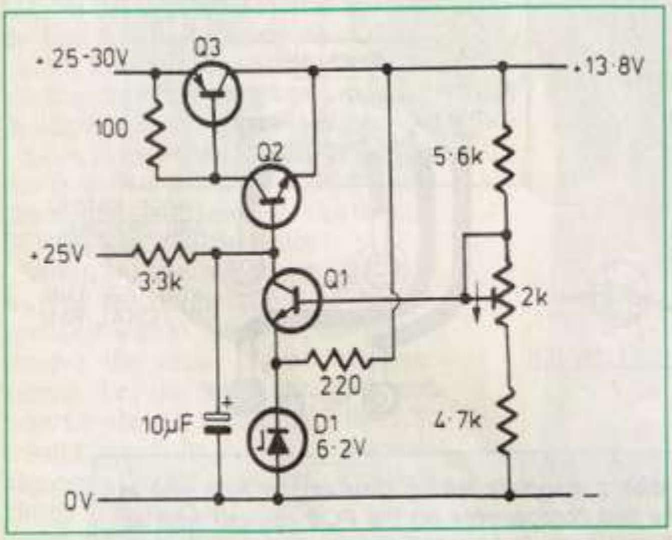



*Fig.1: Here is the basic regulator configuration used in the Powermaster, drawn here using the more usual device polarities. The main circuit uses their complements.*

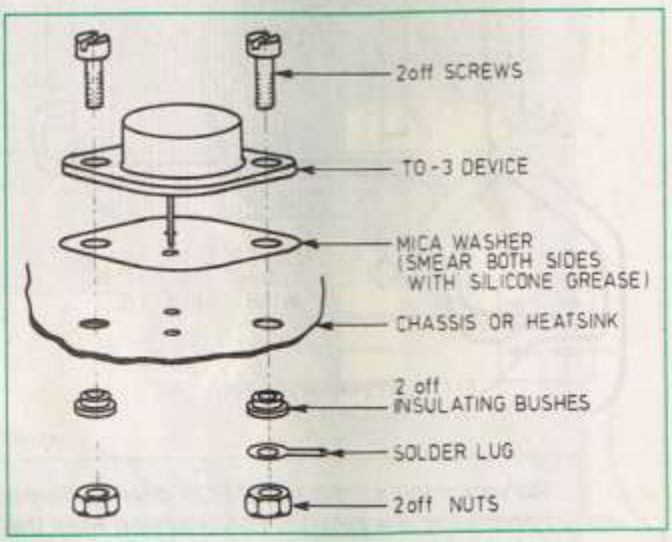



*Fig.2: A detailed drawing showing the correct way of mounting the TO-3 power transistors. Ensure that the holes in the heatsink are carefully deburred first.*

## PARTS LIST

### Resistors

(1/4W 5% unless indicated)
4 0.1 ohms 5W
1 27 ohms
1 100 ohms
1 220 ohms 0.5W
1 1.2k 1W
1 1.5k
1 2.7k 0.5W
2 3.3k
1 3.9k
1 4.7k
1 5.6k
1 2k linear trimpot

### Capacitors

1 2.2nF metallised polyester
2 47nF ceramic
1 4.7uF 10VW electro (RB)
1 10uF 25VW electro (RB)
1 100uF 63VW electro (axial)
1 1000uF 16VW electro (RB)
4 10,000uF 40VW electro (RB)

### Semiconductors

1 PB40 bridge rectifier
2 1N4004 silicon diodes
1 6.2V 400mW zener diode
1 BC558 PNP silicon transistor
1 BC328 PNP silicon transistor
1 BD682 PNP power Darlington
4 2N3055 NPN power transistor
1 C103 or similar SCR

### Miscellaneous

1 Steel case, 275 x 220 x 155mm
1 PC board, 185 x 88mm (DSE ZA-1364)
4 Pre-drilled finned heatsinks
1 0-20A panel meter
1 Two-pole mains rocker switch, with inbuilt neon
1 Fuseholder, 3AG safety type
1 Three-wire mains cable with plug
1 Grille for cooling fan opening
1 Single pole momentary pushbutton(SW2)

Black and red screw terminals, heavy duty; 'Slo Blo' mains fuse (for rating see text); power transistor mounting hardware (4 x TO-3, 1 x TO-126); cable clamp; 10mm rubber grommet; 3-way mains terminal block; solder lugs; space lugs; PCB pins; fast-on connectors and 'double adaptor' lugs; nylon cable ties; 4 x rubber feet; 4 x nylon standoffs for PCB; silicone grease; light, heavy and very heavy hookup wire; heatshrink tubing and cambric 'spaghetti'; insulating paper; machine screws, nuts, flat and shakeproof washers; solder, etc.

### Optional

1 12V 'muffin' cooling fan
1 1mH filter choke
1 1000uF 16VW electro (axial type)
1 Finned heatsink for bridge rectifier

Needless to say the power transformer mounts on the bottom of the case as well, while the mains switch SW1 mounts on the front panel at the left-hand end. The mains fuseholder is of the 'safety' type, and mounts on the rear panel just above the mains cable entry.

Wiring of the components on the PCB should be quite straightforward using the overlay/wiring diagram as a guide, but there are a few points to note. The four 0.1Ω 5W current sharing resistors should be mounted with their bodies about 5mm above the board, as they get quite hot when the supply is delivering higher current.

Another point to note is that although the 1mH filter choke and 1000uF 'axial' electro mount on the PCB, they are only fitted if you are adding the cooling fan option. Both are shown with asterisks on the wiring diagram, as a reminder.

Note too that there are a number of different SCRs that may be supplied with the kit, with two different pin orientations as shown on the schematic. The PCB overlay shows the correct orientation for the C103 type; it should be reversed for the other variety (BT169/C203/PO103).

A final point is that although the 2k preset pot used for output voltage adjustment is of the 'vertical mount' type, it is mounted here with its leads bent, so that it is nearly parallel with the PCB and only just above the surface. This is to permit easy adjustment when everything is assembled.

Once the PCB assembly is completed, it can be put aside while you mount the larger items to the case. Small diagrams are provided to show the recommended way to do this, including a diagram of the way the power transistors are fitted to their heatsinks. Note that all of the power transistors are electrically insulated from the heatsinks, while being thermally bonded to them via silicone grease and mica washers.

The same applies to driver transistor Q2, which is insulated via a TO-126 mica washer and insulating sleeve, while the underside of the bridge rectifier should also be smeared with silicone grease so it makes good thermal contact with the case.

Other small diagrams show the way that the mains cord should be clamped to the case, the mains connector block attached to it, the mains earthing solder lug fitted, and also how the DC output terminals are fitted. Further diagrams show how the optional fan is fitted inside the lid, and how the bridge rectifier is mounted on the optional extra heatsink.

Don't forget to carefully check all of the case and heatsink holes for metal burrs, before you mount anything. If you find any burrs these should be carefully removed with a small file or medium-sized twist drill; a burr on the mains cord entry hole could cut through the rubber grommet, while burrs on the various semiconductor mounting holes could prevent the correct insulation.

The main wiring diagram also shows how the various interconnecting wires inside the case should be sleeved and tied together, for maximum reliability and safety.

Note that the mains rocker switch SW1, which is fitted with an internal neon lamp, is simply snap-fitted into a matching rectangular hole in the front panel. Its connections are made using 'quick connect' push-on connectors, and these are also used for the connections to the bridge rectifier.

After mounting the main power transistors to their heatsinks, and Q2 to the bottom of the case, it would be a good idea to check their insulation from the case metalwork before you wire them to the PCB assembly. Then if there's an insulation problem, you'll be able to fix it before any damage can be done.

Again note that various types of insulated hookup wire should be used inside the supply, depending upon the current and/or voltage they're carrying. For example the mains wiring, between the connector block and the mains switch, and also to the fuseholder, should be in reasonably heavy wire with mains-rated insulation.

The usual colour coding should be observed, too: brown for active, blue for neutral and green/yellow for earth. After the various joints are made, according to the wiring diagram, they should each be covered with either tight fitting 'spaghetti' (varnished cambric) sleeving,

## TABLE 1: Current Ratings[1]

| | Basic with M-2000 transformer | Basic with M-2010 transformer | Upgraded[2] with M-2010 transformer |
|---|---|---|---|
| Continuous | 5A | 8A | 15A[3] |
| Peak (1 min.) | 10A | 20A | 20A |
| Surge (pulse) | 25A | 25A | 25A |

**Notes:**

1. Conditions are 240V AC input, 25 °C ambient temperature.
2. Upgrade consists of adding a DSE H-3470 heatsink to the bridge rectifier, a Y-8507 12V cooling fan to the case and a 1000uF 16VW electro and 1mH filter choke to the PCB.
3. The 15A limit is determined by the 2A primary circuit fuse. However this fuse rating must not be increased as it is designed to fail before the internal and non-resettable thermal fuse in the M-2010 transformer.

or small heat-shrink sleeving — threaded on before the joint is made. In the case of the fuseholder it is also good practice to cover the complete assembly with a sleeve of larger diameter heatshrink tubing, for added safety.

Similarly the leads from the PCB to the output terminals, ammeter and bridge rectifier should be in very heavy 'auto cable', with plenty of copper to handle currents of up to 25A.

Most of the rest of the wiring should be in medium-duty stranded hookup wire, such as 32 x 0.2mm, rated to carry currents of up to 10A. However the leads to driver transistor Q2, the reset pushbutton SW2 and the optional cooling fan can be run in light- duty hookup wire, such as that in 'rainbow' ribbon cable.

To prevent undue flexing and strain on the solder joints where the various leads are attached to the PCB assembly, it's suggested that you prepare all of the leads first and solder them to the PCB, before mounting it into the case. Then after fitting the completed PCB assembly in position you can simply connect all of the 'other ends' of the leads, without having to move the assembly any further.

The rear of the case has four large circular holes, to allow you to make the connections to the power transistors conveniently after they and their heatsinks are attached to the case. As shown in the photo's and indicated in the main wiring diagram, the completed wiring should be tidied up using nylon cable ties. This not only makes the interior a lot less cluttered, but also reduces the likelihood of wires 'wandering' and touching things they shouldn't, if any of your soldered joints should fail.

## Testing & adjustment

When your VK Powermaster is complete, it's a good idea to check all of your wiring carefully before applying the power. Check it against both the wiring diagram and the schematic, if necessary, just to make sure — and be especially careful with the mains wiring.

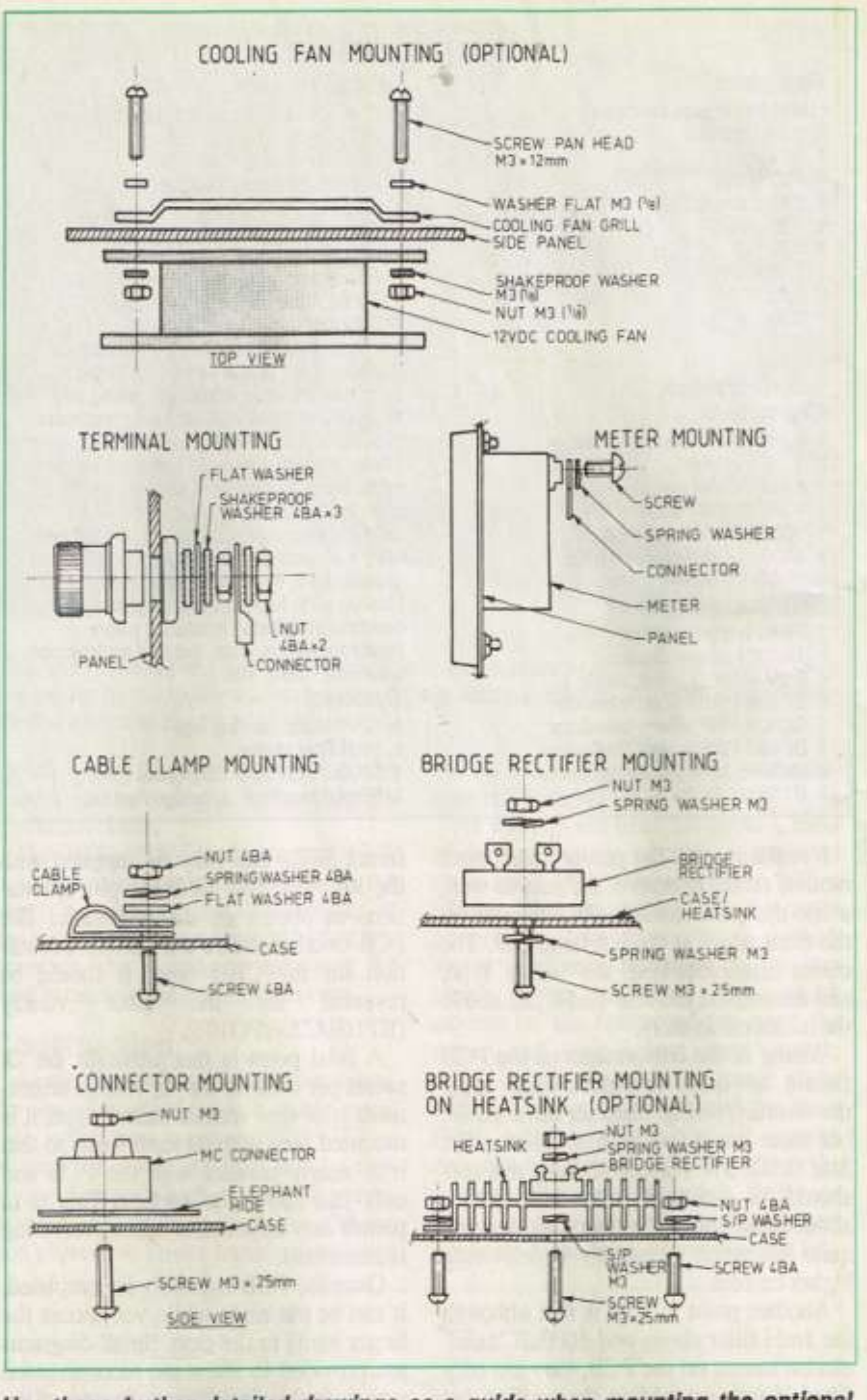
Then, if all seems well, make sure that the appropriate fuse has been fitted into the fuseholder, and you should be ready to apply the power.

Turning on the power should produce very little action, apart from a glow from the neon lamp in SW1 and possibly a slight hum from the power transformer. If you connect a DMM or multimeter across the DC output terminals, set to read DC voltage (say 0- 20V), you should get a reading somewhere between about 11.2V and 14V depending upon the exact voltage of your zener diode and the initial setting of your preset pot.

If the voltage is well outside this range, and particularly if anything is getting hot, switch off immediately and look for a wiring fault. Otherwise, you should be able to adjust the output voltage to exactly 13.8V using the preset pot.

That's really all there is to adjusting the supply, which should now be ready for service. If you wish, though, you can try testing the over-current protection circuit, by briefly applying a short circuit across the output terminals (using a short length of heavy-duty wire). The output voltage should immediately drop to zero, and the ammeter reading should merely give a brief upward flick before returning to zero. This state of affairs should remain even after the short is removed. However if you remove the short and then press the reset button SW2, the output voltage should re-appear as the supply swings back into life.

If your VK Powermaster comes through these tests with flying colours, you can be confident that it's working correctly. ❖




***Use these further detailed drawings as a guide when mounting the optional cooling fan, the main output terminals, the ammeter, the mains connector block, and the bridge rectifier (both options).***