EDITION 1

Assembly Manual

VERSATILE POWER SUPPLY

K-3460

DICK SMITH ELECTRONICS PTY LTD KIT

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This project, our first based on the Versatile Power Supply circuit, is a 'basic', low-cost variable power supply that may be powered from ac (a suitable transformer) or dc (a battery), and is ideal for the enthusiast's workbench or in the service workshop.

This is a straightforward power supply for the experimenter's bench or service workshop, featuring continuously variable output voltage and variable current limiting. No output metering has been included in order to keep costs down - your multimeter can be used here!

The AEM2520 project is a fully adjustable dc power supply which can take its input from almost any supply -either ac or dc - ranging from 10 Vdc volts to a maximum of 40 - 50 Vdc, or about 8 Vac to a maximum of 35 Vac (see 'Using the 2520'). The output current limit is continuously variable up to the maximum, which is in excess of two amps. The output voltage is likewise continuously variable, down to effectively zero volts.

Being a 'budget' project, a jiffy box with an aluminium lid was used to house it. As it may be powered from either ac or dc, "flying" input leads are used to connect the unit to whatever source – transformer or battery – you might employ.

Construction

This procedure is relatively straightforward.

SPECIFICATIONS **as measured on the prototype.**

Output Voltage Range:	0.015 V to 37 V with 40 V input. 0.008 V to 17 V with 20 V input.
Current Limit Range:	<30 mA to >300 mA (range 1) <250 mA to >2 A (range 2)
Load Regulation:	<0.01% at 100 mA load. Below 40 mV, zero to 2 A.
Line Regulation, dc:	<0.05% all conditions, overhead >3 V.
Line Regulation, ac:	Ripple signal 1 mV p-p at 500 mA. PSRR approx 0.1%.
Output Noise:	approx 0.6 mVrms, dc – 100 kHz.
Quiescent Current:	2 mA, plus current for LEDs (3.5 mA typically)

Following normal practice, begin with the metalwork. The first step is to mark out and drill the front panel of the jiffy box. You can use the front labels provided with your kit as a template for this. The panel is soft aluminium and is thus easily torn or warped.

Mark all hole centres with a scriber or pen, then either use sheet-metal drills, or drill small (around 3 mm) pilot holes and then expand them to the required diameter with the appropriate drill. A hand-operated tapered reamer, (available from the larger electronics retailers), does a very good job of enlarging holes in sheet metal, if it is used gently. It is a good idea to clean the sharp burrs from the holes after drilling with a cleaning tool or an oversized drill. This will protect your fingers and the front panel label later.

Next, use the panel itself as a template to mark where the holes should go in the heatsink. The heatsink position is not critical, except that it must not interfere with other things on the panel, including the screw which will hold the panel to the plastic part of the box. Drill the heatsink next.

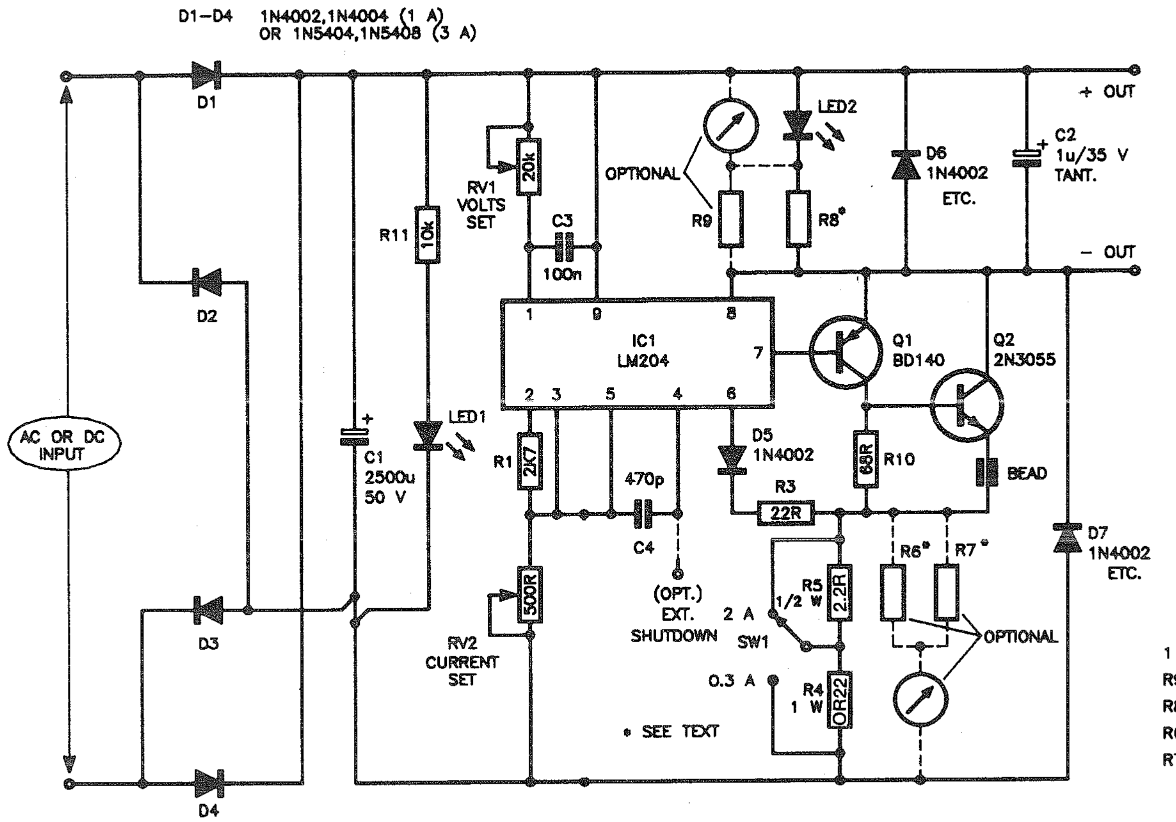
Now we drill the bracket to mount the printed circuit board to the panel/heatsink. We used a small section of 3mm aluminium extrusion.

Use the blank pc board to mark where the holes need to go on the heatsink bracket to take Q1 and Q2. Likewise, use the panel to mark where the holes in the bracket must go so that, in turn, it can be bolted to the panel and the heatsink. This order of marking will ensure that all the holes finish up compatible.

With the panel prepared, you can now place the two Scotchcal labels on the panel.

The project is housed in a commonly available jiffy box. Scotchcal labels are used to dress up the front panel and provide annotation for the controls, etc.

Text and Illustrations courtesy of Australian Electronics Monthly



CIRCUIT OPERATION

This supply is based around the LM204/304 negative regulator IC. Here we describe the function of the IC, and the purpose of all the components in the circuit. The IC has a number of functional parts: A current reference generator, a comparator, a driver amplifier and a current shutdown circuit.

A constant current is fed out of pin 1 of IC1, through RV1 to the positive incoming rail. According to the resistance setting of RV1, some voltage is dropped across it. The current is temperature compensated and thus the voltage dropped across RV1 at any particular setting is very constant. This constant current is set by R1.

The constant current, plus a little overhead current used by the current generator circuitry within IC1, is also passed through the combination of RV2 and R2 in parallel. Thus a fairly (but not rigidly) constant voltage is developed at the junction of R1 and R2 with respect to the other power supply rail, this time the negative one. The constant voltage developed by RV1 will be used to set the output voltage, and the voltage set by RV2 to determine the maximum deliverable output current.

A comparator circuit, again within IC1, looks at the voltage on pin 1 and also on pin 8, which is connected to the output of the regulator circuit as a whole. It then controls the driver circuit to set these two equal, thus copying the constant voltage dropped across RV1 to the load. This achieves very good output voltage regulation, since the comparator has significant gain. (It is really just an op-amp.)

The driver circuit feeds current out of pin 7 in an attempt to pull pin 8 *lower* when the comparator senses that more output voltage is required. This turns on Q1 more. As the current drawn by Q1 increases, the voltage dropped across R10 increases. As the current exceeds about 10 mA, sufficient voltage is dropped across R10 to turn on Q2.

Transistors Q1 and Q2 are connected as a **"Sziklai pair"**, which is like a Darlington pair, except that the transistors are of opposite polarity (pnp-npn). This has the advantage that no more than one Vbe drop is needed between pins 7 and 8, which serves to keep the voltage overhead (sometimes called the voltage burden) of the regulator as low as possible. The disadvantage is that the combination is more prone to instability than a Darlington arrangement, and thus the bead in the emitter of Q2 is required to maintain stability by introducing a high frequency impedance in the emitter of Q2 to degenerate it.

The driver circuitry also has its current used doubly, as did the constant current generator.

The current drawn by Q1 via pin 7 is fed out of pin 6. Now IC1 normally looks to see if the voltage on pin 6 has risen more than one diode drop above that on pins 3 and 5, which are expected to be connected directly to the negative rail. This arrangement is fine, but does not allow for varying the limit current, but fixes it as one Vbe drop across the current sense resistors.

We have arranged to fix pins 3 and 5 at a potential set by RV2. We have added R3 and D5 to cancel the diode drop inside IC1. The load current drawn via pin 7, Q1 and Q2 is passed through a current sensing resistance, selected by SW1 to be either 2.2 or .22 Ohms. The voltage dropped across these resistors is thus directly compared with the voltage set across RV2, and the drive shuts down if the latter is exceeded by the former. Should current metering be required this voltage provides it.

Having SW1 select one of two resistors for the sense resistance allows there to be two current ranges, in this case, one up to about 2 amps, starting at about a quarter of an amp, and the other one order of magnitude lower.

Diode D6 provides protection against external voltages being connected backwards across the output terminals. D7 protects IC1 from externally applied voltages while it has no supply. Resistor R3 allows the current limit to work earlier should Q1 and Q2 saturate, thus protecting the driver circuitry in IC1. Capacitor C4 compensates the op-amp inside IC1.

Finally, C3 removes voltage spikes and noise from across RV1, which prevents such noise and spikes from appearing at the output.

We have put a bridge rectifier and filter capacitor, D1-D4 and C1, in front of the regulator so that the supply can use either ac or dc inputs (of either polarity) for its source.

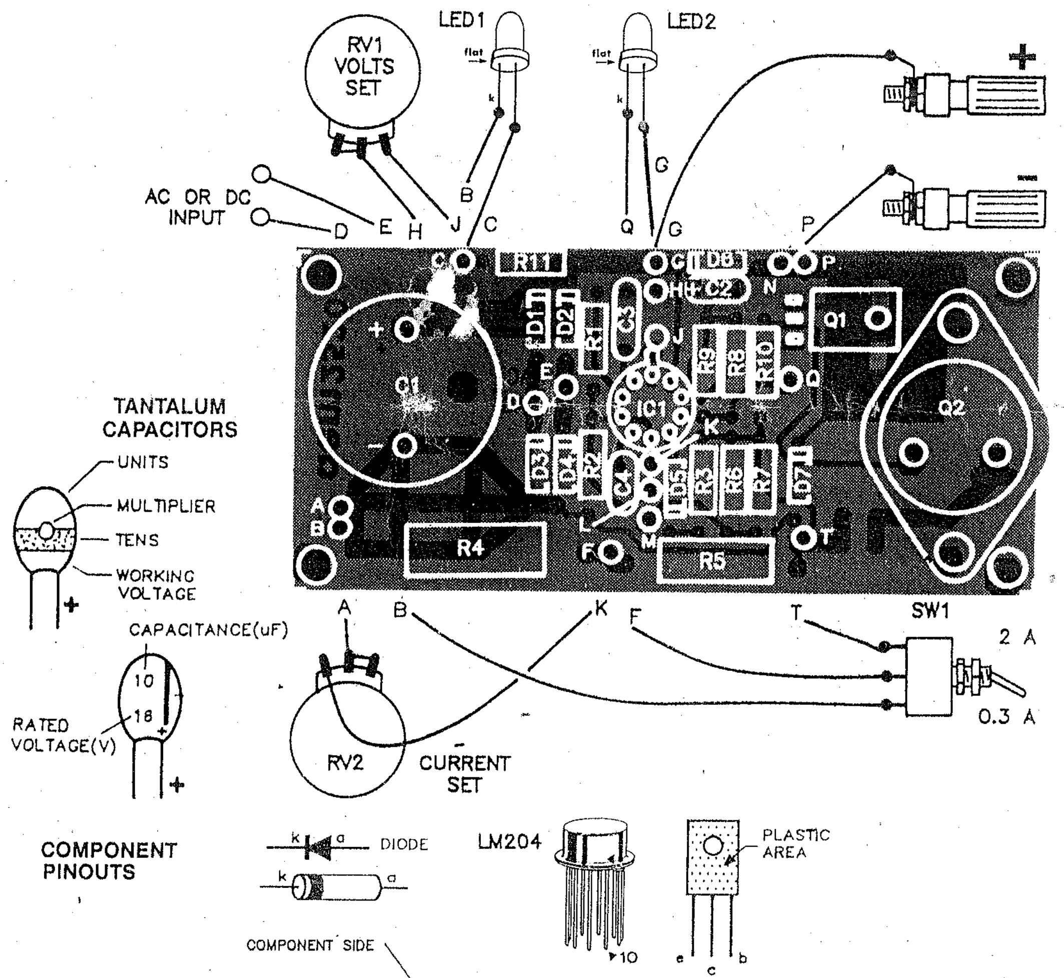
Capacitor C5 is placed across the output to keep the high frequency output impedance low, and the supply stable with large loads and long leads, but its value is small enough to limit the energy available before current limiting can act to less than one millijoule.

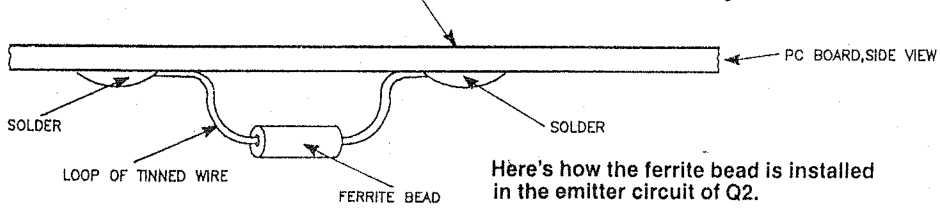
The availability of high efficiency LEDs permits the use of two of them as input and output voltage indicators, without seriously reducing the power economy of the circuit.

Resistors R11 and R8 are selected to obtain good brightness with modest input voltages for LEDs 1 and 2.

Constructors please note, when building our prototype unit we have discovered the need to include this Errata to rectify a few faults discovered in the instruction manual.

Please follow new overlay for corrections.





Here's how the ferrite bead is installed in the emitter circuit of Q2.

PARTS LIST AEM2520

Semiconductors

Q1 .... BD140, etc
Q2 .... 2N3055
IC1 .... LM204/304 (see text)
D1-D4 .... EM401/2/4, 1N4001/2/4,

or 1N5404 (see text)
D5-D7 . EM401/2/4, 1N4001/2/4

LED1, 2 .... LEDs

Resistors all 1/4 W, 5% unless noted

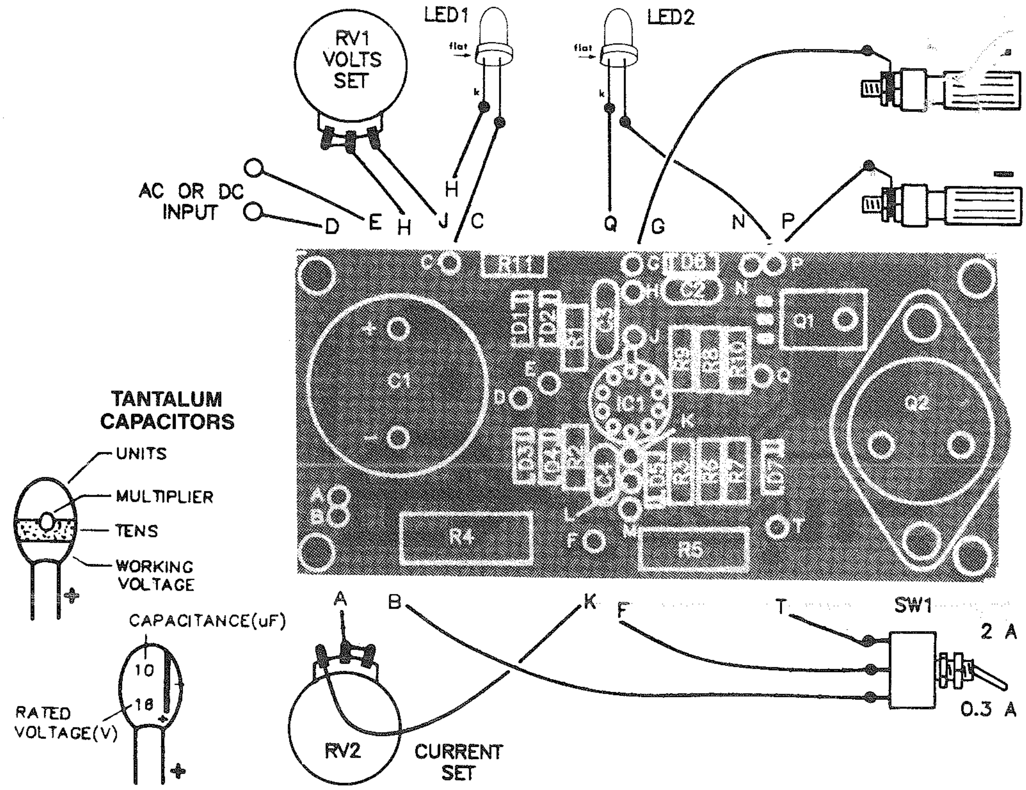
R1 ...... 2k7 1/4 W or 1/2 W
R2 .... Not used
R3 .... 22R
R4 .... .22R 1 W or 5 W
R5 .... 2.2R, 1/2 W
R6, 7, 9 ...... used only with metering
R8 .... 10k
R10 .... 68R
R11 .... 10k
RV1 . 20k/A lin. panel mount pot
RV2 .... 500R/A lin. panel mount pot

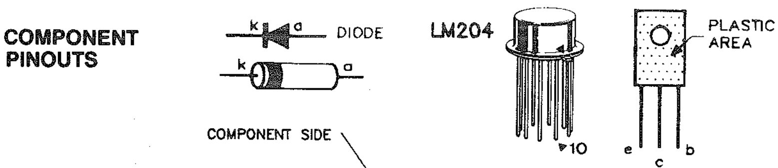
Capacitors

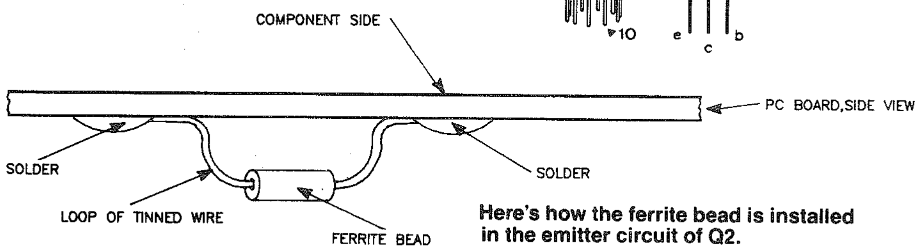
C1 .... 2500u/50 V RB electro.
C2 .... 1u/35 V tant.
C3 ...... 100n (0.1u) greencap (poly)
C4 .... 470p ceramic

Miscellaneous

AEM2520 pc board; ferrite bead; jiffy box – 190 x 110 x 60 mm; knobs to suit pots; heatsink – 100 x 37 mm; two screw-type terminals; SPDT toggle switch; two large alligator clips; two LED mounting bezels; one grommet; panel label; aluminium bracket; insulating washers for Q1 and silicone heatsink compound; heavy duty cable; hookup wire; tinned copper wire; nuts and bolts, etc.







Here's how the ferrite bead is installed in the emitter circuit of Q2.

Now mount all the components on the panel except the bracket: The terminals, the LEDs, the pots (with their knobs), the switch and the grommet in the cable entry hole.

Now turn your attention to the pc board. It is perhaps better to fit the heatsink bracket and Q1 and Q2 first. The case of Q2 does not need to be insulated from the bracket, as the case, which is the collector, is at output negative potential. It does, however, need to have adequate thermal conducting paste applied, since Q2 may have to dissipate a lot of energy.

Note that Q1 requires insulation. First check that there are no burrs or metal filings left from the drilling. Then apply a small amount of paste to the bottom of Q2 between the base and emitter pins and gently seat it in its place on the bracket. Put the pc board in position under the bracket and fit the two bolts to hold the three together.

Fit Q1's legs through the pc board holes, apply some paste to its underside, and also some to the heatsink. Sandwiching the insulating washer between the heatsink and Q1, bolt the three to the pc board. Tighten the bolts and solder the transistors in place.

Fit the remaining components to the pc board. A place for C1 is made on the pc board, but if you wish to use a chassis-mounted capacitor, or you cannot get the large "RB" type capacitor, there is no special need for it to be pc board mounted. If an off-card component is used, be sure to run relatively heavy wires, say of at least 1 mm diameter, since the full load current must be drawn through them, and ripple specification depends upon the low resistance of the connection. Make certain the polarised capacitors, diodes and IC are oriented correctly.

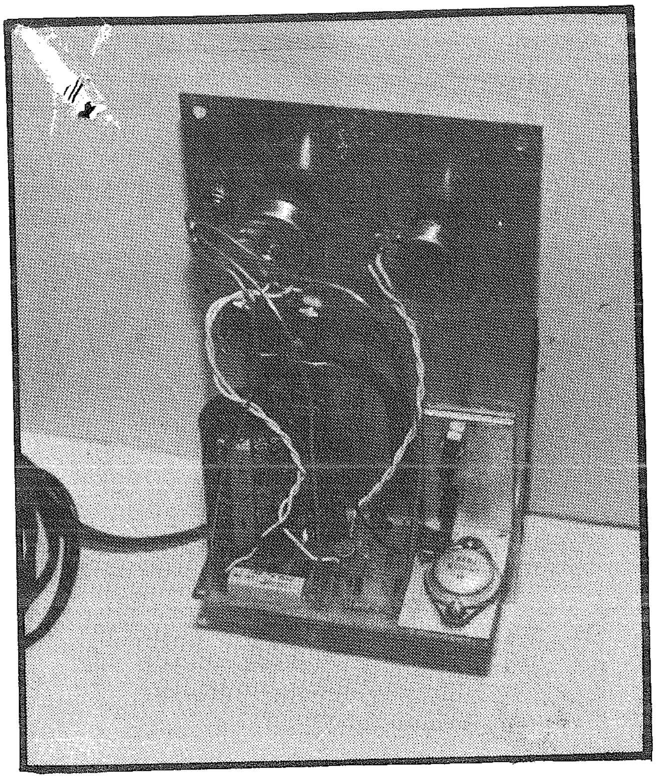
We fitted small posts to the pads to which flying leads are to be run in order to simplify the final wiring-up. It is best to fit the ferrite bead for Q2's emitter lead last. This is because it is brittle and a careless drop could harm it. It is simply threaded on a short piece of tin/cu wire and the wire soldered to the two copper-side pads.

A note concerning IC1. We have specified an LM204, which is an "industrial grade" device, and a couple of dollars more expensive than the plain "commercial" LM304. This specification is to enable the supply to work up to a full 50 volts on the input. The 304 device is only guaranteed to 40 volts. There is no other specification difference of any concern here, so you can use a 304 if you do not need to run over 40 volts on the input.

I should also say something about the input diodes, D1 to D4, at this stage. If you're using a 1A rated transformer as a source, and don't intend using more than 1A output current, use 1N4001/1N4002/1N4004 series diodes which are rated at 1A. Otherwise, use 1N5404 diodes, which are rated at 3A. The Dick Smith Kit is supplied with 1 amp diodes.

Positions have been left on the pc board for resistors associated with panel voltage and current meters. In this project the cost and inherent fragility of panel meters is not really justified. Simply leave the spaces blank. If you wish to fit meters, the method of obtaining the correct resistor values will be explained when the second version (AEM2521) of the supply is described.

When all the components have been fitted and soldered in place, it is time to bolt the pc board and bracket onto the front



This picture shows how the wiring between the pc board and the external components is completed.

panel.

Check the positioning of the pc board behind the panel. You will probably have to bend the LED wires inwards to get clearance for C1. Again, use thermally conductive paste, both between the panel and the bracket and between the panel and the heatsink. When you tighten the bolts, small amounts of the paste should squeeze out of the join, indicating that sufficient has been applied.

Now run all the flying leads. We recommend using heavy duty cable for the input wires; 3 mm diameter automotive cable is quite satisfactory, as is heavy duty "loudspeaker" wire. Solder some suitably heavy duty alligator clips to the cables, and run the end through the grommet. Secure the cable. We simply tied a knot in it, and although purists say that this may harm the cable, it seems most unlikely with automotive cable. Because the supply has a bridge rectifier in it, the polarity of the input is unimportant, and the wires need not be colour-coded.

Run leads to the other items on the panel. Again, heavy duty connections are recommended to the terminals, and to the current range selection switch. We used 1.2mm wire in the prototype, with a little spaghetti insulation where required. This is then easily positioned safely so that it cannot short out onto the panel (which is at output negative potential). Some cable ties can be used to secure all the wiring.

The pots, especially the current limit one, should not be wired rheostat-style (one end open-circuit, using only the wiper and the other end). This is simply because momentary losses of connection which could arise with age in the pots could briefly disable the current limiting circuit. Capacitor C3 has been included to provide smooth adjustment of the voltage even with a "scratchy" pot.

After fitting all the flying leads, the device is ready for testing. Connect some input voltage and see that the power LED comes on. Check that the output LED comes on when the output is turned up. If you connect a short circuit and turn up the current limit control, the supply should eventually become very hot. Check that the heatsink gets hot too. It will actually become too hot to touch after a couple of minutes!

Using the 2520

Using this power supply is like using most others, with just a few interesting points added, which arise because of it's versatility. This section is included for those who might like to have a few of the techniques for correct use of any 'lab.' supply explained.

As stated earlier, the AEM2520 can run off next to anything, except straight mains. Because it has no internal transformer of its own, it has to be connected to some source of voltage. Any transformer with less than 35 Vac output is suitable. Note that many transformers deliver slightly more than their "rated" voltage, so it may not be safe to use a "35 volt" transformer.

We recommend a value of about 32 volts. This means that you can use a cheap and commonly available '6672-type' (nominal 30 Vac at 1 A), the sort of transformer that is meant to run doorbells, or the type for pool lights and pumps, equally safely. Because of the low current consumption, dry batteries or sealed rechargeable batteries are also suitable. We recommend the latter if you want a *totally safe* variable power supply entirely divorced from the mains.

If you have occasion to need a power supply when you are "out in the field," a car battery (or two or three, or even four) can be hooked up and used as the input source.

Because the regulation is very good, you can set the output voltage exactly with a multimeter with no load connected, and expect it to remain pretty constant if you do not alter RV1. We have made the panel with voltage markings around the voltage setting control, so that unless you want very exact control, you can simply work off the scale.

If you wish to set the limit current precisely, just set your meter to current range, and then connect it straight across the output terminals, and adjust the limit control and the range switch to get the level you want. The limit current will not stay *precisely* where you put it under varying load, but it will be constant to within a few percent.

If you run the supply into a short circuit with the limit set towards the maximum, the heatsink will soon get too hot to touch. If built properly, the supply should not be harmed, but you might be if you get your pinkies near the heatsink!

If you use the supply with fairy long leads (say, over one metre) attached between the output terminals and your 'breadboard' circuit, you are advised to put another small capacitor, such as a tantalum, at the end of the leads. This is because C5 cannot bypass the supply at your breadboard.

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