Fully protected dual power supply

This new dual power supply uses only a few ICs but provides accurately matched output voltages from ±5V to ±15V and currents up to 1.5A. The supply has excellent regulation characteristics and the outputs are protected against short circuits and thermal overloads.

by RON de JONG

Perhaps the most often used piece of test equipment on the enthusiast's bench is the regulated power supply, and we've certainly described quite a few of them to date. These supplies offered a wide range of voltage and current capabilities, but most were of the single supply variety. None provided a split supply with the simplicity of this design.

A split power supply is very desirable when experimenting with op-amp circuits. The low price and excellent performance of modern op-amps makes them very suitable for everything for amplifiers, filters and oscillators to exotic function generators, so the usefulness of a split supply such as the one described here is quite apparent.

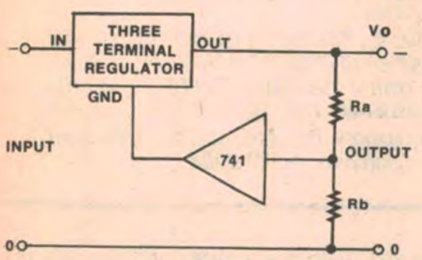


FIG. 1

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

And if the versatility of a split supply can be obtained for little more than the expense of an ordinary single supply, then all the better. This design certainly achieves that objective. It uses only four inexpensive ICs yet provides performance comparable to that obtained from much more complicated discrete designs.

The output voltage is continuously variable between ±5 and ±15, which is the usual operating voltage range of op-amps. The maximum supply current available is a function of the supply voltage, as can be seen by referring to the accompanying graph. It is a maximum of 1.5A at output voltages up to 12V, then falls steadily to 1A at 15V because of the reduced voltage available from the rectifier at high load currents.

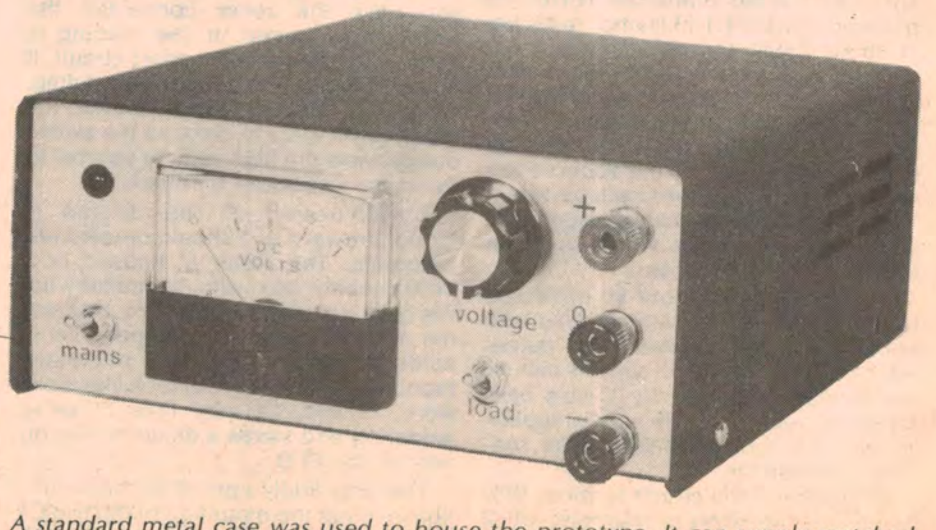
Regulation of the supply output voltage is excellent within these limits, as can be seen from the voltage regulation curves obtained from our prototype. With a load current of 1.2A for example, the positive supply voltage drops only 30mV and that represents a change of only 0.3%.

At the heart of the regulation circuitry are two three-terminal regulator ICs type LM320 and LM340, from National Semiconductor. The LM340 is a positive voltage regulator and the LM320 is a negative regulator, though in all other respects they are similar. Their features include excellent regulation, current limiting and thermal overload protection.

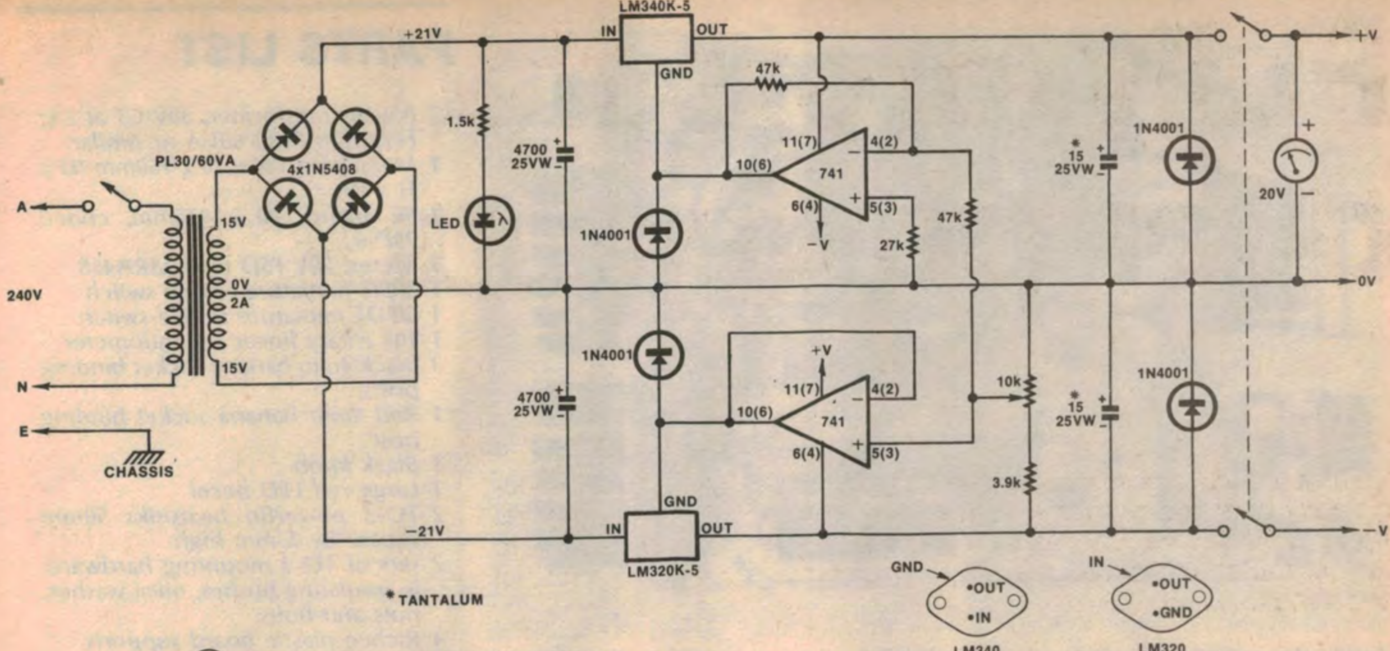
The LM320 is arranged in a negative supply circuit which provides a variable output voltage, while the LM340 is arranged in a positive supply whose output voltage is designed to track the output voltage of the negative supply. Hence the name dual tracking power supply.

Normally a three terminal regulator supplies a fixed output voltage with respect to its ground terminal. To change this situation and so achieve a variable output voltage, it is necessary to change the voltage at the ground terminal of the regulator. This is not difficult to do because even while the regulator is supplying large currents to the load, the current through its ground terminal is only of the order of a few milliamps.

Examining the negative supply first, it can be seen that the ground terminal of the LM320 regulator is connected to an LM741 op-amp arranged as a voltage



A standard metal case was used to house the prototype. It can supply matched output voltages from ±5V to ±15V and has both power and load switching.



DUAL TRACKING POWER SUPPLY 2/PS/-

follower. The input of the voltage follower is obtained from a 3.9k resistor and 10k potentiometer which form a voltage divider at the output of the regulator. This has the effect of feeding an adjustable fraction of the output of the regulator back to its ground terminal.

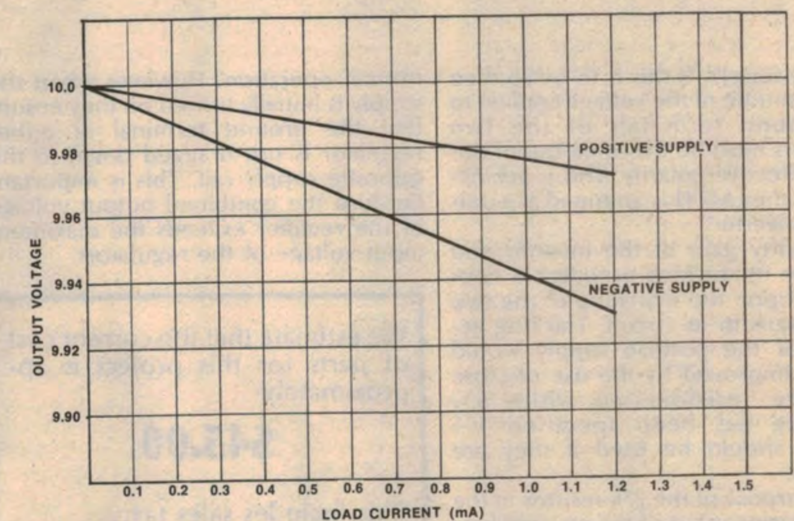
Referring to Fig 1, the fraction of the output voltage obtained from the voltage divider is Rb/(Ra+Rb). Since the regulator is a 5V type its output voltage will equal this feedback voltage plus 5V. Expressing this as an equation relating output voltage to voltage divider resistance we have Vo. Rb/(Ra + Rb)=Vo-5. Rearranging these terms slightly the output voltage is more explicitly given by:

Vo=5(Ra + Rb)/Ra.

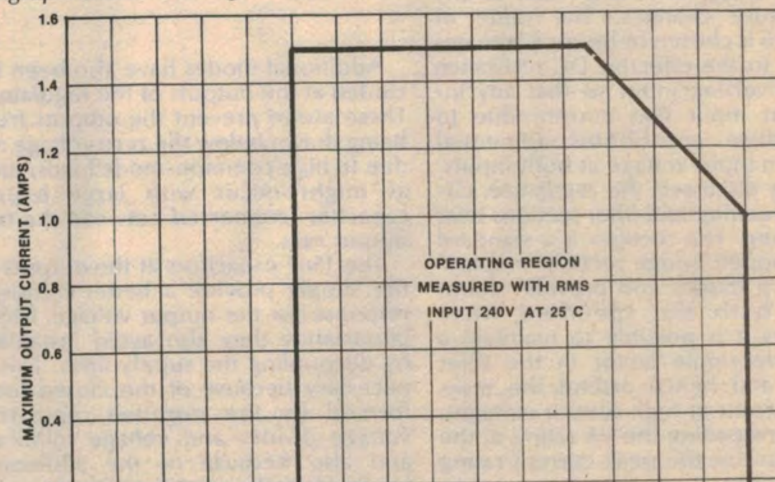
Hence by varying the voltage divider ratio we can change the output voltage of the supply. When for example the wiper of the potentiometer is set to ground, zero volts will be fed back to the ground terminal of the negative regulator and so the output voltage will be -5V. If the potentiometer is set to maximum, the output voltage will be -15V by virtue of the 3.9k resistor between the potentiometer and the output line.

It might be noted that this value of resistance is less than would be calculated by using the equation just discussed. The reason for this is that input resistance of the second LM741 op-amp stage has a loading effect on the voltage divider, since it is connected across the potentiometer. Its input resistance is of course 47k, due to the virtual earth at the inverting input.

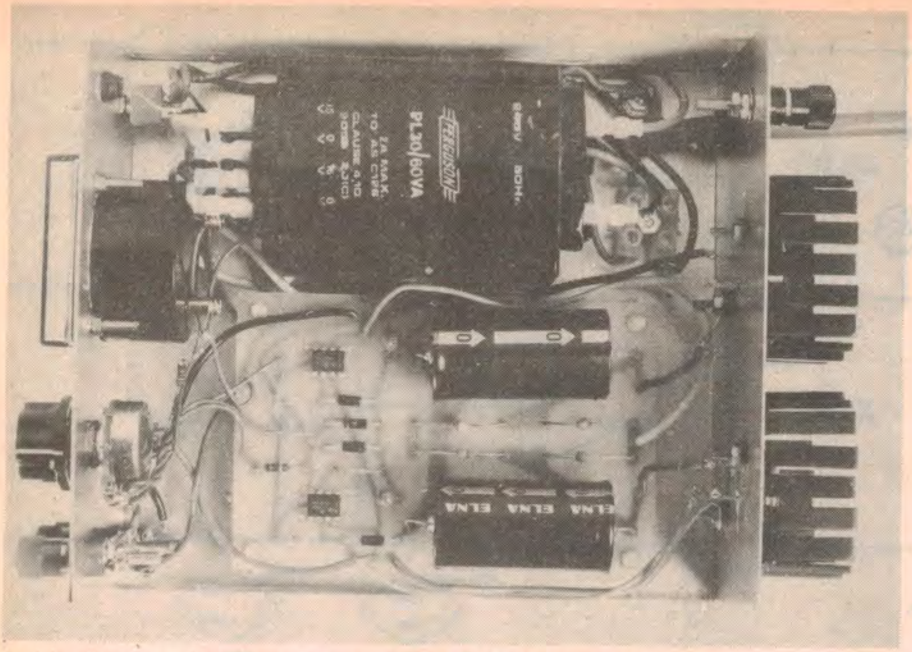
The purpose of the second LM741 is to provide a suitable voltage to the positive regulator, such that the positive supply voltage will track the



This graph shows the regulation characteristics of the prototype.



Graph showing maximum output current as a function of output voltage.



Inside the completed prototype. A single PC board accommodates most of the components and will accept both 8-pin and 14-pin 741 op amps.

PARTS LIST

- 1 Power transformer, 30V CT at 2A; Ferguson PL30/60VA or similar
- 1 Metal case 184 x 70 x 160mm (D x H x W)
- 1 PC board, 80 x 120mm, coded 79PS6
- 1 Meter, 20V FSD type MRA45B
- 1 SPDT miniature toggle switch
- 1 DPDT miniature toggle switch
- 1 10k rotary linear potentiometer
- 3 Black 4mm banana socket binding posts
- 1 Red 4mm banana socket binding post
- 1 Black knob
- 1 Large red LED bezel
- 2 TO-3 powerfin heatsinks 50mm square by 25mm high
- 2 sets of TO-3 mounting hardware, ie insulating bushes, mica washer, nuts and bolts.
- 4 Richco plastic board supports
- 1 Mains cord and plug

Grommet, cable clamp, termination block, solder lugs, hookup wire.

SEMICONDUCTORS

- 1 LM340K-5 positive regulator
- 1 LM320K-5 negative regulator
- 2 LM741 op-amps
- 4 IN5408 diodes
- 4 IN4001 diodes

CAPACITORS

- 2 4700uF 25VW electrolytic, axial lead type
- 2 15uF 25VW tantalum

RESISTORS ½ watt: 2 x 47k, 1 x 27k, 1 x 3.9k

NOTE: Resistor wattage ratings and capacitor voltage ratings are those used for our prototype. Components with higher ratings may be generally used provided they are physically compatible.

negative supply. If this is to be so then the magnitude of the voltage applied to the ground terminals of the two regulators must be the same but of opposite effective polarity. This is achieved since the LM741 is arranged as a unity gain inverter.

The unity gain of the inverter and therefore its tracking accuracy is conditional upon the matching of the two 47k resistors in its circuit. Tracking accuracy of the positive supply would thus be improved by the use of close tolerance resistors, so while 5% tolerance has been specified 1% resistors should be used if they are available.

The purpose of the 27k resistor in the non-inverting input of the op-amp is to reduce voltage drift as a result of any temperature changes. The value of resistance is chosen to be approximately equal to the effective DC resistance at the inverting input so that any increase in input bias current due to temperature contributes an equal change in input voltage at both inputs.

Having discussed the regulation circuit the rectifier and filter sections bear mentioning. The rectifier is a standard centre-tapped bridge rectifier employing 3-amp diodes and provides about ±12V. With the specified filter capacitors it is possible to maintain a reasonable ripple factor in the filter section, and hence extend the maximum current at high output voltages, without exceeding the VA rating of the transformer or the peak current rating of the diodes.

The remaining components do not directly affect the normal operation of the circuit. The diodes at the outputs of the op-amps are normally reverse biased, hence they do not interfere with normal operation. However when the supply is initially turned on they ensure that the ground terminal of either regulator is not dragged down to the opposite supply rail. This is important because the combined output voltage of the rectifier exceeds the maximum input voltage of the regulators.

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

$45.00

This includes sales tax.

Additional diodes have also been included at the outputs of the regulators. These are to prevent the outputs from being drawn below the zero voltage rail due to high common-mode loads, such as might occur with large bypass capacitors connected between the two output rails.

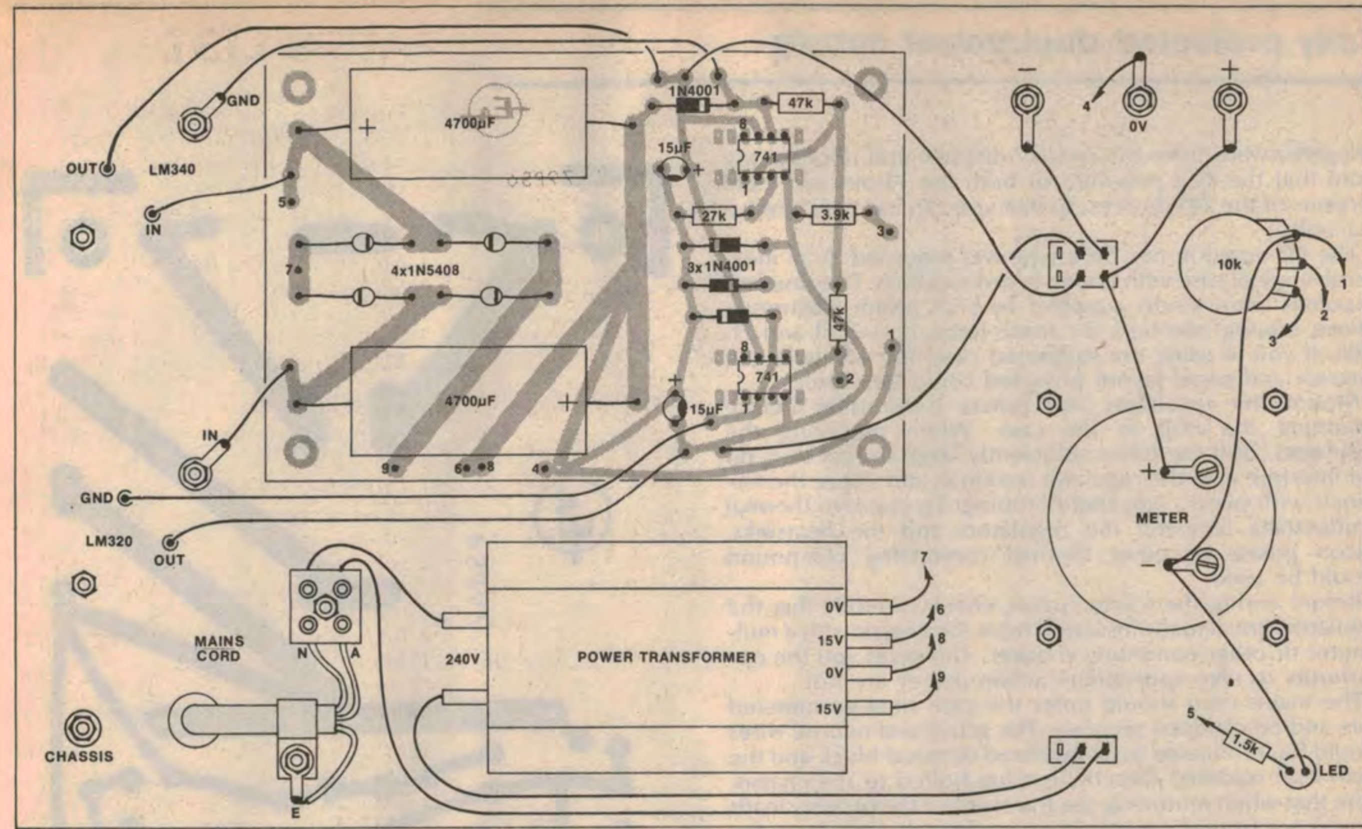
The 15uF capacitors at the outputs of the supply provide a better transient response for the output voltage. More importantly they also avoid instability by decoupling the supply lines. This is necessary because of the closed loop formed by the negative regulator, voltage divider and voltage follower, and also because of the additional feedback path via the op-amp supply lines.

Perhaps at this stage it would be worth mentioning why the op-amp supplies are actually obtained from the output of the regulators rather than directly at the output of the rectifier. This is not because of the reduced ripple content of the regulated supply, although this is an additional benefit. Rather it is because the output voltage of the rectifier, ±21V, exceeds the maximum supply voltage rating of the op-amps — which is ±18V.

An added bonus of this arrangement is that the op-amps also provide a load to the regulators in standby mode. This obviates the need for including hold-down resistors at the outputs of the supply.

Since the output voltage of the supply cannot be reduced to zero, a load switch has also been included. This switch is a double pole type and has the effect of disconnecting both the positive and negative supplies.

The power supply outputs are fully floating with respect to the case and to mains earth, so an additional terminal



Use this diagram, together with the circuit diagram, to guide your construction of the power supply.

connected to the rear of the case has been included. This may be connected to any of the supply outputs, to establish reference levels. Alternatively it can be connected to any associated equipment, to alleviate any hum or interference problems.

In our prototype the meter was wired after the load switch so that it would be immediately obvious when the supply was switched on. Alternatively the meter could be connected before the load switch if you desire. This would permit one to set the output voltage before connecting the supply to the load.

As a final note about the circuitry, it can be seen that the output voltage meter has only been connected to the positive supply without provision for monitoring the negative supply. This is not unreasonable as a compromise, as the positive supply tracks the negative supply. Hence if anything were to change the negative supply voltage, such as a short, it would still be reflected on the output meter.

Looking now to the maximum current characteristic of the supply in the adjacent diagram, there are two major factors which impose a limit on the maximum current available.

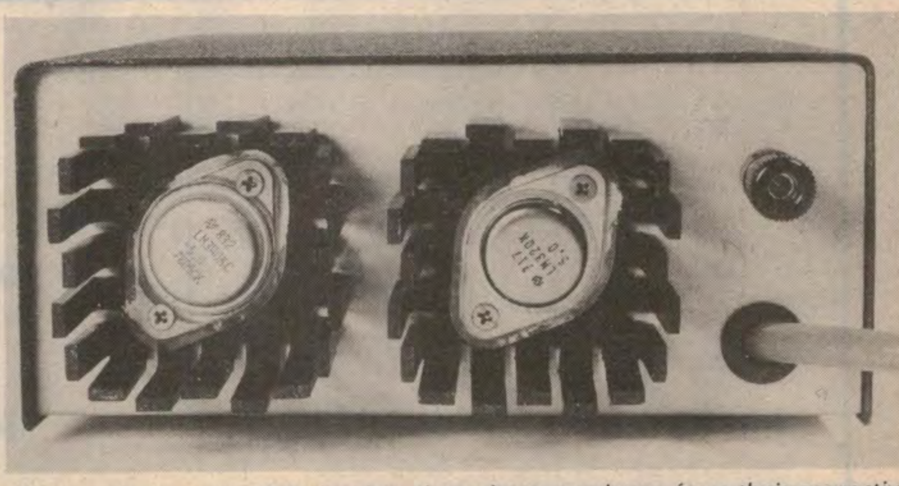
At low voltages the current is limited to 1.5A because of the internal current limiting of the three-terminal regulators themselves. At higher ambient temperatures or if smaller heatsinks are used the power dissipation may reduce this limit even further and the lower end of the curve will appear as a hyperbola.

Toward the end of the current limit diagram, at high output voltages, current is limited because of the increased ripple and reduced DC voltage available from the rectifier and filter.

The regulators require a minimum voltage between their input and output terminals to still maintain regulation. This is referred to as the "drop out" voltage and when the voltage across the regulators is reduced to this value due to large load currents and high output voltages, ripple will break through into the output. This leads to the straight line cutoff seen in the diagram.

To make assembly of the supply easier, I have designed a small printed circuit board (PCB) which supports most of the smaller components. The PCB measures 120 x 80mm, and is coded 79PS6. The pattern for the board is reproduced here actual size, for those who may wish to trace it or photographically copy it to make their own PCB, although boards will no doubt be available from the usual suppliers shortly.

Wiring of the PCB should be fairly



Mica washers are used to insulate the voltage regulators from their respective heatsinks. Note the earth terminal at upper right.

straightforward from the overlay diagram and photograph. Note that the PCB provides for both the 14-pin and 8-pin versions of the 741 devices, so that you can use whichever is available.

The PC board in our prototype was mounted in an inexpensive metal case with plastic board supports. The case and heatsinks were kindly supplied by Dick Smith Electronics whose catalog numbers for these items is H-2744 and H-3400. If you're using the suggested case, the wiring layout diagram and panel layout provided could be useful.

Mount the regulators and power transformer before mounting the PCB in the case. When mounting the regulators, drill the holes sufficiently large so that they do not interfere with the regulator terminals and sleeve the terminals with plastic "spaghetti" tubing. To improve thermal conductivity between the regulators and the heatsinks, silicon grease or other thermal conducting compound should be used.

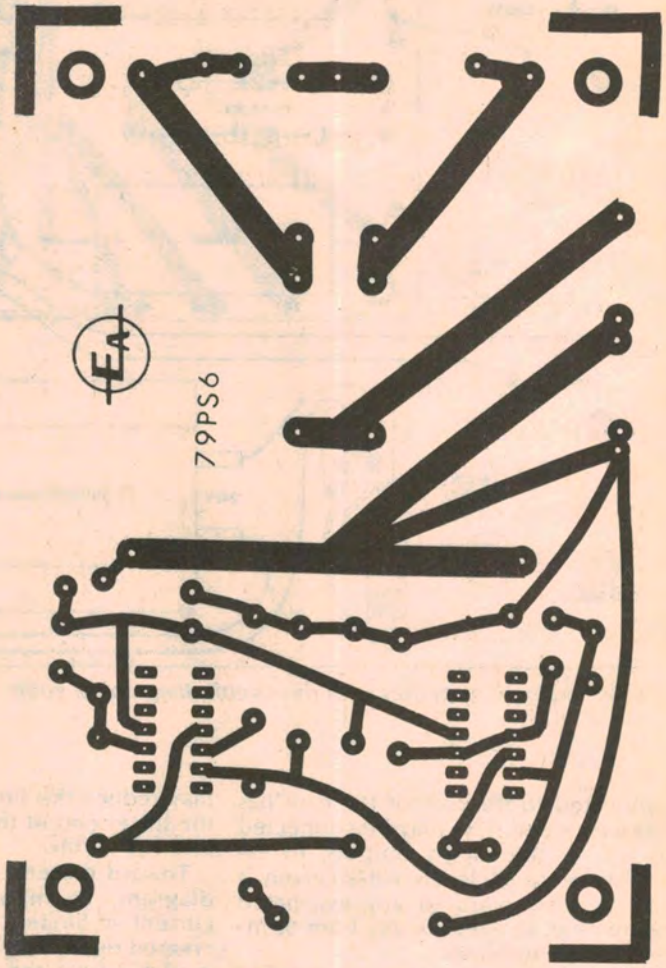
Before wiring them into circuit, check carefully that the regulators are actually insulated from the chassis with a multimeter or other continuity checker. This gives you the opportunity to take appropriate action if they are not.

The mains cord should enter the case via a grommeted hole and be clamped securely. The active and neutral wires should be terminated in an insulated terminal block and the earth lead soldered directly to a lug bolted to the chassis. Note that when mounting the transformer the primary leads should exit from the transformer on the side away from the PC board, to reduce the likelihood of shock.

When wiring up the LED indicator note that the 1.5k resistor in series with the LED is not included on the PC board, so solder this resistor directly to one of the LED leads and insulate it with some plastic tubing.

After carefully checking the wiring of your supply, particularly the polarity of the electrolytics and diodes, switch on the mains and observe the output voltage meter reading. If anything is amiss, disconnect and recheck the circuit. Possible faults include incorrect wiring of the regulators, or the 741 ICs may not be orientated properly.

If all is well you should find the supply a very useful addition to your workbench, especially when working on op-amp circuits. Of course it can also be used for jobs which require a single supply, by using either one of the two outputs — or both in series if you need higher voltage.



ABOVE: Here is an actual size reproduction of the PC pattern. BELOW: this full-size replica of the front panel can be used direct, or it may be copied.