Build this for your workshop

Dual tracking ±21V power supply

Based on readily available components, this new dual tracking power supply can provide voltages from 0 to ±21.5V at currents up to 2A. It also features overload protection, a fixed +5V 1A output, and output voltage metering.

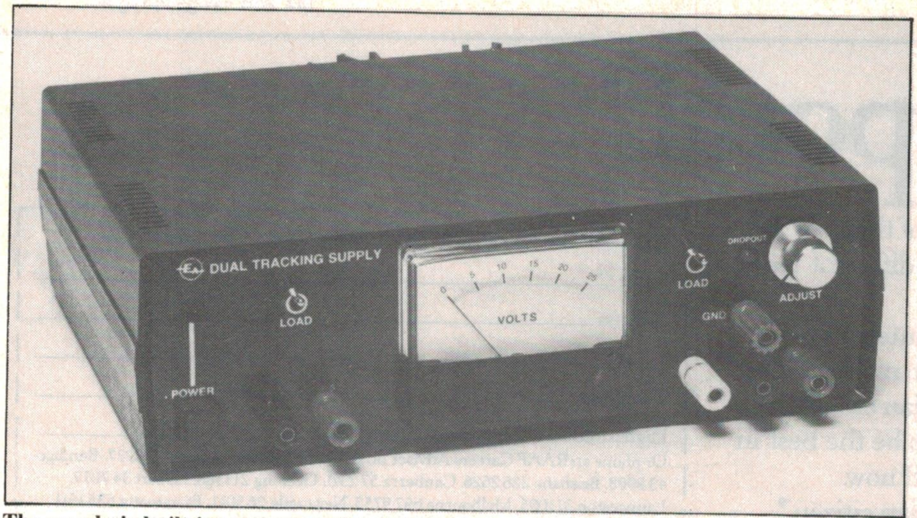
by JOHN CLARKE

Variable power supplies are one of the most important items of equipment for the home workshop or laboratory. They are useful for testing new circuit designs and for general purpose power requirements. This new Dual Tracking Power Supply is a versatile unit that is ideal for both hobby and professional use.

The plus and minus supply outputs are ideal for powering modern op amp circuits which generally require balanced 15V rails. In this design, the supply outputs can be adjusted from zero up to about ±21.5V which will cater for virtually all op amp applications. Note: some special op amps, such as the RCA CA3130 and CA3140, can operate down to ±2.5V and ±2V respectively.

A feature of the design is that the outputs are all fully floating. This means that any one of the common, plus or minus terminals can be connected to the mains earth. Thus, you can opt for tracking plus and minus supply rails which are referenced to ground, or a single supply rail with up to 43V output referenced above or below ground.

The 5V output is referenced to the 0V rail of the tracking supply outputs and is handy for powering TTL circuits, as well as CMOS circuits.



The supply is built into an attractive plastic instrument case.

Other features of this new design include load switching for both the +5V and variable outputs, short circuit protection, and a LED regulation dropout indicator. The latter does just as its name implies — it indicates when the supply has dropped out of regulation on the variable outputs. When the supply drops out of regulation, the hum superimposed on the supply rails will increase markedly and the output voltage will drop severely for any further increase in load current.

Generally, this occurs only when the +5V supply is heavily loaded and the variable supply rails are set to a high voltage.

Performance

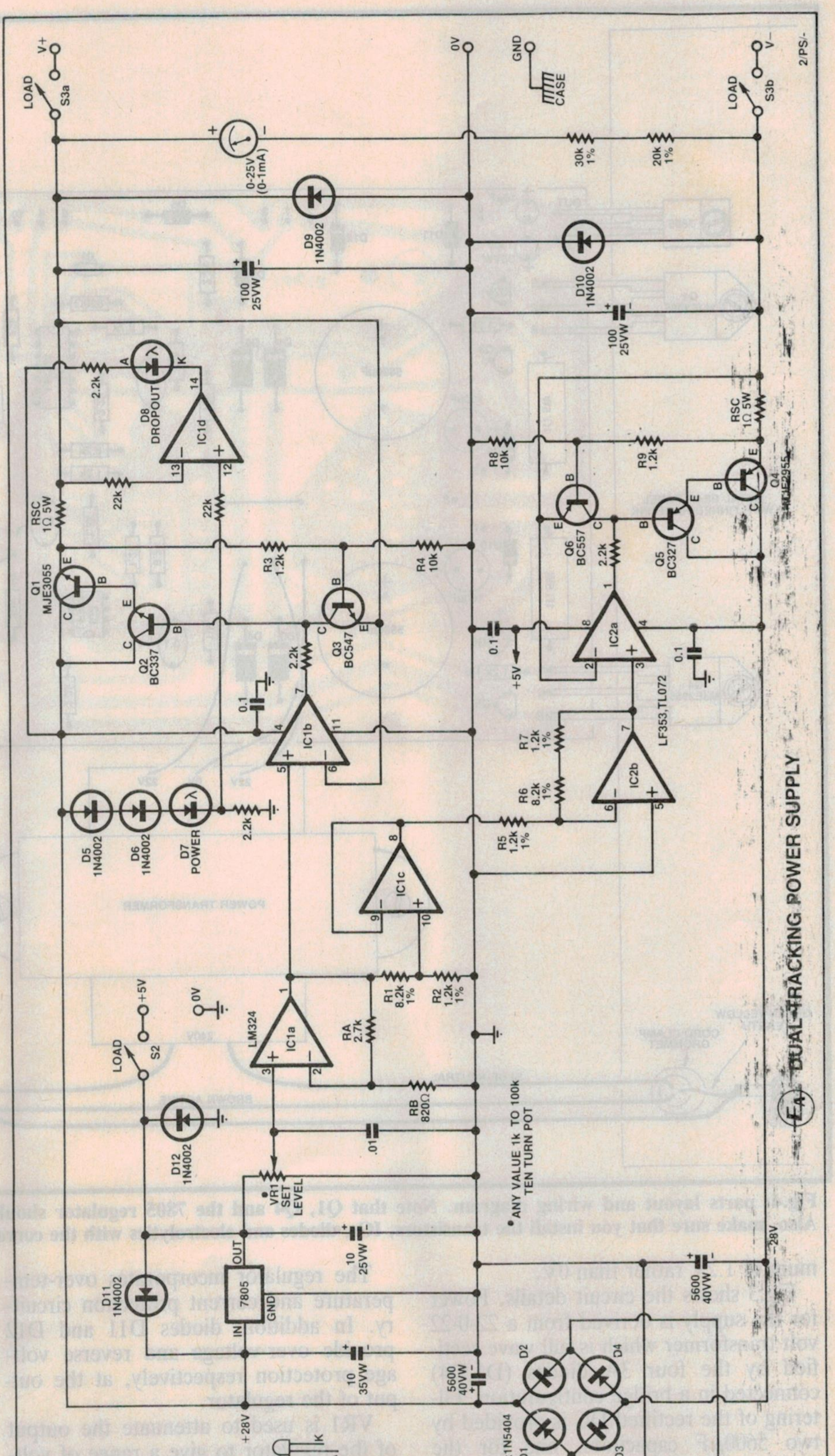
Fig.1 shows the output current capability for various output voltages. Note that up to 2A is available from between 10V and 16V. After that, the maximum output current tapers off to below 1A above 20V and below 5V.

Fig.2 shows the current limiting characteristic at 10V. Once the maximum load current of 2A has been exceeded, the load current begins to reduce or "foldback" until, under short circuit conditions, the current is limited to 0.85A. The idea of this is to limit the dissipation in the output devices under overload conditions and thus prevent over-heating of the supply.

A 10-turn potentiometer is used to set the dual-tracking output voltage. Although a standard potentiometer could have been used here, the 10-turn pot allows easy adjustment of the output voltage to within 10mV of a desired value (provided that you have a digital multimeter).

A 10-turn pot also greatly reduces the risk of destroying a voltage sensitive circuit in the event that the control is accidentally knocked. This is because a 10-turn pot will only change the output by a small amount in these circumstances

Fig.3: the circuit uses a 3-terminal regulator to provide a 5V reference and series pass transistors for the tracking supplies.



while a standard pot could change the supply by several volts.

Tracking performance under no-load conditions between the positive and negative supplies is within 10mV. Note, however, that the absolute voltage difference between the plus and minus supplies could be as much as 100mV. The regulation performance is better than 100mV from no load to full load for each variable output.

How it works

The circuit for our new Dual Tracking Power Supply is rather unusual because it uses just one 3-terminal regulator — and that's to provide a reference voltage and the fixed +5V output. Conversely, the variable outputs rely on good old fashioned series pass transistors and operational amplifiers to provide regulation and tracking.

Regular readers of *Electronics Australia* may remember that our last dual tracking power supply in March 1982 used LM317 and LM337 3-terminal regulators for the tracking supply circuitry. We've discarded them for two reasons: first, they are now quite expensive; and second, their output voltage can only be adjusted down to a mini-

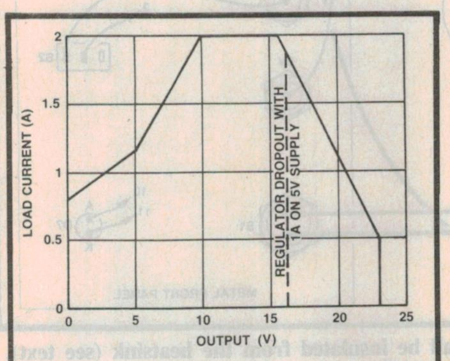


Fig.1: maximum output current vs. output voltage.

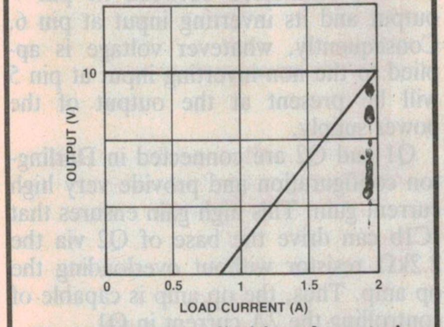


Fig.2: the current limiting characteristic at 2A. Note how the load current "folds back" after reaching 2A.

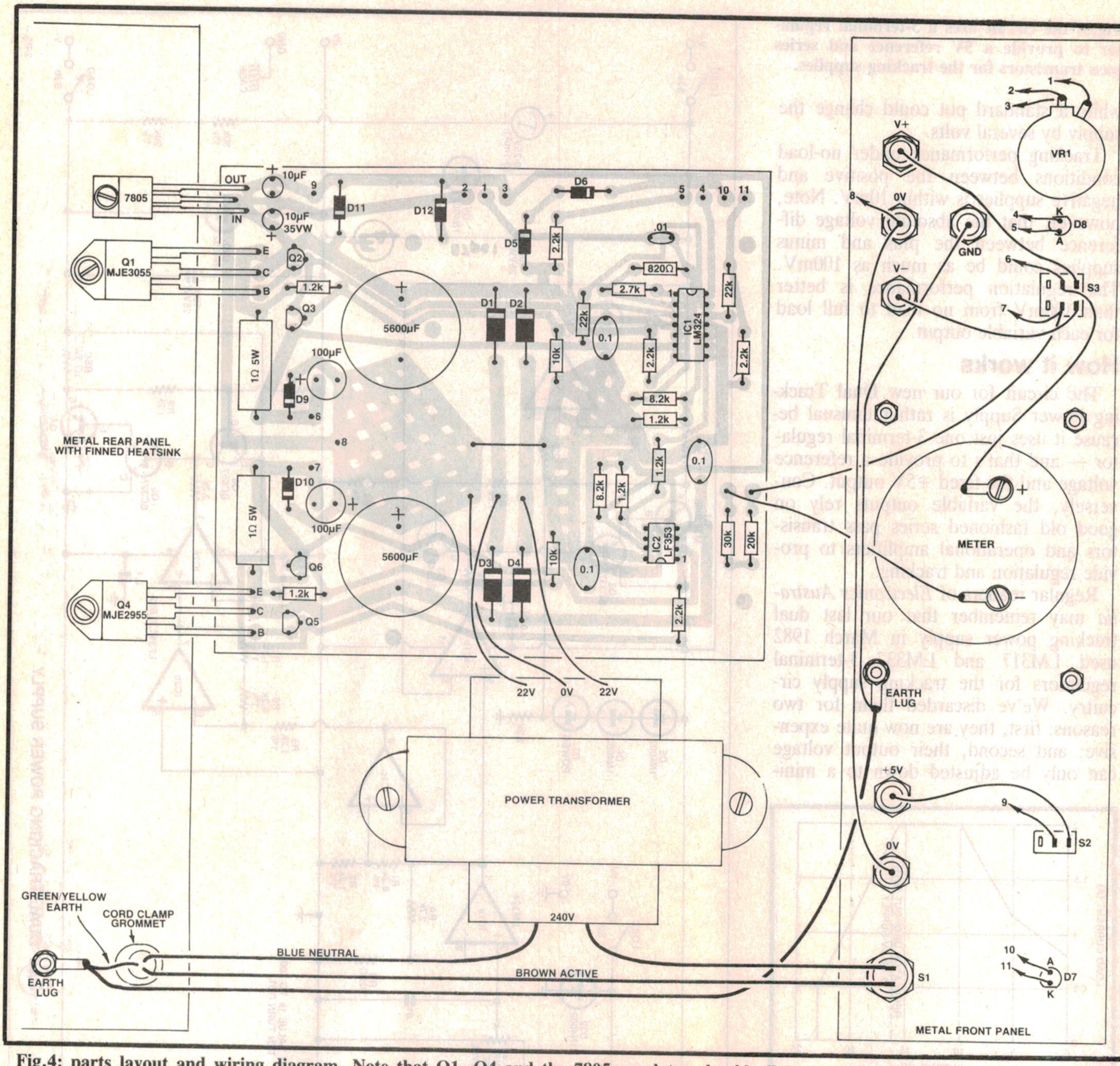


Fig.4: parts layout and wiring diagram. Note that Q1, Q4 and the 7805 regulator should all be insulated from the heatsink (see text). Also, make sure that you install the transistors, ICs, diodes and electrolytics with the correct polarity.

mum of 1.2V rather than 0V.

Fig.3 shows the circuit details. Power for the supply is derived from a 22-0-22 volt transformer which is full wave rectified by the four 3A diodes (D1-D4) connected in a bridge configuration. Filtering of the rectified DC is provided by two 5600µF capacitors, one for the positive and other for the negative rail.

A standard 7805 1A 3-terminal regulator provides the +5V output, as well as a reference for the op amps in the tracking supply circuitry. The 10µF capacitors at the input and output of the regulator ensure stability and good transient response.

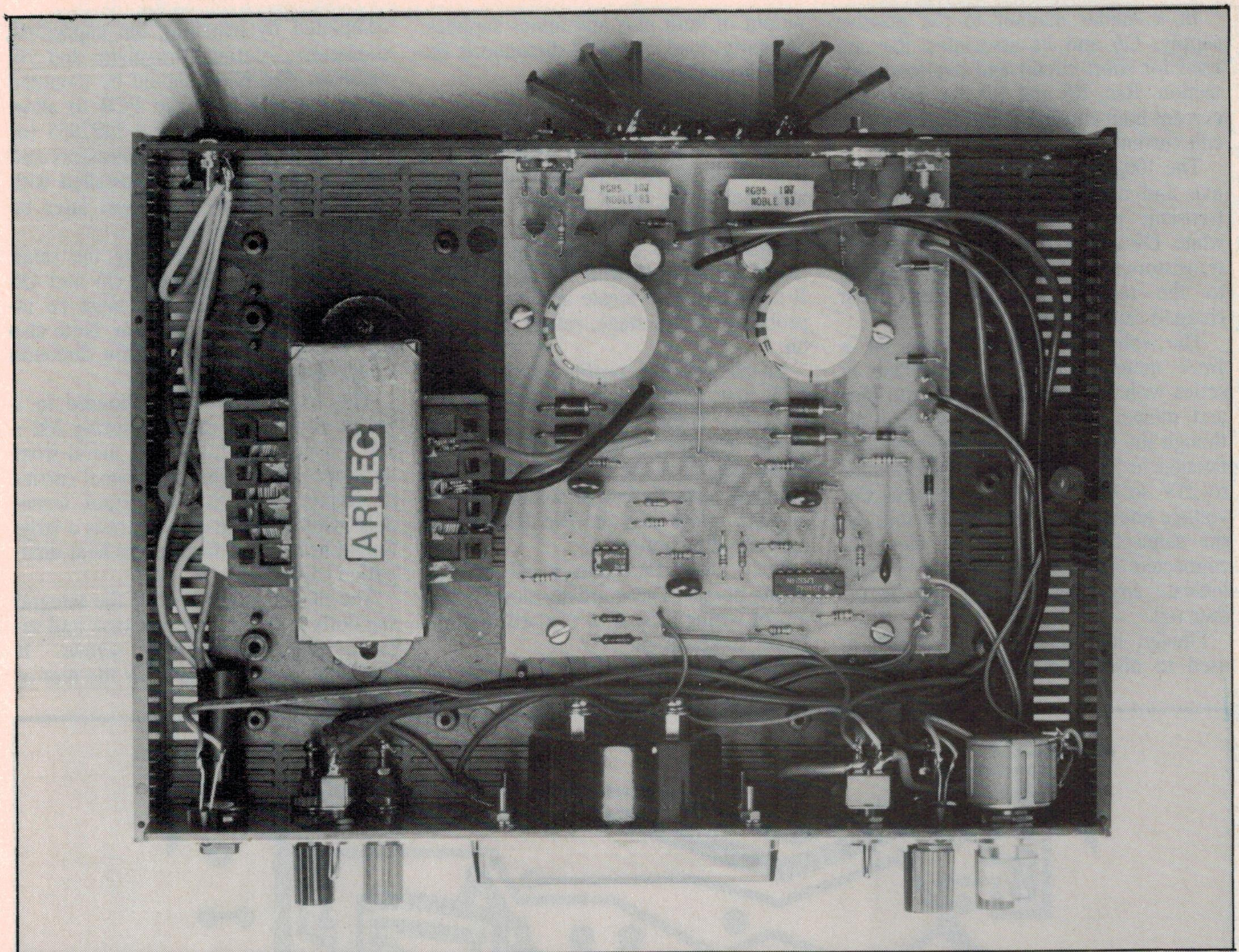
The regulator incorporates over-temperature and current protection circuitry. In addition, diodes D11 and D12 provide over-voltage and reverse voltage protection respectively, at the output of the regulator.

VR1 is used to attenuate the output of the regulator to give a range of voltages from 0 to +5V at the potentiometer wiper. IC1a (LM324) amplifies this voltage by about 4.3 to give a range of voltages from 0 up to 21.5V for various settings of VR1. This is applied to the non-inverting input of IC1b.

IC1b is a unity gain non-inverting amplifier with a 2.2kΩ resistor, Q2, Q1 and Rsc connected between its pin 7 output and its inverting input at pin 6. Consequently, whatever voltage is applied to the non-inverting input at pin 5 will be present at the output of the power supply.

Q1 and Q2 are connected in Darlington configuration and provide very high current gain. This high gain ensures that IC1b can drive the base of Q2 via the 2.2kΩ resistor without overloading the op amp. Thus, the op amp is capable of controlling the 2A current in Q1.

Current overload protection for the positive supply is provided by Rsc and Q3. Rsc, a 1Ω 5W resistor, is used to



View inside the prototype. The two 1Ω 5W resistors should be mounted proud of the PCB to aid cooling.

detect an overload current through series pass transistor Q1.

At low load currents, the voltage at the emitter of Q3 is close to the voltage at the emitter of Q1 and so Q3 is biased off. As the load current increases, the voltage across Rsc also increases until, at about 2A, Q3 is biased on. This removes base drive to the Darlington pair (Q1 and Q2) and thus reduces the output voltage.

As the output voltage decreases, the voltage at the emitter of Q3 decreases at a faster rate than the voltage at the base. This effect is largely due to the voltage divider formed by R3 and R4. Less output current is now required to keep Q3 biased on, and thus the load current also decreases as the output voltage drops (see Fig.2).

This effect is commonly referred to as foldback current limiting and provides very effective short circuit and current overload protection for the series pass transistors.

Regulator dropout indicator

Comparator IC1d and LED D8 provide the regulation dropout indication. The non-inverting input (pin 12) of IC1d samples the input voltage to the regulator (via D5, D6 and D7), while the inverting input (pin 13) monitors the output voltage. When the voltage differential between the input and output of the regulator circuit becomes too small for regulation to take place, the output of IC1d goes low and the "dropout" LED turns on.

Diode D7 is the power indicating LED and typically has a voltage drop across it of 2V. In conjunction with the two 0.6V drops across D5 and D6, the total voltage drop between the collector of Q1 and the non-inverting input to IC1d is about 3.2V. Thus, the dropout LED lights when the input-to-output difference falls below 3.2V.

Note that the dropout indication circuit monitors the positive supply regulator only. However, the LED will also light for negative supply dropouts. This is because any such dropout will also be reflected in the positive supply due to loading effects on the transformer.

The negative regulator circuit also derives its reference voltage from the +5V regulator. Resistors R1 and R2 attenuate the 0 to +21.5V output from IC1a by a factor of R2/(R1 + R2), while IC1c buffers this attenuated voltage and feeds it to the inverting input of IC2b.

This attenuation is necessary to keep the output of IC1c (and thus pin 6 of IC2b) well below the +5V supply of IC2. To regain this loss of voltage, IC2b amplifies by −(R6 + R7)/R5. The resulting voltage at the output of IC2b (pin 7) is simply an inverse of the output from IC1a.

The negative regulator follows the voltage at the non-inverting input to IC2a. Q4 and Q5 are Darlington connected transistors which provide the gain and power handling capability for the negative supply.

In a similar manner to the positive supply, Q6 and its associated Rsc are used for short circuit and overload protection. Rsc, R8 and R9 determine the current limit threshold and the short circuit current.

The 100μF capacitors across the positive and negative outputs improve the transient response of the regulators, while D9 and D10 protect the output transistors from reverse voltages applied to the regulator outputs (eg, from charged capacitors).

The voltmeter circuit consists of a 1mA meter movement connected in series with two resistors across the plus and minus supply rails. Note that although the resistors set the full-scale deflection to 50V, the scale is calibrated 0 to 25V so that the meter indicates the voltage above and below the 0V rail. At the same time, because the meter is connected across both outputs, it will indicate any overload or shorts on either rail.

Finally, load switch S3a and S3b is used to disconnect the load from the output of both plus and minus supplies. Similarly, load switch S2 disconnects the load from the +5V output.

Construction

Most of the parts are installed on a printed circuit board (PCB) coded 87ps1 and measuring 135 x 120mm. Start by checking the copper tracks for any breaks or shorts by comparing the published PC artwork with the actual PCB. It is far easier to locate and correct any problems at this stage, rather than later on.

Install the low profile parts on the PCB first, according to the parts layout diagram. These include the ICs, low power resistors, diodes and a wire link. Make sure that the ICs and diodes are oriented correctly before soldering them in place. Note that the two ICs face in opposite directions.

Next, install PC stakes at all external wiring points. These greatly simplify the job of wiring later on. You will require 16 PC stakes in all.

Assembly of the PCB can now be completed by installing the capacitors, transistors, 3-terminal regulator and 5W resistors. The latter should be mounted about 1mm clear of the PCB to allow cooling. The TIP3055 and TIP2955 (or MJE3055 and MJE2955) transistors and 7805 regulator should be installed with full lead length as they must later be screwed to the rear panel.

Take care when installing the small signal transistors. Q2, Q3, Q5 and Q6 are all different and each must be installed at the correct location. Note also that Q6 faces in the opposite direction to the other transistors.

The completed PCB is housed in a plastic instrument case measuring 260 x 190 x 80mm and fitted with metal front and rear panels. The front panel carries the meter, controls and output terminals, while the rear panel carries a large finned heatsink to increase its heat dissipation capacity.

The PCB is supported on the integral standoffs in the base of the case and secured using self-tapping screws. It should be positioned towards the rear of

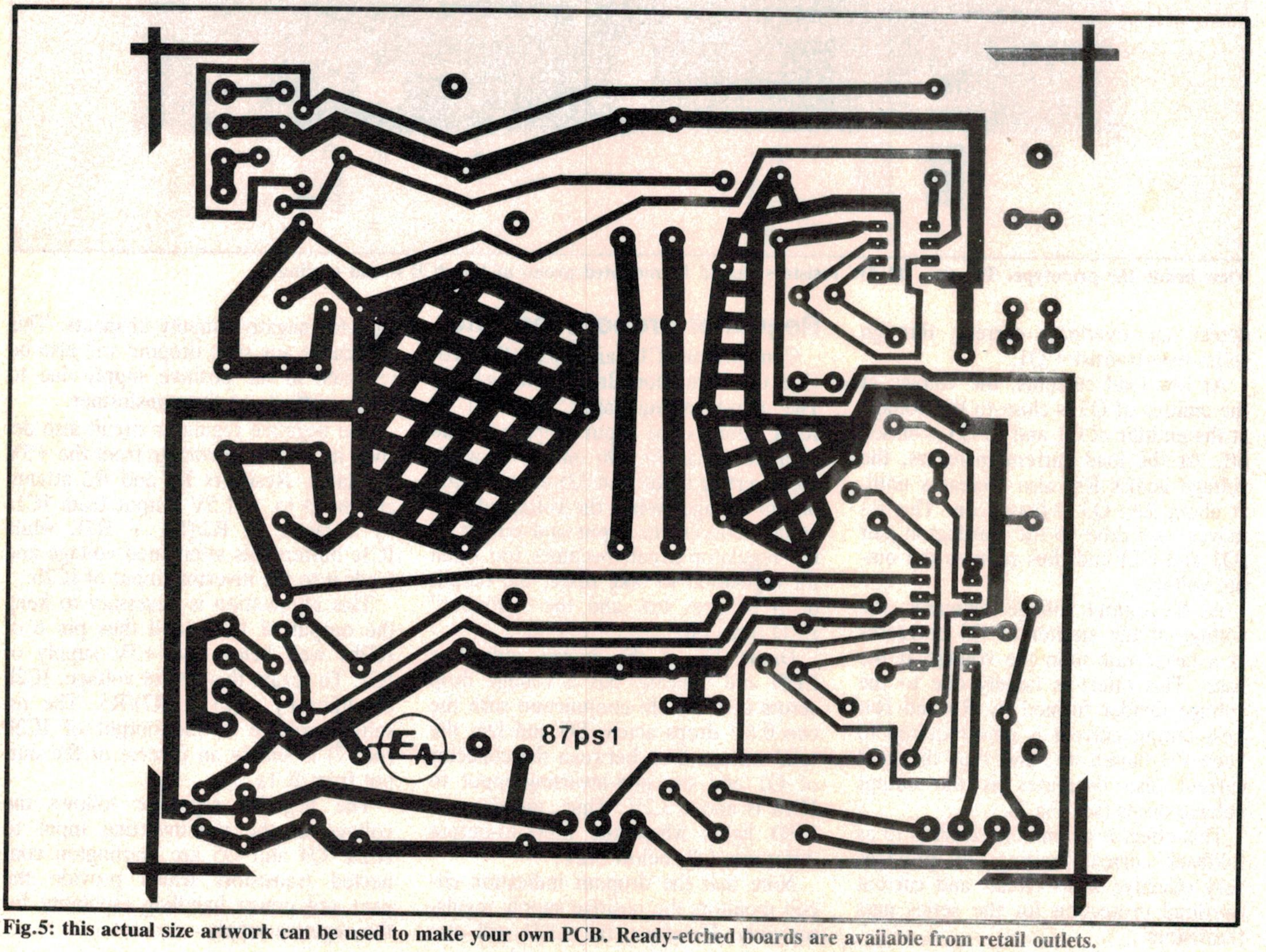


Fig.5: this actual size artwork can be used to make your own PCB. Ready-etched boards are available from retail outlets.

the case and with one row of plastic standoffs to the right of the PCB, as shown in the photograph.

Once the PCB has been installed, slide the metal rear panel into the case and mark the mounting hole positions for the transistors and regulator. You will have to bend the leads of each device slightly so that its metal face sits flush with the rear panel. The panel can then be removed and the mounting holes drilled to 2.5mm.

The heatsink is secured to the rear panel using the same mounting screws as for the series pass transistors. Use the rear panel as a template to mark out and drill the holes for the heatsink. In addition, you will have to drill holes in the rear panel to accept the cord clamp grommet and the earth lug mounting screw.

Fig.7 shows the heatsink assembly details. Note that a mica washer and insulating bush must be used to isolate each output device from the metalwork.

Before screwing the assembly together, make sure that all holes through the rear panel and heatsink have been countersunk and are free of swarf. This done, smear heatsink compound on all mating surfaces and screw the assembly together as shown in Fig.7. The nut for the regulator mounting screw should be installed on the inside of the case to give a neater result.

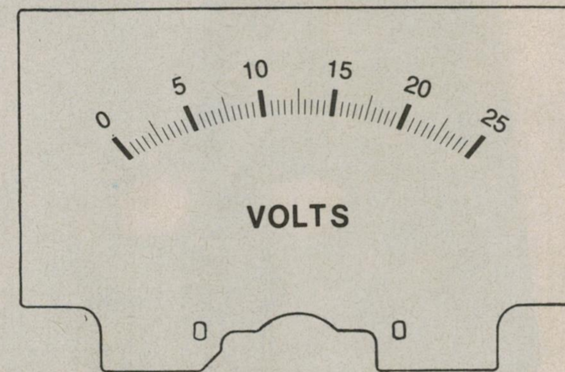


Fig.6: actual-size artwork for the meter scale.

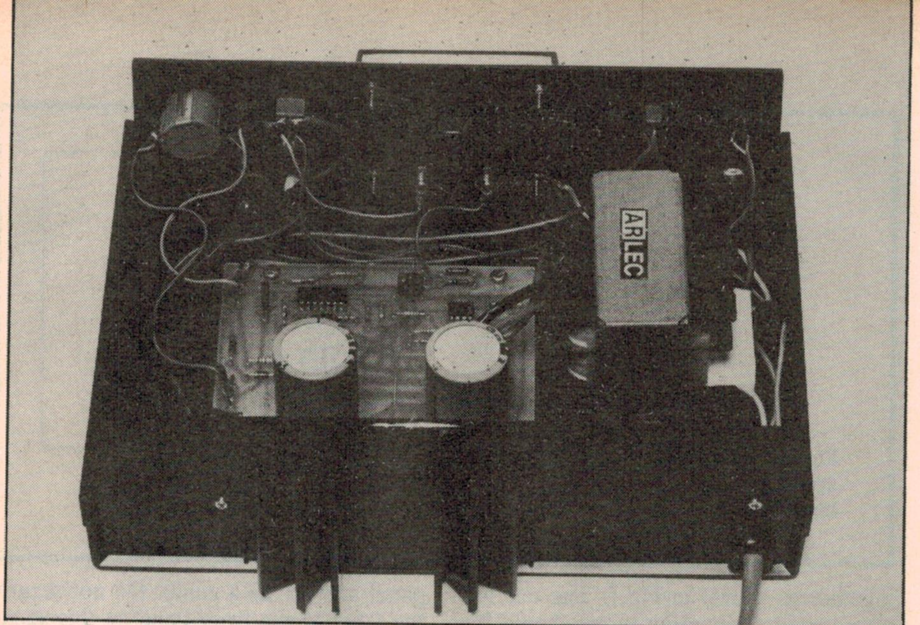
Finally, use your multimeter to check that the metal tabs of the output devices are indeed isolated from the heatsink. Repair any fault immediately if you detect a short circuit.

Front panel assembly

Work can now begin on the front panel. The first job is to mark out and drill the necessary holes, using the front panel artwork as a guide. Do not secure the label to the front panel at this stage — that job comes later.

The meter is centrally located on the front panel and comes complete with a drilling template. Use this to mark out the panel, then drill the four mounting holes. The large clearance hole for the meter body can be made by drilling a series of small holes around the inside circumference of the marked circle and then filing to a smooth finish.

The front panel artwork can now be carefully affixed to the panel and the



The finned heatsink aids heat dissipation and is secured to the rear panel using the transistor mounting screws. Note that the front and rear panels must be earthed (see Fig.4).

material covering the holes removed using a sharp knife. When this has been done, you are ready to mount the front panel hardware. Use red binding post terminals for the positive outputs, black for the 0V terminals, white for the negative terminal and green for the GND terminal.

A label is also provided for the meter. To fit this, first undo the two screws at the front, then remove the two small screws securing the original meter scale. The new scale can now be fitted and the meter reassembled.

All that remains now is to complete the wiring according to Fig.4. You can use rainbow cable to hookup the 10-turn pot, meter and the two LEDs only. All other wiring between the PCB and front panel should be run using heavy duty hookup wire (ie, to the switches and output terminals).

The transformer is mounted on two integral standoffs in the case and secured using self-tapping screws. Be sure to use 240VAC mains-rated cable for all mains wiring.

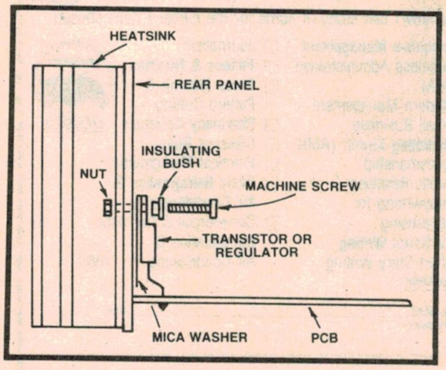


Fig.7: how the heatsink assembly goes together. Use your multimeter to check that the output devices are correctly insulated.

Before installing the mains cord, strip back the outer insulation so that the individual leads can reach from the rear panel to the power switch. The mains cord can then be clamped to the rear panel using the cord clamp grommet and the mains wiring completed. Sleeve the terminals on the mains switch and the transformer with plastic tubing to prevent accidental shock.

Now for the smoke test but first check your work carefully against the wiring diagrams. Do all leads go to their correct destinations? Are all components installed correctly? Is the mains wiring correct?

Powering up

Switch on and check that the unregulated supply rails are at about +28V and –28V. If these are OK, check that the output of the 3-terminal regulator is at +5V.

Now check that the voltage at pin 1 of IC1a can be varied from 0 to +21.5V by rotating VR1. Similarly, check that the voltage on pin 7 of IC2b can be varied between 0V and –21.5V. Finally, check that the tracking supply output voltage can be varied from 0V to ±21.5V and that the two supplies track correctly.

The dropout indication circuit can now be checked by connecting a 4.7Ω resistor across the +5V output. When this is done, the dropout indicator LED should light as soon as the tracking supply voltage is turned up beyond ±17V.

That's it — your new dual tracking power supply is ready for work. Just one final word: if the output voltage rises with anticlockwise rotation of the pot, simply reverse the outside connections for VR1 on the PCB.

PARTS LIST

1 PCB, code 87ps1, 135 x 120mm
1 front panel artwork, 252 x 77mm
1 plastic instrument case, 260 x 190 x 80mm
2 metal panels to suit case, 252 x 77mm
1 MU-52E 1mA panel meter
1 0-25V meter scale
1 22-0-22V 1.5A transformer
1 radial finned heatsink, 106 x 75mm
1 10-turn pot (any value 1kΩ to 100kΩ)
1 pushbutton mains switch
1 DPDT toggle switch
1 SPDT toggle switch
6 4mm binding posts, (2 black, 2 red, 1 white, 1 green)
1 20mm knob
1 cord clamp grommet
1 mains cord and plug
2 earth lugs
16 PC stakes

Semiconductors

1 7805T 5V regulator plus insulating harware
1 LM324 quad op amp
1 LF351, TL072 dual op amp
1 MJE3055, TIP3033 NPN transistor plus insulating hardware
1 MJE2955, TIP2955 PNP transistor plus insulating hardware
1 BC337 NPN transistor
1 BC327 PNP transistor
1 BC547 NPN transistor
1 BC557 PNP transistor
4 1N5404 3A 400V diodes
6 1N4002 1A 200V diodes
2 5mm LEDs plus bezels

Capacitors

2 5600µF 40VW PC electrolytic
2 100µF 25VW PC electrolytic
1 10µF 35VW PC electrolytic
1 10µF 25VW PC electrolytic
3 0.1µF metallised polyester
1 0.01µF metallised polyester

Resistors (0.25W, 5% unless noted)

1 x 30kΩ 1%, 2 x 22kΩ, 1 x 20kΩ 1%, 2 x 10kΩ, 2 x 8.2kΩ 1%, 1 x 2.7kΩ, 4 x 2.2kΩ, 2 x 1.2kΩ 1%, 2 x 1.2kΩ, 1 x 820Ω, 2 x 1Ω 5W

Miscellaneous

Self tapping screws, machine screws and nuts, heatsink compound, mains wire, heavy duty hookup wire, light duty hookup wire, insulating tubing, solder.