TOP PROJECTS

FROM ELECTRONICS TODAY INTERNATIONAL

VOLUME 5 PRICE $3-00

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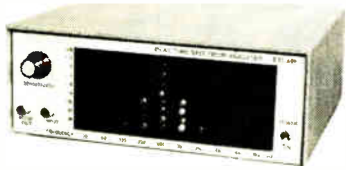

489 Spectrum Analyser

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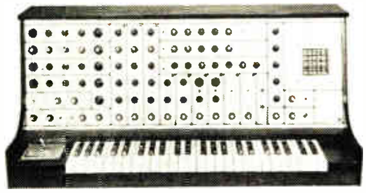

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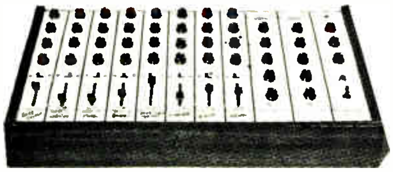

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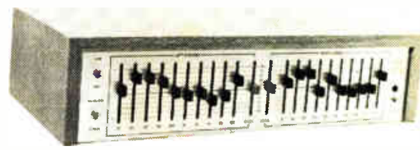

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- 10 adjustable centre frequency controls per channel.
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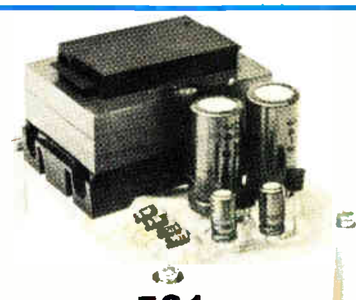

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Contents

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Top Projects Vol 5 was printed in 1978 by Wilke and Company Limited, Melbourne.
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TOP PROJECTS VOL 5 is a collection of some of the most popular constructional projects recently published in Electronics Today International.
New readers of our magazine, readers who missed a particular issue or anyone just developing an interest in constructing electronic equipment will appreciate this book.
The majority of these projects were designed, under contract to Electronics Today International, by Barry Wilkinson of Nebular Electronics Pty Ltd.
All projects in this book have been built (as prototypes by the designers and also by innumerable readers of Electronics Today International) and any known errors in the original published projects have been corrected.

an ELECTRONICS TODAY publication

Bucket Brigade Audio Delay Line

This audio delay line uses the latest in IC technology, the 'Bucket Brigade' to give a simple unit suitable for various effects. However this is a project for the experimenter as full details of how to use it for any particular use are not given.

ANYONE WHO has been in an anechoic chamber will appreciate the need for some reverberation. In music the use of artifical reverberation or echo can compensate for a 'dead' room or create a new effect. Up until recently reverberation was normally obtained by mechanical means such as a spring or plate which is vibrated or excited by an electrical signal; a pickup elsewhere on the plate or spring receives the delayed signal. Due to the nature of resonances in springs, multiple echos occur giving the effect of reverberation.

A single echo is obtainable by using a tape loop, recording the signal on one head and playing back through a second. The distance between the heads and the tape speed determines the delay. Echo can also be obtained acoustically by a long tunnel with a microphone and speaker.

When the price of digital ICs started to come down a number of digital delay lines were developed. These used an A–D (analogue to digital) converter, a long shift register and finally a D–A converter. To accomodate the wide dynamic range required very good, fast, A–D, D–A converters along with a large shift register. Even with the low price of ICs these units still cost around $500.00 or so (this is the main reason we have not published one as a project).

A number of years ago several IC manufacturers started playing with a 'digital' delay line which works by storing an analogue voltage on a capacitor and then transferring this voltage to another and then successive capacitor. This is accomplished by switching FETs on and off under digital control. The circuit became known as a bucket brigade and this name has stuck.

The IC we have chosen is the MN3001 which is a dual 512 step device. This was chosen mainly for its availability through Elcoma. Brief specifications of other devices we know about are given below. All the devices except the SAD 1024 (Reticon) are handled by Elcoma.

Uses of BBD

Variable or fixed delay of analog signals
Reverberation
Echo
Tremolo, vibrato, flanging or chorus effects
Voice control of tape recorders
Time compression of telephone conversations
Voice scrambling

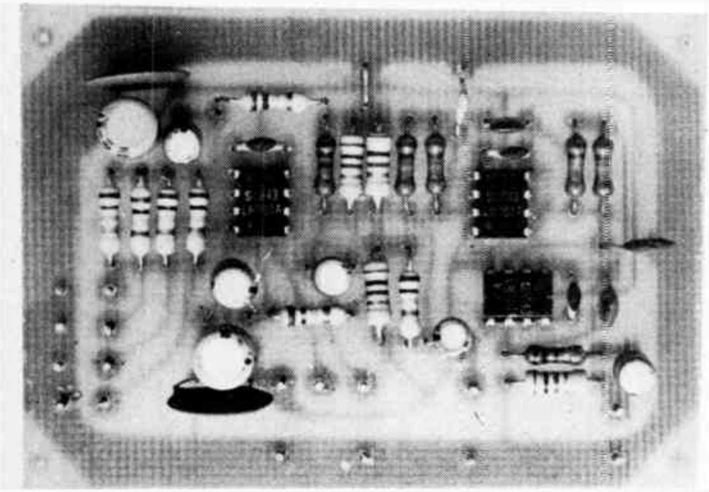
Construction

As we are describing no mechanical arrangement our description of construction is limited to the assembly of the PC board. It is recommended that a socket be used for the BBD IC as it is an expensive MOS device. The inputs are protected but it should be handled with care. The same care should be taken with the CMOS IC but as a socket costs more than the IC it cannot be recommended!

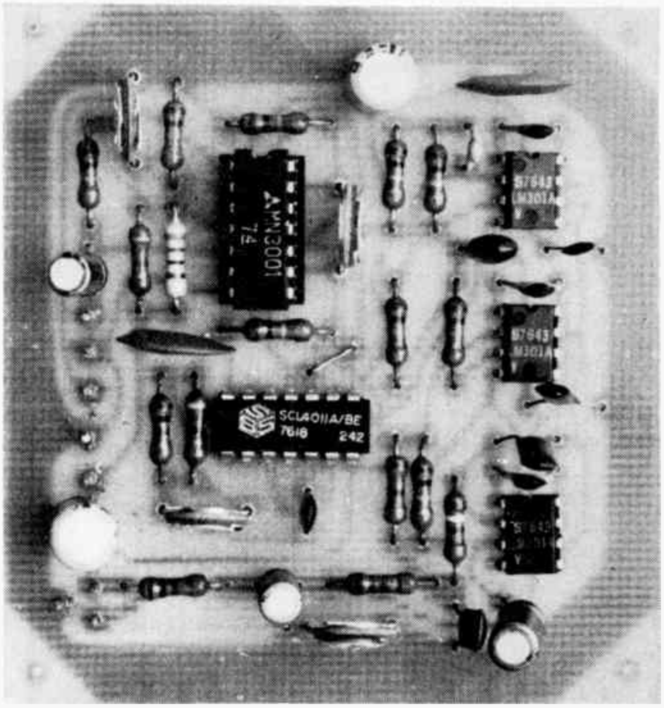
The interconnection between the pc boards depends on the effect needed.

SPECIFICATION – ETI 450

Maximum input < 3% distortion		2.0V RMS
Delay time internal oscillator		6 – 30ms
Frequency response		see graph
Distortion 1V in 1kHz		0.3%
Signal to noise re 2V input		67dB
Supply current (A)	+ 5V	6mA
	– 15V	9mA
(B)	+ 5V	6mA
	–15V	6mA

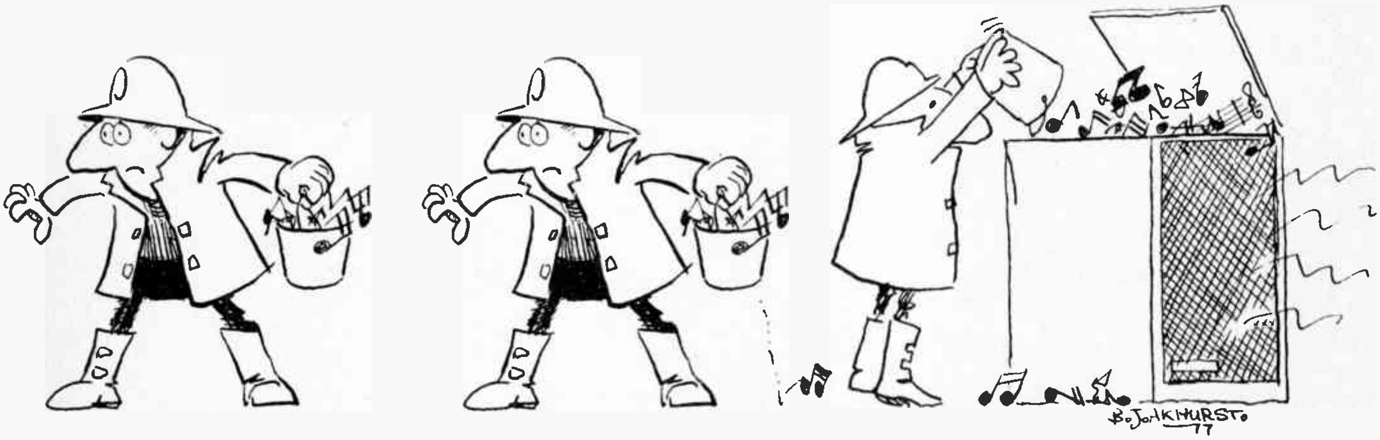


The mixer, filter board ETI 450B.



The bucket brigade board ETI 450A.

The printed circuit board layouts for this project are on page 113.



Bucket Brigade Audio Delay Line

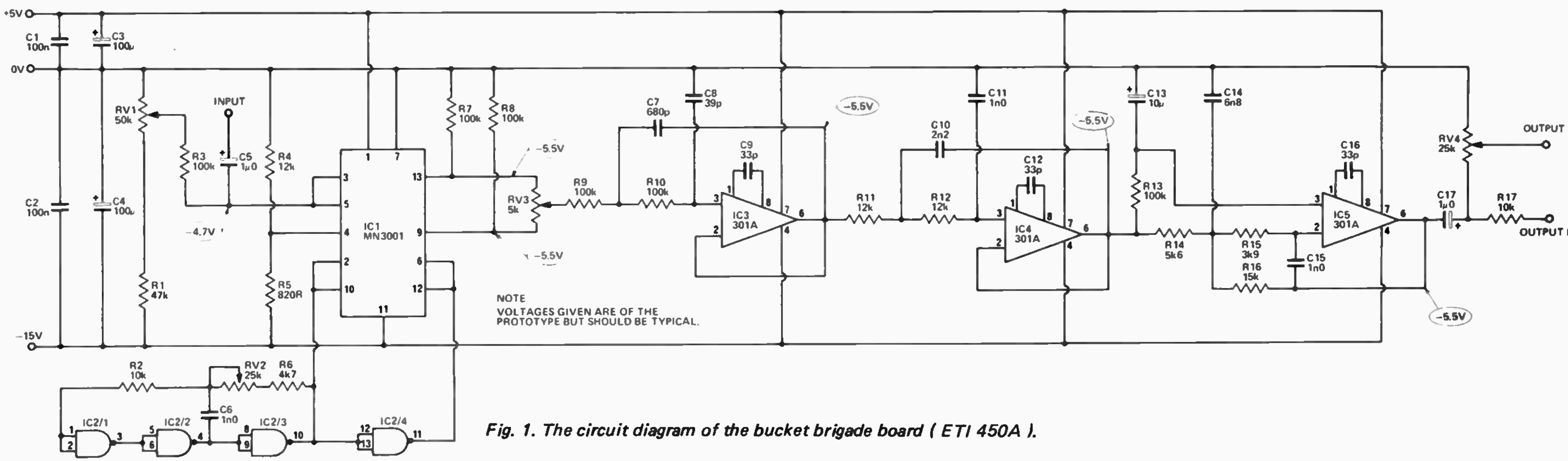


Fig. 1. The circuit diagram of the bucket brigade board (ETI 450A).

HOW IT WORKS – ETI 450

The bucket brigade device is an analogue delay line which samples the input waveform at an instant in time and stores this voltage on a capacitor. As we need more than just one point on the waveform we sample the input ât least 3 times faster than the highest frequency required. A single capacitor cannot store more than one voltage at one time and so a series of capacitors is used. Before the second sample is taken the energy in the first capacitor is transferred to the second capacitor thus freeing the first to sample the input again. Then before the third sample the energy in the second capacitor is transferred to the third. The first into the second and the first again samples the input. This process continues on each sample with the energy in each capacitor being transferred to the next. Eventually we run out of capacitors and this then becomes the output. The number of capacitors, or stages, and the sample (clock) frequency determine the time it takes an input sample to appear at the output.

In the device we have used there are 512 stages in each of two identical and independent sections. The internal circuit diagram of the initial part and of the output stage is shown below (there are over 1000 capacitors and 2000 FETs in the IC!)

The transfer of energy is done using FETs which are controlled by the two clock lines CP1 and CP2. These are complementary square wave signals. Using a 40 kHz signal the input is sampled every 25µs then 'remembered' and transfered every 25µs. On the output, from stage 509 on, the signal is divided into two paths, one having an extra stage. This is needed as the signal on the output is only there for half the 25µs period. By adding these two out-of phase outputs a continuous outpu results.

All of this transferring of energy doe: however waste energy and the output is of à lower amplitude than the input. In the MN3001 it is about 8.5dB lower. To increase the delay it is normal to connect two sections (or more if needed) in series. However the output has then twice the loss and even with an intermediate amplifier this results in a lower signal to noise ratio.

A second method of obtaining a large delay is to run the two sections in parallel with each sampling on alternate half cycles of the clock wave-form giving effectively two sampling periods per clock pulse. This allows the clock frequency to be halved for the same frequency response giving twice the delay with only one attenuation loss. However as you never get anything for nothing the lowering of the clock frequency increases the low frequency energy content of the noise, making the filter do more work.

Getting back to the circuit diagram we see that the input signal is coupled to the input of both halves of the BBD with dc biasing being provided by RV1. IC2 is used as an oscillator with frequency adjustable from about 20kHz to 90kHz giving delays of 6-30 ms. The output of IC2/3 is inverted by IC2/4 giving the two complementary clocks required by the BBD. The outputs of the BBD are mixed with RV3 being used to remove the clock frequency before the 6 pole filter IC2 – IC4 removes all the other hash generated by the clocking. The first two sections of this filter have unity gain while the third stage has a gain of 8.5dB to compensate for the loss in the BBD. These gains are of course below the cut off point!

The second board used is simply a mixer and 4 pole filter which can be used together or in separate parts of the unit. Due to the sampling done by the BBD, the frequency of an input signal must not exceed the clock frequency otherwise it will appear at the output at some other frequency lower than the clock frequency. This is due to the BBD input circuit sampling almost corresponding points on successive cycles of the input waveform. For this reason the 4 pole filter is used before the BBD.

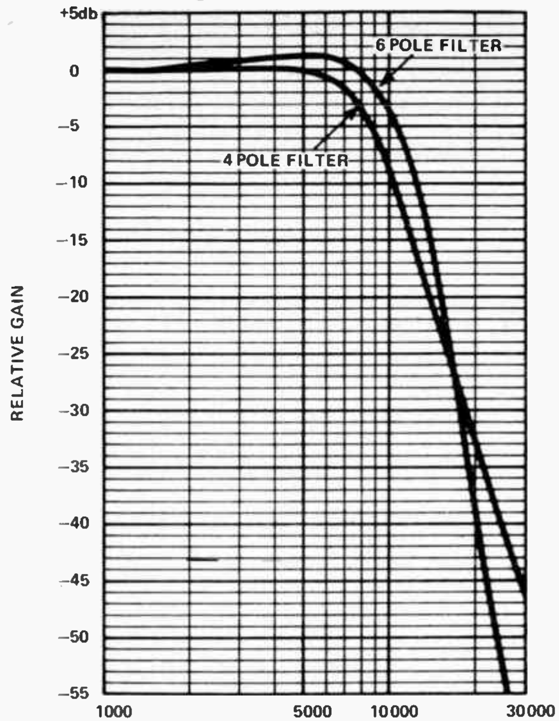


Fig. 3. The frequency response of the two filters. The overall response is approximately the sum of these two filters provided the clock frequency is at least 20 kHz.

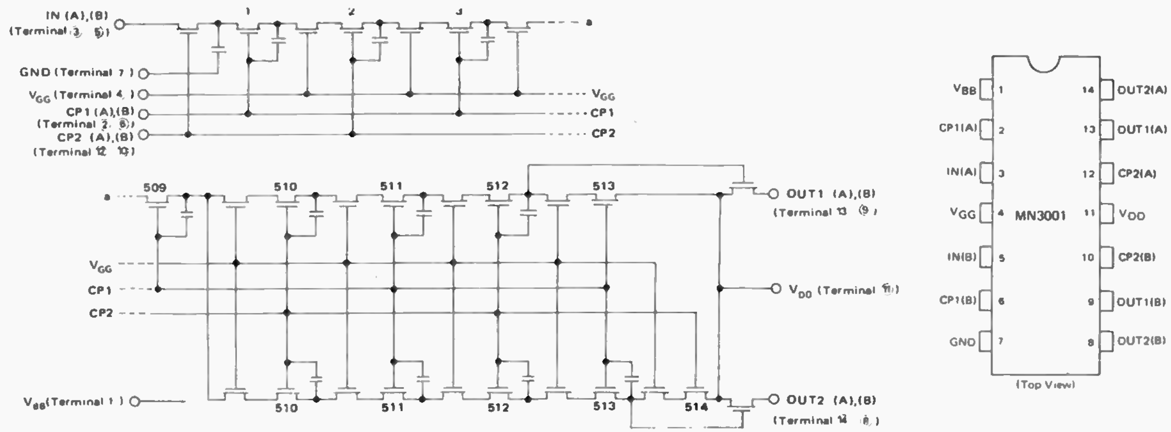
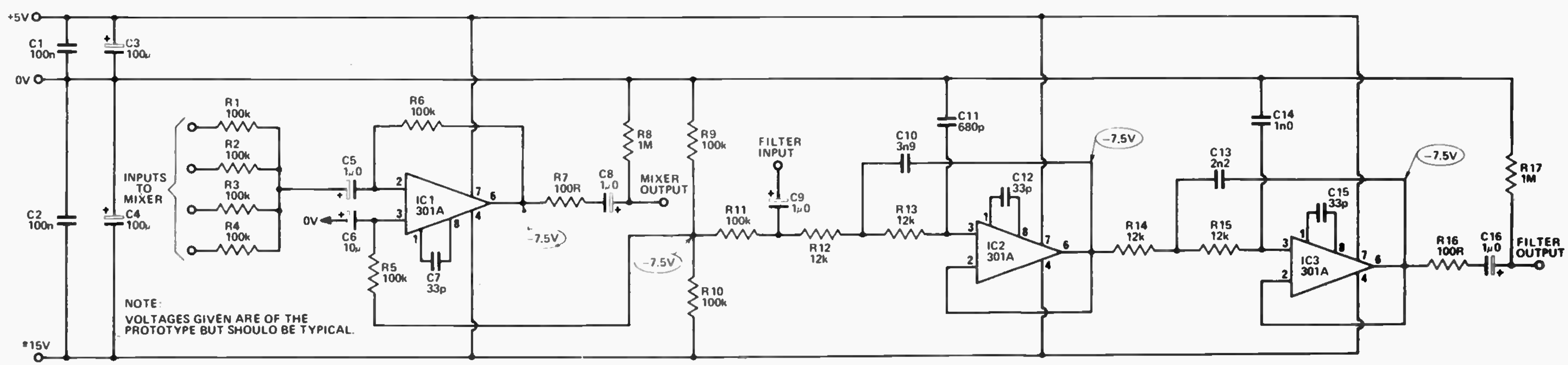


Fig. 2. The internal circuit of the MN3001 showing the first three and last four stages.

TYPE	MN 3001	MN 3002	MN 3003	MN 3004	TDA 1022	SAD 1024
NO OF STAGES	2 X 512	512	2 X 64	512	512	2 X 512
DELAY (ms)	1–25	1–25	0.16–3.2	2.5–3.2	0.5–50	0.2–170
INSERTION LOSS (dB)	8.5	8.5	3.5	1.5	4.0	
DISTORTION (%)	0.4	0.4	0.5	0.4	0.4	1.0
SIGNAL TO NOISE (dB)	70	70	> 68	85	74	> 70
SUPPLY VOLTAGE (V)	+5, –14, –15	+5, –14, –15	–8, –9	–15	–15	–15

Fig. 4. Summary of the bucket brigade ICs which we know exist.

Fig. 5. The circuit diagram of the mixer, 4 pole filter board (ETI 450B).



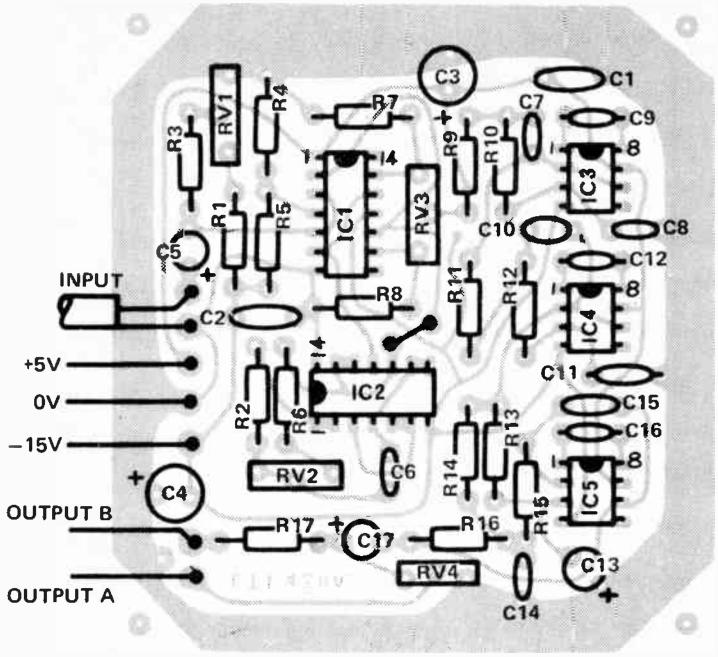


Fig. 6. The component overlay of the bucket brigade board.

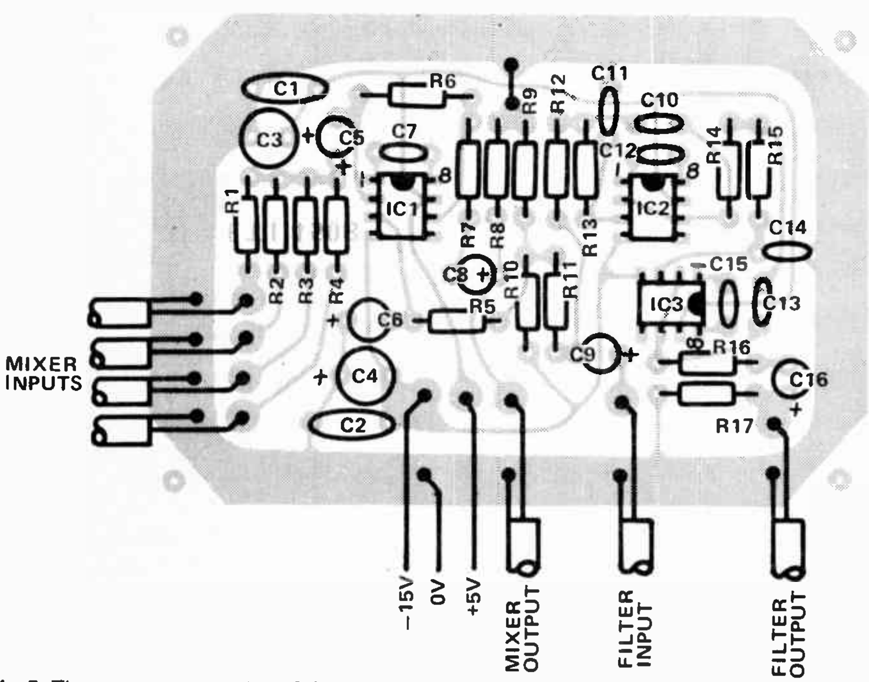


Fig. 7. The component overlay of the mixer — filter board.

PARTS LIST – ETI 450A

Resistors all ½W 5%

R1 . . . . . . 47k
R2 . . . . . . 10k
R3 . . . . . . 100k
R4 . . . . . . 12k
R5 . . . . . . 820R
R6 . . . . . . 4k7
R7–R10 . . . 100k
R11,12. . . . 12k
R13. . . . . . 100k
R14. . . . . . 5k6
R15. . . . . . 3k9
R16. . . . . . 15k
R17. . . . . . 10k

Potentiometers

RV1 . . . . . 50k trim
RV2 . . . . . 25k trim
RV3 . . . . . 5k trim
RV4 . . . . . 25k trim

Capacitors

C1,2 . . . . . 100n polyester
C3,4 . . . . . 100µ 25V electro
C5. . . . . . . 1µ0 25V electro
C6. . . . . . . 1n0 polyester
C7. . . . . . . 680p ceramic
C8. . . . . . . 39p ceramic
C9. . . . . . . 33p ceramic
C10 . . . . . . 2n2 polyester
C11 . . . . . . 1n0 polyester
C12. . . . . . 33p ceramic
C13. . . . . . 10µ 25V electro
C14. . . . . . 6n8 polyester
C15. . . . . . 1n0 polyester
C16. . . . . . 33p ceramic
C17. . . . . . 1µ0 25V electro

Semiconductors

IC1 . . . . . . MN3001
IC2 . . . . . . 4011 (CMOS)
IC3–IC5 . . . 301A

Miscellaneous

PC board ETI 450A

PARTS LIST – ETI 450B

Resistors all ½W 5%

R1–R6. . . . 100k
R7 . . . . . . 100R
R8 . . . . . . 1M
R9–R11 . . . 100k
R12–R15 . . 12k
R16. . . . . . 100R
R17. . . . . . 1M

Capacitors

C1,2 . . . . . 100n polyester
C3,4 . . . . . 100µ 25V electro
C5. . . . . . . 1µ0 25V electro
C6. . . . . . . 10µ 25V electro
C7. . . . . . . 33p ceramic
C8,9 . . . . . 1µ0 25V electro
C10 . . . . . . 3n9 polyester
C11 . . . . . . 680p ceramic
C12. . . . . . 33p ceramic
C13. . . . . . 2n2 polyester
C14. . . . . . 1n0 polyester
C15. . . . . . 33p ceramic
C16. . . . . . 1µ0 25V electro

Semiconductors

IC1–IC3 . . . 301A

Miscellaneous

PC board ETI 450B

Adjustment

RV1 is used to set the bias voltage. If an oscilloscope is available look at the output of the board while feeding in a sine wave signal. Adjust RV1 to allow the maximum input signal without clipping. RV2 adjusts the delay while RV4 sets the output level to compensate for differences in the loss of the BBD sections. RV3 is used to remove the clock frequency from the output. If an oscilloscope is available look at the wiper of RV3 and adjust to give the smoothest output. The switching transients at this point are very high but these are removed by the filter.

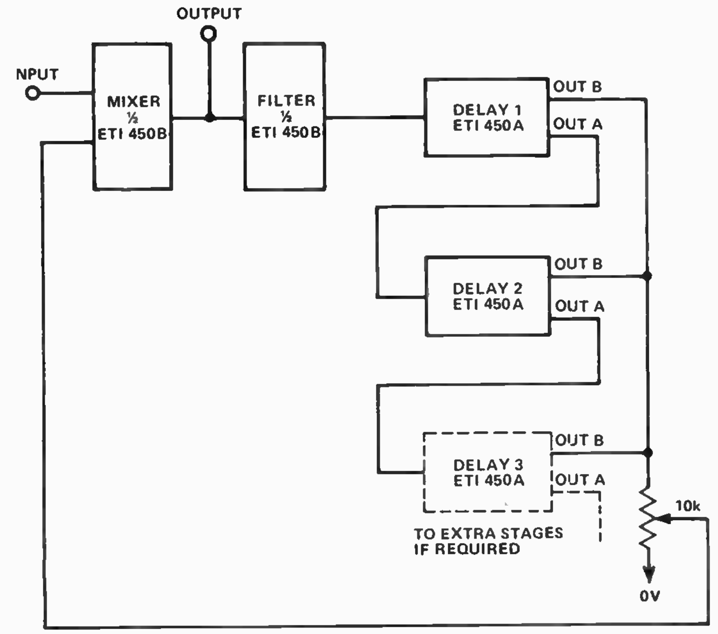


Fig. 8. The interconnection for reverberation.

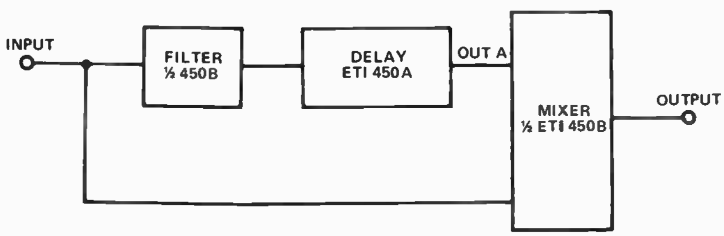


Fig. 9. Connections for a single echo. With a short delay this becomes a phaser.

Reverberation

If the audio signal is fed via a mixer into the delay line and its output fed back into the mixer we have a feedback system which will repeat a single sound many times. This is reverberation. If several different delays are used the effect will seem more natural. With all feedback systems if the sum of all the delayed outputs exceeds the original sound uncontrolled oscillations will result. This is similar to howl-round in PA work and careful adjustment is needed if long reverberation times are required.

Echo

This is similar to reverberation except the delayed signal is not fed back to its own input. A single echo only results (from a single delay) and it can be of any amplitude in relation to the original signal.

Phasing (Flanging)

By varying the delay times and by mixing in the right proportions total cancellation of some frequencies can occur. Now if the clock frequency is made variable a phasing or flanging effect occurs. A variable clock can be made by replacing potentiometer RV2 by an LDR and illuminating it with a globe the brilliance of which is controlled (try a 555 timer). We must leave details of this to the individual constructor.

HOWL-ROUND STABILIZER

Feedback problem in halls can be corrected by the use of this clever gadget.

ANYONE WHO HAS USED a microphone in public address work has come across problems with feedback. These are caused by the level of sound reaching the microphone from the speaker approaching or exceeding that from the person originating the sound. As the reflected sound approaches the level of the original signal, the sound becomes distorted or 'coloured', then audible ringing occurs and finally complete oscillation or howl-round occurs as the reflected sound exceeds the level of the original signal.

The most effective method of eliminating this problem in most cases is to use the correct location for the speakers and the correct choice of microphone. Also the use of the microphone is important so if you are in charge of a sound system don't be afraid to tell the singer or speaker how to use the microphone as a good performer will take advice.

However in certain environments the most effective use and selection of microphone/speakers does not help the problem of feedback. These are the halls and rooms which have little sound-absorbing material on the walls and are very 'live'. If a frequency response curve is drawn for such a room it will be found that there are many peaks and troughs, normally only 4 or 5 Hz apart, along with perhaps major resonances.

The printed circuit board layout for this project is on page 114.

Solutions

There are various electronic devices which have been developed to deal with this problem, the main ones being the graphic equalizer, the variable notch filter and the frequency shifter. The first two (especially the notch filter) are ideal for eliminating major resonances. These however also alter the frequency response of the original sound. They can also help if the offending 'echo' is actually a direct path and not dependent on the room (i.e. if the speakers are behind the microphone). The other method, frequency shifting, is described here.

With a frequency shifter the echo signal is of slightly different frequency on each path round the loop and cannot directly reinforce itself so that while on the first echo it may strike a room resonance the second time it will probably be in a null. This tends to even out the frequency response of the room and allows 5 to 8 dB higher levels to be used in the average room. Also the onset of howl-round is not as dramatic as with the conventional system and the distortion which normally occurs below the howl-round level is not as noticeable. The system does not however do a great deal for howl-round not associated with room resonances.

Only a small shift is normally required and it does not matter if it is an increase or a decrease. We chose to increase the frequency by about 5 Hz as it is easier to tell if a vocalist is flat rather than sharp. As the frequency response of the unit is good it is suitable for vocal work as well as general public address use. The frequency shift and the slight amplitude modulation cannot be detected by most people.

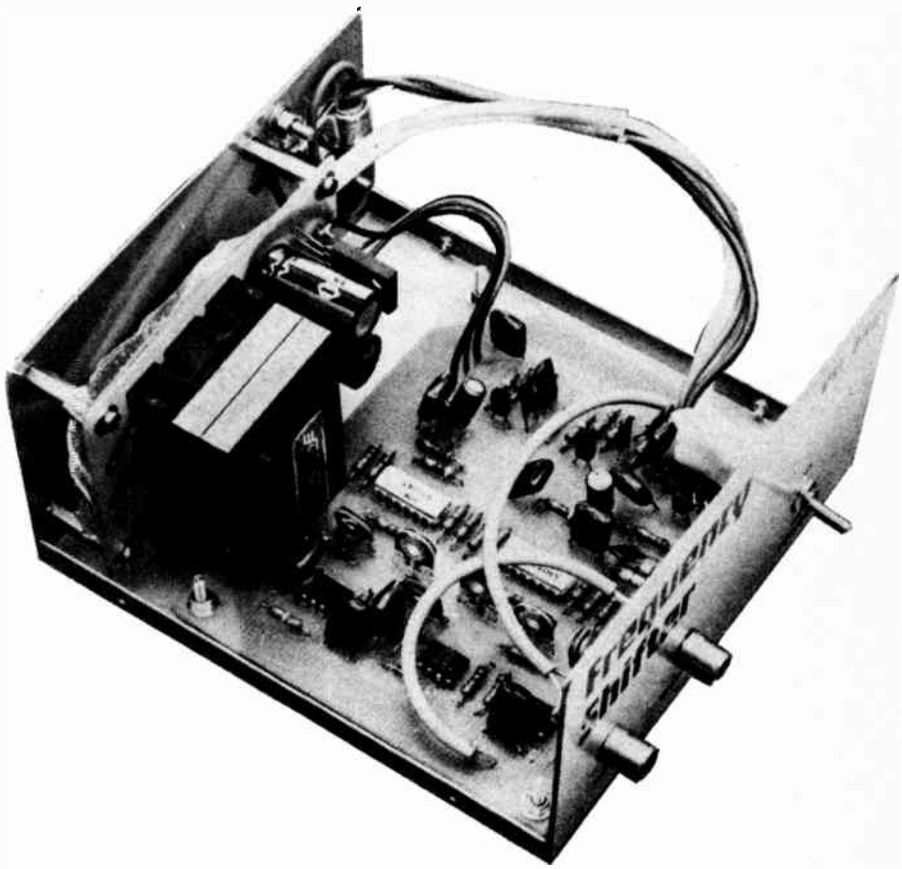
Alignment

Equipment needed — a sensitive AC voltmeter (100 mV or less) or preferably an oscilloscope and an audio oscillator.

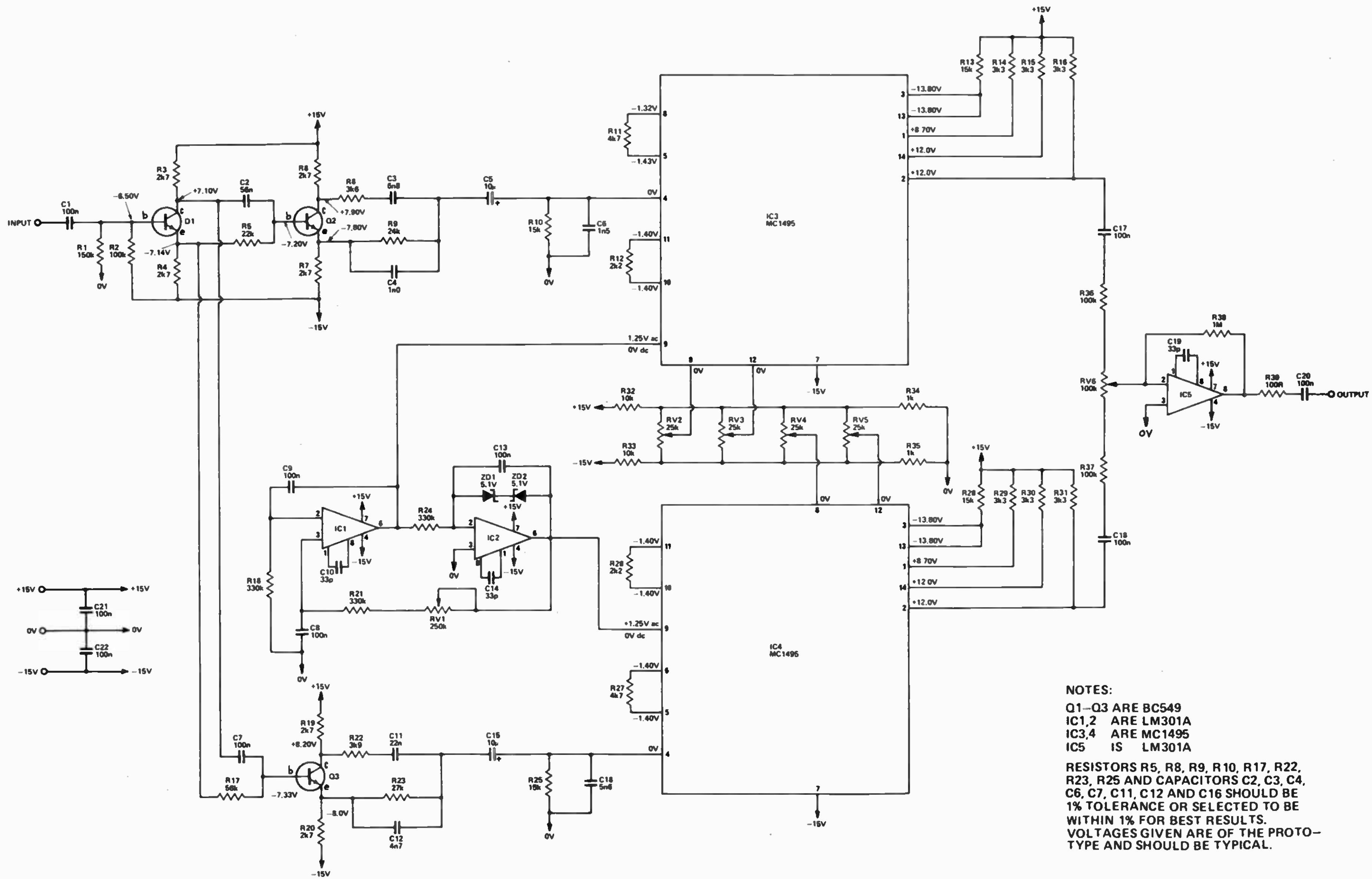
1. Check the output of the 5 Hz oscillator and adjust RV1 until it stops. If it cannot be completely stopped, try a link across C9.
2. Apply a signal of about 1 – 2 V amplitude at about 1 kHz to the input and measure the output of IC3 at pin 2. (If your meter does not reject DC, measure at the junction of C17 and R36). Adjust RV3 to give the minimum output.
3. Measure the output of IC4, pin 2 (or the junction of C18 and R37) and adjust RV5 for minimum output.
4. Measure the output of the 5 Hz oscillator on pin 6 of IC1 and adjust RV1 until it starts, then adjust to give about 1.25 V RMS.
5. With no input signal, measure the output of IC3 (or the junction...) and adjust RV2 for minimum output.
6. Measure the output of IC4 (or...) and adjust RV4 for minimum output.
7. If an oscilloscope is available, monitor the output with a 1 – 2 V input signal and adjust RV6 to give the minimum amplitude modulation. Alternatively, by using an amplifier and speaker, RV5 can be adjusted by ear. The unit is now set up.

SPECIFICATION — ETI 486

Frequency shift	5kHz upwards
Maximium input voltage	3V
Frequency response +½dB, −3dB	30Hz – 20kHz
Signal to noise ration re 3V output	70 dB
Distortion @ 1kHz, 2V out	0.25%
Amplitude modulation	100Hz – 10kHz < 1dB
Phase shift network 50Hz – 20kHz	$90^{\circ} \pm 5^{\circ}$



HOWL-ROUND STABILIZER



NOTES:

Q1–Q3 ARE BC549
IC1,2 ARE LM301A
IC3,4 ARE MC1495
IC5 IS LM301A

RESISTORS R5, R8, R9, R10, R17, R22, R23, R25 AND CAPACITORS C2, C3, C4, C6, C7, C11, C12 AND C16 SHOULD BE 1% TOLERANCE OR SELECTED TO BE WITHIN 1% FOR BEST RESULTS.
VOLTAGES GIVEN ARE OF THE PROTOTYPE AND SHOULD BE TYPICAL.

Fig. 1. The circuit diagram of the phase shifter. For the power supply see ETI Project 581 – page 58.

HOW IT WORKS – ETI 486

There are numerous methods of generating a frequency shift in an audio signal. Most however require coils and precise tuning which rules them out for a project. With this method only resistors and capacitors have to be accurate, yet it gives a result adequate for the purpose.

The audio input is split into two circuits which provide a frequency-related phase shift as shown in Fig. 4. The amplitude however remains constant. Due to the different component values in the two networks the phase shifts are not the same but differ by 90° at all frequencies (50 Hz – 20 kHz +/– 5°).

IC1 and IC2 form a quadrature sine wave oscillator with the frequency set by R18, R21, R24, C8, C9 and C13. Amplitude stability is provided by ZD1 and ZD2 along with RV1 (see adjustment section). The outputs from these two op amps are the same amplitude but 90° phase shifted.

We now multiply (the MC1495 is a four-quadrant multiplier) one of the audio signals by one of the 5 Hz outputs and the second audio input by the second 5 Hz signal. When we multiply two waveforms together the output consists of the sum of the two frequencies and their difference. This means that if the audio signal is 100 Hz the output will contain a 95 Hz signal and a 105 Hz signal. These will beat with each other to produce a 10 Hz beat note as shown in Fig. 2. Due to the phase shift between the inputs of the multipliers the 105 Hz components of the outputs are in phase, while the 95 Hz components are 180° out of phase. Therefore by adding the outputs of the two multipliers in IC5 the 95 Hz components cancel out, leaving only the 105 Hz signal. Provided the multiplier inputs have the 90° phase relationship there will always be a 5 Hz shift, independent of frequency.

Due to the inability to maintain exactly the 90° phase relationship, the 95 Hz, or lower sideband, will not completely cancel and the result is a slight beat giving rise to an amplitude modulation effect (we had about 1 dB). This is not normally noticeable on speech or music.

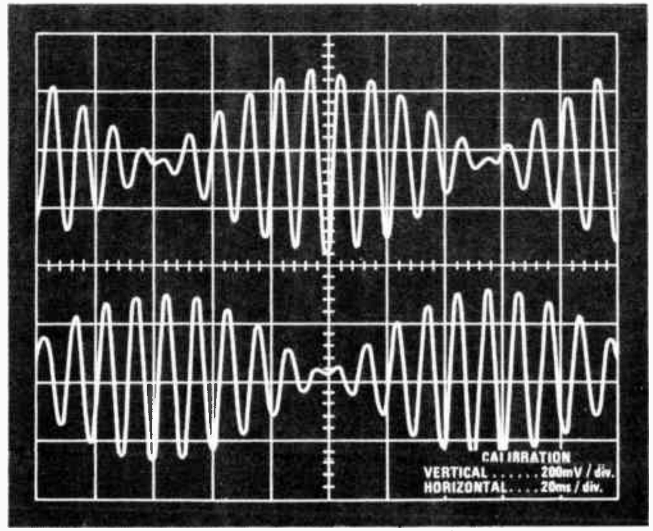


Fig. 2. The output of IC3 (top) and IC4 (lower) with a 100 Hz input signal. Note the phase difference.

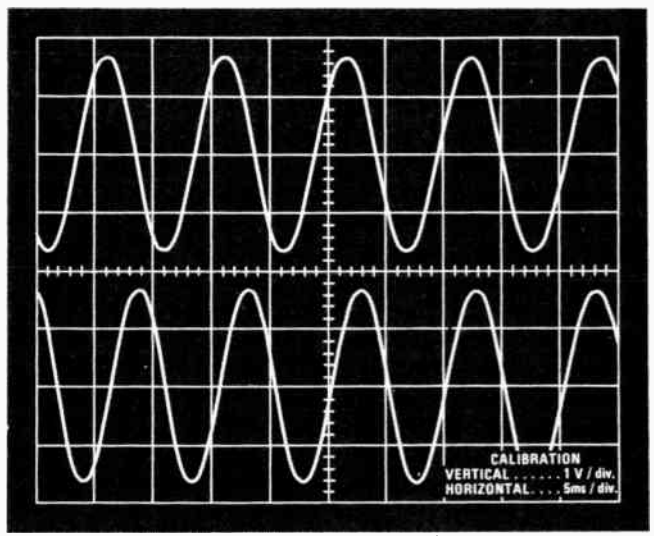


Fig. 3. The input signal (top) and the output (lower). Note the difference in frequency.

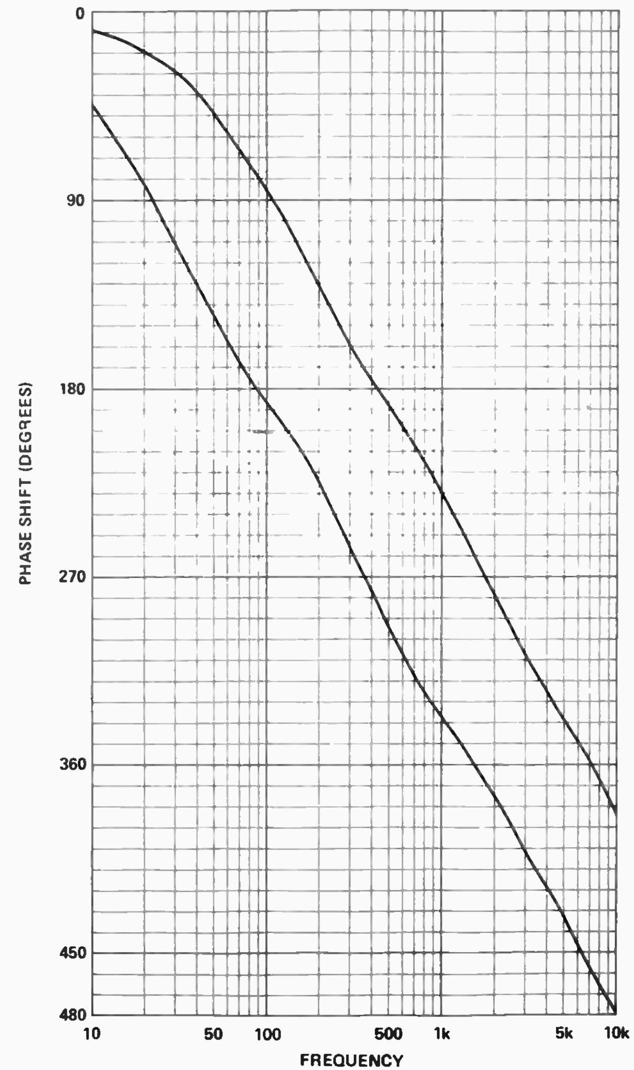


Fig. 4. The phase response of the two filters.

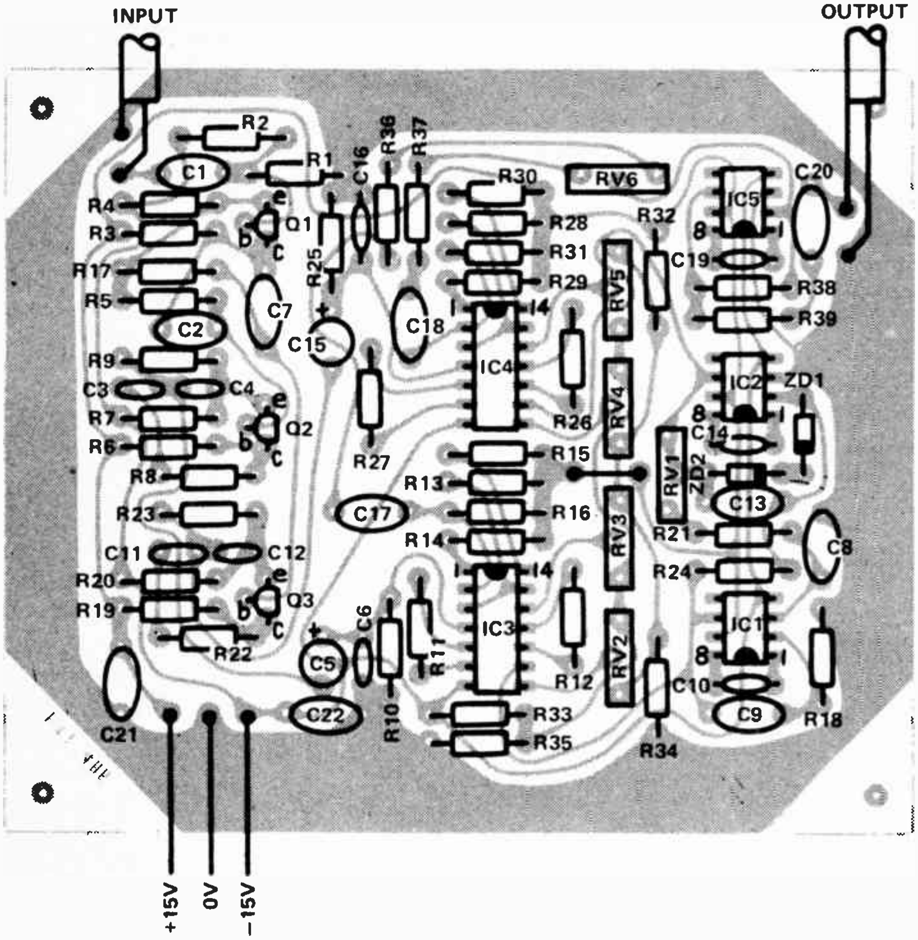


Fig. 5. The component overlay.

PARTS LIST – ETI 486

Resistors all ½ W 5%

R1 . . . . 150k
R2 . . . . 100k
R3,4 . . . . 2k7
* R5 . . . . 22k
R6,7 . . . . 2k7
* R8 . . . . 3k6
* R9 . . . . 24k
* R10. . . . . 15k
R11. . . . . 4k7
R12. . . . . 2k2
R13. . . . . 15k
R14–R16 . . . . . 3k3
* R17. . . . . 56k
R18. . . . . 330k
R19,20. . . . . . . 2k7
R21. . . . . 330k
* R22. . . . . 3k9
* R23. . . . . 27k
R24. . . . . 330k
* R25. . . . . 15k
R26. . . . . 2k2
R27. . . . . 4k7
R28. . . . . 15k
R29–R31 . . . . . 3k3
R32,33. . . . . . . 10k
R34,35. . . . . . . 1k
R36,37. . . . . . . 100k
R38. . . . . 1M
R39. . . . . 100R

Potentiometers

RV1 . . . . 250k trim
RV2–RV5. . . . . 25k trim
RV6 . . . . 100k trim

Capacitors

C1. . . . . 100n polyester
* C2. . . . . 56n polyester
* C3. . . . . 6n8 polyester
* C4. . . . . 1n0 polyester
C5. . . . . 10μ 25V electro
* C6. . . . . 1n5 polyester
* C7. . . . . 100n polyester
C8,9 . . . . 100n polyester
C10. . . . . 33p ceramic
* C11. . . . . 22n polyester
* C12. . . . . 4n7 polyester
C13. . . . . 100n polyester
C14. . . . . 33p ceramic
C15. . . . . 10μ 25V electro
* C16. . . . . 5n6 polyester
C17,18 . . . . 100n polyester
C19. . . . . 33p ceramic
C20–C22 . . . . . 100n polyester

Semiconductors

IC1,2 . . . . LM301A
IC3,4 . . . . MC1495
IC5 . . . . LM301A
Q1–Q3. . . . . . . BC549
ZD1,2 . . . . 5.1V 300mW

Miscellaneous

PC board ETI 486
Power supply ± 15V 40mA (ETI 581)

* For best results the components should be as accurate as possible, preferably 1% tolerance or selected to be within 1%.

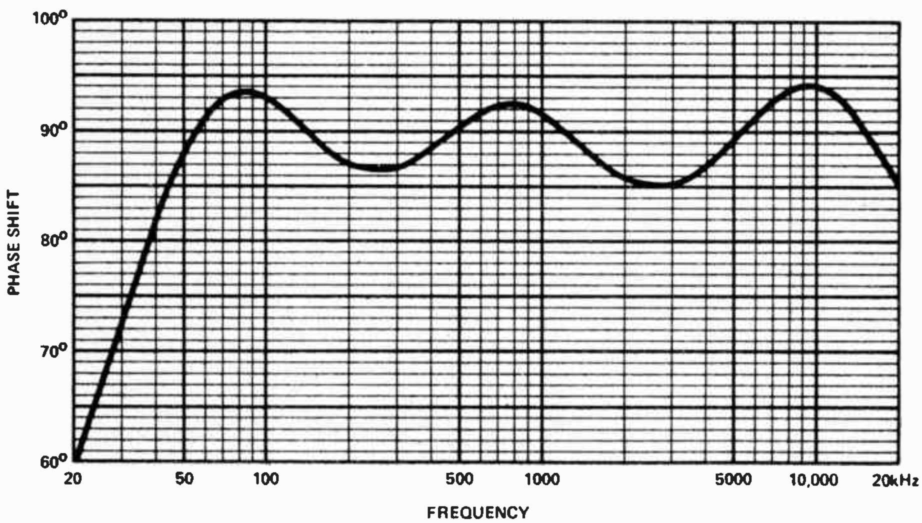
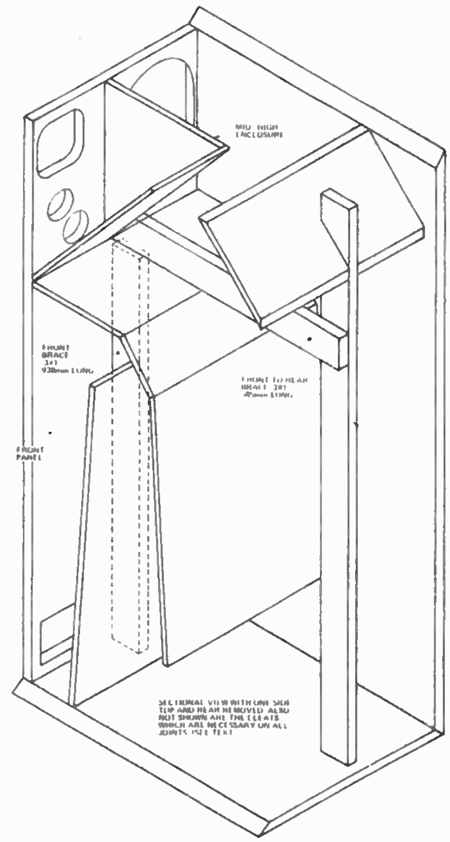


Fig. 6. The phase difference between the two filter networks.

TRANSMISSION LINE SPEAKERS

These transmission line speakers have been designed and progressively developed by audio consultant Richard Timmins. In their final form they have been used as reference speakers by our sister publication Hi-Fi Review.



IN MANY respects transmission line speakers are an attempt to utilise the benefits of infinite baffle speaker enclosures but without the latter's inherent drawbacks – particularly that of restricted bass response.

Theoretically, transmission line speakers are essentially non-resonant over the entire low frequency register. In practice the need to fold the 'line' can introduce resonances and therefore colouration in the upper-bass and lower mid-range though these may be designed out by suitable techniques which are described later in this article.

Other advantages of the design include effective isolation of front and rear diaphragm output, effective control of diaphragm behaviour over the audible frequency range, bass response extended smoothly to the bass-driver's fundamental resonance (typically 25 Hz), and effective damping at that frequency.

As far as we can gather the first transmission line speaker was developed in 1936 by Benjamin Olney and demonstrated at the Acoustical Society of America's meeting in Chicago that year. Olney's enclosure was produced by Stromburg-Carlson for some years but was eventually eclipsed by less costly designs.

The transmission line principle appears then to have been largely neglected – particularly in the USA.

Arthur Radford worked on the principle from 1950 onwards – finally marketing his Radford Studio loudspeaker in 1964.

A.R. Bailey of Britain's Bradford Institute of Technology drew world-wide attention to the transmission line speaker in an article published in a 1965 issue of Wireless World. Bailey packed his labyrinth with long-fibre wool and this damped tube-resonance more effectively than Olney's lined walls of thirty years before.

Bailey compared his stuffed labyrinth to the ideal electrical transmission which is free of signal reflections – and test results indicated smooth, extended low frequency response and excellent transient performance.

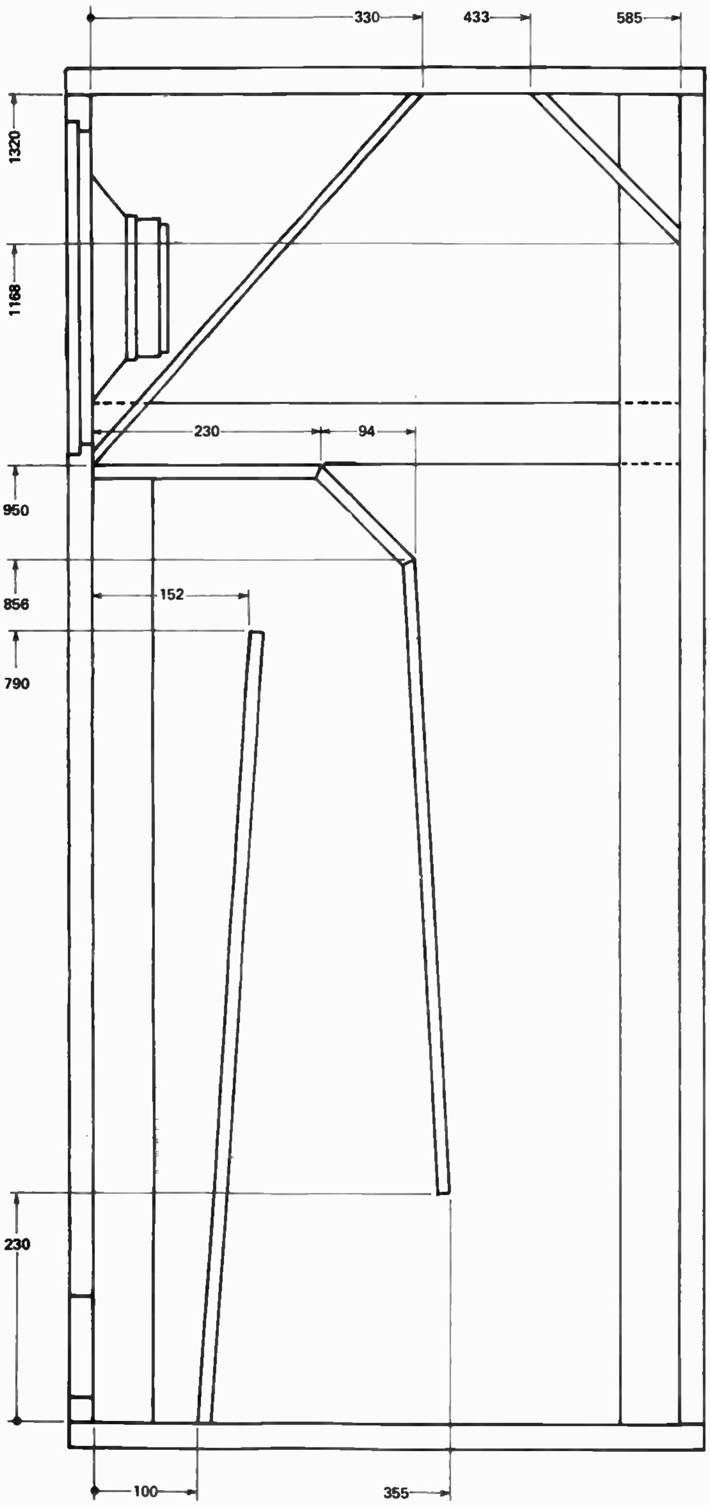
BEFORE BUILDING

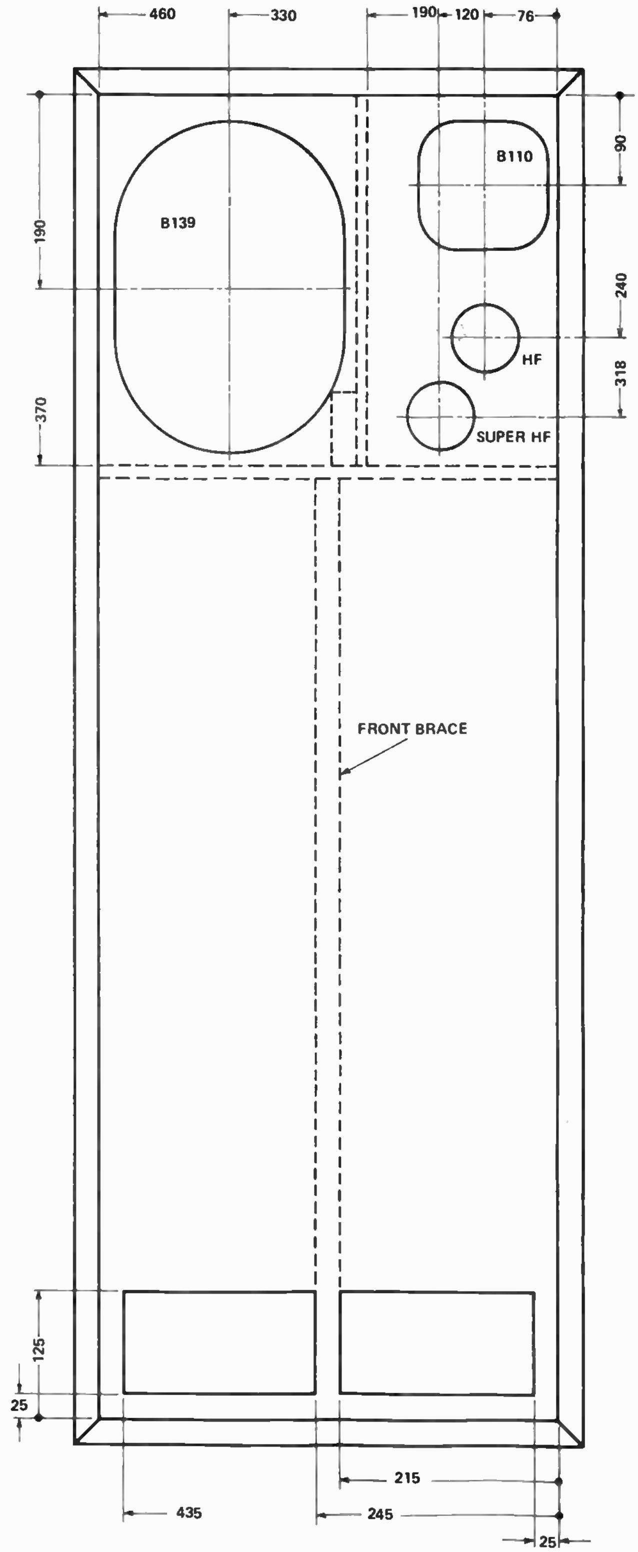
Do read this . . .

These speakers are costly to build and unless you have a medium to high power amplifier – preferably 75 watts or more – and a turntable and cartridge to match, the benefits of these speakers will not be obtained. They are larger than most and heavy to move around.

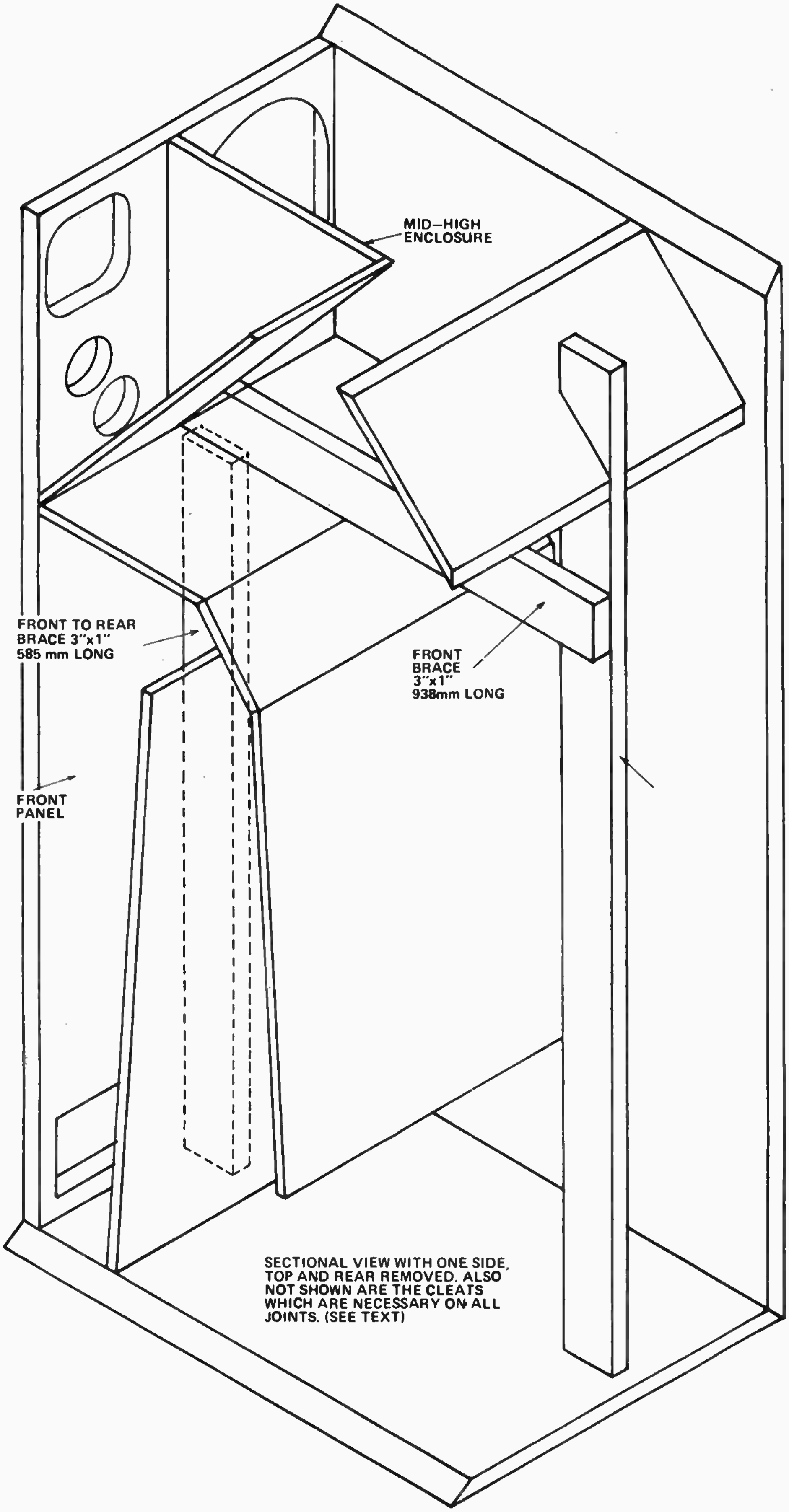
But if you accept all this you'll end up with a pair of speakers massively superior to most commercial designs that you could buy for their cost.

A final note: Transmission line loading can't necessarily be called the 'best'. Results from a good transmission line speaker can be almost unbelievably good – but so can the results from the very best reflex units, infinite baffles and horns. The point to bear in mind is not the loading principle itself – rather how it is applied.





Study these drawings in conjunction with the one on the following page. Note that ideally the speakers should be built as a 'mirror-image' pair — that is, so that when placed in the listening room the tweeters should be innermost.



Since those early days the transmission line speaker has to some extent become the only enclosure design seriously considered by many hi-fi people seeking the 'ultimate sound'.

The Operating Principle

The basic principle is simple. It is to load the rear of a bass driver by a tube of 'infinite' length.

For all realistic audio frequencies an adequate compromise is a tube which is one quarter wave-length long at the bass driver's fundamental resonant frequency.

For the drive unit recommended (KEF B139) this tube will be a little over 2.5 metres long and folding it over enables us to produce an enclosure of acceptable size without serious performance compromises.

It's not *quite* that simple for the pipe will produce resonances at its folds and will also have a high-Q resonance at a frequency associated with its length — for the quarter-wave example discussed this will be at about 100 Hz. Some way must be found to 'lose' both the energy causing the resonance and the resonance itself.

There are several ways by which such resonances may be minimized. One is to use many drive units, each having a different fundamental resonance. By careful design it is then possible to cancel out the worst effects of the 'staggered resonances' to give a remarkably smooth response. A form of this principle is used in IMF's ALS-40 which certainly isn't the simple infinite baffle device it appears to be at first sight!

Another method of reducing resonances is to fill the tube with a damping material — and this also increases the effective length of the tube by slowing down the sound travelling within it.

Various materials may be used for this damping. One of the best is long-haired sheep wool; glass-fibre may also be used, it is less effective than wool but tends to be more constant in its physical characteristics.

Resonances caused by the folds in the tube can be minimised by increasing the density of packing material at these points but a far more effective cure is to use a suitable mid-range driver which takes over well below the point at which the lowest resonance frequency occurs.

Sub-audible Noise

If the tube is correctly packed almost all of the sound radiated from the rear of the bass driver's diaphragm will be absorbed. Only those frequencies below the driver's bass resonance will reach the far open end of the tube. But those frequencies which are not absorbed cause problems, because at frequencies below resonance the diaphragm 'sees' a very much smaller load and even low level signals at such very low frequencies will produce large diaphragm excursions.

This sub-audible problem is the major drawback with transmission line speakers: even the quiestest turntables produce some sub-audible noise, and modern amplifiers of the quality and power output required to do justice to the speakers will provide a goodly amount of amplification of that noise. It's also most disconcerting to watch the bass diaphragms of transmission line speakers emulating the swoop of the pick-up arm as it traces a warped record. You may argue that your turntable is quiet, that you have optimized your pick-up arm and cartridge to reduce resonant effects — yet every record carries some sub-audible noise introduced during manufacture of the master by the cutting lathe itself and the cutter head mechanism.

In itself, reproduction of sub-audible noise isn't disastrous — it's too low to be heard. But it does affect reproduction indirectly by effectively restricting diaphragm movement and by creating intermodulation components and attendant harmonic distortion. The first problem is the greater — and you can visualise how the bass unit would 'bottom' if the diaphragm were close to its limit of movement due to a sub-audible noise whilst a high level musical note was simultaneously superimposed.

The cheapest, simplest and most effective cure is to ensure that the sub-audible noise doesn't reach the speaker in the first place. A high-pass or rumble filter, operative below 30 Hz and having a slope of at least 18 dB/octave is very effective.

Many high-power amplifiers are already fitted with the necessary filter network but for those who own units which aren't, a simple and very effective filter design was published in Electronics Today International in October 1974. (Photostats of this design are obtainable from ETI for $1.00.)

Selecting the Drivers

The first step is to select a suitable bass driver. A long-throw device is essential since a properly designed enclosure will maintain constant output down to the lowest audible frequencies — thus even the diaphragms of large drive units will be called upon to make long excursions.

The cross-sectional area of the tube must be equal to or greater than the radiating surface of the drive unit's diaphragm and therefore the size of the bass driver will largely determine the final size of the enclosure.

A suitable bass driver, combining all the required properties including an ultra-rigid low-mass diaphragm, is KEF's B139. This driver has a low fundamental resonance and its radiating surface and throw is sufficient to enable bass fundamentals to be reproduced at adequate listening levels in the home — but it is not so large that the enclosure becomes of unwieldy size. In addition matching mid-range (B110) and treble units (T27) are available from the same manufacturer and these require minima compensation for use with the loaded B139.

Our own reference units use the B139 and B110 but we use Celestion tweeters (HF1300) and super-tweeters (HF2000). These latter require slightly more attention to matching but provide marginally better performance in our own enclosures.

Construction

At this stage then we need a bass driver mounted in an enclosure which is in reality a folded tube stuffed with absorbent material. The effective length of this tube is related to the fundamental resonant frequency of the bass driver and is open at the far end. The tube has a cross-sectional area no smaller than the diaphragm surface of the bass.

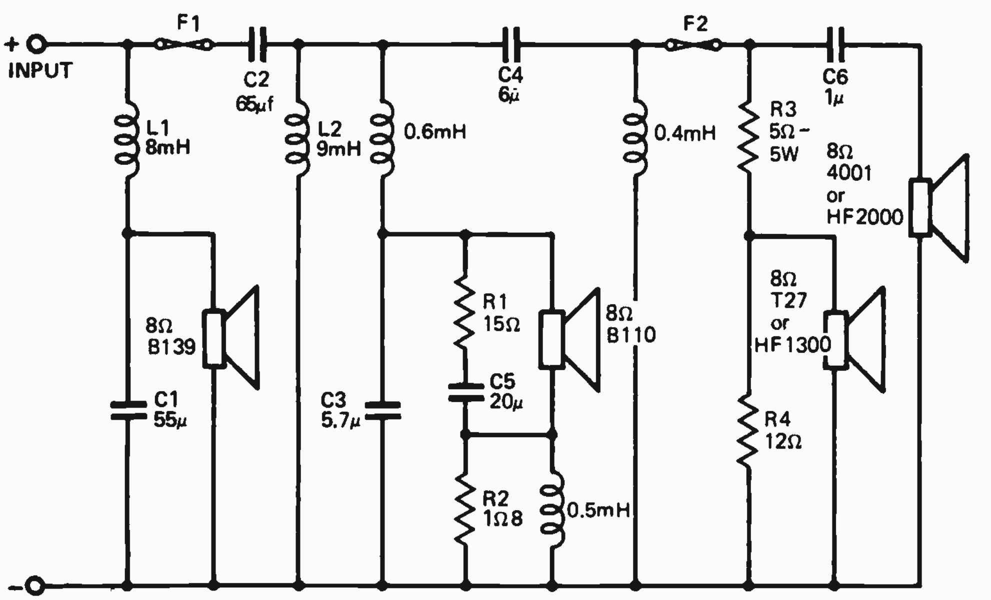
Making the tube isn't that difficult — anyone who's tried to produce a folded norn wouldn't think twice about making a transmission line. Even the legendary Jim Kelly who was once observed repairing a gas chromatograph with a 4lb coal hammer successfully built a pair — and they were magnificent!

Dimensions are not overly critical — except for length which should be within a couple of centimetres of the specified length. The tube should preferably be tapered — so as to reduce or preferably eliminate parallel surfaces and hence standing waves.

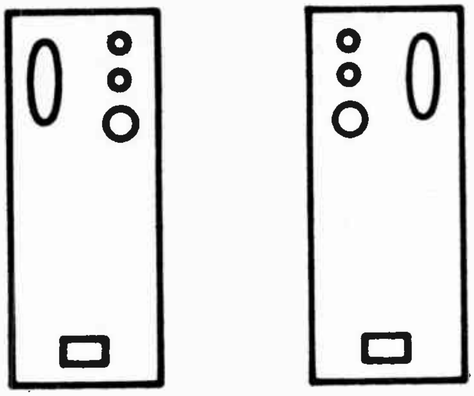
All panels should be cut as accurately as possible, particularly the internal partitions. Check each panel against the job before securing it; an error during the cutting stage could prevent the enclosure from fitting together correctly.

The most suitable material for the enclosure itself is 19 mm particle board, wood veneered preferably, otherwise with plain finish. Pre-veneered board is easier to finish, although ideally it should be mitred at the corners where top and bottom panels join the sides. All joints should be glued using a PBA woodworking adhesive such as Aquadhere, and should be pinned and clamped whilst the glue is setting.

The most secure way to fix the internal partitions is to groove the side panels and cut the partitions slightly oversize to rebate into the grooves. But



Components for the crossover network are both large and expensive. Don't try to economise though, as the design shown is vital for optimum performance. Note that R3 and R4 may be left out if the Celestion HF drive units are used.



Finished enclosures should be located in the listening room such that tweeters are innermost.

this will be beyond the means of most constructors (unless you have access to an understanding cabinet-maker). Cleats, made of offcuts of particle board, or suitable timber, should be provided to give good anchorage. Extra bracing is also an advantage; longitudinal bracing on the 13 mm internal partitions is worthwhile.

Our own units were built by first attaching top and bottom panels to one of the sides. The partitions and midrange sub-enclosure were then added, followed by the rear panel to which connecting terminals and a fuse, mounted on a laminated plastic panel, had already been glued. Wiring was also added at this stage. Next came the front panel — of plywood since this offers greater strength when apertures for drive units have been cut.

All drive units should fit flush; if a Celestion HF 1300 is used, this is designed to be fitted from inside and not from the front. The front panel apertures should therefore be rebated out to accept the drive unit fixing flanges. This involves some rather fiddly chisel work unless you have access to a router.

Once the five sides, partitions and midrange enclosure are in position, the drive units can be mounted and wired to the crossover, which can be placed either on the inside face of the rear panel or on the platform behind the bass unit. The latter position is probably best since it gives access to the network via the bass unit aperture — far easier to remove than the remaining side panel, which should, ultimately, be glued in position once the enclosure is complete.

Drive units originally chosen for our own units were the B139 for bass, KEF B110 for midrange, KEF T27 tweeter and STC 4001K (8 ohm). Later, the T27 and STC were swopped for Celestion HF1300 and HF2000 respectively, (available from the Australian distributor, M&G Hoskins). However, the latest version of the KEF T27 is a vast improvement over the earlier model, and for economy this driver could be used without use of a super-tweeter. The HF1300 exhibits roll-off above 15 kHz and should therefore always be allied to a super-tweeter. Eight ohm versions of both HF1300 and HF2000 should be used, and the drive unit positions indicated on the plan should be adopted, since correct phase relationships are preserved using the crossover network shown.

Our units were filled with fibreglass material — the slab type, not the rolls. This can be secured using suitable pins, or alternatively on small dowels inserted through holes in the partitions and subsequently glued and sealed. It is *essential that all joints* are fully airtight otherwise the enclosures will fail to work correctly. The fibreglass should fill all the available space in the 'line' yet should not be compressed. Density may be increased slightly at bends in the tube. Final adjustment is best done by careful listening and experimenting with packing density. That's why the remaining side panel should be secured by screws. Gaskets should be used to ensure the enclosure is sealed.

Long-fibre sheeps' wool (Dr. Bailey's long hair!) can be used, although this is more difficult to work with and may settle after a period of time, with a consequent change in performance. Bonded acetate fibre such as Innerbond may be used, tightly packed — although not overtightly — in the midrange enclosure. It should not be used in the bass section.

When the enclosures are correctly packed with fibreglass, bass performance should be smooth and extended, with no obvious constriction or colouration. However, *there may be an apparent lack of bass energy by comparison with many speakers,* although fundamentals will be clearly defined and 'tight' sounding.

Transmission line speakers accurately reproduce the bass that is in the original programme material. No more — and very little less. They don't manufacture bass in the form of resonances.

Our crossover network is based on air-cored coils supplied by Transcap (Orchard Road, Brookvale, NSW). All capacitors are paper or polyester, the 55 and 65 microfarad values being made up of oil-filled paper fluorescent lighting ballasts from Plessey Ducon.

Values for R3 and R4 can be altered to achieve correct balance between midrange and treble, and these values actually depend on the drive units chosen. These resistors might best be left out completely if Celestion HF drive units are used.

Fuse protection may be considered necessary if high levels are envisaged — 3 amp fusing should be adequate. The tweeters can be protected separately by a 1 amp fuse. Fuseholders should be fitted in some accessible position such as adjacent to the input terminals.

Our prototypes were used for a long period of time as a high-quality reference speaker system for evaluating the subjective performance of hi-fi equipment and assessment by comparison or other loudspeakers. They were used in mirror-image form, with the enclosures positioned so that each array of tweeters was innermost. This provides optimum stereo performance, since the main axis of each speaker projects into the room, away from boundary walls. Reduction of reflected sound by this means was found to provide a less anomolous stereo image.

Reticulated foam is recommended for the grilles since this causes less colouration than frame/fabric grilles. The prototypes used open grilles constructed of aluminium channel, and these proved aesthetically pleasing and sonically satisfactory.

Once all internal adjustments have been made, the detachable side panels may be secured and sealed in position. It would be advisable, however, to leave these panels removeable in case access to the interiors is necessary in the future.

Overall, the systems as described performed admirably and despite their size, were found to take up little effective space due to their tall, tower-like format.

(continued page 109)

GRAPHIC EQUALIZER

This revised version of our earlier equalizer now uses gyrators to replace the inductors making construction easier.

GRAPHIC EQUALIZERS are popular with both the professional and domestic user alike. However until the presentation of our earlier equalizer (ETI 427) the cost of such a device was very high and this limited its wide use. We have now redesigned the equalizer to simplify the construction and it now has no coils and one additional filter has also been added.

The advantages of an equalizer are not generally well known but are as follows.

Firstly an equalizer allows the listener to correct deficiencies in the linearity of either his speaker system alone, or the combination of his speaker system and his living room.

As we have pointed out many times in the past, even the best speakers available cannot give correct reproduction in an inadequate room. It is a sad fact that very few rooms are ideal, and most of us put up with resonances and dips, sadly convinced that this is something we have to live with.

Whilst the octave equalizer will not completely overcome such problems, it is possible to minimize some non-linearities of the combined speaker/room system.

In a concert hall it is also possible to use the unit to put a notch at the frequency where microphone feedback occurs, thus allowing higher power levels to be used.

Thirdly, for the serious audiophile, an equalizer is an exceedingly-valuable tool in evaluating the deficiencies in a particular system. One adjusts the equalizer to provide a uniform response, the settings of the potentiometer knobs then graphically display the areas where the speaker etc is deficient.

There is a snag, however, one must have an educated ear in order to properly equalize a system to a flat response. It is not much use equalizing to your own preference of peaky bass etc in order to evaluate a speaker.

Ideally, a graphic equalizer should have filters at 1/3 octave intervals, but except for sound studios and wealthy pop groups, the expense and size of such units are too much for most people.

The equalizer described here has 10 octave spaced filters but if desired it could be modified to give 1/2 or 1/3 octave spacing as large values of inductance are easily obtained with gyrators (active inductors).

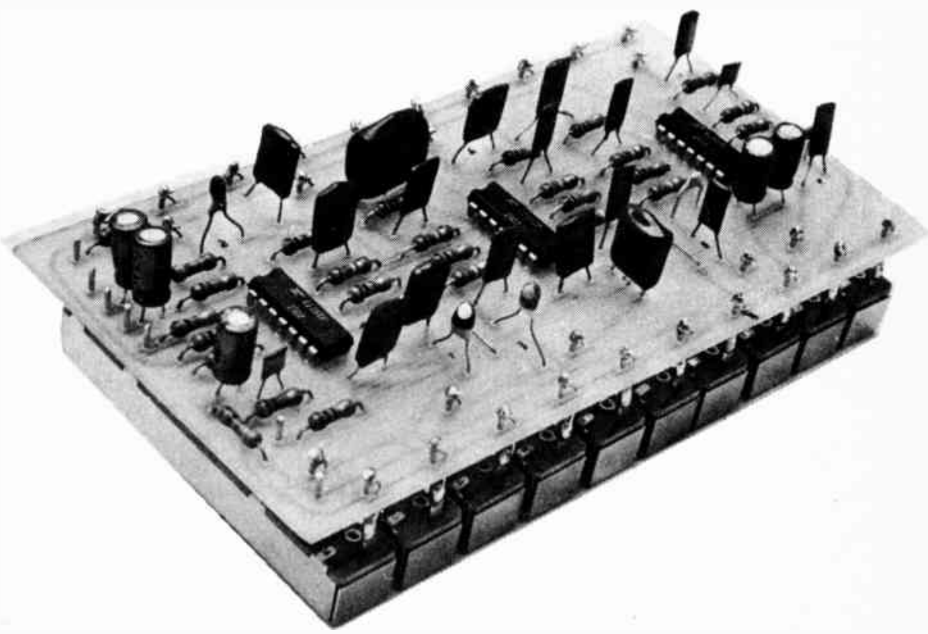
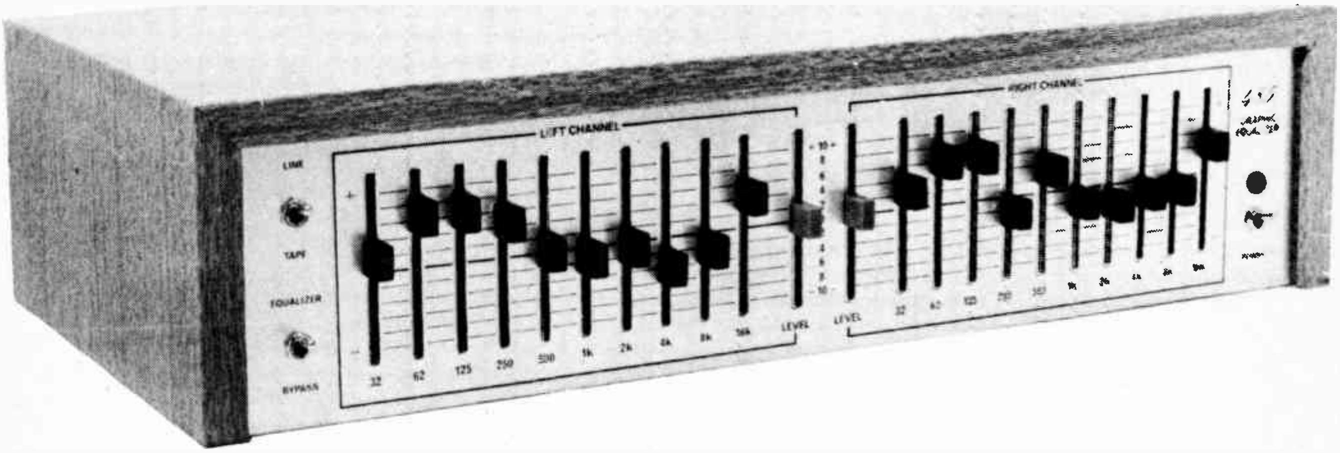


Photo showing one complete channel, less the volume control, removed from the chassis.



Construction

Assemble the PC board(s) with the aid of the overlay in fig 3 initially leaving off the potentiometers. Add pc pins for the external wires and the potentiometers connection points. Now double check the PC board soldering, the positioning and polarity of the components as once the potentiometers are in position changing components is difficult.

Now solder lengths, about 40mm, of tinned copper wire onto the end terminals of the potentiometers, and also onto one of the wiper contacts. Note that half the potentiometers use one wiper connection and the others use the other end. Now slide the wires through the holes provided such that the potentiometers are on the copper side of the board. Before soldering mount the potentiometers onto the support rails, space the board back about 10mm then twist the wire around the PC pins and solder the connections.

The volume controls can now be mounted and connected and the complete assembly mounted into the chassis using 12mm spacers. The power supply can be added along with the other components in the box and finally wire as shown in fig6.

Third octave filters

While we have not built up a third octave unit we see no reason why it will not work. Additional stages can simply be added except that the Q of the circuits must be changed to narrow the band. At the moment the impedance of the capacitor and inductor (gyrator) is about 3000 ohms at the centre frequency and this should be increased to about 8000 ohms for the third octave unit. The capacitors and inductors can be calculated by

$$C = \frac{1}{2\pi f X_C} \qquad L = \frac{X_L}{2\pi f}$$

where $X_C = X_L = 8000\Omega$
and f = centre frequency

It is recommended to reduce loading IC1/2 that the potentiometers be increased to 10k.

SPECIFICATION ETI 485

Frequency response			
Equalizer out			Flat
Equalizer in and all controls at zero	10Hz – 20kHz		± ½dB
Range of controls			
Individual filters			± 13dB
Level control			+ 14dB – 9dB
Maximum output signal at <0.1% distortion			6 volts
Maximum input voltage			10 volts
Distortion at 2 volts out, controls flat	100Hz 0.02%	1kHz 0.02%	6.3kHz 0.04%
Signal to noise ratio re 2 volts out, controls flat			82 dB
Input impedance			47 k
Output impedance			100 ohms

GRAPHIC EQUALIZER

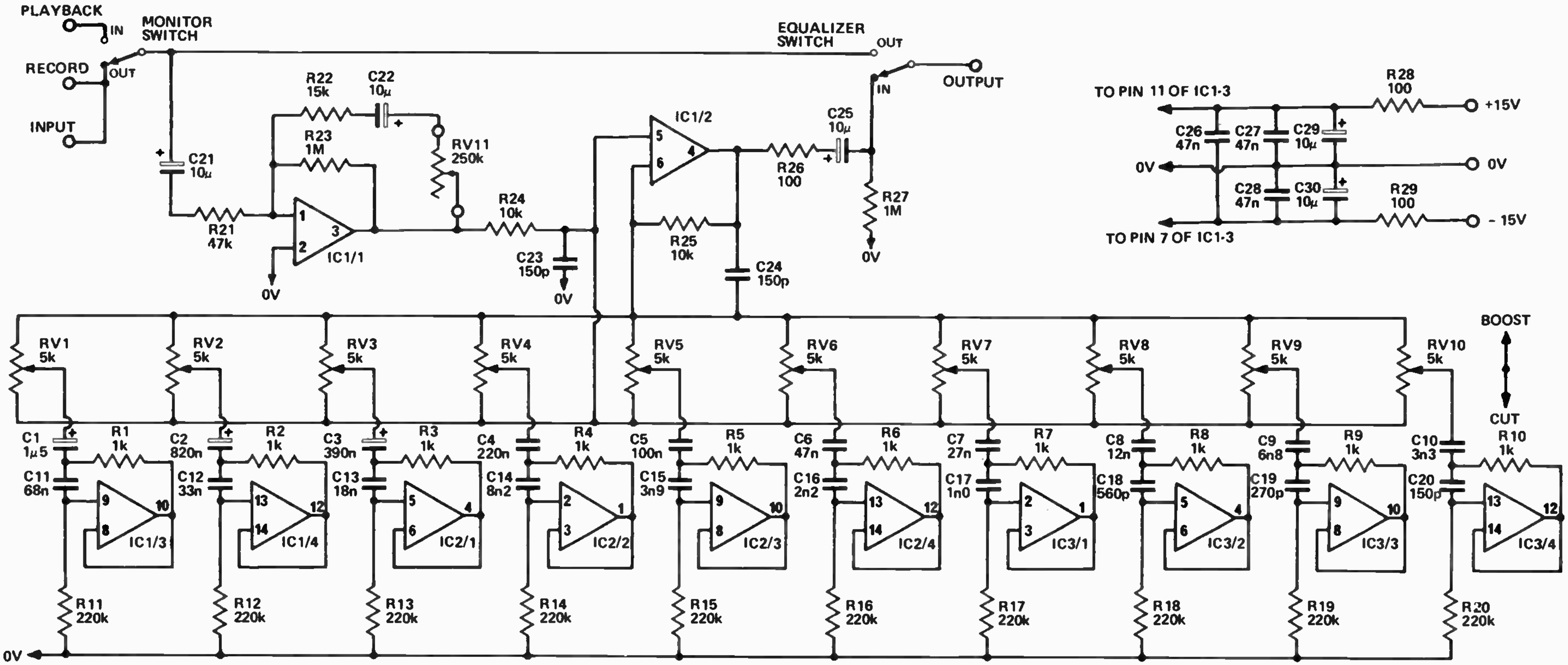


Fig. 1. Circuit diagram of one channel of the equalizer.

How It Works – ETI 485

This equalizer is basically similar to that used in the previous unit with the addition of an extra filter in each channel. The previous unit also used coils (inductors) – these have been replaced by gyrators to simplify construction. We will explain more about gyrators later but at the moment just assume that they are an inductor.

The equalizer stage is a little unusual in that the filter networks are arranged to vary the negative feedback path around the amplifier. If we consider one filter section impedance of the LCR network will be 1 k ohms at the resonant frequency circuit.

With the slider of the potentiometer at the top end (Fig. A) we have 1 k ohms to the OV line from the negative input of the amplifier, and 5 k between the two inputs of the amplifier. The amplifier, due to the feedback applied, will keep the potential between the two inputs at zero. Thus there is no current through RVA. The voltage on the positive input to the amplifier is therefore the same as the input voltage since there is no current through, or voltage drop across resistor RA.

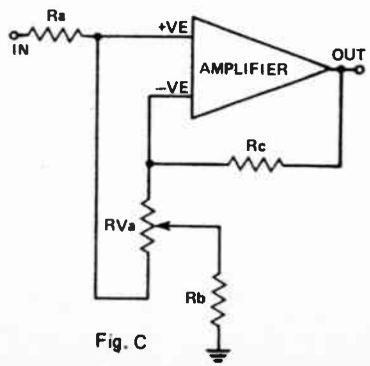
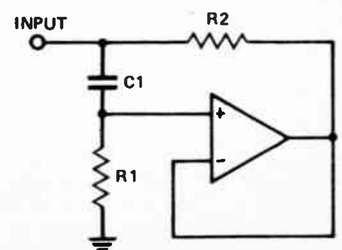


Fig. C

of the amplifier. The use of a second amplifier will increase the resistance to many megohms while the same formula holds for inductance.



of the network. At either side of resonance the impedance will rise (with a slope dependant on the Q of the network which is 3) due to the uncancelled reactance. This will be inductive above resonance and capacitive below resonance. We can therefore represent the equalizer stage by the equivalent circuit below.

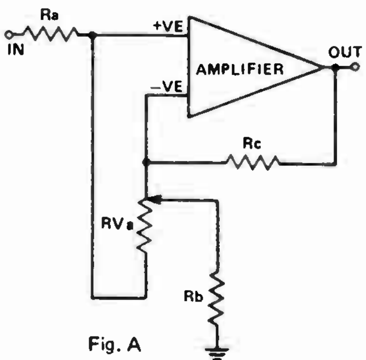


Fig. A

It must be emphasized that this equivalent circuit represents the condition with one filter only, at its resonant frequency. Additionally letters have been used to designate resistors to avoid confusion with components in the actual

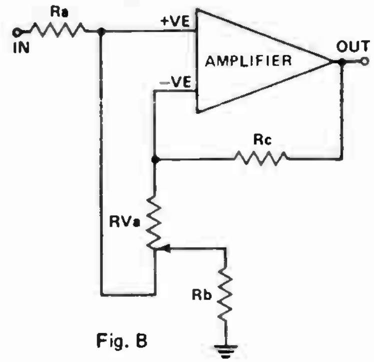


Fig. B

The output of the amplifier in this case is approximately the input signal times (10 000 + 1000)/100 giving a gain of 20 dB. If the slider is at the other end of the potentiometer, (Fig. B), the signal appearing at the positive input, and thus also the negative input is about 0.1 (1000/(10 000 + 1000)) of the input. There will still be no current of the potentiometer and in RC, thus the output will be 0.1 of the input. That is, there will be a loss of 20 dB.

If the wiper is midway, both the input signal and the feedback signal are attenuated equally, and the stage will have unity gain.

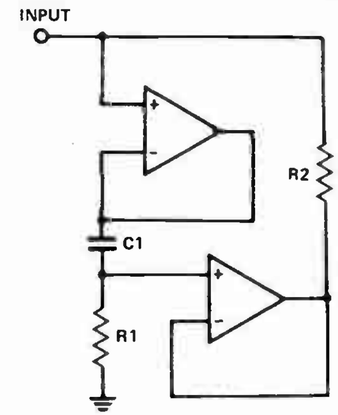
With all filter sections in circuit the maximum cut and boost available is reduced, but ± 14 dB is still available.

In the actual circuit we have used the first op-amp (IC1/1) as a buffer for the input and also as the overall gain control stage. With the values shown the gain is adjustable over a range of −9 to +14 dB. By replacing R22 by a link RV11 will act like a normal volume control. Now to the gyrator.

The only difference between an inductor and a capacitor – electrically, that is, not mechanically – is the phase relationship between the current and voltage. In the gyrator we use an op-amp to reverse the phase relationship of a capacitor and make it appear like an inductor. In the circuit below the inductance is given by the formula

$$L = R1 \times R2 \times C1 \text{ H} \quad \text{where C is in Farads}$$

Like a real inductor there is a series resistance (winding resistance) or R2 and a parallel resistance R1 (in a coil this is due to winding capacitance). The lowest value of R2 depends on the amplifier used but for standard op-amps it would be about 100 ohms. At the high end the value of R1 is limited by input current.



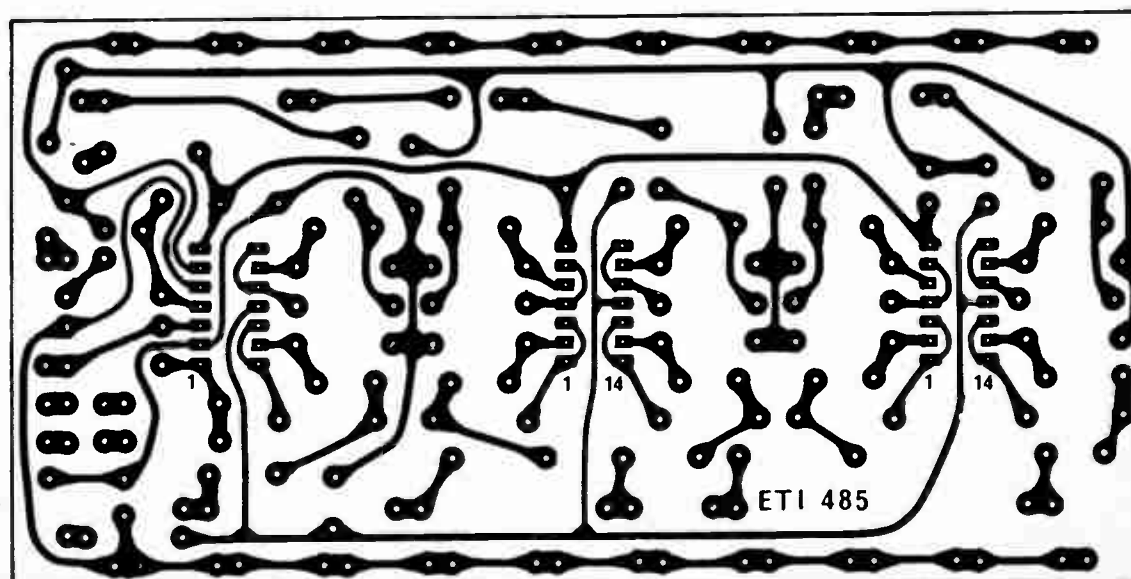


Fig. 2. Printed circuit layout. Full size 150 x 75 mm.

PARTS LIST – ETI 485

Resistors all ½W 5%

R1–R10	1k
R11–R20	220k
R21	47k
R22	15k
R23	1M
R24,25	10k
R26	100
R27	1M
R28,29	100

Potentiometers

RV1–RV10	5k lin 45mm slide
RV11	250k log 45mm slide

Capacitors

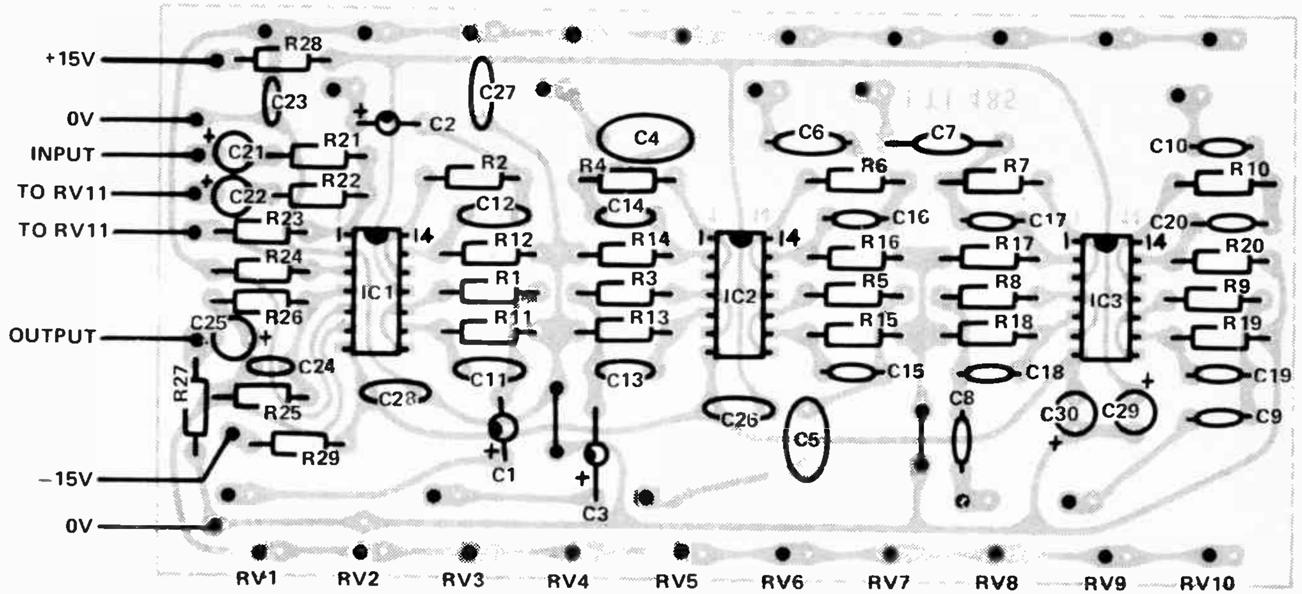
C1	1µ5 tantalum
C2	820n "
C3	390n "
C4	220n polyester
C5	100n "
C6	47n "
C7	27n "
C8	12n "
C9	6n8 "
C10	3n3 "
C11	68n "
C12	33n "
C13	18n "
C14	8n2 "
C15	3n9 "
C16	2n2 "
C17	1n0 "
C18	560p ceramic
C19	270p "
C20	150p "
C21,22	10µ 25V electro
C23,24	150p ceramic
C25	10µ 25V electro
C26–C28	47n polyester
C29,30	10µ 25V electro

Semiconductors

IC1–IC3	4136 Quad op-amp

Miscellaneous

PC board ETI 485
11 knobs McMurdo P/N 4093
For stereo operation twice the above components are required
Power supply ETI 581 (15V 40mA)
Box to suit (see diagram)
Three DPDT toggle switches
Two 4 way RCA sockets
Three core flex and plug
Cable clamp, terminal block



NOTE: RV1–RV10 ARE ON THE COPPER SIDE OF THE BOARD

Fig. 3. Component overlay of the equalizer board.

> **Note**
>
> The 4136 amplifier is manufactured by Raytheon and is distributed in Australia by Soanar Electronics (who supplied us with samples). It is also supplied by Tecnico Electronics.
>
> Tantalum capacitors of 390 nF and 820 nF may be difficult to obtain. 470 nF and 1µF may be substituted causing only a small shift in centre frequency.

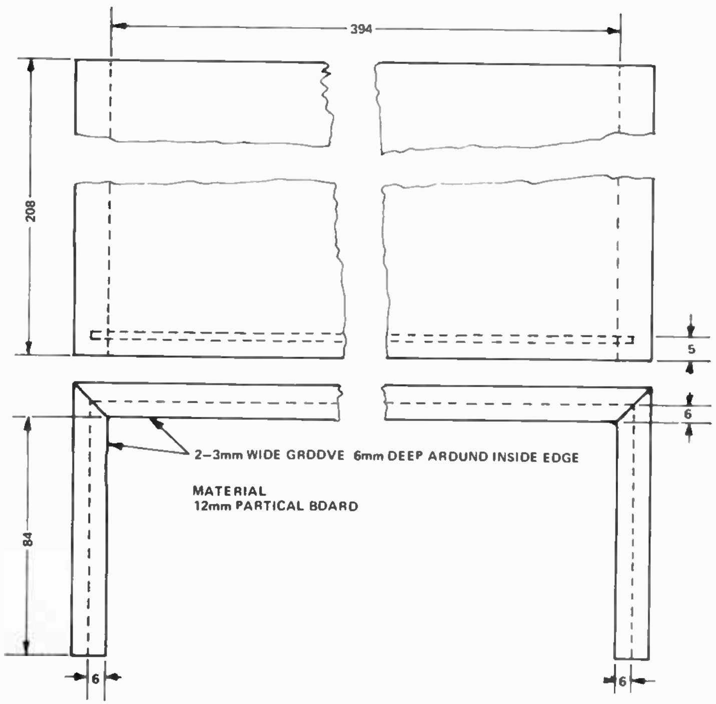


Fig. 4. Constructional details of the cover.

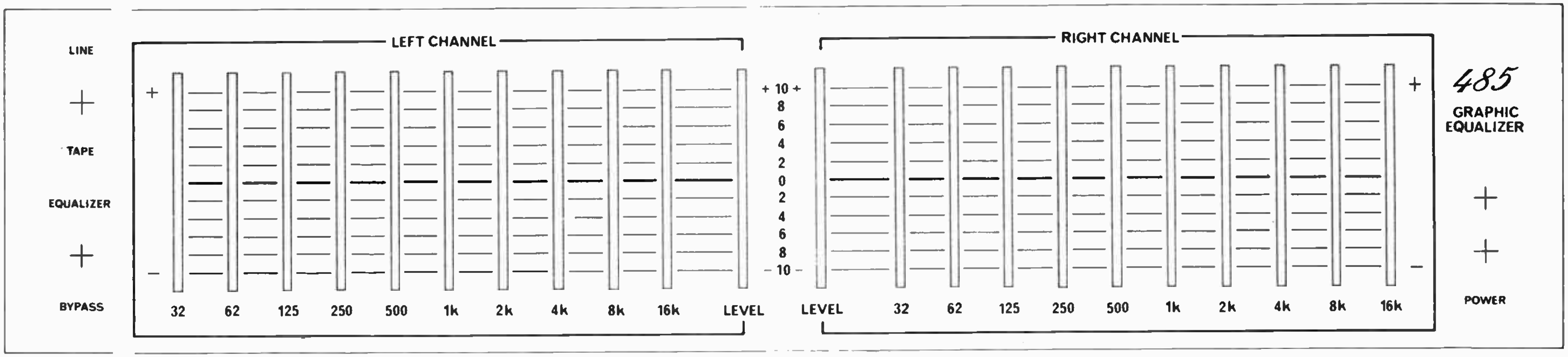


Fig. 5. Front panel artwork for the equalizer. See fig. 8 for dimensions.

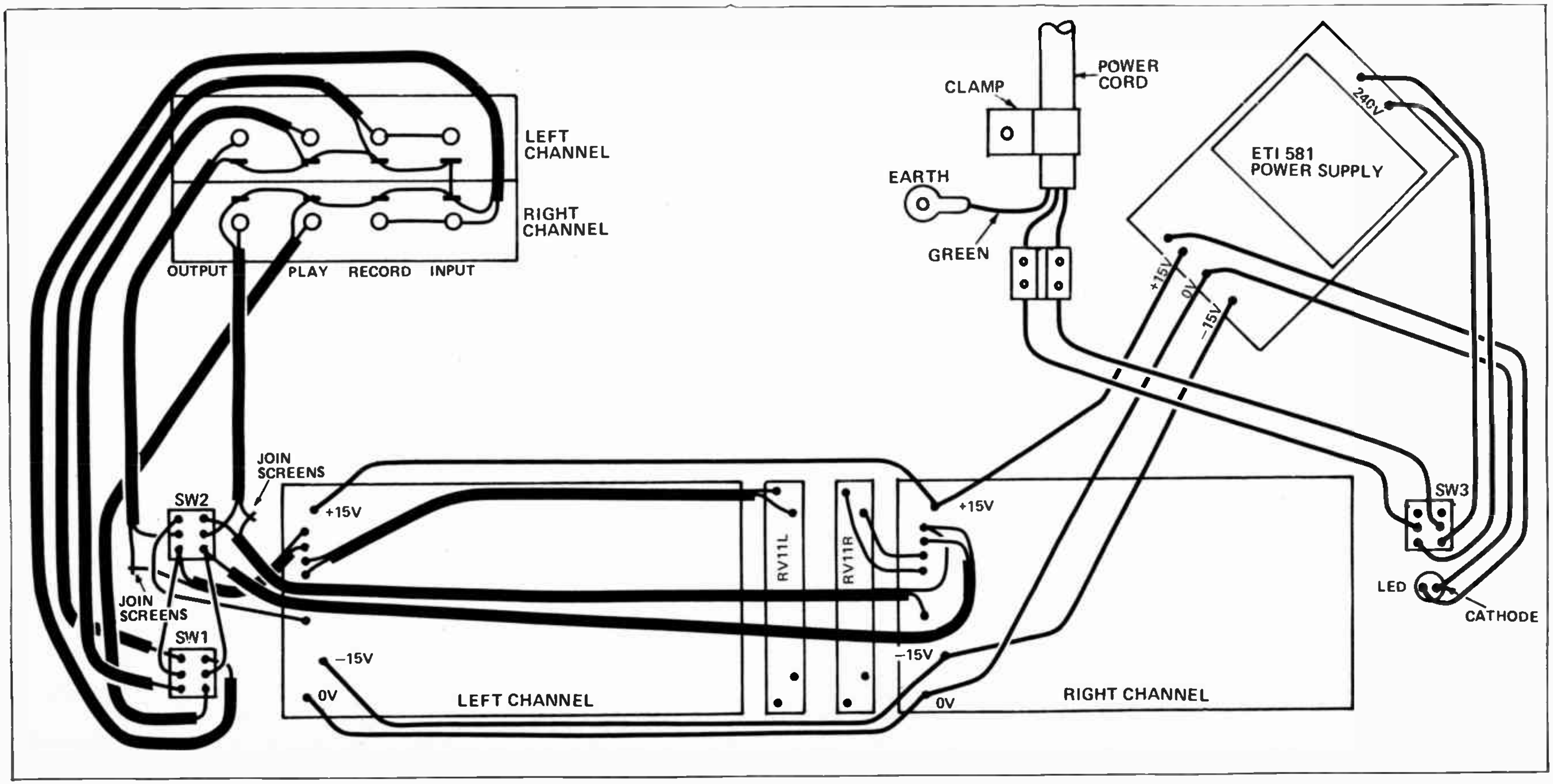


Fig. 6. Interconnection diagram for the unit.

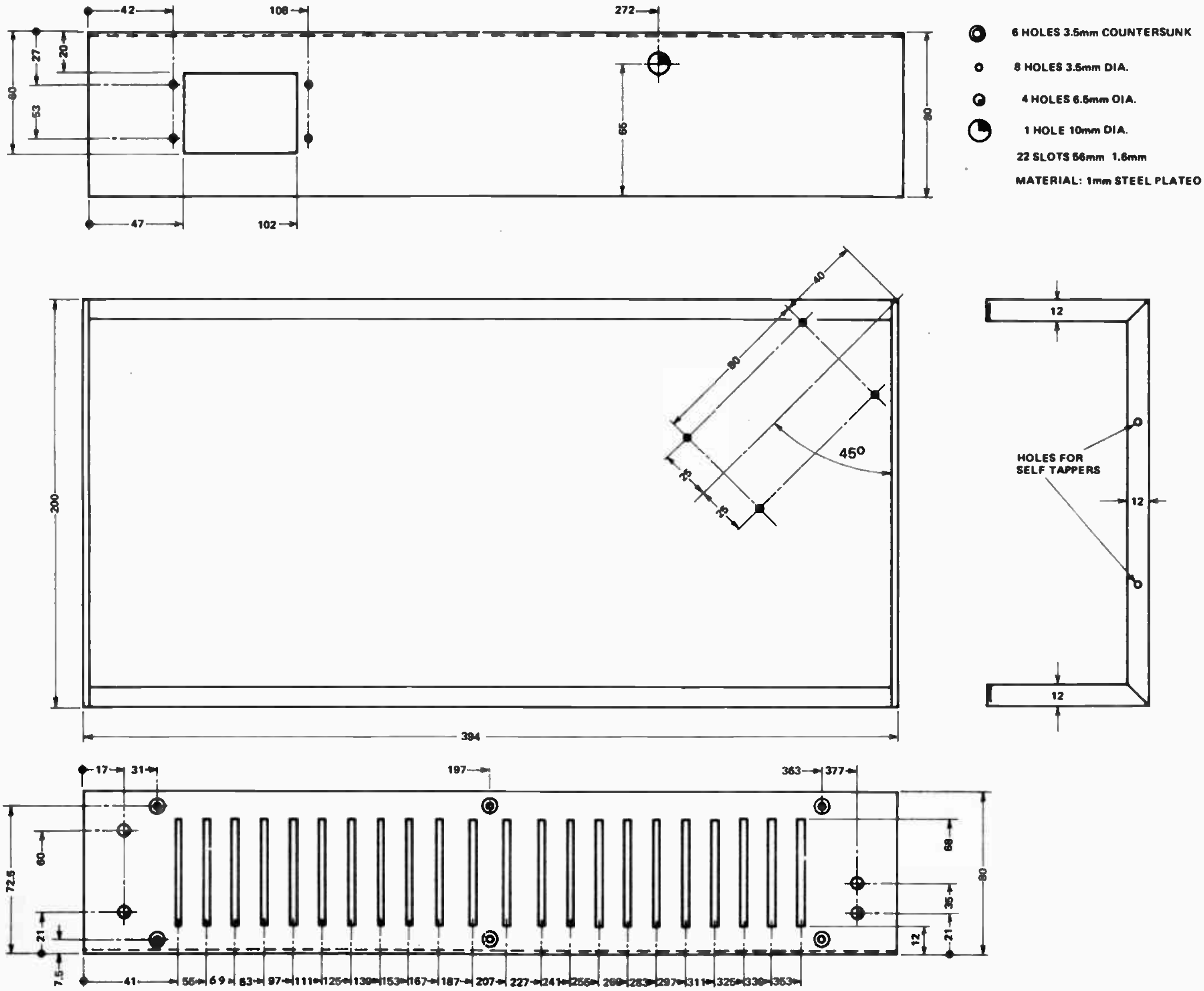


Fig. 7. Details of the chassis.

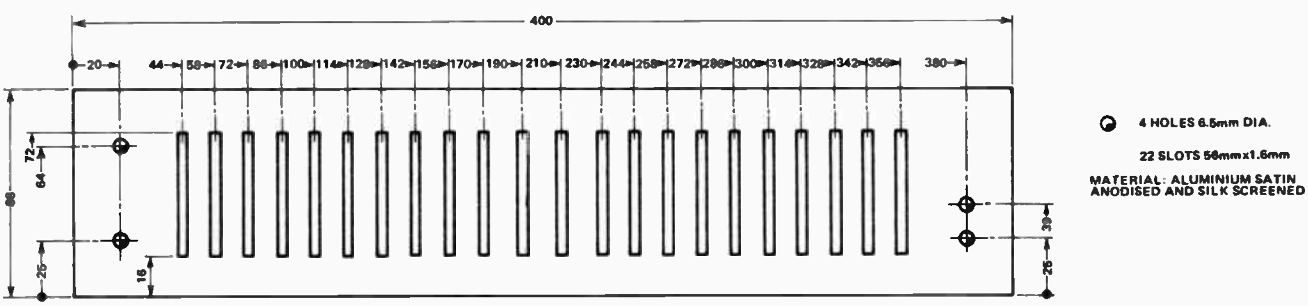


Fig. 8. Metalwork details of the front panel.

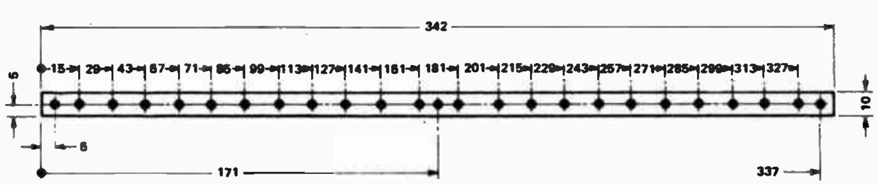


Fig. 9. Drilling details for the potentiometer support

MATERIAL: 10mmx3mm ALUMINIUM
26 HOLES 3.5mm DIA.

SIMPLE COMPRESSOR EXPANDER

Our new compressor expander uses a single IC to replace several components in a previous design, and features a 2:1 compression ratio.

CASSETTE RECORDERS are becoming more acceptable in the hi-fi situation as the use of narrow gap heads and special tapes improves frequency response. In this respect the modern deck rivals the reel-to-reel machine. However, the reel machine and disc recording still offer a better dynamic range, a result of the signal to noise ratio of the cassette equipment not being high enough to blank out background noise in quiet passages.

When recording tapes there has to be a compromise met between signal to noise ratio and clipping the peaks of the music due to tape saturation. Many systems have been devised to help alleviate this problem with the most commonly known one being the Dolby system. This effectively gives an additional 10 dB or so of dynamic range. Limiters are used on a lot of recorders to prevent tape saturation but these alter the dynamic range which is not normally acceptable to the hi-fi listener.

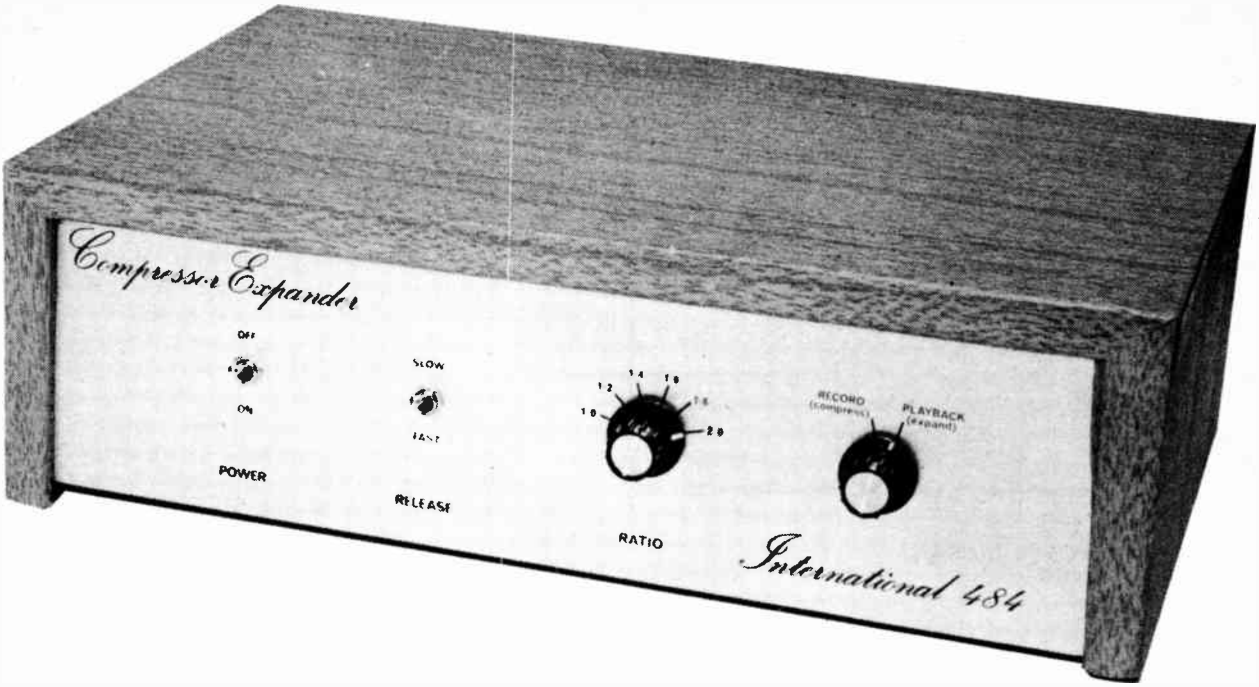
One other system used professionally but not a great deal in the domestic situation is the compressor expander. The best known system here must be the dbx unit. With this type of system the full dynamic range, say 80 dB, is compressed to perhaps 40 dB (compression ratio of 2), then it is recorded. If the signal to noise ratio of the recorder is 50 dB and our peak recording level is 5 dB below maximum our minimum level is still 5 dB above the noise. On replay we now expand by the same factor giving us our full 80 dB dynamic range with the noise 10 dB lower.

We have already published the design of a compressor expander (in ETI, April 1976) which worked well but was complex and used a double sided printed circuit board with eight ICs and four dual transistors. This new design is simplified by the use of a special IC which takes the place of all these separate components reducing the cost and complexity.

SPECIFICATION – ETI 484

Compression ratio	1.0, 1.2, 1.4, 1.6, 1.8, 2.0
Expansion ratio	1.0, 1.2, 1.4, 1.6, 1.8, 2.0
Attack time	
fast	10ms
slow	40ms
Maximum input voltage *	
R25–R28 = 0Ω	1 volt
Distortion 1 volt out	
untrimmed max.	2%
untrimmed prototype	0.25%
trimmed max.	0.2%
trimmed prototype	0.09%
Signal to noise ratio re 1V	
2.0 compression	45dB
2.0 expansion	90dB

* The max. input voltage can be increased to 3 volts using R25,26 = 22k and R27,28 = 10k

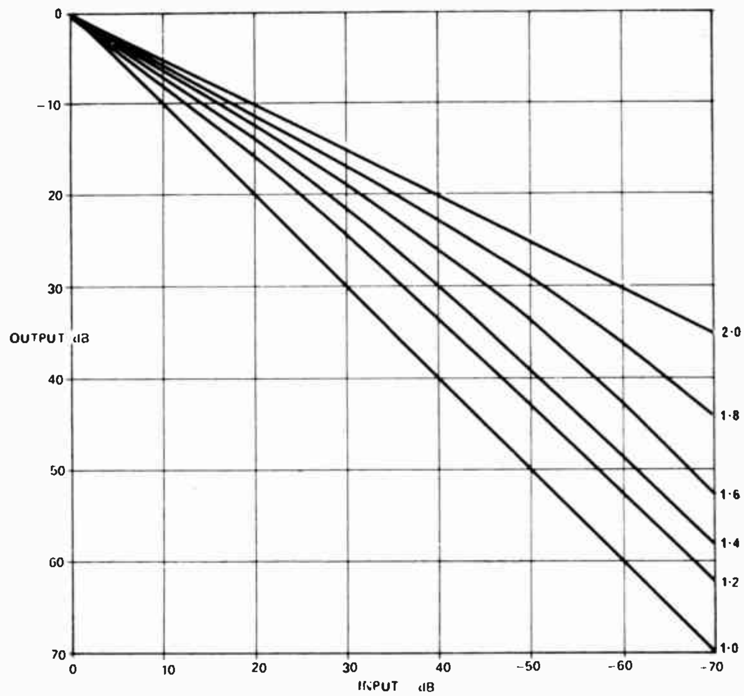


Construction

Commence assembly with all the components which are mounted flat on the printed circuit board. If, and only if, you have distortion measuring equipment add RV1, 2 and R29–R32. If these are not adjusted correctly the distortion may well be higher than without them (it should be less than 2%). Now add to each rotary switch ½ inch long 6BA spacers on the bolts holding the switch together. It may be necessary to remove the rear nuts to give enough thread to hold these spacers. Now bolt the switches onto the printed circuit board (the 6 pos. one is the nearest the IC). Take note of which contact is the wiper on each of the switches. On the 6 pos. one there is a normal contact as well as the wiper in the same position except on the opposite side of the wafer and this normal contact is not used.

There is a series of holes in the printed circuit board around the switches in two rows, one slightly outside the other. The inner row connects to the wafer closest to the printed circuit board. Start connections by the wiper contact (marked W on the printed circuit board) using tinned copper wire and then the other contacts by the appropriate resistor or link. For the links to the top wafer it is recommended that insulation be used over the wires.

The release time switch can now be wired and the printed circuit board mounted into the chasis. The transformer input sockets etc. can now be mounted and wired.



Graph showing relationship between input and output for the various compression ratios.

Distortion Adjustment

Distortion can only be adjusted with a meter. Set the ratio switch to 2 and feed about 1 to 1.5 V at about 1 kHz into the socket marked 'to tape output on amplifier' and measure the distortion at the socket marked 'to tape recorder input'. By adjusting RV1 and RV2 depending on which channel you are measuring it should be possible to adjust the distortion to under 0.2%. This can be repeated with the second channel.

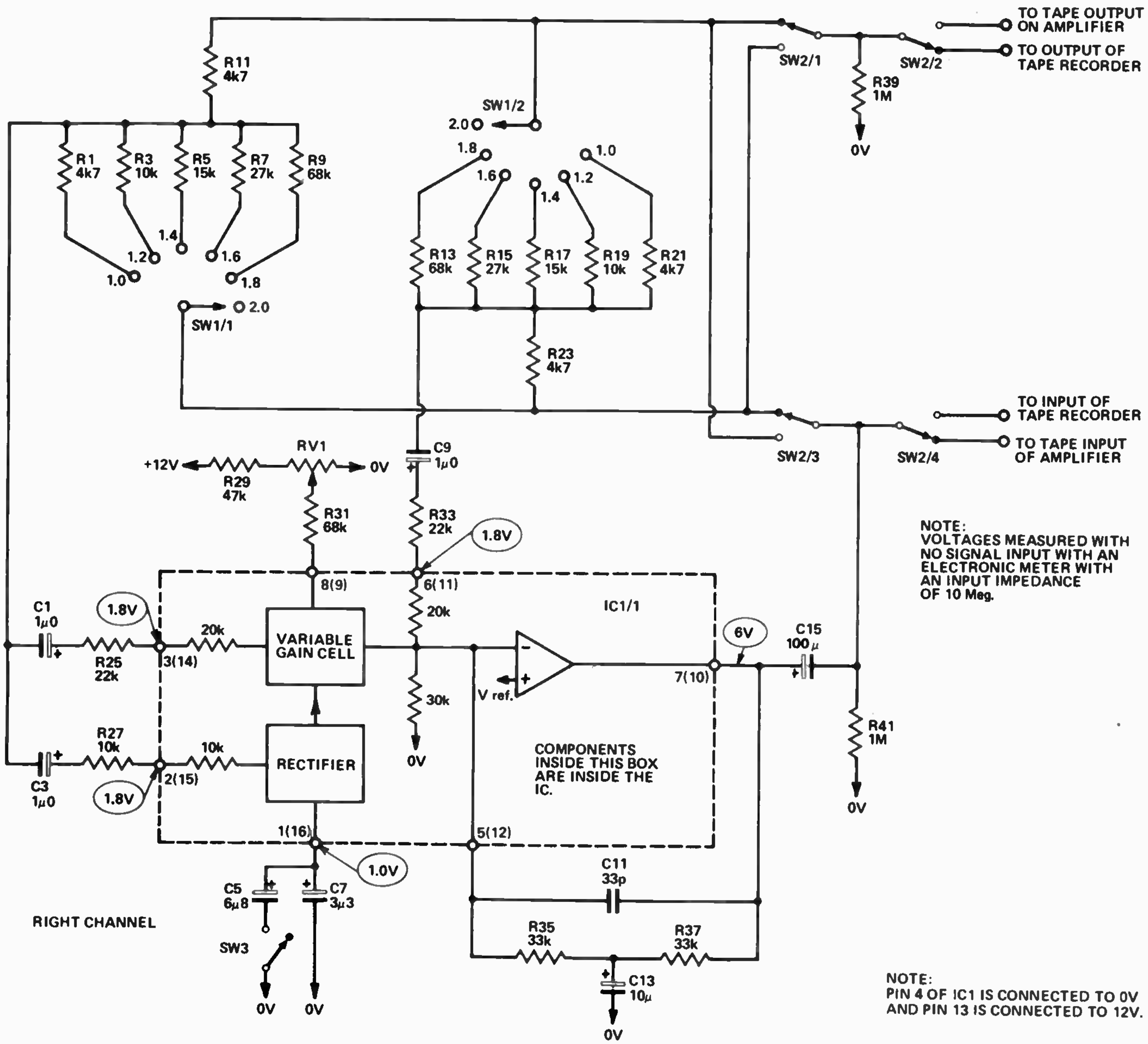


Fig. 1. Circuit diagram of the right channel.

Input Levels

The maximum input level the IC can handle is one volt. However by including resistors R25-R28 the maximum input level is raised to three volts. These resistors also affect unity gain voltage. If input levels higher than one volt will not be used these resistors should be replaced by links. Resistors R33 and R34 should also be replaced by links if R25-R28 are removed.

How It Works – ETI 484

As most of the work is done inside the IC we must look inside the IC to explain the operation. The IC contains a rectifier circuit which is used to measure the actual signal level, a variable gain block which is controlled by the output of the rectifier so that the gain is proportional to the input signal, and an amplifier. By connecting the IC in various ways either a compressor or expander can be formed. We can do either by switching and also by mixing the two by a series of resistors we obtain ratios other than the preset 2. However due to the mixing being done before the logarithmic control of the variable gain cell the ratio is only true in the top 30-40 dB range reverting to a ratio of 1 below this level. Both compressor and expander however follow the same curve and compensate for each other.

We have provided two release times in the unit. With a fast release time there is distortion created at low frequency while if it is too slow the unit appears to 'breathe'. The slow time is slow enough to give reasonable low distortion while minimising breathing. However the distortion created by a fast release time is compensated in the expansion mode provided it is recorded and played back at the same settings.

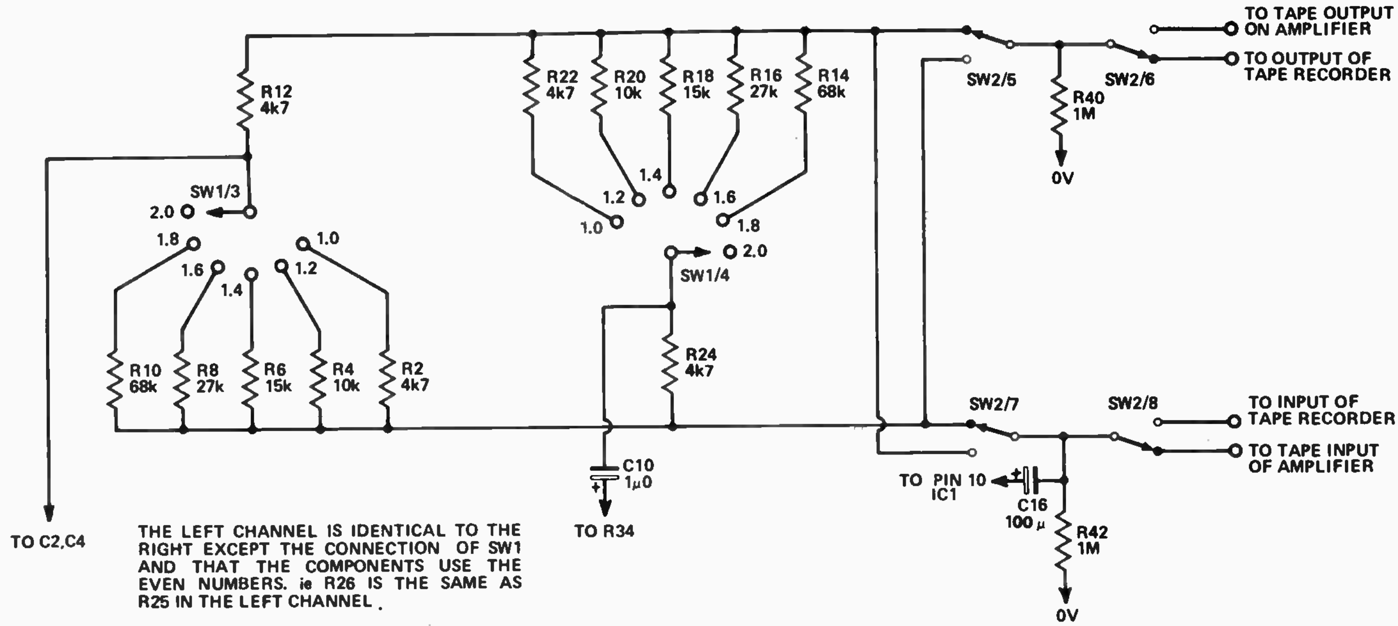


Fig. 2. Changes in the circuit for the left channel. The changes are only to simplify the PCB layout.

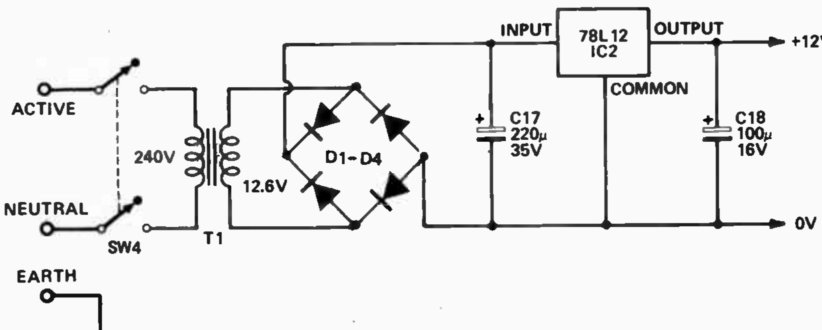


Fig. 3. Power supply of the unit.

Note: A number of people building this unit have been puzzled by a phenomenon inherent in its operation.

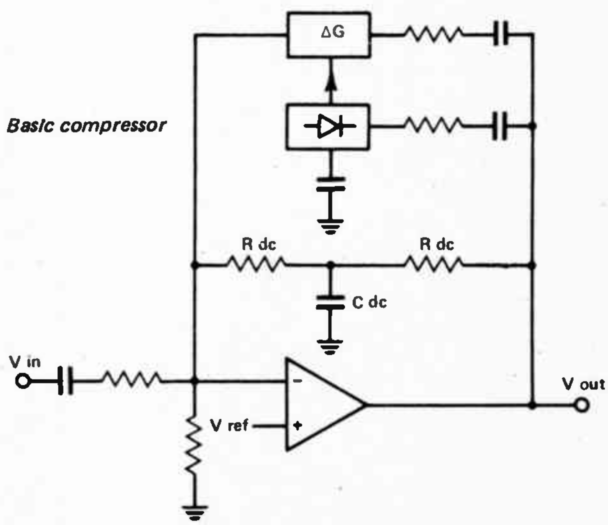
In the expansion mode the output voltage can never exceed the input voltage — it will just equal it when the input is 1.0 volts. Thus if the unit is bypassed whilst in the expansion mode there will be a false impression of expansion simply because the output level will now be higher.

It should be understood that the unit's function is to expand dynamic range and because of this it is necessary to increase amplifier volume when using expansion.

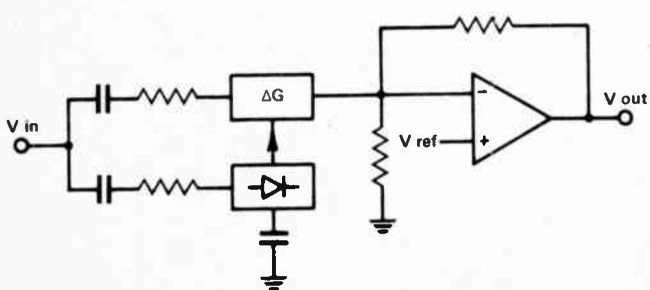
This effect may be minimised by maintaining maximum input level as close as possible to one volt (or three volts —see main text).

Expander or Compressor

These diagrams show how the IC is connected to operate as either a compressor or expander with a fixed ratio of 2.0.



Basic compressor



Basic expander.

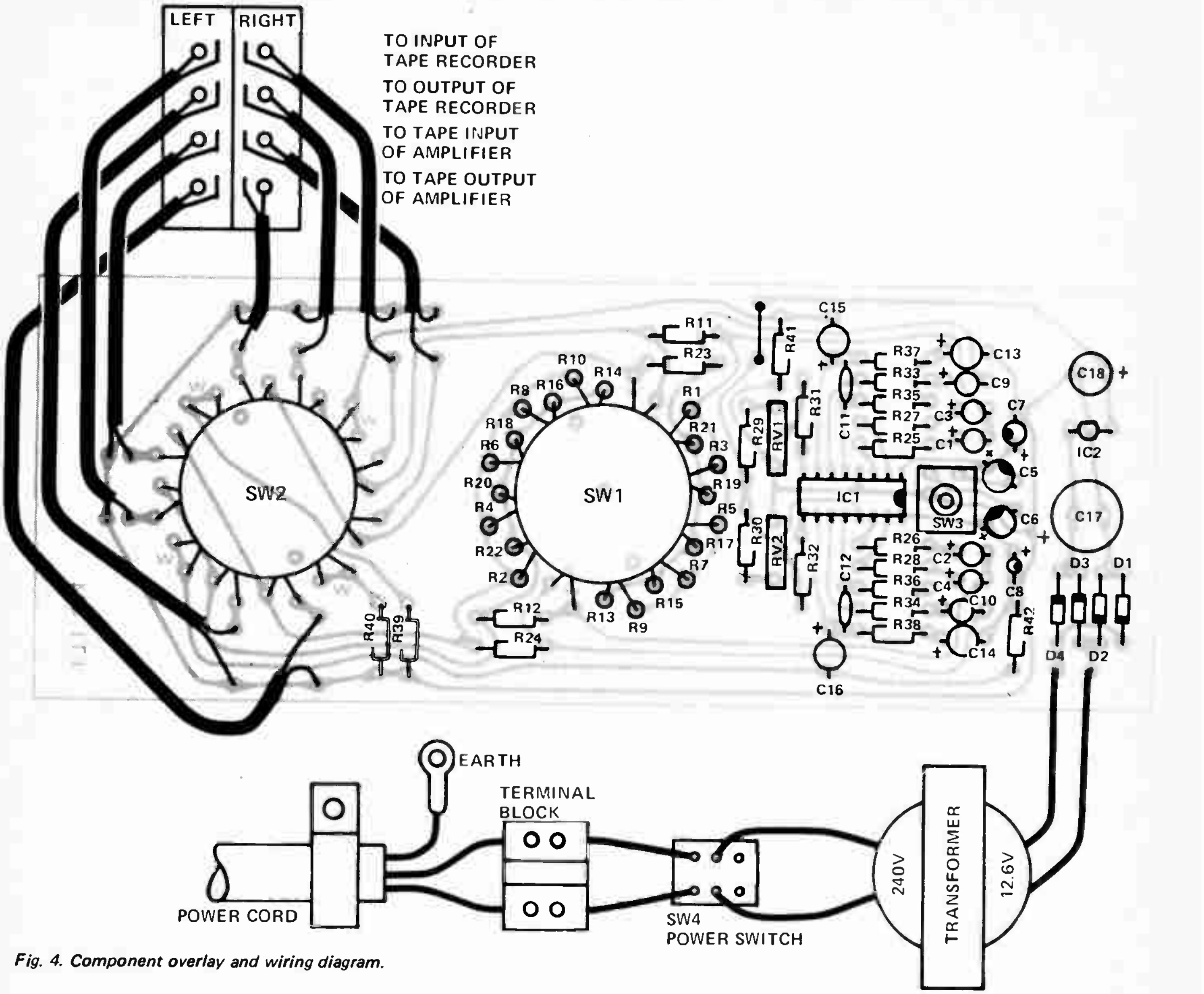


Fig. 4. Component overlay and wiring diagram.

PARTS LIST – ETI 484

Resistors all ½W 5%
R1,2 4k7
R3,4 10k
R5,6 15k
R7,8 27k
R9,10 68k

R11,12 4k7
R13,14 68k
R15,16 27k
R17,18 15k
R19,20 10k

R21,22 4k7
R23,24 4k7
R25,26 22k
R27,28 10k
R29,30 47k
R31,32 68k

R33,34 22k
R35-R38 33k
R39-R42 1M

Potentiometers
RV1,2 25 k trim

Capacitors
C1-C4 1µ0 50V electro
C5,6 6µ8 10V tantalum
C7,8 3µ3 10V tantalum
C9,10 1µ0 50V electro
C11,12 33p ceramic

C13.14 10µ 16V electro
C15,16 100µ 16V electro
C17 220µ 35V electro
C18 100µ 16V electro

Semiconductors
IC1 NE571
IC2 78 L 12
D1-D4 1N4001

Miscellaneous
PC board ETI 484
Transformer 240-12.6V 100mA
SW1 4 pole 6 position OAK switch (2 sec. 2 poles 6 pos.)
SW2 8 pole 2 position OAK switch (2 sec. 4 poles 2 pos.)
SW3,4 DPDT toggle
Two, four-way RCA sockets
Chassis, cover and front panel
3 core flex, plug and clamp

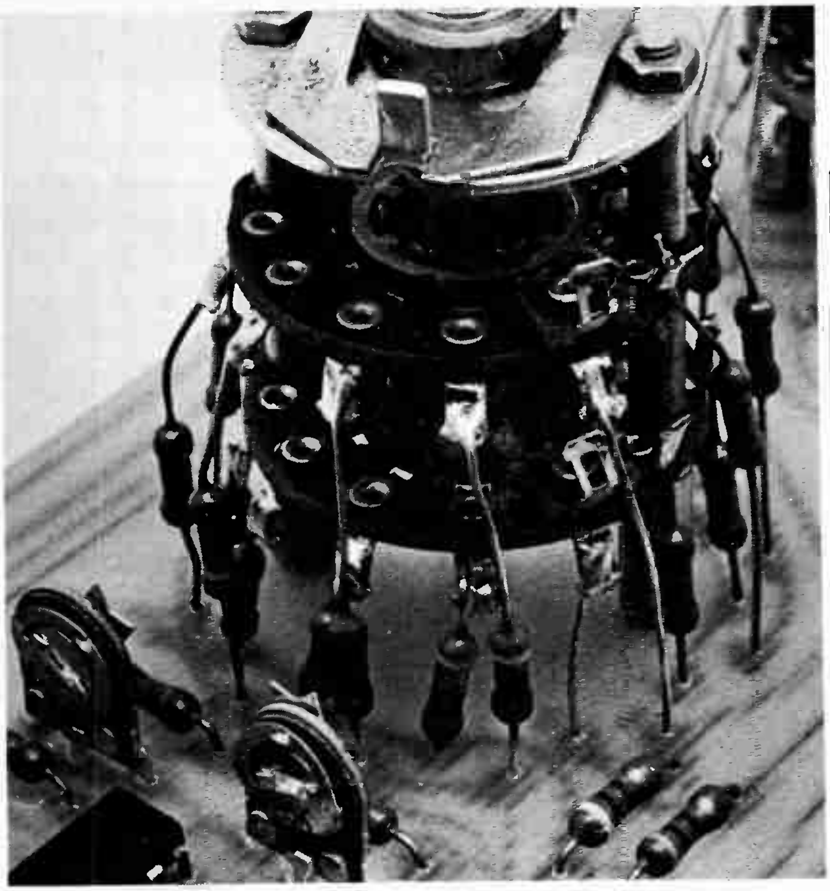
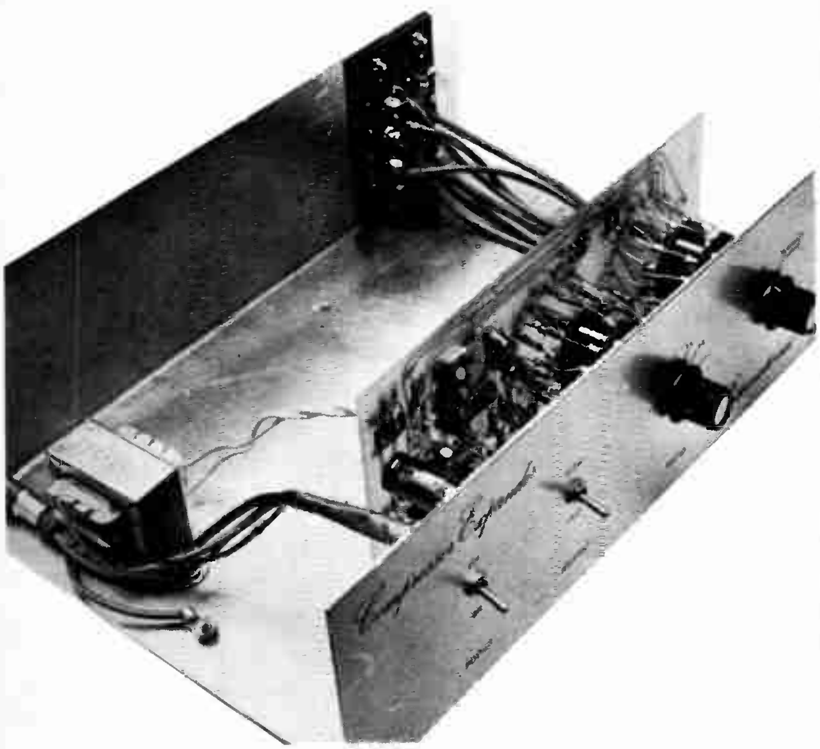


Photo showing how the resistors are connected to the rotary switch.



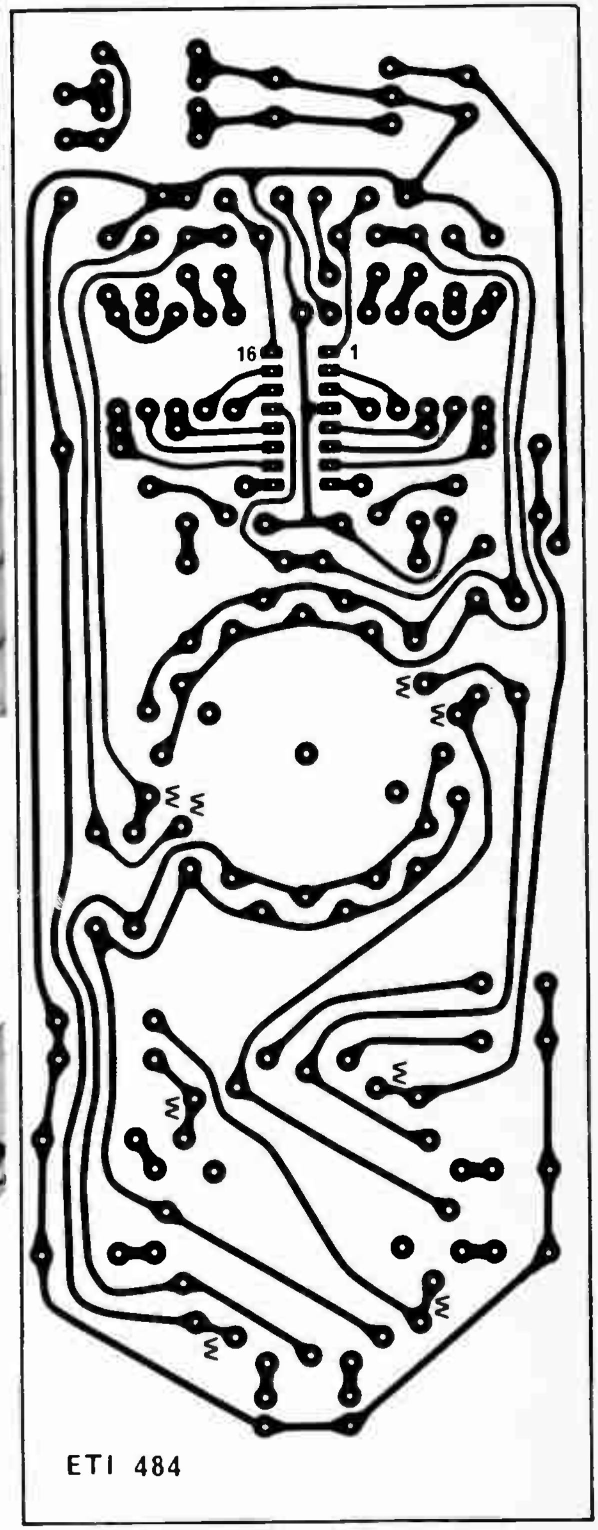


Fig. 5. Printed circuit layout. Full size 200 x 75 mm.

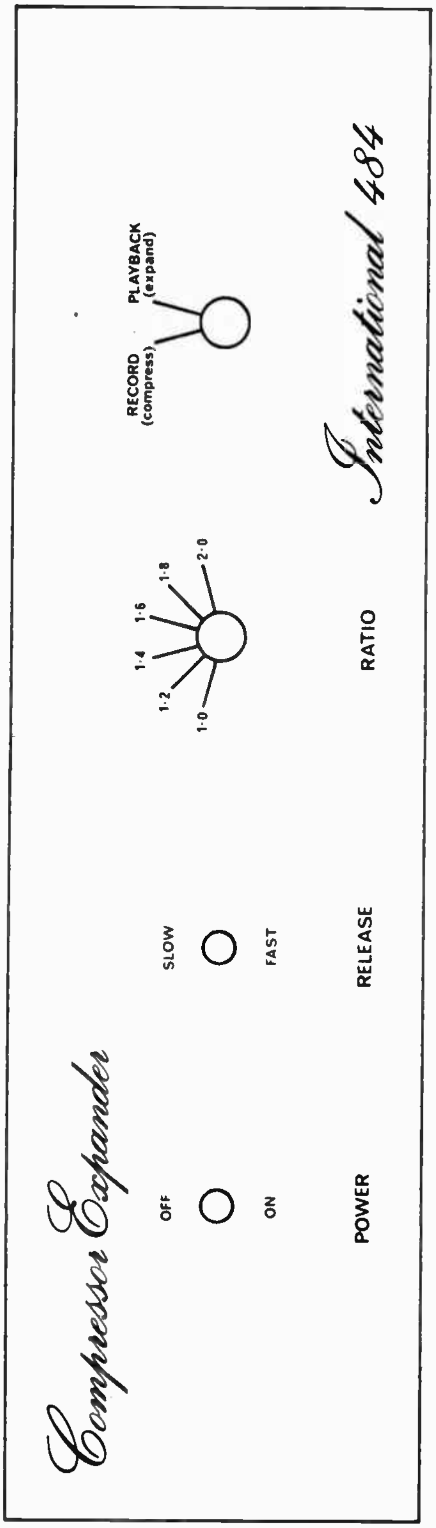


Fig. 6. Front panel artwork.
For dimensions see Fig. 9.

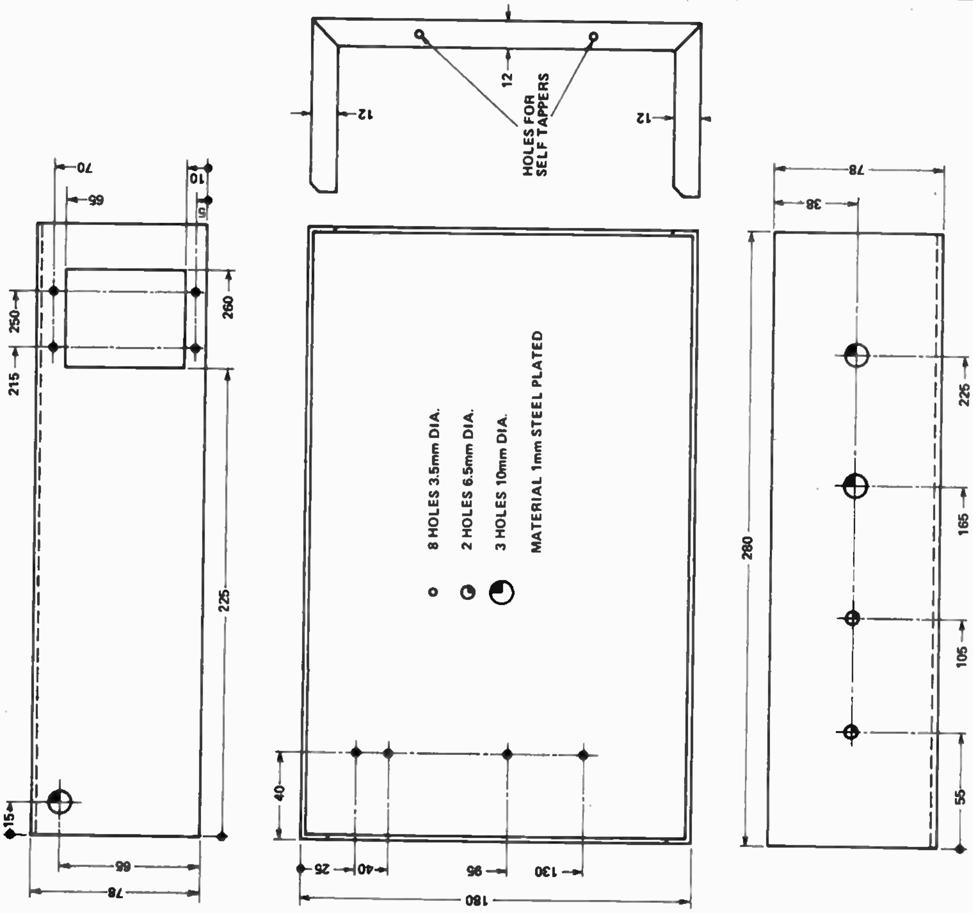


Fig. 7. Chassis details.

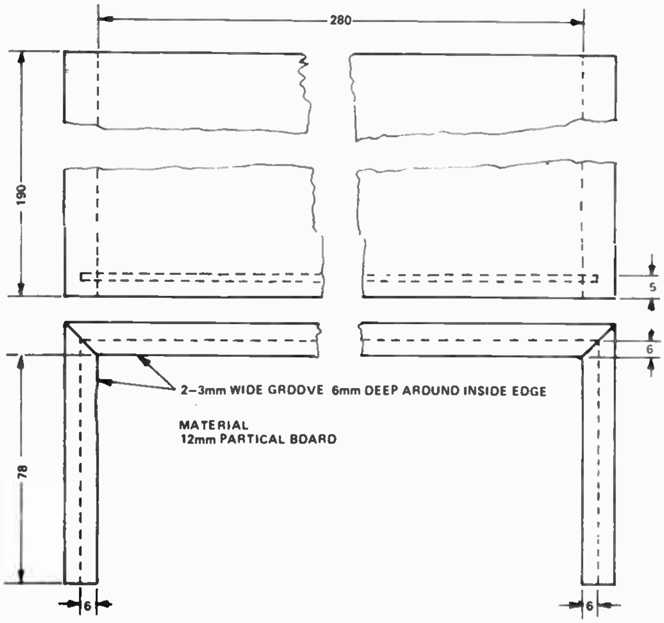


Fig. 8. Cover used on the unit.

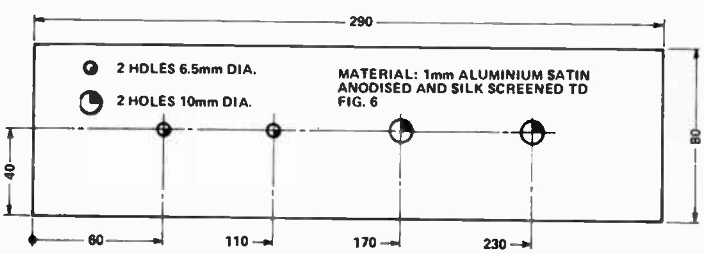
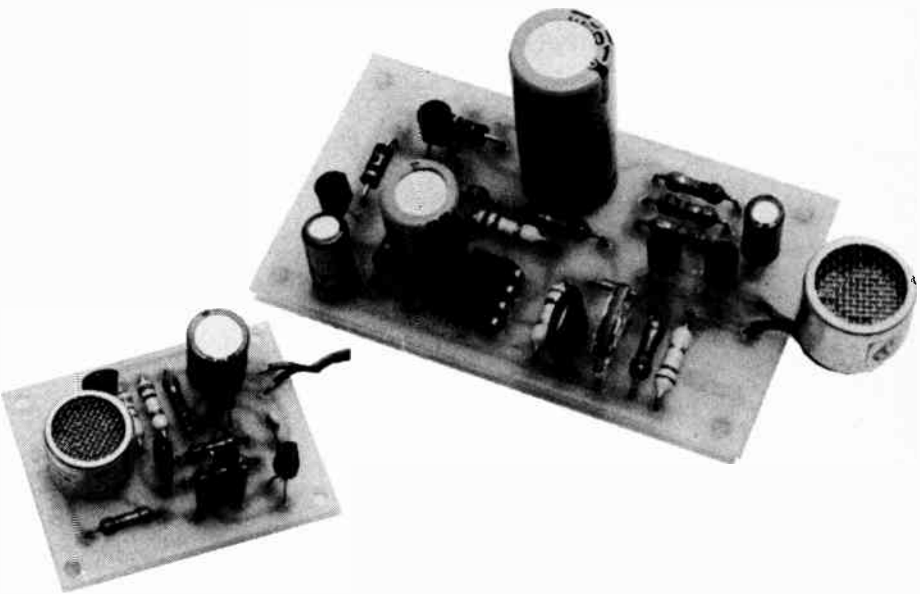


Fig. 9. Dimensions of the front panel.

ULTRASONIC SWITCH

Two-board design forms basis for a wide range of applications from door-bells to data transmission!



THE USE OF an invisible beam to transmit information or to act as an alarm system has always been fascinating. We have described light operated systems of the infra-red (invisible), normal light and laser beam types. We have also published a radar alarm system. This unit uses a high frequency acoustical beam, well above the range of human hearing, which can be used simply as a door monitor, i.e. to give an alarm if the beam is broken, or can be modulated at up to several hundred Hz. This will allow information to be transmitted — details of how to do this may be provided in ETI late in 1978.

Construction

The construction of the units is not critical — any method may be used although the PC boards are recommended. We didn't mount the relay on the PCB as it can vary in size and if the unit is later used with a modulated beam, the relay will not be needed.

The only adjustment on the unit is the sensitivity control and this should be set to give reliable operation. The transmitter needs a supply voltage of 8 V to 20 V at about 5 mA. This could come from the regulated supply on the receiver board.

If it is required to extend the effect of a quick break in the beam or a quick burst from the transmitter, the resistor R9 can be replaced by C4 and this will give a minimum operation time of about 1 second.

SPECIFICATION — ETI 585

Frequency	40 kHz
Range	5 meters
Maximum modulation frequency (not with relay output)	250 Hz
Output	relay, closed when beam is made.
Power supply	
Receiver	10 — 20 Vac or 14 — 25 Vdc
Transmitter	8 — 20 Vdc (only)

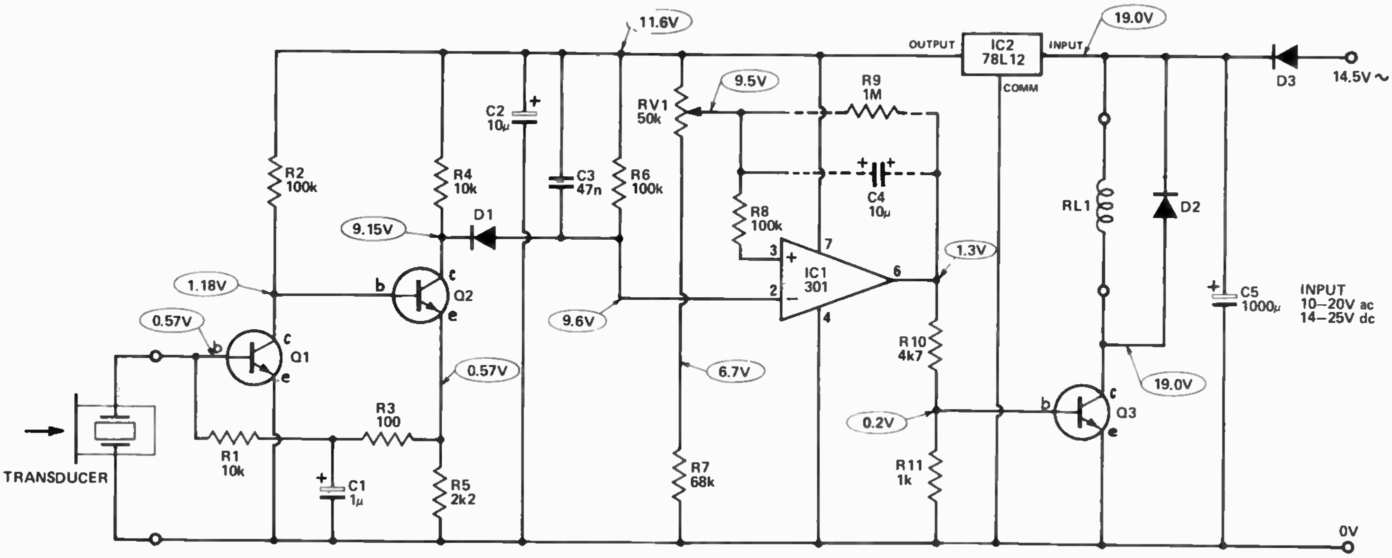
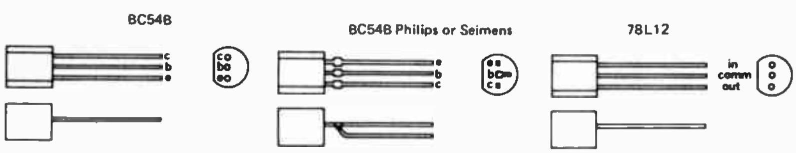
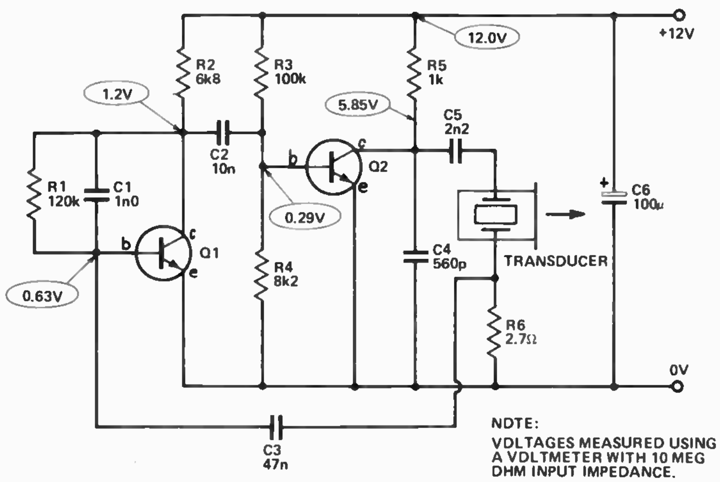


Fig. 1. Circuit diagram of the receiver.



NOTES:
VOLTAGES MEASURED WITH NO INPUT SIGNAL USING A VOLTMETER WITH 10 MEG OHM INPUT IMPEDANCE.
Q1–Q3 ARE BC548
D1 IS 1N914
D2,D3 ARE 1N4001
C4 IS USED INSTEAD OF R9 IF A MONOSTABLE ACTION IS REQUIRED.



NOTE:
VOLTAGES MEASURED USING A VOLTMETER WITH 10 MEG OHM INPUT IMPEDANCE.

Fig. 2. Circuit diagram of the transmitter.

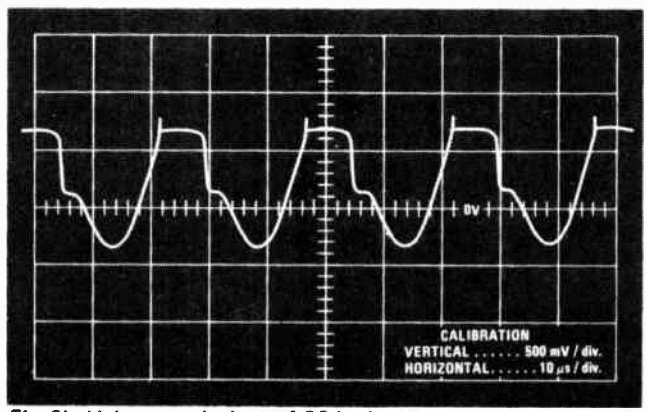


Fig. 3b. Voltage on the base of Q2 in the transmitter.

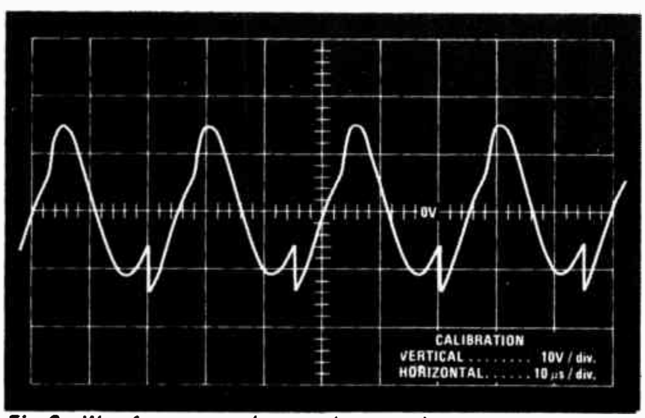


Fig. 3a. Waveform across the transducer on the the transmitter.

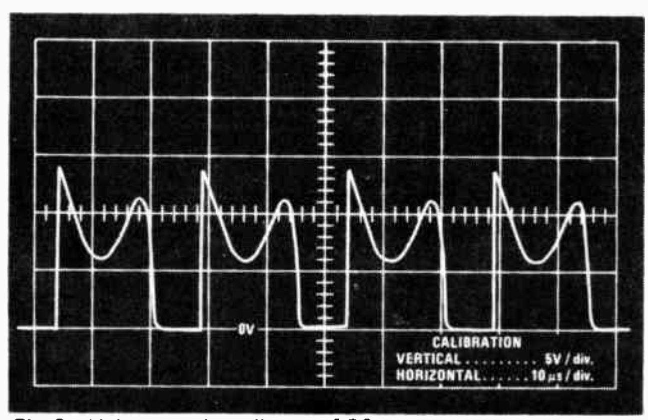


Fig. 3c. Voltage on the collector of Q2.

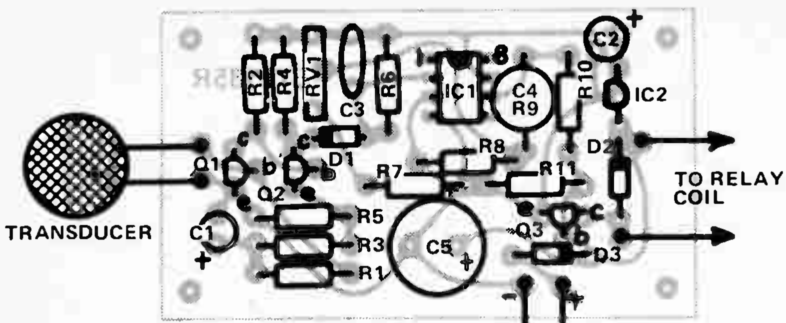


Fig. 4. Overlay of the receiver.

PARTS LIST – ETI 585 T

Resistors all ½W 5%

R1 . . . . . . 120k
R2 . . . . . . 6k8
R3 . . . . . . 100k
R4 . . . . . . 8k2
R5 . . . . . . 1k
R6 . . . . . . 2.7 ohms

Capacitors

C1. . . . . . . 1n0 polyester
C2. . . . . . . 10n "
C3. . . . . . . 47n "
C4. . . . . . . 560p ceramic
C5. . . . . . . 2n2 polyester
C6. . . . . . . 100µ 25V electro

Transistors

Q1,2 . . . . . BC548

Miscellaneous

PC board ETI 585 T
40kHz transmitter
case to suit

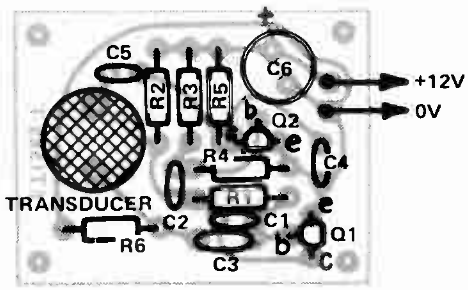


Fig. 5. Overlay of the transmitter.

PARTS LIST – ETI 585 R

Resistors all ½W 5%

R1 . . . . . . 10k
R2 . . . . . . 100k
R3 . . . . . . 100 ohms
R4 . . . . . . 10k
R5 . . . . . . 2k2
R6 . . . . . . 100k
R7 . . . . . . 68k
R8 . . . . . . 100k
R9 . . . . . . 1M
R10. . . . . . 4k7
R11. . . . . . 1k

Potentiometer

RV1 . . . . . 50k trim

Capacitors

C1. . . . . . . 1µ0 25V electro
C2. . . . . . . 10µ 25V "
C3. . . . . . . 47n polyester
C4. . . . . . . 10µ non polarised electrolytic
C5. . . . . . . 1000µ 16V electro

Semiconductors

Q1–Q3. . . . BC548
IC1 . . . . . . LM301A
IC2 . . . . . . 78L12
D1 . . . . . . 1N914
D2,3 . . . . . 1N4001

Miscellaneous

PC board ETI 585 R
40 kHz receiver
12 V relay
case to suit

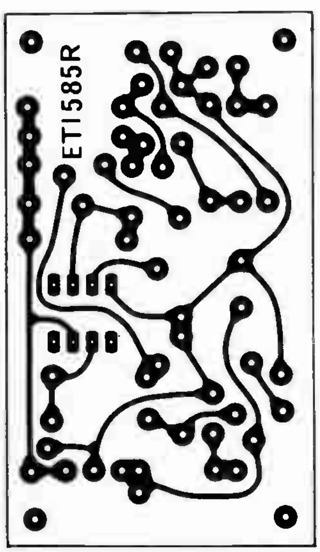


Fig. 6. Printed circuit board of receiver. Full size 70 x 40.

HOW IT WORKS – ETI 585

Transmitter

This is an oscillator the frequency of which is determined by the transducer characteristics. The impedance curve of the transducer is similar to that of a crystal with a minimum (series resonance) at 39.8 kHz followed by a maximum (parallel resonance) just above it at 41.5 kHz.

In the circuit the two transistors are used to form a non-inverting amplifier and positive feedback is supplied via the transducer, R6 and C3. At the series resonant frequency this feedback is strong enough to cause oscillation.

Capacitors C1 and C4 are used to prevent the circuit oscillating at the third harmonic or similar overtones while C5 is used to shift the series resonant point up about 500 Hz to better match the receiver.

Receiver

The output from the transducer is an a.c. voltage proportional to the signal being detected (40 kHz only). As it is only a very small level it is amplified by about 70 dB in Q1 and Q2. D.c. stabilization of this stage is set by R1 and R3 while C1 closes this feedback path to the 40 kHz a.c. signal.

The output of Q2 is rectified by D1 and the voltage on pin 2 of IC1 will go more negative as the input signal increases. If the input signal is strong the amplifier will simply clip the output, which on very strong signals will be a square wave swinging between the supply rails.

IC1 is used as a comparator and checks the voltage on pin 2, i.e. the sound level, to that on pin 3 which is the reference level. If pin 2 is at a lower voltage than pin 3, i.e. a signal is present, the output of IC1 will be high (about 10.5 volts) and this will turn on Q3 which will close the relay. The converse occurs if pin 2 is at a higher voltage than pin 3.

A small amount of positive feedback is provided by R9 to give some hysteresis to prevent relay chatter. If R9 is replaced by the capacitor C4 the IC becomes a monostable and if the signal is lost for only a short time the relay will drop out for about 1 second. If the signal is lost for more than 1 s the relay will be open for the duration of the loss of signal.

We used a voltage regulator to prevent supply voltage fluctuations triggering the unit. The relay was not included on the regulated supply, allowing a cheaper regulator to be used.

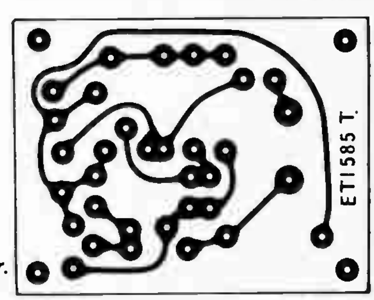
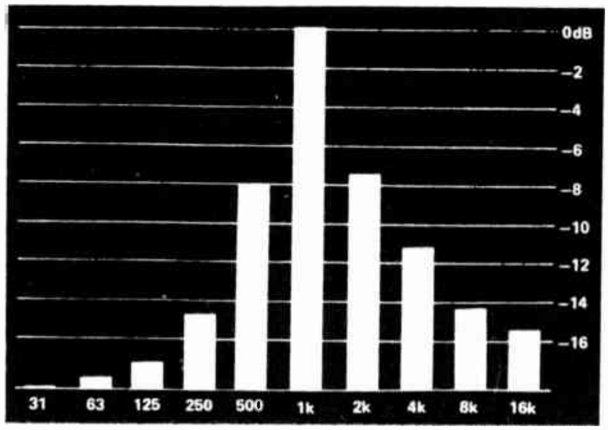


Fig. 7. Printed circuit board of transmitter. Full size 46 x 36.

Audio Spectrum Analyser

Equalise systems for room acoustics accurately using this neat piece of 'test' gear.



AUDIO SPECTRUM ANALYSERS can be a valuable tool used in the setting up of a room acoustically with a graphic equalizer such as the ETI 485; to monitor programme material or just as a gimmick to please yourself and friends.

When setting up rooms pink noise is pumped into the room using an amplifier. A microphone is then used to monitor the sound and its output is the input to the analyser. Now by adjusting the graphic equalizer a flat response can (hopefully) be obtained.

SPECIFICATION – ETI 487

No. of bands	10
Frequencies	31, 63, 125, 250, 500, 1k, 2k, 4k, 8k, 16k
Filter characteristics	−12dB, one octave from nominal centre frequency
Display	CRO in XY mode
Input level	50mV – 10V
Input impedance	200k
Pink noise output	200mV
X output	±4 V approx
Y output	0V to 10V

Design Features

Spectrum analysis can be done by two main methods. The first is to have a tuneable filter which is swept across the band of interest. The output of the filter, when displayed on an oscilloscope, will be a frequency/amplitude graph of the input. While this gives a well-formatted and accurate display it is not "real time" in that if an event occurs at one frequency while the filter is sweeping elsewhere it will not be recorded. For this reason this method is used normally where the spectral content is constant and the sweep is only over a small percentage of total frequency (such as the output of a radio transmitter).

For real time analysis the frequency spectrum is broken into bands using bandpass filters and the output of each rectified. The output from these rectifiers can be displayed on a CRO as in this project or by columns of LEDs or similar methods. The number of bands and the dynamic range required determine the filters used. In this project where only about 20dB is required a single LC network is sufficient. Another unit we have built (not for a project) uses a 6 pole high pass filter followed by a 6 pole low pass one. This gives a flat response (∓ 1dB) over ∓ ½ octave and is 36dB down 1 octave away. However, it uses 6 op amps and 2% capacitors and resistors in each filter!

If there are sufficient requests for it we will publish a LED version of this unit.

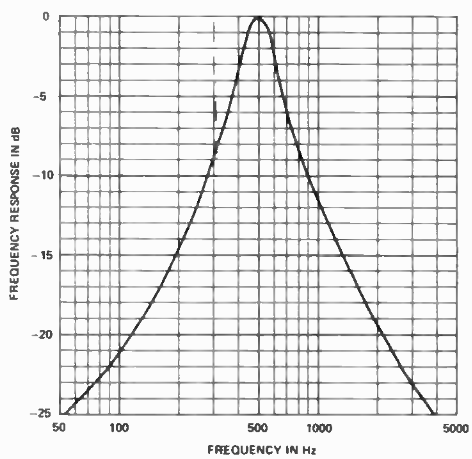


Fig. 1. The frequency response of the 500Hz filter. All other filters follow a similar curve.

HOW IT WORKS – ETI 487

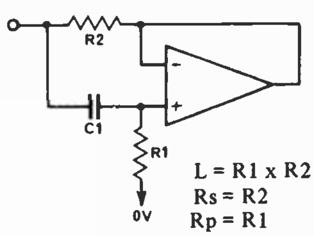
The unit can be broken into eight sections to help the explanation of how it works.

(a) Input amplifier
(b) Ten individual filters and rectifiers.
(c) Ten way analogue switch with decade counter.
(d) Staircase generator controlled by "c". (X output).
(e) Log converter.
(f) Ramp generator and comparator. (Y output)
(g) A pink noise generator.
(h) Power supply.

(a) The input amplifier has an input impedance of 220 k (set by R1) and a gain of 101 ((R3 + R2)/R2). The output of the amplifier drives all ten filters and Q1 and Q2 are used to buffer IC1 to give the drive capability required.

(b) The ten filter-rectifiers are identical except for component values and a bias resistor in the three lowest frequency filters, where tantalum capacitors are used in series. The filter is a parallel LC network which, with a series resistor, gives a band-pass filter.

As large value inductors are expensive we have used an active one using an operational amplifier, two resistors and a capacitor. The value of such a network is as follows:



L = R1 x R2 x C1 H
Rs = R2
Rp = R1

The frequency response of the networks is given in fig. 1.

The rectifier is a half wave type where the gain is variable from about 4 to 12. A diode from the output back to pin 2 keeps the op-amp in the linear region on the negative half cycle allowing operation up to the 16kHz of the top filter.

(c) The analogue switches IC23/1 – IC25/2 are controlled by IC22. This is a decade counter with 10 decoded outputs, each of which is high only for one clock period. As the analogue switches need a high to switch them on, only one will be selected at any one time.

(d) The output of the decade counter also controls the staircase generator IC28 with the weighting networks R58 – R72 giving equal steps of about 0.9 volts. Resistor R89 provides a bias current and the output of IC28 starts at about +4 volts and steps down in 0.9V steps to about -4.2 volts when the output switches back to +4 volts. This is used to drive the X input of the CRO. To add some width to the vertical lines, IC29/1 and IC29/2 form an oscillator of about 300 kHz and after filtering by R90 and C69 is coupled into the input of IC28 by R91.

(e) The output of the analogue switch is fed to the diode-resistor network (D21 - D26, R73 - R77) which gives a simple log conversion. This method is simple, needs no adjustments and is adequate for the purpose. As there is some loss in this network IC26 is used to provide a gain of three to recover this loss.

(f) The ramp generator is formed by the constant current (12μA) source and capacitor C71. The capacitor can be discharged by IC25/4 and the current source is controlled by IC24/3. The voltage out of the log converter (IC26) can vary between zero and +10 volts and this is compared to the ramp voltage by IC30. The output of IC30 controls the oscillator formed by IC29/3 and IC29/4. When the ramp voltage exceeds the voltage from IC26 the output of IC30 goes high allowing the oscillator to start. This immediately discharges C71 and switches off the current source which causes the output of IC30 to go low again after only about 2μs. Diode D27 ensures however that the oscillator acts as a monostable giving an output of about 6μs to ensure the capacitor C71 is completely discharged. The output of IC29/4 also clocks IC22 which selects the next inut. If the input from IC26 is ever negative and C71 cannot be discharged to less than this voltage, IC29/3 and IC29/4 will oscillate continuously at about 100kHz clocking IC22 until it finds an input higher. This prevents possibility of lockup if the offset voltages of the op-amps all go the wrong way.

(g) White noise is generated by the zener action of Q3 which is reversed biased. It is amplified by Q4 to give 200 mV of white noise on its collector. White noise however has equal energy per unit bandwidth and what we need is pink noise which selects the next input. If the input bandwidth (i.e., equal energy per octave). To convert white to pink we need a filter at 3 db/octave. This is performed by IC27 with the RC networks providing the necessary curve.

(h) The power supply is a simple rectifier type with IC regulators to give stable supply voltages.

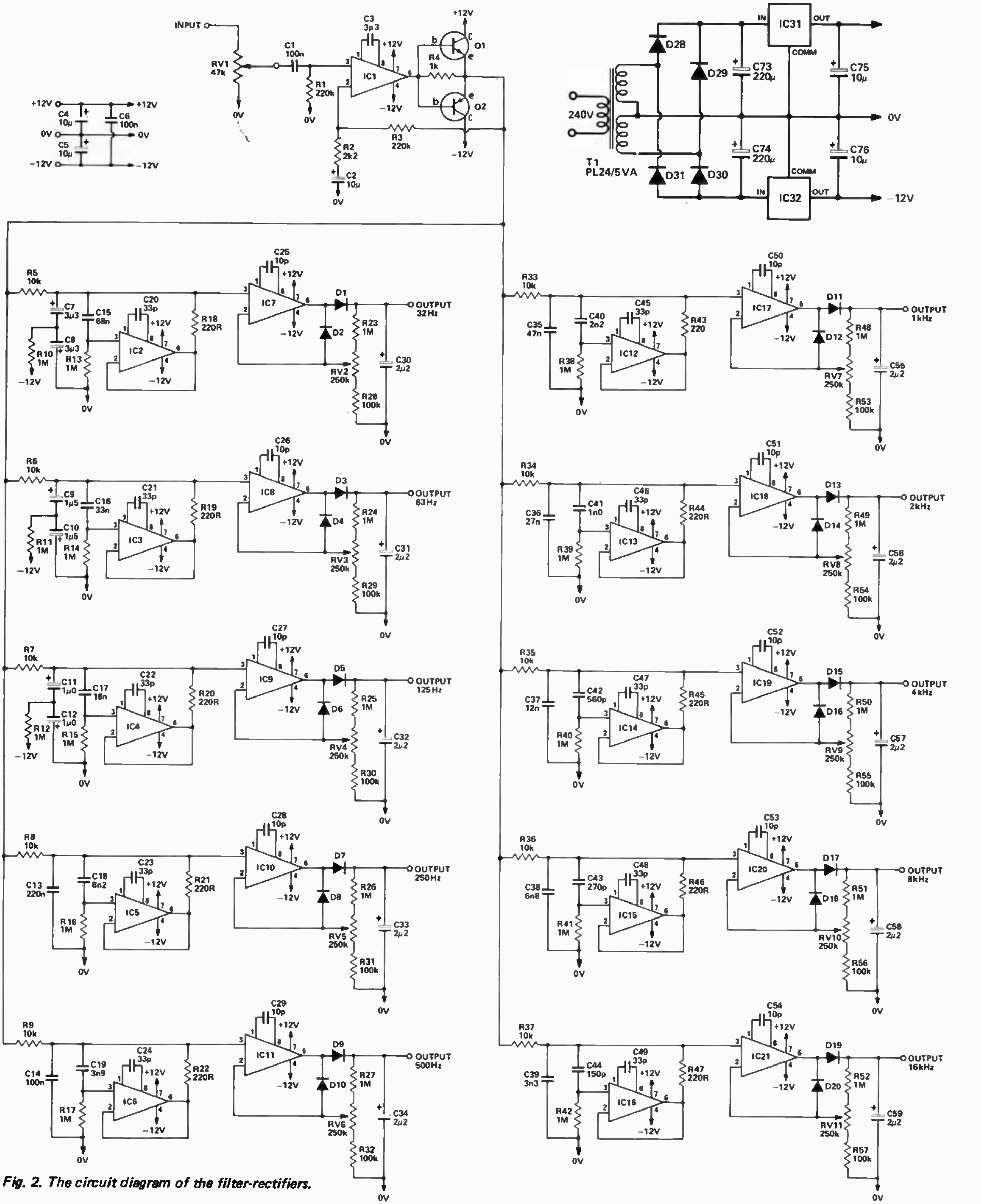


Fig. 2. The circuit diagram of the filter-rectifiers.

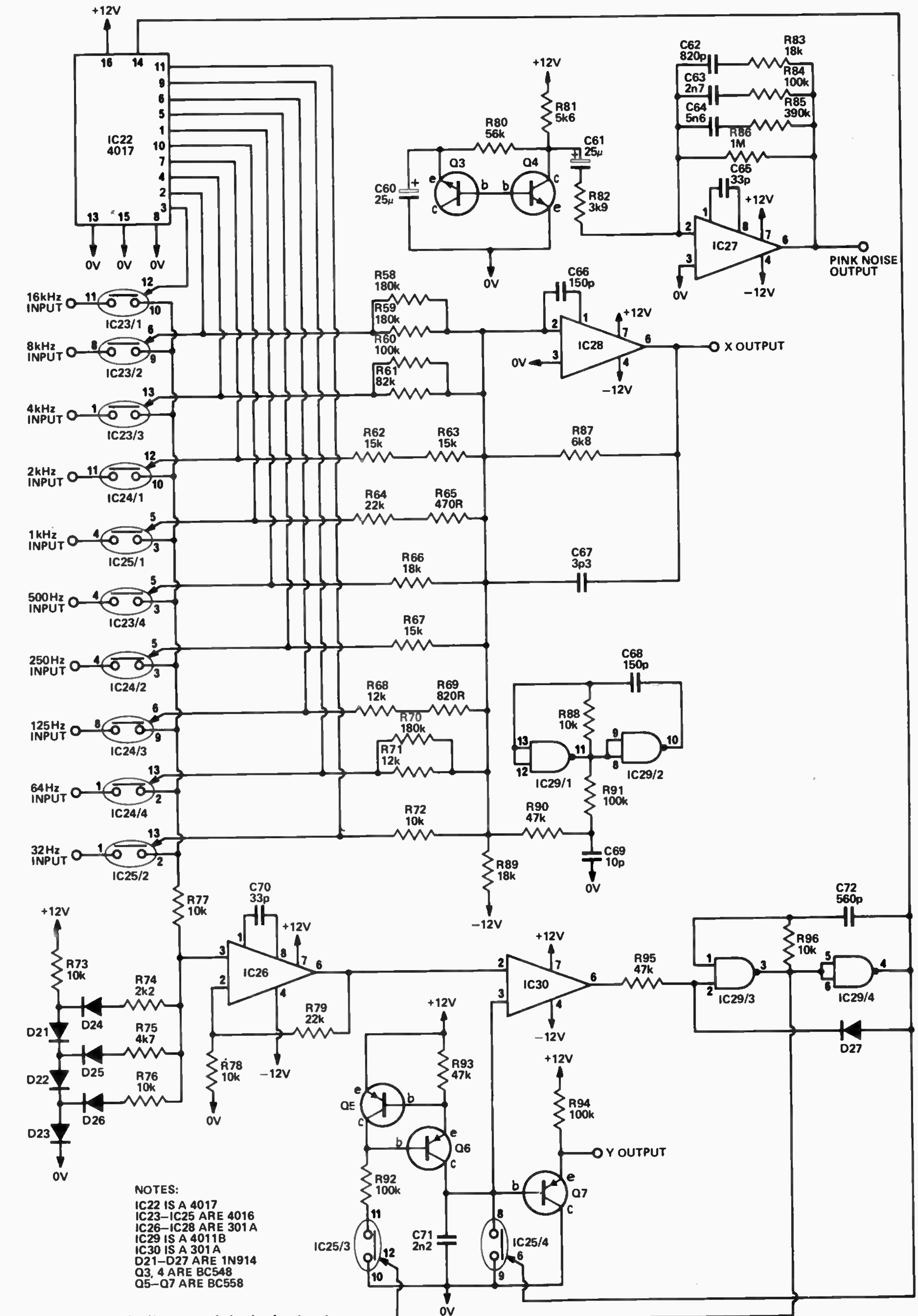
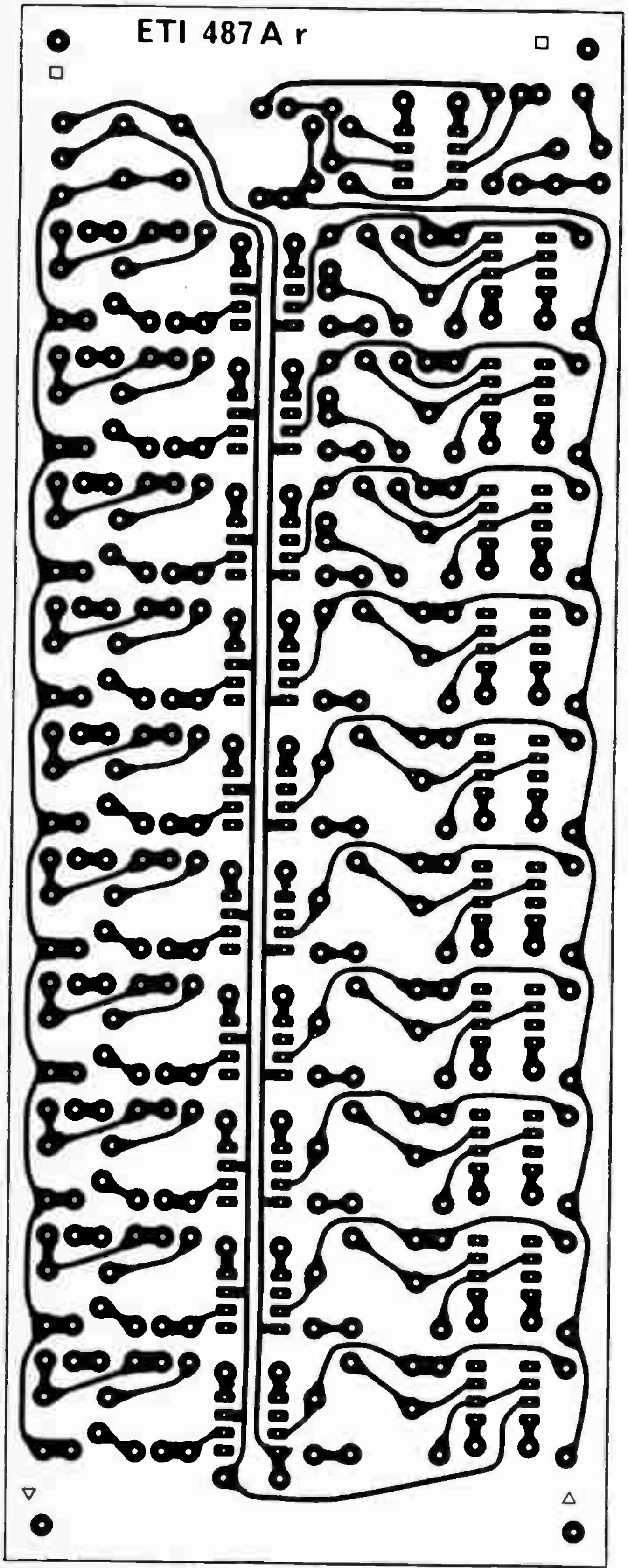


Fig. 3. The circuit diagram of the logic circuitry.

(description continues on page 44)



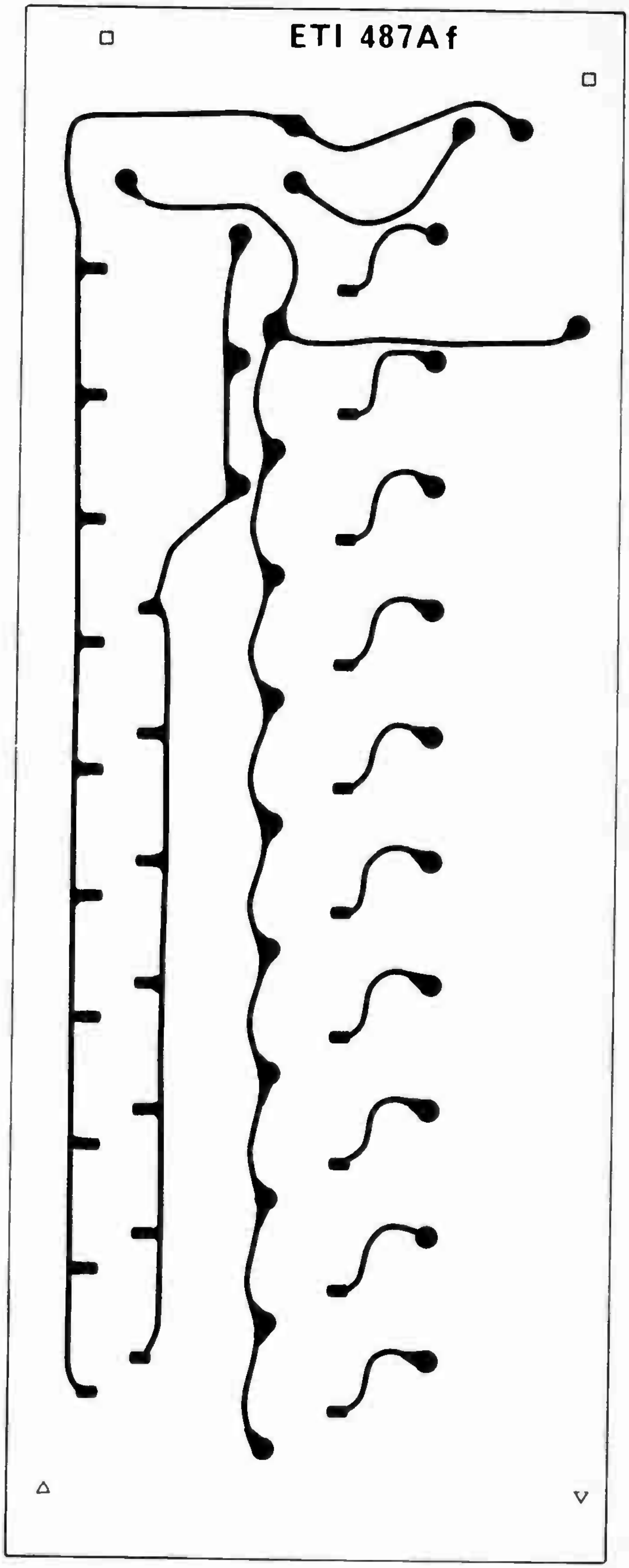


Fig. 4. Both sides of the ETI 487A board shown full size.

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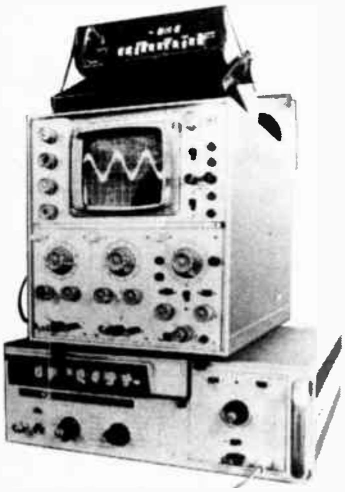

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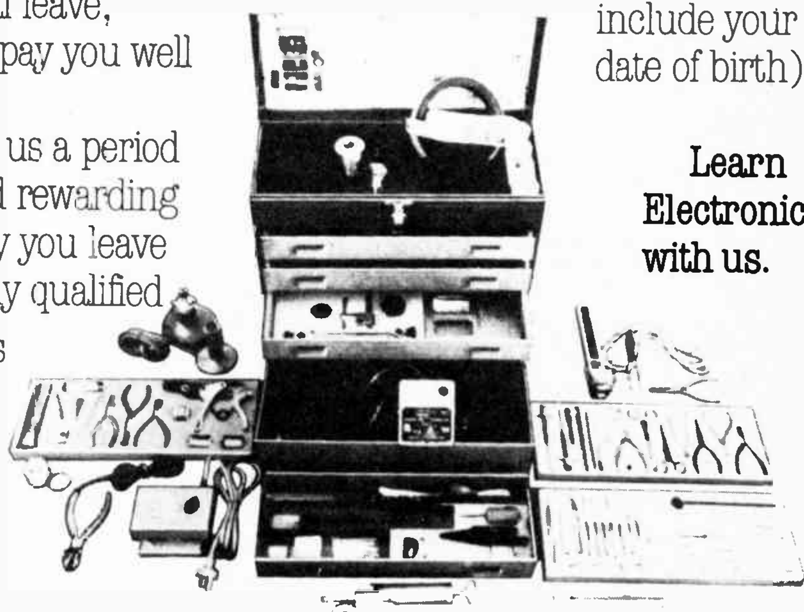

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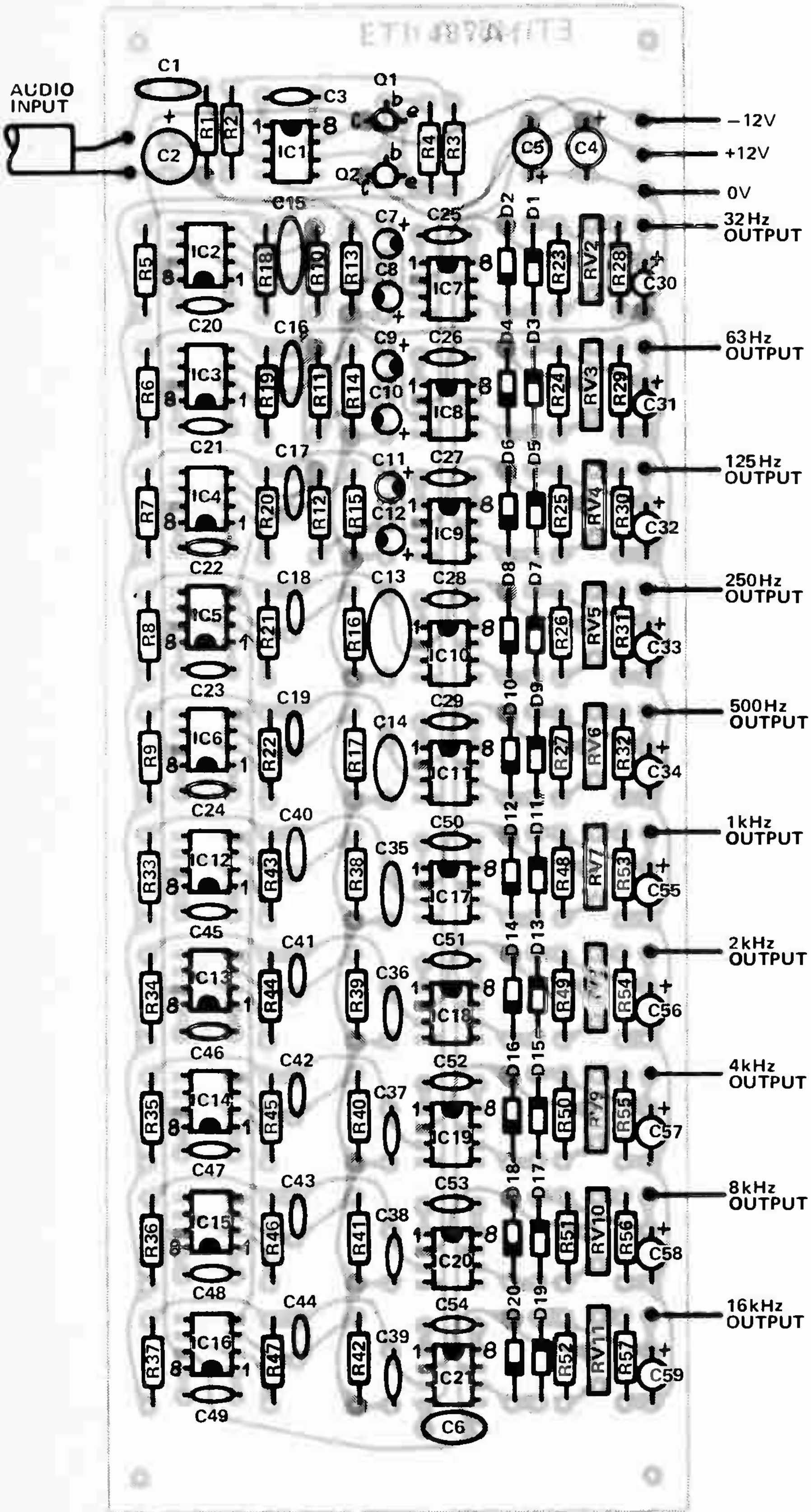


Fig. 5. The component overlay of the filter-rectifier board.

PARTS LIST – ETI 487

Resistors all ½W 5%

R1	220k
R2	2k2
R3	220k
R4	1k
R5–R9	10k
R10–R17	1M
R18–R22	220R
R23–R27	1M
R28–R32	100k
R33–R37	10k
R38–R42	1M
R43–R47	220R
R48–R52	1M
R53–R57	100k
R58,59	180k
R60	100k
R61	82k
R62,63	15k
R64	22k
R65	470R
R66	18k
R67	15k
R68	12k
R69	820R
R70	180k
R71	12k
R72,73	10k
R74	2k2
R75	4k7
R76–R78	10k
R79	22k
R80	56k
R81	5k6
R82	3k9
R83	18k
R84	100k
R85	390k
R86	1M
R87	6k8
R88	10k
R89	18k
R90	47k
R91,92	100k
R93	47k
R94	100k
R95	47k
R96	10k

Potentiometers

RV1	47k log rotary
RV2–RV11	250k trim

Capacitors

C1	100n polyester
C2	10µ 25V electro
C3	3p3 ceramic
C4,5	10µ 25V electro
C6	100n polyester
C7,8	3µ3 16V tantalum
C9,10	1µ5 16V "
C11,12	1µ0 16V "

Construction

Due to the complexity of the unit it is recommended that PC boards are used. These boards are assembled as per the overlay diagrams. Watch the orientation of all the ICs, diodes, capacitors, etc., when installing them. Note that as the board is not a plated through type that the tracks on the top side of the board must also be soldered to the components. This prevents the use of sockets for the ICs but they are not really worth the cost for low priced ICs

Capacitors continued

C13 . . . . 220n polyester
C14 . . . . 100n "
C15 . . . . 68n "
C16 . . . . 33n "
C17 . . . . 18n "
C18 . . . . 8n2 "
C19 . . . . 3n9 "
C20–C24 . . . 33p ceramic
C25–C29 . . . 10p "
C30–C34 . . . 2μ2 25V electro
C35 . . . . 47n polyester
C36 . . . . 27n "
C37 . . . . 12n "
C38 . . . . 6n8 "
C39 . . . . 3n3 "
C40 . . . . 2n2 "
C41 . . . . 1n0 "
C42 . . . . 560p ceramic
C43 . . . . 270p "
C44 . . . . 150p "
C45–C49 . . . 33p "
C50–C54 . . . 10p "
C55–C59 . . . 2μ2 16V electro
C60,61 . . . . . 25μ 16V "
C62 . . . . 820p ceramic
C63 . . . . 2n7 polyester
C64 . . . . 5n6 "
C65 . . . . 33p ceramic
C66 . . . . 150p "
C67 . . . . 3p3 "
C68 . . . . 150p "
C69 . . . . 10p "
C70 . . . . 33p "
C71 . . . . 2n2 polyester
C72 . . . . 560p ceramic
C73,74 . . . . . 220μ 25V electro
C75,76 . . . . . 10μ 25V "

Semiconductors

IC1–IC21 . . . LM301A
IC22 . . . . . . 4017 (CMOS)
IC23–IC25 . . 4016 (CMOS)
IC26–IC28 . . LM301A
IC29 . . . . . . 4011B (CMOS)
IC30 . . . . . . LM301A
IC31 7812
IC32 7912
Q1 . . . . BC548
Q2 . . . . BC558
Q3,4 . . . . . . BC548
Q5–Q7. . . . . BC558
D1–D27 . . . . 1N914
D28–D31 . . . 1N4001

Miscellaneous

PC boards ETI 487A, 487B
Transformer PL24–5VA
Case to suit
3 core flex and plug
240V power switch
Input / output terminals to suit

as used.

With the board 487A be very careful as there is 240V on the board. It is recommended that the wires be terminated directly to the board, without PC board pins, and that the 240V tracks on the underside of the board be coated with epoxy to prevent contact.

We mounted the unit into a home-made box as we did not have a commercial one on hand to suit.

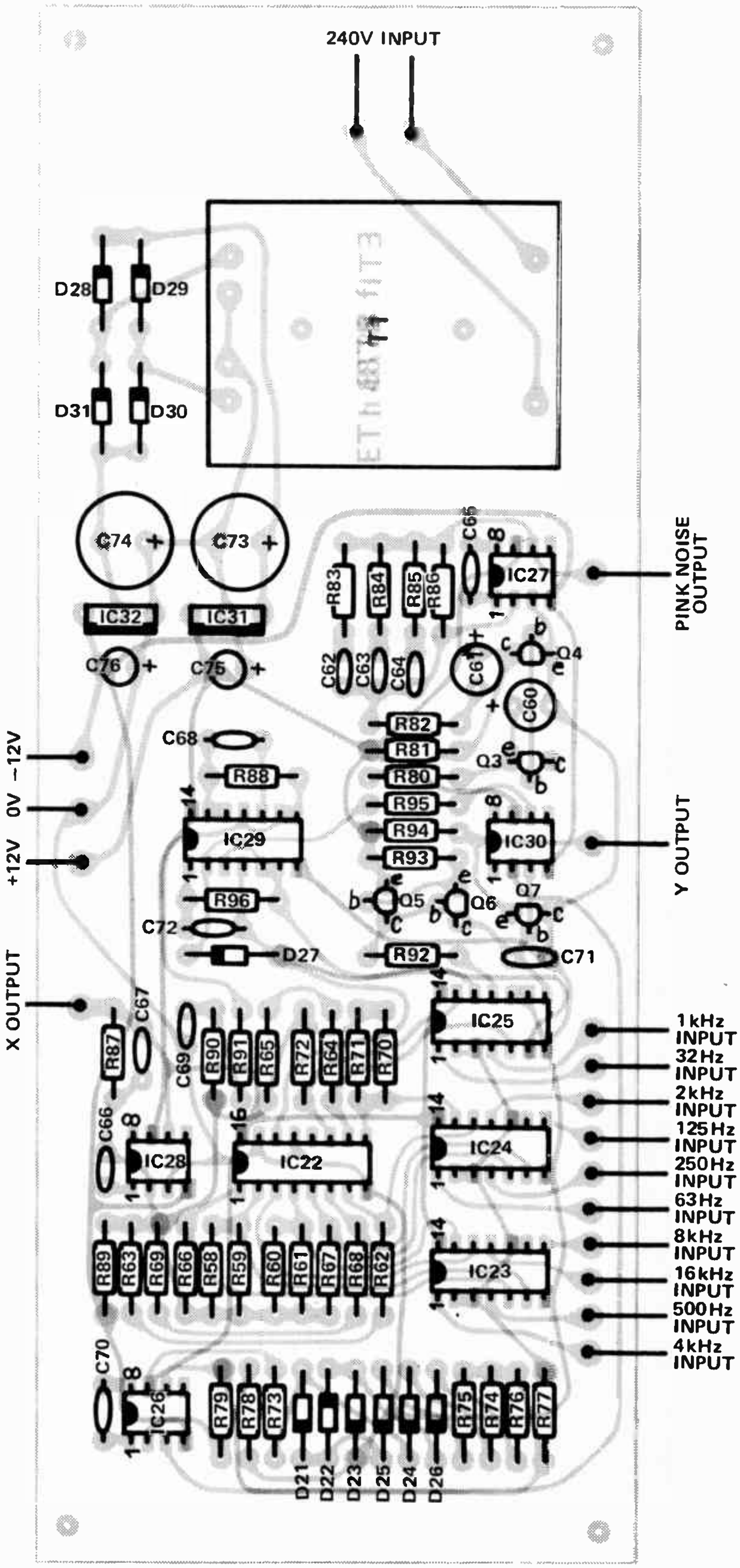


Fig. 6. The component overlay of the logic-power supply board.

Alignment

This can be done using the pink noise generator or preferably with a sine wave oscillator.

Connect the unit to the oscilloscope switched into the X Y mode. With the unit switched on and a signal connected, adjust the X gain and shift to obtain a series of ten vertical bars across the screen. Increase the input signal until the columns will not get any higher. Adjust the Y gain and shift until the column is the height of the screen. Note that the scope should be dc coupled.

Now by sweeping the oscillator frequency it will be found that each column will come up in sequence. Adjust the frequency to peak the 16 kHz column. Now adjust RV11 to about 75% of its travel (wiper towards RV10) and then adjust the overall sensitivity control to give a column height of about 80%.

Now using the same amplitude adjust the signal generator frequency until the 8kHz column peaks and adjust RV10 to give the same height. Each of the filters should be adjusted in the same way. Note that due to component variations the actual peak of a filter may not exactly coincide with its nominal frequency. Also the 16kHz filter has the greatest loss which is the reason for starting with it near its maximum gain.

By taking the pink noise output to the input each column should be approximately the same height. Due to the nature of noise the top of the columns will jump up and down a little and this should be averaged out by the eye.

If an oscillator is not available the noise generator can be used and the potentiometers adjusted to give an even response. Also, if desired, a vertical dB scale can be made.

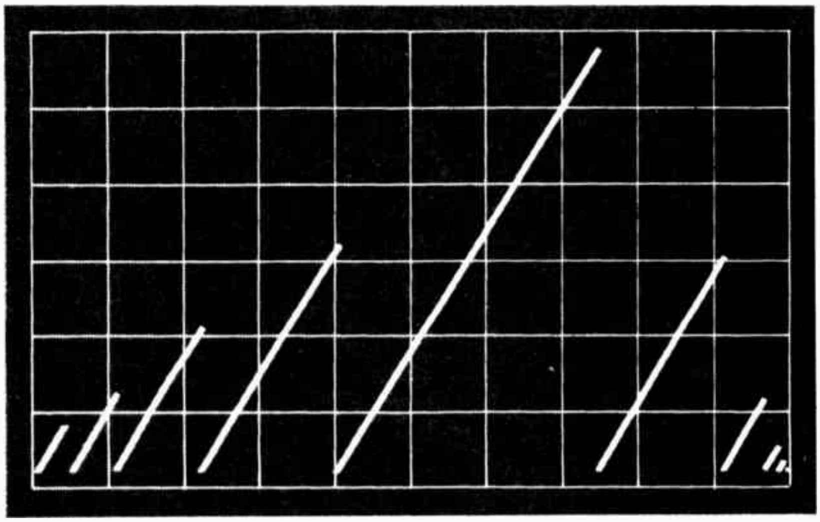


Fig.7. The waveform on the Y output (vertical) with a 1 kHz tone input. See page 38 for the X-Y display. Note that the time between cycles varies with the height.

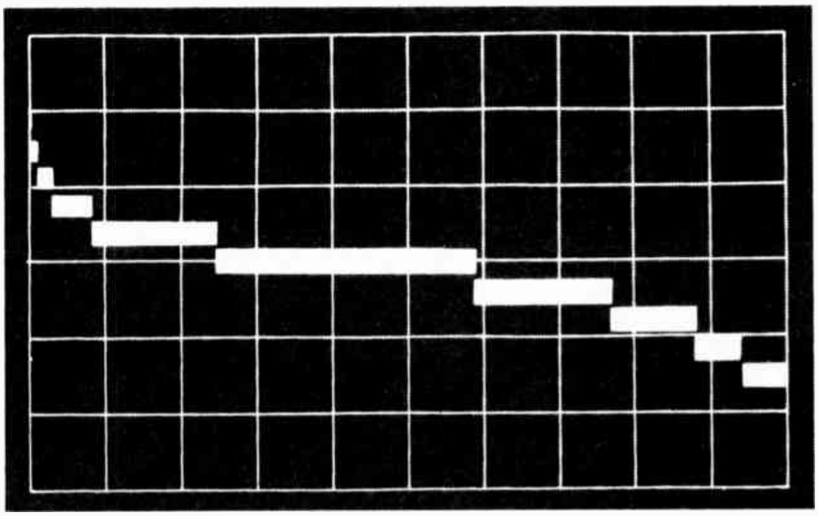


Fig.8. The waveform on the X (horizontal) output. As this starts at +4V which is the right hand side of the screen, the 16 kHz output is sampled first. Note that the time between steps corresponds to that in fig. 7.

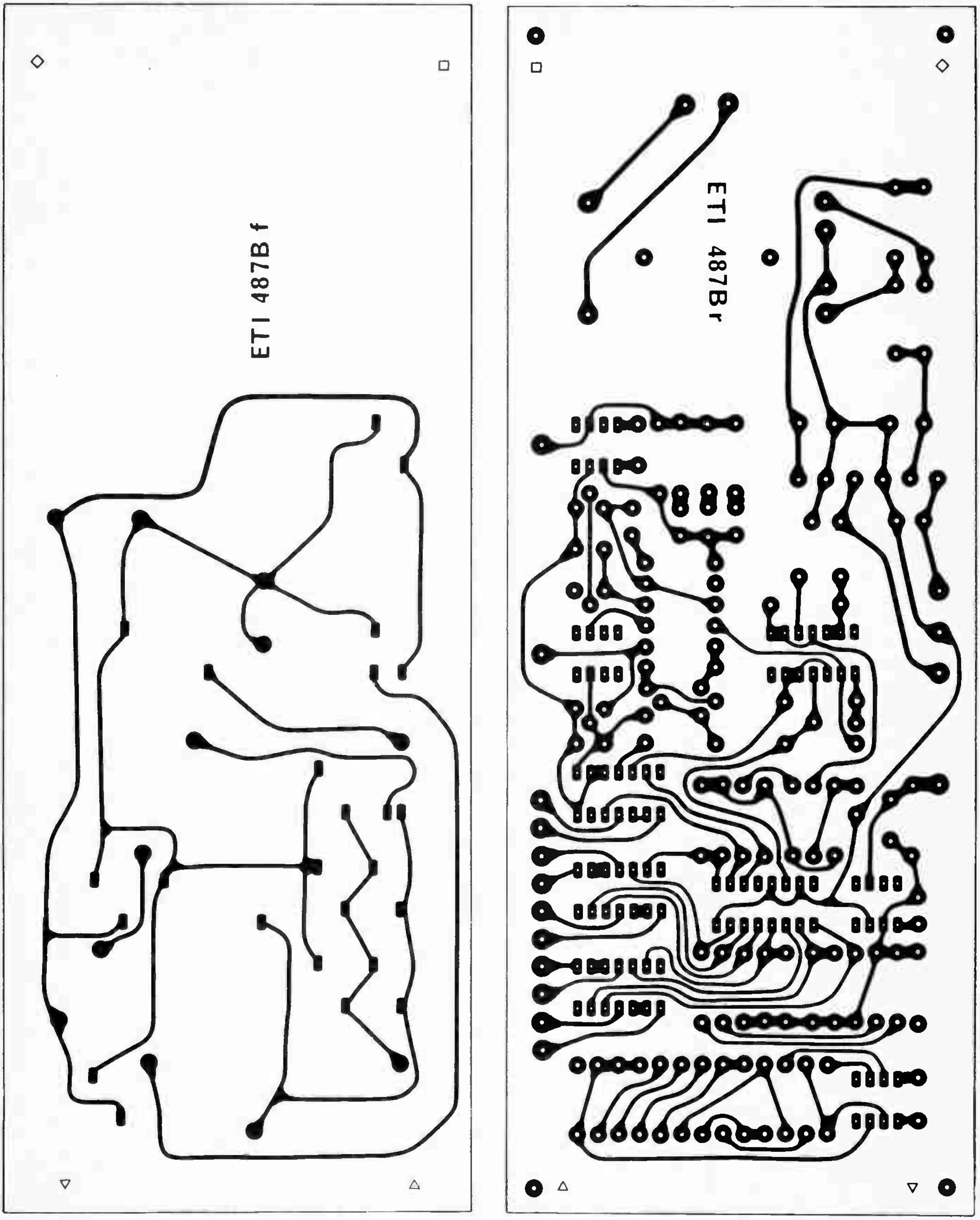


Fig. 9. Both sides of the ETI 487B board shown full size.

Digital Temperature Meter

This simple yet accurate temperature meter will find many uses in the laboratory or home. It utilizes the digital panel meter described on page 55.

THE RELIABILITY OF electronic circuits in the days of valves was, to say the least, poor by today's standards. The introduction of transistors and integrated circuits increased reliability dramatically. One of the main reasons for this is the reduction of power dissipation and the resultant lowering of temperature. Devices and circuits are now designed to minimise power dissipation as this allows a higher component density while increasing reliability. However some circuits by their nature must dissipate high power and the semiconductor devices used must be kept within their temperature limits.

This temperature meter will allow transistor temperatures to be measured and the appropriate heatsink chosen. It is just as useful outside the electronic scene measuring liquid or gas temperature especially where the readout needs to be physically separate from the sensor.

Use and Accuracy

The accuracy of the unit depends on the calibration; provided it has been calibrated around the temperature at which it will be used, accuracy of 0.1 degree should be possible. We could not accurately check linearity but it appeared to be within 1° from 0° to 100°C.

However other errors will affect this reading. If measuring the surface temperature i.e. a heatsink temperature, there will be a temperature gradient between the surface and the junction of

the diode. Silicon grease should be used to minimise the surface-to-surface temperature difference. Also when measuring small objects, e.g. a TO-18 transistor, the probe will actually cool the device slightly. At high temperatures these effects could give an error of up to 5% (the reading is always less than the true value). If the probe is in a fluid, e.g. water or air this problem does not occur.

Construction

Assemble the panel meter as previously described but omitting the zener diodes and R6 and R7. The value of R1 has also been changed. The decimal point drive should be connected to the right-hand decimal point. The additional components can be assembled on a tag strip as shown.

We mounted our unit on a tag strip as shown in the photo. While we have not given any details, knocking up a case should be no problem. For a power supply we used eight penlight Nicad cells giving a 10 V supply. If dry batteries are used six penlight cells are recommended although a 216-type 9 V transistor battery will give about 300 hours of operation.

The sensor should be mounted in a probe as shown in Fig. 1 if other than air temperature will be measured. This provides the electrical insulation needed for working in liquids etc. It should be noted however that the quick dry epoxies are not normally good near or above 100°C and if higher temperatures than this are expected one of the slow dry epoxies should be used.

Calibration

To calibrate this unit two accurately known temperatures are required, one of which is preferably zero degrees and the second in the area where the meter will normally be used and highest accuracy is required. For a general-purpose unit 100°C is suitable. The easiest way of obtaining these references is by heating or cooling a container of distilled water. However temperature gradients can cause problems, especially at zero degrees.

One method of obtaining water at exactly zero degrees is to use a test tube of distilled water in a flask of iced water and allowing it to cool to near zero. Now by adding salt to the iced water its temperature can be lowered to below zero. If you are very careful, the test tube water will also drop below zero without freezing (you should be able to get to about -2°C). However the slightest disturbance at this temperature will instantly cause some of the water to freeze and the remaining water to rise to exactly zero, providing an ideal reference.

For a hot reference the boiling point of distilled water is very close to 100°C especially if the container has a solid base and is evenly heated e.g. on an electric hotplate.

The actual calibration is done as follows:

1. In the 0°C reference adjust RV2 and RV3 until the unit reads zero.
2. In the hot reference adjust RV1 to give the correct reading.

This should be all the adjustment required.

If zero degrees is not available, e.g. if setting up for °F, the following method can be used:

1. In the cold reference use RV2 and RV3 to adjust reading to zero.
2. In the hot reference use RV1 to adjust the reading to indicate the temperature difference between the two standards. If freezing and boiling points are used, this will be 180°F.
3. Now, back in the cold bath, adjust RV2 and RV3 to give the correct reading.

No further adjustment should be required.

SPECIFICATION – ETI 589

Temperature range	– 50°C to +150°C – 60°F to +199.9°F
Resolution	0.1°C or F
Sensor	silicon diode
Power consumption	1.5mA @ 9 V dc

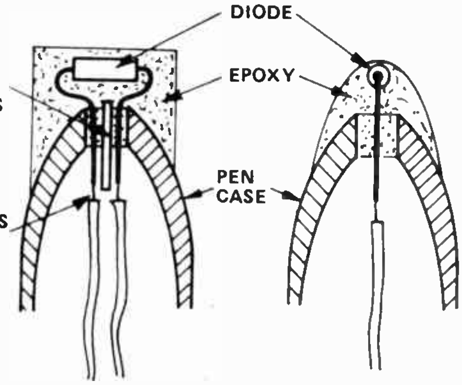


Fig. 1. This diagram shows how the sensor is mounted into a ball-point pen casing or similar.

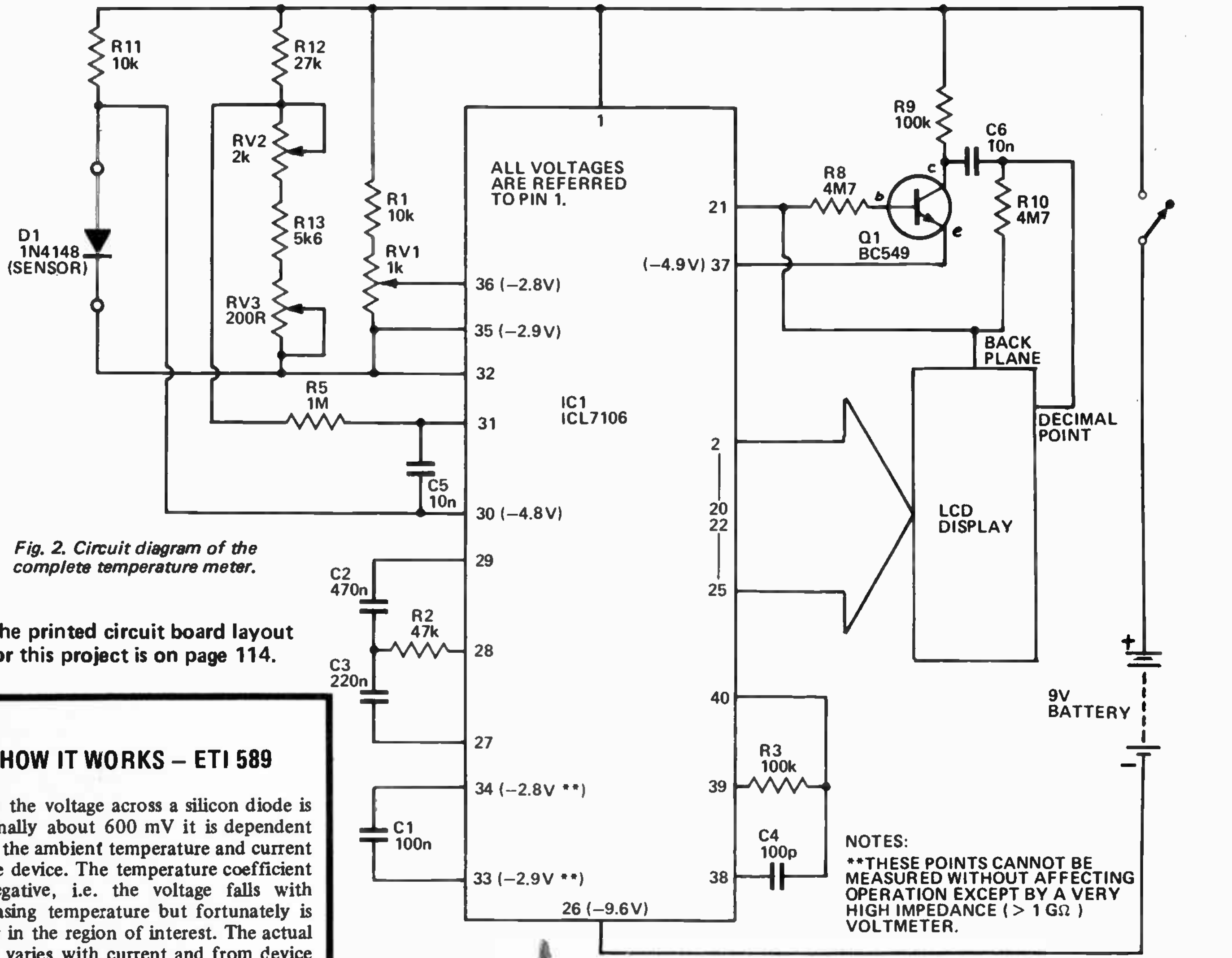


Fig. 2. Circuit diagram of the complete temperature meter.

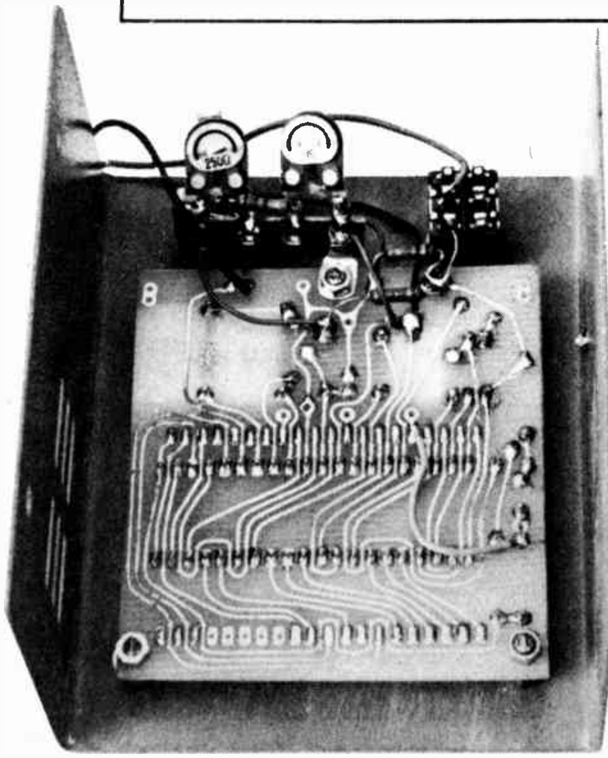
The printed circuit board layout for this project is on page 114.

HOW IT WORKS – ETI 589

While the voltage across a silicon diode is nominally about 600 mV it is dependent upon the ambient temperature and current in the device. The temperature coefficient is negative, i.e. the voltage falls with increasing temperature but fortunately is linear in the region of interest. The actual value varies with current and from device to device, but is typically −2.2 mV/°C at 250 µA.

By measuring the voltage across the diode with a suitable offset voltage to balance the voltage at zero degrees an accurate temperature meter results. The digital panel meter described on page 55 has a stable reference voltage available (between pins 1 and 32) of about 2.9 V; with the 10k resistor R11 this provides a constant current for D1 (the sensor). The offset voltage is also derived from this reference voltage by R12, RV2 and RV3. The panel meter is used as a differential voltmeter and measures the potential difference between the offset voltage and the diode. We have used two trimpots in series in the offset adjustment to give better resolution. If desired a 10-turn trimpot can be used (2k2). Adjustment of the three potentiometers allows the meter to be calibrated in either °C or °F with the upper limit of 199.9°F due to the panel meter over-ranging.

The power supply is simply a 9 V battery, and so the zener diodes and dropping resistors described in the panel meter article should be omitted.



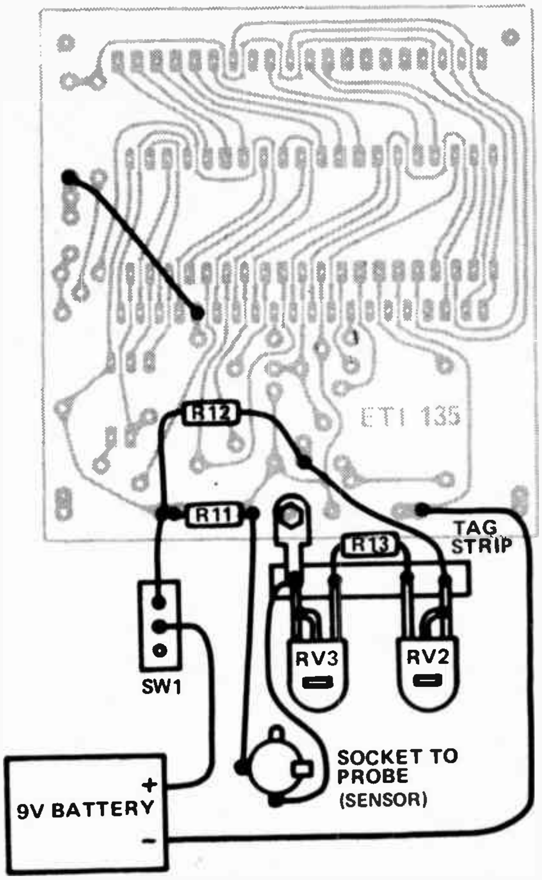


Fig. 3. The external components associated with the panel meter. For details of the panel meter see Project 135, page 55.

PARTS LIST – ETI 589

Resistors all ½ W, 5%

† R1	10k
* R2	47k
* R3	100k
R4	not used
* R5	1M
R6	not used
R7	not used
R8	4M7
R9	100k
R10	4M7
R11	10k
R12	27k
R13	5k6

Potentiometer

* RV1	1k 10 turn trim
RV2	2k trim
RV3	200 trim

Capacitors

* C1	100n polyester
* C2	470n "
* C3	220n "
* C4	100p ceramic
C5	10n polyester
C6	10n "

Semiconductors

* IC1	ICL7106
Q1	BC549
D1	1N4148

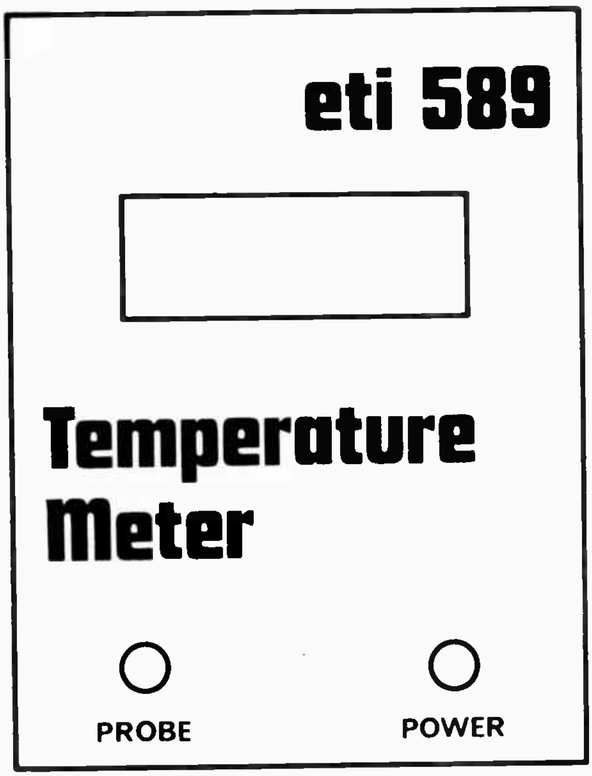
Miscellaneous

PC board ETI 135
Tag strip
* LCD Display
* Socket for LCD display
Box
Switch
9V battery

* These components are supplied with the Intersil ICL7106 EV evaluation kit.

(Addresses of suppliers on page 57)

† This value has been changed from the original panel meter.



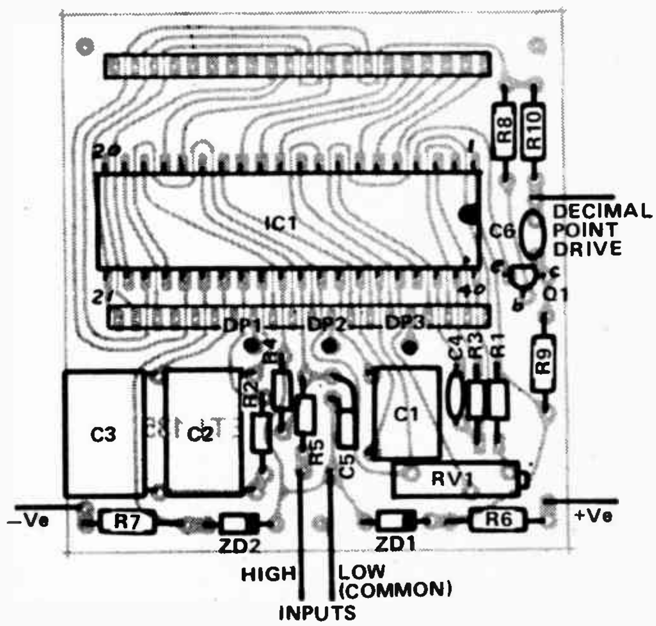


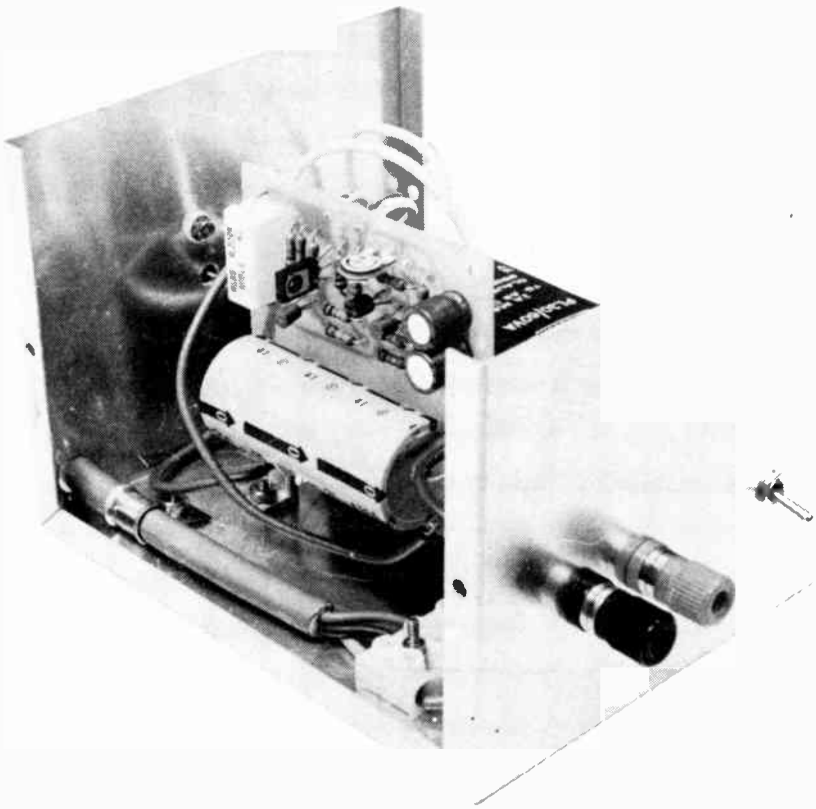
Fig. 4. The component overlay of the panel meter with the display removed. Note that for this project R4, 6, 7, ZD1, 2 and the external leads are not used.

CB POWER SUPPLY

Here's the answer if you want to run the mobile rig off the mains as a base station.

WITH THE EXPLOSION in the popularity of CB radio and its imminent legalization there is a growing demand for a power supply designed to operate mobile transceivers as a base station. In the mobile situation these operate off a 12V battery but while a battery can be used for the base station the problem of keeping it charged is a nuisance. Some people have tried simply a transformer, rectifier and filter capacitor but have run into problems with hum.

This power supply has been designed to operate the base station and can supply up to 2.5A at 13.5V of well regulated and filtered power. While it has been designed for CB use it is a good general purpose fixed voltage regulator. By changing a few components voltages from 5 to 50 volts at up to 3 amps can be achieved. Current protection is of the foldback type which gives less current into a short circuit than at the nominal output voltage so giving more protection to the output transistor without affecting normal operation.

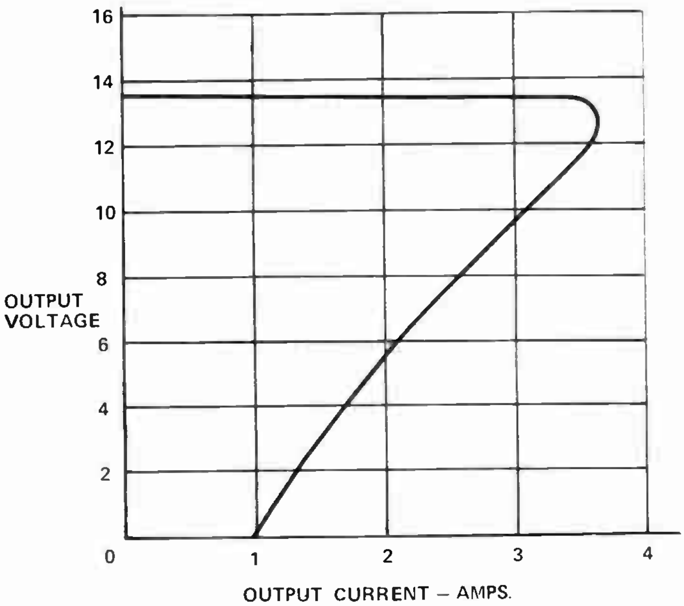


Design Features

While we could have designed this supply using a special voltage regulator IC such as the 723, we decided to use transistors as the availability is better, it allows a wider range of input – output voltages and from an educational point of view it is more worthwhile. By changing the value of R11 the output voltage can be altered provided the input voltage is suitable. We chose foldback current protection as it minimises the power dissipated if the output is shorted, reducing the need for a large heatsink.

SPECIFICATION ETI 712

Nominal output voltage	13.5 volts
Adjustment range	12V – 14.5V
Nominal output current	0 – 2.5 amps
Load regulation 0 – 2.5 A	150mV
Ripple @ 2 A	0.8mV
Short circuit current	1A



Graph showing relationship between output voltage and current. Note that the current into a short circuit is less than that available at 13 V.

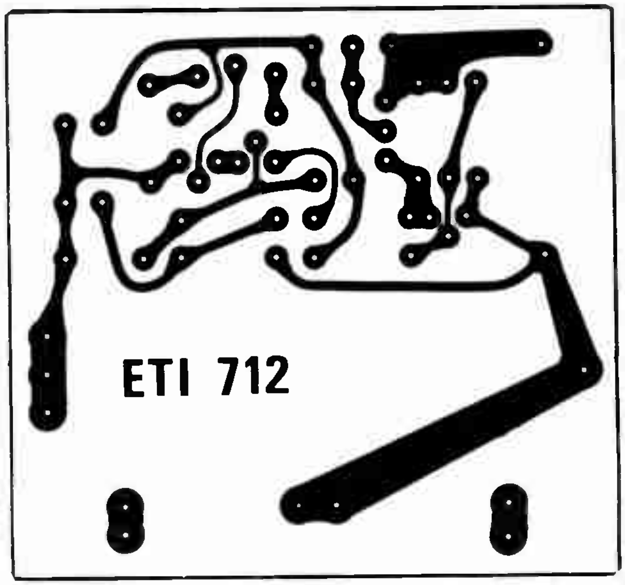


Fig. 2. Printed circuit layout. Full size 80 x 75 mm.

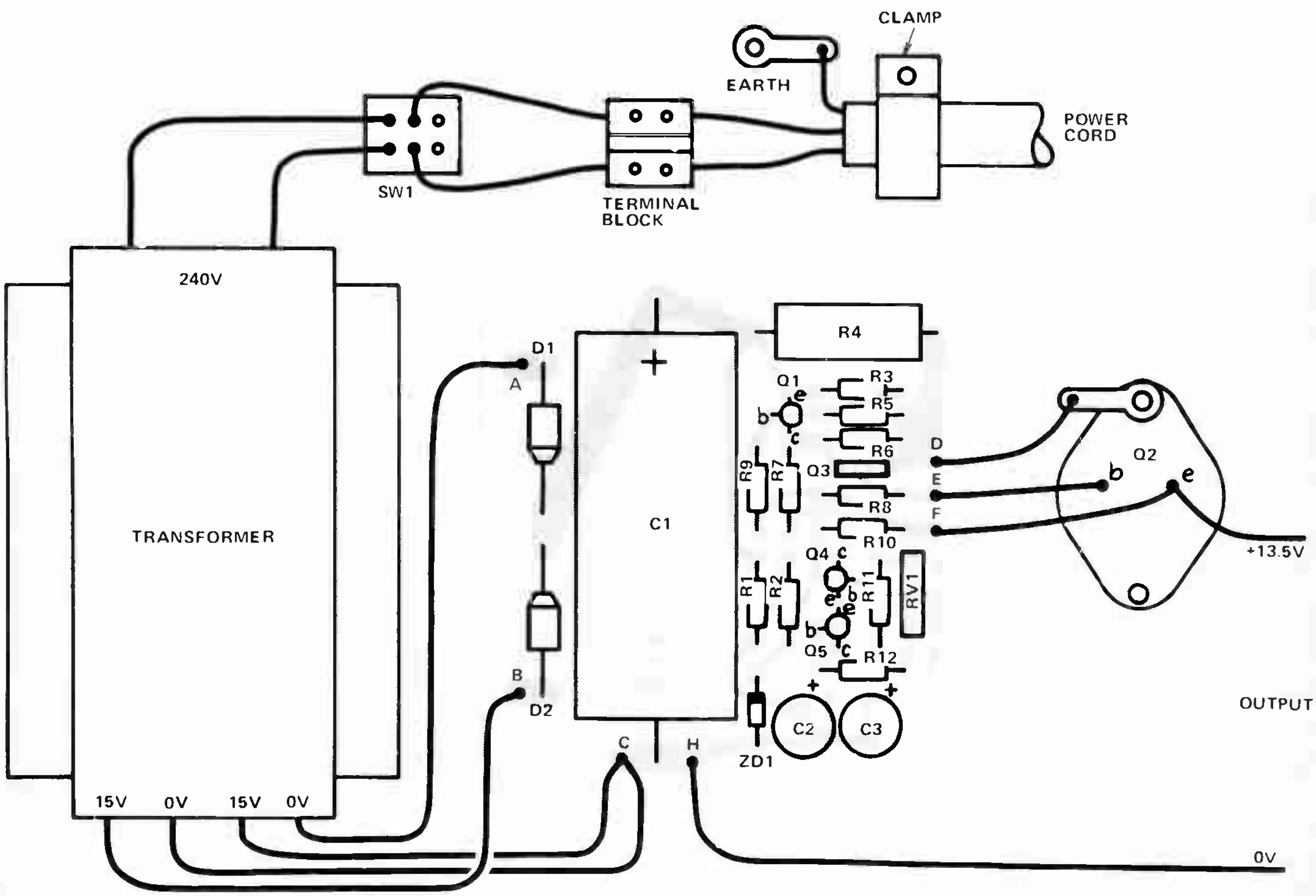


Fig. 3. Component overlay and wiring diagram.

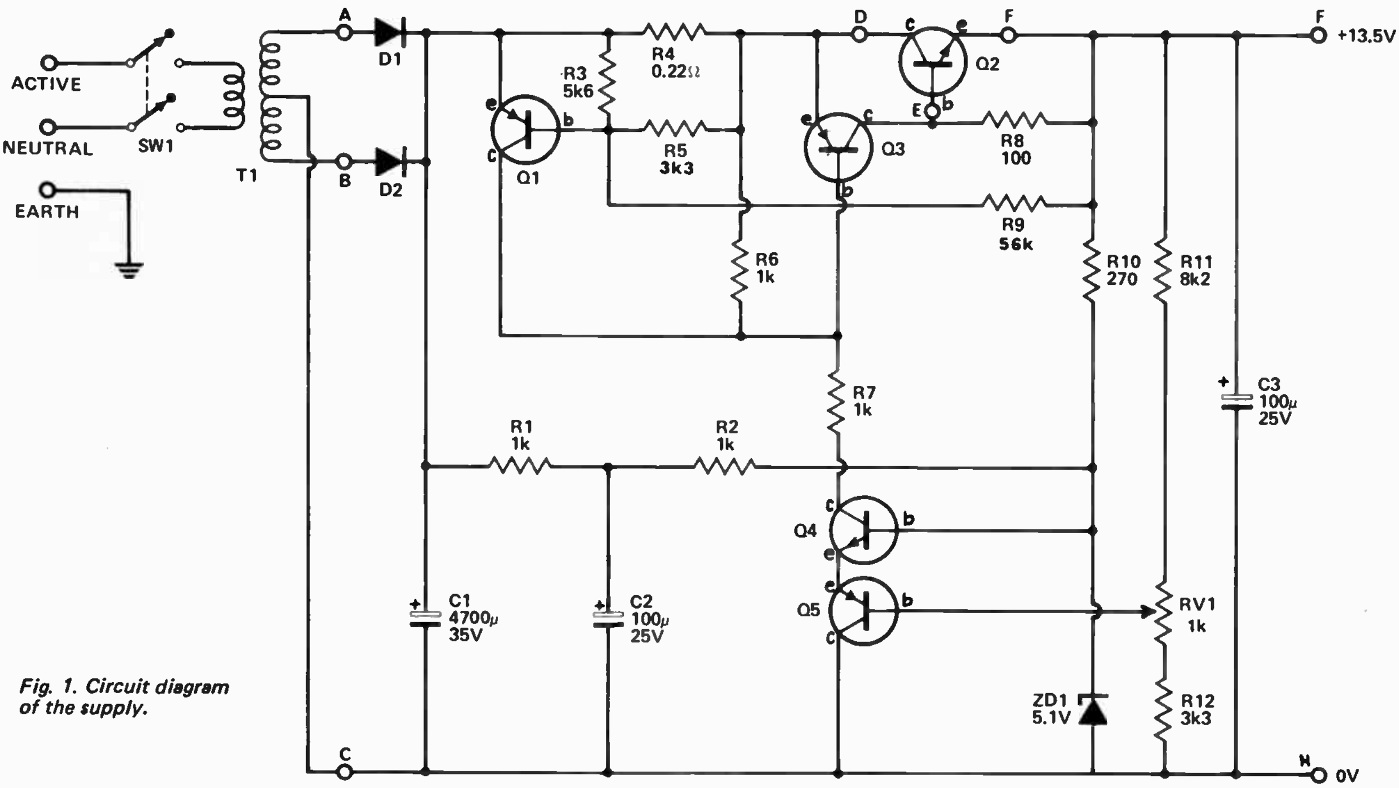


Fig. 1. Circuit diagram of the supply.

How It Works – ETI 712

As high regulation is not required for CB use or most applications, we deliberately chose not to use a high gain circuit with its stability problems. The regulator is of the series pass type with Q3 dissipating the excess power. The gain of this transistor is increased by Q2 and the Q2/3 pair appears as a high gain (> 1000) PNP transistor.

The voltage reference in the supply is a 5.1 V zener diode and the majority of the current needed for this comes from the regulated output. To enable the unit to start R1 and R2 supply some current from the unregulated supply and C2 provides additional filtering to help eliminate 100 Hz ripple from the reference voltage. The output voltage is divided by R11, 12 and RV1 and then compared to the reference voltage by Q4 and Q5 which act as a comparator. There is a 1.2V difference between these two voltages due to the base emitter junctions of the two transistors. The comparator then controls the output stage Q2 and Q3 maintaining the output voltage within limits.

Overload protection is given by Q1 which measures the voltage across R4 (current) and the voltage across the transistor and if the sum exceeds a set level Q1 will bypass some of the current from the base of Q2 so limiting the output current. This technique allows high output currents at normal output voltages but reduces the current, and power dissipation, if the unit is shorted.

Construction

The layout of the circuit is not critical and any construction method can be used. We have given a printed circuit board layout which will make it easier especially if you are not experienced in electronics. When assembling note that all the components except the resistors are polarised and that the orientation of the small transistors shown is for the Philips or Siemens type and should be reversed for other brands.

We used a simple folded aluminium box to house the supply as anything more fancy was a lot more expensive. The transistor Q3 should be mounted on a heatsink preferably on the outside of the box. The wiring diagram is given in Fig. 3.

PARTS LIST – ETI 712

Resistors all ½W 5%

R1,2	1k
R3	5k6
R4	0.22 ohm 5W
R5	3k3
R6,7	1k
R8	100
R9	56k
R10	270
R11	8k2
R12	3k3

Potentiometers

RV1	1k trim

Capacitors

C1	4700µ 35V
C2,3	100µ 25V

Semiconductors

Q1	BC558
Q2	2N3055
Q3	BD140
Q4	BC548
Q5	BC558
D1,2	1N5404
ZD1	5.1V 300mW

Miscellaneous

Transformer PL30–60VA
PC board ETI 712
Heatsink
Case, 3 core flex and plug

DIGITAL PANEL METER

This simple, economical yet highly accurate voltmeter uses a large liquid crystal display for easy reading and low power consumpion. It will be the basis of future projects as well as being a useful meter in its own right.

WE INITIALLY purchased a number of Intersil evaluation kits for our own use but soon realised that while they were very good electronically, the physical layout wasn't too hot. We therefore redesigned the PC board, reducing the size dramatically, adding the decimal point drive circuitry and some dropping resistors and zener diodes to allow the board to run from a dual power supply of +/– 5V or more (e.g. with op-amps). This resulted in a very useful device which we decided to run as a project. While it is basically a panel meter suitable for DC voltages and current (with a shunt) it will be the display module for several future projects.

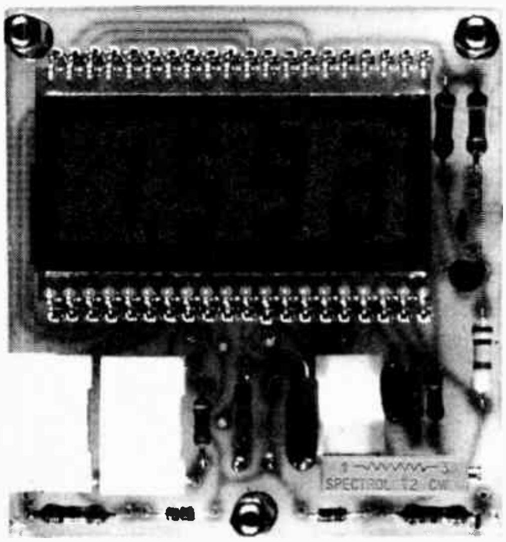
Construction

To save on real estate, the main IC is mounted under the display. We used the Molex connectors supplied with the evaluation kit for the display and soldered the IC directly into the board. If you want to mount the IC in a socket a low profile type should be used, with a high one for the display. As a socket is not available for the display a standard 40 pin one can be cut up to fit.

However before fitting either the display sockets or the IC, fit all the other components first. The over lay in fig. 3. shows the positioning of the components. Most of the components come with the evaluation kit. The large capacitors are laid on their side to minimise height.

When fitting the IC solder pins 1 and 26 first (the power supply pins) so that the protection diodes on the inputs can operate, thus preventing damage by static electricity. It is necessary that a small tipped iron and fine solder be used to prevent bridging tracks. The Molex sockets can now be fitted in two strips of 20 with the top connecting pieces being broken off using long nosed pliers after they are soldered in.

As there are no polarity marks on the display it is necessary to hold it at an angle to the light and look for the outline of the digits. The full format of the display is shown in fig. 2. In this unit the arrow, semicolon and the vertical part of the + sign are not used.



SPECIFICATION – ETI 135

Full scale reading	200mV
Resolution	100μV
Accuracy	$<$1 digit
Display	3½ digit LCD
Input impedance	$>10^{12}$ ohms
Input bias current	≈2 pA
Polarity	automatic
Conversion method	dual slope
Reference	internal ± 100ppm
Power supply	±5V to ± 15V dc 1mA @ ±5V

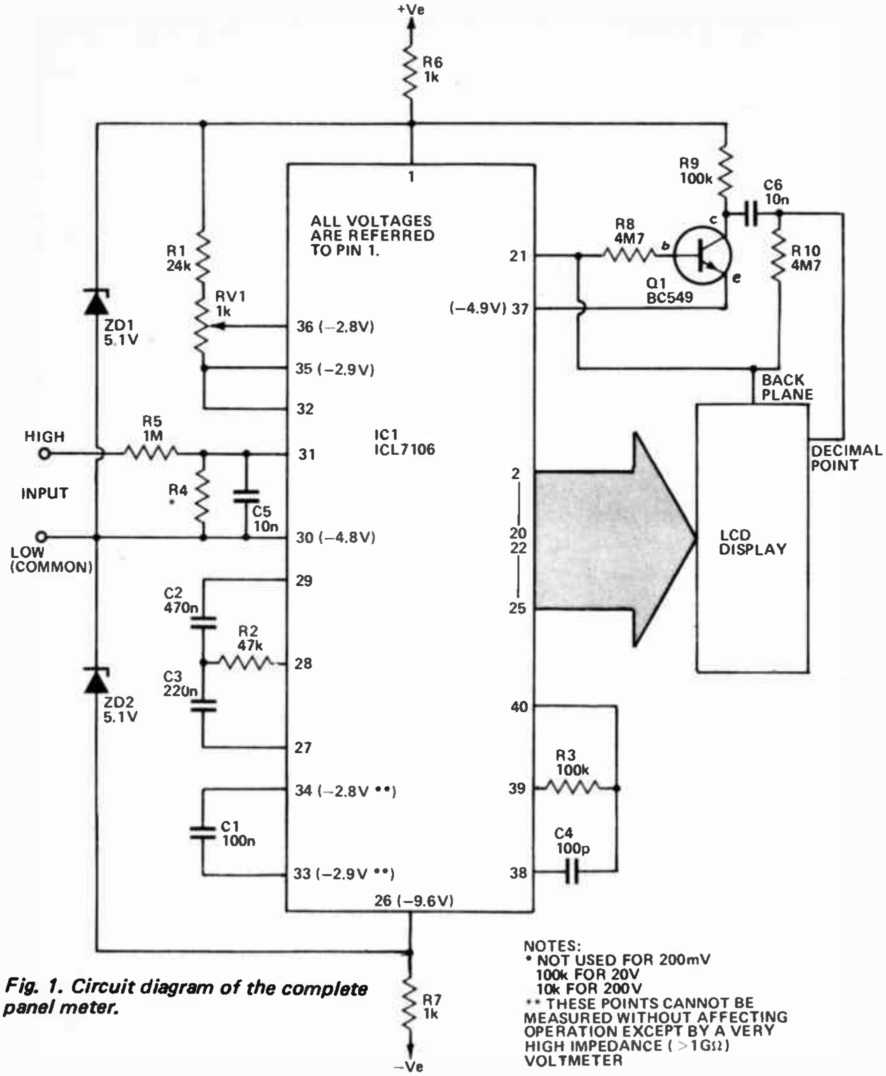


Fig. 1. Circuit diagram of the complete panel meter.

HOW IT WORKS – ETI 135

Not much can be said on how this project works as everything is done by one IC and if anything goes wrong it is usually the IC. We have included some waveform diagrams and voltages for reference purposes. The conversion works on the dual-slope integration technique, which is the most reliable of the simple methods available. A capacitor is charged up at a rate proportional to the input voltage for a predetermined time (in this case 1000 clock pulses), then it is discharged at a constant rate until it reaches the starting point again. The time taken to do this (i.e. the number of clock pulses) is proportional to the input voltage.

It is a true dual polarity system where the integration direction depends on the polarity of the input voltage. Provided AC ripple on the input averages to zero over 1000 clock pulses it will be rejected, hence where 50 Hz mains is to be rejected a 50 kHz clock should be used, giving 80 ms sample time (4 cycles of 50 Hz). The clock can be adjusted by varying R3 if desired.

The printed circuit board layout for this project is on page 114.

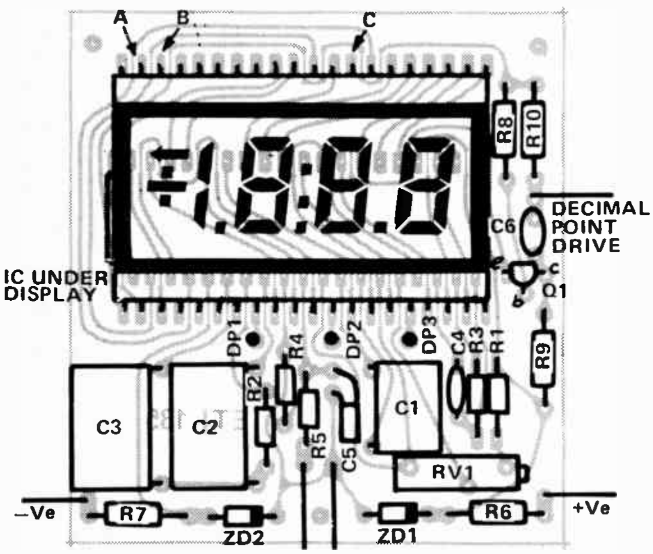


Fig. 2. Component overlay with the display in place. Points marked A, B and C are the unused display segments – the vertical part of the + sign, the arrow and the semicolon respectively.

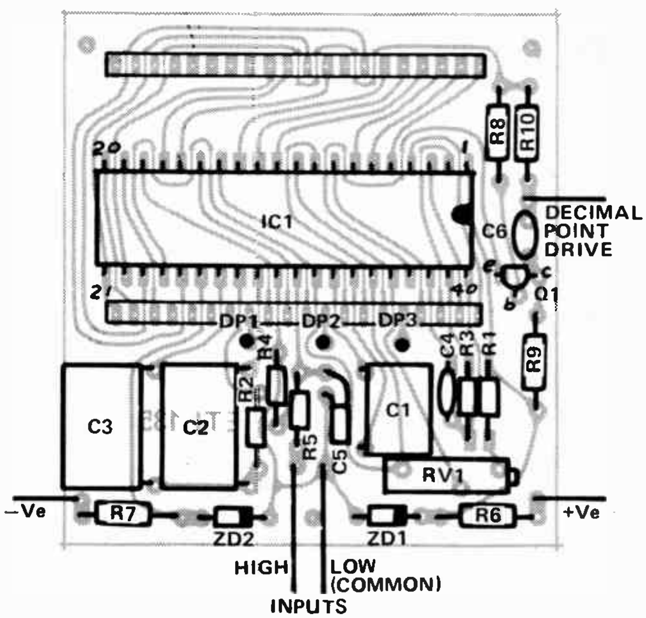


Fig. 3. The component overlay without the display showing the positioning of the integrated circuit.

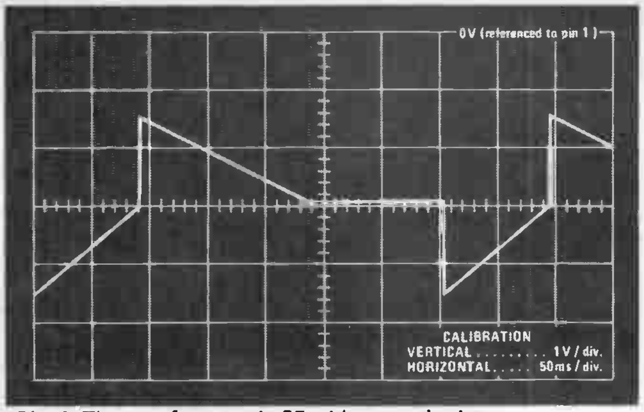


Fig. 4. The waveform at pin 27 with a negative input voltage of about 170mV.

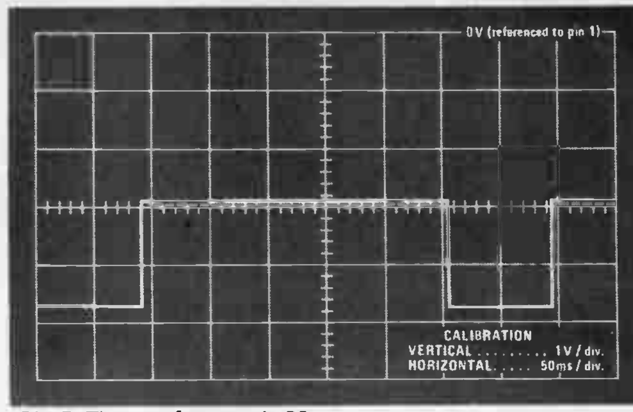


Fig. 7. The waveform at pin 28.

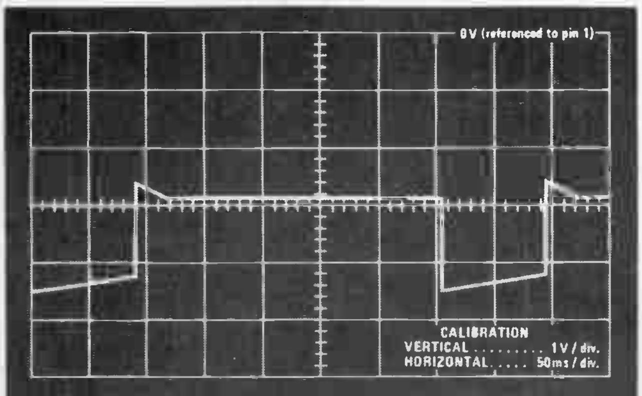


Fig. 5. The waveform at pin 27 with a negative input voltage of about 30mV. Compare this with Fig. 4.

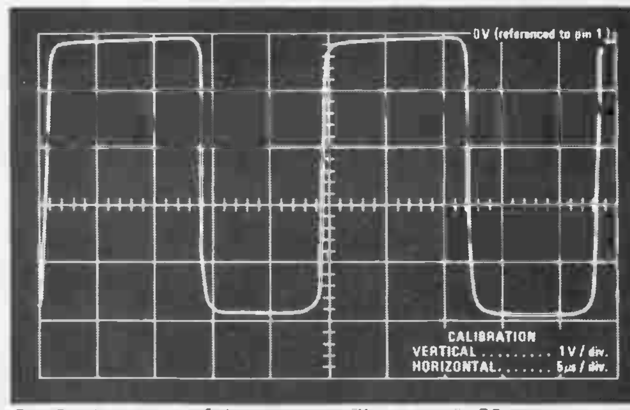


Fig. 8. The output of the master oscillator on pin 38.

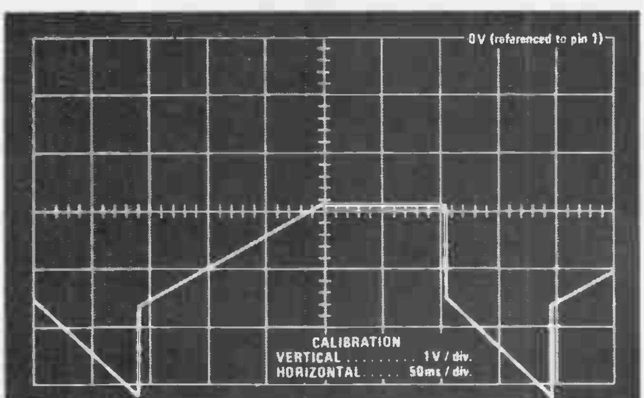


Fig. 6. The waveform at pin 27 with a positive input voltage of about 170mV.

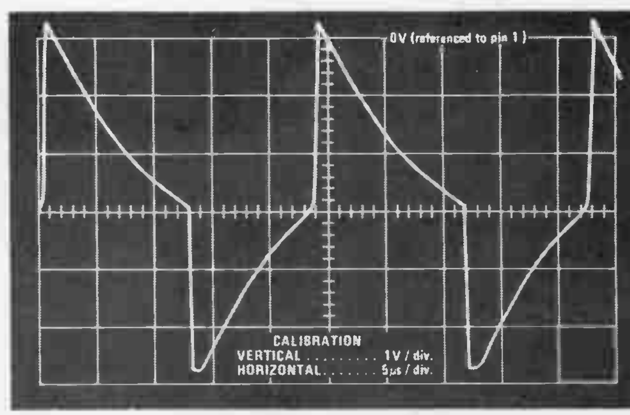


Fig. 9. The input of the oscillator — pin 40.

PARTS LIST — ETI 135

Resistors all ¼ or ½ W, 5%
R1* 24k
R2* 47k
R3* 100k
R4 . . . . . . see circuit diagram
R5* 1M
R6 . . . . . . 1k
R7 . . . . . . 1k
R8 . . . . . . 4M7
R9 . . . . . . 100k
R10 . . . . . . 4M7

Potentiometers
RV1* . . . . . 1k 10 turn trim

Capacitors
*C1 . . . . . 100n polyester
*C2 . . . . . 470n "
*C3 . . . . . 220n "
*C4 . . . . . 100p ceramic
C5,6 . . . . 10n polyester

Semiconductors
IC1* ICL7106
Q1 . . . . . . BC549
ZD1,2 . . . . 5.1V 300mW

Miscellaneous
PC board ETI 135
LCD display
* Socket for LCD display

* These components are supplied with the Intersil ICL7106EV evaluation kit.

The Intersil evaluation kit which contains most of the components for this project is available from R & D Electronics, 23 Burwood Road, Burwood, Victoria 3125 and Semcon Microcomputers, P.O. Box 61, Pennant Hills, NSW 2120. The printed circuit board and all other components to complete the project are available from Nebula Electronics, 15 Boundary Street, Rushcutters Bay, NSW 2011, for $4.50 + .50c p & p.

DUAL POWER SUPPLY

This simple regulated supply is suitable for most projects requiring a dual voltage.

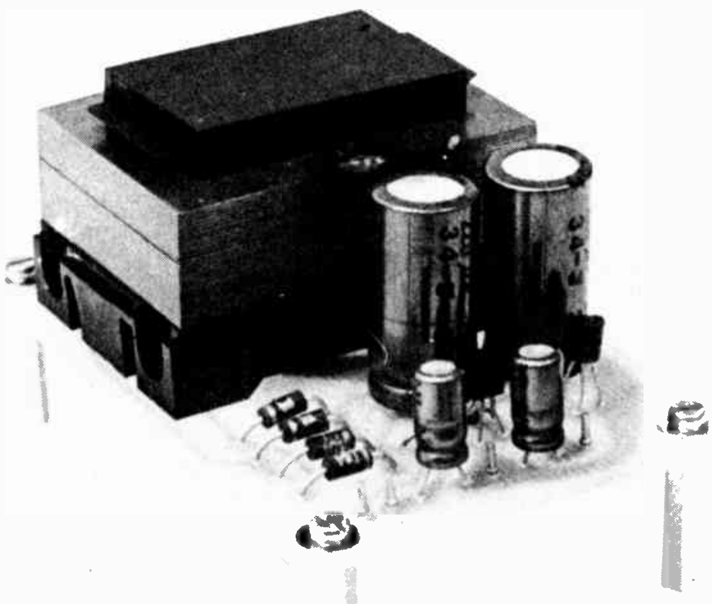
WITH THE PRICE of operational amplifiers being so low today, their use is becoming very popular among home constructors. These devices, however, normally need a dual power supply voltage, usually +15 and −15 volts.

A simple rectified and filtered supply suffers from the drawback that if it is designed to supply the correct voltage at a reasonable current, when a light load is connected the output may rise to an over-voltage condition. This problem is aggravated by variations in mains voltage. The regulated supply takes care of this problem, and also offers better hum rejection as the ripple voltage is also 'regulated'.

Most of the projects undertaken do not use more than 10 or so ICs and a high powered supply is not required. This simple supply has all the components mounted on the PC board including the transformer. Either of two regulators can be used giving either 40mA or 150mA outputs.

If a different output voltage is required regulators of the desired voltage can be used along with a different voltage transformer. If only a single output is required the unwanted components can be deleted.

To drive a power indicator LED we have provided a current limiting resistor R1. This comes from the unregulated supply so as not to load the regulator.



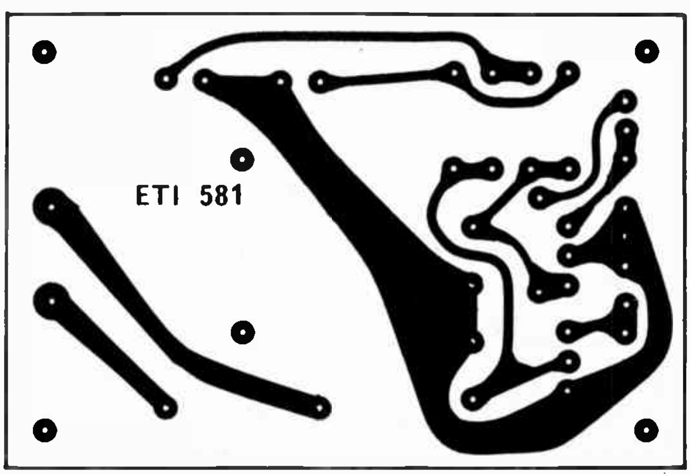


Fig. 1. Printed circuit layout. Full size 90 x 60 mm.

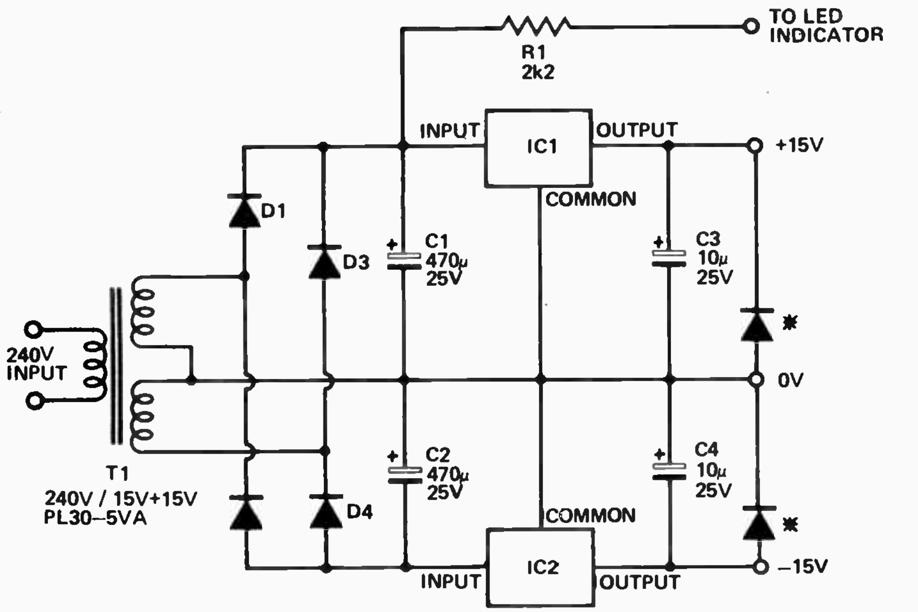


Fig. 2. Circuit diagram. It has been found advantageous in some applications to connect diodes (1N914, 1N4001 etc) across each regulator to prevent the output from being reversed biased. These diodes are shown in the circuit above and in Fig. 4 but are not included in the parts list.

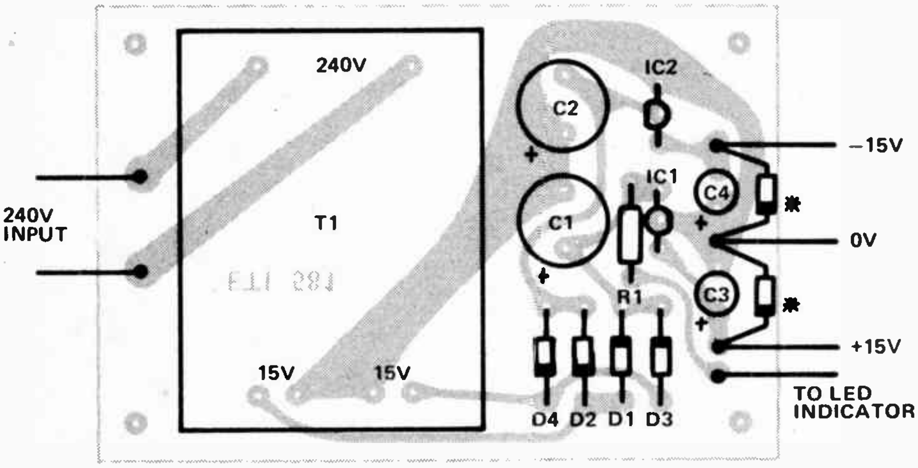
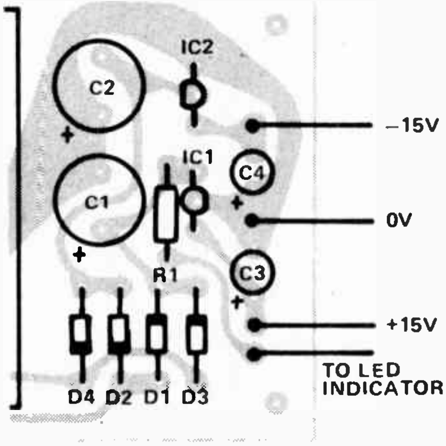


Fig. 3. Component overlay of the higher powered version.

Fig. 4. Changes in the overlay for the low power version.



PARTS LIST – ETI 581

R1	Resistor	2k2 ½W 5%
C1,2	Capacitor	470µ 35V electro
C3,4	"	10µ 25 V "
D1–D4	Diodes	1N4001
LED1	Indicator	
IC1	Regulator	7815 *
IC2	"	7915 *
T1	Transformer	PL30–5VA

* 78L15 and 79L15 can be used if less than 40mA is required

GSR MONITOR

Learn to reduce tension levels with ETI's galvanic skin response meter. Design by Barry Wilkinson — editorial by Jan Vernon.

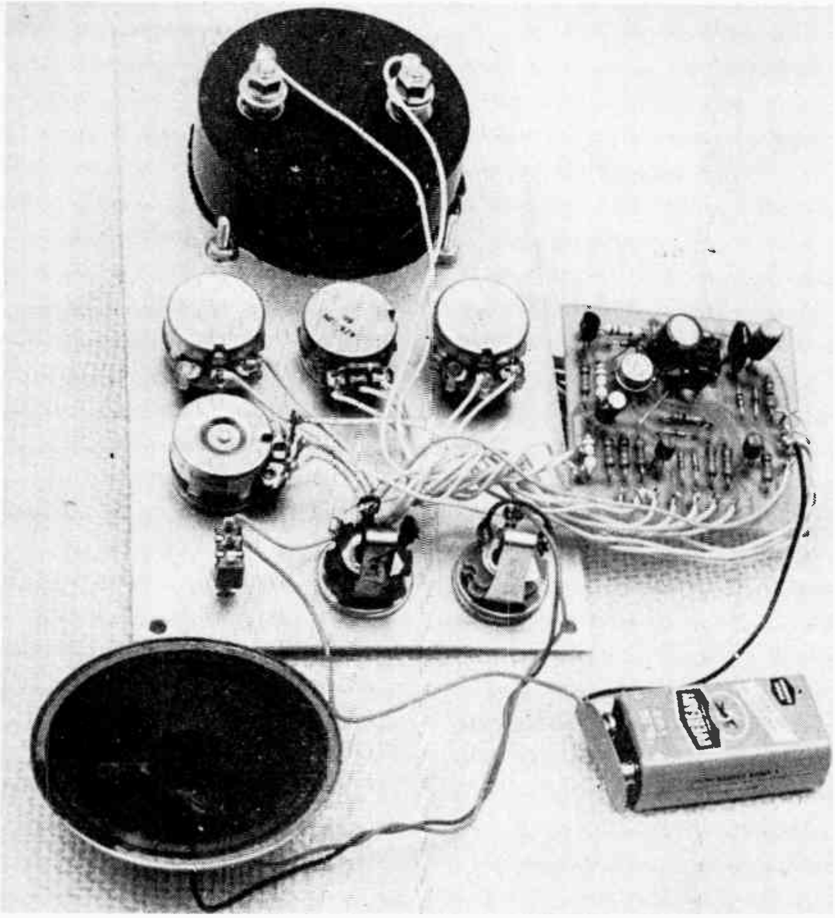
THE BEST WAY TO START EXPERimenting with biofeedback is to use a galvanic skin response monitor, a device which measures changes in skin resistance. In September 1976, we published an article which covered the background and theory of biofeedback and we discussed the various types of biofeedback instruments which are available. The GSR monitor is the most simple to use, the electrodes can be simply attached to the fingers with Velco straps and the technique of using the machine can be quickly learned.

Skin resistance changes with changes of emotional state. When tension increases, the skin resistance falls — when tension decreases there is an increase in skin resistance. (Some biofeedback instruction manuals speak in terms of conductivity rather than resistance and state measurements in mhos, and the meter we use gives a positive deflection for decreasing resistance.)

The connection between skin resistance and tension is not fully understood. Tension affects sweat glands and with the changes in the sweat glands there is a change in the membrane permeability of the skin and this change in permeability is the major cause of changes in electrical activity.

Almost a century ago, a scientist named M. Ch. Fere discovered the resistance of the skin to a small electric current changed in response to aroused emotions. This information has since been used in various ways; one obvious example is the polygraph, or lie detector, which responds to the tension generated when a person is lying.

It was not until 1961 that Dr. J. Kamiya, whilst conducting a series of



experiments with brain waves, found that with feedback his subjects developed the ability to produce 'Alpha waves' at will.

Dr. Kamiya's experiments created considerable interest and started investigations into whether other bodily functions could be brought under conscious control. Since that time it has been demonstrated that with feedback it is possible for people to control heart beat, blood pressure and temperature — all previously considered to be automatic bodily functions mostly beyond conscious control.

Of course it should be stated that various mystics and yogis have previously demonstrated this type of ability but the fascination of biofeedback is the speed and ease with which this type of control can be learned.

Biofeedback has exciting medical possibilities. GSR machines are being used by therapists for the treatment of many disorders related to tension. The average person will find a GSR machine mainly useful for relaxation training. With the GSR machine it is possible to recognise tension and learn how to decrease tension levels. This type of training is so effective that the machine quickly becomes unnecessary.

However not everyone suffers from tension. The biofeedback machine can be a fascinating toy to play with. Discovering that you can bring an internal bodily function under conscious control with the same ease that you can twitch your nose is most interesting. And of course you can then perfect this ability just as you perfect your ability at a game like tennis. For many people this is reason enough to build this machine.

What you do with it once you have built it

The ETI GSR monitor has an on/off switch, a sensitivity control and fine and coarse level controls. The machine also has a connection for headphones.

To start relaxation training, you'll need a comfortable chair, low lighting and no distractions. Taking any type of drug can interfere with your ability to relax. This applies to alcohol and cigarettes. Attach the electrodes to the fleshy part of the first two fingers on one hand — firm but not too tight (the non-dominant hand is recommended). Set the sensitivity control to minimum and the 'fine' level control to mid-range. Turn the volume control to minimum. Now you have to set the level with the 'coarse' level control (when the sensitivity is set low the 'fine' level control need not be used). Start with the 'coarse' control at full anticlockwise and turn it up until the meter needle starts to move. Carefully set the needle to mid-range. Now the instrument is set-up in its minimum sensitivity position.

Having mastered setting up with minimum sensitivity try to set the GSR monitor with the sensitivity set half-way. It will require delicate adjustment of the 'coarse' level control. Now the effect of the 'fine' level control can be seen. This control enables you to set the level on a high sensitivity setting.

Although the GSR machine measures minute changes in skin resistance, the level of skin resistance varies considerably from person to person so a wide range of settings is provided.

Now turn up the volume and observe that the meter reading is accompanied by a medium pitched tone. (A convention has developed to link high-pitched tone with tension increase and low pitched tone with a decrease in tension.) Now you relax and bring the tone down and the needle back to zero.

How? Basically you are supposed to find this out for yourself. After watching the needle for some time you will notice it move up or down. Something has happened to cause a change in your skin resistance. You would be barely aware of what had caused the change but aware enough to try to reproduce the effect. Eventually your awareness grows and so does your ability to control your tension. Many people find that relaxation of the stomach muscles makes the difference. It varies from person to person.

There are several relaxation techniques which work very well. One method is to tense all the muscles of the body as hard as possible, hold them tense for several seconds then very deliberately relax all muscles. There are several books and cassettes available which describe relaxation techniques. The techniques work. The biofeedback machine makes it possible to monitor progress.

As you relax, the needle on the meter and the audible tone will decrease. When the needle reaches zero, reset it again towards the fsd end of the scale and repeat the procedure.

Twenty minutes is the recommended time for a training session. After about one or two weeks of daily relaxation training, it should be possible to produce the same level of relaxation without using the machine and the machine can simply be used occasionally as a reference.

GSR MONITOR

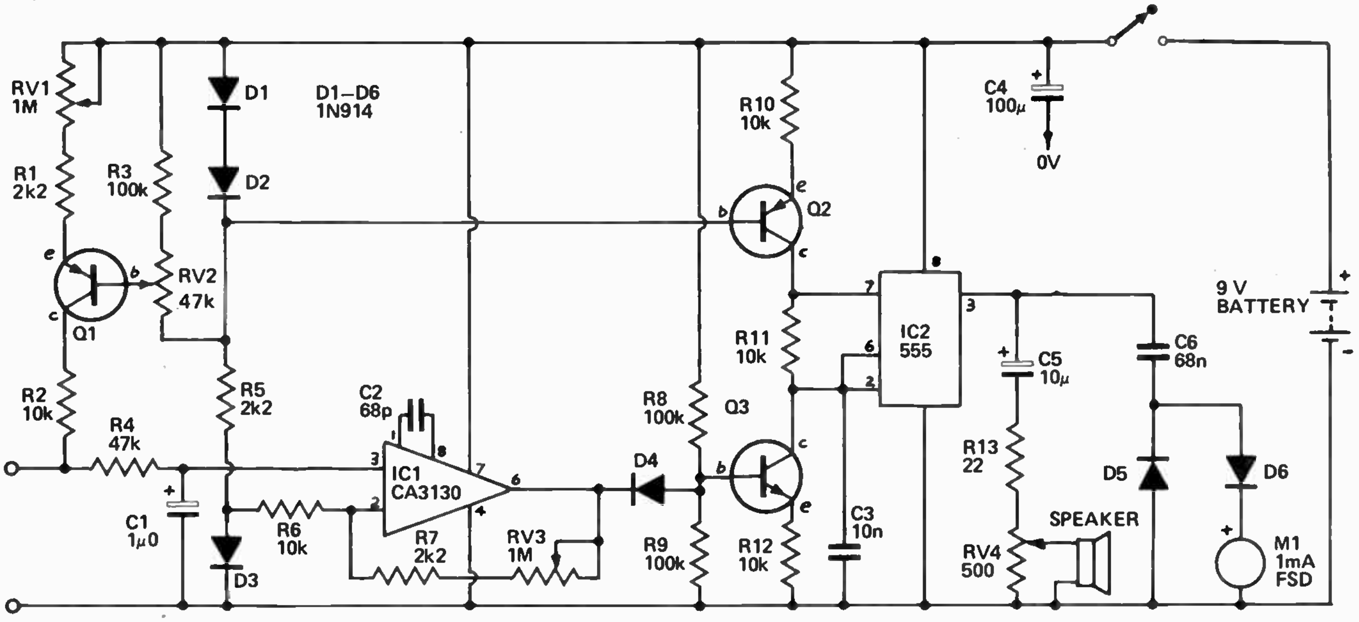
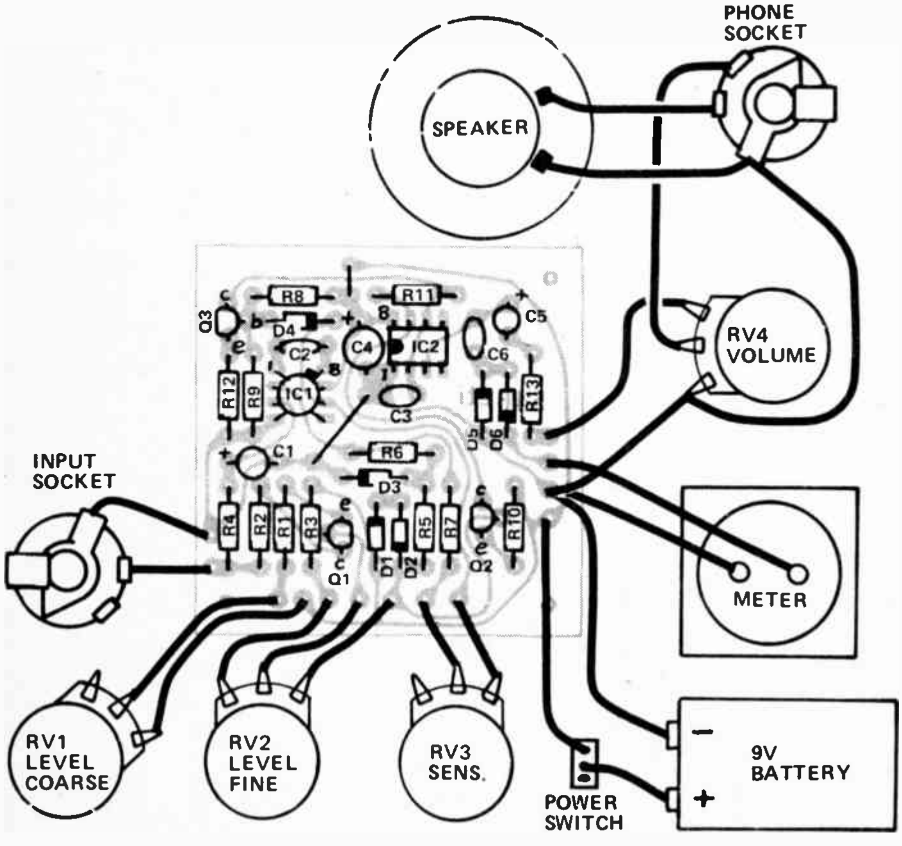


Fig. 1. Circuit diagram of tha GSR monitor.

Fig. 2. Component overlay and interconnection diagram.



PARTS LIST ETI 546

Resistors all ½ W 5%

R1	2k2
R2	10 k
R3	100 k
R4	47 k
R5	2k2
R6	10 k
R7	2k2
R8,9	100 k
R10–R12	10 k
R13	22 ohms

Potentiometers

RV1	1 M log
RV2	47 k lin
RV3	1 M log
RV4	500 ohm lin

Capacitors

C1	1 μ 16 V electro
C2	68 p ceramic
C3	10 n polyester
C4	100 μ 16 V electro
C5	10 μ 16 V electro
C6	68 n polyester

Semiconductors

D1–D6	Diodes 1N914
Q1,2	Transistors BC559
Q3	Transistors BC549
IC1	Integrated Circuit CA3130
IC2	Integrated Circuit NE555

Miscellaneous

PC board ETI 546
Meter 1 mA FSD
Zippy Box 196 x 113 x 60
Two phone jacks
Four knobs
Small speaker
Six AA battery holder
Pickup probes

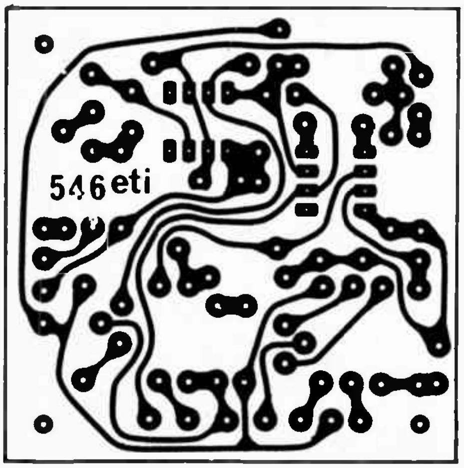
How It Works — ETI 546

This project measures the skin resistance and displays it on a meter. An audio tone gives an aural indication of the meter reading. The meter operates in reverse sense to a usual resistance meter: low resistance gives full scale (or high tone) and high resistance gives zero (or low tone). Skin resistance can vary over a large range but the variations studied in biofeedback experiments are small — so an offset is needed.

Transistor Q1 acts as a constant current source — the actual value can be varied over a large range by RV1 and over a limited range by RV2. These act as the coarse and fine level controls. This current is passed via R2 to the probes. The voltage developed across the probes is proportional to the skin resistance and is fed to the input of IC1. This amplifies the signal with reference to 0.6 V (drop across D3) and the gain is variable by RV3.

The second IC is an NE555 oscillator where Q2 provides a constant current (about 60 µA) to the capacitor C3. When the voltage on C3 reaches 6 V the IC detects this and shorts pin 7 to ground, discharging C3 via R11. This continues until the voltage reaches 3 V at which point the short on pin 7 is released allowing C3 to recharge. The output of the oscillator is connected to a speaker via the volume potentiometer RV4 and the meter via C6 and the diodes D5 — 6.

We vary the frequency of the oscillator and the meter reading by robbing some of the current supplied by Q2 into Q3. In this way the frequency can be lowered and actually stopped. Transistor Q2 is controlled by IC1 completing the connection between the probes and the output.



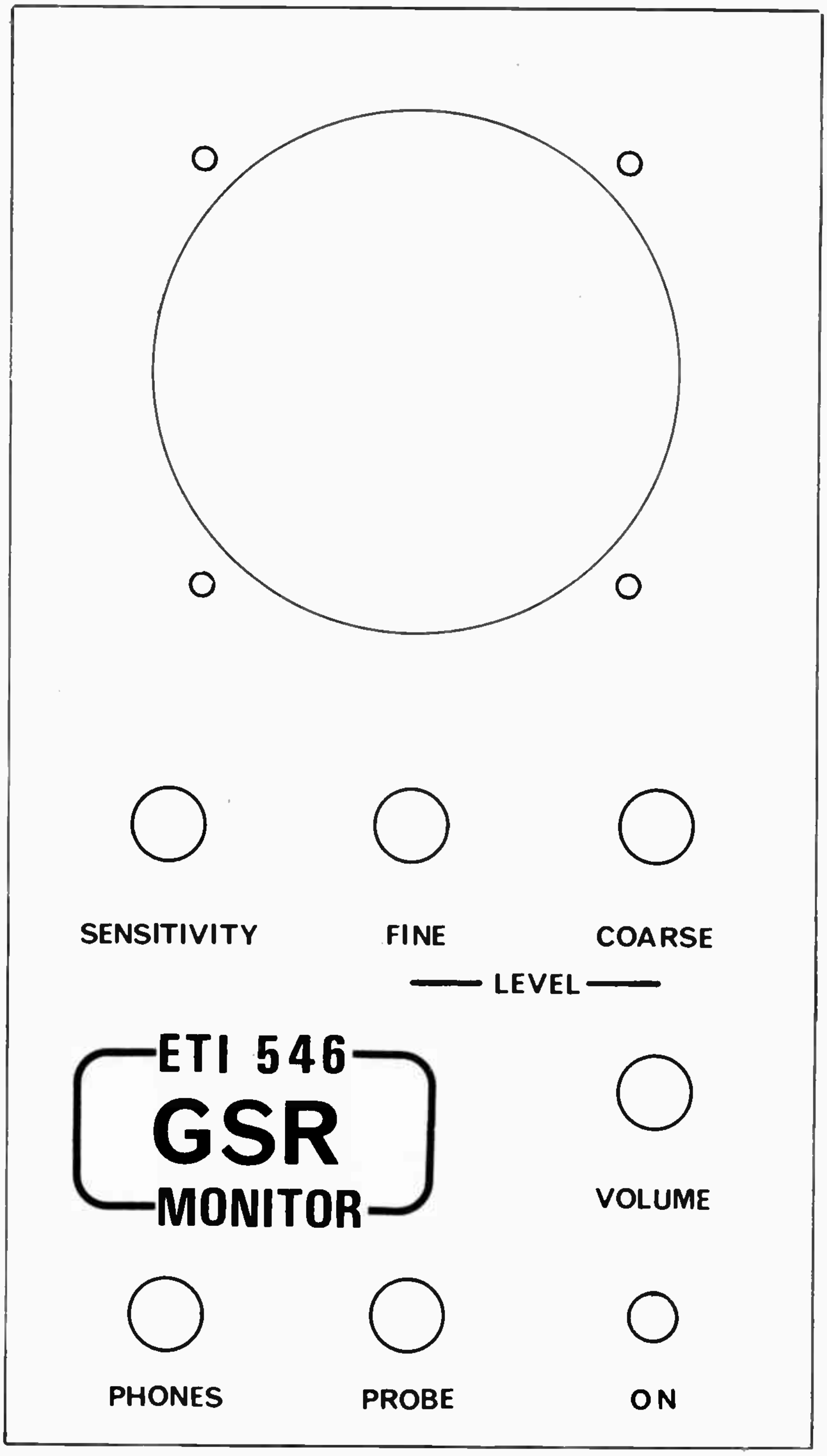
Construction

Construction is not critical although we recommend you use the pc board as it makes things easier. Before soldering the components made sure they are orientated correctly. External wiring can be done with the aid of the overlay-wiring diagram.

Probes

Probe construction and electrical contact is not nearly as critical as with most other biofeedback machines.

Commercial GSR machines use a pad of soft steel wool which is held firmly onto the finger by a short length of Velcro strap (Band-Aids work fine!). However, any method ensuring a firm contact between probe leads and the fleshy part of the finger will do. One method which works very well is to bind tinned copper wire around a guitar finger pick (or solder to a steel pick). Two probe connections are of course required — one for each of the first two fingers.



PHOTOGRAPHIC STROBE

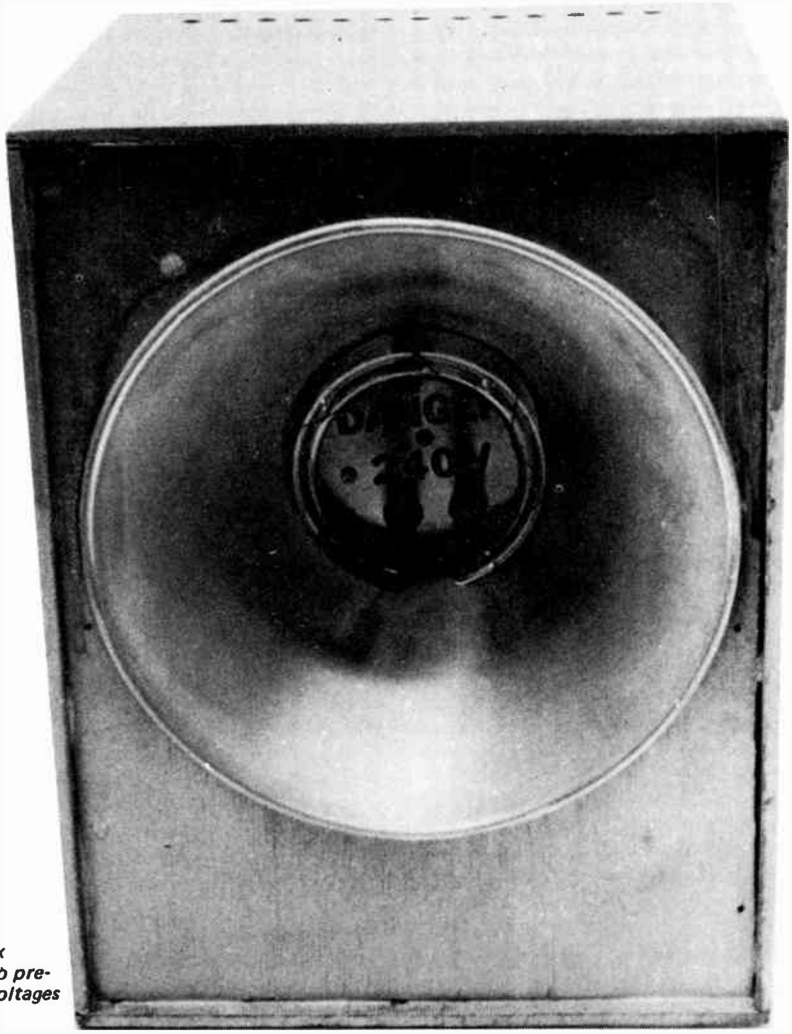
This project gives about seven times the light output of the High Power Strobe we published six years ago. It also has other advantages when used by the photographer . . .

THE HIGH POWERED strobe published back in August 1971 has been one of the most popular projects we have designed and it is still being built and sold. A lot of people have since asked if it can be used for photographic use (and if not how could it be modified).

The existing strobe has several problems in photographic use, the main one being insufficient light output. Other problems are that the electronics is all at mains voltage with no isolation, preventing the safe use of a remote push-button control, and that at high speed there is some jitter in the flash rate (since this is partially synchronized to the mains frequency).

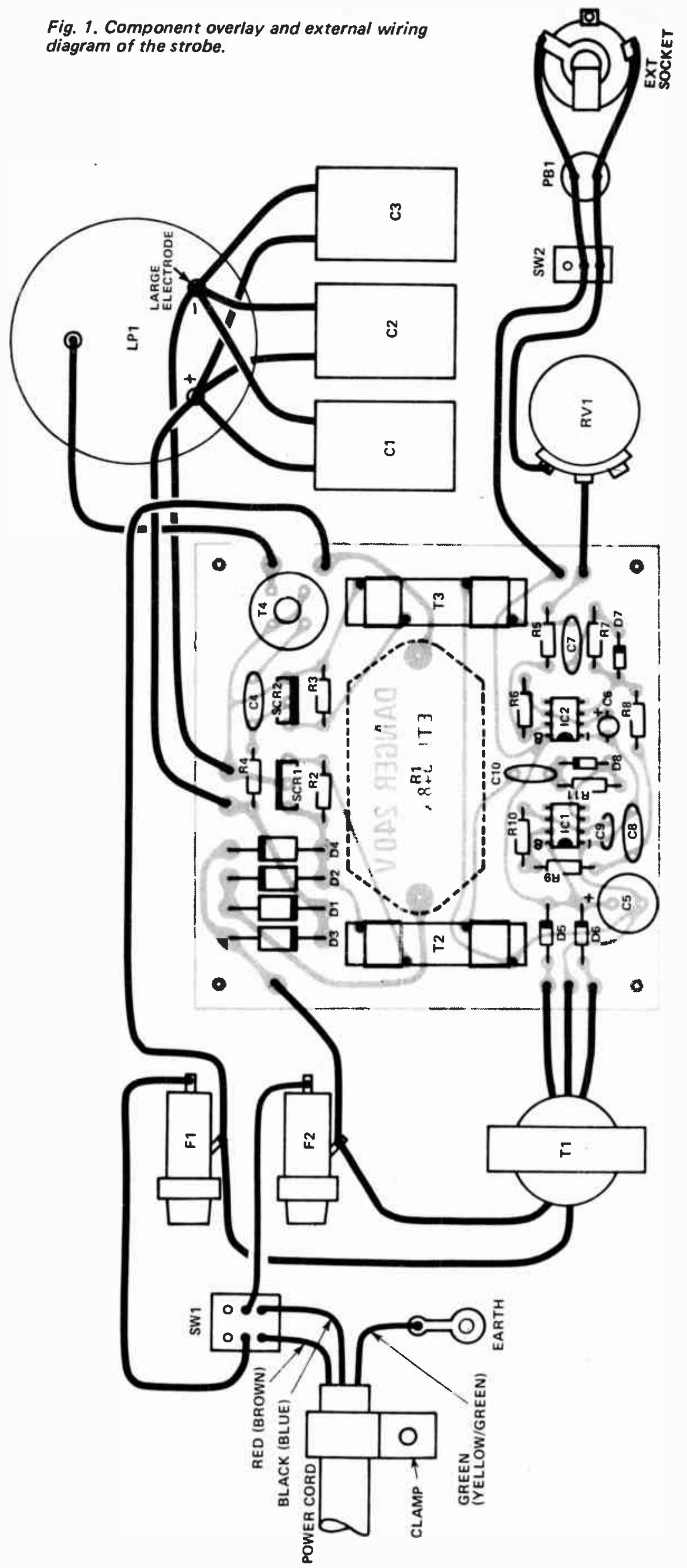
This new unit has about 7 times the light output of the previous unit (this can be increased further if needed). The control circuitry is now isolated and the flash rate is steady as there is no synchronization with the mains.

All this however costs more: we have used a larger flash tube, the capacitors cost about $30, and the control circuitry is much more complex. However, if high power is needed the cost is worth while.



The front of the strobe with the perspex cover removed. The cover is necessary to prevent accidental contact with the mains voltages applied to the flash tube.

Fig. 1. Component overlay and external wiring diagram of the strobe.



PARTS LIST — ETI 548

Resistors all ½ W 5%

R1*	36 ohms 1600 W
R2, 3	1 k
R4	100 k
R5-R7	10 k
R8, 9	68 k
R10	33 k
R11	100

* standard jug element

Potentiometers

RV1	rotary 1M lin

Capacitors

C1-C3	30 µ 250 Vac Plessey type 427/1/00813/002 30/250 V
C4	33 n 630 V polyester
C5	1000 µ 16 V electro
C6	1µ0 25 V electro
C7,8	100 n polyester
C9	2n2 polyester
C10	100 n polyester

Semiconductors

SCR1,2	C106D, BT100A500R
D1-D4	1N5404
D5-8	1N4004
IC1,2	NE555

Miscellaneous

T1	transformer, 240 V — 12.6 V CT
T2-3	pulse transformer, see Table 1.
T4	trigger transformer, TR-6KM
LP1	flash tube, FC6501
PCB	ETI 548
SW1	240 V switch double pole
SW2	single pole switch
PB1	push button (press to make)
F1,2	fuses and holders. 3A 250 V

Reflector
Case
Power cord and plug
100 x 100 mm asbestos sheet
five 25 mm metal spacers
four 12 mm spacers.

Construction

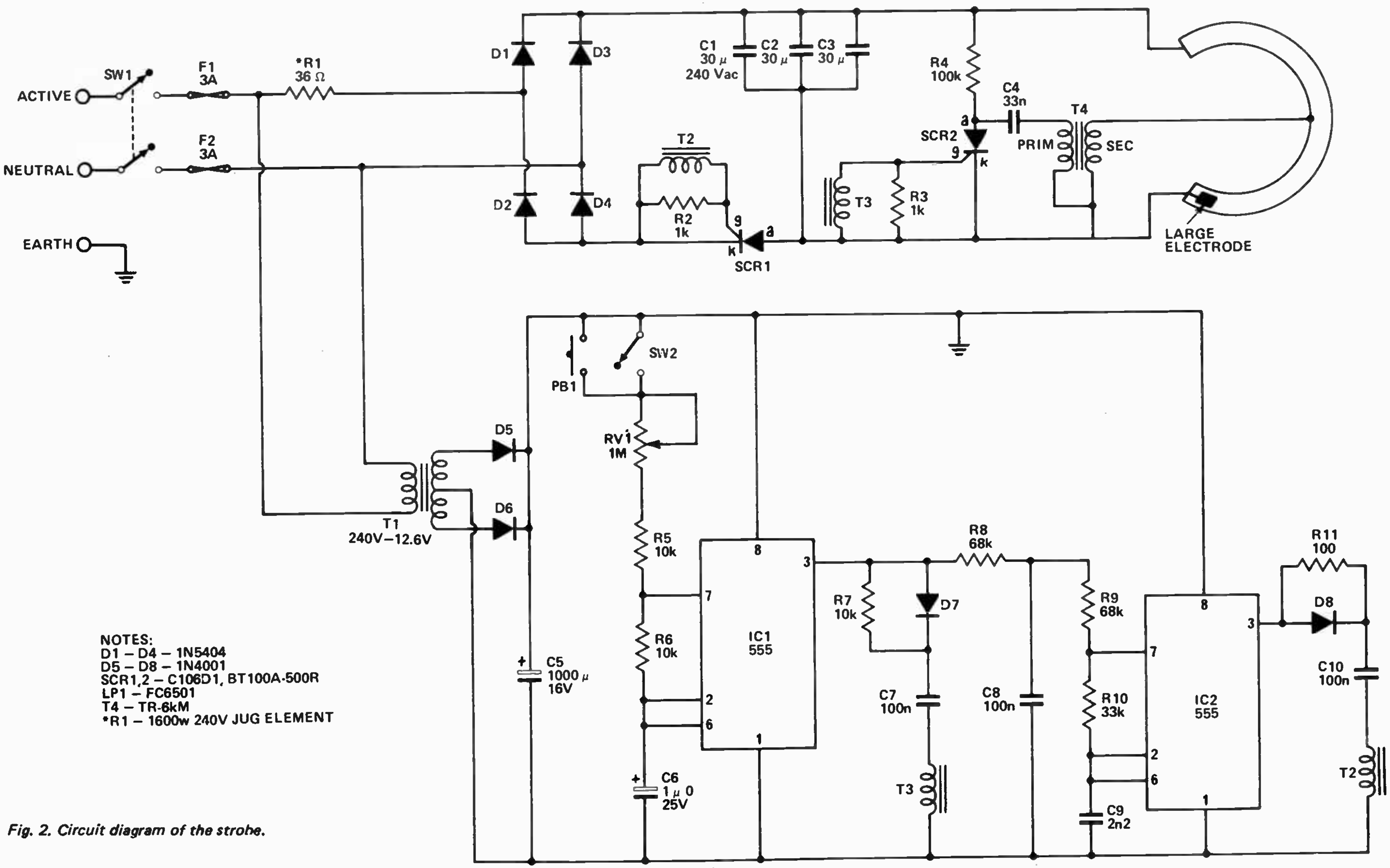
The first thing to remember with this project is that a lot of the circuitry is not isolated from the mains. Contact with these components can be lethal. Therefore be careful to ensure adequate clearances to keep these components from contacting the case and ensure all external metal surfaces are earthed.

We mounted the tube on three banana plugs which fit into sockets on a pc board (see Fig. 3). the pcb is in turn mounted on 25 mm spacers attached to the rear of the reflector. The three mounting holes shown for the spacers were positioned to suit our reflector — these may need to be varied to suit another reflector.

The pcb can be assembled with the aid of the overlay in Fig. 1. Ensure all diodes, electrolytic capacitors, ICs, and SCRs are oriented correctly. The pulse transformer can be wound as shown on Table 1 and soldered in place by its leads. Once the unit is checked the pulse transformers should be glued in to prevent the fine wires from breaking. The resistor R1, which is a jug element, is mounted off the board by 25 mm

(text continued page 69)

PHOTOGRAPHIC STROBE



NOTES:
D1 – D4 – 1N5404
D5 – D8 – 1N4001
SCR1,2 – C106D1, BT100A-500R
LP1 – FC6501
T4 – TR-6kM
*R1 – 1600w 240V JUG ELEMENT

Fig. 2. Circuit diagram of the strobe.

How It Works – ETI 548

To operate a flash tube it is necessary to apply to the ends of the tube a voltage of about 320 volts, with a capacitor also across the terminals. However, this is not sufficient. An additional high voltage pulse (6000 V) is required on a trigger lead. When this occurs the tube appears as a short circuit, discharging the capacitor rapidly. The amount of energy in each flash can be calculated by:

energy = $\frac{1}{2}CV^2$ joules
where C is the value of the capacitor in farads and V is the voltage across the capacitor in volts. For 90 μ and 340 V this gives about 5 joules. A normal flash uses 300 V and 300 μF or 13 joules.

The 240 V mains voltage is rectified by D1-D4 with R1 used to give some current limit. If SCR1 is "on" C1-C3 are charged up to 340 V dc. The SCR is used to allow the power to be switched on and off, which is necessary as the power must be switched off while the tube is triggered on (unless the series resistor is over 500 ohms, but a resistor of this value limits the flash rate). To generate the 6kV pulse the capacitor C4 is charged with 340 V via R4, and if the SCR 2 is triggered on it is discharged into the primary of the trigger transformer, T4, giving the 6kV needed.

Control of the SCRs is done by IC1 and IC2.

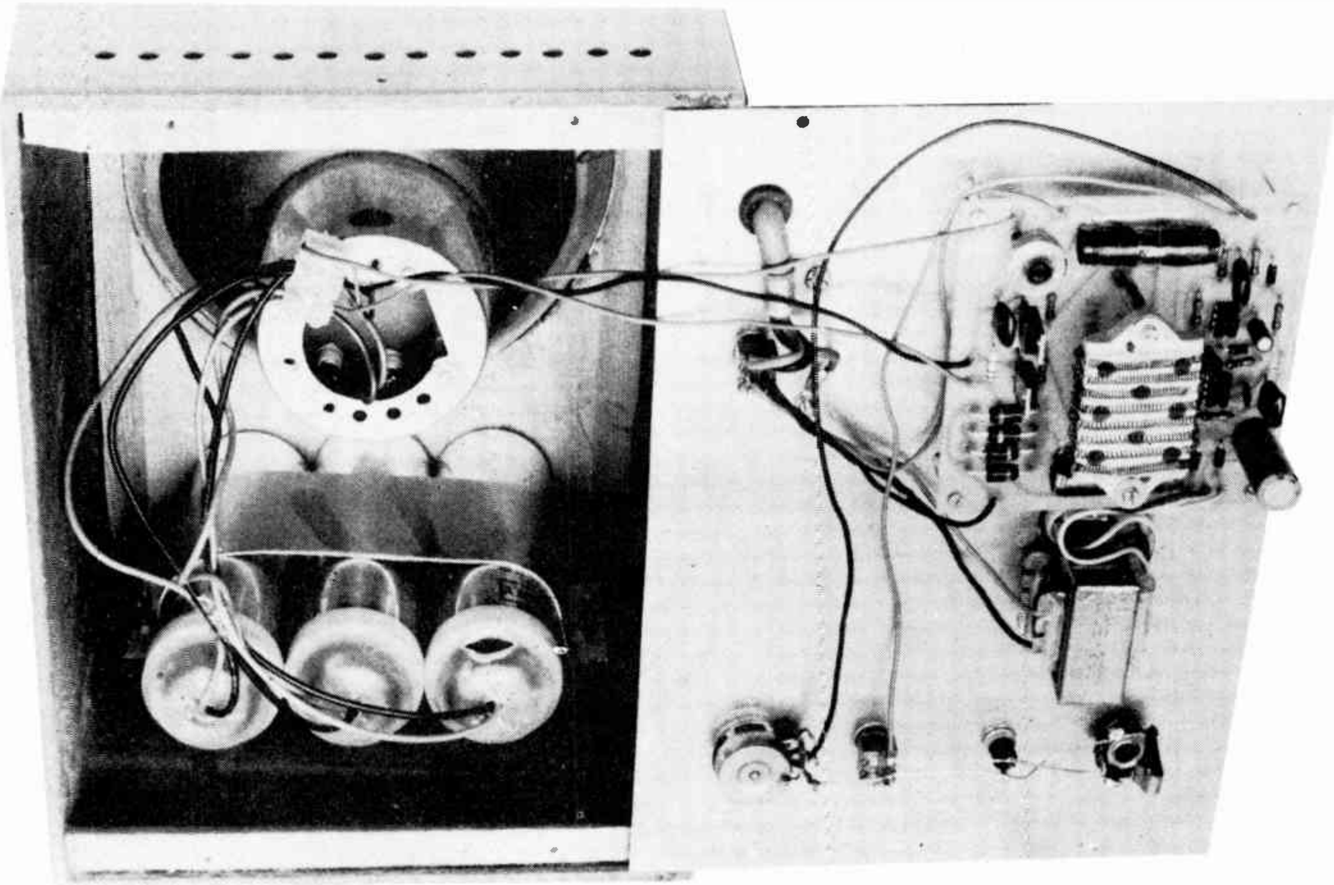
The mains voltage is reduced to 9 V dc by T1, D5,6 and C5, giving the isolation required. IC1 gives the timing of the flash rate which is variable from about 2 to 30 per sec. The output of IC1 is normally high (ie, +9 V) goes low for about 10 ms every flash. When the output goes high again the pulse transformer T2 transfers the transition in the form of a pulse into the gate of SCR2 causing the tube to be triggered. Resistor R7 and D7 prevent the negative transition triggering the tube.

When the output from IC1 goes high R8 and C8 provide about a 10 ms delay before IC2 starts oscillating at about 2 kHz. When it is oscillating the pulse transformer T3 keeps SCR1 on. Therefore the sequence of operation is as follows: IC2 oscillates for the duration between the flashes with SCR1 on and C1-3 is charged up. The oscillation stops for about 15 ms which ensures the SCR1 turns off (more than one half cycle) after which time the tube is triggered, discharging the capacitor C1-C3. This takes about 5 ms and after 10 ms the oscillator turns on again recharging the capacitors.

The oscillation can be started or stopped by SW2 or a push button can be used either local or remote as it is not at mains potential.

Fig. 3. This support is necessary when the sockets for the tube cannot be mounted directly on the back of the reflector. Dick Smith has some new reflectors which do away with the need for this support.

Fig. 4. Printed circuit layout. Full size 100 x 100 mm. Material used MUST be fibre glass due to the heat generated by R1.



long metal spacers to allow for cooling. If you plan to run the strobe at more than 10 or 12 flashes per second a piece of asbestos about 100 mm square must be placed between the resistor and the pcb to prevent heat damage. Similar protection should be given to any burnable substances (the wooden box, if used) near the resistor.

The external (to the pcb) wiring of the unit is also given in Figure 1. The mechanical layout depends on the reflector used and the facility you have for making or purchasing the box. ETI's previous strobe used a metal box behind the reflector to hold the electronics and this approach can easily be adapted. We couldn't find a ready-made box of the right size so we made a wooden box (three ply) with the reflector enclosed. The rear panel (which holds the electronics) is made of aluminium. If this approach is used a row of ventilation holes, about 6.5 mm diameter, should be provided along the top rear and the lower sides. If a metal box is used it will transfer enough heat through the walls without the need for the holes.

Whatever system is used remember again that the circuit is a 240 V (except for the control circuitry) and adequate clearance must be maintained and all

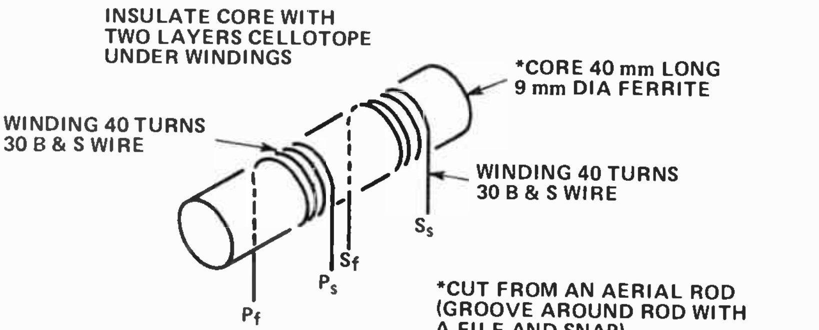


Fig. 5. Diagram showing how the pulse transformers are wound.

external metal parts, including the reflector, must be earthed. Also a **piece of perspex must be fitted over the reflector to prevent accidental touching of the tube.**

If the unit is intended for a disco the use of the switch SW2, the push button, and the external socket will not be needed and SW2 can be bypassed. Also increasing R5 to 39 k will reduce the maximum rate to about 16/sec.

Stroboscopes are dangerous instruments — they can bring about epileptic fits in people who have a history of epilepsy and also in those who are disposed towards this trouble. There are cases of people who never knew of any epileptic disposition who, under the influence of stroboscopic stimulation, have had fits induced and thereafter have suffered from subsequent, non-induced fits.

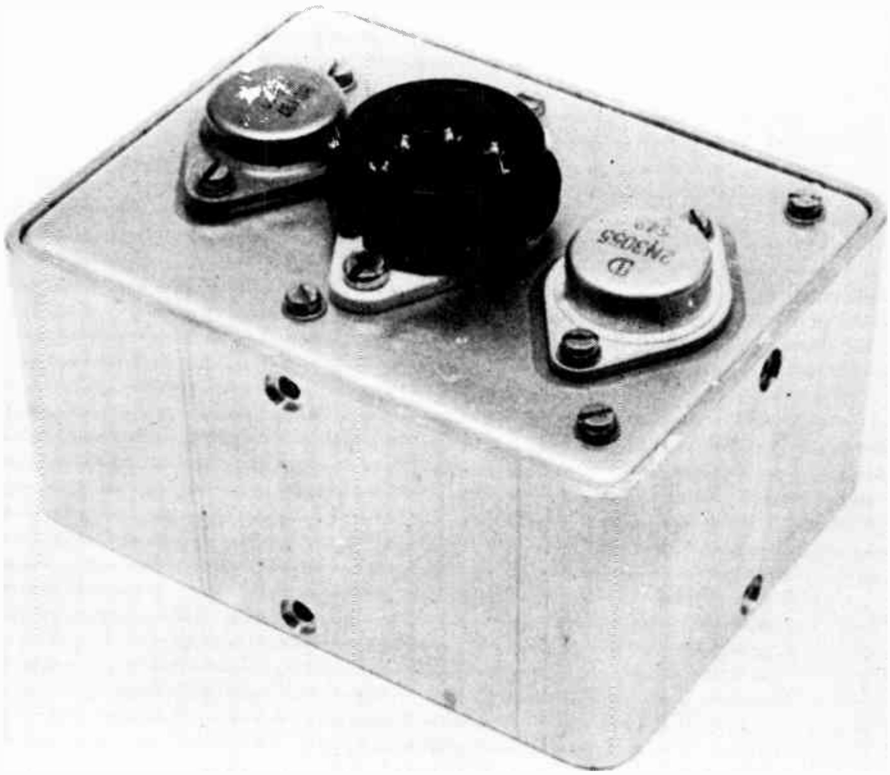
Flash-rates in the order of 5 to 12 flashes per second are the dangerous rates in this respect. In the event of such an attack switch the strobe off immediately.

TRANSISTOR ASSISTED IGNITION

A reliable type of electronic ignition which uses the existing points in the distributor.

THE MOST POPULAR project for use in a car must be some type of electronic ignition. The Kettering system (the one used on most cars) is as old as the car itself and has not changed much over the years. It still works by a set of points which close, to allow the current to build up in the spark coil, and then open so that the energy in the magnetic field of the coil is used to generate the high voltage needed to fire the plugs. The system has problems at high speed in that the current does not have time to rise to a high enough level before the points open — resulting in the output voltage falling as the speed increases. At low speed (when starting) the points open too slowly and some energy is lost in arcing across the contacts. The use of a ballast resistor (usually about 1-1.5 ohm) and a lower inductance coil helps the high speed performance and shorting the ballast resistor while starting helps.

While this system has performance limitations it is reliable. The points need to be cleaned every 10,000 km or so but the system is unlikely to suddenly fail without warning.



Electronic Ignition

Electronic ignition has been around for about 15 years, but until recently no major car manufacturer has used it in production. This is due not only to the additional cost but mainly to the reliability problems (how many NRMA men carry spare transistors?).

The first electronic ignition system simply used a transistor to switch the main current — giving longer points life. Unfortunately in those days a high voltage transistor could handle a maximum of about 150 V and special transformers (ignition coils) had to be wound and a large ballast resistor was needed. These normally consumed about 10 or 15 A from the battery.

Soon afterwards dwell extenders made a brief appearance and these used an SCR to close the points about 1 ms after they opened, giving a longer time for the current to build up. This helped the high speed performance but did not help starting or points life.

The main system, which has been around for many years is CDI, where the required energy is stored in a capacitor and when required it is dumped into the spark coil which is used only as a transformer (not for energy storage). This system is economical on power, is good at both high and low speed and has been most popular with the hobbyist.

(text continues on page 72)

TRANSISTOR ASSISTED IGNITION

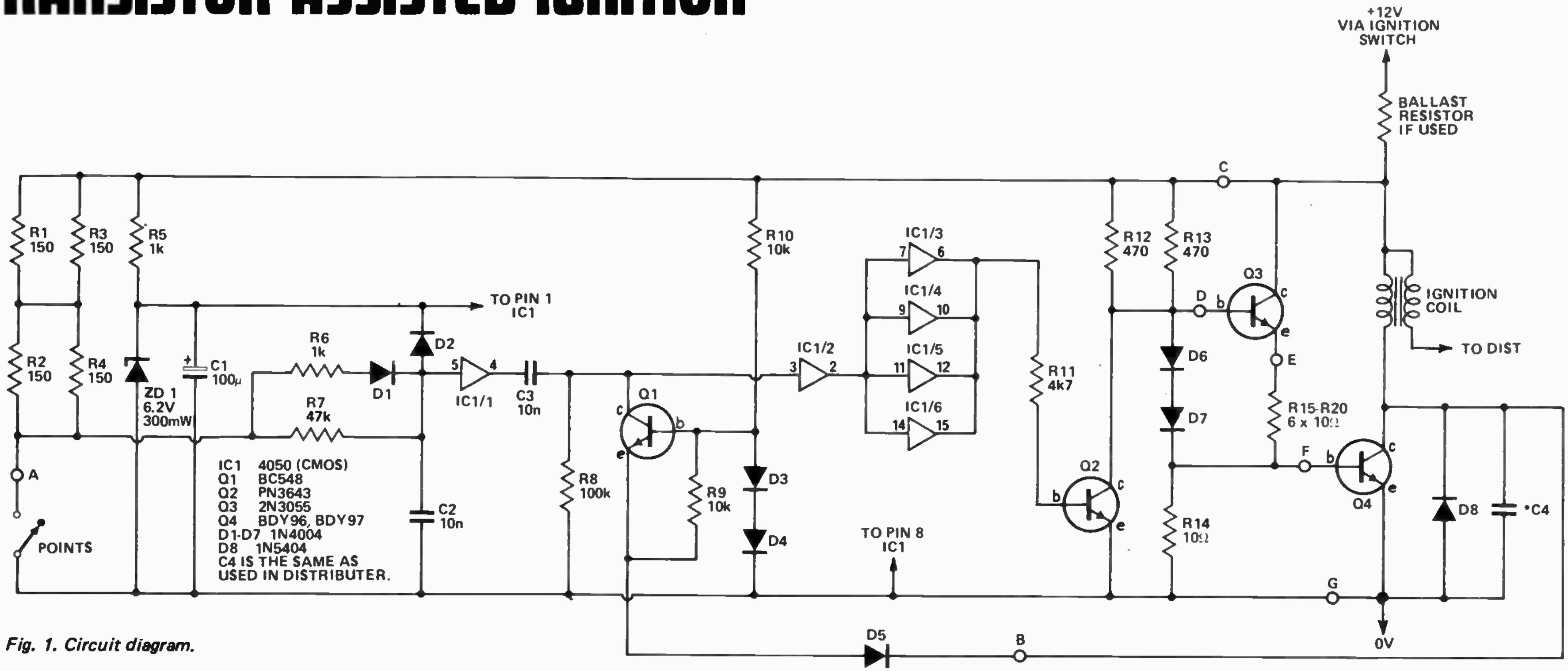


Fig. 1. Circuit diagram.

HOW IT WORKS ETI 316

The main current in the coil is switched by Q4 which is a 750 V 10 A transistor. The base current, of which about 500 mA is needed, is provided by Q3, which acts as a constant current source. We used this instead of a resistor as the supply voltage can vary from 6 to 12 volts (and the power dissipation would be too high). The current source is switched on and off by Q2 (the output transistor being off if Q2 is on). Diode D8 prevents reverse voltage damaging Q4 while C4 prevents the output voltage rising to high.

The points are supplied with a current, by R1-R4, of about 60 mA, which keep them clean, and when they open C2 is charged rapidly via R6 and D1. This is buffered by IC1/1 (IC1 is a CMOS hex buffer) which triggers the monostable made up of C3 and R8. This is then buffered by IC1/2 then by IC1/3-6 and this then controls the output stage. This will turn the output transistor off for about 1 ms (normal dwell) unless Q1 intervenes. This transistor operates if the output voltage falls to, or below, zero and resets the monostable, turning Q4 on again. This occurs after the first transient and ensures that Q4 is not turned on when there is high voltage across it.

When the points close C2 discharges more slowly via R7 and if the points open again quickly (ie, bounce) this is ignored. The supply voltage of IC1 is regulated by ZD1 and C1 to 6.2 V.

Construction

We made our prototype in a metal box – Horwood type 34/2/D. The two power transistors are mounted on the lid along with the changeover socket, capacitor C4, and the diode D8. All other components are mounted on the pc board which is mounted on 20 mm spacers.

The pc board should be assembled with the aid of the overlay in Fig 2. Ensure the transistors are oriented correctly – also check the diodes, IC1, and C1. The IC should be installed last. Mount the power transistors using insulating washers. The capacitor C4 should be the same type as used in the distributor. If desired it can be removed from the distributor and fitted on the coil itself, between earth and the negative terminal. In this place it will

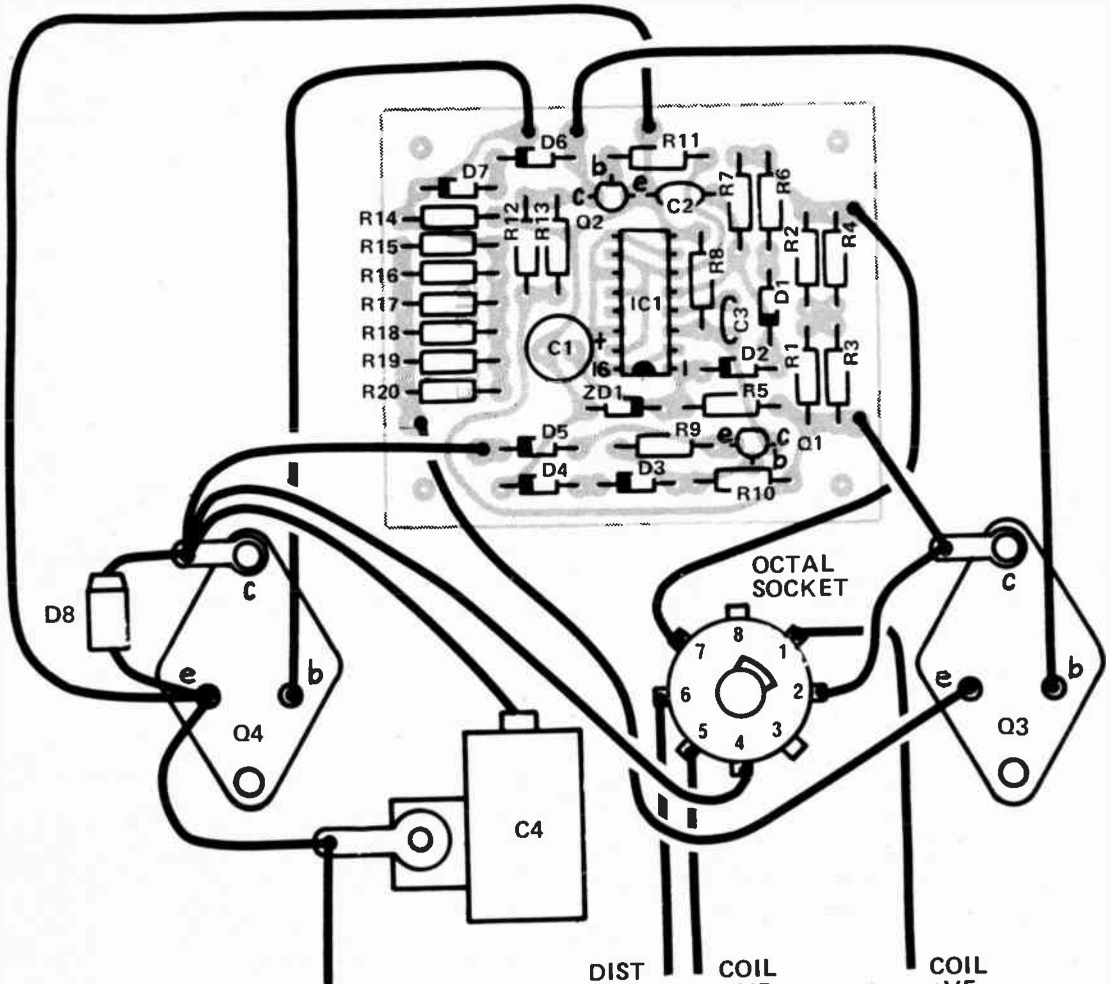


Fig. 2. Overlay and wiring diagram.

work for standard or assisted ignition.

The external wiring can now be done according to Fig 2. Ensure that the outer surface of C4 is connected to the emitter of Q4. When mounting the pc board ensure that the spacers do not touch any of the tracks if they do use a piece of insulation under the end.

As the octal plug has to be capable of plugging-in in two positions, ie, standard or assisted ignition, the socket has to be modified slightly. This entails making a new slot between pins 1 and 2 similar to the one between pins 1 and 8. This can be either a new slot or the existing slot can be widened. There are three links required in the plug, these being between pins 1&8, 3&4 and 5&6. With the plug in the normal position standard ignition is selected and in the second position transistor assisted ignition is operational.

PARTS LIST – ETI 316

Resistors all ½W 5%

R1-R4	150 ohm	
R5,6	1 k	
R7	47 k	
R8	100 k	
R9,10	10 k	
R11	4k7	
R12,13	470 ohm	
R14-R20	10 ohm	
Capacitors		
C1	100 µ 16 V electro	
C2,3	10 n polyester	
C4	see text	
Semi conductors		
Q1	Transistor	BC548
Q2	"	PN3643, 2N3643
Q3	"	2N3055
Q4	"	BDY96, BDY97
D1-D7	Diodes	1N4004
D8	"	1N5404
ZD1	Zener	6.2 V 300 mW
IC1	4050 (CMOS)	

Miscellaneous

PC board ETI 316
Case, Horwood 34/2/D or similar
Octal plug and socket
Four 20 mm long spacers

Project 316

Today many of the major car manufacturers are offering electronic ignition either as standard or as an option. These however are not (generally) CDI but types similar to the earlier transistor switch type (using modern high voltage transistors). Some systems also eliminate the points — using either an optical or magnetic pickup instead.

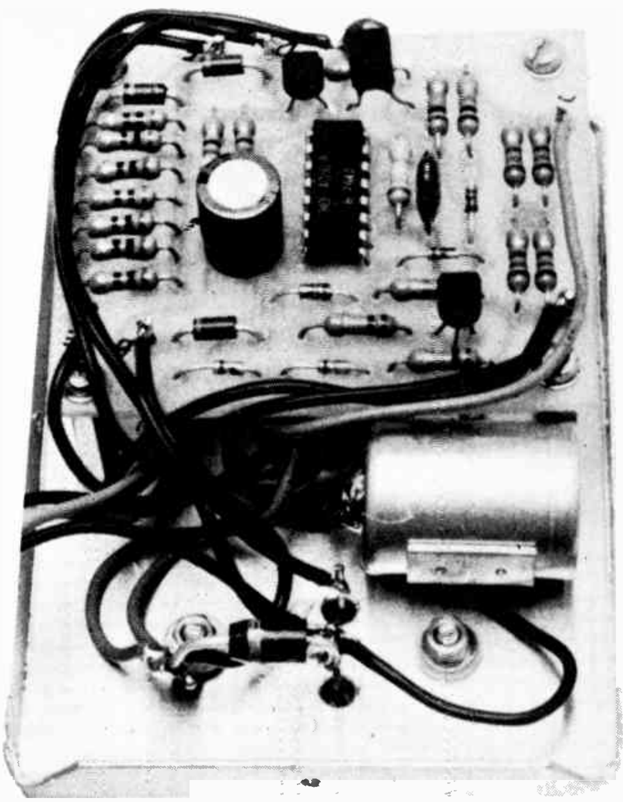
The system described here is a transistor switch type but with dwell extension built in. The unique circuit can provide a spark rate beyond that needed by most motors and will give a good spark at speeds which some CDI systems will stop. It is simple to install and we have provided a change-over plug (just in case you have problems).

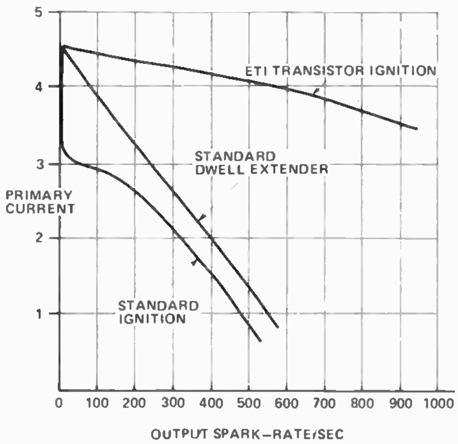
Design Features

The output transistor and the case are the major expenses and both are necessary. We therefore decided to see what other facilities we could add to make the project more worthwhile without making it much more expensive.

Adding dwell extension improves high speed performance but with the standard design method the voltage still falls somewhat at high speeds. After examining the primary waveform it was realised that when the points open a lot of energy is wasted in ringing and that the main spark energy occurs only in the first positive going transient. It was decided therefore to turn on the switching transistor (thus in effect reclosing the points) immediately after this transient. This provides a more stable spark of higher energy and allows very high speeds (over 1500 sparks per second) to be obtained. The primary current remains much more constant as the coil does not completely discharge each cycle.

Since the design was published a few readers found that this early switch-on caused misfiring. This occurs only with a very few, and generally older vehicles. If encountered it will almost certainly be cured by deleting diode D5.





Graph showing relationship between average coil current and spark rate for the different systems.

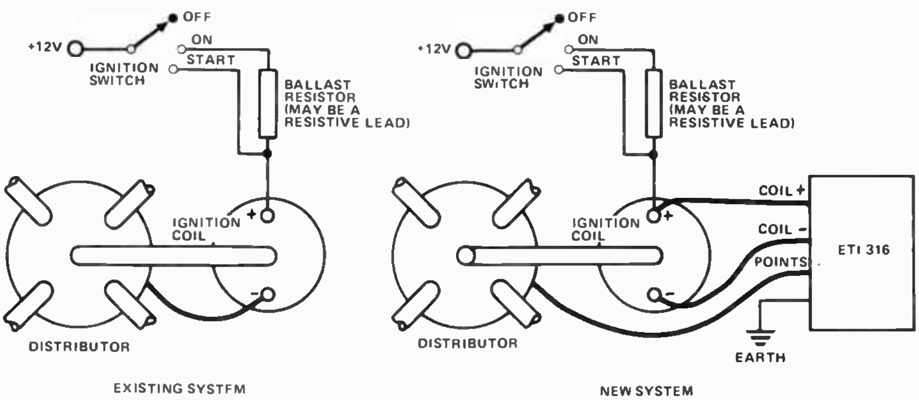


Fig. 4. Diagram showing how to connect the unit to the car.

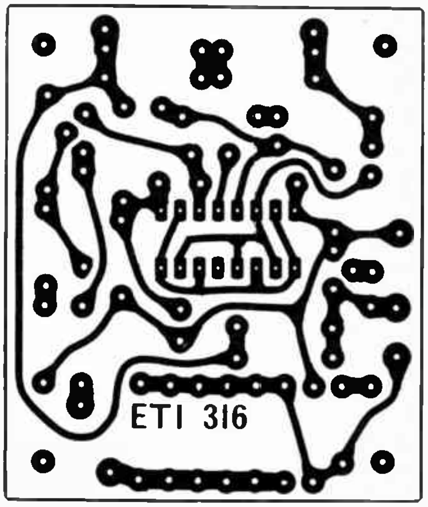


Fig. 3. Printed circuit board. Full size 65 x 55 mm.

Project 134

TRUE RMS VOLTMETER

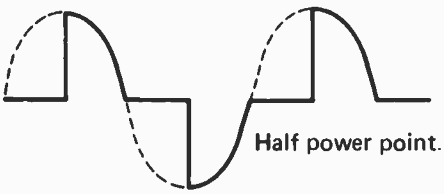
The use of a special IC results in performance greatly improved over conventional designs.

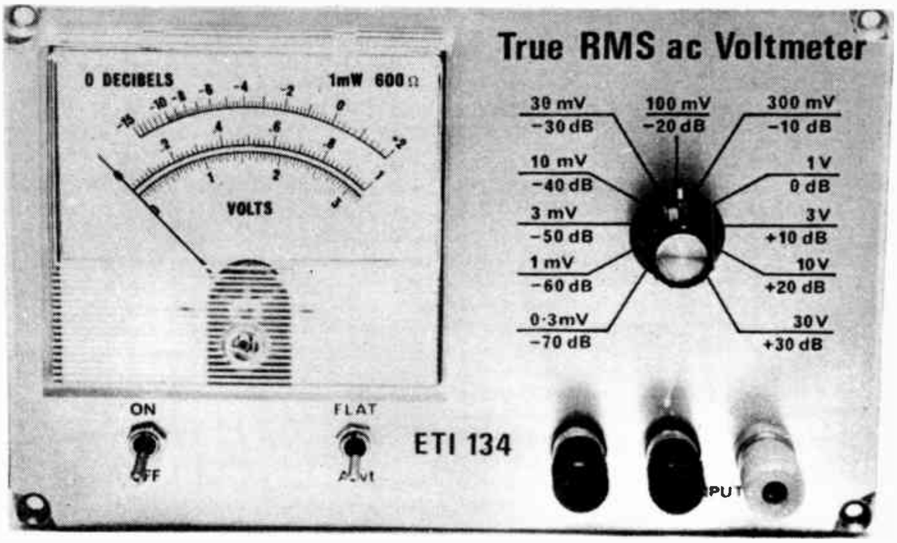
MOST METERS which can measure ac signals do so by rectifying the signal and then measuring the average voltage. With a sinewave the average voltage is 0.637 of the peak voltage while the rms value is 0.707 of the peak. Therefore a correction factor of 1.11 is built into the meter to give the rms value of the signal.

Provided you stick with sinewave signals these meters are adequate. With any other waveform, however, they are not accurate. With a square wave the error is 11% and with pulse wave forms the error increases.

Before continuing we should explain what rms means and its significance. Without getting mathematical, the rms value of any wave form is the same as a dc value which would produce the same heating effect in a resistor. For example:

Power in a load can be varied by using phase control (i.e., light dimmer) where the time the load is connected to the mains is variable. The rms value is difficult to calculate except at the point where it is half on—half off. The power then is obviously half power.





If the input voltage is 240 V and the load is 240 ohms the power (maximum) is given by

$$P = \frac{E^2}{R} \text{ or } \frac{240 \times 240}{240} = 240\text{ W}$$

Half power therefore is 120 W. The voltage corresponding to this is given by

$$E = \sqrt{P \times R} \text{ or } 170\text{ V (rms)}$$

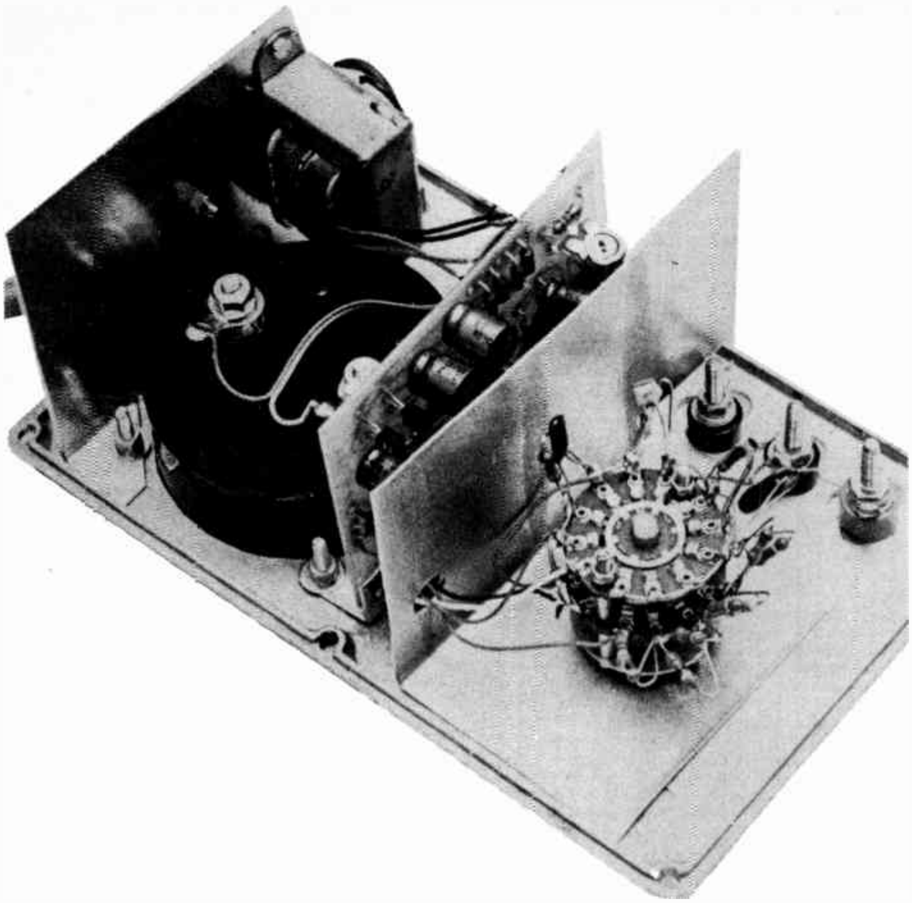
On a "normal" meter this will read 120 V or an error of 30%.

This design uses an rms detector IC, which is basically a small, special-purpose analogue computer to mathematically calculate the true rms value for any waveform.

Design Features

The design of the voltmeter is basically simple, starting with an attenuator in the front end, then an amplifier with a high input impedance and switchable gain which, with the attenuator, gives the range selection. A filter is then added to give the "A" weighting and the rms detector IC (LH0091) does the rest.

The output of the input amplifier is 60 mV, independent of range selected, for an input corresponding to the full scale reading. This gives a maximum gain of 46 dB on the 0.3 mV range. There is a loss of about 2.3 dB in the filter (at 1 kHz) and the spare amplifier in IC2 is used to provide a gain of 20 dB giving 500 mV (for full scale reading) before the rms detection is done. The



SPECIFICATION – ETI 134	
Meter Type	rms reading ac only
Ranges	0.3, 1, 3, 10, 30, 100, 300 mV 1, 3, 10, 30 V
Accuracy	±3% nominal (crest factors up to 3) – 8% at crest factor of 10
Input Impedance	1 megohm in parallel with 25 pF
Weighting Networks	Flat or 'A' weight
Frequency Response	10 Hz – 20 kHz

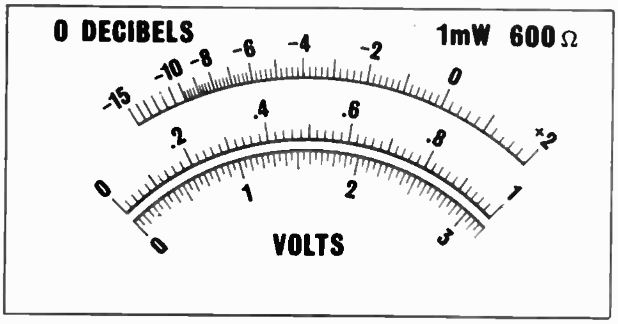


Fig. 1. Meter scale shown full size.

rms detector section has unity gain with 500 mV rms in giving 500 mV dc out.

However things are never that simple. With a total of 60-odd dB gain, along with the requirement for a 1 M input impedence, we have an excellent formula for an oscillator. With the third try (yes, we have failures too) with adequate shielding and layout, stability was obtained and this final design is presented here.

The spare IC in the LH0091 is normally used to buffer, filter or amplify the output of the rms converter but we used it before so as to buffer the filter network and save an additional op amp (the input of the rms converter is only 5 k ohms). The output voltage from the converter is only 500 mV but this is adequate to drive a meter. We could have provided more gain in the buffer stage so giving a higher output but this would lead to greater errors with high crest factor waveforms.

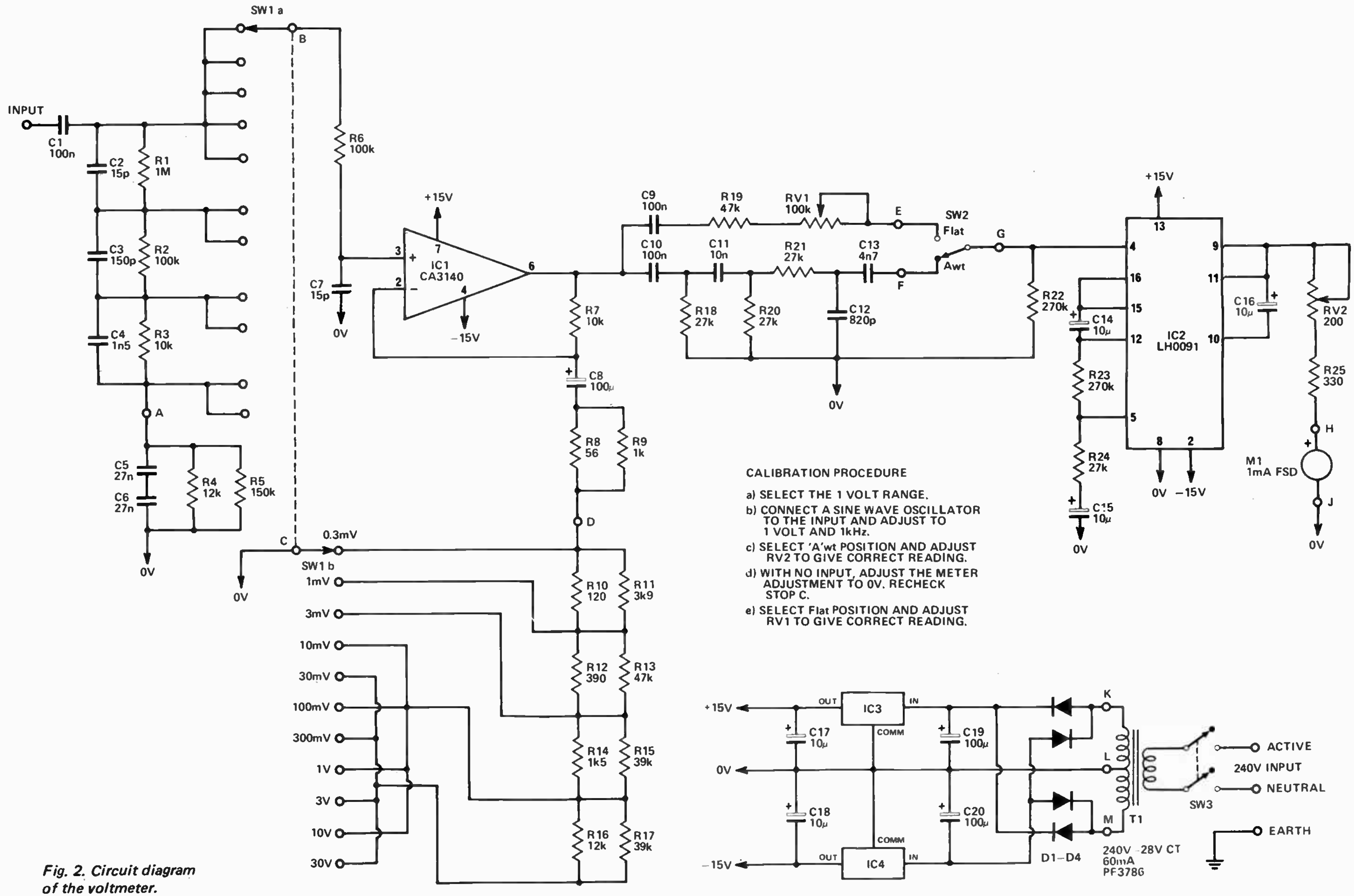
We have limited this instrument to ac signals as this eliminates the need for balance controls to correct for drift when measuring low level signals. This normally is of no consequence as most signals, i.e., output of a tape recorder, sound level meter, etc., have no dc component. If dc capability is needed, capacitors C1, 8, 9, 14, 15 and 16 have to be shorted out, a zero adjustment potentiometer added to IC1 along with the potentiometers needed to offset adjust IC2.

Construction

If the printed circuit board is used along with the layout and shields as described there should be no problems with construction. The wires associated with the rotary switch should be no longer than necessary to minimise any pickup. The box should be earthed to the mains earth and the front panel earth terminal (left hand one) should also be connected to earth.

Use

When measuring low level signals there may be 50 Hz pickup unless the common side of the input signal is connected to ground. This may be done either in the unit under test or on the meter (hence the earth terminal). Also with the meter terminals open circuited the meter will give some reading. However, as the output impedance of low level signals (0.3 mV and less) is normally relatively low this is normally no problem.



CALIBRATION PROCEDURE

a) SELECT THE 1 VOLT RANGE.
b) CONNECT A SINE WAVE OSCILLATOR TO THE INPUT AND ADJUST TO 1 VOLT AND 1kHz.
c) SELECT 'A'wt POSITION AND ADJUST RV2 TO GIVE CORRECT READING.
d) WITH NO INPUT, ADJUST THE METER ADJUSTMENT TO 0V. RECHECK STOP C.
e) SELECT Flat POSITION AND ADJUST RV1 TO GIVE CORRECT READING.

Fig. 2. Circuit diagram of the voltmeter.

HOW IT WORKS – ETI 134

The input signal is attenuated by the network R1–R5 and C2–C6; the appropriate attenuation is selected by SW1a. This gives 0 dB, 20 dB, 40 dB and 60 dB. The output of SW1a is buffered by IC1 which is a FET input op-amp. This amplifier has a gain which is switchable giving 5.56 dB, 15.56 dB, 25.56 dB, 35.56 dB and 45.56 dB. By selecting a combination of these two variables the eleven ranges from 0.3 mV to 30 V are obtained. The output of IC1 for full scale reading is 60 mV.

The output of IC1 goes to the 'A' wt filter network and also directly (via R19) and RV1) to SW2. This selects either 'A' weighting or flat response. As the filter has 2.3 dB loss at 1 kHz the "flat" position is also attenuated (hence R19, RV1) to maintain calibration.

The rms detector IC provides a gain of 20 dB before the detector; the output of the detector is about 500 mV for full scale reading.

The power supply is simply a full wave rectified supply giving both plus and minus voltages of about 20 V, which are then regulated to ±15 V by IC3 and IC4.

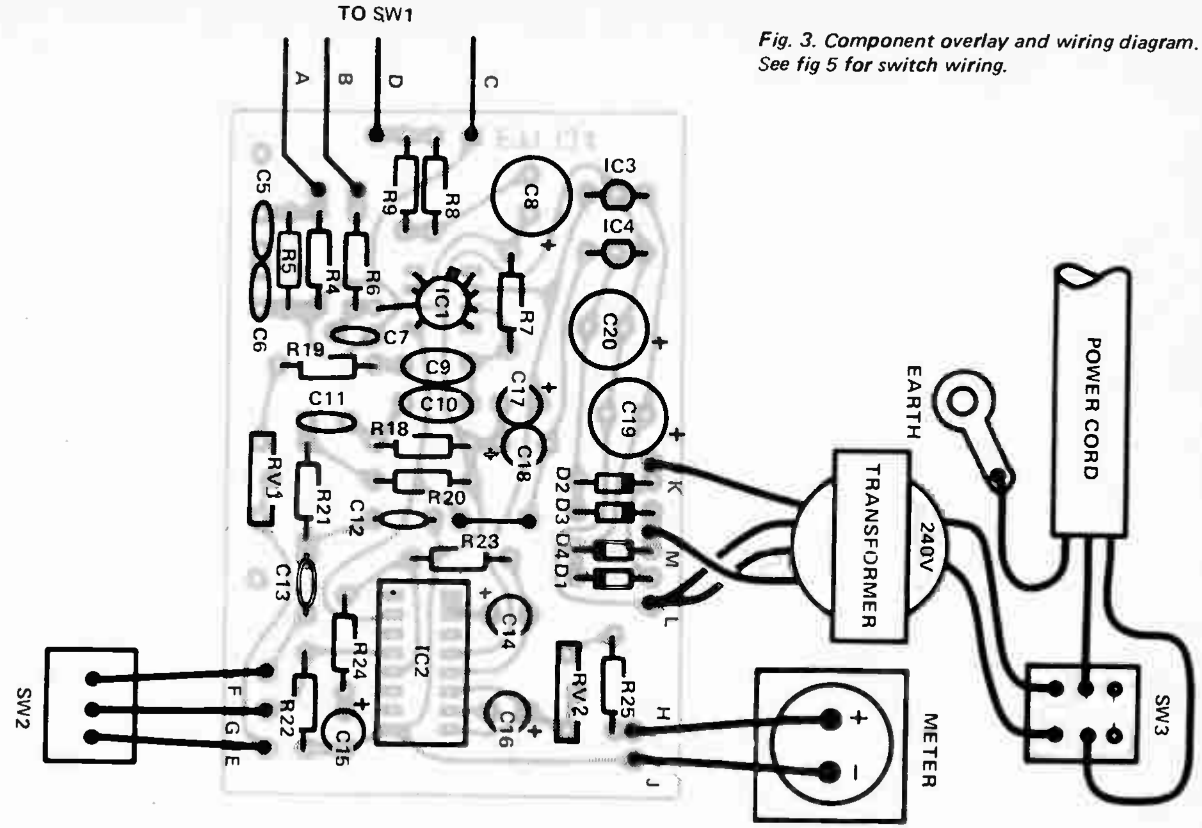


Fig. 3. Component overlay and wiring diagram. See fig 5 for switch wiring.

PARTS LIST - ETI 134

Resistors

All ½ W 5%, except where marked.

R1	1M	1%
R2	100k	1%
R3	10k	1%
R4	12k	1%
R5	150k	
R6	100k	
R7	10k	1%
R8	56	1%
R9	1k	
R10	120	1%
R11	3k9	
R12	390	1%
R13	47k	
R14	1k5	1%
R15	39k	
R16	12k	1%
R17	39k	2%
R18	27k	
R19	47k	
R20,21	27k	
R22,23	270k	
R24	27k	
R25	330	

Potentiometers

RV1	100k	trim
RV2	200 ohm	trim

Capacitors

C1	100n	polyester
C2*	15p	ceramic
C3*	150p	"
C4*	1n5	polyester
C5, 6*	27n	"
C7	15p	ceramic
C8	100µ	25V electro
C9, 10	100n	polyester
C11	10n	"
C12	820n	ceramic
C13	4n7	polyester
C14-C18	10µ	25V electro
C19, 20	100µ	25V electro

* These capacitors should be as accurate as possible as they affect accuracy above 10kHz.

Semiconductors

IC1	CA3140	op amp
IC2	LH0091	RMS converter
IC3	78L15	regulator
IC4	79L15	regulator
D1-D4	1N4001 or similar	

Miscellaneous

PC board	ETI 134
SW1	2 pole 11 position OAK switch
SW2	SPDT minature toggle switch
SW3	DPDT minature toggle switch
T1	Transformer PF3786 (28V ct)
M1	Meter 1mA scaled as shown

3 terminals (red, black green)
Box Eddystone 6357P
Metal brackets and shields (see Fig 7)
3 core flex and plug
Scotchcal or aluminium front panel
16 pin socket for IC2
Knob

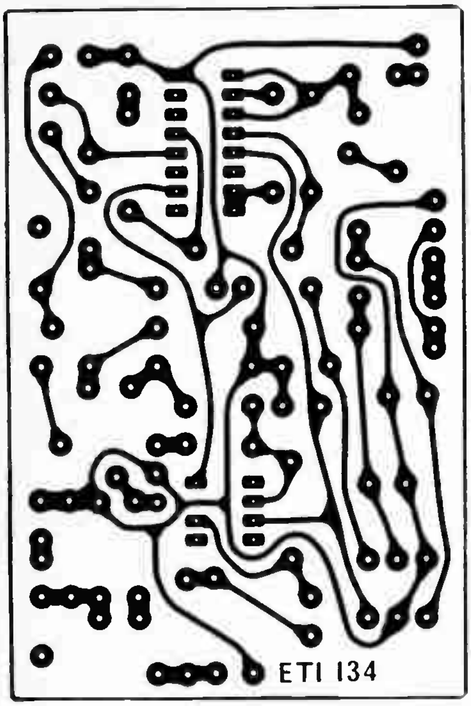


Fig. 4. Printed circuit layout. Full size 90 x 60 mm.

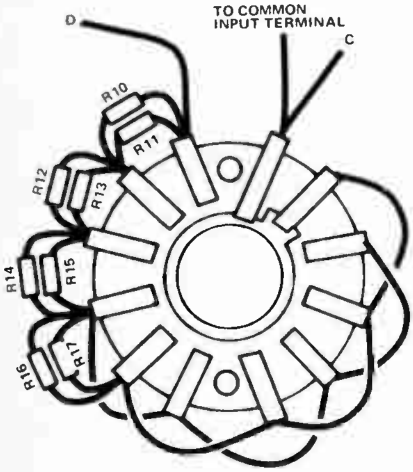
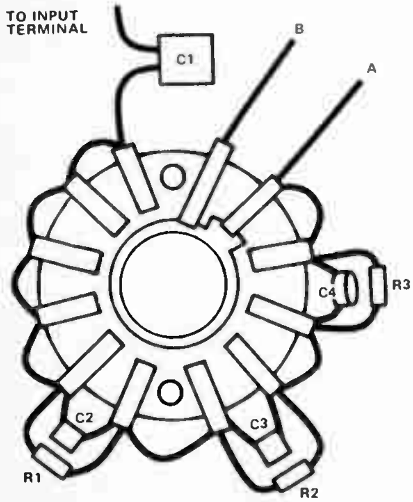


Fig. 5. Connection of the range switch drawn in the 30 V position.



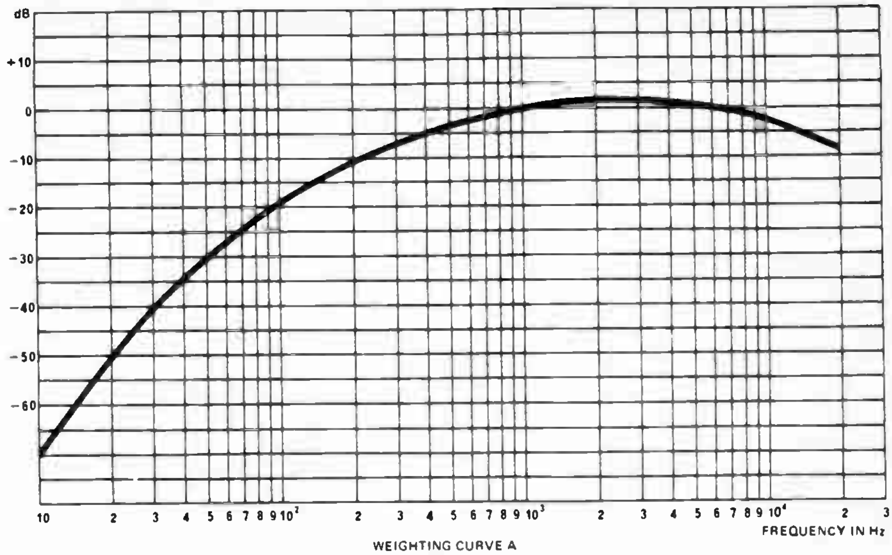


Fig. 6. The response in the " A " weight position.

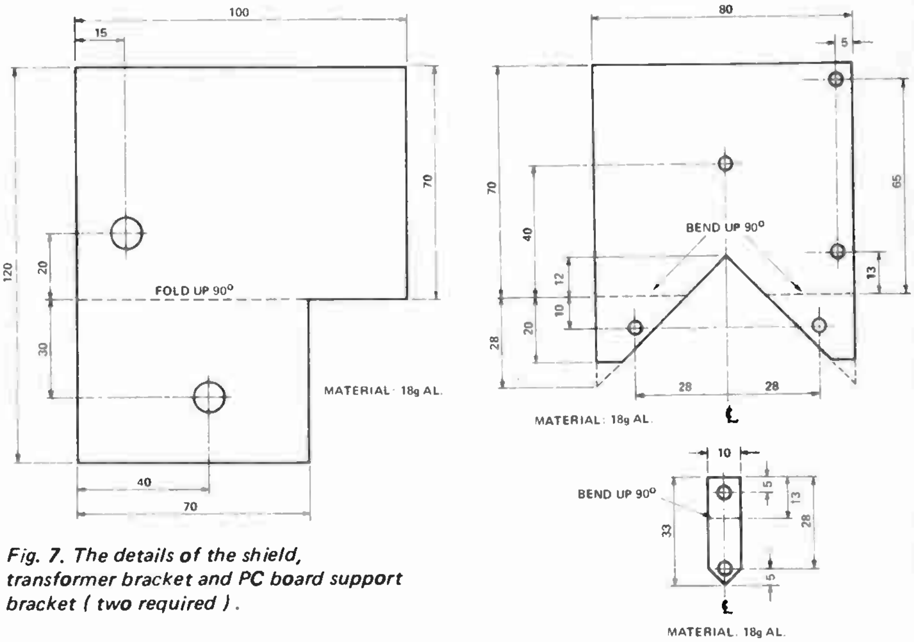
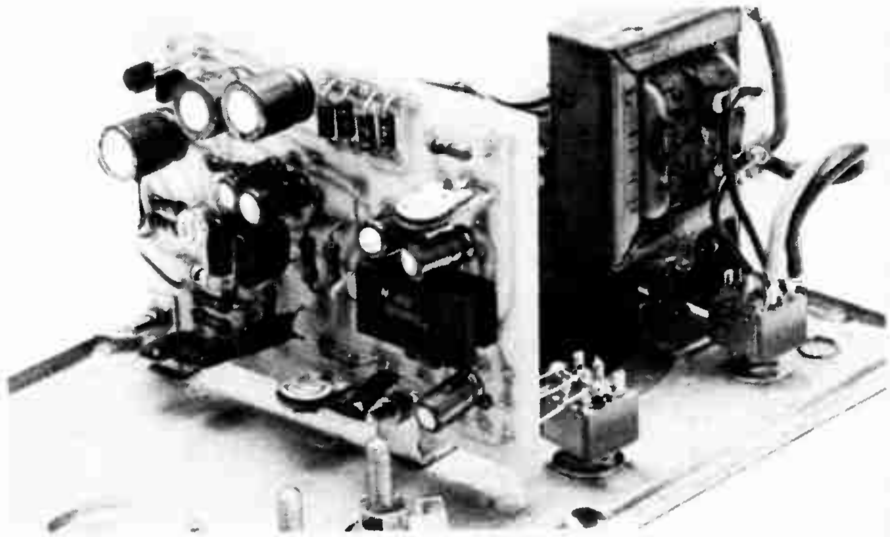


Fig. 7. The details of the shield, transformer bracket and PC board support bracket (two required).



SHUTTER SPEED TIMER

Many electronic enthusiasts are also amateur photographers — here's a project just for them.

THE NUCLEUS of good photography is correct exposure. This is a combination of shutter speed and lens aperture as determined by an exposure meter. If either speed or aperture is not as indicated on the camera the results will be less than perfect.

While the lens aperture is a simple mechanical operation and unlikely to be in error the same cannot be said about the shutter with its springs and things. *(Typical electronic engineer's attitude!— Ed.)* Not only may the speed not be exactly as indicated on the dial, it may (probably) change as the camera gets older. Therefore it is desirable that a simple method of determining the actual speed should be available.

This project describes the design and construction of a unit which is capable of measuring times from 1/10000 sec. to 10 sec. This allows the actual speed to be measured and then used to calculate the correct aperture when taking those important photos.

SPECIFICATION — ETI 586	
Timing range	0.1ms to 9.99sec.
Sensor	Photo transistor
Display	3 digit LED
Power supply	9Volt batteries 65 — 160mA LEDs on 20mA LEDs off
Battery life	≈6 hours — normal ≈20 hours — alkaline

It is suitable for checking cameras with a hinged or removable back so that the sensor can be placed in the film plane. For cameras where the film fits into a slot this unit cannot be used.

SHUTTER SPEED TIMER

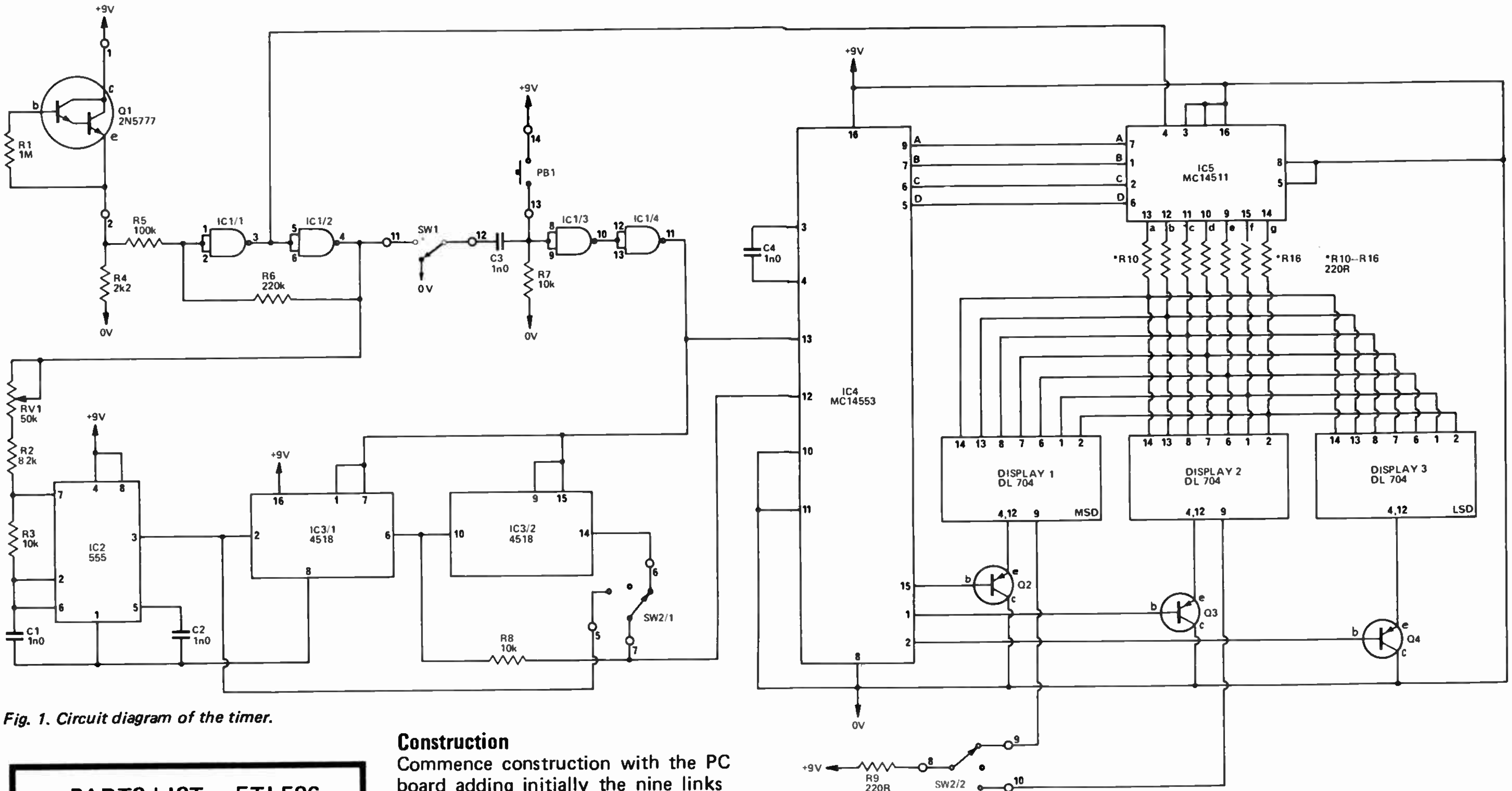


Fig. 1. Circuit diagram of the timer.

PARTS LIST – ETI 586

Resistors all ½ W, 5%

R1	1M
R2	82k
R3	10k
R4	2k2
R5	100k
R6	220k
R7,8	10k
R9–R16	220R

Potentiometer

RV1	50k trim

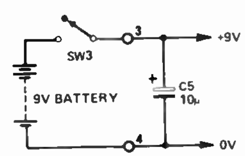
Capacitors

C1–C4	1n0 polyester
C5	10µ 16 V electro

Construction

Commence construction with the PC board adding initially the nine links required. Next add the resistors and capacitors in the appropriate locations as shown in the component overlay. Note that capacitor C5 is polarised and must be inserted the correct way round.

The transistors and the displays can now be soldered in place taking care with orientation of the transistors. If Philips or Siemens transistors are used this will be as shown in the overlay, but if a different brand is used the transistors must be rotated 180 degrees from those shown.



HOW IT WORKS – ETI 586

To measure the time the shutter is open we use a phototransistor, Q1, positioned in the film plane in the camera. When the shutter is operated and if the camera is focusing a bright light on to the transistor, the voltage across R4 will rise to about 7 V for the duration of the

Semiconductors
IC1 . . . . . . 4011 (CMOS)
IC2 555
IC3 . . . . . . 4518 (CMOS)
IC4 . . . . . . 14553 (CMOS)
IC5 . . . . . . 4511 (CMOS)
DISPLAY 1–3 DL704
Q1 . . . . . . 2N5777
Q2–Q4. . . . BC559

Miscellaneous
PC board ETI 586
plastic box
Scotchcal panel
polaroid plastic
SW1,3 toggle switch SPDT
SW2 toggle switch DPDT center off
push button
phone jack & plug
six way AA size battery holder
battery clip
support bracket
spacers, nuts, bolts, wire etc.

The ICs are the last components to be installed and these must be in the correct location and orientation. As they are all CMOS devices (except IC2) the pins should not be handled if possible to minimise the danger of static electricity damaging them. When soldering them in, solder the corner pins (the power supplies), pins 7 and 14 or 8 and 16 first as this allows the internal protection diodes to work while you solder the other pins.

The front panel can now be drilled, cut and if required a Scotchcal panel fitted. A piece of polarised plastic helps as a display window. The switches, pushbutton and phone jack can now be fitted and connected to the PC board as shown in the component overlay. The only point which could cause problems here is that the phone jack connections sometimes vary, and you should check yours before connection.

The PC board can now be mounted onto the support bracket with 6 mm spacers and the bracket into the box with two screws. When positioned correctly, the display will be visible through the window and the battery holders will be held in position at the other end.

The sensor plate which contains Q1 and R1 can now be made. We used a piece of PC board material although any non-conductive material which is opaque or translucent may be used. Start by cutting the plate to size and drilling a 6 mm hole in the centre. The photo-transistor Q1 should be mounted with the curved surface (which is the active side) into the hole and R1 soldered to the leads, the whole assembly then being glued onto the plate with quick dry epoxy. Ensure that all conductive parts are covered with epoxy to prevent touching when in use.

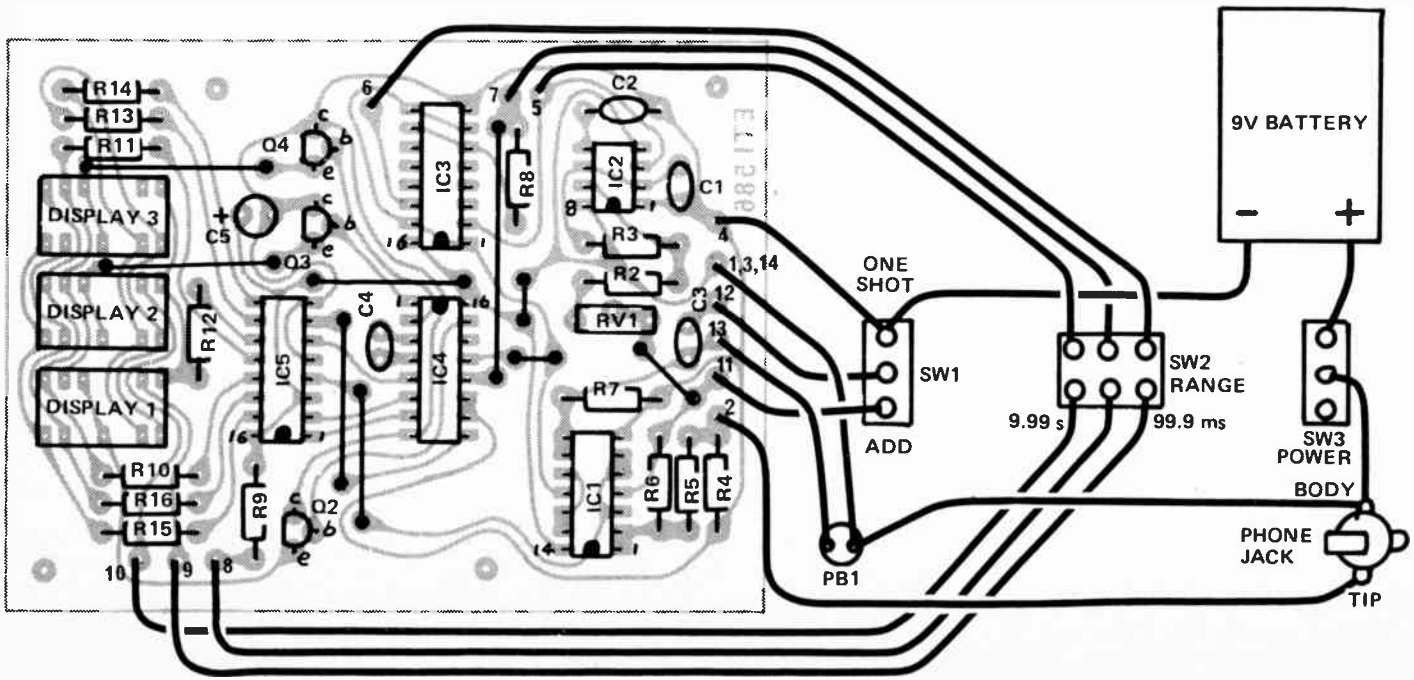
shutter being open. The transistor used is a Darlington type and is normally too slow for measuring times shorter than 1 ms. The addition of R1 increases the speed at the expense of sensitivity – hence the need for a bright light.

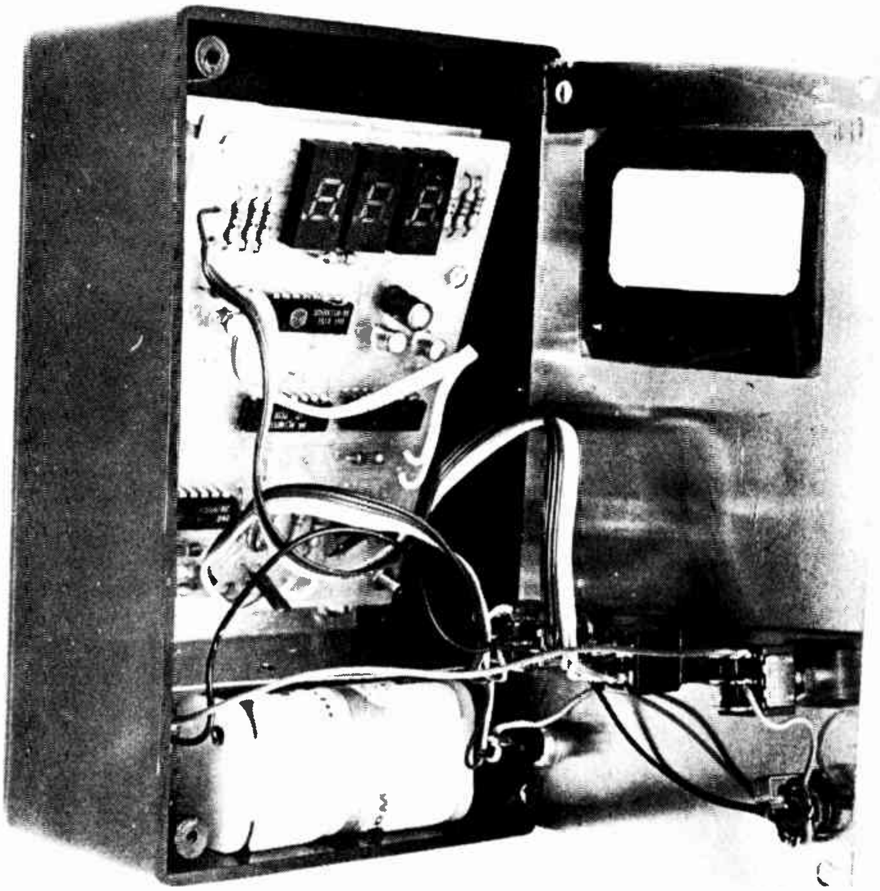
The output across R4 is squared up by the Schmitt trigger formed by IC1/1,2. The output of this controls the input to the 10 kHz oscillator IC2. This is an ordinary 555 oscillator where the frequency is set by C1, R2, R3 and RV1. The output of IC2 is divided by 10 in IC3/1 and again by 10 in IC3/2. We use the enable inputs of IC3 as they give clocking on the negative edges, which is what we need. We now have three outputs of 10 kHz, 1 kHz and 100 Hz. One of these outputs is selected by SW2/1 which is a centre off toggle switch. When it is in the off position, 1 kHz is selected via R8, while in the other positions the 1 kHz signal is swamped by the low output impedance of the other dividers.

Whichever frequency is selected clocks IC4 which is a 3 decade counter-latch-multiplexer. We are not using the latch in this application. This IC simply counts the number of pulses it receives and with the help of IC5 (7 segment decoder-driver) and Q2 – Q4 displays the result on the LED displays. During the counting period the display is blanked to prevent ripple on the supply rail upsetting the 555 timer. The ripple would occur as the current changes with different digits displayed. The decimal point is controlled by SW2/2.

Two modes, single-shot and add, are provided. In the single-shot mode when light hits Q1 operating the Schmitt trigger the monostable formed by IC1/3 gives a pulse about 50 μs long which resets the main counter IC4 and the /10 dividers, IC3. Pins 1 and 9 on IC3 which have to be low to allow clocking are taken high during the reset pulse only because it made the PC board easier and does not affect the operation. In the 'add' mode the reset pulse does not occur and unless the reset button is pressed the second and successive counts will simply add on to the previous count. This allows say ten tests to be made and the total divided by ten to find the average.

Fig. 2. Component overlay and wiring diagram.





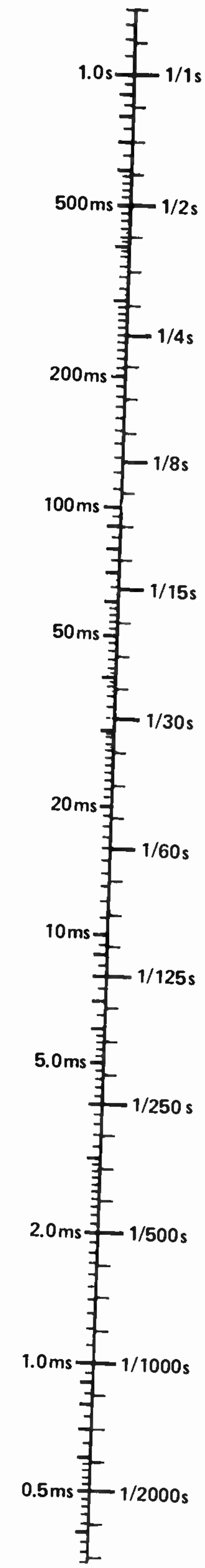


Fig. 4. Graph showing the relationship between time and shutter speed. Each of the small divisions on the right hand side corresponds with a ¼ stop.

Calibration

The unit can be calibrated accurately enough with the aid of a stopwatch with a second hand. Set the camera up as detailed in the operational notes and using the single-shot mode, open the lens for 5 seconds using the 'bulb' setting. By adjusting RV1 get the reading close to 5.00 seconds. Now use a longer time, say 20 s, noting that the first digit will be missing (i.e. a reading of 8.52 represents 18.52 s while 2.31 would be 22.31 s) and finally adjust RV1.

If the camera does not have a bulb position a push button can be substituted for the phototransistor but the 'add' position should be used and the timer manually reset as contact bounce can cause the display to reset on release of the button.

Operation

While the camera can be hand-held it is recommended that a tripod be used. Mount the camera on the tripod pointing at a light of 100 – 500 Watts about 2 – 3 feet away. Open the back of the camera and position the sensor plate so that the light is focused on the sensor. Initially, have the lens wide open; if enough light is hitting the sensor, the display will be blanked. Stop the lens down until the display comes on then go back one stop.

This sets the sensitivity and by selecting the appropriate range the shutter speed can be checked.

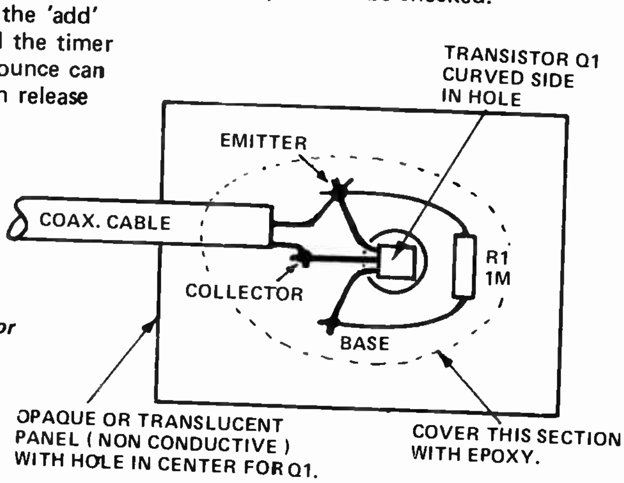


Fig. 3. Connection of the transistor on the sensor plate.

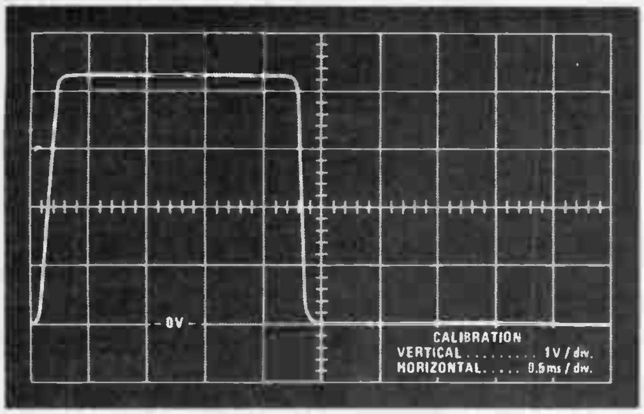


Fig. 5. Waveform on the input (point 2) with the camera on 1/500 sec. The actual time was 2.1ms.

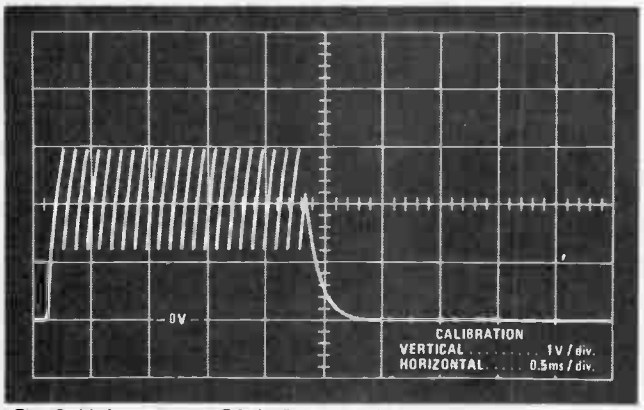


Fig. 6. Voltage across C1 during operation.

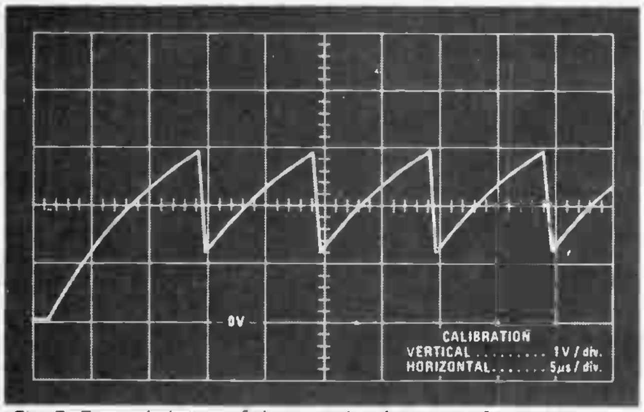
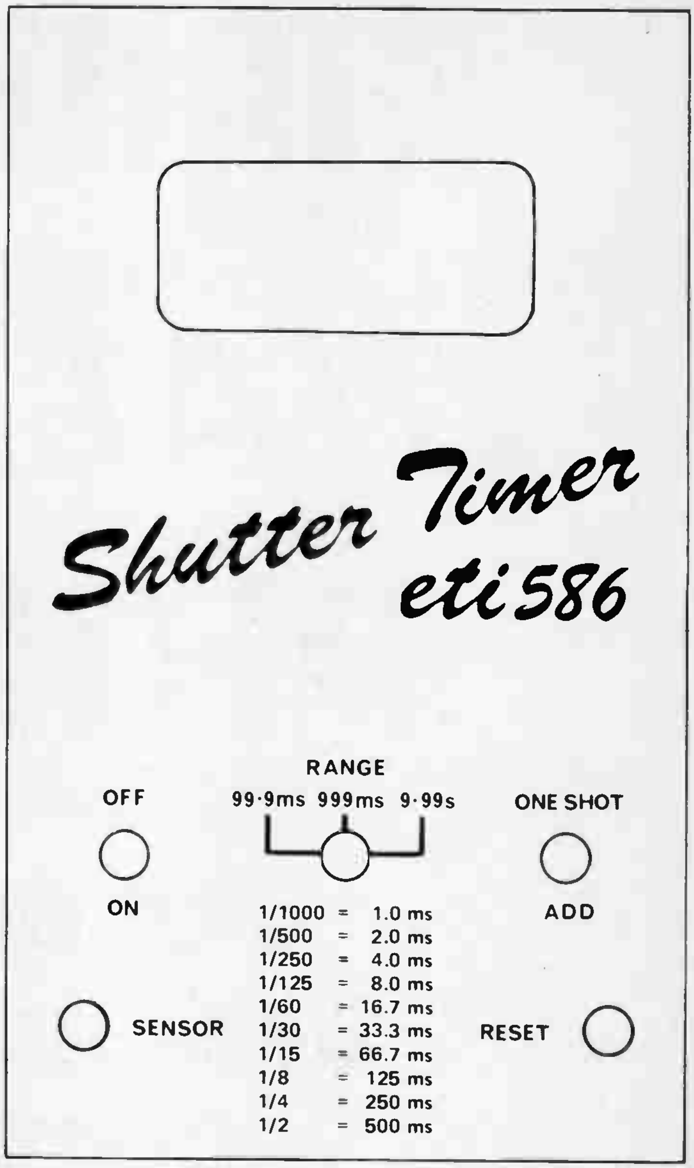


Fig. 7. Expanded view of the start the above waveform.



The printed circuit board layout for this project is on page 114.

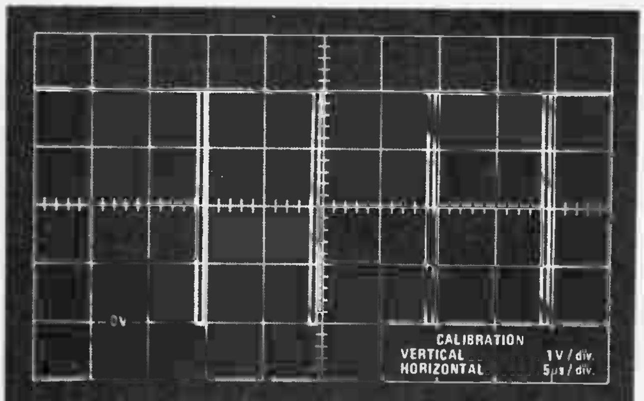


Fig. 8. The output of the 555 showing the first four pulses.

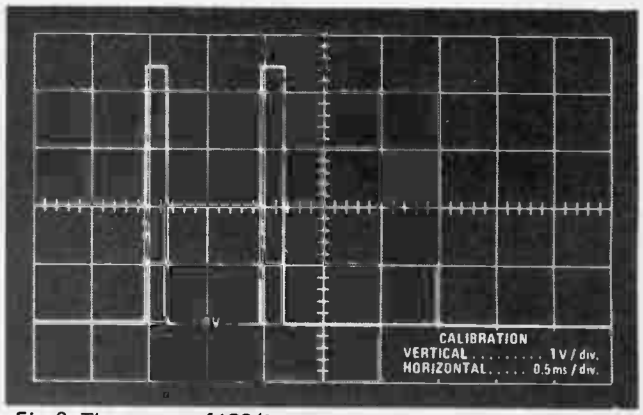


Fig. 9. The output of IC3/1.

ACCENTUATED BEAT METRONOME

This metronome design accentuates one beat out of every bar to help with complex rythms.

IT SEEMS THAT a sense of rhythm is acquired by aspiring musicians as they practise, rather than being an inborn ability. Many people don't have an 'easy' sense of rhythm, and the majority of people, if left to themselves in keeping a rhythm, will speed up or slow down slightly without realising it.

This project is an electronic version of the familiar mechanical metronome. However, we have used the potential of electronics to improve on the old design and have come up with one which will always accentuate a particular beat in the bar, e.g. 3/4 for waltzes. This can be a great benefit to those starting out in music, and can also help the more advanced musician with those awkward rhythms!

SPECIFICATION – ETI 604

Rate	1 / sec. to 15 / sec.
Beat	Off, 1–1 to 1–9
Output power 9 volt supply	8 watts peak
Output frequency	800 Hz, 2500 Hz
Power supply	6 – 15 volts dc

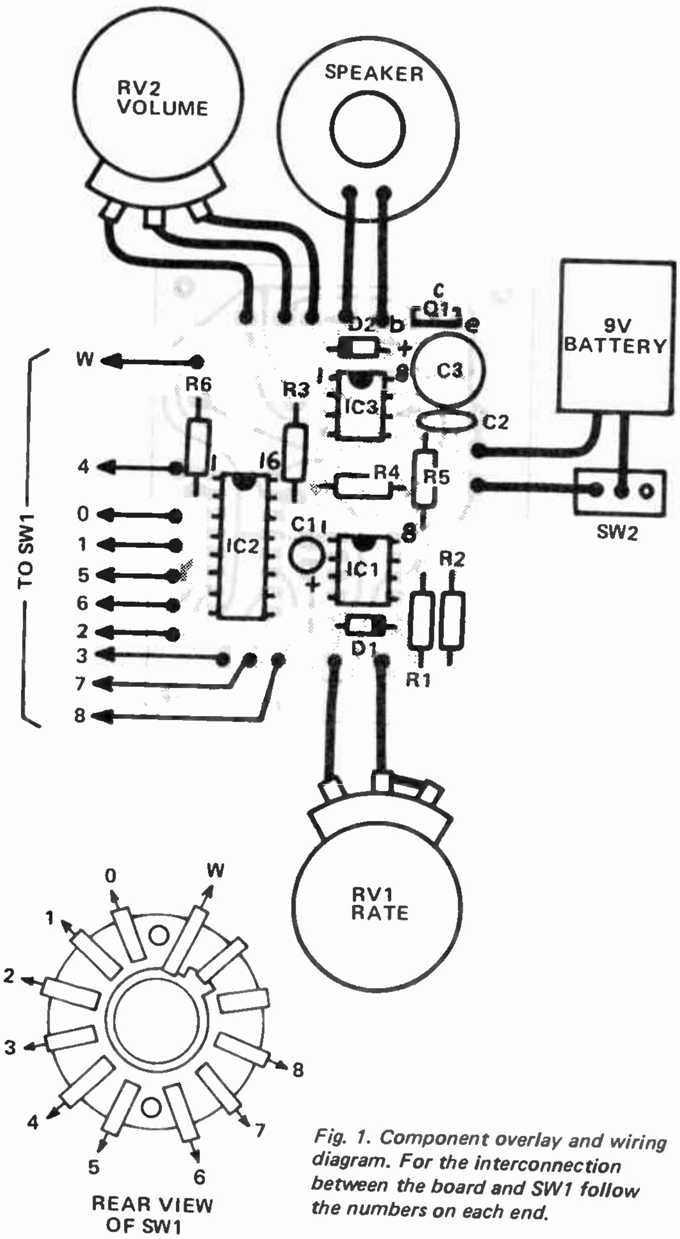


Fig. 1. Component overlay and wiring diagram. For the interconnection between the board and SW1 follow the numbers on each end.

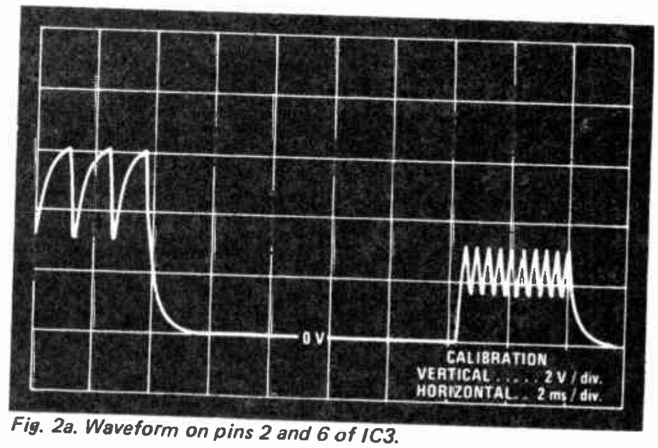


Fig. 2a. Waveform on pins 2 and 6 of IC3.

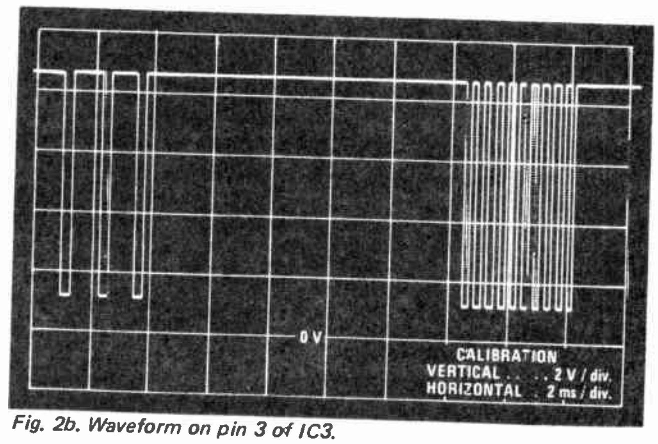


Fig. 2b. Waveform on pin 3 of IC3.

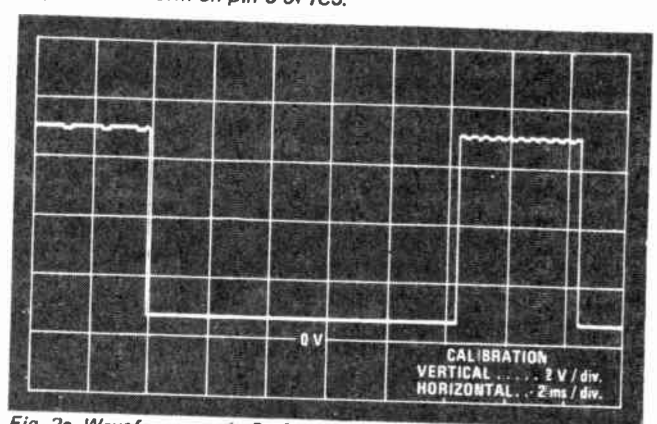


Fig. 2c. Waveform on pin 3 of IC1.
On these waveform diagrams the beat rate has been increased to show the two different outputs available.

The printed circuit board layout for this project is on page 114.

PARTS LIST – ETI 604

Resistor	all ½ W, 5 %	**Semiconductors**	
R1	2k2	IC1	NE555 timer
R2	47k	IC2	4017 decade counter
R3	15k	IC3	NE555 timer
R4	1k	Q1	BD140 transistor
R5	15k	D1, 2	1N4004 diode
R6	4k7		
Potentiometers		**Miscellaneous**	
RV1	1M lin rotary	PC board ETI 604	
RV2	500 ohm lin rotary	Speaker	
		Plastic box	
Capacitors		6 way AA size battery holder	
C1	1μ0 16V	6 AA size batteries	
C2	22n polyester	3 knobs	
C3	100μ electro	SW1 single pole 11 position switch	
		SW2 single pole toggle switch	

Design Features

The metronome designs published so far simply use a dc pulse to drive the loudspeaker. The only way to change the sound of this type of output to give the accentuation required and to maintain an even beat is to change the amplitude. As this is not very satisfactory we decided to use a tone burst method instead.

Initially we tried a pulsed LC network which produced a very good sound but was a little complex and expensive so we finally decided on a pair of 555 timers. With this system we alter the tone frequency simply by

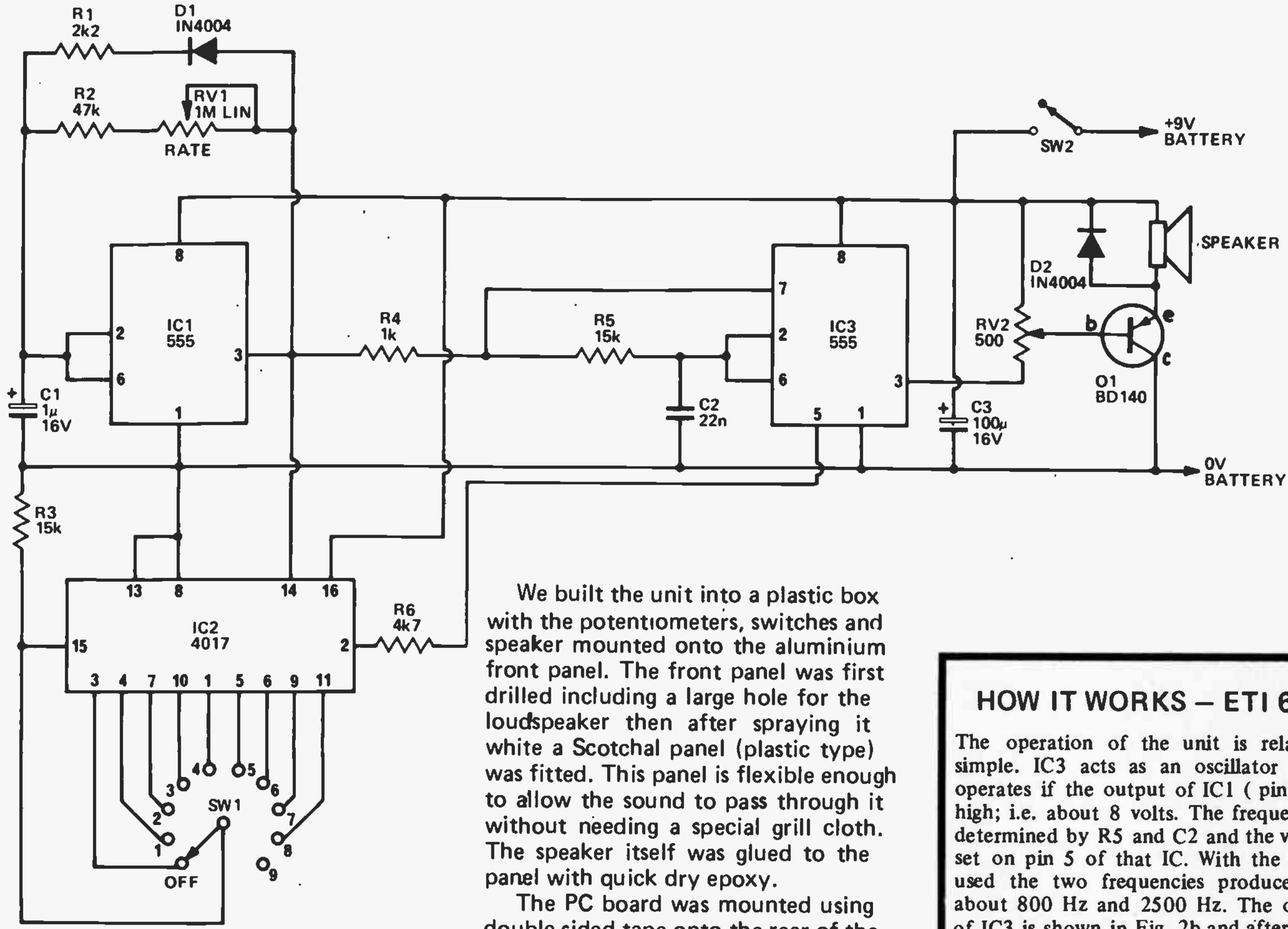


Fig. 3. Circuit diagram of the metronome.

varing the control voltage on the 555 driving the speaker. The other 555 timer is used to give the time between beats and the duration of the burst. A 4017 is used to count the beats and at the required time changes the control voltage of IC3.

When designing the PC board we considered mounting it on the rear of the wafer switch. However due to the number of different switches available we used wires to interconnect the switch to the PC board. The switch we used in the prototype was the OAK type as it was more readily available and also Australian made.

Construction

The unit is simple to build if the PC board is used. Assemble the board with the aid of the overlay diagram taking care to insert the transistor, ICs, diodes and the capacitors the correct way round. Some care should be taken in handling the 4017 IC; the pins should not be touched more than necessary and as well as it being the last component installed, pins 8 and 16 should be soldered first.

We built the unit into a plastic box with the potentiometers, switches and speaker mounted onto the aluminium front panel. The front panel was first drilled including a large hole for the loudspeaker then after spraying it white a Scotchal panel (plastic type) was fitted. This panel is flexible enough to allow the sound to pass through it without needing a special grill cloth. The speaker itself was glued to the panel with quick dry epoxy.

The PC board was mounted using double sided tape onto the rear of the speaker although it can be mounted in the rear of the box. The potentiometers, switches and speaker can be connected with hookup wire as shown in the overlay-wiring diagram. When connecting the battery ensure the polarity is correct as the unit will be damaged if it is reversed.

Late News

In our prototype we used nicad batteries which have a low internal resistance. Later we discovered when using standard dry cells that a slight irregularity occurred on the accentuated beat due to battery voltage fluctuations. If this is a problem with your unit it can be cured as follows:

1. Cut the PC board track between pin 8 of IC 1 and the point where the wire from SW 2 is joined and fit a diode (1N914 etc.), cathode to IC8, across the break.
2. Add a 100 μF 16 V capacitor across pins 1 and 8 of IC 1 (+ve to pin 8).
3. Add a 10 μF 16 V capacitor across pins 1 and 5 of IC 1 (+ve to pin 5).

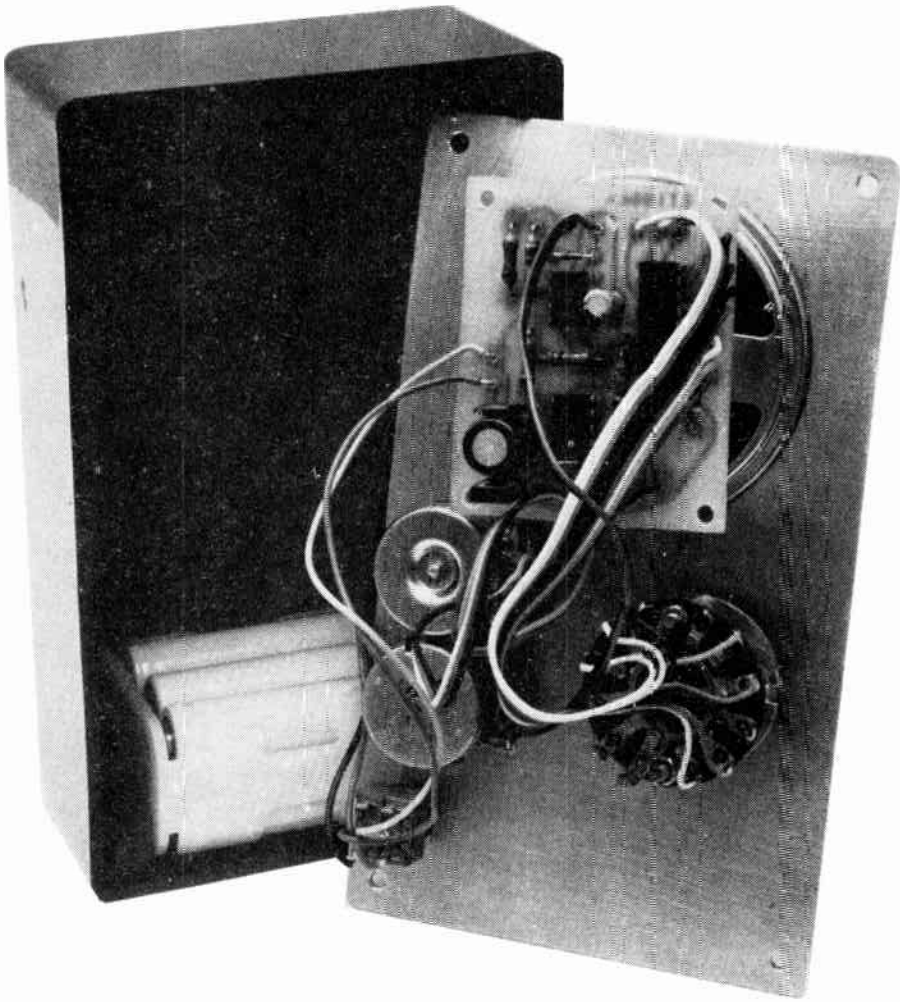
Alternatively, buy some nicads!

HOW IT WORKS – ETI 604

The operation of the unit is relatively simple. IC3 acts as an oscillator which operates if the output of IC1 (pin 3) is high; i.e. about 8 volts. The frequency is determined by R5 and C2 and the voltage set on pin 5 of that IC. With the values used the two frequencies produced are about 800 Hz and 2500 Hz. The output of IC3 is shown in Fig. 2b and after being attenuated (if required) by RV2, is buffered by Q1 which drives the speaker. The diode D2 is used to prevent reverse voltage from the speaker damaging Q1.

The first IC is used to generate the tone duration (about 4 ms.) and the time interval between beats. The interval is adjustable by RV1 while the tone duration is set by R1. Diode D1 isolates R1 in the interval period. The output of IC1 is shown in Fig. 2c.

The output of IC1 also clocks IC2 which is a decade counter with ten decoded outputs. Each of these outputs go high in sequence on each clock pulse. The second output of IC2 is connected to the control input of IC3 and is used to change the frequency. Therefore the first tone will be high frequency, the second low and the third to tenth will be high again. This gives the 9–1 beat. If the reset input is taken high the counter reverts back to the first state. We use this to limit the sequence length to less than ten by taking the appropriate output back to the reset input. If for example the 5th output is connected to the reset, the first tone will be high, the second low, the third and fourth high, then when the 5th output goes to a '1' it resets it back to the first which is a high tone. We then have 3 high and one low tone or a 3–1 beat. Actually the 5th output goes high only for about 100 ns. while the counter resets.



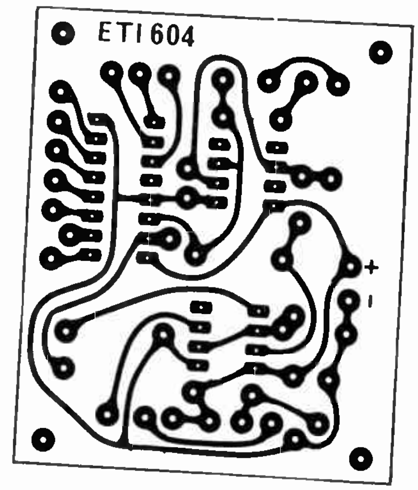
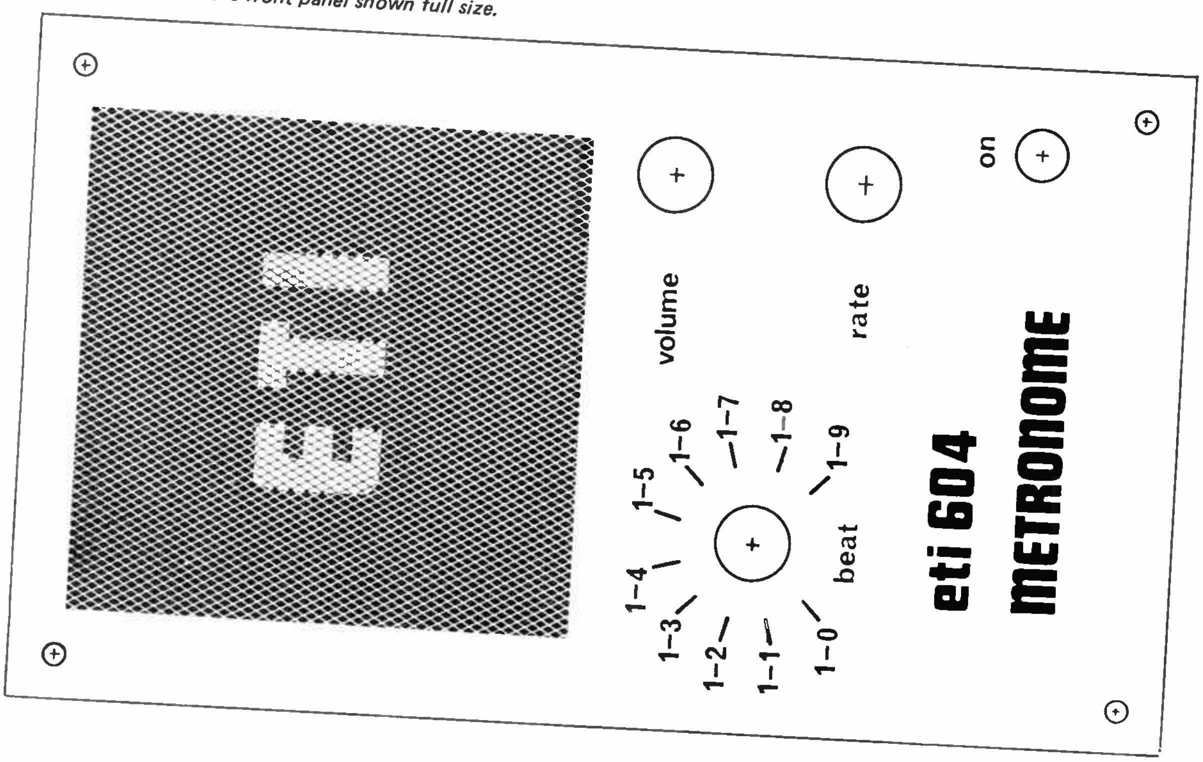


Fig. 4. Printed circuit layout. Full size 60 x 50 mm.

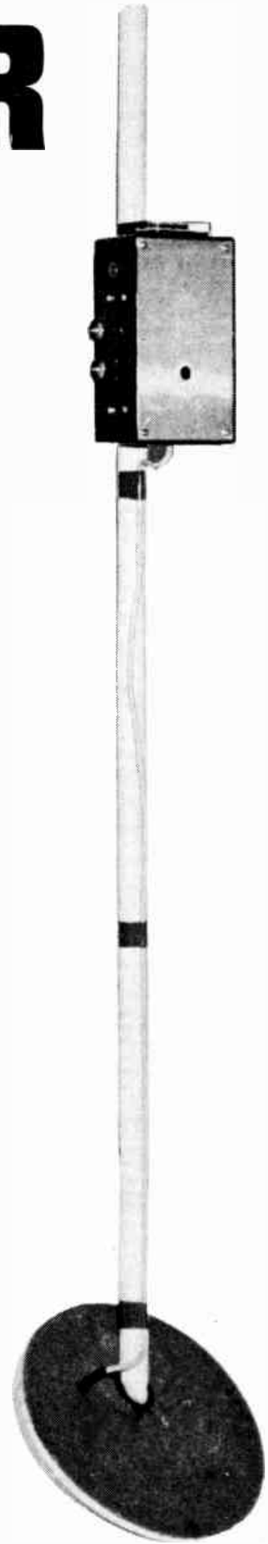
SCOTCHCAL OFFER
Scotchcal panels ready to stick on are available from Electronics Today at $3.00 each. Send order together with a stamped addressed envelope-size at least 160 x 100 mm.

Address to Scotchcal Offer 604,
Electronics Today,
15 Boundary Street,
Rushcutters Bay. 2011

Fig. 5. Artwork for the front panel shown full size.



INDUCTION BALANCE METAL DETECTOR



A really sensitive design operating on a different principle from that of other published circuits. This 'Induction Balance' metal locator will really sniff out those buried coins and other items of interest at great depths (depending on the size of the object).

"ANOTHER METAL LOCATOR," some of you will say. Yes and no. Several designs have been published in hobby electronics magazines around the world, some good, some downright lousy, but they have invariably been Beat Frequency Oscillator (BFO) types. There's nothing wrong with this principle — they are at least easy to build and simple to set up. The design described here works on a very different principle, that of induction balance (IB). This is also known as the TR principle (Transmit-Receive).

First a word of warning. The electronic circuitry of this project is straightforward and should present no difficulty even to the beginner. However, successful operation depends almost entirely upon the construction of the search head and its coils. This part should account for about three-quarters of the effort in construction. Great care, neatness and patience is necessary and a sensitive 'scope, though not absolutely essential, is very useful. It has to be stated categorically that sloppy construction of the coil will (not may) invalidate the entire operation.

IB Versus BFO

The usual circuit for a metal locator is shown in Fig. 2a. A search coil, usually 6in or so in diameter is connected in the circuit to oscillate at between 100 and 150 kHz. A second internal oscillator operating on the same frequency is included and a tiny part of each signal is taken to a mixer and a beat note is produced. When the search coil is brought near metal, the inductance of the coil is changed slightly, altering the frequency and thus the tone of the note. A tone is produced continually when the instrument is in use and metal is identified by a frequency change in the audio tone.

The IB principle, however, uses two coils arranged in such a way that there is virtually no inductive pick-up between them. A modulated signal is fed into one. When metal is brought near, the electromagnetic field is disturbed and the other coil picks up an appreciably higher signal.

Ideally the instrument is initially set up for no pick-up in the 'receiver' coil, but this is impossible in practice — the two coils are after all laid on top of each other. Another problem is that our ears are poor at identifying changes in audio level. The circuit is therefore arranged so that the signal is gated and is set up so that only the minutest part of the signal is heard when no metal is present. When the coils are near metal, a minute change in level becomes an enormous change in volume.

BFO detectors are not as sensitive as IB types and have to be fitted with a Faraday screen (beware of those which aren't — they're practically useless) to reduce capacitive effects on the coil. They are however, slightly better than IB types when it comes to pin-pointing exactly where the metal is buried.

Our detector is extremely sensitive — in fact a bit too sensitive for some applications! For this reason we've included a high-low sensitivity switch.

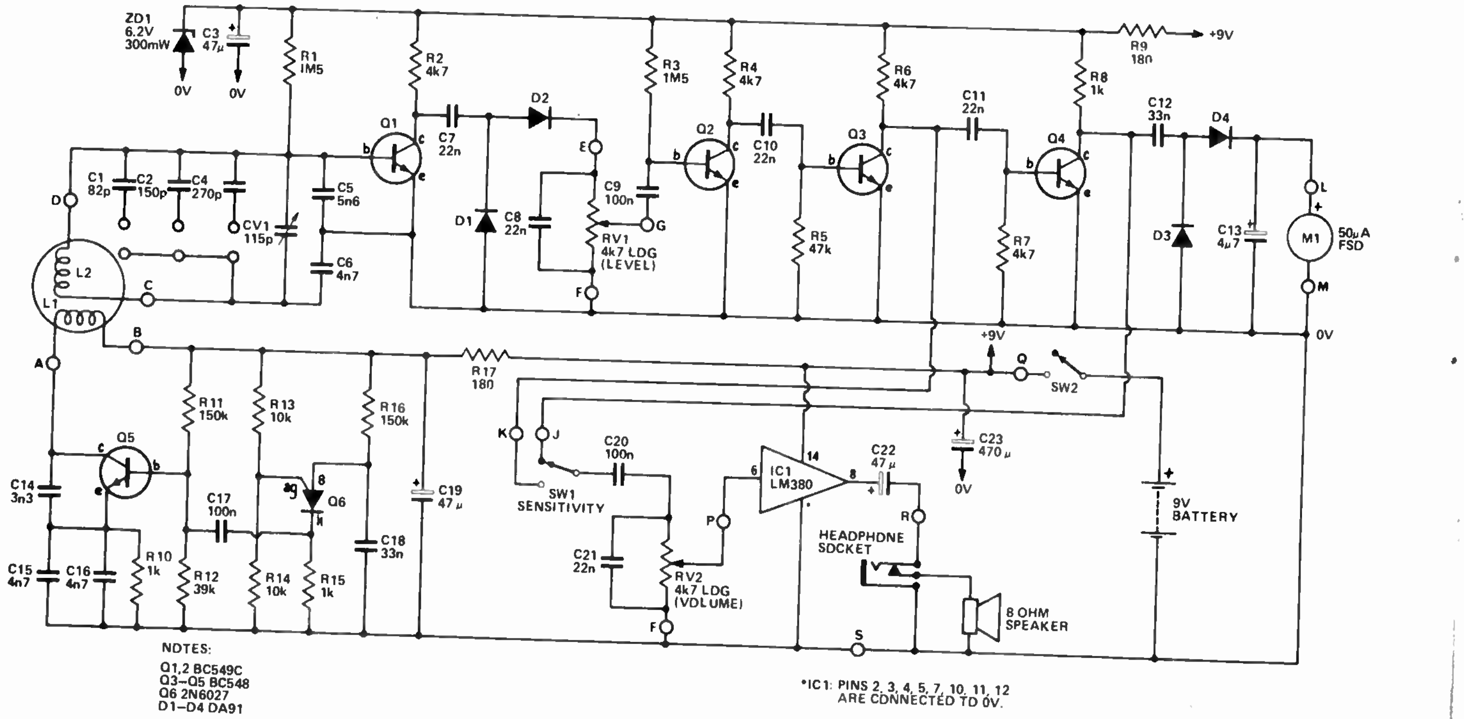


Fig. 1. Complete circuit of the metal locator. Note that though the electronics is simple using very common parts, the whole operation depends on the coil L1 and L2 which must be arranged so that there is minimal inductive coupling between the two. Note also that the leads from the circuit board to the search head must be individually screened and earthed at PCB.

You may ask why low sensitivity is useful. As a crude example, take a coin lying on a wooden floor: on maximum sensitivity the detector will pick up the nails, etc., and give the same readings as for the coin, making it difficult to find.

Treasure hunting is an art and the dual sensitivity may only be appreciated after trials.

Table 1 gives the distances at which various objects can be detected. These are static readings and only give an indication of range. If you are unimpressed with this performance you should bear two things in mind: first compare this with any other claims (ours are excellent and honest) and secondly bear in mind how difficult it is to dig a hole over 1ft of ground every time you get a reading. Try it – it's hard work!

Component Choice

We have specified Q1 and Q2 types as BC549C (highest gain group) for although lower gain transistors worked for us, they left little reserve of level on RV1 and really low gain types may not work at all.

RV1 is the critical control and should be a high quality type – it will be found that it has to be set very carefully for proper operation.

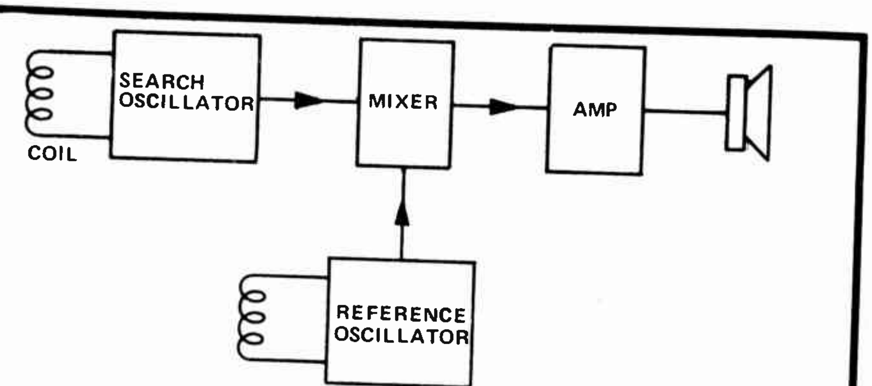


Fig. 2a. Block diagram of the common BFO type metal locator.

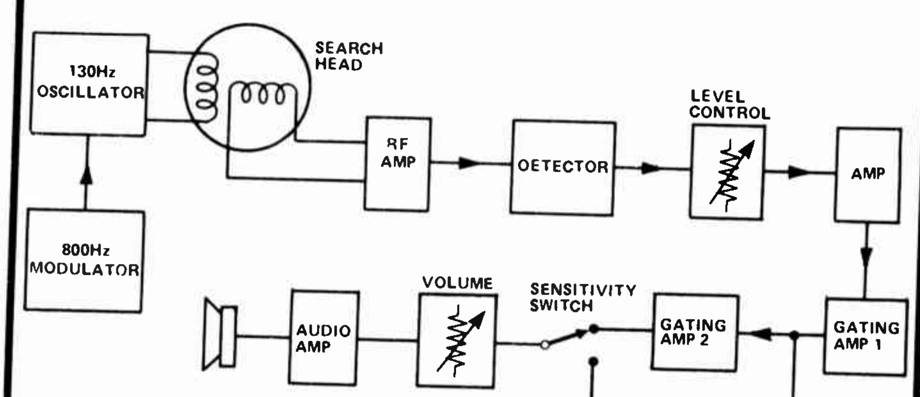


Fig. 2b. Block diagram of our IB design.

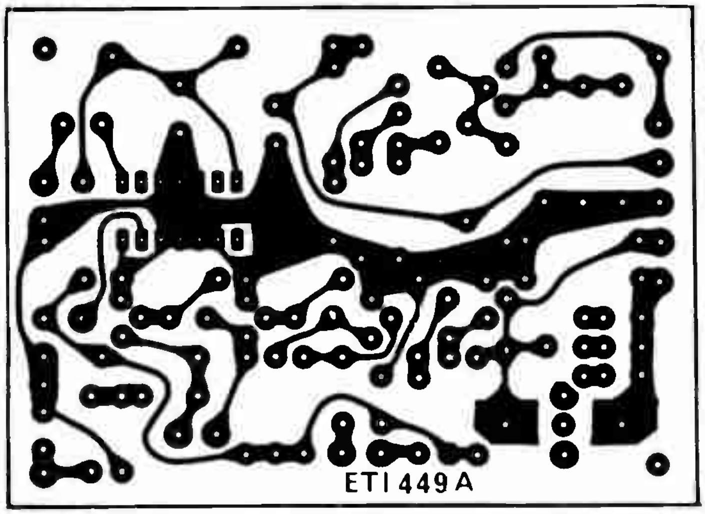


Fig. 3. Printed circuit layout. Full size 90 x 65 mm.

How It Works — ETI 549

Q5, Q6 and associated components form the transmitter section of the circuit. Q6 is a P.U.T. which operates as a relaxation oscillator, the audio note produced being determined by R16 and C18. The specified components give a tone of roughly 800 Hz.

Q5 is connected as Colpitt's oscillator working at a nominal 130 kHz; this signal is heavily modulated by C17 feeding to the base of Q5. In fact the oscillator produces bursts of r.f. at 800 Hz. L1 in the search head is the transmitter coil.

L2 is arranged in the search head in such a way that the minimum possible signal from L1 is induced into it (but see notes on setting up). On all the prototypes we made we reduced this to about 20 mV peak-to-peak in L2. L2 is tuned by C5 and C6 and peaked by CV1 and feeds to the base of Q1, a high gain amplifier. This signal (which is still modulated r.f.) is detected by D1, and D2. The r.f. is eliminated by C8 and connects to the level control RV1.

The signal is amplified by Q2 and then further amplified by Q3 which has no d.c. bias connected to the base. In no-signal conditions this will be turned off totally and will only conduct when the peaks of the 800 Hz exceed about 0.6V across R5. Only the signal above this level is amplified.

On low sensitivity these peaks are connected to the volume control RV2 (any stray r.f. or very sharp peaks being smoothed by C21) and fed to the IC amplifier and so to the speaker.

The high sensitivity stage Q4 is connected at all times and introduces another gating stage serving the same purpose as the earlier stage of Q3. This emphasises the change in level in L2 even more dramatically. Note that RV1 has to be set differently for high and low sensitivity settings of SW1.

Whichever setting is chosen for SW1. RV1 is set so that a signal can just be heard. In practice it will be found that between no-signal and moderate-signal there is a setting for RV1 where a 'crackle' can be heard. Odd peaks of the 800 Hz find their way through but they do not come through as a tone. This is the correct setting for RV1.

The stage Q4 also feeds the meter circuit. Due to the nature of the pulses this need only be very simple.

Since we are detecting really minute changes in level it is important that the supply voltage in the early stages of the receiver are stabilised, for this reason ZD1 is included to hold the supply steady independent of battery voltage (which will fall on high output due to the current drawn by IC1).

It is also important that the supply voltage to Q5 and Q6 does not feed any singal through to the receiver. If trouble is experienced (we didn't get any) a separate 9V battery could be used to supply this stage.

IC1 is being well underused so a heatsink is unnecessary.

Battery consumption is fairly high on signal conditions – between 60 mA and 80 mA on various prototypes but this will only be for very short periods and is thus acceptable. A more modest 20 mA or so is normal at the 'crackling' setting.

Stereo headphones are used and are connected in series to present 16 ohms to IC1 reducing current consumption.

The choice of an LM380 may seem surprising as only a small part of its power can be utilised with battery operation. It is however inexpensive and widely available unlike the alternatives (note it does not require dc blocking at the input).

Output is connected for an 8 ohm speaker and to headphones. Stereo types are the most common and the wiring of the jack socket is such that the two sections are connected in series presenting a 16 ohm load (this reduces current consumption from the battery).

Construction: Control Box

The majority of the components are mounted on the PCB overlay and the additional wiring is shown in Fig. 4.

Exceptional care should be taken to mount all components firmly to the board. Poor connections or dubious solder joints may be acceptable in some circuits — not in this one. Take care to mount the transistors, diodes and electrolytic capacitors the right way around.

The PCB is fitted into the control box by means of 6 mm spacers. The control box has to be drilled to take th speaker, the pots, switches, headphone jack and the cable from the search head.

The Handle Assembly

The handle we used was simply a broom handle with the end cut off at about 45°. After assembling the head, the handle can be glued on with epoxy. A small woodscrew can be used to hold it in place until dry. This should be done before final setting up of the coils — in case the screw cannot be removed after the glue has set.

The Coil

Remember this is the key to the whole operation. The casing of the coil is not so critical but the layout is.

It is best first to make the 6 mm plywood circle to the dimensions shown in Fig.6. A circle of thinner plywood or hardboard is then firmly glued onto this — it's fairly easy to cut this after glueing. Use good quality ply and a modern wood glue to make this.

This now forms a dish into which the coils are fitted.

You'll now have to find something cylindrical with a diameter of near enough 140 mm (5½in). A coil will then have to be made of 40 turns of 32 swg enamelled copper wire. The wire should be wound close together and kept well bunched and taped to keep it together when removed from the

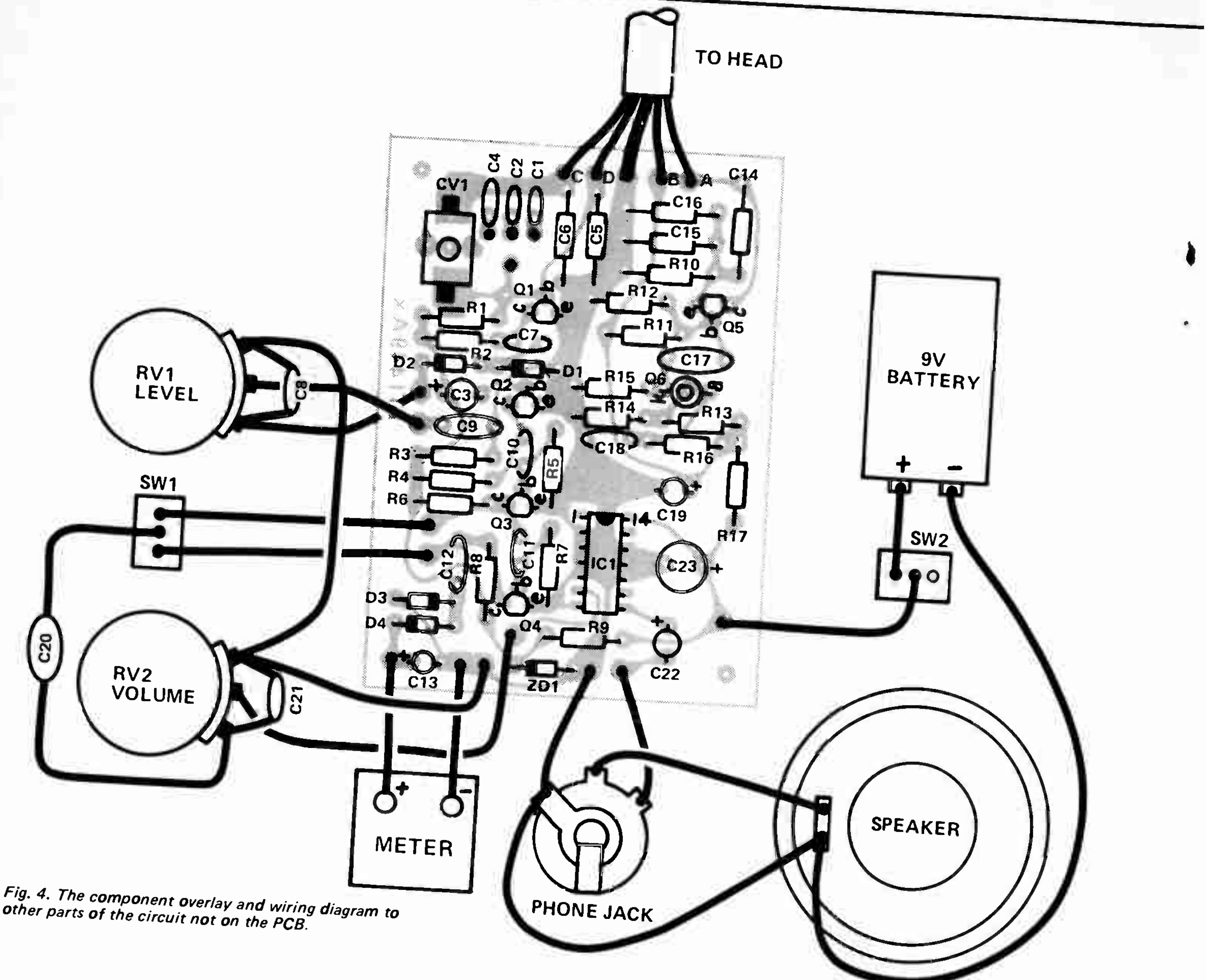


Fig. 4. The component overlay and wiring diagram to other parts of the circuit not on the PCB.

former. Two such coils are required. These are identical.

One of the coils is then fitted into the dish and spot glued in six or eight places using quick setting epoxy resin: see photograph.

L2 is then fitted into place, again spot glueing (*not* in the area that it overlaps L1). The cable connecting the coil to the circuit is then fed through a hole drilled in the dish and connected to the four ends. These should be directly wired and glued in place, obviously taking care that they don't short. The cable must be a four-wire type with individual screens — the screens are left unconnected at the search head.

You will now need the built up control box and preferably a 'scope. The transmit circuit is connected to L1. The signal induced into L2 is monitored; at first this may be very high but by manipulating L2 the level will be seen to fall to a very low level. When a very low level is reached, spot glue L2 until only a small part is left for bending.

Ensure that when you are doing this that you are as far away from any metal as possible but that any metal used to mount the handle to the head is in place. Small amounts of metal are acceptable as long as they are taken into account whilst setting up.

Now connect up the remainder of the circuit and set RV1 so that it is *just* passing through a signal to the speaker. Bring a piece of metal near the coil and the signal should rise. If it falls in level (i.e. the crackling disappears) the coil has to be adjusted until metal brings about a rise with no initial falling. CV1 should be adjusted for maximum signal, this has to be done in conjunction with RV1. The additional capacitors C1, C2 and C4 should be linked in, if the range is not available on CV1.

Monitoring this on a scope may mean that the induced signal is not at its absolute minimum: this doesn't matter too much. Now add more spot gluing points to L2.

You should now try the metal locator in operation. If RV1 is being operated entirely at the lower end of its track, making setting difficult, you can select a lower gain transistor such as a BC548 for Q2.

When you are quite certain that no more manipulation of the coils will improve the performance, mix up plenty of epoxy resin and smother both coils, making certain that you don't move

PARTS LIST – ETI 549

Resistors	all ½ W 5%
R1	1M5
R2	4k7
R3	1M5
R4	4k7
R5	47 k
R6,7	4k7
R8	1 k
R9	180 ohms
R10	1 k
R11	150 k
R12	39 k
R13,14	10 k
R15	1 k
R16	150 k
R17	180 ohms
Potentiometers	
RV1,2	rotary 4k7 log

Capacitors	
C1	82 p ceramic
C2	150 p ceramic
C3	47 µ 10 V electro
C4	270 p ceramic
C5	5n6 polystyrene*
C6	4n7 polystyrene*
C7,8	22 n polyester
C9	100 n polyester
C10,11	22 n polyester
C12	33 n polyester
C13	4µ7 25 V electro
C14	3n3 polystyrene *
C15,16	4n7 polystyrene *
C17	100 n polyester
C18	33 n polyester
C19	47 µ 10 V electro
C20	100 n polyester
C21	22 n polyester
C22	47 µ 10 V electro
C23	470 µ 16 V electro

CV1	115pF trimmer
(modify board if necessary to suit connections)	
Semiconductors	
Q1,2	Transistors BC549C
Q3-Q5	Transistors BC548
Q6	PUT 2N6027
D1-D4	Diodes OA91, OA95
IC1	Amplifier LM 380
ZD1	Zener 6.2 V 300 mW

Miscellaneous
PC board ETI 549 A
Meter 50 µA FSD
Search head as per Fig. 6.
Two changeover slide switches.
Two knobs
Suitable case (158 x 95 x 50 mm)
Phone socket
Small speaker
9 V battery clip
Six by AA battery holder
Six AA batteries.

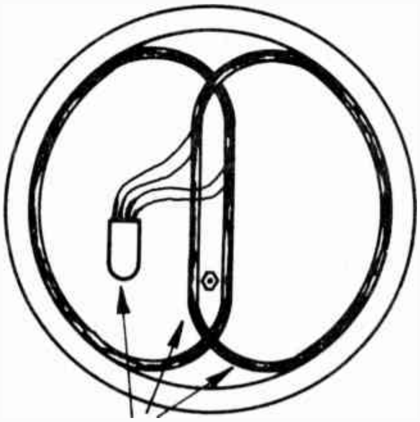
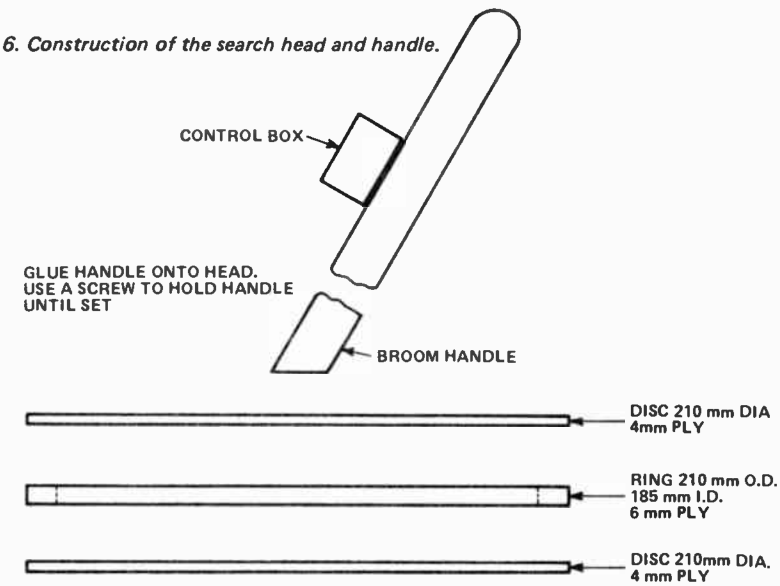


Fig. 5. Diagram showing the position of the coils in the search head.

Fig. 6. Construction of the search head and handle.



them relative to each other.

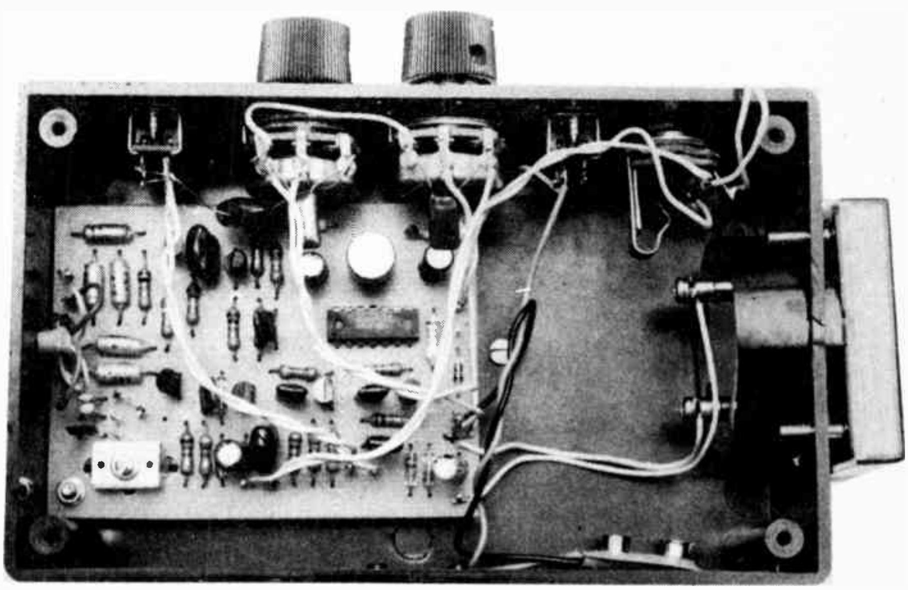
The base plate can then be fitted to enclose the coils, this should be glued in place.

If after glueing in place the balance between the coils is found to be not quite right it should be possible to glue a small piece of metal (such as a washer) somewhere on the head to cancel out the error.

Using The Metal Locator

You will find that finding buried metal is rather *too* easy. 95% will be junk – silver paper being a curse. The search head should be panned slowly over the surface taking care to overlap each sweep the sensitive area is somewhat less than the diameter of the coil.

This type of locator will also pick up some materials which are not metal



– especially coke. And it is not at its best in wet grass.

Think very carefully about where you want to search: this is more important than actually looking. The area you can cover thoroughly is very, very small, but his approach is far more successful than nipping all over the place. As an example of how much better a thorough search is, we thoroughly tried on 25 square feet of common ground (5ft x 5ft); we found over 120 items but a quick search initially had revealed only two!

Treasure hunting is growing in popularity and those who do it seriously have adopted a code; essentially this asks you to respect other people's property, to fill in the holes you dig and to report any interesting finds to museums.

Meter Circuit

Since the circuit is basically sensing a change in audio level, a meter circuit can be incorporated. For the very first indication from the 'crackle' your ears are likely to be more sensitive than the meter but thereafter it will come into its own.

This part of the circuit is optional and the components are not included on the board.

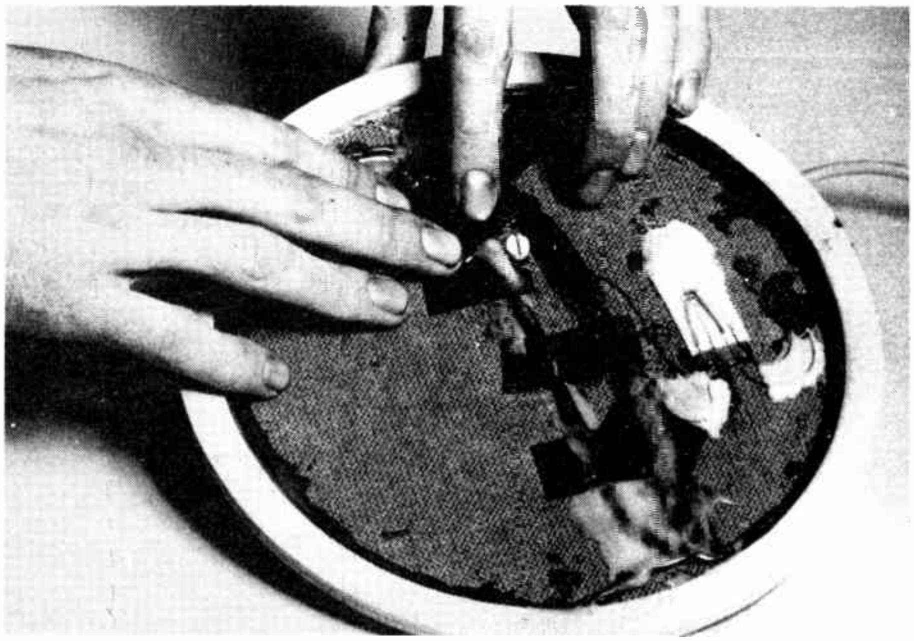


TABLE 1

OBJECT	20_c Coin	Beer Can	150 mm Square copper	150 mm steel rule	MAN S Gold Ring
HIGH SENS	200 mm	450 mm	550 mm	300 mm	200 mm
LOW SENS	150 mm	350 mm	400 mm	220 mm	150 mm

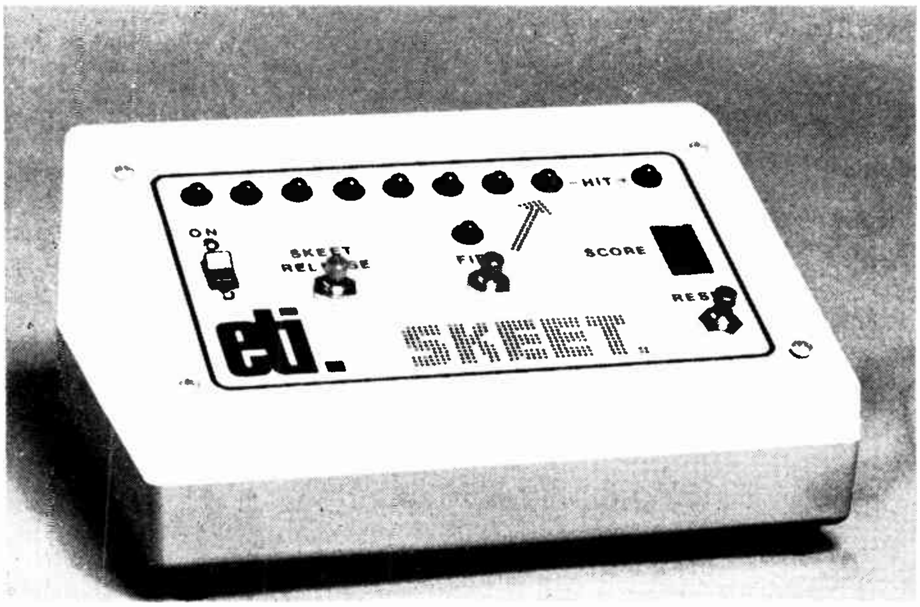
Skeet

Electronic clay pigeons, yet! Play the game!

GAMES, BE THEY electronic or otherwise, may, in general, be divided into two broad categories. There are those which entertain by stimulating the mind and those that involve the more mechanical of skills. In general all games will involve a mixture of these two elements.

The game described here cannot claim to tax the grey matter to any **great extent, but certainly provides a test of hand/eye coordination.**

We have also introduced an element of luck which helps the game meet, perhaps, the most important requirement of any game — it is fun play!



Game Bird

Before going on to describe the game it might be best to explain just why we called it Skeet.

Skeet is the term used in the USA to describe the sport we know as Clay Pigeon Shooting. We thought that a title like "Clay Pigeon Shoot" would be too much of a mouthful, and nobody wants a mouthful of clay pigeon. We therefore chose the American name for the sport that our game attempts to emulate — hence Skeet.

Flight Of Fancy

The line of LEDs, seen in the photographs of the game, represent the flight path of the Skeet. The "gun" of our game is permanently aimed at the last LED of the flight path. This means that there is no aiming involved, the object of the game being to correctly estimate the delay between "firing" the "gun" and the "shot" reaching the Skeet. This delay represents the time of flight for a real shot.

When the firing button is pressed the "shot" LED lights and the time that this remains on indicates the travel time of the "shot."

At the instant that the LED turns off, if the Skeet has just reached the end of its flight, a "hit" is registered and the "hit" LED lit.

Whether or not a "hit" was scored the LEDs representing the flight path will stay off until pressing the skeet release button starts another "bird" on its way.

Score With A Bird

The game is made more interesting because the speed of the Skeet varies from one flight to the next, this is where the luck, and skill come in. You cannot become used to firing the gun at the same position in the flight path as the "bird's" speed can be any one of eight different values determined randomly.

After eight shots the score display, blanked until now, lights up with your score out of eight. This signals the end of a round. In a competitive game, make a note of your score, press the reset button and pass the game to the "hot shot" competing against you. For practice games, the score need not be reset, the counter continuing to register.

Building Birdie

The majority of parts are mounted on the PCB and should be assembled according to the overlay shown. We recommend that sockets are used for mounting all of the ICs as this makes the task of any fault finding that may be necessary far easier than would be the case if the ICs were soldered directly to the PCB.

Note that the link from IC1 pin 16 to IC2 pin 16 is insulated.

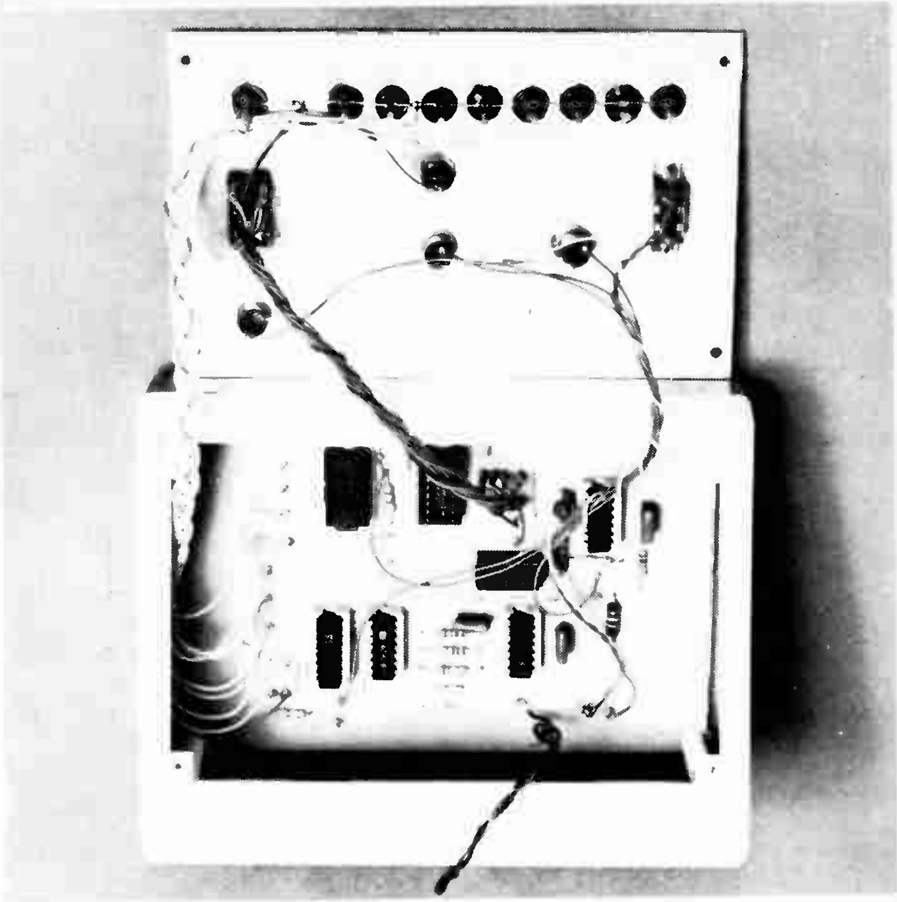
The switches, seven segment display and LEDs are all mounted off-board on the front panel and wired to pins on the PCB. The layout of our game can be seen in our pictures.

Space inside the box was, as is usual in our designs, at a premium and the PP6 battery was squeezed into the back of the case, insulated from the PCB by a piece of foam rubber.

Project 806

An internal view of completed unit. The wiring of the front panel switches and display to the PCB board can be seen. Note the insulated sleeve from IC1 pin 16 to IC2 pin 16 and the insulation on the wires to the display.

Below right we show the full size PCB foil pattern (140 x 105mm). ▶



The first pull

When power is first applied the condition of the various counters is undetermined. To start a game, press the skeet release button first and allow the skeet to complete one cycle. Press the reset button and you're ready to begin shooting Skeet.

PARTS LIST - ETI 806

RESISTORS all ¼W 5%

R1,9	10k
R2,7	1M
R3	220k
R4	390k
R5	820k
R6,8,11	470k
R10	10M

CAPACITORS

C1,3	100n polyester
C2	1u0 35V tantalum
C4	220n polyester

SEMICONDUCTORS

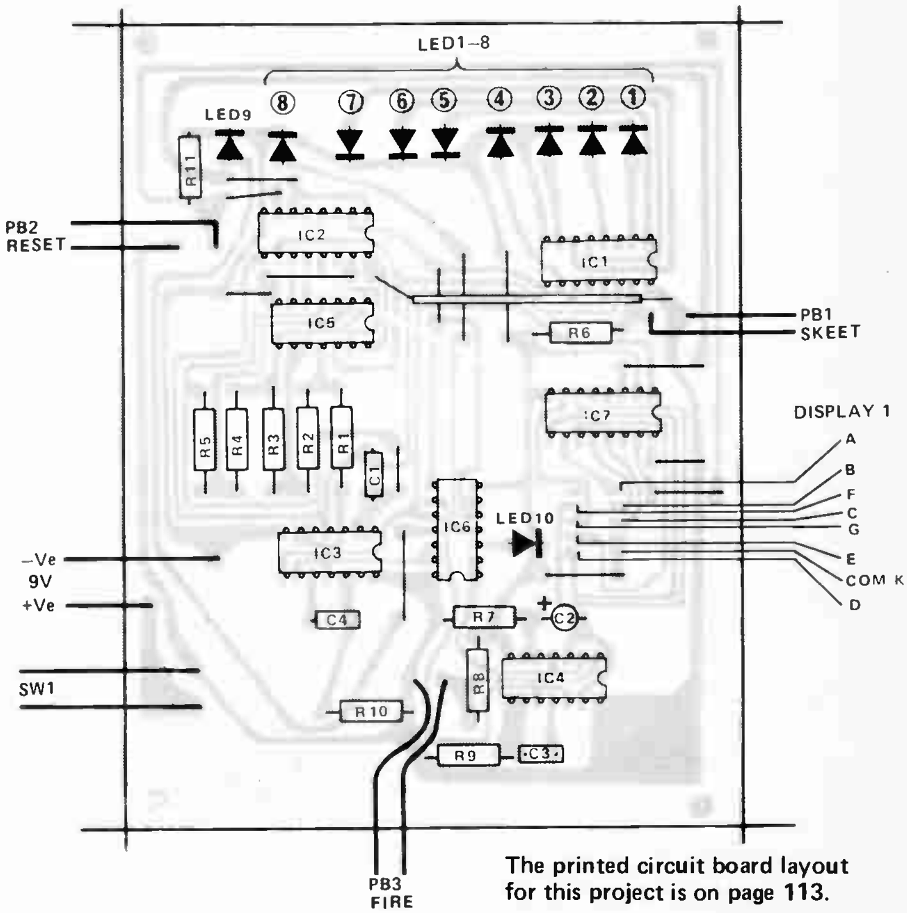
LED 1-9	.2" type red
LED 10	.2" type green
DIS 1	DL704 common cathode or similar
IC1	4017
IC2	4518
IC3,4	4001
IC5	4016
IC6	4081
IC7	4026

SWITCHES

PB1-3	Push to make push type
SW1	Single pole on/off type

MISCELLANEOUS

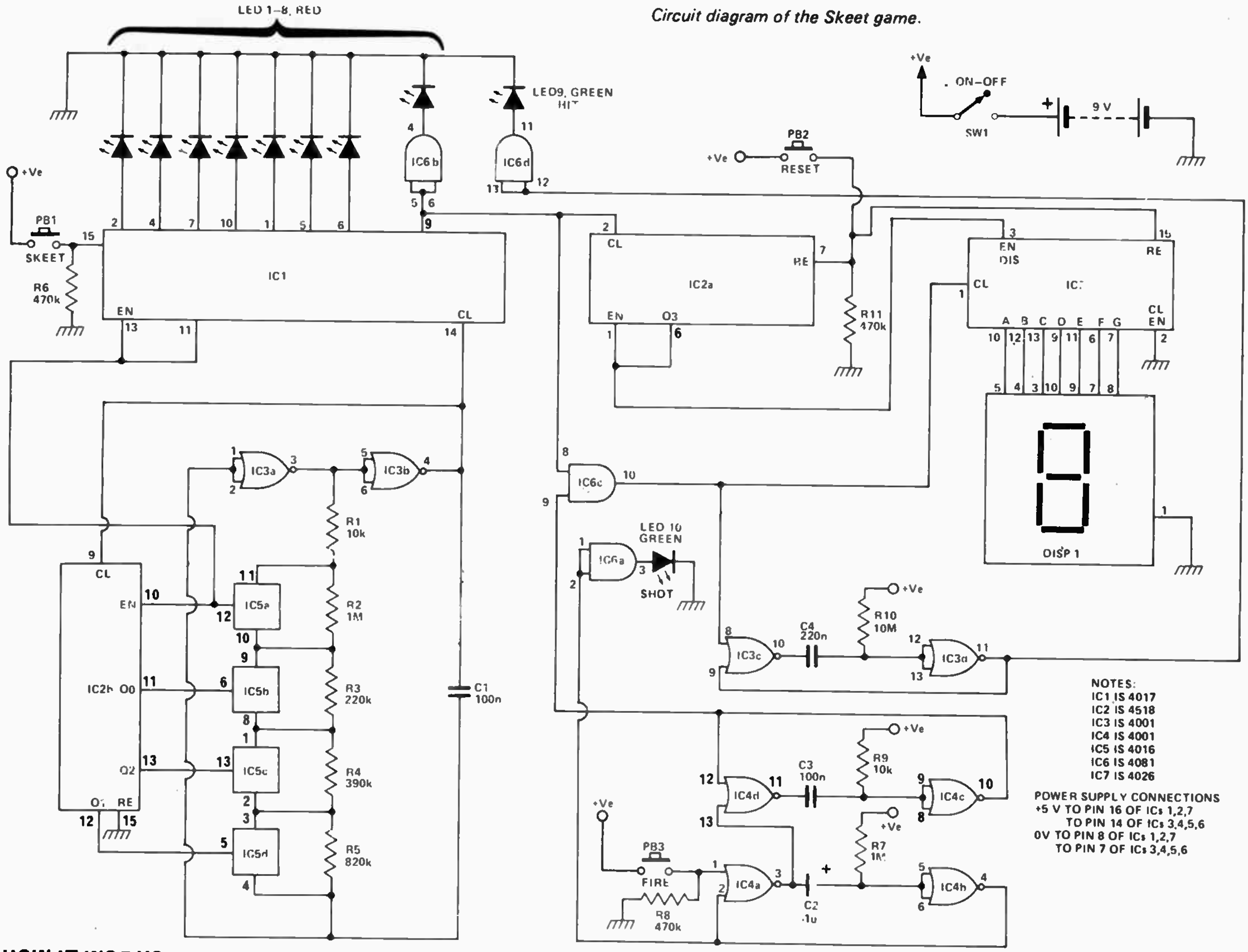
PCB as per pattern, PP6 battery and clip, flexible connecting wire.



Right: the component overlay for the skeet game. All the links but for that between IC1 pin 16 and IC2 pin16 may be made from uninsulated wire.

The printed circuit board layout for this project is on page 113.

Circuit diagram of the Skeet game.



HOW IT WORKS - ETI 806

IC1 is a one of ten decoded counter. The "Zero" output from this IC is not used while the next eight outputs are connected to LEDs 1-8, these LEDs represent the flight of the Skeet. The "nine" output (Pin 11) is coupled to the enable input (Pin 13). This means that the counter will be disabled after it has completed one count cycle.

Pressing the skeet release button PB1 resets the counter, removing the inhibit and allows another cycle to take place.

The pulses which clock IC1 through its count cycle are derived from the CMOS oscillator formed by IC3a and IC3b.

This oscillator has the resistor which forms one of the elements in the timing chain split into five sections. Four of these sections are shunted by the transmission gates of IC5 so that they may be bypassed as required and so control the frequency of the oscillator. The remaining resistor, R1, ensures that there is always some resistance in the oscillator circuit.

The oscillator is running at all times when power is applied to the circuit.

Three of the transmission gates of IC5 are coupled to the outputs of IC2b. IC2b is one half of a dual BCD counter and is clocked by the CMOS oscillator. As IC2b clocks through its count sequence the resistance of the timing element changes altering the frequency of the oscillator.

The enable line of IC2b is tied to that of IC1, and since the enable lines of these counters require signals of opposite logic level, when one is running, the other is halted.

This enable line is also tied to the fourth gate in IC5. This straddles the largest resistor in the timing chain and so has the greatest effect on oscillator frequency.

The sequence of events during play is as follows.

PB1 is operated and so disables IC2b and latches its output. This sets the "random" speed of the skeets flight as IC1 is now enabled and is clocked by the oscillator's output.

When IC1 reaches the count of nine, it is disabled and IC2b in turn enabled. IC2b then cycles through its count sequence changing the oscillator's frequency ready for the next skeet flight.

The fact that IC5d is tied to the enable line means that the oscillator runs much faster when performing its "random" frequency selection function than when controlling the flight of the skeet.

The "gun" consists of two CMOS monostables in series (IC4). The first one has a time constant representing the time of the shot travel to the target. It drives a LED via buffer IC6a to allow timing judgements during play.

The second one shot provides a short pulse after the first is complete. This is the "shot" pulse.

This pulse is AND-ed (IC6c) with that from the "eight" output of IC1 to produce the "hit" pulse.

This pulse is applied to the score counter (IC7) and, via a pulse stretcher (IC3c, IC3d), to the hit LED (LED 9).

IC2a is the other section of the BCD counter and is clocked from the "eight" output of IC1. This IC is used to count the total number of skeet flights.

This BCD counter is arranged to blank the score display, via the enable display pin of IC7, until it reaches a count of eight. At this stage the Q3 output will enable the display and inhibit further clocking of the counter.

Lighting of the score display signals the end of a game.

The buffers (IC6a, IC6b and IC6d) are required because while a CMOS output will drive a LED directly, as LEDs 1-8 are driven from IC1 the load that the LED presents brings the CMOS output to below an acceptable "1" level.

Thus if the output is not used elsewhere in the circuit we can drive a LED directly, but where the signal is required to drive other gates we have used a buffer. ■

MARINE GAS ALARM

This versatile alarm prevents the motor being started or electrical equipment used if there is a build up of petrol vapour or LP gas thus protecting your boat against fire.

PETROL VAPOUR, closed space and electrical sparks are not ideal companions. Many a boat has been destroyed when the owner has switched on the ignition without realising there had been a petrol leak and that the vapour content in the engine compartment is at a dangerous level. Unfortunately the circumstances also lead to injury and loss of life. Therefore any system which can prevent this is of great value.

This unit is designed to meet this requirement and uses a semiconductor gas detector (TGS cell) to monitor the atmosphere in the engine compartment and either prevent the engine being started or shut it down if a high vapour concentration occurs during operation.

Construction

This is relatively easy if the printed circuit board is used and the wiring diagrams are followed. Some precautions should be taken if the unit is to be used in a boat to prevent corrosion. The rear side of the board should be coated with a cellulose spray (dope, nail polish, etc.) and the box, while having to be near the control panel, should be shielded from direct spray. Although we have used a separate box the unit can be mounted behind the control panel if desired.

A small heatsink (about 25 mm square aluminium) should be bolted on to IC1 to keep it cool.

The relay we have specified can handle up to 6 A current but if higher currents are required it can be replaced with any 12 V relay providing its coil resistance is over 100 ohms.

Obviously the sensor must be mounted in the engine compartment and while it must be in free air it must also be protected against mechanical damage.

Installation and Adjustment

The sensor should be mounted in a position where vapour may be expected and should be mechanically protected against damage. The connection to the sensor should be via a 4 core cable (on long runs use a shielded cable) and the connection of the sensor is shown in Fig. 2. Note that it is symmetrical in layout and also the fact that it will fit into a standard 7 pin miniature valve socket.

The only adjustment is the sensitivity control and this is set by bringing a small container of petrol near the sensor and ensuring it operates. The adjustment should be as sensitive as possible without giving false operation.

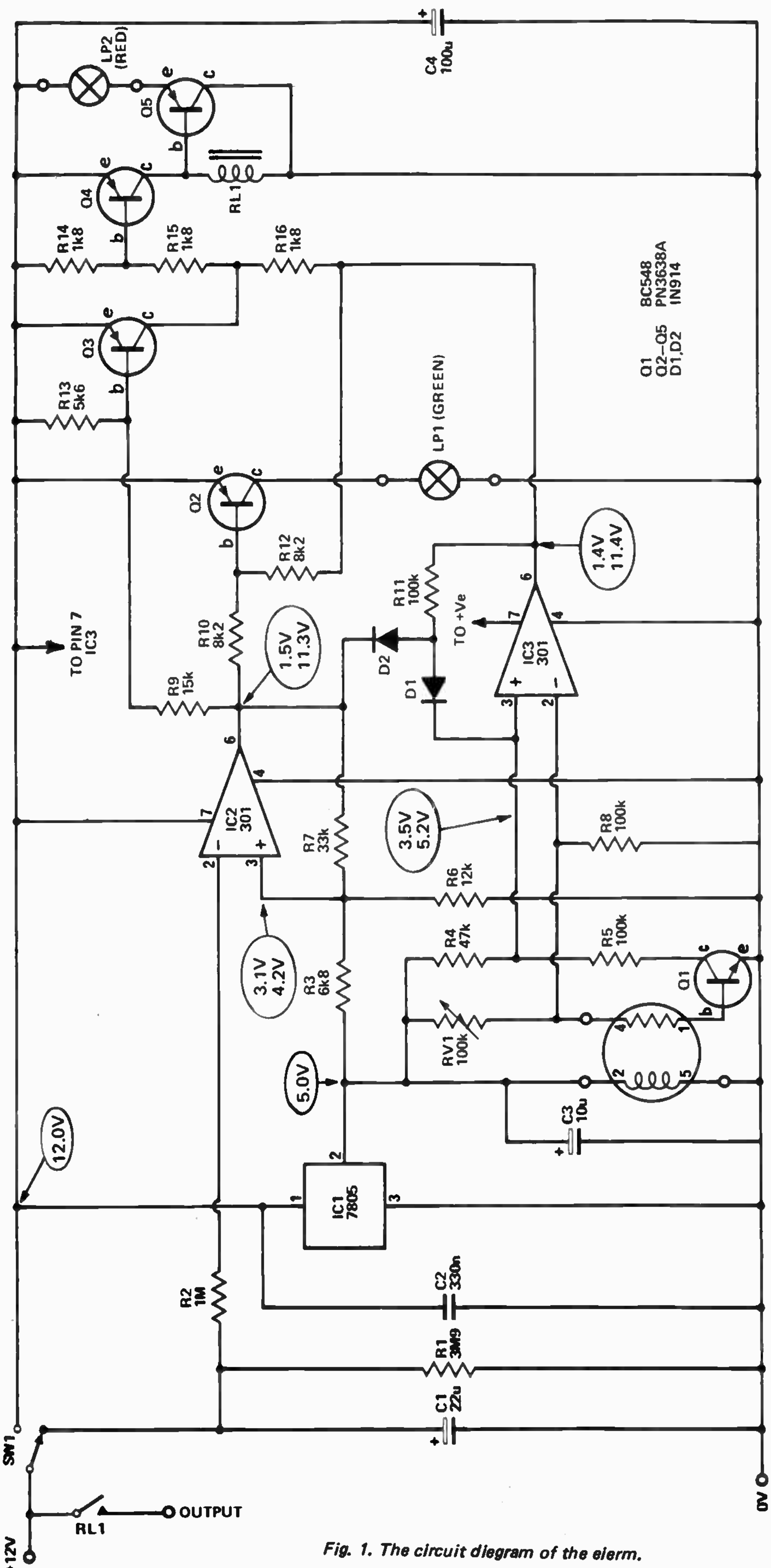


Fig. 1. The circuit diagram of the alarm.

HOW IT WORKS – ETI 583

This project is designed primarily to monitor the concentration of volatile gases inside the bilge of petrol-engined boats. The circuit provides an electrical cutout which prevents the engine from being started if fumes are present and also will remove all electrial power if fumes become present at any time.

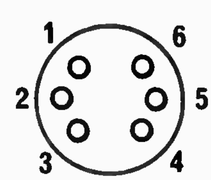
The unit acts as a master switch and due to its warm up requirements, a two minute delay occurs on switch on. Two indicator lights indicate either "safe" or "fail" condition and in the initial warm up period both lights are on. The initial timing is performed by C1 and IC2. With the main switch off there is +12 V across C1. When it is switched on the capacitor is allowed to discharge through R1. IC2 compares the voltage on C1 with that on pin 3 (about 3 V). During this period the output of IC2 will be about +2 V.

IC1 is a 5 V regulator and supplies the power for the heater of the sensor. The sensor's resistance element is in series with RV1 and this voltage is compared to the voltage set by R4/R5.

The transistor Q1 gives a fail safe operation and if the sensor is not connected this transistor will be off giving +5 V on pin 2 of IC3. Resistor R8 ensures that the voltage on pin 2 will always be slightly less than +5 V.

If vapour is present the sensor resistance will be low and the output of IC3 will be high. During the first two minutes the diodes D1 and D2 prevent the feedback loop (R11) operating. After two minutes if the output goes high the reference voltage on pin 3 of IC3 will go above 5 V and therefore the IC will latch in that position.

The relay is operated by Q4 and for it to close the output of IC3 must be low (no vapour) and also the output of IC2 must be high (more than two minutes after switch on). If the unit does switch off, or prevents initial switch on, it must be switched off and then on again (after clearing the fumes) and the two minute delay operates again.



Underneath view.
Note that pins 1 and 3 are internally connected as are pins 4 and 6.
Polarity is not important.

Fig. 2. Connections of the sensor.

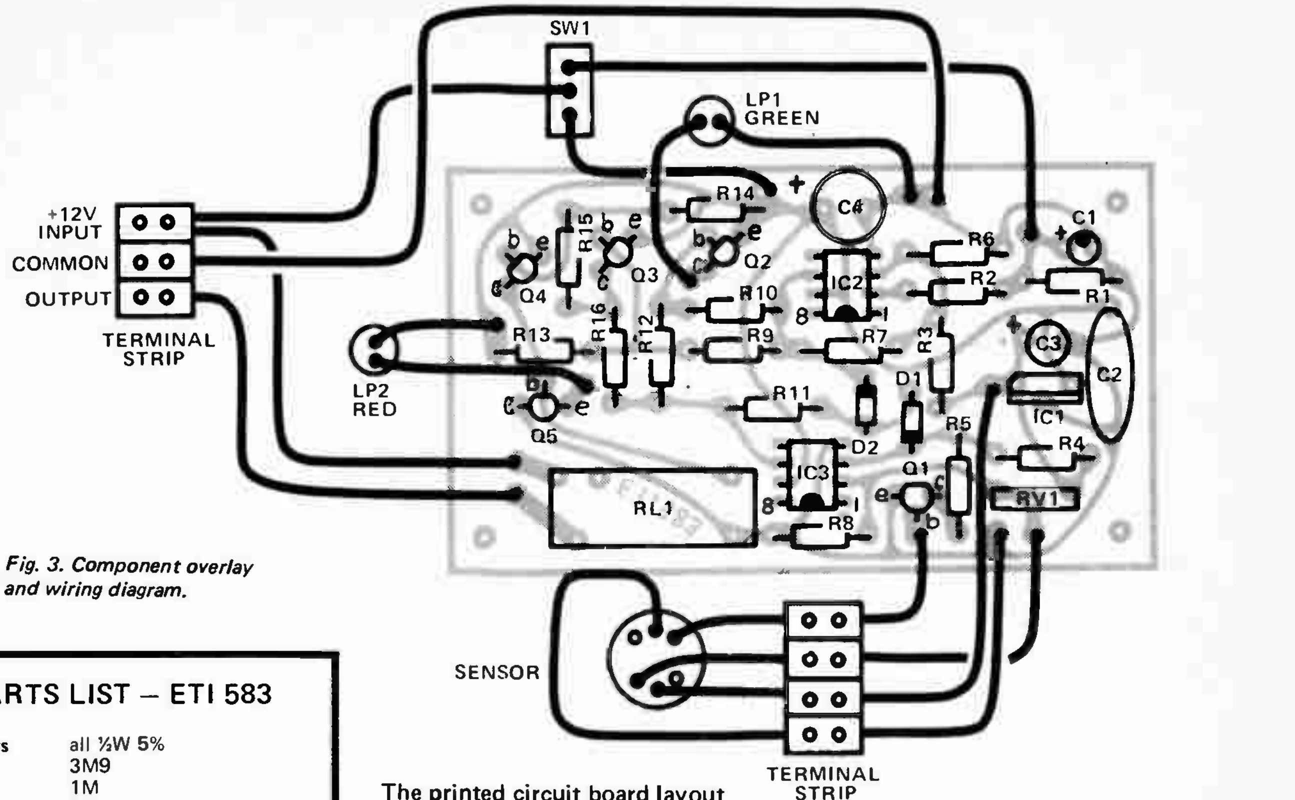


Fig. 3. Component overlay and wiring diagram.

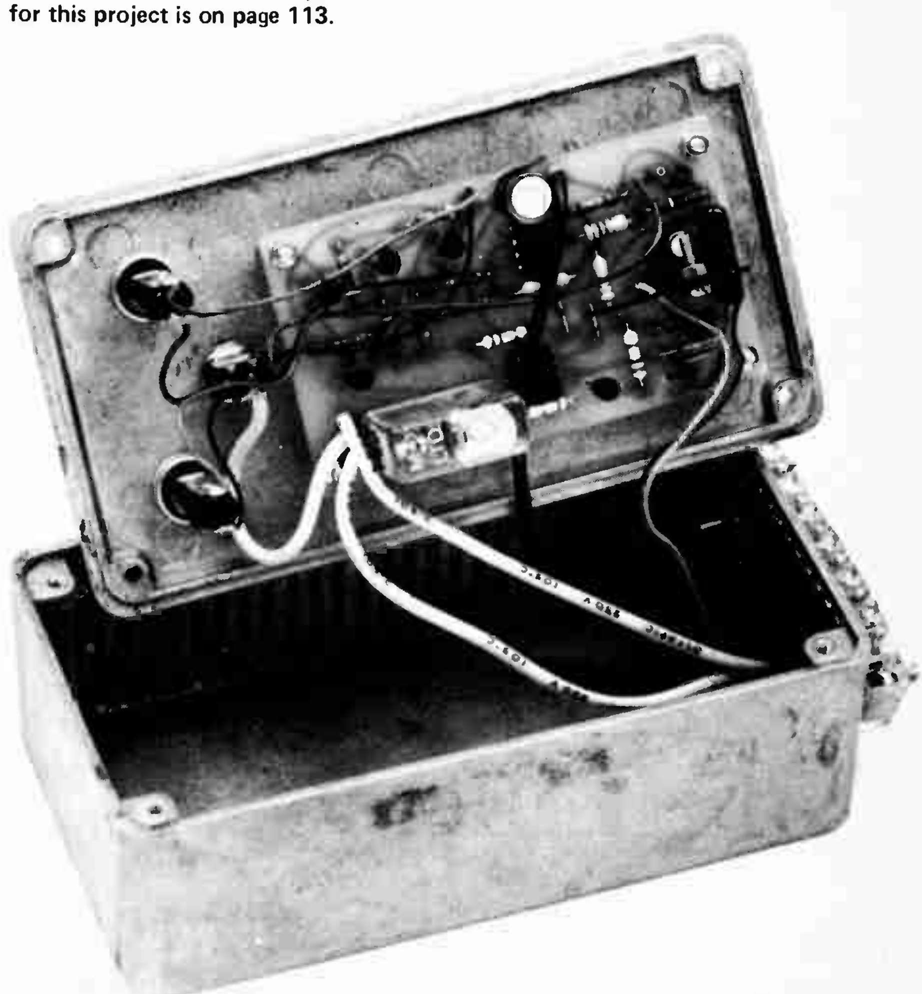
PARTS LIST — ETI 583

Resistors	all ½W 5%
R1	3M9
R2	1M
R3	6k8
R4	47k
R5	100k
R6	12k
R7	33k
R8	100k
R9	15k
R10	8k2
R11	100k
R12	8k2
R13	5k6
R14-R16	1k8
Potentiometers	
RV1	100k trim
Capacitors	
C1	22μ 16V tantalum
C2	330n polyester
C3	10μ 16V electro
C4	100μ 25V electro
Semiconductors	
IC1	7805 regulator
IC2,3	301A op amp
Q1	BC548
Q2-Q5	2N3638A, PN3638A
D1,D2	1N914
Miscellaneous	
TDG sensor	812 or 813
PC Board	ETI 583
LP1,2	Indicator lamps 12V 100 mA max.
SW1	single pole toggle
RL1	12V relay 280Ω coil single pole (E3201)

Metal box to suit

If you find the TDG sensors hard to obtain contact ETI for name of current suppliers.

The printed circuit board layout for this project is on page 113.



HOUSE ALARM

Our latest burglar alarm design is the most sophisticated to date, and includes facilities for a wide variety of sensors.

WITH the noise pollution laws now in force it is illegal to allow an alarm which has any reasonable volume to ring continuously. It must be reset after ten minutes or so and this leads to a problem. Most alarms work on a system where all the windows and doors have normally closed reed switches which are all wired in series so that the opening of a window or door breaks the loop, setting off the alarm. The alarm then rings for ten minutes and resets. However, if the window is still open, i.e., no-one is home to close it, the alarm must be switched off completely to prevent it continuing to ring.

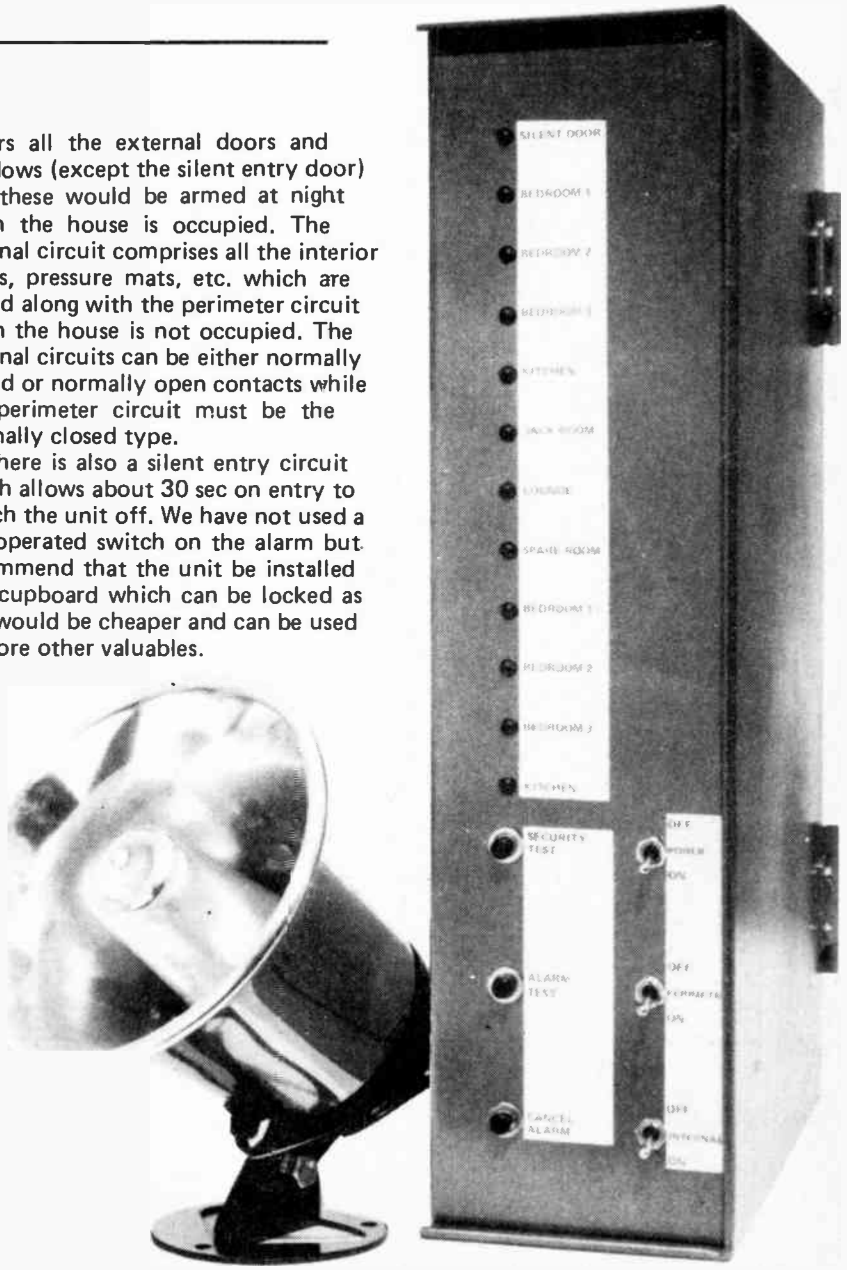
It is for this reason we have not published a reset circuit for the alarms we have described previously, although it has often been requested.

We therefore designed a completely new alarm which does not use a single loop but each window or group of windows in the same room has its own circuit. The alarm is not triggered when the window is continually open, but is triggered by the change of state of the sensor when the window is opened, so that the open window will be ignored when the alarm is reset, but leaving all other doors, windows, floor mats, etc. active. This affords some protection to the house if the alarm has been triggered and reset automatically.

We have provided a test button so that a check on the security of the house can be made before the alarm is set indicating immediately which window is open.

We have separated the alarm into two main sections, a perimeter circuit and an internal circuit. The perimeter circuit covers all the external doors and windows (except the silent entry door) and these would be armed at night when the house is occupied. The internal circuit comprises all the interior doors, pressure mats, etc. which are armed along with the perimeter circuit when the house is not occupied. The internal circuits can be either normally closed or normally open contacts while the perimeter circuit must be the normally closed type.

There is also a silent entry circuit which allows about 30 sec on entry to switch the unit off. We have not used a key-operated switch on the alarm but recommend that the unit be installed in a cupboard which can be locked as this would be cheaper and can be used to store other valuables.



HOUSE ALARM

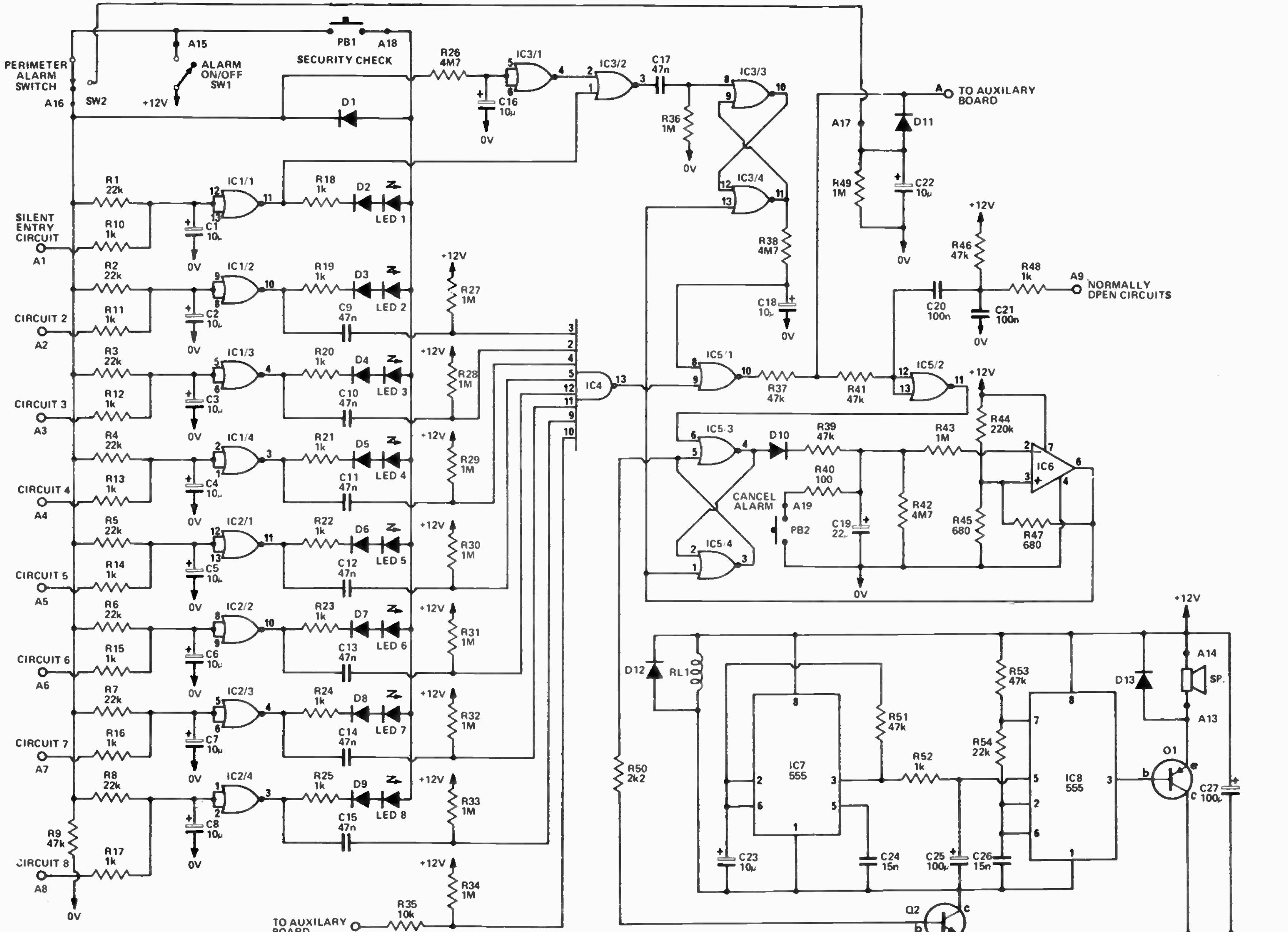


Fig. 1. Circuit diagram of the 'A' board.

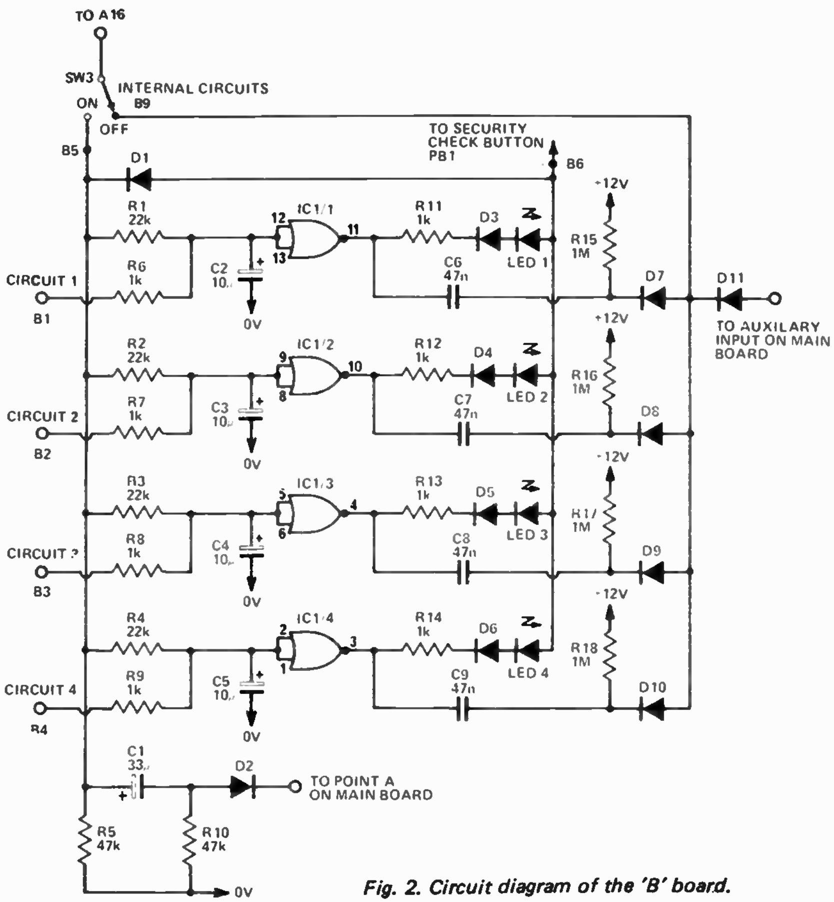


Fig. 2. Circuit diagram of the 'B' board.

CIRCUIT A
IC1–IC3 ARE 4001
IC4 IS A 4068
IC5 IS A 4001
IC6 IS A CA3130
IC7,8 ARE NE555
THE POWER RAILS OF IC1–IC5 ARE NOT SHOWN. PIN 7 IS 0V, PIN 14 IS +12V.
Q1 IS A TIP 2955
Q2 IS A BC 549
D1–D11 IN914
D12,D13 IN4001

CIRCUIT B
IC1 IS A 4001
D1–D11 ARE IN914

Construction

Due to the number of components, it is recommended that the unit should only be built using the PC boards shown here.

Assemble the components, watching the connection of all the polarised components. Also solder the CMOS ICs last and then solder pins 7 and 14 first. This allows the protection diodes inside the IC to be effective. The LEDs should be mounted parallel to the PC board as shown in the overlay as these have to protrude through holes in the chassis.

In the prototype we used both a relay and a siren circuit while in use only one should be required. Therefore simply leave out the unwanted components.

We mounted the unit in a metal box (actually it was a blank chassis for a 440 amplifier) as shown in the photos. We have not given mechanical drawings however.

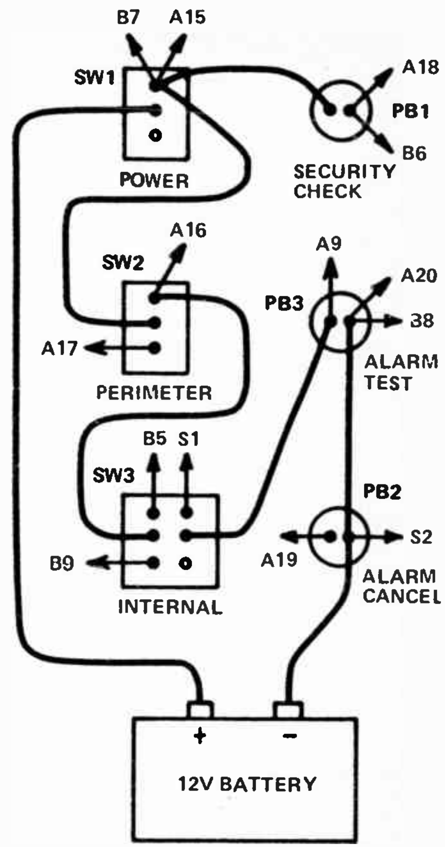


Fig. 3. Wiring of the switching and pushbuttons.

How It Works – ETI 582

Unlike normal alarms which use a single loop around the complete house with all the switches in series, with this alarm each door or window or a group of windows in the same room, uses its own circuit. IC1 and IC2 are used to detect an open window and if so the output of the IC associated with that circuit will be low. Capacitors C1–C8 and resistors R10–R17 provide a slight delay to prevent accidental triggering due to lightning etc. In each output of IC1 and IC2 there is a LED which is connected when the security button is pressed indicating which windows are open. This will allow them to be closed before the alarm is activated.

The normal circuits (ie not the silent entry one) have an RC network to generate a negative pulse if a window is opened and these are connected to one of the eight inputs of IC4. If a window is opened the resultant pulse at the input of IC4 will cause a positive pulse at its output.

With the silent entry door a 30 sec delay due to R26, C16 and IC3/1 overrides the output of IC1/1 immediately after the alarm has been activated allowing time to leave the house. After that time if the door is opened the output of IC3/2 will go high and the pulse generated by C17 and R36 will toggle the RS flip flop formed by IC3/3 and IC3/4. After another 30 sec. the input to IC5/1 will be high and its output will go low. The same output occurs if one of the normal inputs is triggered due to the output of IC4 going high.

The RS flip flop IC5/3 and IC5/4 is toggled by this pulse and this controls two circuits. These are a 5 minute delay for resetting and the alarm circuitry.

The delay circuitry uses a CA3130 IC where C19 is normally charged to +10 volts until the flip flop is triggered allowing it to discharge via R42. When the voltage has fallen to about 20 mV the output of the IC will go high, resetting both of the RS flip flops.

The output device can be either a relay or a siren circuit. In this circuit we have used two 555 timers, one operating at a high frequency and driving the speaker via the buffer transistor Q1 and the other at about 2 Hz which is used to modulate the frequency of IC8. If the capacitor C25 is deleted the result is a hee-haw type of alarm.

If more than seven normal circuits or if internal circuits are required they can be added in modules of four at a time and are connected to the eighth input of IC4. For emergency inputs ie fire alarms, or alarm devices using normally open contacts, a separate input to IC5/2 is provided. The emergency circuits will operate the alarm even if the normal circuits are not switched on.

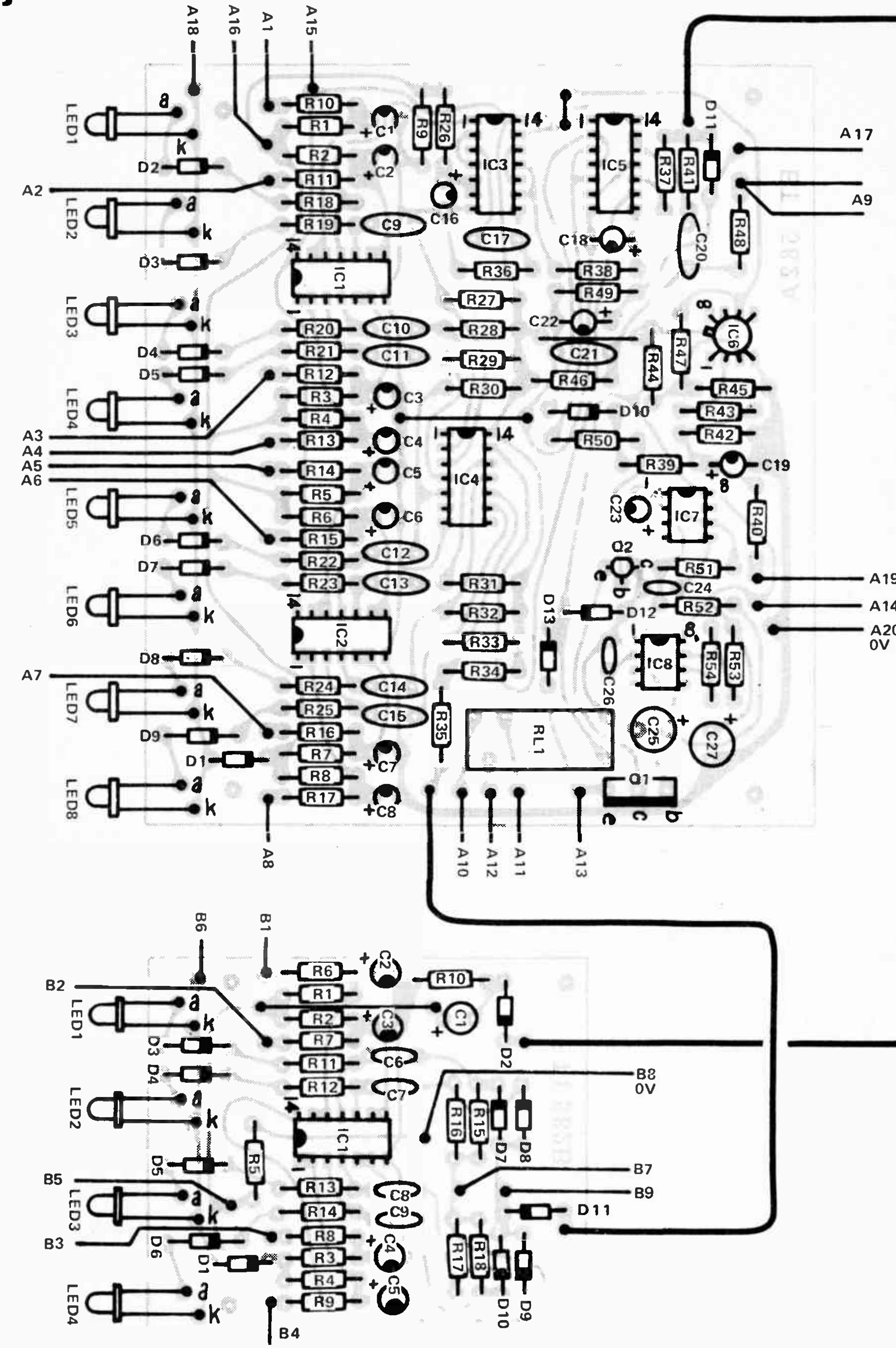


Fig. 4. Component overlay and interwiring of the two boards.

PARTS LIST – ETI 582A

Resistors all ½W 5%

R1–R8	22k
R9	47k
R10–R25	1k
R26	4M7
R27–R34	1M
R35	10k
R36	1M
R37	47k
R38	4M7
R39	47k
R40	100
R41	47k
R42	4M7
R43	1M
R44	220k
R45	680
R46	47k
R47	680
R48	1k
R49	1M
R50	2k2
R51	47k
R52	1k
R53	47k
R54	22k

Capacitors

C1–C8	10μ 16V tantalum
C9–C15	47n polyester
C16	10μ 16V tantalum
C17	47n polyester
C18	10μ 16V tantalum
C19	22μ 16V tantalum
C20,21	100n polyester
C22,23	10μ 16V tantalum
C24	15n polyester
C25	100μ 16V electro
C26	15n polyester
C27	100μ 16V electro

Semiconductors

IC1–IC3	4001 (CMOS)
IC4	4068 (CMOS)
IC5	4001 (CMOS)
IC6	CA3130
IC7,8	555
Q1	TIP 2955
Q2	BC549
D1–D11	1N914
D12,13	1N4001
LED1–8	Light emitting diodes

Miscellaneous

PC board ETI 582A

RL1 12V relay 280 ohm coil

PARTS LIST – ETI 582B

Resistors all ½W 5%

R1–R4	22k
R5	47k
R6–R9	1k
R10	47k
R11–R14	1k
R15–R18	1M

Capacitors

C1	33μ 16V electro
C2–C5	10μ 16Vtantalum
C6–C9	47n polyester

Semiconductors

IC1	4001 (CMOS)
D1–D11	1N914
LED1–4	Light emitting diodes

Miscellaneous

PC board ETI 582B

ETI 582 – GENERAL

SW1,2	single pole toggle switch
SW3	double pole toggle switch
PB1–PB3	press to make push buttons

Case to suit

12V battery type 732 or similar

Terminal strips

SPECIFICATION – ETI 582

Types of inputs	Silent entry Perimeter circuits Internal circuits Emergency circuits
Silent entry	Single circuit, 30 s exit delay, 30 s entry delay.
Perimeter circuits	7 circuits, N/C contacts, can be expanded in units of 4.
Internal circuits	4 circuits, N/C contacts, can be expanded in units of 4. Any number of N/O circuits.
Emergency circuits	Any number of N/O circuits. These circuits are active even if perimeter and internal circuits are switched off.
Current drain and battery life (type 732)	
Emergency only	2.5 mA (4000 hours)
Alarm active	9 mA (2000 hours)
Alarm sounding	500 mA (10 hours)
Alarm time	12 minutes

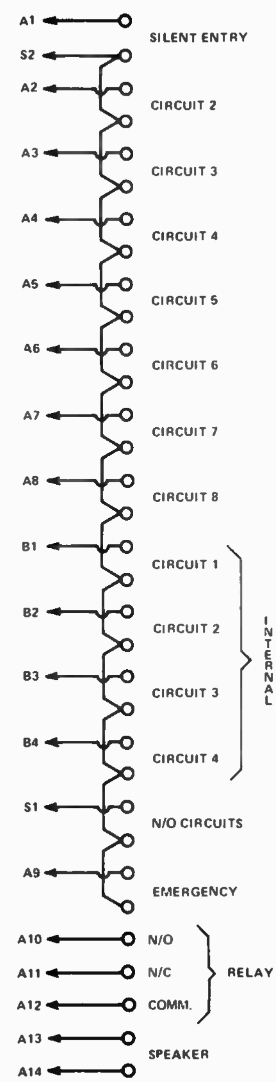


Fig. 5. Connection of the rear terminal blocks.

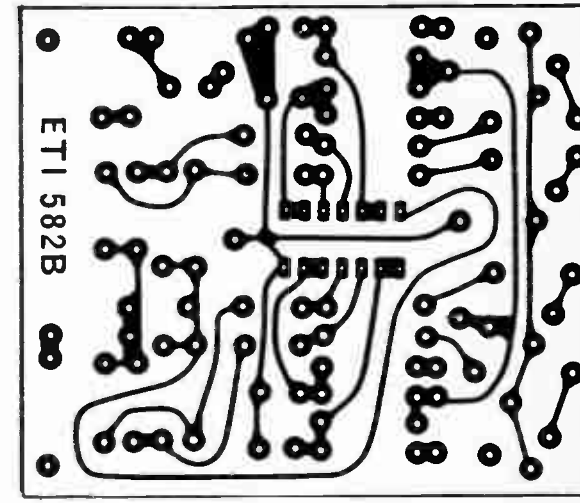


Fig. 6. PC board layout of board 'B'. Full size 75 x 65 mm.

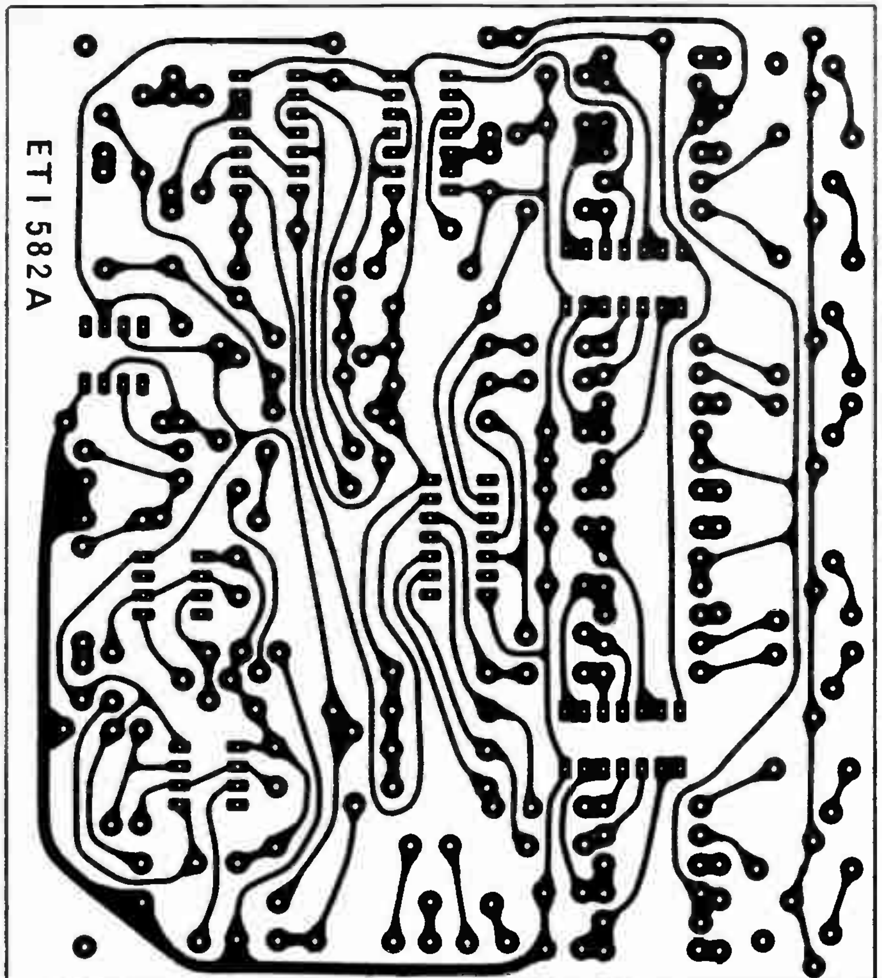
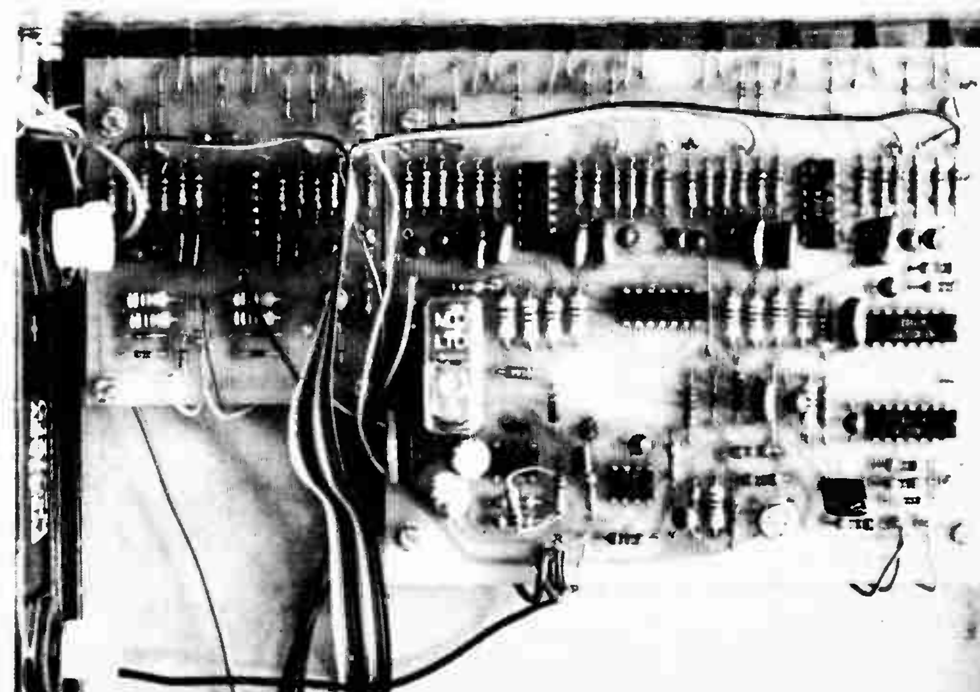


Fig. 7. PC board layout of board 'A'. Full size 130 x 115 mm.



HOUSE ALARM

Here's what you need to know to protect your home or business against forcible entry — with particular emphasis on installing the ETI 582 alarm.

NEARLY 30% of all burglaries are committed by thieves entering via unlocked doors or windows. A further 24.4% are committed via forced door locks, and about the same percentage via forced windows.

Thus nearly four out of five potential breakins can be avoided by installing adequate door and window locking mechanisms.

Use 'deadlatch' locks on all external doors. These locks can only be opened with a key — even from inside — so even if a thief enters via a window he can't remove any large items (such as colour TVs). Few thieves will risk being seen passing items through a window.

Do have the locks fitted by an experienced locksmith unless you have experience in this field — and don't fall for door-to-door lock salesmen — it's not unknown for them to retain a duplicate key!

Consult a specialist security company about window locking devices. Innumerable types are available for metal, wood framed and sash windows. A burglar might break the glass but few risk climbing through a window frame with broken glass in it.

The precautions outlined above will reduce your chances of being burgled by about 80% — the remaining 20% can be reduced to virtually zero by installing a good burglar alarm. The emphasis must be on the word 'good'. A poor system is worse than none at all for it may go off erratically or not at all. (Over 97% of all burglar alarm warnings are false.)

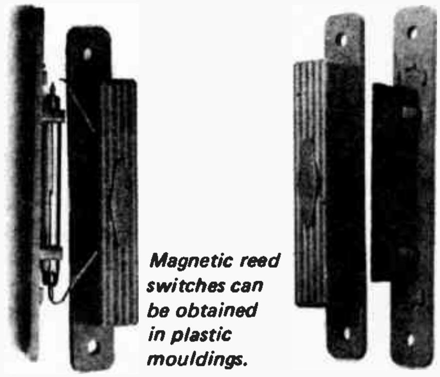
Sensors

For most premises, it is necessary to install sensors to protect front and rear doors, garage entrances, windows, large ventilators and skylights.

A few forcible entries are made *through* the walls or roof, and very occasionally via the floor. Although rare, such forced entries may be guarded against by placing sensors in a strategic passage or area through which an intruder will pass.

The simplest and most reliable switching device for alarm installations is the magnetic reed switch. This consists of a pair of ferromagnetic contacts in a small hermetically sealed glass enclosure. The switch reeds are cantilevered from the ends of the glass tube and overlap slightly at the centre, with a small air gap between them.

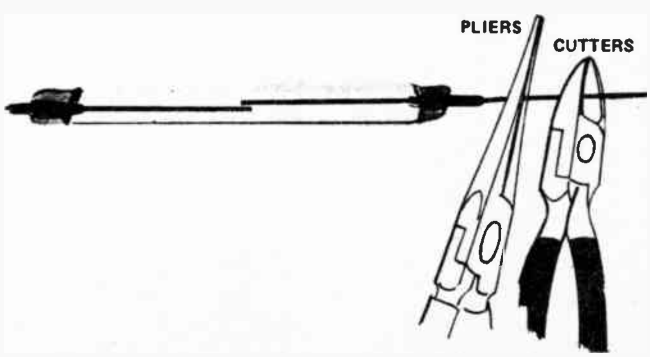
When a magnet is brought near the reed switch, the attracting forces increase and overcome the stiffness of the reeds, bringing them into contact with each other. When the magnet is removed, the contacts reopen. The relative distance for pull-in is always less than for drop-out. This is a valuable feature for small movements of doors and windows will not cause false alarms.



Magnetic reed switches can be obtained in plastic mouldings.

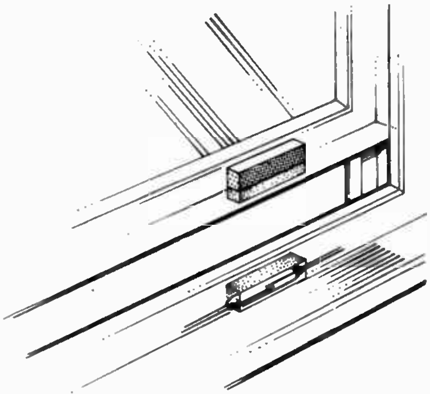
Reed switches purchased for alarm installations must be of a type specifically intended for the purpose — standard reed switches are not suitable.

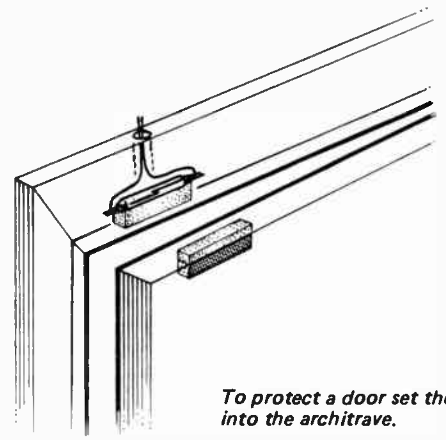
Many professional security companies install reed switches and magnets encased in plastic mouldings. Whilst these mouldings are neat and simple to fit, it is better to conceal both reeds and magnets within the framework of the doors and windows.



Care must be taken if the reed switch connecting leads needs shortening. Hold wire tightly with pliers (as shown) to prevent breaking the glass seal.

Set the reed switch into the window frame and the magnet in to the moving part.





To protect a door set the reed switch into the architrave.

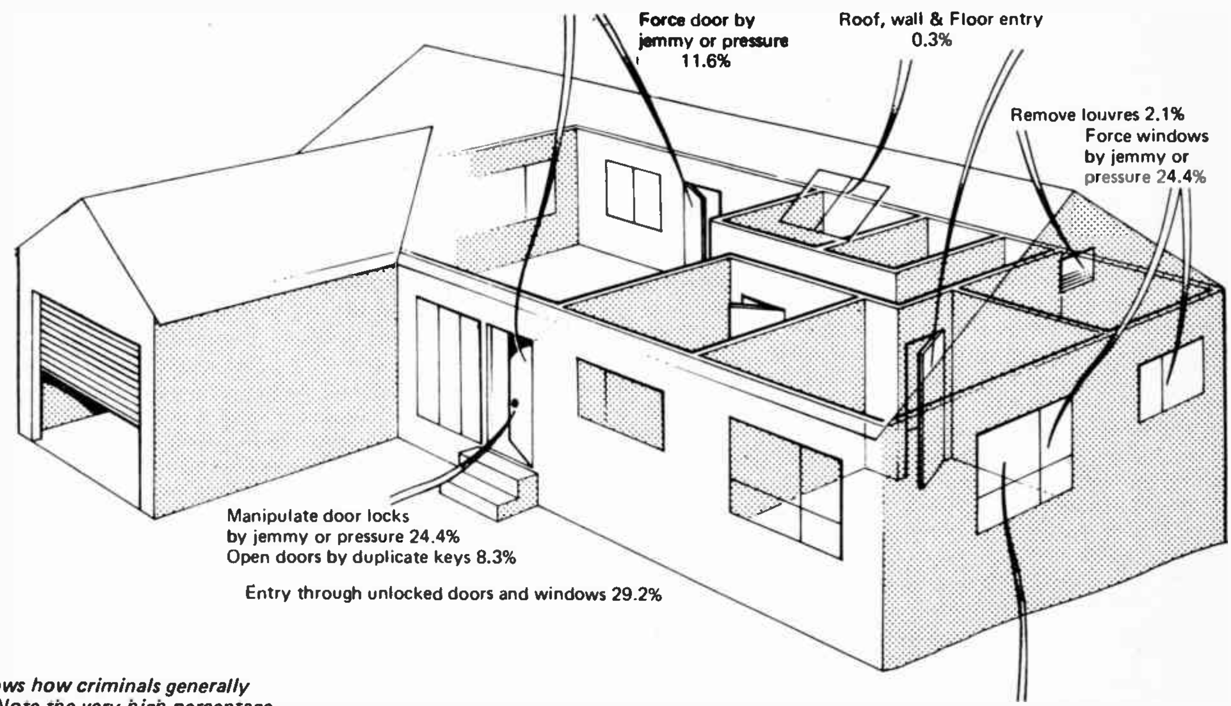
We have shown various methods of locating the reeds and magnets (note that the magnet is always fixed to the moving part of any door or window frame).

Window glass may be protected by glueing on a loop of aluminium foil tape (a self-adhesive type is made specifically for this purpose). The foil is quite thin and breaks if the glass is fractured. Foil will deter all but the most determined burglar. After all why risk being caught when next door doesn't seem to be alarmed?

Vibration sensors may be used to protect large areas of glass, they're effective but prone to false triggering during thunderstorms. Another window protector is a device which listens for the sound of breaking glass! This has an effective range of about five metres on axis and contains circuitry for filtering out false signals.

Many other types of intruder sensing devices can also be included in the system. Pressure mats for example, can be placed under carpets in strategic passageways — or even under the doormat. The mats contain a large number of normally open contacts, some of which will close when the mat is trodden on.

Infra-red beams can be installed if



This sketch shows how criminals generally enter a house. Note the very high percentage of entries made via doors and windows found unlocked.

required. These and other commercially available intruder detectors use a change-over relay output stage.
The intruder alarm itself should be reasonably accessible to people entering and leaving the premises via the 'silent entry' door, but well-hidden from the sight of an intruder.

The intruder alarm output stage is a relay which latches when an alarm signal is received.

For household use, a good-quality 12 volt alarm bell will be adequate. Being mechanically resonant, bells have a very high conversion efficiency of electrical to acoustical energy; in fact, the average 12 volt bell draws less than 500 milliamps and can be heard several hundred feet away.

Good sirens can be heard well over half-a-mile away, but they draw a lot of power and also cost more than a good bell. Small, cheap sirens cannot be recommended.

If at all possible, householders should make mutual arrangements with neighbours to contact the police if the alarm is heard. Similar arrangements should also be made so that neighbours can switch off the alarm after the police arrive.

The alarm bell should be mounted unobtrusively, high up in an inaccessible place. The leads to the bell should be run in 40/0076 (to reduce voltage drop) and concealed from view. We strongly recommend that a separate 12 volt battery be used.

Notes:

One approach is to connect the alarm output relay to switch on a number of floodlights. It will be necessary to drive a heavy-duty contactor to carry the lighting current. Intense lighting will dissuade an intruder as thoroughly as an audible warning, and it's less traumatic for the awakened householder. Where business premises are concerned, the bell should also be retained.

The Alarm Unit

This unit enables each sensor or group of sensors to be connected to a separate sensing circuit. If any one sensor is triggered the alarm will be activated for a period of twelve minutes. At the end of that time triggering of any other sensor will once again initiate the alarm sequence.

The ETI 582's main alarm circuits are triggered by an intruder 'breaking' a normally-closed loop: thus if a switch is opened or the wiring is cut the alarm will be triggered.

The 582 alarm has seven main external 'normally-closed' circuits, plus a 'silent-entry' circuit but it is of course possible to connect two or more alarm switches in series for each main external circuit. If so doing do ensure that any such series-connected alarm switches are grouped together.

The silent-entry circuit shown as A1 in the project article is included so that the occupier can leave and enter the premises without activating the alarm. The silent-entry circuit is wired in the same way as the other external circuits.
The 582 system has provision for connecting a number of internal circuits. These may be actuated by 'normally closed' sensors — in which case the sensors should be connected to circuits B1 — Bn, or by 'normally open' sensors which should be connected to the normally open input point (A9).

It may well be worth considering installing a series of emergency push buttons. Such switches should be mounted on the architraves of the front and rear doors or in a readily accessible position near the doors. They enable the occupant to set off the alarm if a caller forces his way into the house when the door is opened. Although this is not a common event, emergency switches provide elderly or timid people with a feeling of security.

Use good quality bell pushes for these circuits and connect them to the A9 inputs on the circuit board.

Fire Alarms

Fire sensors may be wired across the A9 input. The actual fire sensors should be mounted in the ceilings of rooms in which there is a fire hazard — kitchen, living room, rooms with electrical or heating appliances, or where people smoke (don't forget the bedroom if you've a habit of smoking in bed!). Sensors should also be installed in the roof of the garage especially if this is attached to the house — the laundry, workshop etc.

The installation of an intruder alarm should only be *part* of a co-ordinated campaign to dissuade burglars. There are a number of simple precautions that should also be used. Details of these are contained in an excellent series of leaflets obtainable from the Crime Prevention Bureau of your local police headquarters.

(continued from page 19)

The transmission line speaker project was originally published in ETI August '77 — and proved tremendously popular with readers — virtually all who built them were very pleased indeed with the results.

The original article also triggered off a flood of enquiries from readers seeking advice on various aspects of performance etc, the most typical of these enquiries are answered here.

Non-polarised capacitors can be obtained from Plessey Ducon and also in values sufficient to make up the total values required — from Audioson, Winbourne Rd, Brookvale, NSW — who also supply KEF drivers.

It's been found advisable to connect small value polyester capacitors across the main non-polarised units to allow a 'passage' for small musical details. A microfarad or so will suffice for C2 and a few picofarads for C4 and C6.

The HF1300 and HF2000 drivers were readily obtainable from M & G Hoskins of Kent St, Sydney at the time of writing.

The crossover network shown has turnover frequencies of approximately 400 Hz, 3.5 kHz and 12 kHz. The extra network associated with the midrange driver reinforces output below 600 Hz to compensate for losses below this.

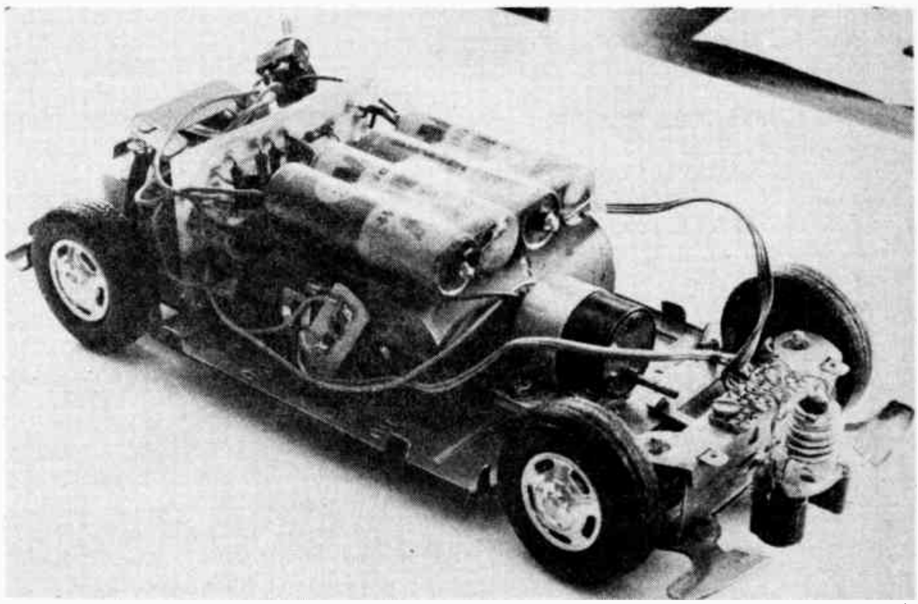
Component values should be adhered to as closely as possible although the 1.8 ohm resistor is not critical — but keep it within 1.5 - 2.2 ohms. This resistor can readily be made from a short length of jug element wound around a former — such as another higher value resistor. All resistors should preferably be ten watt rating although five watt types will do at a pinch for the tweeters.

As for the actual construction and stuffing, it is essential that all panels are accurately cut and fitted together to give an airtight seal the length of the 'line' and between the main enclosure and midrange sub-enclosure. As we mentioned in the previous article, it is very difficult to quantify the precise amount of acoustic fibreglass needed to fill the line, but the best way to estimate requirements will be to calculate the volume required to fill the enclosure without compressing the material, then add another 15% so that a greater density of stuffing can be placed near folds in the tube.

With care and attention in construction these speakers can provide excellent results, with truly musical bass. But if you like a lot of bass (most commercial speakers provide this; it's pretty boomy too) the design may disappoint you. On the other hand, once accustomed to the very accurate bass these speakers provide you'll probably find it difficult to listen to most others unless they happen to be very good infinite baffles or, of course, good transmission lines.

WHITE LINE FOLLOWER

This toy car will follow a track around — but there's always the danger of spinning off!



THE IDEA OF A SLOT CAR that doesn't need a slot is not new — in fact, sophisticated systems based on inductive loops have been used in large factories for some years. This project is at the other end of the complexity scale, and uses a simple light/photocell combination to follow a white line. The electronics involved make up a simple feedback control system — as soon as one photocell sees more light than the other, the differential amplifier applies a correcting voltage to the steering servomotor and so the model steers itself back on to the line.

We are not sure whether to class this project as a toy or as a serious experimental project. Certainly, the basic project makes a great toy, but there is tremendous scope for experimenting and 'tuning' the control circuitry. Like all control systems, this one displays a characteristic called 'damping' — if the system is overdamped, the car will steer sluggishly and will have difficulty following anything except the smoothest curves. If the control circuitry is underdamped, the car will oscillate from side to side on curves — this may also be set off by small deviations on the straights.

The ideal situation is to have a 'critically damped' system, which has just the right combination of characteristics to respond quickly on curves without oversteering. This can be achieved by theoretical analysis, using techniques like Nyquist's Criterion, but it's more fun to tune by trial and error. The damping is a factor of the photocell spacing, the amplifier gain and the servomotor characteristics.

You can have a lot of fun racing these cars, especially since there is quite a bit of scope for tinkering and tuning them. The layout of your race track should include both smooth and tight curves — you may have problems with figure-8's that cross at anything but right angles. And of course you can time races with your ETI stopwatch!

Construction

Construction of the mechanical side we must leave to the individual reader. The car we used was purchased from Woolworth's and already had steerable front wheels, which saved a lot of work in designing and building, although for the enthusiast a plastic kit would be a good start.

The motor for the steering should operate on 1.5 V reliably and has to be geared down. The motor we used had an internal 15:1 gearbox and the steering

arms were driven by a piece of fishing line wrapped around the shaft (see photo). This is only one possible method – we leave the final choice to you.

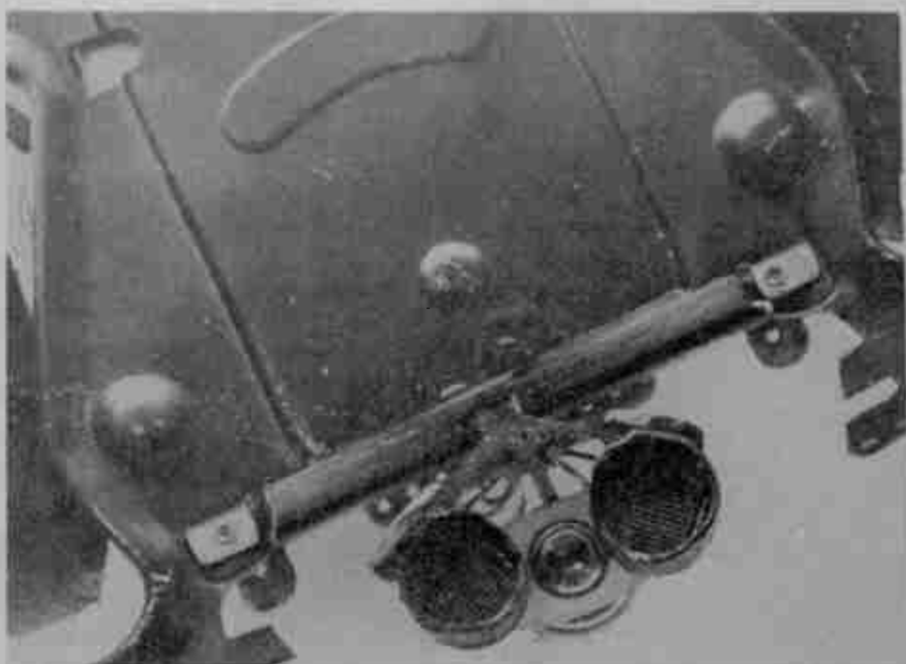
The sensors should be mounted in front of the wheels and should move with them so that when the wheels turn to the right, the sensor also moves to the right and vice versa.

The LDRs were housed in short lengths (about 10 mm) of cardboard tube to act as a shield and were spaced about 15 mm apart (we used a 12 mm wide line) with the globe mounted between them.

Electrically the components can be built onto the PC board described which can be mounted somewhere in the car. We used separate batteries for the electronics and ran the globe off the main batteries, to keep the electronics supply more constant.

Experimenting

Using different motors/gear ratios some changes to the electronics will probably be found necessary. These would mainly involve C1, R1 and R10. Increasing R10 or reducing R1 increases the DC gain, while increasing C1 increases the dynamic damping to reduce overshoot. Track width may also be experimented with as well as LDR spacing.



Underneath view of the photo resistors and the light globe.

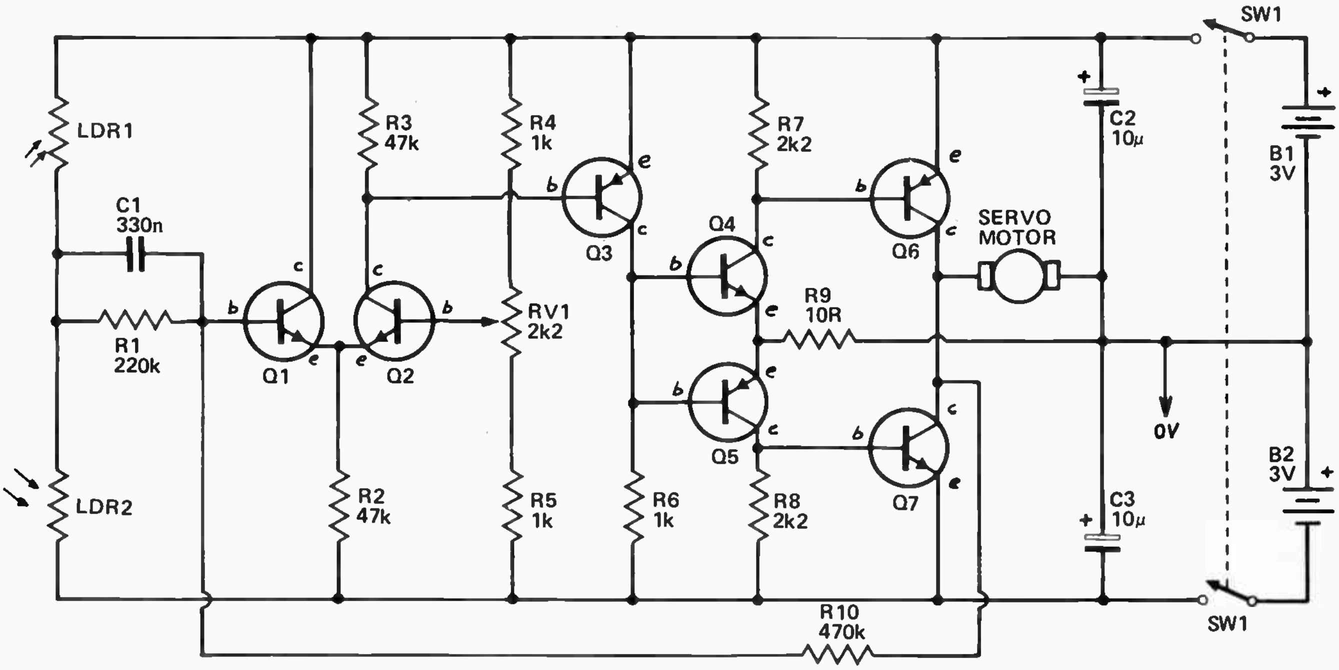
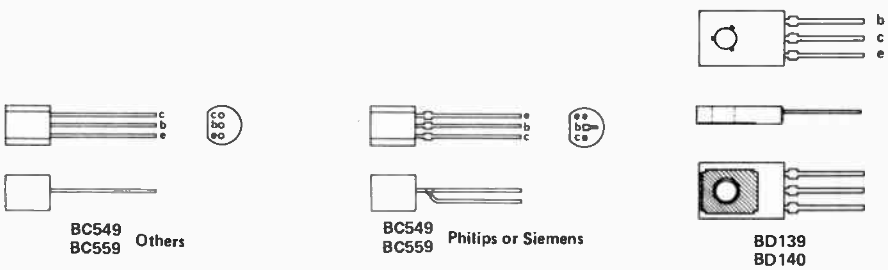


Fig. 1. The circuit diagram of the electronics.



HOW IT WORKS – ETI 245

The sensor used to look for the white line is a pair of light dependent resistors (LDRs) which are aimed at either side of the line so that each sees half white half dark. The line is illuminated by a globe to ensure that the LDRs have a relatively low resistance. If the car is moved off the centre line one LDR will see more 'white' and its resistance will fall. The two LDRs are connected in series across the supply voltage and so the voltage at the junction will vary as the car moves in relation to the line.

This voltage is compared with that set on RV1 by Q1 and Q2, the error signal driving the servo motor in the correct direction to try to eliminate the error. Negative feedback is provided by R10 to reduce the 'open loop gain', and dynamic feedback is provided by C1 which is used to reduce overshoot.

When designing the mechanical side of the car's steering mechanism, provision should be made to somehow move the sensors with the front wheels to provide additional negative feedback.

The motor used in the prototype was an expensive one (about $40) with an internal 15:1 gearbox. While a motor of this quality is probably not justified a reasonably good motor and reduction gear is necessary as the cheap (50c) motor we tried didn't seem to like starting on 1.5 V.

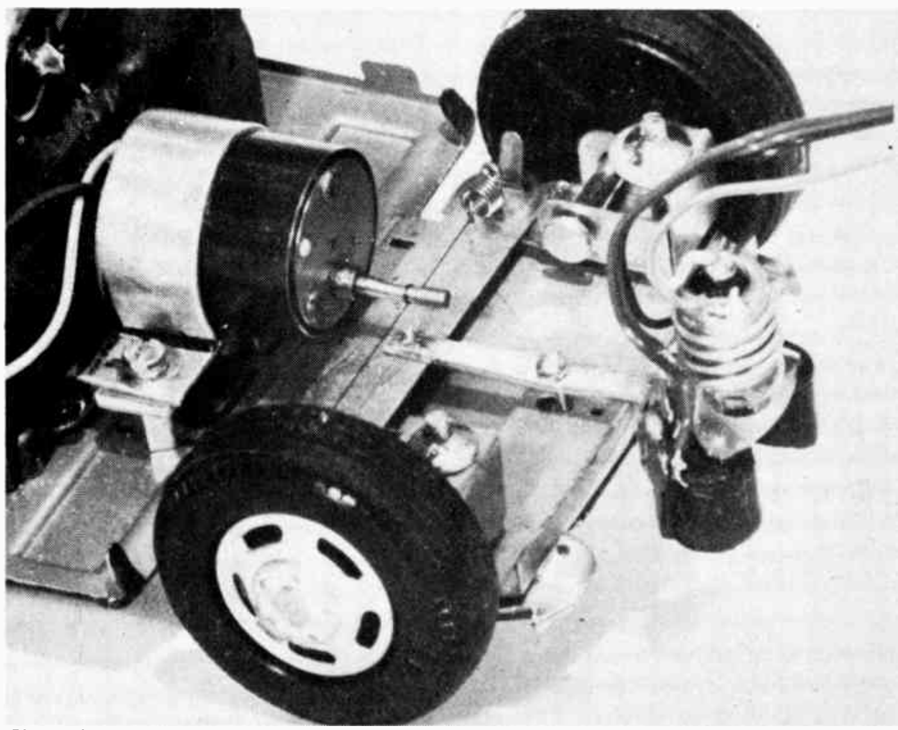


Photo showing the mechanical side of the project.

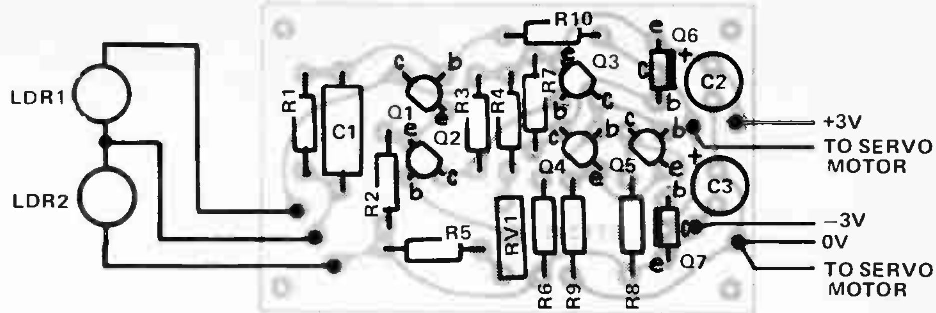


Fig. 2. Component overlay.

PARTS LIST – ETI 245

Resistors all ½W, 5%
- R1 . . . . . 220k
- R2,3 . . . . 47k
- R4–R6. . . 1k
- R7,8 . . . . 2k2
- R9 . . . . . 10R
- R10. . . . . 470k

Light dependent resistors
- LDR1,2 . . Philips 2322 600 94001 or similar

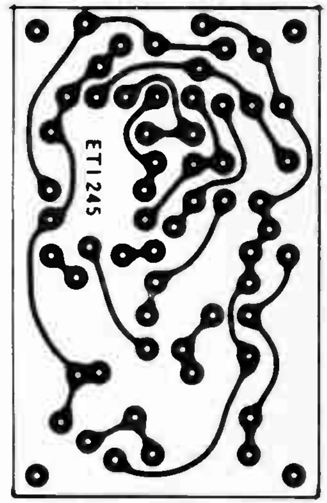
Potentiometer
- RV1 . . . . 2k2 Trim

Capacitors
- *C1. . . . . . 330n polyester
- C2,3 . . . . 10µ 10V electro

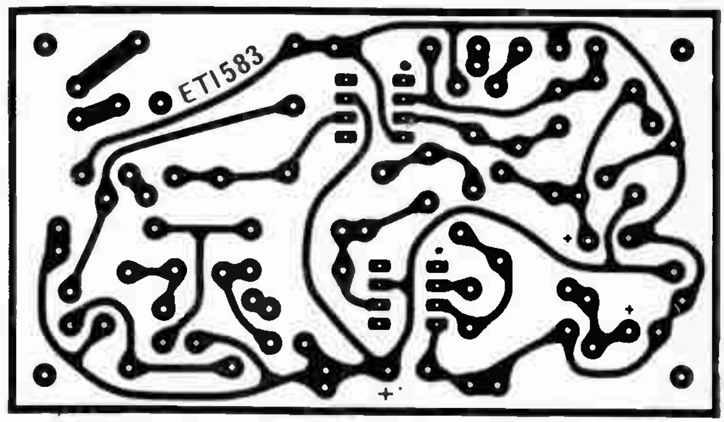
Semiconductors
- Q1,2 . . . . BC549
- Q3 . . . . . BC559
- Q4 . . . . . BC549
- Q5 . . . . . BC559
- Q6 . . . . . BD140
- Q7 . . . . . BD139

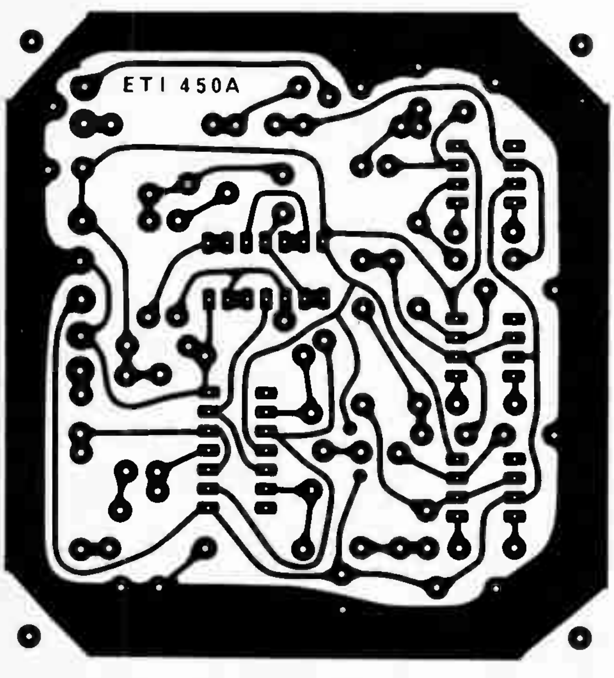
Miscellaneous
- PC Board ETI 245
- 3V globe
- *servo motor and gears
- toy car
- 2 pole toggle switch

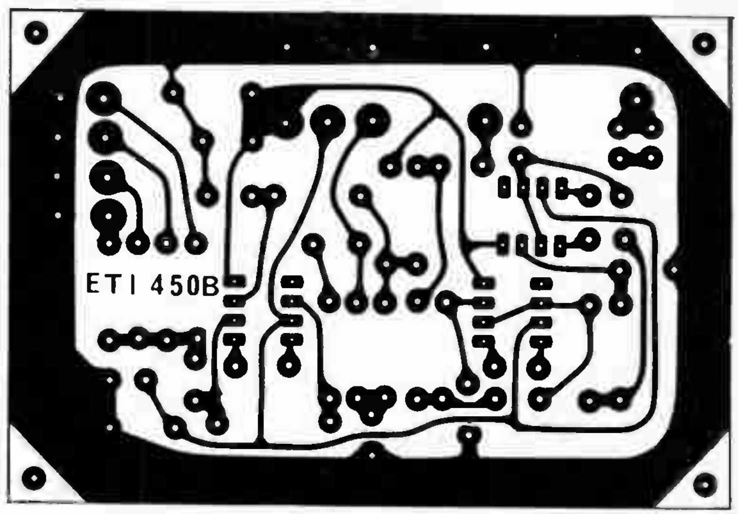
*see text

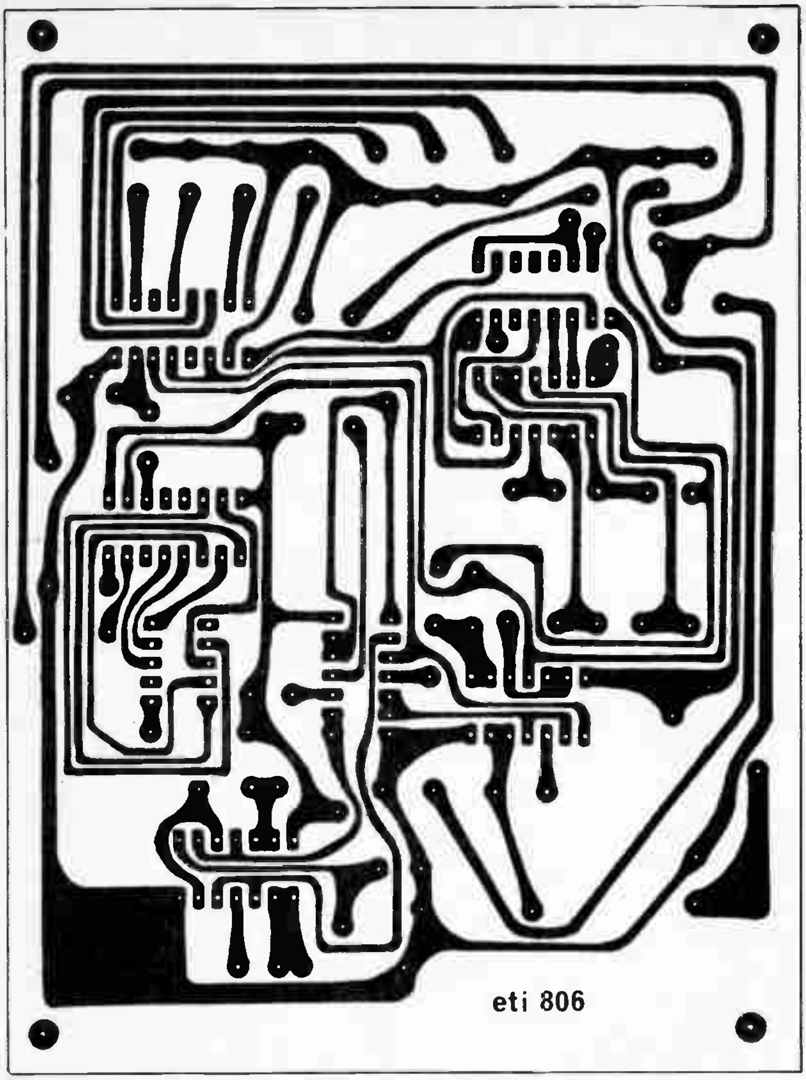


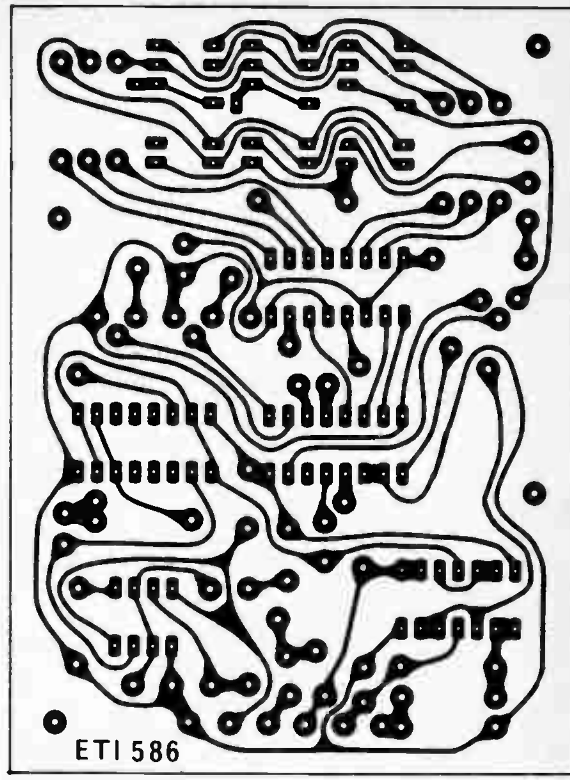
PCB's



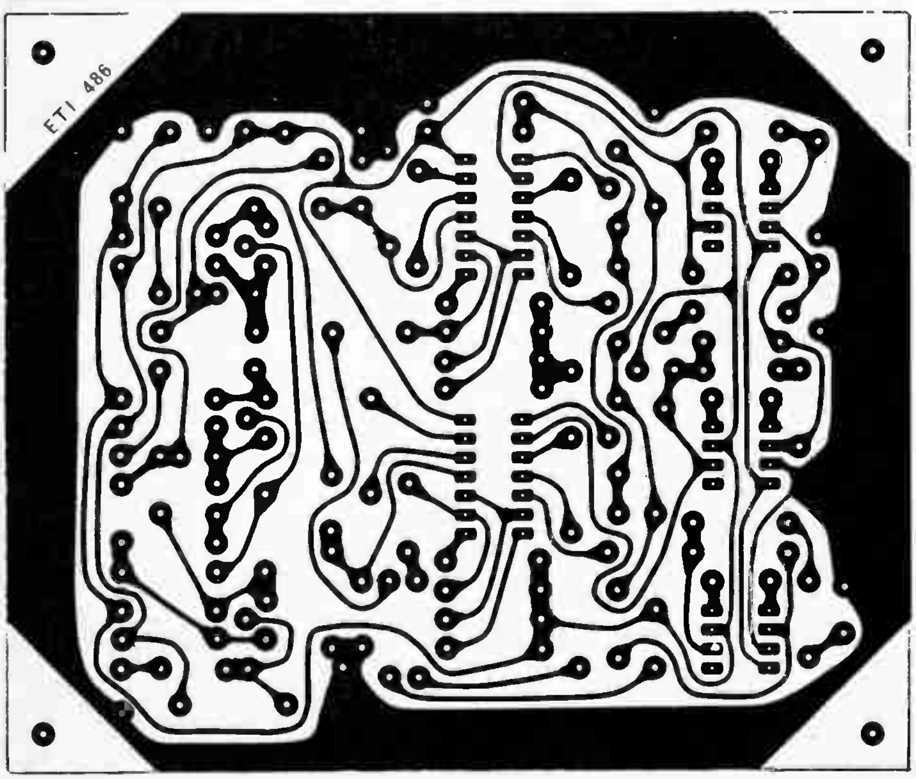


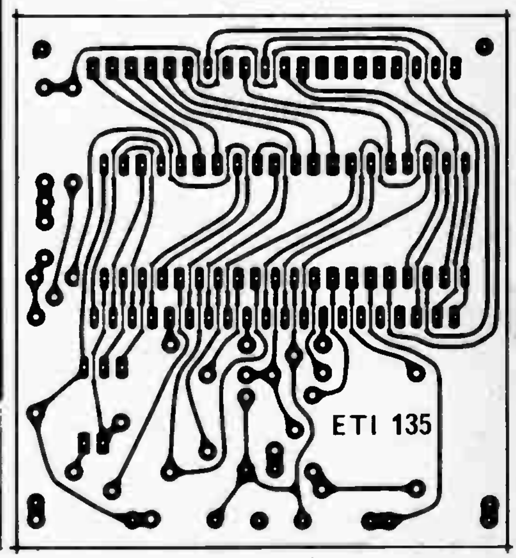






PCB's





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