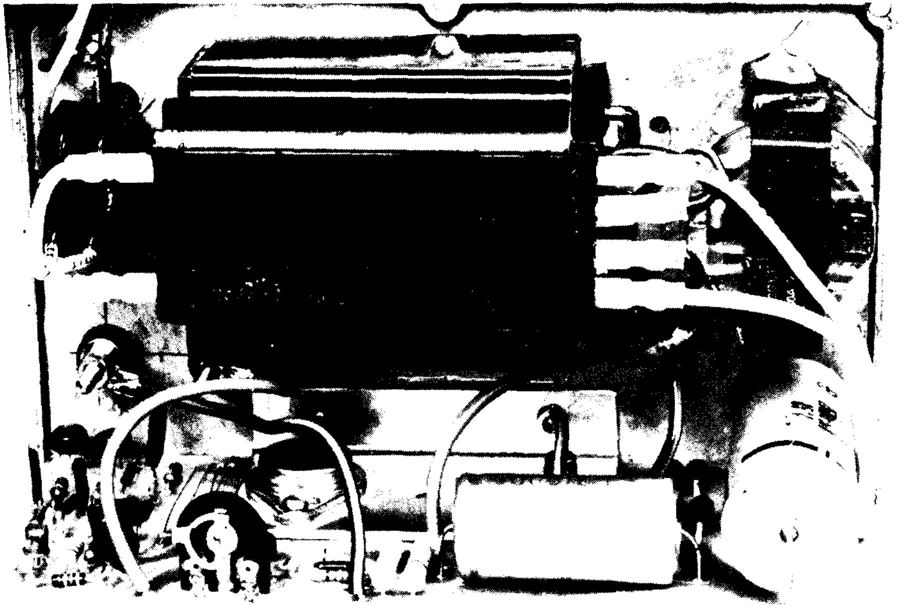
SWITCHING REGULATOR SUPPLY

eti project



Drive those TTL circuits with this 5 volt 10 amp (max) supply.

WHILST the introduction of CMOS has lowered the power requirements of digital equipment using it, many large 'scale systems, because of cost and availability, are still designed around TTL logic. For such systems a five-volt supply having a capability of up to 10 amps is often required.

The choice of power supply for a system depends very much on the output requirements. In very low power applications a shunt regulator consisting of a series resistor and a zener may be entirely adequate. For medium power systems however a series-pass transistor regulator is normally used.

Whilst the series pass regulator is very good with regards to ripple and regulation the specification of the transformer is critical if the supply efficiency is to be above 50%. In a larger system this can be a very important factor.

With a switching regulator the requirements on the transformer are greatly relaxed and an efficiency of 70% or more can readily be obtained with mains-input variations of from 160 to 260 volts.

A fourth type is the switch-mode supply where the mains voltage is first rectified and filtered. The rectified mains then drives a high-frequency inverter which employs a ferrite transformer. Regulation is obtained by controlling the inverter and by this means very high efficiencies may be obtained. Nearly all the components in such a system work at mains voltage and hence for safety reasons this approach was not used in our project.

CONSTRUCTION

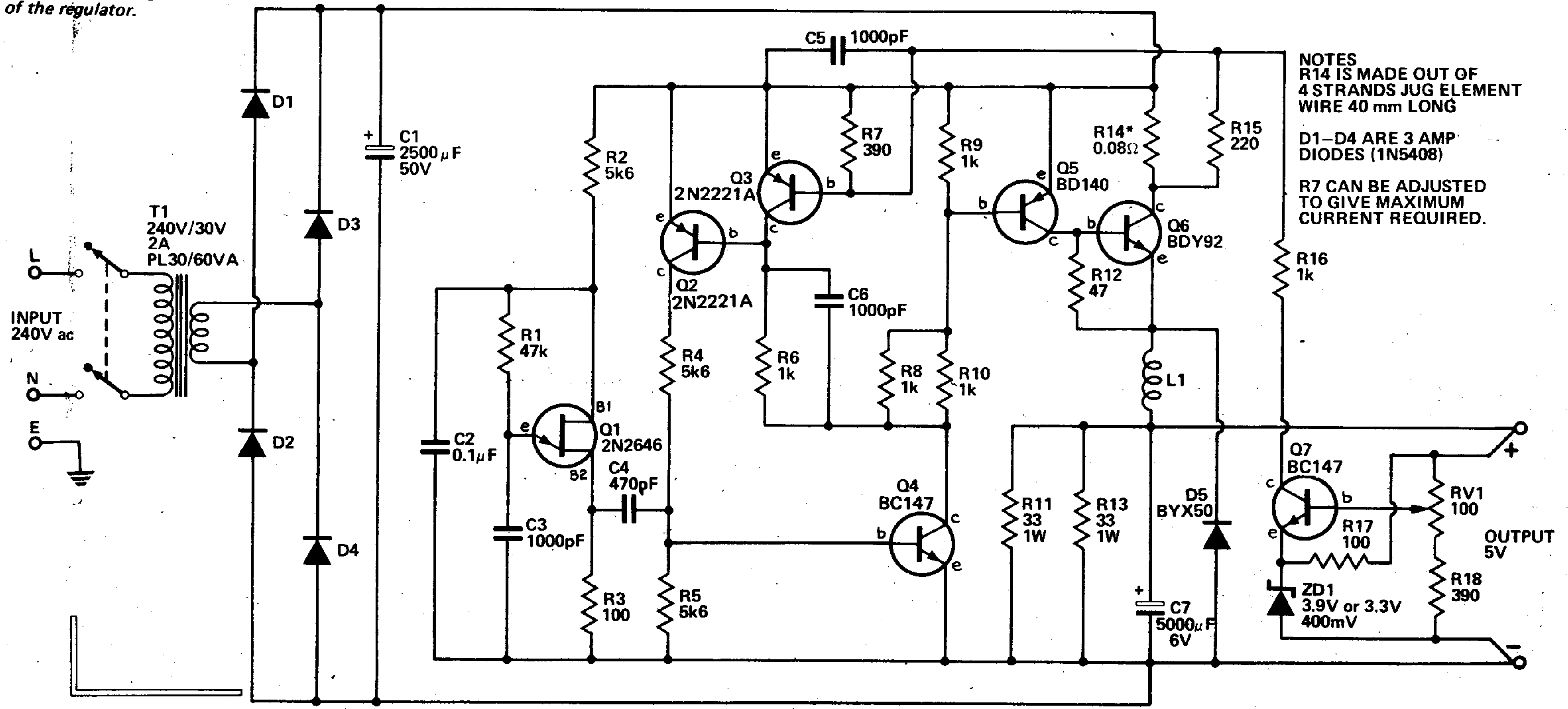
All components, with the exception of the transformer and the choke are best mounted on a printed-circuit board such as the one specified. The choke should be wound as detailed in Table 2 with four layers close wound of 16 swg wire. Due to the dc current in the choke an air gap is necessary to avoid saturation. The easiest method of adjusting this gap for best performance is to run the supply at the maximum current required and adjust the gap by inserting that thickness of insulation between the cores which gives minimum ripple voltage. We found that a 3 mm gap was required at 10 amps for a ripple of 50 mV peak-to-peak.

The prototype was mounted in a ▶

TABLE 1
Comparison of typical series and switching regulators

	SERIES	SWITCHING
Output Voltage	5 V	5 V
Output Current	10 A	10 A
Efficiency		
240 V in	50%	70%
260 V in	40%	70%
Ripple Voltage	< 5 mV p-p	50 mV p-p
Regulation 0-10 A	< 0.05 V	0.3 V
Input Voltage	240 ± 10%	160 to 260 V
Transformer Secondary	8.5 V @ 12 A	20 to 30 V @ 80 VA
Diodes Required	10 A	3 A
Filter Capacitor	33 000 μF	2 200μF
Short Circuit Current	15 A	15 A

Fig. 1. Circuit diagram of the regulator.



NOTES
R14 IS MADE OUT OF 4 STRANDS JUG ELEMENT WIRE 40 mm LONG

D1–D4 ARE 3 AMP DIODES (1N5408)

R7 CAN BE ADJUSTED TO GIVE MAXIMUM CURRENT REQUIRED.

die-cast box which acted as the heatsink as well as a shield to prevent the radiation of RFI generated by the switching action of the supply. If another form of box is used a heatsink must be added to the transistor-diode bracket for cooling.

An external LC filter will reduce the ripple even further if required. For example a series choke of 20 turns of 1.6 mm wire on a 10 mm ferrite rod and a parallel combination of 1000 μF electrolytic and 0.47 polyester capacitors external to the box will provide considerable extra ripple attenuation.

PARTS LIST — ETI 119

R14	Resistor	0.08 Ω *		
R11,13	"	33 Ω	1W	5%
R12	"	47 Ω	½W	5%
R3,17	"	100 Ω	½W	5%
R15	"	220 Ω	½W	5%
R7,18	"	390 Ω	½W	5%
R6,8,9	"	1k	½W	5%
R10,16	"	1 k	½W	5%
R2,4,5	"	5k6	½W	5%
R1	"	47 k	½W	5%

RV1 Trim Potentiometer 100 Ω

C4	Capacitor	470 pF ceramic
C3,5,6	"	0.001 µF polyester
C2	"	0.1 µF polyester
C1	"	2500 µF 50 V electro
C7	"	5000 µF 6V electro

D1-D4 Diode 3 Amp 100V IN5408 or similar
D5 " BYX50-200

ZD1 Zener Diode 3.3 V or 3.9 V 400 mV

Q1	Transistor	2N2646 or similar
Q2,3	"	2N2221A or similar
Q4,7	"	BC147 or similar
Q5	"	BD140 or similar
Q6	"	BDY92 or similar

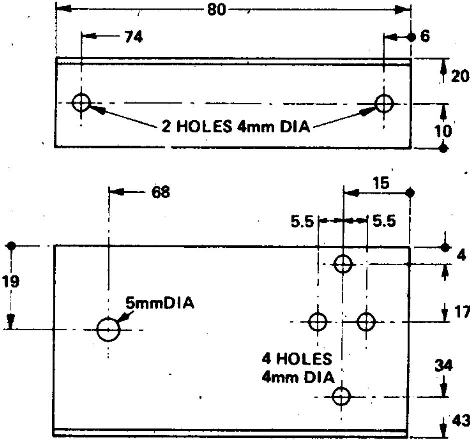
L1 choke see Table 2

T1 Transformer 20V — 30V @
60VA (7.5 Amp output)
75VA (10 Amp output)

SW1 Toggle switch 2 pole 240 V rated.

Heatsink bracket to Fig.3
Diecast Box 6357p
PC Board ETI 119
Insulation kit for Q6 and D5
* R14 is made out of 4 strands of electric fire element each 40mm long.

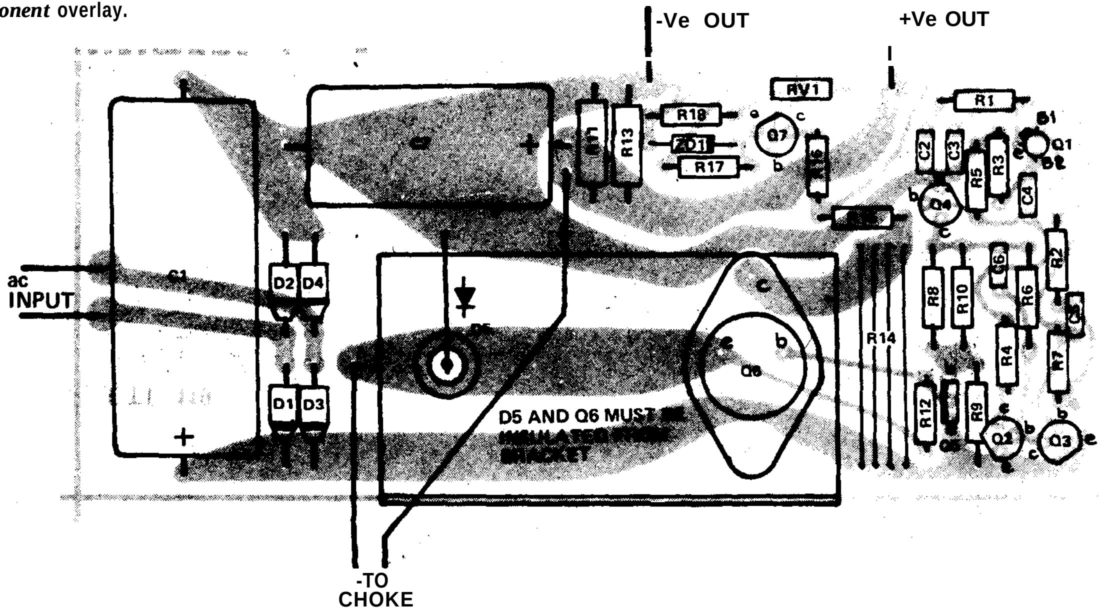
A complete kit of transistors and diodes for this project is available from Marshalls of Cricklewood for £7.75 including VAT and P & P.



MATERIAL 1.6mm ALUM
ALL DIMENSIONS IN MILLIMETRES

Fig. 2. Transistor/diode mounting bracket.

Fig. 3 *Component* overlay.



HOW IT WORKS – ETI 119

In a conventional series regulator power supply the resistance of a series transistor is controlled in order to maintain the correct output voltage. The series transistor dissipates considerable power and therefore at very high load ***currents series*** regulators are quite inefficient. In the switching regulator a Series transistor is still used but does not operate in its linear range. Instead it switches ON and OFF at high speed such that the load is alternately connected and disconnected to a supply voltage that is higher than that required across the load. By controlling the ratio of ON to OFF time we effectively control the average voltage as seen by the load. For example if it is on for 25% of the time the average output voltage will be 25% of the input. Thus by controlling the ON/OFF ratio the output voltage may be stabilized whilst dissipation in the series transistor is very greatly reduced.

However since most loads do not like their supply to be in the form of a square wave an LC tilter is used before the load to pass only the dc component.

Referring to the main circuit diagram we see that transistors Q5 and Q6 are used as the series switch. Ll and C7 form the output filter. Due to the inductance of the choke a flywheel diode is required, not only to protect the transistor, but to provide proper operation. When the switch is on, the load current flows through the transistor, the choke, and into the capacitor and the load **(Fig.** A). When the switch is opened the load current must continue to flow through the choke and this is done via the flywheel diode D5 (see Fig. B). The current through the choke will thus rise during the on period and fall during ‘the off period. The current never falls to zero except at very low load currents and the average is the same as the load current.

The operating frequency is set by the UJT Q1 which runs about 20 kHz; the higher the operating frequency the lower the ripple voltage on the output. However as the operating frequency goes up so also do switching losses in both transistor Q6 and diode DS. The 20 kHz was chosen as a compromise. it is high enough not to be audible but low enough to keep these losses to a minimum.

When the UJT fires the pulse generated is coupled into the base of Q4 by C4 turning Ql on. This, in turn, turns on Q2 and the switch Q5/6. When Q2 turns on Q4 also turns on and both latch on. If the current through Q6 rises above about 12 to 14 amps Q3 will turn on robbing ***curren*** t from the base of Q2 allowing both it and Q4 to turn off. This also turns off the output switch Q5/6. This is the current protection circuitry.

A voltage- proportional to the output is provided by RVl to Q7 for comparison to the voltage of ZDl. If Q7 is turned on sufficiently it will also turn on Q3 thus unlatching Q2/4 and turning off the output switch. Once the supply has stabilised this. action will control the on time of the switch in each cycle of the 20 kHz, such that the output voltage is maintained at a voltage as set by RVl in a smooth and even manner.

We used a 240 V to 30 V 2 A transformer, which is adequate for, supply currents of up to 7.5 amps, however any transformer having an output of 20 to 30 volts and a power rating of 60 VA would do. If up to 10 amps output is required then a transformer with a rating of 75 to 80 VA would be required.

It is also possible to supply the regulator from a dc supply of 10 to 40 volts. If the voltage available is less than 20 volts R2 should be replaced by a link to ensure that the UJT operates correctly.

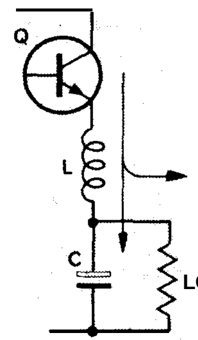


Fig. A. Current paths with switching transistor on.

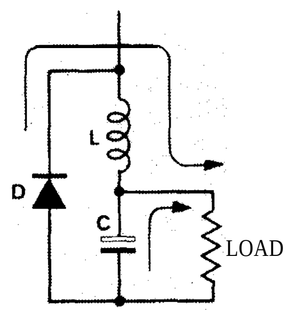


Fig B. Current paths with switching transistor off.

Fig. 4. Printed circuit-board layout. Full size. 178 x 78 mm.

TABLE 2 Choke winding details.

CORE	Philips E core 4322-020-34720 two required
FORMER	Philips 4322-021-31830 or 4312-021-23622 one required

Four layers close wound of 1.6 mm wire core gap 3 mm (see text).

CHOKE COMPONENTS

We have, as yet, been unable to find a source of supply to the amateur of the choke core and former. However the value of this component is not critical and is, in any case, the subject of experimentation in the adjustment of the airgap. We would therefore suggest that, although we haven't tried this, the laminations and former of a 6.3V ac heater transformer may be of suitable dimensions. It may be, in fact, that the secondary of a heavyduty heater transformer may serve without modification, although we recommend that a lk resistor be connected across the primary to prevent the effects of a build-up of induced voltage. Please note that this is a matter for experimentation.