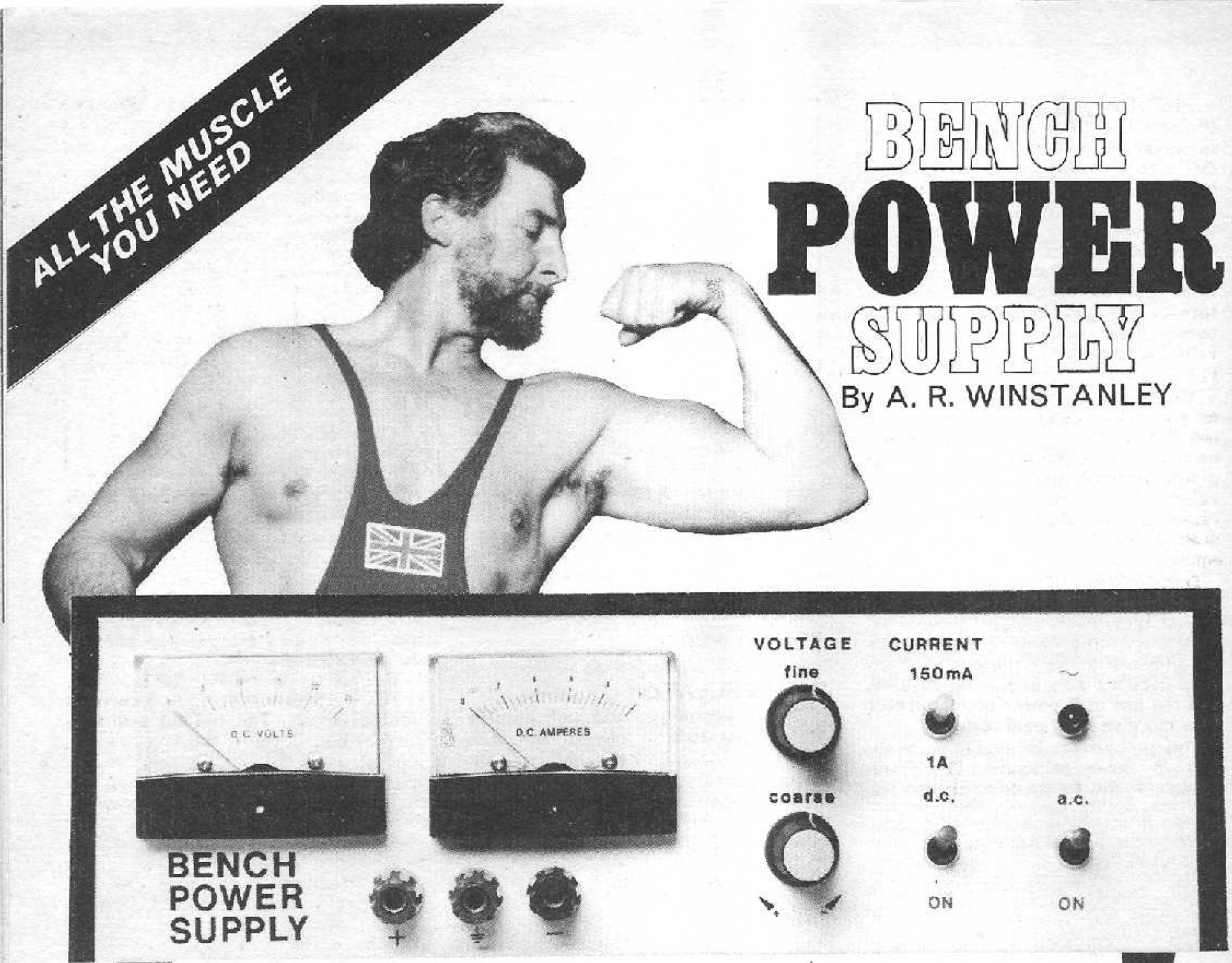


BENCH POWER SUPPLY

By A. R. WINSTANLEY

ANY CONSTRUCTOR who intends taking more than a casual interest in electronics will wish to amass a useful selection of test equipment. Certainly a major requirement for any serious enthusiast is a variable power supply.

This would facilitate the operation of projects and circuits under testing from a highly stable mains-powered source, eliminating problems normally associated with the use of dry batteries in such a role.

The Bench Power Supply unit described here should meet the needs of the majority of enthusiasts.

The electronics behind this project is greatly simplified by the utilisation of two modern integrated circuit regulators, type LM317. Construction therefore is quite straightforward and is suitable for the less experienced enthusiast who possibly wishes to build their first item of test gear.

SPECIFICATION

D.C. Range: 1·25 to 25V variable
A.C. Range: six fixed outlets giving 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24 or 30V.
Current limit: 1A or 150mA switched.
Regulation: ± 3% on prototype.
Ripple: 4mV peak to peak at full load.

REGULATOR I.C.

The integrated circuits are variable voltage regulator/current limiter i.c.s which are extremely easy to use. They are capable of supplying 1·5 amps over a voltage range of 1·2 to 37 volts. Within the device there is all the usual overload protection which is only available in i.c.s, including in-built current limiting and thermal overload shutdown.

The device is shown in Fig. 1 in its basic voltage regulator mode. It can be seen that there are only three terminals, namely input, output and "adjustment".

A 240 ohm resistor is usually placed between the output and adjustment pins, and a highly stable 1·2V reference voltage is present across this resistor. The output voltage is determined by the resistance of R_x and the value of this component is given by:

$$R_x = \frac{(V_o \times R1)}{1 \cdot 2} - R1 \text{ ohms}$$

or with R1 equal to 240 ohms,

$$R_x = 200V_o - 240 \text{ ohms}$$

In practice it is wise to substitute a preset for R_x so that exact trimming of the output voltage can be achieved.

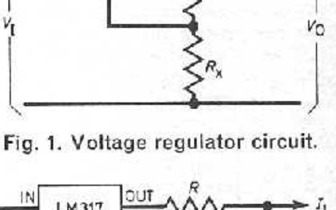


Fig. 1. Voltage regulator circuit.

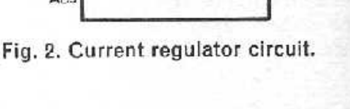


Fig. 2. Current regulator circuit.

Virtually the only way to destroy the device is to exceed the maximum input-output differential voltage of 40V. Power dissipation however is internally limited by the protection circuitry. Otherwise the i.c. is nearly indestructible.

The LM317 already has a built-in current limiting circuit. This limit level depends mainly on the temperature of the chip and also the input-output differential voltage. A typical value for the LM317K (TO-3 package) is 1·5 to 2·2 amps.

The i.c. can also however be utilised as a precision current-limiting circuit, see Fig. 2. Here the precision reference voltage is placed across a series power resistor, and by altering the value of R, various current-limit values can be obtained. If I_L is the desired limit level, the value of R will equal $1 \cdot 2/I_L$.

Due consideration must be paid to the power dissipated in this resistor (equal to $1 \cdot 44/R$). Also, R must not be less than 0·8 ohms or in excess of 120 ohms. Note that the current-limit level does not vary in a linear fashion, and the use of a power potentiometer does not give very good results.

Finally, the i.c. is generally available in three packages. The TO-3 version should be used in this design.

CIRCUIT DESCRIPTION

A block diagram of the Bench Power Supply can be seen in Fig. 3 and the complete circuit diagram appears in Fig. 4.

Mains voltage is applied to the primary of T1, a multi-tapped transformer, via the mains on-off switch S3. The neon indicator LP1 illuminates when the mains is switched on and RV1 is a mains transient suppressor. This is optional and can be omitted if required.

The secondary of T1 has six tappings: 0, 12, 15, 20, 24 and 30V a.c. These are extended to the back panel of the cabinet using SK1-6 as connectors to exterior equipment.

By connecting between different sockets, it is possible to extract all of the fixed a.c. voltages mentioned in the specification. This a.c. facility has proved to be quite useful, but if readers do not consider it necessary to their requirements, then T1 can be substituted by a transformer having simply a 30V a.c. one amp secondary.

The 30V a.c. tapping also provides the main supply rail for the power supply unit proper. This voltage is rectified by D1-4 and smoothed by C4 to give a rough unregulated d.c. voltage of 42V no load, 35V full load.

Transistors TR1 and TR2 form an emitter follower pair of reasonably high gain. Diodes D5 and D6 are Zener diodes which clamp the base of TR1 to about 32V (plus or minus the tolerance on the Zener diodes) and R1 limits the current through the Zeners.

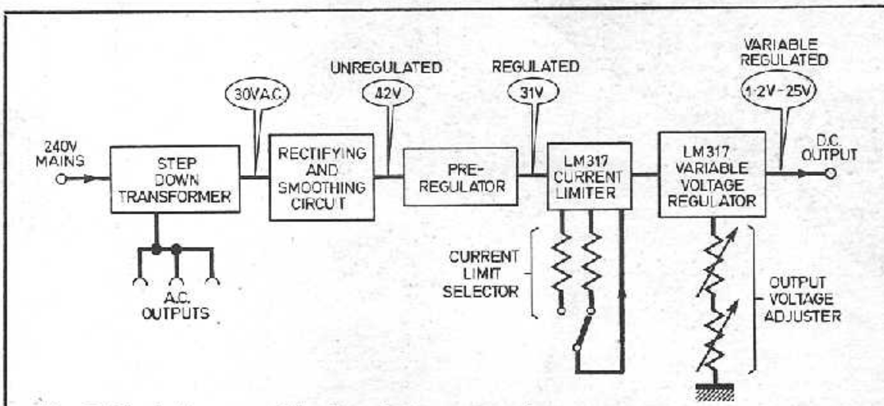


Fig. 3. Block diagram of the Bench Power Supply.

Now, the emitter of TR1 will be 0·6V less than its base, that is about 31·4V. Similarly the emitter of TR2 is 0·6V less than its base, roughly 31V. Capacitor C6 provides local smoothing and reduces any noise across the two Zener diodes.

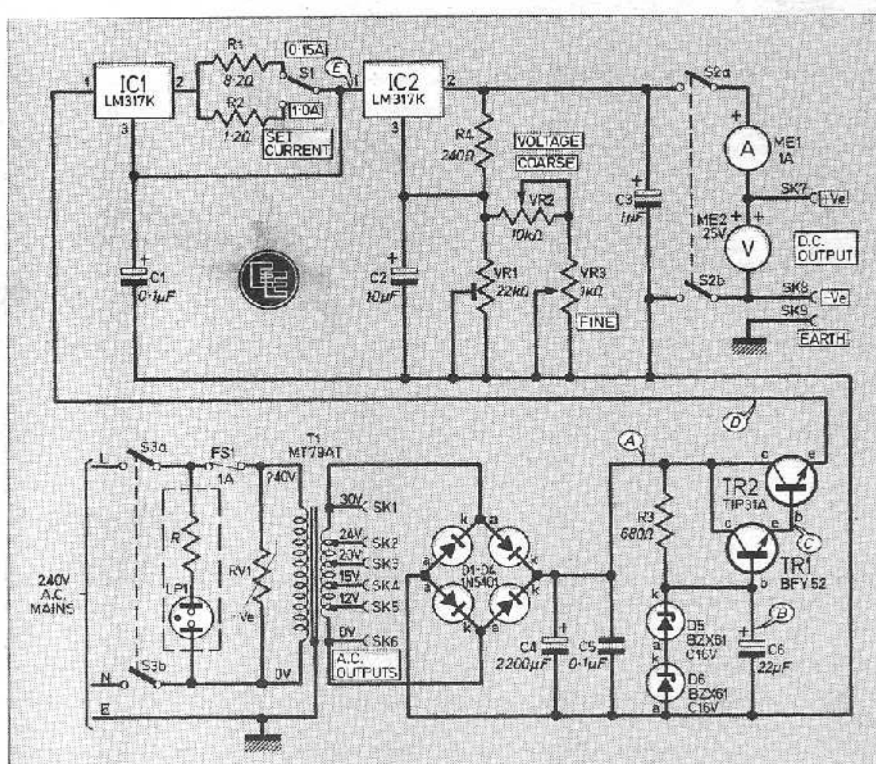
PRE-REGULATOR

Initial prototypes did not employ this two-transistor circuit but the effects of using a "pre-regulator" are several. For example, nearly all of the ripple present on the supply line is filtered out by the Zener diodes and suppressed at the emitter of TR2. The supply rail is pre-regulated to 31V, no matter what the emitter current of TR2, and after allowing for the tolerances of the Zeners a very stable rail is achieved. The smoothing effect of C6 is amplified by the combined gain of the two transistors, its effect being equivalent to using a large smoothing capacitor on the supply line, and, most importantly the maximum input-output differential voltage of the i.c.s will not be exceeded.

The pre-stabilised 31V rail is passed to IC1 which is connected as a current-limiter circuit. The in-built two-amp current-limit level of the i.c.s, was regarded as being too high for Bench Power Supply use and a level of one amp was thought to be satisfactory. Furthermore a glance through some catalogues showed that 2 amp transformers can be very expensive!

The resistor determining the current-limit value is selected by S1.

Fig. 4. Complete circuit diagram of the Bench Power Supply.



Resistor R1 when selected, limits the current to about 150mA by virtue of IC1. When the switch is in this position, should a fault occur in the load under test, the unit will limit the current through the load to a safe value (that is 150mA) thereby protecting most of the components in the test circuit. When R2 is selected by S2, then the maximum current available is one amp.

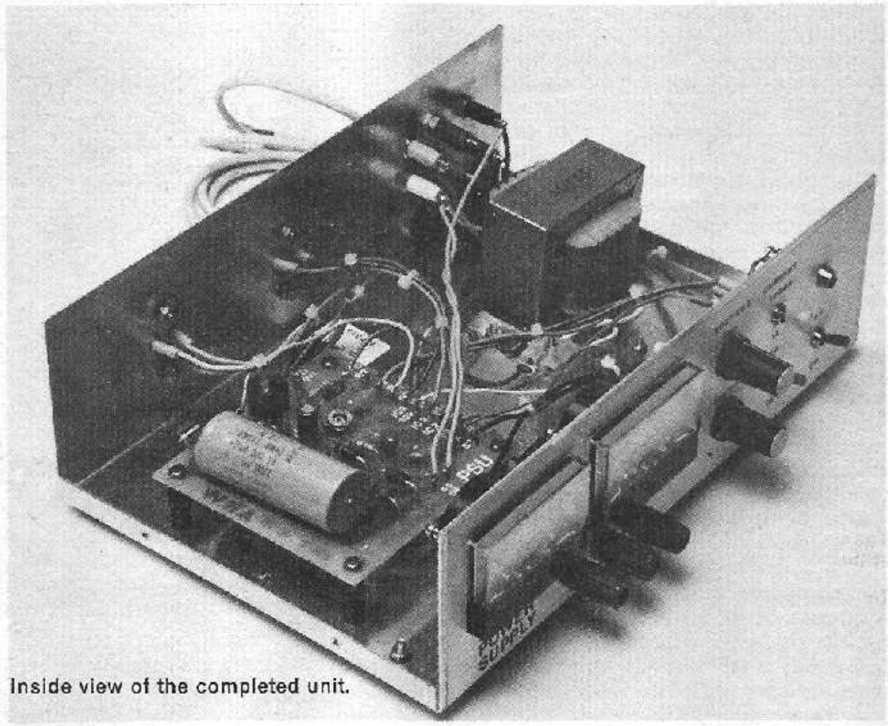
FINAL STAGE

After the current limiter comes the regulator itself, IC2 and associated circuitry. Resistor R4 is the standard 240 ohm reference component and VR2 and VR3 are panel-mounted potentiometers which provide coarse and fine adjustment of the output voltage.

The final control has most effect at the lower end of the output range, and as 25V is approached, it begins to have a decreasing effect.

The maximum output voltage is controlled by VR1. This is the voltage that is available when the two potentiometers are set for a full deflection of the voltmeter (ME2). Preset VR1 enables an exact 25V maximum output to be trimmed, so that the voltmeter is not overdriven.

Capacitors C1, C2 and C3 are additional components which decouple the supply rails and also increase the ripple rejection of IC2 to about 80dB.


Inside view of the completed unit.

Direct current switching is provided by S2. This enables the user to immediately isolate the load undergoing testing and is considerably quicker than using S3 as the on-off switch, because C4 and C3 would tend to retain their charge for many seconds after the unit had been switched "off". Switch S2 compensates for this effect.

Finally, the output current and voltage are together monitored by ME1 and ME2 respectively. The output is connected to SK7 (positive) and SK8 (0V), which are two 4mm binding posts, and also SK9 is a separate earth terminal which enables either the positive or negative line to be earthed if required.

COMPONENTS

COMPONENTS approximate cost £48 complete

Resistors
- R1 8·2Ω
- R2 1·2Ω 3W wire-wound
- R3 680Ω
- R4 240Ω
- All ¼W carbon ±5% except R2

Potentiometers
- VR1 22kΩ lin. miniature horizontal preset
- VR2 10kΩ lin. carbon
- VR3 1kΩ lin. carbon

Capacitors
- C1 0·1μF 35V tantalum bead
- C2 10μF 35V tantalum bead
- C3 1μF 35V tantalum bead
- C4 2200μF 63V elect.
- C5 0·1μF polyester C280
- C6 22μF 50V elect. p.c.b. mounting

Semiconductors
- IC1, 2 LM317K positive variable voltage regulator, TO-3 can (2 off)
- TR1 BFY52 *npn* silicon
- TR2 TIP31A *npn* silicon
- DI-D4 1N5401 100V, 3A silicon rectifier diode (4 off)
- D5, 6 BZX61C16V 1·3W, 16V Zener diode (2 off)

Miscellaneous
- S1 s.p.d.t. miniature toggle
- S2, 3 d.p.d.t. miniature toggle (2 off)
- T1 mains primary/12, 15, 20, 24, 30V secondary at 1A, Douglas type MT79AT
- RV1 mains transient suppressor (see text)
- ME1 1A f.s.d. moving coil meter
- ME2 25V d.c. f.s.d. moving coil meter
- SK1-SK6 4mm sockets, assorted colours (6 off)
- SK7-SK9 4mm screw terminals (1 red, 1 black and 1 green)
- FS1 20mm 1A fuse and panel mounting holder
- LP1 mains panel neon indicator with integral resistor

Printed circuit board, 100 × 100mm; metal case, 280 × 190 × 90mm, Norman type WB5; finned TO-3 heatsink (2 off); finned TO-5 type heatsink; TO-3 type mounting kit (2 off); TO-66 type mounting kit; two knobs; p.c.b. mounting pillars; 3A cable for interior interwiring; 2-way connector block; veropins; nuts and bolts for heatsink and p.c.b. mounting; cabinet feet (4 off).

See Shop Talk page 159

CONSTRUCTION starts here

PRINTED CIRCUIT BOARD

With the exception of TR2, IC1 and IC2, the circuit is built onto a glass-fibre printed circuit board measuring 100×100mm, see Fig. 5.

In designing the p.c.b., due consideration has been given to the current-carrying capabilities of the copper track. Also an adequate air space must be left around most of the components to enable them to dissipate heat efficiently.

Commence construction of the p.c.b. by soldering in the four rectifiers.

These have thick leads which must not be bent close to the rectifier bodies. Furthermore do not mount the rectifiers close to the board but stand them off slightly.

Proceed with the soldering of the Zener diodes. Mount these vertically, observing correct polarity, and again take care when bending the leads.

Transistor TR1 is fitted with a push-on TO-5 heatsink, but this heatsink is not entirely necessary and it has been suggested merely as a precaution. If used, the radiator must be fitted to the transistor can before the transistor is soldered into place.

POWER RESISTOR

The power resistor, R2, is soldered proud of the p.c.b. surface so that it receives adequate ventilation. During maximum output conditions it will get quite warm in operation, assuming of course that the 1A range is in use.

Everything else on the p.c.b. is straightforward. However make quite certain that the electrolytic and tantalum bead capacitors are soldered in correctly.

Finally, Veropins can be used for connecting flying leads to the p.c.b., and although they were not used on the prototype, in retrospect it would be most wise to utilise them. Check the p.c.b. most carefully and then proceed to the casework.

CASE

The case eventually selected for the finalised model was the "Norman" cabinet, type WB5. This measured 280 × 190 × 90mm and comprised a p.v.c.-covered steel cover and folded aluminium chassis.

It is very important that an *aluminium* chassis is used. If a steel chassis is used, then this can seriously affect the accuracy of the panel-mounting voltmeter. Even the relatively expensive Japanese type used in the prototype was found to be misreading when used in a steel chassis on an earlier model.

Furthermore there is quite extensive metalworking to be performed, and an aluminium chassis will make this very much easier.

General points regarding metalworking are given below, but no details regarding dimensions are given. This will of course mainly depend on the case employed by the individual and also the components and parts used in each instance.

FRONT PANEL

This needs to be prepared to take the following: voltmeter and ammeter, three toggle switches, two potentiometers, pilot lamp and three output terminals.

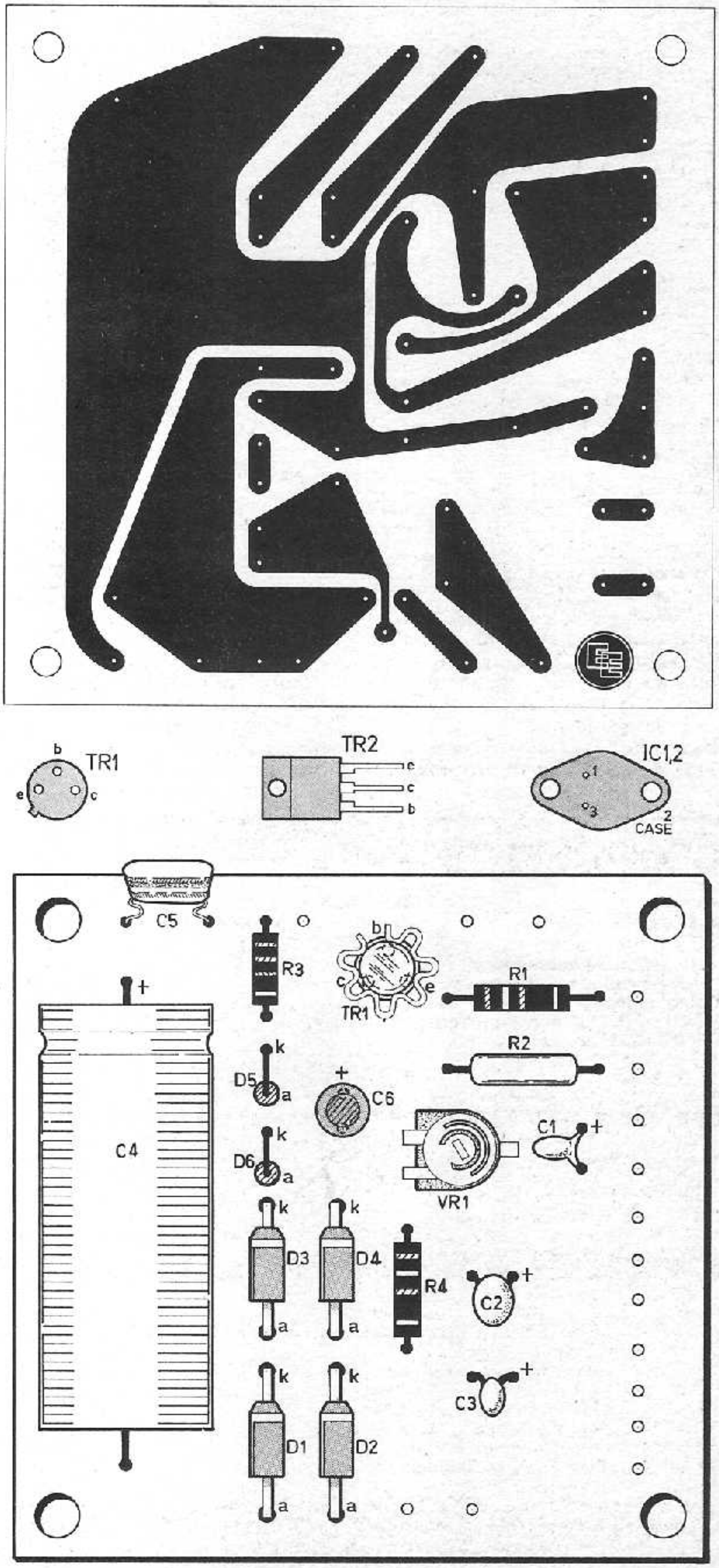


Fig. 5. Foil pattern for the p.c.b. shown actual size. Below this is the component layout and transistor and i.c. outlines. Note that the rectifier diodes D1 to D4 should be mounted clear of the board as should R2.

BENCH POWER SUPPLY

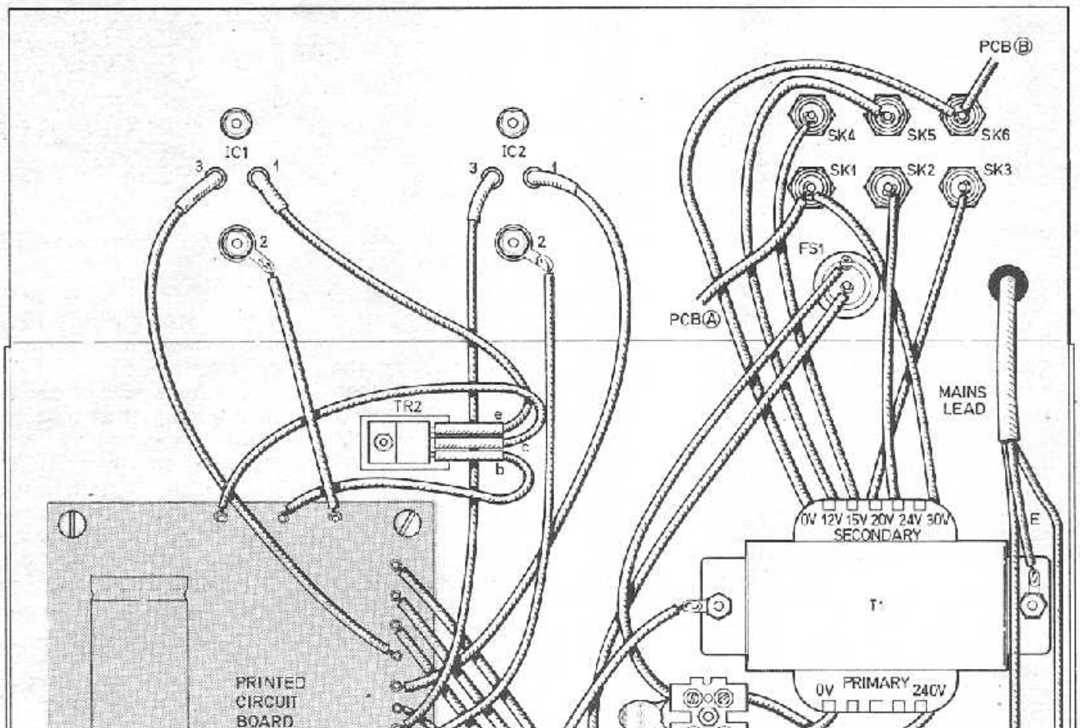
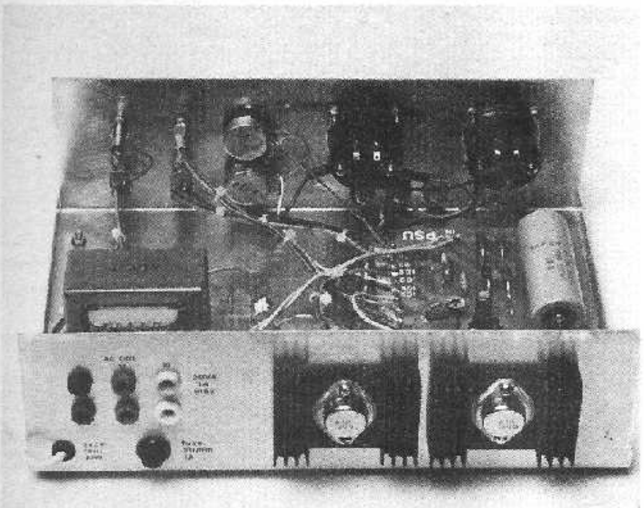
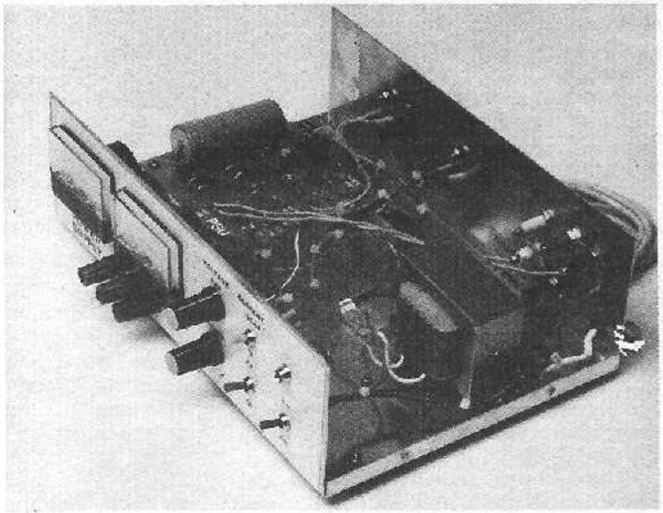


Fig. 6. Wiring diagram of the complete unit. The front and rear panels have been folded down for clarity. The regulator i.c.s, IC1 and IC2, must be mounted on heatsinks using insulating mica washers and plastic bushes.



View from rear showing heatsinks for IC1 and IC2 and rear of front panel.



View from side. Note the output sockets for the a.c. voltage tappings.

The large cutouts required for the meters can be punched by using a tank cutter or hole saw. Both devices must be fitted to drills running at a slow speed. Alternatively, a ring of small holes could be drilled, the centre punched out and then the edges filed until smooth, but this can be hard work!

The three terminals require a "key-hole" shaped cutout to take the insulating bushes.

CHASSIS

The bottom of the case carries the p.c.b. mounting pillars (four off), the mains transformer, two-way terminal block and also the power transistor, TR2. The transistor can be fixed down with a 6BA bolt and so requires a 6BA clearance hole in the chassis.

The positioning of the transformer is quite important. It should be placed in one corner, away from the output terminals. If it is too close to the output sockets, then there is the possibility that mains hum could be induced on the output. Also it has been known for the magnetic field of the transformer to have an adverse effect on the voltmeter readings.

REAR PANEL

The two TO-3 i.c.s are mounted, with finned heatsinks, on the rear panel next to each other. Each i.c. will require a mica washer for mounting, and this can be used as a marking-out guide prior to drilling. The devices are mounted using two 4BA bolts each.

Note that the holes which are drilled to take the integrated circuits must be filed quite smooth. There must be no burrs on the edges.

A small hole is needed to take the mains cable inlet. This hole must have a rubber grommet and cable clamp fitted, in order to avoid fracturing or wearing away of the cable insulation on the metal edges.

Six holes may be required for the 4mm sockets if a.c. outlets are incorporated. One final cutout of appropriate diameter carries the chassis-mounting fuseholder.

TOP COVER

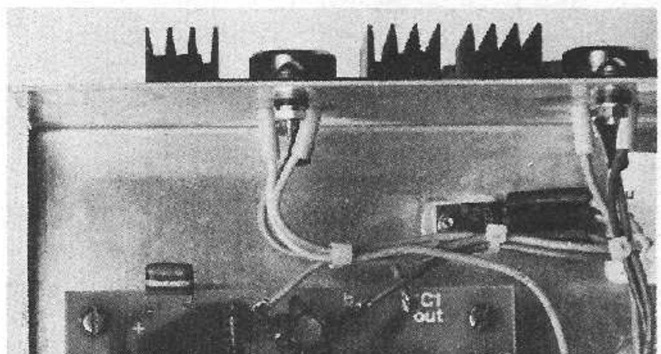
If not already ventilated, then several holes should be made, using preferably a metal punch, in order to allow a throughflow of air.

With drilling completed, all necessary lettering should be carried out at this stage. Use proprietary rub-down lettering and then give the lettered panels several light coats of clear lacquer.

The final part of construction is the interwiring. It is best to start at the mains input and work logically through the circuit. The complete interwiring diagram is shown in Fig. 6.

The earth input is soldered to a tinned tag which is placed under one of the transformer mounting bolts. The mains transient suppressor, if fitted, is connected to the two-way terminal block as shown.

Throughout ensure that interconnecting wire of adequate electrical specification is used. Low tension



Close up view of circuit board. The voltage regulators mounted on finned heatsinks can also be seen and TR2 is shown mounted on the bottom of the case. This must also be insulated from the metal case by using a mica washer and insulating bush. A small amount of silicon grease is smeared between these three items and the metal to aid heat transfer and sleeving is placed over the soldered connections to avoid short circuits.

wires should be rated at least one amp, preferably two to three amps.

Wiring should be completed in accordance with Fig. 6 and then the wires can be arranged into small looms using nylon tying-clips. Note that all looms should be as short as possible and also they should be kept away from the mains transformer and mains interwiring.

Finish off the cabinet with four self-adhesive feet on the bottom of the chassis.

FINAL CHECKS

When construction is complete, check all wiring most carefully. Check the p.c.b. once more and also re-check the connections to the power transistor and two i.c.s.

A resistance check between the earth pin of the mains plug and metal chassis should indicate a short circuit (that is, a good earth connection). Similarly check both the resistance between the tab of TR2 and chassis, and also the cases of the two i.c.s and the chassis.

In both instances the resistances should be infinite, indicating that all three devices are correctly isolated from the chassis. Do not proceed until this aspect is finalised.

If everything appears in order, set VR1 to minimum resistance, and rotate VR2 and VR3 fully clockwise to give maximum voltage output. Switch both S2 and S3 to on. The voltmeter should read approximately 1·2V. Now adjust VR1 to give a maximum reading on the voltmeter of 25V.

Check that rotation of the two potentiometers now give both fine and coarse adjustment of the output.

Table 1: Test readings for the Bench P.S.U

Location	No load voltage	Full load (*25V at 1A*)
A	42V	35V
B	33V	32·5V
C	32·4V	31·9V
D	31·8V	31·3V
E	30V	27·5V
F	1·2V	1·2V

CURRENT LIMITING

Testing the current-limiting circuit depends on what equipment is available, but could consist of placing dummy wirewound resistors across the output and checking that the current-limit switch is performing correctly. If the one-amp current limit circuit appears to operate prematurely, then this could be due to the tolerance on R2.

The effect is that the power supply limits the maximum output current to less than one amp. The remedy is to replace R2 with a similar resistor until a one-amp output is achieved.

Table 1 gives voltage readings taken on the prototype, and can be used if any faults appear to exist in readers' prototypes. Readings for both no-load and full-load conditions are given. ☐