Experimenter's power supply

Basic Electronics

by GERALD COHN

Here is an ideal power supply for the hobbyist who is new to electronics. The output is switch adjustable to give seven different voltages at up to 500mA which means that it will drive most circuits of interest to the beginner. As a bonus, the power supply is completely safe because it has no mains wiring.

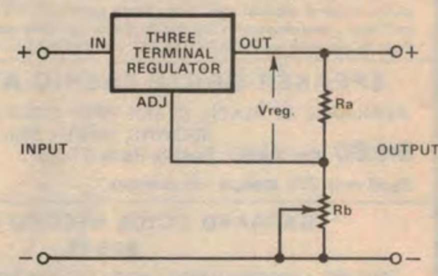


FIG. 1

This diagram shows how a three terminal regulator can be used as an adjustable power supply.

Over the past few months we have presented a variety of beginner's projects, all of which require batteries of one voltage or another. But batteries are fairly expensive these days so we decided to produce a power supply for the beginner. One of the main criteria for this project was that it had to be easy to build and as safe as possible.

The best way of making such a power supply safe is to completely eliminate mains wiring. With the introduction of 12V AC plugpacks from Ferguson Transformers Pty Ltd, this is a practical proposition. We used a Ferguson PPA12/500/2 plugpack which can supply up to 500 milliamps continuous. These are made to meet high insulation standards and are available at a reasonable price.

Using the Ferguson AC plugpack means that all mains wiring, switch and mains transformer can be eliminated from the power supply case. So the power supply really comes in two parts, plugpack and power supply proper.

In spite of the fact that this power supply is so easy to build, it has quite a high performance. It features excellent load regulation and hum and noise on the output are very low, less than one millivolt. It is stable under all load conditions and will withstand short-circuits for short periods (this overloads the plugpack transformer rather than the regulator circuitry).

Our circuit uses the National Semiconductor LM317 three-terminal regulator. This regulator is different from conventional three-terminal regulators in that it can be used in an adjustable circuit which will give low output voltages. "Well, how is that different from a conventional regulator?" you may ask. Good question.

Three-terminal regulators normally provide a fixed output voltage such as 5V or 12V but they can be made adjustable, using the circuit shown in Fig. 1. What this circuit does is to apply the fixed regulator output voltage, Vreg, across resistor Ra. Assuming that no current is drawn by the adjustment terminal, then all the current flowing in Ra must flow in Rb.

The result of the current flowing in resistor Rb is to "jack up" the adjustment terminal so that the total voltage output of the circuit of Fig. 1 is Vreg plus the voltage across Rb. As we have seen, the voltage across Rb is defined by the current through Ra which, in turn, is set by the regulator output voltage Vreg.

For example, if the desired output of Fig. 1 is twice the nominal regulator voltage, Ra and Rb should be equal. If the desired output is three times the nominal regulator voltage, then Rb should be twice Ra. Get it?

So we can define the output voltage of Fig. 1 merely by selection the ratio of the two resistors, Ra and Rb.

The formula to express this relationship is

$$V_{out} = V_{reg} + (V_{reg} \times R_b)/R_a$$

There are two problems with the circuit of Fig. 1 as far as conventional voltage regulators are concerned. First, the current flowing out of the adjustment terminal is not negligible and it tends to vary with the input voltage and temperature. This means that the regulation of the circuit is not particularly good.

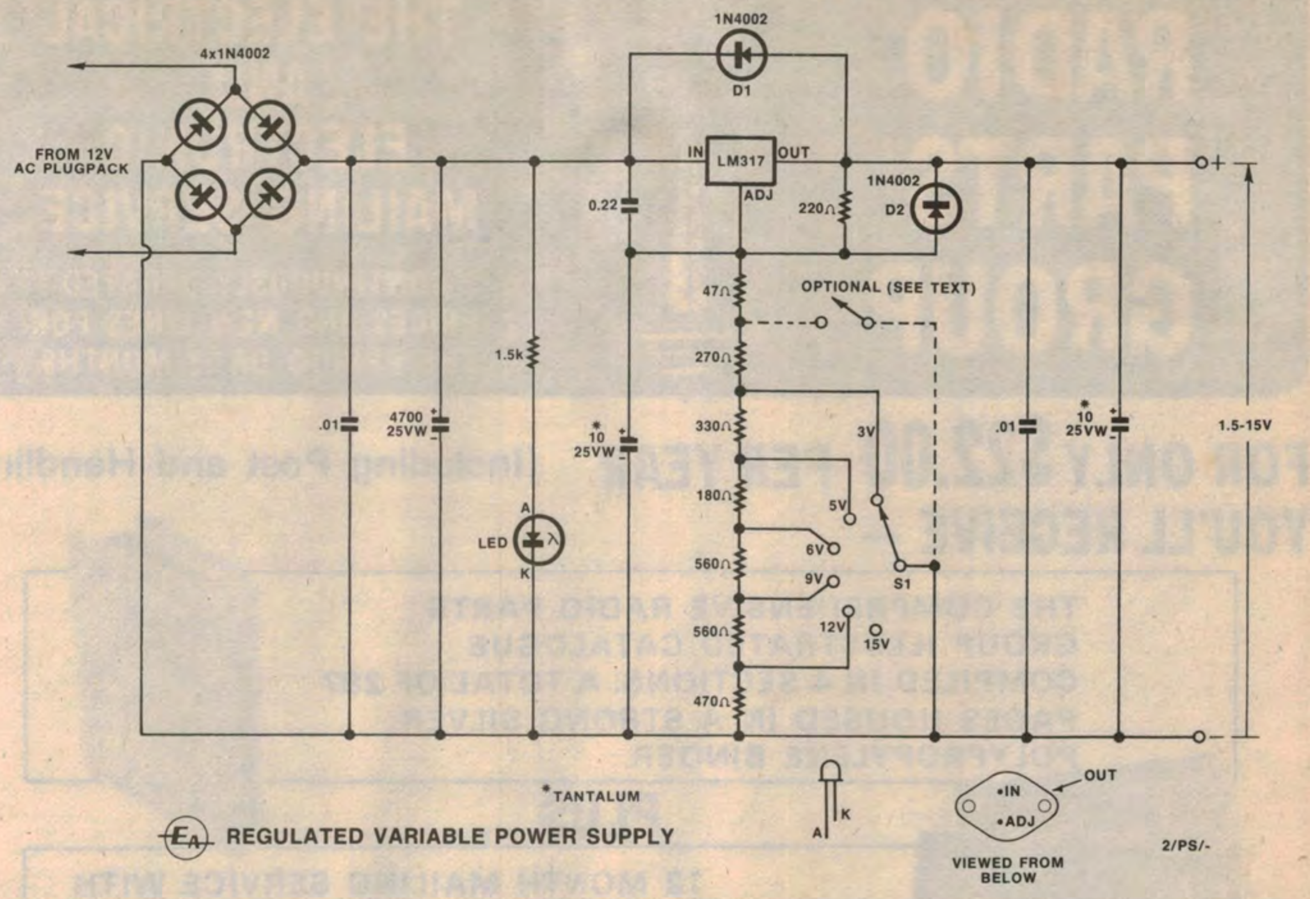
Second, the minimum output voltage of the circuit is equal to the regulator

Here is the completed prototype together with the 12V AC plugpack. The unit is totally isolated from the mains in the interests of safety.

We estimate that the current cost of parts for this project is approximately

$28.00

This includes sales tax.



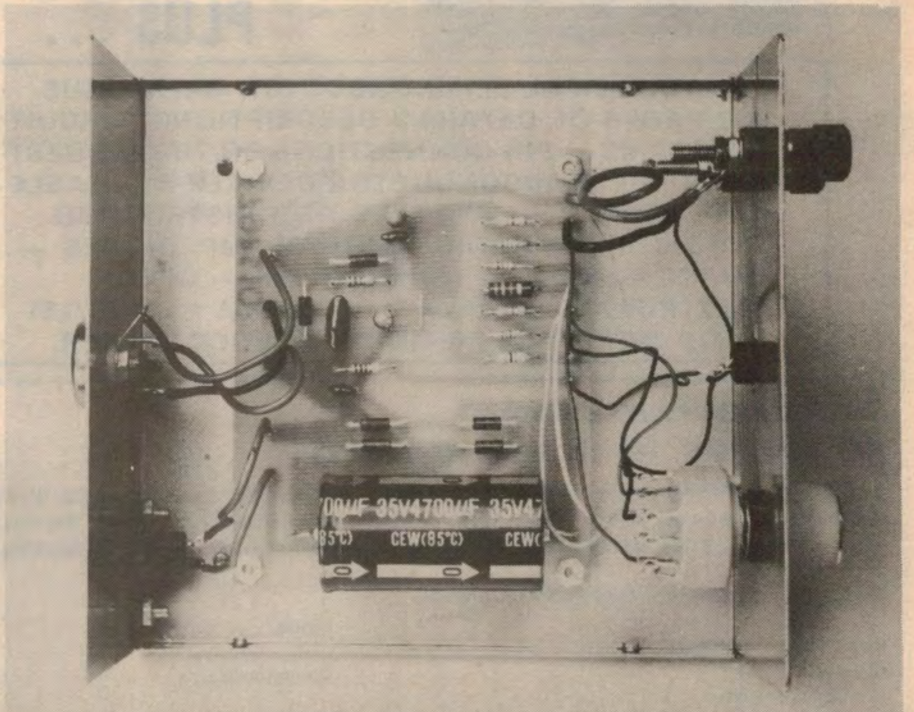
The schematic diagram of the power supply unit. The part of the circuit that appears in dotted lines is the 1.5V option which is explained in the text. The diodes around the regulator IC are to protect it from damage when the supply is connected to charged capacitors.

voltage, Vreg. That stands to reason, when you think about it, because it would be the result if Rb was reduced to zero. So if a 5V regulator was used in the circuit, then five volts would be the minimum output voltage. And five volts is occasionally not low enough.

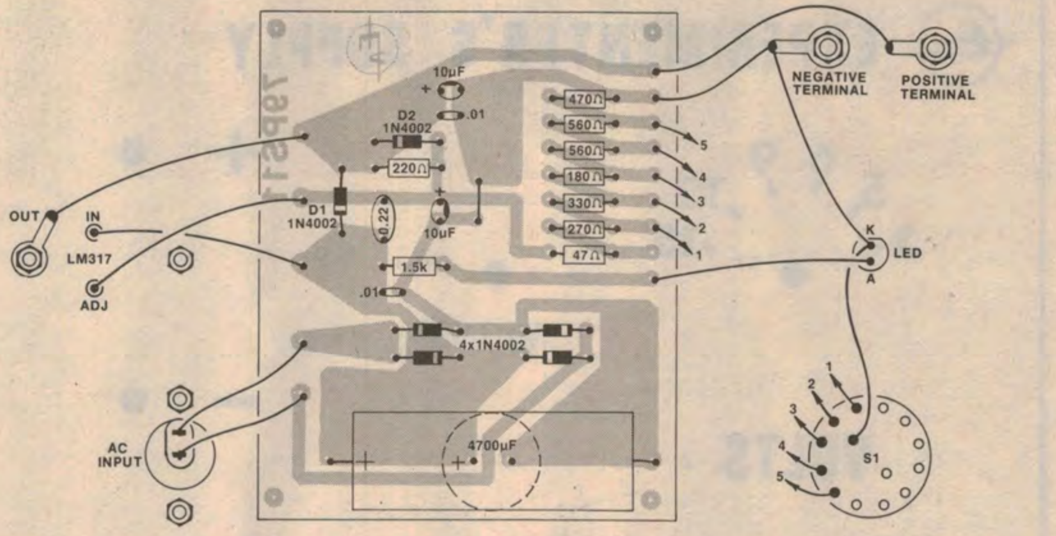
The LM317 overcomes these problems. Firstly, it has a very low current flowing out of the adjustment terminal — less than 50 microamps. Provided we select the resistors in the voltage divider of Fig. 1 so that the current flowing "swamps" this 50 microamp current, we can ignore it. Second, the nominal regulator voltage of the LM317 is 1.25V (typically).

Now have a look at the complete circuit of the Experimenter's Supply. The plugpack transformer feeds a bridge rectifier and a 4700uF filter capacitor to produce about 18 to 20 volts DC. There is however a small 100Hz AC component which is superimposed on the DC voltage. This is referred to as "ripple". This DC voltage, with its small "ripple" content, is fed to the input of the LM317 regulator.

In the complete circuit, Ra has become 220 ohms while Rb is a "ladder" consisting of seven resistors. The output voltage of the circuit is



Inside the completed prototype. Note the heavier wiring between the PCB and the AC input socket, the regulator IC and the terminal posts on the front panel.



This overlay diagram shows how the components are placed on the board. Take care when inserting polarised components.

selected by "shorting out" part of the resistor ladder with a rotary switch. The resistor values are calculated to provide nominal output voltage of 1.5, 3, 6, 9, 12 and 15 volts DC.

Diode D1 serves to protect the LM317 from damage if a charged capacitive load is connected to the output of the circuit when it is not energised. Such a capacitive load would tend to discharge via the junctions of the LM317 in an attempt to charge up the 4700uF filter capacitor. If this happens diode D1 safely shunts any such discharge current around the LM317.

The resistor ladder is bypassed by a 10uF tantalum capacitor to improve the ripple rejection of the LM317 regulator. It does this by removing any remaining ripple across the resistor ladder, and thereby produces an almost pure DC voltage at the adjust terminal. Thus the output of the LM317 is almost pure DC.

There is another potential danger to the LM317, in that, if the output is shorted accidentally, the 10uF capacitor bypassing the resistor ladder will tend to discharge rapidly via the IC. This danger is circumvented by diode D2. Actually, D2 is not strictly necessary in this circuit because of the relatively low voltages used but we have included it as a further safety measure.

The 0.01 and 10uF capacitors provide improved stability and transient response, keeping voltage spikes at the output to a minimum. The output of the circuit is fully floating with neither terminal being connected to the chassis. A light emitting diode pilot light has also been provided on the front panel.

It can be seen from the circuit diagram that the 1.5V tapping is shown as optional. This has been done because six position switches are more readily available than seven position switches. If it is desired to have a 1.5V output, an extra switch can be used to implement this. Another alternative is to replace the six position switch with one that has 12 positions, leaving the other positions blank.

Construction of the power supply is a relatively straightforward task as there is no mains wiring which has already been noted, and most of the circuit is accommodated on a printed circuit board (code 79ps11). Follow the wiring diagram when assembling the PCB and take particular care with those components where polarity is important — the diodes and electrolytic capacitors.

We mounted our prototype in a metal case that was supplied by Dick Smith Electronics. This has an aluminium chassis with a black painted

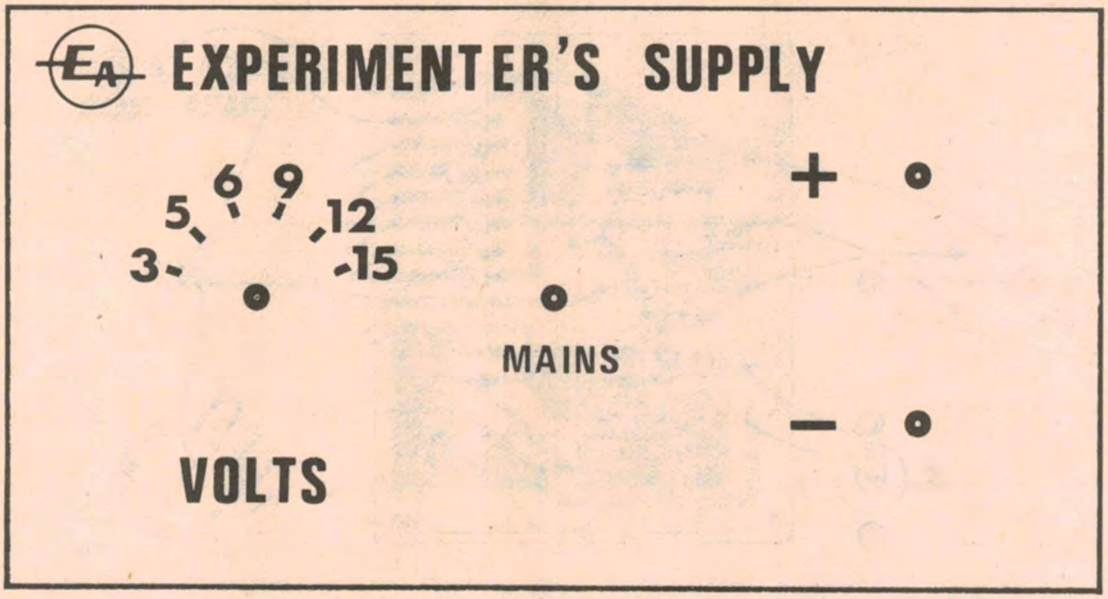
PARTS LIST

1 metal case, 150 x 76 x 134mm
1 PCB, 100 x 80mm, code 79PS11
2 4mm banana socket-cum-binding posts, one red, one black
1 2-pin DIN socket
1 2-pole six-position or 1-pole 12-position rotary switch (see text).
1 12V AC plugpack transformer, Ferguson PPA12/500/2
1 light-emitting diode
1 LM317K three-terminal regulator IC
6 1N4002 or similar rectifier diodes
1 4700uF/35VW pigtail electrolytic capacitor
2 10uF/25VW tantalum electrolytic
1 0.22uf metallised polyester (greencap)
2 .01uF metallised polyester

RESISTORS (½ or ¼ Watt 5%)
1 x 47 ohm, 1 x 180 ohm, 1 x 220 ohm, 1 x 270 ohm, 1 x 330 ohm, 1 x 470 ohm, 2 x 560 ohm, 1 x 1.5k.

MISCELLANEOUS
Heatsink compound, mounting hardware for LM317, screws, nuts, lockwashers, knob for switch, hookup wire, solder.

Identifying tantalum capacitor leads: the lead to the right of the dot is the positive lead. It is also indicated by a row of + signs on some brands.



The full size artwork of the front panel. Scotchcal panels will be available from Radio Despatch Service, 869 George St, Sydney.

steel cover, and measures 70 x 134 x 150mm. It is very reasonably priced at $4.95, and is supplied complete with rubber feet and cover fixing screws.

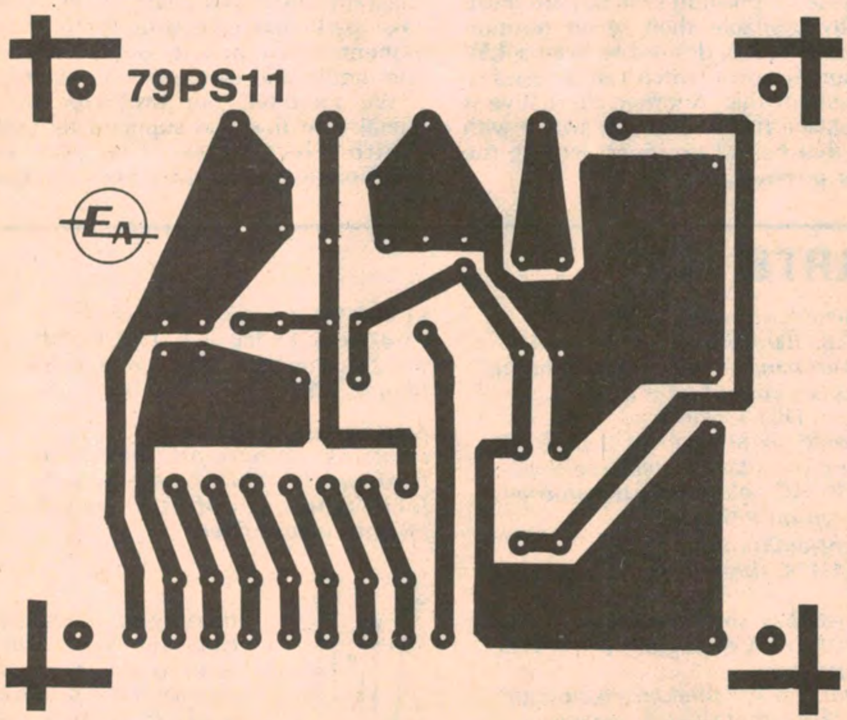
The front panel of the box was "dressed up" using a Scotchcal panel. The artwork for the panel has been reproduced here and can be used as a guide for those that wish to make their own. The artwork can also be used as a guide for the placement of the terminal posts, the indicator LED and the rotary switch.

The LM317 IC is mounted in the centre of the rear of the chassis and insulated from the case using a mica washer and plastic insulating bushes for the screws. Heatsink compound should be used to provide a good thermal path between the IC case and the back panel of the box.

The PCB is mounted on the base panel of the chassis using four screws together with lockwashers and nuts. Space the PCB off the base panel by the thickness of two nuts. Alternatively, you can use four Richco PCB mounts.

The wiring between the printed circuit board and the regulator IC should be reasonably heavy wire (23/019mm would be ideal) and should also be as short as possible. The same wire should be used between the PCB and the output terminals. The wiring between the PCB and the rotary switch can be done using ordinary hookup wire.

When all the wiring has been completed, go back and do a final check. This should cover the PCB, the wiring to the regulator, the LED and the switch. If you are satisfied that all is well apply power to the circuit. Using a multimeter, check the output voltages and make sure that they are reasonably close to the nominal voltages specified. The 1.5 volt setting can be tested by temporarily grounding the junction of the 47 ohm and the 270 ohm resistors.



A full size reproduction of the PCB artwork. Use this to make your own or purchase a complete board from the usual suppliers.