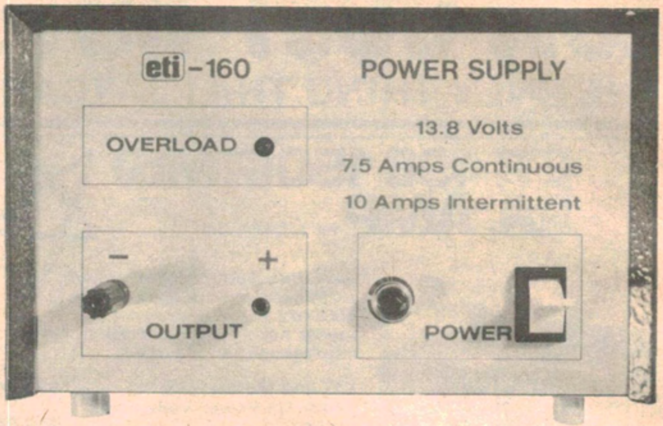
13.8 V regulated high current supply



Here's a supply that's just the thing for operating transceivers, RF power amplifiers, etc, or anything that requires a 13.8 Vdc (nominal) supply and pulls more amps than the general run of 'CB' type power supplies can deliver.

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MANY AMATEURS operate a mobile VHF or UHF transceiver at home as well as in the vehicle — it's convenient and economical. Until a year or so ago, most of these transceivers ran about 10 W output, drawing up to 2 A from the 12 Vdc (nominal) supply. Then transceivers delivering 25-30 W and incorporating multimode operation appeared on the market. These draw about 6-7 A from the 12 Vdc supply, and owners of 10 W output transceivers often add an 'afterburner' to boost the transmitter output. The ETI-710 (April '76) and ETI-716 (Jan. '78) 2 m booster amplifier projects provided around 40-45 W output on 2 m from a drive of 10 W, drawing around 7 A from a 12.5 V supply. A number of commercial amplifiers giving similar performance is available, too.

For novices, HF band transceivers, such as the Yaesu FT-7, are popular, but operate from a 12.5 Vdc supply. The FT-7 draws about 3.3 A on transmit, and similar transceivers from other manufacturers are much the same. Trouble is, the common 'CB'-type power supplies are generally rated to deliver only 2 A continuous, and while some will deliver up to 4 A intermittent, a 3 A load is too much for them.

Marine VHF FM band transceivers require a dc supply and, as they run 25 W, CB-type supplies are unsuitable if mains operation is contemplated for a base installation.

This power supply is intended to suit all the sorts of applications mentioned above — and any others you can think of where dc-operated equipment draws more than 3-4 A.

As most dc operated equipment is specified to operate from a 13.8 V supply, that's the output voltage we have settled on. The current rating we have quoted is based on several factors. Firstly, while the transformer specified has a secondary rating of 18 V/6 A, it is capable of delivering much more before the secondary output voltage loads down seriously. In addition, transformer temperature rise needs to be taken into account. Hence we determined a current rating by experiment, taking these factors into account, and it turns out to be 7.5 A. However, as much as 10 A can be drawn from the supply intermittently. At this point the regulator circuit cannot maintain output voltage, as the input-to-output differential begins getting a little too low. Short circuit current limit was set at this point too, for convenience.

No current meter was provided as this project was not intended as a test bench supply. The only indicators are a bezel lamp to indicate the supply is on and an 'overload' LED to warn that the supply has gone into current limit should you attempt to draw too much current or have a short circuit on the output.

Design notes

A capacitor-input bridge rectifier provides about 25 V input to the regulator circuit. This consists of a 12 V three-terminal regulator with output current being boosted by a pair of MJ15004 PNP bipolar power transistors connected in parallel. Current limiting is provided by a Darlington pair, Q1 and Q2, which senses the emitter current through the power transistors. When the current exceeds an amount determined by R2 (about 10 A), Q2 and Q1 turn on, Q1 robbing Q3 and Q4 of base current drive and preventing further increase in output current. When Q2 turns on, LED1 will turn on, providing indication of the overload condition.

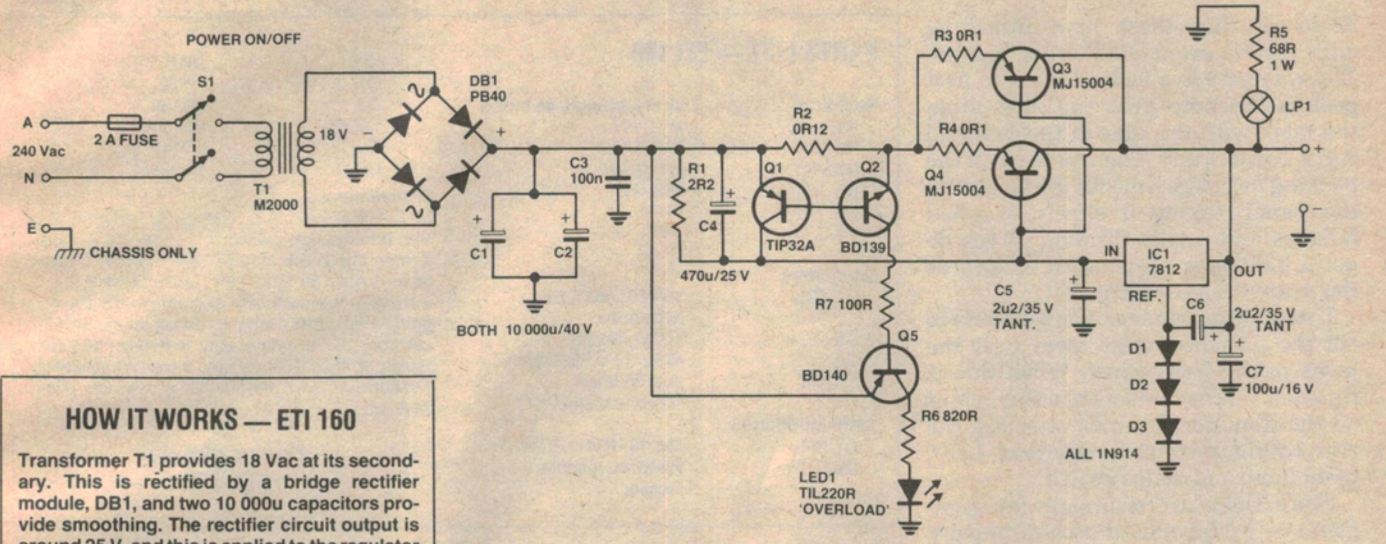
The output voltage is determined by the three-terminal regulator, IC1. Its reference terminal is 'jacked up' by 1.8 V by the drop across the diode string D1 to D3, resulting in an output voltage of 13.8 V.

Construction

We housed the power supply in a large K&W case, model C1064, measuring 155 x 155 x 255 mm overall. This has a U-shaped aluminium chassis with an etched front panel and four plastic feet that mount on the bottom. The case lid is steel, with ventilation slots punched in it and edges which wrap around the front and rear panels. It is secured by eight screws, four on each side panel. We made up a plastic Scotchcal stick-on label for the front panel.

Layout is generally non-critical, so components were placed in convenient positions. The heatsink carrying the major regulator components was mounted in a vertical position in the centre of the rear panel. The transformer was mounted on the bottom of the chassis, slightly to the right of centre, and the rectifier components were mounted to the rear panel. The overcurrent protection components were mounted on a small piece of matrix board on the bottom of the chassis, just to the left of centre and immediately behind the output terminals.

Unless you are purchasing this project as a kit with prepared metalwork, construction starts with the mechanical work. The heatsink should be tackled



HOW IT WORKS — ETI 160

Transformer T1 provides 18 Vac at its secondary. This is rectified by a bridge rectifier module, DB1, and two 10 000u capacitors provide smoothing. The rectifier circuit output is around 25 V, and this is applied to the regulator circuit, which consists of Q1 to Q4, IC1 and associated components. Q5 drives the overload indicator LED.

IC1 is a positive 12 V three-terminal regulator, such as a 7812 or similar. A parallel pair of PNP power transistors, Q3 and Q4, are arranged to boost the output current. A portion of the input current to IC1 flows through the base-emitter junctions of Q3 and Q4. Their collectors are connected to the output and, as they are operated here as current amplifiers, the load current supplied is much greater than the three-terminal regulator can provide. Resistors R3 and R4 ensure collector-emitter currents through Q3 and Q4 are shared equally. About 300 mA of the load current is contributed by IC1.

The reference pin of IC1 ('REF.') is raised by about 1.8 volts by the three series-connected diodes, D1, D2 and D3. They are forward biased by the bias current that flows from IC1's reference pin. Thus the output voltage is nominally 12 + 1.8 = 13.8 volts.

Over-current protection is provided in the following way: when the load current passing through Q3 and Q4 exceeds about 10 amps, the voltage across R2 will be about 1.2 volts. This will forward bias the base junctions of Q1 and Q2, which will turn on. When Q1 turns on, its collector-emitter junction effectively shunts the bases of Q3-Q4, robbing them of drive current and thus limiting their collector current. When Q2 turns on, its collector current forward biases the base-emitter junction of Q5, turning it on. The collector current of Q5 flows through LED1, which lights, indicating the overload condition.

For thermal protection, IC1 is mounted on the heatsink along with Q3 and Q4. Three-terminal regulators incorporate a 'thermal shutdown' mode where, upon reaching an internal junction temperature of 150°C, circuitry on the chip shuts off the output.

Capacitor C3 is a high frequency bypass for the regulator circuit input. Capacitor C4 prevents instability of the overload protection circuit. Capacitor C5 ensures stability of IC1, while C6 improves transient response. C7 provides a low impedance ac shunt for the regulator circuit output. Lamp LP1 provides indication that the supply is on.

Note that the chassis is not connected to the regulator circuit common rail, and the whole circuit 'floats', permitting negative or positive grounded equipment to be connected without fear of possible shorts between the equipment and the power supply.

SPECIFICATIONS
ETI-160 POWER SUPPLY

Output voltage	13.8 Vdc
Output current	
continuous	7.5 A
intermittent	10 A
Regulation	
0-7.5 A	50 mV
10 A	1.3 V

first. Mark out and drill the heatsink according to the accompanying drilling diagram. When drilling the TO3 pattern for the MJ15004 transistors, drill the lower bolt clearance holes first and then use the transistor insulating washer as a template to mark out the positions of the emitter and base pins and the other bolt hole. The emitter and base holes can be drilled to whatever clearance suits you — say 3 mm or 5 mm.

Don't forget the mounting holes on the heatsink flanges.

Using the drilled heatsink as a template, place it on the rear panel of the case as centrally as possible, flanges down and with the fins vertical. Now mark the positions of the four mounting holes and drill them to 3 mm. Draw two lines on the case rear, diagonally between the mounting holes just drilled. Where they cross, drill a 9 mm or 10 mm hole and insert a rubber grommet in it (that's a ⅜" grommet — they don't seem to have gone metric yet).

The transformer mounting holes should be drilled next. Place the transformer in the bottom of the case, orientated as shown in our internal picture, about 10 mm or so from the rear panel and about 15 mm to the right of the approximate centre line (when viewed from the front). The grommet you just inserted marks the approximate centre line. Mark and drill the transformer mounting holes to 6 BA clearance (3 mm is fine). Next mark and drill the mains cable entry hole, the fuseholder hole and holes for the mains cable clamp and terminal block. We mounted the fuseholder above the mains cable entry hole. The terminal block and cable clamp were located in a convenient position adjacent to the transformer on the bottom of the case. Drill a hole for the mains earth lug-mounting screw near the rear corner foot-mounting hole. When the mains cable is installed, the earth lead will thus be the longest, ensuring it is the last to break should the mains cable become detached.

The front panel may be marked out and drilled now, using the artwork or Scotchcal as a template. You can lay the artwork directly on the front panel and prick through it with a scriber or other sharp-pointed instrument at the hole centres. Or, you could trace the hole centres on tracing paper and mark them in the same way.

Three more holes need to be drilled in the rear panel — two to mount the clamps that secure the filter capacitors, and one for the bridge rectifier. The two 10 000 uF filter capacitors are each secured to the rear panel with a 30 mm diameter cable clamp. They are a bit larger in diameter than the caps so we used a strip of double-sided sticky tape to build out the diameter so the clamps gripped effectively. The general mounting and wiring arrangement of the caps and rectifier is shown in the accompanying diagram. Twist the positive and negative leads of the caps together. The positive leads can be brought through the +ve terminal of the bridge rectifier, as we did, if you're careful.

The Scotchcal front panel may be mounted now. We used the plastic-type ▶

Scotchcal, but these need attaching with care to avoid bubbles and ripples. The way we have found best is to first peel the backing from one edge, align the label with the edge of the case and rub it down firmly. Then, peeling off the backing as you go, smooth the label onto the panel, taking it slowly to avoid bubbles and ripples forming. If you do get a bubble, try to smooth it towards the nearest edge to remove it.

Use a sharp knife or scalpel blade to cut the Scotchcal label away over the holes in the front panel. When this is finished, all the components that mount on the front panel can be attached: the two output terminals, overload LED, bezel lamp and mains switch.

Since there are relatively few components, we have used a point-to-point wiring technique rather than assembling most components on a pc board. The regulator components are soldered on a tagstrip mounted in the heatsink 'well' and between this and the device pins. The overload protection components mount on a small piece of matrix board, as can be seen in our internal photograph.

Mount the power transistors, Q3 and

PARTS LIST — ETI 160

Resistors .... **all 5%, powers as noted**

R1	2R2, 1W
R2	0R12, 10W
R3, R4	0R1, 5 W
R5	68R, 1W
R6	820R
R7	100R

Capacitors

C1, C2	10 000u/40 V Elna RB electro.
C3	100n greencap
C4	470u/16 V RB electro.
C5, C6	2u2/35 V tant.
C7	100u/16 V electro

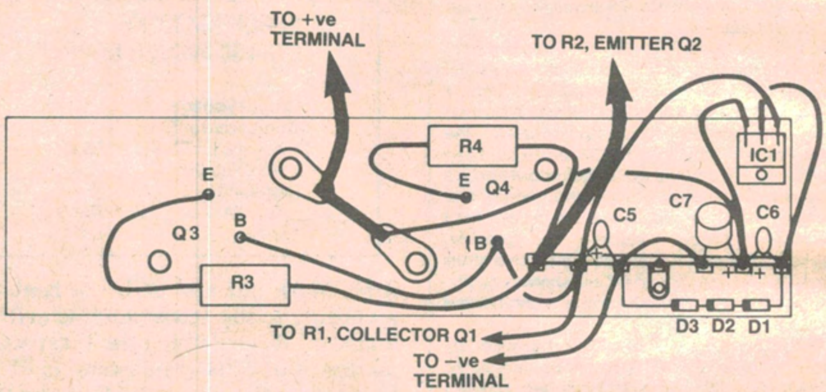
Semiconductors

D1-D3	1N914, 1N4148, etc.
DB1	PB40, 40 A bridge rectifier
IC1	7812
Q1	TIP32
Q2	BD139
Q3, Q4	MJ15004
Q5	BD140
LED1	TIL220R

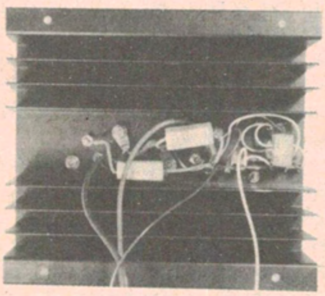
Miscellaneous

LP1 — 6 V/100 mA E.S. lamp; S1 — DPDT 240 Vac rated paddle switch; T1 — 18 V/6 A transformer, e.g: D.S.E M2000; case — K&W C1064; bezel mount for lamp LP1; LED mounting hardware; 240 Vac cable and plug; terminal block; two grommets; cable clamp; three tag strips; Scotchcal front panel; heavy duty terminals; 150 mm length of 45D6CB heatsink; transistor insulating washers, etc; 4 x 6 mm standoff pillars; nuts, bolts, wire, etc.

Price estimate
$72-$80

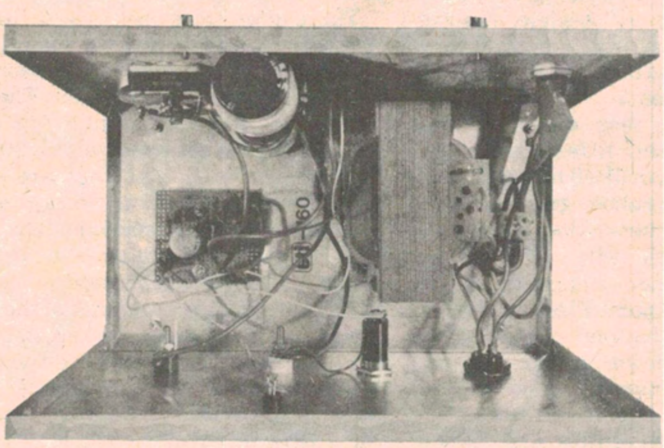


Wiring inside the heatsink.

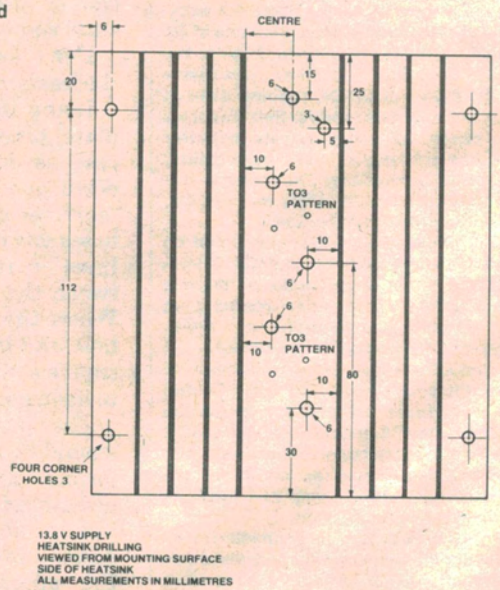


Inside the heatsink.

NOTE: Front Panel artwork for this project can be obtained by sending a stamped, self-addressed A4-sized envelope to:
Project 160 Artwork
ETI Magazine
15 Boundary St
Rushcutters Bay NSW 2011



Inside the chassis, showing general component location.



Drilling the heatsink.

Q4, and the three-terminal regulator, IC1, on the heatsink, along with the tagstrip. You'll have to bend up the legs of IC1 back over its body. Carefully deburr all holes on the heatsink first and use mica washers and insulating bushes to mount them. Smear the mica washers with thermal compound beforehand. Use solder lugs under the nuts on the two mounting screws nearest to one another on Q3 and Q4 — as shown in the accompanying wiring diagram for the heatsink components. With a multimeter, check that the cases of Q3 and Q4 and the tag of IC1 are not shorted to the heatsink. If they are, disassemble the offending device and fix the problem before continuing.

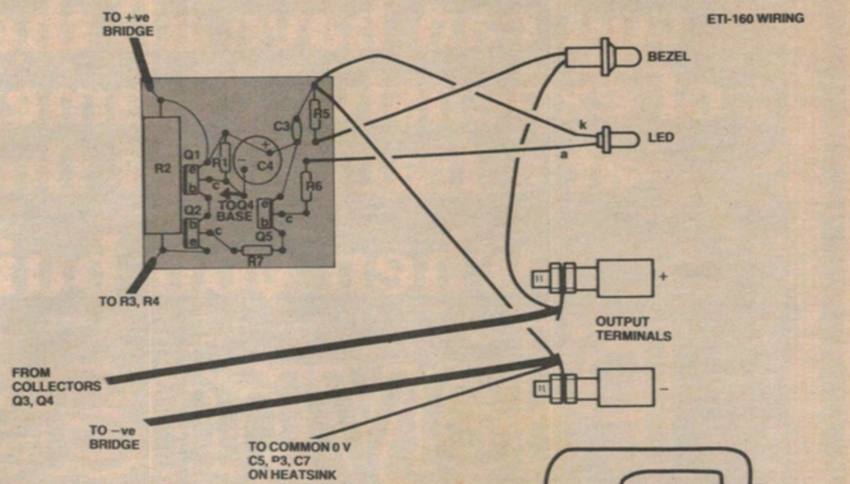
Solder the three 1N914 diodes (D1-D3) in series, with short leads between each, and solder them to the tagstrip as per the heatsink wiring diagram. Now solder C5, C6 and C7 to the tagstrip. Complete the wiring on the heatsink. Wire the collectors of Q3 and Q4 together using heavy duty hookup wire — preferably 32 x 0.2 mm. This point and the juncton of R3 and R4 should then have 250 mm lengths of heavy duty hookup wire attached, ready for wiring to the +ve output terminal and the emitter of Q2 respectively.

Two more wires run from the heatsink circuitry to inside the chassis — to the collector of Q1 and the +ve output terminal. Again, these should be 250 mm long, but only ordinary hookup wire is necessary. The heatsink assembly can now be mounted on the rear panel using 6 mm spacers.

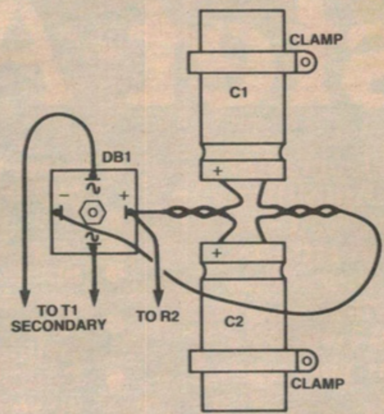
To mount the overload protection components we used a piece of matrix board about 55 mm square. General layout and component wiring is shown in the accompanying diagram. Remember to drill mounting holes in the matrix board and the bottom of the chassis. When completed, this board is mounted using 6 mm spacers.

Complete the construction by bolting in and wiring up the power transformer, the mains cable, fuse and switch, and the components mounted on the front panel. Note that it is important to use heavy duty hookup wire (at least 32 x 0.2 mm) between the filter caps' negative terminals and the −ve output terminal as well as from the rectifier's positive terminal to R2. Don't forget to bolt the four feet on the case.

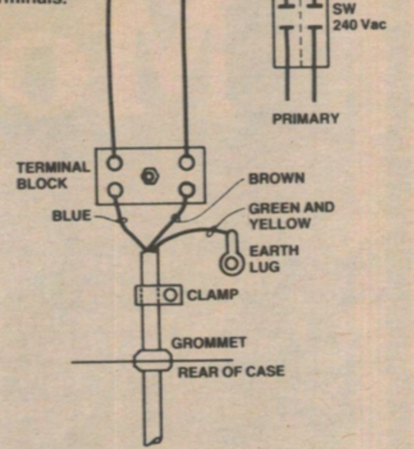
We used a 6 V/100 mA globe and a series resistor for the bezel lamp. You may have to change the value of the series resistor (R5) to accommodate globe rating. A 12 V globe could be used without a resistor, if you wish.



Wiring the overload components, bezel and output terminals.



Wiring the rectifier and filter capacitors.



Mains cable wiring. Be sure to sleeve all exposed connections for your own protection.

Testing it

Carefully check all your wiring. If you're satisfied all is well, plug in and switch on. The bezel lamp should light immediately. Check the output with a multimeter. It should read within ±100 mV (0.1 V) of 13.8 V. If not, switch off and trace the fault. If the output is around 25 V, you have a fault in the regulator wiring. If the output is greatly lower, look for faulty rectifier wiring, or even a faulty rectifier (rare). Generally, problems will be caused by a wiring error.

If the output voltage is OK, you can apply a load and see what happens. A 100 W load consisting of a single car light, or a combination to make up that power, will draw around 7.25 amps. The output voltage should drop no more than 50 mV.

If you can make up a load to draw 10 A (you'll need two multimeters for this one), check that the output does not drop lower than 12.4-12.5 volts.

A multimeter capable of reading at least 12 A can be used to check the overload protection. Connecting the meter directly across the output terminals should result in a current of a little over 10 A (some 300-400 mA of the load current is contributed by IC1). This may vary somewhat, depending on the exact value of R2. If R2 is low, you may have to parallel another resistor across it to bring the overload current closer to 10.5 amps.

The overload LED should light when the load draws more than 10 amps.

When an overload remains on the supply for some time, the temperature of the heatsink will rise until IC1 reaches its temperature cutout point, at which stage it will turn off, turning Q3 and Q4 off, until the heatsink temperature drops. If the overload is still there when IC1 turns back on again, the process will be repeated until the overload is removed. This provides thermal protection to the unit. That's it!

We think you'll find this supply a very handy adjunct to the shack or workshop. ●