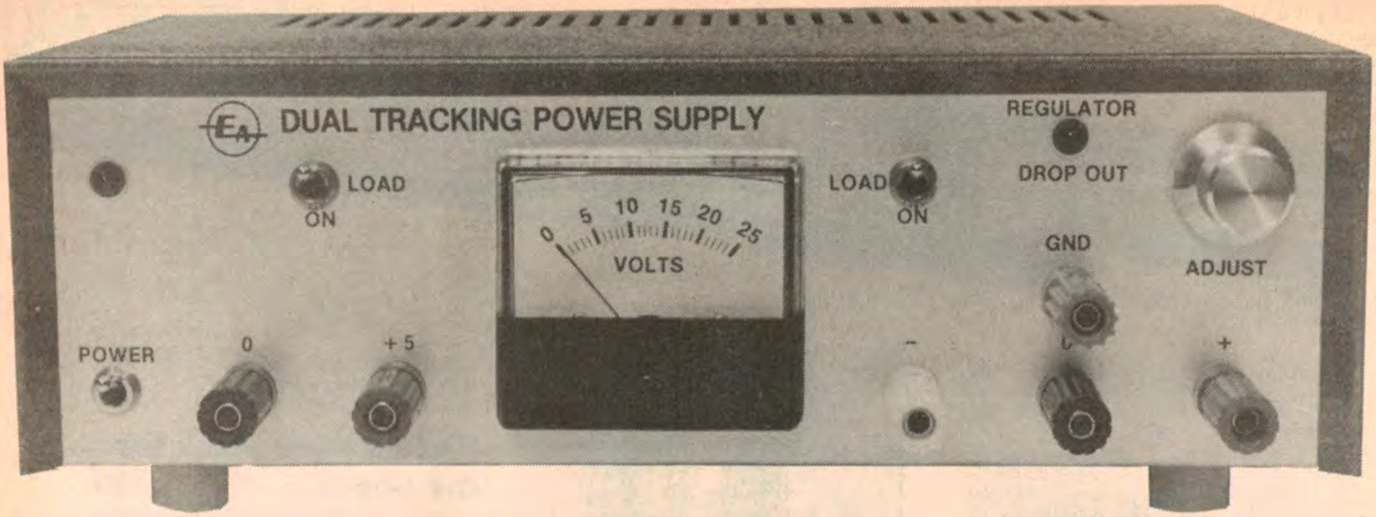


Dual tracking ±22V power supply

Built around positive and negative 3-terminal regulators, this versatile dual-tracking power supply can provide voltages from ±1.3V to ±22V at currents up to 2A. In addition, the supply features a fixed +5V 0.9A output and is completely protected against short circuits, overloads and thermal runaway.

by JOHN CLARKE

Power supplies are always a very useful addition to any workshop or experimenter's bench. They are invariably in constant use for powering battery-operated equipment during servicing and as a power source for circuits under development. By far the most useful power supply is one which can be adjusted to provide a wide range of output voltages and which can supply the necessary current. Add to this the benefits of full protection and regulation and you have an invaluable piece of test gear.

The voltages available from our power supply should be adequate for virtually any modern circuit configuration apart, from high powered amplifiers. Many circuits use operational amplifiers which often require plus and minus supply rails. Some op amps, such as the RCA CA3140, will function from a supply as low as ±2V and most consumer op amps can be operated from voltages up to ±18V. As well as providing these supplies, a fixed +5V supply is also useful for circuits combining logic ICs and op amps.

Extremely low voltages are also a useful feature of a power supply, since many circuits are designed to run from a single 1.5V dry cell or from a 1.35V mercury cell.

Since ±22V can be obtained from the power supply, a total of 44V is available across the positive and negative rails. Of course, the ±5V rail is still referred to the 0V rail. Any of the terminals (either the –, 0, + or +5V) can be tied to the Ground, which is a separate terminal. Alternatively, the power supply can be left floating.

Two separate switches are provided to disconnect the voltage from the output terminals, one for the +5V rail and the other for the variable supply rails. A meter continuously monitors the voltage across the positive supply rail. Loss of regulation at high currents is indicated by a "Regulator Drop Out" LED indicator.

PERFORMANCE

The performance of the prototype with respect to the adjustable plus and minus supplies is shown by the two accompanying graphs. Regulation is such that both outputs vary by less than 100mV for a load change from 0 to 2A. Maximum current is limited to 0.9A at 1.25V, but about 2A can be supplied from between 9 and 18 volts.

The limits of the curve are determined by the internal limits of the regulator IC and also by the regulation of the transformer. When the +5V regulator is supplying its maximum load current of 0.9A, the transformer is loaded to such an extent that the adjustable regulators will drop out of regulation at around 17V. This drop out condition is indicated by the "Drop Out" LED on the front panel of the power supply.

The unloaded tracking ability – ie the accuracy with which the negative supply follows the positive rail – is within 1mV. However, the actual difference between the absolute values of the positive and negative supplies could be up to 100mV, depending upon the reference voltage from each particular regulator. Although we used a low resolution (±0.5V) meter for monitoring the output voltage across the positive supply rail. the actual voltage can be set to within 10mV with a 10-turn voltage adjust potentiometer (provided you have a digital multimeter).

Heart of the design are the National Semiconductor 3-terminal adjustable regulators. The positive supply regulator is designated the LM317, while the negative regulator is the LM337. As well as having a minimum output voltage of 1.2 volts, these regulators have better line and load regulation than standard 3-terminal regulators. Included in the regulator ICs are current limit, thermal overload and safe area protection circuitry.

Turning to Fig. 1, we can see how the three terminal regulators are used as an adjustable supply and how the negative regulator is connected to track the positive regulator. Let's look first at the positive LM317 regulator. This regulator is designed so that a nominal 1.25 volts is developed between the OUT and ADJ terminals, regardless of supply current.

In practice, though, this fixed reference voltage could be between 1.2V and 1.3V, and a minimum load current must be provided.

The reference voltage (VREF1) is impressed across R1 to produce a constant current IQ1, which is equal to VREF1/R1. The ADJ terminal also produces a bias current, IADJ1, and both these currents flow through R2 to produce the voltage (IQ1 + IADJ1) x R2. The voltage at the output of the regulator is therefore the sum of VREF1 and the voltage across R2. This simplifies to: VOUT = VREF1(1 + R2/R1) + IADJ1 x R2.

The maximum IADJ1 current is 100μA, which can be ignored since this value is only 1% of IQ1. The VOUT equation simplifies approximately to: VOUT = VREF1 x (1 + R2/R1).

It follows from this that the minimum voltage is VREF1 when R2 is zero, and the maximum voltage is 22.08V when R2 is 2kΩ (assuming VREF1 is 1.25V).

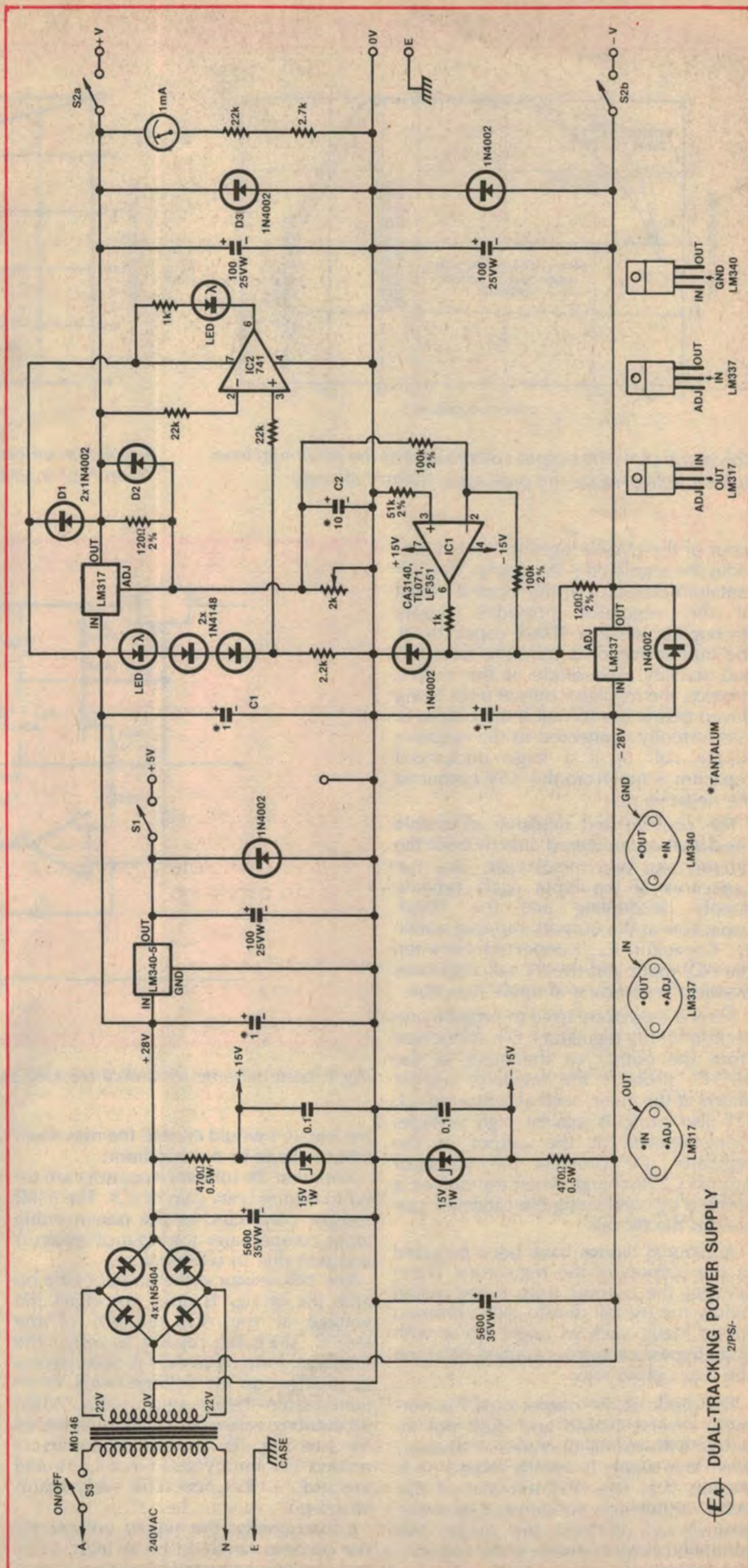
The voltage at the ADJ terminal of the LM317 is inverted with the unity gain inverting operational amplifier and applied to the ADJ terminal of the LM337 negative regulator. The voltage output from the negative LM337 regulator is therefore minus the voltage at the ADJ terminal of the LM317 minus VREF2. This reduces to the equation for VOUT (–) of Fig. 1.

By comparing the VOUT and VOUT (–) equations, it can be seen that the negative rail will track the positive rail and their absolute values will differ only by VREF1 – VREF2. This difference will only be a maximum of 100mV and will generally be much less than this.

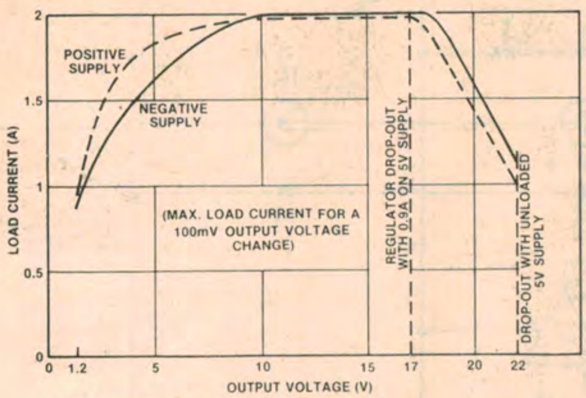
THE CIRCUIT

Looking now to the circuit diagram, a centre tapped transformer is used to provide 22V RMS per winding. The centre tap is used as the zero reference and the positive and negative sides of the power supply are obtained from a full wave bridge rectifier consisting of four 3A silicon rectifier diodes. The resulting DC voltage is filtered by two 5600μF capacitors, one from the positive rail to the centre tap and the other to the negative rail from the centre tap.

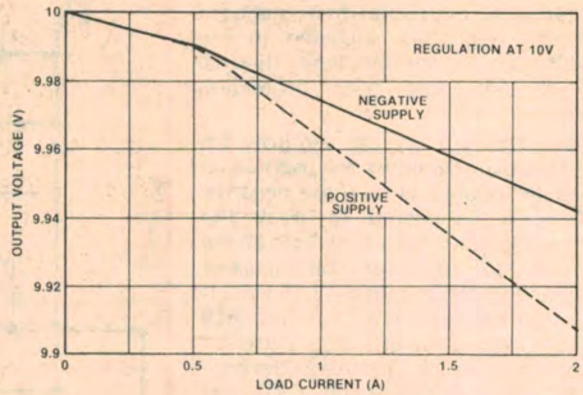
The positive voltage is applied to the



Dual tracking power supply



This graph plots the output voltage against the maximum load current delivered by the prototype (100mV change).



Regulation on both positive and negative rails is better than 100mV for load currents from 0 to 2A.

input of the LM340 regulator which provides the regulated +5V supply. The 1μF tantalum capacitor at the input terminal of this regulator provides supply decoupling while a 100μF capacitor at the output improves transient response and stability. The diode at the output protects the regulator output from being driven below the 0V rail if the output is inadvertently connected to the negative supply rail, or if a large uncharged capacitor is tied from the +5V output to the negative rail.

The positive and negative adjustable regulators are powered directly from the filtered plus and minus rails. The 1μF capacitors at the input again provide supply decoupling and the 100μF capacitors at the outputs improve stability. Capacitor C2, connected between the ADJ input and the 0V rail, improves transient response and ripple rejection.

Several diodes are used to provide protection for the regulators. D1, connected from the output to the input of the LM317, protects the regulator against shorts at the input, such as a shorted C1. D1 also protects against high voltages being applied at the output of the regulator. D2 protects the regulator against C2 discharge when the output is shorted by conducting the capacitor current to the 0V rail.

Additional diodes have been included at the outputs of the regulators. These prevent the outputs from being pulled below the 0V rail due to high common mode loads, such as might occur with large bypass capacitors applied between the two output rails.

The diode at the output of IC1 is normally reverse biased and does not interfere with normal operation. However, when the supply is initially turned on it ensures that the ADJ terminal of the LM337 regulator is not dragged up to the positive rail. Without this diode, the combined output voltage of the negative supply and the positive supply voltage to

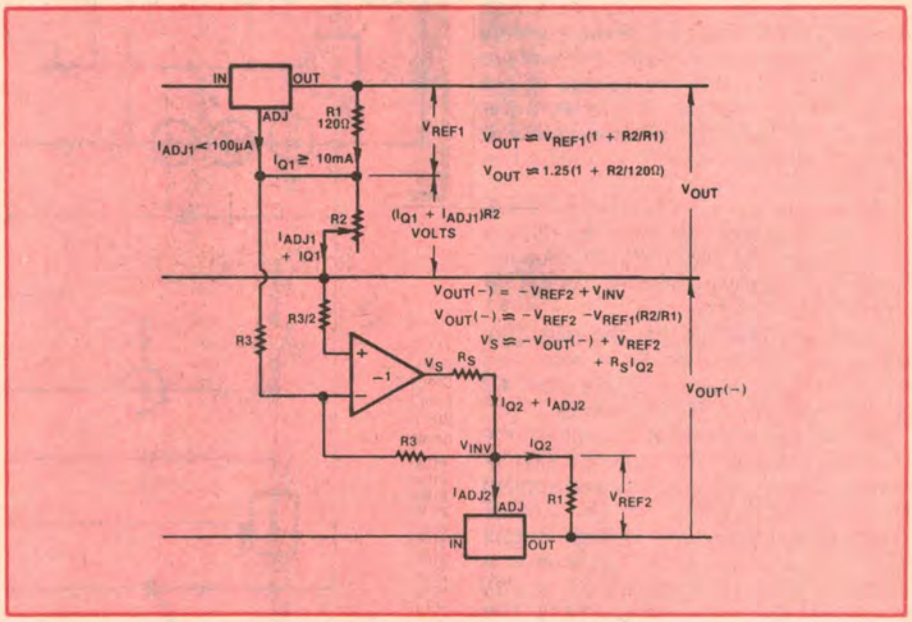


Fig.1: basic scheme for a dual tracking supply using 3-terminal regulators.

op amp IC1 would exceed the maximum input voltage to the regulator.

Note that 2% tolerance resistors are used to ensure unity gain of IC1. The 51kΩ resistor connected to the non-inverting input compensates for input offset error and drift due to temperature.

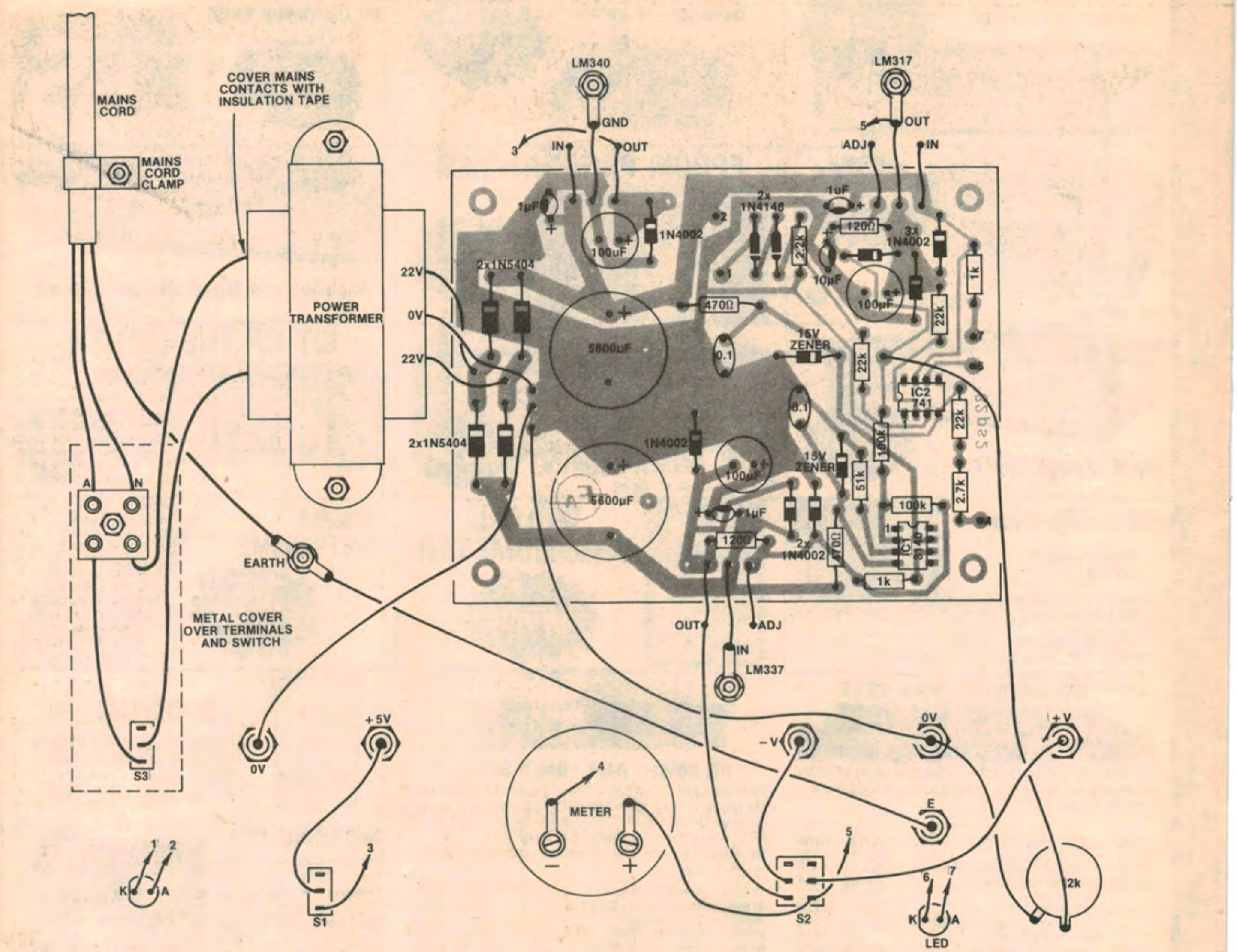
The 1kΩ resistor at the output of the op amp (Rs of Fig. 1) does not effect the voltage at the ADJ terminal of the LM337, since the resistor is within the feedback loop. However it does have a large effect on the voltage swing Vs required from the op amp output. When substituting values into the equation for Vs (see Fig. 1), we obtain values of around 11V for a VOUT (–) of 1.25V and around −12V for the maximum VOUT (–).

Consequently, the supply voltage for the op amp needs to be at least ±12V and preferably greater than this to offset the fact that the op amp will not swing to the full supply rails.

The maximum allowable supply voltage for the op amp is ±18V and so the supplies cannot be derived from the rectified transformer voltage. Instead, zener diodes are used to drop the rectified voltage to ±15V. The 0.1μF bypass capacitors across the zeners reduce the possibility of instability in the op amp.

IC2 is used to monitor the drop out voltage across the positive adjustable regulator. Two diodes and a LED in series are connected to the input of the regulator and are biased on with a 2.2kΩ resistor. This LED is used as the power on indicator and, in conjunction with the other two diodes, gives a voltage drop from the positive supply of about 3V.

IC2 monitors this voltage, as well as the voltage at the output of the regulator. Normally the input voltage to the



Note that the three regulator ICs must be insulated from chassis (see text and diagram). Keep mains wiring neat and tidy.

PARTS LIST

1 K and W instrument case, 256 x 90 x 159mm
1 Scotchcal front panel, 251 x 76mm
1 meter scale, 51 x 43mm
1 PCB, code 82ps2, 95 x 120mm
2 SPDT switches
1 DPDT switch
6 binding post terminals (2 red, 2 black, 1 white, 1 green)
1 transformer, 22-0-22V at 1.25A, M-0146 or equivalent
1 Bourns ten turn potentiometer, 2kΩ, 3540S
1 1mA FSD meter, 58 x 52mm
1 knob
2 red LEDs and bezels
1 mains cable and plug
1 two-way terminal block
1 cord clamp
1 grommet
4 earth lugs
3 TO-3 mica washers and 6 bushes
3 TO-3 plastic covers
1 piece of aluminium, 60 x 60mm

SEMICONDUCTORS
1 LM340-5, 7805 TO-3 3-terminal regulator
1 LM317 TO-3 3-terminal adjustable regulator
1 LM337 TO-3 3-terminal adjustable regulator
4 1N5404 3A silicon diodes
7 1N4002 1A silicon diodes
2 1N4148, 1N914 small signal silicon diodes
1 CA3140, TL071, LF351 Bi-FET input op amp
1 741 op amp
2 15V 1W zener diodes

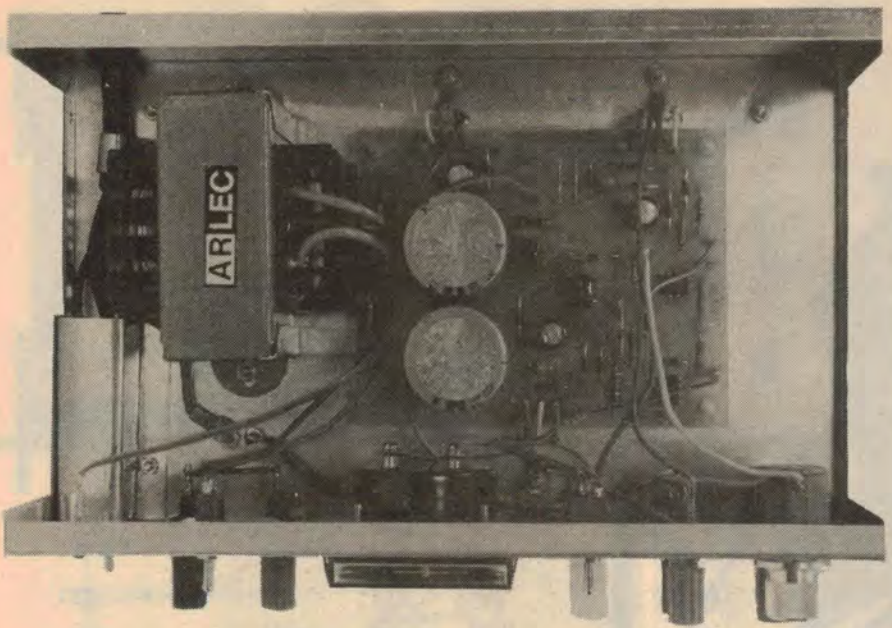
CAPACITORS
2 5600uF 40VW PC electrolytic
3 100uF 25VW PC electrolytic
1 10uF 35VW tantalum
3 1uF 35VW tantalum
2 0.1uF metallised polyester

RESISTORS (5%, ¼ unless noted
3 x 22kΩ, 1 x 2.7kΩ, 1 x 2.2kΩ, 2 x 1kΩ, 2 x 470Ω ½W.

RESISTORS (2%, 1/4W)
2 x100kΩ, 1 x 51kΩ, 2 x 120Ω

MISCELLANEOUS
Screws, nuts, washers, hook-up wire, solder, PC stakes etc

NOTE: Components specified are those used in the prototype. Components with higher ratings may generally be used provided they are physically compatible.



View inside the prototype. We covered the mains terminal strip and the power switch with a small metal cover made from scrap aluminium.

regulator is more than 3V above the output and so the op amp output is high. When the input voltage is less than 3V above the output of the regulator, the op amp goes low and the LED connected to the pin 6 output lights to indicate a drop out.

The drop out LED provides early warning of regulator drop out, which occurs at around a 2V voltage differential between the input and output. Although the drop out is only monitored for the positive supply, the LED will also light for a drop out condition on the negative regulator due to loading on the transformer affecting the positive rail.

A 1mA meter is used to monitor the voltage across the adjustable supply. The 22kΩ and 2.7kΩ resistors in series with the meter allow 1mA (full scale deflection) to flow through the meter when 25V is across the supply rails.

CONSTRUCTION

We constructed our power supply in a K and W instrument case, which has a folded heavy gauge aluminium base and a steel lid with a blue hammer tone finish. The case measures 256 x 90 x 159mm (W x H X D), and is available from most parts suppliers. A printed circuit board, coded 82ps2 and measuring 95 x 120mm, is used for the majority of the circuit components. In addition, a Scotchcal front panel artwork has been produced and measures 251 x 76mm. A 0 to 25V meter scale artwork measuring 51 x 43mm is also available and is suitable for meters measuring overall 58 x 52mm.

Start construction by drilling mounting holes for the mains cable grommet, cable clamp, terminal strip, earth lug, transformer, and the PCB. Use the photographs and wiring diagram to help you position these components within the case. The mounting holes for the regulators should be positioned such that their leads are close to the edge of the PCB and in line with the pads on the PCB to which they are to be wired.

The Scotchcal label can now be sprayed with a hard setting lacquer to prevent scratches and attached to the front panel of the case. Drill the holes for the meter, terminals, pot, switches and LEDs. Clean the burrs from around the holes and mount the components. The transformer, terminal block, grommet and cable clamp can now be mounted.

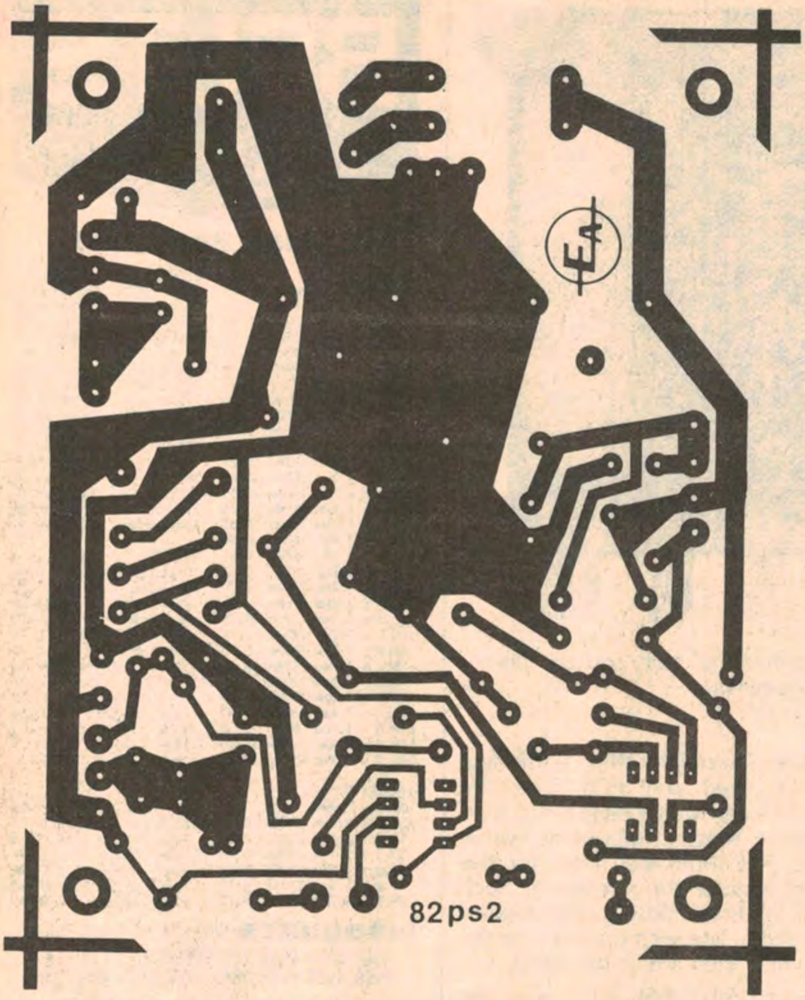
The 0 to 25V scale for the meter is positioned in the meter by removing the plastic front cover, unscrewing the two screws and securing the new label in place.

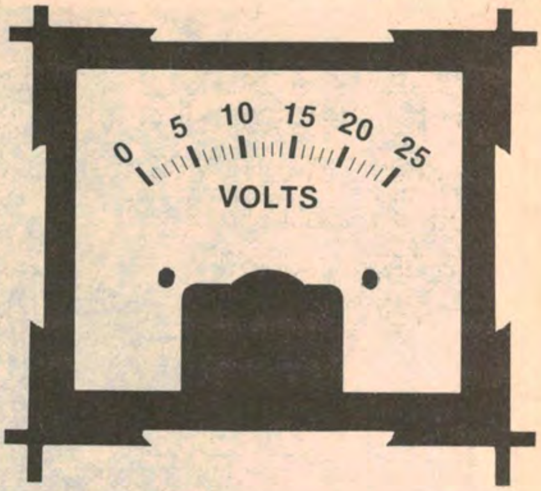
The TO-3 regulators are mounted beneath the base of the case and the leads connected with short wires. Mica washers and insulating bushes are used to electrically isolate each regulator from the case. We used TO-3 plastic covers on the regulators to prevent the otherwise exposed regulator from accidently shorting to the case.

We estimate that the current cost of components for this project is

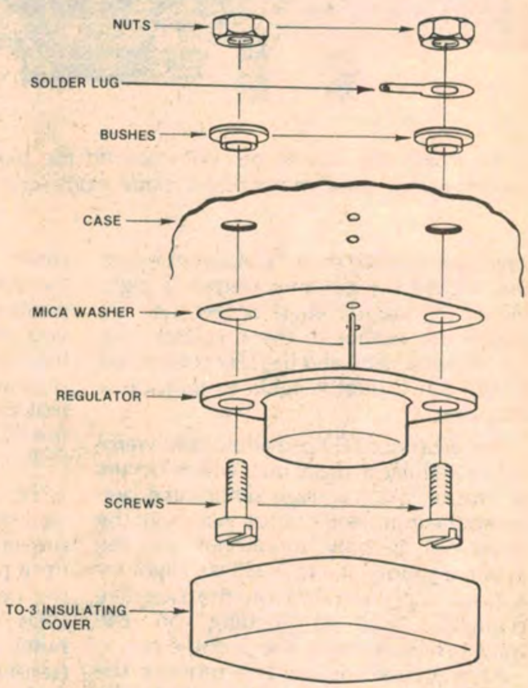
$86

This includes sales tax.





Above are actual size artworks for the PCB and the meter scale. The front panel has not been included because it is too big to fit the page.



RIGHT: This diagram shows how the TO-3 regulators are mounted.

The correct method of mounting the regulators is shown in the accompanying diagram. Make sure that all metal swarf is removed from around the holes and that the mounting surface is clean. Use heatsinking compound between the mica washer-to-case and mica washer-to-regulator surfaces. Note that the mounting screws should not be too long, otherwise they may short to the tracks on the PCB.

After the regulators have been mounted, check that they are in fact isolated from the case by checking with a multimeter set to the ohms range.

Although we recommend the TO-3 case style for all regulators, it is possible to use TO-220 regulators with some sacrifice in available output power but with a reduction in cost. These regulators will directly mount in the pads allocated for the regulators on the PCB, and should also be heatsinked to the base of the case. Electrical isolation of the regulator from the case is necessary.

Work can now begin on the PCB. We used PC stakes for all the external connections, since the wiring is made considerably easier. Mount all the components according to the overlay diagram and make sure that they are oriented correctly. The zener diodes are mounted about 2mm above the PCB and a loop made in one of the leads. This loop allows heat expansion without breaking the delicate glass seal of the zener body.

When complete, the PCB can be mounted within the case with PCB standoffs and the wiring can now begin. Rainbow cable can be used for the LED and meter wirings, but heavy-duty hookup wire (eg 24 x 0.2mm) is recommended for all other wiring. Note that the regulator outputs should be wired directly to the output terminals and not run via the pads on the PCB, except when TO-220 regulators are used.

It is important that the mains wiring be safely covered. If a wire from the power supply circuitry were to come adrift and find its way to the mains active, the whole supply could be at mains potential. Consequently, we covered the mains terminals on the transformer with several layers of insulating tape and made a small metal cover from scrap aluminium to cover the power switch and terminal strip.

When wiring is complete, make a final check that all is correct and apply power. Check that ±5V is supplied by the LM340-5 and that the meter is working correctly (use your multimeter). Measure the voltage from the variable supply and check that the negative rail tracks the positive rail when the adjust knob is rotated. It should be possible to vary the voltage from 1.3 to 22 volts.

Finally, check the operation of the load switches and confirm that the Drop Out LED works when a 0.9A load is applied to the +5V supply with the adjustable supply set to ±22V.