0-40 V/5 A laboratory power supply Part 1.

Here's a laboratory standard power supply featuring truly regulated output from zero to 40 volts capable of delivering a massive 5 A across the whole voltage range, plus current limiting variable from zero to 5 A. Two meters monitor voltage and current and regulator dissipation is reduced by employing an automatic transformer switching circuit.

David Tilbrook

IN APRIL 1976 we published the ETI-131 General Purpose Power Supply. This project could be built in two versions — 0-20 V/2.5 A or 0-40 V/1.25 A. It featured variable current limiting and had pretty close to lab-standard specs. A great many have been built since then and are to be found in development laboratories, service workshops, technical college and university labs and hobbyist's workshops.

Since that time, electronic technology has made considerable strides and the sort of things now being investigated by hobbyists and in electronics labs of all descriptions range much wider than they did when the ETI-131 was in vogue. It came to our notice that a lab-standard supply having 'expanded' specifications was in demand so we set out to investigate what sort of project would best meet that demand.

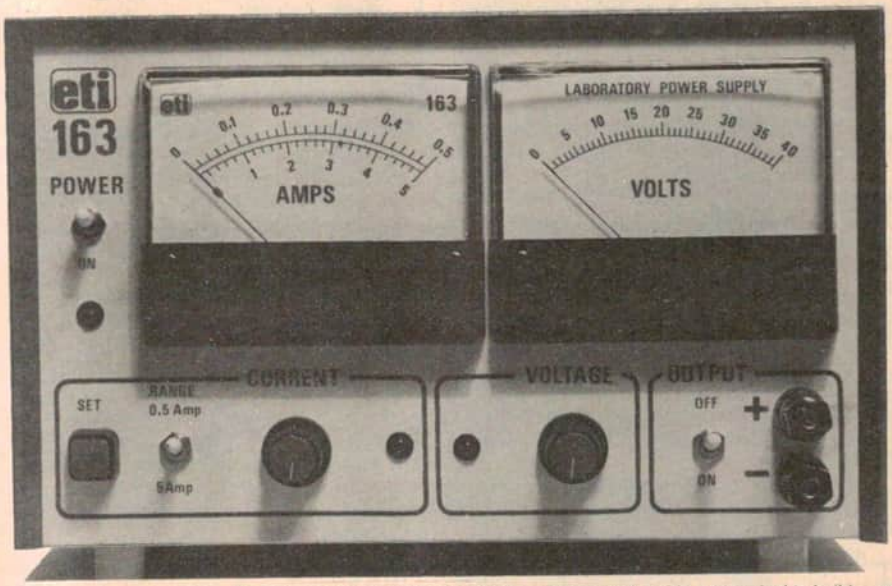
Following considerable discussion with both users and project suppliers, it was apparent that the most generally useful output voltage range would be about 0-40 V or 0-50 V and the required maximum current capability would be in the vicinity of 3-4 A or so. The next thing to do was to define 'lab-standard'.

Defining 'lab-standard'

An 'ideal' power source should provide the following: • a regulated voltage variable from zero to some chosen limit • no extraneous hum or noise on the output and none radiated from the supply • current-limit operation from zero to some chosen limit • simultaneous metering of current and voltage output • protection from short circuits on the output at any output setting.

In addition, handy 'operator features', such as indicators to show voltage and current mode operation, output and current-set switches, are desirable.

What sort of specifications would approach the 'ideal'? With sensitive high gain, dc control, audio or RF circuitry attached to the supply during circuit development or fault locating, you want to be sure that any problem experienced is not caused by some characteristic of the power supply. Hence, hum and noise are an important consideration. ▶

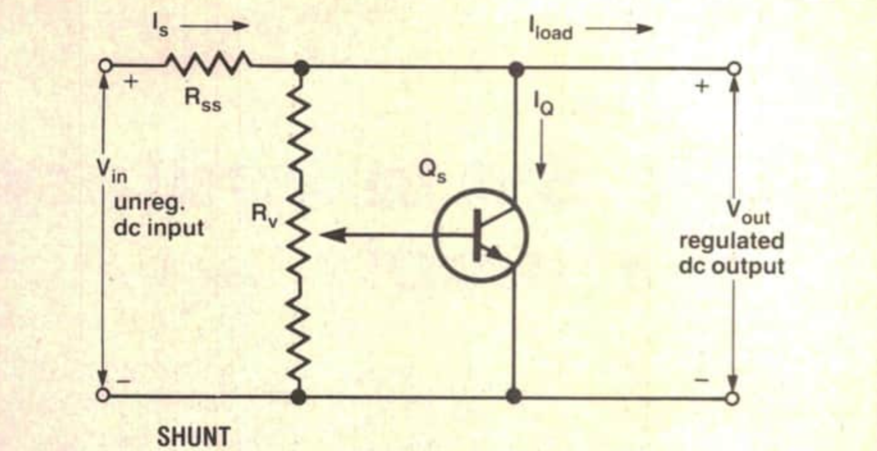


Power and performance. The completed supply looks smart, performs well and is economical to build — at around $150-$160.

SPECIFICATIONS — ETI-163 LAB. SUPPLY — TABLE 1

Output voltage	0-40 V, variable
Output current	0-0.5 A, variable limiting 0-5 A, variable limiting
Output regulation	<50 mV at up to 2.5 A <100 mV up to 5 A
Ripple and noise	
voltage mode	<3 mV RMS
current mode	<10 mV RMS
Maximum output power	200 watts
Metering	
Voltage	0-40 V in 1 V divisions
Current	0-0.5 A in 20 mA divisions 0-5 A in 200 mA divisions

- **LED to indicate voltage mode operation**
- **LED to indicate current mode (limiting) operation**
- **Current-set switch provided for setting current limit value**
- **Output switch provided to isolate supply output**
- **Output terminals isolated from chassis**
- **Full output current available right up to 40 V**



The shunt regulator. Fundamental circuit of a shunt regulator. As the load current (I_{load}) increases, the output voltage (V_{out}) tends to fall, reducing base current to Q_s. This, in turn, reduces the collector current (I_Q) of the shunt regulator, Q_s. The voltage drop across R_{ss} then decreases, maintaining the output voltage. As load current decreases, the opposite happens.

If the input voltage (V_{in}) increases, V_{out} tends to rise, increasing the base current to Q_s. This increases I_Q and the voltage drop across R_{ss} increases, maintaining the output voltage. If V_{in} decreases, the opposite happens.

Varying the wiper of R_v varies the collector current of Q_s, thus varying the voltage dropped across R_{ss}, setting the output voltage. Resistor, R_{ss} dissipates considerable power and Q_s dissipates the maximum output power under no load.

A figure under 10 mV is a desirable goal, preferably less than 5 mV. Performance in the current-limit mode should be similar, but is not as critical a parameter.

As supply voltage variations can adversely affect some circuits, regulation of the output voltage over the whole variation range is paramount. It should remain virtually constant despite relatively large mains input voltage excursions and despite large variations in current drawn (up to the maximum). Regulation can be expressed as a percentage (with respect to full output) or as a voltage variation. The latter is preferred as it shows performance over the whole output variation range.

A regulation figure of 0.1% (100 mV in 100 V) is common for low current output supplies (up to 1 A), but 0.5% is more usual for high current supplies. That would be 250 mV for a 50 V supply.

Regulator techniques

There are a number of basic techniques used to provide a regulated supply voltage. Choice depends on the application. The respective methods and their characteristics may be summarised as follows:

• **The shunt regulator.** This design is suitable mainly for low-power supplies — 15 to 20 watts. It has good regulation and is inherently short circuit proof. However, it dissipates the full amount of power it is capable of handling under no-load conditions.

Current-limit operation is not so easy to incorporate, but cost is low.

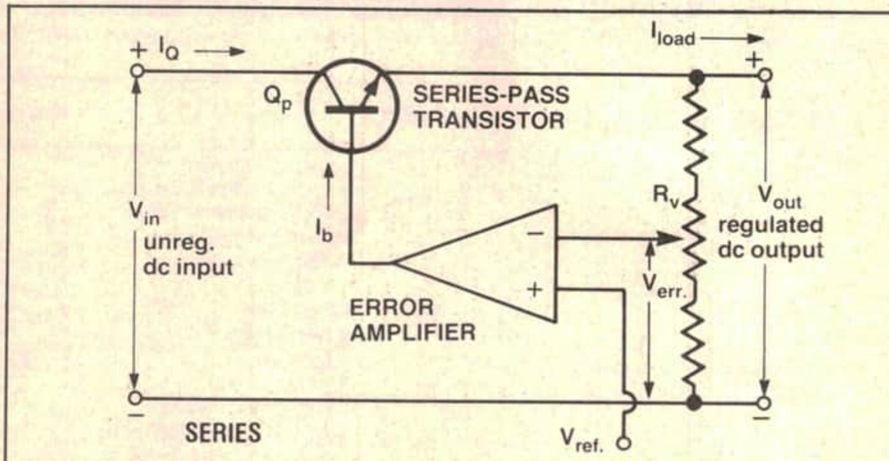
• **The series regulator.** Probably the most widely used technique. It is suitable for power supplies capable of delivering up to 200 watts.

Regulation, hum and noise performance is good, it's easy to arrange current-limit operation and cost is relatively low.

• **SCR regulator.** This technique is mainly suited for medium to very high power applications. The regulator has low dissipation and good regulation, but output noise and ripple are worse than for the series regulator and radiated switching 'hash' requires extensive shielding.

• **SCR pre-regulator and series regulator.** This combines the best features of the previous two and is best suited to medium to high power applications (say to several hundred watts).

An SCR pre-regulator provides a roughly regulated supply about five volts above the required output voltage, followed by a conventional series regulator. This keeps dissipation in the series regulator low. Cost is relatively high.



The series regulator. Fundamental circuit of a series regulator. As the load current (I_{load}) increases, the output voltage (V_{out}) tends to fall. This causes $V_{err.}$ to fall (the 'error voltage'). The error amplifier is operated as an inverting amplifier and thus, as $V_{err.}$ falls, the base current (I_b) to the series-pass transistor (Q_p) will rise. This causes the collector current (I_Q) of Q_p to rise, maintaining the output voltage. If I_{load} decreases, the opposite occurs.

If the input voltage (V_{in}) rises, the output will tend to rise, as will $V_{err.}$. This will produce a decrease in base current to Q_p, reducing I_Q, thus maintaining the output voltage. If V_{in} falls, the opposite will occur.

Varying the wiper of R_v varies $V_{err.}$, setting the output voltage.

• **Switchmode regulator.** This technique is also used in medium to very high power applications. A series switching element stores energy in an inductor or capacitor, the on-time of the switching element being controlled to provide the required regulated output.

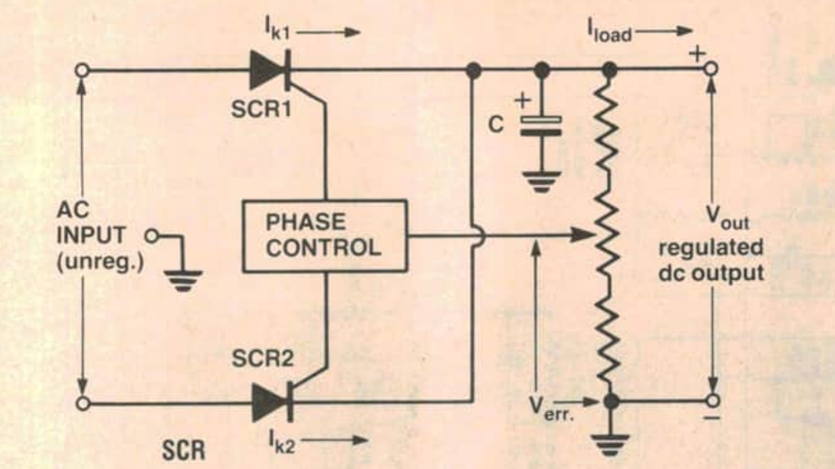
This technique keeps regulator dissipation low and regulation performance is good. With modern ICs purpose-built for the application, cost is about the same as a series regulator. However, noise and ripple on the output can be difficult to suppress and considerable wideband RF energy is radiated by the circuitry, necessitating careful and extensive shielding.

Design features of this supply

I settled on an output voltage range of 0-40 V as this seemed to cover the great majority of supply requirements for circuit testing, development and fault locating. A maximum output current of 5 A was settled on for similar reasons. This results in an output rating of 200 watts, hence choice of an appropriate regulator technique was of paramount importance.

Two techniques were obvious contenders — series regulator and switchmode regulator. Previous experience with switchmode regulators made me wary that I could use one in a 'lab-standard' supply. The ETI-142 0-30 V/15 A supply (Feb. '79) employed a switchmode pre-regulator and a series regulator. Despite elaborate precautions, noise from the switchmode pre-regulator made it impossible to use this supply in the vicinity of, let alone connected to, sensitive circuitry. Pity, but a fact of life.

The inherent attractiveness of high efficiency — low dissipation is generally outweighed in this application. The necessity of elaborate screening and filtering brings problems of its own for constructors and increases costs.



The SCR regulator. Fundamental circuit of an SCR regulator. As the load current (I_{load}) increases, the output voltage (V_{out}) tends to decrease causing the 'error voltage' ($V_{err.}$) to drop. The phase control circuit then advances the triggering of the SCRs so that I_{k1} and I_{k2} and the average rectified voltage increases, maintaining the output voltage. If load current decreases, the opposite occurs.

If the ac input voltage rises, V_{out} tends to rise, causing $V_{err.}$ to rise also. The phase control circuit then retards the triggering of the SCRs, reducing the average rectified voltage, and maintaining V_{out}. The opposite happens if the ac input falls.

Varying the potentiometer varies $V_{err.}$, setting the output voltage.

I looked at the series regulator — and how to reduce the dissipation. For a 40 V output, dc input to the regulator would have to be around 50 V. At 5 A output into a short circuit, worst case dissipation would be around 250 watts! That requires *big* transistors and *lots* of heatsink.

As pre-regulators increased the cost and the noise problems, I had to find another way to reduce regulator dissipation and I hit on the idea of switching the transformer secondary.

Using several cheap ICs as comparators and a couple of relays, I could switch the rectifier across different transformer taps as the regulator output voltage was varied.

However, this technique had the drawback that a 'special' transformer would be required. If I could choose the output taps so that they were at generally 'useful' voltages, the transformer stood a good chance of becoming a 'stock' item. With this in mind, I chose the secondary taps to be 12 V, 24 V and 36 V.

The prototype transformer was wound up for us by Permatran of Melbourne. It is rated at 250 VA.

Astute readers will notice that basically, only two output taps are really required as the 12 V output could be selected by switching between the 24 and 36 volt terminations. However, using relay switching, it is possible under some circumstances to short part of the secondary with consequent disastrous results. The 'switching' tree employed avoids this possibility.

A separate low voltage and current dc supply is necessary to power the op-amps in the regulator and to provide a 5 V reference. In the prototype, I used a small 12 V/150 mA transformer — a stock item from most electronics suppliers — but a 15 V/200 mA winding may be available on the transformers obtained by suppliers of this project.

Worst case regulator dissipation for this supply is around 120 watts, a much more manageable figure than 250 watts. It occurs when the output current is 5 A at a voltage setting near 25 volts. At maximum dissipation, the heatsinks stabilise at a temperature of around 65°C.

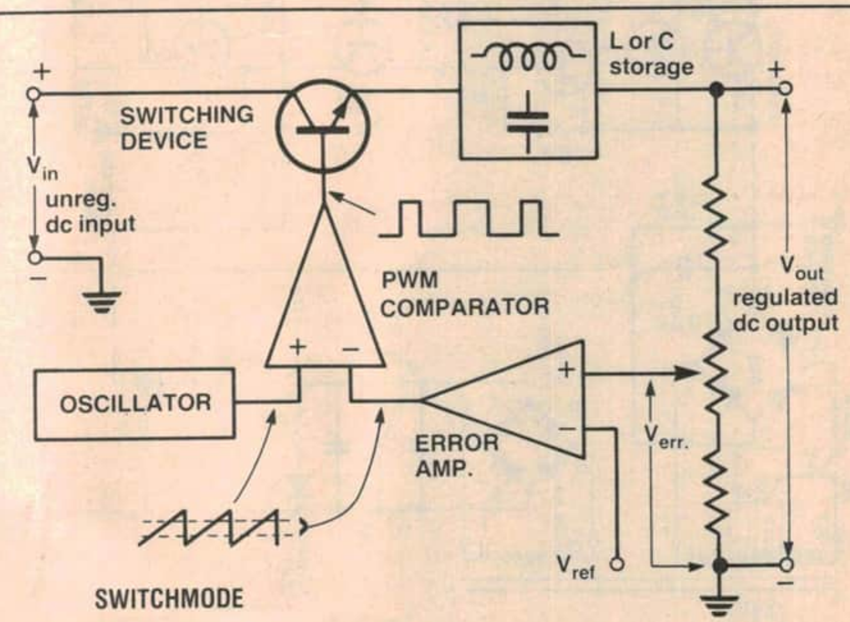
The regulator circuit is similar to the ETI-131 and employs two CA3130s for the voltage-mode and current-mode error amplifiers. A pair of MJ15003 high power NPN transistors connected in parallel are used for the series-pass element.

Another pair of CA3130s are used as comparators for the transformer secondary relay switching circuitry. These were chosen because their output can go right down to 0 V, ensuring the relay driver transistors turn off. The transformer taps are switched as the output voltage passes through about 12 V and about 25 V (these are adjustable over a few volts range). About a volt of hysteresis is added to the switching points so that the relays won't chatter when the output control is set on the switching point.

Separate meters are provided for indicating output voltage and current. There are two current-limit ranges — zero to 0.5 A and zero to 5 A. The point at which the supply switches from constant-voltage to current-limited (constant-current) output is fully variable across the two ranges.

A current-set pushbutton, which shorts the output terminals, is provided on the front panel and two LEDs indicate in which mode the supply is operating. A switch in series with the output allows you to isolate the supply from the load, without having to disconnect the supply or turn it off if you want the supply removed.

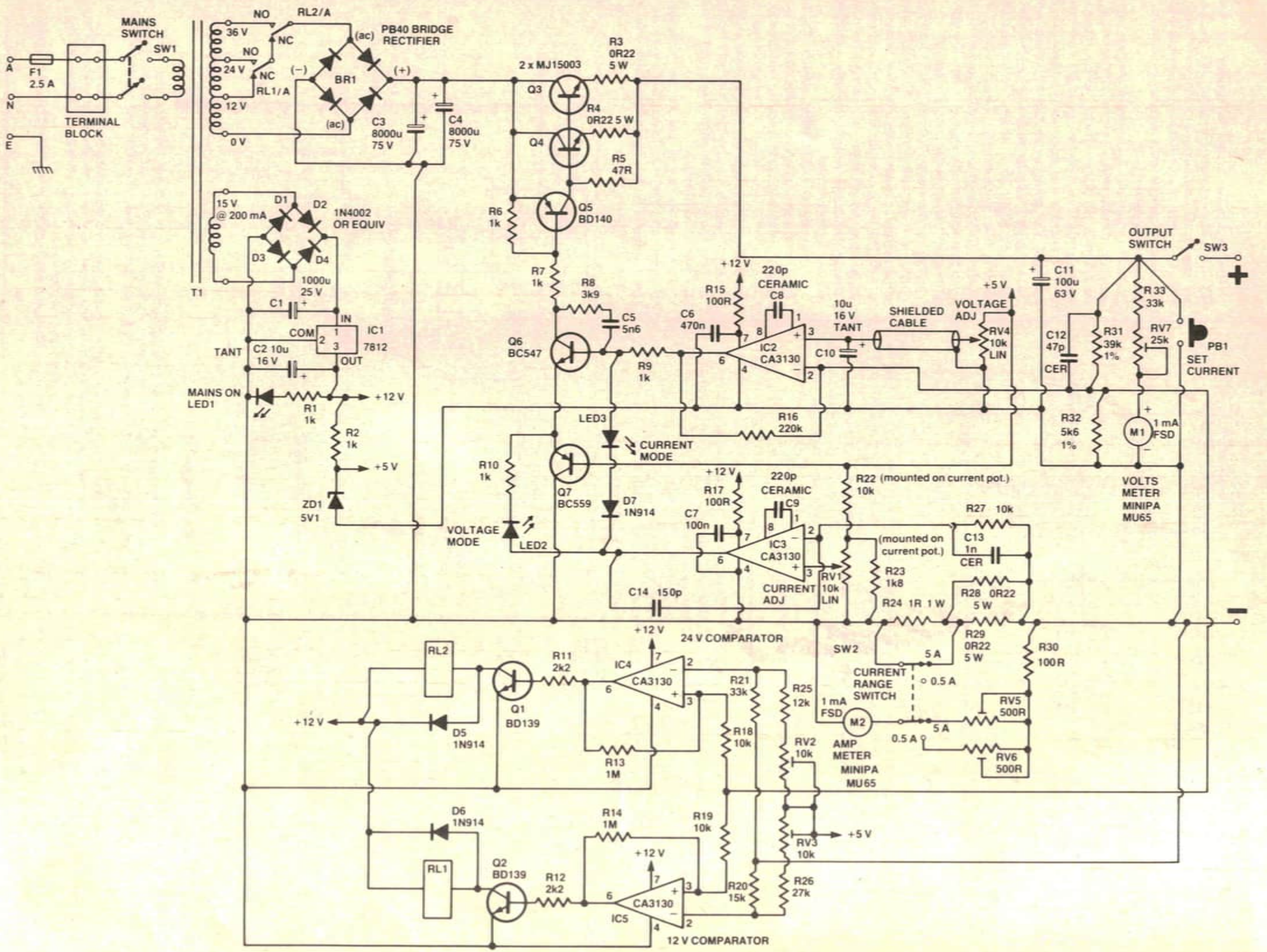
Performance turns out to be generally better than what was discussed as desirable for a lab-standard supply. See Table 1 for a complete run-down. ▶



The switchmode regulator. Fundamental circuit of a switchmode regulator. The output of a sawtooth oscillator and the output level of the 'error amplifier' are compared by the 'pwm comparator' which drives a switching device. The switching device turns on and off, storing energy from the unregulated input in a capacitor or inductor.

As the load current increases, the output voltage (V_{out}) will tend to fall as will the error voltage ($V_{err.}$). The output of the pwm comparator will turn on for a longer period for each cycle of the sawtooth. The switching device then conducts for a longer period, storing more energy in the L or C, maintaining the output voltage. As the output current decreases, the opposite occurs.

As the switching device is either hard on or fully off, it dissipates little power. Varying the potentiometer varies $V_{err.}$, setting the output voltage.


MAINS SWITCH
SW1
F1 2.5 A
A
N
E
TERMINAL BLOCK
NO
36 V
NC
NO
24 V
NC
RL2/A
RL1/A
12 V
0 V
PB40 BRIDGE RECTIFIER
(ac)
(−)
(+)
BR1
(ac)
C3 8000u 75 V
C4 8000u 75 V
2 x MJ15003
Q3
Q4
R3 0R22 5 W
R4 0R22 5 W
R5 47R
Q5 BD140
R6 1k
15 V @ 200 mA
D1
D2
D3
D4
1N4002 OR EQUIV
1000u 25 V
T1
C1
IN
COM
IC1 7812
OUT
TANT
C2 10u 16 V
MAINS ON LED1
R1 1k
+12 V
R2 1k
+5 V
ZD1 5V1
R7 1k
R8 3k9
C5 5n6
Q6 BC547
R9 1k
LED3
CURRENT MODE
R10 1k
Q7 BC559
D7 1N914
VOLTAGE MODE
LED2
C14 150p
+12 V
R15 100R
220p CERAMIC
C8
C6 470n
IC2 CA3130
10u 16 V TANT
C10
R16 220k
SHIELDED CABLE
VOLTAGE ADJ
+5 V
RV4 10k LIN
C11 100u 63 V
C12 47p CER
R31 39k 1%
R32 5k6 1%
OUTPUT SWITCH
SW3
R 33 33k
RV7 25k
PB1
SET CURRENT
M1 1 mA FSD
VOLTS METER MINIPA MU65
+12 V
R17 100R
220p CERAMIC
C9
C7 100n
IC3 CA3130
R22 10k (mounted on current pot.)
(mounted on current pot.)
R23 1k8
RV1 10k LIN
CURRENT ADJ
R27 10k
C13 1n CER
R28 0R22 5 W
R24 1R 1 W
R29 0R22 5 W
R30 100 R
+12 V
24 V COMPARATOR
RL2
R11 2k2
IC4 CA3130
Q1 BD139
D5 1N914
+12 V
R13 1M
R21 33k
R25 12k
R18 10k
RV2 10k
SW2
CURRENT RANGE SWITCH
5 A
0.5 A
1 mA FSD
M2
AMP METER MINIPA MU65
RV5 500R
RV6 500R
D6 1N914
R14 1M
R19 10k
+5 V
RV3 10k
RL1
Q2 BD139
R12 2k2
IC5 CA3130
R20 15k
R26 27k
12 V COMPARATOR
+
−

HOW IT WORKS — ETI-163

The power supply employs a series regulator circuit with current limiting operation added. The 36 V secondary of the power transformer has taps which are switched in automatically by relays as the output voltage is adjusted so that power dissipation in the series-pass transistors is minimised.

An auxilliary 15 V secondary (or an auxilliary transformer) provides a supply for the reference voltage, the relays, relay drive circuitry and voltage and current feedback op-amps (IC2 and IC3).

The main power transformer (T1) secondary of 36 volts is rated to deliver 5 A and is tapped at 12 and 24 volts. The appropriate tapping is selected by the contacts of relays RL1 and RL2.

These relays are controlled by Q1 and Q2, which are driven by a pair of comparators formed by IC4 and IC5 and associated resistors — R13, 14, 18 and 19. These resistors give the comparators some hysteresis which ensures that the relays do not chatter when the output voltage is set exactly equal to one of the trip voltages.

Resistors R21, 25, 20 and 26 and the two preset pots RV2 and RV3 form adjustable potential dividers, driven from the +5 V reference line. These potential dividers set the trip voltages for the two comparators. The presets allow the actual trip voltage to be adjusted over a small range.

Relay RL1 will trip when the voltage is around 12 V, while RL2 will trip when it is around 25 V. In this way the series-pass transistors, Q3 and Q4, are supplied with enough voltage to ensure good regulation but not excess voltage which would cause unneccessary power dissipation.

The main voltage regulator error amplifier is formed by IC2, a CA3130 FET-input op-amp. This compares the voltage on its non-inverting input (pin 3) with that on its inverting input (pin 2) which measures the output voltage via the potential divider formed by R31 and R32. The non-inverting input is connected to the wiper of RV4 which allows the reference voltage at this point to be varied from 0 to 5 V.

The output of IC2 is connected via resistor R9 to the base of Q6 which, in conjunction with Q5, provides the necessary current to drive the bases of the parallelled series-pass transistors, Q3 and Q4.

The RC network R8-C5 serves to provide negative feedback around Q6 and helps to ensure stability by reducing the gain of the circuit at high frequencies.

The tantalum capacitor C10 serves to filter the reference voltage. This is important since the error amplifier uses this voltage to establish the output voltage. Any ripple at the non-inverting input of IC2 will be amplified and appear at the output of the power supply. Capacitor C12 serves a similar purpose as C5 and controls the high frequency phase shift in the negative feedback loop to prevent oscillation. C8 provides compensation for IC2.

The current-limit error amplifier is formed by IC3 and associated components — C14, C9, R17 and C7. Resistor R17 and capacitor C7 simply form a low pass filter to ensure a reasonably clean supply to the op-amp. C9 compensates the op-amp and C14 provides feedback to decrease overall gain of the feedback loop at high frequencies, thereby ensuring stability when the supply is operating in the current-limit mode.

The non-inverting input to IC3 is connected to an adjustable voltage reference formed by RV1, R22 and R23. The inverting input is connected via R27 to the negative output terminal of the supply.

This op-amp is, in effect, measuring the voltage drop across the series resistance of R24, R28 and R29. This voltage is proportional to the current drawn from the supply. The amount of series resistance is switchable by the current range switch, SW2.

In the 5 A range, R24 is shorted by the switch providing a series resistance of 0.11 ohms. If for example, a 5 A current limit was desired, the current adjust pot. (RV1) would be adjusted, after depressing the current-set pushbutton (PB1) to give 5 A, and this would result in a 0.55 V reference voltage appearing at pin 3 of IC3. This op-amp then compares the reference voltage to the voltage developed across the series resistance.

IC3 will provide the appropriate output to bring its two inputs to the same voltage and, since 5 A will cause a 0.55 V drop across the series resistance, the load current will be limited to 5 A.

This assumes that the output voltage has been set high enough to force more than the desired current through the load. If this is not the case, it is impossible for the current error amp. to correct what it sees as a gross error in the current. The reference voltage at pin 3 of IC3 will be greater than the voltage at pin 2 so that the output of the op-amp is forced hard against its positive supply rail, i.e: around 12 V. This forward biases LED2, which indicates that the supply is in voltage mode. i.e: the output is controlled by the voltage pot.

If, however, the reference voltage has been set high enough so that the current flowing in the load approaches that set by the current limit potentiometer, then the current error amp takes over control of the feedback loop and maintains the output so that only the required current flows in the load.

The voltage error amp (IC2) is then incapable of correcting the output voltage and its output swings hard against its positive supply rail (12 V) in an attempt to do so. This forward biases LED3 which indicates that the supply is in current mode. i.e: the output is controlled by the current adjust pot., RV1.

The voltage meter, M1, is a straightforward milliameter arranged to measure voltage via series dropping resistors R33 and the preset RV7 — the latter being for the purpose of calibration.

The current meter, M2, is effectively a voltmeter, measuring the voltage developed across the series resistance in the negative output line of the supply. Independent presets RV5 and RV6 are provided to allow calibration of the two output current ranges.

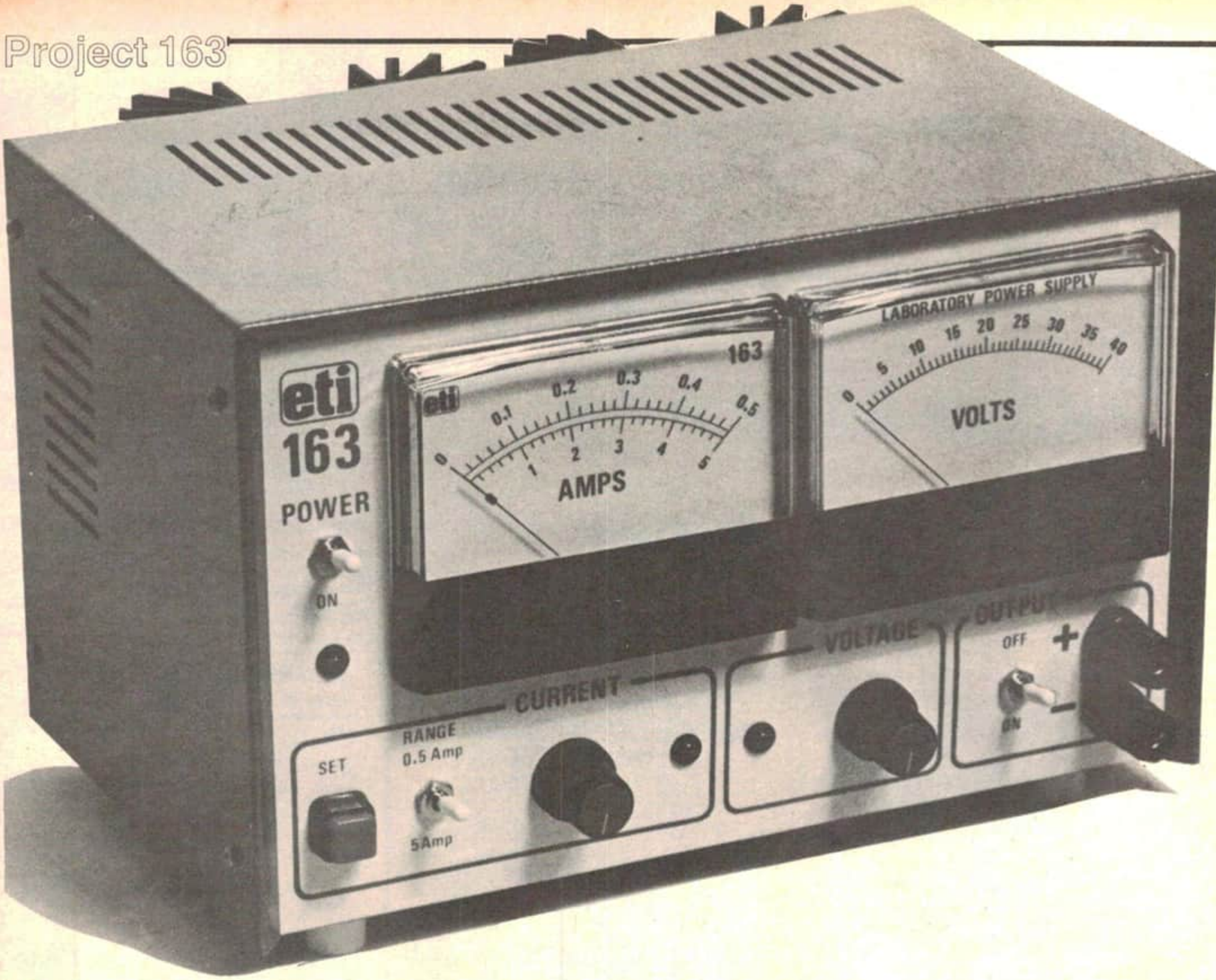
A bridge rectifier (BR1) and two 8000u/75 V capacitors (C3, C4) provide the main supply for the regulator.

The voltage and current error amplifiers must be supplied with a 12 V rail obtained independently of the main tapped secondary winding of the transformer. This can be supplied from an auxilliary winding on the main transformer or from a second small transformer. It should be rated, at a minimum, to deliver 12 V at 150 mA, but a rating of 15 V at 200 mA provides a greater margin.

Diodes D1 to D4 rectify this supply, C1 providing smoothing. This is then regulated by IC1 to 12 V. A 5V1 zener diode connected across this supply provides the 5 V reference used by the reference inputs of the voltage and current error op-amps, IC2 and IC3.

The 'mains on' LED indicator, LED1, is powered from the +12 V rail by the series dropping resistor, R1. The output switch, SW1 permits 'turning off' the supply output without turning off the mains. ●

Next month The interesting bits come next month — putting it together, setting it up and using it. Don't miss the next exciting episode! . . . .



0-40 V/5 A laboratory power supply Part 2.

Having introduced the project and the design technique chosen in Part 1, this part describes the construction and setting up.

David Tilbrook

Construction

This project is not recommended for beginners or inexperienced constructors. However, anyone with a modicum of electronics construction experience should be able to assemble this project with little difficulty.

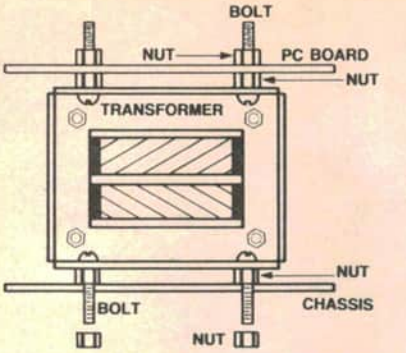
First off, no matter whether you've bought the components individually or purchased a kit, lay out all the parts and see that you have everything you need — including things like thermal compound, the right size nuts and bolts etc. Two basic grades of hookup wire are used to wire up the supply: ordinary 'light duty' (10 x 0.12 mm) hookup wire and 'heavy duty' (24 x 0.2 mm) or 'ultra heavy duty' (32 x 0.2 mm) wire. Those parts of the circuit carrying high currents are wired up with the heavy duty wire, as indicated in the wiring diagram.

The case we used is from K&W of Ballarat, Victoria, model C1066, supplied to us courtesy of Rod Irving Electronics. It is a popular and widely available case. Overall, it measures 255 x 165 x 155 mm and has a U-shaped aluminium chassis and hammertone blue steel lid with ventilation slots. It is supplied with four screw-on feet.

The chassis will need to be marked out and all holes drilled or cut out before any assembly can be commenced. Mark out the front panel according to the accompanying diagram. Centre punch all holes before drilling. Do a trial assembly of each component to see that they all fit and make any necessary adjustments.

No drilling diagrams have been given for the chassis bottom and rear panels as these will depend on the physical dimensions of the exact components used. Tackle the rear panel first. Place the two heatsinks side by side (see rear photograph), leaving room at the right for the mains fuse and power cord inlet. The two heatsinks we used were 150 mm lengths of black anodised radial fin type, manufactured and marketed by Rod Irving, No. HS3. There are similar types available. Any heatsink with suitable dimensions and rated dissipation of 1-1.3°C/watt will be perfectly adequate.

Holes will need to be drilled in the rear panel to accommodate the transistor mounting hardware, the transistor leads and bolts for securing the heatsinks. Having organised



Transformer and board mounting. How the power tranny, T1, and the pc board are mounted.

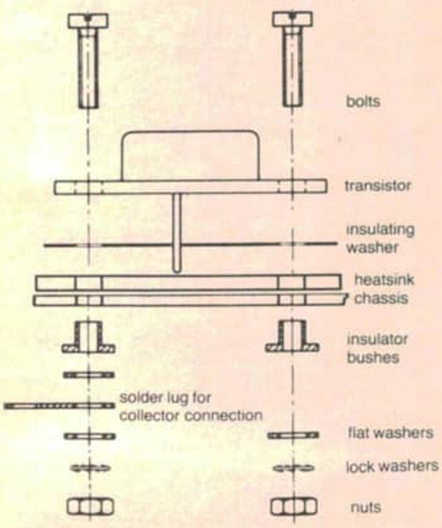
that, then locate the holes for the mains fuse holder and the power cord grommet — which should be a clamp type.

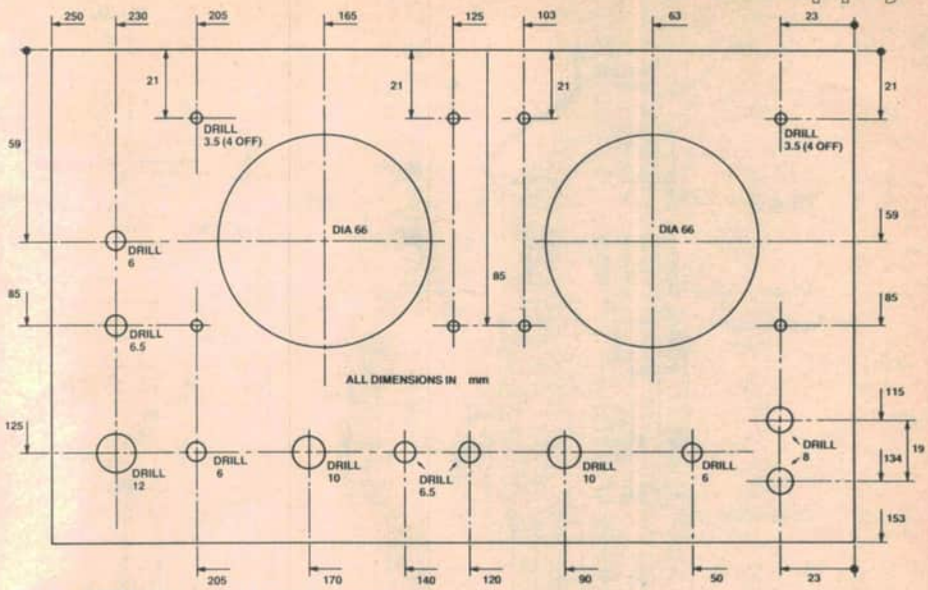
Mark out the case bottom next. Locate the mains transformer centrally between the sides and towards the rear, leaving no less than 15 mm clearance from the rear panel to the transformer bobbin. Four bolts are used to secure the transformer. Then locate and mark out the two filter capacitors, the bridge rectifier, the mains terminal block and earth bolt and the auxilliary 12 V (2851) transformer (if used). Make sure you don't foul the four case feet. Do a trial assembly to see it all fits correctly.

Remove burrs from all holes, then check that you've drilled all the required holes. Now stick masking tape across the rear (inside) of the front panel and spray paint the outside of it white. At the same time, remove the scale panels from the two meters, turn them over and spray paint them white, too. This ensures that the background for the Scotchcal labels is neutral as white Scotchcal is slightly translucent. Remove the masking tape from the chassis after the paint has dried.

Now the Scotchcal labels can be attached. Tackle the meter scales first. Peel off the backing along one edge for a little way then carefully align it on the edge of the scale panel and rub it down. Then peel off the backing further, rubbing down the Scotchcal carefully as you go. Take care not to get any, or many, bubbles under the Scotchcal label.

Transistor mounting. How to mount the two power transistors, Q3 and Q4.





Get the drill? Drilling details for the front panel.

If you do get some, they can be removed by rubbing them away towards the nearest edge. Work from the centre of the panel outwards.

Follow by applying the other meter scale Scotchcal and then the front panel. When the labels have been applied, cut out the holes using a modeller's scalpel or the like. Remember, a little patience prevents accidents. Re-assemble the meters.

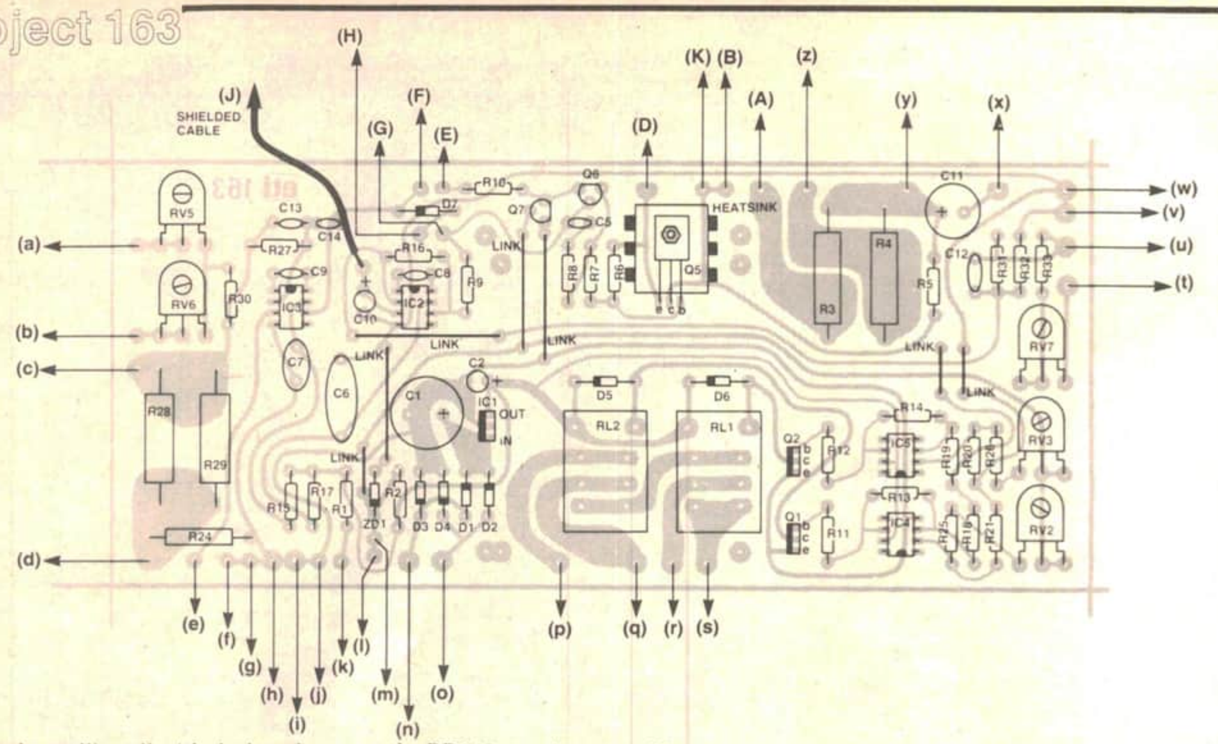
Now, you can mount all the front panel components — the meters, switches, output terminals, etc. Attach wires of appropriate length to them, as shown in the panel wiring diagram. Take care to use light duty and heavy duty hookup wire where indicated. Note that the lead from the voltage control potentiometer (RV4) to the pc board is a shielded cable. The shield braid is soldered only to the pot lug which connects to the 0 V output terminal and is left unconnected at the pc board.

Mount the rear panel components, but leave the mains cord off for the moment. Assemble the transistors to the heatsinks and chassis as indicated in the accompanying diagram. Attach wires to the transistors as per the wiring diagram.

Mount the bridge rectifier and attach heavy duty leads of appropriate length to the lugs. Then mount the mains terminal block and the 2851 auxilliary transformer, if used. Wire the mains switch, mains fuse and mains terminal block. Sleeve the exposed fuse and switch connections. Mount the power transformer as per the diagram here, followed by the filter capacitors.

Assembly of the pc board can be tackled next. First, examine the tracks, looking for any breaks or hairline copper bridges between tracks. Check that all the holes are drilled and that they're of the correct size, particularly where the relays mount. ▶

Rear view. Showing the components mounted on the rear panel. Note that the lip on the chassis lid needs to be cut away around the heatsinks and fuseholder.



If, or when, all's well with the board, commence assembly by soldering all the resistors and capacitors in place. Make sure you place the electrolytics and tantalums the right way round. The trimpots, note, are all laid flat on the board. Solder the pins in first, then carefully bend them so that the body lays flat.

The semiconductors may be soldered in place next. Check that each is correctly oriented before you solder it in place. If you wish, IC sockets may be used. Note that Q5, the BD140, requires a small heatsink. I used a Thermalloy No. 6073B, but any similar type that physically fits will do. Smear a little thermal compound on the metal face of the transistor before assembling it. No insulating washer is necessary.

The two relays can be mounted and soldered in place next, followed by all the pc stakes for terminating the leads to the components on the chassis.

The pc board bolts on top of the transformer. Note that provision has been made on the pc board for mounting holes to suit either the Permatran or the Ferguson transformer, whichever is used. It mounts on top of the transformer, as per previous diagram.

Referring to the wiring diagram, wire up the pc board. Route all the wires carefully. Check it thoroughly when you've finished. Last of all, wire in the mains cable. Make sure the earth (yellow/green) lead is the longest so that, should the cable be accidentally pulled out, the earth lead is the last to break. ▶

PARTS LIST — ETI-163

Resistors .... all ¼ W, 5% unless noted
R1, 2, 6, 7, 9, 10 ... 1k
R3, 4, 28, 29 ...... 0R22, 5 W
R5 .... 47R
R8 .... 3k9
R11, R12 .... 2k2
R13, R14 .... 1M
R15, R30 .... 100R
R16 .... 220k
R17 .... 100R
R18, 19, 22, 27..... 10k
R20 .... 15k
R21 .... 33k
R23 .... 1k8
R24 .... 1R, 1 W
R25 .... 12k
R26 .... 27k
R31 .... 39k, 1%
R32 .... 5k6, 1%
R33 .... 33k
RV1, RV4 .... 10k/A panel mount pot.
RV2, RV3 .... 10k/A min. vert. trimpots
RV5, RV6 .... 500 R min. vert. trimpots
RV7 .... 25k min. vert. trimpot

Capacitors
C1 .... 1000u/25 V single ended electro.
C2, C10 .... 10u/16 V tantalum
C3, C4 .... 8000u/75 V can electro.
C5 .... 5n6 greencap
C6 .... 470n greencap
C7 .... 100n greencap
C8, C9 .... 220p ceramic
C11 .... 100u/63 V single ended electro.
C12 .... 47p ceramic
C13 .... 1n ceramic
C14 .... 150p ceramic

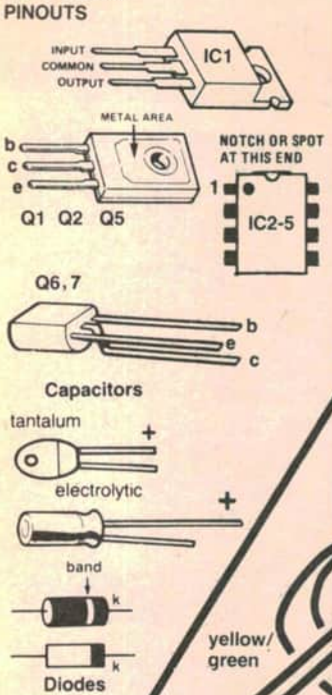
Semiconductors
BR1 .... PB40, MDA2504, MDA3504 etc bridge rectifier
D1, 2, 3, 4 .... 1N4001, 1N4002, etc
D5, 6, 7 .... 1N914, 1N4148
Q1, Q2 .... BD139
Q3, Q4 .... MJ15003, MJ15024 etc
Q5 .... BD140
Q6 .... BC547, BC107 etc
Q7 .... BC559, BC159 etc
IC1 .... uA7812, LM7812 etc
IC2, 3, 4, 5 .... CA3130
LED1 .... TIL220R red LED
LED2 .... TIL220Y yellow LED
LED3 .... TIL220G green LED
ZD1 .... 5V1

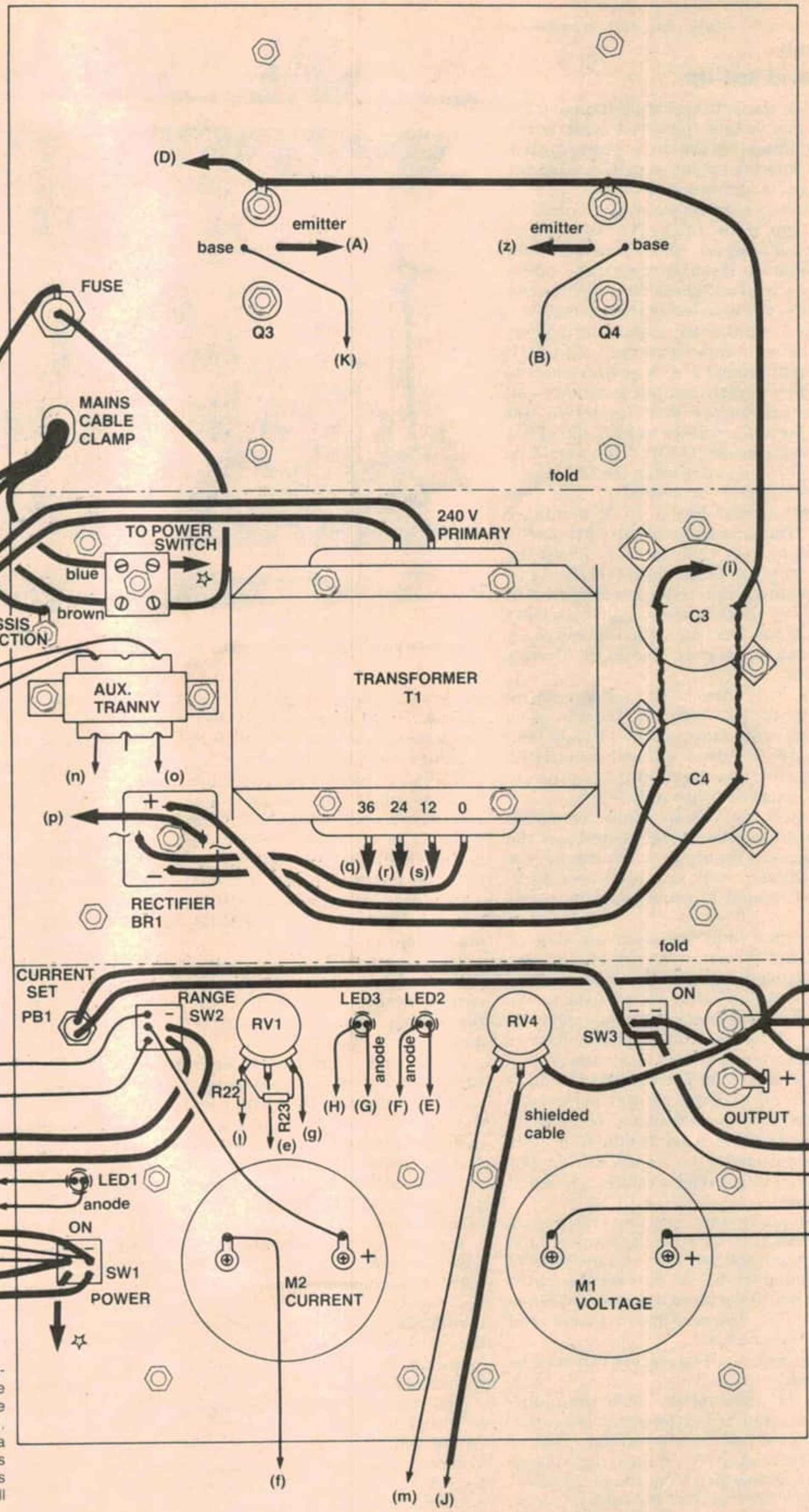
Miscellaneous
F1 .... 2.5 A or 3 A fuse, type 3AG, and bayonet holder (e.g. D.S.E. cat. S-4206 or similar).
M1, M2 .... Minipa MU65 1 mA meter movements, or similar.
PB1 .... SP momentary action pushbutton, 125 Vac/6 A contacts, D.S.E. No. S-1199 or similar.
RL1, RL2 .... DPCO heavy duty relays, 125 Vac/10 A contacts, 12 V coil (160 ohm), Fujitsu FRL-264D012/02CK (D.S.E. No. S-7140 or similar).
SW1 .... DPST miniature toggle switch, 240 Vac/1.5 A contacts or greater, D.S.E. No. S-1174 or S-1168, or similar.
SW2, SW3 .... DPDT miniature toggle switches, 240 Vac/5 A contacts, D.S.E. No. S-1168 or similar.
T1 .... transformer, 240 V primary, 250 VA rating, main secondary to deliver 36 V at 5 A or better, tapped at 12 and 24 V, with auxilliary secondary of 15 V at 200 mA (or additional 2851 12 V/150 mA transformer if 15 V secondary not available).

ETI-163 pc board; K&W case No. C1066; two heatsinks — Rod Irving No. HS3 150 mm long single-sided radial fin type black anodised, or similar (1°C/watt); one Thermalloy TO-220 heatsink 6073B or similar (for Q5); two heavy duty captive-head binding posts (one red, one black); one two-way terminal block; TO3 insulating components — two sets; one clamp grommet; mains cord and plug; Scotchcal labels for meter scales and front panel; short length of shielded cable; three LED mounts; hookup wire — light (10 x 0.12 mm) and heavy (24 x 0.2 mm or 32 x 0.2 mm); 6 BA and 4 BA bolts and nuts, solder lugs etc.

Price estimate $165 — $170

COMPONENT PINOUTS





General wiring diagram. Wires of suitable length should be attached to the chassis-mounted components before mounting the pc board on top of T1. Ignore the auxilliary tranny if T1 has a 15 V auxilliary winding. The light wires should be 10 x 0.2 mm, the heavy wires either 24 x 0.2 mm or 32 x 0.2 mm, all plastic insulated.

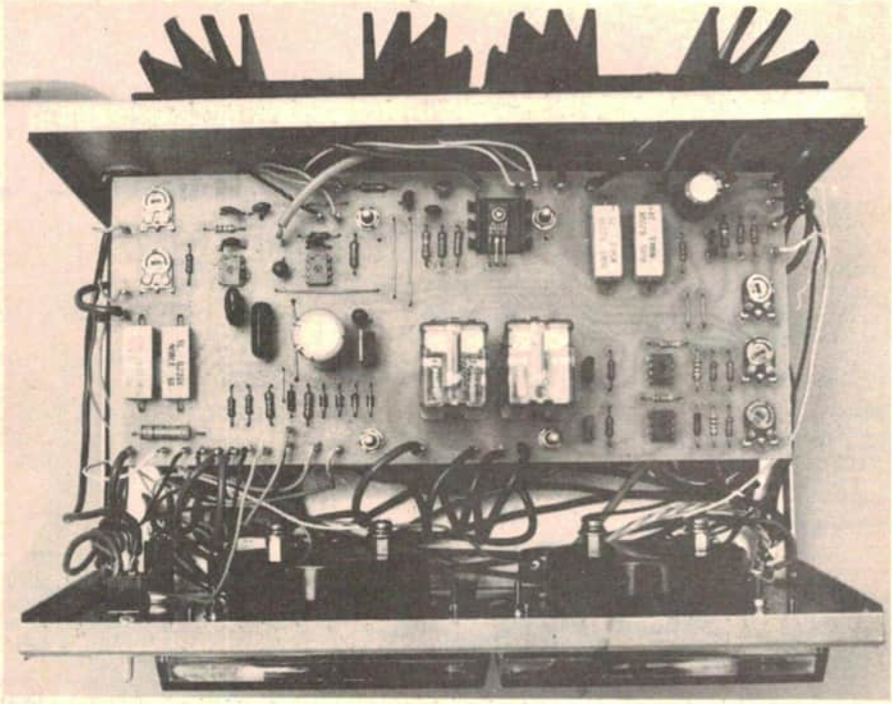
Now you're ready for the traditional 'smoke test'.

Test and set-up

Set all the trimpots to mid-position and the current and voltage controls a quarter-turn from minimum. Set the current range switch to 0.5 A and the output switch on. Plug the mains cord in and switch it all on.

The mains LED should come on, along with the voltage mode LED. The volts meter should read forwards, somewhere on the low end of the scale. If you don't get these indications, switch off and check for a wiring error (make sure you've a fuse in the fuseholder!).

Using a multimeter, check the voltage across the main filter capacitors (C3-C4). It should read around 17.5 V (with respect to the supply's negative output terminal — all readings are quoted with respect to this point). Check the voltage at pin 1 (in) of IC1 (i.e: at cathodes of D2-D4). This should be around 17.5 V if you're using the 12 V auxilliary transformer, or around 21 V if your main transformer has a 15 V auxilliary winding. Then check the output of IC1 (pin 3). It should be very close to 12 V. Check the voltage on the cathode of ZD1. It should be very close to 5.1 volts. No other voltages will tell you very much at this stage. If you don't get the correct readings switch off and check wiring and component placement. Correct any errors.



Top down view. Inside the lab. supply, showing board mounting and wiring.

If all's well, advance the voltage control until you hear RL1 'click' on. The voltage on the positive terminals of C3-C4 should then be around 36 V. Advance it further until RL2 clicks on and the voltage on the positives of C3-C4 should rise to about 54 V or so.

Now check the voltage across the output terminals. Vary the voltage control over the full range and ensure that you can vary it right from zero volts to a little over 40 V. We'll get around to calibrating the meter later.

The current-limit operation can now be checked. Set the output switch off. Connect your multimeter directly across the output terminals. Set it to the 5 A or 10 A range. Ensure the supply's current range switch is set to 0.5 A. Set the voltage control back to about a quarter-turn from minimum. Throw the output switch on. The voltage mode LED should go off and the current mode LED should go on. (This should also occur when the voltage control is set at minimum.) See that the multimeter reads a low current. If it doesn't, you've got the current range switch upside down.

Set the multimeter to a convenient scale (1 A or 2 A). Turn the current control around to maximum and see that the multimeter reads around 0.6-0.7 A. Now set the multimeter to the 10 A scale and the current range switch to 5 A. The multimeter should read between 6 A and 7 A.

If all's well, the two meters can now be calibrated.

First, the volts meter. With the multimeter still connected to the output terminals, set it to a convenient scale so that you can accurately read 20 V. Adjust the voltage control to obtain 20.0 V on the multimeter. Now adjust RV7 so that the volts meter on the project also reads precisely 20 V. Then set the voltage to read 5 V on the meter and check that the output's within ;0.25 V.

I have done this because many devices, TTL ICs and op-amps in particular, require accurate supply voltages and most are driven from supplies of less than 20 V. With TTL ICs a supply in excess of 5.5 V can destroy the device. Calibrating the meter at 20 V ensures that the meter accuracy at the low end is sufficient to obviate problems. If it's a volt or two out on the 20-40 V end of the scale, it doesn't matter so much.

To calibrate the current meter, first set the supply's output switch off. Set the current range switch to 0.5 A and set both the voltage and current controls about a quarter-turn off minimum.

Switch on the supply output and adjust the current control to obtain a reading of 500 mA on the multimeter. Then adjust RV6 so that the current meter reads full scale. Set the multimeter to the 5 A or 10 A scale and the current range switch to 5 A. Set the current control so that the multimeter reads 5.00 A and adjust RV5 so that the current meter reads full scale.

The current control has to be re-adjusted when switching from 0.5 A to 5 A as the current sensing resistor for the 5 A range is not exactly 0.1 ohms, being made up from two 0R22/5 W resistors in parallel which are the only ones generally available. Some tolerance in values will account for a difference in any case.

Now the relay 'trip' points can be set. Turn RV2 and RV3 fully anticlockwise. Set the output voltage to something less than 10 V. You can do this adjustment using either the project's volts meter or your multimeter connected across the output terminals.

Slowly advance the voltage control until the output is 12.5 V or thereabouts. Then rotate RV3 clockwise until RL1 just clicks in. This trimpot gives a trip point range of about 3 V from about 11 V to about 14 V. You may notice the output actually drop a few hundred millivolts when RL1 pulls in, but this is of no consequence.

Having done that, slowly advance the voltage control until the output voltage reaches about 25.5 V. Then rotate RV2 clockwise until RL2 clicks in. The output will drop a few hundred millivolts when you do this, but as before, it's unimportant. This trimpot has a trip point range of about 6 V, from roughly 24 V to about 30 V.

That's it! Now you can screw the lid down and put your ETI laboratory supply proudly on the workshop shelf.

Tips on using it

Always set up the power supply with the output switch *off*. Set the output voltage to what is required by the circuit you're working on. Then set the current limit range switch to the appropriate range, press the current set button and adjust the current control so that the current meter reads a little above what you expect the circuit to draw. Don't forget to allow for relay turn-on currents, lamps, indicators and etc in the circuit.

With straight CMOS circuits, even those with a dozen or more ICs, a current limit of 100-150 mA is a good safe limit.

Beware of circuits which may draw peak currents several times the average current and set the current limit to take this into account (i.e: audio amplifiers, pulse circuits).

With a little experimentation and experience, you'll soon learn how to set up and effectively use the ETI-163 Lab. Supply. ●

Artwork. Here is full-size artwork for the pc board and the two meter scales. Unfortunately, the artwork for the front panel is too large to reproduce here. A photostat can be obtained by sending us a stamped-addressed A4-sized envelope. Scotchcal and pc board suppliers were listed on page 80 of the May issue.

You can obtain 1:1 positive or negative film of all the artwork for this project for $15 post paid from **ETI-163 Artwork, ETI Magazine, P.O. Box 21, Waterloo NSW 2017.** Make cheques or money orders payable to 'ETI Artwork Sales' and ensure you ask for **positive** or **negative** film, as you require.