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SIMPLE PROJECTS

Vol.3

Editor-in-chief: Roger Harrison
Assistant Editor: Jennifer Whyte

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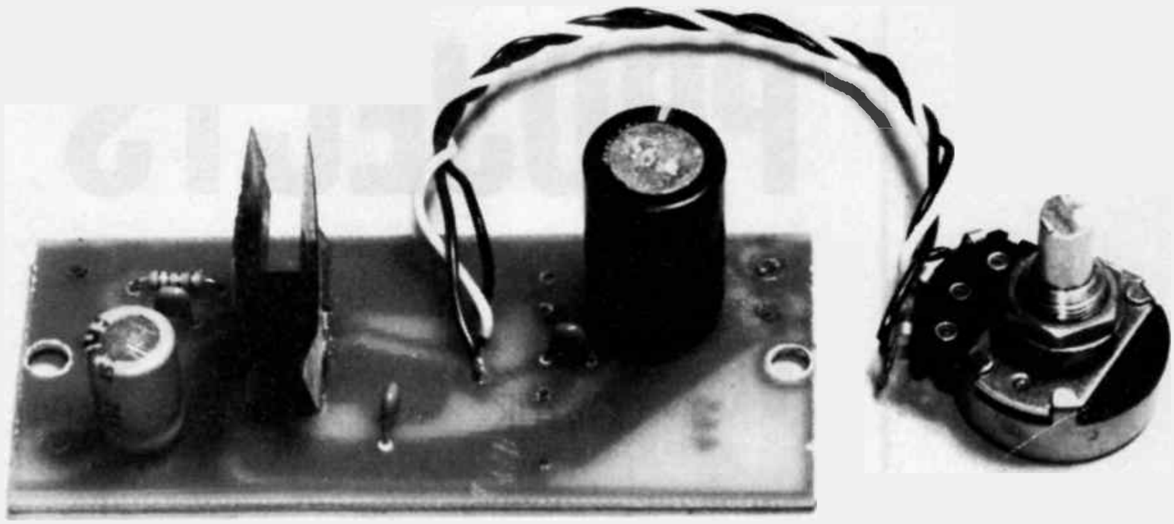


A general purpose IC audio amplifier module

This is an ideal project for the beginner. In fact, most constructors will find it handy to have at least one around. A general purpose small audio amplifier finds many useful applications. Just two described here are an intercom and a 'baby minder'.

Geoff Nicholls

A VERY USEFUL object for any electronics enthusiast to have around is a simple audio amplifier. It can be used to test the operation of many circuits or employed in some practical item of equipment — such as an intercom.

This simple, yet versatile, module is easy to construct and can be powered from a variety of supply voltages, depending on your application. It will drive loudspeakers of 4, 8 or 16 ohms impedance and can deliver a maximum output of five watts.

The project has been designed around an integrated circuit audio power amplifier, the LM380 (from National Semiconductor) or the uA380 (from Fairchild). This is quite a versatile little IC and, using it, an audio amplifier is very simple indeed to make.

The '380 is generally available in a 14-pin dual-in-line package, and this is what I have employed here. An 8-pin version is available, but cannot be used in the pc board I have designed for this project. Pins 3, 4 and 5 plus 10, 11 and 12 of the 14-pin package are all connected together by a copper bar inside the '380 package, on which the chip is mounted. These pins can be soldered to a large area of copper on the pc board to act as a heatsink in relatively low power applications.

Where the full power output capability of the '380 may be used, copper shim or tinplate heatsink 'flags' are soldered to these pins to get rid of more heat and keep the temperature of the IC down.

The '380 has a gain of 50 times. That is, it will amplify the input signal level by 50, which is a gain of 34 decibels (34 dB). That is:

$$\text{Gain in dB} = 20\log_{10}(50) = 20 \times 1.7 = 34\text{ dB}.$$

The gain of the '380 is fixed by the manufacturer. But what if you want a volume control, as is so often necessary on an audio amplifier? That can be simply arranged by connecting a potentiometer as a voltage divider to the input of the IC. You can see how that's done from the circuit and construction diagrams.

You can use this project to amplify the output of a crystal set or one-transistor receiver to loudspeaker level simply by connecting the output directly to the input of the module.

You can make a 'baby minder' — for keeping an ear on the baby in its cot, from another room — as shown later in this article, or you can make a simple intercom — which is also illustrated later. Another article in this issue shows how to use the module in a loudhailer.

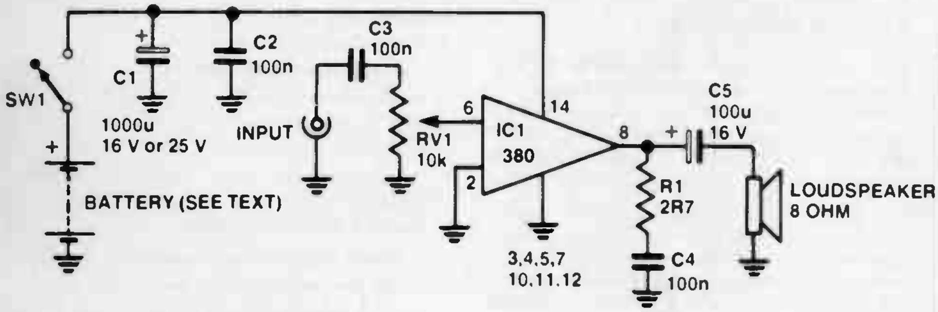
Right, let's get down to the business of building it.

Construction

As you can see from the overlay and wiring diagrams, there's very little to it. Start with the pc board. Whether you've made your own or purchased one, just give it a quick check-over to make sure all the holes are drilled correctly, that there are no small copper 'bridges' between closely spaced tracks (particularly between the IC pins) and no tiny cracks in any tracks. It's unlikely you'll have trouble, but it's always a good idea to check, *before* you run into trouble!

Note that mounting holes are located at either end of the board. These should be drilled to suit a 4 BA bolt, or whatever size you are using.

You can commence assembling the board by soldering resistor R1 in place, followed by capacitors C2, C3 and C4. All components



HOW IT WORKS — ETI-464

There's not much you can say about this! The whole job is done by the '380 IC audio power amplifier. The input is coupled to the '380 via a capacitor (C3) and the volume control, RV1. The latter is just a voltage divider, applying less or more voltage to the IC's input as the potentiometer is varied, thus varying the volume.

The output of IC1, pin 8, is biased at half the supply rail (e.g: it will be at 4.5 V if the supply is 9 V). For this reason, the output is capacitively coupled to the loudspeaker via a large value electrolytic capacitor, C5. This presents a low impedance in series with the loudspeaker, which is a relatively low impedance device.

Any tendency to instability of the amplifier is suppressed by the network of R1-C4 connected from the output to common.

The supply rail is bypassed by an electrolytic capacitor, C1, at the low frequencies, and a greencap or ceramic capacitor, C2, at the higher audio frequencies.

Note that provision has been made on the pc board for powering an electret type microphone, simply by adding a resistor adjacent to C3.

mount on the non-copper side of the board. Next identify the positive and negative leads of the two electrolytic capacitors. These are 'polarised' devices and can only go in one way. Solder them in place, putting the positive lead of each in the hole marked with a '+' on the overlay diagram.

The '380 IC can be soldered in place next. Make sure you place it in the board the right way round before soldering the pins. Do not use an IC socket as the board is designed to act parially as a heatsink and pins 3, 4, 5, 10, 11 and 12 *must* be soldered to the copper area for this purpose.

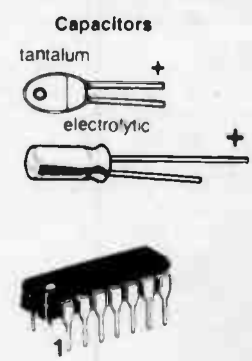
The heatsink flags can be constructed next if you need to use them. Use heavy gauge copper 'shim' or tinplate sheet (obtainable at hardware and motor spares stores). Two are required and the dimensions and cutting details are shown in the accompanying diagram.

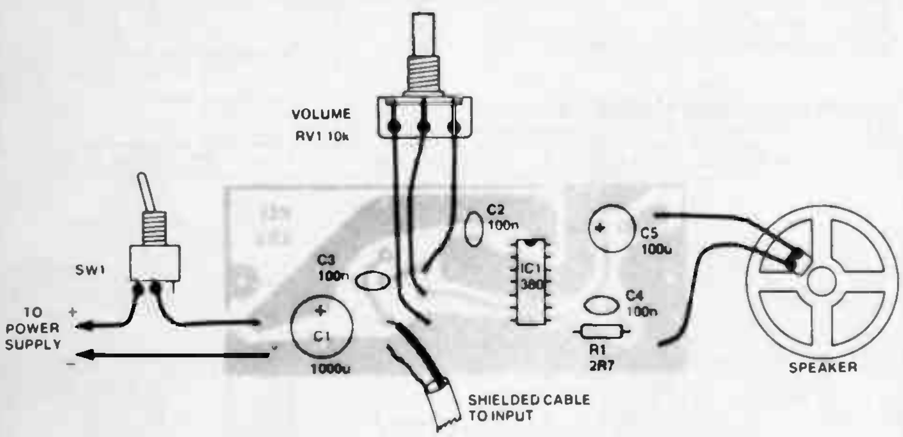
General details for wiring up the speaker, volume control and an on/off switch are also provided with the overlay diagram. Note that the input lead should be run in shielded cable, in general, especially if this lead needs to be more than 300 mm or so long. This prevents hum pickup from house mains wiring. For short runs, a pair of tightly twisted hookup wires will suffice.

This module will drive any size loudspeaker, from the tiny 50 mm 'transistor radio' types to 400 mm diameter 'monsters'. In fact, the larger a loudspeaker, the more sensitive it's likely to be and the louder it will sound! You don't need more power to drive a larger loudspeaker, despite what you might at first think.

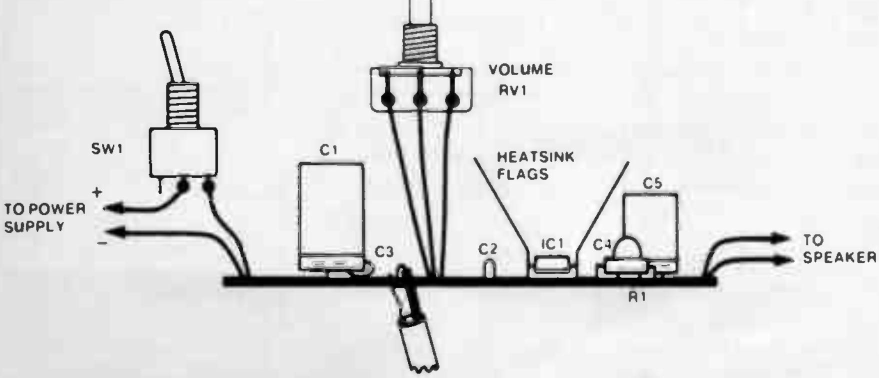
The bigger loudspeakers generally have a more powerful magnet than the smaller types. This makes them more sensitive to the currents flowing in the voice coil. This and the larger cone combine to produce a louder sound.

COMPONENT PINOUTS





Overlay and wiring diagram. Showing component placement and general wiring details.



Side view. Showing assembly of the heatsink flags

PARTS LIST — ETI-464

Resistors .... all ¼ or ½ W/5%

R1	2R7
RV1	10k log. pot

Capacitors

C1	1000u/16 VW or 25 VW RB electro
C2,C4	100n ceramic bypass
C3	100n greencap
C5	100u/16 VW RB electro

Semiconductors

IC1	LM380

Miscellaneous

ETI-464 pc board. SPST switch. shielded cable. wire. etc

Price estimate $7-$8

Testing it

The easiest way to test it is simply to connect a 9 V battery to the module and turn up the volume control. Then, touch your finger to the 'top' end of the volume control — the right hand lug when looking at the rear of the pot. You should hear hum and noise, or perhaps a loud 'blurting' sound. If not, check that the battery is connected the right way round and that the speaker and volume control wires are all intact and correct. Check that you have the IC correctly orientated.

Connecting a 9 V battery in reverse to the module is unlikely to destroy the IC, but any higher supply voltage connected in reverse sure will, so watch this point.

If the amplifier tends to be unstable, 'squealing' or otherwise 'acting up', try connecting a 4u7/16 V tantalum capacitor between pin 1 of the IC and the adjacent grounded area of the pc board, directly on the underside of the board. The positive lead goes to pin 1. Keep the lead lengths short. This should cure it.

Always keep the amplifier's input leads away from the speaker leads, to avoid feedback which may result in 'howl round' — an uncomfortable whistling or howling sound that is affected by moving the leads.

Power supplies

This module can be powered form batteries, a suitable plugpack or transformer and rectifier to suit yourself. The power output depends on the supply voltage and the speaker impedance. As stated earlier, the '380 can drive 4, 8 or 16 ohm speakers. By far the better speaker to use is an 8 ohm impedance type. Fortunately, they're also the most common type.

Powered from a nine volt battery, you will get about half a watt (500 mW) output, which is more than adequate for 'personal' listening stations; e.g: providing loudspeaker output from a crystal set or one-transistor radio, etc. The power dissipated by the IC under these circumstances is about three quarters of a watt maximum, so no heatsink flags would be necessary. The module draws only about 5 mA with no signal (called the 'quiescent current').

The *absolute maximum* supply voltage the IC will tolerate is 22 V. With an 8 ohm speaker, the project will deliver five watts output, which is remarkably loud! Under these circumstances, the power dissipated by the '380 will be a little over three watts maximum and heatsink flags will definitely be necessary. The quiescent current is about 8 mA on a 22 V supply.

A plugpack or transformer and rectifier supply suitable for powering this module should provide 12 Vdc at 200 mA or so. Using such a supply, the project will deliver about one to 1½ watts to an eight ohm speaker, which is quite suitable for an intercom, for example. The heatsink flags are not entirely necessary with this sort of application, especially in an intercom where the amplifier is only used intermittently.

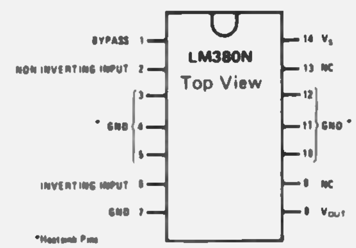
Two nine volt batteries connected in series will supply 18 Vdc or so to the module, which will deliver about three watts to an 8 ohm speaker. Heatsink flags are necessary in this case. Note that, when using a 4 ohm speaker, the supply should not exceed 15 volts.

LM380 audio power amplifier general description

The LM380 is a power audio amplifier for consumer application. In order to hold system cost to a minimum, gain is internally fixed at 34 dB. A unique input stage allows inputs to be ground referenced. The output is automatically self entering to one half the supply voltage.

The output is short circuit proof with internal thermal limiting. The package outline is standard dual-in-line. A copper lead frame is used with the center three pins on either side comprising a heat sink. This makes the device easy to use in standard p-c layout.

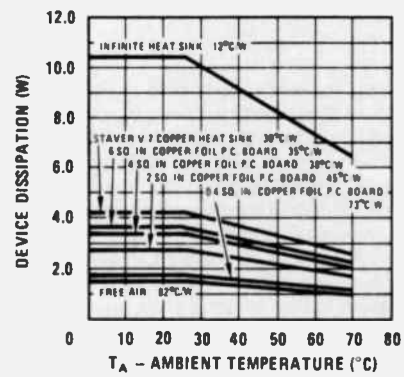
Uses include simple phonograph amplifiers, intercoms, line drivers, teaching machine outputs, alarms, ultrasonic drivers, TV sound systems, AM-FM radio, small servo drivers, power converters, etc.



features

- Wide supply voltage range
- Voltage gain fixed at 50
- High peak current capability
- Input referenced to GND
- High input impedance
- Low distortion
- Quiescent output voltage is at one-half of the supply voltage
- Standard dual-in-line package

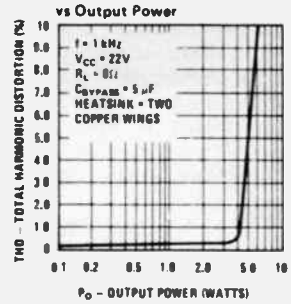
Device Dissipation vs Ambient Temperature



absolute maximum ratings

Supply Voltage	22V
Peak Current	1.3A
Package Dissipation 14-Pin DIP (Notes 6 and 7)	10W
Input Voltage	±0.5V
Storage Temperature	-65°C to +150°C
Operating Temperature	0°C to +70°C
Junction Temperature	+150°C
Lead Temperature (Soldering, 10 sec)	+300°C

Total Harmonic Distortion vs Output Power

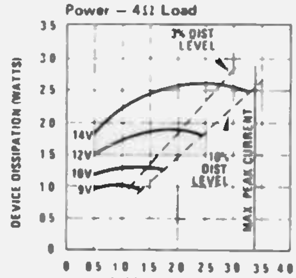


electrical characteristics

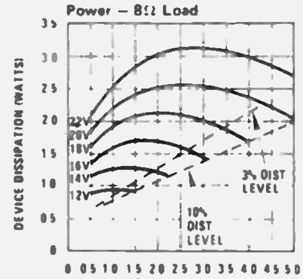
Note 1: V_S = 18V and T_A = 25°C unless otherwise specified

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Power	$P_{OUT(RMS)}$	R_L = 8Ω, THD = 3%	2.5			W
Gain	A_V		40	50	60	V/V
Output Voltage Swing	V_{OUT}	R_L = 8Ω		14		V_{p-p}
Input Resistance	Z_{IN}			150k		Ω
Total Harmonic Distortion	THD			0.2		%
Power Supply Rejection Ratio	PSRR			38		dB
Supply Voltage	V_S		8		22	V
Bandwidth	BW	P_{OUT} 2W, R_L 8Ω		100k		Hz
Quiescent Supply Current	I_Q			7	25	mA
Quiescent Output Voltage	V_{OUTQ}		8	9.0	10	V
Bias Current	I_{BIAS}	Inputs Floating		100		nA
Short Circuit Current	I_{SC}			1.3		A

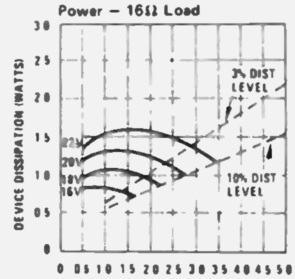
Device Dissipation vs Output Power – 4Ω Load



Device Dissipation vs Output Power – 8Ω Load



Device Dissipation vs Output Power – 16Ω Load



A 'baby minder'

You can 'keep an ear' on a baby asleep (or supposed to be!) in its cot in another room by organising some sort of microphone to pick up sounds from the baby's room to be amplified and heard in another room.

The general wiring diagram for a baby minder is shown in Figure 1. Here, a small 8 ohm loudspeaker is employed as a microphone — and they're remarkably effective. A transformer is needed to 'step up' the tiny voltages produced by the speaker-microphone. A suitable type is generally described as a 'transistor output transformer, 1k centre-tapped to 8 ohm'. Dick Smith Electronics lists a suitable type — cat. no. M-0216. Altronics have a similar one. Tandy lists one also, no. 273-1380.

The '8 ohm' side is connected to the speaker-microphone — this is the side with just two leads. The 1k side of the transformer is connected to the input of the module. Mount the transformer close to the module. The module could be mounted in a suitable cabinet with the speaker, volume controls and on/off switch mounted on the front.

The speaker-microphone could be mounted in a small jiffy box placed in a convenient position in the baby's room, near the cot. This connects to the amplifier via a length of 'twisted pair' cable or light 'figure-8' flex. Try and avoid running this lead adjacent to house mains wiring to avoid possible hum pickup.

I have specified an 8 ohm speaker as a microphone as it is of such a low impedance that the possibility of hum pickup on the cable between the microphone and the amplifier is greatly reduced.

You can either use a battery supply or a 12 Vdc plugpack.

Intercom

The general details for wiring a simple intercom are shown in Figure 2. You'll need two single-pole, double-throw (SPDT) toggle switches with a spring return. Double-pole types are also suitable, just use one side (e.g. C&K type 7208 or similar). You'll also need an M-0216 transformer, or similar, as for the Figure 1 circuit.

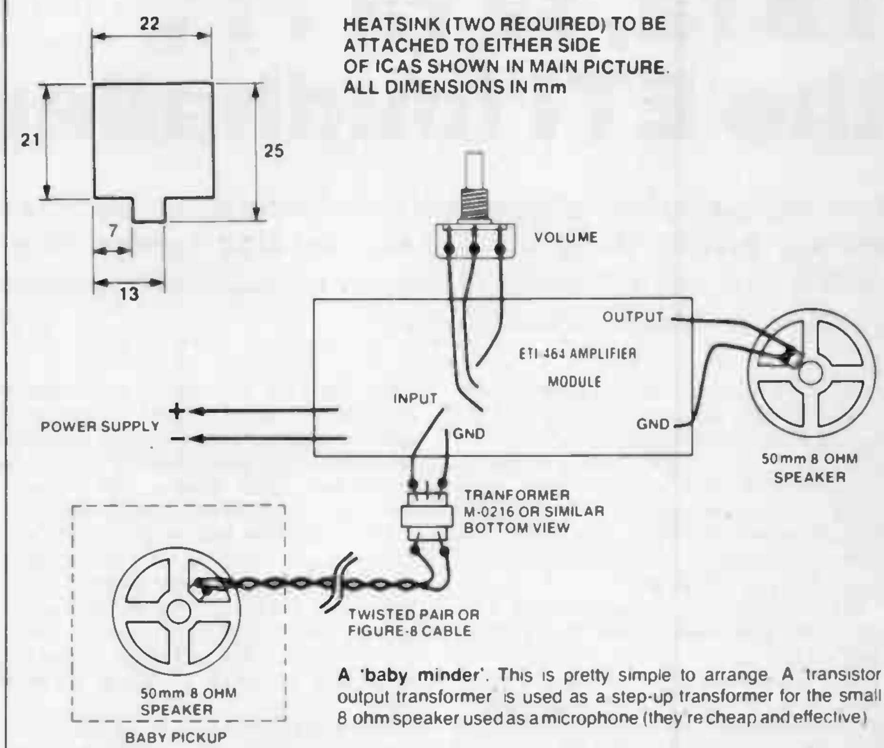
Two small 8 ohm speakers are used as both speaker and microphone at each end of the intercom.

A volume control is necessary on an intercom and a small 'trimpot' can be mounted on the pc board where the volume control connections are made. The hole spacings are suitably placed for soldering a common vertical mounting trimpot in place. Use on of the same value — i.e: 10k. Test out the intercom and set the volume control to suit yourself.

A suitable cable can be made by twisting together three strands of light hookup wire or buying a suitable length of light multicore cable. Note how the various common, or earth, connections are made to the one ground point on the pc board.

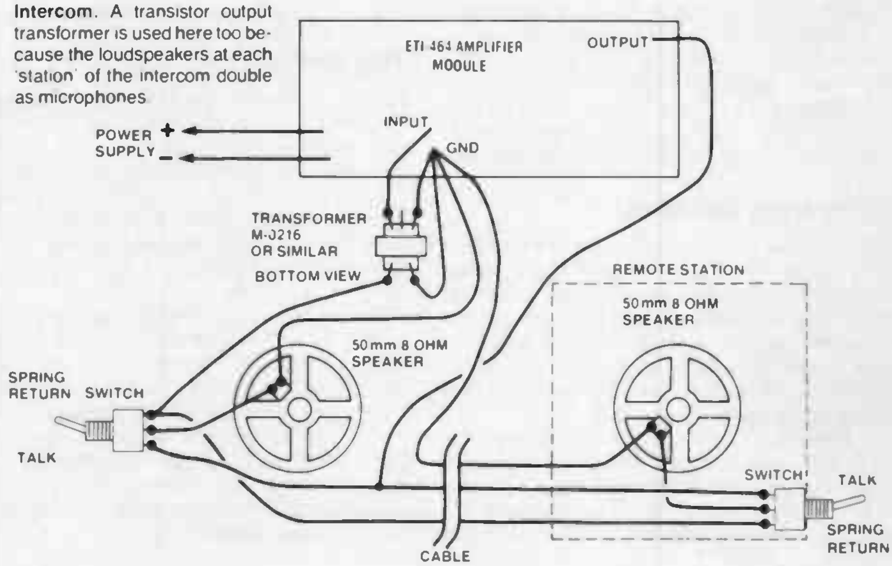
Conclusion

Well, I've described how to build yourself a general purpose audio amp module and how to use it in a couple of applications — the rest is up to you. Have fun! ●

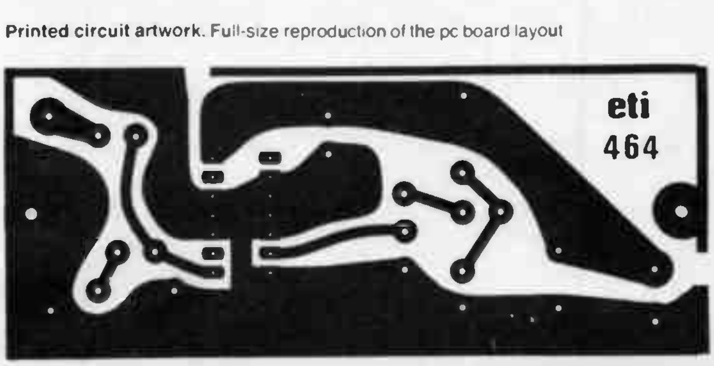


A 'baby minder'. This is pretty simple to arrange. A 'transistor output transformer' is used as a step-up transformer for the small 8 ohm speaker used as a microphone (they're cheap and effective).

Intercom. A transistor output transformer is used here too because the loudspeakers at each 'station' of the intercom double as microphones.



Printed circuit artwork. Full-size reproduction of the pc board layout



Ta ra, ta ra . . . the ETI loudhailer!

Build this loudhailer and make yourself heard at rallies, picnics or sporting events. Using the ETI-464 General Purpose Amp. Module mounted in the back of a locally available horn speaker, it's simple to build and quite effective.

Geoff Nicholls

PROJECTING your voice outdoors is quite a difficult task without some means of 'directing' your voice and amplifying it. Generally, you'll want to address a group of people located some distance away, or a group of people spread out in front of you for some distance. If you can direct your voice over a narrow 'beam', then less of the sound you make is wasted.

The old-fashioned megaphone did that job before 'electronics' entered the picture. Outdoor public address systems came into being with the advent of valves. For many years PA systems were cumbersome, hardly portable beasts until minaturisation came along post World War II. The first 'loudhailer' PA systems portable by one person used miniature valves, a small horn speaker and a set of cumbersome, heavy batteries that didn't last all that long.

When power transistors came along, loudhailers proliferated. They could be held in one hand, used a small number of 'torch' batteries and did the job better than before.

The horn speaker

The horn loudspeaker is by far the best type for outdoor use. Horns can be made weatherproof and have an efficiency of better than 20% compared to a few per cent for ordinary speakers. This allows an amplifier of lower power to be used, with consequent savings in power consumption, physical size and weight.

Horns are intrinsically limited in their frequency response, and their efficiency is inversely proportional to their bandwidth. PA horns are designed to operate over the voice band at maximum efficiency. The horn itself is essentially an impedance transforming device which increases the acoustic loading on the driving diaphragm to allow better 'matching' to the air. The throat area of the horn increases exponentially as you move away from the driver.

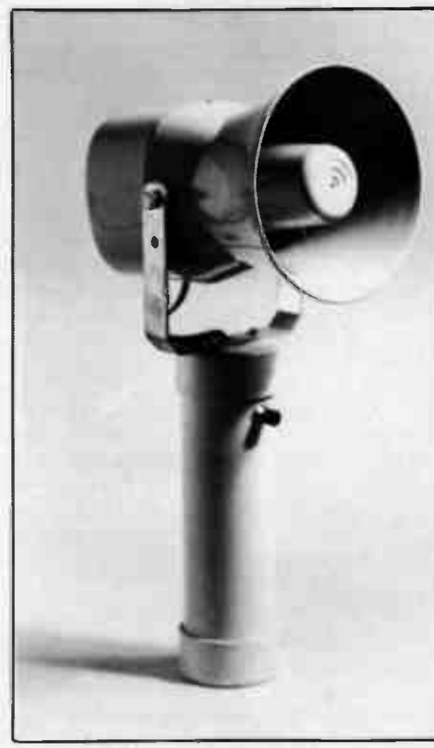
The horn may be straight, as shown in Figure 1, or folded, as shown in Figure 2. The folded horn is physically smaller and is the most common type in low cost PA systems. Folding the horn reduces the efficiency slightly but increases the coverage or dispersion, which is usually an advantage.

The straight horn has a long 'throw' and is useful for narrow sound coverage at greater distances, but is more cumbersome, especially for handheld applications!

The project

For our loudhailer, we had to search around for a suitable small folded horn. There is a variety available and prices vary widely. Probably the most common are 130 mm diameter (5") low power folded (or 'reflex') horns generally sold for boat or CB PA use. Rectangular folded horns are also available, having an opening of 200 mm wide by 120 mm or so high.

Efficiencies vary widely and are best judged by the weight! Drivers with larger, heavier magnets are more efficient than those with smaller, lighter magnets. Most have a 'dispersion angle' — the angle over which the majority of sound is dispersed from the horn — of between 60° and 90°. The narrower the dispersion angle, the greater sound level you get at a given distance from the speaker.



Your shout! Not beautiful, but effective.

The horn we chose for our prototype is imported and marketed by Benelec Pty Ltd, model no. 8-224. It is a 130 mm diameter folded horn, measuring 170 mm long overall. There is a cover on the rear of the horn with plenty of room inside to mount the power amp. module. It has a mounting ▶

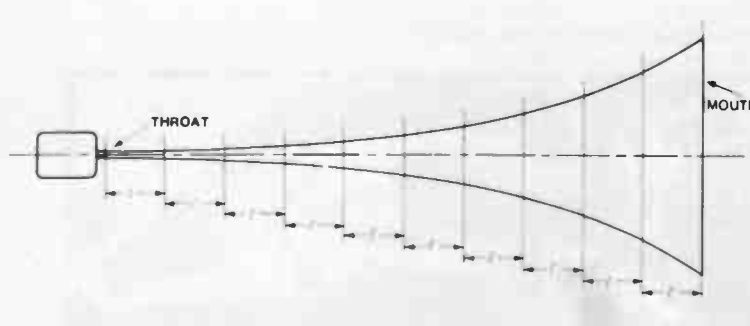


Figure 1. A straight horn has the width of the throat growing exponentially larger with increasing distance from the driver

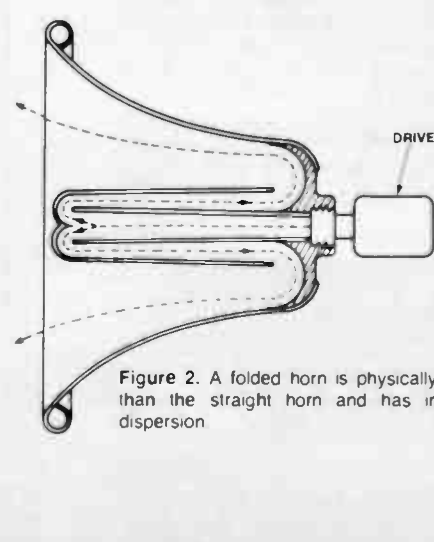


Figure 2. A folded horn is physically smaller than the straight horn and has increased dispersion

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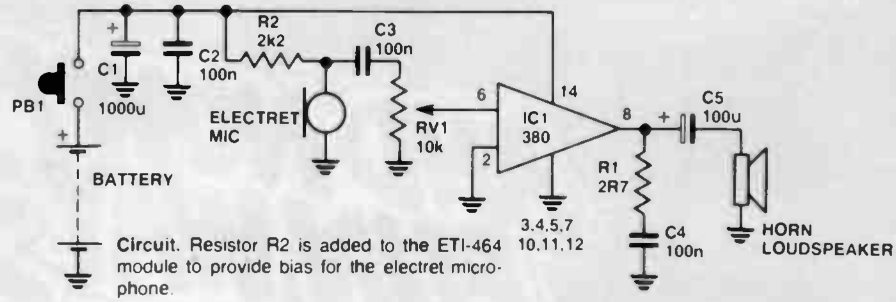


Circuit. Resistor R2 is added to the ETI-464 module to provide bias for the electret microphone.

bracket that allows the horn to be swivelled over a wide range of angles. It is available with driver impedances of 4 ohms or 8 ohms, though the latter is best in this application. The dispersion angle is quoted as 60°, which we saw as desirable, and the output is quoted as being 122 dB (presumably with 1 W drive at one metre). It weighs 1.15 kg, which is not too heavy, yet ensures the sort of driver efficiency desirable for maximum effectiveness.

Using this horn, and constructing the loudhailer as described here, you can make yourself heard at 100 metres. If you don't need that much throw, then a lower cost, less efficient horn will suffice, but construction details will have to be worked out to suit yourself. See Shoparound in this issue for horn suppliers.

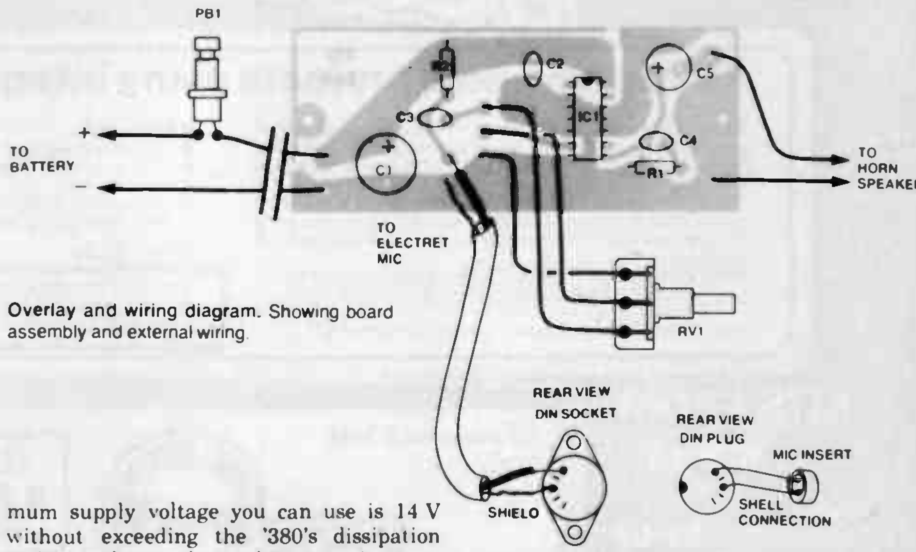
An electret microphone insert was employed to make a microphone. It proved cheap and effective. To provide a handle and battery case, a short length of 50 mm (i.d.) PVC water pipe was used, along with two end caps. This mounts, via one end cap, on the horn's mounting bracket and the batteries are slipped inside. A momentary action pushbutton switch, mounted on the 'handle', serves as an on/off switch.

Originally, I tried mounting the mic insert in the centre of the horn's rear cover, but feedback proved a problem and I couldn't utilise the full gain and output of the amplifier module. A little experimentation solved the feedback problem and improved an operator's visibility at the same time.

I mounted the mic insert in a DIN plug which plugs into a socket mounted at the top of the horn's rear cover. I also mounted a gain control pot on the cover. These measures overcame feedback problems and allowed you to see over the top of the horn.

The maximum output a '380 will deliver is five watts into an 8 ohm load using a 20 V supply. With an 18 V supply, the '380 will deliver a maximum of four watts (@ 10% distortion — which is tolerable) into an 8 ohm load. With a 4 ohm load the maximum supply voltage you can use is 14 V without exceeding the '380's dissipation rating, and you only get three watts' output. In a loudhailer, every watt counts.

Hence, I opted to use an 18 V supply. There are two ways you can arrange this with batteries. Two no. 2362 9 V batteries can be 'snapped' in series. These are 75 mm long with a male snap clip at the positive end and a female snap clip at the negative end. Alternatively, you can use 12 AA cells mounted in three four-cell battery holders. There are two advantages to the latter: the batteries last longer and the whole assembly is considerably cheaper.



Overlay and wiring diagram. Showing board assembly and external wiring.


Insides out. The amplifier board mounts inside the rear cover of the Benelec 8-224 horn

PARTS LIST — ETI-465

This requires construction of the ETI-464 amp. module with the addition of the following components:

R2 .... 2k2, ¼ W/5%
RV1 .... 10k/C panel mount pot
Electret mic insert (e.g. D.S.E no C-1160), 5-pin DIN plug and socket, knob; horn loudspeaker — Benelec no 8-224 8 ohm (see text), three 4-cell AA battery holders and clips plus 12 x AA batteries or 2 x 2362 9 V batteries and snap clips DPDT momentary action pushbutton (e.g. D.S.E no. C-1220), length of 50 mm PVC pipe and two end caps, wire, etc.

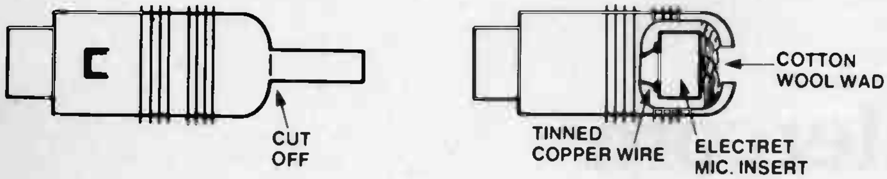
Price estimate $45-$50

Construction

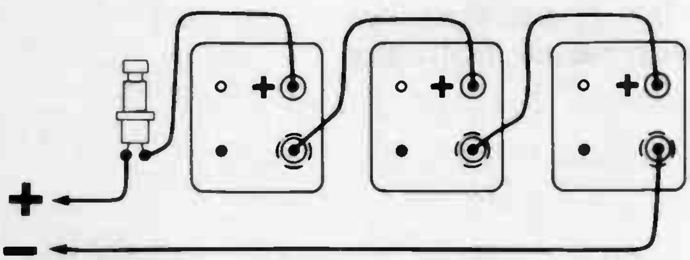
Putting the loudhailer together is quite straightforward. The ETI-464 pc board has mounting holes which match the mounting posts on the inside of the 8-224 horn speaker's rear cover. Self-tapping screws are used to mount the board and the mounting holes should be drilled to size before assembling the components to the pc board.

Assemble the power amp module according to the instructions given in the previous article on the ETI-464. Note that R2 has to be added, as shown on the overlay diagram. Don't attach any wires yet until the mechanical assembly has been completed.

Drill the mounting holes for the volume pot and the DIN socket in the speaker's rear



Making the microphone. A DIN plug is modified as shown to house the electret mic insert.



Battery holder wiring. If you use a dozen AA cells, as I did, this is how the battery holders are wired up to provide 18 volts.

cover. The DIN socket goes at the top, the volume pot at the bottom. Also drill a hole in the bottom lip of the cover so that the leads from the battery may be passed through.

Now tackle the handle/battery compartment. Cut a 200 mm length of 50 mm i.d. PVC pipe. File the ends smooth and square and slip the end caps on. Holding them in place with masking tape, drill holes on either side, right through the cap and pipe, so that self-tapping ('PK') screws can be used to secure the end caps in place. Drill these holes to the root diameter of the PK screws.

Remove the end caps and enlarge the holes to the appropriate clearance diameter

Now take the tube and mark a hole position at the 'top' end for the on/off pushbutton switch. It should be located such that it clears the upper end cap, yet is not too far down the tube so that access to the switch connections is restricted.

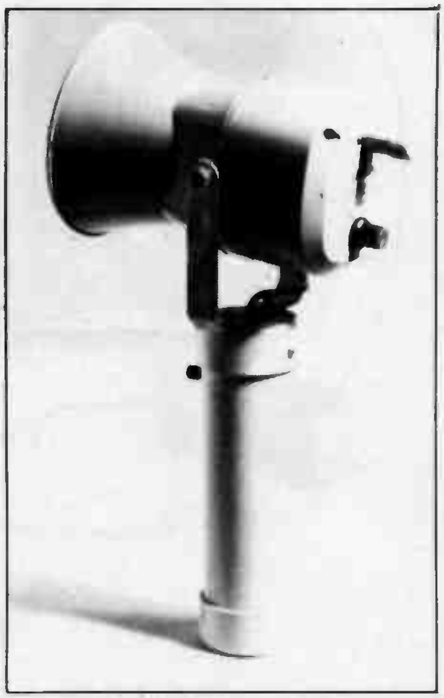
Now wire up all the battery connectors, the pushbutton switch, the DIN socket, the volume pot, the speaker and the pc board. Check it all carefully when finished, then screw it all together. A little wad of sponge rubber in the upper end of the handle secures the batteries.

Now you can make the microphone. The basic assembly is shown in the accompanying diagram. We found that angling the mic insert *down* (when the unit is plugged in) helped reduce feedback problems and a tendency to 'breathiness'.

The accompanying photographs show the internal and overall assembly, when completed.

Using it

For an initial try-out, set the volume pot about halfway advanced, plug in the microphone, position your mouth about 10 mm or so from the mic, press the button



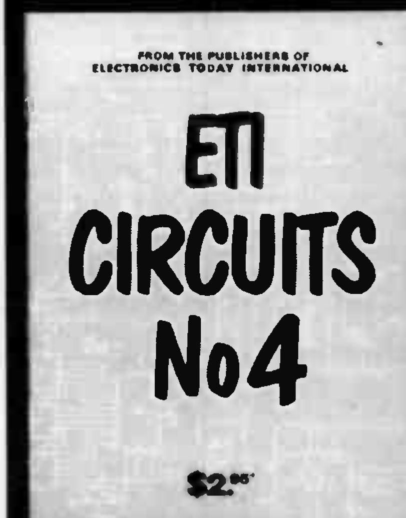
Rear view. The mic plugs into the DIN socket at the top. The volume control is below it. The 'handle' houses the batteries.

and say a few words. No 'howl round' feedback or 'ringing' should be experienced, except perhaps if you're in a small room. Best try the unit outdoors.

Adjust the setting of the volume control for maximum output without feedback or ringing being evident. Always speak very close to the microphone.

If you wish, it may be convenient in some applications to have a 'remote' microphone. An electret insert can be readily installed in a CB-type handheld mic case, with the push-to-talk switch wired in parallel with the loudhailer's on/off pushbutton via the DIN plug and socket.

Happy hailing!



Project 262

A simple intercom

The perenially popular intercom — this circuit illustrates how to wring the maximum performance from the minimum number of components.

AN INTERCOM is an eminently *practical* device. Communication between rooms in a house is immensely aided by an intercom. The same goes for house and garage – or any other outbuilding.

The drawback with many intercoms is that that can be *too* effective. They shout at you. Whilst one can turn down the volume by one means or another, it's rather like using a sledge hammer to crack an acorn – as the saying goes. This intercom is simple, inexpensive and is ideally suited to quiet situations where volume is not all-important.

A small loudspeaker serves as both microphone and speaker in this intercom. Housing the project we have left up to you. It is quite possible to fit the components in a palm-sized box, such as one of the small 'zippy' boxes available inexpensively from a number of suppliers. The intercom may be powered from a 3 Vdc plugpack if you wish.

How it works

At first glance this circuit looks very simple, but its operation is quite ingenious as it performs different functions for transmit and receive.

To allow us to understand how it works, let's look at the receive mode first. When the pushbutton is not pressed the loudspeaker is connected across the line, in series with the battery. None of the remaining components are used in the receiver as they are isolated from the battery by the pushbutton. The battery voltage is connected across the line in series with the loudspeaker and is fed to the transmitter. Any change in current drawn by the transmitter will cause a movement of the cone of the loudspeaker. If a speech signal is fed down the line it will be heard in the remote speaker.

If you speak into the cone of a loudspeaker, the cone will vibrate in sympathy with the changing air pressure from the sound. The vibration of the cone moves the voice coil of the speaker which cuts the lines of force in the magnetic field of the speaker magnet. When a wire is moved through a magnetic field it generates a current in the wire in sympathy with the movement. The loudspeaker can thus be used as a microphone, the speech signal output being taken from the voice coil as it converts the sound energy impinging on the cone to electrical energy in the voice coil.

In the transmit mode, the battery is isolated from the circuit by the depressed pushbutton and the supply voltage appears across the line from the receive station. The signal from the loudspeaker passes through a capacitor, C2, which blocks the dc from the battery but allows the speech signal to pass to the base of Q3. The transistors Q2 and Q3 form a high gain pair which amplifies the speech signal and drives the output stage, Q1. The output transistor varies the amount of current drawn from the line in sympathy with the speech. Because this current moves the cone in the receiver loudspeaker, the speech can be heard at the receiver.

As the frequency spectrum of speech is mainly within the range 200 Hz to 3 kHz, the frequency response of the transmitter has been limited to about 3 kHz by placing a small capacitor across the base-collector junction of Q3. This causes a reduction in gain of that stage at high frequencies by introducing negative feedback which increases with frequency. Resistors R2, R3 and R4 set the bias on the stages and the one ohm resistor, R1, provides some emitter bias on the output stage as well as limiting the maximum output current.

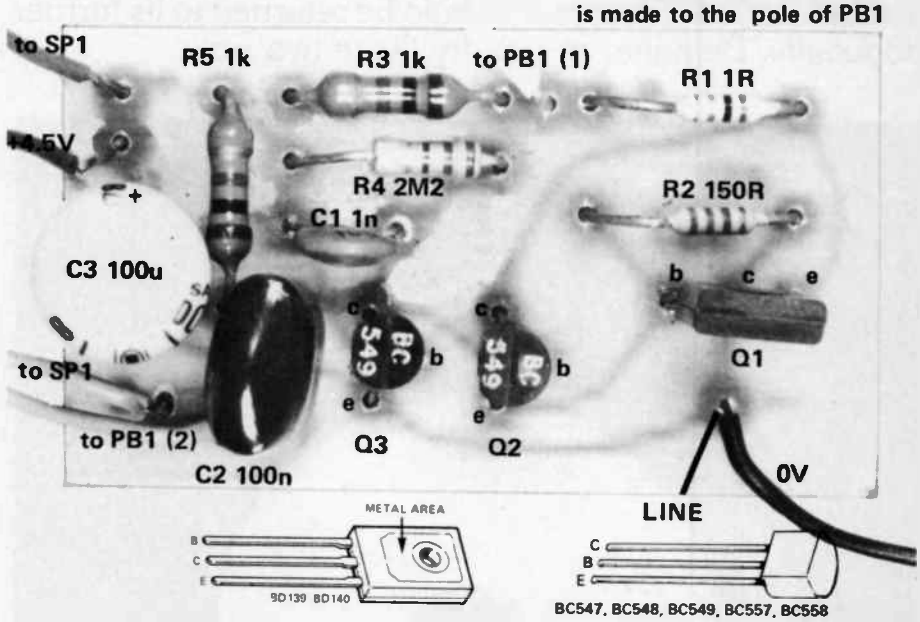
The transmitters have been designed to work with supply voltages as low as 2½ volts. However, a 4½ volt supply allows for quite a high voltage drop in the line so that the intercom may work over quite a long line. We tried it over the length of the office (about 30 m) but some readers will, no doubt, have much greater distances in mind. For really long line lengths, the battery voltage could be increased to say, six volts.

Construction

We constructed one of our units on matrix board and the other on a pc board. Both methods work equally well, though constructing the matrix board version is a little more tedious and requires some care so that incorrect connections are not made. The orientation of the transistors is the only point to watch.

To power the intercom units, a standard 4½V battery may be used at each end. For longer battery life, three D-cells would be better, wired in series. If power is available, a 3 V plug-pack battery eliminator at each end should provide about four to five volts with the unit in operation. ●

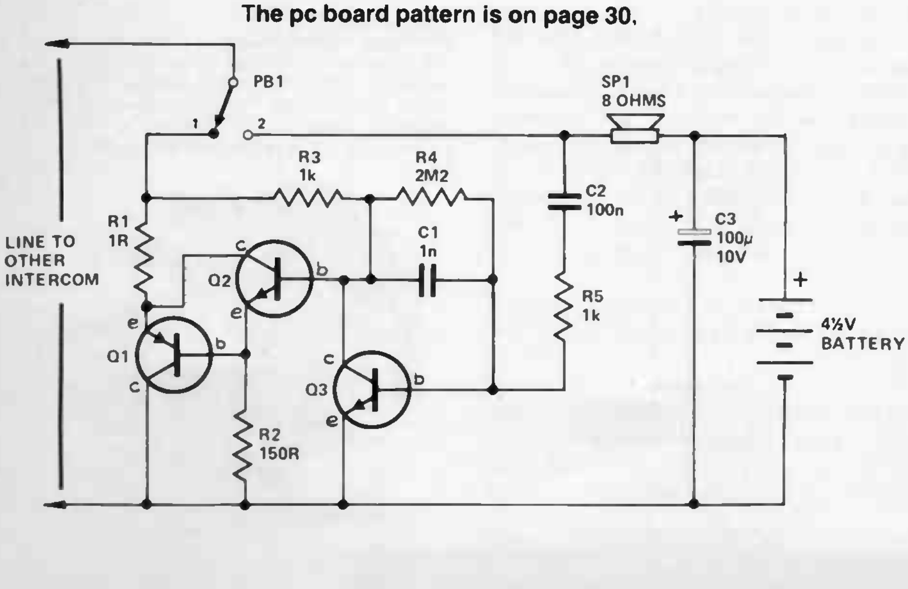
The second line connection is made to the pole of PB1



Overlay for the pc board. Take care with the orientation of the capacitor C3 and the transistors.

We assembled one unit on a piece of matrix board, laid out as shown.

The pc board pattern is on page 30.



PARTS LIST - ETI 262

Resistors all ½ W, 5%
R1 . . . . 1R
R2 . . . . 150R
R3 . . . . 1k
R4 . . . . 2M2
R5 . . . . 1k

Capacitors
C1. . . . . 1n
C2. . . . . 100n
C3. . . . . 100µ 10V electro

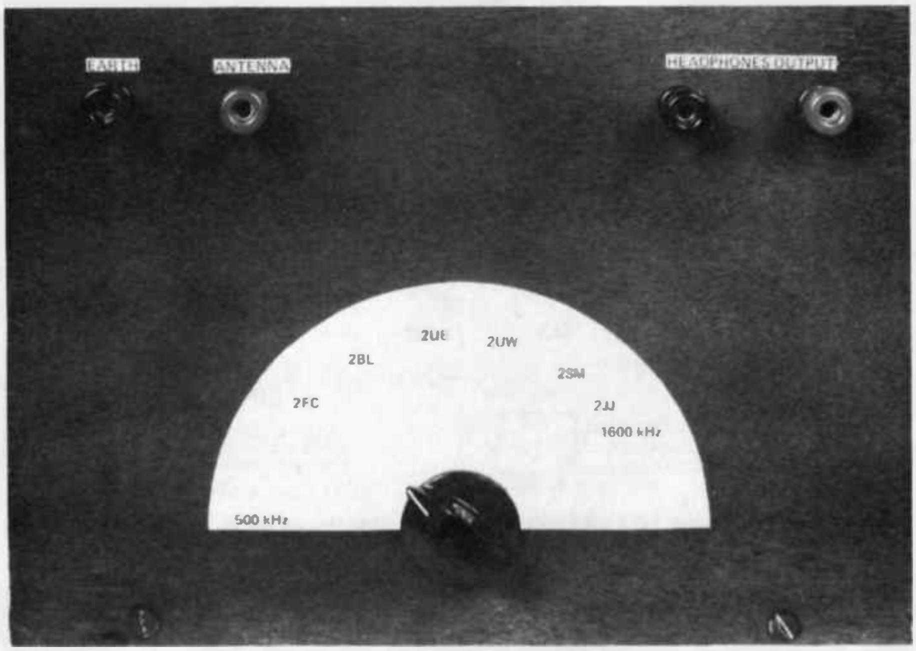
Semiconductors
Q1 . . . . BD140
Q2, Q3 . . . . . BC549, BC109, DS549.

Miscellaneous
PB1 . . . . SPDT push button
SP1 . . . . eight ohm speaker
B1. . . . . 4½ V battery or three 1½ V cells in series (with holders if required), ETI 262 pc board.

Projects 266/267

Two crystal sets to build

The crystal set was once every radio/electronics hobbyist's 'starter' project. Perhaps it should be returned to its former popularity. Beginner or not, try these two now.



We built our crystal sets on a chipboard base with plywood front panel, all sprayed matte black.

"IN MY DAY", said the old timer in his quavering rasp, "we built crystal sets with spider-wound coils and galena-and-catswhisker crystal detectors and listened to the stations on 2000 ohm Brown's headphones".

In deference to the old gent, we won't mention the era but that was a pretty hot-shot (read 'sophisticated') set-up in his day.

Modern beginners in electronics are more likely to cut their teeth on a project that includes at least one integrated circuit or a handful of transistors plus the usual resistors and capacitors.

Some hobbyists subscribe to the view that, if you haven't built a crystal set (*and* got it going!), then you haven't *lived*.

How it works

The crystal set basically consists of a tuned circuit, which selects the wanted station, and a detector, which separates the sound (music, speech etc) from the radio transmission, producing an audio voltage which is then impressed on the earpiece or headphones. This audio voltage is an exact copy of the sound from the radio station which has been superimposed on the radio signal at the transmitter.

The aerial receives all the electromagnetic radiation (radio waves) in your area. These signals have to be separated somehow, and the one station you're interested in must be sorted out from the mess otherwise, the signal will be hopelessly lost in the scramble of thousands of stations.

To select one station at a time we use a tuned circuit consisting of a coil of wire connected to a tuning capacitor. Signals picked up by the antenna cause the tuned circuit to 'resonate'. That is, signal currents close to a particular frequency will be greatly magnified, while those away from that frequency will be reduced, or attenuated.

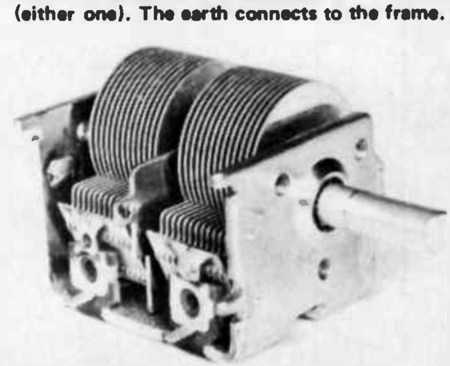
In our tuned circuit the frequency of resonance is determined largely by the number of turns on the coil, its diameter, and the value of the tuning capacitor. One way to tune the circuit over a range of frequencies is to use a fixed coil and make the capacitor variable. This is what we have done as components are convenient and readily obtainable. The variable capacitor enables us to tune the frequency range of interest, about 550 kHz to 1.6 MHz. Increasing the capacitance (plates more in mesh) decreases the resonant frequency; with the plates more out of mesh (less capacitance) the resonant frequency is increased.

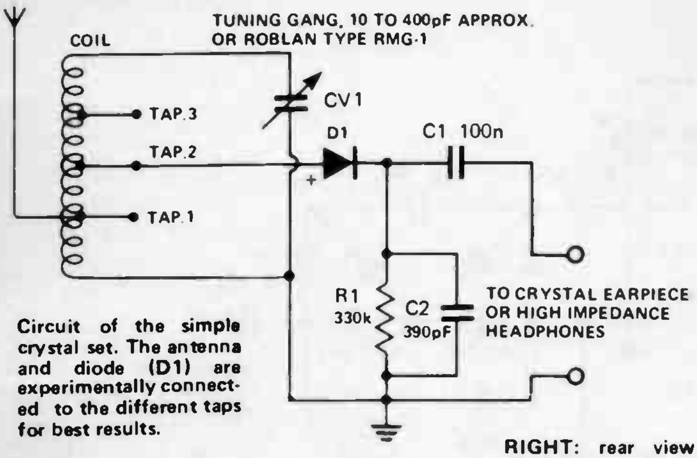
Now different stations can be selected, removed from the mess, and passed on to the detector. The size of the coil and the range of the capacitor must be selected to give a frequency coverage over the range of stations that you want to listen to.

Since tuned circuits are not perfect – nothing ever is in electronics! – frequencies close to the resonant frequency are also passed to the detector. The ability of a tuned circuit to select only one frequency is called its 'selectivity'. Our crystal set has a rather poor selectivity, but it's adequate for our purposes.

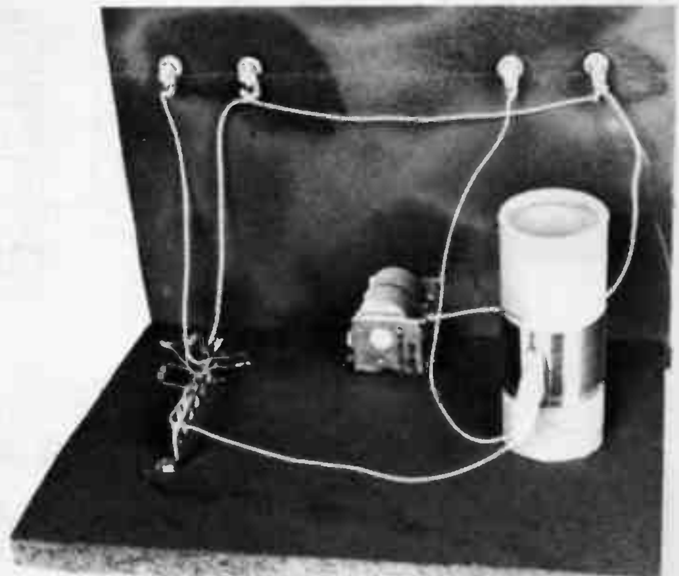
After the signal has been selected it is fed to the diode detector. At this point it is a high frequency radio signal, called a carrier, with the audio (music etc) superimposed or 'modulated' onto it. If this signal was fed directly to an earpiece, nothing would be heard as the earpiece cannot respond to the radio frequency signal. The diode "rectifies" the signal, leaving a half-wave radio signal which varies in amplitude with the audio signal. The fixed capacitor

Dual-gang tuning capacitors like this one are the most commonly available type. Only one section is used for these projects. The fixed plates are insulated from the frame and connection is made to the terminal on the side (either one). The earth connects to the frame.





Circuit of the simple crystal set. The antenna and diode (D1) are experimentally connected to the different taps for best results.



RIGHT: rear view of the crystal set showing placement of components and interconnections.

The dial on the front panel was cut from cardboard and lettered with rub-down lettering (see opposite page).

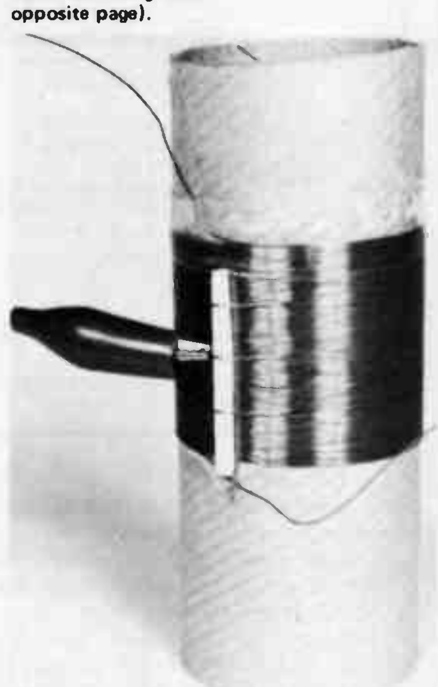
from the diode to earth 'shorts out' or 'bypasses' the RF signal, leaving the audio which is then fed to the earpiece.

In the first circuit, a single diode is used which gives good results, especially in areas with a local station, and is very easy to construct. The second circuit uses a more complex 'voltage multiplier' detector. This multiplies the signal level by four, increasing the volume in the earpiece. This circuit is commonly seen in high voltage power supplies.

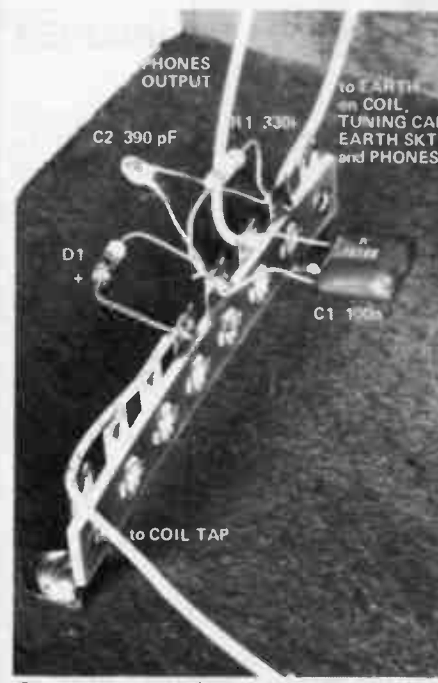
Construction

We built our two crystal sets on a chipboard base fitted with a plywood front panel. The tuning knob, terminals for the antenna and earth, and the earphone socket are mounted on the front panel.

The tuning capacitor we used was a common type available from most suppliers. This is the most expensive part in the set and a variable capacitor from a discarded mantel or floor-model radio will do equally as well. Some tuning capacitors may have two sections. If you obtain one of these 'dual-gang' capacitors, only use one section.



We wound the coil for these projects on a former cut from a cardboard mailing tube. The matchstick is slid under each of the turns to be tapped. Clean the enamel from the wire at each tap to get a good connection.



The components for our simple crystal set were mounted on an eight-lug tag strip screwed to the baseboard.

PARTS LIST - ETI 266

R1 . . . . .330k ½W, 5% resistor

C1. . . . . .100n greencap capacitor
C2. . . . . .390p ceramic capacitor

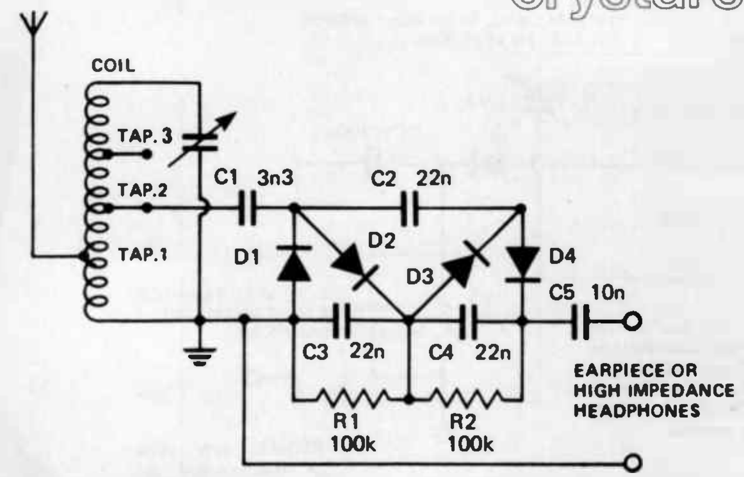
CV1. . . . . tuning gang approx. 10-400p, Roblan type RMG1 or similar, see Shop-around, p. 83.
D1 . . . . OA90, OA91, OA95, OA202 or similar germanium diode
Coil. . . . . see text

Crystal earpiece or *high impedance* headphones; miniature jack socket to suit earpiece or terminals to suit headphones; screw terminals for aerial and earth connections; base board and front panel (see text).

TABLE 1

NUMBER OF TURNS FOR WIRE GAUGE

COIL DIA.	22 SWG	24 SWG	26 SWG	28 SWG	TAPS
30 mm				110	at ¼, ½ and
40 mm			96	90	¾ of the turns.
45 mm		88	80	70	You may tap
50 mm	82	72	68	60	every ten turns
55 mm	71	64	60	52	if you wish
65 mm	61	56	54	47	for more range
70 mm	54	52			of adjustment.



The voltage-multiplier crystal set provides more volume in your earphones.

PARTS LIST - ETI 267

R1, R2	100k ½W, 5% resistor
C1.	3n3 ceramic capacitor
C2–C4	22n ceramic capacitor
C5.	10n greencap capacitor
D1–D4.	OA90, OA91, OA95, OA202 or similar germanium diode
CV1.	tuning gang, approx. 10-400p, Roblan type RMG1 or similar, see Shoparound, p.83.
Coil	see text

Crystal earpiece or *high impedance* headphones; miniature jack to suit earpiece or terminals to suit headphones; screw terminals for aerial and earth connections; base board and front panel (see text).

Various coil sizes can be used and we have given a table for different former sizes and wire gauges. All these coils will work equally well on formers made of cardboard, plastic or wood. We used a cardboard mailing tube.

Winding the coil is easy, but rather tedious. Anchor the wire at one end of the former with adhesive tape, or threaded through two holes, and start winding. The coil must be 'tapped' at ¼, ½, and ¾ of the winding. To do this, slide a piece of match stick under the turn to be tapped to raise it above the other turns, as shown in the photo. When the coil is finished, fasten the end as you did the start. You could coat the ends with five minute Araldite to hold the windings in place. Carefully scrape the enamel off the wire at the tapping points.

The other components can be mounted on a tag strip, as we have done, and flying leads with small alligator clips taken to the tapping points on the coil.

Getting them going

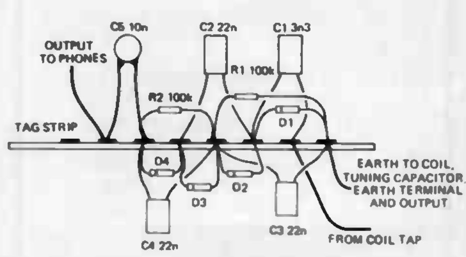
The performance of your crystal set will depend on the length and height of the antenna and the distance from the station. Remember, crystal sets are very crude devices compared to modern radios, and require long antennas, especially if you live a long way from a station.

An antenna can be made by running a long wire from the eaves of your house to a tall tree or mast. The wire can be any gauge as long as it can support itself, and can be insulated or uninsulated. NEVER run an antenna wire near or above mains electricity wires.

An 'earth' usually helps reception. This can be provided by driving a metal stake into the ground to a depth of about one metre or attaching a wire to the house water pipes. NEVER attach an earth to a gas pipe or the house wiring earth.

The optimum position for connecting the antenna and diode to the taps on the coil is best found by experiment and will be affected largely by the size of the antenna.

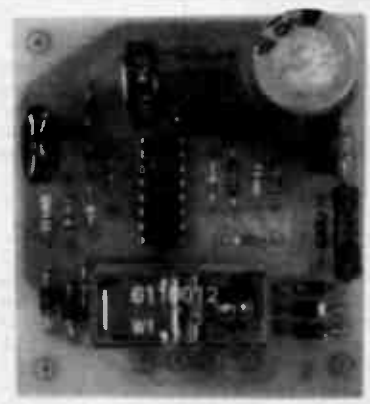
Have fun with your crystal sets! ●



As with the simple crystal set, we mounted the components for the voltage-multiplier crystal set on an eight-lug tag strip. We have supplied a drawing as it is clearer than a photo in this instance.

Signal powered loudspeaker protector

David Tilbrook



This unit affords both dc and over-power protection of loudspeakers or loudspeaker systems rated at up to 1500 watts! The unit requires no power supply and has no discernible audible effect on sound quality making it suitable for both hi-fi and sound reinforcement applications.

THE ETI-455 loudspeaker protector has proved to be a very popular project. It was published in March 1980 and since then we have had numerous phone calls from readers with stories of how the unit had saved their loudspeakers from almost certain disaster. Usually the power amplifier had gone faulty and applied the full dc supply rail to the loudspeaker terminals. Without the loudspeaker protector in circuit the result would be at least an open circuit bass driver and probably worse. The protector prevents this by monitoring the loudspeaker lines for the presence of dc, opening a set of relay contacts if this occurs, disconnecting the loudspeaker from the faulty amplifier.

The ETI-455 works well but requires its own power supply, either batteries or a small regulated mains supply. Another disadvantage results from the type of filter used to distinguish between dc and the audio signal. This was a conventional passive filter set to around 10 Hz. The problem is that it is still possible with very large amplifiers to trigger the protector on low frequency audio content. So the circuit, although perfectly satisfactory for its quoted maximum power of around 100 watts or so, is unsuitable for very high powered amplifiers.

We decided to overcome these limitations in this new loudspeaker protector, the ETI-494. Since the old one was published we have had numerous requests for a circuit that could be mounted inside a loudspeaker enclosure. These requests have come largely from the sound reinforcement industry although the unit would obviously be applicable to all loudspeakers. The protector would not be able to be powered from a mains supply since it is not always desirable or even possible to run mains to the loudspeakers. This is particularly true in a sound reinforcement or public address system. Similarly, batteries are unsuitable since access would have to be provided to facilitate testing and changing them when required. In addition, when we first published the ETI-499 MOSFET PA Module (ETI March 1982), we promised to follow up with a loudspeaker protector. This is it. The solution, used in this project, is to power the unit from the audio signal itself.

This is done in this case by placing a fullwave rectifier across the speaker lines and charging a 1000u capacitor through a 47 ohm resistor. The worst possible load presented to the speaker line is therefore 47 ohms and this is only while charging the capacitor and for signal voltages in excess of 12 V. This ensures that the unit has no discernible effect on audio quality but makes possible a truly 'set-and-forget' loudspeaker protector that can be mounted inside the loudspeaker enclosure if desired.

The ETI-494 tests for both dc and over-power, which can be adjusted by a preset on the board to suit a particular loudspeaker or application. The circuit also uses a new filter design with an almost 'brick wall' response enabling it to be connected to very high power amps. This is discussed in more detail in the 'How it Works' section.

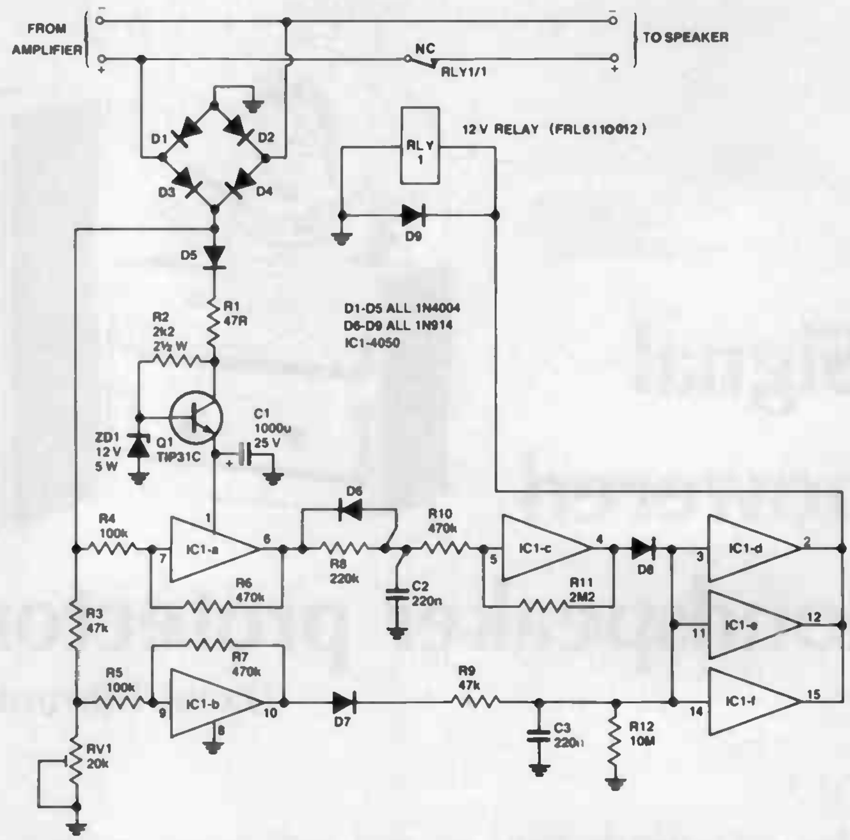
The maximum power that can be applied to the unit is determined by the type of regulator transistor (Q1) used. We have specified a TIP31C for this device which has a 100 V collector-to-emitter breakdown voltage. Since the emitter is at 12 V, the maximum voltage that can be applied to the unit is 112 V. This is equivalent to an amp capable of

HOW IT WORKS — ETI 494

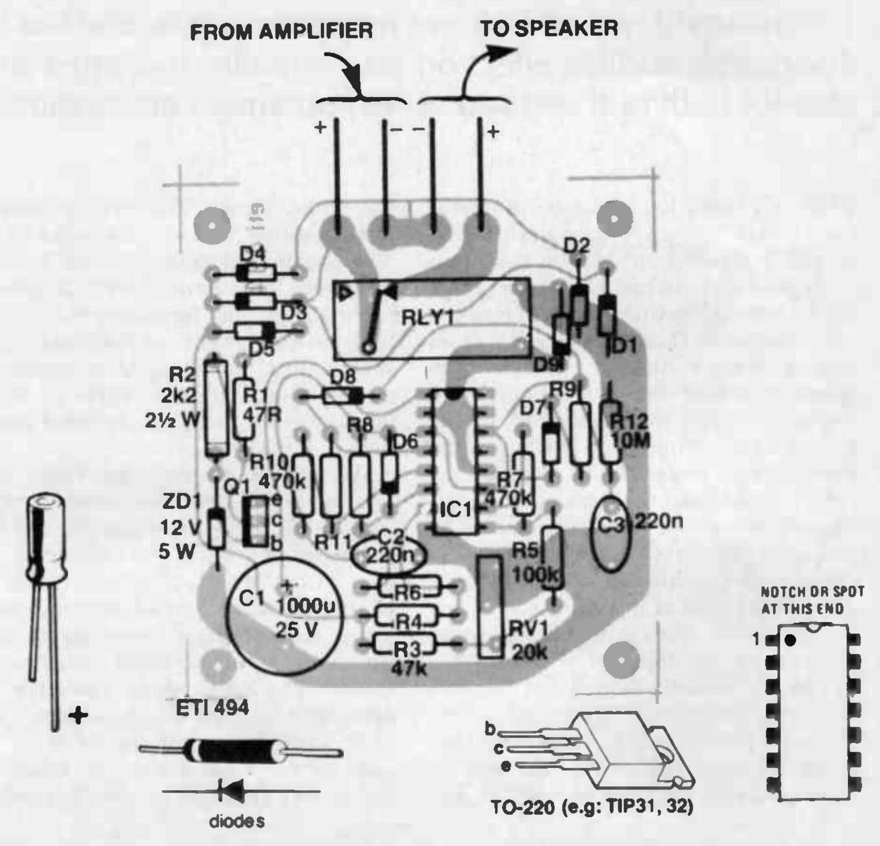
The signal from the power amp is rectified by the fullwave rectifier formed by D1-D4. The output of this is fed through a 12 V regulator circuit formed by Q1 and its associated resistors and zener diode, and charges the electrolytic capacitor, C1. The output of the rectifier is also fed to the input of the dc sense and over-power detection circuitry.

IC1 gates a and c form the dc filter. Resistors R4 and R6 form a Schmitt trigger with a small deadband. When the signal goes above the trigger voltage the output of the trigger swings hard to the positive supply rail of the IC, charging C2 through the 220k resistor, R8. Resistors R10 and R11 with gate c form a second Schmitt trigger monitoring the voltage across C2. If the voltage across C2 reaches the trigger voltage of this second Schmitt, gates d, e and f are activated, pulling in the relay contacts and disconnecting the loudspeaker. It takes about 100 ms to charge C2 through R8, and on normal audio content the output of gate 'a' will be driven low before this occurs, discharging C2 rapidly through D6. Only signals which do not have a zero crossing for longer than 100 ms will trigger the protector.

The over-power protector consists simply of a voltage divider feeding a third Schmitt trigger. Whenever the signal voltage exceeds the trigger voltage the output of gate 'b' is driven high and C3 starts to charge. If this condition persists for long enough the output gates are turned on and the relay pulls in. Note that both the dc and over-power sense circuits charge C3 when activated. The circuits are decoupled from this capacitor by diodes so that, once charged, C3 can only be discharged by the parallel resistor R12 (the effect of the input impedance of the gates is negligible). Since it takes about one second to discharge this capacitor, the relay will hold in for this time. The protector therefore reconnects the loudspeaker approximately one second after the fault condition has been removed.



The pc board pattern is on page 30.



PARTS LIST — ETI-494

Resistors	all ½ W, 5% unless notec
R1	47R
R2	2k2, 2½ W
R3, R9	47k
R4, R5	100k
R6, 7, 10	470k
R8	220k
R11	2M2
R12	10M
RV1	20k min. trimpot
Capacitors	
C1	1000u/25 V RB electro
C2, C3	220n greencap
Semiconductors	
D1-D5	1N4004, EM404
D6-D9	1N914, 1N4148
IC1	4050
Q1	TIP31C
ZD1	12 V, 5 W zener

Miscellaneous
ETI-494 pc board; RL1 — Fujitsu FRL611D012, 12 volt SPDT 10 A contacts or similar relay (pc mount type).

Price Estimate
$20-$24

supplying approximately 784 watts into an 8 ohm load or 1568 watts into a 4 ohm load. If the amplifier to be used is capable of powers greater than these the regulator transistor should be substituted for a device with a higher V_{ceo} rating. The relay pulls around 40 mA when operated, so power dissipation in the regulator transistor will be around 4 watts when dropping 100 volts. Although this is not a particularly high dissipation it is high enough to lie outside the SOAR rating of many high voltage transistors, so be careful when choosing an alternate regulator transistor.

Construction

Construction is straightforward since all of the components are mounted on the pc board. The usual precautions should be taken to ensure that all polarised components have been mounted with the correct orientation. The IC used is a CMOS type and is therefore static sensitive. Solder this last and preferably using an earthed soldering iron. It is a wise precaution to discharge yourself before handling the device by first touching an earthed metal appliance. For a more detailed description of precautions when handling CMOS refer to our article 'Electrostatic discharge — nemesis of electronic systems' in the June edition, 1981.

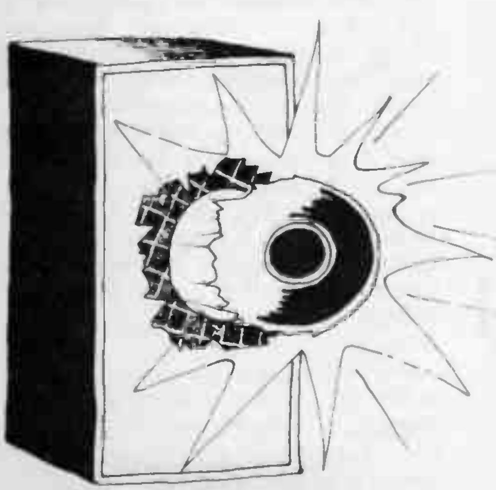
It is a wise precaution to space the 2.5 W resistor, R2, off the pc board slightly. In the case of a high powered loudspeaker going faulty with dc this component will get quite hot and spacing improves ventilation around the component and prevents the possibility of charring the pc board. If you can't obtain a 2.5 watt type (e.g. Philips PR52), then a 5 W type may be substituted.

Before mounting the unit check operation by connecting around 20 V dc across the speaker input terminals on the pc board. The relay should cut in after about one tenth of a second. If the protector passes this test connect the speaker wiring. If the preset is turned fully down (turn it anticlockwise when viewing the board with the components on top and the relay to the right) the relay will cut in when the power exceeds around 20 watts for an extended period. The protector allows transients to the full supply rail to pass but will prevent a continuous 20 W from being applied to the loudspeaker. To increase this, turn the preset clockwise until the desired response is achieved.

Performance

We tested the loudspeaker protector for its effect on audio performance as well as its reliability. A variety of power amps were used to ensure that the load represented by the protector would not affect audio performance. Even a very low power amplifier, with a comparatively small damping factor (high output impedance) could drive the unit with no degradation to the sound quality. During every test the protector worked well and cut in at the correct time to prevent damage to the loudspeakers.

NOTE. *Some amplifiers are unstable when driven into an open circuit. This is particularly true of valve power amplifiers some of which destroy themselves the moment the speaker is disconnected. Loudspeaker protectors are however, not usually required for use with valve power amps since the possibility of dc on the speaker lines is remote, but over-power protection may be required.* ●



OPERATING NOTES — PROJECT 494

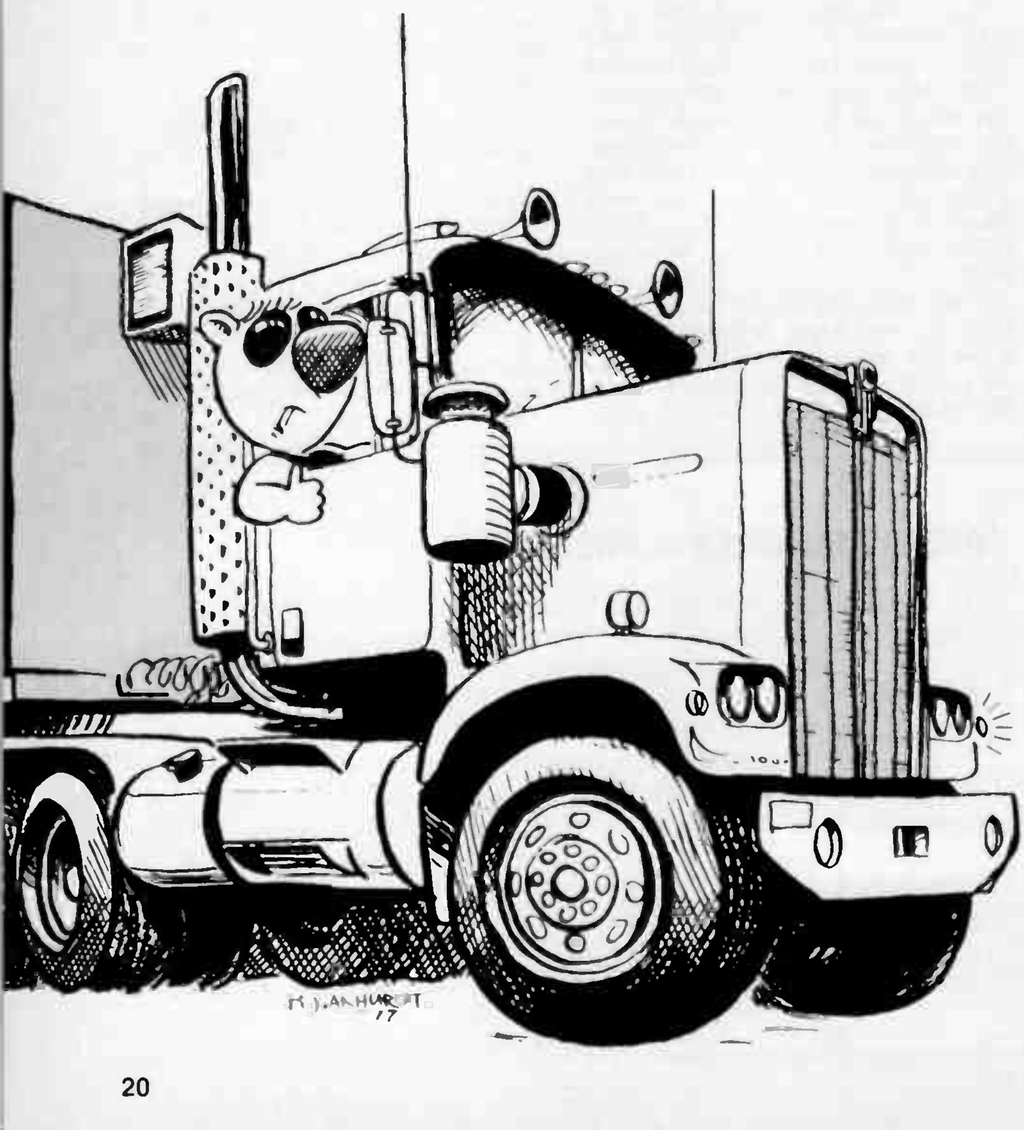
A loudspeaker protector such as this is basically meant for a *once-only* operation. It is not meant for successive cut-in, drop-out operation, particularly in the case of a dc fault. This project should not be used if you're trying to trace an intermittent dc fault. If the relay operates, it's time to switch off the amplifier, disconnect the load and find the fault — preferably using a dummy load. For amplifiers having supply rails in excess of about 50 V, it is advisable to add dc-quenching across the relay contacts. A series RC network is all that's necessary. Use a 100 ohm, 1 W resistor and a 630 V rated capacitor of about 100 n or greater value.

For really high power amplifiers having supply rails of 100 V or more, it is probably best to use two relays with their coils connected in parallel and their contacts (with de-quenching) connected in series.

Turn and hazard indicator for your vehicle

Staff

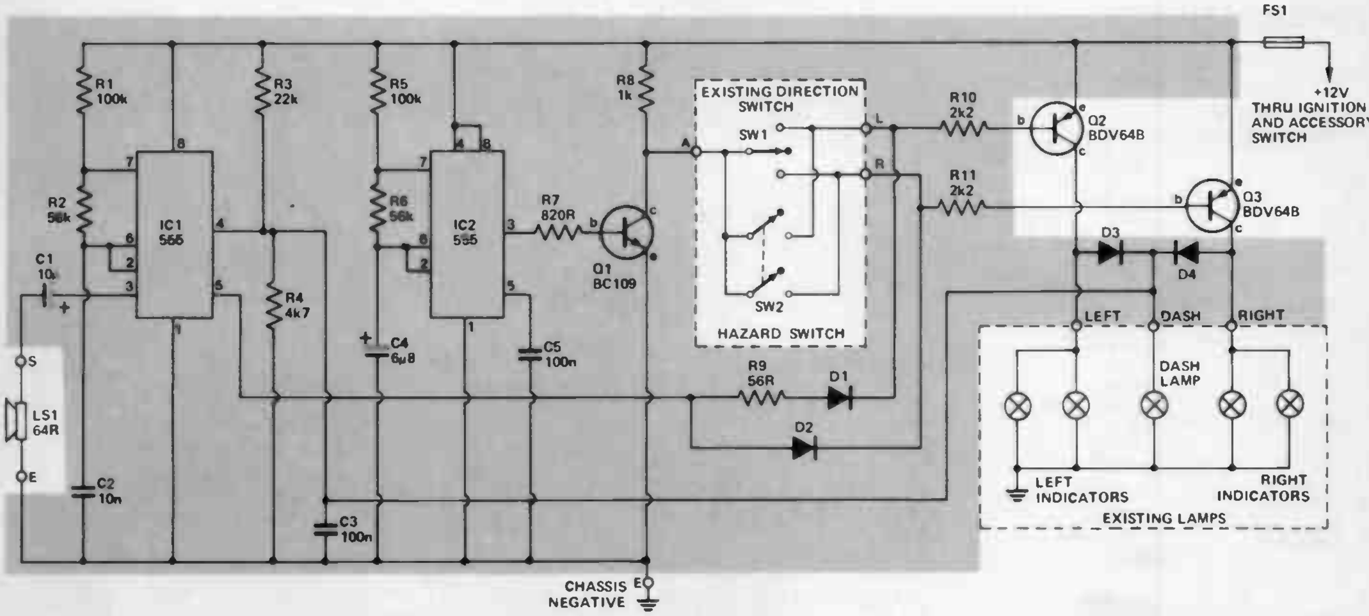
This 'electronic flasher' is a great improvement on the electromechanical flashers fitted as standard equipment on most cars. It features a stable flash rate, high reliability and the ability to drive up to 144 watts worth of indicator lamps !



IF YOUR CAR was made before 1960 it probably doesn't have any kind of indicators, but all cars built after that date are fitted with turn indicators of some sort and post-1970 models have hazard flashers too. However, the conventional bimetallic strip flashers fitted to nearly all cars have a few shortcomings which we have attempted to overcome with our new solid state unit.

The bimetal flashers give only a weak sound indication, which can easily be drowned out by general vehicle noise. They are especially difficult to hear if the ravages of time (or uproarious living, or overindulgence in very loud music etc.) have left you with less than perfect hearing. Another disadvantage of conventional units is that they cannot cope with the extra power drained by the turn/hazard indicators on a trailer or caravan. Also the flash rate of bimetallic units is preset by the manufacturer and cannot be adjusted to compensate for drift caused by battery voltage variations and ageing of the metal strip.

Our solid state flasher connects easily to the car's wiring and is designed to completely replace the existing bimetal unit. It can handle up to 12 amps, which allows it to drive a substantial load (up to 144 W at 12 V). The flash rate will remain substantially the same through-



HOW IT WORKS — ETI 327

The flasher consists of a low frequency oscillator, IC2, producing a pulse at about one Hertz, driving either or both of two Darlington output transistors, Q2 and Q3. These switch the vehicle's battery to the turn indicators and dash light. An audio oscillator, IC1, gives an audio tone through the speaker at a different frequency for *left*, *right* and *hazard*.

The output of IC2 (a 555) gives the flash frequency. The frequency and duty cycle (on to off time) are set by the values of R5 and R6 and can be made variable by substituting trim pots for these two resistors.

The pulses from IC2 are fed to an inverter, Q1, and then to the vehicle's turn and hazard switches. If the vehicle doesn't have a hazard switch, one can be added. Transistors Q2 and Q3 are Darlington output transistors used here for their very high current gain. Darlington transistors have two transistors in the one package in a gain multiplication configuration.

The pulses are fed to either of the Darlington transistors for turn indication, or to both for the hazard indication. The transistors switch the battery to the appropriate indicator lights on the vehicle.

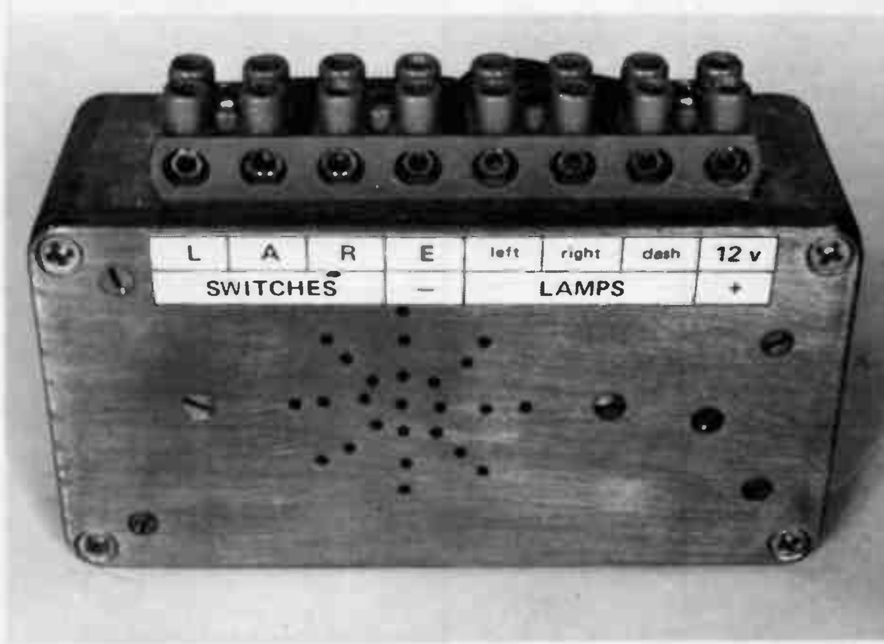
The dash light is illuminated through D3 and D4 whenever either of the Darlington transistors are turned on.

IC1 is an audio oscillator with a variable frequency controlled by the voltage on its control input, pin 5. This pin is tied to the bases of Q2 and Q3 through D1, D2 and R9 in such a way that the oscillator gives a different tone for left, right, and hazard. The oscillator is enabled by the voltage on pin 4 which is normally held low through the dash light. When the dash light turns on pin 4 goes high and the oscillator starts, beeping in time with the flash of the indicators.

out the life of the unit. A special feature is that it provides an audio tone whose pitch is different for each of the three modes — 'left turn', 'right turn' and 'hazard'. If you want to alter the flash rate, two of the fixed resistors can be replaced by trimpots to allow variation of the frequency and duty cycle.

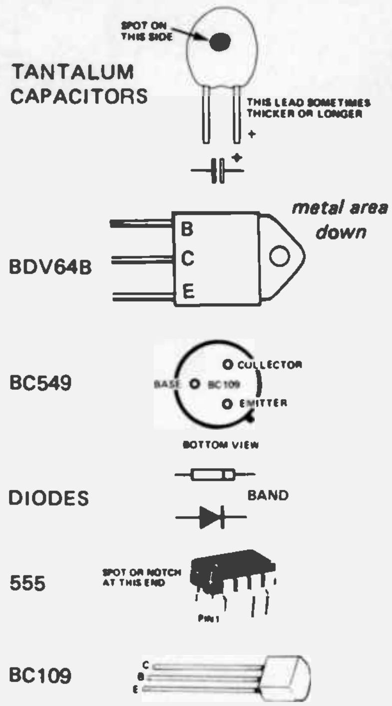
The flash rate is determined by a 555 timer IC, whose output is routed through the car's turn indicator switch on the steering column and turns one of two Darlington power transistors on and off. These transistors are actually two transistors connected in the same package in such a way as to provide a very high current gain. This allows them to be operated with a low base drive current to switch quite high currents, making them ideal for this application.

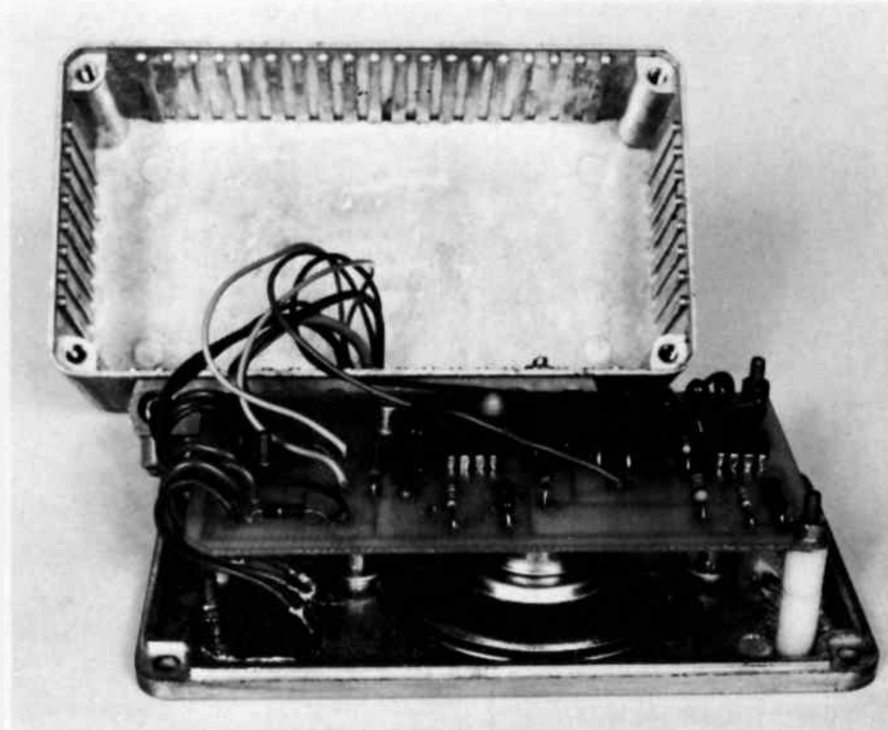
A second 555 IC is used as an audio oscillator to drive a small loudspeaker. This oscillator is held off until one of the Darlington transistors is turned on and then turns on and off in time with the Darlington, producing a beeping sound which is synchronised to the flashes.



Project 327

COMPONENT PINOUTS





Our unit was assembled into a diecast box using standoff pillars to support the pc board. If you use an 8 ohm or 16 ohm speaker with a series resistor, the value of the resistor may be varied to alter the speaker volume. With a high impedance speaker, a suitable value resistor may be inserted in series to lower the volume. Try 100 ohms as a start.

Construction

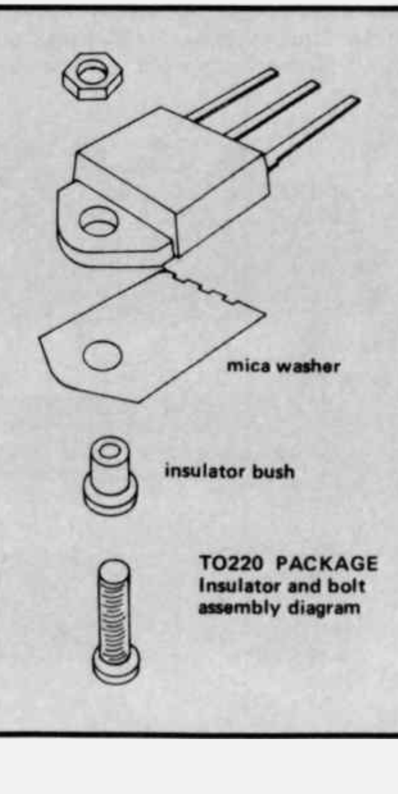
Since the unit is designed to operate inside a car it should be made as rugged as possible. Our prototype was constructed in a diecast aluminium box which doubled as a heatsink for the switching transistors.

Connection to the vehicle's wiring is made via a terminal strip mounted along the outside of the box. The speaker and the pc board are mounted inside the lid of the box to facilitate wiring.

Start by mounting the resistors and non-polarised capacitors on the pc board. Next mount the two tantalum capacitors, the diodes, the ICs and the transistor, paying particular attention to their orientation.

If you wish to vary the flash rate and the duty cycle, the two timing resistors R5 and R6 can be replaced by trimpots as the pc board has been designed to accomodate either trimpots or fixed resistors. Drill holes in the lid of the box for the pc board, the Darlington transistors and the speaker. We drilled a series of small holes in front of the speaker but this may not be necessary in some circumstances because the sound from the speaker is quite loud.

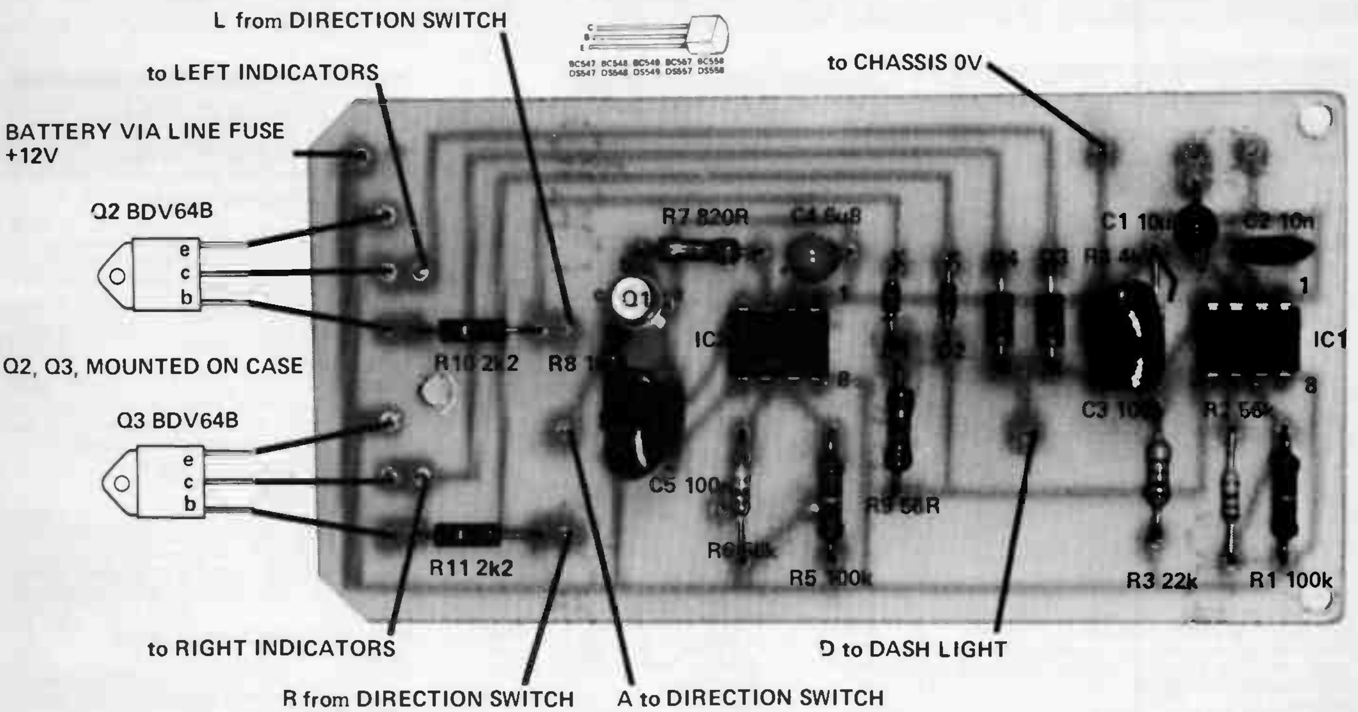
The two Darlington switching transistors are mounted on the lid of the box as shown in the photo of the prototype. The cases of these transistors are connected to the collectors and must therefore be insulated from the diecast lid. Mount the transistors using a mica or plastic insulator and plastic sleeves as shown in the diagram. Use an ohmmeter to check that there is an open circuit between the collectors and the diecast lid after the transistors are mounted.



TO220 PACKAGE
Insulator and bolt assembly diagram

Mount the loudspeaker on the lid, using nuts and bolts with two large washers clamping the edge of the speaker against the lid. If you have an eight ohm speaker you can use that instead, if a 47 ohm, ½ watt resistor is connected in series with one of the speaker leads.

Solder all the connecting wiring from the pc boards and Darlington transistors, using heavy gauge wire to the emitters and collectors of the transistors. Then mount the pc board on 20 mm standoffs above the speaker and transistors. Connections to the car's electrical system are made via a length of screw terminal strip with the wires to the pc board run through a grommet in the side of the box.



Component overlay and external component connections.

NOTE: The printed circuit board artwork is reproduced on page 90.

Installation

The flasher unit can be installed in any convenient position under the dash within earshot of the driver. However, it is not a good idea to mount it near the output pipe of the heater as it could get quite hot there. The connection to the battery can be taken from the battery terminal through a 10 A line fuse, or from the accessories position on the ignition switch. This way the hazard flasher can still be used with the engine turned off.

If your car is too old to have turn indicators you can mount a double pole switch on the steering column and run wires under the dash to the unit. You can buy switches with long lever extensions which are ideal for the purpose. The hazard switch should be a push-off/pull-on type (to avoid accidentally knocking it on) and can be mounted in any convenient position on the dash with the dash turn indicator.

External lights are easily mounted and are available from motor accessory stores. Make sure the connection from the light to the chassis is good. If in doubt, run a wire from the light case chassis connection to a good chassis contact point on the vehicle or direct to the battery negative terminal. ●

Flashers and the Law

Flashing turn and hazard indicators fitted to motor vehicles must comply with Australian Design Rule No. 6 (ADR 6), whose provisions are summarised below.

Colour:	Rear and side flashers must be amber or orange. Front flashers on Australian-made vehicles must be orange; on imported vehicles they may be orange or white.
Flash Rate:	Not less than 60 and not more than 120 flashes per minute.
Duty Cycle:	Not specified.

PARTS LIST — ETI 327

Resistors	all ½W, 5%
R1	100k
R2	56k
R3	22k
R4	4k7
R5	100k or 250k min. trimpot
R6	56k or 100k min. trimpot
R7	820R
R8	1k
R9	56R
R10,R11	2k2
Capacitors	
C1	10u/25V tantalum
C2	10n greencap
C3,C5	100n greencap
C4	6u8/25V tantalum
Semiconductors	
D1,D2	1N914, 1N4148 etc.
D3,D4	1N4001, A14A etc.
Q1	BC549, BC109 etc.
Q2,Q3	BDV64B Darlington transistor
Miscellaneous	
SW2	DPDT toggle switch
LS1	small, high impedance speaker (48-80 ohms) or eight ohm speaker with 47R series resistor.

ETI-327 pc board; line fuse with 10 amp fuse; diecast box to suit (65mm x 120mm x 40mm); eight-connector barrier strip.

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Postal Address: ETI Book Sales, PO Box 227, Waterloo, NSW 2017.

Fuel level monitor sounds alarm when your fuel runs low

Have you ever been caught with your fuel level down (to zero)? Despite the inclusion of fuel gauges in dash panels, many motorists still get caught. It's understandable under circumstances where great concentration is required and the fuel gauge is forgotten. Don't you get caught — build our low-fuel warning project.

THIS PROJECT is a medically non-approved ulcer generator. It's designed to make you *worry* for twenty minutes or so before you are finally stranded through lack of fuel!

This alarm is designed for use in modern vehicles fitted with 12 V electrical systems only. It is driven from the vehicle's existing fuel gauge system and operates a LED and an alarm (optional) when the fuel level falls below a pre-set value.

Design

The fuel metering system in a modern car consists of a rheostat 'transmitter' in the fuel tank with its wiper mechanically linked to a float, an instrument regulator, and the fuel gauge. The current through the gauge is controlled by the float and the voltage supply is regulated to ensure reliability of calibration and to avoid the meter varying with battery voltage. The regulator output to the instrument is usually five or ten volts.

The fuel gauge is a bi-metallic type of meter with a coil of resistance wire wound around a strip of two dissimilar metals. When the current is passed through the coil it heats up and heats the bi-metal strip which bends, moving the pointer. This type of meter is used for its ruggedness and damping effect. When the ignition is switched off the gauge is returned to empty by a return magnet inside the gauge, otherwise it would show a reading when the ignition was turned off. The voltage across the rheostat increases as the level in the tank drops, developing typically three to four volts when the tank is empty.

The circuit monitors the voltages across the rheostat (wire C) and compares it to a reference voltage taken from the instrument regulator (wire B). The trigger point can be adjusted so the alarm will switch at any level on the fuel gauge by adjusting the pc-mounted trim pot, RV1.

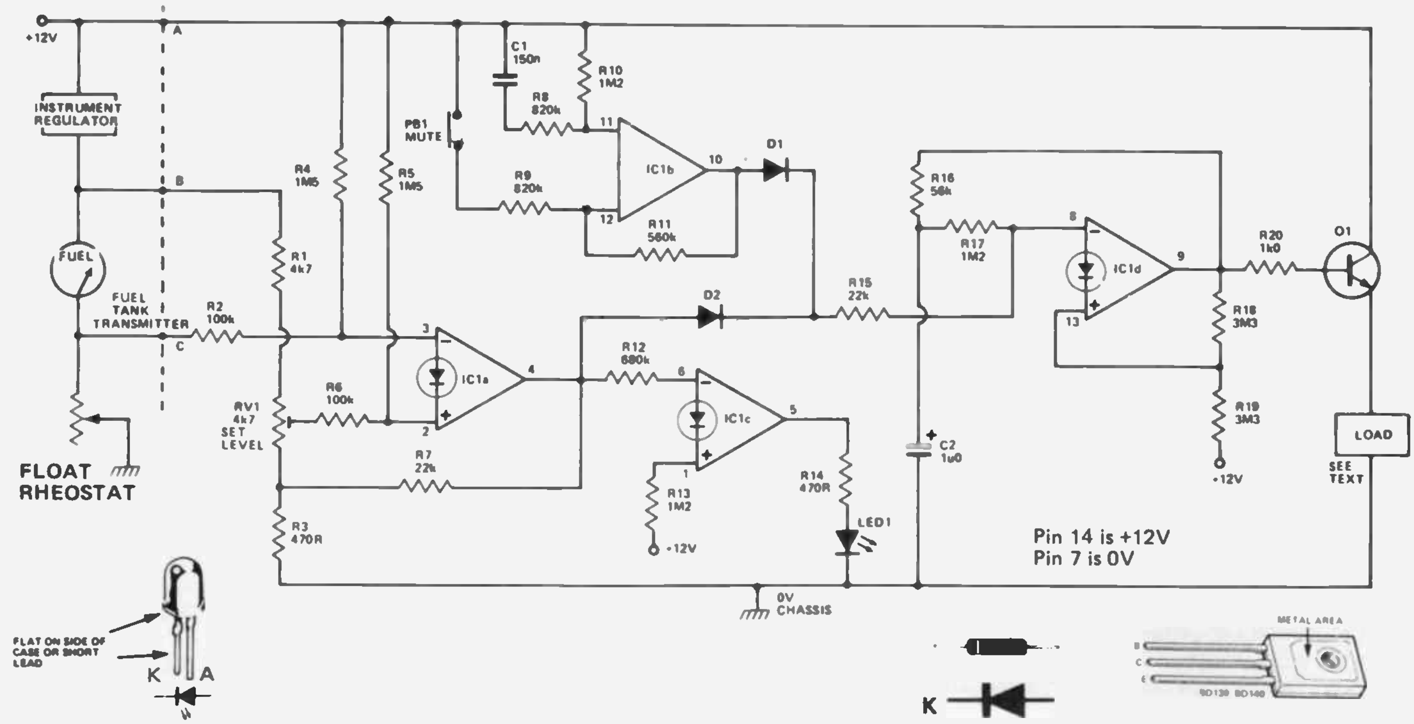
When the fuel level drops below the pre-set point the alarm sounds and the LED lights. The alarm output is a low frequency oscillating voltage which can be used to drive any 12 V alarm device greater than 100 ohms impedance. We used a Sonalert piezo-electric alarm, which is very loud and should be heard readily over quite high noise levels that may occur inside a vehicle.

A mute circuit is included to stop the noise at the push of a button. However, the LED remains lit as a reminder. When the ignition is switched off the mute is re-set, and the alarm is activated immediately the ignition is turned on if the fuel level is still low.

Construction and installation

Construction is quite simple as all the components are mounted on the pc board, except the LED, push button and alarm. Be careful to orient the diodes and the tantalum capacitor the right way round. The unit can either be mounted under the dash with the LED, push button and alarm mounted on a bracket, or the complete unit built into a small box. We used a good looking slim box by PacTec, distributed by Associated Controls (see Shoparound) with the LED, pushbutton and alarm mounted on the front panel. The connections to the car's wiring are taken from a plastic terminal strip mounted on the rear of the box.

Connection into the car's wiring system may be a lot more difficult. Make sure that you know what you're getting yourself into before you think about building the unit! The dash in

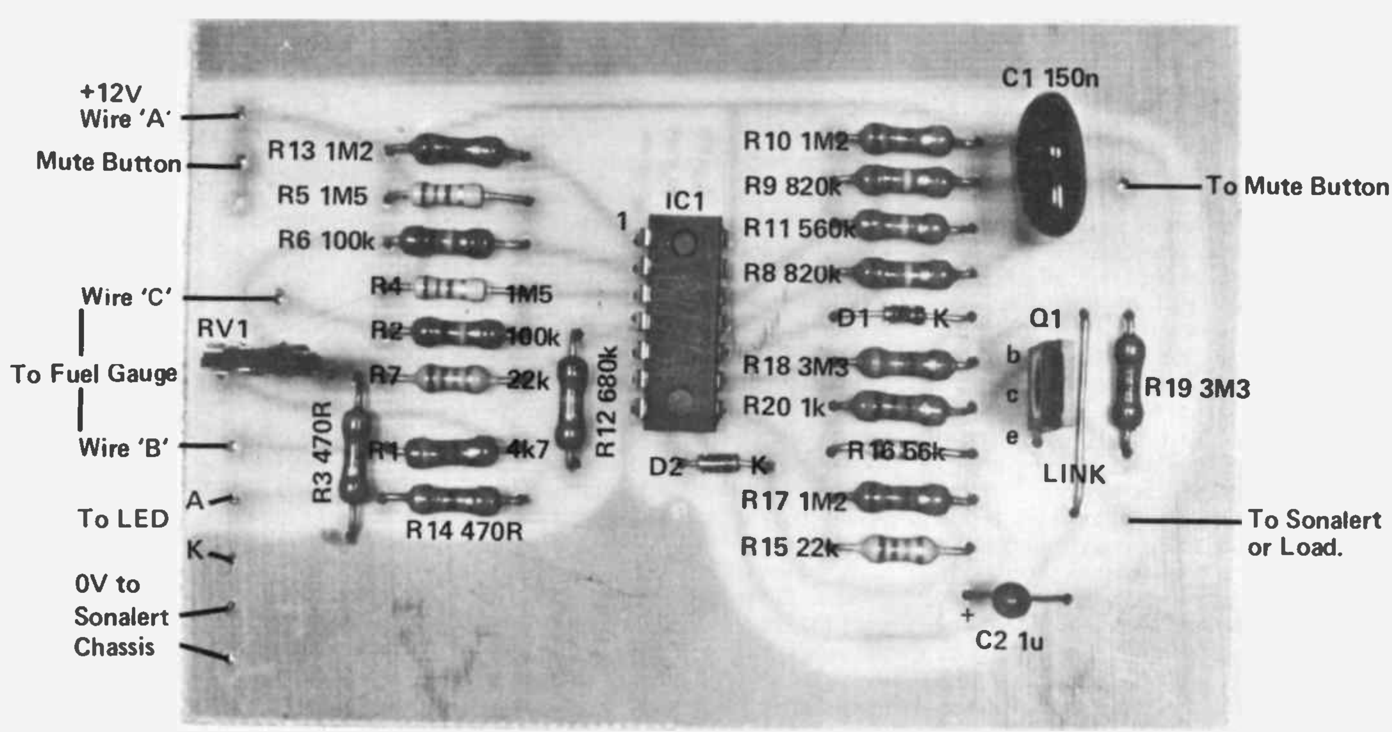


most cars will have to be removed and the wires to the fuel gauge identified and tapped. This can take the best part of a day, so give yourself plenty of time. Some cars use a printed circuit dash instead of a wiring loom and the connections can be soldered onto the back of the pc board, taking care not to damage it.

The other two wires, 12 volts and earth, can be taken to any convenient point in the car's wiring, however the 12 volts must be switched via the ignition switch.

After the unit has been assembled and installed the fuel alarm level must be set. Run the fuel in the tank down to the desired level and adjust the trimpot until the alarm just sounds. The adjustment should allow you to do this at any fuel level for a check of correct operation after the unit is installed.

When the fuel gets near the pre-set level the alarm will 'blip' as the fuel sloshes around in the tank, making quite a fuss if you let the fuel drop below the set level. ●



PARTS LIST - ETI 321

Resistors	all ½W, 5%
R1	4k7
R2	100k
R3	470R
R4, R5	1M5
R6	100k
R7	22k
R8, R9	820k
R10.	1M2
R11.	560k
R12.	680k
R13.	1M2
R14.	470R
R15.	22k
R16.	56k
R17.	1M2
R18, R19 . . .	3M3
R20.	1k
RV1	5k or 4k7 min vert mounting trimpot
Capacitors	
C1.	150n greencap
C2.	1μ tantalum
Semiconductors	
D1, D2	IN914 or similar
LED1.	TIL 220R Red Led or similar
Q1	BC139, BC184 or similar
IC1	LM3900

Miscellaneous
ETI 321 pc board, Sonalert or similar warning device, box to suit (see text), pushbutton (push to make), terminal strip.

BELOW LEFT is the pc board overlay. Take care with the orientation of the diodes and tantalum capacitor (C2). Initially, we cut the board for behind-dash mounting and had to secure it in the PacTec case with a strip of double-sided tape. The pc board artwork is below.

HOW IT WORKS – ETI 321

The circuit consists of a voltage comparator, IC1a, an LED driver, IC1c, an astable multivibrator used as a low frequency oscillator, IC1d, and a mute circuit, IC1b.

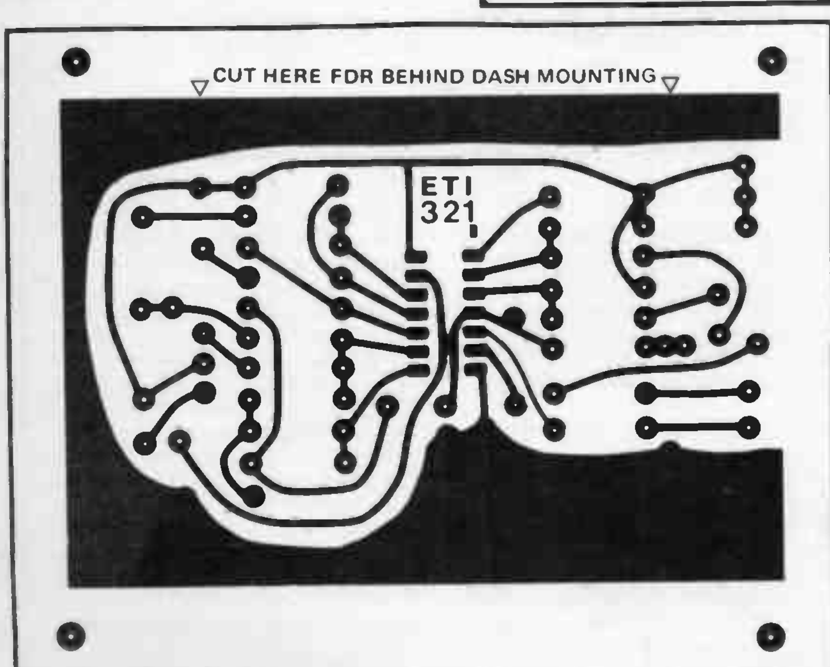
IC1a is wired as a voltage comparator with a small amount of hysteresis provided by R7 and R3. When the fuel level in the tank drops, the voltage across the rheostat rises. This voltage is fed to the inverting input of IC1a and is compared to the preset voltage level from RV1 on the non-inverting input. When the voltage across the rheostat is low, the output of IC1a is high. When the tank empties to the point where the voltage on the inverting input is just higher than the reference, the output of IC1a goes low.

The output of IC1a is connected to the inverting input of IC1c. When the output of IC1a goes low, the output of IC1c goes high, lighting the LED.

The low from IC1a is also fed to the negative input of IC1d, through D2 and R15, enabling the oscillator. The output of the oscillator is fed to an emitter follower, Q1, which drives the alarm.

When the ignition is first turned on the mute circuit, IC1b, is automatically set to have a low on its output (pin 10) by C1 charging via R8. D1 is reverse biased and the circuit is isolated from the oscillator. When the mute button is pressed the output is latched high, D1 is forward biased and the inverting input of IC1d is held high disabling the oscillator. Diode D2 is reverse biased when this occurs and the output of IC1a remains low. The LED will still be lit.

When the power is turned off and re-applied the mute circuit is reset to a low output and the circuit is ready to be retriggered.



CUT HERE FOR PAC TEC BOX

Headlight delay unit

With this simple project you can use your car headlights to illuminate your pathway for about 50 seconds; safe on a dark night from the horrors of stumbling into bushes or slipping on those nasty smelly things lying on the footpath. The unit is easy to build and install and switches off automatically.

Jennie Whyte

THIS IS a simple circuit which lets you use your car headlights to light your way. It saves you from falling over rubbish bins or walking into fences on a dark night.

After you have parked your car and turned the delay unit on, the headlights will come on for a pre-set period of about 50 seconds. At the end of this period the unit turns the headlights off automatically. So if you haven't manoeuvred the obstacle course by this stage then you're out of luck.

THE 555 AND HOW IT WORKS

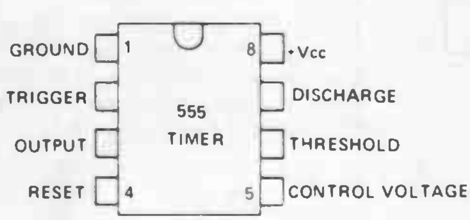


Figure 1.

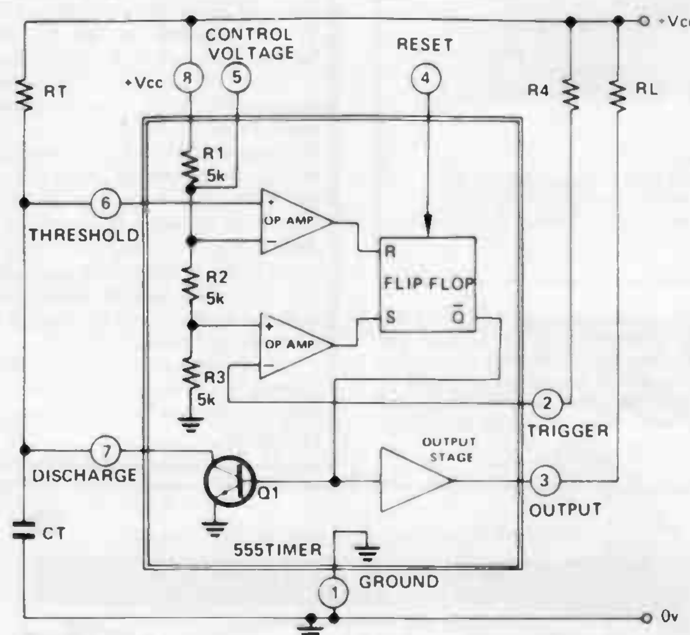


Figure 2.

The 555 timer is a very versatile IC designed specifically for precision timing applications.

It can operate from 4.5 V to 16 V and its output can source (supply) or sink (absorb) any load current up to a maximum of 200 mA. It can directly drive loads such as relays, LEDs, low-power lamps and high impedance speakers.

When used in the timing mode, the IC can produce accurate timing periods variable from a few microseconds to several hundred seconds, via a single resistor-capacitor (RC) network. Timing periods are virtually independent of supply rail voltage, can be started via a trigger command signal and can be stopped by a reset command signal.

The device is available in a number of packaging styles, including 8 and 14-pin dual-in-line (DIL) and 8-pin TO-99 types. Figure 1 shows the outline and pin notations of the standard 8-pin DIL version of the 555. Figure 2 shows the functional block diagram of the same device (within the double lines), together with the connections for using it as a basic monostable generator or timer.

The 555 houses two diodes, 15 resistors and 23 transistors. These components are arranged to form one voltage-reference potential divider, two voltage comparator op-amps, one reset-set (RS) flip-flop, a low-power complementary output stage and a slave transistor.

The period timer, as it is used in the headlight delay unit, gives a direct voltage output at pin 3 which is normally low, but goes high for the duration of the timing period.

The timing action is initiated by momentarily shorting pin 2 to ground via the PB1 START switch. As this voltage is below the reference value of the built-in potential divider the output of the lower voltage comparator op-amp changes state and causes the RS flip-flop to switch over.

As the RS flip-flop switches over it cuts off Q1 and drives the pin 3 output of the 555 to the high state. As Q1 cuts off it removes the short from the timing capacitor connected to pin 7 and the capacitor starts to charge up. Then the RS flip-flop switches back to its original condition, Q1 turns on, the capacitor discharges and simultaneously the pin 3 output of the IC reverts to its low state.

PARTS LIST — ETI-323

Resistors .... all ½W, 5%
- R1 .... 22k
- R2 .... 470k
- R3 .... 1k

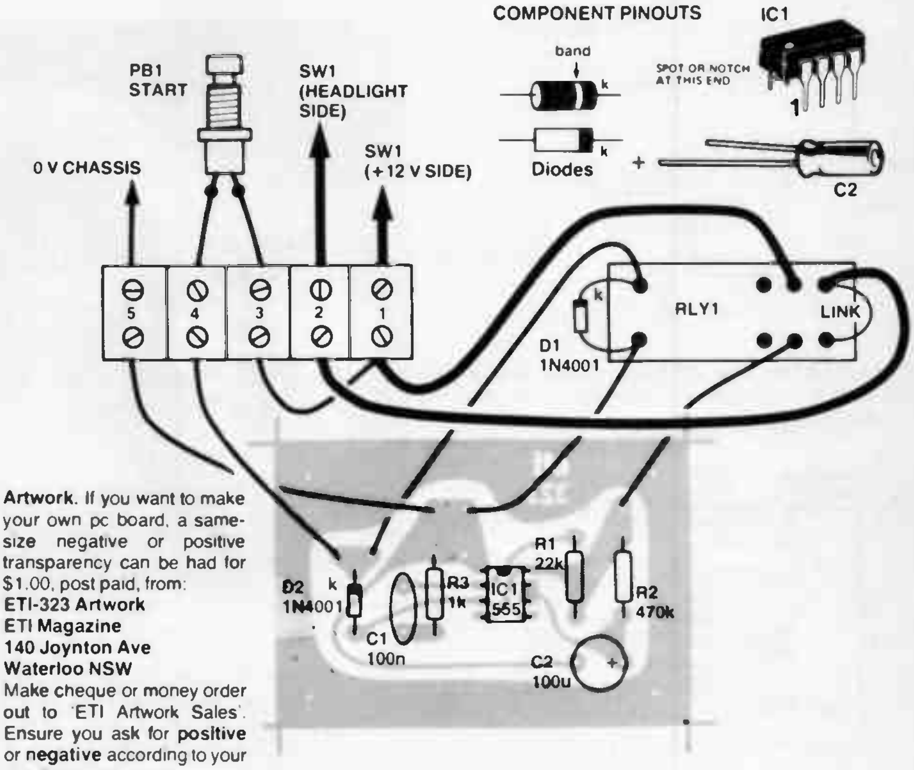
Capacitors
- C1 .... 100n greencap
- C2 .... 100u/25 V RB electro

Semiconductors
- D1, D2 .... 1N4001, 1N4002, EM401, EM402, etc.
- IC1 .... uA555, NE555, LM555, DS555, etc.

Miscellaneous
- RLY1 .... DPST or DPDT relay, 5A-rated contacts with 12 V coil (120 ohms or greater).
- PB1 .... momentary action pushbutton (e.g: D.S.E. S-1102, S-1199 types, or similar).

ETI-323 pc board; five-way plastic terminal block; box (if necessary); wire etc.

Price estimate
$14 — $16



Artwork. If you want to make your own pc board, a same-size negative or positive transparency can be had for $1.00, post paid, from:
ETI-323 Artwork
ETI Magazine
140 Joynton Ave
Waterloo NSW
Make cheque or money order out to 'ETI Artwork Sales'. Ensure you ask for **positive** or **negative** according to your requirements.

Component overlay and external wiring. How the parts are assembled onto the printed circuit board — watch which way around you assemble D2, IC1 and C2. Wiring to the external components is also shown. The pc board and relay may be housed in any suitable box, if you wish.

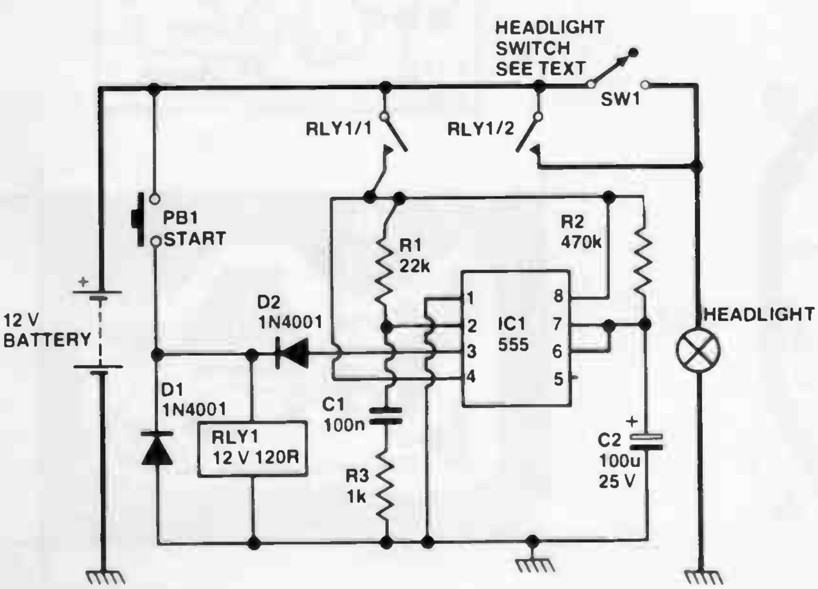
Construction

The unit is easy to build and install and works off the car's 12 V battery. The circuit does not interfere with normal headlight operation under actual driving conditions.

Construction is simple because there are only a few components and the layout on the pc board is clearly shown. Before you assemble the components on the board, check that the board has no track breaks or shorts between the tracks, particularly between the IC pins. Make sure you solder the diodes the correct way round.

The relay can be any 12 V DPDT (double-pole, double-throw) type with a coil resistance of 120 ohms or greater. The contacts should be rated to switch 5 A or greater at 12 Vdc. Note that the IC, a 555, is shown on the circuit diagram with all its connections in the standard manner. Look for the notch and make sure that it's positioned on the pc board correctly, soldering it in after the other components.

Kits and components. See 'Shoparound' in this book to find suppliers stocking kits or components for this project.



Circuit diagram. The parts in the shaded area are located on the pc board.

HOW IT WORKS — ETI-323

This circuit has been designed around the 555 IC timer which has already been described.

The pin 3 output is connected to a relay which has two sets of normally open contacts. D2 is wired in series with the relay coil to counteract the slight residual voltage that appears at pin 3 of the IC under the OFF condition and this makes sure that the relay turns fully off. The START switch, PB1, is also normally open so there's no power going to the timer circuit and the lights are off. Capacitor C1 is discharged under this condition.

When PB1 is momentarily closed power is fed directly to the relay coil and the relay turns on. As the relay turns on, contacts RLY1/2 close and apply power to the vehicle lights and contacts RLY1/1 close and apply power to the timer circuit. At this moment pin 2 of the IC is briefly tied to ground via C1 and R3 so a negative trigger pulse is immediately fed to pin 2 and a timing cycle is initiated.

Consequently, pin 3 of the 555 switches high at the moment that the relay contacts close, and thus locks the relay into the ON condition irrespective of the subsequent state of the PB1 START switch so the lights remain on for the duration of the timing cycle.

The period of the timing cycle depends on the values of R2 and C2. With the component values shown, this period is roughly 50 seconds.

At the end of the timing cycle pin 3 of the IC switches to the low state, so the relay turns OFF and contacts RLY1/2 and RLY1/1 open, disconnecting power from the timing circuit and the lights. The operating sequence is then complete.

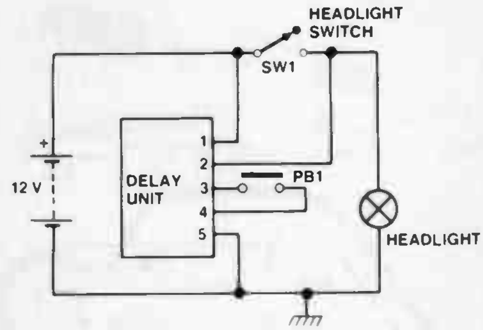


Figure 3. Connection of the delay unit to a car system where the headlights are independent of the ignition switch.

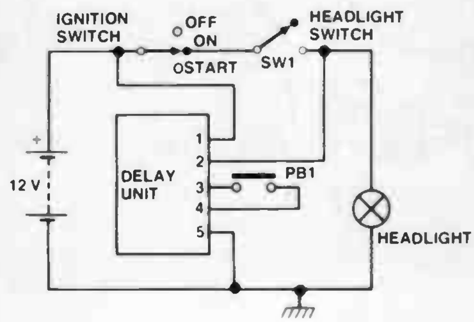
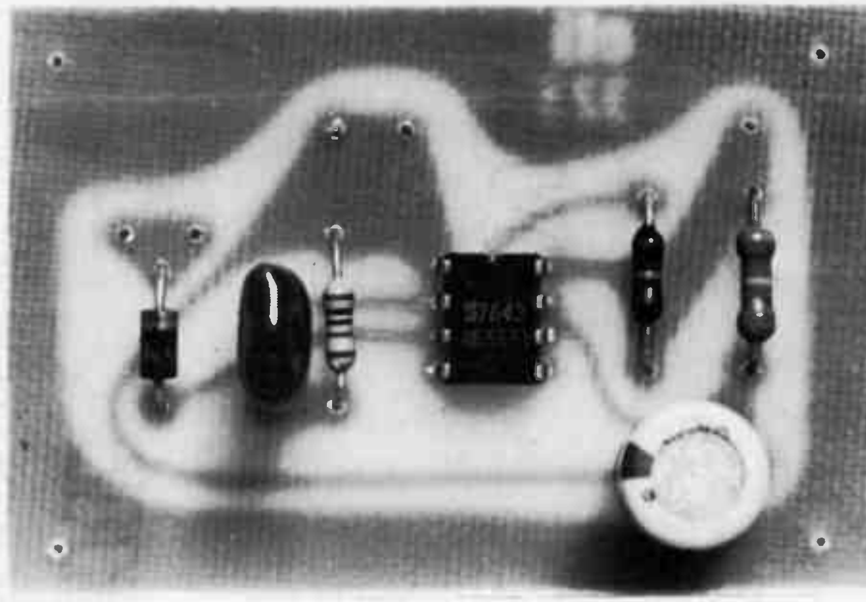


Figure 4. Connection to all other systems.

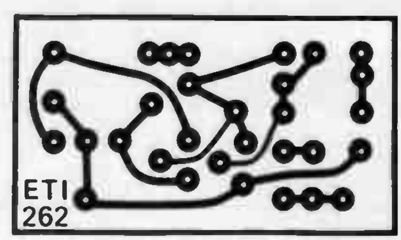


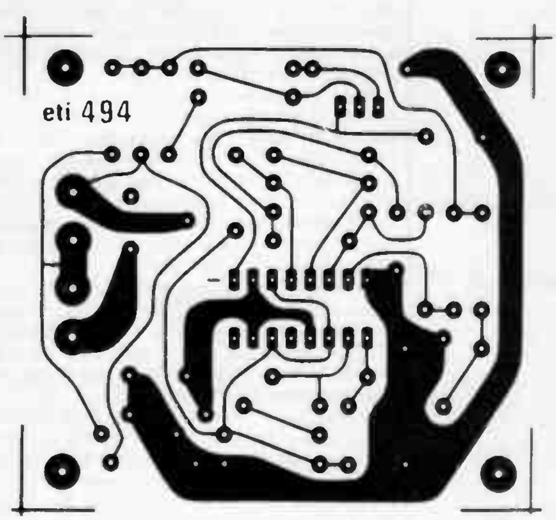
Closeup. View of the assembled printed circuit board, about four times life size!

When it comes to installing the unit, note that two methods of connection to the vehicle are possible. On some vehicles the headlight switch is connected directly to the battery so that the headlights operate even when the ignition is turned off (see Figure 3).

Many vehicle manufacturers are now adopting the practice of feeding the headlight switch via the ignition switch, so that the headlights operate only when the ignition is turned on. If your car uses this type of connection then you'll have to install the unit as shown in Figure 4. ●

PCBs





Speed controller for appliances powered by a 'universal' electric motor

Electric drills, saws, grinders, food blenders etc, all benefit from having some sort of control over their speed. Simple electric motor speed controllers, while providing speed control, have limited ability to maintain motor speed constant over widely varying loads. This project overcomes the limitations of these simple units and, despite its simplicity and low cost, is remarkably effective.

Jonathan Scott

JUDGING BY users' remarks on the shortcomings of speed controllers on a variety of electrically driven appliances, and from much personal experience and observation, there is a *considerable need* for a well-designed speed controller for use with electric drills, grinders, saws, food blenders and other appliances driven by 'universal' electric motors.

The more expensive power drills now come with a variable control built into the trigger. Food blenders come *festooned* with an array of buttons marked with a ludicrous range of words with every synonym from 'mix' to 'masticate' represented!

These gadgets all have a severe limitation, namely, that they really only have voltage controllers, not speed controllers, for the motor in the unit. They vary the speed but provide little or no feedback speed control.

In the case of the power drill with a speed control in the trigger, the operator is in a position to adjust the trigger continuously in response to variations in the speed of the shaft, thus effectively becoming part of a feedback loop and serving as the speed *regulating* element.

The variable speed function of these latest drills is really not designed to allow the slow steady pace needed for delicate or laborious jobs, but to allow the unit to act as an electric screwdriver, when fitted with the appropriate bit, where constant speed is not necessary.

Blenders, however, are items which you typically want to turn on and add more and more ingredients (adding more load) as the process progresses. What happens? The jolly blender slows down as the load increases and it's a real bother to have to keep adjusting it. If you're not careful, or in too much of a hurry, you can stall the motor quite easily.

Older electric drills and most high rpm grinders never had any sort of variable speed adjustment, electrical or mechanical. Grinders fitted with a special 'pad' wheel are used for buffing, too. But you have to be quite deft, otherwise it's easy to buff right through the undercoat of a painted object because of the ferocity of the thing.

If you need to drill a particularly tough substance with an older drill, then you have to be prepared to wear out the fine, sharp drill tip very quickly.

So, there is a distinct requirement for some device which can be placed between the appliance plug and the mains that can be used to not only *set* the motor speed, but to *regulate* it as well.

The perils of simplicity

There seems to be fundamentally three degrees of complexity in the way one can design these circuits, each with advantages and disadvantages. All techniques employ some method of sensing the motor back-emf and adjusting the power delivered to keep the back-emf relatively constant.

For the sake of attaching 'handles' to each fundamental technique, I shall dub them — the *crude/economical* method, the *refined/economical* method and the *complex/ultimate* method.

For this project I have chosen the middle course for reasons which will become apparent shortly.

The crude/economical method is the simplest and for that reason has an extraordinary advantage in that it has a low parts count. This sort of circuit requires a diode or two, a pot, a couple of resistors or thereabouts and little else apart from the SCR switching element (see Figure 1). Now, it is hard to beat this sort of economy, but such circuits have a few annoying limitations.

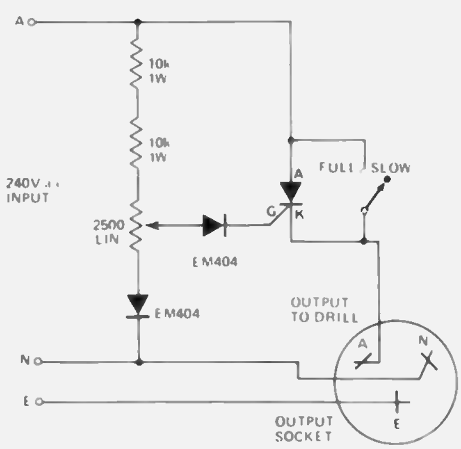


Figure 1. An example of the crude/economical type of motor speed controller. This is the circuit of the ETI-525 Drill Speed Controller (Oct. '74).

Firstly, they will not usually drive anything but the most sensitive SCRs because they deliver very low gate currents. Secondly, some component values can be critical, resulting in touchy or erratic response if tolerances are a bit out or the unit is driving an unusual motor. Lastly, the lack of an amplifying element in the feedback means that the speed regulation, while being above normal for a universal motor, is nowhere near perfect and the speed does drop under load.

To separate the two further types of controller requires a reasonable familiarity with what goes on when controlling a universal electric motor, so I will discuss the technique I have used in this project now and then go on to the explanation of further refinement.

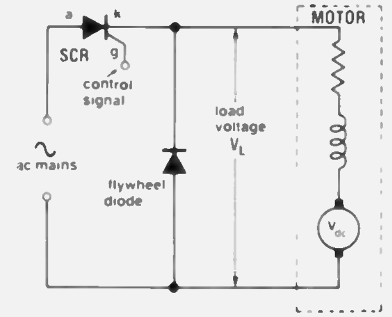


Figure 2. Fundamental circuit elements of the controller used in this project. Note that 'V_{dc}' is the back-emf of the motor.

Controller technique

A universal electric motor appears as a resistance, an inductance and a voltage source in series. The elements of the phase control system I have used — an SCR and a 'flywheel diode' — are connected as shown in Figure 2.

The voltage across the motor terminals during operation of this circuit will appear something like that shown in Figure 3. (Note that the vertical axis is not to scale.)

Considering the cycle from the peak onwards, let us examine the reason behind the appearance of each part of the waveform.

Say that, at some speed setting, the SCR is fired into conduction at about the 100° point of each positive half cycle. The load voltage jumps to a value very nearly equal to the mains voltage at that point (less the small drop across the SCR) and follows the mains cycle variation until the end of that half cycle (i.e. at the 180° point).

Thus, the point between 0° and 180°, of the positive half cycle, where the SCR fires, defines how much voltage is delivered to the load (the motor). Varying the delay before firing provides a means of varying the power delivered to the motor. This is known as phase control, for clearly obvious reasons.

At the point where the mains voltage falls below the back-emf voltage of the motor you would expect the current through the motor to become zero and the SCR to turn off. But, this is not quite the case as the load is not purely resistive. The inductive component of the motor forces its terminal voltage negative in an attempt to maintain motor current, and indeed, the load voltage would follow the mains negative for some way if it were not for the diode connected across the motor terminals.

This diode conducts as the motor voltage goes beyond about 0.7 volts negative and carries the 'flywheel' current from the motor's inductance, generated by the collapsing magnetic field, allowing the SCR to isolate.

The flywheel current persists until the energy stored in the motor's windings is exhausted. This takes typically two to five milliseconds.

Were the diode not there, a large negative-going pulse would result. This, in itself, is not a bad thing, but it is easy to block this and reduce the net dissipation in the SCR, allowing it to control a larger device for the same ratings and prevents the need to make the controller circuitry more complex to resist the negative-going voltage.

At any rate, some way into the negative supply half cycle, the inductance ceases to be the dominating voltage source within the motor and the back-emf becomes evident.

As you may see from the diagram, the motor voltage rises to a level defined by the apparent dc source within the motor equivalent circuit. (The 'back-emf generator'). This voltage is a result of residual magnetism in the metal of the armature and field coils and the relative motion of these two elements.

The actual back-emf developed depends on a number of factors, a major one being speed so it is a good representation of the motor's instantaneous speed.

There is some noise evident on the back-emf voltage, it is not a smooth dc level. This noise is partly due to commutation hash (high frequency spikes) and partly due to different amounts of residual magnetism in different armature segments etc. However, the noise is not sufficient to obscure the speed signal, or back-emf.

In a typical universal electric motor the back-emf would average around 10 volts at full rpm. The control circuitry in the ETI-1515 looks at this dc signal and varies the point at which the SCR fires, increasing the delay if the motor attempts to speed up under decreasing load, or decreasing

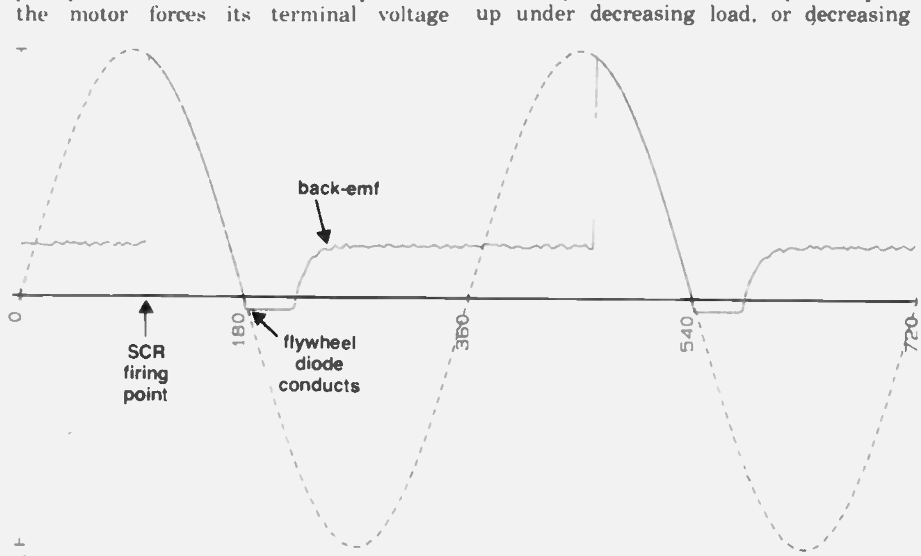


Figure 3. Waveform of the voltage across the motor when using the ETI-1515 speed controller. (Vertical axis not to scale.) The dashed line shows the mains input waveform.

HOW IT WORKS — ETI-1515

The speed of an appliance's motor attached to the project is controlled by applying the mains voltage to it at a set point of the mains positive half cycles, as seen in Figure 3. This is done by turning an SCR on at the appropriate point in the cycle. Turning on the SCR earlier in the cycle applies more voltage, increasing the speed, while turning the SCR on later applies less voltage, decreasing the speed.

The SCR (SCR1) is 'fired' by applying a positive pulse to its gate. This is effected by IC1, an optically-coupled triac driver containing a LED coupled to pins 1 and 2 and a bidirectional optically-operated 'switch' coupled to pins 4 and 6. When the LED in IC1 is off, the switch is off. When the LED is turned on, the switch conducts. If pin 4 is positive with respect to pin 6, it will forward-conduct from pin 4 to pin 6 and vice-versa if pin 6 is positive with respect to pin 4. So that only positive-going pulses are applied to the gate of SCR1, D3 ensures that the switch in IC1 can only conduct during mains positive half cycles.

Resistor R6 simply limits the current through IC1 pins 4 and 6 while R10 prevents false triggering of SCR1 due to small leakage currents.

The control electronics consists of Q1, Q2, PUT1, IC1, RV1 and associated components. The 'flywheel' diode is D6. Power supply for the control electronics is derived by a half-wave rectifier from the mains input. This consists of D2, R2 and C1. This supply is regulated by ZD1, a 33 V zener, R2 providing current limiting. C1 is charged up during the mains positive half cycles and substantially holds its charge during the negative half cycles.

The SPEED control, RV1 is part of a potential divider — R3/RV1/R4. The wiper of RV1 sets a reference level on the emitter of Q1. This can be anywhere between about 4 V and 15 V (with respect to the neutral line), depending on the setting of RV1.

Now, let us see what happens from the point where the mains positive half cycle crosses through the zero point, going negative, at 180° assuming SCR1 has been fired during the preceeding half cycle.

Referring to Figure 3, as the mains crosses through zero, going negative, D6 (the flywheel diode) will conduct, holding the active (A) load terminal at about −0.6 V. The SCR then becomes reverse biased and ceases conducting.

Capacitor C3 will have been charged to a certain voltage (via R12/R13) but will now be discharged via D5. Any charge on capacitor C2 will be discharged via D4/D1/R1.

Diode D6 remains conducting until the inductive backlash of the motor (as explained in the text) dissipates. The voltage at the load active terminal (with respect to the neutral line) then rises to the back-emf level. D5 is now reverse biased, allowing C3 to charge again via R12/R13 until it reaches the level of the back-emf + 0.6 V (D5's forward conduction voltage). Small positive-going 'spikes' on the back-emf level are ignored (momentarily reverse biasing D5) due to the time constant of R12/R13 and C3. This prevents erratic control circuit operation due to this noise. Nevertheless, small fluctuations are still present in the negative peak level held by C3.

Transistor Q2 is forward biased by the voltage drop across R12. The collector of Q2 sources charging current to C2, but this is held discharged via D4/D1/R1 until the mains negative half cycle crosses the zero point and the next positive half cycle begins. When it does, and D1/D4 are reverse biased, C2 will commence charging at a rate determined by the collector current of Q2.

The programmable unijunction transistor (PUT1) has its gate held at about 4 V (with respect to the neutral line) by the potential divider of R7-R8. When C2 charges to 0.6 V above this level, the PUT will 'fire', delivering a current pulse to the LED in IC1. This will operate the switch in IC1 and SCR1 will fire.

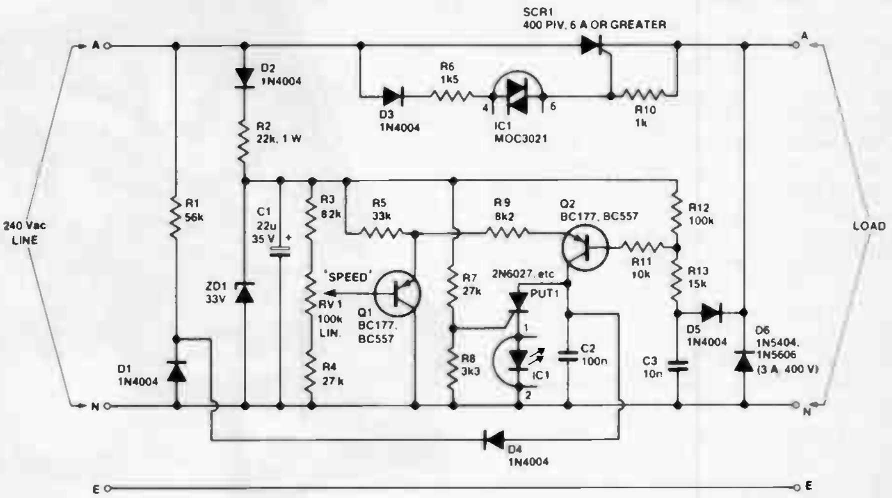
The rate at which C2 charges determines at what point in the cycle the PUT, and thus the SCR, will be fired. There are two mechanisms for determining the rate at which C2 charges, and thus the point in the cycle at which SCR1 is fired.

Firstly, a reference level is set at the emitter of Q1 by the setting of RV1, the speed control. The collector-emitter current of Q2 will depend on the value of the voltage at this point and the value of R9, assuming the base voltage is held constant. Thus, varying RV1 varies the charging rate of C2, setting the point at which SCR1 fires.

Secondly, the base current of Q2 varies (and thus the collector current) depending on the voltage drop across R12. If the back-emf of the appliance motor falls, such as with an increase in motor loading, the voltage held on C3 will decrease (pulled down by D5 conducting current through the load) until it reaches the new value of the back-emf plus 0.6 V (D5 forward drop). This will increase the voltage drop across R12 and thus increase the base and collector current of Q2. Thus, C2 will charge more rapidly each mains positive half cycle, firing the PUT and SCR1 earlier in the cycle. This applies more power to the motor so that its speed is maintained.

If the back-emf rises, such as it would from a decrease in motor loading, the voltage on C3 will rise and the voltage drop across R12 will decrease, decreasing the collector current of Q2. Thus, C2 in this case will charge more slowly, causing the SCR to fire later in the cycle. This will reduce power to the motor so that the set speed is maintained.

The function of R11 is simply to limit the currents in Q2 during those parts of the cycle when Q2 is not responding to the back-emf signal.



the delay if the motor attempts to slow down under increasing load.

In other words, if the motor is slowed by a heavy load the back-emf will drop and the control circuit will fire the SCR earlier in the cycle than where it was originally set to fire. This applies the mains voltage to the motor for a longer period, bringing the motor speed back up again. If the motor speeds up when load is reduced, the opposite happens.

Thus, the motor speed will be held constant. It sounds as if the motor will slow down then speed up, or vice versa, but the control variation actually happens within one mains cycle or so and any variation in motor speed will not be apparent.

Readers familiar with control theory will notice that this mechanism forms a control feedback loop. Within the control electronics of this project I have included some amplification which enables the unit, firstly, to drive even quite insensitive SCRs, secondly, to reduce the speed error to a relatively small value and, thirdly, to have a relatively high impedance presented to the reference level (speed) control which is a voltage produced by a potentiometer. This overcomes the limitations of the cruder controllers.

However, the controlled element is a mechanical system with a lot of inertia which represents a significant pole in the transfer function. Hence, it can be anticipated that there will be a trade-off: increasing the amplifier's effective gain will improve regulation all right, but if it is increased too far the system will become unstable and the engine speed will 'hunt', or oscillate about a mean value at a low frequency.

The perils of complexity

It turns out that, in the case of most motors, a very satisfactory degree of speed regulation can be achieved with only a hint of hunting detectable at *very* low speeds. This is most fortunate as it means that one does not require to advance to the next step of complexity, namely using the third technique mentioned earlier — the *complex/ultimate* circuity with its own compensating system incorporated to guarantee the stability of the system under *all* conditions, despite large loop gain.

The reason that this type of circuitry is to be avoided, for the applications considered in the introduction to this article, is that it would require a great deal more electronics (and cost!). This would basically entail a mechanism capable of smoothly holding the back-emf signal so it could be further processed, which means some kind of sample-and-hold gate plus some synchronising signal. Once isolated, the signal is easily dealt with, but the process is much more complex than the simple instantaneous method employed in the ETI-1515.

One further refinement in a complex/ultimate controller may occur to the astute reader: namely, having the circuit capable of using the full 360 (or very nearly) of the mains supply cycle. The systems described so far all assume that an SCR will be used to control the current delivered and not a triac. Hence, at most, only 180° of the mains cycle is available as the SCR must remain in a blocking state during the negative half cycle. Although a triac would permit use of the negative cycles, as would full-wave rectifying the mains before applying it to the SCR, these methods have one problem.

The sensing of speed, so that the speed may be regulated, requires access to the back-emf voltage, blanked immediately after a current zero. Hence, any attempt to employ near-continuous power application would be hampered by the inductive 'backlash' concealing the motor's true back-emf value. Any such system would have to be capable of operating in a mode which left only every fourth or sixth half cycle unemployed for the purpose of 'getting at' the back-emf for speed sensing.

While possible, this would not only require considerable circuitry, but would also tend to impart some roughness to the torque delivered. Hence, such methods are well abandoned for the applications for which the ETI-1515 has been designed. It is a realm of circuit complexity which returns benefits only with physically large machines.

Back to the project

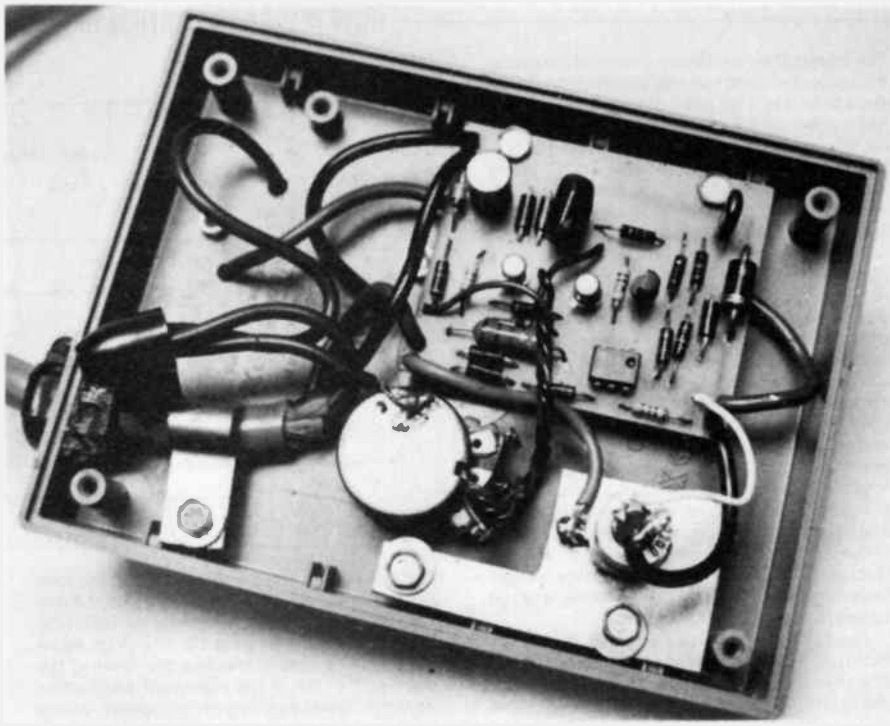
The ETI-1515 has been designed to be a good compromise between the crude/economical and complex/ultimate controller. Speed can be set from full rpm on no load (at 'half power') down to less than one-tenth normal. This is lower than you're ever likely to need. On low speeds and without any load there is a tendency for motors to 'hunt' about the set speed, power being applied in detectable jerks. But, even when only a light load is applied, this has the effect of damping the control loop, improving the control and smoothing out the variations

The torque characteristics of the circuit are excellent, until you approach the 180 limit of the cycle — which is, in any case *way* beyond what you will need in common situations.

A good 'worst case' example is that of making houmous, a particularly thick and pasty (tasty, too!) dip, in a blender. Initially, the mixture is oily, but as the blending proceeds it changes to a *very* glutinous consistency and blenders invariably begin to labour *agonisingly* at this point. With the ETI-1515 in control — no problems!

Construction

Safety is a major consideration in a project such as this. Choosing a box in which to house the components has to be done carefully



Inside. Construction is quite straightforward — but take heed of the safety precautions mentioned in the text! Note that, in use, there may be a slight 'dead band' at either end of the speed control rotation where nothing happens

because the project will be used in a work environment and is likely to encounter more than the usual amount of rough treatment.

I chose a strong, but not brittle, plastic case which comes in two halves, secured by recessed self-tapping screws that set into plastic pillars in the bottom half of the case. The particular case used on the prototype was a 'Unibox', model P/N 140 which measures 135 mm long by 100 mm wide by 38 mm deep.

Shape is unimportant, along with size, just so long as all the components can be fitted with ease and the box is not cumbersomely large. If you choose a box with a metal facia or panel, make sure this is *securely* earthed. If you can, get a box which provides internal posts to which the pc board and SCR mount can be secured with self-tapping screws so that no metal parts attached to these can protrude through the exterior of the case. If you must use a case that doesn't meet this requirement, secure 'the workings' with nylon nuts and bolts. All this is for your own protection.

The potentiometer used was of the conventional type, having a metal case, bushing and shaft. I earthed the pot. case, as shown in the wiring and overlay diagram. If possible, it would be an even better idea to obtain a pot with a plastic bushing and shaft.

The mains cable *must* be firmly secured with either a clamp-type grommet where it enters the case, or with an ordinary grommet followed by a cable clamp. I used both a clamp-type grommet *and* a cable clamp, for good measure. (That's probably overdoing it, but, please yourself — Ed.)

Best place to start assembling the project is by drilling the few necessary holes in the box. If you are making a direct copy of the prototype, then positioning of the major components is clear from the internal photograph. If you're using a different box then arrange the major components first and determine where you have to drill holes. Don't crowd the parts against one another. Use the blank pc board as a template for marking its mounting hole positions.

If you're using an SCR type that is not in a stud-mount package, then you'll have to arrange a suitable mount for it. I used a C220D type in a stud-mount, screwing it to a small piece of aluminium which also serves as a heatsink of sorts. SCR dissipation is small, so this heatsink/mount need only be small.

Just bolt the SCR to the heatsink, without any insulator, and use some thermal compound to improve thermal contact between the body of the device and the heatsink. REMEMBER — the heatsink will be at MAINS POTENTIAL, so make sure when mounting it that no securing bolts protrude through the case or use nylon nuts and bolts.

I mounted the SCR separately to the pc board so that a wide range of SCR types and packages could be readily accommodated, from the stud-mount C220D I used in the prototype to small, 6 A-rated, flange-mount plastic pack devices.

It is difficult to specify a 'load rating' for the project in terms of the SCR's characteristics because of motor surge current characteristics and the range of motor ratings in appliances. A 6 A-rated SCR will happily handle an appliance rated to draw a nominal 2 A under 'normal' load. The C220D used in the prototype will reliably handle an appliance rated at four to five amps, right up to full revs setting under almost-stalled-rotor conditions.

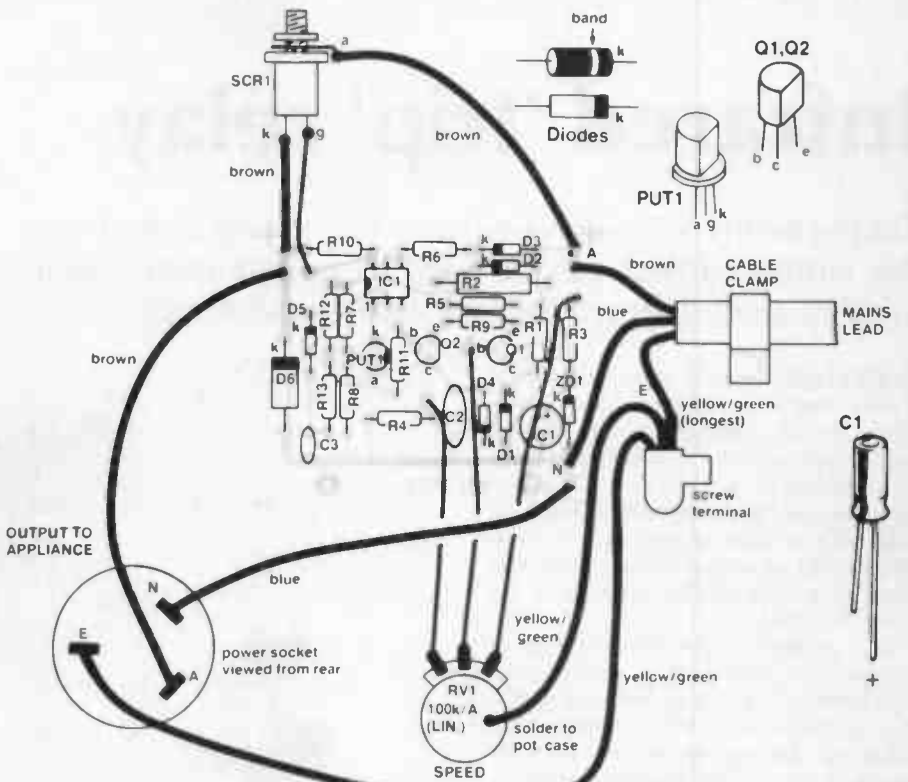
Before attaching the 3-pin panel-mount mains outlet socket to the outside of the case,

PARTS LIST — ETI-1515

Resistors	all ½W, 5% unless noted
R1	56k
R2	22k, 1 W
R3	82k
R4	27k
R5	33k
R6	1k5
R7	27k
R8	3k3
R9	8k2
R10	1k
R11	10k
R12	100k
R13	15k
RV1	100k/A linear pot.
Capacitors	
C1	22u/35 V RB electro.
C2	100n greencap
C3	10n greencap
Semiconductors	
D1-D5	1N4004, EM410 etc.
D6	1N5404, 1N5606 etc.
IC1	MOC3021 triac opto-isolator
PUT1	2N6027, D13T1 etc
Q1, Q2	BC177, BC557
SCR1	any type, 400 PIV/6A or greater

Miscellaneous
ETI-1515 pc board; case — Unibox P/N 140 (135 x 100 x 38 mm) or similar size to suit; 3-pin panel-mount mains socket; mains cable and plug; small scrap of aluminium, self-tapping screws; screw terminal block, etc.

Price estimate
$20 — $24



Overlay and wiring diagram. Follow this to assemble the pc board and wiring up of the external components

The pc board pattern is on page 90

Note. If you find your speed potentiometer has a considerable dead band at the top (towards full speed) end this indicates your drill has lower back-emf than that designed for. The cure is to increase R3. If all the speed control is crowded over about 60° of rotation, increase R3 to 330k. If you get 90° or 100° of rotation for zero to full speed, change R3 to 220k or 180k, etc. You may need to increase R4 from 27k to 56k or 68k also. DISCONNECT THE UNIT FROM THE MAINS BEFORE MAKING ANY MODIFICATIONS

attach *colour-coded* wires to its terminals and thread these through the holes drilled for them in the case. Take care that you get the active (A), neutral (N) and earth (E) wires correct. Use wire from a short length of stipped-down mains flex.

When attaching the mains cable, cut back the sheath so as to expose some 150 mm of the three wires to provide connections later. Make sure the cable is very firmly secured.

Mount the potentiometer using nuts on *both sides* of the case panel and lock the bushing tight so that there's no possibility of the pot. body coming loose and being rotated when the knob is turned.

Assemble the pc board next, according to the overlay diagram. You'll find it easier to solder the diodes in place first, followed by the resistors, capacitors and the rest of the semiconductors. As usual, watch the orientation of all the semiconductors and the electrolytic capacitor (C1).

Having done that, *check it*. Make an especially careful examination of the soldering as diagnosis of problems will be dangerous and/or difficult later because the board operates 'live'. In other words, if you are going to make only one project work first time this year, make it this one.

Attach the three wires that go to the potentiometer. Better colour-code or mark these in some way to avoid confusion and wiring errors. Make sure they're long enough. Ordinary hookup wire will do for these. An ordinary piece of hookup wire can also be used for the lead to the SCR gate. The leads to the SCR anode and cathode carry mains potential and load current and should be wired using mains-rated wire. Get it from some stripped-down mains flex, like before.

Now wire up the mains input cable and the mains outlet socket to the pc board, then *check it*.

Note that the earth wire on the mains input cable should be longer than the active and neutral wires. Should the mains cable come adrift, the earth wire would then be the last to break.

The try out

When you're satisfied the project is correctly together it's time for a try-out. Just plug in your drill, blender or whatever into the outlet socket, set the speed pot. a bit up from minimum, plug the controller into the mains and switch on. See that the appliance's motor rotates at some low speed. Advance the speed control and see that the motor speed increases, as expected. If nothing's happening at this stage, switch off, unplug everything and go over your wiring (this assumes you *know* the appliance works).

If that works, then try applying a load with the motor set at some convenient speed and see that the controller maintains the motor speed. If not, you've got troubles on the pc board and you'd better unplug everything and go over it.

If you are using the unit with an unusual motor, where the inertia of the armature may be greatly different to that expected by this circuit, you can vary the gain of the feedback amplifier by simply changing the value of R9. This can be varied between a minimum of about 150 ohms and a maximum of 22k.

Thus, if the motor hunts excessively (especially at low speed settings), R9 may be increased from the 8k2 value shown, reducing feedback loop gain and restoring stability at a small price in speed constancy. If the reverse is the case, you can acquire tighter regulation by reducing R9 — but check that hunting is kept to a minimum.

Finally, several words of caution are in order. The power bursts which are applied to the motor by the SCR switching and the control system variations with the motor armature running at low speed, applies a lot of stress to the motor's brushes and armature windings, so the controller should not be used in applications where it's not really necessary. Wear from the controller's use is unlikely to significantly shorten the life of an appliance, but it is never good practice to strain a mechanical device unnecessarily.

In addition, many appliance motors, particularly drills, employ a small cooling fan on the armature. The cooling effect of the fan is reduced and extended periods of operation at low speeds should thus be avoided. ●

Infrared 'trip' relay

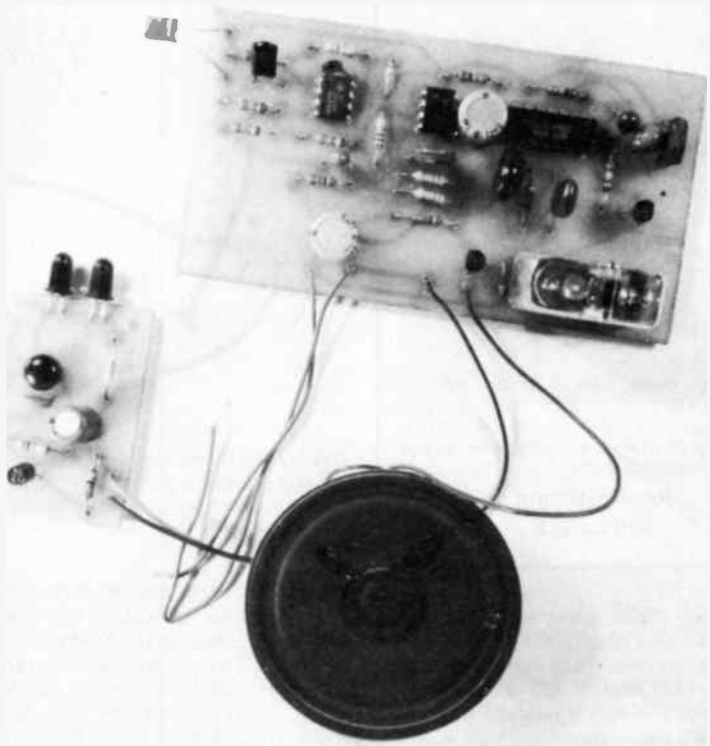
Cut the beam of invisible light and 'trip' a relay or alarm — this simple project can be used as an automatic 'door minder', door opener, a burglar alarm or whatever.

Phil Wait
William Fisher

EVERYONE is familiar with the kind of door that's operated by an invisible beam. As you approach the door your body interrupts the beam, which triggers a switch to open the door. The same principle can be used for other things as well, like a 'door minder' alarm. The beam is set up across the doorway and when a person walks through it an alarm is set off.

This project is the basis of such a system. It comprises a transmitter which emits a beam of infrared radiation and a receiver which detects that radiation. As long as the receiver continues to receive the radiation nothing happens, but if the beam is interrupted a relay is energised (or 'tripped') and latched on for a fixed period of time. The contacts of this relay could carry the current for any 12 volt device, like a lamp, a piezoelectric siren, a small motor or whatever the application calls for. At the same time as the relay is energised, a low-level oscillator is switched on so that a buzzing noise can be heard through a loudspeaker if this is wanted.

The infrared beam is produced by two infrared light emitting diodes. These are just like any other LED, except that the light they emit has a longer wavelength. They use quite a lot of current, so to prevent batteries going flat too quickly they are supplied with very brief pulses of current at intervals of a few milliseconds, so that they emit short, intense bursts of radiation. This also makes it easier to detect the radiation. The range of the system is about two metres, which we thought was adequate for many applications. You could increase the range to about three metres by using two transmitters instead of one, but to increase it further requires a disproportionate amount of power. The range is inversely proportional to the square of the radiated power, so that doubling the range means quadrupling the amount of radiation transmitted, tripling the range means increasing the transmitted radiation by nine times, and so forth.



Construction

We recommend that you use our designs of printed circuit boards to construct the transmitter and receiver, but they are not essential.

Start by mounting the resistors on both boards, referring to our layout diagrams for their positions. Like all the components, these go on the plain side of the board, with their leads pushed through the holes and soldered to the tracks on the other side. Next, solder in all the capacitors on both boards, making sure that all the electrolytic or tantalum capacitors are correctly oriented with their positive leads at the ends we have shown.

Now mount the two infrared LEDs (LED1 and LED2) on the transmitter board. They must go in the right way round, with their cathodes (marked k on our diagrams) at the correct end. After that, mount the two transistors on the transmitter board (Q1 and Q2), making sure that their base, emitter and collector leads (marked b, e and c on our diagrams) are in the correct positions.

Turning to the receiver board, mount the two potentiometers (RV1 and RV2), then insert the diode (D1) and the infrared detecting diode (IRD1), making sure their cathodes are at the correct ends. In the case of IRD1 you also have to make sure that the sensitive side, of the diode faces away from the board so that it can be pointed at the transmitter. The diode has two faces, one flat and one bevelled near the top, the flat side being the sensitive side. Mount IRD1 high enough above the board for it to be bent over to face the proper way.

Then mount the two transistors (Q1 and Q2), making sure you get all their leads in the right places. After that you can tackle the integrated circuits (IC1, IC2 and IC3). Make sure you put them in with the notch or spot at the same end

The pc board pattern is on page 45.

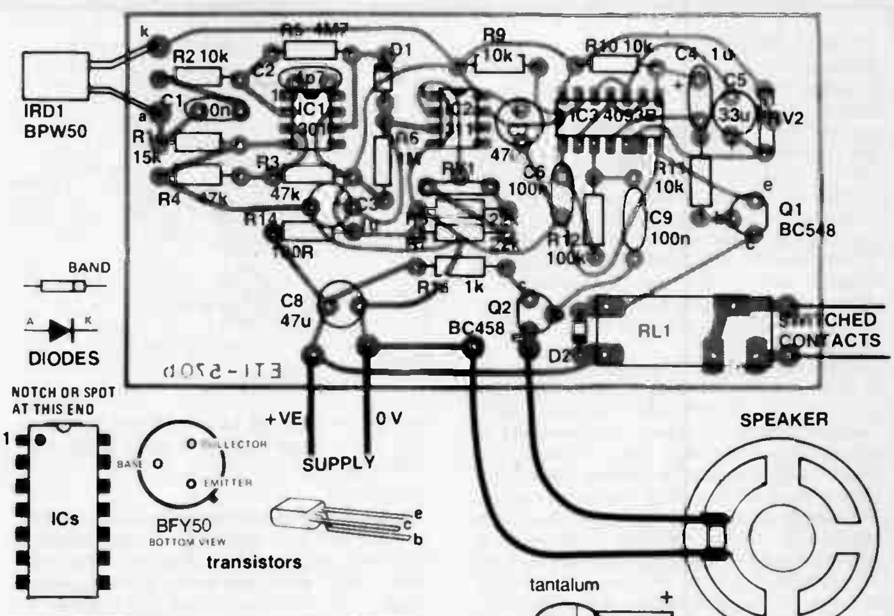
PARTS LIST — ETI 570

ETI-570a Transmitter

Resistors	**all ½W, 5%**
R1	47R
R2	10M
R3	3R3
Capacitors	
C1	1n greencap
C2	100u/16 V electro.
Semiconductors	
LED1,2	CQY89A or similar
Q1	BC558, BC178 or similar
Q2	BFY50 or similar
Miscellaneous	
ETI-570a pc board; case to suit, etc.	

ETI-570b Receiver

Resistors	**all ½W, 5%**
R1	15k
R2,R9-R11	10k
R3, R4	47k
R5	4M7
R6	1M
R7, R8	22k
R12	100k
R13	1k
R14	100R
RV1	100k min. vertical mount trimpot.
RV2	1M min. vertical mount trimpot.
Capacitors	
C1	10n greencap
C2	4p7 ceramic
C3, C4	1u/16 V tantalum
C6, C9	100n greencap
C5	33u/16 V tant, or RBLL
C7, C8	47u/16 V electro
Semiconductors	
D1	1N914,1N4148 or sim
D2	1N4002, etc.
IRD1	BPW50 or similar
Q1,Q2	BC548,BC108 or similar
IC1	301
IC2	311
IC3	4093B



Miscellaneous

RL1	SPDT pc mount relay with 12 V coil

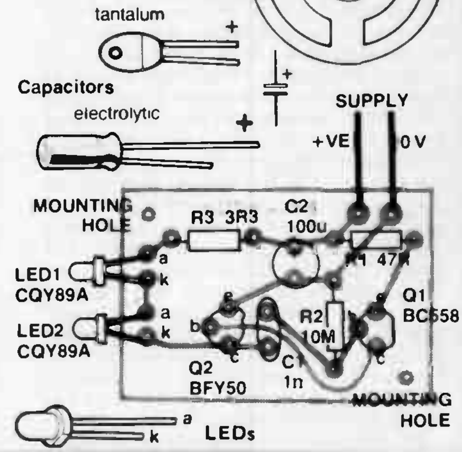
ETI-570b pc board, miniature 8 ohm speaker, case to suit, etc.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$21—$25

Note that this is an estimate only and not a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.



as our layout diagrams show, and take care when soldering them in that you don't overheat them. Use a reasonably small bit, don't spend too long over each pin and allow the whole IC to cool down for a few seconds between soldering each of the pins.

Finally mount the relay, connect the loudspeaker to the board (using insulated hookup wire), attach two insulated leads for the power supply, and attach the battery clip to the transmitter board. The transmitter and receiver are now both completed.

Setting up

Connect a 12 volt battery or power supply. Adjust RV1 for minimum resistance. With the transmitter turned off, increase the value of RV1 until the relay just operates. You will notice that the relay will switch off as the latch resets at the end of the timing period, then switch on again as the latch is set again.

Turn on the transmitter and move it away from the receiver, keeping the two LEDs pointing towards the receiver all the time. You should be able to move two metres away without anything happening. If you find that the receiver is not sensitive enough, you can add another infrared receiving diode in parallel with IRD1 to increase the amount of radiation it picks up. If the range is OK, check that the relay operates when the beam is broken.

The volume of sound from the speaker can be altered by altering the value of R13. Reducing the value of R13 increases the volume, increasing R13 reduces it. You can also vary the time that the relay contacts are closed by varying the setting of RV2.

Housing

As individual applications of this project will vary widely, we have not described how to house it in any specific way. However, a few hints may help. The transmitter could be housed in any convenient small container, such as a jiffy box or even a cheap plastic soapholder from a chain store. The two infrared LEDs can be mounted in any convenient position, secured with common LED 'collar' mounts. When mounting the LEDs, keep in mind how you will mount the transmitter box so that the LEDs face in the desired direction.

The receiver can also be mounted in any suitable housing. The infrared receiver diode may be mounted off the pc board or the board positioned so that the diode is held against a hole cut in one side of the case. Alternatively, the receiver diode may be mounted on a tagstrip bolted in an appropriate position. You can secure a small piece of infrared filter plastic over the hole in the case. This will provide some physical protection for the diode. Kodak 'Wratten 89c' or a similar type of filter plastic will do. Make sure you correctly identify the sensitive face of the diode.

For outdoor applications, where the units may be exposed to the weather, we recommend you use aluminium diecast boxes. They're more expensive than other housings, but they're very robust and can be sealed against the weather.

HOW IT WORKS

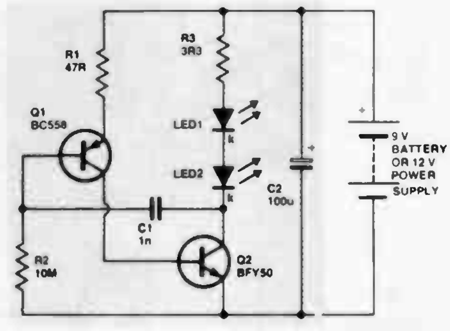
TRANSMITTER

A serial multivibrator allows frequent short pulses of current through two infrared LEDs, so that they emit pulses of radiation towards the receiver. To ensure a reasonable battery life, the duration of each pulse is kept short compared to the interval between pulses. Because the pulse length is short, the LEDs can pass a current of more than one ampere without burning out, thereby producing a high level of radiation that can be detected at a distance of about two metres. The radiation output is further increased by using two LEDs in series.

When the circuit is turned on, the base of Q2 is at a low voltage and Q2 is therefore turned off. This means that Q2's collector is at a voltage close to the battery supply voltage. A small current therefore flows through R3, LED1, LED2, C1 and R2 to ground. The voltage drop across R3 caused by this current keeps the base of Q1 at a 'high' voltage, so that Q1 is turned off. As C1 charges, it develops a voltage across its plates that opposes the flow of current through R3. The voltage on the base of Q1 therefore starts to drop, and when it has dropped about 0.7 volts below the supply voltage, Q1 turns on. This allows current to flow through the base-emitter junction of Q2 and turn that transistor on also, so that a large current can flow through R3 and the two LEDs.

The current through Q2 is large because of the low value of R3, and the high internal resistance of the battery means that it cannot supply this current without a considerable drop in the voltage across its terminals. The current therefore comes mainly from the discharging of capacitor C2. Once C2 has discharged, the low voltage across the battery terminals cannot drive enough current through R1 and Q1 to keep Q2 turned on, so this transistor turns off again, cutting off nearly all the current through the LEDs and allowing the battery voltage to rise again.

While Q2 is turned on, its collector voltage is low, which allows C1 to discharge, so that when Q2 turns off again the circuit is in the same state as it began in and the whole cycle repeats itself over and over again until power is turned off. The frequency of the pulses depends on the time taken for C1 to charge (which depends mainly on the battery voltage and the values of C1 and R2). The duration of each pulse depends on the time taken for C2 to discharge (which depends mainly on the battery voltage and the values of C2 and R3). The values we have specified for components give pulses a few microseconds long at intervals of a few milliseconds. The peak



INFRARED TRANSMITTER

current through the LEDs is about one amp, but the average current is only about one milliamp.

RECEIVER

The pulses of infrared radiation emitted by the transmitter are detected by an infrared receiving diode and amplified by an op-amp. The output pulses from the op-amp are used to keep a capacitor discharged, and a comparator IC compares the voltage across this capacitor to a reference voltage. As long as the reference voltage is higher, the comparator puts out a 'high' voltage and nothing happens. When the infrared beam is interrupted, there are no current pulses to keep the capacitor discharged, so its voltage rises and the comparator output swings low. This low voltage operates a latch, one of whose outputs switches on a transistor to allow current through a relay to close its contacts. The other latch output switches on an oscillator to produce a tone in a loudspeaker. When a set period of time has expired, the latch is automatically reset, cutting off current to the relay and loudspeaker.

When a pulse of infrared radiation strikes the receiving surface of the reverse-biased infrared receiving diode (IRD1), it conducts a pulse of current. The voltage drop across R1 caused by this current pulse is applied to the inverting input of op-amp IC1 via coupling capacitor C1. The non-inverting input of IC1 is held at a steady voltage by the potential divider R3 and R4. Negative feedback through R5 sets the gain of IC1 at around 500. Since the input pulses are applied to the inverting input of IC1, the amplified output pulses are negative-going.

The diode D1 passes only the negative pulses, which discharge capacitor C3. Because R6 has a high value, C3 cannot charge much between pulses, so that a continuous series of pulses from the transmitter keeps C3 discharged, with a low voltage across its plates. If the beam from the transmitter is interrupted, C3 charges up and the voltage across it rises.

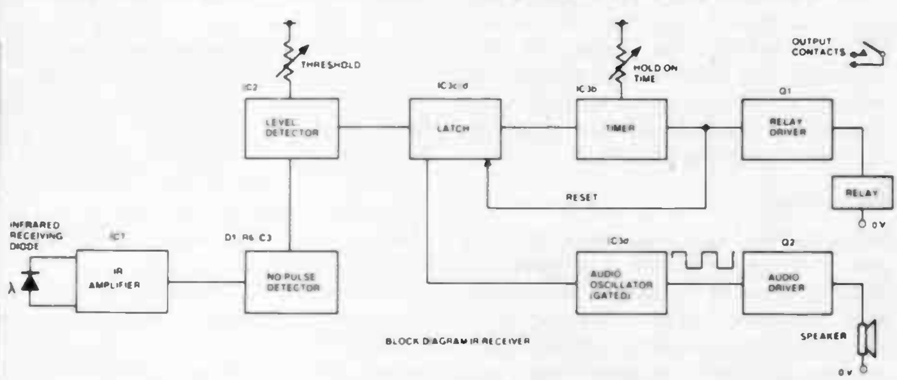
IC2 is a comparator. Its output (at pin 7) is high when the voltage on pin 2 is higher than the voltage on pin 3. If the voltage on pin 3 is higher than the voltage on pin 2, the output of IC2 is low. Pin 2 is held at a constant preset voltage by the potential divider chain of R7, RV1 and R8. When pulses are being received, C3 is discharged and the voltage on pin 3 is therefore low; when the beam is interrupted, C3 charges up and the voltage on pin 3 rises, switching the output of IC2 from high to low.

IC3b, IC3c and IC3d are Schmitt-triggered NAND gates connected as a latch circuit. If either of the inputs of a Schmitt-triggered NAND gate is low, then its output is high. If both inputs rise above a 'threshold' voltage, the output goes low. If either input then falls below a second threshold voltage, the output goes high again.

When power is first turned on to the circuit, pins 5 and 6 of IC3b are held high via RV2, so that its output (pin 4) is low. This means that current can flow through R10 and C4 to pin 4 of IC3b and the voltage drop across R10 caused by this current makes pin 8 of IC3c go low. Output pin 10 of IC3c therefore goes high and so does input pin 12 of IC3d. If pulses are being received from the transmitter, pin 13 of IC3d is also high, so that output pin 11 is low. Input pin 9 of IC3d is therefore held low also, and this low on pin 9 keeps the output of IC3c high, even after pin 8 goes high again, because capacitor C4 has charged up and stopped current flowing through R10.

When the pulses are interrupted, pin 13 of IC3d goes low, sending output pin 11 high. Pin 9 therefore goes high too and since pin 8 is also high, output pin 10 goes low. Current then begins to flow through RV2 and C5 to pin 10, causing a voltage drop across RV2 which sends pins 5 and 6 of IC3b low. Output pin 4 of IC3b therefore goes high and current flows from this pin through R11 to turn on transistor Q1, allowing current through the relay to close its contacts. At the same time, the high on pin 11 of IC3d is applied to input pin 2 of IC3a, which is another Schmitt-triggered NAND gate configured as a square wave oscillator. Capacitor C5 slowly charges up from current through RV2, developing an increasing voltage across its plates. After a while, the voltage on C5 forces the inputs of IC3b above the threshold voltage and its output (pin 4) goes low, cutting off the bias current to Q1, which therefore turns off and stops current to the relay so that its contacts open again. The low on pin 4 of IC3b allows a pulse of current to flow through R10 and C4, which resets the latch.

When pin 2 of IC3a goes high, the other input (pin 1) is initially low, so that output pin 3 is high. This allows current to flow from pin 3 through R12 and C6 to ground. At first the voltage drop across R12 caused by this current keeps pin 1 low, but after a short time C6 has charged up and developed a voltage across its plates which forces pin 1 above the threshold level. Pin 3 therefore goes low and C6 discharges into it through R12. As C6 discharges, its voltage drops and after a little while pin 1 drops below the threshold, so that pin 3 goes high again. The oscillator is then in the same state it began in and the process repeats itself over and over again, producing



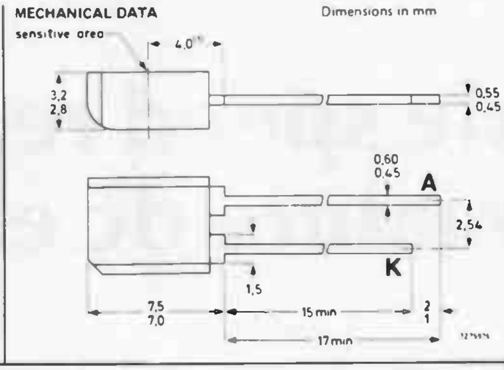
BLOCK DIAGRAM IR RECEIVER

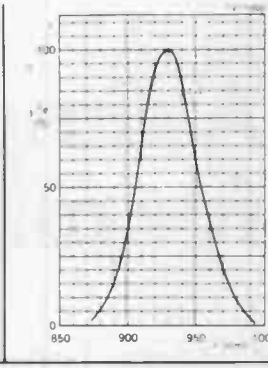
SILICON PHOTO P-I-N DIODE

Silicon photo p-i-n diode in a plastic envelope with an infrared filter.

QUICK REFERENCE DATA

Continuous reverse voltage	V_R	max.	32	V
Total power dissipation up to T_{amb} = 47,5 °C	P_{tot}	max.	150	mW
Junction temperature	T_j	max.	100	°C
Dark reverse current V_R = 10 V; E_e = 0	$I_{R(D)}$	<	30	nA
Light reverse current V_R = 5 V; E_e = 1 mW/cm²; λ = 930 nm	$I_{R(L)}$	>	30	μA
Wavelength at peak response V_R = 5 V	λ_{pk}	typ.	930	nm
Sensitive area	A	typ.	5	mm²



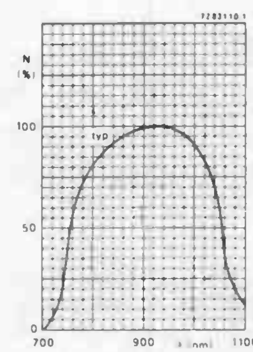


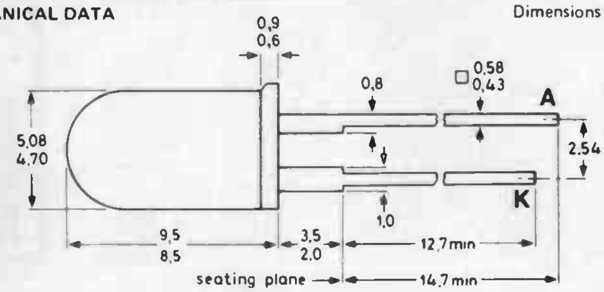
GaAs LIGHT EMITTING DIODE

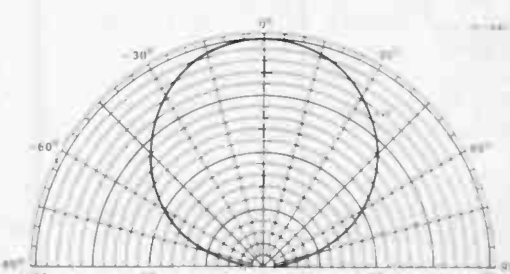
Epitaxial gallium arsenide light emitting diode intended for remote-control applications. It emits radiation in the near infrared when forward biased. Infrared translucent epoxy encapsulation (dark blue).

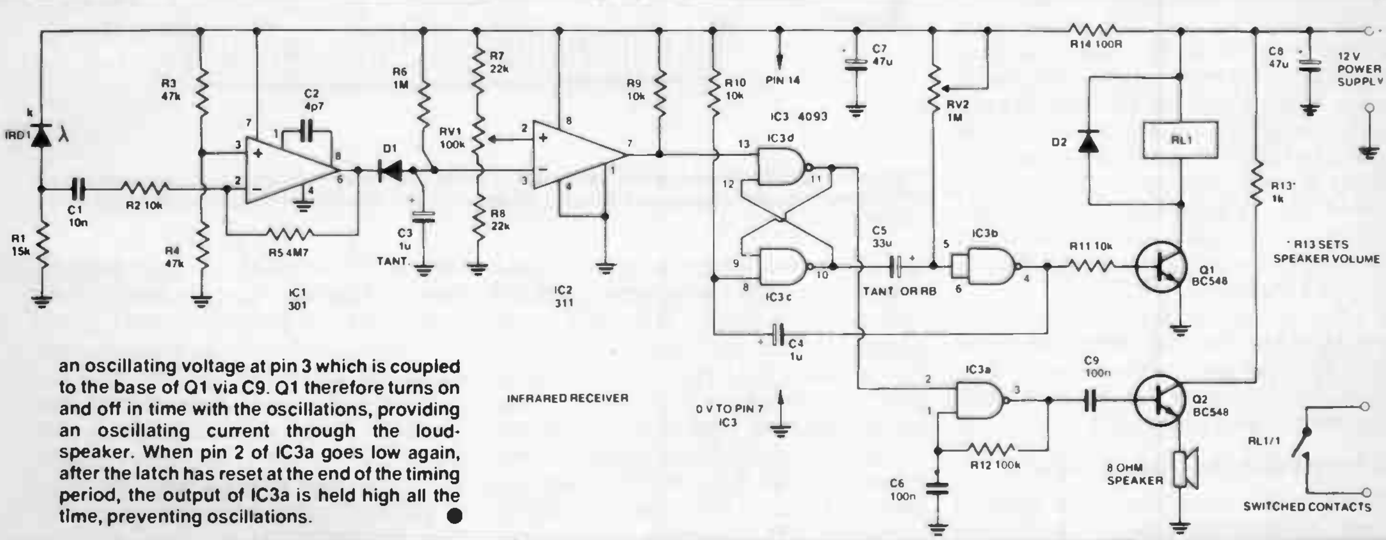
QUICK REFERENCE DATA

Continuous reverse voltage		V_R	max.	5	V
Forward current (d.c.)		I_F	max.	130	mA
Total power dissipation up to T_{amb} = 25 °C		P_{tot}	max.	215	mW
Junction temperature		T_j	max.	100	°C
Radiant intensity (on-axis) at I_F = 100 mA	CQY89A	I_e	>	9	mW/sr
	CQY89A-1	I_e		9 to 20	mW/sr
	CQY89A-2	I_e	>	15	mW/sr
Wavelength at peak emission		λ_{pk}	typ.	930	nm









an oscillating voltage at pin 3 which is coupled to the base of Q1 via C9. Q1 therefore turns on and off in time with the oscillations, providing an oscillating current through the loud-speaker. When pin 2 of IC3a goes low again, after the latch has reset at the end of the timing period, the output of IC3a is held high all the time, preventing oscillations. ●

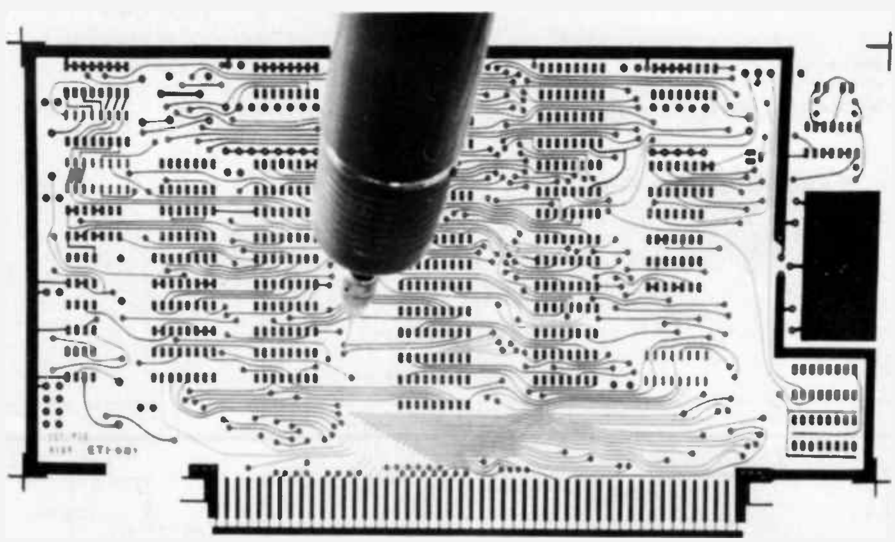
A simple speed regulator for miniature dc electric drills

Graeme Teesdale

Mini-drills are inexpensive, handy and widely used amongst electronic hobbyists, servicemen and technicians. Their one drawback is poor speed regulation under load. This simple circuit fixes that!

'MINI-DRILLS' are widely used by a whole range of hobby and craft enthusiasts — electronics hobbyists, technicians, etc, finding them very useful for drilling holes in pc boards, deburring holes in panels and similar applications. Many mini-drills locally available incorporate a 12 Vdc motor and have a chuck speed of around 6000 to 10 000 rpm. Unfortunately, this tends to drop dramatically when you're trying to drill a pc board — particularly if it's a fibreglass pc board. Many are meant to be operated from batteries, often at a reduced voltage (and lower chuck speed, but fast enough for many applications). Operation is best with fresh batteries but the motor stall current can be as much as one amp. Operating current may be 200 mA or more under a reasonable load. The output voltage of most dry batteries 'sags' rather a lot under such loading owing to their internal resistance and the drill speed drops accordingly. The drill bit's efficiency therefore drops alarmingly and all of a sudden you have difficulty drilling the hole.

This project consists of a dc supply which senses the load on the drill motor by sampling the current drawn, then boosting the supply output to maintain the motor speed under load.



Perhaps the most common use for a mini-drill is drilling the holes for components in pc boards. It's a time-consuming job unless your drill has a suitably high chuck speed (over 6000 rpm) and good speed regulation.

The problem, the solution

What causes the speed of the motor to drop when it is loaded? Normally, a fairly constant voltage is applied to the motor from either a battery or a fixed voltage power supply. When the motor is run without any load the speed increases until the power consumption is exactly sufficient to cover losses in the motor. When a load is placed on the motor, the speed drops, back-emf reduces and the difference between the back-emf and the supply voltage increases. This causes the motor current to increase. A new reduced speed is reached when the losses of the motor and the power delivered to the load equal the increased power consumption. Since the motors in these mini-drills generally have a fixed flux magnetic field (i.e: permanent magnet stator), to increase the speed to the unloaded speed (or to increase the speed at all) the supply voltage to the motor must be increased.

The circuit used in this project employs a standard three-terminal positive voltage regulator IC and a transistor differential pair in a feedback circuit to increase the output of the regulator under load. An LM340T5 (National Semiconductors) regulator was used here. A 7805 could equally well be used.

How's it used? Well, the output voltage of a 5 V three-terminal positive voltage regulator can be increased by returning the 'reference' (REF.) pin to the junction of a resistive divider connected between the output terminal and 0 V, as shown in the circuit.

The output voltage is determined by the formula:

$$V_{out} = 5\ V + \left(\frac{5}{R_2} + I_Q\right) R1$$

The output voltage can be varied by making the resistor R1 in the circuit adjustable. In this project, R1 is replaced by a suitably biased transistor (Q1 in the circuit).

PARTS LIST — ETI 258

Resistors	all ½W, 5% unless noted
R1, R2	470R
R3	0R22, 5 W
R4, R5	100k
R6	220R
RV1	10k
Capacitors	
C1	2200u/25 V electro.
Semiconductors	
D1-D5	1N4004 or similar
Q1, Q2	BC547
IC1	LM340T/5 3-terminal regulator
ZD1	12 V, 400 mW or 1 W zener

Miscellaneous

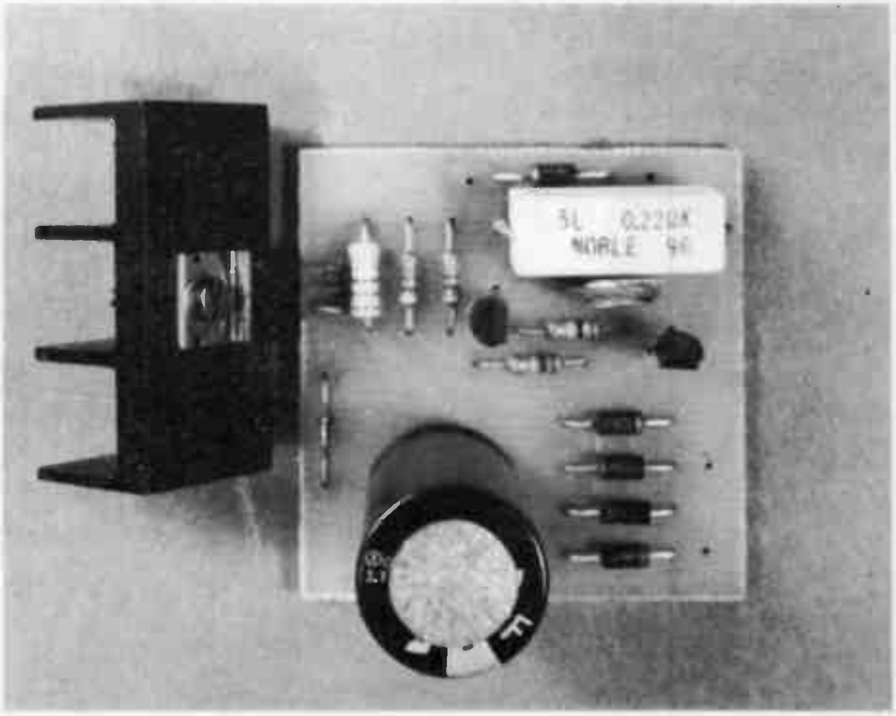
ETI-258 pc board; 12-14 Vac supply (i.e: plugpack); wire; zippy box to suit, etc.

Price estimate

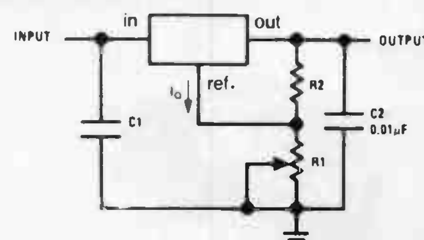
We estimate that the cost of purchasing all the components for this project will be in the range:

$6 - $8

Note that this is an **estimate** only and not a recommended price. A variety of factors may affect the price of a project such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel (if used) supplied etc — whether bought as separate components or made up as a kit.



Construction is very simple — as you can see! The pc board is not absolutely essential, but convenient. The trimpot, RV1, visible just adjacent to the 0.22 ohm 5W resistor (R3), is adjusted to provide a nominal 12 Vdc at the output terminals under no load. Adjustment is relatively non-critical.



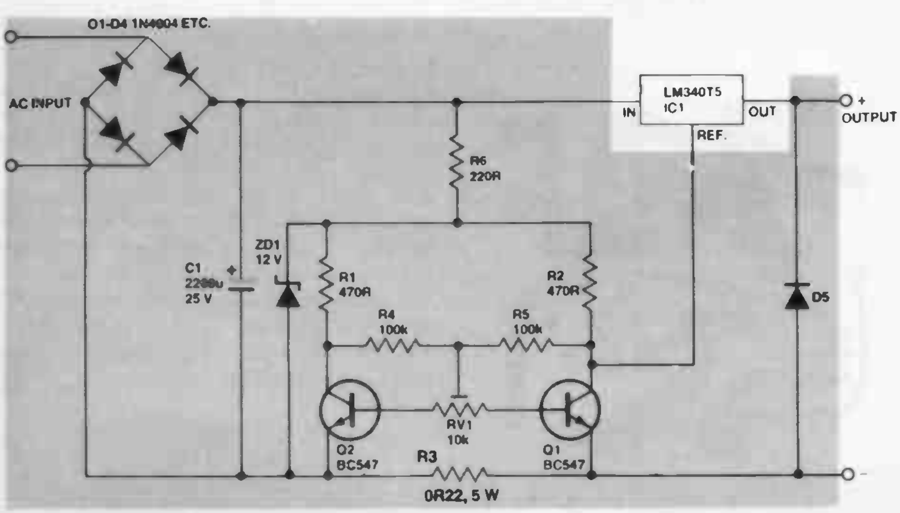
Showing how a three-terminal regulator can be arranged to have an adjustable output. The variable resistor, R1, here is replaced by a transistor in our regulator circuit below left.

HOW IT WORKS — ETI 258

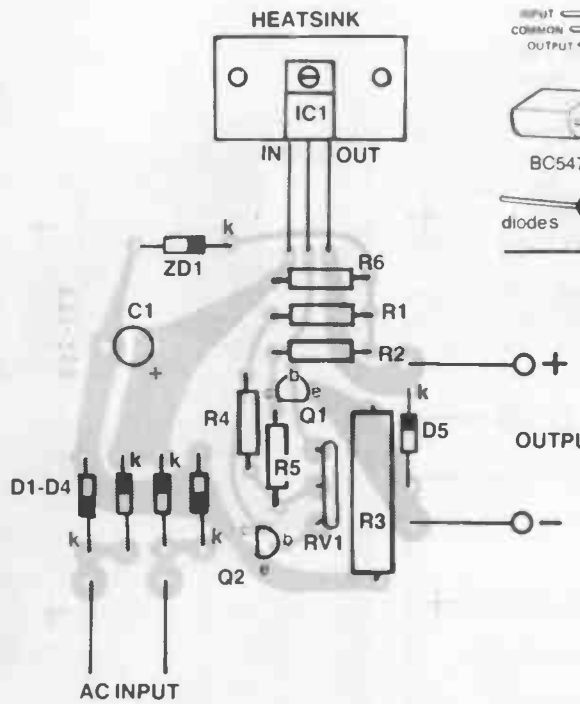
A conventional bridge rectifier (D1 to D4) and capacitor-input filter (C1) provides dc input to the regulator circuit consisting of IC1 and Q1, Q2 plus associated components. Output with no load is set by adjusting RV1 for a nominal 12 Vdc at the output terminals. With the drill connected and operating the voltage drop across R3 causes Q2 to conduct more. As Q1 and Q2 are connected as a differential pair, the collector current through Q1 will decrease. This results in an increasing collector voltage on Q1. The reference pin of IC1 will be raised to a higher voltage with respect to the −ve line and the output voltage will increase.

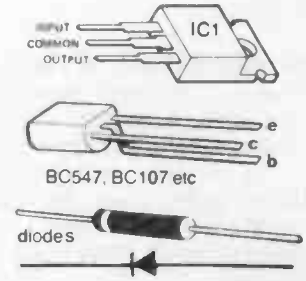
Diode D5 is fitted to protect IC1 against back-emf spikes from the motor. There is no need to worry about the IC suffering damage from this source as it is internally protected. If you stall the motor, the maximum current delivered will be limited by IC1, which is internally protected to limit at a maximum current of 1 A.

Different voltage motors can be accommodated by changing the reference zener, ZD1.



mini-drill controller





Construction is best tackled by mounting all the resistors, diodes and transistors on the pc board first — leaving R3 till last as it's a bulky item. Watch the orientation of the diodes and transistors as usual. Mount C1 next. Mount IC1 last of all and then attach a small heatsink to it.

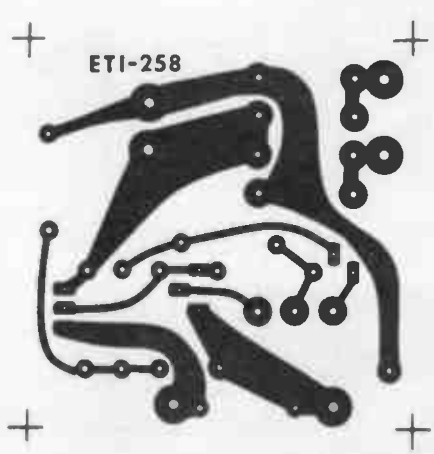
The completed unit can be housed in any convenient box or case, to suit yourself.

Supply input

The project may be supplied from any transformer, or a plugpack, that will deliver between 9 Vac and 12 Vac at 200 to 500 mA, or up to 1 A. A transformer such as the ubiquitous model 2155 (e.g: Arlec AR-2155 or Dick Smith M-2155, etc.) will do the job nicely using the 9.5 V tap.

A dc plugpack may be used if you leave out D1-D4 and connect the plugpack's output directly across C1 (watch the polarity!). A 12 Vdc plugpack rated at 200 mA or more would be suitable.

Although the mini-drill we used originally ran off two 1.5 V batteries (i.e: 3 V) it ran quite happily from our speed regulator. If you have to use the drill for prolonged periods, rest it at intervals so that the motor temperature does not rise too high.



Construction

Construction is quite straightforward, no tricks here. Using our pc board will ensure you have a compact unit that can be conveniently tucked somewhere out of harm's way. The pc board is not essential, however. Layout is not really critical, but keep all leads to and from IC1 short to prevent high frequency oscillation. If you have trouble with the latter, a 10n ceramic or greencap capacitor soldered directly between the output and reference pins of IC1 will cure the problem, although we didn't find it necessary. But that's getting ahead of ourselves! ●

'Universal' relay driver board

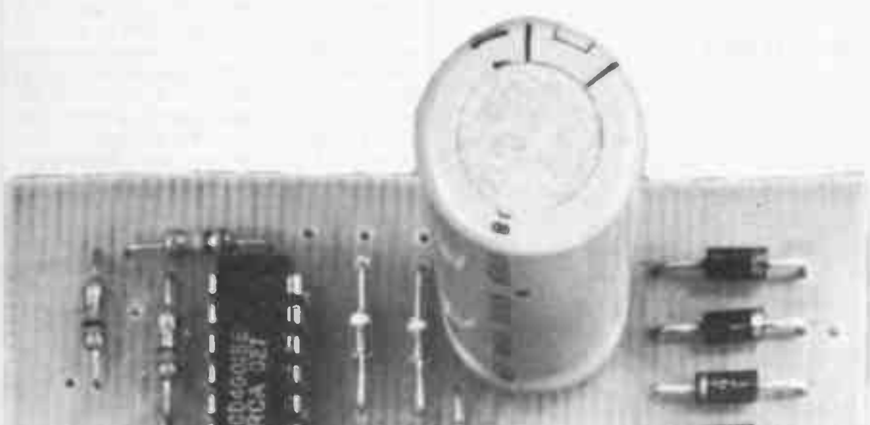
Operating a relay to switch heavy current or mains voltages is a common requirement in electronic control applications. This project permits a relay to be switched in a variety of ways and from a variety of inputs.

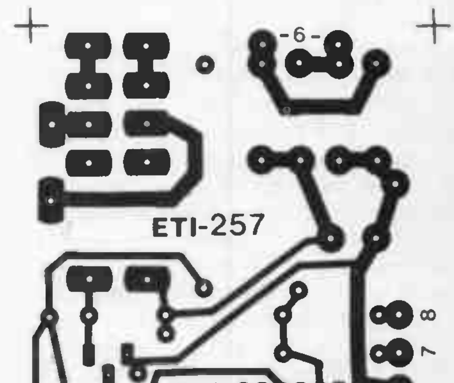
Graeme Teesdale

THIS VERSATILE relay driver unit is intended to be used with projects or devices not normally providing a switched relay output. In addition, power for external circuitry can be obtained from the board.

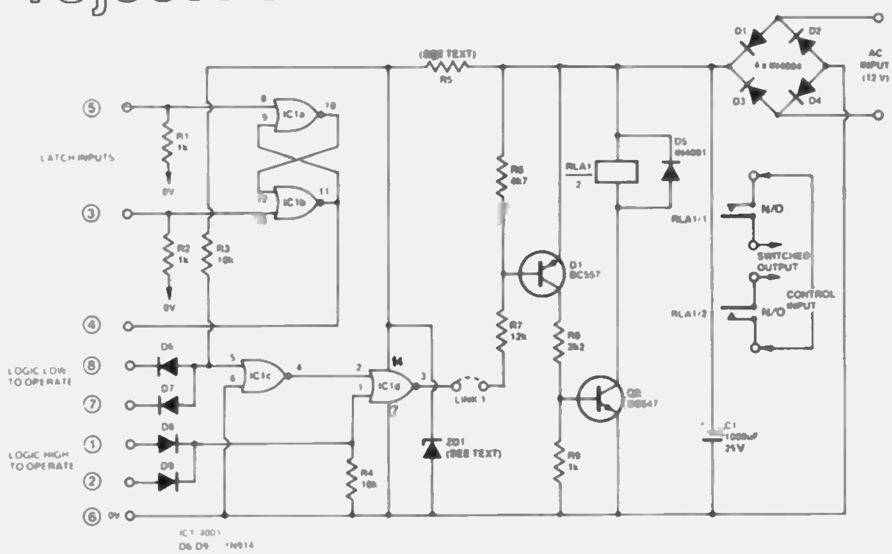
The unit has three groups of 'logic' inputs and a direct input. The relay itself is driven by two transistors, Q1 and Q2, and the direct input goes to the base of Q1 via a resistor (R7). Linking this input to the unit's 0 V rails — via a switch, a transistor which is turned on by a signal (open-collector logic) or a logic gate output — will operate the relay.

The logic circuitry on the board can be implemented by installing Link 1, which connects the output of the logic circuitry to the direct input. There are two "logic high to operate" inputs (pins 1 and 2). A logic high level — i.e: voltage level above about 2 V — on either of these inputs will operate the relay. There are also two "logic low to operate" inputs (pins 7 and 8). Pulling either of these inputs below logic low — about





The relay driver board is simple, yet versatile. The external input/output pins are located around the edges of the board.



Circuit diagram of the relay driver board. Note that the rectifier diodes may be any of a range of types, such as 1N4001-2-4, etc, or EM401, EM402, etc. A variety of common relays will fit the pc board.

0.5 V — will operate the relay. Note that these input pairs are ORed with diodes and can be linked so that one input inhibits the other. In addition there are two "latch" inputs, pins 3 and 5. Pin 4 is the output of the latch circuitry and latch operation is implemented by linking this pin to one of the other inputs. All the logic inputs are high impedance and can be driven from CMOS circuitry.

This unit is powered from a 12 to 15 Vac source such as a plugpack or 5 VA transformer. Supply for IC1 (and perhaps any off-board circuitry) is obtained from a simple zener regulator circuit. This can be chosen to suit individual requirements. We used a BZY96/8V2 zener (1N4738) to provide an 8.2 V rail for IC1. We used a 220 ohm, 1 W resistor for R5. You can use any convenient zener from 5.1 V to 15 V — but no higher, and we recommend 1 W types run at around 50-60 mA current. You will have to work out the value of R5 according to your choice of zener. For a 15 V zener, R5 could be 47 ohms, for a 5.1 V zener, 270 ohms, or for a 12 V zener, say 100 ohms. There's plenty of latitude and these values are only given as a guide.

The logic circuitry (i.e: IC1) can be supplied from an off-board source if you wish. To do so, remove R5 and use a 15 V zener for ZD1 to prevent spikes on the external supply line causing damage to IC1. Note also that the logic levels on inputs 1, 2, 3 and 5 should also be no higher than 15 V.

The accompanying drawings illustrate how the unit is used in its four basic modes of operation.

Construction

Construction is very straightforward. The components may be mounted in any order but you will probably find it easiest to leave the relay and C1 until last. Watch the polarity of all the diodes, the transistors and the IC. However, leave out link 1 at this stage.

Once you've got it together and have checked everything, apply 12 V ac to the ac input and check various modes of operation as follows:

(1) Bridge the free end of R7 to ground. The relay should operate.
(2) Install link 1, then bridge pin 7 to ground. The relay should operate. Likewise for pin 8.
(3) Bridge pin 1 to the cathode of the zener. The relay should operate. Likewise for pin 2.
(4) Connect pin 4 to pin 1 or 2. The relay may operate. Apply a pulse to pin 3 or 5 and see that it latches on. A pulse on the other input will drop it out again.

If all is well, your unit is ready for installation! ●

HOW IT WORKS — ETI 257

The best place to start is right in the middle of the circuit — because that's the 'business' end!

Transistor Q2 has relay RLA1 as its collector load. Diode D5 provides protection for Q2 when the coil current is cut off whenever Q2 is turned off. The base of Q2 is driven by the collector of Q1 via R8 and R9. Base bias for Q1 is obtained from the resistor network of R6 and R7. The 'free' end of R7 can be linked to on-board logic circuitry (IC1) or driven by an external source.

If the free end of R7 is connected to 0 V then base current will flow in Q1, which will turn on. This will turn on Q2 and the relay will operate. In fact, all that is required to turn Q1 on is to 'pull' the free end of R7 about 1 V below the positive supply rail to overcome the 0.6 V base-emitter turn-on voltage of Q1.

Effectively, a 'low' level on the free end of R7 will operate the relay.

Two groups of logic circuitry built around IC1 are included to provide a variety of operating 'modes'. IC1 is a quad NOR gate package. One gate, IC1d, is arranged to provide a 'logic high to operate' mode. Two diodes connected as a simple OR gate have their cathodes connected to pin 1 of IC1d. The output of another gate, IC1c, drives the other input, pin 2, of IC1d. IC1c has one input (pin 6) connected to 0 V, which is thus held at logic low. Pin 5 IC1c is held at logic high by R3 and thus its output, pin 4, will be high. As this drives pin 2 IC1d its output, pin 3, will be high. With Link 1 fitted, Q1 will normally be off and the relay not operated.

When a high logic level is applied to either input pin 1 or 2, or both, the diode(s) will conduct driving pin 1 IC1d high. The output, pin 3, will go low and the relay will operate. The relay will remain operated only while the input remains high.

Two diodes (D6, D7) are connected as a simple OR gate with their anodes connected to pin 5 IC1c. A logic low on either input pin 7 or 8 ('logic low to operate') or both will pull pin 5 IC1c low and its output, pin 4, will go low. Pin 2 IC1d will go low and thus pin 3 IC1d will go low and the relay will operate. The relay will remain operated only while the input remains low.

The remaining two gates from IC1 are connected as a set-reset (SR) flip-flop. Pin 4 on the pc board provides an output which may be coupled to the other inputs. Assume the SR flip output is initially low. A pulse applied to input pin 3 or 5 will cause pin 4 (pins 9, 11 of IC1a, b) to 'latch' high. A pulse then applied to the opposite input pin will cause the output to go low again, and remain low.

This part of the circuit can be used as a 'switch debouncer' as illustrated.

Power is derived from an off-board 9 Vac or 12 Vac source. This drives a bridge rectifier, diodes D1 to D4, smoothing being provided by C1. A zener diode, ZD1, is used to provide a regulated supply to the logic circuitry (IC1).

PARTS LIST — ETI 257

Resistors — all ½W, 5% unless noted

R1, R2, R9	1k
R3, R4	10k
R5	220R, 1W (see text)
R6	4k7
R7	12k
R8	2k2

Capacitors

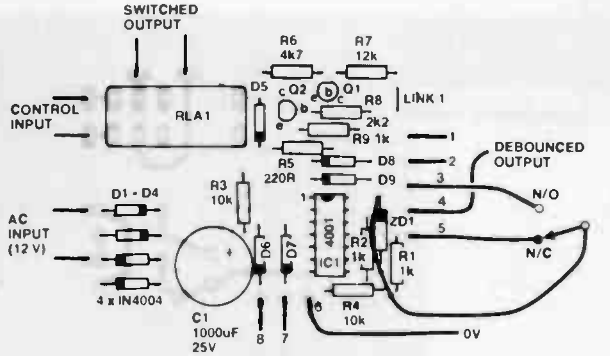
C1	1000 u/25 V electrolytic

Semiconductors

IC1	4001B
Q1	BC557
Q2	BC547
D1-D5	1N4001, 1N4002 etc
D6-D9	1N914, 1N4148 etc
ZD1	400 mW or 1 W zener, see text

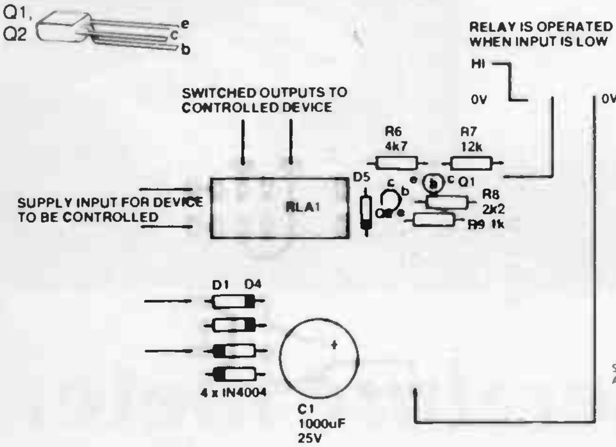
Miscellaneous

ETI-257 pc board; RLA1 — relay, Fujitsu FRL-621D012 or Takamisawa VB 12STAN or Pye 265/12/G2V.



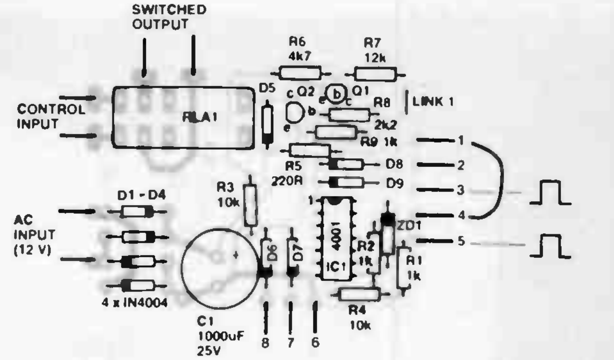
SWITCH DEBOUNCING

The SR flip-flop (IC1a and b) is not electrically connected to the rest of the circuit and may be used in external circuitry — for example, as a switch debouncing circuit.



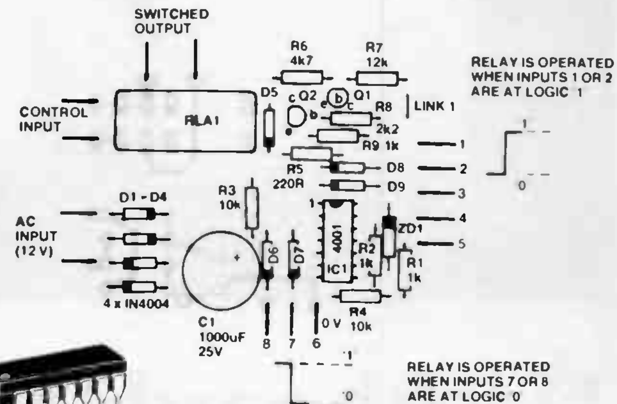
DIRECT INPUT

The relay will operate when the input is low (i.e: 0 V) or 'pulled' about 1 V lower than the positive supply rail. Only those components shown are necessary for this mode of operation.



LATCH OPERATION

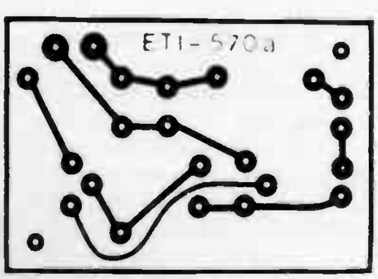
Pin 4, the output of the set-reset (SR) flip-flop, must be linked to either pin 1 or pin 2, or pins 7 or 8. A positive-going pulse on pin 3 or pin 5 will cause the relay to latch. A positive-going pulse on the opposite latch input will then cause the relay to unlatch.

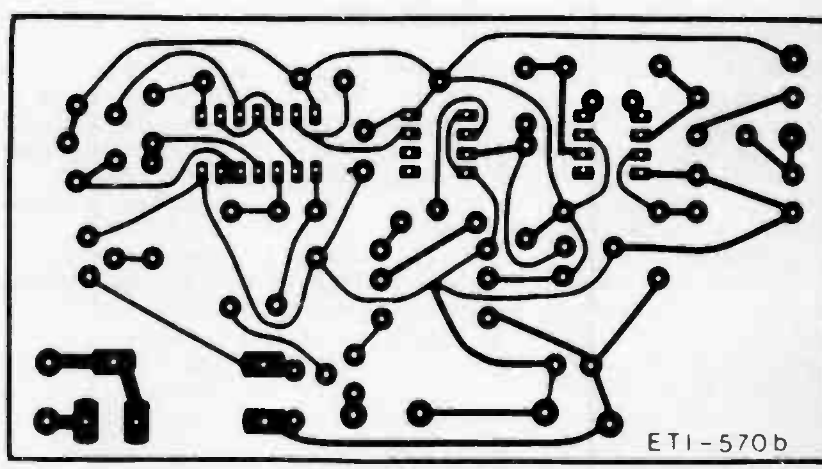


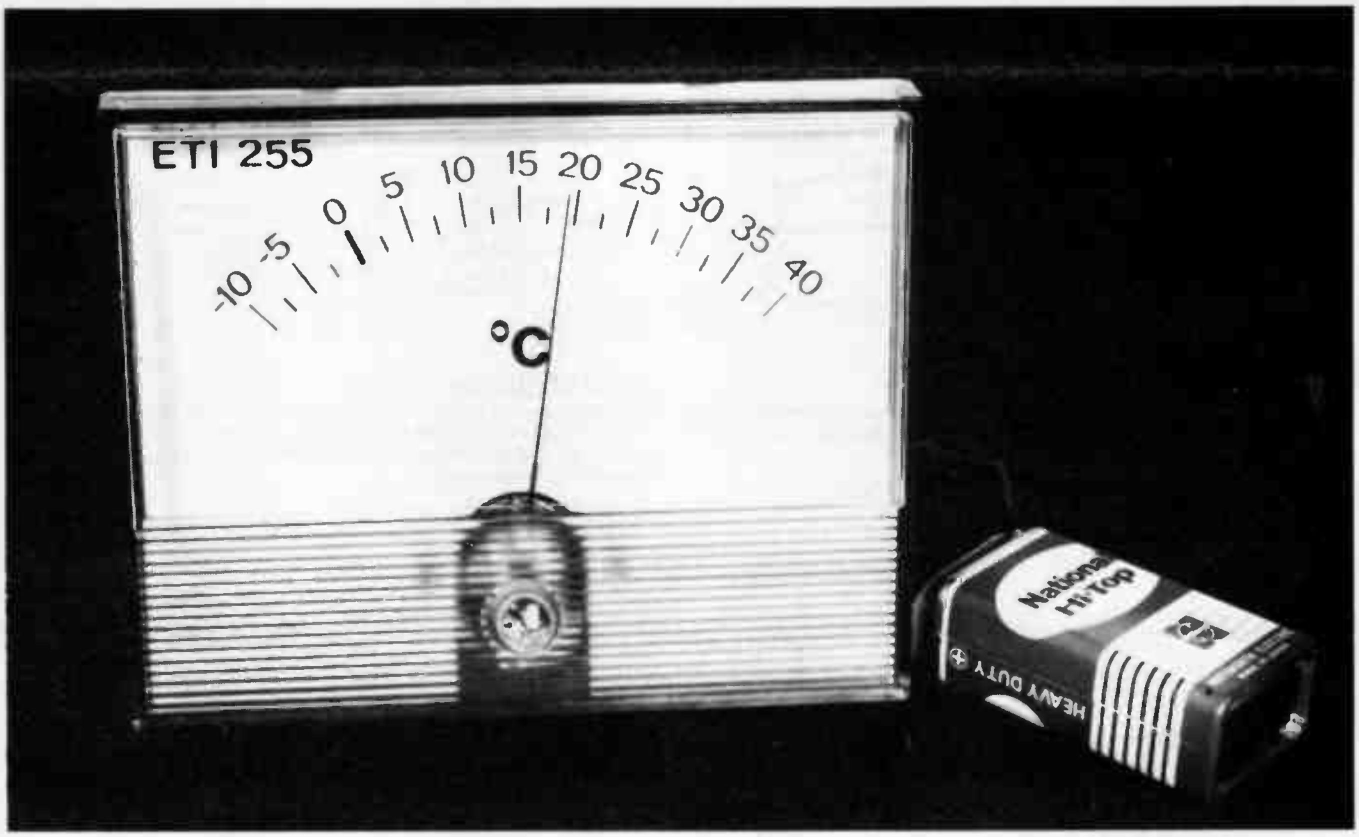
LOW OR HIGH TO OPERATE

The relay will be operated when pins 1 or 2 are held at logic high. To operate the relay from a logic low, pins 7 or 8 must be held at logic low. The inputs are ORed so that up to two input signals can be employed to operate the relay in each mode.

PCBs







Dashboard temperature meter

Jonathan Scott

Clear, easy to read dial makes this little thermometer a useful addition to the dashboard.

THIS TEMPERATURE meter project can stand alone or you can mount it in a desk top or even in the dash of your car if you don't mind cutting a hole for it. (If you've built all the ETI projects for motorists your dash must look like a piece of swiss cheese by now, so one more hole won't matter!)

Why an electronic thermometer, you may ask ? What's wrong with the ordinary mercury-in-glass type that's been with us for hundreds of years? It's hard to read, that's what. You have to go right up close to see the scale. And mercury thermometers are fragile, too.

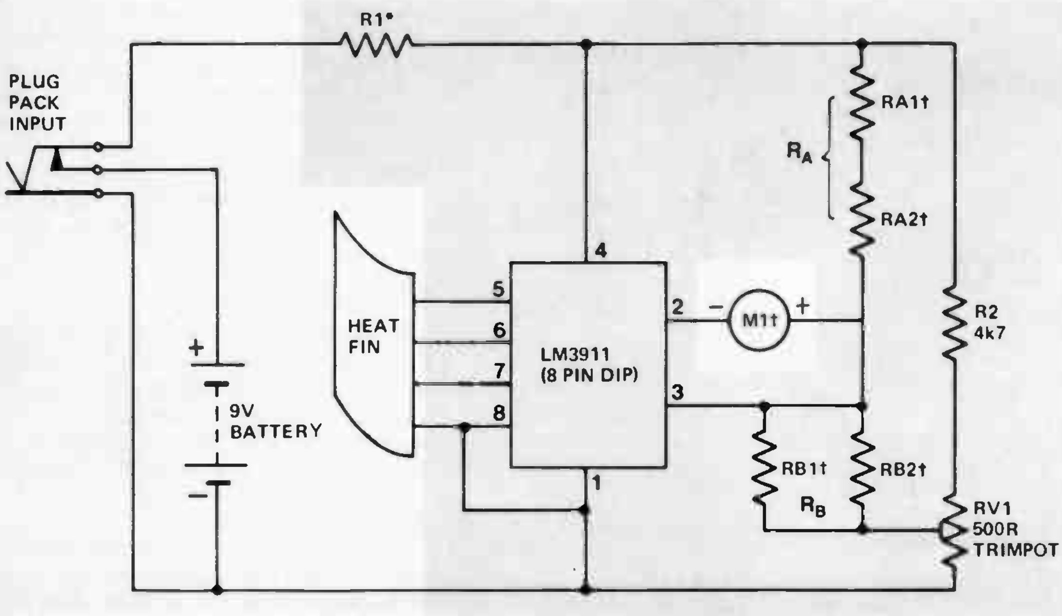
If you want to be able to read off temperature on a nice clear dial you need some kind of electric or electronic sensing element. There are several kinds of sensors you might use, including thermocouples, thermistors and diodes, all of which have their own advantages and drawbacks.

We chose to use a temperature sensing IC, the LM3911, recently introduced by National Semiconductor. There's a more detailed description of it on page 48, but basically it relies on the well-known fact that a transistor's base-emitter voltage varies with temperature — the warmer the transistor gets the greater the b-e voltage.

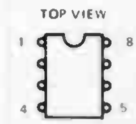
Because the LM3911 chip includes its own amplifer, it's very easy to use it to drive a meter. Apart from the IC and the meter, the only components in this project are five resistors and a trimpot. By choosing different values of resistors, you can build this temperature meter so that it indicates any temperature range you choose as , long as it's between −25°C and +85°C.

We've specified resistor values to make the meter read from −10°C to +40°C, which should be fine for most locations, but in case you live somewhere like Birdsville we've also given values for a temperature range of −10°C to +90°C. But you don't have to stick to the ranges we suggest. Opposite you'll find formulae for calculating the necessary resistance values for any temperature range.

One more useful feature of this project



IC



*R1 = 470R (¼W or ½W) for 9 V operation; 1k8 for 12 V battery (11 - 15 V) operation.
†See table below for resistor values to suit different meter ratings.

The pc board pattern is on page 90.

HOW IT WORKS — ETI 255

Almost all the functions take place inside the LM3911 chip. Pins 5 - 8 are thermally connected to an internal temperature sensor circuit and transmit the external temperature from a small sheet of copper. The copper fin will generally be at air temperature.

An internal voltage reference, connected between pins 1 and 4, regulates the supply rail to 6.8 volts for the chip and external circuitry. The dropping resistor R1 sets the current to about 3.5 mA, maintaining about 1.2 mA to the IC and about 2.5 mA to the external circuit. It is desirable to keep the current into the IC as low as possible to prevent excessive temperature rise in the chip giving rise to inaccurate readings.

An internal op-amp sinks current from pin 2 in order to hold the voltage on pin 3 at a level which is linearly proportional to the temperature on the sensing pins. The meter, M1, monitors the current into pin 2 giving a reading which is directly proportional to temperature. The resistors R_A and R_B are calculated to give the required zero reading and full-scale temperatures. We have included a table with suitable values as well as formulae so you can roll your own.

The meter reading is linear with temperature and is calibrated to cover the desired range.

The trimpot RV1, compensates for variations between different ICs as well as compensating for temperature rise within the chip.

SUGGESTED VALUES

Range (°C)	Meter F.S.D.	R_{A1}	R_{A2}	R_{B1}	R_{B2}
0 to +100 (note: 85 max.)	100 μA	10k	6k8	27k	270k
0 to +50	50 μA	10k	6k8	27k	270k
−10 to +90	100 μA	8k2	8k2	27k	480k
−10 to +40	50 μA	8k2	8k2	27k	480k
−10 to +40	100 μA	8k2	zero	82k	15k

NOTE: maximum rated temperature is 85°C; minimum is −25°C.

Other temperature ranges can be covered, within the specified limitations of the LM3911, the required range resistor values being calculated from these formulae:

$$R1 = \frac{V_s - 6.9}{0.0035} \quad \ldots\ldots (1)$$

V_s = supply voltage

$$R_A = R_{A1} + R_{A2} \quad \ldots\ldots (2)$$

$$R_B = \frac{1}{1/R_{B1} + 1/R_{B2}} \quad \ldots\ldots (3)$$

$$\text{Let } T_1 = T_0 + 5 \quad \ldots\ldots (4)$$

using equation (4), calculate 'M'

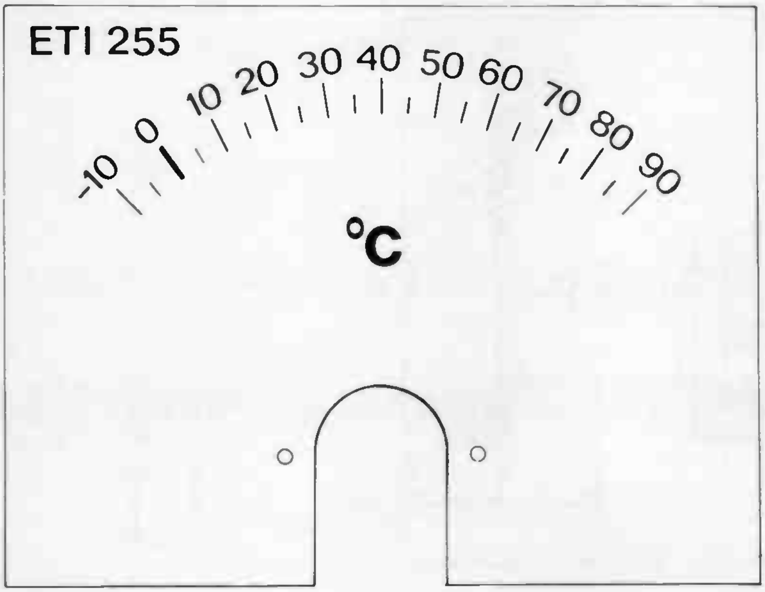
$$M = \frac{T_1}{685} \quad \ldots\ldots (5)$$

where T_0 = zero scale reading in °K and T (°C) = T(°K) − 273 ...... (6)

$$\text{then } R_B = \frac{10^4}{M.s} \quad \ldots\ldots (7)$$

$$\text{and } R_A = \frac{10^4}{s(1 - M)} \quad \ldots\ldots (8)$$

where s = meter sensitivity in μA/°C (For example; if you choose a 100 μA meter and wish to cover a range of 50°C, then s = 2 μA/°C)



Full size artwork for meter scale covering −10°C to +90°C. Note that the limit for the LM3911 is +85°C.

THE LM3911 — HOW IT WORKS

The LM3911 is a highly accurate temperature measurement IC for use over a −25°C to +85°C temperature range. Fabricated on a single chip it includes a temperature sensor (pins 5 — 8), stable voltage reference (pins 1 and 4) and an operational amplifier.

The output voltage on pin 2 is directly proportional to temperature in degrees Kelvin having a sensitivity of 10mV/°K. By using the appropriate external resistors with the internal op-amp, any temperature range can be selected.

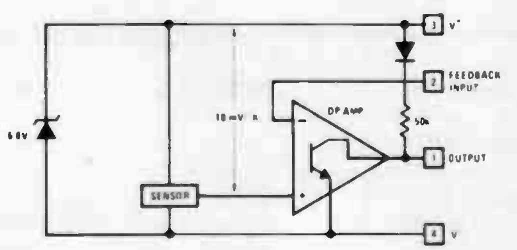
An active shunt regulator across the supply pins provides a stable 6.8 volt reference for the sensing circuitry, and allows the use of any supply voltage with the correct dropping resistor.

The input bias current is low and relatively constant with temperature to ensure high accuracy when a high source impedance is used. The output pin can be returned to a supply up to 35 volts to allow the circuit to drive lamps or relays.

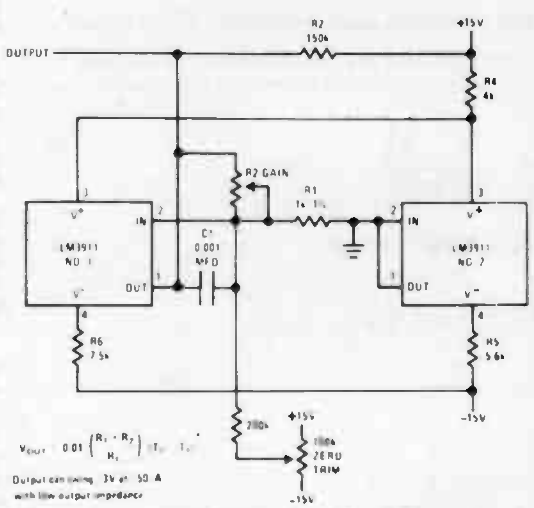
The temperature sensing element uses the difference in base-emitter voltages of two transistors operating at different current densities. Since this output depends only on transistor matching, very good stability and reliability can be obtained.

The op-amp can either be connected as an amplifier to give a linear temperature/voltage output or as a comparator to switch the output at a preset temperature. Therefore, the device can be used either as a measuring instrument or as a temperature controller.

The output can be calibrated for degrees Celsius, Fahrenheit or Kelvin.



Internal block diagram of the LM3911.



*The 0.01 in the above equation is in units of V/°K or V/°C and is a result of the basic 0.01 V/°K sensitivity of the transducer

Two LM3911s can be configured as a differential thermometer.

is that the meter doesn't need to be closely connected to the IC and the rest of the circuitry. You could, for example, have the electronics outside the house and the meter inside, so you could find out how cold it is outside without having to open the door and get chilled. Or less frivolously, suppose you're trying to grow exotic plants in a controlled temperature hothouse, you could use our project as a remote indicating thermometer to keep a check on their environment.

Construction

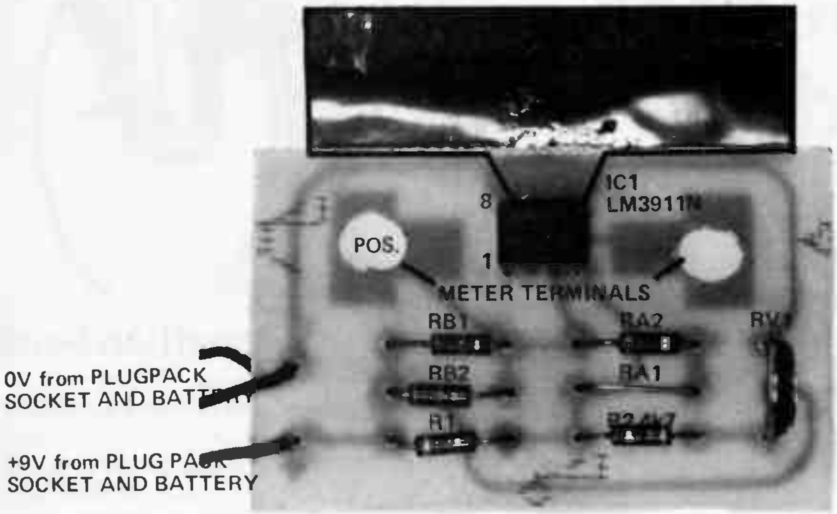
The entire circuit, including the heat fin, is assembled on a small pc board which is then mounted onto the rear of a moving coil meter. Connection to the meter is made by large copper pads on the pc board which can accommodate a variety of meters with different terminal sizes and spacings.

The thermometer can be mounted in a small plastic box, fitted into a car dash or perhaps built into a neat, desk-top unit for the 'shack'. Whichever you choose, be sure to leave a large enough hole in the box to allow free air flow across the heat fin so the meter reads the room air temperature and not that inside the box. If a remote reading unit is required the pc board can be mounted away from the meter.

The first job is to drill the holes into the pc board to suit the type of meter you have. Next fit all the components as shown in the overlay, taking care with the orientation of the IC and the polarity of the battery or power supply connections. The value of R1 is different depending on whether the unit is operated from a 9 V supply (battery or plugpack) or a 12 V supply (vehicle battery or plugpack). Values are beneath the circuit. The values of R_A and R_B are selected from the table for the required temperature range and meter used. Note that R_A consists of two resistors in series (R_{A1} and R_{A2}), while R_B consists of two resistors in parallel (R_{B1} and R_{B2}). Either 2% tolerance or selected 5% tolerance metal film resistors should be used for the sake of accuracy.

Power from a plugpack is applied through a shorting type socket so the unit can be battery operated when the plugpack lead is removed.

The 50 mm by 20 mm heat fin is cut from a small piece of 0.25 mm thick copper shim. Solder it to the pc board track connected to pins 5 - 8 of the IC (see overlay photo). A larger size fin may be used, but we found this one works nicely. In fact, the circuit will work well without any heat fin, but has a longer response time. Make sure the



Rear view of the instrument showing general assembly. You may prefer to use a rechargeable NiCad type, rather than the dry battery shown, for battery operation of the unit.

fin is not touching any other part of the circuit.

Finally, fit the meter after cleaning the meter pads on the pc board. The spring washer supplied with the meter should be assembled on the copper side of the board so it digs into the surface of the copper for good contact. If this is not done the meter connections may become a high resistance when the copper tarnishes after use.

PARTS LIST — ETI 255

IC1	LM3911N
R1	470R or 1k8
RA1	See table
RB1	"
RA2	"
RB2	"
R2	4k7

All resistors should be 2% or selected 5%, ¼W or ½W metal film types.

RV1	500R miniature vertical mounting trimpot
M1	50 or 100 microamp meter (to suit range) University TD 106 or similar.

ETI-255 pc board; case (if required); plug pack adaptor socket and 9V Plug Pack (Ferguson PPA-9/500 or similar); 9V battery (No. 216) and battery clip if required; small piece of 0.25 mm shim copper.

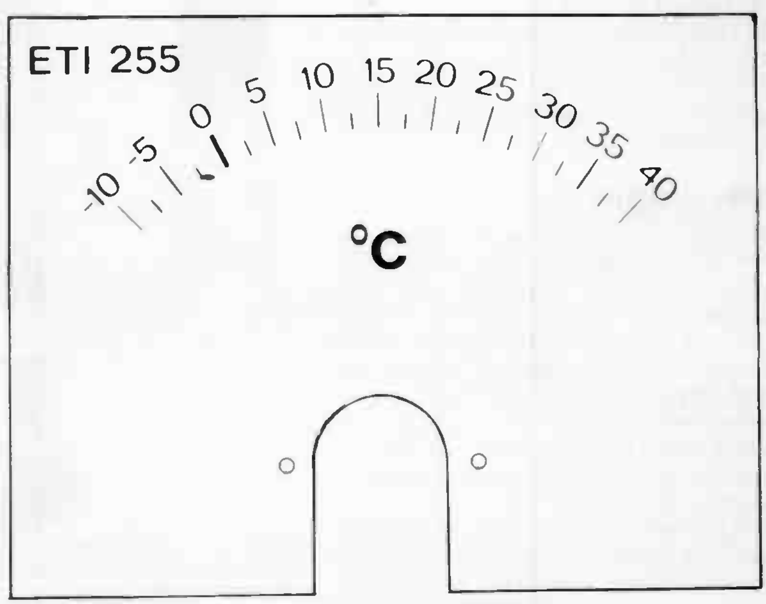
Apply power and adjust the zero set trimpot which should be capable of adjusting the reading about +/−10°C.

Calibration

Place the unit and a reference thermometer (choose a good one) in a cool place close together and after a few minutes note the difference in readings. Adjust the trim pot for the correct reading.

Two different meter face scales have been included for two temperature ranges, —10°C to 40°C and −10°C to 90°C. Values have also been calculated for 0°C to 50°C and 0°C to 100°C scales to allow standard scales on 50 μA and 100 μA meters to be used. ●

Full size artwork for meter scale covering −10°C to +40°C.



Project 1506

Xenon flasher for pushbike riders

If you go riding your pushbike on a dark night during a power blackout, you'll need this project. Even if you just ride your bike at nights, being visible to other vehicles is important for safety. A bright flashing light will see to that.

Jonathan Scott

THIS IS an idea which is only just catching on in the US (so who knows how long it will be before it gets proper commercial release here), and it's a good thing indeed. Let's face it — bicycle lights are pretty useless for seeing things, but they serve the valuable purpose of letting the rider *be seen*. It is also not a recent realisation that a xenon flash is easily seen at a distance and potentially very power economical, which is what you want if you have to purchase (and carry) the batteries.

So here it is: the low-cost, high visibility bicycle flash. It will flash for many hours on one single cell, a Nicad being best as you only have to pay about ten times the initial price for 100-500 times the life.

Our prototypes, one constructed using a dismantled $10 flashgun and one from commercial electronic suppliers' parts, ran for 15 hours and 8 hours at 1 Hz and 4 Hz respectively, on $7 Nicads. One quarter of this can be expected from $2 Nicads.

The unit can be recharged from any convenient source including the ETI-563 Fast Nicad Charger, a bicycle dynamo, or the charger we include in this project.

Bits and pieces

As we mentioned before, we have built one 1506 using parts from a $10 flashgun purchased expressly for this purpose. The advantage of this is that you get the xenon tube, trigger transformer and neon lamp all customised and prepacked. You also get a prewound converter transformer, though we recommend that you wind your own, as we did, as the result is about twice as power efficient.

Alternatively the project can be made entirely from easy-to-find parts, with one small circuit modification. Perhaps at this stage you are rather confused by all the options, so let's break the project up into its two basic sections and describe how you go about each part.

Two versions of the Flasher. On the left, one from a junked photo flashgun; on the right, from over-the-counter parts.

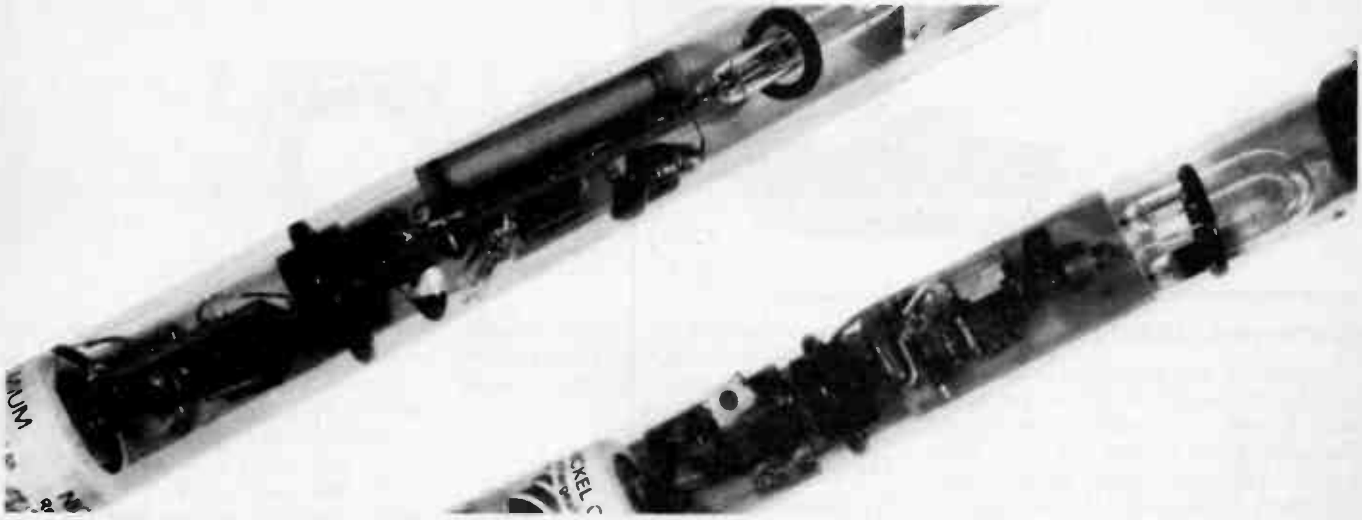
Our preference

Referring to the circuit in Figure 1, which is our preferred and recommended circuit, you see that it is composed of a dc-ac converter board (taken directly from the ETI-575 Light Wand) and its transformer, and an ac-dc flash driver board. Starting with the latter, if you then have or purchase a cheap flashgun, you will also have the tube, trigger transformer and 220 V neon.

The small flash-type xenon tubes seem to be slightly more light-efficient than the 'U'-tube type locally sold, and are less easily broken, so we prefer them. If you don't get hold of it this way you may have difficulty getting the neon, so we have made provision on the pc board for using three of the local 70 V type (NE2) in series, in place of the single 220 V one.

An advantage of using the 220 V tube is that it delivers a non-regular flash rate, which we feel improves recognisability and reduces risk of confusing you on the bicycle with any other flashing light. We won't go into the physics of why the xenon tube does this, but suffice it to say that the 70 volt types do not have sufficiently significant erratic factors to give a visibly varying rate over short time periods.

If you use the three neons in series, you will have to cut off the SCR's heatsink tab to make the necessary room. This is quite safe, as it dissipates negligible power. See the two overlay diagrams for details of this. The tab can be removed by hacksaw, side cutters or simply by bending it until it fatigues, as it is made of thin, soft metal. This should present no problem.



Inside views of the 'preferred' flash unit.

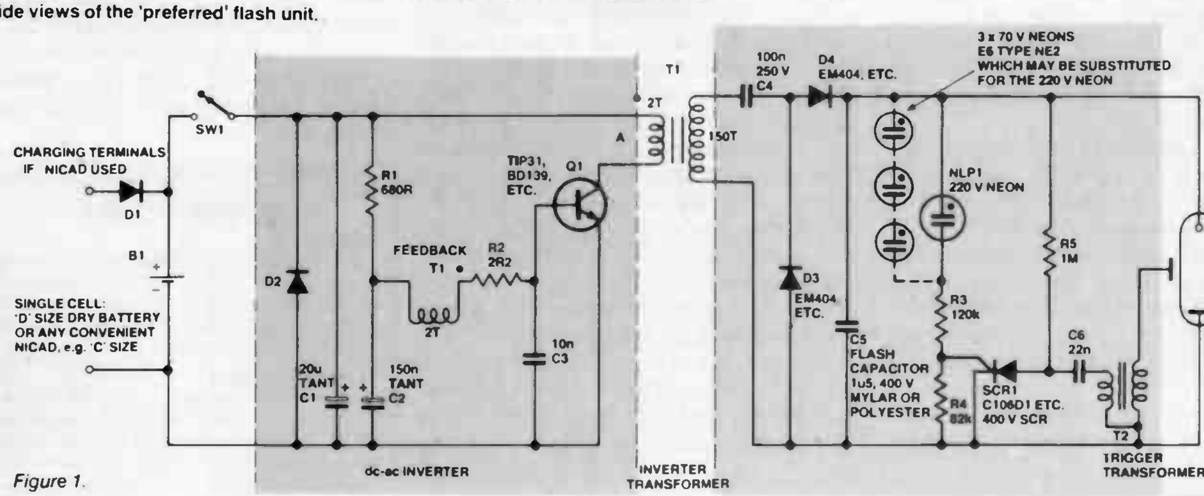


Figure 1.

HOW IT WORKS — ETI 1506

There are two major sections to the circuitry: first the dc-ac inverter, followed by the xenon flasher.

INVERTER

This employs the inverter circuit from the ETI-575 Light Wand (ETI, Aug. '79). This section of the circuit is shown on the left in Figure 1. R1, R2, C2, C3, Q1 and T1 comprise a self-oscillating dc-ac inverter.

Initially, Q1 is turned off. At switch-on, current flows through R1, charging C2. Subsequently C3 charges up via the feedback winding and R2. When C3 reaches about 0.55 volts, Q1 begins to conduct. The feedback winding then forces more current into C3 via R2 because of the phase of its connection. Q1 is then turned hard on. During this positive feedback cycle C2 is actually forced to discharge. R2 limits the maximum base current, and C3 removes fast spikes from the base circuit. These together serve to protect Q1's base.

Eventually, the magnetic field induced by the collector current of Q1 in the primary ceases to increase and the positive feedback ceases. Q1 then begins to turn off and the magnetic field in the core begins to collapse. This produces a negative voltage across the feedback winding which biases Q1 hard off. Then the cycle repeats, R1 and C2 defining the frequency and the power delivered to the tube, since a constant amount of energy (equal to I^2 max times L) is transferred to the load each cycle.

XENON FLASHER

This part of the circuit is shown on the right in Figure 1. C4, C5, D3 and D4 form a 'diode pump', which rectifies the ac output from the secondary of T1 and will 'fill' C5, the 'reservoir capacitor', after a number of cycles, raising the voltage across it to the peak-to-peak input voltage. On negative excursions of the voltage from the secondary of T1, C4 charges via D3. On positive excursions, the charge in C4 is transferred via D4 to C5, and C4 is reverse charged. The period taken to charge C5 is of course dependent on its capacitance and the peak input voltage, which varies because of the inverter's output impedance. However, C5 will, after some time, exceed the 'breakover' voltage of the neon, NLP1 (or the string of three neons). This then conducts, triggering the gate of SCR1, via R3/R4. Resistor R4 prevents false triggering of the SCR by tying it to the cathode with a relatively low impedance.

Before SCR1 triggers, C6 will have charged up to the supply voltage on C5, via R5 and the primary of T1. When SCR1 fires it suddenly connects C6 directly across the primary of T1, whereupon C6 discharges rapidly, producing a large voltage spike at the secondary. This is connected to a 'trigger' electrode wrapped around the outside of the xenon flash tube, and the voltage stress produced causes the gas inside the tube to ionise. Current then flows between the anode and the cathode of the xenon tube, the gas emitting much light in the process. The current flowing in the xenon tube discharges C5. When the voltage on C5 falls far enough, the xenon tube cannot maintain ionisation and it ceases conducting, as does NLP1. The SCR1 will also return to the non-conducting state as less than the anode-cathode latching current required flows through R5. Thus C5 starts re-charging and the whole cycle repeats.

The point at which NLP1 ionises varies with the immediate electrostatic field it is experiencing and also with the ambient radiation level, as these are significant factors in the ionisation process in neon lamps of this type. Thus flashing is erratic when a 220 V neon is used.

The function of diode D1 is to prevent B1 discharging via the charging terminals if they are accidently shorted, while D2 protects Q1 in the event of reverse polarity connection of the battery. (This is particularly likely if you ever use dry batteries, as they are changed often and it's easy to slip them in a battery holder the wrong way round.)

Capacitor C1 provides a low impedance bypass for the supply rail.

Overall view of the Flasher constructed from a cannibalised flashgun.

Converter circuit

Considering the converter circuit, we decided we would build one ourselves and 'borrow' one from a commercial flashgun. Ours turned out to be more power efficient, and quite easily adapted to using only 1.2 V of supply. It is, of course, the more effort-consuming option, as you have to wind your own transformer and make up an ETI-575 pc board, but this is the more pleasing way, electronically speaking.

If you have bought a flashgun that uses one, two or four cells, you must of course use that number if you want to use its transformer. You will have to quickly trace out their circuit to get the pin connections of the transformer before you dismantle it. It is almost certain to look like Figure 2, from which you can get a converter circuit like Figure 3.

Use the original transistor(s) as well if you like. We used a BD139 to show that it too will do the job. We suggest you only undertake this if you know what you are doing tracing around someone else's pc board.

Housing

We elected to build our units in the same perspex tubing which we used for the Light Wand. It has 26 mm inside diameter and 32 mm outside diameter, and so just accommodates the 'C' size batteries neatly. There is no reason why you can't build it in any transparent housing, such as a plastic kitchen container, and use a battery larger or smaller as you wish. A penlight Nicad will comfortably run the unit, though not for as long as a 'C' cell, as its capacity is 0.45 Ah rather than about 1.8 Ah (if you have the high density ones).

The charger circuit supplied here is specially designed to charge a single or two 1.8 Ah batteries, and is thus suitable for the units as we have built them.

A dynamo on a bicycle may also be used, connected directly to the charging terminals. The series charging diode must be a 3 A type.

One last note. C5, the flash capacitor, can be any value from 0.5 uF to about 10 uF. We used 1.5 uF. The larger its value, the brighter the flash, but the less frequent. 1.5 uF gives about 3-4 Hz, visible for at least a kilometre of open ground. You may select the capacitor you use for its physical convenience, as we did.

INVERTER TRANSFORMER, T1 WINDING DETAILS

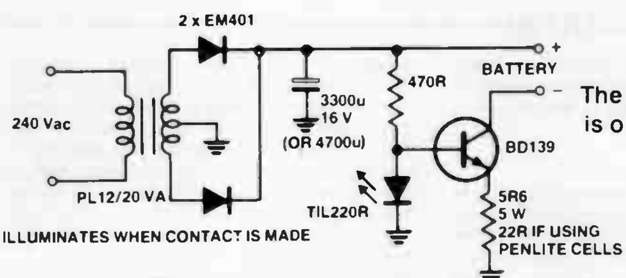
Potcore
Phillips P26/16, 3H1 material, ue68 potcore with single section former, No. 4322-022-28250. Alternatively, a P18/11, 3H1 material, ue1750 potcore could be used. It is physically smaller, which may be an advantage.

Secondary winding
This should be wound first. Wind on 150 turns of 0.2 mm diameter enamelled copper wire (32 B&S), close-wound in layers. As you complete a layer, wrap a length of sticky tape over it before winding the next layer. You'll take about four to six layers. Put a layer of sticky tape over the completed winding.

Primary and feedback
These are wound *bifilar* — two lengths of wire wound side by side. Two turns are required. Use any convenient wire diameter greater than or equal to 0.5 mm (e.g: 22 B&S enamelled copper). **Note:** Mark the *start* leads of each winding — these correspond to those points on the circuit marked with a '•'.

If you've never done this sort of thing before, the article on the ETI-575 Light Wand (August '79) gives a detailed description of the sort of technique employed.

Charger for Nicads suitable for the Flasher



The pc board pattern is on page 90.

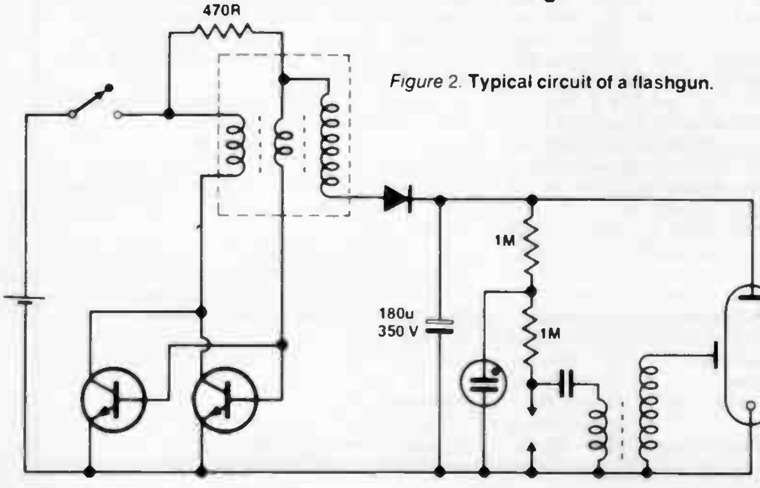
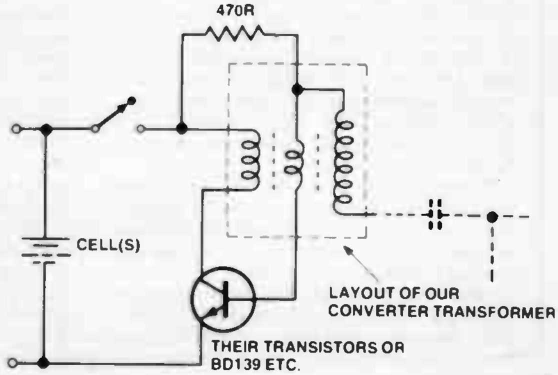
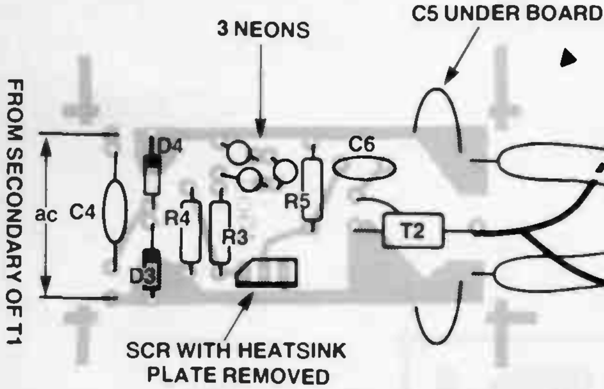


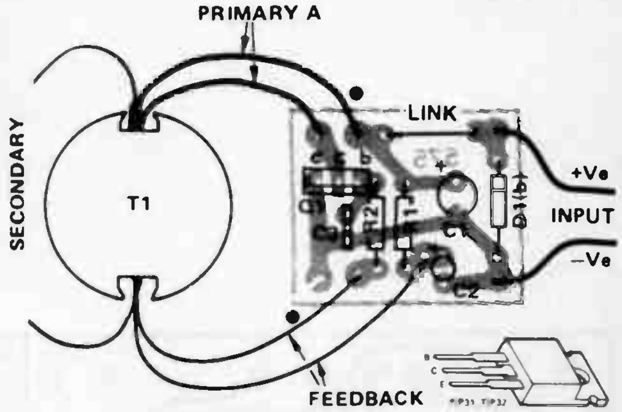
Figure 2. Typical circuit of a flashgun.

Figure 3. Converter circuit from typical flashgun.





1506 PCB OVERLAY — USING 3 NE2 NEONS



Construction

Construction is best commenced by winding the converter transformer, T1, if you're not using one from a cannibalised flashgun. Details are given in the accompanying panel. Having wound this, carefully scrape about 10 mm of the enamel from the end of each wire and tin carefully. Make sure you have the leads clearly identified.

The inverter board should now be assembled. This employs the ETI-575 pc board, and the accompanying component overlay shows the general construction and wiring. As usual, watch component orientation with D2, Q1, C1 and C2.

The flasher board can now be assembled. The component overlay shows general assembly for the U-shaped tube, but accompanying photographs show how a straight tube from a flashgun was mounted. Note that the discharge capacitor, C5, is mounted on the 'underside' of the pc board (i.e: copper side). Again watch the orientation of semiconductors. If you've gutted a flashgun, the single 220 V neon mounts between the free end of R3 and the track to the cathode of D4.

With the U-shaped flash tube, note that a length of tinned copper wire needs to be wrapped around the tube as a trigger electrode, and connected to the secondary of the trigger transformer, T2.

Once it's all together, apply power and see that it flashes as desired. If not, check the voltage across C5. If nothing there, reverse the feedback winding connections on T1 and it should work.

The housing is left up to you as individual requirements are likely to vary widely. If you want to mount the project in a perspex tube, the technique is described in the ETI-575 Light Wand article, ETI August 1979, p.55.

Happy flashing! ●

Close-up of Flasher construction from gutted flashgun, top side.

Same unit, bottom side.

PARTS LIST — ETI 1506

Resistors .... all ½W, 5%

R1*	680R
R2*	2R2
R3	120k
R4	82k
R5	1M

Capacitors

C1*	20u tant.
C2*	150n tant.
C3*	10n greencap
C4	100n/250 V poly.
C5	1u5/250 V poly. This could be any value from 470n to 10u, at least 250 V or greater rating.
C6	22n/250 V poly.

Semiconductors

D1, D2	1N5404, A15P; 3 A diode. (1 A type may be used if slow charging only is used)
D3, D4	400 V (PIV), 1 A diodes — EM404 or sim.
Q1	TIP31 or BD139, etc.
SCR1	C106D1 or similar 400 V SCR

Miscellaneous

T1*	see winding details or text
T2	trigger transformer for xenon flash tube** (e.g: Circuit Components TR4KN)
NLP1	220 V neon or 3 x 70 V NE2 type neons.
B1	single Nicad battery
SW1	SPST miniature toggle switch

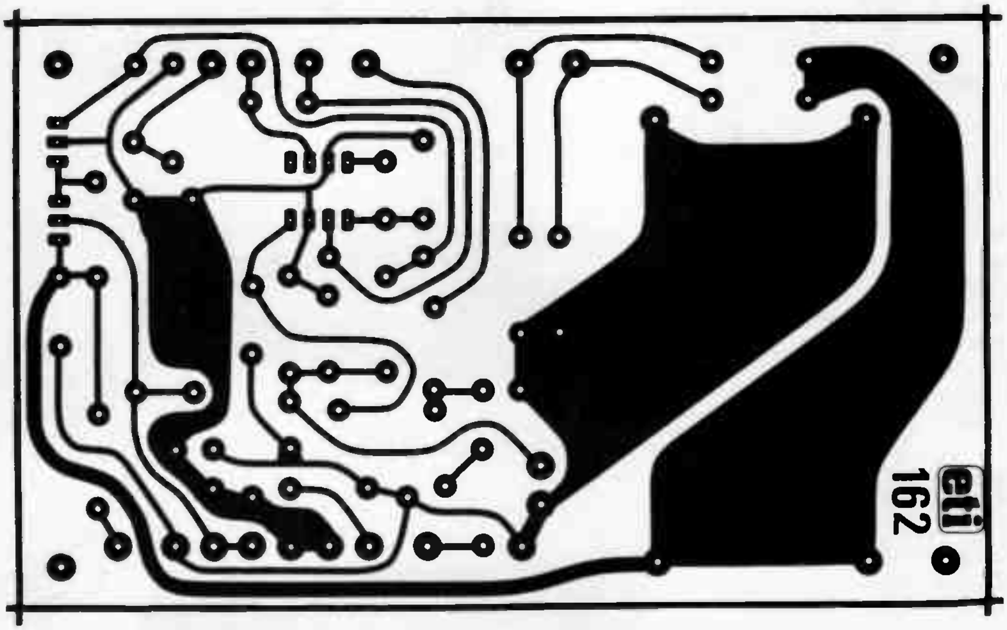
Xenon flash tube** (e.g: Circuit Components type MFT1210); ETI-575 and ETI-1506 pc boards; clear case or tube to suit.

* Delete these components if using inverter components from flashgun.

** These components may come from scrapped flashgun.

Price estimate **$25-$28**

PCBs



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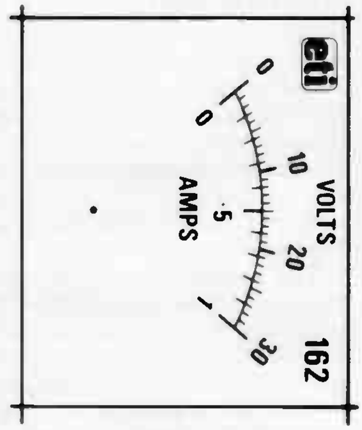

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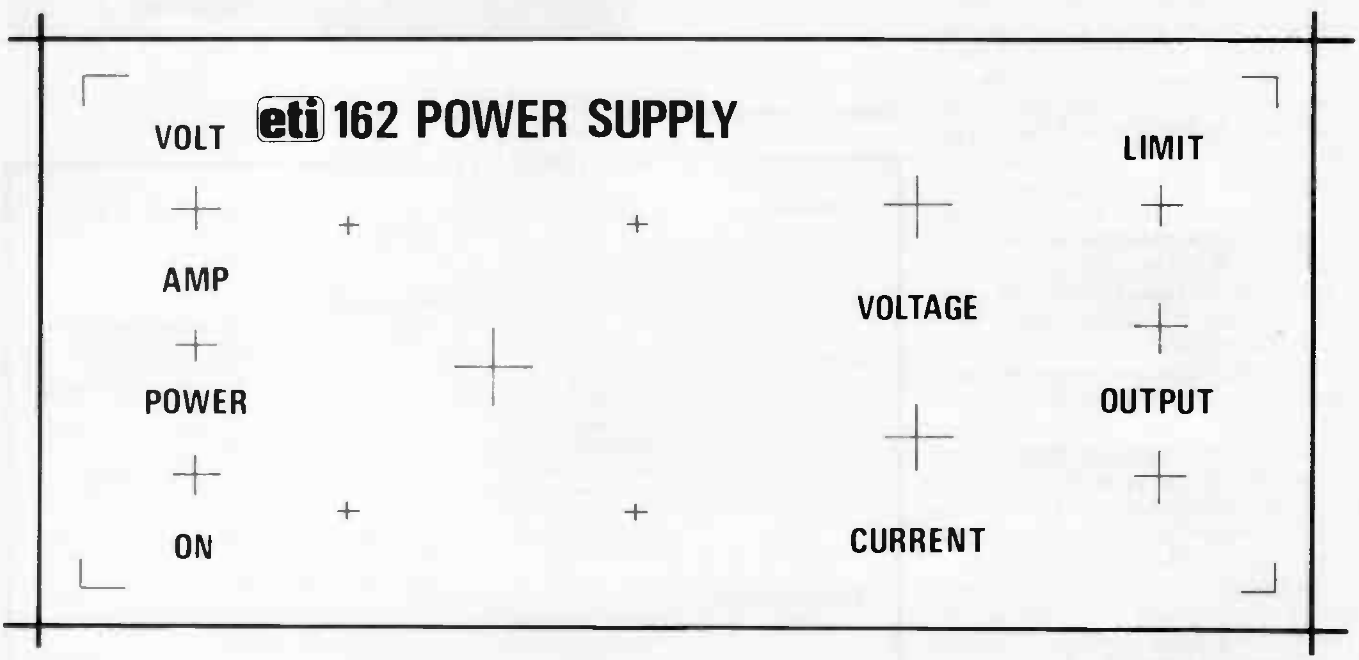
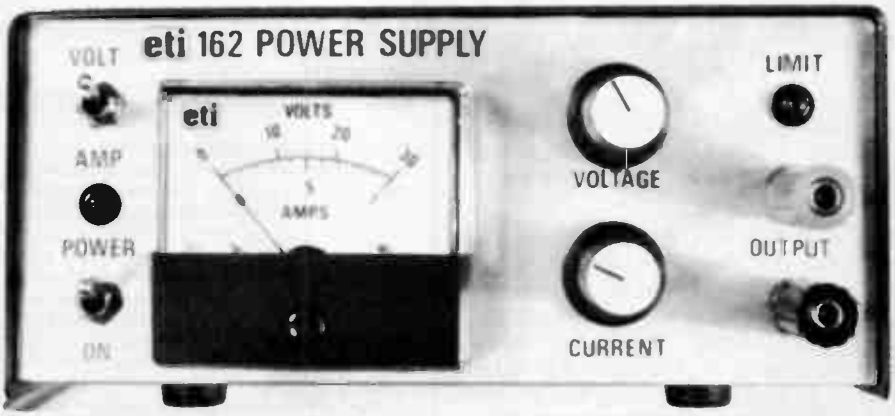


VOLT
eti 162 POWER SUPPLY
LIMIT
AMP
VOLTAGE
POWER
OUTPUT
ON
CURRENT

30 V/1 A fully adjustable, protected power supply

This low cost, easy to build power supply features full protection, variable voltage output from 1.3 to 30 volts, variable current limit from zero to one amp plus metering of both voltage and current output.

David Tilbrook
Roger Harrison



Our power supply presents a neat, functional appearance. It uses low cost, readily available components and is housed in a standard 184 x 70 x 160 mm metal case. Scotchcals were made up and applied to the front panel and meter scale.

THE FIRST piece of test gear an electronics enthusiast or technician wants after a good multimeter is a *power supply*. But, exactly *what* does that hypothetical person want, we asked ourselves? After much discussion, examining past projects etc, we came up with a specification like . . . A, B, C. As he happened to be a captive in the advertising sales office, which is next door to ETI's lab, we put it to a famous Irish West Australian electronics dealer who walks on water for a hobby (see ETI, April '81, p.11), to 'test the water', so to speak. He said, "No, no, no! What they want is a power supply with D, E, F for XY.Z dollars". Conceding he might be right but that there was an element of pecuniary interest to be deducted, we counter-proposed a power supply with G, H, I but the Irishman said that would cost ZY.X dollars and no electronics person in their right mind would pay that. At this stage we thought compromise would result in a power supply with a camel-hitching rail on the front panel and thought retreat/rethink the wiser move.

Suspecting XY.Z dollars was something like $49.50 ($10 above a current kit supply and $10 below our last low-cost supply project) it was apparent some awful constraints were looming up. Rather than taking a 'better' supply and pruning it to meet a price, we started from the ground and looked at what was necessary and asked could it be done?

Obviously, a 'laboratory standard' power supply with dual digital metering, programmable voltage and current and nuclear blast proofing was not necessary. Most solid-state circuitry requires voltages between 3 V and 30 V and may require currents up to half an amp or so. Any circuitry run from the supply would need to be protected from damage by excess current should there be a fault in it, so current limiting was necessary. Current limiting also has the advantage of providing protection for the power supply if the output should be short-circuited. So, variable output up to 30 V and variable current limit were two prime goals. A pot costs less than a toggle switch so continuously variable current limiting could be included, perhaps.

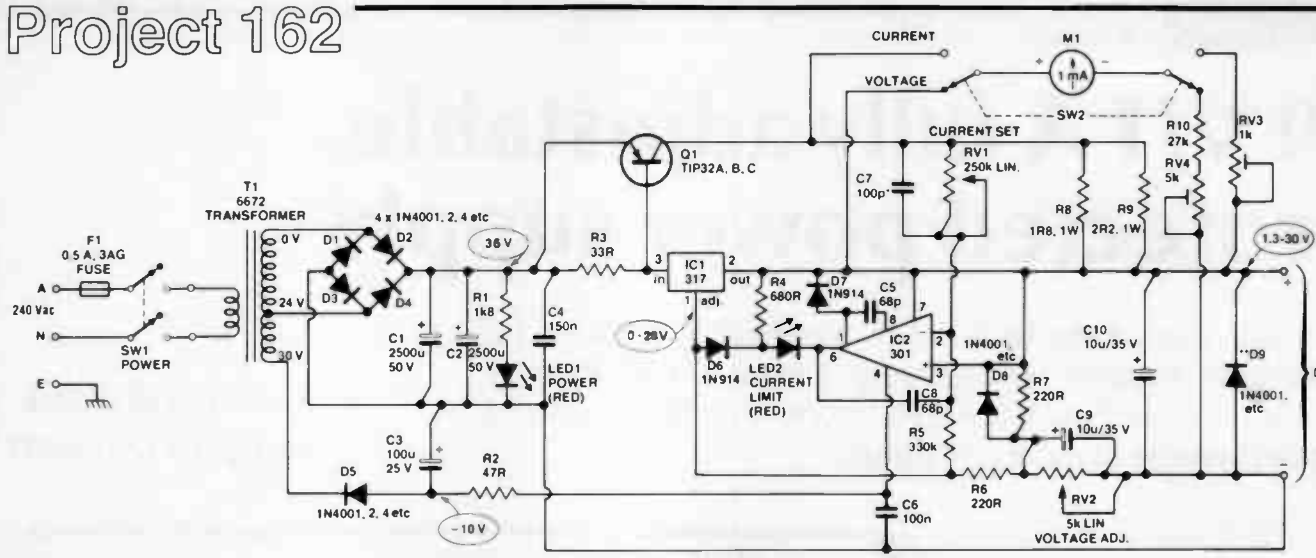
Meters are a relatively expensive item. Assuming the user has a multimeter (you bought that first, remember) then the meter on the power supply only needs to read either voltage or current at any one time. Voltage metering for the supply is an obvious requirement, leaving current to the user's multimeter. But, from experience, you often need an extra meter. Thus, switched metering was desirable. Dual meters are nice, but relatively *expensive*.

Three-terminal IC regulators are cheap, readily available and provide good results. They can also provide thermal overload protection. Internal circuitry turns them off if the case temperature of the device rises above a specified maximum. Getting a variable output from a three-terminal regulator is easy, but providing variable current limit is another matter. Use a specialised regulator? "You'd be in all sort of compost if, and it's inevitable, it was hard to get", said the Irishman-who-walks-on-water. Point there. We looked at some op-amp and transistor regulator circuits, tried one or two, but thermal overload protection was unavailable and the circuits got a little complex — and expensive. Back to the three-terminal regulator and scouring of

SPECIFICATIONS — ETI-162 PROTECTED POWER SUPPLY

Output voltage	1.3— 30 V, variable
Output current	0 — 1 A, variable limiting
Output regulation	better than 0.2% zero to full load
Hum and noise on output	less than 1 mV at full load

- **LED indicates current limiting mode**
- **Output terminals isolated from chassis**



application notes. Voila! National Semiconductor's Linear Data Book had something very close to what we wanted. In next to no time (read, close to *deadline*) a circuit was lashed up and working! The project you see before you is the culmination of the aforegoing.

There were a few more parameters to consider. The case? Metal, but cheap. The transformer? Appropriately rated and available *everywhere*. The meter? Ditto. The price? On target.

Specifications are given in the accompanying table.

The design

The power supply is built around an LM317 three-terminal voltage regulator. This device, apart from being inexpensive and widely available, has the following desirable features: internal current-limiting (self-protection), thermal shutdown (more self-protection), adjustable output between 1.2 V and 37 V and excellent regulation figures. We elected to use the TO-220 flat pack style as it's easy to mount (one bolt). National and Motorola designate it LM317T. Fairchild have an equivalent designated uA317UC.

The regulator serves two purposes in this design — to provide a regulated voltage reference and thermal overload protection. The output current is supplied by a transistor. We used a TIP32, which also comes in a TO-220 package. This is a pnp device connected here as a 'collector follower'. This sort of circuit provides current amplification, but no voltage gain. The regulator and transistor are mounted side by side on a heatsink. If the output voltage and current limit are set to maximum and a short circuit occurs on the supply's output for a lengthy period, then a considerable amount of power will be dissipated in the transistor. The temperature of the heatsink will rise considerably, but before it can rise destructively, the internal thermal overload circuit of the regulator will operate and limit the maximum dissipation. You'll burn your fingers on the heatsink by the time that happens.

In normal use, at maximum dissipation the heatsink only gets warm to the touch.

Output voltage variation is provided more or less in the normal manner by 'tapping' the 'adj.' terminal across a resistive voltage divider connected across the regulator output (this involves R7 and RV2). Current limiting is provided by an op-amp. This senses the output current and 'short circuits' the voltage applied to the regulator's 'adj.' terminal. The regulator output, and thus the supply output, drops and only the predetermined current flows in the load on the supply output.

HOW IT WORKS — ETI-162

The heart of the project is the LM317 regulator, IC1. This device is used in conjunction with the main 'pass' transistor, Q1. The IC regulator compares the voltage in its output pin with that — on the 'adj.' pin and regulates the output voltage accordingly. The bias for the pass transistor is derived across resistor R3 and is due to the current drawn by the IC regulator. If the 317 detects excess voltage, for example, on its output pin, it decreases the current pulled through R3, hence decreasing the bias to Q1. In this way the 317 controls the ouput voltage and ensures good regulation for the output.

The control voltage for the 317 is derived from a potential divider formed by R7 and RV2. The electrolytic capacitor (C9) connected across RV2 is to reduce noise on the output. Diode D8 is there to discharge this capacitor in the event the output is short circuited, otherwise it will attempt to discharge via IC1 and IC2, possibly causing some damage.

Capacitor C10 is placed directly across the output to provide both circuit stability and to supply short term peak currents often required by some circuits. It also functions as a low impedance ac bypass.

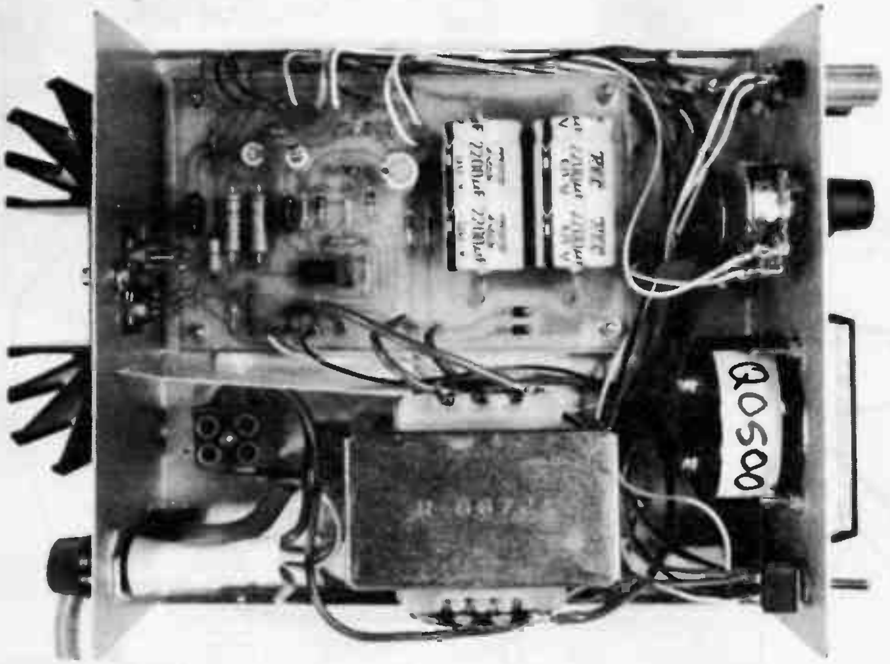
Since multiple power supplies are often used to power a single circuit, it is possible for the power supply to be supplied with a reverse voltage from an external source. To protect against this, diode D9 is included. The 1 A continuous current rating of this diode should be sufficient in most cases, and it will stand very high peak forward currents.

The remaining components are related to the variable current limit feature of this supply. The main device involved is the 301 op-amp, IC2. This device compares the output voltage, which is connected to its non-inverting input pin 3, to the voltage dropped by a potential divider formed by the CURRENT SET potentiometer (RV1) and R5. For any given setting of the CURRENT pot, the voltage on pin 2 of IC2 is proportional to the output current.

When the output current rises high enough, the voltages on pin 2 of IC2 will be 'pulled' above that on pin 3 (which is at the output voltage). The output of IC2, pin 6, then swings toward the negative rail, drawing current via D6 and LED2. LED2 will light, indicating current limit is in operation. The output of IC2 pulls down the voltage on the 'adj.' pin of IC1, lowering the output voltage.

Capacitors C5, 7 and 8 and diode D7 are included to ensure stability in the current limit stage when it is operating. This circuit uses a feature of the LM301 whereby it is capable of working as a differential amplifier with its inputs driven right up to the positive supply rail. The positive supply for the op-amp can therefore be the main output of the power supply and vary as the output voltage is varied. To ensure that the op-amp always has a supply across it, a negative supply rail has been derived by D5 and C3, a half-wave rectifier system that generates about 10 V from a tap on the secondary of T1.

The meter switch, SW2, allows the meter to be connected either as a voltmeter or a current meter. In the voltmeter position, the meter circuit is placed directly across the output with R10 and RV4 in series with M1. RV4 allows voltage calibration of the meter. When SW2 is in the current position, the meter measures the voltage drop across R8 and R9, which have the output current flowing through them. RV3 permits current calibration of the meter.



Overall internal view of the power supply. Note the cardboard 'shield' separating the mains terminal block and leads from the pc board.

Construction

For most electronic enthusiasts the mechanical work involved in a project is usually the tedious bit. We would expect most constructors to purchase a pre-punched and drilled chassis, but if you want to do it yourself or plan to use a different chassis, then start by carefully laying out and marking up the metalwork. Component placement is not critical, but we would suggest you keep a strict division between the mains components and wiring and the rest of the circuitry and components. If you're using the same chassis, or something similar, then our Scotchcal front panel artwork can be used as a template for the front panel. General placement of components can be determined from the photographs. The 184 x 70 x 160 mm chassis we used could have done with some bracing of the front and rear panels. Some small brackets could be made up from scrap aluminium pieces to do this job, if you wish. If you do this, tackle it first, but make sure the brackets won't foul any components attached to the panels.

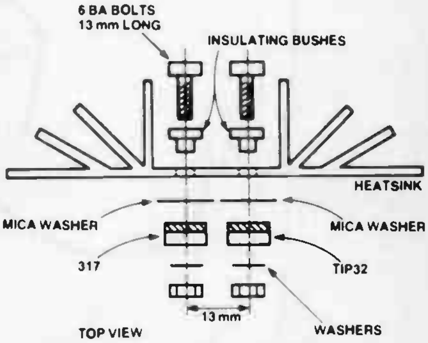
If you're using the same chassis we used and all holes are prepared, first thing to do is apply the Scotchcal front panel. We made up a metal Scotchcal, rather than plastic, as it's more durable. Carefully lift the backing from one edge and align the edge on the chassis panel. Peel off the backing and carefully smooth the Scotchcal into place across the panel making sure it's correctly aligned as you go. When it's in place, smooth out any bubbles by carefully rubbing them toward an edge. You can cut out the holes with a sharp penknife or modelling scalpel.

We also made up a metal Scotchcal label for the meter scale. Disassemble the meter and carefully apply the Scotchcal to the original scale, trim the edges if necessary and then re-assemble the meter.

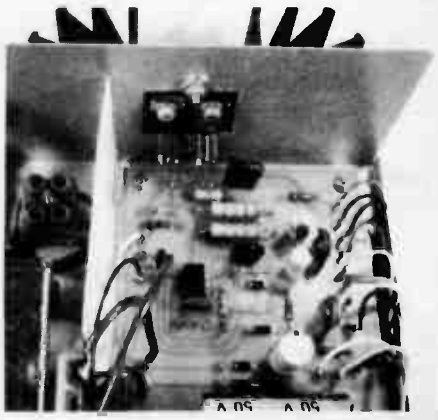
Mount the meter to the front panel first, otherwise you will have great difficulty reaching the nuts that secure it as they will be obscured by other components. Then mount the LEDs, switches, pots (and their knobs) and output terminals. On the rear panel, mount the mains fuse and install the mains cable with its clamp grommet, leaving enough of the cable protruding inside the case so that it reaches the terminal block. Mount the terminal block on the chassis bottom next, then terminate the mains cable. Make sure the green and yellow earth lead is the longest so that it's the last to break in the event of a catastrophic accident.

Insert the four pc board mounting bolts next. We used 13 mm long 6 BA bolts. Put two nuts on them to space the pc board up from the chassis. Cut a 'shield' for the mains wiring from a 70 x 70 mm piece of heavy cardboard, bend up one edge about 8 mm in and secure it under the rear mounting nut nearest the mains terminal block by punching a hole in the appropriate place in the bent-up piece — see the internal photograph.

Assemble the 317 regulator and TIP32 transistor to the heatsink next. Insulate each with a mica or plastic thermal washer and bolt insulators. Using a multimeter, check that the metal tag of each device is not shorted to the heatsink. Bend the leads of each device up from the heatsink.



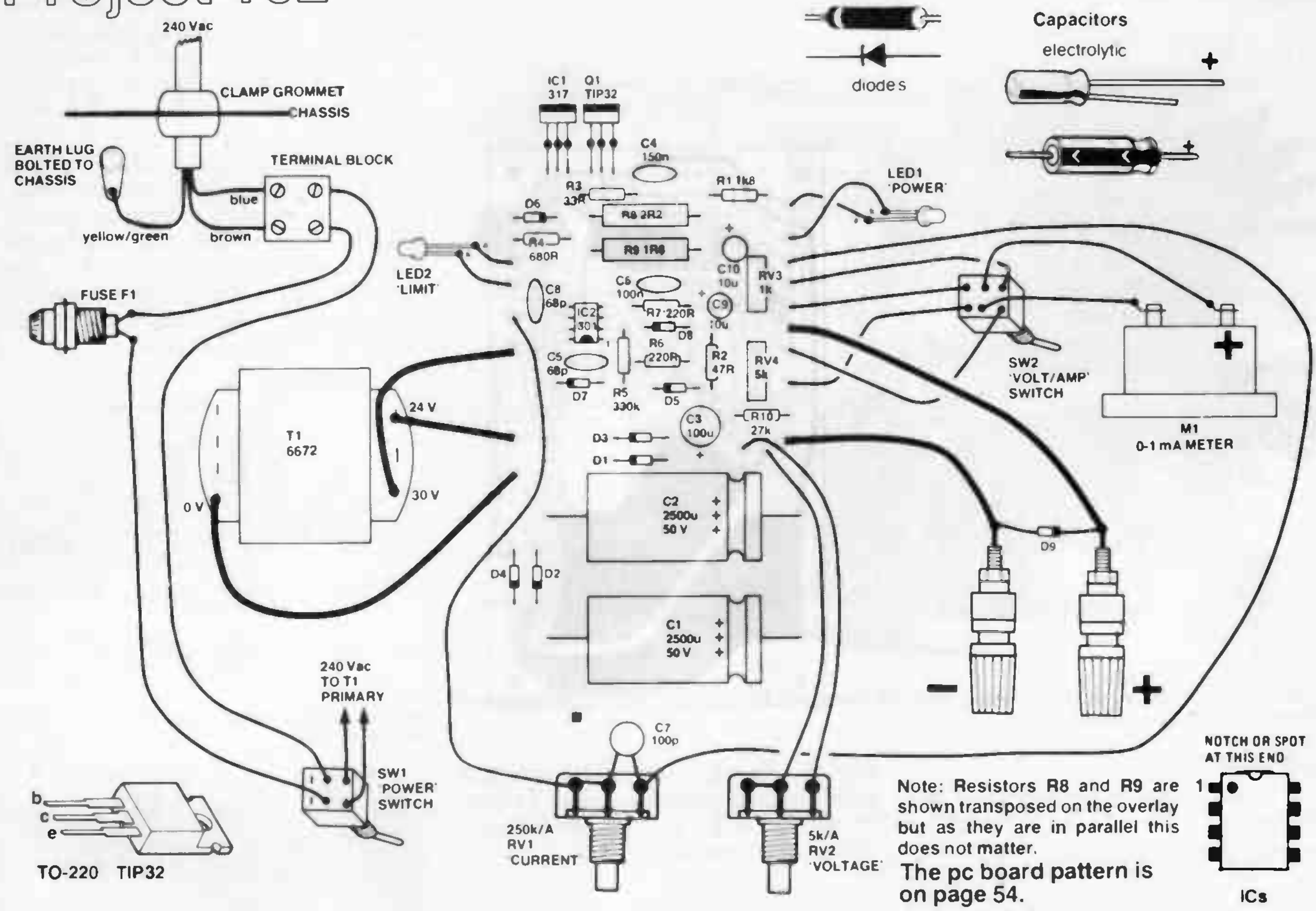
Mounting the 317 regulator and TIP32 transistor to the heatsink.



Internal view of the power supply showing mounting and terminating details for the regulator and transistor. These are assembled to the heatsink as shown above and the heatsink mounted to the rear panel using bolts above and below the cutout visible here.

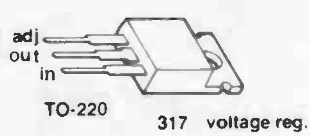
Now you can attach flying leads to all the components mounted on the front panel and between the mains terminal block and fuse to the mains switch. Put heatshrink tubing over the mains fuse and mains switch, ensuring they are well covered. Make sure all leads are long enough to reach their destination. Solder C7 to the terminals of RV1 and D9 to the output terminals, as shown in the overlay and wiring diagram.

Mount the power transformer next, oriented such that its 240 Vac input terminals are away from the pc board. Terminate the leads from the mains switch to the transformer primary connections, using heatshrink tubing again to shroud the terminals.



Note: Resistors R8 and R9 are shown transposed on the overlay but as they are in parallel this does not matter.

The pc board pattern is on page 54.



Now you can tackle the pc board. Start with all the resistors. Then mount the two trimpots. Next, solder all the semiconductors in place. It is *most important* you get all of these the right way round, especially the rectifier diodes. The capacitors can be mounted next. There are five electrolytics and all have to be mounted with the correct orientation. Note that the two filter capacitors are given as 2500 uF in the parts list but the photograph shows 2200 uF types. Either can be used without affecting circuit operation at all. Remember, electrolytic capacitors have a very wide tolerance (like +80%, −20%). We used pc stakes to terminate the leads from the off-board components. You could use short lengths of 22 gauge tinned copper wire with a loop bent at the top, if you wish. Six 30 mm lengths of tinned copper wire are needed to connect the 317 and TIP32.

Carefully check the pc board to see that all components are mounted and the semiconductors and electrolytics are correctly polarised. Mount the pc board and terminate the flying leads from all the off-board components. Use heavy duty hookup wire from the transformer secondary to the board and from the output terminals to the board.

All OK? *Check it!*

Now you're ready to switch it on and try it out.

PARTS LIST — ETI-162

Resistors	all ½W, 5% unless noted
R1	1k8
R2	47R
R3	33R
R4	680R
R5	330k
R6, R7	220R
R8	1R8, 1W
R9	2R2, 1W
R10	27k
RV1	250k lin. pot
RV2	5k lin. pot
RV3	1k min. vertical mount trimpot
RV4	5k min. vertical mount trimpot
Capacitors	
C1, C2	2500u/50 V axial electro
C3	100u/25 V RB electro
C4	150n greencap
C5, C8	68p ceramic
C6	100n greencap
C7	100p ceramic
C9, C10	10u/35 V RB electro
Semiconductors	
D1-5, 8, 9	1N4001, 1N4002, 1N4004, EM401 etc
D6-D7	1N914, 1N4148
IC1	LM317T, uA317UC
IC2	LM301, uA301
Q1	TIP32A, B or C
LED1, 2	TIL220R red LED

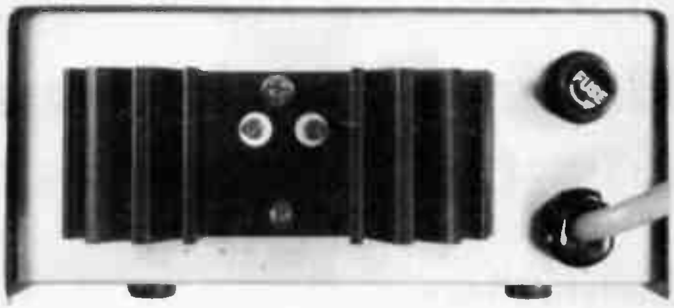
Miscellaneous	
F1	0.5 A, 3AG fuse
M1	1 mA MU-45 meter, or similar
SW1, SW2	DPDT miniature toggle switches, 250 Vac/1 A rated.
T1	6672 transformer, 240 V primary, 30 V/1 A multi-tapped secondary

ETI-162 pc board, two binding posts — one red, one black, case — metal, U-chassis & lid type, 184 x 70 x 160 mm (e.g. D.S.E. H2744, Altronics H0444, Electronic Agencies HE1742); two small knobs, mains cable, clamp grommet and terminal strip, fuseholder, Scotchcal panel and meter scale, heatshrink tubing; heatsink — flat sided radial fin type, 30 mm long (e.g. Rod Irving HS1), nuts, bolts, hookup wire etc

Price estimate
$45 — $50

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.

Internal view from the rear of the front panel.



View of the rear panel showing heatsink and mains fuse placement.

Switch on

Set the CURRENT and VOLTAGE control to about half rotation and the VOLT/AMP switch to read volts on the meter. Hook your multimeter to the output, switched to the 30 V range or a higher one, plug in and switch the power supply on. If all is well, the POWER LED should light and the multimeter will read some voltage. The power supply meter will probably read something quite different. If you don't get these indications, switch off and look for a wiring error or components misplaced or incorrectly oriented.

If all is well, set the VOLTAGE control so that you get a reading of 20 V on your multimeter. Then, adjust RV4 (the trimpot nearest the front panel) until the power supply meter reads the same. Vary the VOLTAGE control and check that the supply's meter corresponds closely with the multimeter. See that you get around 1.3 V at minimum and 30 V (within 0.5 V) at maximum.

Turn the power supply off. Wind the VOLTAGE control fully anticlockwise and set the CURRENT control half way. Set the VOLT/AMP switch to read current on the supply's meter. Switch your multimeter to the 1 A range, or higher. Turn the power supply on. The LIMIT LED should light and the multimeter should indicate about half an amp of current flowing. The supply's meter will likely read something quite different. Wind up the CURRENT control so that your multimeter reads one amp. Adjust RV3 (nearest the back panel) so that the supply's meter reads the same. Vary the CURRENT control and see that the supply's meter corresponds closely to your multimeter. The LIMIT indicator should go out when the CURRENT control is at minimum.

If at any time you don't get the correct indications, or worse still — burning smells!, switch off and hunt for a fault.

If all is well, you can put the lid on your supply and put it proudly on your workbench.

Using it

In use, you set the output voltage to what is required by the circuit you are working on then apply a short to the output terminals and set the current limit to something a little above what you judge the circuit will draw. With most CMOS circuitry, even that containing many ICs, 100 mA is a good safe limit. Allow for relay and indicator (LEDs, lamps etc) currents. A little experimentation will teach you what to expect under a wide range of circumstances.

We trust you get many useful years of use from your ETI-162 power supply. ●

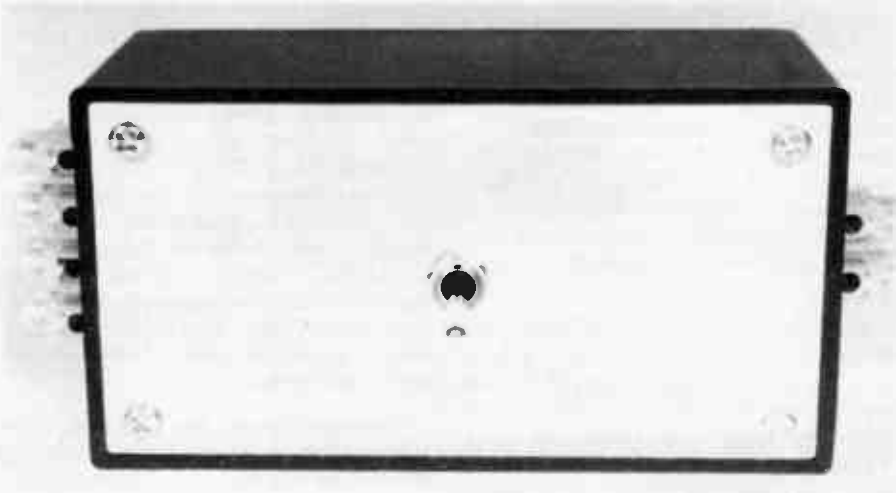
NOTE: this supply is not meant to be used as a battery charger so don't connect lead-acid batteries to it. Accidental reverse connection of a lead-acid car battery will likely destroy D9 and maybe other components. Nickel-cadmium batteries could be charged from the supply operated in the constant-current mode and D9 will prevent damage to the supply if you accidentally reverse-connect them. However, take the usual precautions regarding the charging period and charging current.

NOTE: The supply should not be turned on or off while operating in the current mode. Disconnect the load first, otherwise the LM301 and TIP32 could be destroyed. To protect against this, a mod. sheet can be obtained by sending a SSAE to ETI-162 Mods, ETI Magazine, PO Box 21, Waterloo, NSW 2017.

House alarm is simple to construct, features high reliability

Collyn Rivers

This project is adequate for the average household or small business and will provide years of reliable operation.



WHEN YOU HEAR a burglar alarm the chances are less than three in a hundred that the alarm has been set off by an intruder. The other 97 times it's been falsely triggered. And if it's raining at the time — especially if there's a thunderstorm — the chances of the alarm being genuine are very much smaller still.

This is a thoroughly unsatisfactory situation and one that has caused police and security organisations many headaches over the years.

False alarms are generally caused by poor installation techniques and/or the wrong choice of alarm control unit for the specific application. In the case of non-professional designs and installations the cause is usually lack of appreciation of the problems inherent in what at first seems to be a simple problem in electronic circuit design.

The alarm unit and installation techniques described in this article have been devised to combine total reliability with immunity to false triggering. Both were progressively developed over a number of years and the unit itself was produced commercially (by the author) in large quantities for the security industry some years ago. It is still one of the simplest and most reliable units around.

The system is adequate for the average household or small business. If built and installed as described it will provide years of reliable operation.

Defining the risk

Really determined and skilled burglars will find ways to break into almost anywhere — no matter how well it is protected. But experts like these will be far too occupied sizing up the local bank to bother about most houses or small businesses. Who you're mainly up against are 15-25 year olds with generally limited intelligence.

Figure 1 shows how and where most forced entries will be attempted. A surprising 29.2% of illegal entries are made through unlocked doors or windows. Most other entries are made by forcing with a jemmy. Only rarely is entry made by breaking glass.

So your first step should be to 'harden up' the house. Fit really strong concealed catches, especially to those windows which are not overlooked from the street or by neighbours' houses. You'll have to search around for decent fittings — the sliding bolt catches sold by most hardware stores are jokes. One good kick will tear them in half — if the toy screws supplied don't pull out first! So consider carefully how the various devices will withstand a jemmy used in earnest — and whether the woodwork to which they are attached will need strengthening.

Once this is done it's time to think about alarm protection.

The basic system

The simplest adequate alarm system detects the opening of doors or windows and when an 'opening' signal is received causes the alarm to sound continuously even after the door is subsequently closed.

The alarm should also sound and continue to sound if any associated wiring is detected and cut. The alarm should be battery operated so that it will continue to operate if mains power fails or is disconnected.

This all seems simple enough to do but there are a number of unsuspected traps along the way.

Detecting entry

Doors and windows may be protected by switches which are closed when the openings to be protected are closed. All such switches are connected in a series loop so that if one or more are opened, or interconnecting wiring is cut, the alarm is actuated.

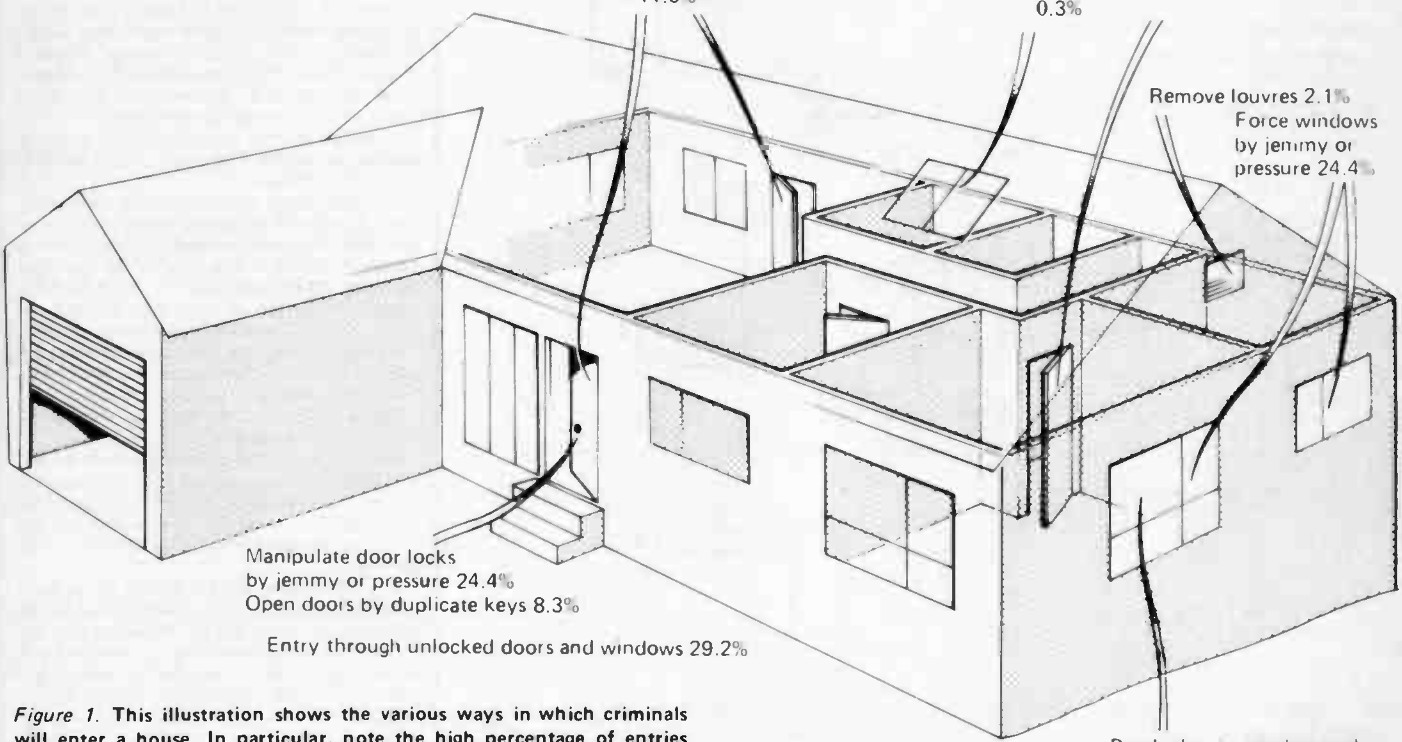


Figure 1. **This illustration shows the various ways in which criminals will enter a house. In particular, note the high percentage of entries made through locked doors and windows. The necessity for adequate locking arrangements is obvious. We acknowledge the assistance of the Crime Prevention Dept. of the NSW Police in making these statistics available.**

Many of the windows to be protected may remain closed for months — sometimes years — so the switches chosen must be absolutely reliable and resistant to corrosion. Most switches are designed so that the contacts are automatically cleaned every time the switch is operated — but this doesn't help much if the switch is actuated only once in ten years!

Another essential requirement is that the door or window must be able to open at least 20 mm before the switch is actuated. This will allow for movement caused by swelling in wet weather and rattling during storms.

The ideal device for this purpose is the magnetic reed switch. This consists of a pair of ferro-magnetic reeds and contacts, hermetically sealed in a small glass tube, and held closed by a magnet a few millimetres away. The contacts open when the magnet is moved away from them.

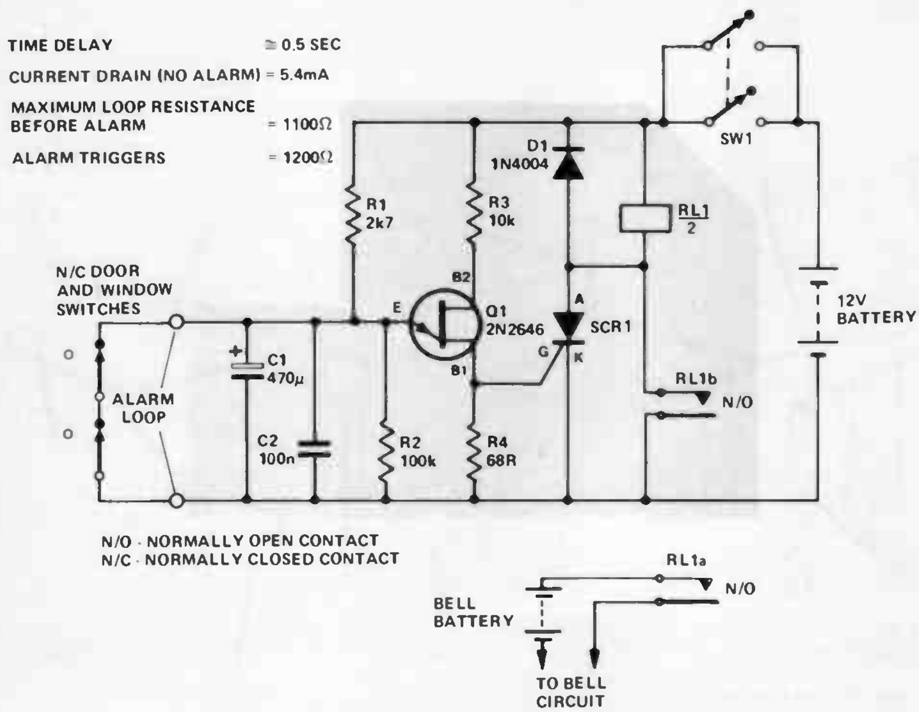
Commercial installers use these switches extensively but they generally keep them packaged in rectangular plastic mouldings. A neater, but more time-consuming method, is to recess them into the architrave surrounding the opening. Whichever type is used the magnet should always be attached to the moving part of the door or window.

The reed switches *must* be designed specifically for security and similar applications — standard reed switches may not necessarily be suitable as some tend to remain closed when the magnet is removed if they've been held closed for any length of time. To be on the safe side, buy your switches from a security equipment supplier — you'll find addresses in the Yellow Pages.

The best magnets are ferritic-ceramic bar types — they're made by many companies and should not be hard to locate. They're usually round or square and sections 25 mm or so long will be fine. These will pull in the switch at a distance of 10-12 mm and will hold it closed at 15-20 mm.

Choose suitable locations and install switches and magnets as shown in the accompanying picture. Before making the final choice of position make sure that the door can open 20-30 mm with-

External connections to the unit are made via the two plastic screw-terminal blocks.



HOW IT WORKS — ETI 250

Resistors R1, R2 and R3, capacitor C1 and the unijunction transistor Q1 form a basic pulse generator. With the external alarm loop 'open', C1 charges via R1 until the voltage across it reaches about half the applied battery voltage. When this level is reached the unijunction 'fires' — C1's charge being dissipated via R4. This action causes a positive-going pulse to appear across R4, the pulse in turn causing the SCR to conduct.

An SCR once conducting will remain so even though the triggering signal is removed, provided the anode-cathode voltage remains steady. The SCR is thus 'latched on' and energises the double-pole relay RL. The instant the relay is energised contacts RLb connect the relay directly across the battery supply, 'latching' the relay on. The relay will now stay latched even if the entire circuitry — both internal and external — subsequently fails.

Diode D1 protects the SCR against voltage transients generated by the relay coil.

In use, the external alarm loop shorts out C1, and whilst voltage spikes may well appear across C1, they will not charge the capacitor sufficiently to raise the voltage level to the firing potential of the UJT's emitter — B1 junction.

The time taken for the circuit to respond following an alarm signal is determined by the combination of R1 and C1. Do not *reduce* the value of C1 nor substantially *increase* the value of R1. Capacitor C1 may be increased by a desired amount if a longer time delay is required.

out triggering the switch. One trick that's not immediately obvious is to mount the switch and magnet closer to the hinged side rather than the moving side of the door. Keep the wires leading to and from the switches as far apart as possible. Leave a small amount of slack in the wiring so that building movements will not stress the wiring or connections.

It is worthwhile protecting one or two internal doors — particularly if you have one leading from a garage or carport into the house — but don't overdo the number of protected entry points. Every additional switch increases the probability of false alarms.

The switches should be connected in series using multi-strand wire (14/0076 is about right). Don't use single strand wire — it's more prone to failure if moved. Solder the wires to the switches using *non-corrosive* solder and clean off any residual flux with detergent and clean water. When all switches are installed and connected, check the overall resistance around the loop with a multimeter. The total should not exceed 20 ohms — preferably less.

If all is OK, paint over the solder points and any bare wire with bituminous paint — or smear well with Vaseline. This may seem technical overkill but it's surprising what pollution can do to wire left bare for several years.

The unit itself

The alarm unit should ideally be battery powered and draw little current. It should be capable of accommodating *some* resistance in the external signal loop but must *not* accept more than two hundred ohms before triggering. And that's where so many amateur and magazine-designed alarms go wrong, for in the quest for low current consumption designers plump for a high impedance input. Figure 2 shows what can happen if the woodwork around the

PARTS LIST — ETI 250

Resistors	all ¼W, 5%
R1	2k7
R2	100k
R3	10k
R4	68R
Capacitors	
C1	470u16 V electro
C2	100n greencap
Semiconductors	
Q1	2N2646 UJT
SCR1	C106D SCR
D1	1N4004 or similar

Miscellaneous

RL1 — cradle relay, 12 V coil with two change-over contacts (Pye, type 265/12/G2V); SW1 — DPST toggle switch; 12 V battery; pc board ETI-262; small box to suit; barrier strip terminals (six-way), plated type; suitable reed switches; magnets etc as per the article.

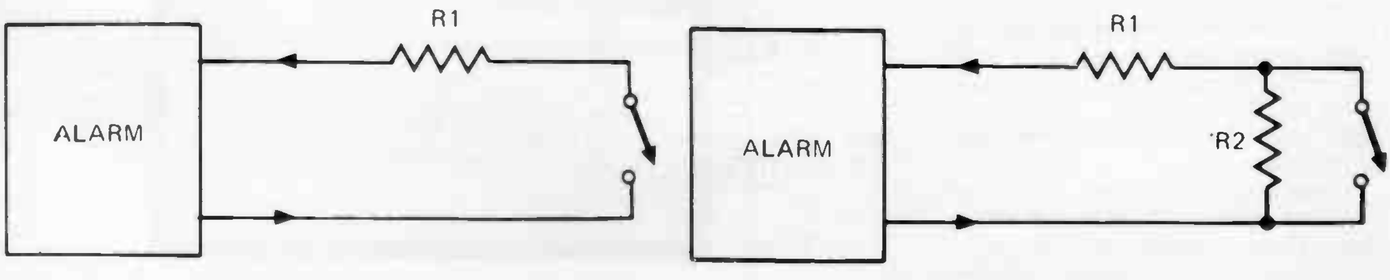
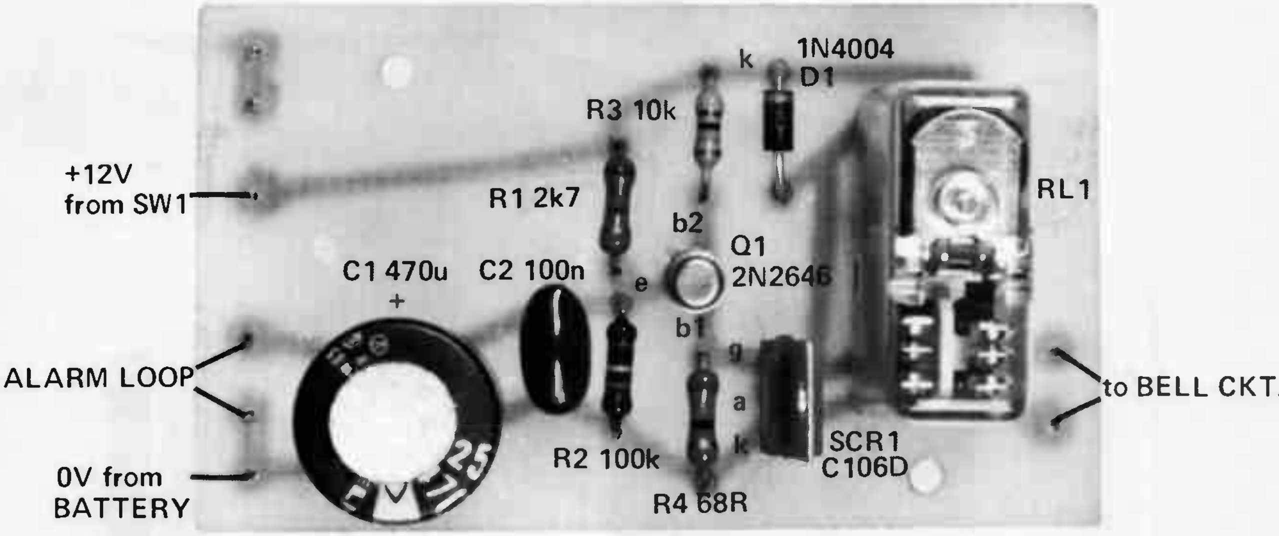
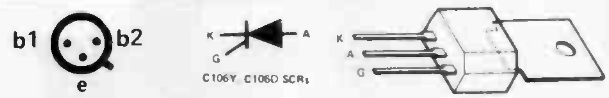


Figure 2. Resistance R1 represents series resistance of the loop (see text). Resistance R2 represents leakage paths across alarm contacts.





2N2646 BOTTOM VIEW

switches gets moist — a leakage path may develop in parallel with the switch (that's why you keep those leads apart) and if this happens when the control unit can tolerate more than a few hundred ohms, that switch can be opened *without triggering the alarm* !

The alarm unit must be insensitive to voltage spikes picked up by the external loop — remember that's quite an antenna you'll have there. Such voltages can be surprisingly high and are caused by lightning strikes, arc welders, faulty fluorescent lighting starters, capacitor start motors (often found in 'fridges and freezers), contactors, etc. Existing alarms can be protected to some extent by connecting two capacitors (in parallel) across the input terminals. One should be about 10 uF, the other about 10n. Figure 3 shows how — and why you need the two.

A good test for voltage spike immunity is to wind fifty to a hundred metres of wire around a power drill. Connect the two ends to the input of the alarm unit and switch the drill on and off about fifty times. If the alarm isn't triggered by this it's a fair bet it will be satisfactory when installed. Very few alarm control units will withstand this test and those that don't will sooner or later cause problems.

Don't for a moment consider any alarm unit in which the external loop is connected directly to the gate of an SCR. It is *impossible* to protect such a circuit if the external loop is more than a few centimetres long. Yet, incredibly, such circuits are shown time and again in electronics magazines — presumably because at first sight an SCR is (almost) a single component control unit.

Likewise, don't connect a bell or siren directly to the anode of an SCR. Voltage spikes induced in the wiring to and from the bell can and will trigger the SCR into conduction. If you have such a device at present, modify it by interposing a relay between the SCR and the bell circuit — and connect a diode across the relay coil to protect the SCR against the relay's collapsing magnetic field.

The circuit of the ETI-250 alarm con-

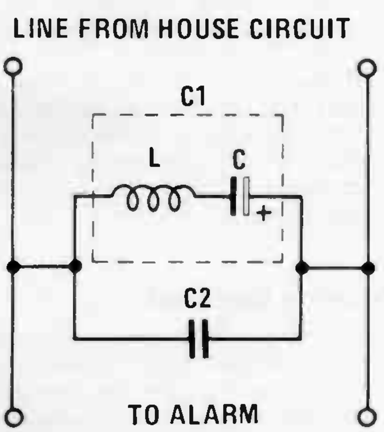
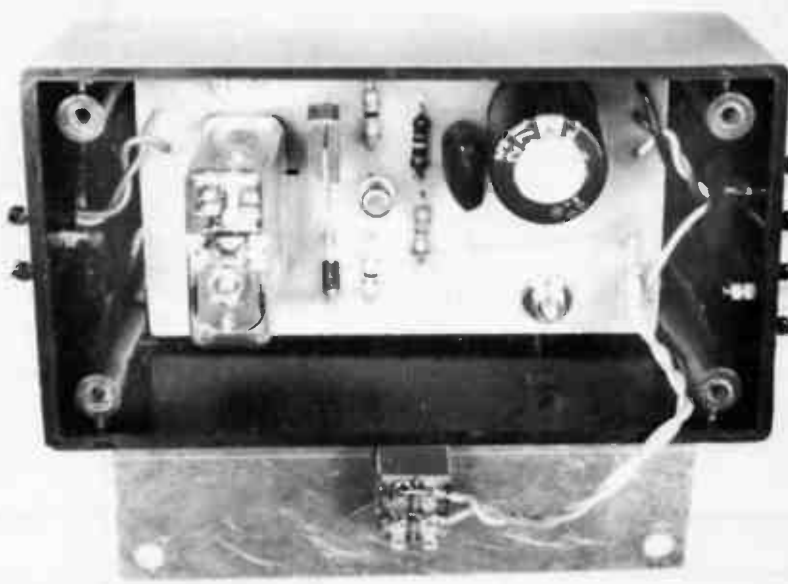
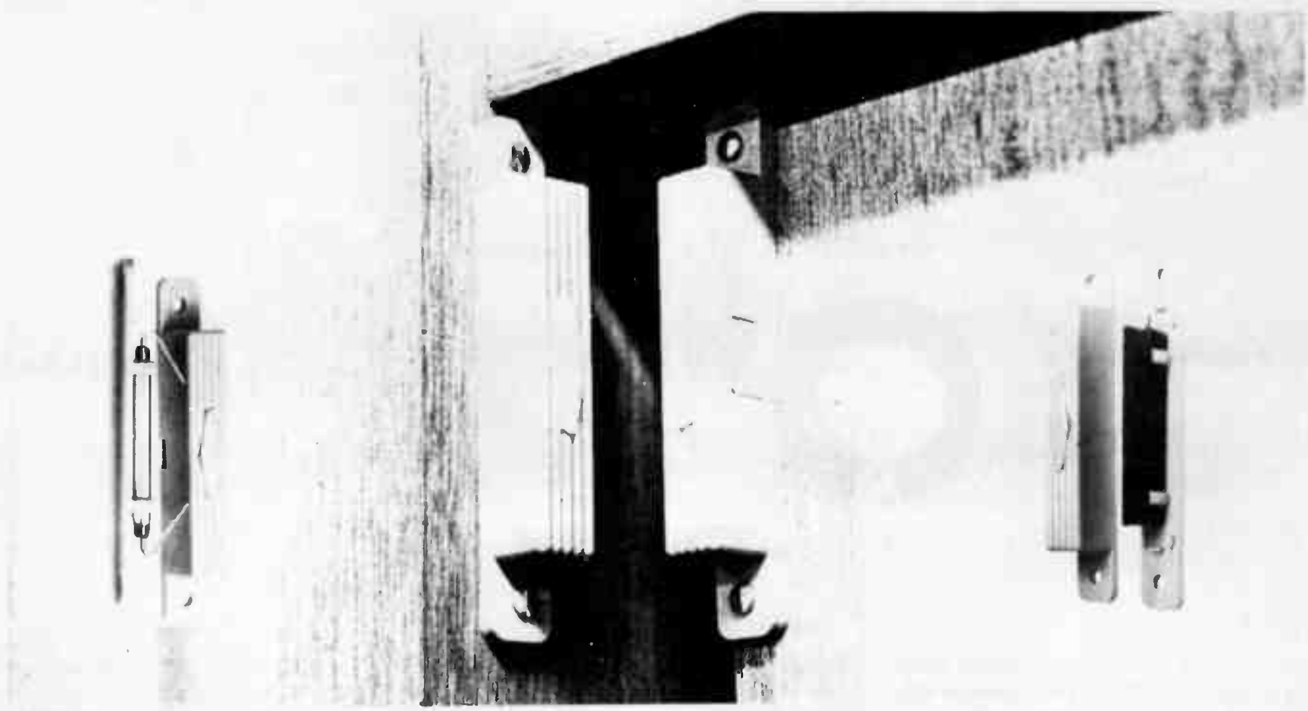


Figure 3. The large value capacitor, C1, will effectively bypass low frequency interference but its high series inductance, L, will prevent the bypassing of high frequency interference. A smaller value capacitor, C2, usually a ceramic type with a low series inductance, will bypass the high frequencies effectively.





Reed switches and magnets for burglar alarm systems are designed for easy installation.

trol unit is shown in the accompanying diagram. It's essentially a simple circuit but one in which several components perform more than one function. The basic idea is that a unijunction pulse generator is normally prevented from operating by the closed external alarm loop. When the loop opens, the unijunction 'fires', causing an SCR to conduct and latch on, which in turn actuates the alarm relay.

The best way to construct the control unit is to use the printed circuit board shown full size on page 65. Make sure that C1 is inserted the right way round and that all joints are very carefully soldered. Clean off any residual flux after soldering.

Resistor R1 controls the length of time between a switch being opened and the alarm being triggered. The value shown will trigger the circuit after approximately ¾ sec. Altering values to reduce the triggering delay will increase battery drain. The delay enables doors to rattle in a gale without triggering the alarm accidentally (it is impossible to open a door, pass through and close it again in less than one second).

Don't be tempted into replacing R1 by a potentiometer — it will rarely be moved once the alarm is installed, so that corrosion will eventually build up between the wiper and the track.

Keep the leads from the alarm unit to the battery as short as possible — 300 mm at most. Preferably build the battery in with the unit as we've shown. Use a *second* battery to power the alarm bell.

Do not delete the relay and run the bell straight off the SCR. *It will work*, but with reduced reliability and increased susceptibility to false alarms.

The alarm unit draws very little current, so batteries will normally last for nine to twelve months. It is advisable however to replace them routinely every six months. It's not worth building a mains power supply. You'll need an automatic mains/battery changeover unit to cater for mains failures — so you'll have to have a battery anyway. The best power sources for this application are six volt 'lantern' batteries. Use proper soldered terminal lugs on the ends of the battery leads.

It is worth considering powering the *bell* from a small Nicad battery with an automatic charger. This is also an elegant way of ensuring that the bell cuts out after an hour or two when the Nicad has exhausted itself.

Arrange for a key operated switch to short out the alarm switch on a chosen 'silent entry' door. Suitable switches may be obtained from security equipment companies. The associated wiring should be concealed.

The main on/off switch on the unit itself should be double-pole single-throw with the contacts wired in parallel (to enhance reliability). Do not attempt to economise by fitting a cheap switch.

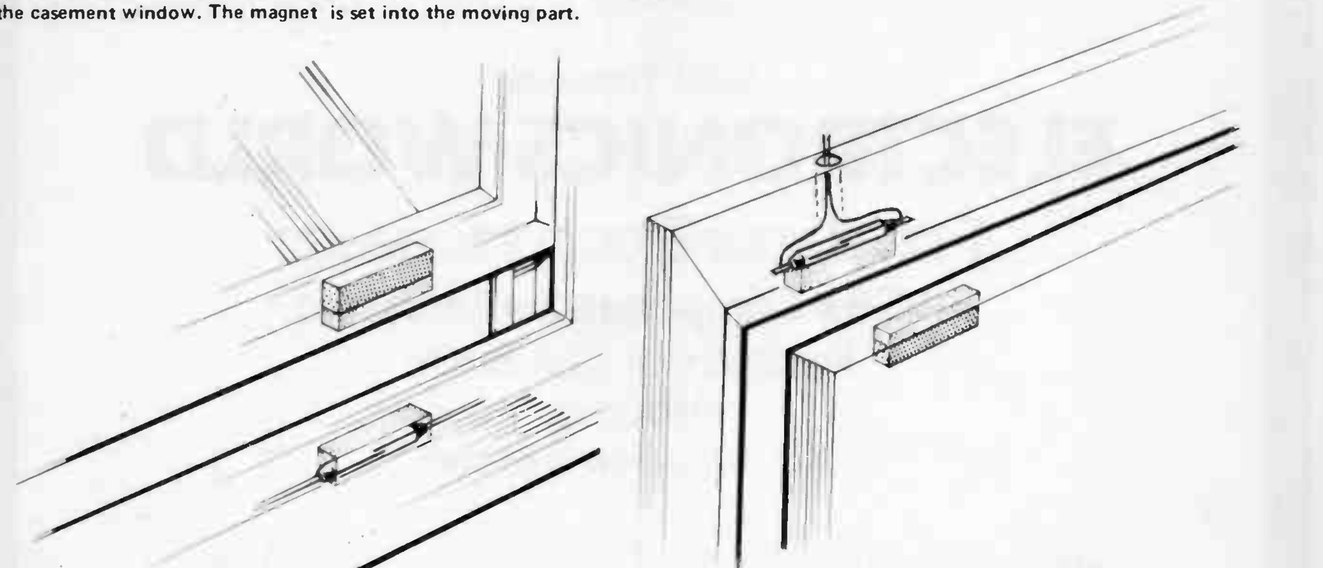
If you wish to further increase reliability you could duplicate the entire system, but as long as the unit and external wiring is put together carefully the chance of failure is almost negligible anyway.

A magnetic reed switch.

Scaring them off

Good quality electro-mechanical bells are still the best form of audible alarm for household protection. Being mechanically resonant they make a very large amount of noise and consume little power whilst doing so. The average 12 inch bell (it's an old-fashioned industry and they still think in inches) draws less than half an amp and can be heard at least a hundred metres away.

For window protection, the reed switch is recessed into the frame of the casement window. The magnet is set into the moving part.



Door protection -- the reed switch is set into the architrave.

A siren has a potentially larger range but is more directional. Good ones draw a lot of power — five to ten amps or more. Small cheap sirens should not be considered. The alarm bell should be mounted unobtrusively, and high up in an inaccessible position. Leads to the bell should be totally concealed. Use 40/0076 wire to reduce voltage drop.

It is worth locating one or two spotlights in strategic positions and arranging for these to be switched on as the alarm is actuated.

Finally, don't be put off by stories about people ignoring alarm bells — burglars don't!

Should you tell

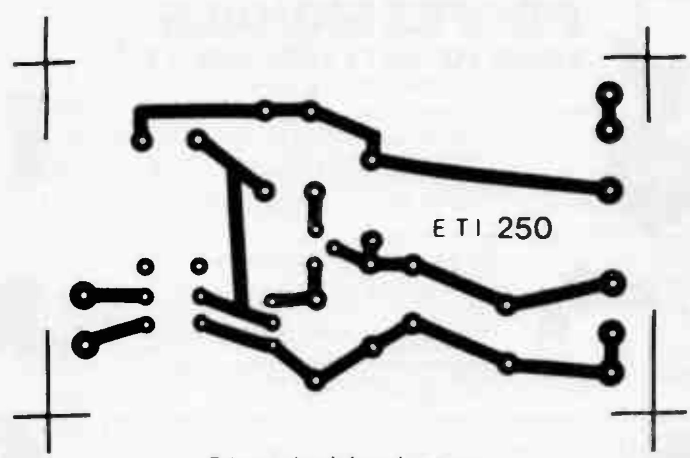
Providing you have a good installation and a concealed bell there's a lot to be said for making it clear to intending intruders that the premises *are* protected.

One way of doing so is simply to place warning notices in strategically chosen windows. This is done by most professional security companies — to such effect that there's quite a strong argument for using just notices alone!

We've included a suitable warning notice (extra copies printed on heavier paper can be obtained for 50 cents each plus a large, stamped, addressed envelope — address to write to is Electronics Today International, 140 Joynton Ave, Waterloo, 2017.

A further very worthwhile tactic is to install a circuit which flashes red LEDs set into the frames of all visible windows and doors. The old 555 will do nicely, or those new-fangled self-flashing LEDs. Combine these with the printed notices plus the alarm circuit, just in case anyone thinks you're bluffing, and your chances of being robbed are negligible.

One final note: no matter how good the installation, it's *useless* unless you switch it on. ●



Printed circuit board pattern.

THESE PREMISES
PROTECTED BY
E.T.I. SECURITY ALARM
SYDNEY, AUSTRALIA. eti 250

Simple NiCad battery charger

Protect your investment in Nickel-Cadmium cells (NiCad for short) with this simple charger. It's very reliable, easy to build and won't ruin the cells by over-charging, which is a common cause of NiCad battery failure.

Design: **staff**
Article: **Andrew Kay**

PRACTICALLY EVERYONE who owns and/or uses battery driven equipment that is used regularly is aware of the staggering cost of the batteries that seem to need replacement with monotonous regularity. They seem to have the perverse habit of running flat at the most inconvenient time (Murphy's law notwithstanding): they are getting dearer all the time: their output voltage drops quite rapidly with discharge and last, but most importantly, they deteriorate almost as quickly on the shelf as when they are in use.

Since it's not always practical to use mains-powered battery eliminators, one solution is a battery with a high 'ampere-hour efficiency'; that is, one whose voltage is much less affected by the discharge rate than the dry cell type. Also, it's handy if the battery can be recharged. The NiCad cell meets both these requirements. Although they are pretty pricey to start with, NiCad cells are capable (if treated properly), of up to *five hundred* charge/discharge cycles!

Just multiply the cost of your last battery replacement by five hundred and see the money that can be saved.

Care and feeding of NiCads

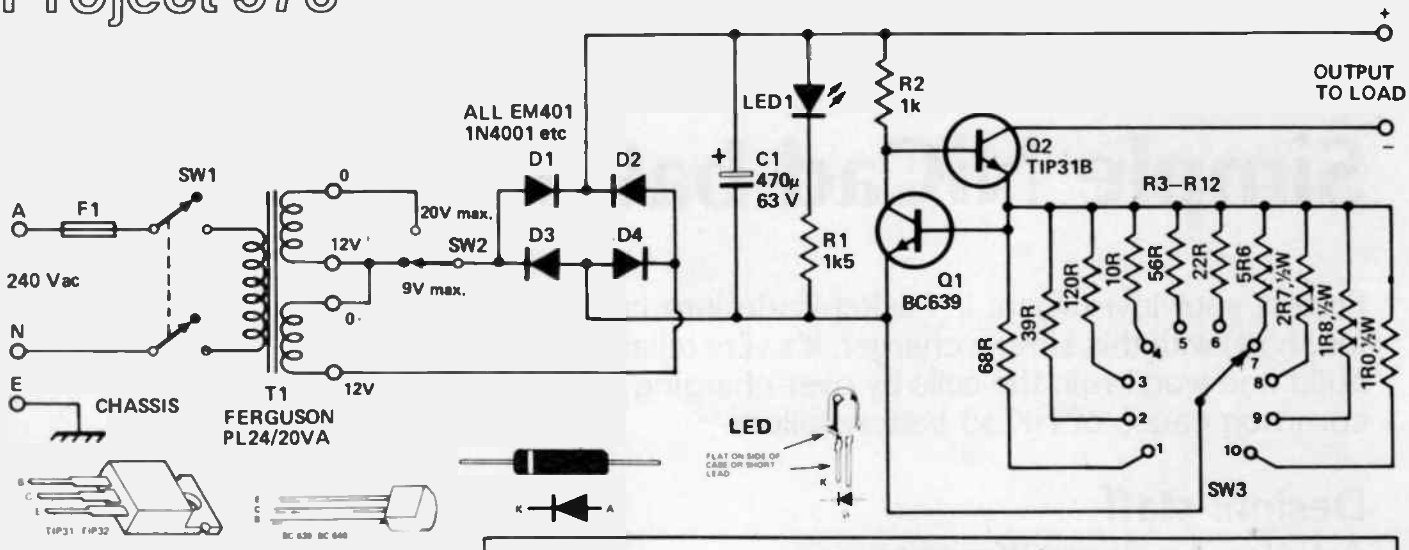
Now that you've been convinced of the economics of the matter, here are some basic but essential facts regarding NiCad cells.

The NiCad cell, like the lead acid unit, is a *secondary* cell or accumulator; i.e.: its chemical action is reversible. Passing direct current from an outside source (charger), converts electrical energy into chemical energy within the cell. The process is reversed when the cell is connected to an electrical load; the chemical energy stored within it during charging is converted to electrical energy which is dissipated by the load.

The NiCad cell needs a fairly constant charging current, this current being a function of the cell's capacity and the charging period. Cell capacity is expressed in Ampere-hours, abbreviated Ah, this being the current delivered by the cell, multiplied by the number of hours it will do so before reaching the discharged state. Take for example the 'AA' size NiCad cell which is equivalent to the U11 dry cell in dimensions and output voltage. It has a nominal capacity rating of 0.5 Ah; i.e: it will deliver half an amp for one hour; or 50 mA for 10 hours, 5 mA for 100 hours and so on.

However, there are physical limitations at higher current levels — one cannot expect to draw 50 A for 36

Project 578



seconds or even 5 A for six minutes!

In fact, it is accepted practice to load the cells to only one tenth of the nominal Ah rating; i.e: if your circuit draws 50 mA average current, you should use at least a 0.5 Ah NiCad battery as a power source.

Similarly, to recharge a NiCad cell or battery to full capacity requires the same current-by-time multiplication sum. For example, to recharge an 'AA' NiCad cell it needs 0.5 A for one hour or 250 mA for two hours and so on.

Once again, owing to certain limitations — danger of cell rupture in particular — fast charging of our 0.5 Ah AA cell at 5 A for six minutes is definitely not on! Under certain circumstances NiCads can receive a 'rapid' charge and actually benefit, but perhaps we'll leave that subject till another time.

At this point we come to the basic problem of charging NiCad cells.

Danger of Overfeeding

Due to the nature of the NiCad cell, overcharging causes permanent damage. And it is quite hard to determine by ordinary means (such as a voltmeter) precisely where full charge occurs and overcharging begins. So it would seem that one must disconnect the cell from charging at, or before, the moment of full charge occurring!

Fortunately, there is a way around this problem which involves using a pre-determined low value of charging current. It is not a well known fact, but if the charging current is kept at one sixteenth of rated capacity then no permanent damage occurs, regardless of how long the cell remains on charge. In other words, you could leave your AA size NiCad cell connected to the charger for any convenient period, as long as the current was maintained at (500/16) mA

HOW IT WORKS — ETI 578

This charger consists of a step-down transformer, T1, a full-wave rectifier with capacitor-input filter (D1-D4 and C1), followed by a constant-current regulator involving Q1, Q2 and resistors R2 to R12, R3-R12 being selected by SW3 to provide the required charging current.

To understand how the constant-current regulator works, let's examine a simplified version of the circuit above - see Figure 1, below.

As the circuit stands, base current for Q2 will flow through R1 and Q2 will be turned on. Emitter current from Q2 will flow through R2, and if the voltage drop across R2 is above about 0.5 - 0.6 V, Q1 will turn on. Current through R1 will then be shared between the base of Q2 and the collector of Q1.

Now, with a load connected across the "constant current" terminals, collector current will flow through Q2 via R2. Thus, the voltage across R2 will attempt to rise. However, the base-emitter voltage of Q1 cannot vary greatly from a value of 0.6 V — this is a characteristic of the transistor. Thus, more base current will flow in Q1. This results in a greater collector current in Q1, which "robs" some of the base current from Q2, reducing its collector current. Thus, we have negative feedback and the current through the collector of Q2, which is also the load current, will settle to a value such that about 0.6 V is maintained across R2. Therefore, a constant current is delivered to the load, the value of which is entirely determined by the value of R2.

The power dissipated in R2 is kept quite low as the voltage across it will be no greater than about 0.6 V, thus low wattage resistors may be used.

In the project's circuit diagram above, Q1 and Q2 can be readily identified as they are identical with those in Figure 1. Base current to Q2 is supplied by R2 (a 1k resistor) and the output, or charging, current is determined by the resistor selected by SW3, from resistors R3 to R12.

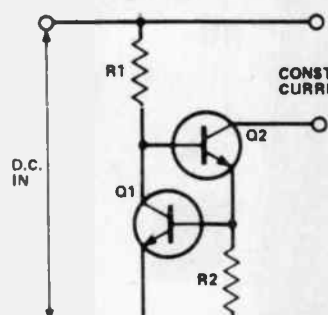


Figure 1.

PARTS LIST — ETI 578

Resistors all ¼W, 5% unless noted

R1	1k5
R2	1k, 1W
R3	68R
R4	39R
R5	120R
R6	10R
R7	56R
R8	22R
R9	5R6
R10	2R7, ½W
R11	1R8, ½W
R12	1R0, ½W

Semiconductors

Q1	BC639
Q2	TIP31B
D1-D4	1N4001, EM401 or similar, 1A diodes
LED1	TIL220R or similar red LED plus mount

Capacitors

C1	470u, 63V electrolytic

Miscellaneous

F1	¼A fuse and fuse holder to suit (240 Vac rated)
SW1	DPST switch, 240 Vac rated
SW2	SPDT switch
SW3	single pole, 10 or 12 position switch
T1	Ferguson PL24/20VA or similar, 12+12 V sec. at 800 mA.
pc board	ETI-578

Metal case to suit (we used a David Reid Electronics type, No.4., measuring 140 mm deep by 120 mm wide by 95 mm high); two "flat pack" heat sinks (Dick Smith H-3402 or similar) mains cable and three-pin plug; terminal block and cable clamp; rubber grommet; four rubber feet; piece of 1.6 mm thick cardboard; spaghetti sleeving; hookup wire; output terminals; solder lugs, nuts and bolts, two standoffs, Scotchcal front panel.

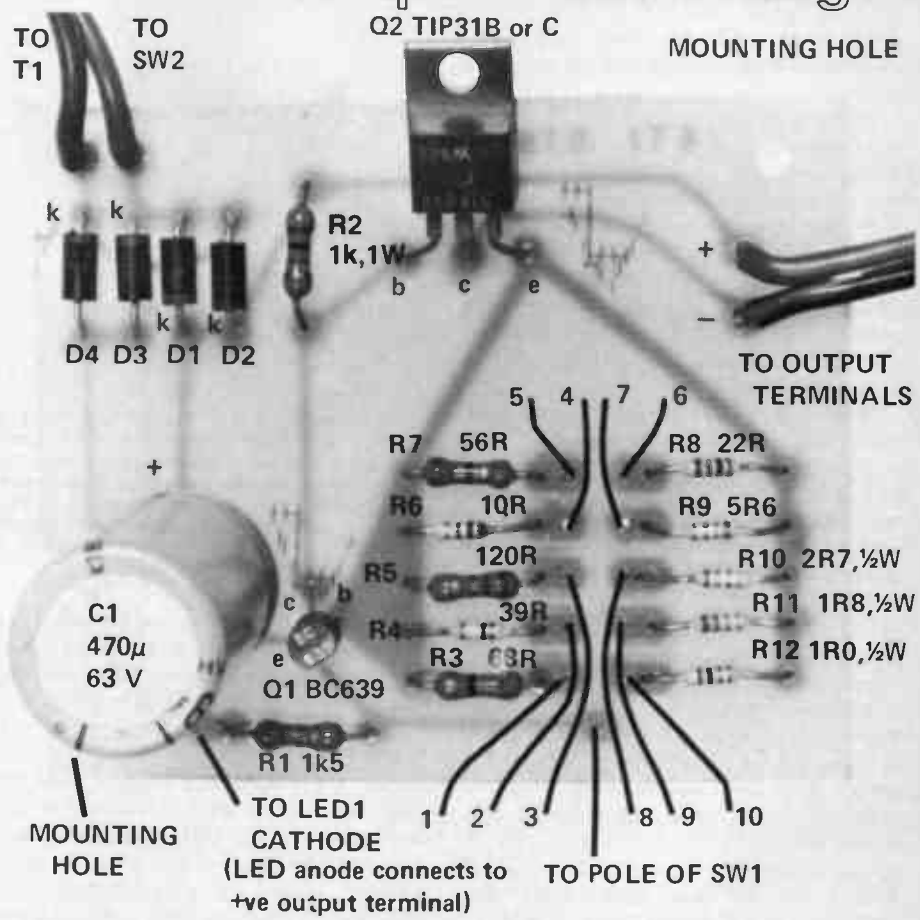
or 31 mA. Note that it would take at least 16 hours to fully recharge the cell.

The important thing of course is, you can't overcharge at this rate. The ETI-578 NiCad Charger is designed with this in mind. It provides a controlled charging facility for any one of ten types of commercially available NiCad cells. Table 1 shows the actual current ranges and the corresponding cell type numbers.

We used a simple voltage regulator and pre-determined values of current limiting resistors to get a ten-range constant current source. The output of the charger is very easily checked upon completion by connecting a current meter directly across the output. Remember that since this is a *constant current* source, the output current remains practically the same even if the output is shorted. The voltage goes up and down of course depending on the load.

One feature we have added is a switch (SW 2) to vary the input to the current regulator so that you can charge a string of cells, to a maximum of 16 (totalling about 20 V when charged).

Incidentally, the small sealed lead-acid batteries that have recently become available can also be charged using the ETI-578. These are generally available in ratings ranging from 2 Ah to about 9 Ah in 6 V and 12 V sizes.



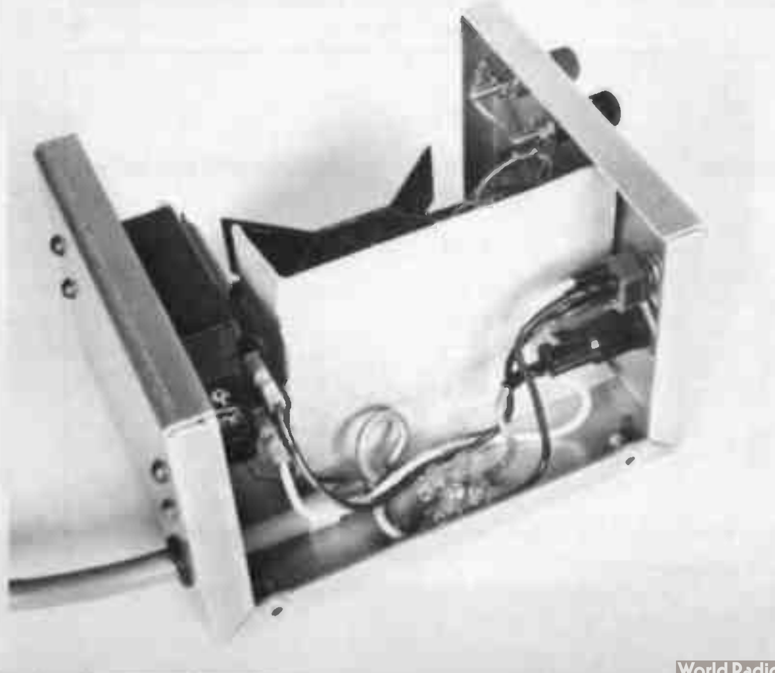
Component overlay for the pc board. Take care with orientation of the semiconductors.

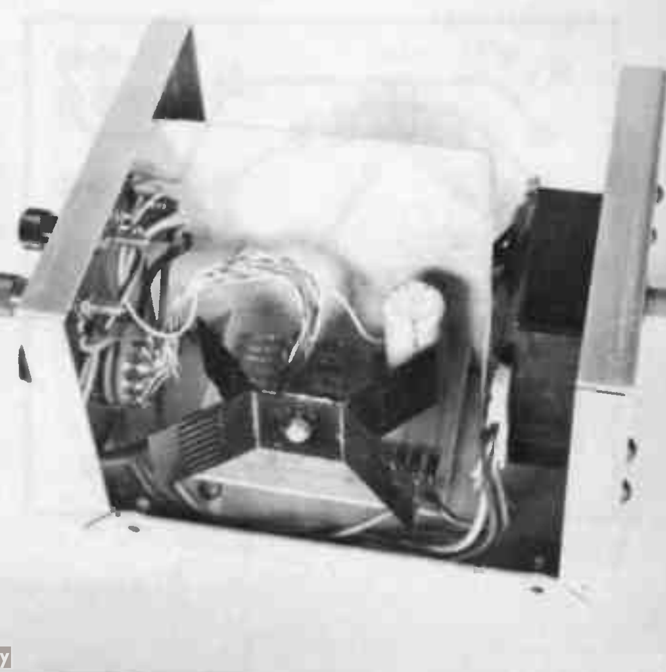
Construction

This should be very straightforward. Layout is absolutely uncritical so you can use any available case or box. We have not included any constructional details on suitable connectors between the output terminals and the cells because in most cases connection can be made via flying leads to the battery holder in the equipment itself.

Having collected all the necessary parts, start by laying out all the major components in position in the box. A little effort at this stage can save a lot of teeth-gnashing, filing, drill-snapping and other time wasting later on. Using a fine felt pen or soft lead pencil mark the holes for *every* chassis-mounted

Internal views of the completed project. Note that a 1.6 mm thick cardboard 'divider' separates the mains wiring from the other components as a safety measure. It stands the full height of the chassis and may be glued or bolted in position. The view at left shows the general arrangement of the mains wiring (see also the diagram over the page). Sleeve all exposed connections. Use a rubber grommet at the mains lead entry, then a cable clamp and two-way terminal block. The earth lead is longer than the other two and is secured under a bolt used for it alone. The picture at right shows the pc board wiring to the major components.





component. Check that adequate clearance is allowed for later wiring and access.

One important point; keep all mains wiring to one side of the layout and use the following:-

- a suitable anchor for the mains cable,
- an insulated terminal block, and
- a fuse with fuseholder

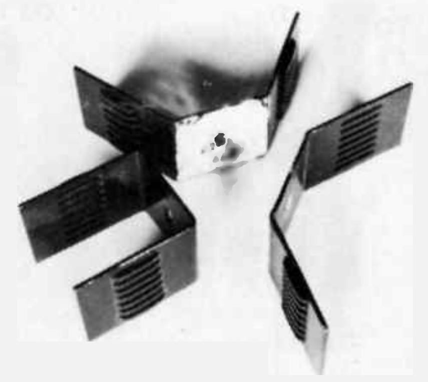
Having marked all the hole positions, drill and shape each one as necessary; remove all burrs and stray bits of metal, then check that all components fit properly before installing them.

After all panel-mounted parts are mounted, with the exception of the printed circuit board, assemble the pc board components. Fit the pcb-mounted wires (twelve for the range switch and one for the front panel LED). Check the polarity of the four rectifier diodes as well as the 470 uF capacitor.

Fit the printed circuit board into place using stand-off pillars. Identify the slider contact and the No. 1 position of the switch and connect the switch wiring starting at number one through to ten. Check the wiring, range by range, after you have finished.

When fitting the heatsink to the power transistor Q2, use a little silicon grease smeared on the contact surfaces; failure to do this may cause the transistor to fail on the higher ranges.

Fit the mains cable, terminal block, mains switch, and the fuse. Identify the earth lead and make a secure connection to the metalwork of the case.



The heatsink we used for Q2 was made up from two 'flatpack' heatsinks, Dick Smith No. H3402, bent as illustrated and mounted back-to-back on the transistor. This ensures they fit in the case. Use plenty of silicone heatsink compound to get good thermal conduction. The unmodified heatsink is shown at lower left.

Check this connection to the earth pin on the plug with a multimeter. Also check the active and neutral wires from the transformer to the mains plug.

Powering up

When all wiring is complete, insert a 250 mA fuse into the fuseholder and apply power. The LED should glow and you should be able to measure about 17 Vdc across C1 with SW2 in the "9V max." position and about 34 Vdc with SW2 in the "20V max." position. The reading should be within about 10-15%, if not, switch off and check your wiring immediately.

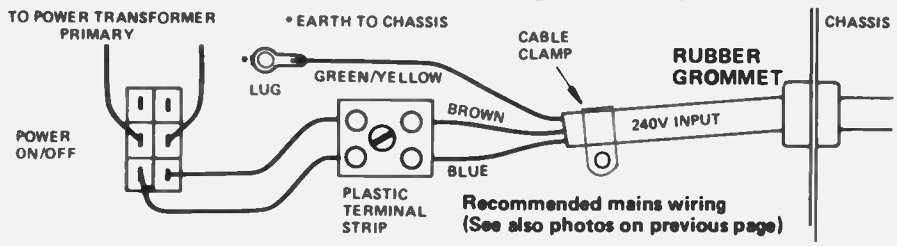
Assuming that everything is OK and your charger has not vaporised in the first five seconds carry out the following functional checks:

- connect a multimeter across C1 and short the output terminals while observing the meter reading. This should change only slightly, no matter which range has been selected. Typically, with SW2 on '20 V max.' on the 10 Ah range, the readings should be about 34 V with the output unloaded and 27 V with it short circuited. Switch off after this test.
- Set the meter to read current and connect it across the output, positive lead to positive terminal. Set the charge range switch to position 1 and the meter to a suitable current range. Switch the charger on. Check the reading against the figure given in Table 1. Repeat this check range by range, not forgetting to change the meter ranges of course!

If most of the ranges check out OK (within 10%) but one or two are a long way out, it's most probably caused by an incorrect value series limiting resistor (R2 to R11).

If the first two or three ranges are fine but the output is insufficient on the higher ones, either Q1 or Q2 is faulty. Finally, short the output, switch on, and leave running for a few minutes. Test the temperature of Q2 by placing your finger tip against the body of the transistor. If an imprint of the manufacturer's name is left in your flesh, overheating is indicated! Check that the heatsink is attached tightly to the transistor.

When connecting up the unit for use do not forget to observe correct polarity; the positive terminal on the charger connects to the positive on the battery, the negative charger terminal to the battery negative. ●



Recommended mains wiring (See also photos on previous page)

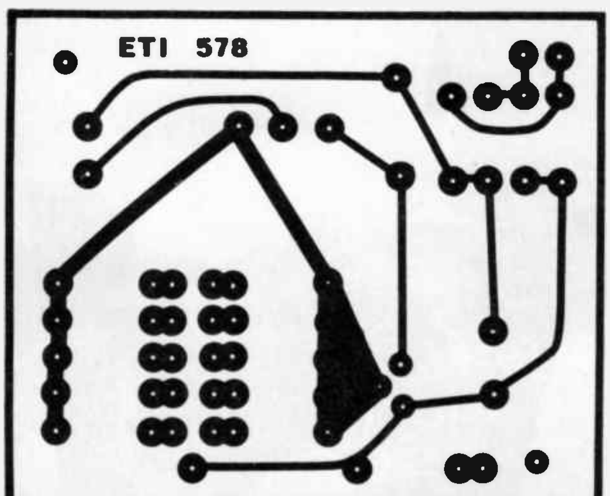


TABLE 1

Position	Resistor	Current	Cell type and capacity
1	R3	9 mA	150 mA hour Button cell
2	R4	17 mA	280 mA hour Button cell
3	R5	5.5 mA	90 mA hour, PP3
4	R6	75 mA	1.2 A hour, PP9
5	R7	11 mA	0.18 A hour, AAA
6	R8	31 mA	0.5 A hour, AA
7	R9	125 mA	2 A hour, C
8	R10	250 mA	4 A hour, D
9	R11	375 mA	6 A hour
10	R12	625 mA	10 A hour

Soil moisture indicator

Phil Wait
Simon Campbell

Don't drown your plants or dry them out! Take some of the guesswork out of watering with this handy little instrument.

EXPERT GARDENERS can tell by touch when their plants have too little or too much water, but the rest of us could use a little help sometimes. This instrument makes use of the fact that the resistance of soil decreases as the soil gets wetter. A constant current is fed through the soil between the two electrodes of a probe and the voltage drop between them is measured. A line of five light emitting diodes is used to give a simple and robust indicator of the moisture content which can easily be recalibrated to suit different soil types.

For this kind of measurement to work, it is important that both of the electrodes are made of the same metal. Dissimilar metals will set up a small electrochemical cell, generating a voltage which can upset the reading.

Soil and circuitry

If you take an ohmmeter and insert the probes into the soil quite close together the resistance reading you will obtain can vary from as little as 3 k to several megohms. The reading will depend on a number of factors: the distance between the probes, soil density, acidity/alkalinity of the soil, surface area of the probes and the moisture content of the soil. Dissimilar metals in the probe affect the reading as previously explained. If the physical dimensions of the probes are fixed in some way then the greatest variation in soil resistance will be due to the moisture content of the soil. Quite large variations in soil density will have less effect, surprisingly enough.

At first thought, it seems a common moving coil meter could be used in a simple ohmmeter-type circuit. However, with pointer-type displays, non-technical people using the device tend to worry about quite minor variations in the position of the pointer

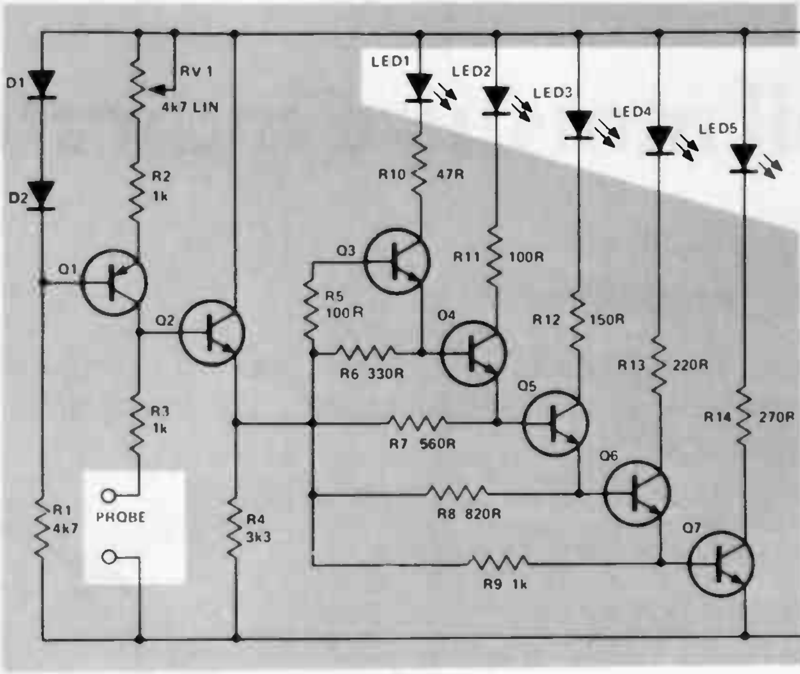
With the probe in 'soggy' soil, only the top LED will light. In 'wet' soil, the top two LEDs will light — and so on until, with the probe in 'parched' soil, all LEDs will light!

— even if the scale is only calibrated in gross sections. (This gives rise to comments such as: "The needle is two millimetres further up the scale than when I took a reading this morning"). Secondly, the device should be inexpensive and rugged. Whilst we're not accusing gardeners of being clumsy, one must recognise that accidents do happen and few low cost moving coil meters would survive a one metre drop onto a hard floor!

We opted for the 'all solid state' approach and chose to use an LED display arranged as a sort of bargraph. The resulting project is quite a rugged instrument that gives repeatable results, is easy to build and inexpensive. The unit is powered by four AA cells.

The probe problem was neatly solved

using a standard 6.5 mm jack plug. The circuit passes a constant current through the soil via the probe and the resulting voltage drop across the probe connections drives the LED display circuitry. This consists of a series of transistors that turn on in turn as the voltage across the probe connections rises with increasing soil resistance. If the soil is quite dry, all LEDs will light, if the soil is 'soggy' only one (LED5) will light. At this juncture, we should point out that the front panel lettering showing "soggy-wet-moist-dry-parched!" is a little tongue-in-cheek but it does give a general guide as to what the display indicates.



Construction

Our unit was housed in a plastic zippy box measuring 150 mm long by 90 mm wide by 50 mm high. This is a convenient size and the completed unit is easily held in one hand while the probe is inserted into the soil with the other hand.

HOW IT WORKS — ETI 247

The electrical resistance of soil varies primarily with the moisture content. The greater the moisture content, the lower the resistance. If a constant current is passed through two electrodes inserted in the soil, the voltage drop occurring across the electrodes will vary with the soil resistance, increasing with increasing resistance. This fact can be used to indicate moisture content of the soil in conjunction with a suitable display.

The circuit employs a constant current generator to pass current through the probe contacts via the soil. The voltage across the probe contacts is then buffered by an emitter follower which drives the display circuitry. This consists of five transistors, the collectors of each driving a LED, each transistor being connected to turn on successively as the voltage across the probe contacts increases with increasing soil resistance. A block diagram is shown in Figure 1 here.

Transistor Q1 and associated components provide the constant current source for the probe contacts. Figure 2 shows the collector characteristics of a typical silicon transistor. They show that, if you hold the base current constant, the collector current will remain substantially constant for a widely varying range of collector voltage. Figure 3 shows the general circuit of a constant current generator. The voltage between the base and the emitter return (common, the +ve supply line here) is fixed by the zener diode. Thus, the voltage across the emitter resistor (Ve) is fixed at a value equal to the zener voltage (V_z) minus the base-emitter voltage drop of the transistor (0.6 V for silicon transistors). With a fixed voltage across R_e, the current through it will be constant. Thus, the emitter current, and therefore the collector current, of the transistor will be constant. The resistor supplying current to the zener is generally chosen so that zener current is five to ten times greater than the base current of the transistor.

With this circuit, so long as there is about one volt between the emitter and collector, the collector current will remain constant at the chosen value until a load of too large a value robs the collector of its working voltage.

In the project circuit diagram, two forward-biased silicon diodes are used to 'clamp' the base voltage of Q1 to about 1.2 volts below the positive supply rail. Thus, the voltage across RV1/R2 will be about 0.6 V. The collector current can be adjusted by RV1 between a maximum of 600 μA and about 100 μA minimum.

The collector of Q1 drives the probe contacts via R3. The collector voltage of Q1, which varies with the variation in soil resistance across the probe contacts, drives the base of Q2, which is connected as an emitter follower. The emitter load of Q2 (R4) will thus have a voltage across it directly proportional to the collector voltage of Q1, less the 0.6 V base-emitter voltage drop of Q2.

The voltage across R4 then provides drive to the bases of the display transistors Q3 to Q7.

When the voltage across R4 reaches about 0.6 V, Q7 will turn on and LED5 will light. Now, the emitter of Q6 is connected to the base of Q7 and 'rides' up on the base-emitter voltage of Q7. The voltage across R4 will have to reach 0.6 V above the base-emitter voltage of Q7, or 1.2 V, before Q6 will turn on, lighting LED4. Similarly, the emitters of Q5, Q4 and Q3 each ride up on the base voltage of the previous transistor and the LEDs will light in turn as the voltage across R4 exceeds successive 0.6 V increments. Thus, LED3 will light when the voltage across R4 reaches 1.8 V, LED2 will light when it reaches 2.4 V and LED1 will light when it reaches 3.0 V. The voltage across R4 will be maximum when there is a high resistance across the probe contacts and thus all LEDs will light when the soil in contact with the probe is dry. When the soil is quite wet, the voltage across the probe contacts will be low and the current set by RV1 should be just sufficient to permit LED1 to light.

Resistors R5 to R9 inclusive limit the base current of the display transistors while resistors R10 to R14 limit the current passed through the LEDs. Resistor R9 is a higher value than R5 so that excessive base current does not occur in Q7 as the voltage across R4 increases. Resistors R6 to R8 are successively higher in value than R5 for the same reason.

The collector currents of transistors Q3 to Q7 will vary with the variation in base current as the voltage across R4 rises and falls. Thus, resistors R10 to R14 have values chosen to limit the maximum current through the LEDs to about 10 - 15 mA.

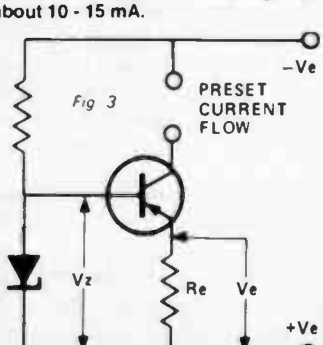


Fig 3

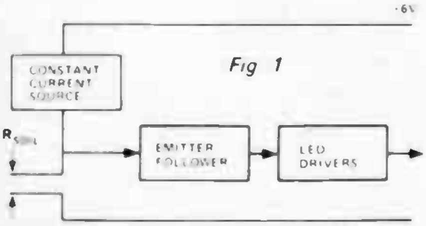


Fig 1

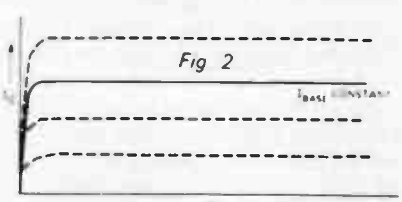


Fig 2

PARTS LIST — ETI 247

Resistors all ½W, 5%

R1	4k7
R2,R3,R9	1k
R4	3k3
R5,R11	100R
R6	330R
R7	560R
R8	820R
R10	47R
R12	150R
R13	220R
R14	270R

Potentiometer

RV1	4k7 min. vert. mounting trimpot.

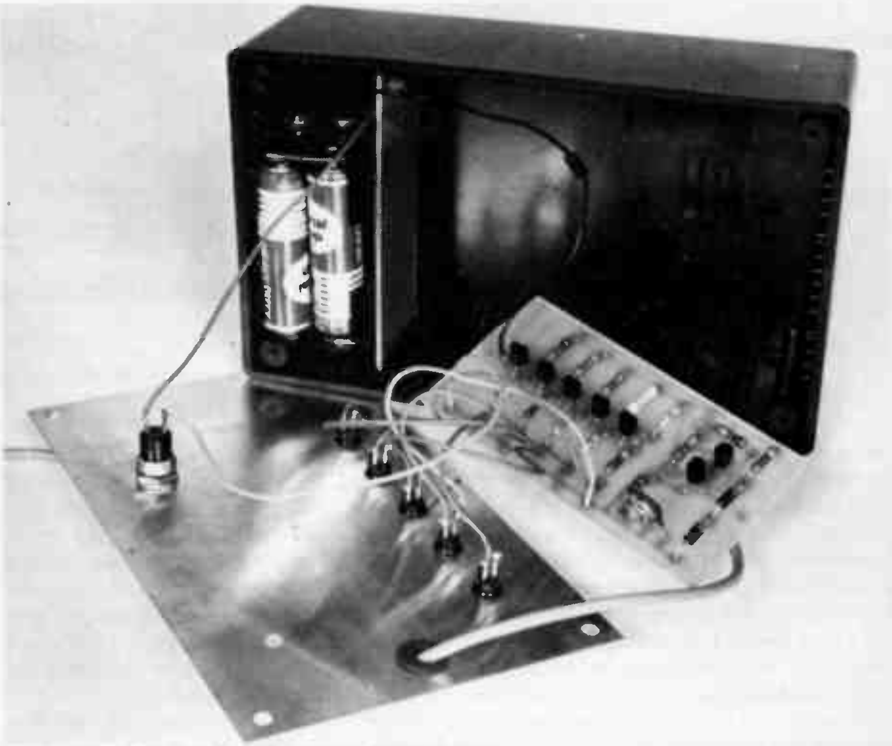
Semiconductors

D1,D2	1N4148 or sim.
Q1	BC557, BC 177 or sim.
Q2-Q7	BC547, BC107 or sim.
LED1-LED5	any LED, TIL220R or sim.

Miscellaneous

PB1	momentary push button switch

ETI-247 pc board; four AA batteries with holder; mono phono plug for probe; Pentel pen type R56 for probe handle (or similar); plastic zippy box to suit.



Internal view. Note how the battery holder is held in place.

The five LEDs and the pushbutton switch are mounted on the aluminium front panel and the probe lead is passed through the panel via a grommeted hole. Another hole in the panel provides access to the SET trimpot so that the unit can be readily calibrated.

All the other components are mounted on a pc board which fits neatly across the box, held in place by the grooves on the walls which are readily seen in the internal photograph. Although this project could be constructed on matrix board or tag strips, we recommend you use the pc board as it helps prevent wiring errors.

The probe is constructed using a standard 6.5 mm phono jack plug which ensures a constant distance between the electrodes, a uniform contact area to the soil and electrodes of similar material. A ballpoint pen barrel serves as a handle. A piece of pc board with two strips of copper to act as electrodes could equally well be used, but it would be necessary to have the electrodes plated to prevent corrosion which would adversely affect the operation of the project.

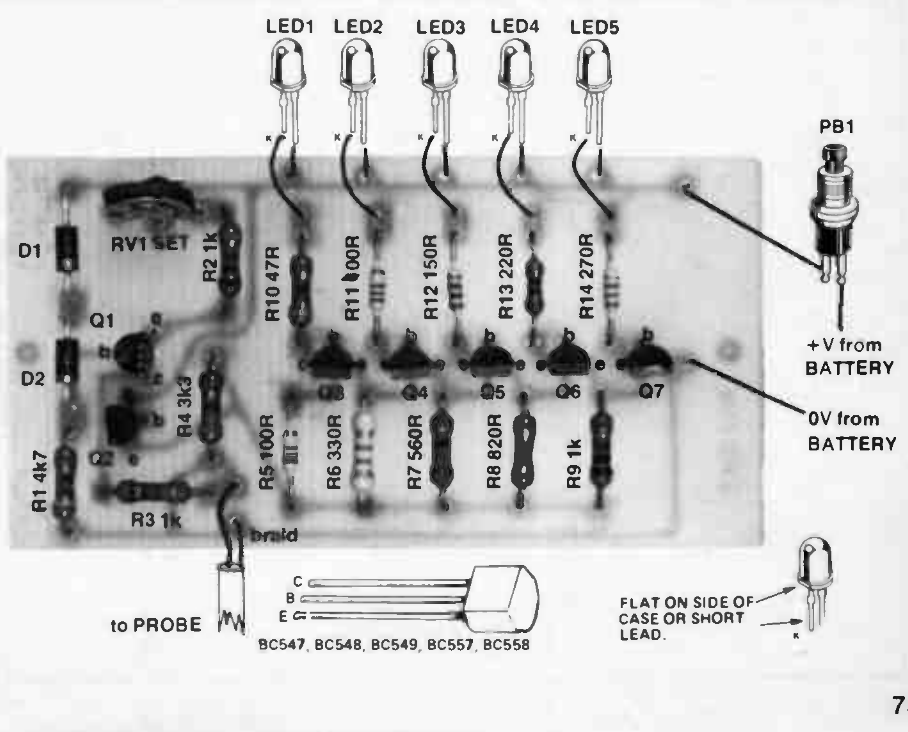
It is best to commence construction by drilling the holes in the aluminium panel. We have reproduced the front panel artwork here and you can use that as a guide. There are eight holes altogether. The hole which provides access to the SET trimpot is 4 mm in diameter while all the rest are 6 mm in diameter.

We dressed up our project using a Scotchcal front panel. This gives the unit a permanent finish and a 'professional' appearance. If you are using a Scotchcal front panel then this should be attached to the aluminium panel before any components are mounted on it.

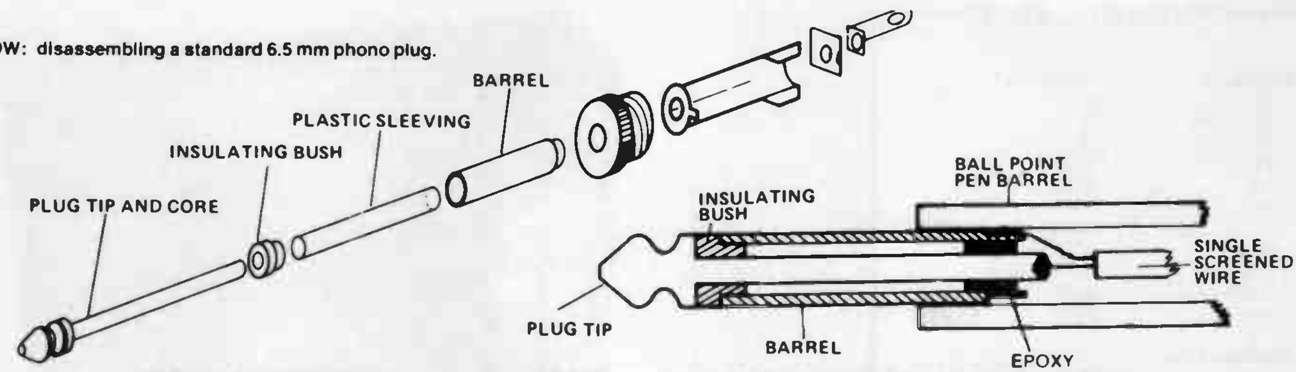
Scotchcal panels for this project should be available from a number of suppliers.

The next thing to do is trim the pc board to size so that it fits into the box without jamming. You might strike it lucky and find it fits without trimming, but if not, file one end of the board until it slides neatly into place. Using the pc board as a template, mark and cut a scrap of pc board or aluminium sheet to size to act as a retainer for the battery holder.

Component overlay for the pc board and external wiring. The pc board pattern is on page 90.



BELOW: disassembling a standard 6.5 mm phono plug.



CONSTRUCTING THE PROBE

ABOVE: assembling the phono plug barrel and tip into the pen barrel.

Mount the components on the pc board next, using the component overlay here as a guide. Take care with the orientation of the transistors and the two diodes. Most common small signal transistors will work in this circuit, but if you use a type different to that specified then check the pin connections to ensure correct orientation on the board.

The LEDs and pushbutton switch can be mounted on the front panel now and wired to the pc board. Take care to wire the LEDs correctly. A grommet should be mounted in the hole through which the lead to the probe passes. The probe lead is passed through this hole and wired directly to the pc board. Next wire the leads to the battery holder, making sure you have the polarity correct, insert four AA cells and mount the battery holder in place. Note that the retaining piece securing the battery holder in the zippy box should not be the full depth of the box to allow the battery leads to pass between its top edge and the front panel.

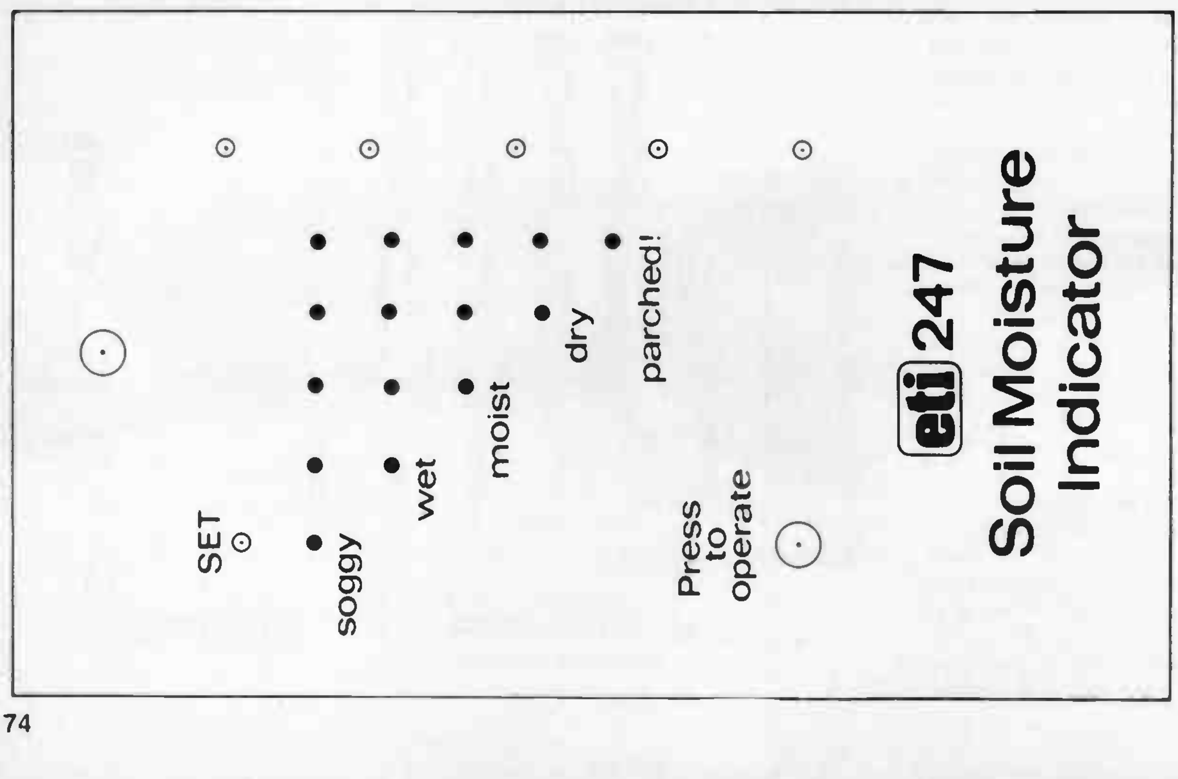
The probe can be constructed next. The exploded diagram here shows how it's done. We cut the ends from an exhausted type R56 Pentel ball pen and used the empty barrel as the barrel of our probe. The 6.5 mm phono jack plug is a neat fit inside the barrel.

Pass the shielded wire through the barrel and solder the end to the jack plug connections as shown in the diagram. Be careful to avoid short circuits between the braid and inner conductor of the cable. Don't use too much heat or the insulation on the inner conductor of the cable will melt back up inside the braid and you may get intermittent short circuits.

At this stage you can do a dry run (pardon the pun . . . Ed.). Press the pushbutton and most or all of the LEDs should light. If not, try adjusting the SET trimpot. If you still have no joy, check your wiring and the orientation of components on the pc board.

Setting up

The unit needs to be set to give the correct indication. Set up a few pots with earth 'as you like it', ensuring one is thoroughly dry and one is thoroughly wet. Insert the probe in the wet soil and adjust the SET trimpot so that only the top LED (LED 5) lights. Then insert the probe in the dry soil and see that all the LEDs light. Try the probe in soil of varying wetness and you'll get a good idea of how to interpret the display. After all, correct interpretation of the indication is just as important as the operation of the unit. Once set, the unit should not require any further adjustment. ●



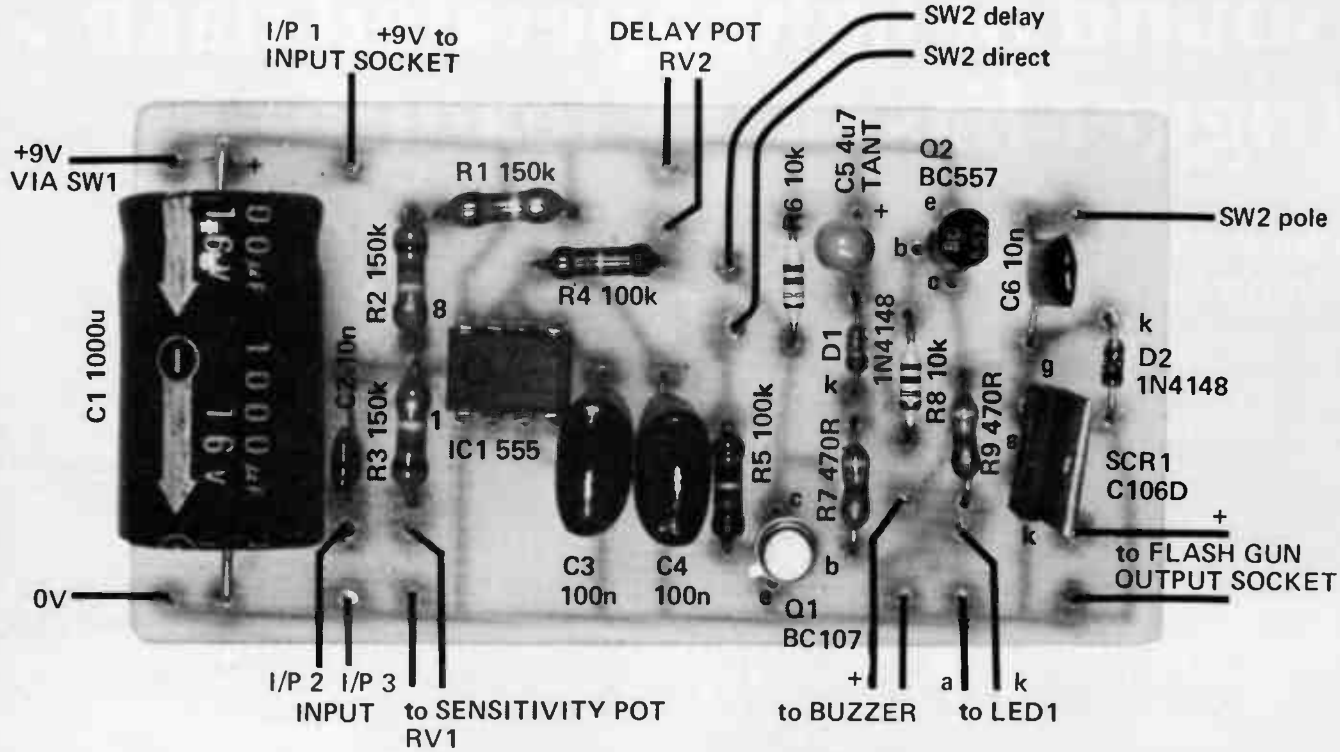
Full size reproduction of the front panel artwork.

Project 568

Sound or light operated flash trigger has many features

Phil Wait
Simon Campbell

You too can take spectacular action shots just like those shown in these pages. This project is simple to build, suits any flash unit and can be triggered in a number of ways.



NOTE: The pc board pattern is on page 90.

PHOTOGRAPHICALLY 'freezing' an action while it is in progress is an extraordinarily difficult task unless you can accurately time the flash to 'fire' at a particular instant during the event. This project does exactly that. You can trigger your flash from a sound, such as that produced by a bouncing ball, or by light — by having an object break a beam of light for example. You can arrange to trigger the flash by a light source turning on, or turning off. In addition, this unit permits you to *delay* the triggering of the flash by a preset amount, allowing you to 'catch' the action at differing periods after the triggering event.

The attraction of this unit is that you need no fancy equipment to take good pictures like those you see on these pages. You don't have to have a fancy SLR camera — just a simple model on which the shutter can be locked open. We haven't tried it, but with a powerful flash gun even a pinhole camera should work!

The circuit

A 555 timer IC (surprise, surprise!) is employed to provide a trigger pulse from a suitable input sensor. This can be an inexpensive crystal microphone or a phototransistor connected to trigger the 555 from a light source turning on or a light source turning off. Obviously, the unit can be used as a slave flash trigger also.

The 555 is operated in the *monostable* mode. That is, when triggered by the input signal detector it provides a single pulse output, the width of this pulse being predetermined by a preset control. The pulse output of the 555 is arranged to turn on an SCR which is connected in series with the flash gun's power supply via an interconnecting cable.

To provide a variable delay, the SCR is triggered from the *trailing* edge of the pulse output from the 555. The width of the pulse can be varied with a potentiometer control. A minimum delay of about 10 milliseconds and a maximum delay in excess of 200 milliseconds can be obtained. If you require a shorter delay, the value of R4 may be reduced, but do not use a value less than 1k.

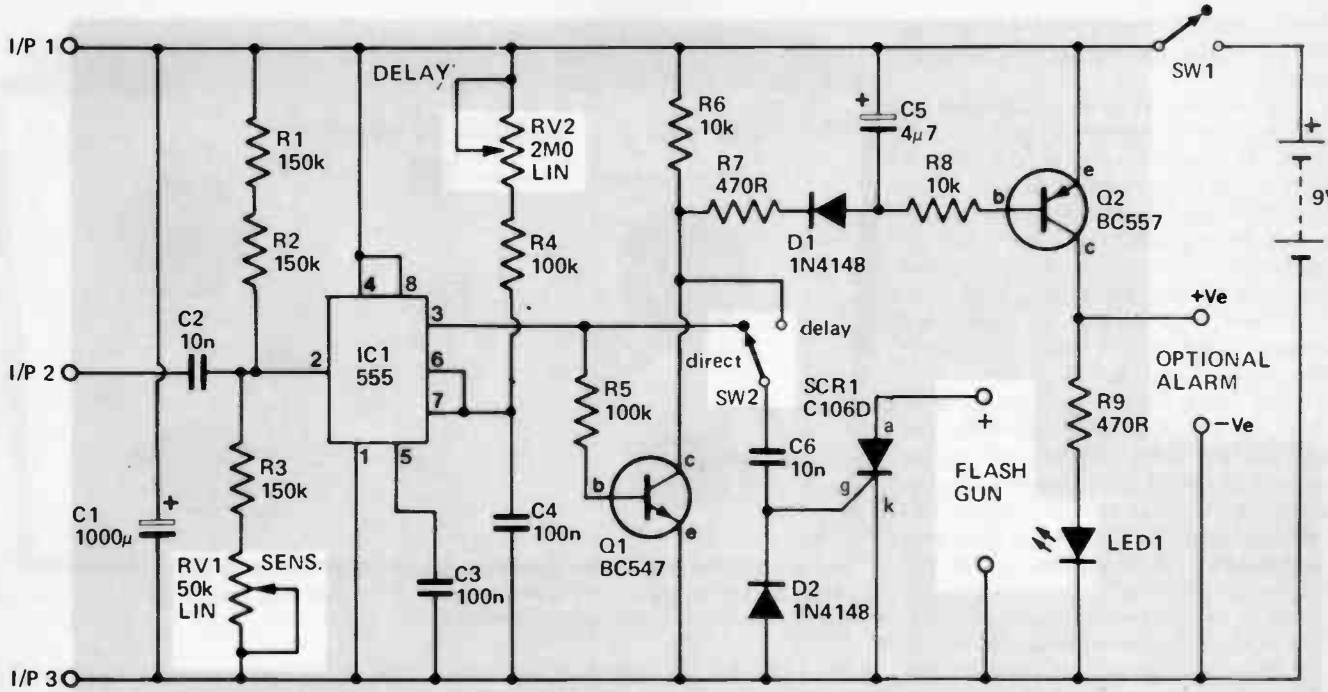
When setting up a shot, one needs some indication that the trigger unit is being correctly fired by the action, without having the flash gun 'popping' numerous times. For this reason we have included a LED on the front panel and a piezo buzzer to provide both a visual and an audible indication. The piezo buzzer is optional, but we found it handy as you can't always be involved in the action and watch the LED at the same time.

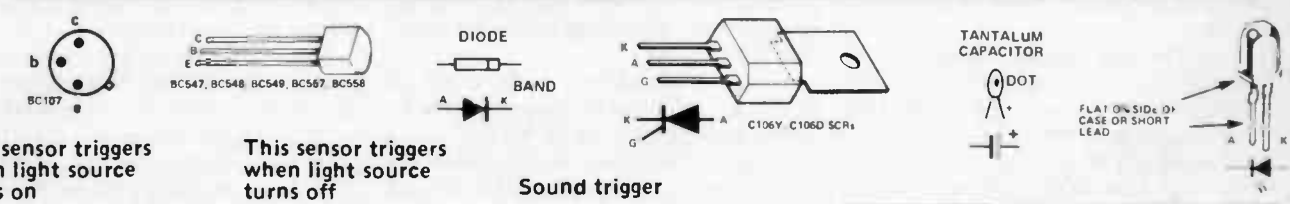
For 'rehearsals', the flash gun cable is disconnected. With everything set to go the sensitivity control on the trigger unit is set at some arbitrarily chosen level and the action initiated. If all is well, the LED will light and/or the buzzer will sound.

The whole unit is powered by a single 9V battery. A No. 216 transistor radio battery does the job nicely and should give long life.

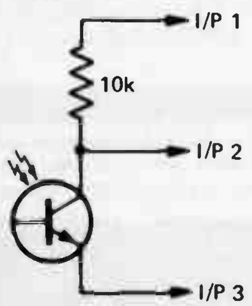
Construction

We constructed our unit using a pc board to mount all the minor components. We recommend you use the pc board as it simplifies construction and avoids the more common wiring errors. The whole unit was assembled into a convenient 'jiffy' box measuring 160 mm long by 95 mm wide by 50 mm deep. All the major components were mounted on the aluminium front panel and wired to the pc board with hookup wire. We used a five-pin standard DIN socket for the input connector and a two-pin socket, usually used as a speaker connector, as a connector for the flash gun cable. The sensors generally need to be placed in a convenient position re-

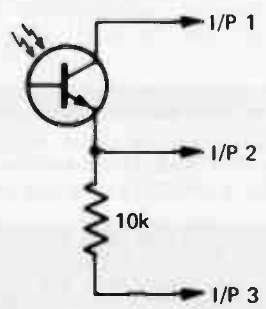




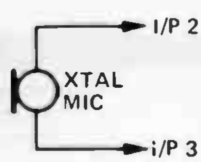
This sensor triggers when light source turns on



This sensor triggers when light source turns off



Sound trigger



Use phototransistors, type FPT100 or TIL78 or similar

HOW IT WORKS — ETI 568

IC1 is a 555 timer connected in the monostable mode. The timing period is determined by RV2, R4, C4 and is adjustable between 11ms and 230ms with the values shown. The trigger input of the chip is held just above its firing potential of one third supply voltage by adjustment of RV1 which acts as a sensitivity control. A negative-going signal is coupled to the input by capacitor C2. Note that the values of R1, 2, 3, RV1 provide a medium input impedance and screened cable may be required when the sensor must be separated from the unit.

When IC1 is 'fired' its output (pin 3) goes high for the monostable period. With SW1 switched to 'direct', this positive going pulse will fire the SCR and discharge the flash enabling the unit to be used as a slave flash. There will be a finite delay owing to rise time of phototransistor response, propagation delay within IC1 and rise time of its output. However, this will be measurable in microseconds and should be negligible.

When used in the 'delay' mode, the output pulse is inverted by Q1 causing the flash to fire on the trailing edge of the monostable pulse. To avoid repeated use of the flash when setting up the unit, indicator LED1 is provided. Each negative excursion of Q1 collector causes C5 to charge via R7, D1 effectively stretching the monostable pulse and providing a clearly visible flash.

An optional alarm, for example a solid-state buzzer, can be connected into the circuit providing audible indication of triggering.

Capacitor C1 provides overall decoupling. Supply current is about 10 mA.

PARTS LIST — ETI 568

Resistors all ¼W, 5%

R1,2,3	150k
R4,5	100k
R6,8	10k
R7,9	470R

Potentiometers

RV1	50k lin
RV2	2M lin

Capacitors

C1	1000u electrolytic
C2,6	10n polyester
C3,4	100n polyester
C5	4u7 tantalum

Semiconductors

IC1	555
Q1	BC547, BC107 etc
Q2	BC557, BC177 etc
SCR1	C106D or similar
D1,2	1N4148 or 1N914
LED1	any LED

Miscellaneous

SW	SP DT toggle switch
SW2	SP DT toggle switch

ETI-568 pc board; flash gun connector, crystal microphone with plug and socket (if used); 9V battery and battery clip; box to suit; buzzer (if required).

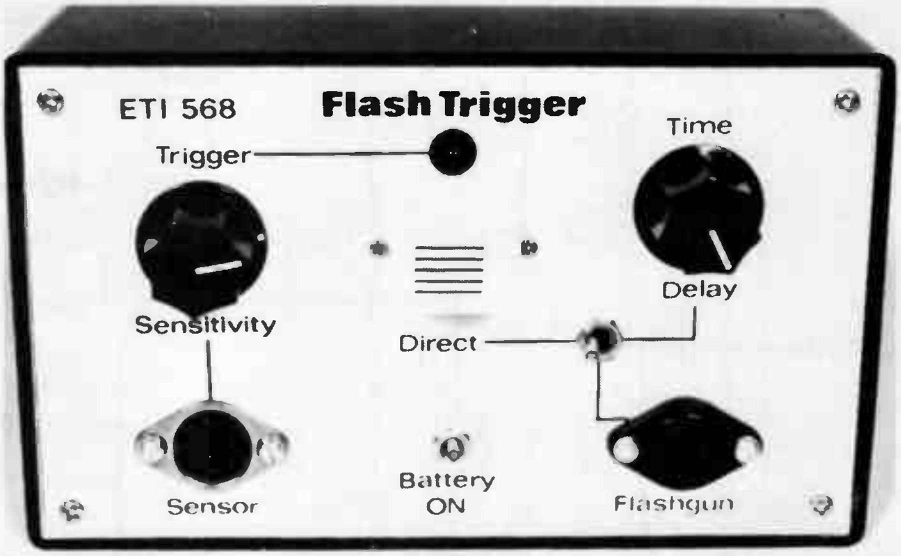
Additional Components for Light Operation:
Phototransistor FPT 100, TIL78 etc
10k resistor.

mote to the trigger unit and we made up several cables for each of the different sensors.

Construction is best commenced by loading the components into the pc board. It is usually convenient to start with the resistors and capacitors. Take care with the orientation of the 4.7 μF tantalum capacitor and the 1000 μF electrolytic. The semiconductors can be mounted on the board next. Here too, take care to get them the right way around. Particularly watch the orientation of the IC and the two diodes.

Some mechanical work comes next. Mark out the front panel carefully and drill all the holes. Temporarily mount each individual component on the panel, just to make sure that they all fit without problems. We used a Scotchcal front panel to dress up the unit. If you are doing likewise, now's the time to attach it to the panel of the jiffy box. Having done that, finally mount the two pots, the two sockets, the switches, the LED and the buzzer (if you've elected to use one).

Now you can install the wiring between the pc board and the components on the front panel. Note that pin 1 of the input socket is wired to the pc board via a short length of shielded cable. This is to avoid pickup of stray signals, such as hum, which may cause triggering difficulties. Be careful with the connections to the LED and the two pots. The component overlay and wiring diagram should make this stage of the construction fairly clear.



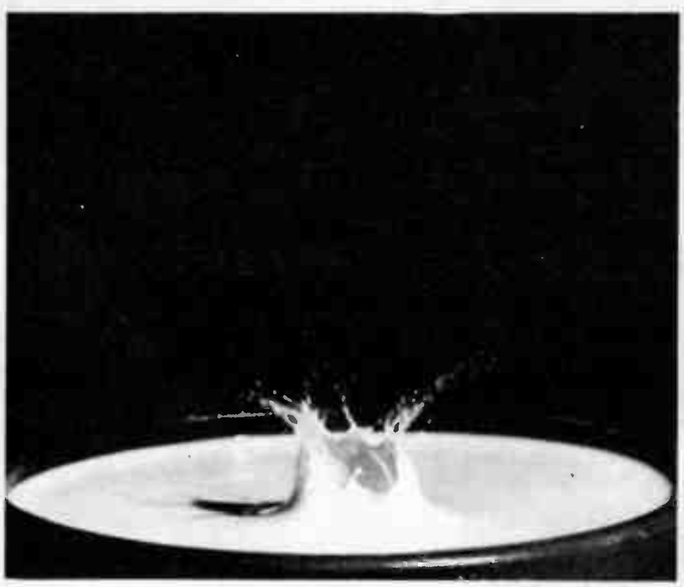
The prototype was housed in a 'jiffy' box measuring 160 mm long by 95 mm wide by 50 mm deep. The front panel was dressed up with a Scotchcal transfer.

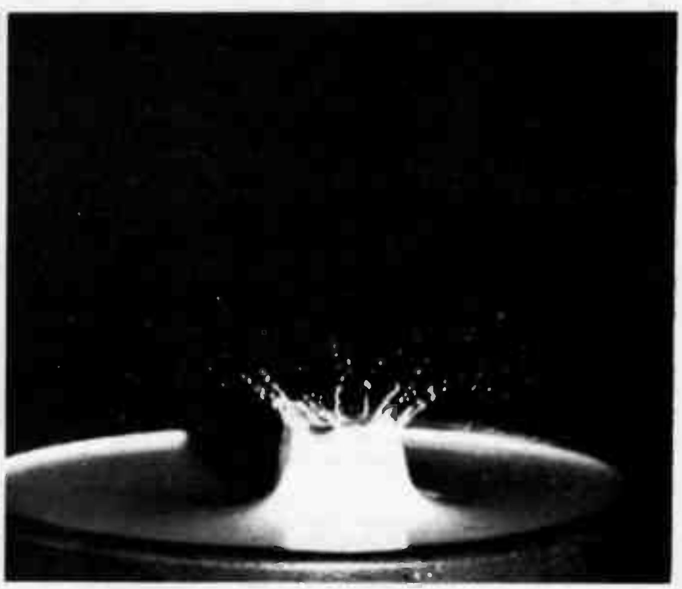
You don't have to use a DIN socket for the input connector as we have, indeed a tip-ring-and-sleeve jack socket could equally well be used. Any sort of socket having three connections will do the job. Similarly, we used a two-pin socket for the flash gun connector as we had it on hand. Both these connectors are readily available and this was the main consideration in our choice.

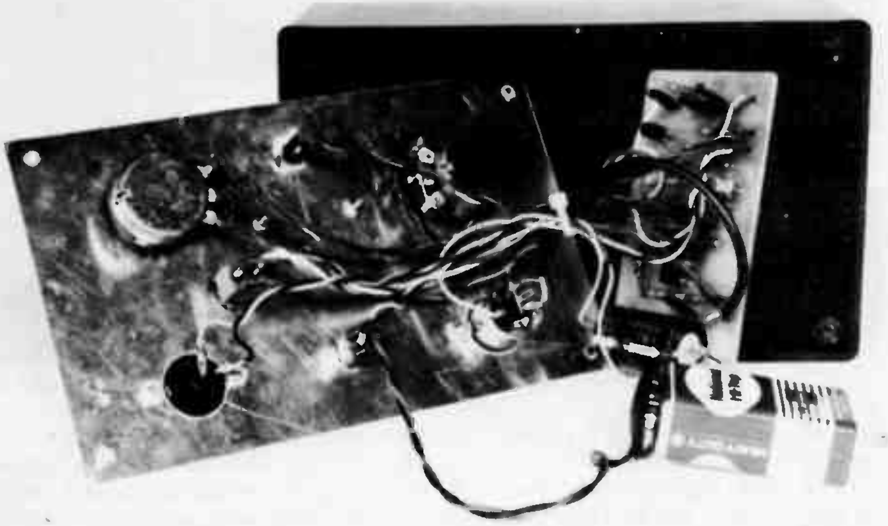
You will have to make up a suitable lead to go between the trigger unit's output connector and the flash gun's remote trigger connector. Use the appropriate connectors at each end.

Polarity is important as the trigger unit employs an SCR for the triggering 'switch' device. One way of determining

This series of pictures shows how the variable time delay facility can be used to capture the effect of a ball bouncing in a container of fluid (milk here). The shots were sound-activated and the time delay was set for delays between







Internal view of the completed prototype. Note that wiring between I/P2 and the panel-mounted input socket is via shielded cable. Sensors should be wired with shielded leads also.

the polarity of the flash gun is to measure the voltage present at its trigger socket with a multimeter.

Sensors

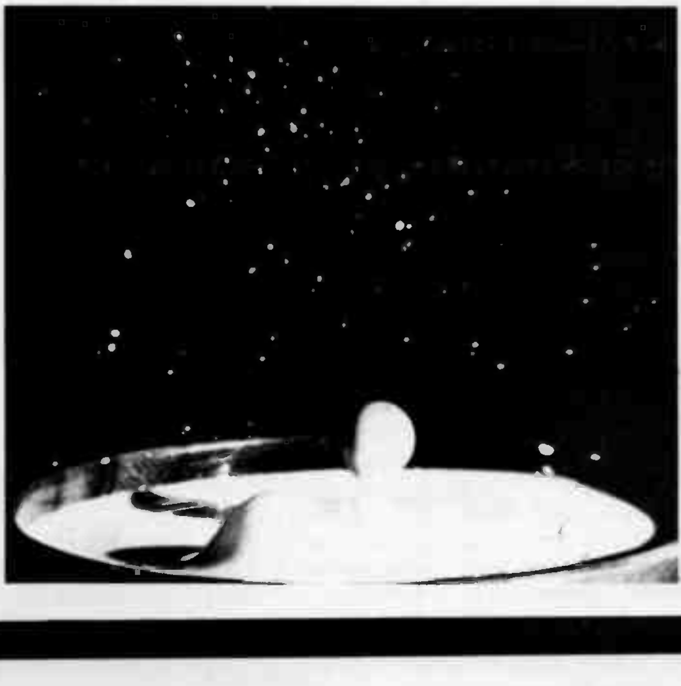
Before you can try out the unit, you will need to assemble some suitable sensors. The simplest is just a crystal microphone. We used an inexpensive 'lapel' mic and obtained excellent results. A crystal mic is recommended as it has quite a high output level. You can give the unit a 'dry run' at this stage. Set the Direct/Delay switch to Direct and the Sensitivity control to mid range and turn on. Clap your hands once and, if all is well, the LED will light and the buzzer will sound for a brief period. Set the unit to Delay and the Time control fully clockwise. Clap once more and again the LED will light following a brief delay. Experiment a little with the sensitivity control so that you get some idea of how it affects the operation.

There are two ways the unit can be triggered from a light source, as we said before — by a light source turning on, or a light source turning off. The different sensor circuit configurations are given in the accompanying circuits. An inexpensive, readily available phototransistor is employed — either a Fairchild FPT100 or a TIL78 from Texas Instruments. There are many similar devices available and no difficulty should be experienced here.

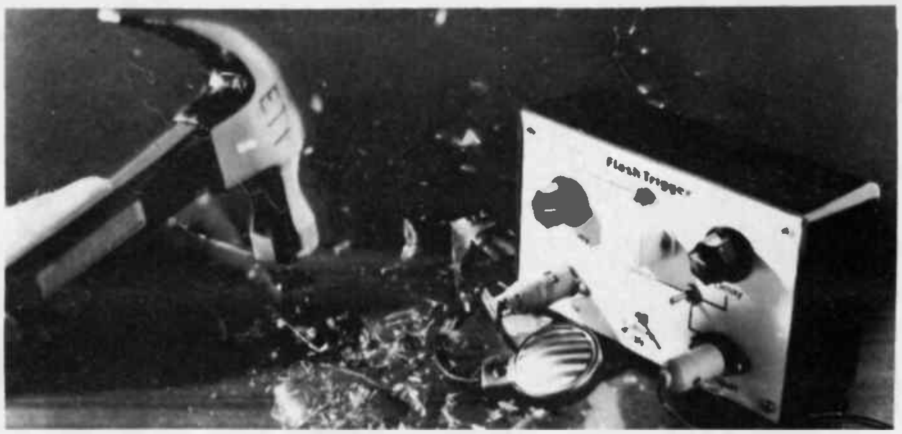
The phototransistor can simply be 'hung' from the leads at the end of a cable, the other end being terminated in the input plug (which suits the input socket used). The 10k resistor may be mounted in the input plug housing. There is plenty of room in a DIN plug. If you want something a little more salubrious, the phototransistor could be inserted in a small diameter plastic tube (say, 12 mm dia.) with the 'business' end of the device flush with the end of the tube. The tube can then be filled with epoxy resin. It's advisable to have the phototransistor attached to the cable before you do this!

Microphones usually come in their own housing, so there's no need to go to any trouble with them. The lapel mics come with a handy clip, so they can be attached to any convenient support.

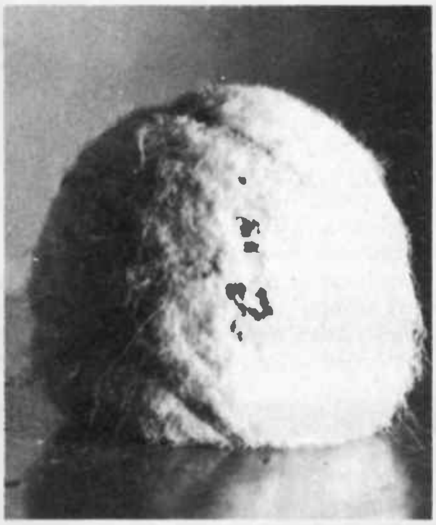
50 milliseconds and 200 milliseconds. Similar shots could be light activated by arranging the ball to break a beam of light.



Project 568



Another sensor to try out is a silicon solar cell. To use one as a sensor with this unit, you will need to obtain one of those small 'transistor radio audio transformers' — the type having a "1000 ohm" primary and an "8 ohm" secondary, or similar. It is used 'back to front' in this application. Connect the solar cell directly across the transformer's low impedance winding and connect the high impedance winding between I/P2 and I/P3. It's simple, but it's sensitive. Suitable solar cells, or solar cell pieces, are obtainable from David Reid Electronics stores, Dick Smith Electronics stores, Ellistronics, Electronic Agencies, Radio Despatch Service (all advertisers in ETI) or Amtex Electronics of P.O. Box 285, Chatswood NSW 2067.



Above, a ball on the bounce. Top right, breaking a light bulb.

Using the trigger

You'll probably need a fair bit of practice before you get properly used to working with our flash trigger, but persevere — the results will be well worth it.

First of all, position the microphone or light sensor near the object to be photographed, taking care to keep it out of the camera's field of view. The sensitivity of the trigger is quite high, so it should be possible to place the sensor quite remote from the action. For scenes involving explosions or splashing liquids this is certainly advisable!

Set up your camera for the shot you want and then do a dry run of the action with the camera shutter closed and the flash gun disconnected. The purpose of this is to make sure that the trigger is being reliably fired by the action. If all is working well, the front panel LED will light and the buzzer (if one is fitted) will sound. If not, adjust the sensitivity control or move the sensor.

Once you're happy with the operation of the trigger, you're ready to start shooting in earnest. Connect the flash gun to the trigger unit and set your camera aperture according to the exposure guide table supplied with the flash gun. Remember that the aperture setting given in the guide relates to the distance from the object being photographed to the *flash gun*, not to the camera. Take another look through the viewfinder, just to check that all the action will be in frame and neither the flash gun nor the sensor is visible.

The camera shutter cannot be triggered by the flash, so it must be set to the 'time exposure' or 'B' position. Before you open the camera shutter, make sure the room is in TOTAL darkness. Try not to trip over any of the equipment in the dark!

Open the camera shutter and set off the action, releasing the shutter button when the flash has fired. You may find a cable shutter release very useful if you don't have a friend helping you to set up the shots.

You should now have a picture, but at this stage you won't know whether or not you've captured the exact instant of the action you wanted. So set the trigger unit to give a different delay and shoot again. If your trigger is sound operated, you can get very fine control over the delay by taking advantage of the relatively slow speed of sound. Sound waves move at about 330 metres per second, so for every metre change in the object-to-microphone distance there's a 3 millisecond change in the triggering delay.

By this time you'll have spent quite a lot of time and trouble (and some money) in constructing and setting up your flash trigger, so don't be mean with film. Shoot a whole roll if necessary, to make sure of getting the one or two shots that you really want.

The ability of the flash trigger to freeze very fast action such as explosions or collisions will depend on the speed of your flash. Most camera flashes have a flash period around one millisecond which may produce a blurred picture in some circumstances. If you find your picture is blurred you will have to use a faster flash or strobe unit.

Calibrating the delay

If you wish you can use an oscilloscope to calibrate your delay control.

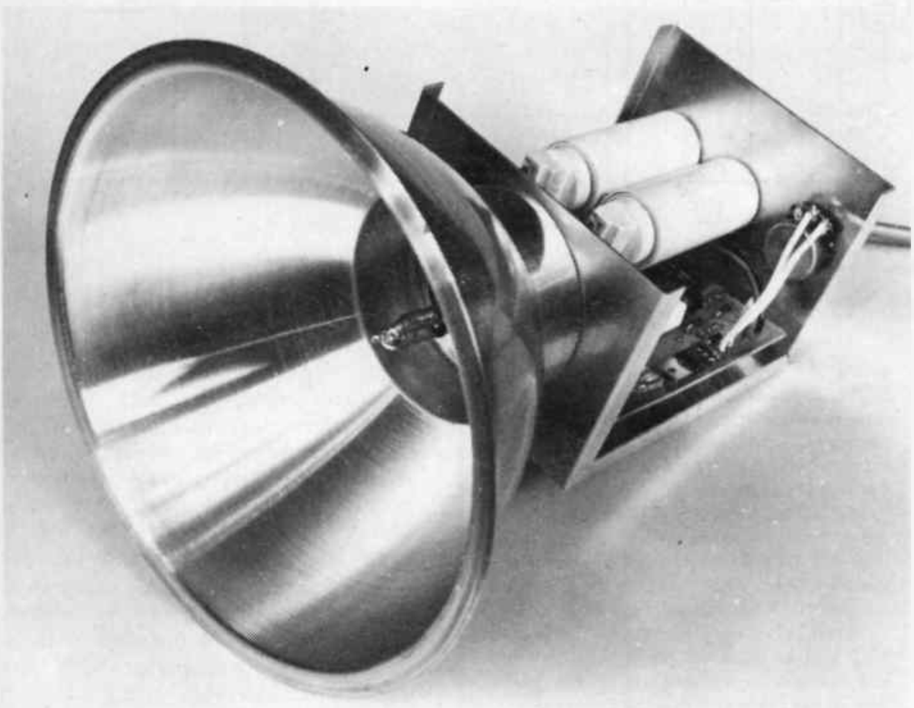
If you have a dual-trace oscilloscope, connect one vertical input to the sensor output and the other to the gate of the SCR. Set the oscilloscope to trigger from a positive going edge on the sensor output and the time base to 10mS per division. Switch the flash trigger to the delay mode and activate the sensor. Looking at the CRO you should see a delay between the first negative edge of the sensor output and the gate pulse. You should be able to vary the gate pulse, by rotating the delay control, from about 10 ms to 200 ms. As the trace will only sweep once for each trigger pulse, it may be difficult to see. Re-triggering the sensor quickly with a flashing light will improve the visibility of the trace. Alternatively the sensor can be replaced with a low frequency pulse generator, but be careful not to have a pulse period shorter than the delay you are trying to measure. Measure the delay for each 20 degrees or so of the delay potentiometer and calibrate your scale. Our unit measured close to 11 ms minimum delay to a little over 200 ms at maximum.

The procedure for using a single trace oscilloscope is similar, except that the sensor output is fed to the external trigger input on the oscilloscope, and the trigger control set to trigger from a negative going edge. The vertical input is connected to the gate of the SCR and the sensor activated. The delay is then measured from the left hand edge of the trace to the gate pulse. ●

Disco strobe light

We published our first strobe unit way back in August 1971. It has been one of our all-time popular projects. This unit is an up-dated version featuring a number of improvements.

Phil Wait



STROBE LIGHTS are very popular as lighting effects devices at parties and discos. Emitting a series of bright flashes of light several times per second, the movement of dancers takes on a jerky 'stop-motion' effect. Used in conjunction with coloured 'light show' effects units that vary the colour and intensity of a bank of lights, the overall effect achieved can be quite stunning.

We first published a strobe unit for this application back in August 1971. That was the ETI 505 High Power Strobe. It has been by far the most popular project we have ever described. The ETI 505 was still available as a kit – and a steady seller by all accounts – quite recently.

When the demand for a new strobe became apparent earlier this year, we sat down and took a long hard look at the original design. But despite all the revolutionary technology that has appeared since then, there was no way we could see of significantly altering the device to any advantage. That original design was just about the simplest, least expensive and most effective for a strobe that could be devised. However, experience over the years showed up a number of minor shortcomings and we have modified the circuit to eliminate these – and this Disco Strobe is the result.

The effect

How does a strobe produce the 'stop-motion' effect? Quite simply, really. At each flash of light, in a darkened room, you will see everybody in the position they are in at the instant of the flash. During the short interval before the next flash, they will have moved and you will see them in a slightly different position, and so on.

Thus, it seems they 'jump' from position to position and anything or anybody that moves does so in the characteristic jerky fashion. If the flash rate of the strobe is fairly close to the rhythmic movements of the dancers, the effect is quite dramatic.

Improvements

There were a couple of points on which we though the old strobe could be improved. Firstly, some constructors reported intermittent false triggering of the strobe tube, resulting in a disturbing 'flutter' in the flash rate. In the original circuit, the gate of the SCR pulsing the strobe tube was connected directly to the two neon trigger tubes with no resistor from the SCR gate to ground. Without being 'clamped' to ground by a resistor, the sensitive SCR gate is prone to being triggered by mains-borne noise 'spikes' capacitively coupled to it via the neon tube or adjacent circuitry. This has been corrected in the current project.

The second point was more of a construction problem. The capacitor charging circuit and the flash timing circuit on the original strobe were each powered by separate half-wave rectifiers. Now that appears like a full-wave bridge rectifier with the bridge not completed. Many constructors saw this and immediately took it to be a mistake – so they 'put it right' by connecting the cathodes of D3 and D4 in that circuit. The result was always disastrous! Our sympathies to those who were caught.

To avoid this occurring again we decided to use a conventional bridge rectifier to power the complete circuitry.

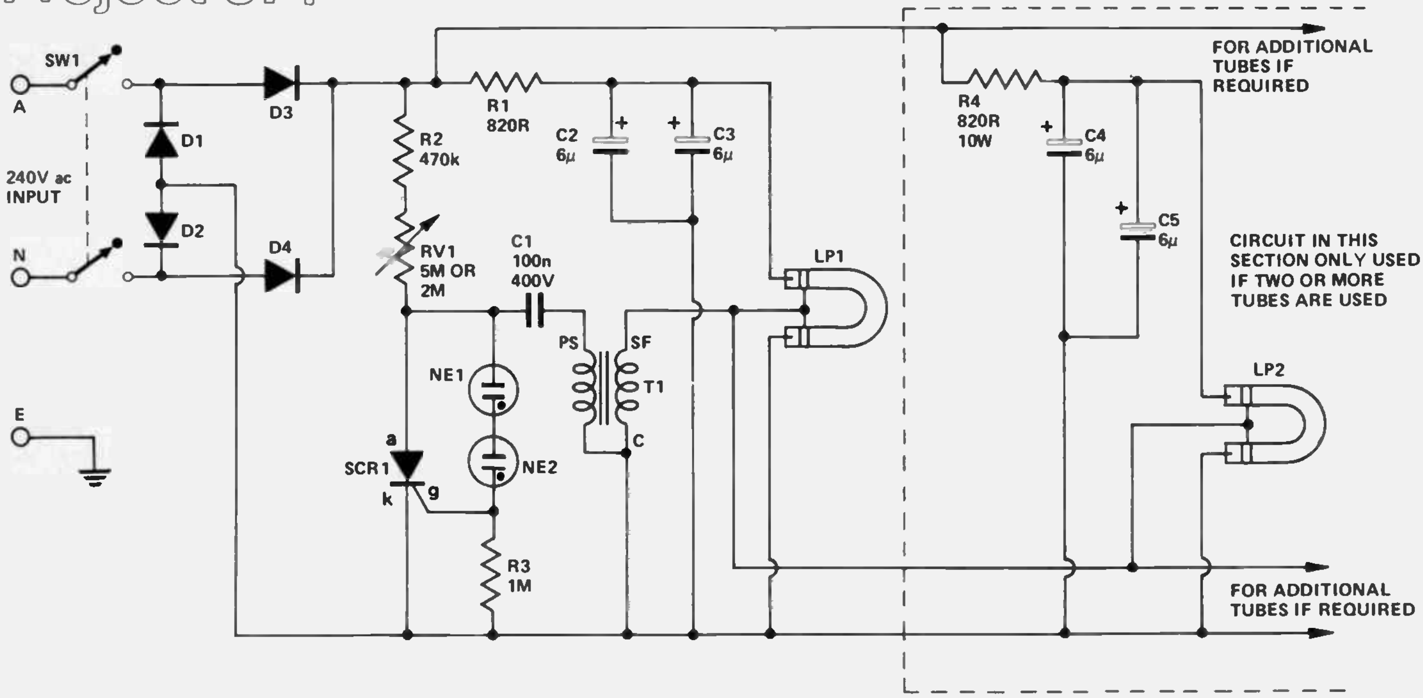
Construction

Carefully examine the photographs and the construction diagrams. Assembly is quite straightforward and little difficulty should be experienced. Care must be taken with the wiring though, as the unit operates directly from the mains.

The electronics is all mounted in a 145 x 115 x 90 mm aluminium box. A 180 mm diameter spun aluminium reflector is mounted on one end, the strobe tube(s) being mounted inside this by a plug and socket arrangement. An octal valve socket is used, its mounting screws being used to secure the reflector to the box.

At the opposite end of the box, the discharge capacitors are mounted, two or four being used depending on whether one or two strobe tubes are

Project 574



HOW IT WORKS – ETI 574

The principle of operation of the strobe tube is discussed in the general text, so here we'll concentrate on the overall circuit.

The mains voltage is rectified by a diode bridge circuit formed by D1, D2, D3 and D4. Since there is no capacitor directly across the dc output of the bridge rectifier, the output consists of a series of half-wave pulses at a frequency of 100 Hz (i.e.: twice the mains frequency). The storage capacitors, C2 and C3 (plus C4, C5 etc if extra tubes are added) are charged from the bridge rectifier output via R1 (R3 etc for extra tubes). They will charge to the peak value of the rectifier output, about 340-350 volts. (That is, 1.414 times the mains voltage: 240 x 1.414 = 339 volts).

The resistor in series with the storage capacitors (R1, R3) limits the peak charging current to prevent damage to the rectifier diodes and also serves to isolate the strobe tube from the mains.

The two neon 'trigger' lamps, NE1 and NE2, each have a 'striking potential' of around 120 volts. That is, the neon gas inside will ionise, ('break down') and the lamp 'fires', conducting current very suddenly when this striking voltage is reached or exceeded.

Now, C1 is charged from the bridge rectifier output via R2 and RV1. As the voltage across C1 rises it will eventually reach the striking voltage of the two neons. As these are in series, the voltage across C1 must reach about 240 volts before they strike. When this occurs, a pulse of current will flow into the gate of SCR1, causing it to conduct. This effectively places C1 across the primary of T1 as the anode of SCR1 is then connected to earth for all intents and purposes. C1 will then rapidly discharge, the resulting pulse in the primary of T1 being transformed to about 4 kV at the secondary.

As the secondary of T1 is connected to the trigger electrode of the strobe tube, this will 'break down' and emit a bright flash of light when the trigger electrode receives the 4 kV pulse from T1.

After C1 has discharged, NE1 and NE2 will extinguish, SCR1 will turn off and C1 will commence to charge again. The whole cycle will then be repeated.

Varying the rate at which C1 charges, and thus the amount of time it takes to charge C1 to about 240 volts, will vary the time between flashes. Thus RV1, a 2 M or 5 M potentiometer, serves as a 'flash speed' control. Increasing the resistance of RV1, increases the time it takes C1 to charge to 240 volts, increasing the time between flashes – which decreases the flash rate.

The storage capacitors, C2 and C3 (with one tube), discharge when the strobe tube fires, recharging between successive flashes.

When two (or more) tubes are used, each must have a separate storage capacitor (made up of two capacitors here, for convenience) and limiting resistor, otherwise – as explained in the text – the first tube to fire in a parallel-connected arrangement would prohibit the other tube(s) from firing.

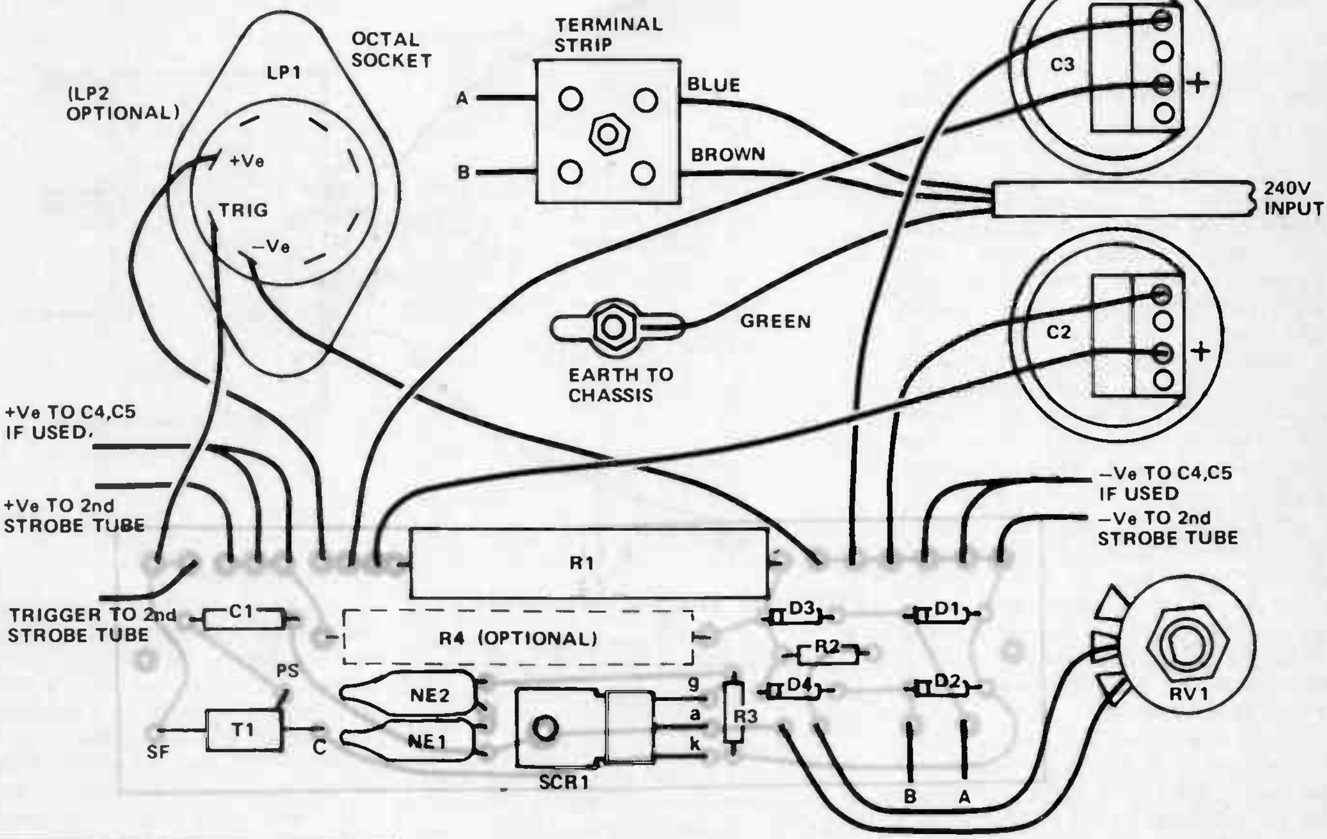
The resistor between the gate of SCR1 and ground, R4, prevents spurious triggering of SCR1.

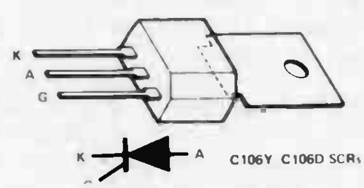
used. The capacitors specified have a threaded mounting bolt protruding from the base, making mounting a simple matter. Also mounted on this end of the box are the flash speed potentiometer and the power switch. The power cord passes through the panel also, being secured by a clamp-type grommet. A two-pole mains switch must be used and can be either a separate switch or integral with the flash speed potentiometer. Note that a switch-pot. has been specified in the parts list.

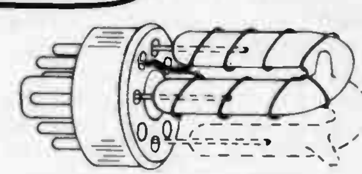
If one strobe tube is used, only two capacitors will be required. These should be mounted, so that two more may be mounted at a later stage if another strobe tube is added. The potentiometer may have a value of either 5M or 2M, depending on which is the more readily available. The 5M pot. will give a speed from about one flash per second to about 20 flashes per second. The slowest speed is somewhat too slow for most applications, but this matters little as the desired flash rate will be within the general speed range in any case. The 2M pot. gives a range of about two or three flashes per second up to about 20 flashes, as before.

Whatever you do, do not omit the plastic cover over the front of the reflector. This is to prevent accidental contact with the flash tube and the lethal voltages present.

The pc board pattern is on page 90.







PARTS LIST – ETI 574

Resistors
- R1 . . . . .820R 10W
- R2 . . . . .470k ½W
- R3 . . . . .1 meg
- R4* 820R 10W
- RV1 . . . . . . .2M or 5M linear potentiometer with double pole switch (see text)

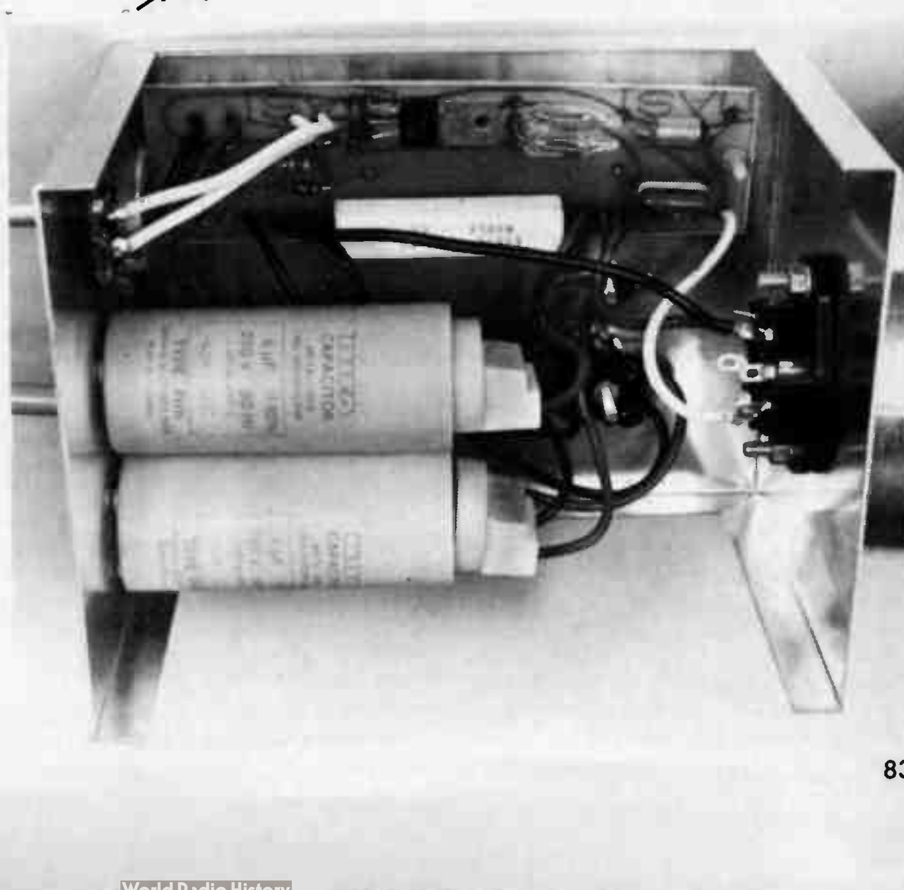
Capacitors
- C1. . . . . .100n 400Volt polycarbonite
- C2,C3,C4*, C5* . . . . . 6μF 240Vac capacitor (RIFA type PHN)

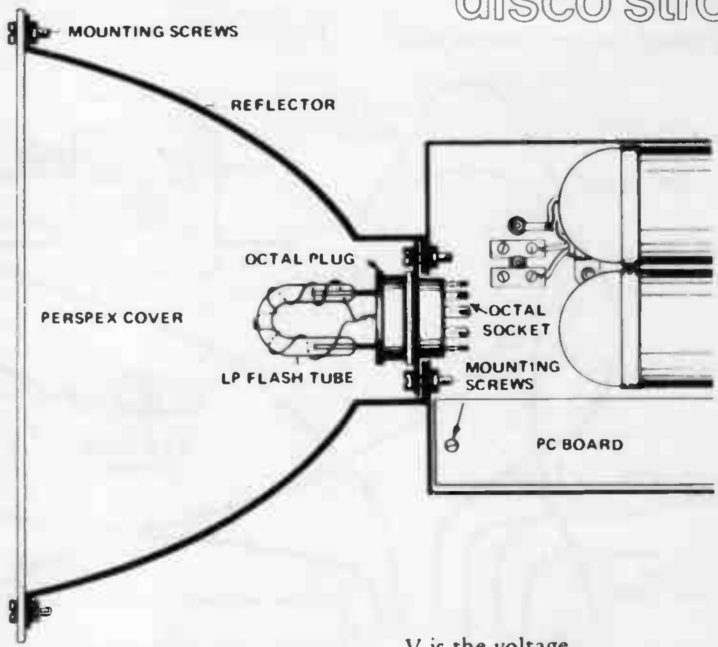
Semiconductors
- D1-D4 . . . . IN4004,EM404,A14A or sim.
- SCR1 . . . . . . .C106D,BT100A 500R, or sim.

Miscellaneous
- NE1,NE2. . . .neon indicator tube GE - NE2
- LP1,LP2* . . .Strobe tube, Circuit Components type MFT 1210 or Dick Smith type.
- T1. . . . . . . .pulse transformer to suit tube type TR4KN or sim.
- Octal Plug . . .McMurdo L8USR1

Octal Socket McMurdo type RT8, reflector, metal box 145 mm x 115 mm x 90 mm, perspex cover, hinge, magnetic catch, power cable, ETI 574 pc board.

*Components marked with an asterisk are only used for two tubes.





Caution!

The entire circuit is at mains potential (including the tube) and, if you don't want to fry yourself – or be responsible for somebody else accidentally doing likewise – it is essential that the case be securely earthed. The power cord must be arranged and secured strictly as shown in the diagrams. Use proper 240 Vac rated wiring (23-0076 PVC insulated) for all connections. For safety's sake, a perspex cover is bolted over the open end of the reflector.

Assemble the printed circuit board according to the overlay, noting the polarity of the diodes. If two strobe tubes are to be used, include the additional 820 ohm, 10 watt resistor as shown.

Plastic standoffs must be used to mount the pc board. These standoffs decrease the chance of a short to the metal case. They are necessary secondly because the trigger transformer develops 4 kV pulses which could possibly develop arcs across the pc board should metal standoffs be used.

The strobe tube itself is not a critical component. Two types are commonly available. The type MFT1210 from Circuit Components of Bexley NSW is one such unit. Another is that advertised by Dick Smith, (catalogue No. S-3882).

Neither of these tubes includes a trigger electrode, so one must be attached. This is simply made by winding a length of 22 gauge (or some gauge thereabouts) tinned copper wire around the glass and taking it down to a spare pin in the octal base on which the strobe tube is mounted. The diagram shows how one or two tubes, together with their trigger electrodes, are mounted in the octal plug.

When you have the assembly complete make sure all components are securely mounted and there are no short circuits – or any possible – and **RE-CHECK THE EARTH CONNECTION.**

The smoke test

Perhaps that's a little too strong! Nevertheless, once you have the unit assembled and carefully checked, set the speed potentiometer to minimum flash rate (fully anticlockwise), plug in and switch on. If all is well, the strobe should flash about once per second or a little faster, depending on which value pot. is installed. Advancing the control should increase the flash rate.

How the strobe tube works

For those not familiar with a strobe tube and the way it works, the following explanation should, er . . . throw some light on the subject.

A strobe tube is a simple tube of glass, sealed at the ends and bent into a convenient shape, evacuated and then filled with a tiny amount of one of the rare gasses – in this case Xenon. Small metal electrodes are sealed in the ends of the tube, projecting into the interior. A third, 'trigger' electrode is attached in some manner around the outside of the tube, though not completely covering it. Some 300 to 500 volts dc is applied between the two end electrodes, generally from a storage capacitor, but the resistance of the gas is very high at this stage and negligible current will flow. When a very high voltage pulse, about 4 kV, is applied to the trigger electrode, the gas inside the tube ionises ('Breaks down'), its resistance falling quickly to a very low value. The storage capacitor discharges through the tube and an enormous current flows – amps of it! – the voltage across the electrodes falling in about 100 microseconds to a value below that necessary to maintain the gas ionised. When the gas ionises it emits an intense burst of light, extinguishing when the discharge ceases.

The amount of light produced during each flash is dependent on the value of the discharge capacitor and the voltage across it. For those interested, the formula for the energy of the discharge is: –

$E = \frac{1}{2}CV^2$

where E is the discharge energy, in joules
C is the capacitance in Farads
V is the voltage

Increasing either the capacitance or the voltage will increase the energy of the discharge, and hence the light output. However, as the output is increased, tube life falls off dramatically.

A better way to obtain more light output is to use two tubes. Separate storage capacitors are necessary as each tube varies with regard to discharge characteristics. If two tubes are simply connected in parallel, whichever commences to discharge first – even though it may only be microseconds earlier – will prevent the other tube from firing.

In the circuit used for this strobe unit, two 6 uF capacitors are used in parallel for the storage capacitor. For two tubes, another two capacitors are used. The same trigger transformer may be used to trigger both tubes in a twin-tube model.

For small rooms or total darkness, the light output of a single tube unit will be more than adequate. For larger rooms, halls etc, two tubes will be necessary. ●

WARNING

Repetitive pulses of light – especially around nine flashes per second – may cause epileptics to have convulsive seizures.

Those prone to grand mal, or psychomotor attacks should avoid areas where strobe lights are operating. In fact, most people will suffer nausea or headaches after long exposure to a strobe.

In the event of an attack whilst the strobe light is operating, it must be turned off immediately.

The 'sure start' model engine ignition system

No more flick-flick-sputter, flick-flick-sputter. This 'glow plug regulator' ensures a lively start for that model petrol engine in your favourite model aeroplane, boat or whatever.

Jonathan Scott

HOW MANY OF YOU have one of those infernal model petrol engines lying around the garage or store room somewhere? And why exactly are these things so often left unapproached and undisturbed in these dark crannies — because they are noisy? No. It is usually because they are *so difficult to start* that you have decided that they are not worth the trouble or the cost.

I recall spending ages as a kid with model aeroplanes trying in vain to get them going, wearing my fingers to the bone — flick, flick, flick . . . and no start. Often they would appear to kick over, encouraging the soul, only to remain in that half-starting phase turn after turn.

I gave up then — anyone with any sense and/or no money does. Yet, with the development of the 'magical' ETI-1516, friends and relatives have been volunteering their discarded models for testing, encouraged by the effortless instant starts which can be produced on demand. (The author had already bought several engines and wasn't interested in any more, thank you!)

So this project should provide the incentive to resurrect that long-stored model with the promise of quick ignition which, we hope, will encourage you to give it another go. After all, for under $40 plus fuel you can buy a complete aeroplane kit including the engine and all the accessories to have the thing flying on a control line almost instantly.

Ah, but the experts (read fanatics if you like) seem to be able to get their models to go promptly, so you might think that the complexity of the ETI-1516 is rather unnecessary. What do the regular modellers use to get the same end?

Firstly there is experience. They have probably been just where we have but they didn't give up, the blockheads. However, the endless tinkering and fiddling has payed off; they have tried all the possibilities and learnt to tell quickly what is the problem. Too much fuel or a flat-ish battery are dead giveaways when you have been at it for life. Misadjusted mixture takes thirty seconds to spot with enough experience, while a major failure may be the only problem not eliminated after two minutes.

All this is fine, but useless if you don't have a pet modeller on hand. Next, there are the current commercial inroads made by electronics which are available at the model shops. For around $30 you can buy what is termed a 'power board'.

This thing connects to a car battery and allows you to deliver 0 to 5 A to the plug while giving a rough indication of current by means of a meter. It is basically a single transistor or Darlington and a few resistors, and not surprisingly delivers a lot of heat to the atmosphere and the unwary modeller's fingers! Also, of course, it takes the same current from the main 12 V battery as it delivers to the plug, necessitating the use of a car-sized battery rather than a small set of sealed cells.

Again, with experience, but less this time, you can adjust it neatly so as to allow starting without regular incineration of the glow plug.

But for a similar outlay, our new unit is significantly superior in its operation. Firstly, it regulates not the current (bad) or the voltage (better) but the actual resistance of the glow coil, and hence the temperature of the plug (best).

Secondly, it employs a switchmode supply, which means that it dissipates only a modicum of power, typically five watts, rather than something over 50 watts.

What is more, it draws only a small fraction of the current that it delivers to the load, typically 20 to 25%! Result: less of a heat problem and smaller batteries for the same performance (penlite NiCads are fine) or even longer, lighter wires, running to your car cigarette lighter or whatever.

In addition to these features, it has a few more. It is cleanly and sharply current limited, which makes it infinitely harder to ruin a glow plug. We have equipped it with a button to allow the current meter to act as a battery check meter.

It has two potentiometers which are alternately selected by another switch: these can be preset to provide the correct starting temperature for two different engines or two different grades of glow plug for the one competition engine.

In case you thought that 'glow plugs was glow plugs' then it is about time that you took another wander through a model and hobby shop and saw the range of glow plugs which are available for tuning your engine. There are even several devious speciality twists you can get for improving some aspect of the running performance.

These features put the ETI-1516 ahead of anything commercially available, and coupled with its relatively simple construction and lack of critical or rare components, we feel it is the best option both for those not heavily involved in modelling and as a replacement piece of equipment for the serious model enthusiast.

Construction

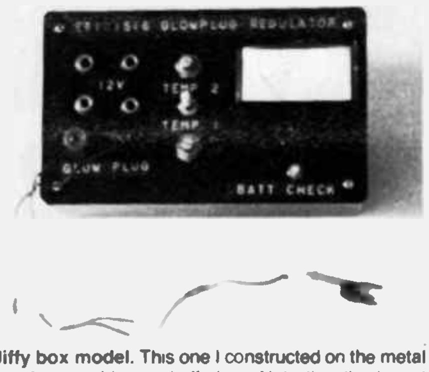
The commercial power boards I saw sold at hobby shops are constructed on a small flat plate of aluminium with the components mounted by bolts or silicone glue, to the back of the plate. The user is presumably free to mount this plate in a box or use it as is.

Out of a desire to conform to the expected structural format, I built one prototype on such a small plate, but it is the front panel of a jiffy box, so that you have a ready-made enclosure if you want.

If you are not concerned with the compactness or the appearance but rather the robustness, I recommend using a tent-shaped panel quickly bent up from 14 or 16 gauge aluminium sheet or similar.

This structure provides its own heatsink mount for the power transistor (Q7), as well as allowing access to the innards at short notice (very handy with the situations you find cropping up on the runway when you're miles from home). I built another unit like this. If your metalworking facilities do not stretch to this, the jiffy box is easier to prepare.

Also provided as a convenience, because commercial units often have it, is a second pair of banana sockets for the 12 volt supply so that more than one device running on the same source can be accommodated simultaneously without piggyback plugs. This can be deleted if you prefer.



Jiffy box model. This one I constructed on the metal lid of a suitably-sized jiffy box. Note that the layout is laterally reversed to the model pictured on the front cover.

Perhaps the first stage to construction is the winding of the coil, L1. I wound about 50 turns of 1.45 mm (15 B&S) enamelled copper wire on the former of an FX2243 45 mm diameter potcore assembly. This produces 20 mH inductance and is easy to buy and wind. In fact, any value of inductance from a minimum of about 5 mH up to 50 mH will do, but remember that it must be wound of wire sufficient to handle five amps. I suggest that you use 1.45 mm diameter wire, but at the very least 1 mm wire might do as the unit will not be used continuously. This inductor is the bulkiest component, so choose the box you wish to use with an eye to the size of this as well as the meter, M1. The next stage is to drill and prepare the front panel. My advice here is not to go overboard on the cosmetic side as the working environment and chemicals will make a mockery of any efforts at glamorous packaging.

While indelible pen is probably the most cost effective method of marking the front panel, I sprayed it with aerosal paint and marked the controls with labels on one prototype which were later covered with some clear lacquer. The result is clear and durable.

If you have the panel area, the pc board can be mounted on it. I have made provision for mounting holes on the board.

Next mount all the panel components. I used pots with the short ribbed spindles and screwdriver slots, intended as 'chassis presets'. I recommended them as you do not want to alter the settings often and knobs make it likely that there will be some potentially hazardous (to the glow plug) twiddling by well-meaning or curious persons.

For the pushbutton, SW2, I used one of the small positive action momentary switches which cost a little more but are crisp in their action and fairly robust.

Now comes the assembly of the pc board. Two factors are worth noting. Firstly, if there is no chance of the incoming polarity being reversed, forget D3, the supply protection diode. Otherwise fit it either as I did, between the pc board V- connection and the lead going to the terminal, or at the incoming terminal junction.

You could even fit it in such a fashion as to protect components further down the chain by placing it between the first and second positive input banana sockets.

I used the banana sockets as these are what the commercial units are normally equipped with, but a polarised-type plug would be preferable as D2 can be dropped and then you can run to a lower input voltage before the electronics gives up.

As the voltage coming in to the box must run the op-amp, it is desirable to keep the input as high as possible. My prototype ran down to 9 V (after D2) comfortably.

Warning: polarity reversal will be quite lethal, so use D2 if you are not otherwise guarded.

The second factor concerns the heatsink on Q1. If you will not be running the unit for more than one or two minutes at most (the usual case), about 3 cm x 3 cm of heatsink is quite adequate, but a 6 cm x 4 cm heatsink at least must be used if you wish complete protection from burnout in continuous operation.

The consideration of operation duration also effects the choice of D1, the freewheel diode. It should actually be rated for about four amps continuous forward current but a three amp diode will be quite safe if you are only running it for a minute or two at a spell. Five amp diodes are more costly and harder to get, and our unit ran quite well using a three amp type. Higher current diodes tend not to be pigtail types too, which complicates mounting.

HOW IT WORKS — ETI-1516

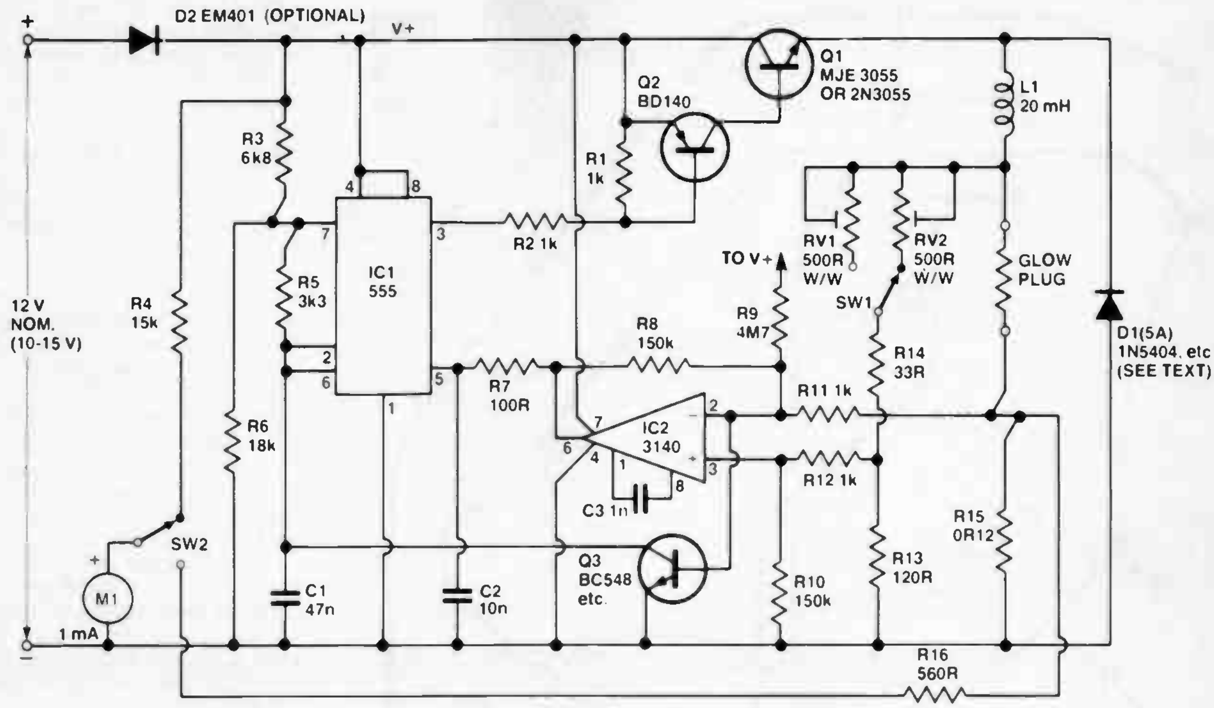
The block diagram of this unit is shown in Figure 1. There are three main parts to it: the resistance 'bridge' and the bridge amplifier, the pulse generator and the switching regulator.

The pulse generator provides constant-width pulses at regular intervals to the switching regulator. This provides current to the bridge, most of which (I_L) flows down through the glow plug (R_L) and a low value resistor (R_S). The ratio of R_A:R_B is compared to R_L:R_S by the bridge amp. If the ratios are different, then a voltage will appear across the op-amp inputs. If the glow plug (R_L) is cold, its resistance will be low. The ratio of R_A:R_B is set such that, when the glow plug is cold, R_A:R_B is greater than R_L:R_S.

Under these circumstances, the output of the bridge amp will cause the pulse generator to speed up, increasing the output of the switching regulator which then drives more current through the glow plug. The glow plug's resistance then increases and the ratio of R_L:R_S decreases. This causes the bridge amp to slow up the pulse generator until R_L:R_S equals R_A:R_B. i.e: the bridge is 'balanced'. The pulse generator then provides pulses at such a rate to the switching regulator so as to maintain the resistance, and thus the temperature, of the glow plug as desired. Varying the value of R_A thus sets the temperature of the glow plug.

Note that the majority of current supplied by the switching regulator passes down the R_L-R_S 'leg' of the bridge, only a small amount passing down the R_A-R_B side. The load current (I_L) thus flows through R_S and the voltage across R_S is used to drive the current-limit circuitry.

Looking at the circuit, the bridge consists of RV1/RV2-R14 (R_A), R13 (R_B), R15 (R_S) and the glow plug (R_L). The bridge amplifier comprises IC2 and associated components. The pulse generator is provided by IC1 and associated components while the switching regulator comprises Q1, Q2, L1 and D1. The voltage drop across R15, through which the glow plug current



(I_L) flows, is sensed by Q3 which provides current-limiting.

Initially, C1 will be discharged and the output of IC1 will be high (i.e: at +12 V). Thus Q2, and therefore Q1, will be biased off. C1 will begin to charge via R3 and R5. Now, the inverting input of IC2 has a small positive bias applied to it via R9 and thus IC2's output is low (0 V), pulling pin 5 of IC1 (the control pin) low. This allows the 555 to trigger its output to the low state after C1 has charged only a little way.

When pin 3 (the output) of IC1 goes low, Q2 will be biased on, turning Q1 on. This applies 12 V to L1 and current will commence to flow through L1, the glow plug and R15 (also a little through RV1/RV2-R14 and R13). Because of the inductance of L1, the load current (via the glow plug, etc) will rise slowly. As the glow plug is cold to start with, the ratio of the glow plug resistance to R15 will be much less than the ratio of RV1/RV2+R14 to R13. Thus, the voltage at the inverting Input of IC2 will be greater than that at the non-inverting input and the output of IC2 will continue to hold pin 5 of IC1 low. Thus, Q2 and Q1 will remain on, allowing the current through L1 and the glow plug to continue building up.

When IC1 first triggers, pin 7 goes low and C1 will begin to discharge via R5. The output of IC1 will remain low for as long as it takes C1 to discharge to half the level it was previously charged to, at which point pin 3 of IC1 goes high again and Q2-Q1 turn off.

The magnetic field built up in L1, having nothing to sustain it now, will begin to collapse, the voltage across L1 will reverse and forward bias D1. Thus, the current generated by the collapsing magnetic field in L1 will continue to flow through the glow plug and R15, but now via D1.

The current now supplied by L1 will fall as the coil's energy is dissipated by the glow plug and R15. As the glow plug is still relatively cold, the inverting input of IC2 will be higher than the non-inverting input as the voltage drop across the glow plug will be less than the voltage drop across RV1/RV2+R14. Thus, IC2's output will hold pin 5 of IC1 low, allowing C1 to charge again.

When pin 3 of IC1 went high, pin 7 also went high, thus allowing C1 to charge again. When the voltage across C1 reaches the trigger point of IC1, pin 3 again goes low, turning Q2-Q1 on again.

Once again, current is applied to the glow plug, which continues to heat up. As the glow plug heats up, the voltage on the inverting input of IC2 will eventually reach that on the non-inverting input and the output of IC2 will then switch to the high state. This drives pin 5 of IC1 high and pin 3 low once C1 has completed its current discharge cycle.

The time taken for C1 to discharge will remain constant irrespective of the level on pin 5 of IC1. Thus, the pulses produced by IC1 will be of constant length, but the level on pin 5 will affect the pulse rate. If the glow plug is cool, the pulse rate will be high. As the glow plug heats up and its resistance increases, the pulse rate will decrease.

With IC1 operating at a high pulse rate, Q2-Q1 turn on more frequently, delivering a lot of power to the glow plug. When IC1 operates at a slow pulse rate, less power is delivered to the glow plug.

Switch SW1 selects either of the two preset pots, RV1 or RV2. As the setting of these determines the ratio of R_A to R_B, they will determine the ultimate temperature of the glow plug.

If the current through the glow plug exceeds that necessary to develop a voltage drop across R15 of about 0.6 V (about 5 A), then Q3 will be biased into conduction. The collector-emitter junction of Q3 then shorts C1, preventing IC1 from firing, turning Q2-Q1 off until the current through R15 drops below the limit. Thus, the current through the glow plug is limited to a safe value, preventing burnouts.

A 1 mA meter is used to monitor the supply voltage and the glow plug current. Resistor R4 provides the meter with 1 mA of current at a supply of 15 V. Resistor R16 provides 1 mA of current through the meter when 5 A flows through R15. Switch SW2 allows switching the meter so that it reads supply voltage and glow plug current as you wish.

Capacitor C2 protects IC1 against 'spikes' present on pin 5 of IC1. Capacitor C3 compensates IC2.

A diode, D2, may be added to prevent damage to the unit should the supply be connected in reverse polarity.

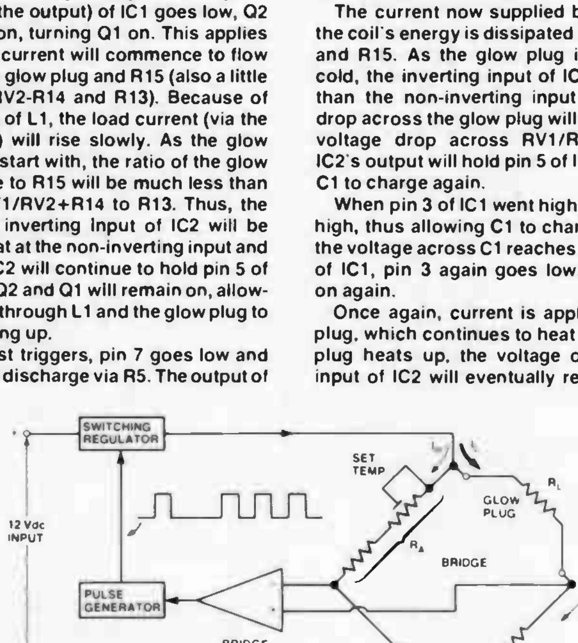
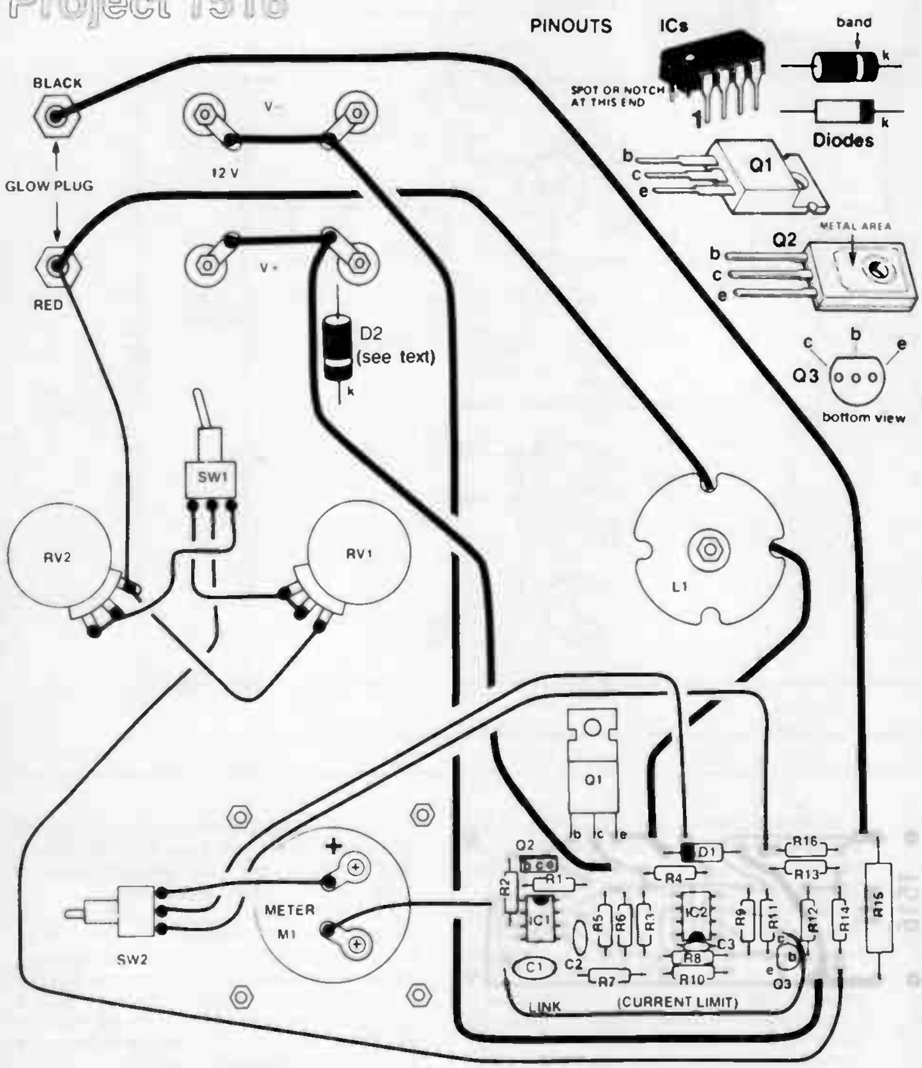


Figure 1.



Component overlay and wiring diagram.
General wiring diagram and pc board assembly. Note that SW2 is a pushbutton switch. Push in to read voltage.

Components & Kits
Suppliers of components and kits for this project are listed in the 'Shoparound' page in this issue. ETI does not sell kits or components for projects.

PARTS LIST — ETI-1516

Resistors	all ½ W, 5% unless noted
R1, 2, 11, 12	1k
R3	6k8
R4	15k
R5	3k3
R6	18k
R7	100R
R8, R10	150k
R9	4M7
R13	120R
R14	33R
R15	0R12, 5 W
R16	18k
RV1, RV2	500R preset or panel mount type pots
Capacitors	
C1	47n greencap
C2	10n greencap
C3	1n greencap
Semiconductors	
D1	3 A or 5 A, 100 PIV (e.g. 1N5405 or 1N5408)
D2	EM401, EM402, 1N4001, 1N4002
IC1	uA555, NE555, LM555 etc
IC2	CA3140
Q1	MJE3055, TIP3055, 2N3055
Q2	BD140
Q3	BC548, BC108, DS548 etc
Miscellaneous	
L1	20 mH inductor, wound on FX2243 potcore assembly with 1.5 mm enamelled copper wire, 40 mm 4 BA bolt, nut and fibre washers
M1	1 mA meter movement, e.g. University TD48 or Minipa MU45
SW1	SPDT or DPDT miniature toggle switch, e.g. D.S.E. S-1245 or similar
SW2	SPDT or DPDT momentary action pushbutton, e.g. D.S.E. S-1220 or similar

ETI-1516 pc board, banana sockets or polarised plug/socket, metalwork (see text), heavy duty hookup wire (24 x 0.2 mm or heavier), meter scale, terminals for plug cable termination, standoff pillars, nuts, bolts, wire, solder etc.

Price estimate $35 — $40

So, having settled for the option you wish, assemble the pc board components with particular attention to the IC polarity. Note that the two ICs are oriented oppositely to simplify the pc board pattern. There are no electrolytic (polarity conscious) capacitors specified. If you are far away from the battery you may find you need a 10 uf/16 V tantalum capacitor across the supply terminals, but my prototype was quite happy without one. Check the board when you've finished it.

The last stage of assembly is to fit the pc board and run the interconnecting wires. Be sure to use heavy guage hookup or automotive wire for the connections to L1, the supply, D1 and the glow plug current loop. Fit Q1 to its heatsink using some thermal compound. Use an insulating washer if you are fitting it to the panel as a heatsink. Be sure to remove any burrs from the mounting holes which might prevent close mating of the transistor and heatsink, or puncture the washer if used.

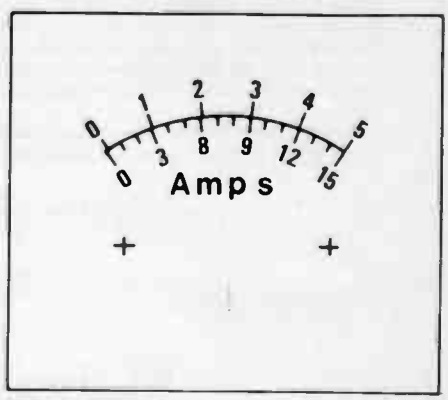
My prototypes used the least reliable option in each of the above cases, to prove that the unit could work that way: small heatsink on Q1, 3 A diode for D1, a diode in place for D2, no capacitor on the supply and the whole thing inside a jiffy box.

After five minutes of heavy work (at 3 A) I had to turn it off to prevent Q1 failing, but all else worked.

If you are not skimping we think that you should use a large heatsink on Q1 and perhaps a capacitor on the supply terminals if you are not sure what leads will be used in the field. The other construction suggestions will all aid reliability also.

The second unit tested used the tent-shaped metalwork and Q1 was bolted to the rear panel. This will run indefinitely without sign of failure.

Once construction is completed, check it over thoroughly. When you're satisfied all's well, apply power and listen carefully before connecting up the glow plug. The inductor is almost certain to emit a 'singing' noise as the switcher idles along. Short the output and the current meter will respond with about 4½ amps and the singing note will change. This indicates normal operation.



Meter scale. Full size reproduction of the meter scale. For those who want to make their own from Scotchcal, a same-size negative or positive transparency can be had for $1 post paid from: **ETI-1516 Artwork, ETI Magazine, P.O. Box 21, Waterloo NSW 2017.** Make cheque or money order payable to ETI Artwork Sales. Ensure you ask for a **positive** or **negative** according to your requirements.

Using it

Tent model. This is the tent-shaped model I built The wiring diagram on the previous page shows the physical layout of the rear panel of this unit

In practice, nothing could be simpler than this device to use. Ideally, you should set the temperature control while viewing the glow plug removed from the head of the engine.

Connect a 12 V battery to the input of the unit. Remove the glow plug from the engine head. Reduce the selected temperature pot. to minimum resistance and connect the glow plug to the output terminals. Slowly bring the temperature up by adjusting the pot. *away* from the minimum resistance end of its travel (rotate clockwise). The plug coil will begin to glow.

Clearly, if you bring the temperature up too far you will burn the plug out, so be careful. A glow just beyond red is best, just tending to orange. If you are in doubt, it is best to try a lower setting and go up later.

You can set one pot. for red-orange plug coil and the other for orange-white, using this higher setting by flipping the temperature select switch if the lower setting will not effect motor starting.

Once you have seen the level which causes no starting problems it is simple to set up all further plugs in a like manner.

Once the plug is reinstalled in the head you should proceed to start the engine in the usual manner as recommended by the manufacturer. Because of the temperature regulating action of the controller you will find it much more difficult to foul the plug or flood the engine.

Any foreign matter in the glow plug fitting tends to cool the element and so elicit an increase in the power delivered, burning the extraneous stuff off quickly. The current limit mechanism prevents plug failures due to one part of the coil cooling and producing higher currents while another part of the coil is uncooled and overstressed.

You will also notice certain other effects. When coming close to starting by firing on the first compression stroke, but not further ones, the current needle will be seen to dip momentarily. This is on account of the heat produced by the single ignition, which heats the plug somewhat, reducing in turn the need for the controller to supply heat to keep the coil up to the commanded temperature.

On the other hand, too rich a fuel mixture or tendency to flood will be evidenced as the reverse; momentary rises in the current delivered to the plug indicate that the coil has been splashed or otherwise cooled, necessitating a moment of boost. (You may feel free to consider at these moments how another system would be labouring to boil off the contaminant.)

Again, when the engine has started there will be a significant fall in current, simply because the repeated combustion explosions in the head are doing most of the heating of the glow plug.

Other non-temperature sensitive systems would tend to overload the glow plug at this point, a fact that was only brought to our attention by the observation of the power drop upon starting.

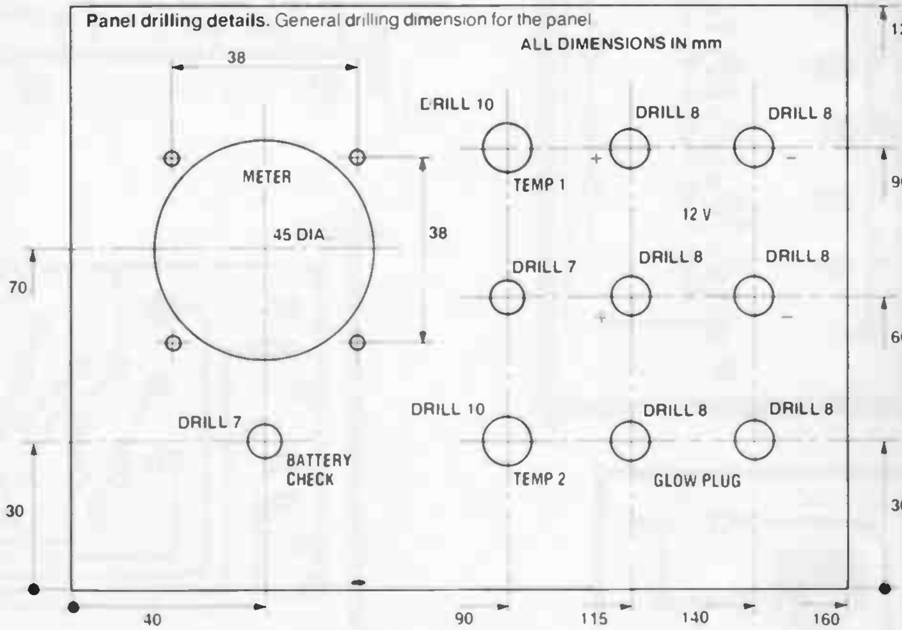
One final note: The ETI-1516 may seem like overkill to some, realising that there would be significant feedback action if the glow plug were merely connected to a sound voltage regulated output (preferably with remote sensing to eliminate the constant resistances of wires and so forth) by virtue of the sharply non-linear nature of the temperature/resistance characteristic.

This is indeed true, but the complexity of a current-limited switchmode voltage supply falls short of the complexity of the system here by only such a small margin that it turns out not to really be worth it.

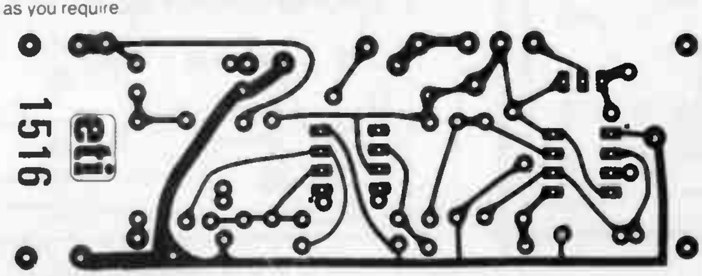
One could save the odd few resistors and a diode or so, but it would require all the major semiconducting elements with which we have managed to achieve temperature regulation merely to provide a sharp low impedance source, so why not go the whole hog, so to speak?

May your starts be many, now that they're virtually all 'sure starts'! ●

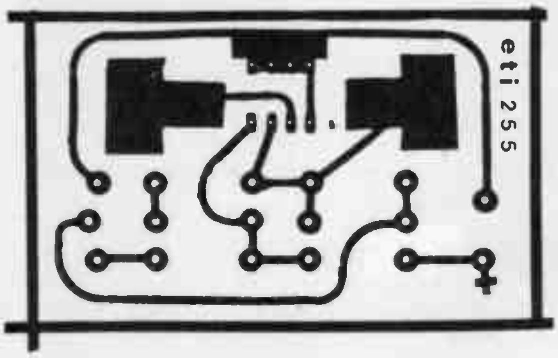
Panel drilling details. General drilling dimension for the panel

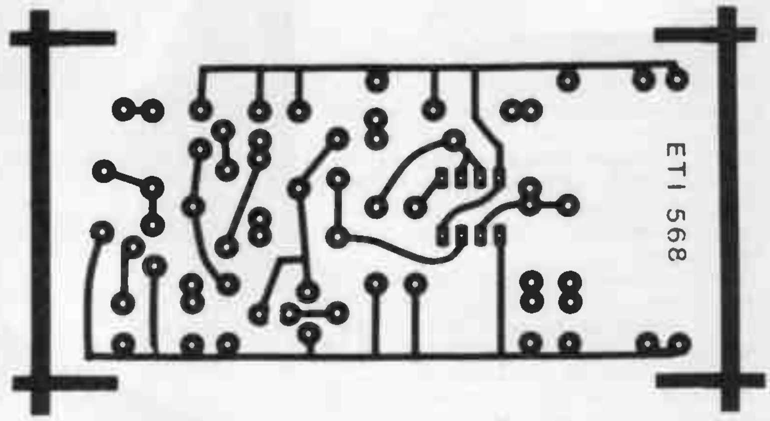


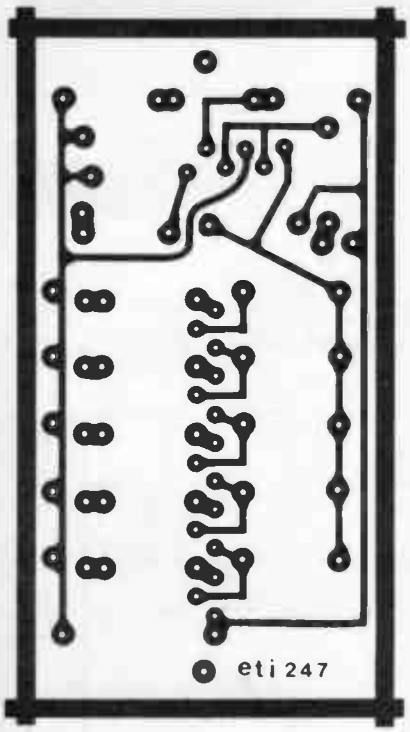
Printed circuit artwork. Full-size layout of the pc board copper side A same-size positive or negative transparency can be had for $1 post paid from **ETI-1516 Artwork. ETI Magazine, P.O. Box 21, Waterloo NSW 2017.** Make cheque or money order payable to ETI Artwork Sales Ensure you ask for a **positive** or **negative** as you require

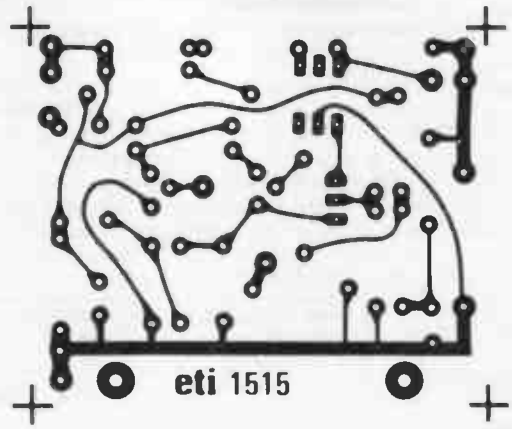


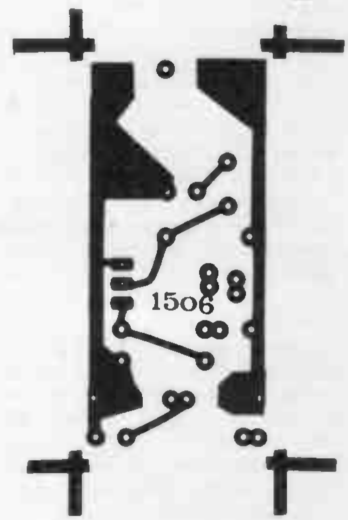
PCBs

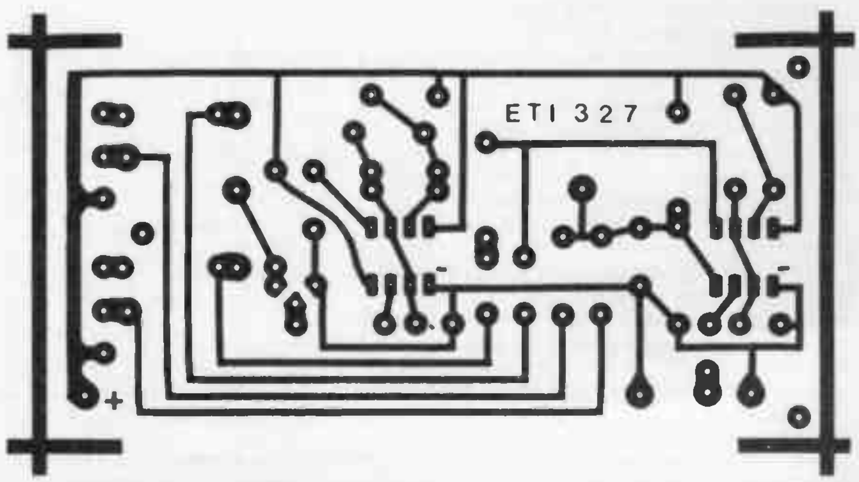


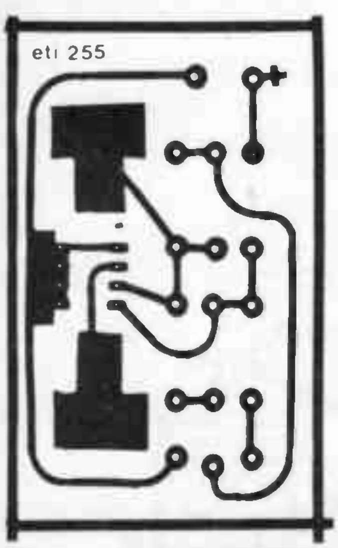


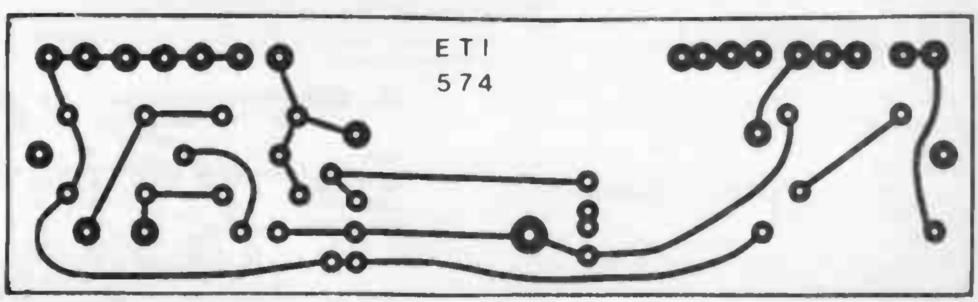












Bell, inventor of the photophone, pictured in 1876, the year he patented the telephone.

Build a 'photophone' light beam transceiver

Unlike the telephone, the photophone is probably Alexander Graham Bell's most obscure invention. Instead of wires, you can talk on a beam of light. This modern — solid state! — version is simple to build and remarkably effective.

Phil Wait
William Fisher

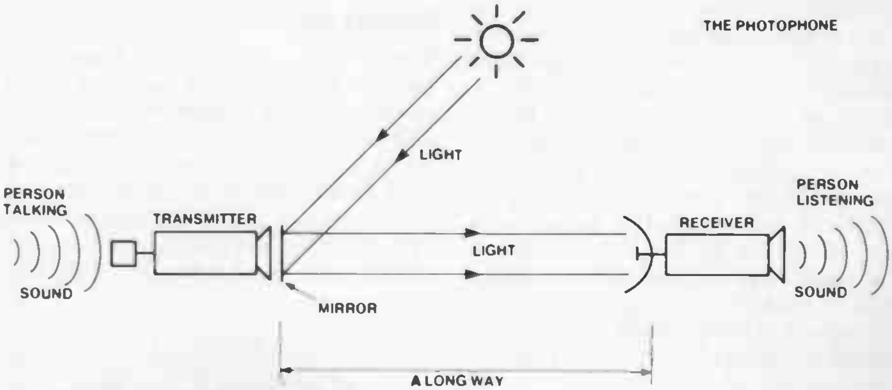
A PHOTOPHONE is a device for sending voice signals along a light beam. The word 'photophone' dates from 1880, when Alexander Graham Bell coined it to describe his own light-beam communication system. At his death in 1922, Bell was still convinced that the photophone was his most important invention, more important even than the telephone, which by that time had spread into a worldwide network.

However, the world in general disagreed with Bell and went ahead with communication systems using wires or radio waves as carriers, in preference to light waves. (The development of fibre optics may reverse this trend, but that's another story.) The photophone was forgotten by everyone except a few historians of science.

In the interests of nostalgia and entertainment we have revived this ancient invention, using some modern electronics instead of the cumbersome and unreliable modulation and detection equipment that Bell was forced to use. (He was working in the pre-electronic age, nearly thirty years before triode valves were invented and seventy years before transistors.)

The principle

The basic principle of the photophone is that a normally flat mirror is made to flex slightly by sound waves impinging on it. A light beam is reflected off the mirror and aimed at a photosensitive receiver. As the mirror is flexed by the sound waves it becomes alternately convex and concave, which means that the beam reflected onto the receiver becomes alternately wider and narrower, in time with the sound wave. The total number of photons in the light beam is not altered by these changes in its width, but the fraction of that energy which falls on the receiving surface does vary (providing the beam is always wider than the receiver). So the intensity of the light received varies with the width of the light beam, which in turn varies with the curvature of the mirror, which is caused by the pattern of sound waves hitting it.

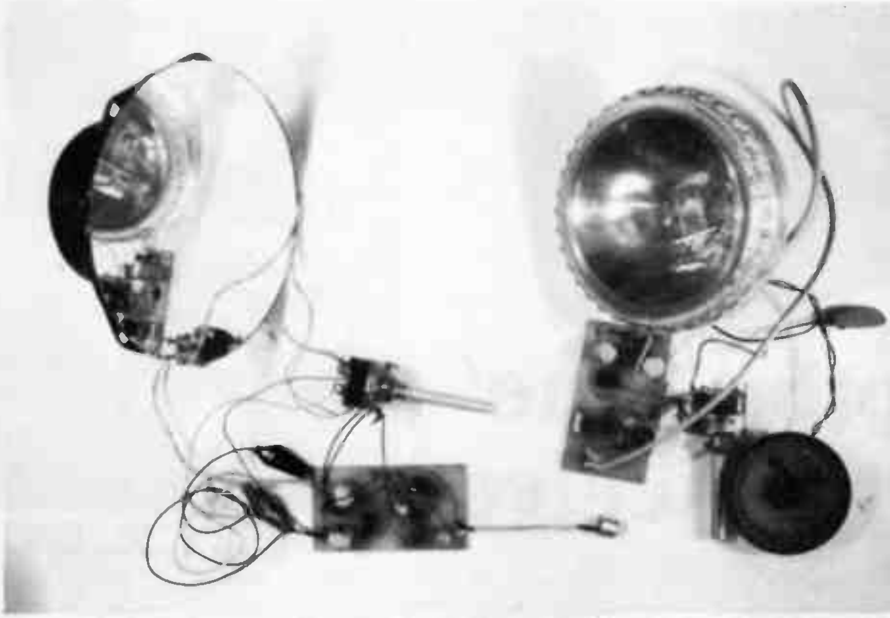


Illustrating the basic principle of the photophone.

The variations in light intensity at the receiver can be converted into an electrical signal which drives a loudspeaker via an amplifier to reproduce the sounds originally produced at the transmitting end. The whole arrangement is a kind of amplitude modulation of the light beam, with the mirror acting as the modulator and the photosensitive surface acting as the demodulator.

Transmitters

The first problem is to make the mirror flex in time with the sound wave. Bell's original mechanism for doing this was very simple. He used a thin mirror



The assembled prototype transmitter and receiver. The transmitter was powered by a 6 V lantern battery, the receiver by a 9 V transistor radio battery. We used a solar cell mounted in a lantern reflector, as described below.

firmly glued over the end of a flexible tube. When he spoke into the other end, sound waves travelled down the tube to make the mirror vibrate. This method is quite effective and you can use any kind of tube — a rigid cardboard or metal cylinder, for example. The mirror is more of a problem, because it needs to be quite thin to flex enough in response to unamplified voices. You may be able to obtain an ultra-thin glass mirror from a scientific equipment supplier, but some kind of reflective foil will be easier to get. Ordinary aluminium foil is an excellent reflector but it tears easily and it's hard to keep it uncreased, although these problems can be avoided to some extent by sticking adhesive tape to the back of the foil. Aluminised mylar (or other plastic) foil is probably best, if you can find any.

For our own transmitter we opted to use a circular glass mirror of normal thickness, such as you might buy in any chain store as a shaving mirror (the flat variety — not concave). We mounted this on the frame of a 150 mm diameter circular loudspeaker and made an amplifier to drive the speaker with sufficient power to flex the mirror. If you want to use this method, buy the speaker first, then look around for a shaving mirror the same diameter or slightly larger. Remove the metal or plastic rim and you will usually find two mirrors, one flat and one concave. Discard the concave mirror and glue the flat one to the metal rim (NOT the cone) of the speaker, using epoxy resin. Don't use a silicone compound like Silastic, because the joint must be rigid. The wider the speaker and mirror you use, the better the range and the lower the distortion, because a wider mirror can flex more. The amplifier and microphone are described under 'Electronics'.

Receivers

There are several photosensitive devices which might be used in a receiver. Light dependent resistors respond too slowly, but a phototransistor is much faster and could certainly be used. Bell's original photophone receiver used selenium photoresistors in series with a battery and a telephone earpiece, but he had great difficulty with this system. (Bell deserves credit for any success with this astonishingly crude arrangement. As Dr. Johnson remarked about a dog walking on its hind legs — it was not done well, but it is astonishing that it was done at all!)

Close up of our receiver input device. This consists of a small solar cell piece mounted in a reflector taken from a 'Dolphin' lantern. To mount the cell, we cut a slot in one side of the reflector, put Silastic on the rear of the solar cell (leads already attached) and inserted it in place. It proved very effective.

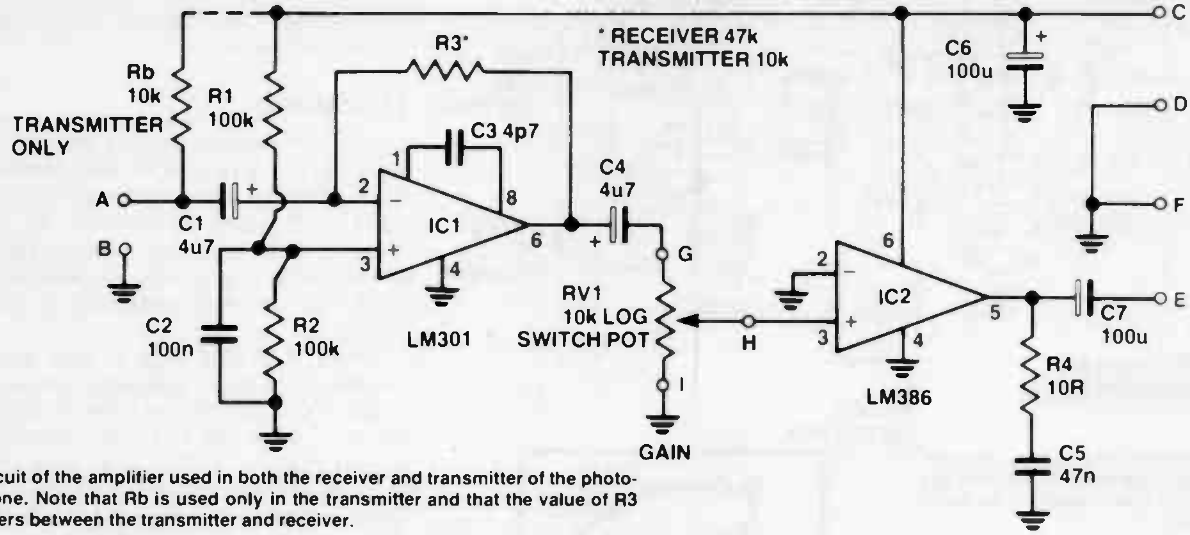
For our receiver we opted to use a 'solar cell', which is a kind of silicon photodiode. The large area and easy availability of solar cells make them the best choice overall. The effective area of the cell was made even larger by mounting it near the focus of a parabolic reflector taken from a hand lantern and an even larger effective area could be obtained by using a car headlamp reflector. Bell's original photophone used a reflector nearly a metre in diameter to gather the light, but anyone thinking of using very large reflectors should remember that the reflector must not be wider than the beam it is collecting, otherwise the modulation cannot be detected.

Light sources

In principle any light source will work. At night, with no other lights nearby, a pocket flashlight has been reported to work by some experimenters, but we haven't tried this ourselves. In daylight you need an intense and collimated (i.e: parallel) beam to get any reasonable range. A gas laser (such as a helium-neon type) is an ideal source, which in principle could give you a range of several kilometres in open country or over water, but some precautions are necessary. A low power laser is safest, preferably one having an output of one milliwatt. If possible, a 'beam expanding telescope' should be fitted to it. This increases the diameter of the beam making it easier to aim and reducing possible harmful effects to the eyes of any person who may accidentally look into the beam. The person setting up the receiver should not look toward the laser. Note that the beam at the receiver must be larger than the receiving device. This is where a beam expanding telescope helps.

This project makes a good 'science demonstration' project if your school science department has a suitable laser.

However, a much more readily-available light source is the Sun whose light output is quite intense and has reasonably parallel rays. Using reflected sunlight, we found that we could communicate intelligibly by photophone over distances of a few hundred metres. With more efficient transducers (ours were deliberately simple) this distance could probably be extended.

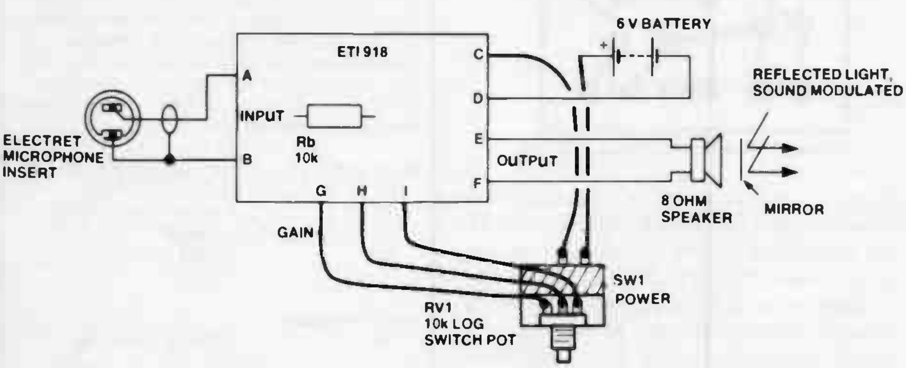


Circuit of the amplifier used in both the receiver and transmitter of the photophone. Note that Rb is used only in the transmitter and that the value of R3 differs between the transmitter and receiver.

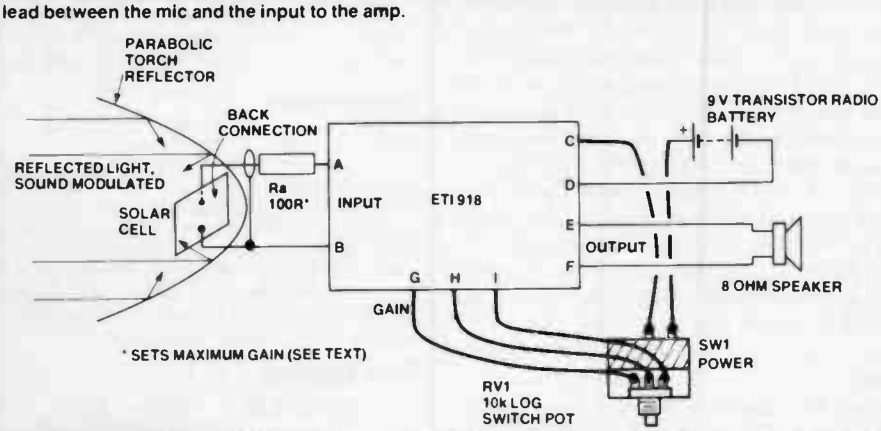
Electronics

To amplify speech to drive the loudspeaker of the transmitter, we designed a simple amplifier around two ICs — an LM301 voltage amplifier and an LM386 power amplifier. There was no point in making a low noise, low distortion amplifier because the transmitting and receiving transducers are relatively noisy and non-linear. However, performance is quite acceptable. Speech signals from an electret microphone insert are amplified by the LM301, then attenuated by a gain-control potentiometer before being fed to the LM386, whose output drives the loudspeaker. The large speaker needs a lot of current to drive it, so a six volt lantern battery is the best kind of power supply.

The receiver uses a very similar amplifier to boost the tiny signal derived from the solar cell, the dc component of this signal being blocked by a capacitor. The receiver amplifier is so similar to the transmitter amplifier that it uses the same pc board design. The only differences are that the feedback resistor (R3) around the LM301 op-amp has a larger value in the receiver to give



Wiring diagram of the photophone transmitter. Note the wiring to the rear of the electret microphone insert. You'll find one connection attaches to the mic case. This is the 'common' and goes to B on the pc board. Some inserts have leads already attached. Usually the common lead will be black. Use a shielded lead between the mic and the input to the amp.



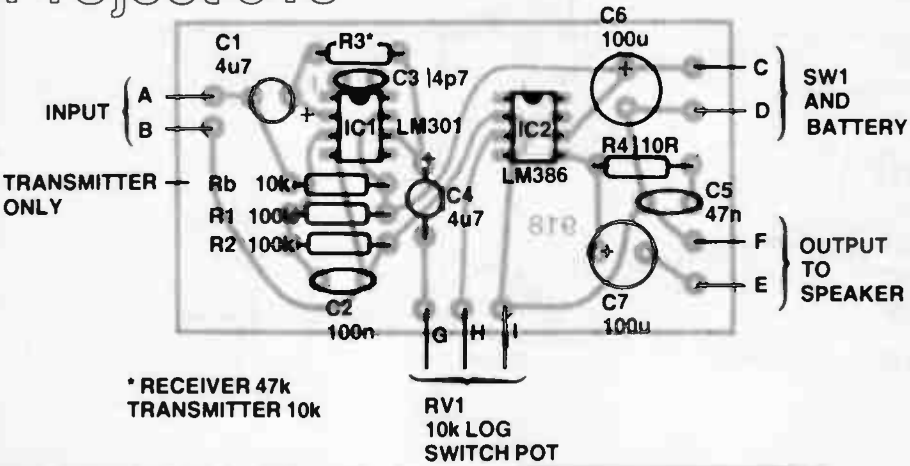
Photophone receiver wiring diagram. Use a shielded lead between the solar cell and the amplifier input. Don't forget to connect a 100 ohm resistor in series with the lead to terminal A on the amp.

HOW IT WORKS — ETI-918

Sound received by an electret condenser microphone is amplified by the transmitter amplifier and used to drive a loudspeaker. A plane (i.e: flat) mirror attached to the housing of this loudspeaker is flexed by the sound wave emitted by the speaker, so that it becomes alternately convex and concave as the sound pressure increases and decreases. A beam of sunlight reflected by the mirror onto a solar cell at the receiving end becomes broader or narrower as the mirror flexes, in phase with the sound pressure variations. Providing the beam always completely covers the collecting surface, a broader beam means that fewer photons are collected by the solar cell and a narrower beam means that more photons are collected.

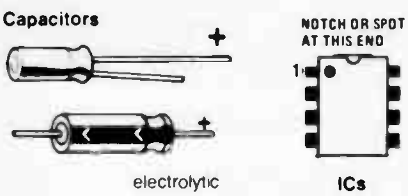
The variation in the number of photons collected causes a proportional variation in the current generated by the solar cell. These current variations cause variations in the voltage across resistor Ra, and these voltage variations are amplified by the receiver amplifier, which drives a small loudspeaker to reproduce the sounds spoken into the transmitter microphone.

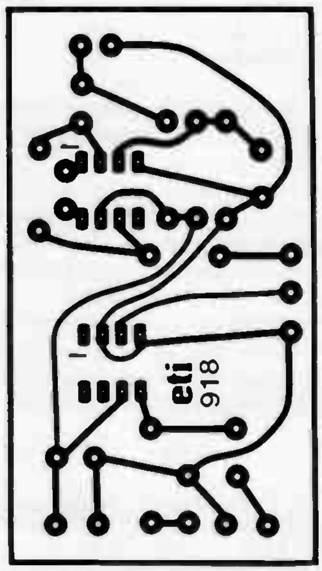
The transmitter and receiver amplifiers are essentially similar, each using an LM301 op-amp (IC1) for voltage multiplication and an LM386 power amplifier (IC2) with a switch potentiometer (RV1) between these two ICs for manual gain control. Resistor Rb (in the transmitter amplifier only) provides bias for the electret microphone. Capacitor C1 blocks dc signals. The gain of IC1 is set by the ratio of the resistance of R3 to the impedance of C1 at audio frequencies. The potential divider formed by R1 and R2 biases the non-inverting input of IC1 up to half the supply voltage, so that IC1 can be used with a single ended supply. C4 blocks any dc offset of IC1's output, R4 and C5 prevent instability around the output stage and C8 prevents any dc offset from being applied to the speaker. C4 and the internal resistance of the battery form a low-pass filter that removes battery noise from the supply line.



Component overlay for the amplifier. Note that Rb is not needed in the receiver amplifier and that the value of R3 differs between the transmitter and receiver.

COMPONENT PINOUTS





Printed circuit board artwork, full size.

higher gain, and the transmitter has an extra resistor (Rb) to bias the microphone. Only a small speaker is necessary for the receiver, so that a nine volt transistor radio battery can be used as power source.

Construction

We haven't designed any kind of box for this project. Obviously permanent housings for the transmitter and receiver will make the photophone much easier to use, but you can't make them until you've done some experimenting and finally decided what shape and size of reflectors you are going to use. In any case, this is a magazine about electronics, not carpentry or metalwork!

The two amplifiers should present no difficulties in assembly, providing you remember the usual precautions — check the orientation of capacitors, diodes and transistors, use a smallish bit when soldering the IC pins and let the ICs cool down for a few seconds between soldering each pin.

The electret microphone insert is polarised, so it can only go one way round. Make sure you solder the negative lead (usually black) to point B on the pc board and the positive lead (usually red) to point A. Glue the flat mirror to the metal rim of the transmitter loudspeaker (not to the cone), using epoxy resin (not any other adhesive).

Some solar cell pieces come with leads attached, some do not. If you have to attach your own leads, do it very carefully, using a low wattage iron and thin flexible wire. Most cells have electrodes on the front and back surfaces: solder to the back electrode first, by forming a small pool of solder near the edge of the cell and holding the end of the wire in the pool until it cools. The front electrode is usually in the form of a thin strip and needs more care. Apply enough solder to form a bump or ridge, reheat the solder and position the second wire. The leads must be protected from strain and can be glued to the reflector if one is used. Connection to the amplifier should be made through shielded cable. Don't forget to insert the 100 ohm resistor (Ra) in series with the lead that connects to point A on the pc board (see the overlay diagram). The solar cell can be held in position with plasticene while you are experimenting, or with silicone compound (such as Silastic) for a more permanent bond.

Operation

Leave the receiver with a friend and walk in the direction of your shadow, then point the transmitter so that the sun's reflection is directed at the receiver. It helps to put the receiver in the shade, so that you can see the spot of light from the transmitter mirror more easily.

You'll find that only a very small movement of the transmitter is enough to move the spot off the receiver, so it's easier if, once you've got the direction approximately right, you keep the transmitter steady on the ground or on a table and move the receiver to make the fine adjustments. Alternatively, you could keep the receiver fixed and mount the transmitter on a tripod.

A word of warning — don't point the light beam at your assistant's eyes (or anyone else's) if you're using the sun as the light source. To be safe, wear sunglasses (half-silvered types cut out most light) and never look directly at the mirror. ●

PARTS LIST — ETI-918

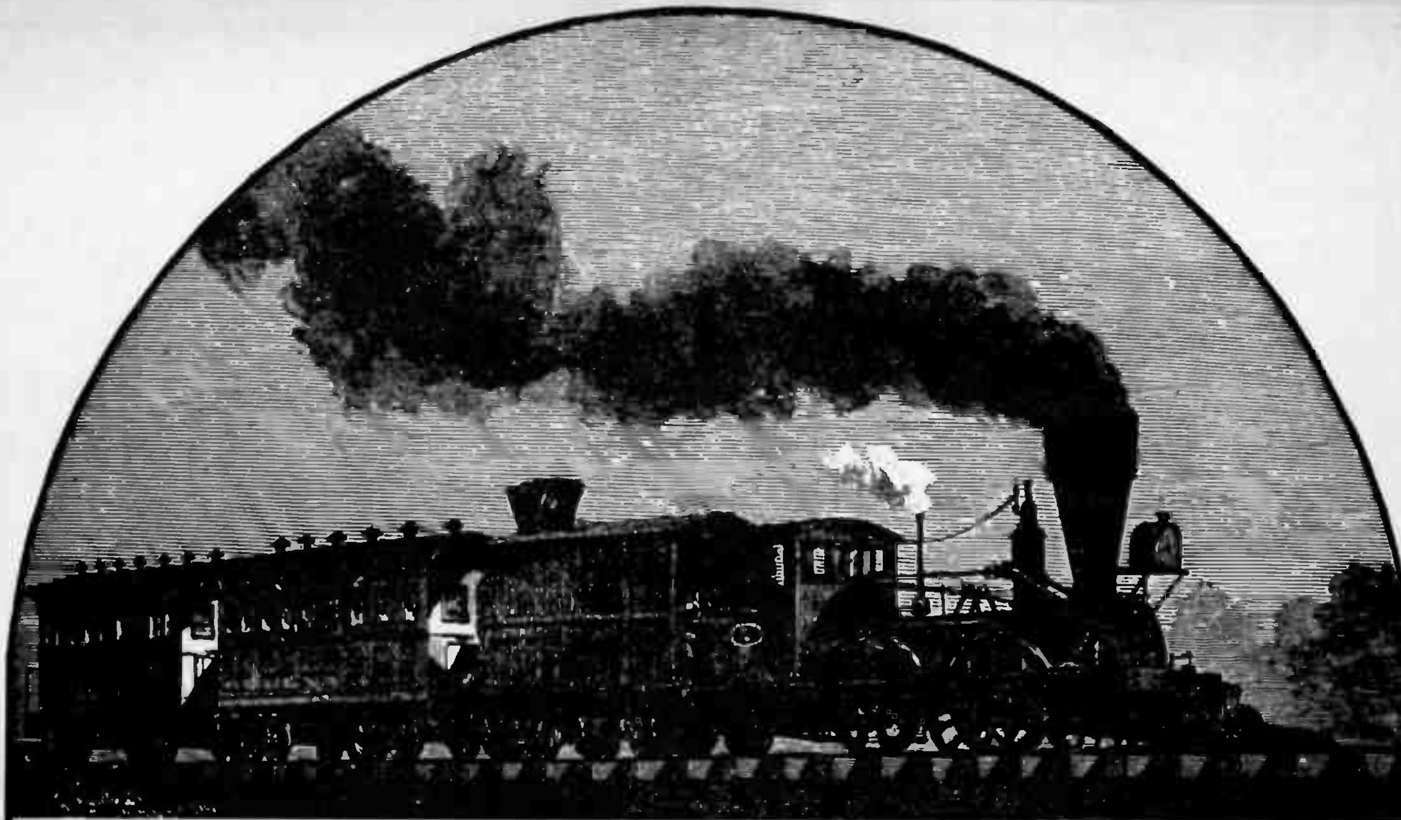
The following is a list of parts needed to build an electronically amplified transmitter and receiver to our specifications. The numbers in brackets represent the total number of components required of that value or type. If you are not using an amplifier in your transmitter, you will only need one of each component listed (i.e: one of R1, one of R2, etc.)

Resistors	all ½ W, 5%
R1, R2	100k (4)
R3	(2) see text
R4	10R (2)
Ra	100R (1)
Rb	10k (2)
Potentiometers	
RV1	10k log. switch pot
Capacitors	
C1, C4	4u7/16 V RB electro. (4)
C2	100n greencap (2)
C3	4p7 ceramic (2)
C5	47n greencap (2)
C7, C8	100u/16 V RB electro. (4)
Semiconductors	
IC1	301 op-amp (2)
IC2	386 power amp (2)

Miscellaneous
One or two ETI-918 pc boards, one electret microphone insert, small solar cell piece, parabolic torch reflector, small 8 ohm speaker, 150 mm 8 ohm speaker, 150 mm or larger diameter round mirror to match diameter of speaker, 6 V lantern battery, 9 V transistor radio battery, short length of shielded cable, insulated hookup wire.

Price estimate

$35 — $40 (complete) $22 — $25 (electronics only)



Simple Sound Effects

Phil Wait

One of the attractions of the more sophisticated video games seen in 'fun' arcades these days is the realistic array of sound effects that go with the action — gunshots, bomb whistles and explosions, etc. This simple group of projects employs just one IC that does all the hard work.

THOSE 'CANNON SHOTS' and explosions that go with the popular 'Space Invaders' video games and its variants add a measure of interest, feedback and stimulation to the action in which you participate on screen. Those sounds are electronically synthesised — that is, they consist of a complex mixture of waveforms that make up the required sound.

A 'bomb drop and explosion' is a remarkably complex sound when analysed carefully. Looking at it simply, there is a descending tone followed by a burst of noise that dies away in intensity. The descending tone starts at quite a high pitch and is not a 'pure' tone (i.e: a sine wave). The explosion is a burst of noise that commences suddenly and dies away slowly in a recognisable way (usually exponentially). While it is possible to electronically produce very nearly an exact replica of a bomb drop and explosion, some compromises are acceptable to reduce the complexity and cost of the task and yet produce a recognisable replica of the sound.

To produce such sound using conventional components — transistors, diodes, op-amps, resistors and capacitors — would require a whole legion of components. Fortunately, the IC manufacturers can come to our rescue here and much of the circuitry can be incorporated into a complex integrated circuit requiring the addition of a minimum of external components and the appropriate interconnections to synthesise the required sound. Generating a wide variety of sounds fortunately requires only a limited number of functional blocks, such as: a noise generator, voltage-controlled oscillators, multivibrators, envelope generators (a sort of modulator), mixers and amplifiers.

Texas Instruments, the giant US-based component and equipment manufacturer, has designed a series of complex function ICs for various applications and amongst them is the SN76488 Complex Sound Generator. This chip contains both linear and digital circuitry and is intended for use in applications requiring audio feedback to the user — video games, pinball, alarms, toys, etc, or industrial indicators, feedback controls and the like. Power consumption is quite low, allowing battery operation, and only a single supply rail is required.

The SN76488 is contained in a 28-pin package and can be purchased for less than $10. It is quite a versatile chip, but we have chosen to describe how to obtain only six sound effects, these being:

(a) bomb drop and explosion
(b) steam train and whistle
(c) alarm ('phasor')
(d) phasor and explosion
(e) gunshot
(f) aircraft propellor sound

All six projects can be made on the same design of pc board, but you will need a separate board for each project you make.

Before going on to the general construction details, let us take a look at what's inside the SN76488 and what each function block does. Not every function block inside the IC is used to produce each sound, so it is necessary to learn what each does before you can understand how individual sounds are produced or how you can use the chip to synthesise sounds for your own requirements.

Inside the SN76488

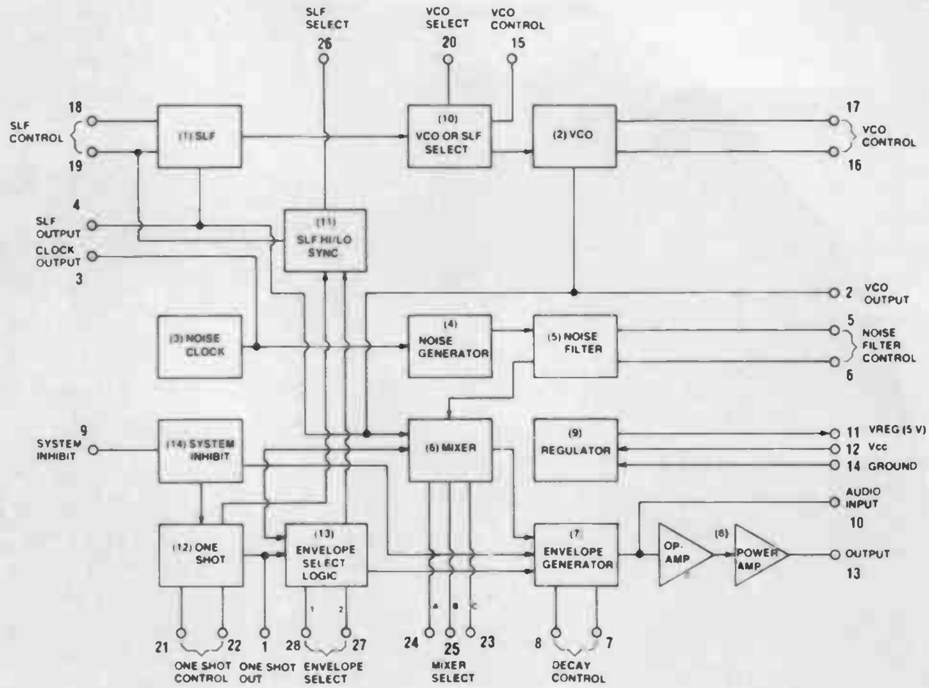
There are 14 functional circuit blocks contained within the IC.

(1) super low frequency oscillator (SLF)
(2) voltage-controlled oscillator (VCO)
(3) noise clock
(4) noise generator
(5) noise filter
(6) mixer
(7) envelope generator
(8) op-amp and power amp
(9) regulator
(10) VCO/SLF select
(11) SLF hi/lo synchroniser
(12) one shot
(13) envelope select
(14) system inhibit

Note that blocks one to four can be considered the basic *sound generators*, blocks five, six and seven are *sound modifiers*, while block eight provides the *output* and block nine distributes the power supply. Blocks 10 to 14 *control* the other functions.

(1) The SLF

This is an oscillator that can operate over the range from 0.1 Hz (one cycle every ten seconds) to 20 kHz, but it is not normally used at frequencies above about 30 Hz. The frequency of oscillation is determined by a resistor and capacitor, the resistor from pin 18 to 0 V, the capacitor from pin 19 to 0 V.



Internal block diagram of the SN76488.

The required frequency can be determined from the following formula:

$$\text{SLF (Hz)} = \frac{0.66}{(9000 + R_S)\,C_S}$$

where: R_S is resistor on pin 18
C_S is capacitor on pin 19

The SLF produces a square wave with a 50% duty cycle (high and low for equal periods) and a triangular wave. The square wave is internally connected to the mixer (6) and is available as an output on pin 4. The triangular wave goes to the VCO/SLF select block (10).

(2) The VCO

This is an oscillator which can be swept over a 10:1 frequency range by either the SLF output or an externally applied voltage (via pin 15 and the VCO/SLF select). Control of the VCO via the VCO/SLF select is discussed in (10).

The VCO can also be controlled by varying the voltage on pin 19 (SLF control, capacitor pin). The minimum frequency of the VCO is set by a resistor between pin 17 and 0 V and a capacitor between pin 16 and 0 V. The maximum frequency will always be 10 times the minimum frequency. The required minimum frequency can be derived from the following equation:

$$\text{VCO}_{\text{min.}}\text{ (Hz)} = \frac{0.6}{(9000 + R_l)\,C_l}$$

where: R_l is resistor on pin 17
C_l is capacitor on pin 16

The output from the VCO is a square wave, available on pin 2. Internally, the VCO output is applied to one input of the mixer (6).

(3) Noise clock

This is an oscillator that feeds timing pulses to the noise generator (4), which generates pseudo-random noise digitally. The noise clock operates at a frequency of about 10 kHz and its output is available on pin 3. This output can be used for multiplexing.

(4) Noise generator

This is a digital circuit that produces pseudo-random white noise. The output is not directly available on one of the IC pins, being passed internally to the noise filter.

(5) Noise filter

This is a variable bandwidth low pass filter. The filter cutoff point is determined by an RC network consisting of a resistor between pin 5 and 0 V, and a capacitor between pin 6 and 0 V. The cutoff frequency is determined by:

$$F_c\text{ (Hz)} = \frac{0.43}{(9000 + R_c)\,C_c}$$

where: R_c is the resistor on pin 5
C_c is the capacitor on pin 6

The output of the noise filter feeds an input to the mixer (6).

(6) Mixer

The mixer selects one or a combination of the inputs from the VCO, SLF or noise generator (via the filter), its output passing directly to the envelope generator. The mixer has three 'select' terminals, pins 23, 24 and 25, permitting eight output combinations according to Table 1. A 'low' (L) or a 'high' (H) on the appropriate pins

Mixer Select Inputs			Mixer
C (Pin 23)	B (Pin 25)	A (Pin 24)	Output
L	L	L	VCO
H	L	L	SLF/NOISE
L	H	L	NOISE
H	H	L	SLF/VCO
L	L	H	SLF
H	L	H	SLF/VCO/NOISE
L	H	H	VCO/NOISE
H	H	H	INHIBIT

Table 1. Mixer Select logic.

Envelope Select 1	Envelope Select 2	Selected Function
Pin 28	Pin 27	
L	L	VCO
L	H	Mixer Only
H	L	One-Shot
H	H	VCO with AC

Table 2. Envelope Select logic.

activates the selection. A low is 0 V, a high is +5 V.

The mixer performs as an AND gate, actually. To obtain two sounds simultaneously, multiplexing is required. This is accomplished by switching the mixer select lines at a sufficiently rapid rate that the two sounds seem to occur simultaneously. To prevent interaction with the sound output, the multiplexing rate is usually set above the human hearing frequency range. To provide equal amplitudes for both sounds the multiplexing drive signal must have a 1:1 duty cycle.

(7) Envelope generator

This block modulates the mixer output to give the sound the required 'decay' characteristics. The sound from the mixer can be made to die away (decay); the length of time it takes to do so is determined by an RC network connected to the 'decay control' pins — a resistor between pin 7 and 0 V and a capacitor between pin 8 and 0 V.

The decay is actually a ramp at the end of the sound. The approximate time it takes to ramp the sound amplitude to zero may be derived from:

$$\text{Decay (seconds)} = 1.5(9000 + R_d)C_d$$

where: R_d is resistor on pin 7.
C_d is capacitor on pin 8.

The decay has no effect on the mixer-only function, but for the one shot, the VCO, and the VCO with alternating cycle envelopes, the decay ramp is triggered by each high-to-low transition of the envelope and prolongs the sound at a decaying volume.

(8) Op-amp and power amp

This provides the audio output. The op-amp brings the level out of the envelope generator up to that required by the power output stage, the latter providing 125 milliwatts maximum to an eight ohm speaker. A higher impedance speaker can be used, with reduced output power, but a four ohm speaker is not suitable.

The input to the op-amp is accessible on pin 10 and an externally produced audio signal may be mixed in at this point. Coupling to this input should be via a capacitor.

(9) The regulator

An internal 5 V regulator is provided and it can operate from a supply rail of between 7.5 and 10 volts, connected with the positive to pin 12, negative (0 V) to pin 14. This conveniently permits operation of the SN76488 chip from a 9 V battery. The 5 V regulator output is accessible on pin 11 and can supply up to 5 mA current.

(10) VCO/SLF select

The VCO can be swept by the SLF or an external signal applied to pin 15 (VCO control). Pin 20 controls the operation of this logic block, which is in effect a switch. A high on pin 20 permits the VCO to be controlled by the SLF, a low permits the VCO to be controlled by the external voltage or signal, applied to pin 15.

The frequency of the VCO is inversely proportional to the voltage on pin 15. The higher the voltage, the lower the VCO frequency. Voltages above 2.35 V applied to pin 15 will produce an inaudible frequency from the VCO's output.

(11) SLF hi/lo synchroniser

This block permits control of the SLF by the one shot (12) and the envelope select (13). The SLF can be inhibited at any time by applying a logic low to pin 26.

(12) One shot

A high-to-low transition on pin 9 triggers 'one shot' sounds such as a gunshot or explosion. The maximum duration of a one shot sound is about 10 seconds and is determined by an RC network; a capacitor between pin 21 and 0 V and a resistor between pin 22 and 0 V. The duration can be determined from the formula:

$$\text{Duration (seconds)} = 0.91\,(R_d + 9000)\,C_d$$

where: R_d is the resistor on pin 22
C_d is the capacitor on pin 21.

If the one shot is terminated early by taking the system inhibit high, the one shot timing must be allowed to end so that an internal latch will be reset before another one shot can be triggered. The one shot may also be controlled by external logic eliminating the need for the one shot resistor and capacitor. This is done by triggering the one shot in the normal way with the system inhibit input, and terminating it by taking pin 21 (one shot capacitor) high.

The output of the one shot is fed through the envelope select logic to the envelope generator, and is therefore operable only when the one shot envelope is selected by the envelope select inputs. The one shot does not generate sound as such, but provides an envelope for the sound supplied to the envelope generator by the mixer.

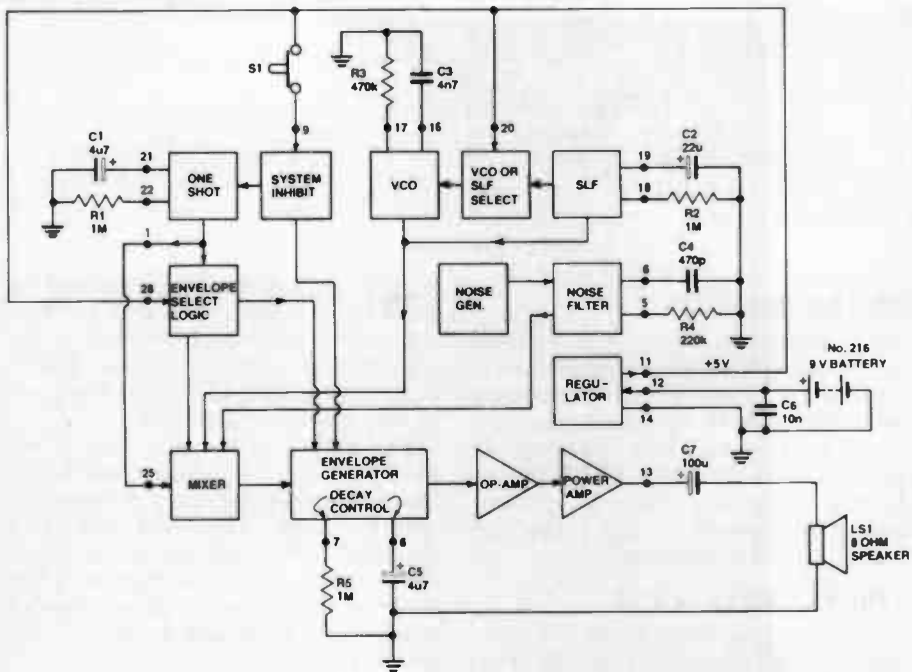
A one shot output pulse is available at pin 1. In the one shot mode, the SLF ramp can be started either high or low by placing a high or low on the SLF Sync Select, pin 26.

(13) Envelope select

This block determines how the envelope of sound is formed, whether directly from the signals applied to the mixer or from the one shot. Pins 27 and 28 control the operation of this block, and a combination of highs and lows determines which function is selected according to Table 2. The VCO output to the mixer can be selected (SLF inhibited), mixer only output (one shot inhibited), one shot and VCO plus other (ac) signals

(14) System inhibit

The system inhibit logic provides inhibit/select control for the sound output of the system: a high logic level at the system inhibit terminal (pin 9) inhibits the sound output, a low logic level (or open) enables it. This input also triggers the one shot circuit for momentary sounds such as gunshots, bells, or explosions. The one shot logic is triggered on the negative-going edge of the system inhibit input. This may be accomplished by means of a momentary switch or by a square wave input to system inhibit. The system inhibit input must be held low for the entire duration of the one shot sound, including attack and decay periods if the sound is to be completed. Taking the system inhibit input high early terminates the sound. Note that the one shot is operable only when the proper envelope select logic is selected.



Circuit for the ETI-607A Bomb Drop & Explosion. The pushbutton is held down for the duration of the event. Release it and press again to repeat.

HOW IT WORKS — ETI 607A BOMB DROP AND EXPLOSION

This unit employs most of the function block in the SN76488. The SLF provides a linearly increasing voltage waveform, or ramp, to the VCO, taking several seconds for the ramp voltage to rise from zero to maximum value. This causes the VCO to produce a tone which 'glides' down in pitch, making the 'bomb drop' effect. The explosion is generated by the Noise Generator/Filter and the Envelope Generator. It starts with a burst of noise, which dies away in intensity exponentially in a few seconds.

The whole sequence is triggered by operating the pushbutton, S1. This applies a high (+5 V) to the input of the System Inhibit block, pin 9. This in turn triggers the One Shot and the Envelope Generator. At the commencement of the One Shot timing period, the One Shot triggers the SLF HI/LO Sync. (see SN76488 block diagram), starting the SLF, and the VCO does its thing. At the end of the One Shot timing period the Envelope Select Logic becomes operative, the SLF is disabled and the Envelope Generator commences to do *its* thing. The Mixer selects the VCO output at the start of the One Shot timing period and the Noise Generator/Filter output at the end of the One Shot timing period. Thus the two sounds are switched through to the audio output stage in sequence, the Envelope Generator modifying the noise so that it dies away, the time it takes to do so being controlled by the time constant of R5, C5.

The starting pitch of the VCO is determined by R3 and C3, the rate of rise of the voltage ramp produced by the SLF is determined by C2 and R2, while the One Shot timing period is determined by the time constant of C1 and R1. The frequency characteristics of the broadband noise produced by the Noise Generator are modified by R4 and C4 connected to the noise filter control pins (5 and 6).

Audio output is coupled to the loudspeaker via C7, a 100u electrolytic capacitor.

General construction

All the projects described use the one pc board design. As the SN76488 is available in two packages of different sizes and pin spacings — the A package, a conventional 28-pin package with 15.24 mm spacing between the pin rows and 2.54 mm pin spacing, and the smaller NF package having 10.16 mm spacing between the pin rows and 1.52 mm pin spacing — we have had to provide two pc board designs to accommodate the different packages. Each board is marked accordingly. Make sure you purchase the correct board to suit the device package you have. All the component pads and holes are in exactly the same position on each board and the overlay diagrams given in these articles apply to either board.

The SN76488 dominates the pc board. Only the required components are assembled into the board according to each overlay diagram to obtain the required sound generator. Naturally enough, the polarity of the IC should be noted as well as the polarity of electrolytic and tantalum capacitors used. Commence construction by assembling the passive components, followed by the IC. This is not a CMOS device and no special care is required, apart from being careful not to bend any pins under the device when inserting it. If you wish, a socket may be used for the IC. This way, you can assemble the six projects and purchase only one IC, swapping between the boards as you need to use them!

Wiring to the switches, the speaker and the supply should be attached last.

The unit may be mounted in any convenient-sized box and the speaker mounted on the front. Alternatively, it may be wired into an existing piece of equipment. We'll have to leave these arrangements up to you.

PARTS LIST — ETI 607A BOMB DROP + EXPLOSION

Resistors	all ½W, 5%
R1, R2, R5	1M
R3	470k
R4	220k
Capacitors	
C1, C5	4u7/16 V electro.
C2	22u/16 V tant. or RBLL
C3	4n7 greencap
C4	470p ceramic
C6	10n greencap
C7	100u/16 V electro.
Semiconductors	
IC1	SN76488
Miscellaneous	
S1	SPST push-to-make pushbutton switch

ETI-607 pc board; 50 mm diameter 8 ohm speaker; No. 216 9 V battery and clip

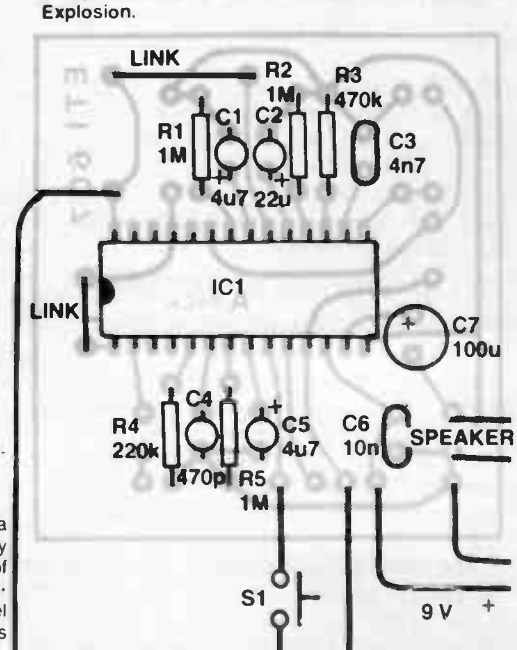
Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$16 - $19

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.

Component overlay for the ETI-607A Bomb Drop & Explosion.



PARTS LIST — ETI 607B STEAM ENGINE + WHISTLE

Resistors all ½W, 5%
R1 .... 330k
R2 .... 470k
R3 .... 56k
R4 .... 100k
R5 .... 1k

Capacitors
C1 .... 1u/16 V tant. or RBLL
C2, C3 .... 470p ceramic
C4 .... 10n greencap
C5 .... 100u/16 V electro.

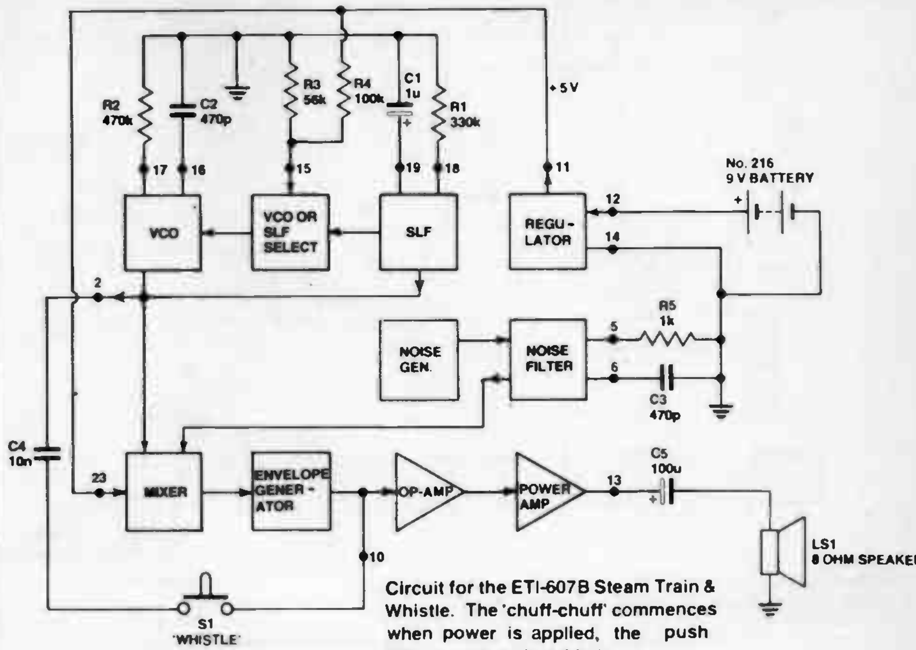
Semiconductors
IC1 .... SN76488

Miscellaneous
S1 .... SPST push-to-make pushbutton switch;
ETI-607 pc board; 50 mm diameter 8 ohm speaker; No 216 9 V battery and clip.

Price estimate
We estimate the cost of purchasing all the components for this project will be in the range:

$14 - $17

Note that this is an estimate only and not a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.



Circuit for the ETI-607B Steam Train & Whistle. The 'chuff-chuff' commences when power is applied, the push button sounds the whistle.

HOW IT WORKS — ETI 607B — STEAM TRAIN AND WHISTLE

In this unit the Noise Generator/Filter is employed to produce the basic 'steam engine' sound, this being modulated by the SLF to produce the 'chuff-chuff' so characteristic of steam locomotives. The whistle is produced by the VCO, which is set to a particular non-varying pitch, and the output is switched into the audio input pin to produce the whistle.

The broadband noise from the Noise Generator is modified by the Noise Filter, the frequency characteristics being determined by R5 and C3 connected to the Noise Filter Control pins (5 and 6). The Noise Filter Output is fed via the Mixer and the Envelope Generator (which doesn't function here) to the audio output stages. The SLF square wave output effectively modulates the noise to produce a noise burst followed by a silent period, then another noise burst. Thus the chuff-chuff sound is produced. This sound is continuous whilst power is applied to the unit.

A resistive divider, R3/R4, provides about 1.8 volts at the VCO programming input, pin 15. This sets the VCO frequency to a convenient pitch within its range, providing a suitable pitch for the whistle. The VCO output is coupled to the audio input (pin 10) via C4 and the pushbutton, S1. When S1 is pressed, the whistle is heard over the chuff-chuff sound.

The SLF frequency is determined by C1 and R1, while the combination of R2/C2 and the voltage on pin 15 determines the VCO frequency. Output to the loudspeaker is coupled via C5, a 100u electrolytic capacitor.

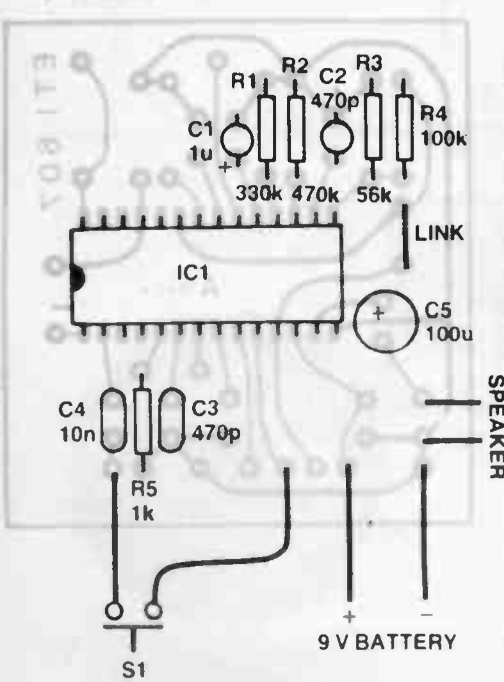
ETI-607A Bomb Drop

This produces a 'bomb drop and explosion' sound at the press of a button. Alternatively, the pushbutton, S1, could be replaced by a pair of relay contacts operated by a piece of equipment or a transistor (emitter to pin 9, collector to other side of S1) that is turned on by a logic high applied to its base via a resistor.

This project is one of the most complex, using almost every functional block within the SN76488. Varying R3 and C3 a little will vary the pitch range of the 'bomb drop' (descending whistle), while varying R4 or C4 a little will vary the characteristics of the explosion. Note that it is generally easier to 'fine tune' things by varying the resistor values. The duration of the event can be varied by varying the value of either C1 or R1 and the decay of the explosion can be changed by varying R5 (varying C5 produces quite gross changes in the decay period).

Watch that you insert the link on the pc board in this one, located at the 'notch' end of the IC.

Component overlay for the ETI-607B Steam Train and Whistle.

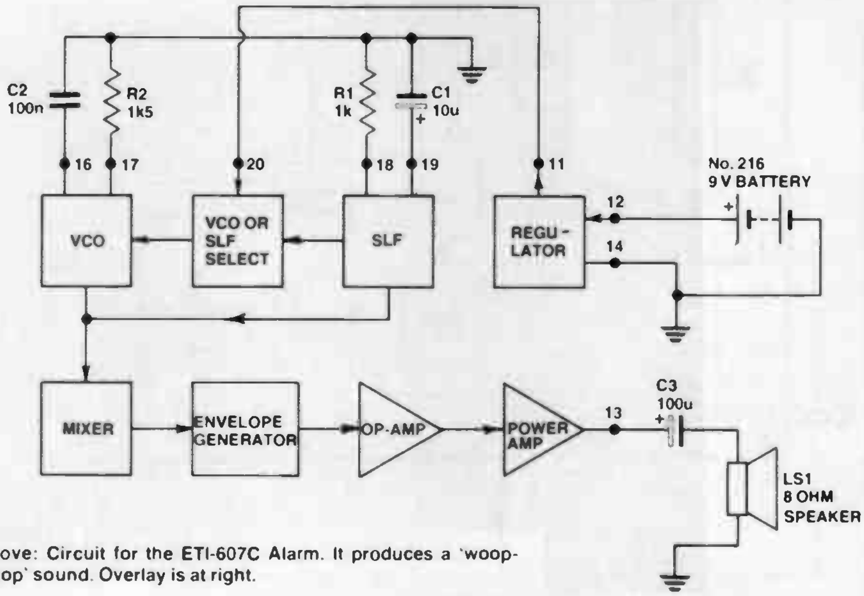


ETI-607B Steam Train

Aahh, the nostalgia! Clive Robertson (*), this is for you — a steam train (chuff-chuff) and whistle. For that *authentic* touch, deft constructors can fashion a cow-catcher out of tinned copper wire to attach to the unit!

The chuff-chuff runs continuously once power is applied and the whistle sounds when the pushbutton is pressed. The VCO is used to provide the whistle while the SLF modulates the noise generator/filter output to produce the steam train's chuff-chuff sound. The chuff-chuff rate may be varied by changing the values of R1 and C1, while the chuff-chuff sound may be varied by altering the values of R5 and C3. The pitch of the whistle may be varied by changing the values of R2 and C2. For a special effect, you can control the chuff-chuff rate manually by replacing R1 with a 1M potentiometer.

**(In)famous breakfast announcer on ABC second network station 2BL in Sydney.*



Above: Circuit for the ETI-607C Alarm. It produces a 'woop-woop' sound. Overlay is at right.

ETI-607C Alarm

The Texas Instruments' application notes include a 'phasor' circuit that produces a sound rather like a 'woop-woop' alarm. It's about the simplest project of the lot! The SLF is simply employed to sweep the VCO over a convenient range at a suitable speed. Turning the power supply on and off by inserting a switch or relay contacts in series with either the positive or negative battery leads serves to trigger the alarm. The VCO pitch may be varied to suit your requirements by changing the values of either C2 or R2, while the rate at which the VCO is swept may be varied by altering the value of either R1 or C1.

HOW IT WORKS — ETI 607C ALARM ('PHASOR')

This produces an alarm sound that's a real attention-getter! Operation is simplicity itself. The SLF is set to operate at a few cycles per second, determined by R1/C1. The ramp output of the SLF is selected to sweep the VCO by applying a high (+5 V) to the control input of the VCO/SLF Select block (pin 20). The VCO is thus swept across its range several times per second. Maximum frequency of the VCO is determined by R2/C2. Output from the VCO is coupled to the audio output stages via the Mixer and Envelope Generator (inoperative here). The speaker is connected via the obligatory 100u electrolytic capacitor, C3.

PARTS LIST — ETI 607C

Resistors	all ½ W, 5%
R1	1k
R2	1k5
Capacitors	
C1	10u/16 V electro
C2	100n greencap
C3	100u/16 V electro
Semiconductors	
IC1	SN76488

Miscellaneous

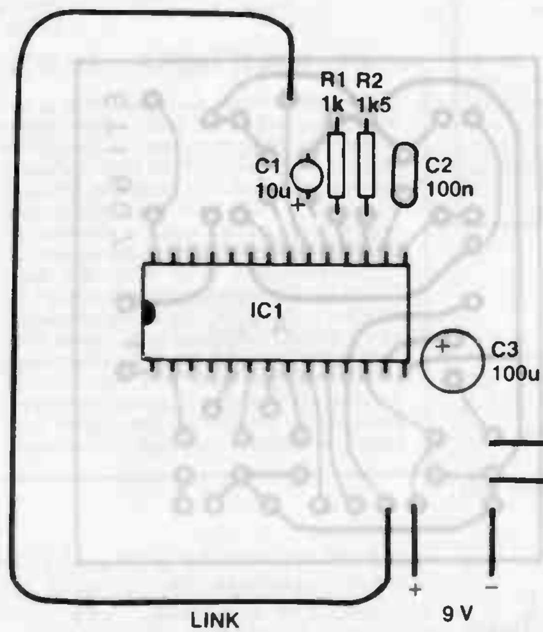
ETI-607 pc board; 50 mm diameter 8 ohm speaker; No. 216 9 V battery and clip; switch (if needed).

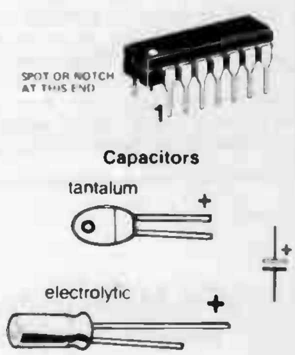
Price estimate

We estimate the cost of purchasing all the components for this project will be in the range

$14 - $17

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.





This photograph shows the Steam Train & Whistle built up. We leave the housing to you as individual requirements will vary.

ETI-607D Explosion

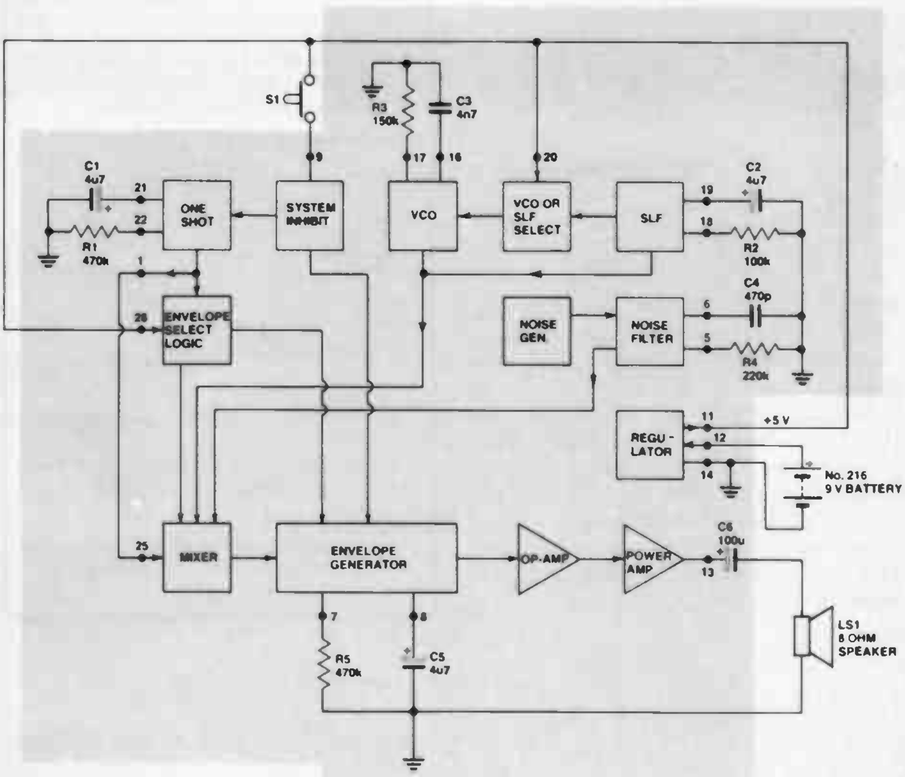
This combines the 'phasor' effect employed in the Alarm unit and the explosion effect employed in the Bomb Drop & Explosion unit. One could liken the sound produced to what you would expect after shooting down a 'flying saucer' or somesuch! This project uses about as many components as the Bomb Drop & Explosion board.

The SLF sweeps the VCO up and down in pitch at quite a rapid rate — somewhat faster than we did in the Alarm unit. The pushbutton is held down to start the effect, which takes several seconds to complete. The explosion is heard following a period of the phasor sound. As with the other units, if you wish to vary any of the parameters of the effect, it is best to vary the resistor values.

Take care with the orientation of the electrolytic and tantalum capacitors during construction. Note that, as with the ETI-607A Bomb Drop & Explosion unit, there are two links on the board; make sure you don't miss the small link at the 'notch' end of the IC.

ETI-607E Gunshot

This unit is quite straightforward. The Noise Generator blocks in the IC are employed to produce a suitable sound, which is heard for about a fifth of a second, dying away rapidly. The effect is triggered (pardon the pun) by the pushbutton. Only half a dozen components are required apart from the IC! With car[illegible] patience and a little juggling, the unit could be fitted inside a toy plastic gun by simply soldering the components



Circuit for the Phasor & Explosion.

PARTS LIST

607D PHASOR & EXPLOSION

Resistors .... all ½W, 5%
R1, R5 .... 470k
R2 .... 100k
R3 .... 150k
R4 .... 220k

Capacitors
C1, C2, C5 .... 4u7/16 V electro.
C3 .... 4n7 greencap
C4 .... 470p ceramic
C6 .... 100u/16 V electro

Semiconductors
IC1 .... SN76488

Miscellaneous
S1 .... SPST push-to-make pushbutton switch
ETI-607 pc board; 50 mm diameter 8 ohm speaker; No. 216 9 V battery and clip.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range

$16 - $18

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.

HOW IT WORKS

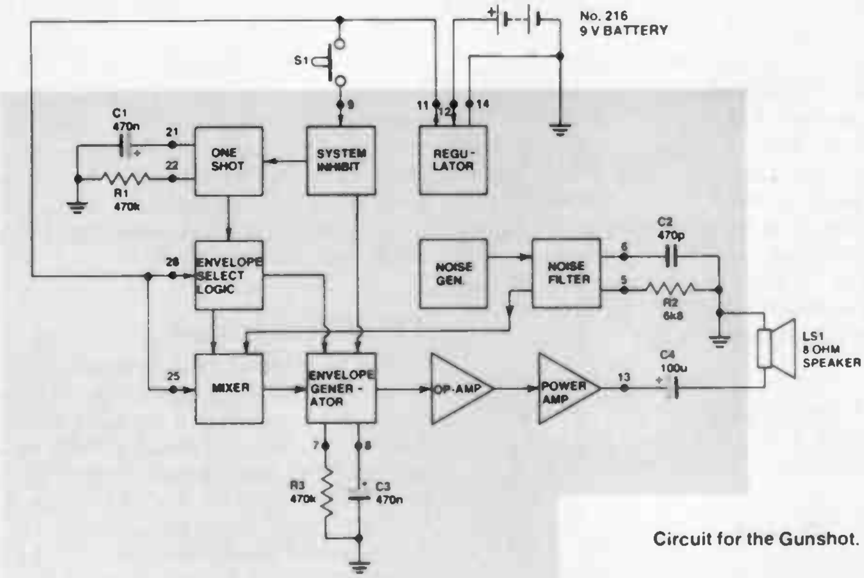
607D PHASOR & EXPLOSION

This unit is closely related to the ETI-607A Bomb Drop & Explosion. In fact, if you compare the two circuits you will find very little difference! In this unit the SLF is programmed to oscillate at several Hertz and the triangle wave output employed to control the VCO frequency. Thus the VCO is swept up and down in frequency several times per second. This creates the Phasor sound as in the ETI-607C Alarm unit. The explosion is triggered after the phasor sound runs for a few seconds, the whole sequence being controlled by the System Inhibit block in much the same way as done in the Bomb Drop & Explosion unit.

When S1 is pressed, a high (+5 V) is applied to the input of the System Inhibit block, pin 9. This triggers the One Shot and the Envelope Generator. The One Shot triggers the SLF HI/LO Sync. (see SN76488 block diagram) at the start of the One Shot timing period, starting the SLF oscillating. This sweeps the VCO up and down as explained above and the signal passes to the speaker through the Mixer, Envelope Generator (which is inoperative at this time) and amplifier stages. When the One Shot completes its timing period the Envelope Select Logic becomes operative, the SLF is disabled and the Envelope Generator commences to do its thing. The Mixer now selects the Noise Generator/Filter output and the sound is heard to decay away, simulating an explosion.

The oscillation frequency of the SLF is determined by R2 and C2, while that of the VCO is determined by R3 and C3. The One Shot timing period is determined by R1 and C1, while the noise characteristic is determined by R4 and C4 on the Noise Filter programming pins (pins 5 and 6).

Audio output is coupled to the speaker via the obligatory 100 uF electrolytic capacitor, C6.



Circuit for the Gunshot.

between the IC pins. You would have to obtain a tiny loudspeaker, headphone unit or rocking armature insert for a speaker — whatever will fit in the gun assembly.

Supply bypassing

A short word on this subject may prevent difficulties in some cases. In general, we found that the power supply rail doesn't really need bypassing. However, provision has been made on the pc board for the inclusion of a bypass capacitor. This is located near the battery positive lead input on the pc board, which connects to pin 12 of the IC. Have a look at the component overlay for the ETI-607A Bomb Drop & Explosion unit. Locate C6, a 10n greencap. This is the supply bypass. A capacitor having any value between 10n and 10u, and which will fit on the board, will do the job.

607E GUNSHOT HOW IT WORKS

A gunshot is simulated by producing a burst of noise that decays very quickly. This unit employs the Noise Generator, Noise Filter, One Shot, Mixer and Envelope Generator to generate the required sound.

The Mixer select pin (25) and the Envelope select pin (28) are both held high (+5 V), selecting the One Shot output function from the Mixer. When the pushbutton, S1, is pressed this puts a high on pin 9 and the System Inhibit block triggers the One Shot and activates the Envelope Generator. For the duration of the One Shot period, the modified noise from the Noise Generator/Filter is passed through the Mixer and Envelope Generator and then to the audio output stages.

The One Shot period, determined by R1 and C1, is quite short (about 1/5 second) and the decay period of the Envelope Generator a little longer. Audio output is coupled to the speaker via the 100µ dc blocking capacitor, C4.

PARTS LIST

Resistors .... all ½W, 5%
R1, R3 .... 470k
R2 .... 6k8

Capacitors
C1, C3 .... 470n tant. or RBLL
C2 .... 470p ceramic
C4 .... 100u/16 V electro.

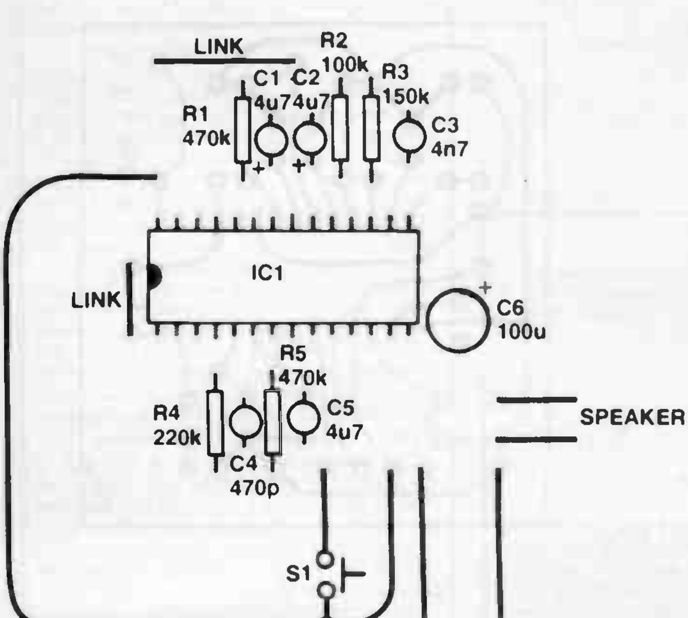
Semiconductors
IC1 .... SN76488

Miscellaneous
S1 .... SPST push-to-make pushbutton switch
ETI-607 pc board, 50 mm diameter 8 ohm speaker, No. 216 9 V battery and clip.

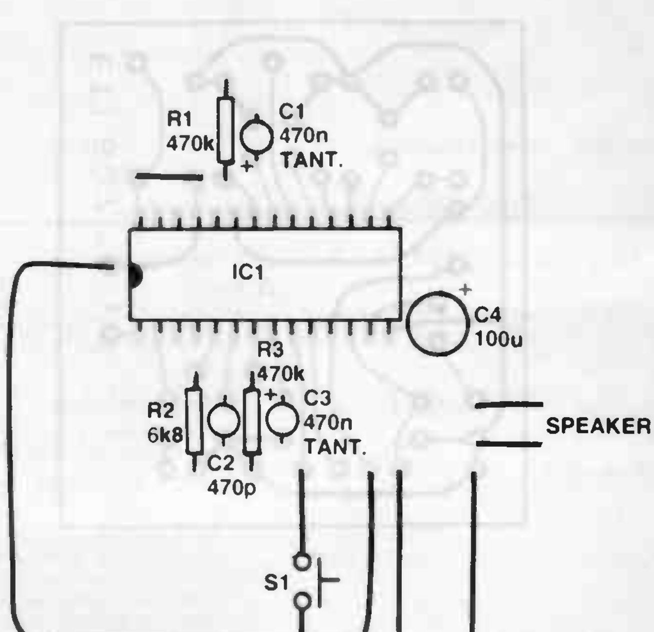
Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$14 - $17



Overlay for the Phasor & Explosion.



Overlay for the Gunshot. Don't forget the link.

ETI Book Sales

constructional projects

ELECTRONIC PROJECTS FOR YOUNG SCIENTISTS
D0045E — *$3.95*
PH meter, geiger counter, helium-neon laser, sound-level meter, solar cells, negative ion generator and more.

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D0046B — *$6.95*
Covers radio, infra-red, visible light, ultrasonic controls. Full explanations are provided so that the reader can adapt the projects for domestic and industrial use.

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D0047B — *$5.95*
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D0061B — *$7.75*
A wide range of designs for electronics enthusiasts who are capable of producing working projects from just a circuit diagram without the aid of detailed information.

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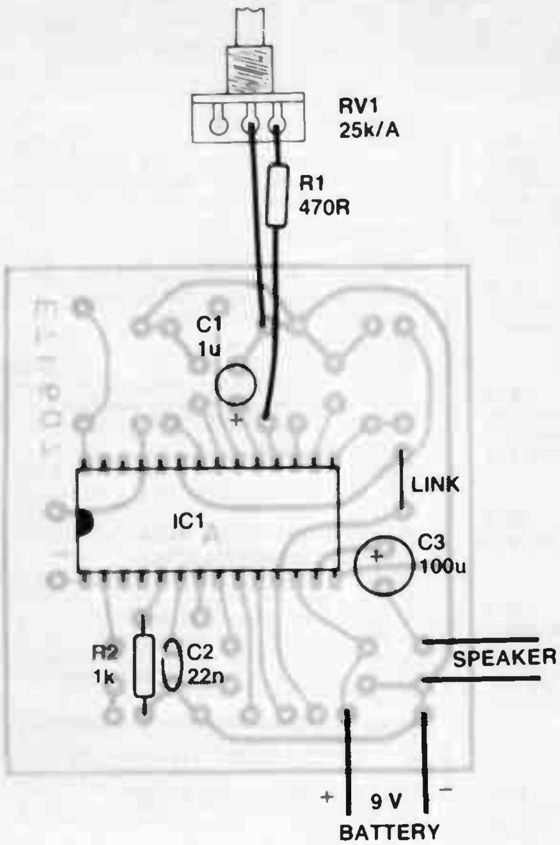
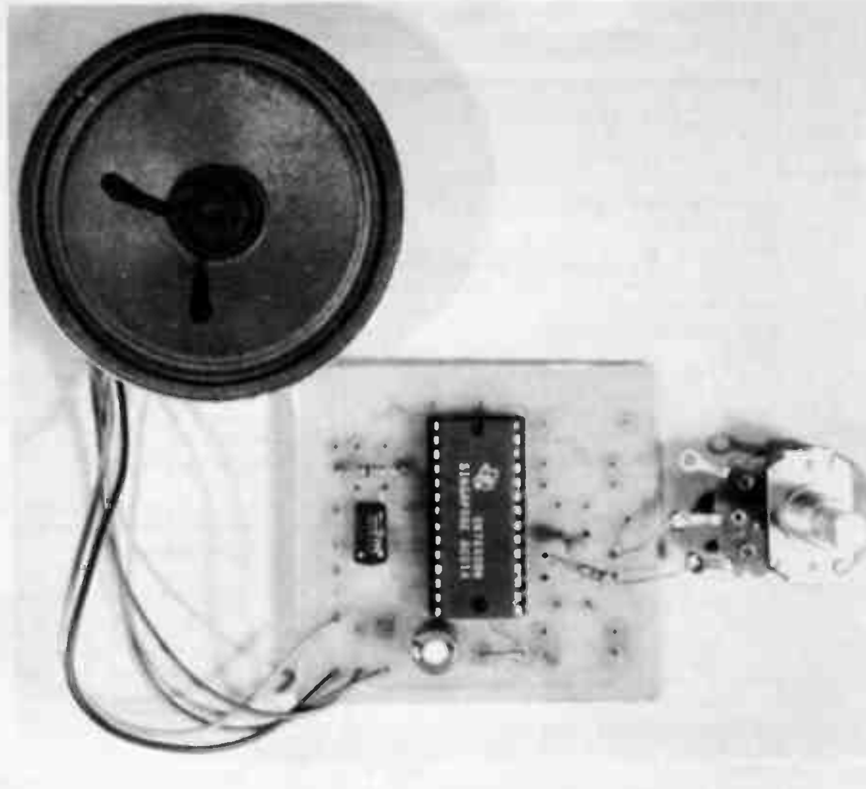




ETI-607F Prop Aircraft

A propellor and engine make a 'chop-chop-chop' sound that contains quite a bit of 'white' noise energy. In this unit the super low frequency oscillator is used to modulate the output of the noise generator/filter — producing the 'chop-chop chop' sound. The filtering is fairly 'savage' so that low frequency noise predominates. The chop-chop rate may be varied by the potentiometer from 'taxi-ing' to 'full climb'.

Construction

The overlay diagram shows where all the components are located. It is generally easiest to install the resistors, capacitors and link first of all. Watch the polarity of C1 and C3. You may use an IC socket to mount the SN76488 if you wish, or just solder it to the board. Watch you get its orientation correct.

Last of all, solder up the leads to the battery connector (you may add a switch to turn the unit on and off if you wish), the loudspeaker and the potentiometer. Note that R1 mounts from one lug of the potentiometer.

The unit may be mounted in a jiffy box with the speaker and potentiometer

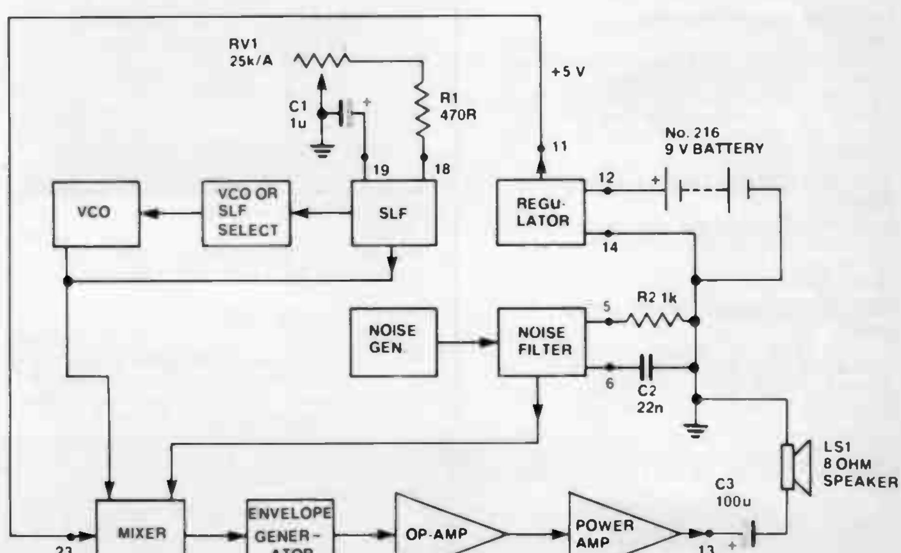
HOW IT WORKS

ETI-607F PROPELLOR AIRCRAFT

This unit is closely related to the Steam Train & Whistle (ETI-607B). The SLF is set to oscillate at a few Hertz and the Noise Generator/Filter output is modulated by this to produce the 'chopping' sound of a propellor and engine.

The broadband noise from the Noise Generator is heavily filtered by the Filter stage so that low frequency noise predominates. Capacitor C2 and resistor R2 set the Filter cutoff frequency somewhat below 2 kHz. The SLF oscillates at a rate determined by C1 and R1 + RV1. This rate may be varied by RV1, ranging from less than 20 Hz to more than 1200 Hz.

Pin 23, the 'C' select input of the Mixer, is connected to +5 V (pin 11 of the regulator) and this selects the SLF/NOISE mixing function. The output of the mixer passes to the audio output via the envelope generator — not used here — the speaker being driven by pin 13 via C3, a 100u dc blocking capacitor.



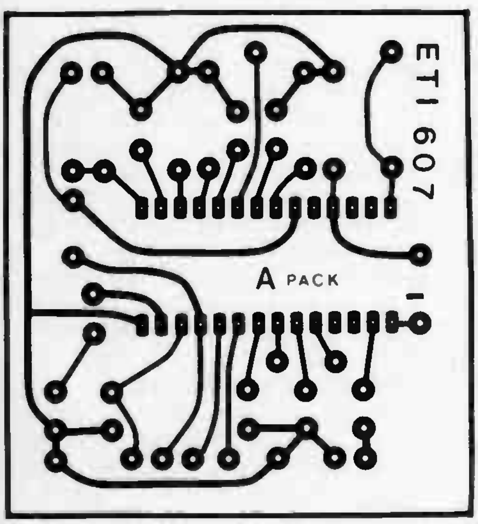
mounted on the lid and the pc board and battery held in the base with double-sided sticky pads. That's just one suggestion; we'll have to leave the details up to you as individual requirements will vary — let your ingenuity loose! ●

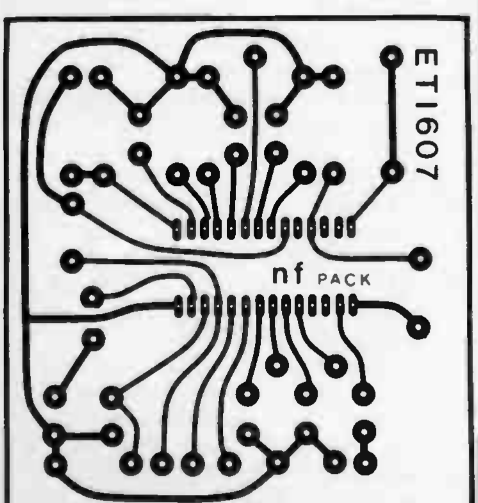
PARTS LIST — ETI 607F

Resistors	all ½W,5%
R1	470R
R2	1k
RV1	25k/A 1in. pot.
Capacitors	
C1	1u/10 V tant.
C2	22n greencap
C3	100u/16 V RB electro
Semiconductors	
IC1	SN76488
Miscellaneous	

ETI-607 pc board; 50 mm diameter 8 ohm speaker; No. 216 9 V battery and clip; switch (if needed).

Price estimate
$10-$14





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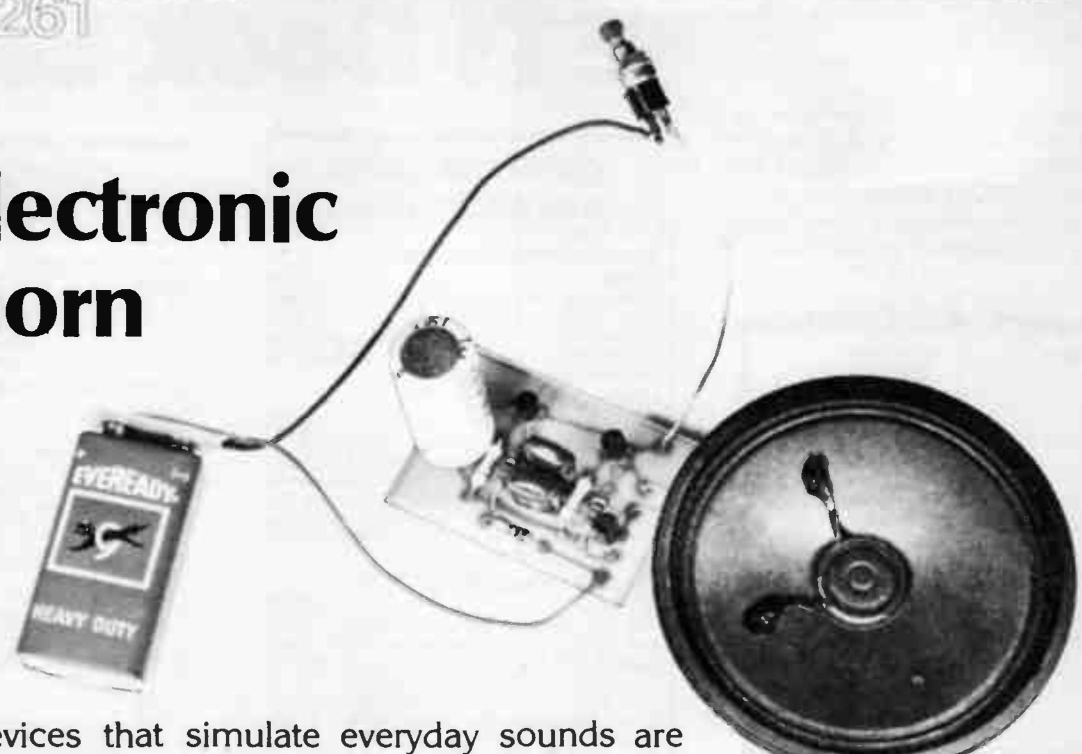
An electronic fog horn



Electronic devices that simulate everyday sounds are always interesting. This fog horn is also instructive.

IF YOU LIVE ON the shores of a busy harbour, you have probably been woken up occasionally in the early morning by the sound of a ship's fog horn. Before the advent of radar, fog horns were the only means ships' captains had of avoiding collisions. The distance and direction of the low-pitched sound gave an indication of another craft's position. Despite radar, many boats and ships (Sydney ferries in particular!) still have fog horns in active service.

This project won't wake the household (or the neighbours!) but it certainly makes a realistic sound.

How it works

The fog horn consists of an oscillator, which generates the basic sound, and a speaker driver. The oscillator we used is known as a "multivibrator". This type of circuit is widely used – in one form or another – in electronics, it is one of the 'building blocks' used in many complex circuits. For example; you will find multivibrators in 'clocking' circuits for timing applications, in function generators and many digital circuits.

The multivibrator here consists of Q1, Q2, C1, C2 and R1 to R4. To understand how it oscillates, we must first make an assumption: let us assume Q2 turns on when the push-button, PB1, is operated. One or other of the transistors, Q1 or Q2, will turn on first as no two devices are *exactly* the same.

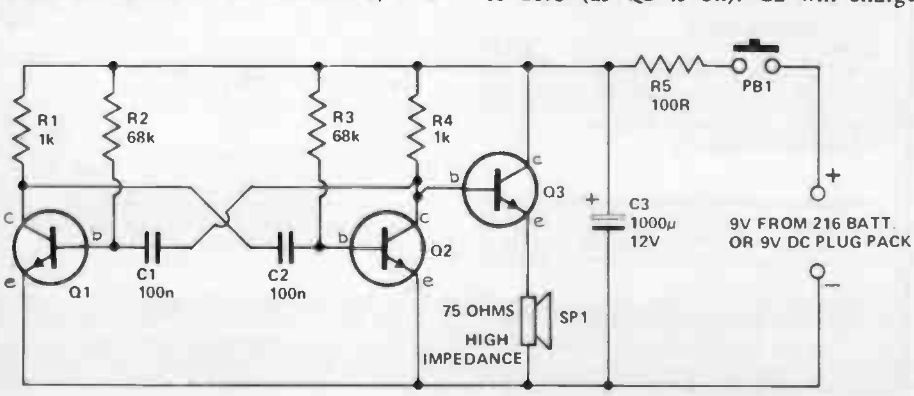
Now, when PB1 is pushed, Q2 conducts and Q1 will be 'cut off' (not conducting). The collector voltage on Q1 will be at the supply voltage (about +9 V) and the base of Q1 almost at zero volts as C1 will not be charged and the collector voltage on Q2 will be close to zero (as Q2 is on). C2 will charge via R1 and the base of Q2, keeping Q2 on while it charges. C1 will begin to charge via R2, and when the base voltage on Q1 has risen sufficiently, Q1 will commence to conduct. The collector voltage on Q1 will rapidly fall. This will cause the charge on C2 to reverse-bias the base of Q2, immediately turning it off. Thus, the collector voltage on Q2 will jump to the supply voltage and C1 will begin to charge via R4 and the base of Q1, holding it on while C1 charges.

However, C2 will begin to charge – in the opposite direction to which it was first charged – and the negative voltage on the base of Q2 (from C2) will decrease, pass through zero and rise in a positive direction. When it has risen sufficiently for the base of Q2 to conduct once more, Q2 will turn on.

And the whole business begins again. The charge on C1 will reverse bias Q1 which turns right off, C2 will charge via R1, driving Q2 further on . . . until C1 charges (via R4) sufficiently to turn Q1 on again, etc.

Thus, the collector voltages on Q1 and Q2 will alternately rise, stay up for a period, fall and stay down for a period, then rise again – a square wave.

That's your basic, or common-garden-variety, multivibrator. The frequency of oscillation is dependent on the values (and thus the time-constant) of R1, C2 and R2, C1. An output can be taken from the collector of either Q1 or Q2. The signal on one



collector will be the opposite phase to that on the other collector (while one collector is up, or 'high', the other collector is down, or 'low').

The output from the oscillator will not be able to drive the speaker directly. This is because the oscillator has a high impedance output and cannot supply enough current to drive the relatively low impedance of the speaker. To increase the available current, and lower the output impedance, we use an emitter follower, where the input is fed to the base of a transistor, Q3, and the output is taken from the emitter. The voltage output from the emitter follower is very close to the input voltage, but the current is amplified sufficiently to drive the speaker.

But what about R5 and C3. Well, these help to give the oscillator its characteristic sound. The multivibrator generates the basic low pitch of the fog horn. But, if you listen carefully to a real fog horn, you will notice that the pitch and volume vary slightly as it sounds. Now, the frequency of a multivibrator depends on the supply voltage to a large extent. The lower the supply, the lower the frequency, and vice-versa. Also, the output, and thus the volume, is lower at lower supply voltages – vice-versa.

When PB1 is pushed, C3 will take a short while to charge and therefore the voltage supply to the oscillator (and speaker driver) will take a short while to rise. Thus, the sound from the speaker will have the characteristic rising pitch and volume of the first part of a fog horn's blast. When PB1 is released, C3 will take a short while to discharge and the sound level and pitch will die away.

In this way, the circuit simulates the characteristic sound of a ship's fog horn.

Construction

This circuit is simple enough to be constructed on matrix board or tag strips. However, we have used a printed circuit board. If you are not yet confident of getting all the connections right, we suggest you construct this project as we have. Printed circuit boards should be available from quite a number of suppliers.

No matter what method of construction you elect to use, as always, take care with the orientation of the transistors and the polarity of the battery connections. The speaker we used is rather an unusual item. Small speakers commonly have an impedance of either eight or 16 ohms. The one used here has an impedance of 75 ohms.

You can modify the sound of the fog horn if it is not quite to your satisfaction – normal component variations will produce differing results. You can vary the basic sound produced by the multivibrator by varying C1 and C2. Changing these by one standard value higher or lower will produce quite a gross variation in pitch. Smaller variations can be obtained by having several capacitors in parallel. Use a large value – close to that specified – and connect a smaller value capacitor in parallel, for each of C1 and C2.

The rising and falling pitch and volume is controlled by R5 and C3. The value of R5 can only be practically varied a small amount. You get a much more satisfactory result by varying the value of C3 or varying its discharge time. You can decrease the 'die away' period by putting a low-value resistor in parallel with C3, increasing the discharge current. Start experimenting with something like 680 ohms. ●

PARTS LIST · ETI 261

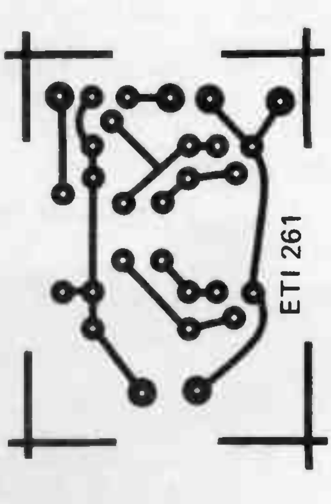
Resistors all ½ W, 5%
- R1 . . . . 1k
- R2, R3 . . . . . 68k
- R4 . . . . 1k
- R5 . . . . 100R

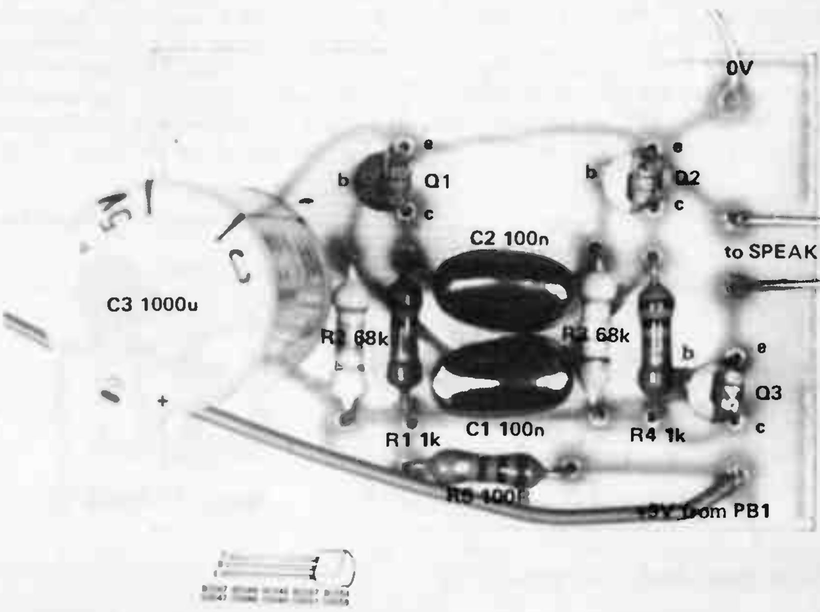
Capacitors
- C1, C2 . . . . . 100n Greencap
- C3. . . . . 1000µ, 12V electro

Semiconductors
- Q1–Q3. . . . . BC548, BC108, DS548 or similar

Miscellaneous
- SP. . . . . high impedance speaker, greater than 40 ohms
- PB1 . . . . push-to-make momentary push button

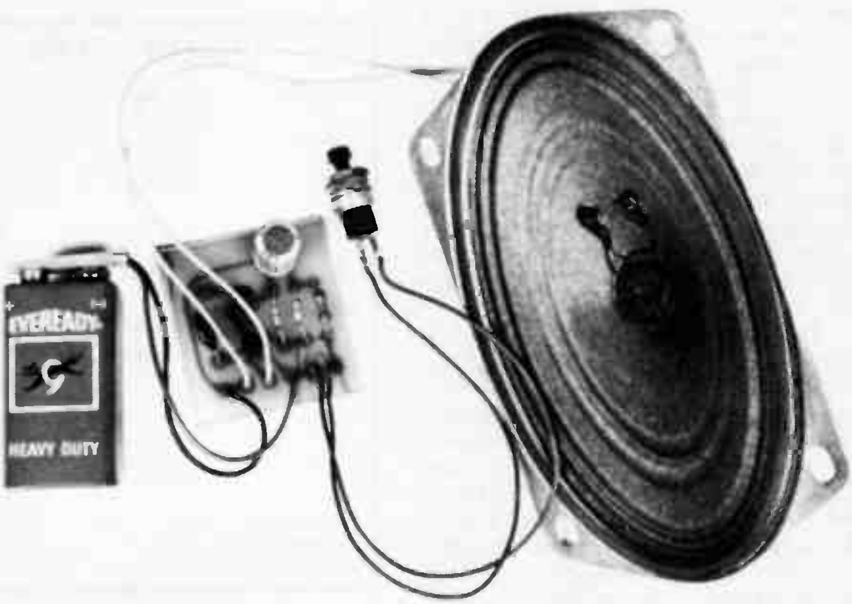
No.216, 9 V battery or suitable battery eliminator (Ferguson PPA 9DC or similar); ETI 261 pc board.





Simple siren is fun to build and interesting to play with

You can simulate an air raid siren, or that of a fire engine, with this simple project. Learn while you build, too.



ELECTRONIC CIRCUITS that simulate everyday sounds are always popular with beginners. We receive many requests, and quite a few circuit suggestions, for such things. This project comes from a circuit idea sent in by Mr. W.T. Geary of Rossmoyne in Perth, W.A.

The circuit employs a cunning, yet simple oscillator, the frequency of which is made to rise and fall in pitch by charging and discharging a capacitor.

How it works

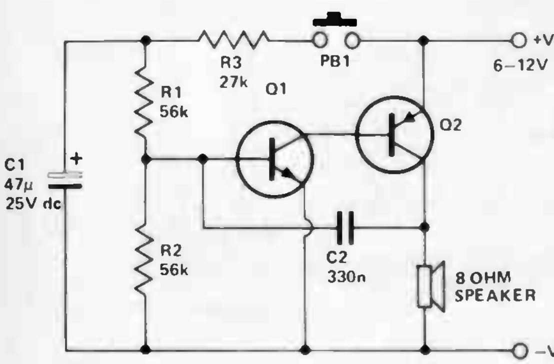
For the moment, let's ignore what C1 does and look at the circuitry around Q1 and Q2. These two transistors, an NPN and a PNP type respectively, are connected as a non-inverting amplifier. That is, a rising voltage (positive-going) on the base of Q1 will cause the voltage across the speaker to rise towards the positive rail. Conversely, a falling voltage (negative-going) on the base of Q1 will result in a falling voltage across the speaker.

This circuit has been arranged to have positive feedback applied via the capacitor C2. This means that some of the output signal is fed back to the input in the same phase. The amplifier must have sufficient gain to overcome any losses in the feedback components. That's no problem in this circuit. As the input and output are in phase, the feedback (i.e: C2) is simply connected between the collector of Q2 and the base of Q1.

When the pushbutton, PB1, is pushed (still remembering that C1 is 'not there'), Q1 will be forward biased and collector current will start to flow. It must flow via the base-emitter junction of Q2, thus Q2 will start to turn on. The voltage across the loudspeaker will start to rise. The feedback capacitor, C2, will start to charge then causing Q1, and thus Q2, to 'turn on' harder. The voltage across the loudspeaker will rise more . . . and so on until both Q1 and Q2 are 'hard on' and the voltage across the loudspeaker is pretty much that of the supply. All this occurs very rapidly.

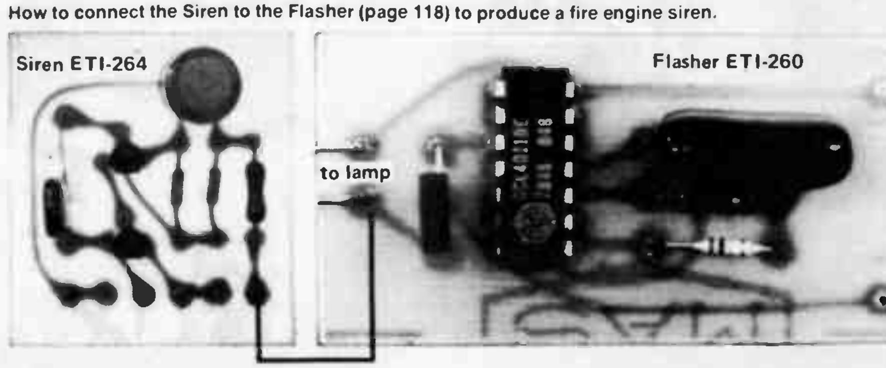
The amplifier now has no gain and Q1 will commence to turn off, causing Q2 to turn off. As the voltage across the speaker will then begin to fall, the feedback via C2 will cause the voltage on the base of Q1 to fall, turning it off further, along with Q2. This proceeds until Q1 and Q2 both turn off. C2 will discharge via R2 and the speaker, removing the feedback.

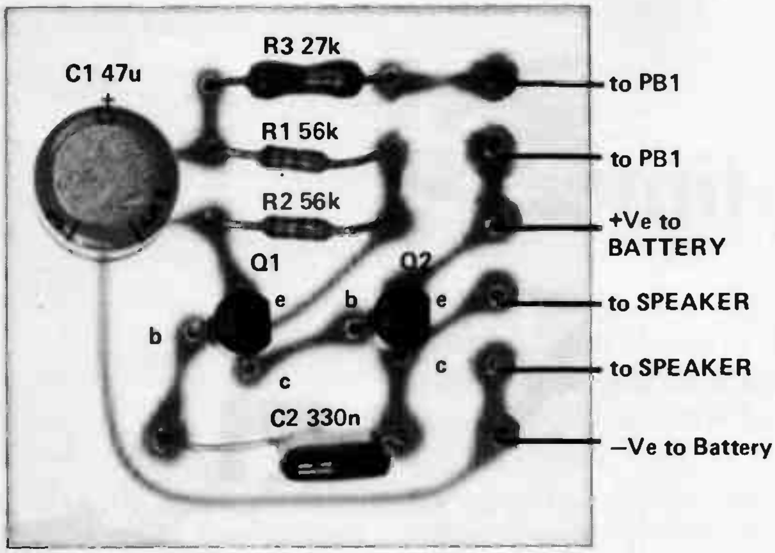
Now Q1 will start to turn on again, and the whole cycle will repeat. In fact, it repeats at many thousands of cycles per second, the frequency of oscillation being largely determined by C2, the resistor values and the supply voltage. Increasing the value of C2 will decrease the frequency of oscillation and vice versa. The operation of this circuit, simple though it appears, is quite



The pc board pattern is on page 129.

How to connect the Siren to the Flasher (page 118) to produce a fire engine siren.





complex, requiring some fancy mathematics to understand it properly. The above explanation should be clear enough for most purposes.

Now, let's see what C1 does. When the pushbutton is operated, C1 will initially appear as a short circuit and the oscillator will not work. However, C1 will begin to charge via R3 until the voltage across it is sufficient to forward bias Q1, starting the oscillator. But, it will start at a low frequency, increasing as the voltage across R1/R2 increases. When the pushbutton is released, C1 will discharge via R1 and R2 and the oscillator frequency will fall. As the pushbutton is alternately pressed and released, the pitch of the sound from the loudspeaker will rise and fall in sympathy.

Construction

This is fairly straightforward as there is nothing critical about placement of the components. However, take care with the orientation of the electrolytic capacitor (C1) and the two transistors. Although this circuit can be readily assembled on a piece of matrix board (as per the actual circuit diagram!) we elected to use a pc board. The speaker, battery and pushbutton are all attached via flying leads as shown in the photograph. Note that the pushbutton is a momentary-contact, push-to-make type and that a 10 ohm speaker will also work in this circuit.

When connecting the battery or supply, make sure you have the leads the right way round as reverse connection could destroy the transistors.

Try these changes

If you increase the value of capacitor C1 you can make this circuit sound like an air raid siren. Swap the pushbutton for a toggle switch. When you turn it on, the pitch will rise slowly over some seconds until it reaches a maximum frequency. Try a value of 470u or 1000u for C1. You can increase the maximum pitch of the sound by decreasing the value of C2. Try a 270n. For a lower maximum pitch, increase the value of C1 to say 470n or even 680n.

To make a continuous 'fire engine' siren you'll need to build up the flasher, project 260, described on page 118. The pushbutton will not be needed; instead, connect R3 of this siren to the emitter of Q1 in the flasher as shown in the accompanying diagram. The two projects should share the same supply, of course. You can omit the lamp in the flasher if you wish.

Now, as the flasher cycles on and off, the siren will operate, rising and falling in pitch in sympathy . . . and you have a fire engine siren. ●

PARTS LIST - ETI 264

Resistors	all ½W, 5%
R1, R2	56k
R3	27k
Capacitors	
C1.	47μ, 25V electrolytic
C2.	330n greencap
Semiconductors	
Q1	BC108, BC548, DS548 or similar
Q2	BC178, BC558, DS558 or similar
Miscellaneous	
PB1	momentary pushbutton, push-to-make type, eight ohm speaker, ETI 264 pc board

A simple egg timer

Delay timers, as illustrated in this project, have a wide variety of applications. The most practical way to illustrate the technique that we could think of was this egg timer:

TIMING, for a comedian, is an important 'tool of trade', it has been said. So it is with electronics. Delay timers and period timers are used throughout a wide variety of applications in electronics. Delay timers activate something *after* a predetermined period while period timers operate something *for* a predetermined period.

Hobbyists cannot live by electronics alone . . . to twist an old saying, and if one can combine the hobby with food preparation, one survives to build another project!

Hence, the egg timer.

Now all one needs is an electronically-controlled beer and wine fermenter and nourishment would be complete.

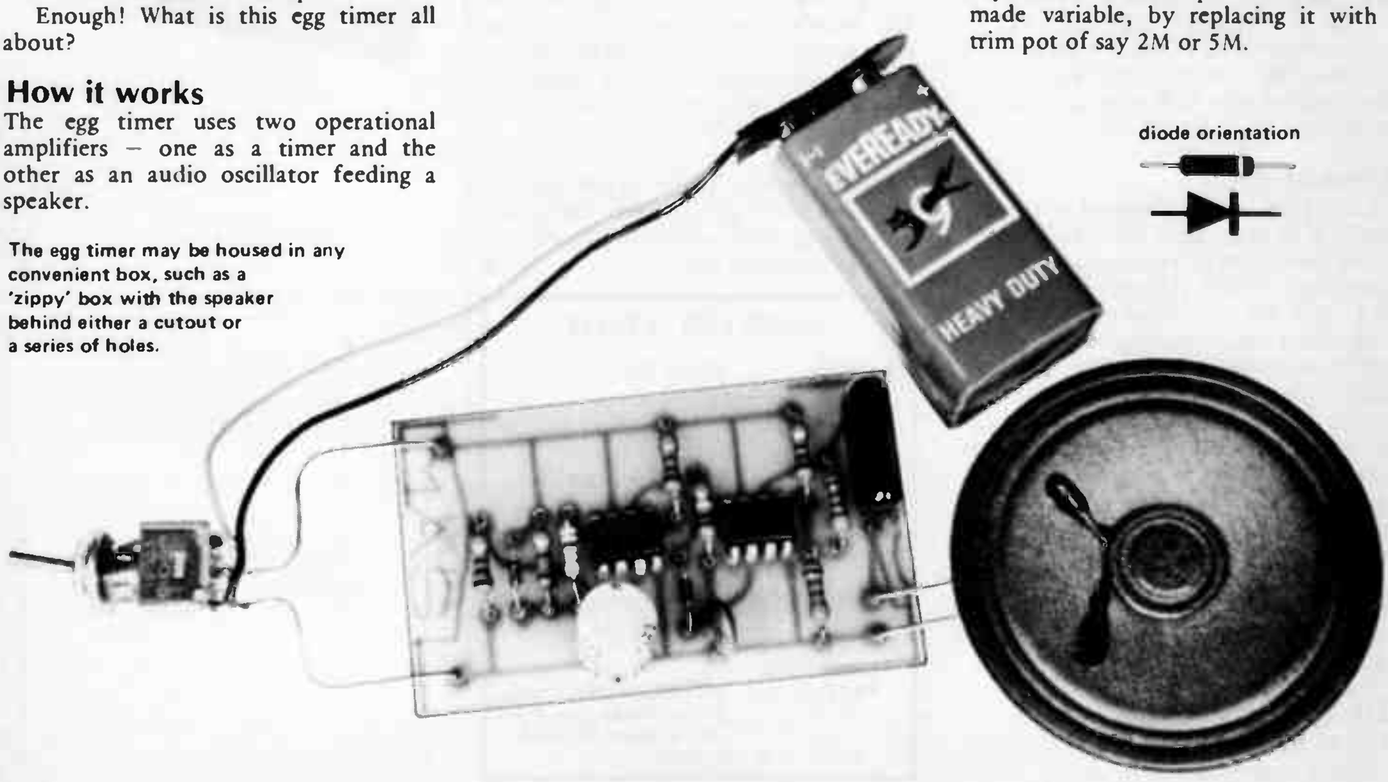
Enough! What is this egg timer all about?

How it works

The egg timer uses two operational amplifiers – one as a timer and the other as an audio oscillator feeding a speaker.

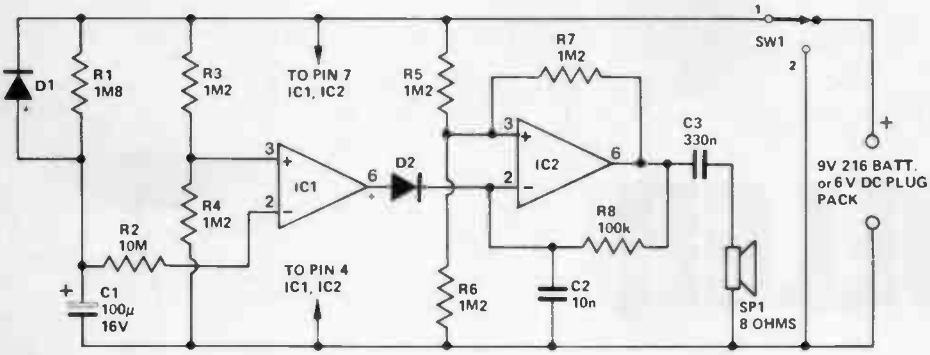
IC1 performs the timing function. As there is no negative feedback from the output back to the inverting input (marked '-') the amplifier works at maximum gain. The output will swing hard from one supply rail to the other for very small voltage differences between the inputs. A resistive divider, R3 and R4, holds the non-inverting input (marked '+') at half supply voltage so, when the inverting input is slightly lower than the non-inverting input the output will go high, and when it is higher the output will go low. The op-amp acts as a very sensitive switch controlled by the voltage polarity between the inputs.

The R-C network R1 and C1 forms a charging circuit on the inverting input of the op-amp. When switch SW1 is in the off position the capacitor is shorted out via the diode D1 and the switch. This insures the capacitor is always fully discharged before the circuit is turned on. When SW1 is switched to the on position the timing capacitor, C1, starts to charge through R1. The output of the op-amp remains high (at full supply voltage) until the voltage on C1, and therefore the inverting input, rises to just over the voltage on the non-inverting input. At this point the op-amp output goes low. The period of the delay time is set by the values of R1 and C1. If an adjustable time is required R1 could be made variable, by replacing it with a trim pot of say 2M or 5M.



diode orientation

The egg timer may be housed in any convenient box, such as a 'zippy' box with the speaker behind either a cutout or a series of holes.



The second op-amp IC2 is used as a gated audio oscillator. Positive feedback, sometimes called hysteresis, is provided by R7 and negative feedback by the network R8 and C2. The positive input is again held at half the supply by R5 and R6.

When the unit is first switched on the output of IC1 is high, holding the negative input of IC2 high and preventing the circuit from oscillating.

After the timing period the output of IC1 goes low, forcing the negative input of IC2 low through D2. The output of IC2 goes high because its non-inverting input is at a higher voltage than the inverting input. The positive feedback through R7 increases the voltage on the non-inverting input, increasing the differential voltage between the inputs. Capacitor C2 starts to charge through R8 and the voltage on the inverting input rises. Diode D2 becomes reverse biased and the voltage on the inverting input continues to rise until it is just above the voltage on the non-inverting input. The op-amp output then goes low.

Now the positive feedback reduces the voltage on the inverting input and C2 starts to discharge through R8 until the voltage on the inverting input is just lower than the non-inverting output. The op-amp output switches over again – it's oscillating.

The oscillation continues at a frequency which is determined by the values of R8 and C2 and the amount the positive feedback changes the voltage on the non-inverting input, this also depending on the value of R7. The voltage on the inverting input swings between the upper and lower voltage limits on the non-inverting input.

The output from the oscillator is a square wave which is fed to the speaker.

Construction

This project could be constructed on matrix board or printed circuit board as we have shown here. Take care with the orientation of the diodes and ICs. Other than that, construction is quite straightforward. Mind you connect the battery leads correctly or the project could be a disaster microseconds after you first switch it on.

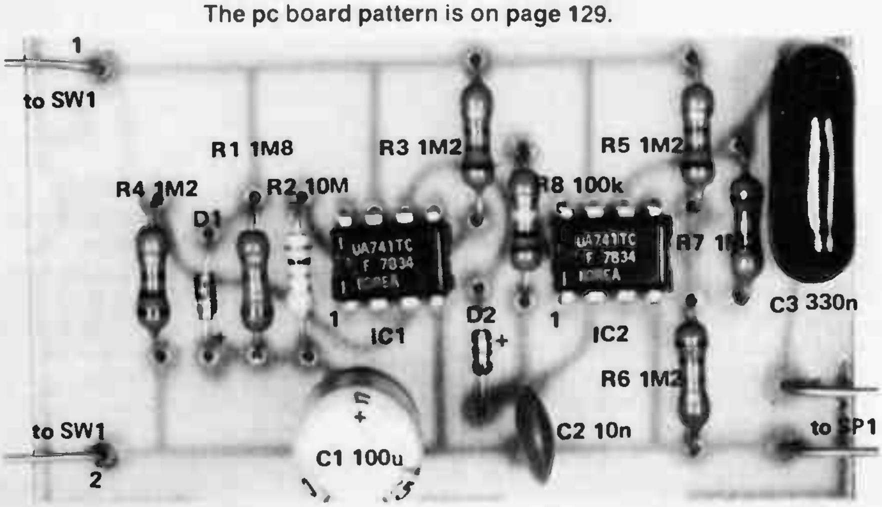
The egg timer can be mounted in any convenient box but be sure to label the switch "OFF-TIME" as it could get confusing. If you want a variable time (if you like your eggs running all over the plate or hard as nails) the timing resistor R1 can be substituted with a 2M or 5M trim pot, or could even be a potentiometer mounted on the front of the box. As the circuit draws no current when it is not being used it should give very good battery life, unless you forget to switch it off (but boy, is that noise annoying after five minutes!). ●

PARTS LIST - ETI 263

Resistors	all ½W, 5%
R1	1M8
R2	10M
R3–R7.	1M2
R8	100k
Capacitors	
C1.	100μ 16V electro
C2.	10n greencap
C3.	330n greencap
Semiconductors	
D1, D2	1N914
IC1, IC2	741 op amp
Miscellaneous	
SW1.	SPDT min toggle switch
SP1	8 ohm speaker

ETI 263 pc board, 9 V battery and battery clip or Plug Pack.

The pc board pattern is on page 129.



TRAIN CONTROLLER

Many train sets have battery operated controls. This project uses the household mains power and has variable speed, forward/reverse and current limit.

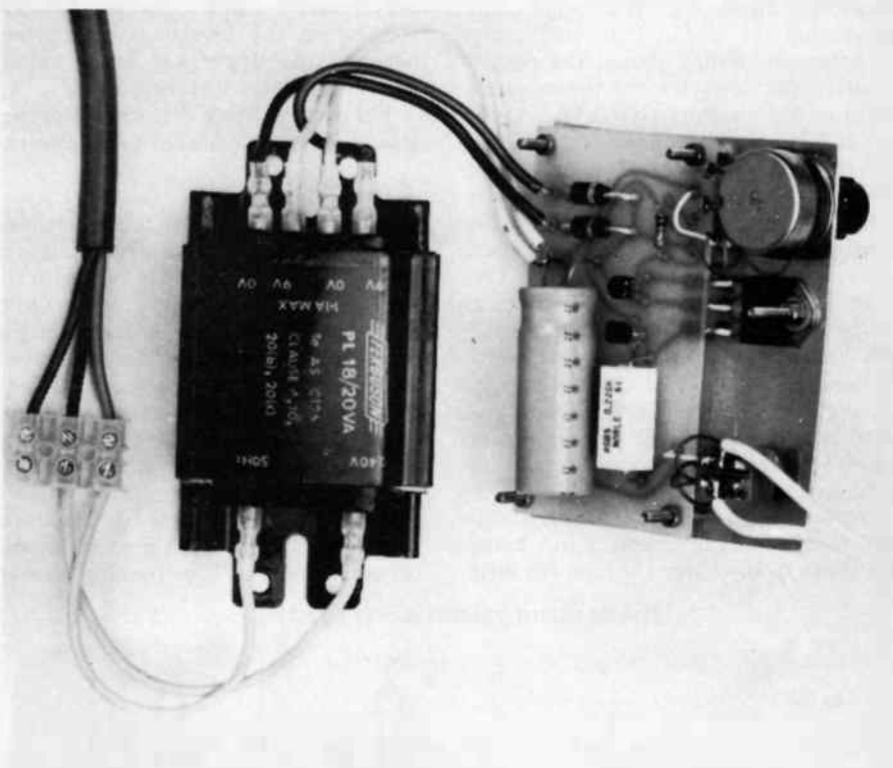
MODEL TRAINS are usually powered by a transformer which converts the mains 240 volt 50 Hz supply to about 12 volts. A wirewound rheostat or a series of switched resistors then reduces the voltage to obtain the speed required. A rectifier circuit is included on all but the cheapest models as the trains must be run from a DC supply so that polarity may be switched to obtain forward and reverse motion.

The traditional supplies described above are heavy and expensive to build and adequate short circuit protection is not often included. It's not at all uncommon for rolling stock or metal oddments to fall across the rails and thus short out the supply. But many older type controllers are either not protected at all – or have merely a fuse which blows each time a short occurs – which may be quite often.

Because of these problems and objections there is a growing tendency towards electronic control.

We must emphasise at this point that this unit is mains operated. There is no more danger in building this unit than in wiring a three-pin plug – but if you know nothing at all about mains circuits do consult an experienced person during construction and particularly before connecting it to the mains.

We must also emphasise that the type (or class) of transformer specified MUST be used. In Australia, at least, the law requires that where the secondary side of a mains energised circuit is likely to be touched then the transformer used must be constructed to an Australian Standard known as C126. Included



within this specification are the requirements that the mains input connections be shielded, that they be on the opposite side of the transformer from the output, that specially heavy insulation be used (in that the primary winding is kept right away from the secondary winding) – and so on.

The things are so safe that it's virtually impossible to have an accident – short of dropping it on your foot!

An interesting feature of the design is that we have included automatic current limiting. This means that the unit is totally short-circuit proof. No matter what load is placed across the rails the current will be limited to a presettable value. Nothing will overheat or burn out – even if you short them out for a week.

Speed is controlled by potentiometer RV1. This may be a conventional rotary unit as shown here – or it may be a sliding type. Sliding potentiometers are now readily available from most electronics and kit set suppliers. They don't cost much more than rotary potentiometers – but are harder to mount as you need to cut a long slot to take the moving control arm.

Switch SW1 enables you to select forward or reverse. Whatever form of construction you choose, this switch should be located close to the speed control.

Construction

The unit may be built into a metal or wooden enclosure. It is essential that the transformer be securely screwed down and that ample ventilation holes be provided next to the transformer base and also above the transformer itself – or at least close to it.

The power cord must be connected to the transformer via a terminal block – not connected directly. The power cord must also be clamped to the enclosure by a metal clip. It is not sufficient (or legal) to just tie a knot in the cord. If a metal case is used it is also necessary to take another connection from the earth point on the terminal block to the metal case. The connection to the case must be made via a screw which is clamped by a nut and spring washer – and a second nut which clamps the earth lead. If a metal lid is used this too must be earthed separately, using the same methods.

Transistor Q2 has to handle the total power drawn by the load: it is of a type known as a 'power transistor'.

Unlike other transistors, power transistors are unable, by themselves, to dissipate the heat that they generate. It is necessary to clamp them to some form of metal 'heatsink'.

The first and possibly simplest way is to mount the completed circuit board onto a larger aluminium or steel plate (remember to space the board off the plate so that nothing short-circuits), and then to clamp the transistor to this plate. The one drawback is that if you do this you MUST insulate the transistor from that plate electrically but not thermally. This may be done by inserting a very thin piece of mica or teflon between the two. A piece about 0.002" is more than thick enough.

Another way is to arrange for *Q2 and its heat sink* to be located away from the main circuit board and electrically insulated from the case. The actual choice of method is not too critical: just bear in mind that the heat sink is 'live', albeit at only 12 volts.

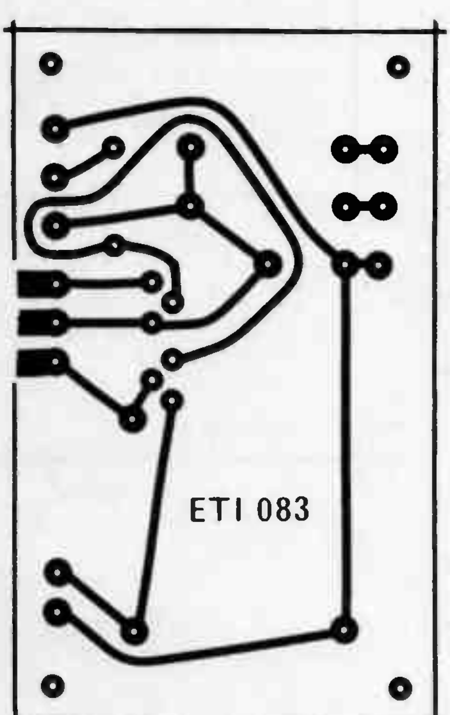
Neither the switch SW1 nor the potentiometer need necessarily be mounted on the board or metal plate as shown. We have shown this way for convenience only.

When assembling the board do take careful note of the polarity of the diodes. Put them in just as shown on the overlay drawing. Note also the polarity of the capacitor.

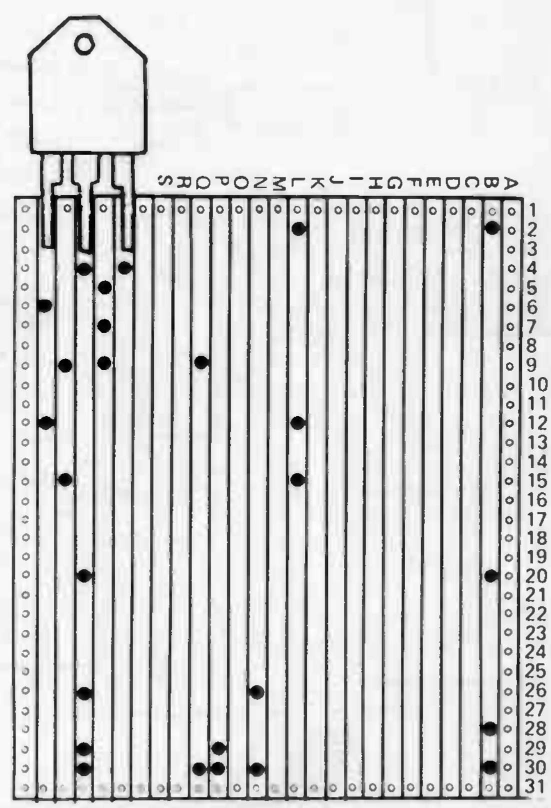
Notes: The components chosen will allow the circuit to be used continuously at currents of up 2.5 amps. We have set the current limiting circuit to clamp at about this level. The clamping level is controlled by resistor R2 – the higher the value the lower the clamping level. Thus if R2 is increased to 0.47 ohms the unit will clamp at about 1.5 amps. No matter what.

In our parts list we recommend that you use a Ferguson type PI 24/20VA transformer. If you decide to use another brand do make absolutely sure that it is built to Australian Standard AS126. DON'T take someone's word that it is. If it meets the Standard it will say so on it, and/or accompanying literature.

Resistor R2 can be made from a short length of resistance element from a toaster or jug if you find a proper resistor hard to obtain.

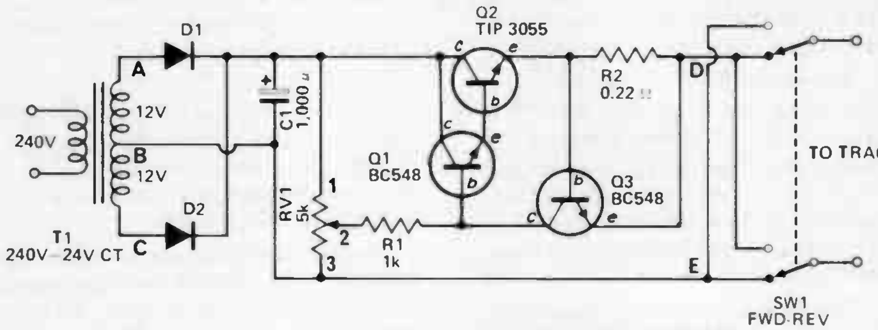


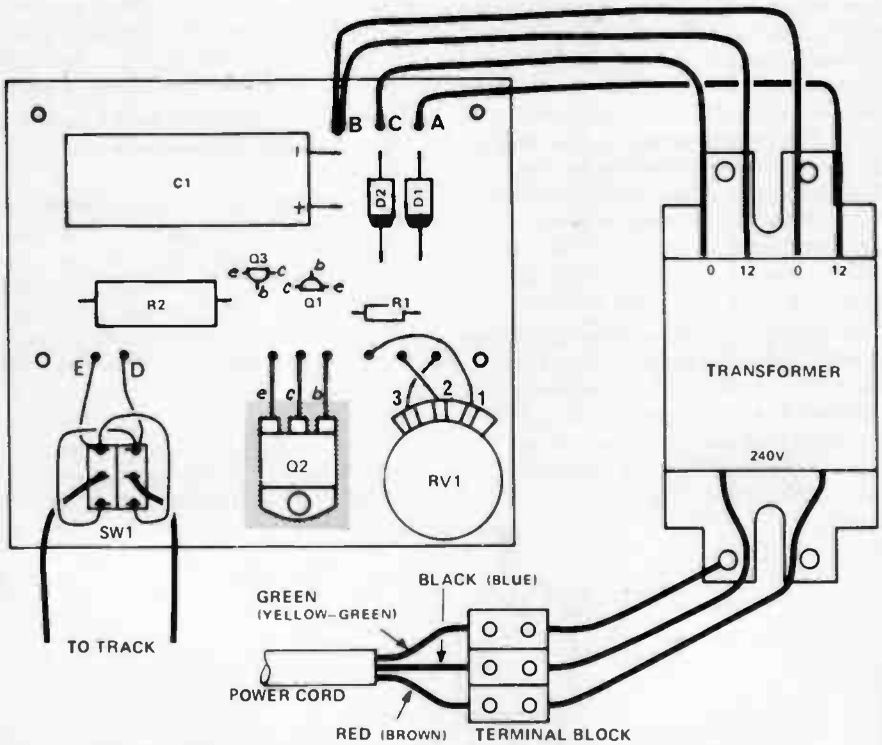
Printed circuit board pattern (shown here full size).

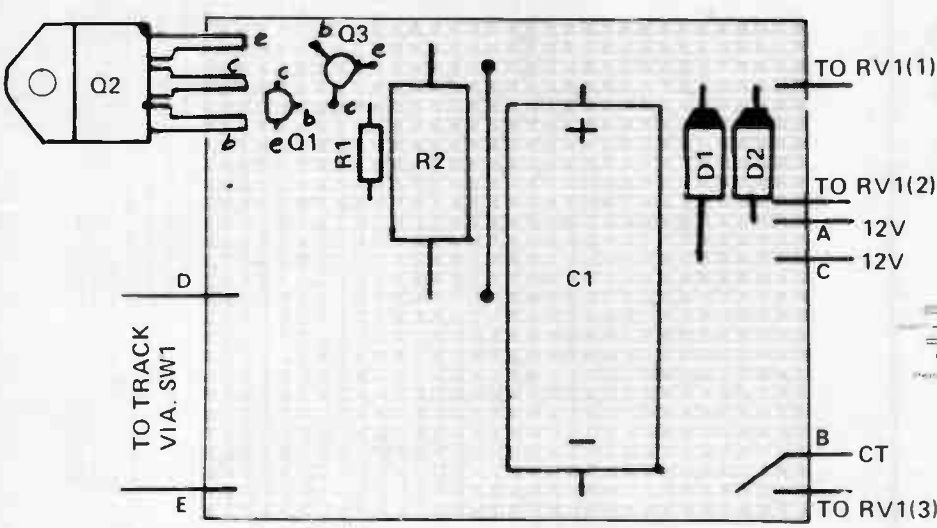


Veroboard solder connections – note no break holes are required in this board.

TRAIN CONTROLLER







This is a typical heatsink for small power transistors. (20 mm x 20 mm). It can easily be bolted on to the rear of the transistor — heat sinks such as this may be bought from most component suppliers — or made up from a short strip of copper or aluminium.

HOW IT WORKS – ETI 083

The 240 volt 50 Hz supply is reduced by transformer T1, rectified by D1 and D2 and filtered by C1. Transistors Q1 and Q2 form an emitter follower controlled by RV1. Transistors Q3 and R2 act as a current limiter, clamping to about 2.5 amps with the value of R2 shown.

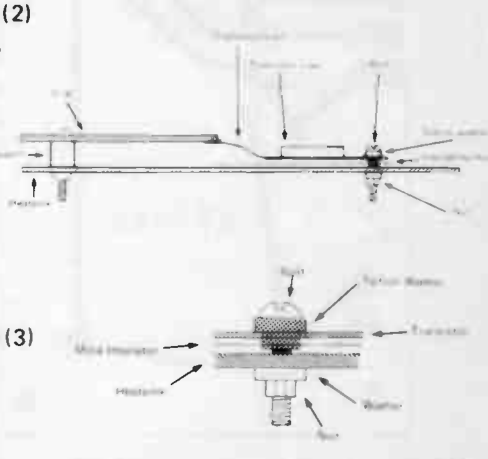
A heatsink must be used for Q2, and as the tab of this transistor is connected to the positive rail it must not touch any other part of the circuit.

PARTS LIST

R1	Resistor	1k ½ watt 5%	
R2	"	0.22 ohm 5 watt 5%	
RV1	Potentiometer 5k (linear)		
C1	Capacitor 1000 uF 25 volt electrolytic		
Q1	Transistor BC 548		
Q2	"	TIP 3055	
Q3	"	BC 548	
D1,2	Diodes	1N5401 (3A-100V) or similar	

Transformer 240 volt input, 12 + 12 volt output at 20 VA. Ferguson type PL24/20VA or similar.

Switch double pole double throw toggle type Printed circuit board ETI 083 or Veroboard. Power cord, terminal block, cord clamp.



These two drawings show how the heatsink attached to Q2 may be insulated. Note that the transistor should be mounted tight against the heatsink to increase thermal conductivity.

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Project 043

HEADS OR TAILS

Learn about the laws of chance and various random phenomena with this interesting electronic multivibrator circuit.

IF YOU TOSS a coin a dozen times and it comes up heads every time — what are the chances of it coming up heads the thirteenth time. Thirteen to one against? Or fifty/fifty?

If you said it was thirteen to one against, imagine putting that coin in your pocket and repeating the experiment with the same coin in a week's time. What then are the odds? If they're not fifty/fifty — why not?

Here's an interesting circuit which will enable you to experiment with similar chance or randomness effects.

The circuit is one of the basic building blocks of electronics. It is called a 'multivibrator' and consists of two transistors which alternatively switch each other on and off.

When the pushbutton is held down the multivibrator switches to and fro at 700 or so oscillations per second (i.e. 700 Hz).

When the button is released the circuit will assume one of two possible states. Either Q1 will be conducting and Q2 shut off — or vice-versa. The transistor that is conducting draws sufficient current through its associated resistor (R1 or R6) to cause the light emitting diode (LED) to light.

Note the circuit is totally symmetrical and that the two transistors are cross-coupled. If corresponding components are exactly matched there is precisely equal probability that either transistor will be on when the button is released.

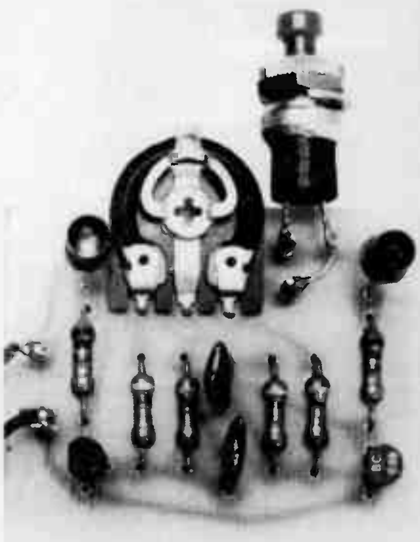
In practice, electronic components never *are* absolutely identical, so RV1 has been included so that the circuit can be adjusted for total symmetry. Alternatively RV1 may be adjusted so that the effect of bias can be observed. If more precise control is required, RV1 may be made smaller (10k or so). It may be necessary to pad out R2 or R5 to enable the circuit to be balanced with the smaller value of RV1 in circuit.

To alter the flash rate change the value of capacitors C1 and C2. Increasing these to 10 uF will reduce the rate to approximately once per second and a half. If electrolytic capacitors are used make sure that the positive terminals are connected to the transistor collectors (marked 'c' on Q1 and Q2).

Construction

As the circuit is simple and symmetrical it lends itself to assembling onto a pair of 6-way tag strips. Alternatively the unit may be assembled on a small printed circuit board — as shown in Fig 2.

Do make sure that the transistors are the right way round — likewise the



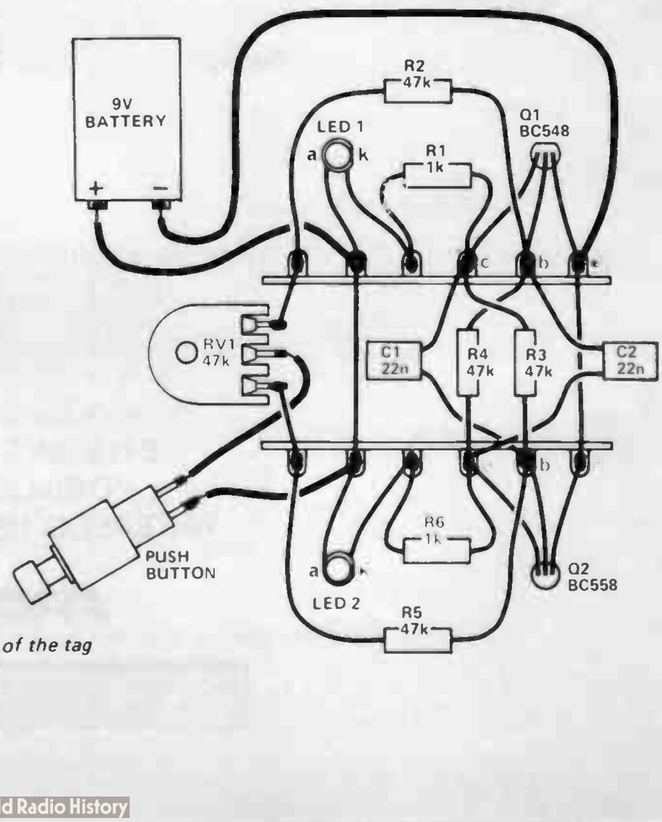


Fig. 1. Layout of the tag strip version.

HOW IT WORKS – ETI 043

This circuit may be considered as a multivibrator, when the button is pressed, and as a flip flop, when the button is released. If initially we consider the circuit with R2,R5,C1 and C2 deleted we have a standard flip flop. If Q1 is on it robs current from the base of Q2, thus turning it off. Transistor Q1 will be held on by the current through R6 and R4. However, if Q2 is on, the reverse is the case. Thus only one of the transistors can be on at any time – never both.

The addition of R2,R5 and C1,C2 will not alter the above, providing the push button is not pressed. However if the button is pressed the current through R2 and R5 will try to turn on both transistors.

Take the case where initially Q1 is on and Q2 is off. The voltage on the collector of Q1 will be about 0.5 volts and the voltage on Q2 collector about seven volts. We therefore have about 6.4 volts across C2 (as the base of Q1 is at about 0.6 volts). When the button is pressed Q2 will turn on and its collector will drop to 0.5 volts.

However a capacitor cannot instantly change its voltage and the base of Q1 will therefore be forced to -5.9 volts which turns off the transistor. Capacitor C2 then discharges via R2 and R4 until the base voltage is again at +0.6 volts when Q1 will turn on again. This however forces the base of Q2 to -5.9 volts (due to C1) thus turning Q2 off. This process continues back and forth until the push button is released. The circuit then stops in the state it was at the instant of releasing the button.

To add bias to the circuit RV1 can be adjusted to change the discharge time of C1 or C2 by up to 50%. In this case the two transistors will not be on for equal times and the results will be biased towards one side.

LEDs are included in the collector circuits of each transistor to indicate which transistor is on. If, for display purposes, a slower-running unit is required the values of C1 and C2 may be increased. If both are 10 microfarad electrolytic capacitors the rate will be about 1.5 seconds. Make sure if electrolytics are used that the positive terminal is connected to the collector of the transistor.

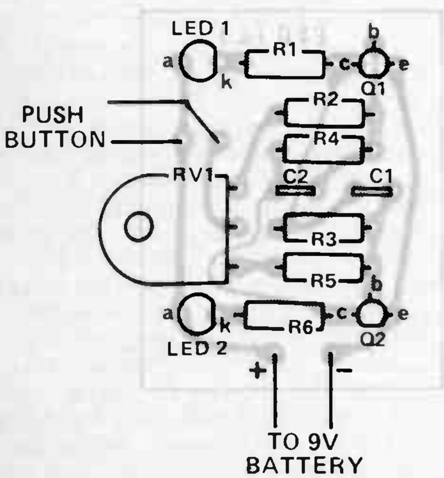


Fig. 2. Layout of the printed-circuit board version.

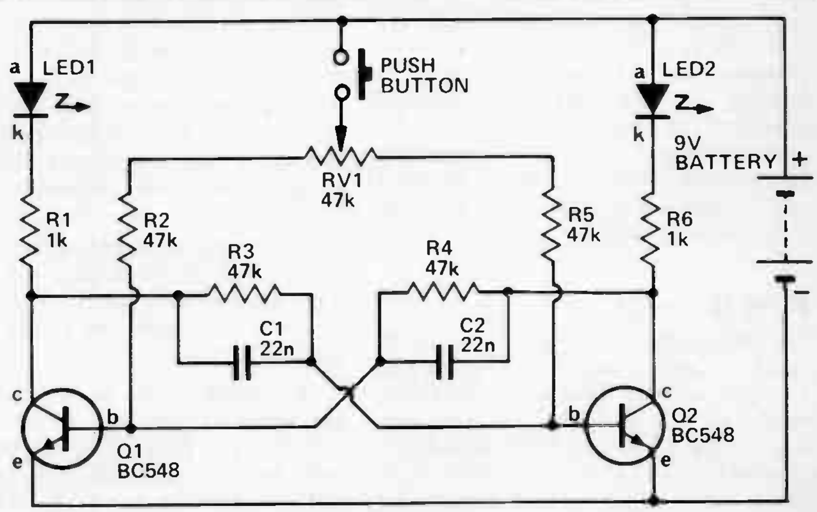


Fig. 3. Circuit diagram of the unit.

PARTS LIST – ETI 043

R1	Resistor	1 k ½w 5%
R2-R5	Resistor	47 k ½w 5%
R6	Resistor	1 k ½w 5%
RV1	Potentiometer	47 k trim type
C1,2	Capacitors	22n polyester
Q1,2	Transistors	BC548
LED 1,2	Light emitting diodes	

Push button press-to-make
9V battery clip
Two 6 way tag strips

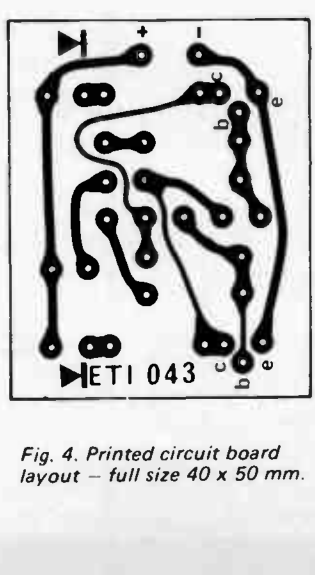


Fig. 4. Printed circuit board layout – full size 40 x 50 mm.

LEDs – the latter will have their cathode terminals (k) marked in some way. Usually this will be via a small flat on the body of the LED adjacent to the cathode lead. Some LEDs are marked simply by having the cathode lead shorter than the anode, so don't cut the leads until you're sure you know which is which!

Don't switch on until you have double checked that all components are the right way round. A transistor or LED may be destroyed if wrongly connected. Also double check the battery connections – a reversed battery may also destroy the semiconductors.

This is a very simple circuit and providing it is wired as shown it will work first time – if only one LED (or neither) flashes it is virtually certain that one or both LEDs are faulty. ●

This lamp 'flasher' is simple, has many applications

This circuit, simple though it is, illustrates a number of common circuit 'building blocks'.

CIRCUITS which flash a light, or turn something on and off at a fairly slow rate, are widely used in electronics. Many car alarms, for example, have a light installed on the dash of the car that flashes about once per second to indicate that the alarm is 'armed'. A flashing light is used as a warning indicator in many situations. This circuit illustrates the electronic principles involved, as well as having practical uses – but we'll leave those to your inventive imaginations!

How it works

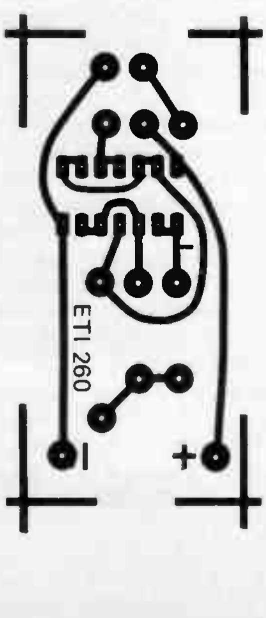
The heart of this circuit is a CMOS digital IC containing four NAND gates. Two are used to form a low-frequency oscillator, ICla and IClb. A NAND gate is a functional circuit block which has two 'inputs' and an 'output'. When both inputs are 'high', the output will be 'low'. For any other combination of input conditions, the output will be high. The 'high' and 'low' terms here refer to the voltage on the gate's terminals. Above a certain limit, the terminal (input or output) will be 'high', below that limit, it is said to be 'low'. A 'high' level will be close to the supply voltage; a 'low' level, close to zero volts.

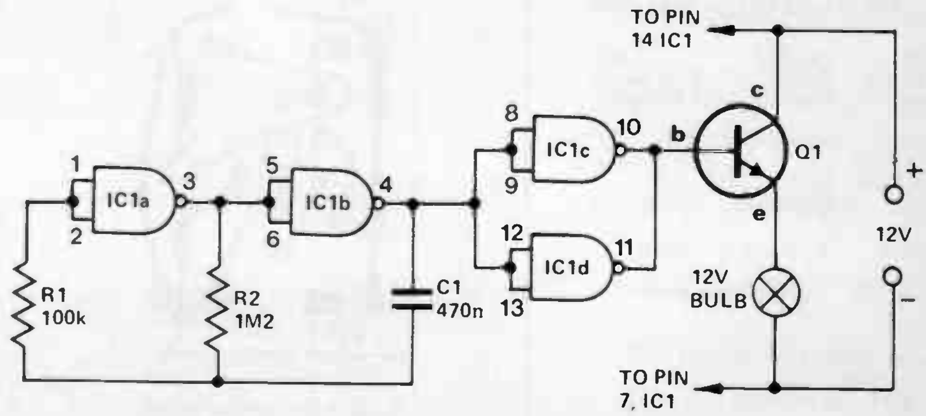
If we connect the two inputs of a NAND gate together then it will act as an 'inverter'. Thus, if the input to this inverter is high, the output will be low; if the input is low, the output will be high.

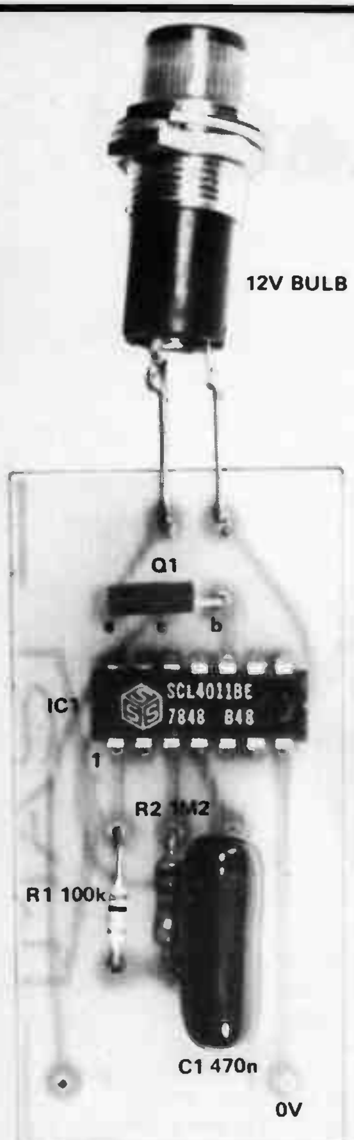
The oscillator in this circuit consists of two NAND gates from the package connected as inverters with the output of one (ICla) connected to the input of the other (IClb).

When the circuit is first turned on, the input of ICla will be low and its output (pin 3) high. The output of IClb will therefore be low. The capacitor, C1, will start to charge via R2 as one end of R2 is connected to pin 3 of IC1a which is high (in this case, at 12 V). The voltage on C1 is fed back to the input of IC1a via R1. Eventually, the voltage on C1 will reach a point where the input of IC1a will be high and the output (pin 3) will go low. This will produce a high on the output of IC1b and C1 will then discharge via R1 as the input of IC1a and the output of IC1b are both high. C1 will not charge via R2 as the value of R1 is very much less and the discharge current will be much greater than the possible charge current. The current through R1 will hold the output of IC1a high until the capacitor is discharged. At this point there is nothing to hold the input of IC1a high and it will go low, the output (pin 3) will go high and the output of IC1b (pin 4) will go low, and – you guessed it, we're back where we started!

The whole process will repeat itself, the frequency of oscillation depending on the values of R2 and C1. In this case, the frequency is about one cycle per second, or 1 Hz. This oscillator is one form of "multivibrator". Another is illustrated in our Fog Horn project.







To turn a lamp on and off requires a little more circuitry. We couldn't connect the lamp at the output of IC1b as it would rapidly discharge C1 at the wrong time! To switch the 150-200 mA required by the lamp, we use a transistor to amplify a small current supplied to its base, the lamp being connected between the emitter and the negative side of the supply. This sort of circuit is called an "emitter follower". This is a *current* amplifier.

The output of IC1b is still unable to drive the base of Q1 directly as, again, when the output of IC1b (pin 4) would be supplying current to the base of Q1, the capacitor, C1, would discharge rapidly, upsetting the frequency of oscillation. Thus, we have used the other two NAND gates to form a "buffer". IC1a and IC1d are connected as inverters with their inputs and outputs connected in parallel. As the inputs require a miniscule current to operate the gates they can be connected directly to the output of IC1b. The outputs of IC1c and IC1d will supply enough current to the base of Q1 to turn it on, the emitter current lighting the lamp.

Each time the output of IC1 goes low, the outputs of IC1c and IC1d (pins 10 and 11) go high, Q1 turns on and the lamp lights. When the output of IC1b goes high, pins 10 and 11 of IC1 go low, Q1 turns off and the lamp goes out.

Construction

There is nothing critical about the construction. You can use the printed circuit board we have designed for this project or build it up on matrix board – tag strips are a bit impractical for mounting IC1!

Take care with the connections to IC1 and Q1 – see that you have them correctly oriented. Q1 has a metal plate set into one side of it. This is to enable heat to flow from the transistor chip inside the package to a heatsink to which the device may be bolted. In this application a heatsink is unnecessary. Note that the collector is connected to the metal plate on the package, as well as having its own connection pin.

The power supply must be connected correctly – reverse connection will almost certainly damage IC1 and Q1.

This circuit may be modified to operate a relay which controls something else – to pulse a horn or a siren, for example. The lamp may be replaced by a 12 V relay; common types have a coil resistance of between 180 and 300 ohms or so and may be substituted directly. The relay contacts should be rated to switch the voltage used on the device being controlled as well as handle the current drawn by it. Your supplier should be able to assist. ●

PARTS LIST - ETI 260

Resistors	all ½W, 5%
R1	100k
R2	1M2
Capacitors	
C1.	470n greencap
Semiconductors	
IC1	4011
Q1	BD139

Miscellaneous
Printed circuit board ETI 260; 12 V bezel lamp with holder.

The 'Passionmeter'

— a party novelty project!

MANY OF YOU have probably seen those small glass vessels, available from 'joke' and 'magic' novelty stores, sold as 'passionmeters'. They consist of a series of glass bulbs, one above the other, containing a red liquid at the lower end. At the touch of a hot palm the liquid bubbles its way toward the top — how high it bubbles depending on how hot the grasping palm happens to be!

The ETI passionmeter uses an electronic technique to measure the passionate user's level of excitement — or stress — indicating this on a 'ladder of LEDs'.

Now, a person in the throes of a passion (or under some stress, all the same thing for our purposes) undergoes certain physiological changes (see reference 1). Amongst such obvious and observable alterations as bulging eyes, flushed visage, foaming at the mouth and steam issuing from the auditory orifices . . . are more subtle phenomena. The one we are concerned with is skin resistance.

Skin resistance has a number of characteristics which make it a suitable variable for measuring the level of personal passion. The *lower* the skin resistance of a subject, the greater level of emotional stress (reference 1). And vice versa.

Skin resistance increases with age, decreases with perspiration (as from exertion) and varies according to the activity recently engaged in. A finger which has just finished the washing up will exhibit a lower skin resistance than one which has just assisted reading a newspaper.

With high skin resistance, few (or none at all!) of the LEDs will light. With decreasing skin resistance more of the LEDs in the ladder will light, climbing all the way to the top with a subject at the height of passion — or one who has just finished the washing up.

You will notice the lack of an on/off switch. As a CMOS IC is used in this project, the 'no-finger' (i.e. non-operating) current consumption is so low that battery drain is three-fifths of five-eights of half of 30% of the leakage across the battery terminals — negligible in fact. Hence, no switch.

We built the project into a small plastic and aluminium 'jiffybox', with a hole in the front panel for the insertion of a finger. This size of box is very handy as the battery just fits in behind the printed circuit board and is neatly held with a little packing.

The LEDs poke through the holes in the panel — you can get clips to hold them in place but we decided to dispense with them.

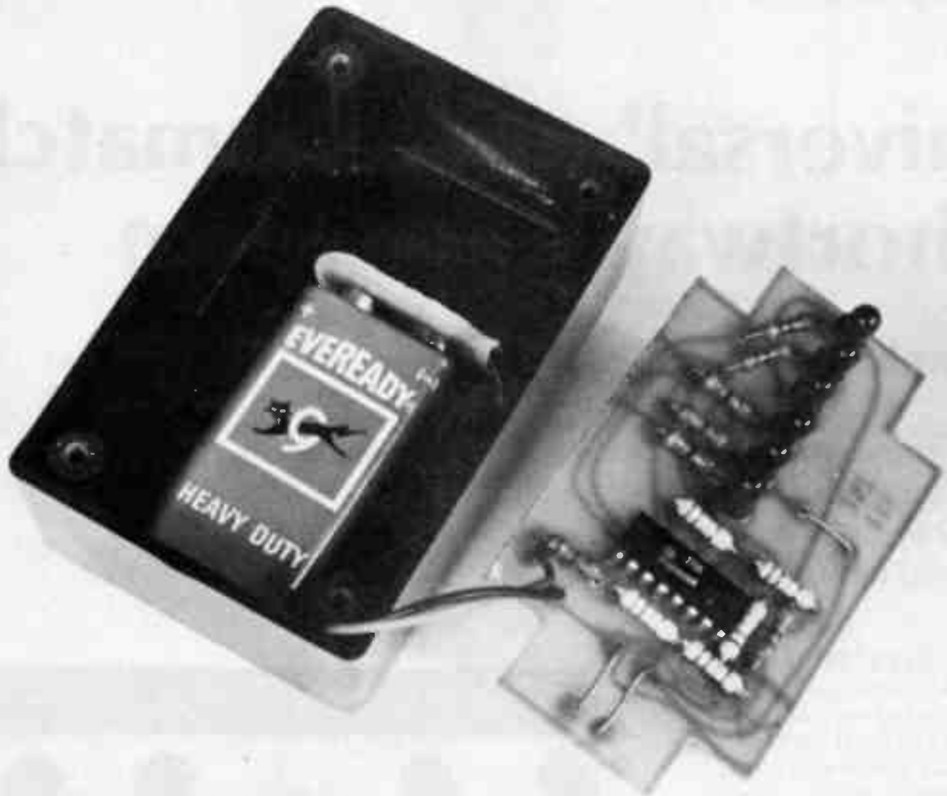
When soldering the components in, keep all of them (with the exception of the LEDs) as close to the board as possible. The LEDs should be stood a few millimetres off the board, with their flanges, which butt up against the front panel, level with the top of the IC.

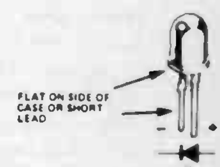
Make sure that all of the LEDs are the right way round (notice the flat face, indicating the cathode, on one side of each). Also make sure that the integrated circuit is fitted the right way round.

Don't forget the wire link LK3. LK1 and LK2 are the contacts, which are soldered in to the circuit board in exactly the same way that a wire link would be, except of course that you must use un-insulated wire.

It's also a good idea to cut a piece of hard paper or card to fit between the circuit board and the battery to prevent shorting when a finger is pressed down onto the contacts. ●

*Reference 1: "Zen and the art of motorcycle maintenance", Robert M. Pirsig. Corgi.





HOW IT WORKS – ETI 252

The operation of this circuit depends on the difference in skin resistance between different people. The lower the skin resistance, the more of the LEDs will light up.

This resistance is measured between LK1 and LK2. As the finger of the person to be tested is pressed against the circuit board, it will cover both of these links and the resistance between them will drop from its 'un-fingered' state in which the resistance across LK1/LK2 is high) to a value less than 1M. This will cause the voltage on the resistor chain R1 to R6 to drop.

The 'gates' in the 4049 integrated circuit are inverters. That is, whatever happens on the inputs, the opposite will happen at the outputs. In this case, the inputs are being dragged to a low voltage. When the voltage on the input of any particular gate drops below about 4.5V (half the supply voltage) the output will change from 0V to 9V. This will drive current through the appropriate LED.

As the resistance across the contacts decreases, more of the gates will be turned on, causing LEDs in the line to light up.

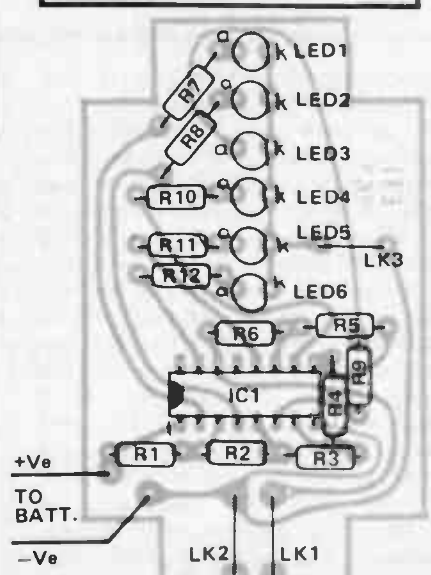
When no finger is present, none of the LEDs are lit and the current drawn by the circuit is so small that an on/off switch is unnecessary.

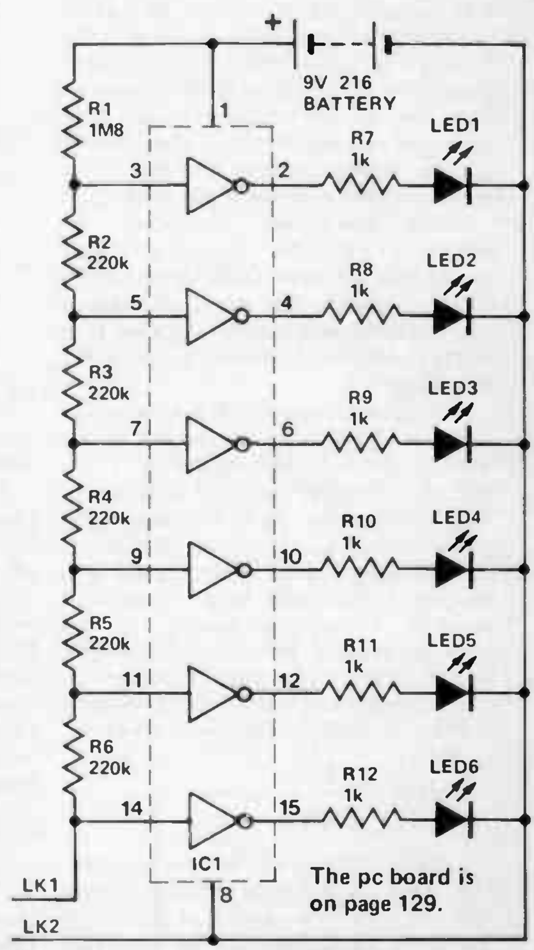
PARTS LIST – ETI 252

Resistors all ½W 5%
- R1 . . . . 1M8
- R2-R6 . . . . . 220k
- R7-R12. . . . . 1k

Semiconductors
- IC1 . . . . 4049B
- LED1-LED6 . . TIL220R Red LEDs or similar

Miscellaneous
- B1. . . . . 216 9V battery
- Battery clip, ETI 252 pc board, small 'zippy' box to suit.





The pc board is on page 129.

A 'universal' antenna matcher for shortwave reception

Simon Campbell
Phil Wait

This simple project can be connected in almost any desired configuration to match a random 'long wire' antenna to the input of a shortwave receiver and give much improved performance.

The project is housed in a plastic utility box, the front panel being dressed up with a Scotchcal Panel.

FOR GENERAL RECEPTION purposes over the 1.7 MHz to 30 MHz range, an end-connected wire antenna is popular. This may be anything from a few feet of insulated wire indoors, to a long, high outdoor aerial. Such antennas can, and do, provide good long-distance reception, but the matter of matching the aerial impedance to the receiver is often totally disregarded. There is a maximum transfer of energy from the aerial to the receiver only when the end impedance of the antenna approximately matches the input impedance of the receiver input circuit.

Many specialised shortwave receivers have an antenna input impedance of about 50 ohms. With other receivers, the input impedance may be unknown, and in any case it is likely to alter with changes in operating frequency.

The end impedance of the antenna, in its turn, depends on the length of the wire in terms of wavelength. If it is a half wavelength long, or a multiple of half wavelengths, its end impedance is high — it may easily exceed 1000 ohms. On the other hand, if the aerial is a quarter wavelength long, or an *odd* multiple of quarter waves, its end impedance is low. In fact it will probably be under 50 ohms at some frequencies.

The length of a half-wave antenna is found with sufficient accuracy from

$$\text{Length} = \frac{143}{f(\text{MHz})} \text{ metres}$$

As much specialised shortwave listening takes place on the amateur bands, and as they are spaced at harmonic intervals throughout the HF spectrum (see accompanying table), it is convenient to use them as examples.

Say you have a long wire erected that has a total length of 10 metres. Now, this would work as a half-wave antenna on the '20 metre' amateur band since 143/14.3 gives an antenna length of 10 metres. The antenna would have a very high impedance at either end and this would have to be 'transformed down' to match the receiver's relatively low input impedance. At twice the frequency where the antenna is a half-wave long, i.e: 28.6 MHz, the antenna is clearly *two* half-waves and the end impedance is again high. But, at half the half-wave frequency, or 7.15 MHz, the antenna will be one-quarter of a wavelength long and its end impedance will be low. The exact impedance will depend on the height, ground conductivity and overall construction.

If you measured the impedance of the antenna throughout the HF range, from 30 MHz down to 1.7 MHz, it would be found to swing from one extreme to the other, reaching a low impedance at 'quarter-wave' frequencies and a high impedance at 'half-wave' frequencies.

Amateur Bands up to 30 MHz

160 metres	1.8 - 1.86 MHz
80 metres	3.5 - 3.7 MHz
40 metres	7.0 - 7.15 MHz
20 metres	14.0 - 14.35 MHz
15 metres	21.0 - 21.45 MHz
10 metres	28.0 - 29.7 MHz

Any random length of wire will exhibit these general characteristics.

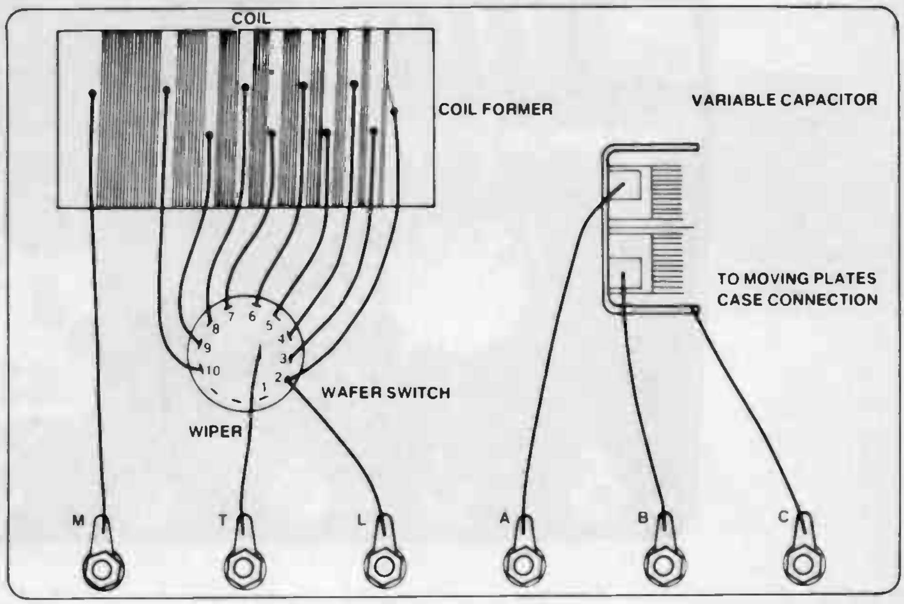
To enable one to tune a wide range of frequencies, and to gain the maximum power transfer from the minute signals on the antenna to the receiver input, some variable compensation or 'matching' system must be employed.

The best way to go about this is to use a resonant circuit that can be tuned across the entire range of frequencies of interest and can be connected in a variety of impedance transforming configurations. The matcher described here uses a coil tapped at convenient intervals and a dual-gang variable capacitor. The actual capacitance range of the latter can be different to the 10-415 pF (nominal) of the Roblan gang specified but you may experience some restrictions at the low frequency end of the spectrum if the range is smaller, apart from mechanical problems, unless you intend to use a different case or style of construction.

The coil tappings are selected by means of a single-pole rotary switch, while the coil and capacitor may be connected as desired by means of coloured terminals and jumper leads. Suggested circuit configurations are shown on page 125, but we'll get to that later.

Construction

We housed our matcher in a plastic utility box measuring 190 x 110 x 60 mm. The plastic 'lid' of the box is used as the front panel and all the components were mounted on this. Six 'banana' socket-binding post terminals were mounted along the 'top' of the lid to provide the coil and capacitor connections. The rotary switch and capacitor are mounted in line beneath the terminals, the switch on the left and capacitor on the right. The capacitor we bought uses three screws which hold it to the front panel, mating with threaded holes in the front section of the capacitor frame. If you have or wish to use a different type, then mounting arrangements may have to be different. The Roblan, and similar type, gangs are quite small and fit neatly into the box we chose. If you plan to use a different type, make sure that it will fit in this box without fouling any of the other components, otherwise you will have to vary the mounting arrangements or use another box. Many of the older-style 'broadcast' tuning gangs have a capacitance swing of 5 -



Wiring diagram. Compare this with the photograph on the right.

HOW IT WORKS — ETI 727

The unit contains a coil with multiple taps which may be selected by a single-pole, multi-position switch, and a dual-gang variable capacitor. Terminals provide connections to the circuit elements such that they may be interconnected in a variety of configurations. Thus, various common matching configurations may be achieved. i.e: L-match, Pi-match, T-match, parallel tuned, series tuned, end-loading (L or C only) etc.

The matching circuit will transform the unknown impedance of the feedpoint of a random length antenna to the impedance of the antenna input of the receiver, effecting maximum power transfer of the signal.

PARTS LIST — ETI 727

- 1 x dual-gang variable capacitor, 10 - 415 pF (nominal, Roblan type RMG2 or similar)
- 1 x single-pole, ten-position switch, C&K type RA or similar
- 6 x banana socket-binding post terminals, all different colours, plus banana plugs to suit (get the stackable variety)
- 2 x knobs with numbered skirts
- 1 x plastic jiffy box, 190 x 110 x 60 mm

Miscellaneous

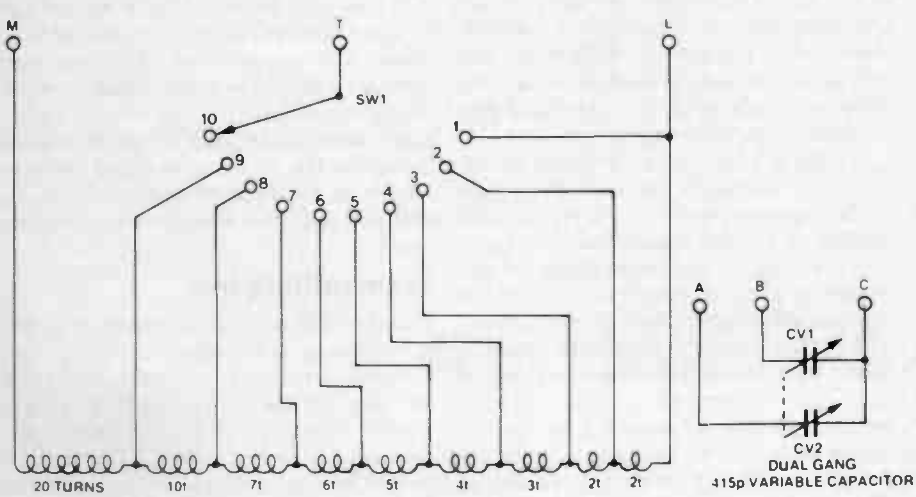
Coil former 40 mm diameter, 80 mm long (see text), enamelled coil winding wire, any gauge between 22 swg and 28 swg, tinned copper wire, hookup wire, nuts, bolts etc.

Price estimate

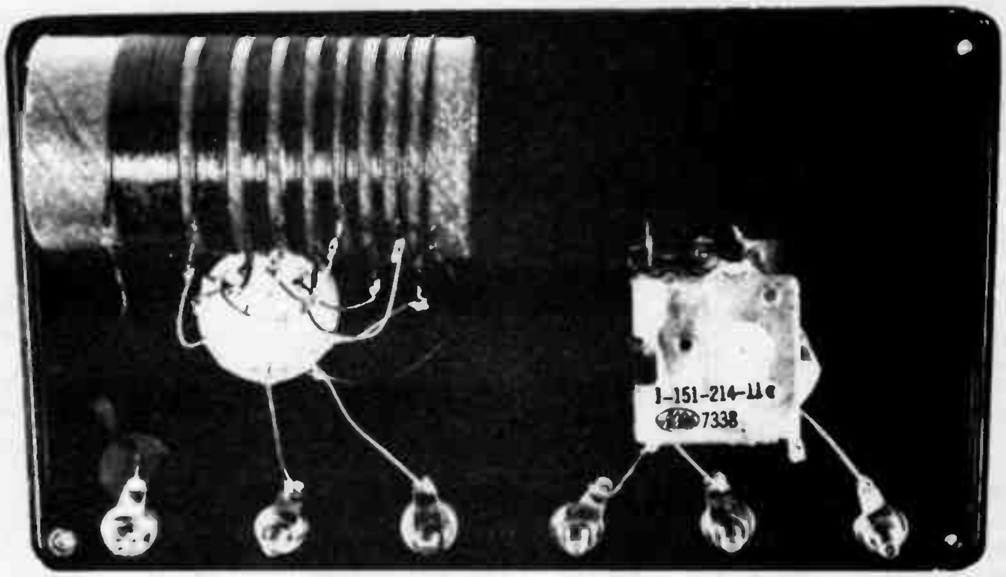
We estimate that the cost of purchasing all the components for this project will be in the range

$15 - $20

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the actual price of a project, whether bought as separate components or made-up as a kit.



General circuit diagram, showing the number of turns on each coil section.



365 pF, which is quite adequate, but are about twice the size of the modern types and may have a 9 mm diameter shaft, necessitating a 'shaft reducer' extension piece. We'll have to leave that up to you.

The coil is mounted directly behind the switch and, since it is very light, the wires from the windings to the switch lugs are used to support it. All interconnecting wiring in the project is made with 20 swg tinned copper wire.

First, drill the lid of the box. Mark out carefully the hole positions and centre-punch each one before drilling. You can use the front panel artwork as a template. If you are using a Scotchcal front panel, don't remove the backing at this stage. Drill the holes in the front panel *before* attaching the Scotchcal, otherwise you're likely to tear it.

Having drilled the holes, carefully deburr them with a larger size drill bit. Now you can attach the front panel artwork. Next step is to attach the terminals, switch and capacitor. Take care not to damage the front panel artwork when tightening screws or nuts.

The coil

Now wind the coil. We wound ours on an 80 mm long piece cut from a cardboard mailing tube about 40 mm in diameter. You can buy these from newsagents and stationery suppliers. Alternatively, the centre tube from a toilet roll could be used but is not quite as rigid. The drawing here shows how the coil is wound. Start by 'locking' the wire to one end of the former by looping the wire through two small holes poked in the end of the former about 5 mm apart. Pull the wire tight and commence winding from left to right, passing the wire over the former, away from you then up towards you etc, for 20 turns to the first tap. The coil is wound in sections, the tap in between each section being wired to the switch. To make the first tap, form a small loop in the wire and, while still maintaining tension on the already-wound section, put several twists in the loop. Commence winding the next section about 4 mm from the end of the first. Wind 10 turns and make another tapping. Start each successive section 4 mm from the end of the previous section, making tappings as you go, until you reach the finish. Refer to the diagram for the correct number of turns for each section. Anchor the end of the winding as you did the start. Don't forget to leave sufficient length of wire at the start and finish of the coil to reach the terminals to which they connect. About 80 - 100 mm is sufficient. You can give the coil a coating of acrylic cement to help hold it in place and prevent moisture affecting it.

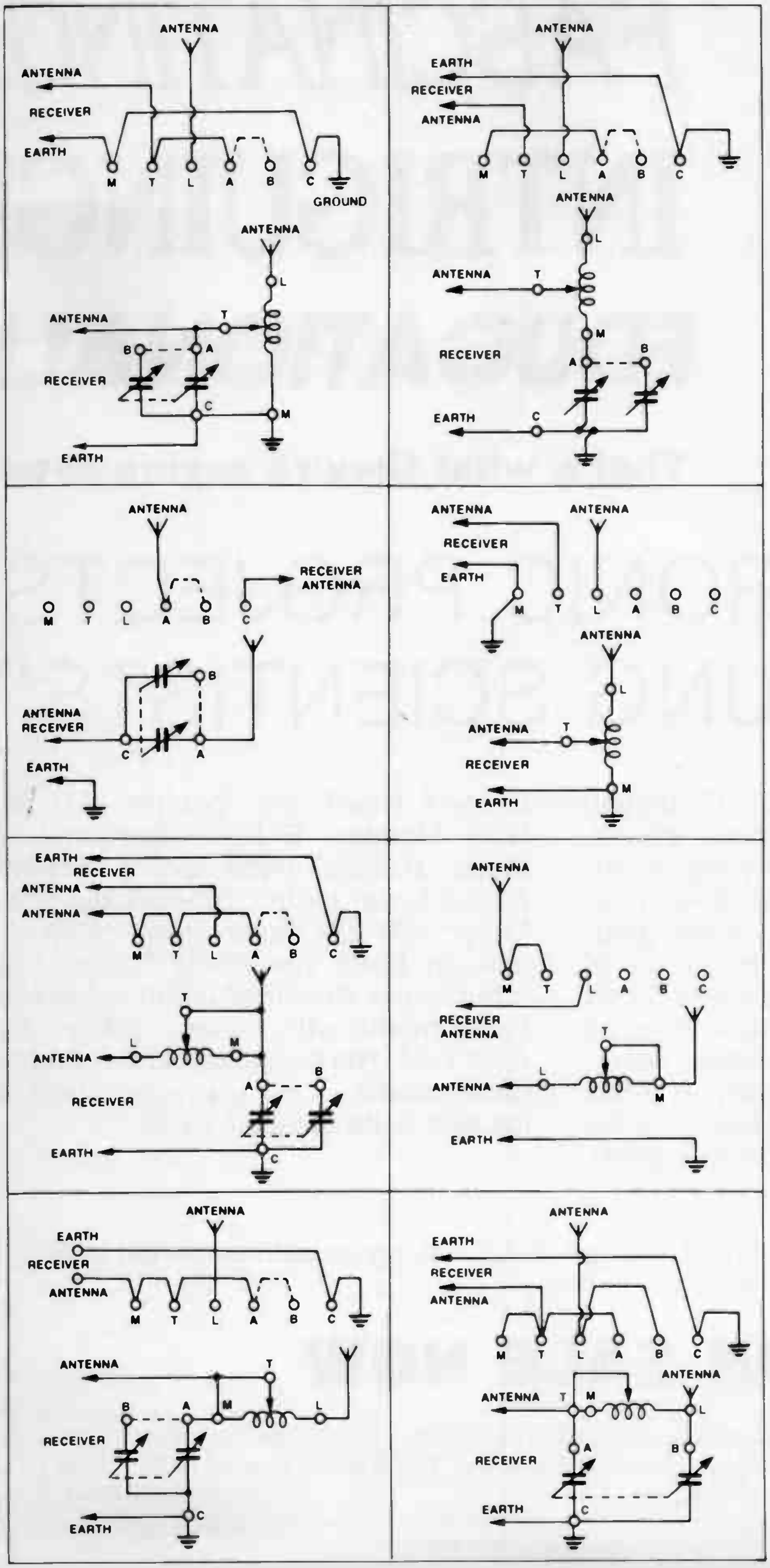
Using a knife or other sharp blade, carefully scrape the enamel off the ends of the tapping points and solder 50 mm length of tinned copper wire to each. Taking care to get everything in the correct sequence, solder each wire to the appropriate lug on the rotary switch. The coil will then be supported by these wires from the switch. The 'start' end of the coil (beginning of the 20-turn section) should be soldered to the 'M' terminal, while the other end of the coil connects to the 'L' terminal. Terminal 'T' is connected to the pole of the rotary switch with a length of tinned copper wire.

Next wire the capacitor. The frame (common connection for the moving plates) connects to terminal 'C', while the two fixed plates' connections go to terminals 'A' and 'B'. If your capacitor doesn't have a solder lug connection for the frame you will need to attach a bolt to some convenient point on the frame and put a solder lug under the bolt head to provide a connection point.

That completes the internal wiring of the project; however, you will need to make up a number of 'jumper' wires to 'patch' the different terminals together to get the circuit configuration you want. 'Banana' plugs are convenient connectors and will mate with the terminals we have specified. Get the 'stackable' variety. The jumper leads should be no longer than 200 mm, and something between 100 mm and 200 mm will be fine. It's an advantage to use different coloured hookup wire to make the jumpers so that you can identify the leads more readily when changing or making up a circuit configuration. Make up a length of coaxial cable for the receiver antenna connection with the appropriate coax plug on one end and the banana plugs on the other.

Transmitting use

It is possible to use this project to match a low power transmitter to a long wire antenna, but we haven't actually tried it. We estimate transmitter output power should be no higher than 5 W - 6 W carrier or 12 - 15 W PEP on SSB. It would be fine for Novice amateur use or for the QRP enthusiast, providing the power limitation is kept in mind. The principal problem is the voltage rating



of the capacitor and switch when using the matcher on an antenna having a high impedance at the feedpoint. Voltages can get *very* high, sufficient to cause flash-over, possibly destroying your matcher and/or your transmitter final amplifier.

Using the matcher

A variety of useful circuit configurations (by no means all the possibilities) are indicated in the accompanying diagrams.

Write down or make a mental note of the *total* length of your antenna, including the lead-in wire. When you tune to a particular band of interest, do a quick calculation to determine whether the antenna is close to an even number of half wavelengths long, close to an odd number of quarter wavelengths long, or shorter than a quarter-wave. This will indicate whether the antenna is likely to have a high, low or high impedance at the lead-in, respectively, and will point to the sort of circuit configuration to use.

Having determined that, make the appropriate jumper connections and tune in a signal. Adjust the matcher controls for a peak in the receiver's S-meter reading. For best results, use a weak signal when peaking the matcher's controls.

You'll find that tuning adjustments are relatively broad when you have a longish antenna connected, but peak more sharply for short antennas. A little experimentation will soon indicate the best configuration for each band of interest. It is wise to keep a note of the circuit, jumper connections and control settings for each situation. Those configurations using the coil *and* the capacitor will allow small increments of adjustment, permitting better 'fine tuning'.

For best receiver performance, a configuration that shows 'sharp' (i.e: high circuit Q) tuning will considerably reduce the strength of signals away from the band of interest. This will aid 'double-spotting' problems with those inexpensive single-conversion receivers prone to this problem as well as reduce the problem of crossmodulation and front-end overload — quite apart from the benefit of improving the signal strength by matching the antenna to the receiver input! However, there is a slight drawback in that if you wish to move frequency by several hundred kilohertz within a band then you will most likely have to retune the matcher's capacitor. If you want 'broader' tuning (i.e: lower circuit Q) then use less 'L' and more 'C'. Some 'hand capacity' effects may be noticed at the higher frequencies when tuning high impedance antennas. ●

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Radio Microphone

Not just for secret agents! There are all kinds of uses for this amazing little microphone/transmitter. It can be built in next to no time and only needs an ordinary FM radio to detect its signals.

Developed by Phil Wait

RADIO MICROPHONES are used extensively by stage performers and by professional eavesdroppers (i.e: spies), but they do have more mundane uses as well. They can be used for any kind of remote monitoring of sounds. For example, you can use one to hear your phone or doorbell ringing when you're sitting out in the yard, or to make sure you don't miss a word of your favourite TV programme while you're in the kitchen. They make excellent baby alarms, too, because they can go anywhere that baby goes.

Our radio mic consists of a simple condenser microphone which is used to modify the output of a small radio transmitter. The transmitter radiates a continuous wave whose frequency is altered in sympathy with the sound waves striking the microphone. (The 'How It Works' box on the next page gives a more detailed description of the circuit). In other words it's an FM (that is, frequency modulated) transmitter.

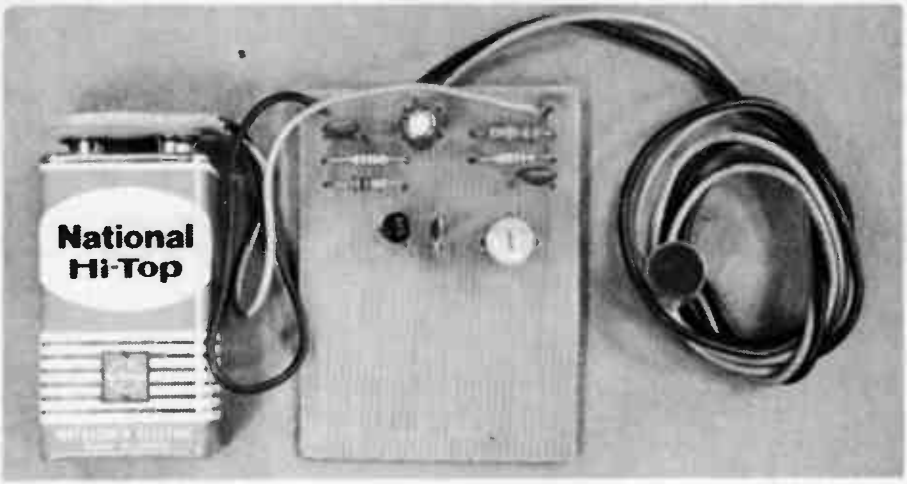
The circuit components have been chosen so that the transmitter works in the 88 MHz to 108 MHz broadcast band, so you can use an ordinary domestic FM radio receiver to pick up its signals. If you tune across the FM dial of such a receiver you will find one or more wide gaps where there are no broadcast signals. If you use a radio microphone *only* in those parts of the waveband, you will pick up its signals loud and clear and you won't cause any annoying interference to your neighbours.

Construction

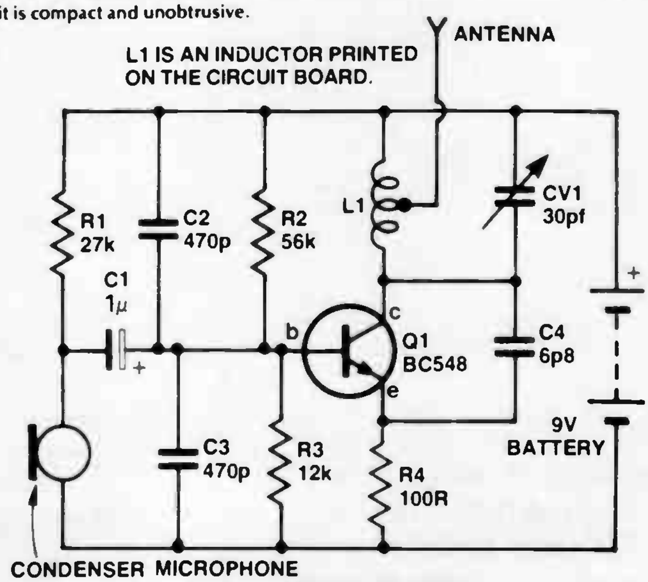
It's absolutely essential to use our design of pc board, because one of the vital components, the inductor L1, is actually part of the pc board itself. On page 130 is a list of places where you can buy the boards, as well as a list of those component suppliers who are selling complete kits for this project.

Begin by soldering the resistors onto

Project HE 106



The complete unit is compact and unobtrusive.



PARTS LIST

RESISTORS	all ½W, 5%
R1	27k (1)
R2	56k (1)
R3	12k (1)
R4	100R (1)
CAPACITORS	
C1	1u, 16V electrolytic or tantalum (1)
C2, 3	470p ceramic (2)
C4	6p8 ceramic (1)
CV1	30p trimmer cap (1)
SEMICONDUCTOR	
Q1	BC108, BC548, 2N3564, or similar (1)

MISCELLANEOUS

HE 106 pc board, electret or similar capacitance microphone insert, 9 volt battery and clip.

HOW IT WORKS

This circuit is basically an oscillator which runs at around 100 MHz. The most important parts of the oscillator are the transistor Q1 and the tuned circuit, which comprises the inductor L1 and the variable capacitor CV1.

When the battery is first connected, a brief surge of current flows from the collector to the emitter of Q1, causing an oscillating (i.e: alternating) current to flow back and forth between L1 and CV1. An oscillating voltage therefore appears at the junction of L1 and CV1. The frequency of the oscillation depends on the values of L1 and CV1, so that varying the value of CV1 tunes the oscillations to the exact frequency required.

The oscillating current would very soon decay to nothing, but for the fact that the oscillating voltage is fed back via C4 to the emitter of Q1. This makes the base-emitter current of the transistor vary at the oscillation frequency and hence causes the emitter-collector current to vary at the same frequency, keeping the current flowing in the tuned circuit and maintaining the oscillations. Some of the energy in the oscillating electric and magnetic fields of the tuned circuit is radiated as radio waves.

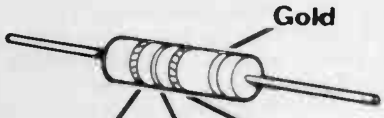
But how do sound waves arriving at the microphone vary the frequency of these waves? They can do this because the frequency of the oscillations depends on the TOTAL capacitance in the oscillator circuit. Although CV1 accounts for the major part of this capacitance, other parts of the circuit also make minor contributions. In particular, the capacitance between the base and the collector of Q1 has a small but noticeable effect on the oscillation frequency. This capacitance, which is known as the 'junction capacitance', is not fixed but varies when the voltage on the base of the transistor varies. Sound waves hitting the microphone induce a voltage that varies in time with the sound and this voltage is applied via C1 to the base of Q1, thereby frequency modulating the transmitter.

the board, referring to our diagram for their positions. Next mount the fixed capacitors (C1, C2, C3 and C4), taking care that C1, the electrolytic or tantalum capacitor, is inserted the right way round. If it's put in backwards it won't work and may even go up in flames when you connect the battery! Check with our small drawings to make quite sure you know which side is positive and which is negative.

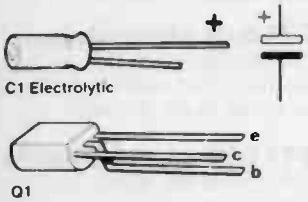
That leaves only two components to be mounted on the boards. The variable capacitor, CV1, shouldn't present any problems, because it will only fit one way round, but the transistor Q1 must be oriented correctly. Refer to our small diagram to make quite sure that the emitter, base and collector leads go in their right places.

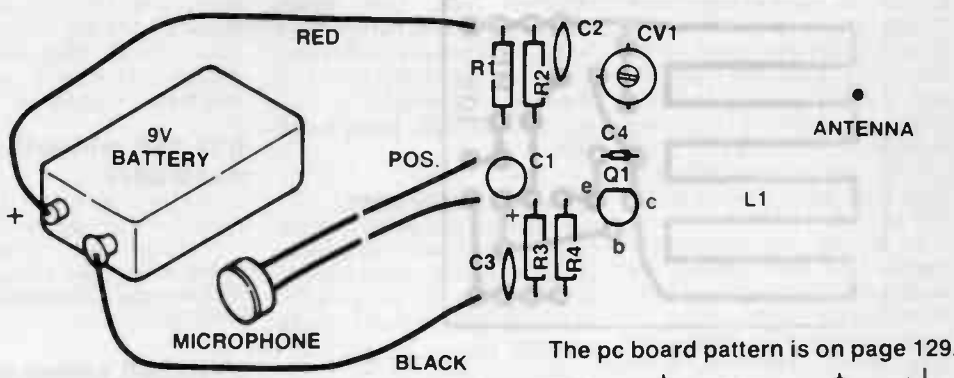
Since this is intended to be a short-range transmitter, only a small antenna is necessary. We found we got excellent results with an antenna about 12 mm long, made from a piece of stiff wire soldered onto the pc board at point A on our diagram. Longer antennas will increase the range considerably, with the best range being achieved with an antenna about 750 mm long. However, apart from being unwieldy, such an efficient antenna is unwise — if the transmitter is too powerful it will begin to interfere with other users of the airwaves.

Once the pc board is finished, you can connect up the external components. The red wire from the microphone is the positive lead and likewise the red wire from the battery clip is positive, as you might expect. We haven't included a switch in our diagram because it's almost as easy to simply

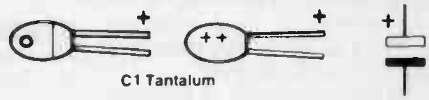


Resistors			
R1	Red	Red	Orange
R2	Green	Blue	Orange
R3	Brown	Red	Orange
R4	Brown	Black	Brown





The pc board pattern is on page 129.



disconnect the battery when you're not using the unit. Of course you can insert a switch in one of the battery leads if you prefer.

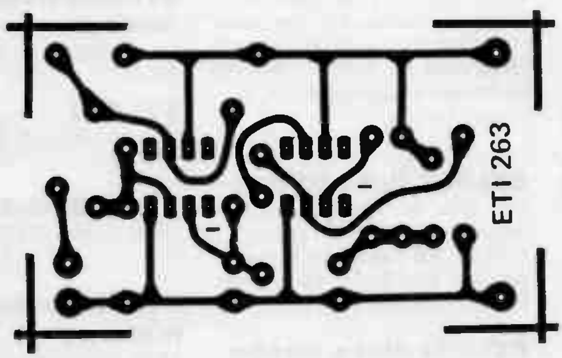
We didn't design any kind of box for this project. All we did was stick the pc board and battery down on a small piece of board with double-sided sticky pads. It works perfectly well naked like this, but if you like a neater appearance there's no reason why you shouldn't make up any kind of box you like for it. Only don't enclose the antenna inside a metal box, because then it won't radiate very well!

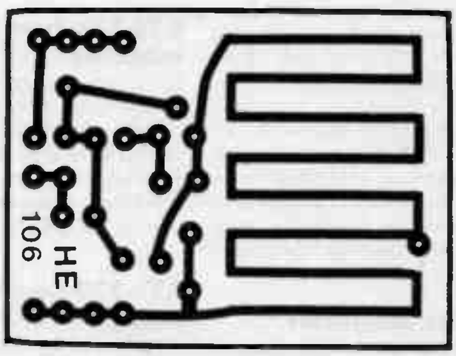
Setting up

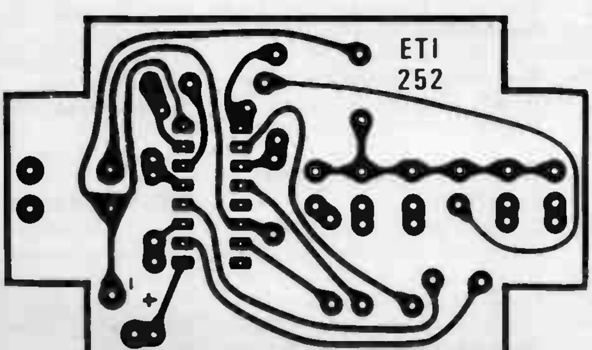
Tune your radio receiver to a point on the FM dial where there are no broadcast stations close by. With the radio microphone fairly close to your receiver and turned on, use a small screwdriver to adjust the variable capacitor CV1. At some point you should hear a terrible 'howl' through the receiver. The radio mic is now transmitting on the same frequency that your receiver is tuned to, and is causing acoustic feedback because it is too close to the loudspeaker. So turn the receiver off, leave CV1 set in the same position and move the receiver away from the microphone. Now turn your receiver on again and get a friend to speak at the microphone. For complete clarity you may need to alter the tuning of your receiver slightly.

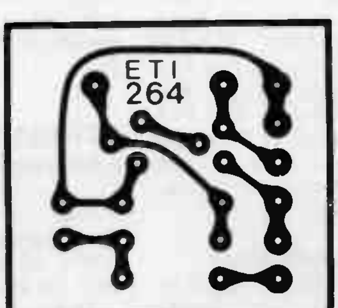
The unit consumes power all the time it is on, whether there is any sound being transmitted or not, so batteries don't last too long. You can expect a small 9 volt battery like the one in our photograph to last about ten hours. Use a bigger battery or a 9 volt power supply if you want continuous use for longer periods.

PCB's









SHOP AROUND

THE COLLECTION of simple projects for this book were selected from issues of Electronics Today, Hobby Electronics and Project Electronics based on interest and popularity over the period since they were first published. If you're a beginning hobbyist, you should find amongst this selection plenty to hold your interest or do a job you require.

In general, the components specified for these projects are widely available from most electronics retail stores, many of whom also stock the printed circuit boards. However, it is always wise to make a 'phone call first to check they have supplies to suit your needs.

If you're the sort of hobbyist who prefers to build projects 'from scratch', including making your own pc board, you could try the following stores (apart from the kit suppliers also mentioned): In Sydney — **Sheridan Electonics** in Redfern, **Radio Despatch Service** in Broadway, **David Reid** and **Avtek** in York St ('Silicon Alley'), **Geoff Wood Electronics** in Rozelle and **Tomorrow's Electronics** in Gosford.

In Melbourne — **Magraths, Ellistronics** and **Radio Parts**, all in the city, **Truscotts** in South Croydon, **Kalex** in Heidelberg and **Billco** in Dandenong.

In Brisbane — **Delsound**, and in Perth — **Altronics**. All over Australia you can try **Tandy** or **Dick Smith** stores.

If you've got a well-stocked 'junk box' or component shelves and only need the odd bit plus pc boards, the following firms can probably supply most, if not all, the pc boards for the projects published in this book: In Sydney — **RCS Radio** in Bexley and **Jaycar** stores. In Melbourne — **All Electronic Components** and **Ellistronics** in the city, **Rod Irving Electronics** in Northcote and **Billco** in Dandenong.

ETI-464 amplifier

Components for this project should be widely available off the shelf. The '380 IC power amp is made by National Semiconductor (LM380), Fairchild (μA380) and others. For kits, try **Dick Smith stores, Rod Irving Electronics** in Melbourne, **Altronics** in Perth and **Jaycar** in Sydney. You might also try **All Electronic Components** in Melbourne.

ETI-465 loudhailer

This project employs the ETI-464 amplifier project, so the previous item applies in regard to that. However, kits might be obtained from **Dick Smith stores, Altronics** in Perth or **Rod Irving Electronics** in Melbourne. The speaker specified (8-224) is distributed by **Benelec** in Sydney, **P.O. Box 21, Bondi Beach 2026.**

ETI-262 intercom

All parts for this project should be obtainable over the counter at almost any electronic components supplier. So far as we're aware, nobody actually stocks complete kits.

ETI-266 crystal sets

Most parts for these projects can be obtained from any component supplier, with the exception of the tuning gang. However, try **All Electronic Components** in Melbourne or **Sheridan Electronics** in Sydney.

ETI-497 loudspeaker protector

Kits for this project may be obtained from **Altronics** in Perth, **Jaycar** in Sydney, **Rod Irving Electronics** and **All Electronics Components** in Melbourne. Parts are generally obtainable from most component suppliers.

ETI-327 turn/hazard flasher

This project uses commonly available components and parts should be generally available. For kits, try **All Electronic Components** in Melbourne.

ETI-321 fuel level monitor

Even the case and piezoelectric buzzer used in this project are common items, so constructors should have little difficulty in assembling this project. Try **All Electronic Components** in Melbourne for a kit.

ETI-323 headlight delay

All components for this one are 'bog-standard', as they say. Same comments as for the last two, but try **Rod Irving Electronics** in Melbourne for kits too.

ETI-1515 motor speed controller

Kits and components for this project should be widely available. Try **Dick Smith, Altronics** in Perth, **All Electronic Components** and **Rod Irving Electronics** in Melbourne.

ETI-570 infrared relay

Components should be generally available, including the infrared LED and detector. For a kit, try **All Electronic Components** in Melbourne, as well as **Rod Irving Electronics.**

ETI-258 minidrill controller

A must for the home hobbyist. Parts for this one are avilable everywhere, kits from **Rod Irving Electronics** and perhaps **All Electronic Components**, both in Melbourne.

ETI-1506 xenon bike flasher

'Short form' kits for this project may be obtainable from **Rod Irving Electronics** and perhaps **All Electronic Components**, both in Melbourne. The Philips potcores might be obtained from **George Brown Electronics** stores.

ETI-162 power supply

This project is widely available as a kit. Try: **Altronics** in Perth, **Dick Smith stores** everywhere, **Avtek** and **Jaycar** in Sydney, **Rod Irving Electronics** and **All Electronic Components** in Melbourne. As all parts are readily available, contructors assembling the project from scratch should experience few difficulties.

ETI-578 NiCad charger

Components for this project are widely available. The particular case used came from **David Reid Electronics** in Sydney. Try **All Electronic Components** in Melbourne for a kit.

ETI-568 flash trigger

For kits of this project, try **Altronics** in Perth, **Jaycar** in Sydney, **All Electronic Components** and **Rod Irving Electronics**, both in Melbourne.

ETI-574 disco strobe

This one is stocked by **Dick Smith stores** all over Australia and New Zealand, as well as **Rod Irving Electronics** in Melbourne. Components are usually widely available, too.

ETI-1516 sure start ignition

Components are generally obtainable, with the exception perhaps of the FX2243 potcore. However, the latter might be obtained from **Jaycar** and **Radio Despatch Service** in Sydney or **All Electronic Components** in Melbourne. You'll need two cup cores and a bobbin. The potentiometers with slotted shafts were obtained from **Dick Smiths**, but you can make your own by cutting a pot shaft very short and then cutting a slit across the shaft end with the hacksaw.

If you're after a kit, try **Rod Irving Electronics** and **All Electronic Components**, both in Melbourne.

ETI-918 photophone

Components for this are widely available, but nobody stocks a kit so far as we are aware.

ETI-607 sound effects

'Composite kits' of this series of projects are usually supplied, comprising a pc board, SN76488 IC and all the necessary bits to make any of the effects. Try the following firms for kits: **Altronics** in Perth, **All Electronic Components** in Melbourne, **Dick Smith stores** everywhere, **Electronic Agencies** in Sydney and **Rod Irving Electronics** in Melbourne.

ETI-261 fog horn

Parts for this project should be available at almost any electronic components supplier, but no kits are stocked, we understand.

ETI-264 siren

Same comments as for the previous project.

ETI-083 train controller

Same comments as for project 261.

ETI-043

Same comments as for project 261.

ETI-260 flasher

Same comments as for project 261

ETI-727 antenna matcher

Most parts should be available from electronic component suppliers, with the exception of the tuning gang. The latter might be hard to get these days, but try **All Electronic Components** in Melbourne or **Sheridan Electronics** in Sydney.

HE-106 radio mic

Kits for this project are stocked by **Altronics** in Perth, **Jaycar** in Sydney, plus **Rod Irving Electronics** and perhaps **All Electronic Components** in Melbourne.

High Speed Drill

Precision drill with 3 interchangeable collettes for sizes from .1mm to 2.4mm. 10,500 RPM 9-16V. Ref 20,000

$16.50

Deluxe Drill Set $69.00

Includes Drill, stand and flexible drive complete with 30 accessories in carrying case. Includes the High Speed Drill shown above plus the drill stand shown below. Ref 20100

Drill Stand

Stand for Ref 20,000 drill (above). Ideal for PCBs Ref 20,400

$12.50

Knockout Bargains

Save on SolderVac

Buy the best quality desoldering tool at the lowest price around. The incredible U.S. made Soldervac comes with teflon™ tip, powerful low inertia plunger and self lubricating trigger latch. Gets parts out of PCBs in seconds.

don't pay $12.50

only $8.50

Current/Polarity Checker

Incredibly versatile AC and DC checker works over the range 3.5V to 400V. Ingenious three LED system indicates AC (both lights), DC positive (plus light) DC negative (minus light). Use it in the home, the car and the workshop.

don't pay $6.95 **$3.95**

Centronics Plugs at Knockout Prices

Our opposition are asking around $20.00 for these plugs. Come to Sheridans for a Knockout deal!!

Amphenol type 57/303/60 solder spill type **$9.50**

Ribbon cable type **$9.70**

Jawbreaker purchase!!

Top quality English Made by SAE. 10 way .1" DIL DIP switch. Special top quality pushbutton type. At a punchup price!! $1.30 each 10+ $1.20

Less than 1/2 price

The Ultimate joystick for the VIC-20 and Atari

The incredible Pointmaster is truly the finest Joystick on the market and will add incredibly to your enjoyment of video computer games. Just look:

- High speed thumb trigger
- Unique hand grip (as on actual aircraft)
- Self centring
- Long 150cm cord.

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Illuminated Pushbutton

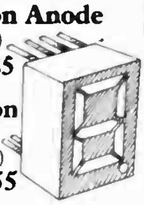
These superbly made IMO pushbuttons are perfect for car and other alarm situations. SPDT momentary action with 12V long life globe. Available in red, green or yellow lense. Others are asking $15.00. Put them in the losers corner!!

only $8.95

Hewlett Packard Opto

HDSP-5301 .56" Common Anode
Equivalent to FND507 (but better)
only $2.05 each, 10+ $1.85

HDSP5303 .56" Common Cathode
equivalent to FND500 (but better)
only $1.70 each, 10+ $1.55



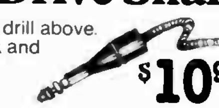
HP 5082-7730 .3" common anode
equivalent to MAN71, DL707)
only $1.50 each, 10+ $1.35

HP 5082-7740 .3" common cathode
equivalent to MAN74, DL704 etc
only $1.50 each, 10+ $1.35

Flexible Drive Shaft

Suits the high speed drill above. Complete with chuck and colletes. Ref 20,700

$10.95



NEW! Precision High Speed Model

Capacity to 3.5mm, 9 to 18 volts. 20,000RPM. A really superb drill that will give years of use.

$24.00

Drill Set

This fantastic drill set includes the high speed precision drill shown above plus a wide range of 15 accessory drills, brushes and grinders. Ref 40,100

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Heavy Duty Stand

Suits precision high speed drill. Perfect for any hobbyist work. Ref 40,400

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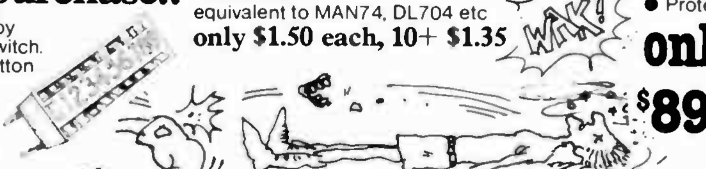
Modutec Car Alarm

This is the most powerful and comprehensive car protection system on the Australian market we have seen. Compare the features. Then you'll know its the best.

- Automatic or Manual start
- When tripped it sounds horn and disables ignition system
- Dash mounted warning light
- Variable entry and exit times
- 12 months warranty
- Protects accessories.

don't pay $129.00!!

only $89.00



Relay Bargain

New Shipment of these superb miniature PC mount relays. Both types have SPDT contacts. Rated at 1A/125V and 2A/30V. Two types: 5V/75ohm coil and 12V/400ohm coil. Quality at a really low price.

$1.75 each $1.50 ten up

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minitune

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Specification

Function	F S D	Resolution	Accuracy
Voltage (d.c.)	20V	10mV	0.5% 1 digit
	200V	100mV	0.5% 1 digit
Resistance	200Ω	100mΩ	0.5% 1 digit
	20kΩ	10Ω	0.5% 1 digit
R P M	20,000 r.p.m.	10 r.p.m.	1% 3 digit
Dwell	90°	0.1	2% 3 digit

Following the spectacular success of the DP2010 Digital Multimeter kit, we now have an ENGINE ANALYSER KIT! But the spectacular thing is the price! It is ACTUALLY CHEAPER than the DPM 05 Display and Case!! The Minitune will measure voltage, resistance (down to a very low range), RPM and Dwell Angle.

Cat. KJ-7012 $42.95

TEST LEADS TO SUIT ONLY $2.95

low cost IC inserters AND EXTRACTORS

Up until now these have cost a fortune!!

Features:

- CMOS SAFE conductive plastic
- Exclusive bent pin alignment guides in handle. 8 to 40 pins.
- Ground strap can be connected.
- One hand operation.

INSERTERS

Cat. No	Model	Description	
TH1810	CIT820	8 – 20 pin	$5.95
TH1812	CIT22	22 pin	$6.50
TH1814	CIT2428	24 – 28 pin	$6.95
TH1816	CIT3640	36 – 40 pin	$8.95

EXTRACTOR

Deceptively simple looking device. One piece metal construction. 8-40 pins

TH1818 ET40

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FANTASTIC Multimeter

- FUSE/DIODE PROTECTED!
- 4mm BANANA SOCKET PROBES!
- BIFURCATED SELECTOR SWITCH CONTACTS!
- ABS IMPACT–RESISTANT CASE!
- LARGE! MEASURES 90(w) x 135(h) x 45(d)mm

SPECIFICATIONS:

DC		AC	
	0 – 0.25		0 – 10
	0 – 10		0 – 50
	0 – 50		0 – 250
	0 – 250		0 – 1000
	0 – 1000		AT 9,000 ohms/volt
	AT 20,000 ohms/volt		

RESISTANCE	DC CURRENT
0 – 5K	0 – 0.05
0 – 50K	0 – 25
0 – 500K	0 – 250mA

dB: 20 to +22dB

BATTERY CHECK FACILITY: AA, C & D CELLS

ACCURACY: DC +/–3% F.S. AC +/–4% F.S. OHMS +/–3%

BANANA PLUG PROBES AND BATTERY INCLUDED

This is an unbelievable meter bargain. Normally this unit would sell for around $25. Japanese made quality.

Cat. QM-1005 $17.95

$17.95

LOW COST DIGITAL MULTIMETER KIT

ONLY $45

Ref. EA March 1983

Almost everyday we are asked for a multimeter kit. Up until now we thought that it was just not worth it considering the fine low cost built up units available. The DP2010 changed all that.

This kit, fully imported from the UK uses the famous DPM 05 custom LCD/Voltmeter to achieve phenomenal accuracy at very modest cost!

All parts are included to complete the meter including an attractive and colourful front panel (a 9V battery is required)

Set of test probes to suit $2.95

Probe to suit Cat. WT5312 ONLY $2.50

Eveready 216 (red) 9V Battery Cat. SB2370 ONLY $1.40

AMAZING VALUE

DP2010 kit Cat. KJ7010 ONLY $45

AC VOLTAGE AND CURRENT RANGES

When S3a selects a.c. functions the output from either the voltage attenuator or current shunts is fed through C1 to remove any d.c. component

SPECIFICATIONS

Function	f.s.d.	Resolution	Accuracy	Protection
Volts (d.c.)	2V	1mV	1% ± 1 digit	500V for
	20V	10mV	1% ± 1 digit	one minute
	200V	100mV	1% ± 1 digit	
	500V	1V	1% ± 1 digit	
Current (d.c.)	2mA	1uA	1% ± 1 digit	1A/250V
	20mA	10uA	1% ± 1 digit	
	200mA	100uA	3% ± 1 digit	
	2000mA	1mA	5% ± 1 digit	
Volts (a.c.)	2V	1mV	2% ± 5 digit	500V for
	20V	10mV	2% ± 5 digit	one minute
	200V	100mV	2% ± 5 digit	
	500V	1V	2% ± 5 digit	
Current (a.c.)	2mA	1uA	2% ± 5 digit	1A/250V
	20mA	10uA	2% ± 5 digit	
	200mA	100uA	4% ± 5 digit	
	2000mA	1mA	7% ± 5 digit	
Resistance	2K	1	1% ± 1 digit	260V
	20K	10	1% ± 1 digit	r.m.s.
	200K	100	1% ± 1 digit	
	2000K	1K	1% ± 1 digit	
Diode Test	2V	1mV	1% ± 1 digit	260V r.m.s.

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3¼" Square Super Horn for PA's, Disco's etc. Very efficient. Around 50Wrms equivalent capacity

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Hi Fi version of the PH 1005A. Slightly less sensitive but a smoother response

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