Low cost power supply for experimenters

This easy to build power supply is ideal for the experimenter on a limited budget. It features switch adjustable output voltage and current limiting, and uses a standard AC plug pack as a safe power source.

by ROB EVANS

It is hardly surprising that many power supplies have been published over the years, considering their usefulness to the electronics enthusiast or technician. Many of these designs have been quite complex and expensive offering facilities rarely needed by the average experimenter — particularly those just starting out. The main criteria for this project was that it had to be inexpensive and easy to construct, yet offer useful facilities and performance. A tall order perhaps, but the prototype has cost far less than other small power supplies and at least equals their performance.

In this design we have used rotary switches for the voltage and current selection for user convenience, and to avoid the need for expensive panel mount meters.The voltages have been chosen to match common battery types, with a 5 volts "logic circuit" setting thrown in for good measure. The current settings have been selected with protection of the load in mind.

The circuit can accommodate different voltage and current ranges by minor component changes, the only real limitation being the capabilities of the transformer or plugpack used for the AC supply.

Although a common mains transformer (and associated wiring) could have been used, we have selected a plugpack to simplify construction and maintain high safety standards. These units are commonly available with a 12 or 15 volt AC (500 mA) output, which is recommended for this project.

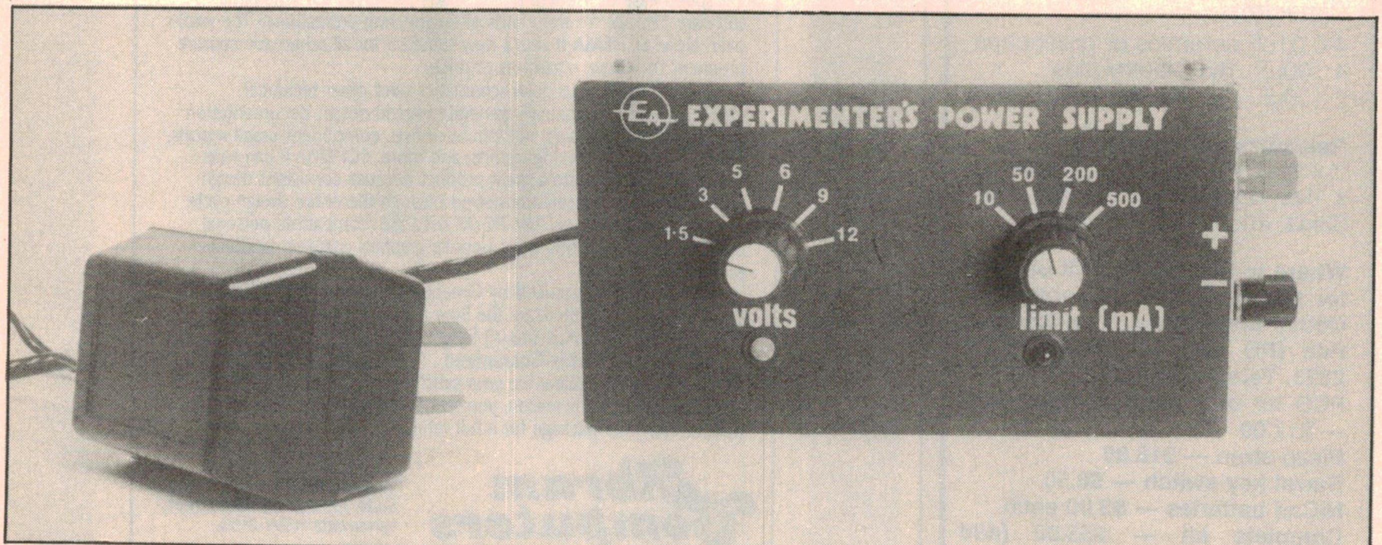
The design

Three-terminal regulators such as the LM317 and the 78xx series were immediately considered due to their availability and low cost, but the circuitry for an absolute current limit became a little complex — and expensive. So we went back to the traditional op-amp and transistor series regulator design.

A relatively standard circuit is used, with a zener diode voltage reference and a current limiter on the output. The latter will never let the output current exceed the selected amount, even under short circuit conditions. Most small power supplies only employ current limiting to prevent overload of the unit itself, whereas this design has a couple of very low settings. Hence your delicate (and often expensive) circuit components need never be at risk!

Circuit principles

The basis of this design as shown in Fig.1 is simply an op-amp (LM741) in a



The supply is built into a low cost aluminium case. An AC plug pack provides total isolation from the mains.

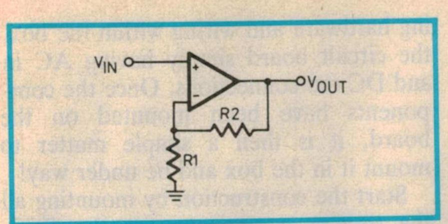


Fig.1 (above): an inverting op amp stage is the basis of the circuit.

Fig.2 (right): the addition of an emitter follower Q1 increases the current capability of the circuit. Also shown is a variable voltage source, twice this voltage appearing at the output.

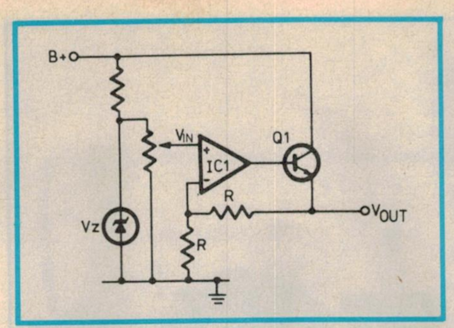
standard non-inverting configuration, set to a gain of 2:

$$\text{Gain} = \frac{\text{Vout}}{\text{Vin}} = \frac{\text{R2} + \text{R1}}{\text{R1}}$$

So if R1 = R2 then Gain = 2

The output will always drive so as to balance out any voltage difference between the inverting (-) and non-inverting (+) inputs. Therefore a level of say 3 volts at the input will produce an output of 6 volts.

In Fig.2 an emitter follower transistor has been added to increase the current sourcing capability, the op-amp itself only being able to supply about 25mA. Any voltage level changes or non-linearities introduced by the transistor are automatically corrected because it is



within the negative feedback loop of the op-amp.

The maximum current this circuit can supply is the op-amp capability multiplied by the gain of the transistor. Or in this case,

I(out) = 25mA x (say)50 = 1.25A

The gain of the transistor can effectively be increased by adding another to form a Darlington pair, which will in turn increase the available current, but for our modest needs this is not necessary.

By adding a variable voltage reference to the input, as shown in Fig.2, the circuit will amplify this by a factor of two, and consequently provide a stable high current output source.

The final circuit

The final circuit (Fig.3), is basically Fig.2 with the addition of a current limiting facility. This uses another transistor to sense the voltage across a resistor network in series with the output. The current limit rotary switch (SW2a) selects a combination of resistors, R14 to R18, for a voltage drop corresponding to the desired current limit. This voltage plus the Vbe of Q1, will eventually equal the combined conducting voltage of LED2 and Q2's Vbe. When Q2 begins conducting LED2 will illuminate, drawing current from the output of IC1. This will tend to pull down the voltage at the base of Q1, with its emitter and the power supply output following suit.

The LM741 has internal current limiting, which in this case will allow a maximum of 25mA to flow through LED2, ensuring a consistent brilliance and preventing its destruction. In this current limiting action the LM741 behaves somewhat like a constant current source, sharing its current between LED2 and the base of Q1.

A 6.8V zener diode (ZD1) is the voltage reference for a resistor ladder (R4 to R10), which supplies IC1 via the voltage selection switch SW1a. As the circuit has a gain of two, the reference voltage required will be half of the desired output voltage, therefore for the 9V position the reference is 4.5V.

When a reference for the 1.5V range is selected by SW1a, the same voltage as the 3V range is applied to IC1, but the gain of the circuit is dropped to one rather than two. This is achieved by

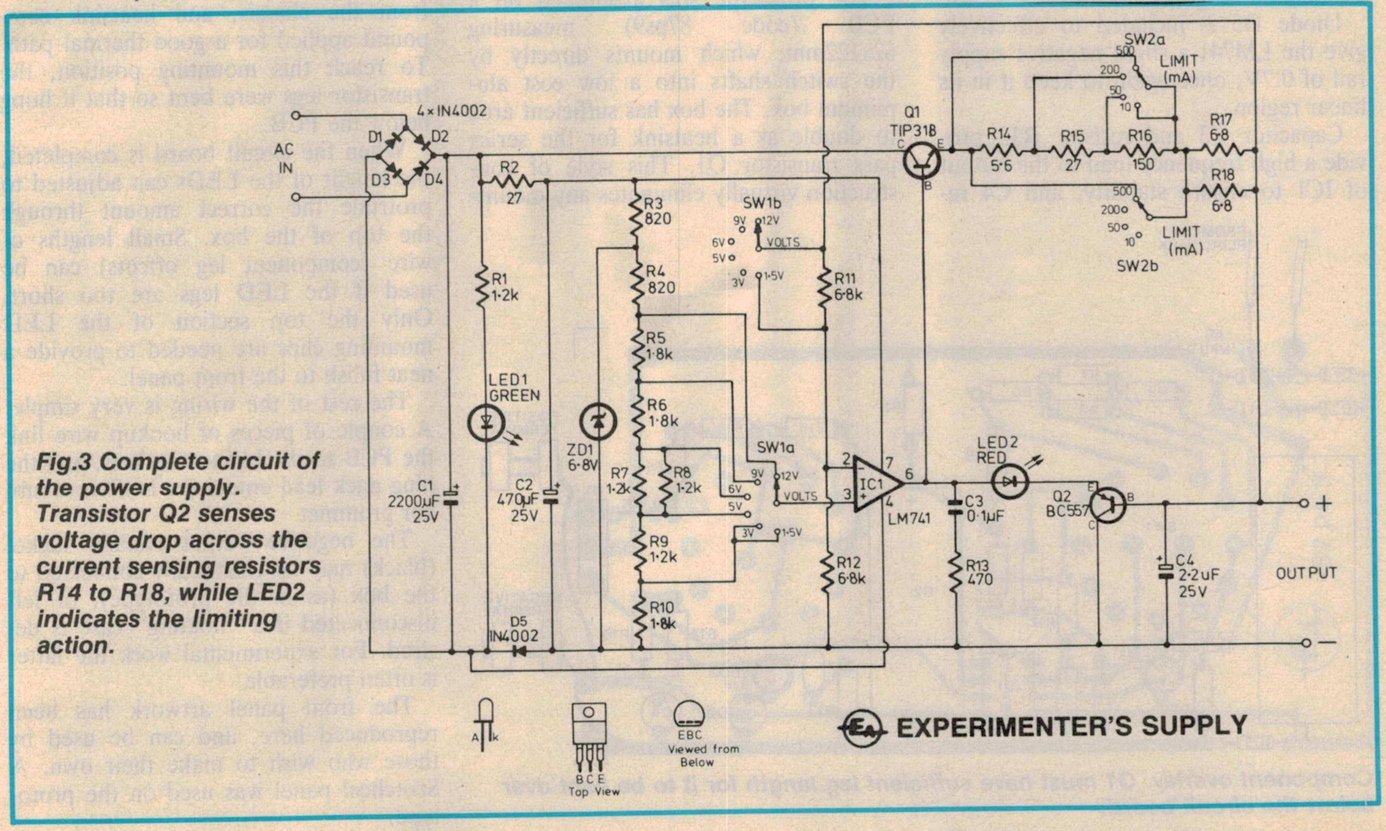
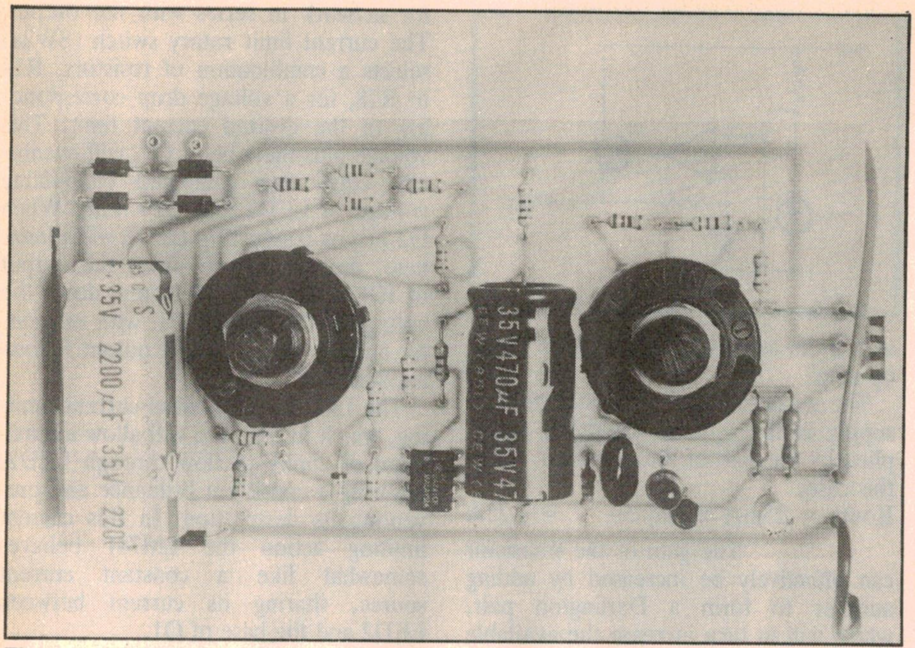


Fig.3 Complete circuit of the power supply. Transistor Q2 senses voltage drop across the current sensing resistors R14 to R18, while LED2 indicates the limiting action.



The completed circuit board. Note the mounting of Q1.

SW1b shorting out the feedback resistor R11 when the 1.5V setting is selected. A level of 0.75V was out of the linear region of the inputs of the LM741, and resulted in poor output regulation. Since SW1 was a double pole switch, utilising the second half was a simple solution to the above problem.

Similar advantage was taken of the current selector switch SW2b, used to boost the current capacity of SW2a on the 500mA range.

Diode D5 is included to effectively give the LM741 a slight negative supply rail of 0.7V, once again to keep it in its linear region.

Capacitor C3 and resistor R13 provide a high frequency load to the output of IC1 to ensure stability, and C4 removes any remaining ripple from the output.

The AC voltage from the plugpack feeds the bridge rectifier of D1 to D4 and the 2200uF filtering capacitor C1, whilst further filtering for the reference and IC1 is provided by R1 and C2. A green LED indicates a DC source voltage is present.

Construction

The prototype was assembled on a PCB (code 87ps9) measuring 62x122mm, which mounts directly by the switch shafts into a low cost aluminium box. The box has sufficient area to double as a heatsink for the series pass transistor Q1. This style of construction virtually eliminates any mounting hardware and wiring within the box, the circuit board simply having AC in and DC out connections. Once the components have been mounted on the board, it is then a simple matter to mount it in the box and be under way!

Start the construction by mounting all the smaller components on the PCB, following with the larger components such as the main capacitors, and finish with the rotary switches.

The switches used in this project are the sealed PCB mount rotary type, which have a removable ring under the locknut to set the number of positions. This ring has a tab that may be placed in a choice of slots labelled from 2 to 11, the 12th position being available with the ring removed. Therefore, S1 and S2 are set to the 6 and 4 positions respectively. The PCB holes for the switches will need to be quite large, because the large number of pins makes them a little tricky to install.

Construction of the rest of the unit is quite straightforward, the components fitted to the board as shown in the component overlay. Particular care must be taken with the polarity of the semiconductors and electrolytic capacitors. The resistors should be mounted a couple of millimetres off the board to allow enough airspace for cooling.

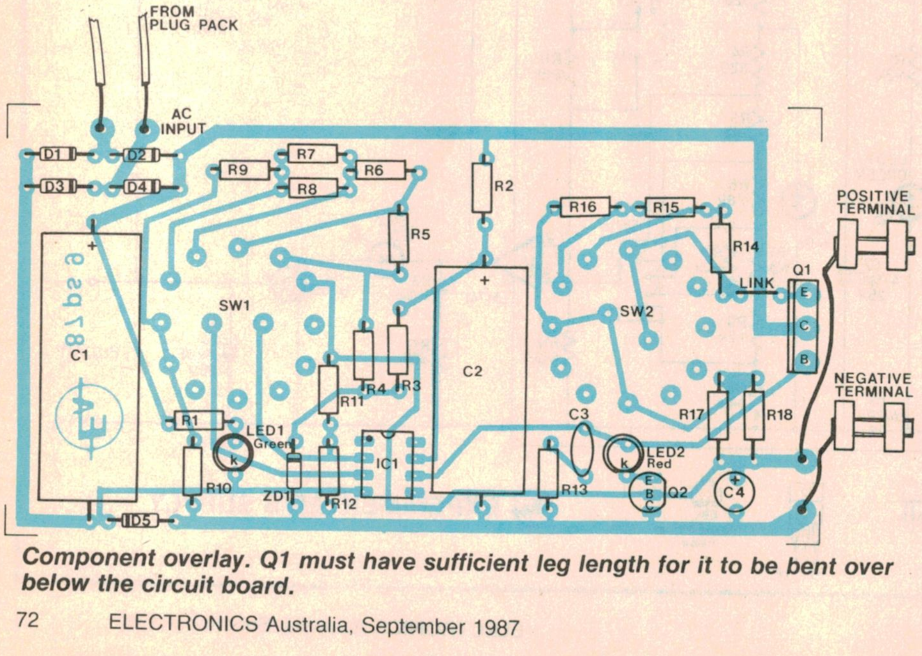
The TIP31 transistor is bolted to the box between the output terminals, a mica washer being used to insulate it from the chassis, and heatsink compound applied for a good thermal path. To reach this mounting position, the transistor legs were bent so that it hung below the PCB.

When the circuit board is completed, the height of the LEDs can adjusted to protrude the correct amount through the top of the box. Small lengths of wire (component leg offcuts) can be used if the LED legs are too short. Only the top section of the LED mounting clips are needed to provide a neat finish to the front panel.

The rest of the wiring is very simple. A couple of pieces of hookup wire link the PCB to the banana sockets, and the plug pack lead enters the box via a rubber grommet.

The negative output banana socket (black) may be electrically connected to the box (as in the prototype), or left disconnected if a "floating" case is desired. For experimental work the latter is often preferable.

The front panel artwork has been reproduced here, and can be used by those who wish to make their own. A Scotchcal panel was used on the prototype.



Component overlay. Q1 must have sufficient leg length for it to be bent over below the circuit board.

Testing

When all is completed, the unit can be tested with a multimeter (if available), for the correct output voltages. These voltages should be quite close to those specified, but are largely at the mercy of the resistor tolerances, which in this case is 5 percent.

The current ranges may be tested by simply shorting the output with a multimeter on the Amps range. The "limit" LED should illuminate to indicate the current limiting action, with current being limited to a value as set by S2. Care should be taken not to exceed the multimeter maximum current rating.

If a 12VAC plug pack of moderate current capacity (500mA or less) is used with this power supply, the 12V position may not yield the full 500mA current. This is due to the plug pack voltage dopping below its rated 12V at higher currents, consequently the circuitry has insufficient DC supply for good regulation. A 15VAC plug pack of at least 500mA capacity is recommended for maximum performance. EA

PARTS LIST

- 1 metal box, 133x76x54mm (or larger)
- 1 PCB, code 87ps9, 66x122mm
- 2 4mm binding posts, (1 red, 1 black)
- 1 2-pole 6 position PCB mount rotary switch
- 1 2-pole 4 position PCB mount rotary switch (see text)
- 2 Knobs for switches
- 1 Plug pack 12 or 15 VAC, 500mA or greater.

Semiconductors

- 5 1N4002 diodes
- 1 5mm red LED
- 1 5mm green LED
- 1 LM741 op-amp
- 1 TIP31 (B or C) transistor
- 1 BC557 transistor
- 1 6.8 volt 400mW zener diode

Capacitors

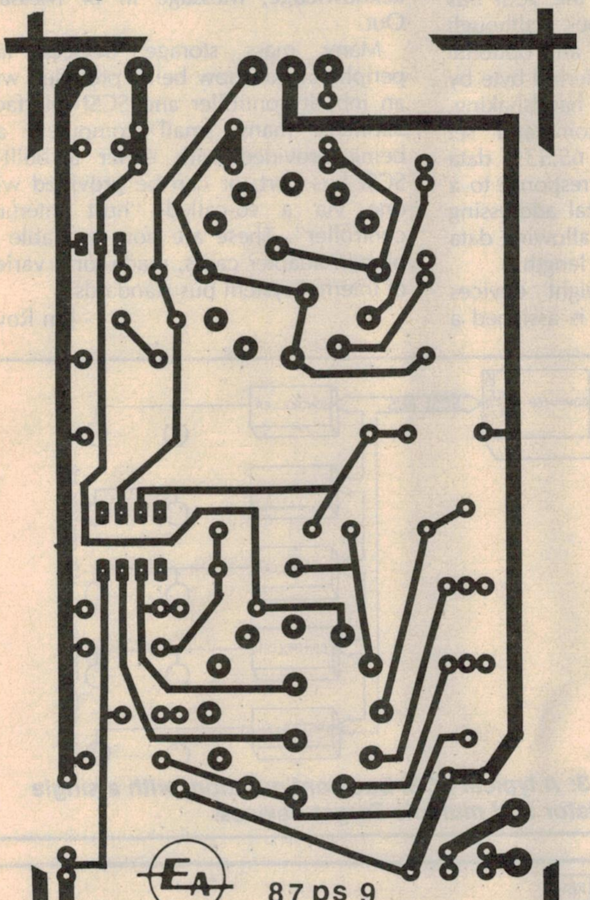
- 1 2200uF 25VW axial type electrolytic
- 1 470uF 25VW axial type electrolytic
- 1 2.2uF 25VW PCB mount electrolytic
- 1 0.1uF greencap

Resistors (all 0.5W 5%)

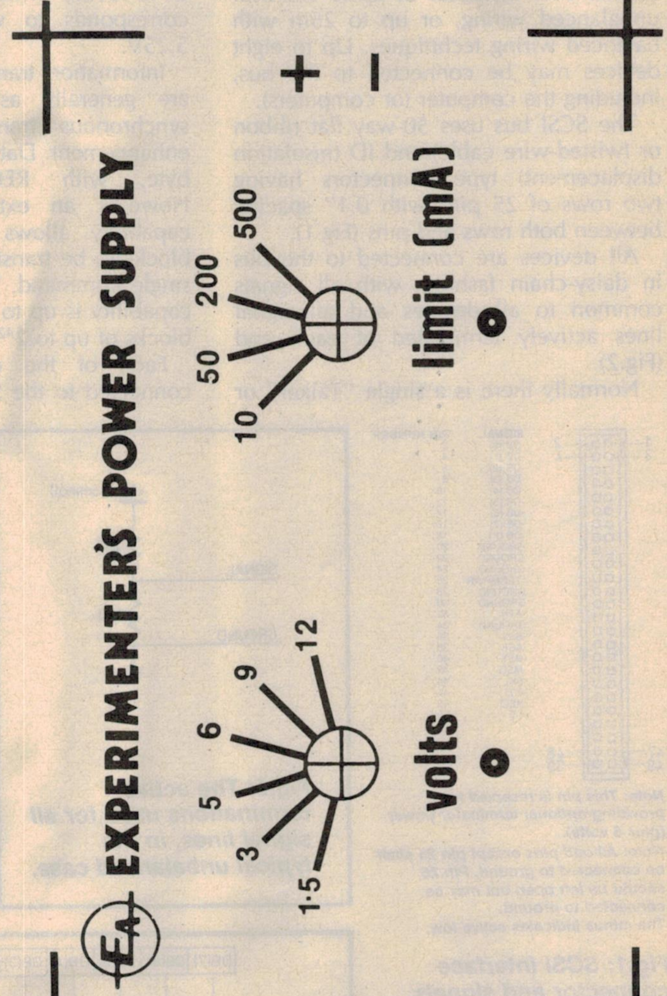
- 1 5.6Ω
- 2 6.8Ω
- 2 27Ω
- 1 150Ω
- 1 470Ω
- 2 820Ω
- 4 1.2kΩ
- 3 1.8kΩ
- 2 6.8kΩ

Miscellaneous

Mounting hardware for TIP31, Heatsink compound, 2 x LED mounting kits, hookup wire, solder, rubber grommet.



This full size artwork may be used to make your own PCB.



The actual size artwork for the front panel.