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Electronic PROJECTS

BOOK 1

STAN MUTCH

Audio
Radio
Test Gear
Music
Disco
Alarms
Lighting
Motoring
Computing
Metal Detecting

EVERYDAY ELECTRONICS

MAGENTA ELECTRONICS LTD

Electronic PROJECTS BOOK 1

CONTENTS

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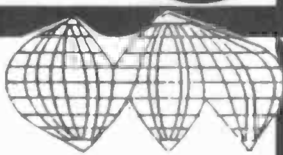

EE AUG 87

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KIT REF 718

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DIGITAL FREQUENCY 200 MHz METER

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An 8 digit meter reading from AF up to 200 MHz in two ranges. Large 0.5" Red LED display. Ideal for AF and RF measurements. Amateur and C.B. frequencies.

KIT REF 563

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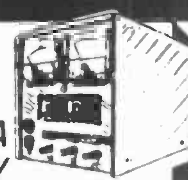
MOSFET VARIABLE BENCH 25V 2.5A POWER SUPPLY



EE FEB 88

A superb design giving 0.25V and 0-2.5A. Twin panel meters indicate Voltage and Current. Voltage is variable from zero to 25V. A Toroidal transformer MOSFET power output device, and Quad op-amp IC design give excellent performance.

KIT REF 769

£52.96

MINI STROBE

EE MAY '86

A hand held stroboscope which uses 6 "ultra bright" LEDs as the light source. Designed to demonstrate the principles of stroboscope examination, the unit is also suitable for measuring the speed of moving shafts etc. The flash rate control covers 170–20,000 RPM in two ranges.

KIT REF 529

£14.76

ACOUSTIC PROBE

EE NOV '87

A very popular project which picks up vibrations by means of a contact probe and passes them on to a pair of headphones or an amplifier. Sounds from engines, watches and speech travelling through walls can be amplified and heard clearly. Useful for mechanics, instrument engineers and nosey parkers!

KIT REF 740

£18.65

MAINS TESTER & FUSE FINDER

EE MARCH '86

A handy unit which sounds an audible warning when the mains supply is disconnected and gives visual indication on three neon lamps of the connections to mains sockets. Designed for checking correct connections of mains wiring and for tracing which socket connects to which fuse in fusebox. Can detect no live, no neutral, no earth, L/N reversal, L/E reversal.

KIT REF 512

£9.39

EE EQUALISER

EE MAY '87

A mains powered Ioniser with an output of negative ions that give a refreshing feeling to the surrounding atmosphere. Negligible current consumption and all-insulated construction ensure that the unit is safe and economical in use. Easy to build on a simple PCB.

KIT REF 707

£16.54

MUSICAL DOORBELL

EE JAN '86

This project uses a special I.C. pre-programmed with 25 tunes and 3 chimes. A Magenta design, the circuit is battery powered and only draws current whilst producing sounds. Two rotary switches select the tune required. Provision is made for three bell pushes, each of which sounds a different tune, so that three points of entry can be identified.

KIT REF 497

£19.95

EPROM ERASER

EE OCT '88

Safe low-cost unit capable of erasing up to four EPROM's simultaneously in less than twenty minutes. Operates from a 12V supply. Safety interlock. Convenient and simple to build and use.

KIT REF 790

£26.57

LIGHT RIDERS

EE OCT '86

Thre projects under one title – all simulations of the Knight Rider lights from the TV series. The three are a lapel badge using six LEDs, a larger LED unit with 16 LEDs and a mains version capable of driving six main lamps totalling over 500 watts.

KIT REF 559 CHASER LIGHT	£14.52
KIT REF 560 DISCO LIGHTS	£20.89
KIT REF 561 LAPEL BADGE	£10.86

EE TREASURE HUNTER

EE AUG '89

A sensitive pulse induction Metal Detector. Picks up coins and rings etc., up to 20cms deep. Low "ground effect". Can be used with search-head underwater. Easy to use and build, kit includes search-head, handle, case, PCB and all parts as shown.

KIT REF 815 — £39.95

Headphones — £1.99

STEPPING MOTOR INTERFACE

EE JULY '85

This interface enables 4 phase unpolar stepping motors to be driven from four output lines of any computer user port. The circuit is especially suitable for the ID35 motor and our MD200 which are commonly used in buggies and robot arms. Supplied complete with ribbon cable and connector for the BBC user port.

KIT REF 464

£8.95

Electronic PROJECTS BOOK 1

All the projects contained in these pages were originally published in Everyday Electronics magazine.

They have all been well tried and tested and updated where necessary. Kits for all of them are available from Magenta Electronics.

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

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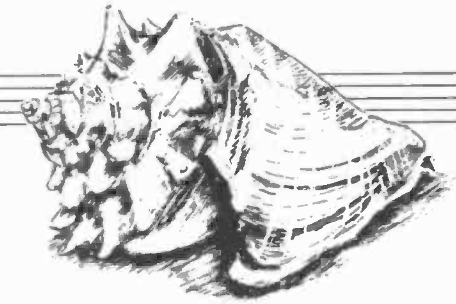
Constructional Project



SEASHELL SEA SYNTHESISER

ANDY FLIND

Why pay out hundreds of thousands of pounds for the latest marine dwelling? Now you can bring the relaxing sounds of the sea into your own living room for a fraction of the cost.

FROM time to time, most of us wish we lived near the sea. That is, with the exception of those fortunates who actually do! For the rest, the glorious pounding of surf on the beach is just a distant, fading holiday memory.

Imagine actually hearing the waves from your workshop . . . the therapeutic properties could work wonders in a stress-filled life and might even inspire real creativity.

As children, we were sometimes exhorted to take sea-shells home and listen to the "sea sound" that might be heard in them, but these were always a disappointing substitute for the real thing. The memories quickly fade and for those with jobs, families and the usual financial obligations, actually moving to the coast is an impossible dream. Those waves had to remain just a distant memory.

Until now! This project will re-create that sound, either through headphones (try the effect during a stressful day at the office!) or through a hi-fi, where judicious use of tone controls will simulate anything from actual presence on the beach to the muffled roar as heard from a distance. The realism is quite incredible; after a few minutes one tends to forget it's a simulation, the sound is unconsciously accepted as the real thing, with all the accompanying sensations of relaxation and timelessness.

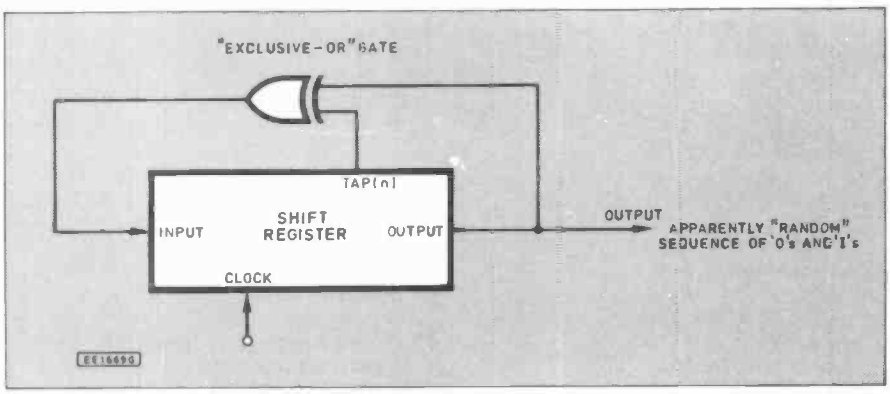


Fig. 1. Simplified digital noise generator using a shift register.

DESIGN OBJECTIVES

The design objectives for this project were simple. The sound should be as realistic as possible, in stereo, with appropriate tone and volume changes plus apparently random variations.

There would be absolutely no compromise in sound quality. Also, if possible it was to be pocket-sized, portable and capable of driving Walkman-type headphones.

In practice this meant low-current operation for prolonged use from a single PP3 battery. Unfortunately the first objective led to a fairly complex circuit, which raised difficulties with the second, but eventually a successful design was arrived at.

Although the circuit is rather complex, all the components are fairly cheap so it is inexpensive to build. The complexity stems mainly from there being two of almost everything; if only one channel were needed it would be much simpler. However, the stereo sound produced is incredibly realistic; constructors will probably agree that the final result is well justified.

WHITE NOISE

The first problem was generation of suitable "white noise". Considering the effort sometimes needed to minimise electronic noise, it's amazing how difficult it is to find some when it's wanted!

Most recognised sources are not, in fact, very noisy; they only cause problems where high gain levels are used. The usual "noise generators" found in projects are Zeners and reverse-biased diode or transistor junctions.

Most Zeners and diodes produce less than a millivolt and, of transistors tried, fewer than one in five proved suitable. The quality of sound also varied widely between devices.

A prototype of this project used special "noise diodes" which were very effective, but subsequently these were withdrawn by the manufacturers and no suitable substitute could be found. Eventually, the circuit was redesigned with a digital noise source, based on IC4, IC5 and IC6 (see Fig. 2). The principle is shown in simplified form in Fig. 1, where a shift register has its output exclusive-OR'd with the output from a tap at stage "*n*" and returned to the input.

If the shift register is clocked at a suitable frequency, the output will be a "pseudo-random" series of 1's and 0's which will take a considerable time to repeat. Just how long depends on the number of stages and the tap position; choice of tap for the longest possible sequence requires involved calculation and is best left to experts, but the arrangement used in this design has a 33-stage register with a tap at stage 14 and when clocked at 1MHz takes over two hours to repeat!

CIRCUIT DESCRIPTION

In the full circuit diagram for the Seashell shown in Fig. 2, the clock consists of IC4a and IC4b, running at approximately 1MHz and driving a 33-stage register made up from IC5 and IC6. The register output, from IC6 pin 9, is EX-OR'd with the output from the tap, IC6 pin 13, by IC4c for return to the input, IC5 pin 1.

It is possible for the circuit to get into a state where all the circulating bits are "0's". This would result in an input of 0, so the output would appear to be continuously low. This condition is avoided by the inclusion of capacitor C12 and resistor R27, which will rapidly inject a "1" to break the sequence should it occur.

Two apparently independent noise sources are required by this project. If a stereo amplifier is switched to "mono" and turned up until the background hiss is audible, the effect of switching to stereo will immediately be apparent. From being a mere irritant, the noise will acquire "depth", suggestive of wind and wide open spaces, and this is the type of sound needed for processing into "waves".

Instead of building two separate sources (with six chips!) the register input is EX-OR'd with another tapping point by the remaining gate IC4d to become a second output. A pair of two-stage low-pass filters convert the digital outputs into audio analogue signals, and attenuation by resistors R32 and R33 reduce them to a suitable level, about 35mV r.m.s., for the following stages. The two sources look sufficiently unrelated for the intended purpose on a 'scope, and they certainly sound "right".

Volume and tone are controlled by diodes. Taking the channel following capacitor C17, the signal passes through diodes D5 and D7 to appear across resistor R40. The diodes act rather like variable resistors whose resistance falls as the d.c. current flowing through them is increased. The current needed is just a few microamps, supplied mainly from resistor R36. From here the signal passes through C21 and R44, which with capacitor C23 provides "top cut" tone control varying with the current, from resistor R42, passing through diode D9.

The full control network includes diode D3, resistors R8, R11, R38, and capacitors C19, and C25, and with the values given produces a realistic "crashing wave" sound when supplied with a positive pulse lasting about two seconds. The tone change lags slightly behind the volume, so the "wave" crashes initially at high pitch, shifts rapidly to a deep roar, then as it dies away the pitch gradually rises again for a realistic "backwash" effect.

Volume control VR1a lets the user adjust the level before amplifier IC7a, which can produce an output of about 200mV r.m.s. maximum. IC7 is a 1458, the dual version of the trusty old 741. Tests proved this to be capable of directly driving Walkman-type headphones for portable use.

Switch S1b offers two levels of overall tone control if required. The tone positions could well, in fact, be labelled "near", "far" and "furthest"! The second channel, following capacitor C18, works in exactly the same way.

SOUND WAVES

The rest of the circuit is concerned with providing suitable pulses to control the sounds. IC1a and IC1b form a simple clock, cycling about once every ten seconds. The output is differentiated by capacitator C2 and resistor R3, so the coupled outputs of IC1c and IC1d are normally high, but go low for about one second with each clock cycle.

Each output pulse discharges capacitators C3 and C4 through resistors R4 and R5, taking about four seconds to reach half supply voltage where IC2c and IC2d each go high for about two seconds.

These positive (high) pulses are fed to the "wave" generators by D3, R11 and D4, R12. When the outputs go low again they provide the discharge paths for slow sound decay through resistors R8 and R9.

If the "waves" simply crashed regularly and in unison they would sound boring and unrealistic (though less control circuitry would be required!), so IC3 introduces a little "randomising". The two amplifiers in this chip are configured as very slow running astable oscillators, with slightly different rates set by resistors R19 and R20.

The signals found on capacitors C7 and C8 are very slow triangle waves (approximately), of which small proportions are fed to capacitators C3 and C4 by resistors R13 and R14 respectively. This alters the times taken by these capacitators to charge to half-supply, slightly varying the switching times of the following gates.

The apparent effect is that the waves occasionally crash initially a little to one side. A little crosstalk introduced by resistor R10 improves the realism. Two further signals taken from IC3 are fed directly into the amplitude controlling stages by resistors R34 and R35. The high value of these resistors keeps the effect small, but it results in the "backwash" effect after each wave varying in volume and apparently swinging around. Again a little crosstalk, this time through resistor R25, improves the effect.

COMPONENTS

MAGENTA KIT 796

Resistors

R1, R3	10M (2 off)
R2	5M6
R4, R5, R23, R24, R25	100k (5 off)
R6, R7, R34, R35	4M7 (4 off)
R8, R9, R50, R51	220k (4 off)
R10, R38, R39	47k (3 off)
R11, R12, R44, R45	22k (4 off)
R13, R14	330k (2 off)
R15, R16, R17, R18, R21, R22, R28, R29, R30, R31, R40, R41, R46, R47	10k (14 off)
R19	120k
R20	150k
R26	27k
R27, R36, R37	1M (3 off)
R32, R33	1k (2 off)
R42, R43	560k (2 off)
R48, R49	3k9 (2 off)
R52, R53	22 (2 off)

All 0.6W 1% metal film

Potentiometer

VR1	100k dual rotary carbon, log.

Capacitors

C1	1µ polyester layer
C2, C12, C21, C22	100n poly. layer (4 off)
C3, C4	22µ single-ended elec. 16V (2 off)
C5, C6, C17, C18	470n poly. layer (4 off)
C7, C8, C36, C37	100µ single-ended elec.10V (4 off)
C9, C10, C19, C20, C25, C26, C31, C32, C33	10µ single-ended elec. 50V (9 off)
C11	10p ceramic plate
C13, C14	1n poly. layer (2 off)
C15, C16, C23, C24, C27, C28	4n7 poly. layer (6 off)
C29, C30	10n poly. layer (2 off)
C34, C35	220p ceramic plate (2 off)
C38	470µ axial lead elec. 10V

Semiconductors

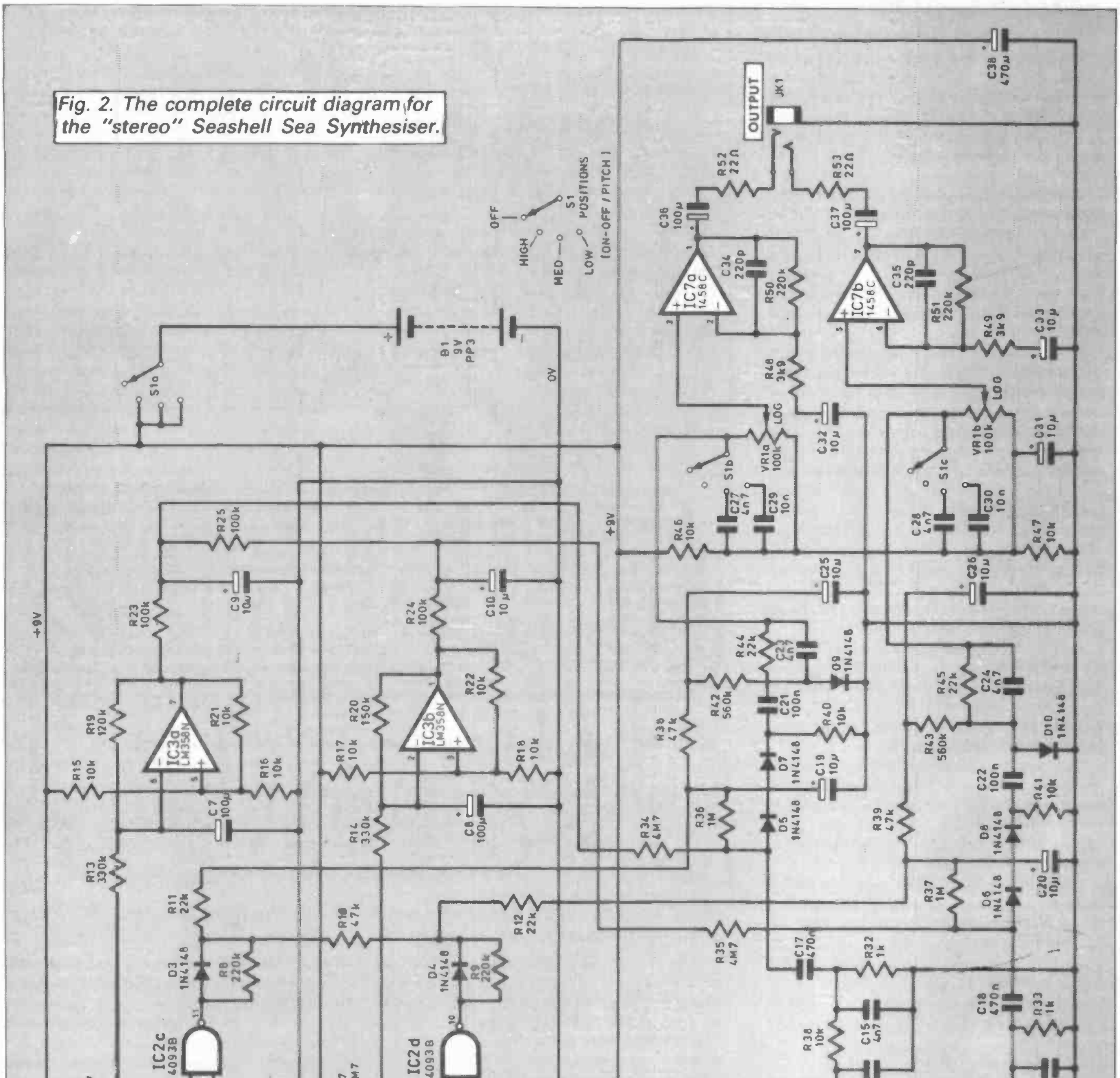
D1, D2, D3, D4, D5, D6, D7, D8, D9, D10	1N4148 signal diode (10 off)
IC1	4011B CMOS quad NAND gate
IC2	4093B CMOS quad Schmitt NAND gate
IC3	LM358N Dual op-amp
IC4	4070B CMOS quad EX-OR gate
IC5, IC6	4006B CMOS shift register (2 off)
IC7	1458C Dual op-amp

Miscellaneous

S1	3-pole 4-way rotary switch
JK1	3.5mm stereo jack socket

Printed circuit board, case (ABS plastic box 120mm×65mm×40mm), with p.c.b. runner guides; knobs (2 off); 8-pin d.i.l. sockets (2 off); 14-pin d.i.l. sockets (5 off); PP3 battery and connector; wire, solder; etc.

Fig. 2. The complete circuit diagram for the "stereo" Seashell Sea Synthesiser.



CONSTRUCTION

All components except the Volume control VR1, Tone (or Presence) switch S1 and the Headphone socket JK1 are accommodated on a printed circuit board. The component layout (assuming the board has not been cut) and copper foil master pattern is shown in Fig.3.

There can be few projects where intending constructors are advised to begin by sawing the circuit board in half! This isn't necessary, of course, if it is to be housed in a case that will accept it in one piece. However, if pocket-size is required this is the first step.

The cutting line is marked by a dotted track, along the centre of the copper side of the board which should be carefully sawn with a fine-toothed hacksaw. The two halves should then fit lengthwise into the moulded slots of the recommended case and the lid should fit; they can be trimmed with a file if necessary. Their edges can be smoothed with emery paper when cutting is complete.

As the components are quite densely packed together a fine-tipped iron is essential for construction. The components should be of the correct type, otherwise they may not fit. In particular, all the non-electrolytic capacitators, save C39 and C40, are miniature polyester layer types, not the larger polyester film variety.

All the electrolytics save capacitor C11 are the single-ended p.c.b. mounting type. Their dimensions are 11mm (high)×5mm (dia.) for 10µF and 22µF and 11mm×6.3mm for 100µF. The height is important as space between the boards is limited.

The layout of all components is shown in the overlay drawing, Fig.3. Care should be taken over the polarity of the diodes; Fig. 4 provides additional guidance for their installation. If they are bent and placed as shown their polarities will be correct.

The electrolytic capacitators normally have their negative leads identified with a broad stripe and all except capacitators C36 and C37 are fitted with positive sides uppermost. They must be fitted close against the board to minimise overall height. DIL sockets should be used for all the i.c.s, which should NOT be plugged in at this stage.

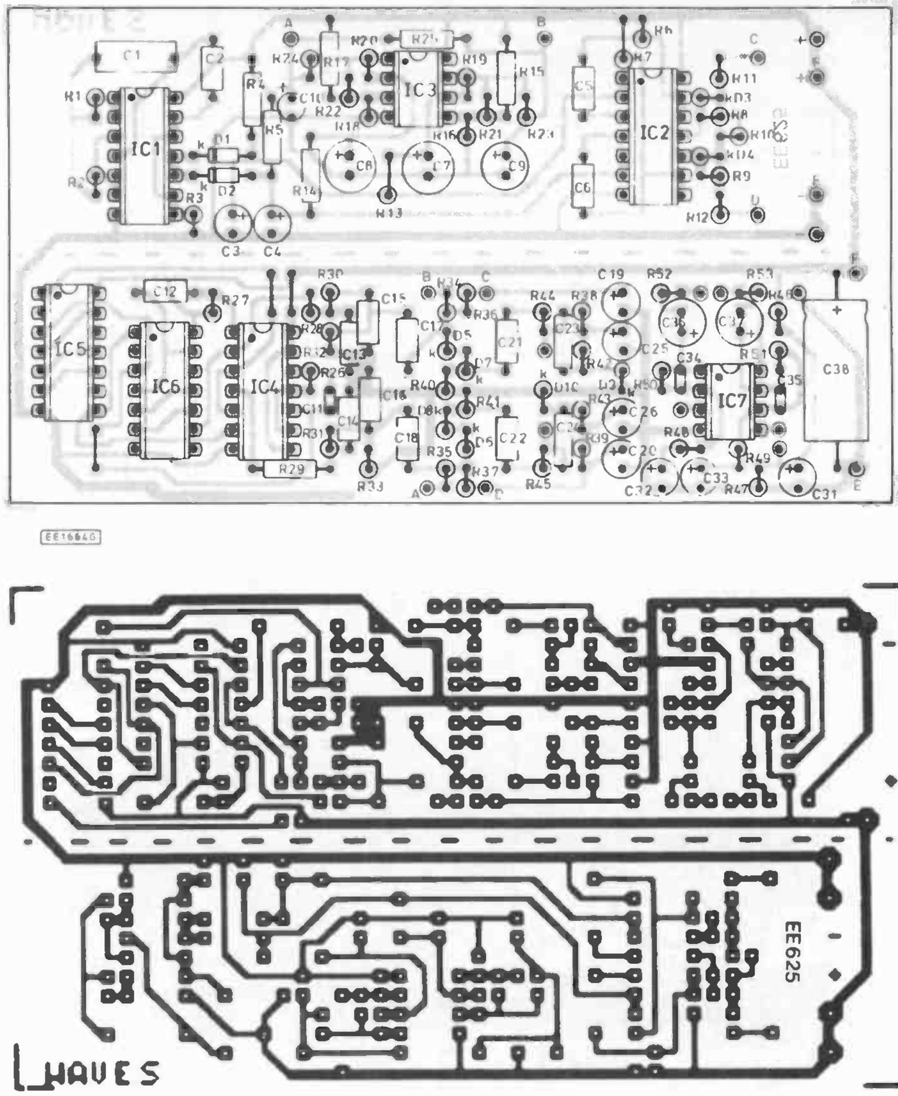
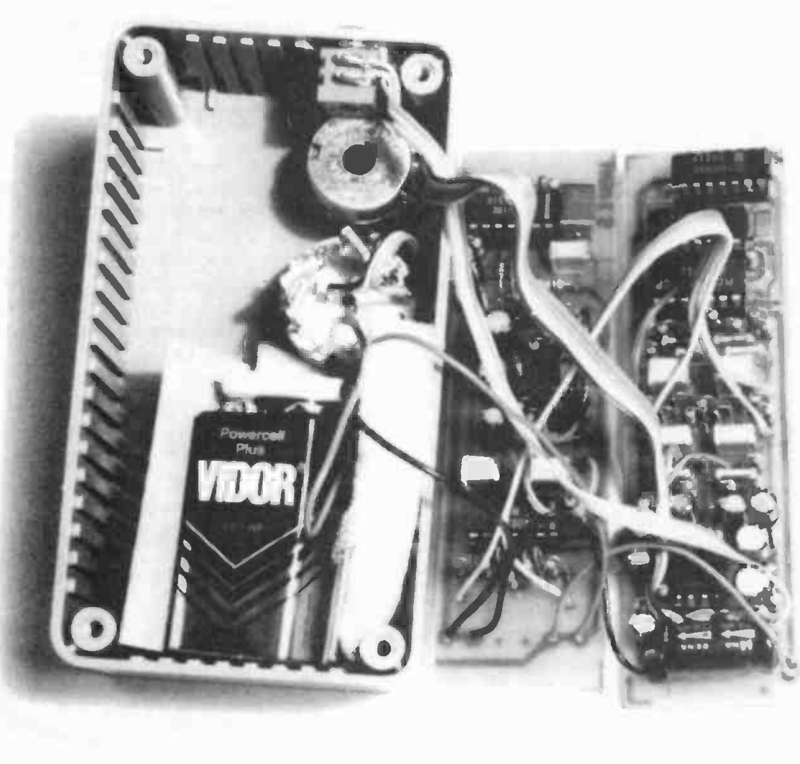


Fig. 3. printed circuit board component layout and full size copper foil master pattern. This board is cut in half to form two boards, if using the case specified.



It is always preferable where possible to test a new project in stages, to minimise chances of catastrophic damage and simplify location of any faults which may be present.

Before starting to test this project, all connections between the boards and controls should be completed, temporarily if preferred, except those to the rotary switch S1 which should be added afterwards.

The use of coloured ribbon cable, though not essential, makes for a neater job and reduces risk of error. The interwiring connections are shown in Fig. 5. Note the lead between the "common" point on VR1 and its case, to reduce hum pick-up. If the board is not cut, the power rails will be unnecessary. None of the i.c.s should be plugged in yet.

TESTING

If a 9V supply is connected to the project with a milliammeter in series the drain, following a brief initial surge, should be around 1.3mA to 1.4mA. Any obvious deviations from this figure should be investigated before progressing further.

If all seems well, IC7 can be fitted and power reapplied. This will raise the consumption to about 3.5mA. The voltage on pins 1 and 7 of this i.c. should be half the supply, or about 4.5V.

If the headphones are plugged in a fair amount of hum will probably be heard, especially if volume control VR1 is turned up. Touching the top ends of the volume control sections should produce loud hums on the corresponding headphone. Following this test, the volume should be turned right down.

The next stage is to fit IC4, IC5 and IC6.

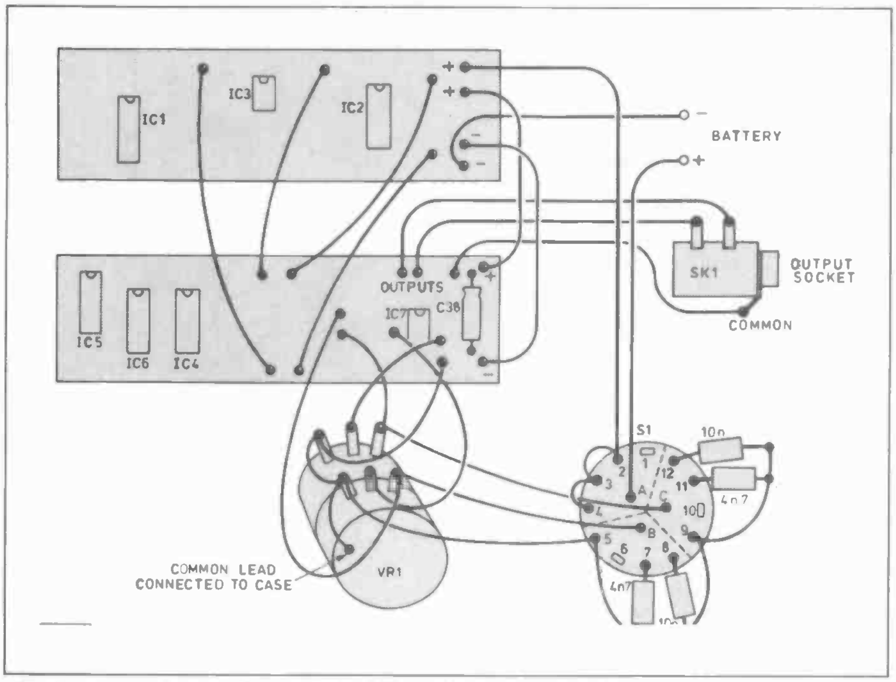


Fig. 5. Interwiring to the boards, VR1, JK1 and switch S1.

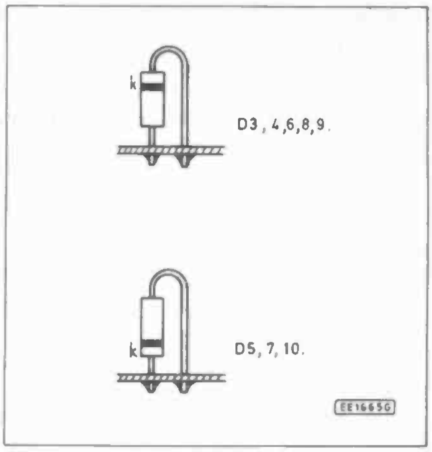
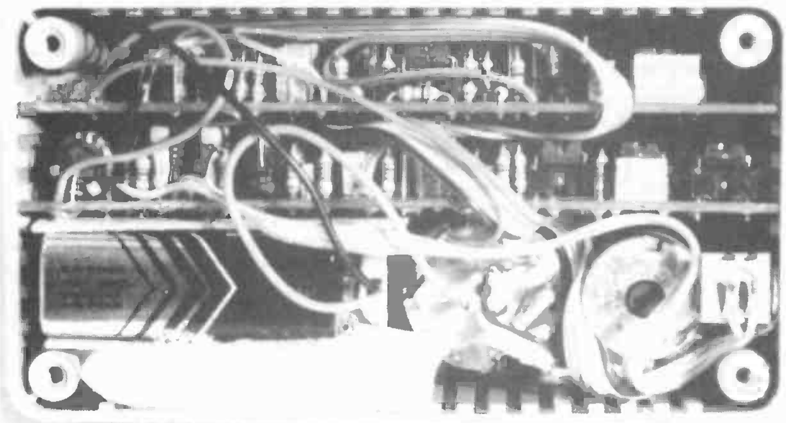


Fig. 4. Polarity guide for mounting the diodes on the p.c.b.



Close "packing" of components inside the case. Note that the volume control should be mounted and wired before mounting the output socket.

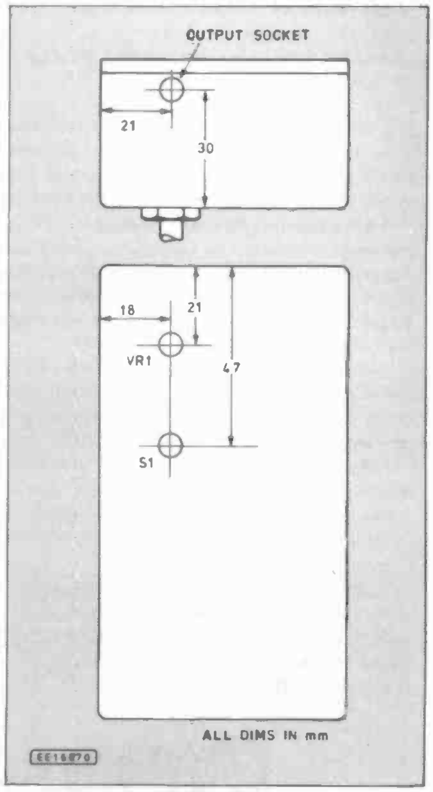


Fig. 6. Case drilling details.

This will raise the drain to about 7mA. IC4 pin 4 and IC6 pin 9 should, if tested for d.c. voltage, show about half the supply. These are the outputs and if they are operating correctly this will be their average level. If there appears to be a problem, a check on IC4 pin 10 should show about half the supply voltage, indicating that the clock oscillator is running.

Fitting IC3 will increase the current to 7.7mA. IC3 pins 1 and 7 should be switching from 0.5V to 7.5V and back very slowly, about every 20 to 30 seconds. These provide a small amount of drive to the diode attenuator circuits, so if the volume is turned up a little the output sounds should be heard whilst they are positive.

If IC1 is now plugged in the current taken will start to vary slightly with oscillator action. Pin 4 of IC1 should be clocking up and down at about 10 seconds per cycle, whilst pin 10 and pin 11 will be normally high, pulsing low about once every 10 seconds as pin 4 goes high.

IC1 on its own will not affect the audio output. Fitting IC2 should, however, result in the full "wave" sounds appearing.

If testing is needed here, pin 3 and pin 4 of IC2 should be normally low but go high for about three to five seconds in every 10 seconds, whilst pins 10 and 11 should also be normally low, going high for about two seconds in every 10 and triggering "waves" as they do so.

The total drain of the complete circuit depends on the output volume, point on the clock cycles etc., but should be around 8mA to 12mA. With an operating current of around 10mA this circuit will operate for long periods from a single PP3 battery.

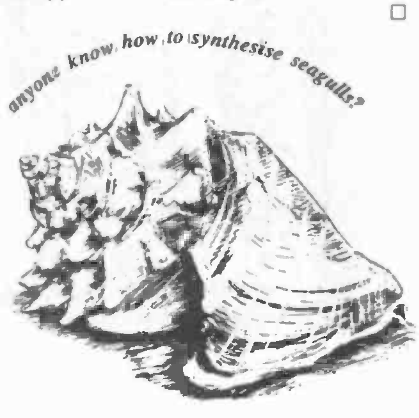
FINAL WIRING

Following satisfactory results of these tests the tone switch S1 can now be wired up. The capacitators C27 to C30 are mounted directly onto the tags of this switch as shown in Fig. 5, with a piece of heavy gauge wire attached to tags 5 and 9 forming their common connection. Three wires connect S1 to VR1.

The drilling details for mounting the volume control, function switch and output stereo jack socket in the case are shown in Fig. 6. The project can now be assembled into the case following the photograph above. The output jack socket should be fitted after the volume control, which in turn will have to be connected before installation.

In the prototype the battery is held by a plastic clip cut from a 35mm photographic slide box and glued into place, with a piece of foam plastic to prevent rattling. The small clearance between parts of this project means there is some risk of parts touching, so check carefully and use small bits of plastic to insulate adjacent items if necessary. On the prototype the presence of the wiring between the boards keeps them apart satisfactorily.

Applications are limited only by the ingenuity of the individual; for stress reduction after (or during) a hard day, as a background for meditation or yoga classes, sound effects for amateur dramatic productions or musical compositions, or simply (with a little imagination) to return to that beach during a winter's evening. Only one thing appears to be lacking . . . . □



Constructional Project

EE TREASURE HUNTER

MARK STUART

A highly developed pulse induction metal locator that has excellent performance for price and is easy to build and set up.

THIS metal detector project is the result of considerable thought and development. It is sensitive and easy to use and, most importantly, it can be assembled and tested without special tools and equipment.

The pulse induction principle is sensitive to both ferrous and non-ferrous metals and does not offer any discrimination between the two. It is relatively insensitive to foil and similar thin conductive items and very sensitive to coins, rings, and other small objects. Larger objects, of course, are easily detectable at considerable depth.

The best aspect of the pulse induction method is that it is virtually free of "ground effect". So much so that it works perfectly well with the search-head under water (including sea water) provided the coil is adequately protected.

The sensitivity of this design is such that a 10p coin can be detected at up to 20cm from the centre of the coil.

DESIGN POINTS

The object of this design was simplicity, and the avoidance of special "close tolerance" components. This has been achieved by using a 40kHz quartz crystal to provide highly accurate timing for all of the necessary pulses in the system. This approach also removes many sources of jitter and background noise and so allows stable highly sensitive performance.

The use of a power MOSFET to drive the coil also helps to simplify the circuit. It can be driven directly from a standard CMOS gate and has a very low "on" resistance, a high voltage rating and also is able to switch rapidly between on and off. Such devices are almost ideal to work with especially as they are very forgiving, easily withstanding short overloads.

The final aspect of the circuit design is the use of a simple voltage converter to provide a higher voltage than the battery (the boost supply). This allows the pulse amplifier i.c. to work with both of its inputs at the battery positive supply level, and also provides a higher drive voltage to the MOSFET.

HARDWARE

A full set of hardware is available for this detector, and provides a good looking, well balanced design at a reasonable price.

Other housings may be used and providing the coil is wound correctly the detector will work well. The search head must not have any metal parts within 60cm as this will be detected and reduce the sensitivity to wanted objects.

PULSE INDUCTION PRINCIPLE

The pulse induction or P.I. method of metal detection works by subjecting objects to a rapidly changing magnetic field. The field is first produced electromagnetically by switching on current to the search coil. The field is then forced to change very rapidly by switching off this current. As the field decays it induces a voltage back into the coil and also into objects near the coil.

Poor or non-conductive objects near the coil are unaffected. In conductive items however, a current flows producing a small magnetic field which opposes the decay of the original field. This opposing field means that when detecting metal objects the magnetic field around the search coil falls more slowly than it does without metal objects. The voltage in the search coil is produced by the falling magnetic field and so changes in the presence of metal.

An exaggerated view of the search coil voltage, measured at point B of the circuit diagram (Fig. 2) for one complete pulse is shown in Fig. 1. Initially TR1 is on and the coil current is building up from the battery. When TR1 turns off the voltage at point B flies to a very high voltage as the magnetic field around the coil falls rapidly. After a time the field has fallen almost to zero and the voltage across the coil also falls. Note that as point A of the coil is held at +9V, point B will also end up at +9V when the voltage across the coil is zero.

The dotted section of the curve shows how metal near the coil reduces the rate of decay of the field so that the coil voltage is higher when metal is being detected. The scale of the voltage waveform has been stretched for clarity, and in fact the change detected is much less than one millivolt at the limit of detection. This must be detected following a pulse of over 400V!

CIRCUIT-OSCILLATOR

The full circuit diagram for the EE Treasure Hunter is shown in Fig. 2. Crystal oscillator IC1c provides an output of 40kHz which is the master clock. Resistor R6 provides d.c. bias for IC1c, and R5, C4, and C5 provide the correct feedback conditions for X1 to resonate correctly.

The output from the clock drives transistors TR2 and TR3 via resistor R4. These devices are connected as a complementary output stage and produce a 40kHz square wave that is coupled via capacitor C3 to rectifiers D3 and D4 to produce an additional seven volts which is added to the battery positive supply. This boosted supply voltage is smoothed by capacitor C2 and used to power IC1, IC2 and IC4 directly and IC3 via additional decoupling components R11 and C7.

The 40kHz output from IC1 also drives the multi stage divider IC2. This i.c. consists of a series of divide-by-two stages the first of which is driven by an input to pin 10 and all of which can be reset simultaneously by a positive level on pin 11.

Two outputs from the chain of dividers are combined via IC1b and inverted by IC1a to produce a reset pulse. The two outputs are after 4 stages and 9 stages of division representing time intervals of 200 microseconds and 6.4 milliseconds. They are combined in such a way that a 200 microsecond pulse is produced after 6.4 mil-

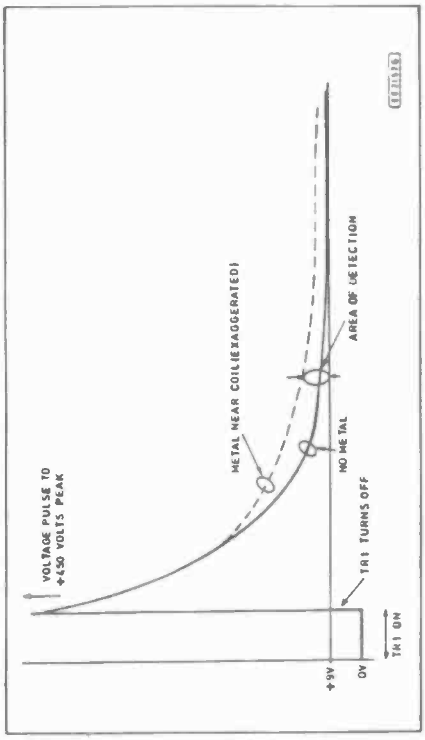


Fig. 1. Search coil voltage waveform, measured at point B on the circuit diagram.

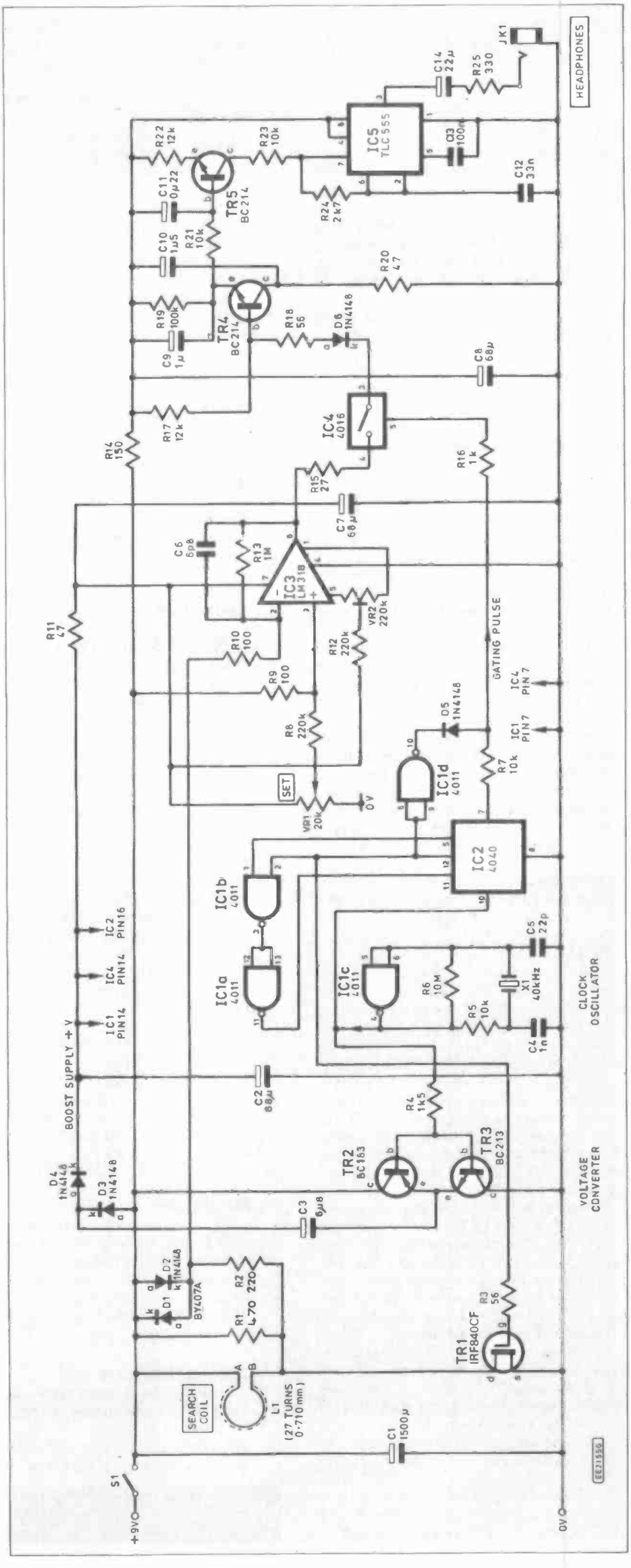


Fig. 2. Complete circuit diagram for the EE Treasure Hunter. Note that the headphone socket (JK1) should be a stereo type.

liseconds whereupon the dividers are reset and the cycle repeats. This pulse output appears at pin 12 of IC2 and is used to drive the MOSFET TR1 via R3 directly.

DETECTION

The pulses produced across the coil L1 have been discussed earlier. Resistors R1 and R2 provide loading for the coil so that the voltage pulse does not "backfire" into TR1, and also that the coil does not act like a tuned circuit and "ring" with its own self capacitance producing an undesirable a.c. waveform. Diodes D1 and D2 clip part of the coil voltage passed via R2 and so limit the voltage swing which is passed to the amplifier IC3 to one volt.

The diodes are of different types because D2 has to handle only 50mA during the time that TR1 is turned on, whilst D1 must handle 3A peaks from the coil as TR1 is turned off. This clipping only affects voltages from the coil above one volt, it leaves the low level area of interest completely intact.

After clipping, the coil pulses are fed via R10 to IC3. This is an extremely fast op-amp i.c. which is particularly suited to the amplification of pulses. It has a very high "slew rate" which is a measure of the ability to change its output voltage at a fast rate and so reproduce pulses accurately. In this circuit it is connected as a standard inverting amplifier with feedback via R13 and C6. The non-inverting input is taken from the positive supply via R9 so that the output is biased correctly with its output at the battery positive supply.

Two controls around IC3 allow the output voltage to be adjusted. Preset VR2 is the standard "offset null" control and is used to set the output of the i.c. to "zero" when its inputs are conneected to the same point; potentiometer VR1 provides a means of unbalancing the circuit to allow the output to be set manually. This is used to set up the detector in operation to produce an audio signal to the preferred pitch.

ANALOGUE GATE

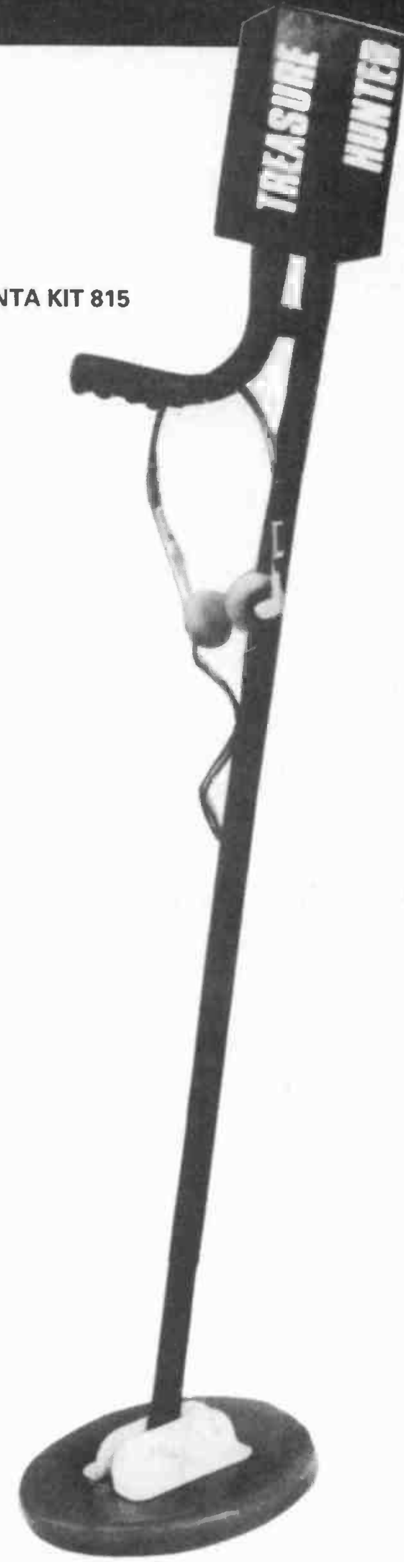
The output from IC3 is a clipped and inverted version of the coil voltage. The next step is to separate the part containing the low level wanted signal from the preceeding relatively high pulse. This is achieved by means of the analogue gate IC4. This is a switch which can be opened by applying a voltage to its control pin. This control voltage is derived from IC2 via IC1d, D5, and R7 and consists of a pulse which is timed to open the switch just as the output from IC3 approaches "zero" (zero in this circuit is the positive battery supply).

The pulse is timed at exactly 50 microseconds after TR1 turns off. At this point the switch is opened and the output voltage from IC3 passes via R15, D6, and R18, and is rectified by the base-emitter junction of TR4 so that C9 is charged to the peak level. This is a negative peak of course because IC3 is an inverting amplifier.

The use of a transistor as a rectifier in this way is necessary because in order to reach the peak value, C9 must charge very quickly indeed. The current gain of TR4 adds to the base-emitter current so that most of the charge in C9 is provided via R20 so reducing the loading on the output of IC3.

The time constant of C9 and R19 is 100mS, this is long enough to change very little between pulses and short enough to

COMPONENTS



MAGENTA KIT 815

Resistors

R1	470 2W carbon film 5%
R2	220 2W carbon film 5%
R3, R18	56 (2 off)
R4	1k5
R5, R7, R21, R23	10k (4 off)
R6	10M
R8, R12	220k (2 off)
R9, R10	100 (2 off)
R11, R20	47 (2 off)
R13	1M
R14	150
R15	27
R16	1k
R17, R22	12k (2 off)
R19	100k
R24	2k7
R25	330

All 0.25W 5% carbon film except R1 and R2

Potentiometers

VR1	20k rotary, lin
VR2	220k skeleton preset, vertical

Capacitors

C1	1500µ radial elect 10V
C2, C7, C8	68µ radial elect 16V (3 off)
C3	6µ8 radial elect 16V
C4	1n ceramic plate 50V
C5	22p ceramic plate 50V
C6	6p8 ceramic plate 50V
C9	1µ radial elect 10V
C10	1µ5 radial elect 10V
C11	0µ22 radial elect 10V
C12	33n polyester 100V
C13	100n ceramic disc 50V
C14	22µ radial elect 10V

Semiconductors

D1	BY407A
D2-D6	IN4148 (5 off)
TR1	IRF840CF power MOSFET
TR2	BC183 *npn* general purpose
TR3	BC213 *pnp* general purpose
TR4, TR5	BC214 *pnp* high gain (2 off)
IC1	4011B CMOS quad NAND gate
IC2	4040B binary counter
IC3	LM318 high slew rate op-amp
IC4	4016B quad bilateral switch
IC5	TLC555 CMOS 555 timer

Miscellaneous

S1	s.p.s.t. min toggle switch
JK1	panel mounting stereo 3.5mm jack socket

6×AA battery holder and clip; 20m of 0.71mm enamelled wire; p.c.b.; Paxolin panel to form battery compartment; p.v.c. tape and sleeving; i.c. sockets — 2×8 pin, 2×14 pin, 1×16 pin; 7/0.2 connecting wire 0.5m; case 150×100×50mm; control knob; fixings and suitable headphones.

Special Hardware

Search head moulding; search head reinforcing plate 100×150mm; 1m×20mm dia. plastic shaft; right angle bend 20mm plastic; plastic angle 2×100mm 25/25mm; handgrip 20mm; 2×threaded end couplers 20mm; 2×saddle clips 20mm; 6×M4×10mm nylon screws and nuts; M5×50mm nylon screw and wing nut with captive washer.

respond rapidly as a piece of metal is swept into and out of range.

To reduce the number of components in the circuit, the gating pulse logic is simplified by allowing more pulses to follow the initial one. This is not a problem because the signal voltage decays after the first gating pulse and so subsequent gating pulses pass levels only below the peak already stored thus having no efect.

AUDIO

The final part of the circuit is the audio oscillator section, this is a conventional 555 circuit except that the charge circuit for the capacitor C12 is not a resistor but a transistor TR5. TR5 is driven from the peak detector TR4 via a low pass filter consisting of R21 and C11.

Large pulses cause TR5 to turn on more and so C12 charges more quickly and the output pitch rises. This arrangement is at its most sensitive for the lowest pulse levels and so provides the ideal characteristic for sensitivity.

The output from IC5 is fed directly to a pair of personal stereo headphones via C14 and R25. The two earpieces can be connected in series by connecting to the tip and ring connections of the 'phones. This is more efficient than parallel connection and although the earpieces are then connected in antiphase this does not seem to matter in this type of application.

CONSTRUCTION

All components are mounted on a single printed circuit board (available from the *EE PCB Service*, code E652). Fig. 3 gives the component layout and the foil pattern, this is a compact board and so must be assembled with care. Before assembly it is wise to check that the board will fit into the guide slots of the case, and that all holes are clear.

Begin by fitting the resistors, diodes, and four wire links. Be careful to get all of the diodes the right way round with their cathode marking bands as shown.

Next fit sockets for the i.c.s and the smaller capacitors. Note that all of the electrolytic capacitors must fit the right way round. They are usually marked with a string of "–" signs down the side by the negative lead.

Depending on their size it may not be possible to get all of the capacitors flush to the board. This does not matter however, as the leads are generally thick and will support them well above the board.

Now fit the transistors, being careful to identify the different types and insert them the right way round; TR1 has a metal side which is shown as a thick line on Fig. 3. Take care with resistors R1 and R2 as these are large and must be mounted on end exactly as shown. A length of sleeving over the upper lead is advisable.

The crystal X1 should be fitted with care, its leads bent gently over, and its body glued to the board with Evo-Stick or similar. It can go either way round.

Larger components such as VR2 and C1 should be fitted last. Wires to the headphone jack, VR1, and the battery clip and switch should be connected directly to the board by stripping a short length of insulation from one end of the leads and passing the bared wire into the board from the component side and soldering it on the reverse.

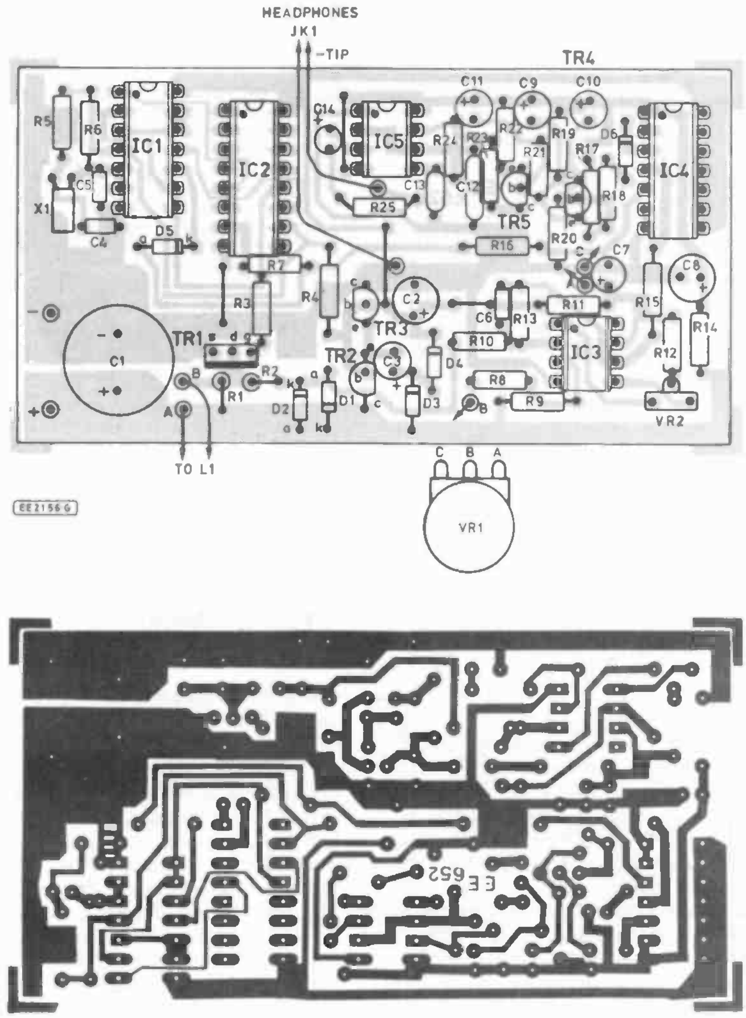
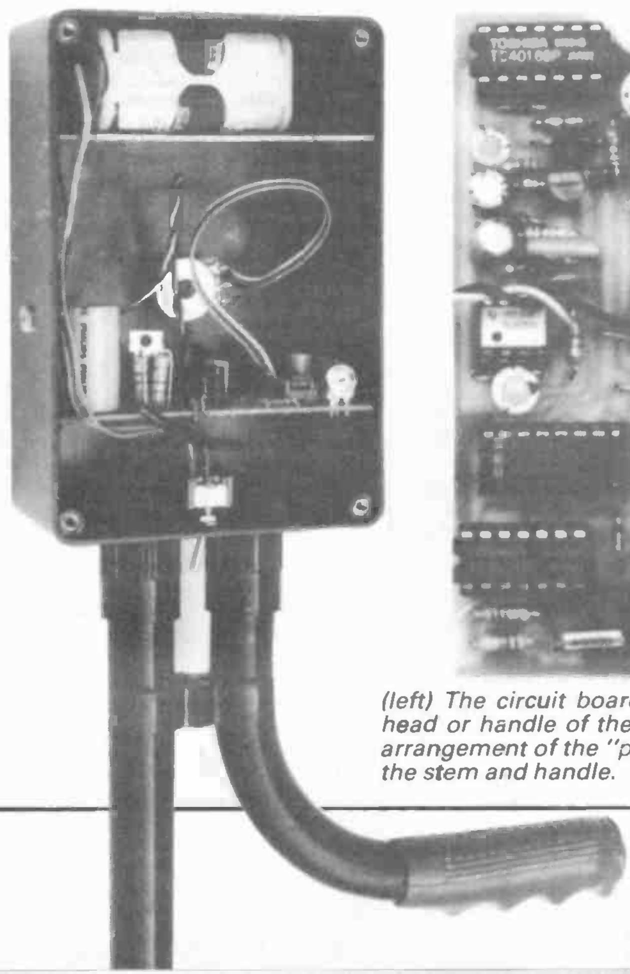
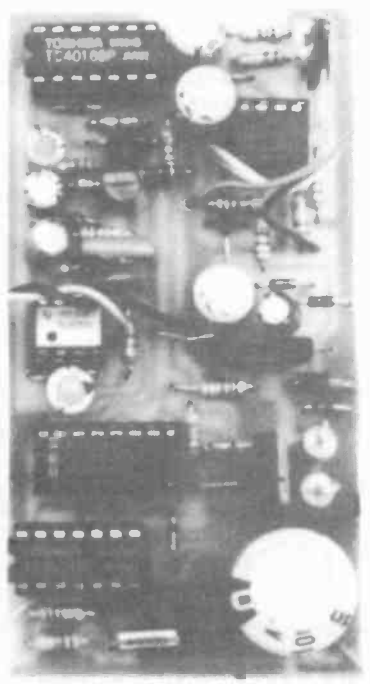


Fig. 3. Printed circuit board component layout and full size copper foil master pattern. The completed board is shown in the photograph below right.





(left) The circuit board slotted into the head or handle of the detector and the arrangement of the "plumbing" to form the stem and handle.

SEARCH COIL

The winding of this coil is not difficult but the size and number of turns are critical. There must be 27 turns, each single turn being a loop from start to finish. This sounds obvious but it is surprisingly easy to misinterpret "one turn" especially the first and last ones.

To make a coil former all that is required is a piece of wood upon which a 190mm circle can be drawn. A veneered chipboard offcut is ideal. Use 16 panel pins or other small nails fitted with a 10mm length of sleeving and space them equally around the circle as shown in Fig. 4. The winding wire should be 0.71mm diameter enamelled copper and 20m long, leave a free length of 1.5m and carefully wind 27 turns around the pins.

It is not necessary to neatly layer the winding, as it will finally be bunched into a circular section. Secure the ends with p.v.c. insulating tape and then carefuly slip short lengths of tape under the windings between the nails and fasten the ends together. Fit eight pieces of tape like this, then remove the winding from the board, either by bending or removing some of the pins. The result should be a neat coil that can now be bound with a spiral of tape to completely enclose it.

The start and finish of the winding must leave the binding at the same point and should be sleeved together with a 1m length of p.v.c. sleeving. The end 30mm of the sleeving should be bound to the coil and the whole coil can then be given a further two layers of binding.

The coil is now suitable for most applications without further protection. There are numerous possibilities for complete waterproofing, but dipping the coil in varnish and allowing it to dry is probably the simplest way. Several coats can be applied and apart from the drying time the method is convenient and effective. The final appearance of the coil should be tidy if it has been carefully made, but this is not important as it will rarely be seen.

TESTING

Before connecting the coil, it is possible to check some parts of the board for correct operation. Connect a set of headphones and a 9V supply preferably from six AA cells in a battery holder. Set both controls to mid position and switch on. A tone or clicking sound should be heard. Turn VR2 carefully until the tone becomes a steady clicking sound, and then check that VR1 has a similar but finer control over the pitch. Those with a multimeter can check that the voltage across C2 is approximately 16V and can set the output of IC3 to 9V (the battery supply voltage) using VR2, with VR1 set to mid position.

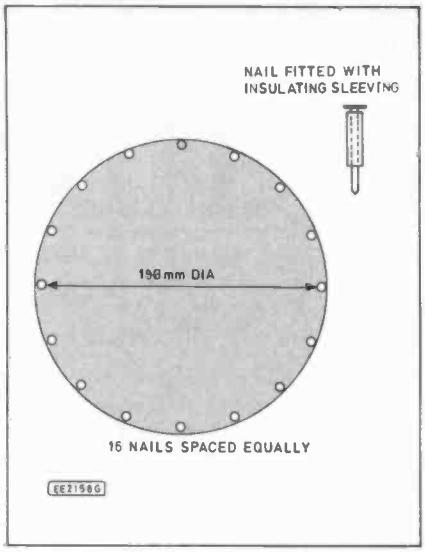


Fig. 4. Making up a search coil template from a piece of wood with insulated panel pins nailed around the circumference.

Connect the coil to the board (either way round) and position the coil on a cardboard box well away from any wiring and large metal objects. Note that as enamelled wire is used the thin coating must be scraped or melted from the wire ends before soldering. If a solderable enamel is used the wire can be tinned directly by applying solder and heat from the iron.

Leave sufficient wire on the coil leads to allow the p.c.b. to be slid out of the box, and for the search head to be folded down. Once the coil is connected it should now be possible to set the circuit for a steady clicking noise which increases as metal is brought near. There may be a slight warble or rise and fall in pitch due to mains wiring in the area (not a problem when in use).

By setting the circuit for very slow clicks it is possible to get the maximum sensitivity. Move a 10p coin near and the clicking rate should rise at good distances. Note that metal rivets in the cardboard box and jewellery on the hands of the tester will be detected as well—metal chairs make themselves known from over a metre away.

A large object near the coil will produce a rather harsh sounding high pitched note. This is breakthrough of the very large pulse signal to the output. In normal situations this is unimportant as smaller signals are normally being sought.

The current consumption is around 80mA giving a good day's use from a fully charged set of AA NiCads and much longer from alkaline cells.

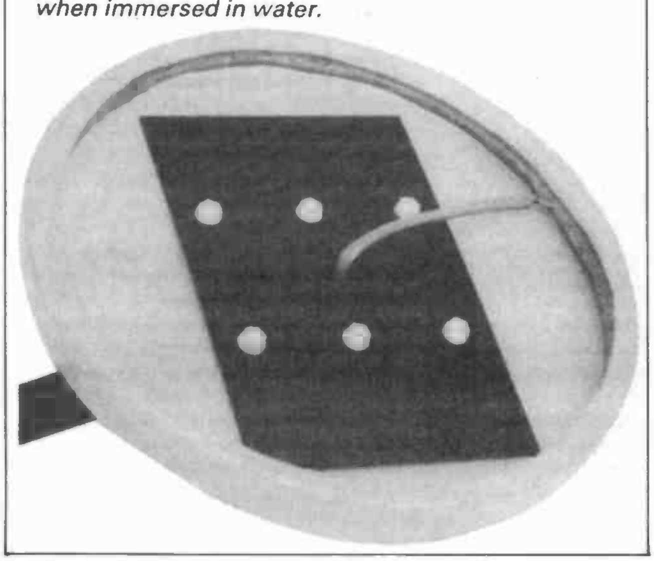
HARDWARE CONSTRUCTION

As discussed before the hardware can take many forms. The printed circuit board has been made to fit the guide slots in the specified case, but other cases could be used. It is important to get the mechanical balance of the detector right and this is achieved by fitting the handle some way between the electronics box and the search head. The batteries are a particularly good counterbalance and are fitted as far back as possible in the prototype and held in place by a panel slotted into the housing.

The detector head can be made from any plastic material and fixed to the shaft using plastic angle and plastic nuts and screws. The prototype used a special moulding for the head and 20mm plastic tubing and fittings for the shaft and handle, plus a bicycle handgrip. A wing nut allows the head to be swivelled flat for easy transit. Wood could be used but the weight is rather a problem after an hour or two's use. School CDT departments will no doubt be able to go to town on this project and produce wonderful results.

For the "kitchen table" constructors a full set of hardware (undrilled) as used in the prototype and pictured here is available from Magenta. □

The search coil is inserted in a small recess around the plastic search head. The cavity of the search plate can be filled with a resin so that it can be used when immersed in water.



Mounting the detector stem to the search coil is accomplished by using nylon brackets, nut, bolts and wing nut. Metal fixings MUST NOT BE USED.

MINI STROBE

MARK STUART

An ultra bright project with many illuminating applications

A STROBOSCOPE is a device which produces very brief flashes of light at pre-determined intervals. Most people will be aware of the "strobe" effect used as part of a disco light show. Also, the strobe light used for setting the speed of record player turn-tables gives a very good demonstration of how a moving component can appear stationary.

The strobe light is provided by an l.e.d. which is powered from unsmoothed bridge-rectified mains and so flashes on and off at 100Hz. Marks around the turntable are spaced so that at the correct speed the turntable moves by exactly 1 mark between flashes. The marks are identical and so it appears that they are stationary. If the turntable runs slightly fast or slow, the next mark is not quite in the same position as the last and so the mark appears to be moving slowly forwards or backwards.

Another common use is the "timing strobe" which produces a short flash of light synchronised to the firing of a spark plug in a petrol engine. A small timing mark on the crank shaft pulley is illuminated each time the spark plug fires. As the pulley is in the same position each time the light flashes, it appears to be stationary. The position of the timing mark relative to a fixed pointer on the engine indicates the ignition timing.

FREEZE ACTION

The most important feature of stroboscopes is that they enable fast moving machinery to appear apparently stationary or running in slow motion. If the light flashes are in exact synchronism with the mechanism being observed it appears to be stationary. If the flashes are slightly out of synchronism the mechanism will have moved by slightly more than one full cycle between flashes and so appears to be moving slowly forward. By observing the behaviour of machines in this way designers are able to study and control effects such as vibration which only occur when running at speed.

A good stroboscope needs to be able to produce very short, very bright flashes of light. If the flashes are not short the moving parts being examined will move significant amounts during the flash, and so will appear blurred.

The flashes need to be bright because the parts being examined are only lit for a fraction of the time. The eye averages the flashes and perceives an average light level which is much less than the level during the flash.

The light source which produces the flashes must be driven from an oscillator, the frequency of which can be varied to match the speed of the mechanism being observed. A facility to synchronise the oscillator to the mechanism is useful as it enables very precise timing of the flashes, giving a sharp, stable image.

LIGHT SOURCES

The best light source for generating flashes is a Xenon tube similar to those used in photographic flashguns. A good stroboscope using Xenon flash tubes can be expensive to build because the tubes need high voltages and heavy duty capacitors. Neon lamps and standard l.e.d.s can also be used to produce short flashes of light but are not very bright.

Recently a range of very bright "ultra bright" l.e.d.s have become available. The brightness of these has to be seen to be appreciated. Their brightness, and their ability to be flashed at high speed makes them ideally suited for use as stroboscope light sources. As l.e.d.s require low voltages

COMPONENTS

Resistors

R1	10k
R2,R4	47k (2 off)
R3,R5	470 (2 off)
R6	100
R7	1k
R8	270
R9,R11	220 (2 off)
R10,R12	27 (2 off)

All 0·25W 5% carbon film

Potentiometer

VR1	470k (front) 4k7 (rear) dual reverse log

Capacitors

C1,C4	100n poly C368 (2 off)
C2	1µ poly multilayer 100V
C3	1n ceramic plate
C5,C6	47µ elec radial 16V
C7	220µ elec radial 16V

Semiconductors

TR1	BC183 npn silicon	
TR2	BC213 pnp silicon	
IC1	555 timer	
D1,D2	1N4001 silicon	
D3,D6	HLMP3750 Red (2 off)	Ultra-bright l.e.d.s
D4,D7	HLMP3850 Yel (2 off)	Ultra-bright l.e.d.s
D5,D8	HLMP3950 Green (2 off)	Ultra-bright l.e.d.s

Clips to suit above (6 off)

Miscellaneous

SK1	3·5mm jack socket
S1	DPDT centre off slide switch

B1 12V (made up from two sets of four HP7's); PP3 type battery clips (2 off); 2 × 2 battery holders; Veropins (10 off); 8-pin i.c. socket; case; connecting wire; printed circuit board.

MAGENTA KIT 529

to operate it is possible to produce a useful stroboscope at low cost and with simple circuitry.

The Mini Strobe described here was designed on these principles. It is ideal for demonstrating stroboscope principles and operation. It produces a useful amount of illumination over short distances in daylight and becomes very effective under conditions of subdued light.

The flash rate is variable from 170 to 20,000 flashes per minute in two ranges. A socket is fitted so that the flash rate can be synchronised to an external source of pulses if required. When accurately calibrated the Mini Strobe can also be used as a tachometer to measure the speed of rotating parts.

CIRCUIT DESCRIPTION

The circuit diagram of the Mini Strobe is shown in Fig. 1. A standard 555 timer i.c operating in the astable mode is used to provide pulses which drive the l.e.d.s D3 to D8 via transitor TR2.

The frequency of oscillation is set by the dual potentiometer VR1a/VR1b. This component is unusual in that its two sections are of different values and are of the "reverse log" type.

In the astable mode used here the timing capacitor C1 or C2, depending upon the position of the Range switch S1, is charged via VR1a, R4, VR1b, and R5 in series. When the voltage across the capacitor reaches two thirds of the supply the i.c. switches over and the capacitor is discharged via R5 and VR1b. When the voltage has fallen to a third of the supply the i.c. switches back and the charge cycle begins again.

During the charge cycle the output on pin 3 is high so transistor TR2 and the l.e.d.s are turned off. During the discharge cycle the output is low and provides TR2 base current via resistor R7. TR2 is therefore turned on and the l.e.d.s are lit.

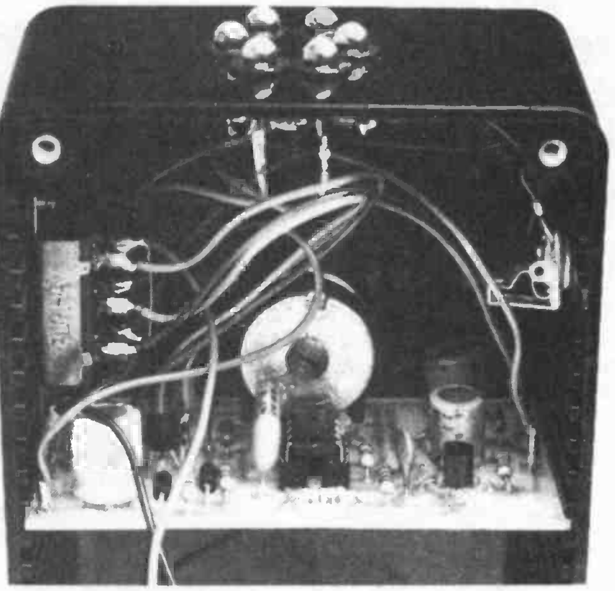
The values of VR1a and VR1b are such that the charge time is 100 times larger than the discharge time. This means that the l.e.d.s are lit for just 1 per cent of the time. As the two parts of VR1 share the same spindle the percentage applies regardless of the speed setting. This arrangement means that the l.e.d.s appear to be the same brightness at all speed settings.

The figure of 1 per cent is a compromise between the duration of the flash and the apparent brightness. Shorter flashes give a sharper image to the object being viewed at the expense of apparent brightness.

Capacitor C3 enables transistor TR2 to be turned on and off rapidly so that its power dissipation is minimised. Each l.e.d. has a forward voltage drop of about 2V and so each set of three diodes requires 6V. When TR2 is turned on it drops about 1V, leaving 5V across the current limiting resistors R9 to R12 and capacitors C5 and C6.

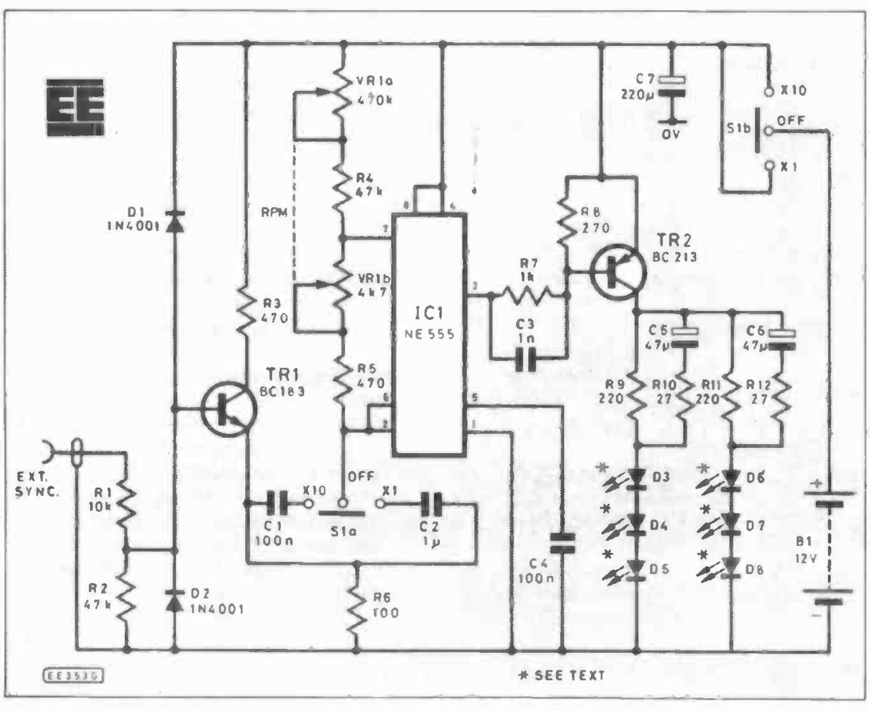
Resistors R9 and R11 provide a current of 20mA to each set of l.e.d.s. The main current path however is via the capacitor resistor networks C5 R10 and C6 R12. The capacitors behave like short circuits to the pulses and so an additional 180mA is passed to the sets of l.e.d.s during the pulses. The l.e.d.s are only designed to take a continuous current of around 40mA so in the event of a circuit fault that turns on TR2 permanently they would all be damaged.

Capacitors C5 and C6 allow the pulses to pass unimpeded but completely block any d.c. that would appear in the event of a fault. In this way the l.e.d.s are completely protected from circuit failure. Note that the 1 per cent pulse to interval ratio means that average l.e.d. currrent is only about 2mA.



Showing the printed circuit board mounted in guide slots in the sides of the case.

Fig. 1. Complete circuit diagram for the Mini Strobe.



EXTERNAL SYNC

Synchronisation of the oscillator to external signals is achieved by applying pulses across resistor R6 which is in series with the timing capacitors C1, C2. A positive pulse which occurs near the end of a charge cycle lifts the capacitor voltage over the two thirds supply threshold and so triggers the discharge cycle.

If the oscillator frequency is set just below the frequency of the synchronising pulses then these will take over and the frequency will be locked in synchronism. It is also possible to synchronise to the harmonics of the incoming pulses, especially if a high level input signal is used. This can be an advantage but must be taken into account when it is desired to lock on to the correct frequency. Synchronising pulses between 1V and 50V a.c. or d.c. can be used.

Diodes D1 and D2 protect transistor TR1 from very high positive or negative input signals. The dual potentiometer VR1 needs to have a "reverse log" law in order to give an evenly graduated scale. Standard linear tracks would give extreme cramping at the high speed end of the scale. S1 is a centre-off DPDT slide switch which enables the range selection and panel on/off functions to be combined.

CONSTRUCTION

The circuit is built on a single printed circuit board and fits neatly into the guide slots of the specified case. The p.c.b. component layout is shown in Fig. 2 and the track pattern (full size) in Fig. 3.

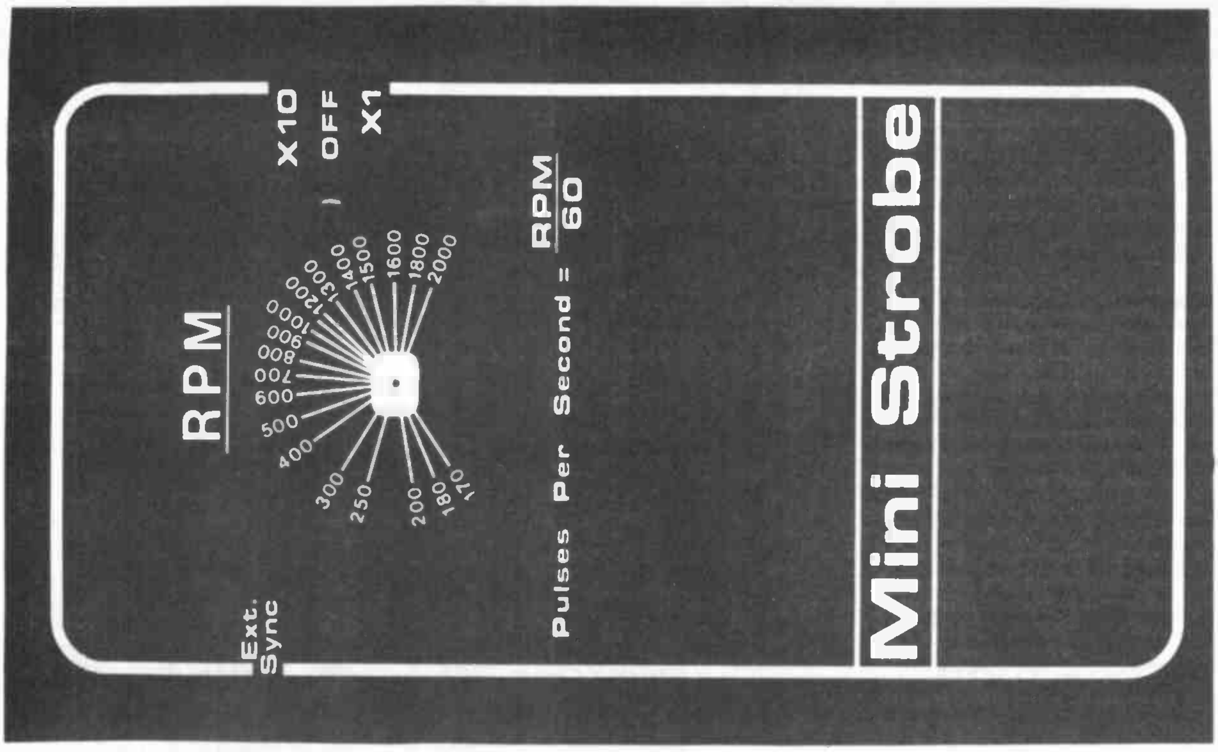


Fig. 5. Full size front panel label used on the prototype unit. This label can be cut out and stuck on the case.

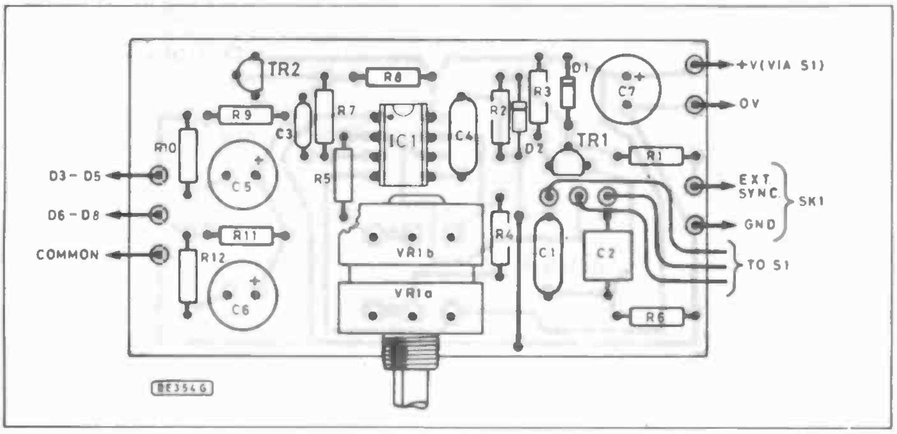


Fig. 2. Component layout on the printed circuit board. The integrated circuit IC1 should be mounted on the board via an i.c. socket.

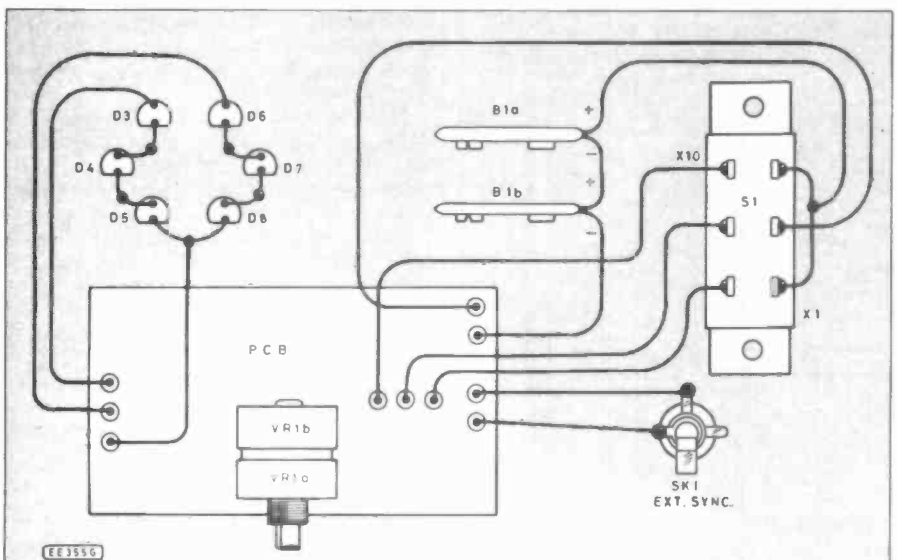


Fig. 4. Interwiring to "off-board" components. Be careful to connect the l.e.d.s correctly, the cathode connection is indicated by a "flat" on the body.

Begin construction by fitting the 10 terminal pins to the board. These should be pushed in from the foil side so that their spined sections engage with the board and then soldered.

Next fit the wire link, the resistors, and a socket for IC1. Then fit the capacitors and transistors. Ensure that capacitors C5, C6 and C7 are fitted the right way round and that the flats on the transistor bodies are positioned as shown. Note that the transistors are not interchangeable.

Complete the board assembly by fitting VR1a, VR1b. The specified potentiometer fits directly to the board. Alternative types may be mounted separately and connected with wire leads.

The board is mounted in guide slots in the case so that the spindle of VR1 passes through the bottom. The "lid" of the case therefore becomes the base. This arrangement is ideal because the batteries can be changed without disturbing any components.

INTERWIRING

The wiring from the board to the other components is shown in Fig. 4. The diodes D3 to D8 are arranged in a circle 18mm diameter. Their polarity is indicated by a flat on the body and a short lead on the cathode side. It is not possible to fit locking rings to the l.e.d. clips because of the thickness of the case. Instead a small amount of contact adhesive can be used.

The slide switch S1a S1b, is mounted in the side of the case and requires a rectangular cut-out for the slider. This can be made by drilling a number of small holes and filing out the corners with a rat-tail file. When the rectangular hole is cut the switch can be used as a template to mark the position of the two fixing holes.

The power supply is made up from two sets of four HP7 batteries mounted in "2 × 2" battery holders.

A full size front panel label is shown in Fig. 5. This can be cut out and stuck on the case. The flash rate or r.p.m. on the scale is from 170 to 20,000, in two switched ranges.

Continued on page 39

DIGITAL CAPACITANCE METER

MARK STUART

Unmarked or obscurely coded capacitors from 1p to 1000μ may be directly read by this unit

SOME multimeters do have a capacitance range but its use is fiddly. Usually a separate a.c. source is required and the capacitor to be tested is connected between the source and the meter which is set to an a.c. current range. A high value capacitor allows more current to flow than a lower value so the capacitance value can be read off a suitably marked scale. The accuracy and range of values that can be read by this method is very limited, and since a.c. is used it is unsuitable for electrolytic capacitors.

In the laboratory capacitance values can be measured accurately by means of an instrument called a 'Bridge'. A Bridge contains a bank of close tolerance capacitors which can be switched in and out of circuit to make up any value. Circuits inside the Bridge allow the unknown capacitor under test to be compared with the value set by the switches. When the two are equal the Bridge is said to be balanced, The value of the internal capacitor and hence the one under test can then be read off from the switch settings.

Bridges are very accurate but since they contain large numbers of close tolerance capacitors they are expensive. They are also slow to operate and can easily be misread.

What is needed is a simple-to-use direct reading capacitance meter which covers a wide range of capacitance values, and gives clear unambiguous readings. It should also be capable of dealing with electrolytic and non-electrolytic capacitors. The design that follows satisfies all of these needs and is a delight to use.

DESIGN OBJECTIVES

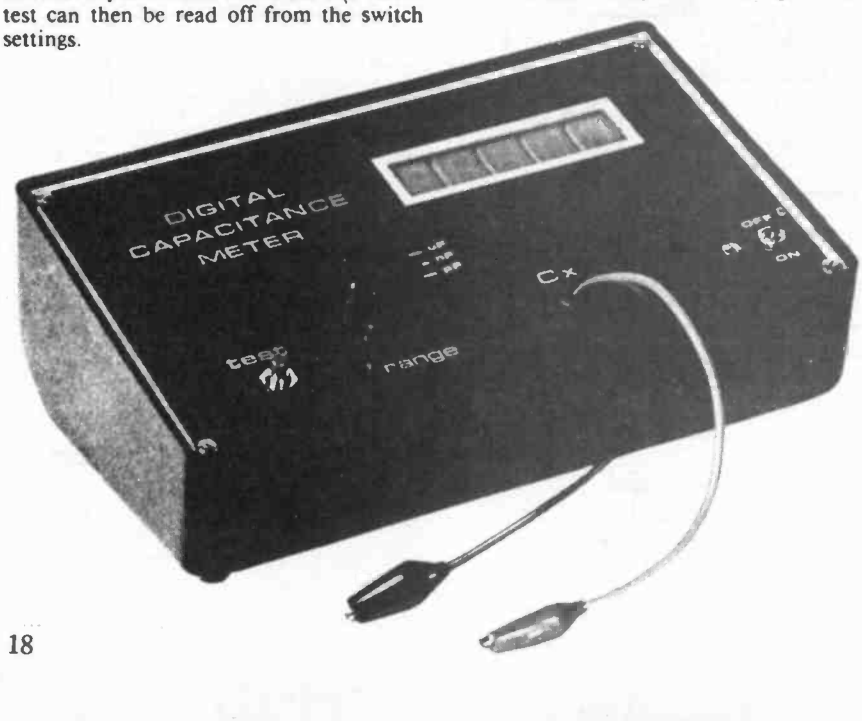
From the start it was decided that the instrument should have a digital display and cover as wide a range of capacitance values as possible. It was considered essential that the circuit should be battery powered with the option of a mains adaptor. Great care was to be taken to ensure that even a novice could read capacitance values without being confused by such things as range multipliers. Finally, setting up of the circuit after construction was to be eliminated if possible.

SPECIFICATION

The final practical design is capable of displaying directly capacitance values from a few pF up to 1,000μF. Values above 1,000μF can also be measured easily by extrapolation. Capacitance values are shown on a five digit l.e.d. seven segment display 0·5″ high. There are three ranges, giving direct readout of pF, nF and μF. The five digit display means that there is a substantial overlap between ranges. The pF range reads from 1pF to 99,999pF. The nF range from 0·01nF (10pF) to 999·99nF. The μF range from 0·01μF to 999·99μF. This overlap may not seem to be needed but it has two big advantages. The first is that it allows all values to be displayed to at least three digits. The second advantage is that values may be read in whichever units are preferred. For example a 100nF capacitor will be displayed as 0·1μF on the μF range and 100nF on the nF range. This facility is particularly useful for beginners who are unsure of the multiplying factors.

The accuracy of the circuit is set by the resistors used in critical areas. Using 1% tolerance components enables capacitors to be measured to the same degree of accuracy.

The use of a quartz crystal for the circuit timebase avoids the need for setting up.



PRINCIPLE OF OPERATION

The principle of operation is simple. The unknown capacitor is charged through an accurately known resistor, and the time taken for the capacitor to charge from zero to a known 'set' voltage is measured. The time is directly proportional to the value of the capacitor.

Fig. 1 shows a simplified block diagram of the whole system.

The monostable circuit controls the charge and discharge of the capacitor under test. It produces an output pulse during the time that the capacitor is charging from zero to half of the supply voltage. This pulse is used to gate the output signal from a stable crystal 'clock' oscillator in such a way that the output from the gate is a burst of clock pulses lasting for the length of the monostable pulse.

The clock pulses passed during the monstable period are counted and displayed on the five digit seven segment display. A large value capacitor produces a long monostable pulse which allows a lot of clock pulses through the gate to be counted. A small value capacitor produces a short monostable pulse and so allows only a few clock pulses to pass to the counter.

By arranging the clock pulse frequency and the charging resistor value correctly the number of pulses counted can be made exactly the same as the capacitance value. In this way a direct read out is obtained.

CIRCUIT

The entire circuit is shown in Fig. 2. The monostable is made up from IC1, TR1, IC3a, b, c and associated components. IC2 provides the clock pulses, and IC4, IC5d and IC6 along with the displays and driver transistors provide the count and display

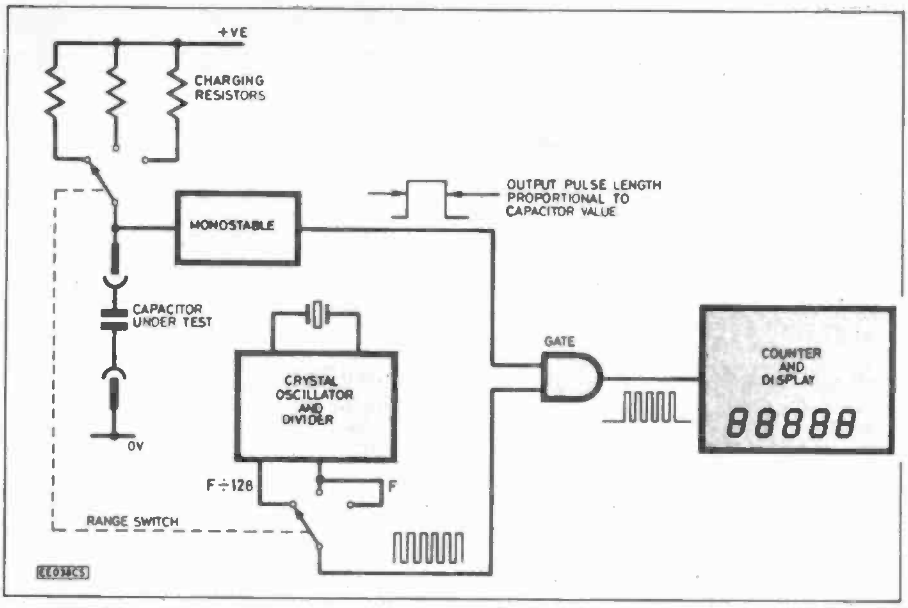


Fig. 1. Block diagram of the Capacitance Meter.

function. IC5a is the gate which takes the monostable and clock signals as inputs and provides the burst of clock pulses at its output which are counted and displayed. IC4b and c are used to provide pulses which trigger the monostable, reset the counter and blank the display. For simplicity each section of the circuit will be described separately.

CLOCK OSCILLATOR

The accuracy of the capacitance meter is determined by the monostable and the clock oscillator. To avoid any setting up procedures and ensure excellent accuracy a crystal oscillator is used to provide the clock signal. The frequency chosen, 3·579545MHz, is that of American colour TV reference oscillator crystals. These are cheap and readily available. IC2 is a very useful CMOS i.c. which contains an oscillator section and several divider stages. Only three external components are needed. Resistor R5 provides d.c. stabilisation and C1 and C2 give the necessary loading capacitance to the crystal.

Two outputs are used, one at the full crystal frequency, and the other after seven divider stages is at 1/128 of the crystal frequency. The lower frequency is necessary on the μF range to avoid having unreasonable charging resistor values in the monostable.

The clock oscillator outputs pass via the range switch S1b to IC5a where they are gated with the monostable pulses.

THE MONOSTABLE

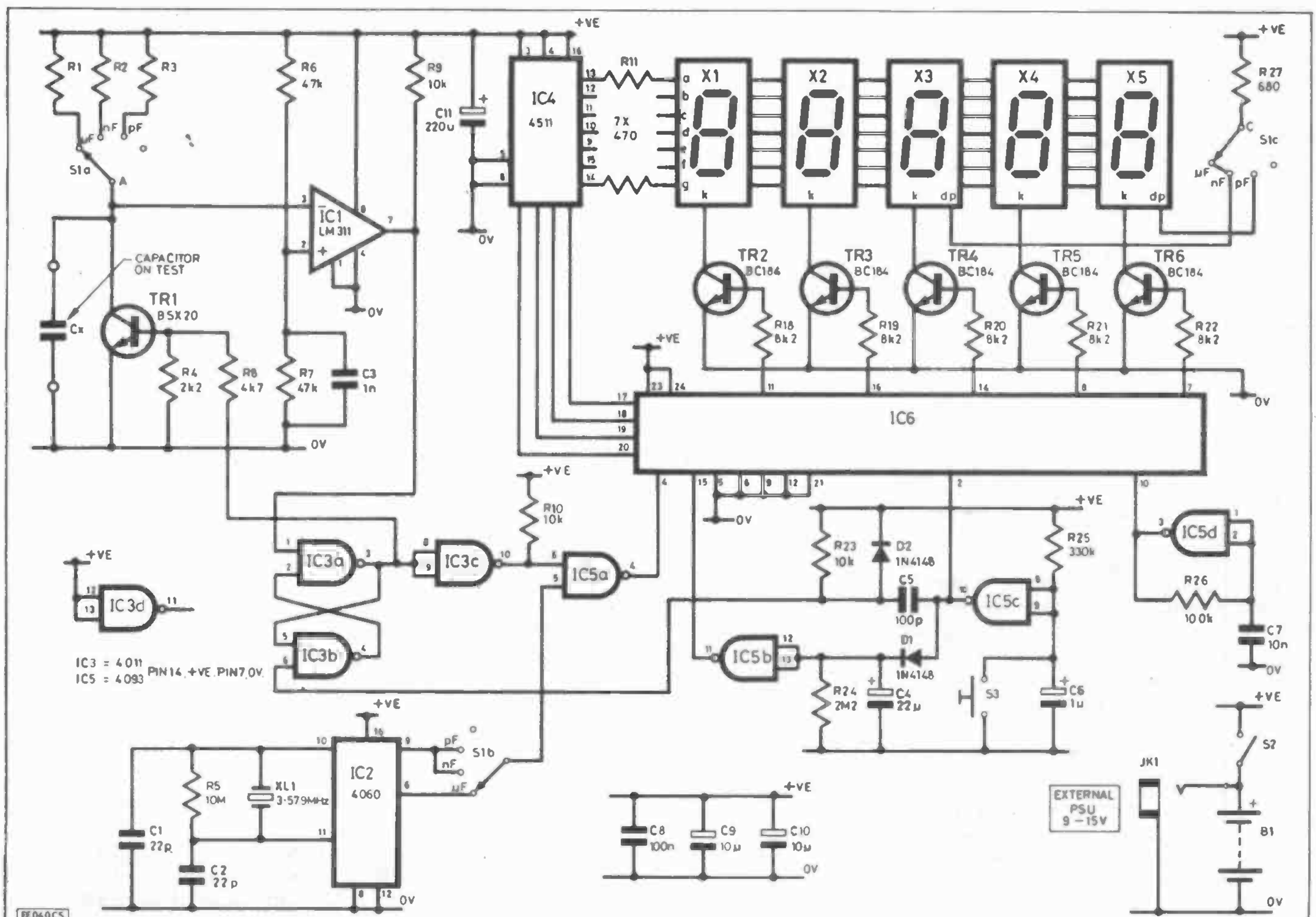
This part of the circuit produces a single output pulse the length of which is determined by the time it takes for the capacitor on test to charge from zero to half supply voltage. It was originally intended to use a 555 i.c. in this part of the circuit, however it was found that pulses shorter than 10 microseconds could not be produced even though the appropriate resistors and capacitors were used. Reference to the data books eventually revealed (in the small print) that the lower comparator storage time can be as long as 10 microseconds. This meant that the 555 would be unsuitable for measuring values much below 200pF in the proposed circuit.

After considering various options it was decided to build a monostable from scratch using individual components.

The circuit operates as follows:

Initially the two inputs to IC3b are high. The output of this NAND gate is low and this is linked to one of the inputs of the other NAND gate IC3a. The output of IC3a is high and so TR1 is turned on by the bass

Fig. 2. Circuit diagram.



current received via R8. Pin 3 of the voltage comparator, IC1, is held low and as this is an inverting input, the output of IC1 is high. To help in understanding the circuit operation the truth table for a two input NAND gate is given in Fig. 3.

To initiate a capacitor measurement S3 is pressed and released. IC5 and its associated components produce a short negative going pulse just under 1 microsecond long which passes to one of the inputs of IC3b.

From Table 1 it can be seen that when either one of the inputs of the NAND gate is low the output must be high. Thus the output of IC3b changes from low to high so that IC3a now has both inputs high. When both inputs become high Table 1 shows that the output of IC3a must change from high to low. This takes the other input of IC3b low holding its output high even when the original negative pulse has passed. The circuit is now stable in this state and would remain there except for the action of TR1 and IC1.

Input 1	Input 2	Output
H	H	L
H	L	H
L	H	H
L	L	H

H = High, or Logic 1
L = Low, or Logic 0

Table 1. Two-input NAND gate truth table.

When the output of IC3a changed from high to low the base drive current was removed from TR1 turning it off. With TR1 turned off the capacitor under test (Cx) charges via whichever of the charging resistors (R1, R2 or R3) is in circuit. IC1 compares the voltages applied to its two inputs. Its output stays high as long as the voltage on pin 2 is more positive than that of pin 3. Pin 2 is held at half supply voltage by means of the bias resistors R6 and R7. As Cx charges the voltage across it steadily rises and when it reaches half of the supply voltage the output of IC1 changes from high to low. The affect of this on IC3a and b is the exact reverse of the affect of the original pulse from IC5c. The timing circuit switches back to the starting condition, with IC3a output high and IC3b output low. TR1 is turned on and Cx is discharged.

The important part of this cycle of events is that the output of IC3a is a negative pulse lasting for exactly the time taken by Cx to charge from zero to half of the supply voltage. This pulse is inverted by IC3c and connected to one input of IC5a. Reference to Table 1 shows that when one input of the gate is high the signal on the other input appears (inverted) at the output. Thus clock pulses are passed via IC5a to the counter during the charge time of Cx.

PULSE COUNTER AND DISPLAY

The train of pulses from IC5a passes to IC6 which contains a five decade counter and multiplexing circuits which enable five seven segment displays to be driven.

The multiplexing works as follows: Each seven segment display consists of seven independent l.e.d.s whose anodes are brought out separately to the pins lettered *a* to *g*. The cathodes of all the l.e.d.s are connected together—hence 'common cathode displays'—and are connected to the pin labelled *k*. The information for each display appears in sequence as a 4 bit binary number on pins 17–20 of the i.c. This is translated to the necessary code to drive the display anodes by IC4. First the number for X1 appears and simultaneously TR2 is turned on via pin 11 of IC6. Thus X1 turns on and indicates the appropriate number. TR3–TR6 are turned off during this time so the other displays cannot be lit. Next the number for X2 appears and TR3 is turned on, TR2,4,5 and 6 being turned off. Then X3 number appears and TR4 turns on and so on. The speed at which this occurs is sufficiently rapid that the eye perceives all of the displays to be continuously lit each with its own particular number.

The multiplexing speed is determined by IC5d which is a simple Schmitt trigger oscillator.

The display decimal points are lit independently via R27 and the range switch S1c. The µF and nF ranges use the decimal point on the centre display whilst the pF range uses the right hand display.

Two other inputs of IC6 are used. Pin 2 resets the counter to zero whenever it is taken high. This occurs each time S3 is pressed. Pin 15 blanks out the display whenever it is taken high and is used to provide a very useful battery saving feature.

DISPLAY BLANKING

When S3 is pressed to test a capacitor the input of IC5c is pulled down to ground. IC5c is an inverter so when its input is low its output is high. During this time C4 charges via D1 and IC5b input is pulled high. The output of IC5b (another inverter) goes low and so the display is turned on. When S3 is released the input to IC5c returns to a high level and its output switches from high to low. This removes the reset condition from IC6 which allows it to count and produces the short negative pulse that initiates the monostable.

The input to IC5b is held high by the charge on C4 so its output is low and the display remains on. C4 gradually discharges via R24 and eventually the input to IC5b becomes low, its output changes from low to high and the display is turned off. The time taken for this to occur is set by the values of C4 and R24 and is about 40 seconds. This allows plenty of time for the display to be read. Since the display takes much more current than the rest of the circuit an automatic blanking feature such as this is a very effective way of reducing the standby current, greatly extending battery life.

CONSTRUCTION

Nearly all of the components are mounted on a single printed circuit board. Fig. 3 shows the component layout and Fig. 4 the track pattern. Before assembling the board it is a good idea to use it as a template to mark the front panel for cutting. Start by drilling a single 9mm diameter for the range switch. Next drill a 3mm diameter hole for a fixing screw in the bottom right hand corner of the board. The display position can be obtained by marking through the display mounting holes with a sharp instrument. These hole positions can then be used as a guide and a rectangle 75mm × 18mm marked around them. The rectangle can be cut out by drilling four corner holes and then using an Abrafile tension file in a junior hacksaw frame. Alternatively rows of

COMPONENTS

Resistors

R1	5k15 (5k 1 + 47R in series) 1%
R2	40·3k (39k + 1k3 in series) 1%
R3	403k (390k + 13k in series) 1%
R4	2k2
R5	10M
R6,R7	47k 1%
R8	4k7
R9,R10, R23	10k
R11–R17	470 (7 off)
R18–R22	8k2 (5 off)
R24	2M2
R25	330k
R26	100k
R27	680

¼W 5% carbon film unless stated

Capacitors

C1,C2	22p ceramic (2 off)
C3	1n disc ceramic 50V
C4	22µ 16V axial electrolytic
C5	100p ceramic
C6	1µ radial electrolytic
C7	10n C280 polyester
C8	100n disc ceramic
C9,C10	10µ 16V radial electrolytic (2 off)
C11	220µ 16V radial electrolytic

Semiconductors

TR1	BSX20
TR2–TR6	BC184 (5 off)
D1,D2	1N4148
IC1	LM311
IC2	4060
IC3	4011
IC4	4511
IC5	4093
IC6	4534
X1–X5	FND500 common cathode seven segment displays (5 off)

Miscellaneous

S1	3-pole 4-way rotary switch
S2	SPST toggle switch
S3	Push to make switch

3·5mm jack socket; 3·579MHz crystal; ½" mounting pillar, and screw and nut; case—sloping style with aluminium top panel 215 × 130 × 47mm (73); printed circuit board; crocodile clips 1 each red and black; extra flexible wire red and black approx 20mm of each; connecting wire; soldercon pins (50); i.c. sockets—1 8-pin, 2 14-pin, 2 16-pin, 1 24-pin; battery holder (2 × 3 HP7); PP3 battery clip; tinned copper wire; knob for S1; red perspex; grommet, etc.

MAGENTA KIT 493

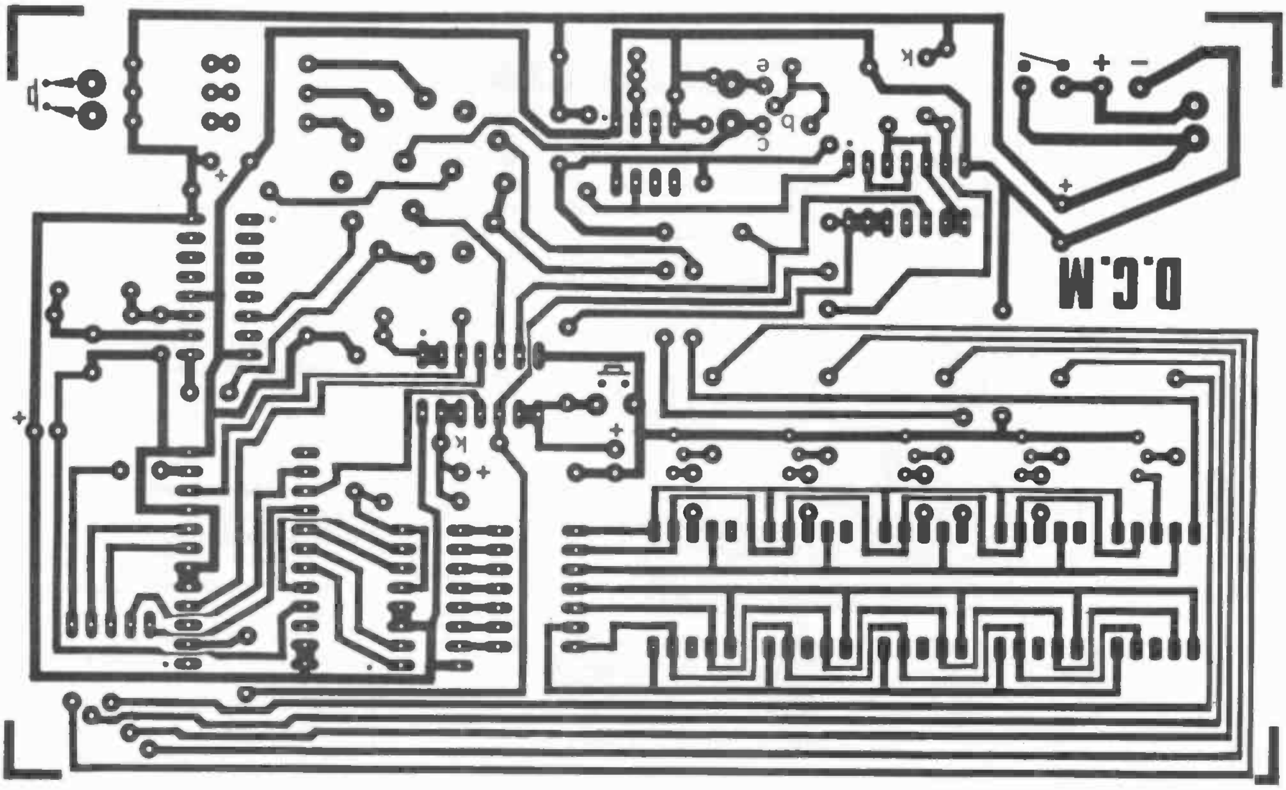


Fig. 3. Printed circuit (actual size).

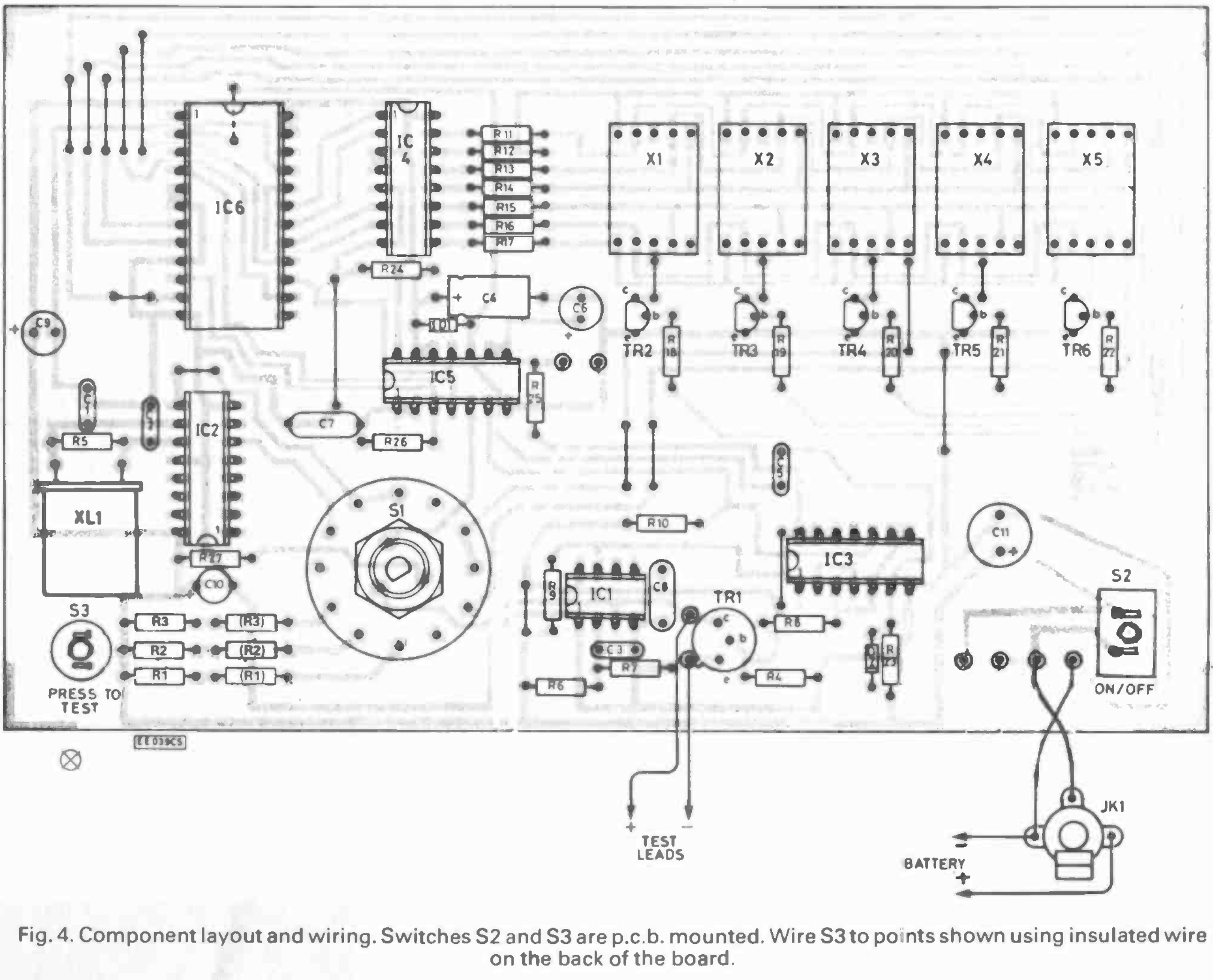


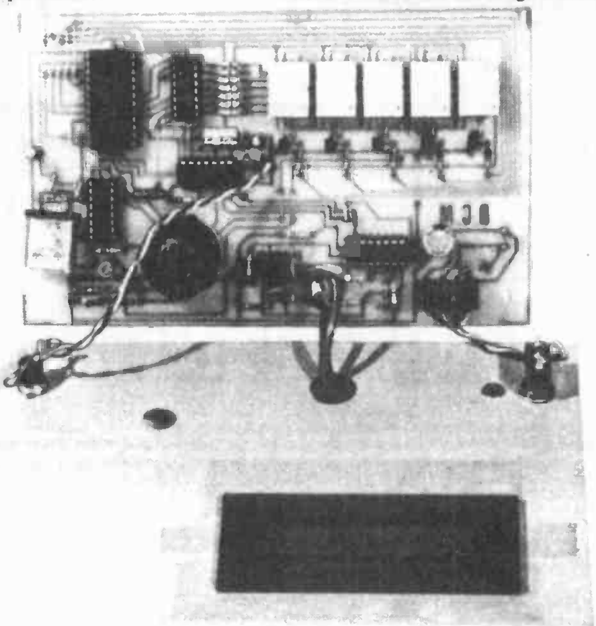
Fig. 4. Component layout and wiring. Switches S2 and S3 are p.c.b. mounted. Wire S3 to points shown using insulated wire on the back of the board.

holes can be drilled around the cut-out, the centre removed and the edges smoothed with a file. With patience and care a very good cut-out can be obtained. Three other holes are needed in the panel.

Two 6mm diameter for the S3 and S2 and one 9mm diameter for the test leads. Position S3 over the lower left corner of the board ensuring that its tags are clear of the crystal and resistors R1, 2, 3. S2 is too deep to mount over the board and should be positioned just beyond the right hand end. The test leads should be brought directly above their point of connection to the board to minimise stray capacitance.

Stranded connecting wire should be used to connect to the off board components. A 3·5mm jack socket is used to connect an external 9–12V d.c. supply if required. The socket should be fitted in the side or rear of the case. When an external supply is connected the internal battery is automatically switched out of circuit by the 'break' contact on the socket.

The test leads in the prototype were made from red and black extra flexible wire 20cm long fitted with small insulated crocodile clips. Longer test leads are not recommended as they add stray capacitance which adds to the readings on the pF range.



The case specified comes with a plastic protective film over the front panel. This should be left in position until all the cutting and drilling is complete.

Start the p.c.b. assembly by fitting wire links in the positions shown. There are 19 of them altogether. Bare tinned wire can be used as there is no danger of short circuits to other components provided the links are straight. Next fit the resistors and i.c. sockets. The displays are mounted using 'soldercon' pins. These are single sockets assembled onto a perforated carrier strip. Cut the strip into ten rows of five pins, and fit each row of five to the board. After the pins have been soldered the carrier strip must be removed by flexing it backwards and forwards until it breaks off. Fit the capacitors, diodes and transistors next, taking care that C4, C6, C9, C10, C11, D1, D2 and all the transistors are the right way round. The crystal leads should be carefully bent 90° whilst supporting the part around the glass seals with pointed nose pliers. A small piece of double-sided tape should be used to secure the crystal can to the board. Eight terminal pins should be fitted to take the connections to S3, S2, the battery and the test leads. Single sided veropins are ideal, inserted from the track side of the board, pressed fully home so that the splined part of the pin engages with the board material and then soldered. Considerable force may be required to push the pins fully home. S1 is of a type normally supplied with solder tags, these tags can be adapted to suit printed circuit board mounting by cutting off the broad looped section at the end of the tag leaving about 6mm of straight lead. The switch will fit in three ways, the correct one being with the spindle flat as shown in Fig. 4 with the switch in its fully anti-clockwise position.

The circuit is now ready for the i.c.s and displays to be fitted, after which it can be tested. After testing a red perspex window 100mm × 25mm should be fitted on the rear of the panel by means of double-sided adhesive tape. Stick the tape to the panel first and then press the window into place.

The board is fitted to the panel by means of S1 at one end and with a countersunk screw with a 12mm spacer and nut at the other end. If S1 has a plastic locating 'pip' this should be removed and the locking washer should be discarded. Only three positions out of four are used on the switch. The switch rotation is limited by an adjustable stop which consists of a small metal washer with a tab mounted underneath the switch fixing nut. Remove the washer, set the switch to its fully anticlockwise position and replace the washer with its tab in the slot marked with the number 3. A knob with a suitable skirt should be fitted to S1 so that the fixing nut is not visible. The front panel of the finished unit can be labelled by whatever method is preferred. The use of dry transfer print protected by clear lacquer produces a neat and durable finish.

TESTING

As the wiring is so simple there is very little that can go wrong provided all of the components are correctly positioned and soldered. It is recommended that some time is spent checking for dry joints, solder bridges and incorrect component positions and values before applying power. If all appears to be correct connect a 9V battery and switch on. Set S1 to the µF position and check that the display is a row of zeros with a possible 1 in the right hand digit. Switch to the nF range and press and release S3. On this range the right hand digit will probably be a 1 or 2 with all the other digits reading zero. Now repeat the procedure for the pF range. The stray capacitance indicated on this range will be about 20pF. The effect of this is covered in the 'use' section.

Check the operation of the display blanking circuit which should switch off the display after somewhere between 30 and 90 seconds. Pressing S3 should restore the display for a further period.

If a means of measuring supply current is available the values are 60–80mA running and 8–12mA with the display blanked.

USE

The meter has been designed with ease of use as a prime consideration. Just connect a capacitor, press and release S3 and wait for the display to settle. The value is displayed in µF, nF or pF according to the range selected.

Electrolytic capacitors must be connected the right way round of course. Before connecting a capacitor always make sure that it is not charged by touching the two leads together. A charged capacitor will 'dump' its charge into TR1 and so may damage it.

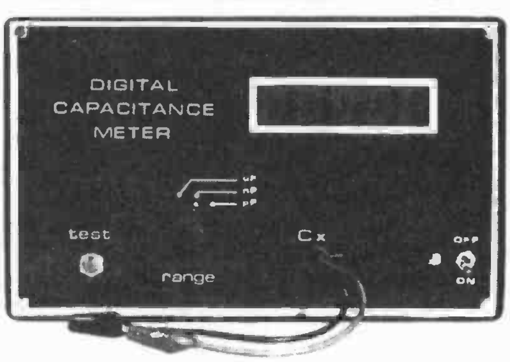
On the pF range the stray capacitance of the leads and printed circuit board tracks will add 20pF or so to the value being measured. This should be subtracted from the value displayed to yield the correct value of the capacitor under test.

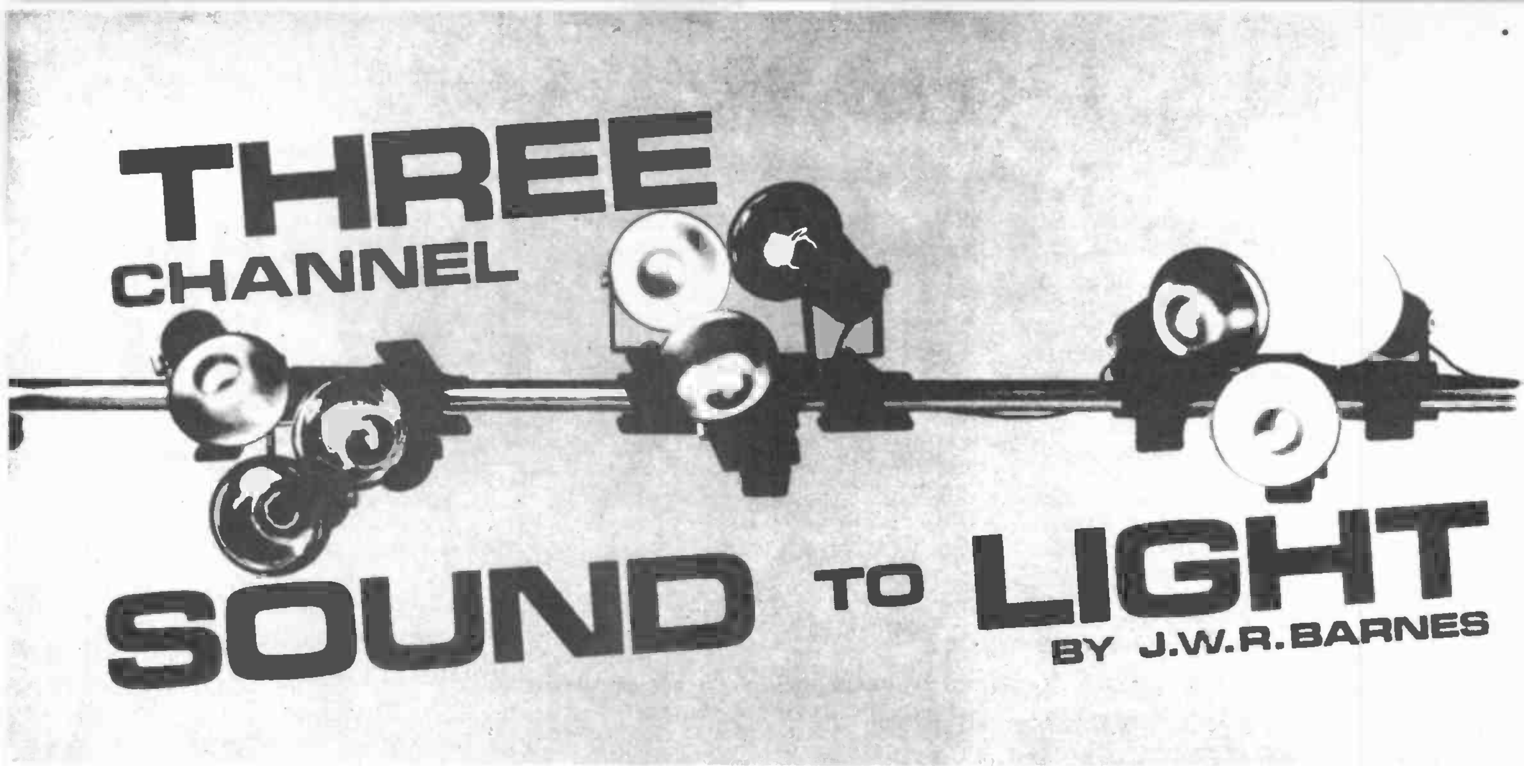
When measuring an unknown capacitor always start with the µF range and work downwards so that the most significant figure of the value is not lost. On the µF range it takes about three seconds for the circuit to indicate 999·00µF. If a 2200µF capacitor is to be measured it is easy to watch the display as it counts to 999·00 twice over. In this way capacitors above 1000µF can be tested and measured accurately by counting the number of times the display reaches 999·00 and adding 1000µF each time.

The use of a five digit display means that some values of capacitance are indicated to five digits. For all of these digits to be meaningful the circuit would need to have an accuracy of 0·001 per cent. Since 1 per cent components are used only the first two digits of any displayed value are correct, the following digits are useful for making comparisons when selecting matched capacitors but do not give any more information about the actual capacitance value. When making repeated measurements of the same capacitor the last two digits may vary from reading to reading due to circuit noise, hum pick-up, etc. Since these are not valid figures this effect is insignificant.

It is anticipated that 6 AA size nicad or alkaline cells will be used in a suitable battery holder. An external d.c. source of 9–12V d.c. may be substituted for prolonged bench use.

The first sign of low battery voltage is a dim display after which the readings will become erratic or non-existent. □





THREE CHANNEL SOUND TO LIGHT

BY J.W.R.BARNES

IN THESE post-Travolta days no disco is quite complete without its complement of flashing lights and special effects. The most common of these is the sound-to-light converter and despite its simplicity, the unit described here compares favourably with many other designs.

For those people unfamiliar with this kind of equipment, the principle of operation is quite simple. An audio signal is used to trigger an electronic switch which illuminates a light.

Usually the system is arranged such that only the loudest peaks trigger the light and quite often the audio spectrum is split up into bands using filters so that different frequency peaks trigger different lights. This is what has been done here.

CIRCUIT

The full circuit diagram of the sound-to-light unit is shown in Fig. 1 and can be seen to consist of six distinct sections: input isolator, low pass filter, bandpass filter, high pass filter, three identical power switches and mains rectification.

An audio signal is taken from one of the loudspeaker sockets on the amplifier and fed into SK1. The speaker is then connected up via SK2 thus avoiding the necessity for split leads.

SECONDARY

This audio signal is fed via the master level control VR1 to the primary of T1, which is in fact the intended secondary of this low voltage mains transformer. Besides providing the necessary isolation, it also offers some degree of voltage gain.

The "secondary" of T1 is fed to each of the three filters. The first one, a low pass filter, is made up of R1 and C2. As the frequency increases the reactance of C2 decreases. This results in the potential at the junction of R1 and C2 being progressively reduced with increasing frequency.

BANDPASS FILTER

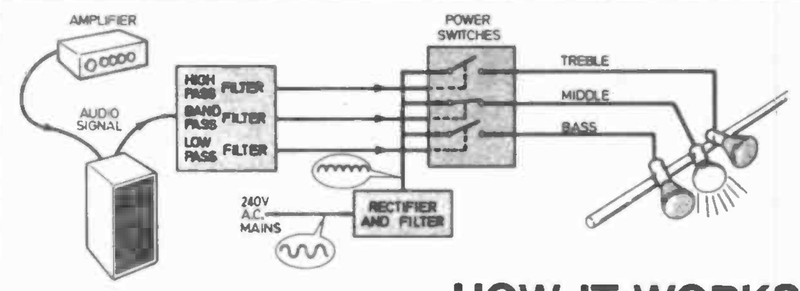
A bandpass filter is made up of R2, C3 and C4. As the frequency increases the reactance of C3 decreases allowing more current to flow into the network. This is counterbalanced by the shunting action of C4 and the combination of the two components gives the desired filter characteristic.

Finally C5 and R3 are used to provide a high pass filter. As the frequency increases, the reactance of C5 decreases thus allowing the top end of the frequency spectrum through.

The graph in Fig. 2 illustrates this clearly.

THYRISTORS

Each filter output is passed via a control potentiometer to the gate terminal of its respective thyristor. These are connected via a fuse to the main output socket.



HOW IT WORKS

The audio signal is fed into the unit. It passes through an isolating transformer and is then split up into three frequency bands using simple *RC* filters.

The voltage peaks in each frequency band trigger a thyristor switch which in turn illuminates a lamp.

The mains input to these lamps is passed through a rectifier and filter before going to the thyristors in order that they may fire on negative half cycles as well as positive ones, and not cause mains borne interference.

Since the trigger signal is not amplified in any way it is essential to use the thyristor type specified as other less sensitive types may not work in this circuit.

INTERFERENCE SUPRESSION

The actual mains power applied to the lamps is fed through a filter network (C1 and L1) and then through a diode bridge. The filter minimises interference passing back down the mains and the bridge is used so that the thyristors will fire on what would have been negative half cycles as well as positive ones.

As a further refinement each channel is provided with a monitor l.e.d. (D5 to D7), which indicates when its respective channel is live. This is a great help when setting up the system and enables the user to keep a continuous check on the performance of the unit.

View of completed unit showing front panel layout and lettering.

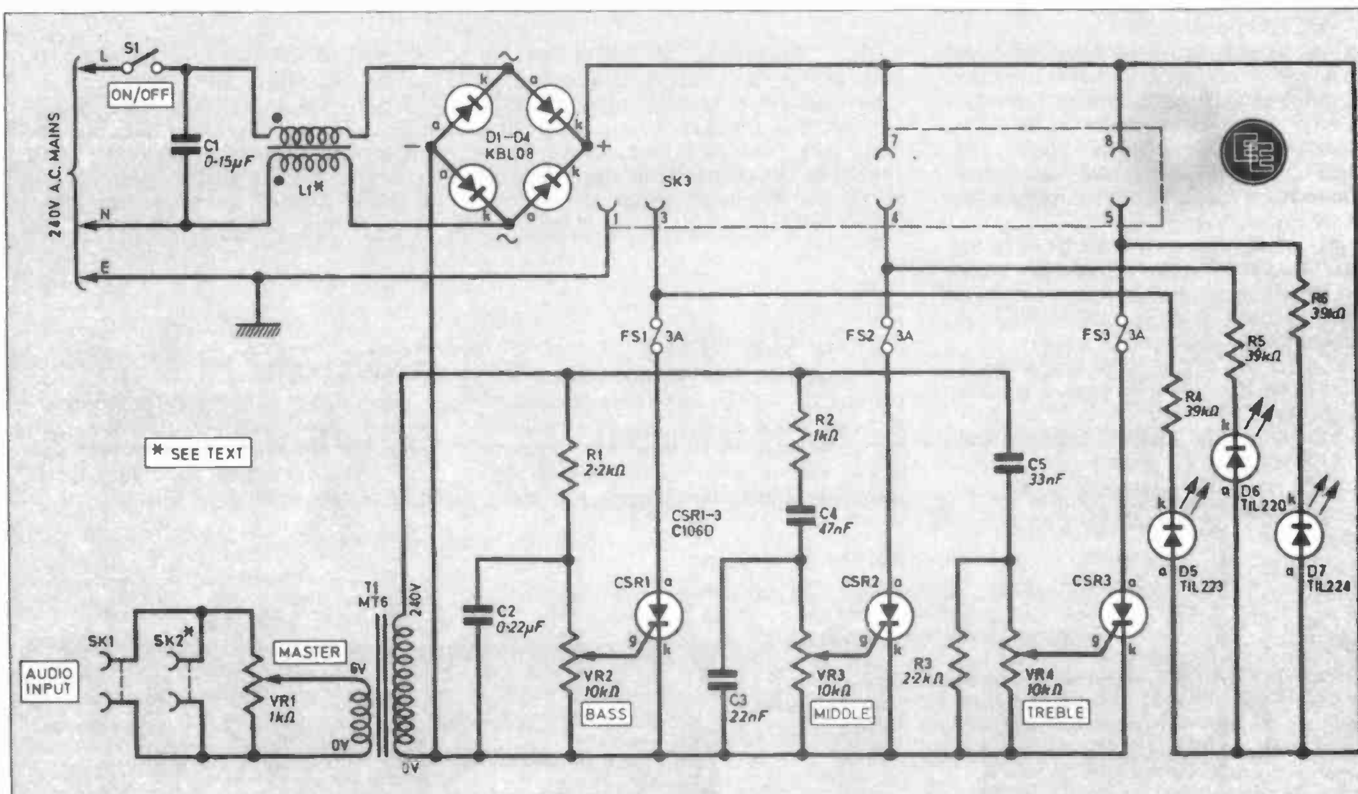
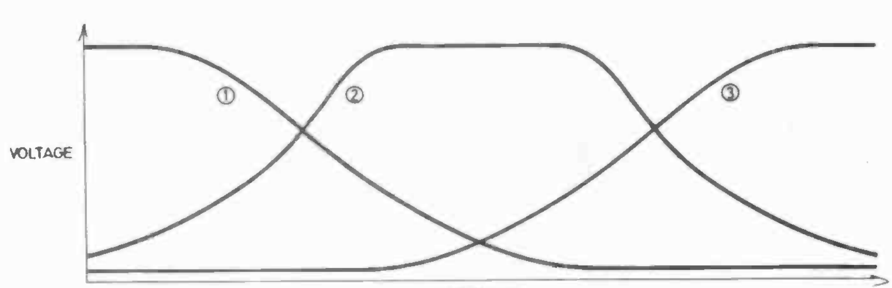


Fig. 1. (above) Full circuit diagram of the Three Channel Sound to Light.

Fig. 2. (right) Graph of output voltage plotted against frequency for the three filter stages in the unit. Curve 1 is the low pass filter, curve 2 is the band pass filter, and curve 3 is the high pass filter.



CONSTRUCTION starts here

CIRCUIT BOARD

Begin construction with the printed circuit board (p.c.b.). Although not essential a p.c.b. makes the final product more reliable and reduces the possibility of errors during construction. The foil pattern and component layout are shown in Figs. 3 and 4.

The filter inductor L1 is home made by winding two separate lengths of insulated connecting wire side by side in a "bifilar" fashion. In the prototype a toroidal ferrite core (Siemens type 29830) was used as a former and this was wound with 20 turns of the wire. It is however much easier to use a slab of Ferrite material and this gives good results with 20 turns added.

The components are then inserted in the board and soldered according to Fig. 4. The inductor L1 is fastened to the board with cable ties and the flying leads are connected into the circuit with Veropins at the appropriate locations. Note that the anode connections on the thyristors are made using the mounting tag rather than the middle pin. This makes the p.c.b. layout easier to design. The unwanted pin is simply snipped off.

COMPONENTS

MAGENTA KIT 150

Resistors
- R1 2·2kΩ
- R2 1kΩ
- R3 2·2kΩ
- All ½W carbon ±5%
- R4-R6 39kΩ 1W (3 off)

Potentiometers
- VR1 1kΩ lin. carbon miniature
- VR2–VR4 10kΩ log. carbon miniature (3 off)

Capacitors
- C1 0·15μF plastic 630V a.c. working
- C2 0·22μF polyester
- C3 22nF polyester
- C4 47nF polyester
- C5 33nF polyester

Semiconductors
- D1–D4 400V 6A bridge rectifier
- D5 TIL223 or similar 0·2 inch green l.e.d.
- D6 TIL220 or similar 0·2 inch red l.e.d.
- D7 TIL224 or similar 0·2 inch yellow l.e.d.
- CSR1-3 400V 4A thyristor type C106D (3 off)

Miscellaneous
- T1 mains primary/6V 100mA secondary
- S1 single-pole mains toggle 6A
- L1 20 turns bifilar wound on ferrite slab (see text)
- SK1,2 two-pin DIN speaker socket (2 off)
- SK3 Bulgin type P552 eight-way socket
- PL1 Bulgin type P551 eight-way plug
- FS1-3 3A 20mm cartridge fuses and p.c.b. mounting clips (two per fuse) (3 off)

Copper clad glass-fibre board for p.c.b. size 150 × 100mm; metal case, size 200 × 125 × 50mm; insulated 1/0.6mm connecting wire for L1; four-knobs; three-core mains cable; four-core mains cable for connecting light displays; 6BA nuts amd bolts for mounting circuit board; 6mm plastic spacers (4 off); rubber feet (4 off); materials for lighting display; veropins.

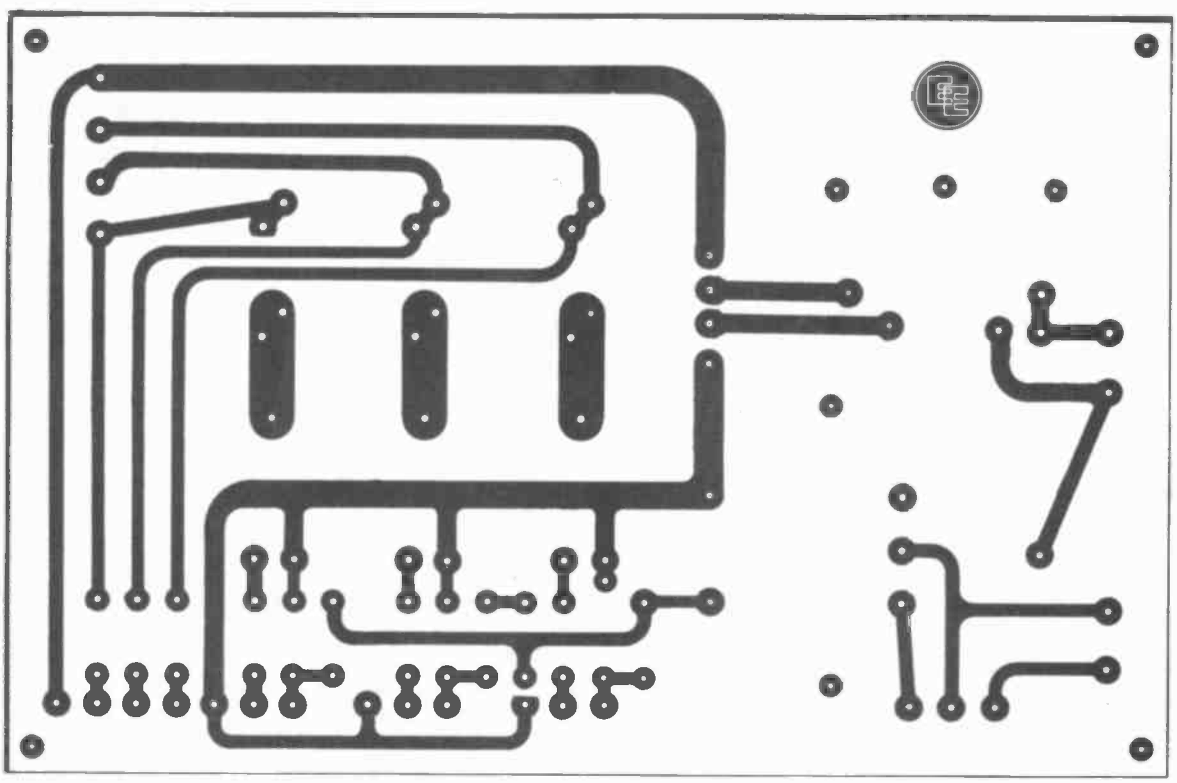


Fig. 3. The foil pattern for the p.c.b. This is reproduced full size.

THREE CHANNEL SOUND TO LIGHT

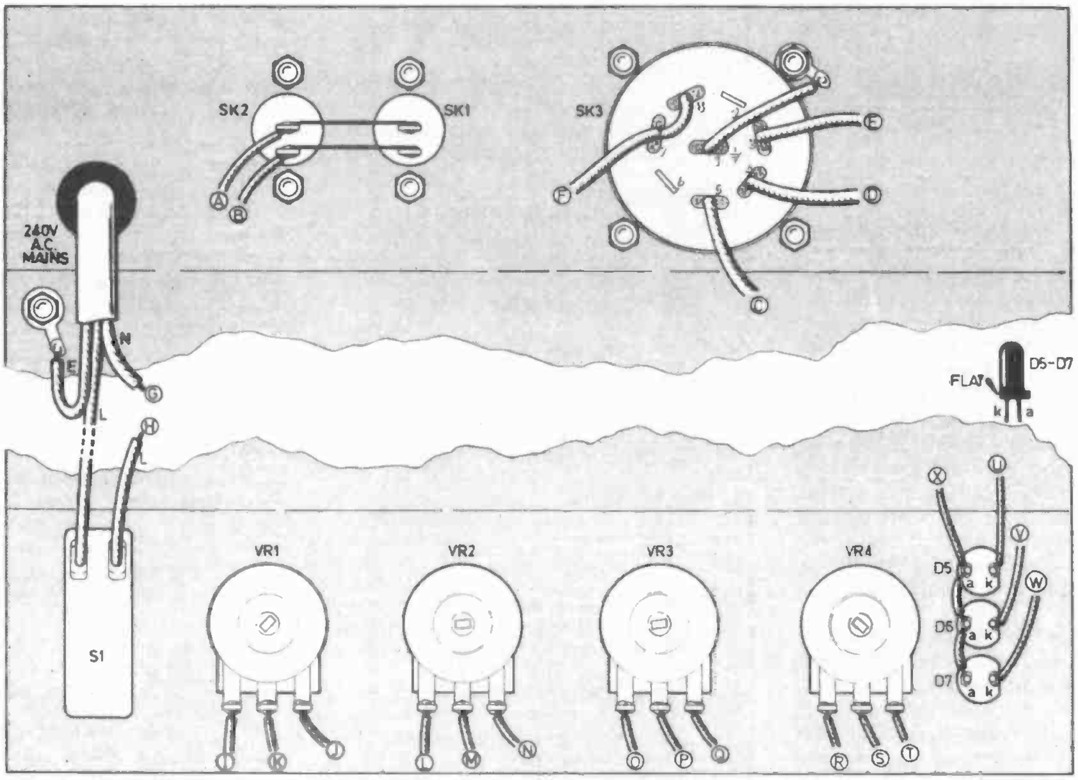


Fig. 4. Drawing above shows connections to off-board components. All mains wiring must be with 10A mains cable. Drawing below shows circuit board layout. Note that the anode connection to the thyristors is via the mounting tag. The centre pin connection has been snipped off.

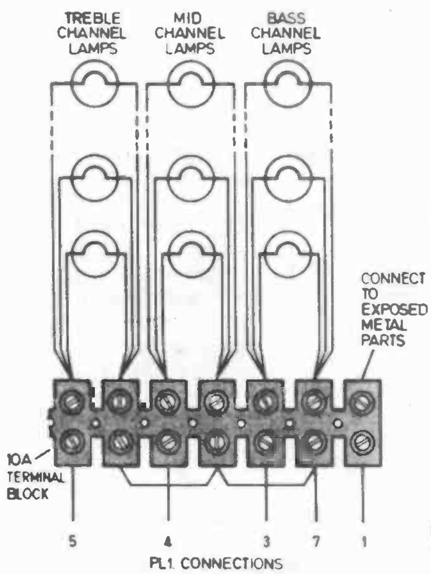
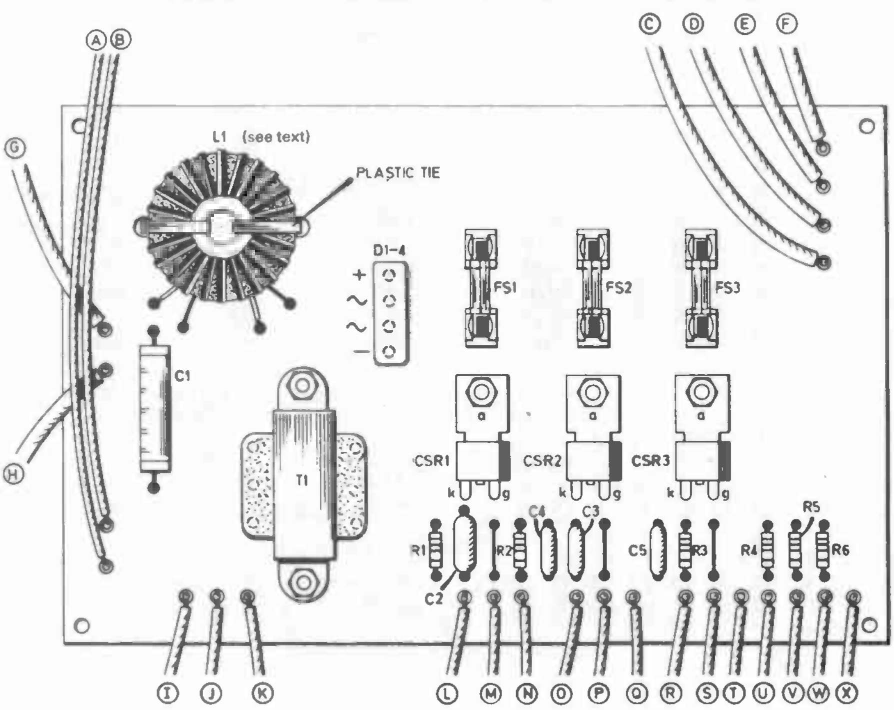
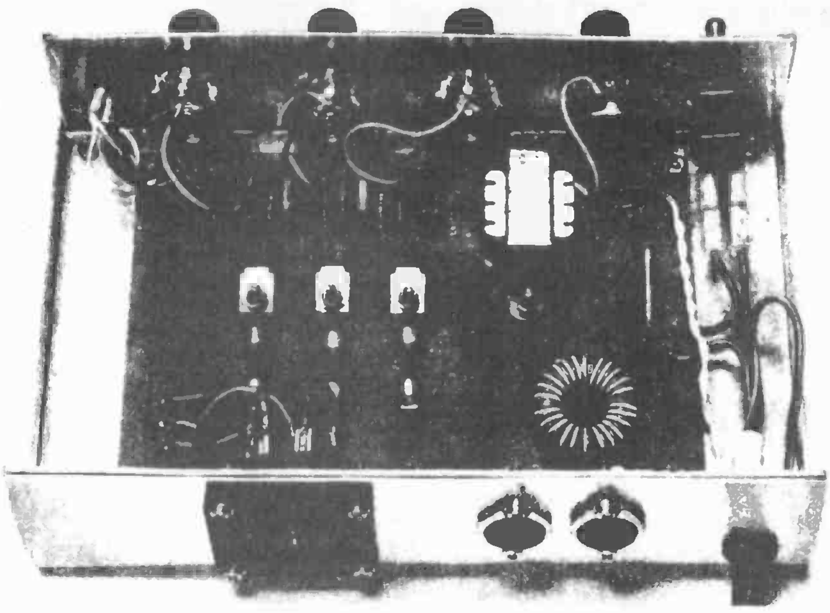
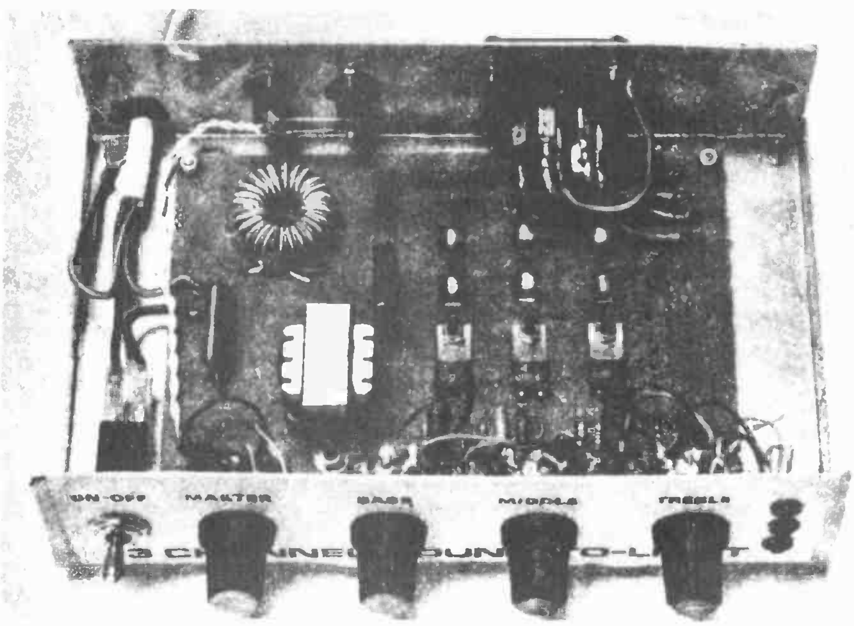


Fig. 5. One suggested wiring diagram for the display lamps. The terminal block must be housed in a protective plastic box or mounted inside the display housing.





The front panel mounted components wiring is shown above and below the wiring to SK3 and other rear panel mounted components can be seen.



THE CASE

Once the board is complete the next stage is to mark and drill the case to take the off-board mounted components. The prototype is housed in a metal case with detachable vinyl covered lid size 200 x 125 x 50mm.

The output socket to the lamps is a Bulgin type P552. This is strongly recommended as the output socket *must* have shrouded contacts and this is one of the very few multi-way sockets that satisfy this criterion.

A quick look at the circuit diagram will confirm that mains voltages are present on the output pins and so for this reason cheap substitutes such as terminal strips should *not* be used.

The large hole for SK2 can be made by drilling a series of smaller holes and finishing with a file.

FINISHING OFF

Before mounting the front panel components, the panel should be lettered, preferably using dry transfers such as Letraset. These components can then be fastened in position and wired up to the circuit board according to Fig. 4.

For safety ensure that the case is securely earthed and the p.c.b. is mounted on 6mm insulated pillars with a thick piece of card underneath.

DISPLAYS

No doubt constructors will be full of ideas when it comes to designing their own lighting displays, but certain points should be remembered.

First of all the sound-to-light unit is limited to a maximum rating of 300 watts per channel. Also remember that whatever bulbs are used they must be provided with adequate ventilation.

The 300 watts can be made up of a few large bulbs or a lot of small ones and you can use either home made light boxes or even the clip on spot light lamps which are very popular nowadays.

The diagram in Fig. 5 shows one method of wiring up the lights. If a light box has been constructed then this will most likely have been terminated with a four pin connector of some sort, that is, one common connection and a separate lead to each channel.

In fact it is safer to hard wire a four-core cable straight into the light box rather than fit a make-shift termination on the box. Four-way chassis mounting plugs are rare and a make-shift connection such as a four-way terminal block mounted on the outside of the box is quite unsuitable. Of course any exposed metal parts must also be earthed and this will involve running a fifth wire to PL1.

SPOTLIGHTS

Alternatively separate clip-on type spotlights may be used. In this case connecting up poses something of a problem and the easiest way of achieving this is to use a small plastic box with a terminal strip inside as a junction box.

The cables from each lamp are fed into the box and the necessary connections made at the terminal strip.

The four-way cable can then be attached to the terminal block and plugged into the unit in the usual way. Lamp fittings of this type are usually double insulated and do not need earthing.

TESTING

The sound-to-light converter should first be tested on its own without lamps being connected. Connect up an audio source and turn the unit on.

With some adjustment of the controls the monitor l.e.d.s should flash on and off in sympathy with the music. If this test is satisfactory, the unit can be tried with the lamps attached. Obviously some experimentation will be necessary with the controls to achieve the best results and each record may well require a slightly different setting.

Warning

One word of warning is necessary should you want to service the unit whilst it is running. The anode tags of the thyristors are all at mains potential as will be the connections to SK3.

Obvious precautions MUST be taken to ensure that accidents do not happen. ⌑

16K SIDEWAYS RAM

TIM PARKER

A cheaper alternative to buying a complete sideways RAM board

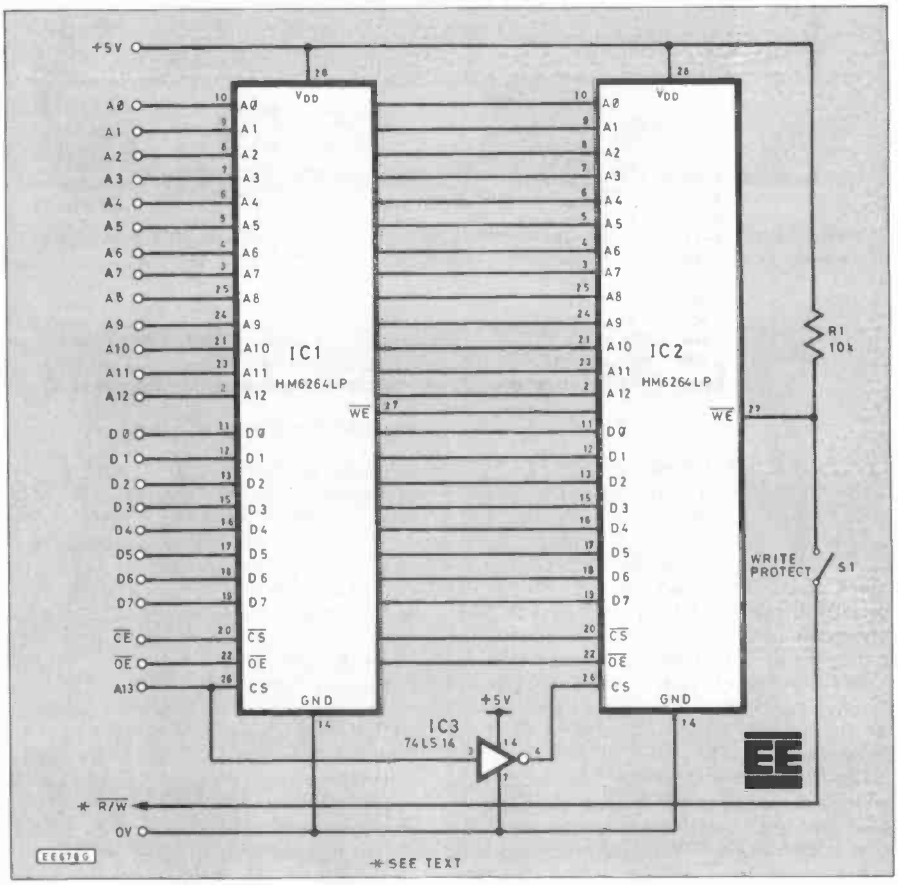


Fig. 1. Circuit diagram of the 16K Sideways RAM.

THERE are many different sideways RAM boards on offer to the BBC micro user nowadays. However, these tend to be a little expensive if all you require is 16K of RAM to develop sideways ROM software ready for transferring to EPROM. The design presented here is a reasonably small unit which plugs directly into one of the spare ROM sockets inside of the BBC computer and allows up to 16K of software to be developed in RAM before "blowing" it into an EPROM. This method eliminates the need to keep erasing EPROMs if the software does not function as it should (and it usually doesn't!) the first time.

Ease of construction and installation were considered important factors in the design of the module, which is evident from there only being one external connection to be made to the computer. Cost was also considered important and this is kept low by using readily available components. Only three chips are required and two of these are the RAM devices themselves. The third chip is a standard LS TTL device which is needed to ensure that the correct RAM chip is accessed at the appropriate time.

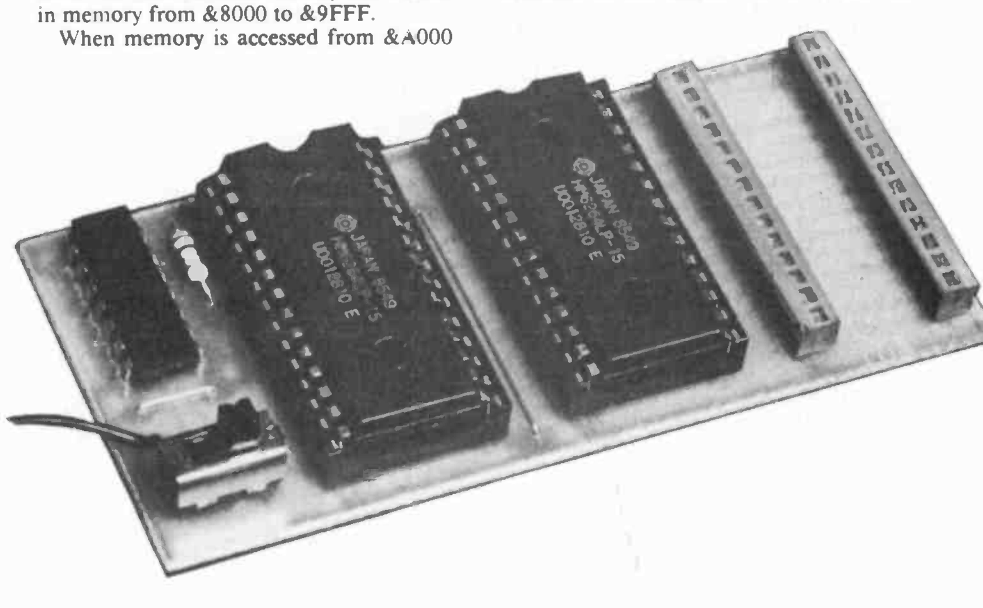
CIRCUIT DESCRIPTION

The complete circuit diagram is shown in Fig. 1. Do not be misled by its simplicity, this really is all that is needed. Two 6264 8K by eight bit RAM chips are used connected in parallel to give 16K by eight bit configured as 8K lower and 8K upper RAM. The only other chip is a 74LS14 hex Schmitt inverter and is used to enable either the lower 8K or the upper 8K accordingly.

Pin 20 of the 6264 RAM chip is the $\overline{CS}$ (Chip Select) line as found on most other memory devices. This pin must be taken to a logic 0 (low) in order for the chip to be active. In addition the 6264 also has a CS line (pin 26) which must be taken to a logic 1 (high) for the chip to become active. Both of these pins must have the appropriate logic on them at the same time in order for the chip to operate and this feature is made use of in this application.

IC1 and IC2 are 8K devices so only one can be active at any time. This function is performed by IC3. When memory from &8000 to &9FFF is being accessed the computer address line A13 is low. This is inverted by IC3 and applied to pin 26 of IC2 thus enabling the chip and giving us the lower 8K area. In other words, IC2 resides in memory from &8000 to &9FFF.

When memory is accessed from &A000 to &BFFF the computer address line A13 goes high and enables IC1. Once again IC3 inverts A13 and pulls pin 26 of IC2 low, thus disabling it. This now means that IC1 operates as the upper 8K of RAM and



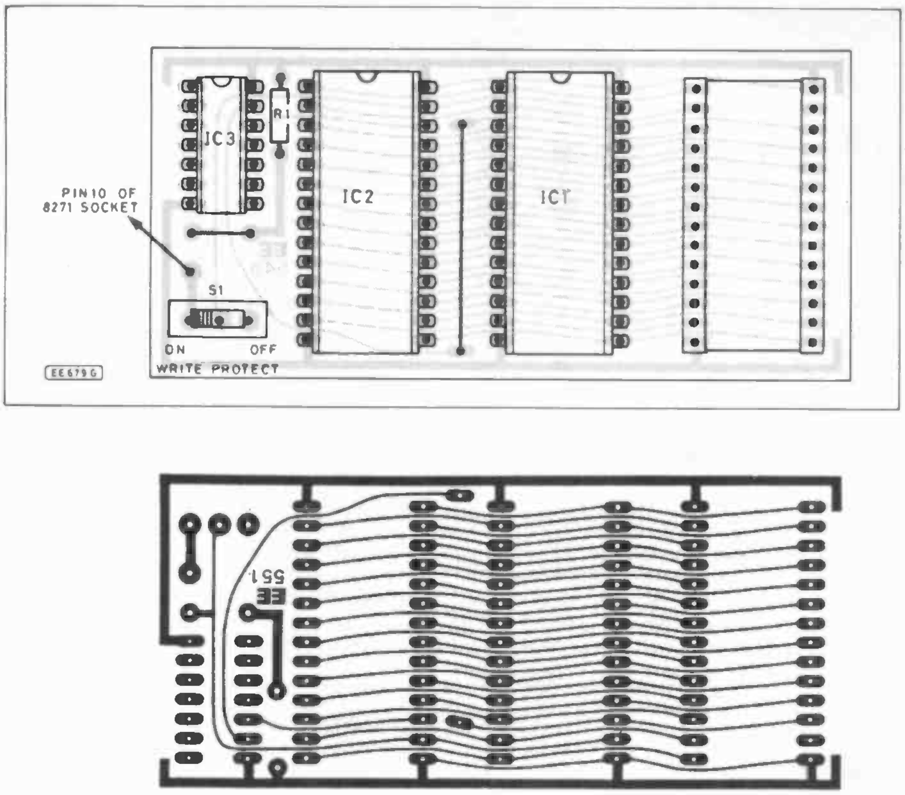


Fig. 2. P.C.B. layout and wiring for the sideways RAM.

COMPONENTS

MAGENTA KIT 568

Resistor

R1 — 10k $\frac{1}{4}$Watt Resistor

Semiconductors

IC1,IC2 — HM6264LP-15 8K static RAM (2 off)

IC3 — 74LS14 hex Schmitt inverter

Miscellaneous

S1 — p.c.b. mounting slide switch

28 pin i.c. sockets (2 off); 28 pin turned pin i.c. socket (see text); printed circuit board and software Cassette, 300mm of single stranded insulated wire.

occupies memory from &A000 to &BFFF, which incidentally is the highest allowable memory location for any sideways ROM or RAM.

There is one minor problem with plugging RAM into a sideways ROM socket inside the BBC micro, and that is the provision of a write strobe in order to program it. This pulse is not connected to the ROM sockets and we must obtain one from elsewhere in the computer. Unfortunately there is a flaw if it is taken directly from the CPU. The problem is that the R/$\overline{W}$ (Read/$\overline{W}$rite) signal is still valid when the data bus has changed, which leads to spurious and unpredictable results. Fortunately we can obtain a R/$\overline{W}$ pulse from another chip inside the computer which has the advantage of being gated with the 2MHz processor clock and gives us the correctly timed write pulse we require.

Having obtained the write line we must connect it to the $\overline{WE}$ (Write Enable) pin of the two RAM chips. This is done via switch S1 which acts as a simple write protect switch. When the switch is closed it applies the R/$\overline{W}$ strobe to pin 27 of IC1 and IC2 thus enabling them to be written to. When the switch is open, the R/$\overline{W}$ strobe is disconnected and resistor R1 holds pin 27 of the two ICs high preventing accidental (or intentional!) writing to the RAM.

CONSTRUCTION

The design is built on a single sided printed circuit board the layout of which is shown in Fig. 2. Begin by soldering in the two wire links followed by R1 and IC3. It is recommended that i.c. sockets are used for the two RAM chips and these should be soldered to the board next. This requires some careful soldering as there is very little space between the i.c. pads and the tracks running in between them.

A good quality 28-pin turned pin i.c. socket is required for insertion into the ROM socket. Normal long pin wire wrap sockets have rather thick pins and these tend to splay out the ROM sockets in the computer. This leads to unreliable connections to the ROMs if one is inserted into a socket which has had a wire wrap socket forced into it then later removed. A possible cheap alternative is to use a 0·1 inch 23-way edge connector (the type used for ZX-81 peripherals) cut to a lower profile. This is then cut down to 28 way and in half along its length. These two halves are then soldered in place of the 28 pin socket.

Although the p.c.b. is designed to have a small low profile slide switch mounted on board to perform the write protect function, there is no reason why two lengths of insulated wire cannot be soldered to the board and the switch mounted in a more convenient place. If this method is used it must be remembered that it is the computers internal R/$\overline{W}$ signal on these wires and if they are too long it is possible to pick up other stray pulses from inside of the computer which could lead to data corruption in the system, and not necessarily just in the sideways RAM. Finally, solder about 300mm of single stranded insulated wire to the board as shown in the layout.

INSTALLATION

Before plugging the board into the computer give it a thorough check for any solder bridges that may have occurred during construction, especially between the i.c. pads where space is minimal. Once you are satisfied everything is all right it can be fitted inside the computer as follows.

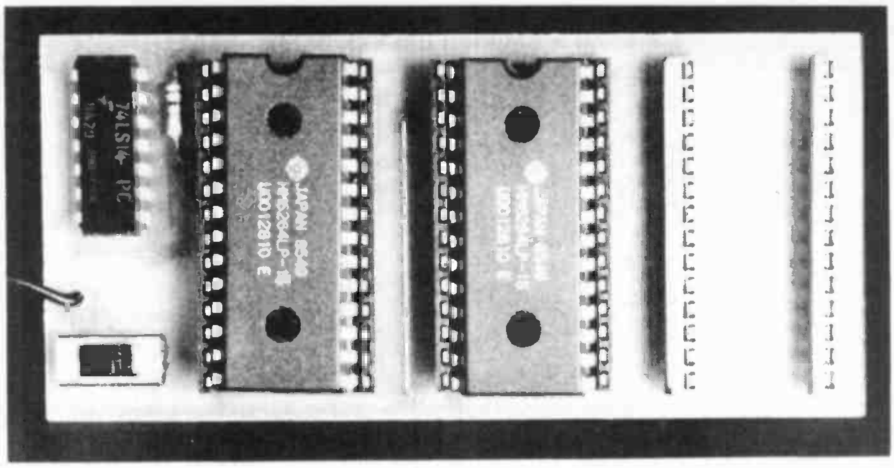
Switch off the BBC micro and remove the top half of the casing. This is done by removing the two screws found on the outer edges of the back of the case (on some older models these are marked "FIX") and the two larger headed ones underneath the keyboard at the front of the case, the top half of the case can now be lifted clear of the bottom. Next, remove the two screws securing the keyboard in place, lift the keyboard slightly and gently pull it towards the front of the case. There is no need to remove the connector between the keyboard and the main board as there is enough room available for what we want to do.

The following information refers to a BBC micro with no extra ROMs except perhaps for a DFS ROM, if this is the case there will only be two spare ROM sockets instead of the usual three found on tape based machines.

At the bottom right hand side of the main board are the ROM sockets. Actually only four of the five sockets are for sideways ROMs, the one on the far left is the Operating System and must not be moved. The socket we require is the one on the far right and there are two main reason for this. Firstly, this is the highest priority ROM socket which means if a language ROM is present here it will have the first chance to initialise itself on power-up or when BREAK/CTRL-BREAK are pressed. If ROM priority is not important the unit can be installed in any of the other available spare sockets. Secondly, the size of the RAM module is such that it will sit comfortably over the top of the rest of the ROMs without over-hanging the left hand side. If this socket is occupied it is a simple matter of carefully "shuffling" all of them to the left by one socket.

The module can now be plugged into the vacant socket. It may be a tight fit (especially if the socket was already empty) but should go in if it is rocked slightly to and fro. The flying lead for the R/$\overline{W}$ signal can now be connected. Remove about 5mm of insulation from the end of it and push in into pin 10 of the 8271 disc controller chip, this is the large (40 pin) i.c. located three chips in from the left hand side of the main p.c.b. about half way down the board. If you do not have this chip fitted it is simply a matter of pushing the lead into pin 10 of the i.c. socket. If the 8271 is in place, push the wire in between the pin and the socket.

Once the module is in place it is necessary to slide a small piece of cardboard or other insulating material underneath the board between the RAM module and the ROMs,



warning! do not switch the computer on until this is done. There are three diodes directly above the operating system ROM which have the computers 0V rail connected to them and since the track at the top of the RAM board is connected to the +5V rail, the BBCs power supply unit will be short circuited if the power is applied without the insulation in place. Replace the keyboard on its locating lugs but do not secure it in place yet. Switch on the micro and if all's well the usual start-up message should appear, if not switch off immediately, remove the board and re-check the soldering, also check orientation of the components. If the start-up prompt does appear, the keyboard and casing can be reassembled. All that remains now is to program the RAM with the machine code routines you require.

SOFTWARE

As the board is designed to be built and installed by the novice, it is not possible to *LOAD code directly into the RAM or write machine code programs that will assemble the code into the RAM area. The ability to do this would involve too much "fiddling about" inside the computer for the inexperienced. Space does not permit the software listing to be published here. However a cassette containing software which enables code that is assembled into the computers main memory to be written into the sideways RAM with relative ease is available The software is self documented with instructions on how to use it and includes a few utilities to help get you started. □

SIMPLE SHORT WAVE RADIO

MARK STUART

A three band 1·6 to 30MHz radio providing excellent results plus loud-speaker output

OVER the last ten years or so a number of good short-wave radio designs have been published. Nearly all of them have used expensive coils and air-spaced tuning capacitors, and have outputs suitable only for crystal earpieces, or high impedance headphones.

The design described here was produced to combine the advantages of these previously published circuits whilst using modern miniature coils and capacitors and having the benefit of a built-in loudspeaker. It is a TRF (tuned radio frequency) design covering approximately 1.6 to 30MHz in three bands. The audio output is provided by a single i.c. amplifier capable of supplying over one watt when operated from a nine volt supply.

CIRCUIT

The complete circuit diagram of the Simple Shortwave Radio, showing the r.f. tuner and the audio amplifier sections, is shown in Fig. 1. The five transistors in the tuner circuit are not discrete devices but are all contained in the "transistor array" chip IC1.

This approach has been taken mainly because of the close matching, and excellent thermal tracking of the transistors, which solve a lot of biasing problems. Another advantage of the transistors in IC1 is their excellent high frequency performance and low noise characteristics. Fig. 2 shows the schematic and connection diagram of IC1.

The "active" part of the tuner circuit consists of transistors TR1, TR2, and TR5. TR1 and TR2 are connected in what is known as a long-tailed pair configuration. This arrangement has several advantages. One is that the input of the circuit (TR1 base) is very well isolated from the output (TR2 collector). This allows a good amount of gain to be produced as there is very little negative or positive feedback from the output to the input.

Negative feedback is undesirable because it reduces the gain of the circuit. Positive feedback is undesirable because it reduces the stability of the circuit and can lead to oscillation problems. The input to TR1 base is obtained from a tapping on the main tuning coil L2.

Variable capacitors C3 and C4 form a parallel tuned circuit with L2 providing the circuit with its initial selectivity. A tapping is necessary on L2 so that the coil is

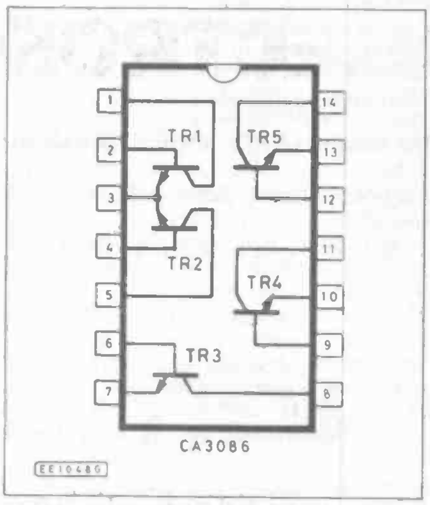
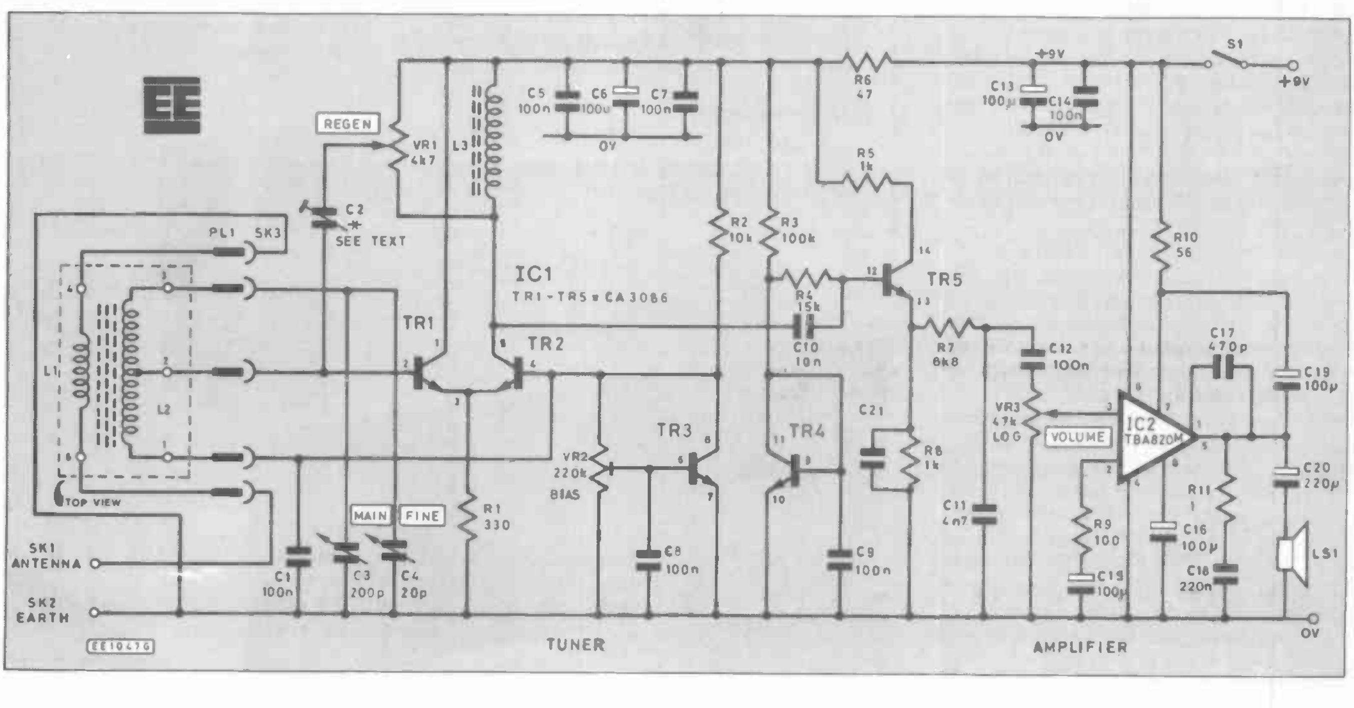


Fig. 2. Internal structure of IC1 (CA3086).

Fig. 1. Complete circuit diagram for the Simple Shortwave Radio



properly matched to the relatively low input impedance of TR1 base. If the base of TR1 was to be connected straight to the top of L2 the result would be much lower selectivity and a loss of gain. The exact position of the tap is not critical and on the coils used has been pre-set by the manufacturer to give a reasonable match in transistor circuits.

The aerial coupling winding L1 is a small winding on the same core as L2 to which the aerial is connected. The number of turns on this coil again have been chosen by the manufacturers to suit most commonly used aerials. It is worth noting however that accurate matching of the aerial to the coil is extremely unlikely especially over the wide frequency range involved. This is one of the compromises necessary with such a simple circuit. Aerial matching over such a wide frequency is extremely difficult and it is unusual for even good quality communication receivers to be particularly clever in this respect.

REACTION—REGENERATION

The signal at the collector of TR2 is an amplified version of the input signal. By coupling a small amount of this signal back to the input an effect known as reaction or regeneration comes into action.

As previously mentioned the presence of feedback is generally undesirable. If a controlled amount of positive feedback is applied however the effect is that the circuit "boosts" itself. The gain and selectivity of the circuit increase as more feedback is applied until at a certain level the circuit provides its own input and begins to oscillate.

At a point just before oscillation the performance of the circuit is dramatically improved. It is the function of the reaction of regeneration control to allow the feedback to be adjusted so that operation at this point can be achieved over the whole tuning range (see *Regenerative Receivers* EE June and July 1987).

Potentiometer VR1 is used to "tap-off" some of the output signal from TR2 which is coupled via C2 to the input. Advancing VR1 provides a higher level of feedback eventually leading to oscillation. The effect of the onset of oscillation can be quite violent in some circuits as the whole input stage "bursts" into oscillation.

In this circuit the onset of oscillation is very well controlled because of another very useful characteristic of the "long-tailed pair" connection of TR1 and TR2. This characteristic is that the gain of the stage decreases as the signal level increases. Thus any increase of signal level as the circuit approaches oscillation is opposed by a gradual fall in gain so that the circuit cannot "burst" into oscillation at all.

Instead as the reaction control is advanced gentle oscillation begins and the level of oscillation increases in a controlled way as the control is further advanced. It is therefore relatively easy to set the circuit to its most sensitive operating point by use of the reaction control.

The bases of TR1 and TR2 are biased to approximately two volts produced by R2, VR2 and TR3. This circuit uses the base-emitter voltage of TR3 as a reference voltage (0.6 volts) which is boosted by TR3 to a pre-set level adjustable by the setting of VR2. The gain of TR1 and TR2 is dependent on the setting of the bias control and increases with increasing bias voltage. A good initial setting of VR2 is two thirds of a turn clockwise which gives a bias voltage of 2V. Increasing the setting further increases the gain, but beyond a certain point this becomes excessive and good control of regeneration becomes difficult.

DETECTOR

From the collector of TR2 the amplified r.f. signal is coupled via C10 to the detector stage TR5. The job of the detector circuit is to remove the modulating audio signal from the unwanted high frequency carrier signal. The principle of detection will not be discussed here as it has been covered in previous articles. Usually a diode is used as a form of half wave rectifier to remove the modulation. The old "cats whisker" was a form of diode, nowadays usually replaced by an OA90 or similar germanium point contact device.

In this circuit a more sophisticated approach has been used which results in better sensitivity and lower distortion than a simple diode detector. It is known as an "infinite impedance" detector and operates by using the action of a transistor which is biased so that it is just at the point of conduction. Positive signals increase the bias on the transistor and so are amplified, whilst negative signals reduce the bias, turn off the transistor, and produce no output.

The output at the emitter of TR5 thus consists of just the positive half of the modulated r.f. signal. R7 and C11 form a low pass network which removes the r.f. carrier frequency leaving the low (audio) frequency modulation to be passed to the audio amplifier section of the circuit.

Transistor TR4 provides the correct amount of d.c. bias voltage to keep TR5 at

COMPONENTS

Resistors

R1	330	R4	15k	R7	6k8
R2	10k	R5,R8	1k	R9	100
R3	100k	R6	47	R10	56
				R11	1

All 5% ¼ watt carbon film

Potentiometers

VR1	4k7 lin.
VR2	220k min preset (horiz)
VR3	47k log.

Capacitors

C1,C5,C7,C8,C9,C14	100n ceramic disc 50V
C2	preset (see text)
C3	200-300p variable
C4	20-30p variable
C6,C13,C15,C16,C19	100μ radial elect. 16V
C10	10n ceramic disc 50V
C11	4n7 ceramic plate
C12	100n polyester
C17	470p polystyrene/ceramic
C18	220n polyester 100V
C20	220μ radial elect. 16V
C21	27p ceramic plate

Inductors

L1/L2 A	KAN3333 miniature low range 1 r.f. coil
L1/L2 B	KAN3334 miniature med range 2
L1/L2 C	KAN3335 miniature high range 3
L3	1mH radial r.f. choke

Semiconductors

TR1 to TR5	CA3086 (IC1 transistor array)
IC2	TBA820M

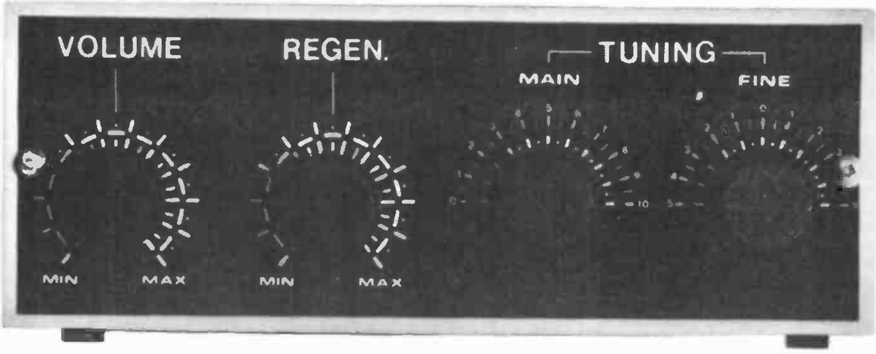
MAGENTA KIT 718

Switch

S1 s.p.s.t. min toggle

Miscellaneous

LS1 8ohm 50mm loudspeaker SK1, SK2 4mm banana sockets; SK3 DIN socket 5 pin 180 deg. (3 off—see text). DIN plugs 5 pin 180 deg. (3 off—see text); p.c.b.s knobs (4 off); battery holder; 6 × HP7; wire; fixings etc. 8 pin d.i.l. i.c. socket; aluminium case 200 × 150 × 75mm.



the optimum point for maximum sensitivity. As TR4 and TR5 are on the same piece of silicon inside IC1, and have matched characteristics, the bias voltage from TR4 will vary in exactly the correct way to match the needs of TR5 as ambient temperature varies.

DECOUPLING

Most of the capacitors in the circuit are for decoupling purposes, C1, C5, C7, C8 and C9 are all used to keep high frequency from interfering with circuit stability. C6 and resistor R6 are there to remove audio signals present in the supply rail from the audio amplifier section.

The layout and wiring of circuits operating at high frequencies can be quite critical. It is recommended that the p.c.b. and wiring shown should be followed to ensure good results, although this circuit is quite well behaved.

AUDIO AMPLIFIER

From the tuner section a signal ranging from 10mV to about one volt is passed to the volume control VR3 via coupling capacitor C12. There is little to say about the amplifier circuit as it is all contained in a single i.c. (IC2).

The TBA820M can produce over one Watt into an eight ohm speaker providing a very good loud signal. The output could be connected to an external speaker (a larger one would give even better volume) or to any type of headphones from eight ohms upwards. Of the components surrounding IC2, C13, C14, and C16 are supply decoupling capacitors. C20 is the output coupling capacitor. R10 and C19 provide a type of feedback known as "bootstrapping" which temporarily boosts the positive supply voltage to the i.c. internal circuits during positive half cycles of the output. The benefit of this is higher power and lower distortion. R11 and C18 provide a controlled load at high frequencies and ensure that the circuit is stable. C17 sets the high frequency response of the circuit. Its value can be increased to reduce adjacent signal whistles if required. The remaining components R9 and C15 set the maximum gain of the circuit.

CONSTRUCTION

The radio is built on two printed circuit boards. Construction of the audio amplifier board should be undertaken first as this is the simplest and can be tested on its own. Fig. 4 shows the component layout for the amplifier board. Take care to put the electrolytic capacitors in the right way and to fit the two wire links as shown. A socket can be used for the i.c. if required.

If the correct p.c.b. mounting potentiometer is not available, VR3 can be wired to the board using short lengths of stiff tinned wire. It is important to use stiff wire as the board is mounted solely by the bush and nut on VR3.

Attach a twisted pair of wires approximately 120mm long for the loudspeaker connections, and three other single wires for the positive, negative, and audio input connections.

When the loudspeaker and a battery are connected to the circuit, it should be possible to hear the familiar "mains hum" sound when the input wire is touched (with VR3 set to maximum). If an audio signal source is available the circuit can be tested more thoroughly. Once this section is complete proceed to the assembly of the tuner board.

TUNER P.C.B.

The assembly of the tuner board shown in Fig. 3 is only slightly more complicated than the audio board. Begin by inserting the four wire links followed by the resistors, ceramic capacitors, VR2, C6, L3, and VR1. IC1 should be soldered directly to the board to minimise stray capacitances which could reduce stability.

When the board is complete the wires should be attached for the battery clip, S1, SK1, C3, and C4. These connections should all be made using solid core wire which is soldered directly to the board in the same way as component leads. This method has the advantage that no loose strands of wire can cause short circuits and that the relatively stiff wire will stay in position. Capacitor C2 is made by twisting two 40mm lengths of wire together as shown in Fig. 6. Initially a single twist should be made so that the final adjustment can be done when the radio is tested.

ASSEMBLY

The main components should be assembled into the case approximately as shown in Fig. 6. The case used for the prototype had a wrap-over lid into which all of the components were fitted. This useful arrangement means that there are no wires trailing between the top and bottom of the case, and that there is plenty of room to work.

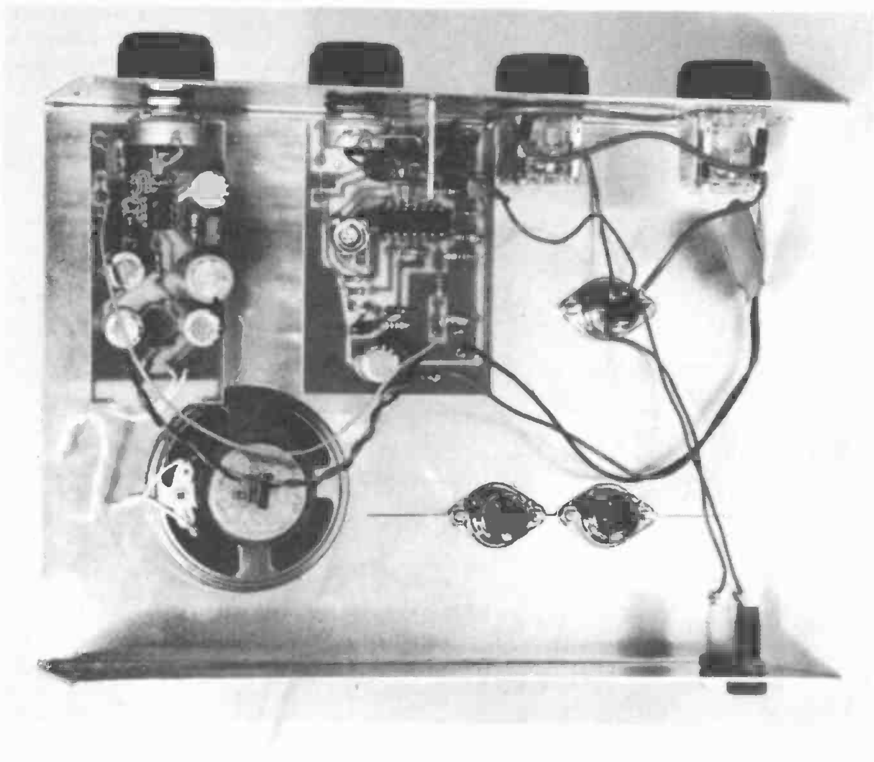
If the specified case is used the full size drawing of Fig. 5 can be photocopied and stuck onto the case front as a drilling guide (a second photocopy can be covered with transparent plastic and used as a proper case label when construction is complete).

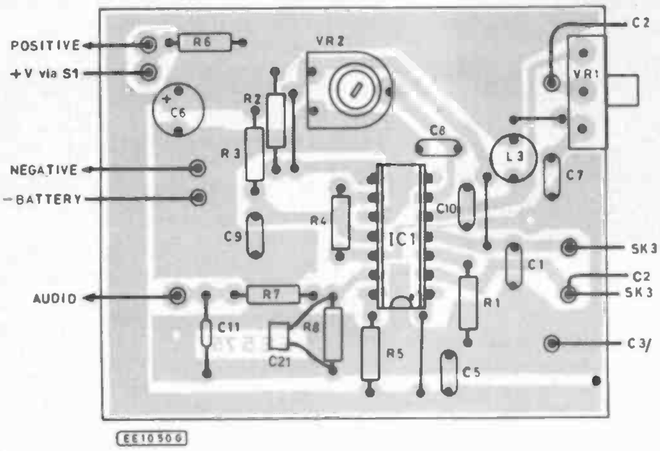
The two tuning capacitors are each fixed to the case by means of two small M2.5 screws. Make sure that these are not too long as they will otherwise damage the vanes inside the capacitor.

Socket SK3 can be mounted inside or outside the case as preferred. In the prototype two further (unwired) sockets were added as parking places for the unused coils. To keep the front panel simple the on/off switch S1 was mounted on the rear of the case. If this is not convenient it can be re-positioned as required.

The connections to SK3 are simply made as shown in Fig. 6. The earth tag of SK3 is used to link the earth socket and one end of L1 to the chassis. Connections to the Main and Fine tuning capacitors C3 and C4 are as

Internal layout and interwiring of the prototype radio. The transistor buffer stage shown on the tuner board was found to be unnecessary.





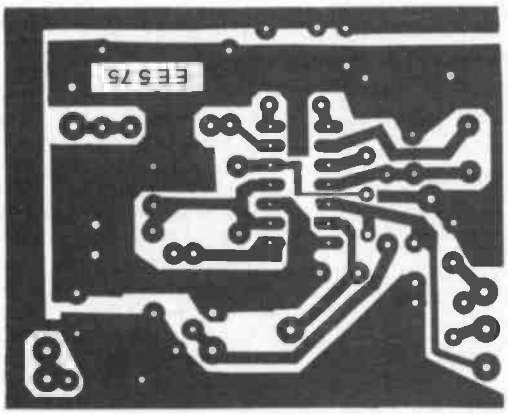
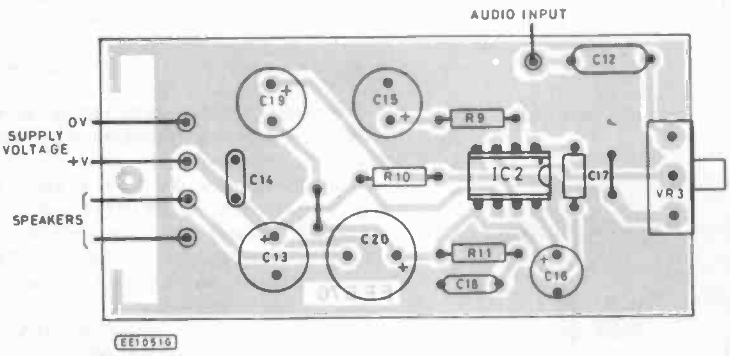


Fig. 3. Component layout and full-size printed circuit board foil master pattern for the tuner stage. Note than an i.c. holder is NOT required here.



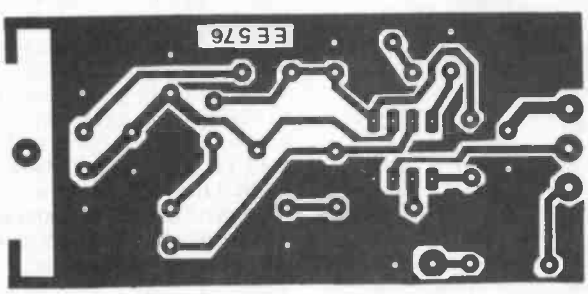
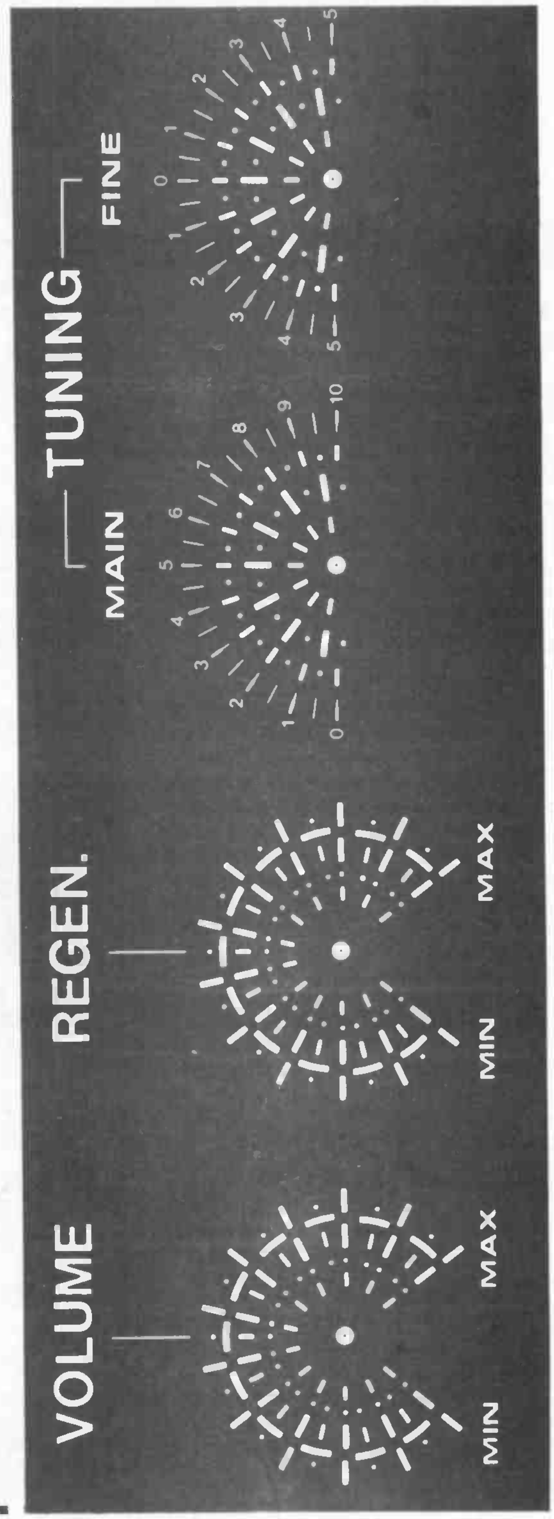
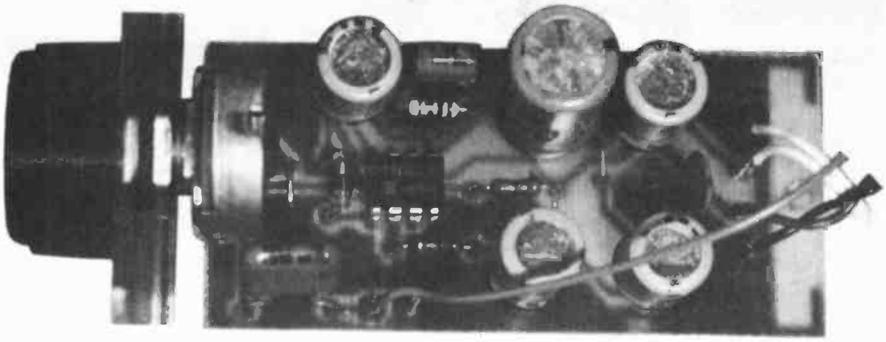


Fig. 4. Component layout and full-size printed circuit board foil master pattern for the amplifer stage.

Fig. 5 (right). The full-size front panel labelling can be cut out or photocopied and fixed to the case as shown in the photographs.





shown if the specified components are used. Other capacitors may have totally different connections and so should be wired accordingly. The specified capacitor is of the type that has two a.m. sections of approximately 250p each and two f.m. sections of 30p each. One section of each type is used on the prototype, but it may be better to use both a.m. sections in parallel to extend the low frequency coverage of each band.

Other tuning arrangements can be used instead of the ones shown, for example, an air-spaced capacitor with a reduction drive attached should give very good results, but would be quite a lot more expensive. As the "common" terminal of the tuning capacitors are connected to the chassis there is no difficulty in using standard metal types.

The antenna socket is wired directly to one pin of SK3 using the same solid core wire formed to run along close to the chassis.

COIL ASSEMBLY

The miniature tuning coils used in the circuit have been chosen for their excellent performance and low price. The penalty of using them is that a special socket arrangement must be adopted for them as shown in Fig. 7. This has been done by using "standard" 5 pin DIN audio plugs and sockets. The type of plug must be the one that has a removable plastic "insert" into which the pins are moulded. Apart from the insert, the rest of the plug is discarded.

Each coil should be fitted with a 50mm length of thin (28s.w.g.) tinned wire soldered to each pin. The wires should then be carefully formed so that they will pass easily into the rear of the DIN plugs and cut so that 5mm of each wire will be inside each hollow pin of the plug. At this point the assembly is quite rigid and the wire to each socket pin can be soldered into place. An additional small link from the screening can to the earth pin should be made as shown in Fig. 7.

In the prototype the coils were protected by lengths of insulating tubing pushed over the plug inserts which had been thickened by wrapping them with p.v.c. tape. This gives the coils excellent appearance but is not strictly necessary.

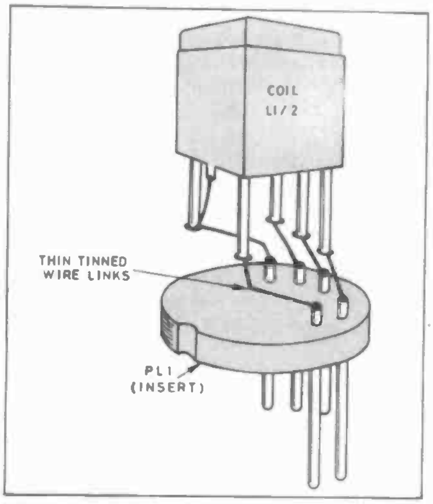
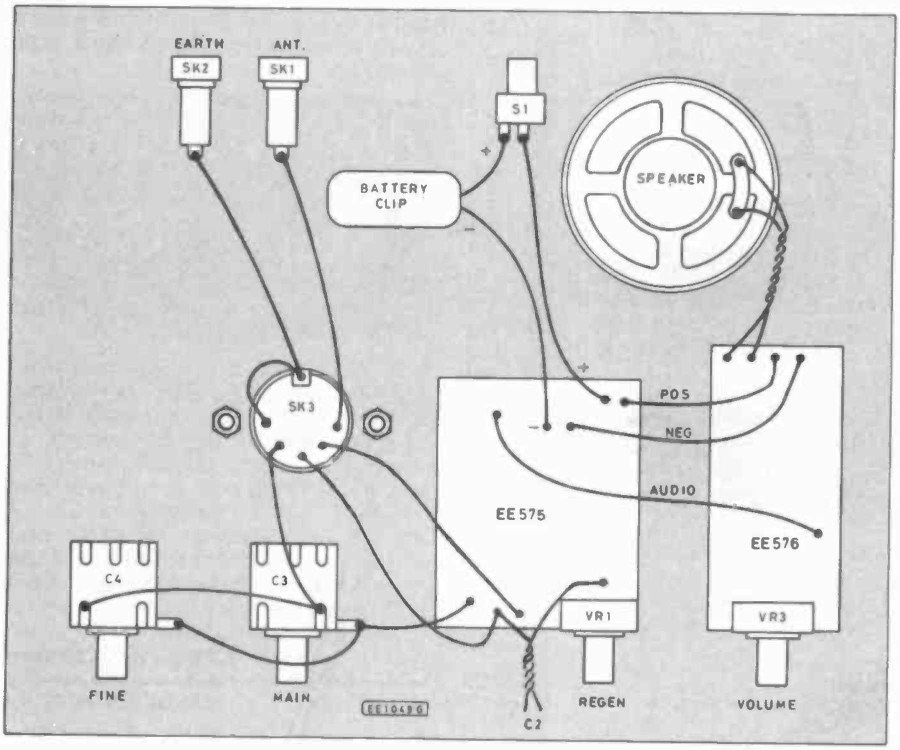


Fig. 6. Interwiring details for the off-board components. Note pin 4 of coil L1 is "earthed" through socket SK3 chassis tag.



OPERATION

Once the coils are complete the circuit can be tested by plugging in the middle range coil, attaching about 30 feet of aerial wire and switching on. Set VR1 to minimum and VR3 mid-way. VR2 should be set two thirds of a turn clockwise as mentioned earlier.

If all is well it should be possible to pick up a few strong stations somewhere within the range of C3. Once a station is heard, advance the setting of VR1. The signal should become louder as VR1 is advanced until at a certain point distortion begins to occur and a whistle becomes audible. Reduce the setting of VR1 so that the best possible position is obtained and then rotate C4 to see if other stations can be heard.

With a good aerial and provided there are not too many interference sources (lamp dimmers, TV sets, fluorescent lights) dozens of stations will be heard.

Each time the Main tuning control is rotated the Regeneration control will have to be re-adjusted for the optimum position. It would be nice if a single setting for regeneration would cover the whole band, however this is impossible because of the varying impedance of the coil, the aerial, and the tuning capacitors themselves. If there is insufficient regeneration an extra twist on C2 may be required.

Once the circuit is operating with one coil try plugging in the other coils and tuning through the range. Note that because of propagation effects some parts of the short-wave bands will be completely silent at some times of the day and extremely busy during others.

When all ranges are working the effect of advancing VR2 can be tried. There will be an optimum position for C2, VR2 and VR1 for each station but as this is impractical it is best to set VR2 and C2 for good all round performance and do the fine adjustments with VR1. On some ranges adding a 470 ohm resistor in series with the aerial was found to improve reception of weaker stations.

The calibration of the radio is left to the user. The "log" scales on the tuning knobs enable dial setting to be repeated so that known stations can be found again. A chart of scale settings, station names, times of day, and frequencies will soon be built up as time is spent listening. The author was quite fascinated by the number of interesting stations that can be heard throughout the day. It is very interesting to compare the Russian news programmes (in English) with the American ones.

Whilst testing the prototype the author was rather intrigued when a telephone dialling sound was heard at about 4MHz. It soon became apparent that this was the cordless telephone of someone living about 200 metres away. Both sides of the conversation could be heard very clearly. So much for privacy!

EXPERIMENTS

Finally, for those who become really keen on radio, there is no reason why home-made coils should not be used with the radio. Varying the numbers of turns, the aerial coupling, and the position of the coil tapping can be very interesting and produce rewarding results. □

INSULATION TESTER

MARK STUART

MOST electronics enthusiasts will at some time have been called upon to install or check domestic appliances and mains wiring.

Using a standard multimeter on resistance range it is easy to check for continuity, and the correct operation of switches etc. The difficulty comes when the *quality* of insulation is to be tested. Most meters use standard 9V or 15V batteries on the 'high' resistance ranges; this voltage is clearly a long way below the working voltage of the wiring and so the readings obtained can be very misleading. Insulation which breaks down dangerously at mains voltage can appear to be fine at 15 volts.

To overcome this limitation it has become standard professional practice to measure insulation at a potential of 500 volts using an instrument known as a 'Megger'. The original Meggers used a small hand cranked generator to produce the 500 volts. Modern versions are now available which derive the test voltage from a few 1·5V cells via an electronic inverter. The problem is that commercial instruments are rather expensive for occasional use by the hobbyist.

This project is a reliable 500 volt insulation tester at a reasonable price.

CIRCUIT

The circuit diagram is shown in Fig. 1. IC1 produces a 30kHz pulse waveform which drives TR2, the inverter output transistor, via R4. The collector of TR2 drives L1, which is the primary of a toroidal transformer. When TR2 is turned on the current in L1 builds up and energy is stored in the ferrite core. At the end of a drive pulse TR2 is turned off.

The sudden interruption of the current in L1 causes a high voltage 'back e.m.f.' pulse to be produced in L1, and in the other windings on the core. This high voltage pulse on L1 is stepped up by the winding ratio of the transformer (50:9) and produces a pulse of 250 volts across L3. The maximum voltage of the pulse is determined by the amount of energy stored in the core of the transformer and by the load connected to L3.

A third winding on the core (L2) provides feedback, which stabilises the voltage of the back e.m.f. pulse regardless of the battery state or the load presented across the probes. Diode D1 and capacitor C4 rectify and smooth the voltage from L2. The resulting d.c. voltage is fed via D7 to the base of TR1.

If the voltage across C4 rises to more than 3·6 volts TR1 begins to turn on. As TR1 turns on the Threshold Control pin of IC1 is pulled towards the negative supply rail. This alters the output waveform from IC1 resulting in narrower drive pulses being supplied to TR2. In turn this means that less energy is stored in the transformer core during each pulse and the output voltage falls.

This feedback results in the circuit settling so that the voltage across C4 is always maintained at 3·6 volts. Allowing for the efficiency of D1 this gives a peak voltage of 5 volts across the single turn winding L2. The peak voltage at TR2 collector is 9 × 5 = 45 volts and the voltage across L3 is 50 × 5 = 250 volts.

The secondary voltage from L3 is connected directly to D2 and also via C5 to D3 and D4. This arrangement works as a voltage doubler producing 500 volts across the series combination of C6 and C7. Resistors R7 and R8 ensure the rapid discharge of the capacitors when power is removed.

The test voltage is fed to the meter via R6, which limits the output current to 500µA.

The components around the meter are arranged to remove some of the scale non-linearity which occurs in ohm-meters at high values of resistance. At low currents there is insufficient voltage across the meter to enable D5 to conduct and so the meter acts as a standard 100µA meter. Above half scale D5 begins to conduct and introduces the shunting effect of VR1 across the meter. This changes the sensitivity to 500 microamps. In this way the meter can display a wider range of resistance values without scale cramping.

CONSTRUCTION starts here

A single p.c.b. is used for this circuit. Fig. 2 shows the copper foil pattern. Refer to Fig. 3, the component layout diagram, and fit the components as shown. The inverter transformer consists of a ferrite toroid core upon which three windings must be threaded for L1, L2 and L3. The windings should be neat single layers positioned as in Fig. 3. Begin by winding L3. Approximately 2 metres of 28 s.w.g. enamelled copper wire are required. Leave approximately 10cm of free wire at each end and secure the winding with adhesive tape. Note that the winding does not need to be covered with tape, use just enough to stop the ends unwinding.

Next use ½-metre of 28 s.w.g. enamelled wire to wind the primary winding L1. It is important that the windings have the correct polarity. The 'dots' shown on Fig. 1 and Fig. 3 indicate the starts of the windings. Keep the same side of the core uppermost and start each winding by passing the wire up through the centre of the core. The polarities of the windings will then be correct.

When L1 and L3 are complete, wind L2 by passing a length of insulated connecting wire once through the core. Attach the core to the board using a length of insulating sleeving passed around the core and through the holes in the board, as shown in Fig. 3. Do not use bare wires to fix the core as this would become a shorted turn, and prevent the circuit from working.

Carefully scrape away the enamel from the ends of L1 and L3 before soldering the wires to the p.c.b.

It is important to note that only the specified ferrite core should be used. The design of inverter circuits depends upon the inductance of the windings and the properties of the ferrite. Some types of ferrite core may look very similar but be completely unsuitable for this circuit. It is also important to use the specified diodes for D1, 2, 3 and 4. Ordinary rectifiers such as 1N4005 are designed for use at 50Hz. They are practically useless at 30kHz because of their slow response.

When the board is complete the case lid should be cut out to take the meter and the test switch S1. The p.c.b. is mounted in the bottom of the case using two bolts with nuts as spacers—the high voltage end lies beneath the meter. This leaves sufficient room for a PP3 battery next to the low voltage end of the board. Fig. 5 shows the layout of the components in the case.

Wiring up must be done before the p.c.b. is finally fixed in position. Ensure that leads between the case and the lid are long enough to allow access for setting up adjustments, and battery changing. The two test leads pass out through a grommet at the meter end of the case. Use well insulated flexible leads, about 1 metre long. An insulated crocodile clip on one lead and a hook grip probe on the other are best for the type of measurements that will usually be made.

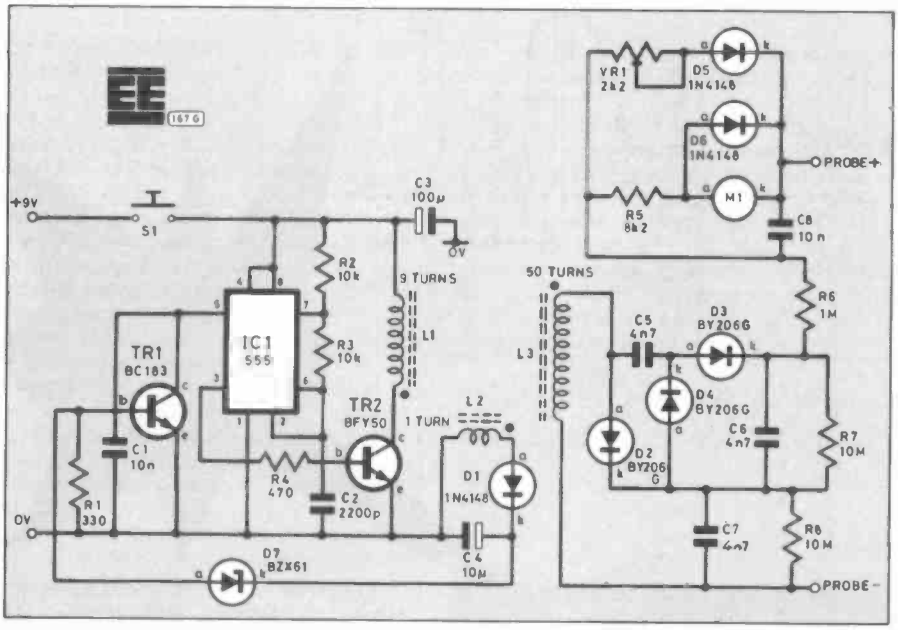
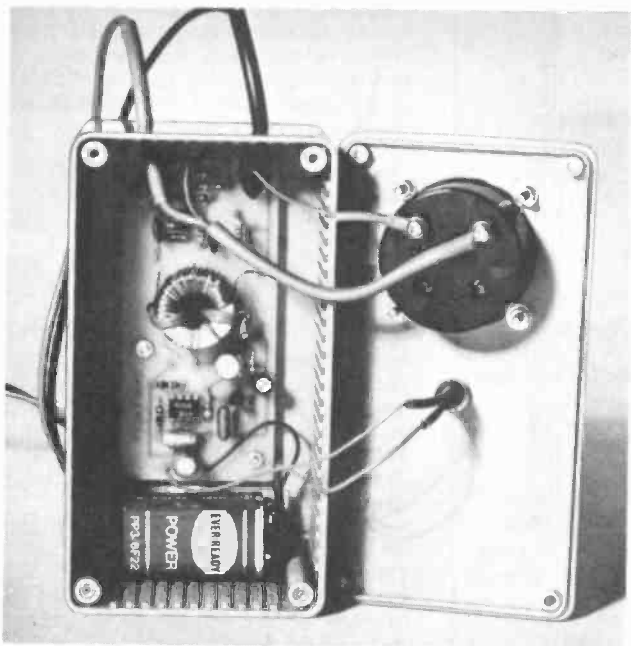


Fig. 1. Complete circuit diagram for the Insulation Tester.



TESTING

Before applying power, double check the transformer windings, and that D1–D6, D7, C3 and C4 are the right way round. If everything looks correct set VR1 to mid position and connect a PP3 battery. Clip the two probes together and press S1. The meter M1 should read somewhere between half and full scale. Set the meter reading to exactly full scale by adjusting VR1. Release S1 and separate the probes. Clip a selection of high value resistors, one by one, across the probes and check the meter reading given for each. Take care—only press S1 when your fingers are away from the probes. The circuit is incapable of producing dangerous levels of current; however, 500 microamps can feel quite unpleasant.

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SAFETY

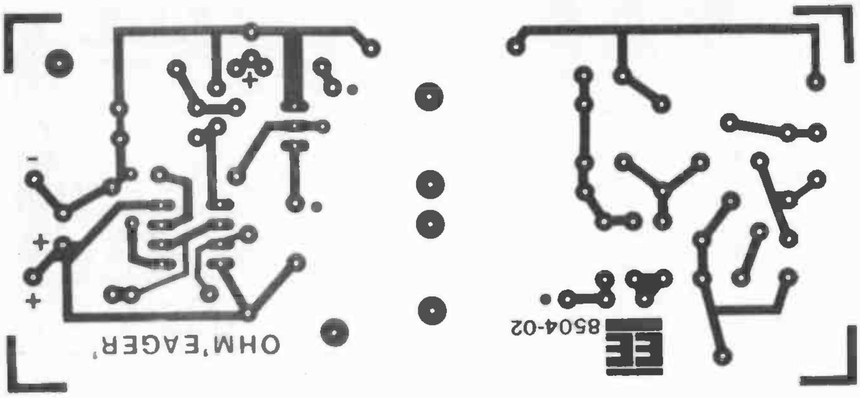


Fig. 2. Printed circuit layout (actual size).

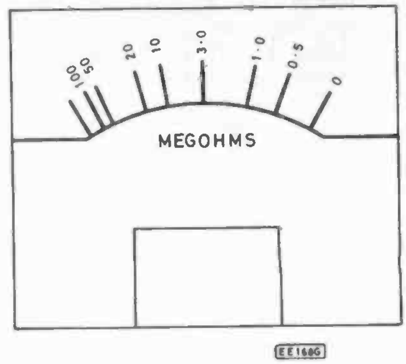


Fig. 4. This scale may be used with the specified meter.

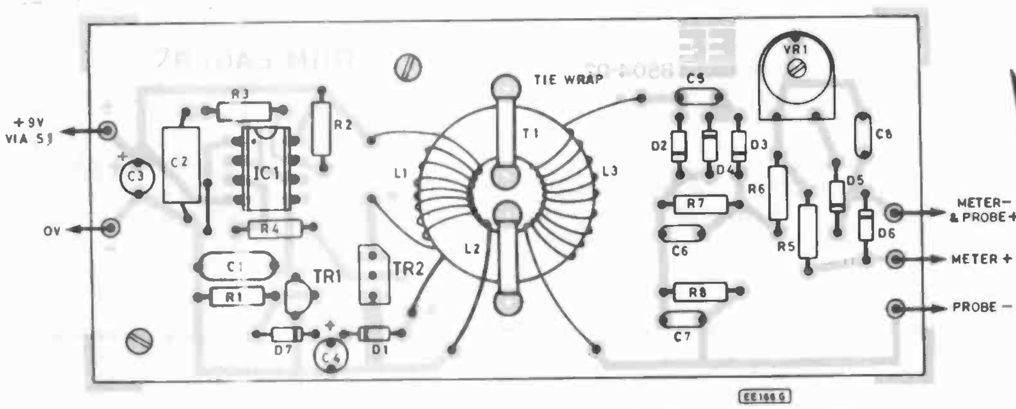


Fig. 3. Component layout on the topside of the printed circuit board. TR2 may be a TO5 can transistor.

CHECKS MAINS INSULATION TO 500V

COMPONENTS

Resistors

R1	330
R2,3	10k (2 off)
R4	470
R5	8k2
R6	1M
R7,8	10M (2 off)

All resistors ¼W 5% carbon film

Potentiometer

VR1	2k2 preset

Capacitors

C1	10n C280
C2	2200p poly
C3	100µ 16V elect. radial
C4	10µ 10V elect.
C5,6,7	4n7 ceramic 500V
C8	10n 50V ceramic

Semiconductors

D1,5,6	1N4148
D2,3,4	BY206G high speed 300V
D7	BZX61 C3V0
TR1	BC183
TR2	BFY50
IC1	555

MAGENTA KIT 444

Miscellaneous

S1	Momentary action push button switch
T1	Toroidal transformer core type ROF241212
M1	100µA meter approx. 4K resistance (MR45)

Leads—1M red and black well insulated

Probes—1 probe and 1 crocodile clip

Case plastic—approx. 150 x 80 x 50mm

PP3 battery, clips, feet, fixings, 28 s.w.g. enamelled copper wire, sleeving. Printed circuit board

The meter can be calibrated by using a range of resistors and marking the readings each time on a blank piece of paper fitted over the scale. Alternatively, if the specified meter is used Fig. 4 can be cut out or traced and fitted to the meter.

If a multimeter is available the voltage across the probes can be measured. This should be between 450 and 550 volts. The battery current consumption is between 20 and 60 milliamps depending upon the resistance across the probes. With the probes open-circuited the battery current should not exceed 35mA.

USE

An insulation tester is very straightforward to use. Clip the probes across the component or wiring to be tested and press the test button. When testing mains wiring take care to disconnect the power first and check between Live and Earth, and Neutral and Earth, as well as between Live and Neutral. When testing electrical appliances always check for insulation between the mains terminals and exposed metal parts.

Take special care when testing circuits with suppressor capacitors. These will be charged to 500 volts and will give a very nasty shock if touched. To prevent this problem always release the test button and wait for a few seconds before discon-

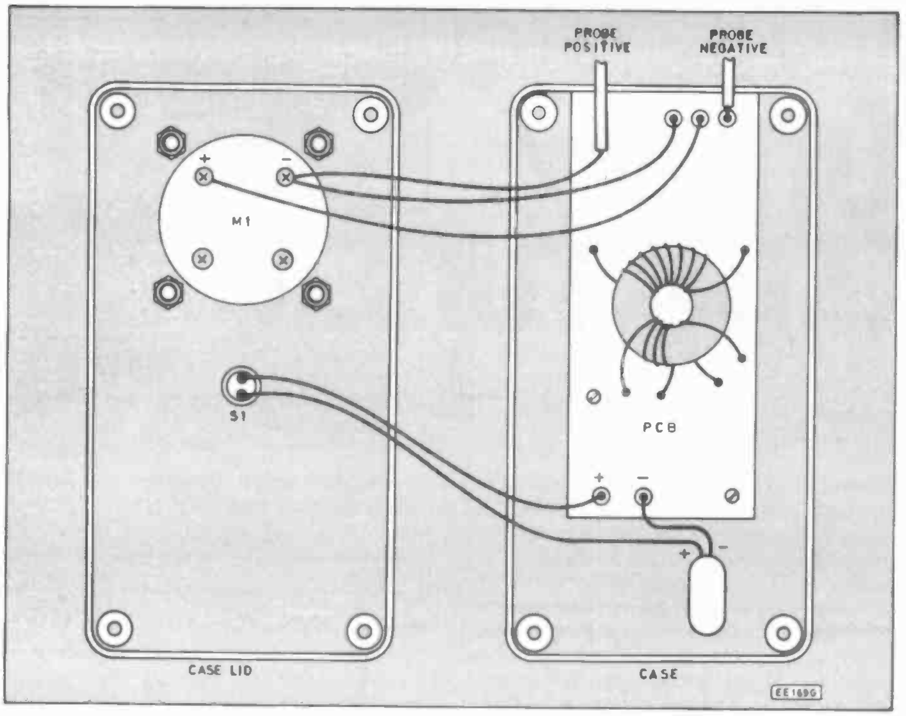


Fig. 5. Wiring diagram and mechanical layout of the Insulation Tester.

necting the probes. This will allow the external capacitor to discharge via R6, R7 and R8.

The tester can be used to check high voltage semiconductors such as power rectifiers and thyristors etc., provided they are rated above 500 volts. Never use the tester on integrated circuits or low voltage semiconductors. The circuit is designed to withstand being accidentally connected to the mains. The battery life should be very long since current is only taken during tests. When the battery is getting low it will no longer be possible to get full scale readings on the meter when the probes are shorted. This is a simple test that should be carried out prior to each test. □

Continued from page 17

TESTING

Testing is very straightforward. Just switch on and check that the l.e.d.s are all lit. Switch to the X1 range and turn the speed control VR1 to minimum. The l.e.d.s should flicker at about 3Hz. Advance the control and check that the speed gradually increases. At the maximum setting the flickering will not be visible because of persistence of vision.

Check that the brightness of the l.e.d.s remains the same on both ranges and that both sets of three l.e.d.s. are equally bright. The supply current should be between 10mA and 20mA.

To check the synchronisation, a record turntable which has a built in strobe lamp is needed. Connect an a.c. signal of between 3 to 30V from a mains transformer and set the Mini Strobe to 300 on the X10 range. (3,000 flashes per minute = 3,000/60 = 50 flashes per second).

Set the turntable rotating and bring the Mini Strobe up to the strobe marks on the turntable. The marks should appear to be moving in exactly the same patterns as those lit by the built-in strobe lamp.

It should be possible to move the Mini Strobe speed control some distance in each direction without any change in the pattern of the strobe. Disconnect the synchronising signal and check that moving the speed control produces smooth changes in the observed pattern.

The strobe can now be used to illuminate some moving object. Such things as electric fans are ideal for demonstrations. In a darkened room it should be possible to make the fan blades appear to be completely stationary.

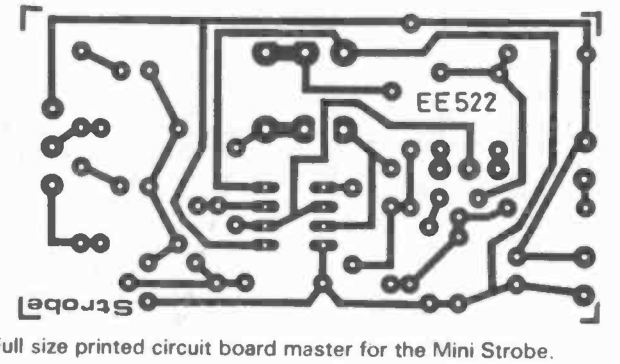
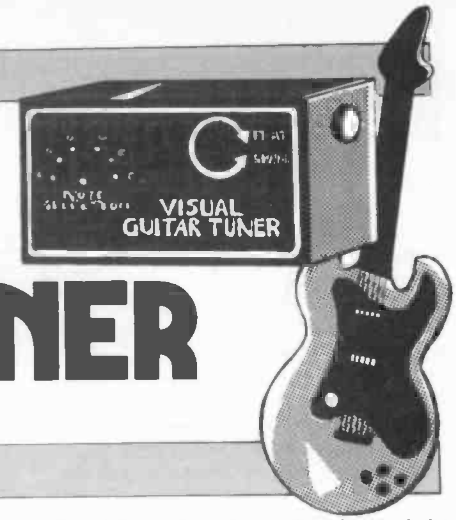


Fig. 3. Full size printed circuit board master for the Mini Strobe.

TAKE CARE

Note that although mechanisms appear to be stationary they are actually moving at speed and cannot be touched. Keep this in mind whenever using stroboscopes of all types. □

VISUAL GUITAR/ INSTRUMENT TUNER



MARK STUART

Keep in tune with this crystal controlled musical instrument tuner

THIS circuit was designed as a multi-purpose musical instrument tuner that could be pre-set to cover a wide range of crystal controlled reference frequencies. Tuning the instrument to the reference frequency is achieved by a novel and very effective display using a ring of l.e.d.s which light in a pattern that indicates relative phase and frequency.

The display also indicates whether the incoming frequency is above or below the reference frequency by the direction in which the pattern appears to rotate. As tuning becomes nearer, the apparent speed of rotation reduces, until the pattern is stationary when the tuning is exact. The display thus combines the benefits of a meter and an l.e.d.-type beat in indicator and is better than both.

The tuner is quick and easy to use, has a clear unambiguous display and is not over sensitive to input signal waveform or amplitude. Being a solid state display means that the tuner is robust and compact. The tuner requires a low level signal from either a microphone or an instrument pick-up (input impedance 47k).

A built-in acoustic resonator allows the reference frequency to be heard if required by pressing a button. This facility is useful when a suitable microphone or pick-up signal is not available as it enables simple tuning to be achieved by ear.

CIRCUIT

The circuit diagram of the tuner is shown in Fig. 1. The switch connections shown are set to produce the standard guitar string frequencies E, A, D, G, B, E through two octaves. The production of other notes and octaves for other instruments is achieved by the use of alternative pin connections to IC2 and IC3.

The crystal reference frequency is produced by X1 which is connected in a standard i.c. oscillator circuit using a single inverting gate from IC1. Capacitors C1 and C2 provide the correct loading for the crystal and R1 provides a d.c. bias path which ensures that IC1 is operating in its "linear" range. The output from IC1 is a square wave at 4MHz. This is too high for some of the notes required so it is divided in two stages in IC2 to produce alternative outputs of 2MHz and 1MHz. These outputs are on pins 9 and 6 of IC2 respectively. A third output from IC2 on pin 11 provides a buffered, undivided output at 4MHz.

Switch S1 is a two-pole six-way switch which is used to select the required note in two stages. For the two lower notes a 1MHz clock is required, the next three notes require a 2MHz clock and the top note uses the full 4MHz. The first section of S1 (S1c) selects the appropriate clock frequency which passes to the input of a "top octave divider" IC3.

IC3 is a chip designed to generate 13 output frequencies at the correct musical intervals over one octave from C to C. Only five of the outputs are used in this application—the difference between top and bottom E being determined by the selection of 1MHz or 4MHz for the input clock frequency. All of the other outputs are available of course and may be used if required by arranging suitable switching.

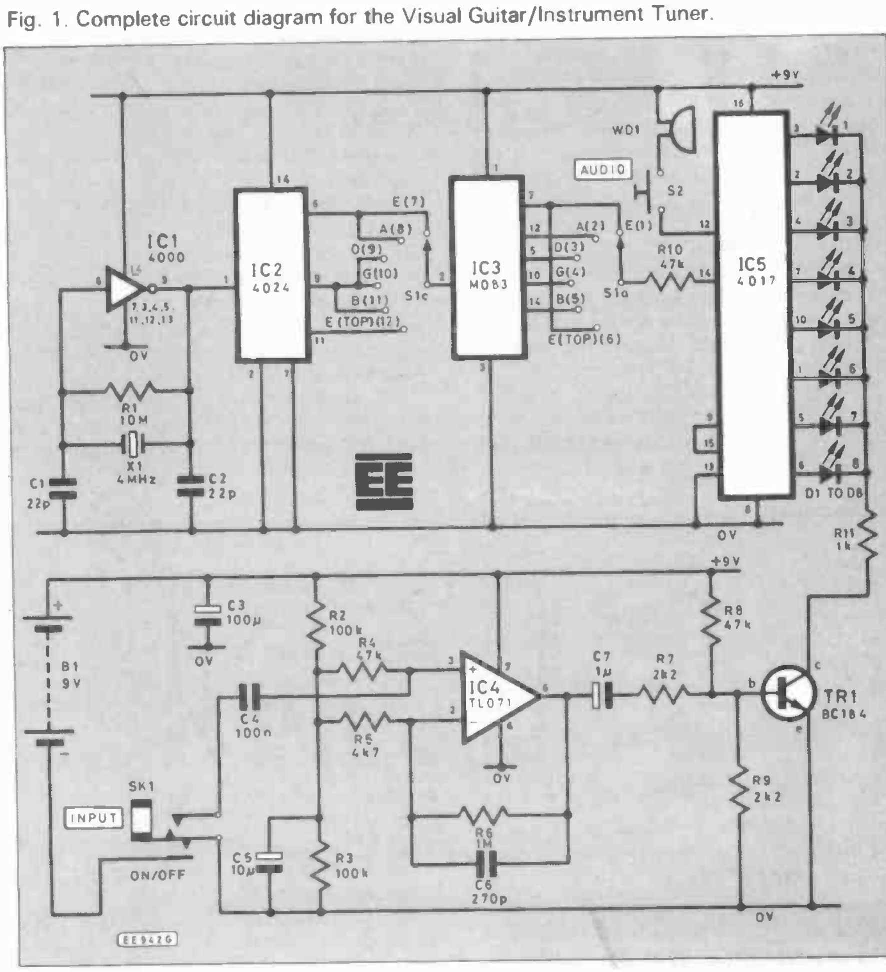
The table below shows the pins and the notes available from IC3

Available notes

Pin	Note
4	C sharp
5	D
6	D sharp
7	E
8	F
9	F sharp
10	G
11	G sharp
12	A
13	A sharp
14	B
15	top C
16	low C

The frequencies at the output of IC3 are exactly eight times the frequency of the note being tuned. This factor is required to give the correct display action. The selected output of IC3 is passed on to the "clock"

Fig. 1. Complete circuit diagram for the Visual Guitar/Instrument Tuner.



input IC5 which is a 4017 decode counter. The extensively used i.c. has ten outputs which switch from low to high and back again in turn on each clock pulse. Only one output can be high at any time so that a ripple effect is provided with a sequence of ten outputs each going high and then low again one by one in turn. For this circuit a sequence of only eight outputs is required not ten. This is achieved by connecting the ninth output to the "reset" pin on the i.c. (pins 9 and 15). This ensures that as soon as the ninth output attempts to go high the counter is automatically reset and assumes the starting state with the first output high.

The effect of this arrangement on the l.e.d.s (D1 to D8) is to scan through them one by one, taking the anode of each one in turn up to the positive supply voltage. If the cathodes of all of the l.e.d.s were held at 0V each l.e.d. would be lit when its turn came and all l.e.d.s would appear equally bright. This would be the case if transistor TR1 were to be turned on all the time. If TR1 were turned off all the time all l.e.d.s would be off.

In this circuit the state of TR1 is determined by the input signal to the tuner. The signal, from a microphone or pickup, passes via C4 to IC4 which is a standard non-inverting i.c. op-amp circuit. D.C. bias for the two inputs at half of the supply voltage is produced by potential divider resistors R2 and R3. C5 decouples this bias voltage which is then passed to the inputs via R4 and R5. Feedback around the amplifier is provided by R6 and C6, which in conjunction with R5 set the gain of the stage to 200. From IC4 the amplified signal is coupled to the base of TR1 via C7 and R7. Resistors R8 and R9 set the standing bias on TR1 so that in the absence of any input it is turned off.

COMPONENTS

Resistors

R1	10M
R2,R3	100k (2 off)
R4,R8,R10	47k (3 off)
R5	4k7
R6	1M
R7,R9	2k2 (2 off)
R11	1k

All 5% carbon film 0.25Watt

Capacitors

C1,C2	22p ceramic plate (2 off)
C3	100μ radial elect. 16V
C4	100n polyester
C5	10μ axial elect. 16V
C6	270p ceramic plate
C7	1μ axial elect. 16V

Semiconductors

IC1	4000B CMOS
IC2	4024B CMOS
IC3	MO83 top octave generator
IC4	TL071 op-amp
IC5	4017B CMOS
TR1	BC184 (see text)
D1 to D8	KLMP1700 high efficiency low current red l.e.d.s (8 off)

Miscellaneous

S1	2-pole 6-way rotary switch
S2	Push to make switch
SK1	¼in. mono jack socket with 1 make contact and 1 break
X1	4MHz crystal HC18U wire-ended
WD1	PB2720 ceramic resonator

Knob; connencting wire; p.c.b.; case; PP3 battery clips; d.i.l. i.c. holders 8-pin, 14-pin (2 off), 16-pin (2 off).

MAGENTA KIT 711

SCANNING

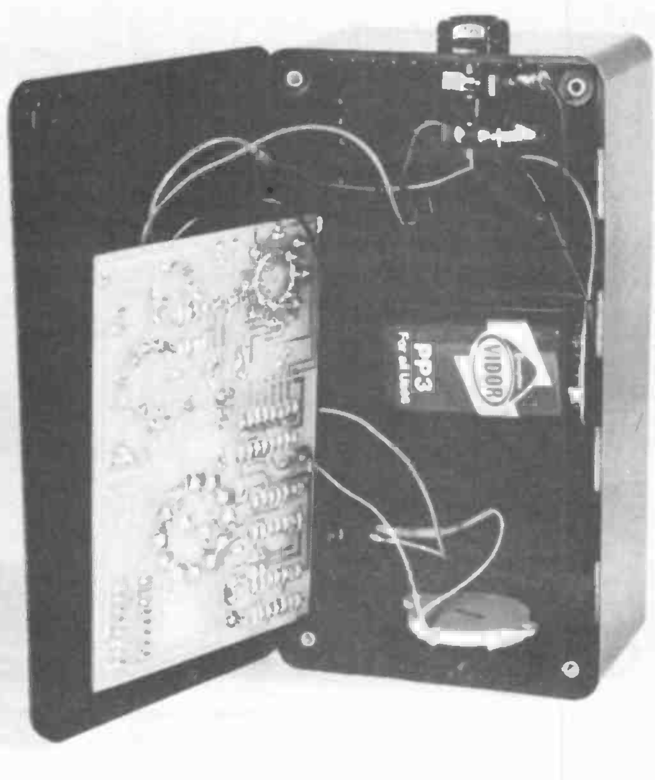
When a note of the correct frequency is applied to the input, TR1 will be turned on during the positive half cycle and off during the negative half cycle. During this time all eight l.e.d. anodes will have been scanned by IC5. Those l.e.d.s enabled during the positive half cycle of the input will be turned on and those during the negative half cycle turned off. This process repeats rapidly for each cycle of the incoming signal and provided the input is exactly one eighth of the scan frequency a stationary pattern of four l.e.d.s on and four l.e.d.s off will result.

In fact the four l.e.d.s that appear to be on are flickering at the input frequency as they are scanned. This is too fast for the eye to follow and so a steady pattern is perceived. When the input frequency is slightly different from the reference frequency the relative phase of the two signals changes progressively through successive scans. This has the effect of making the l.e.d. pattern appear to rotate slowly, the frequency of rotation being the difference frequency between the two signals. A slightly higher input signal makes the rotation go one way and a lower input signal reverses the rotation. This is an extremely useful feature as it shows which way tuning is required.

At higher difference frequencies the pattern rotates faster and when the difference is very large all that can be seen is a general flickering effect. By the time this occurs the difference is so great that it is usually obvious which way to start tuning, if not, a quick process of trial and error soon results in a rotating pattern.

So far a perfect input signal waveform has been assumed which turns on exactly four l.e.d.s. A waveform which is rich in harmonics may result in a larger or smaller number of l.e.d.s, being lit. The rotational effects are still exactly the same however, and so practically nothing is lost. As the combined gain of IC4 and TR1 is very high the input signal can decay a long way before any effect is noticed on the brightness of the l.e.d.s. Use of the special high efficiency low current l.e.d.s specified is not essential but does produce a far superior display than ordinary "cooking" l.e.d.s. As the signal dies away it eventually falls below the level necessary to turn on TR1 and the l.e.d.s all go out.

The circuit is switched on and off by means of the input jack socket which is of the make/break type. Piezo-electric transducer WD1 allows the unit to be used as a pitch-pipe for tuning instruments by ear. It allows the tuner to be used when a microphone or pick-up is not available.



Positioning of components inside the case. The p.c.b. is mounted on the lid of the case so that the ring of l.e.d.s can protrude through the top of the case.

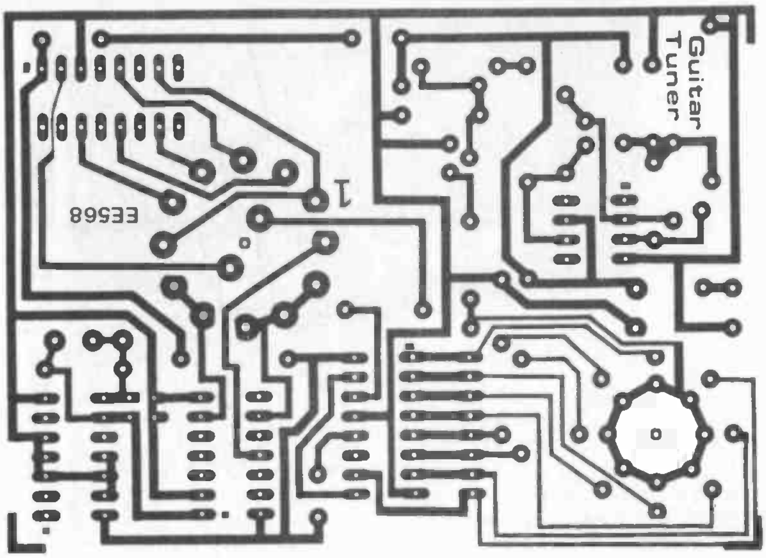


Fig. 2. Printed circuit board foil master pattern.

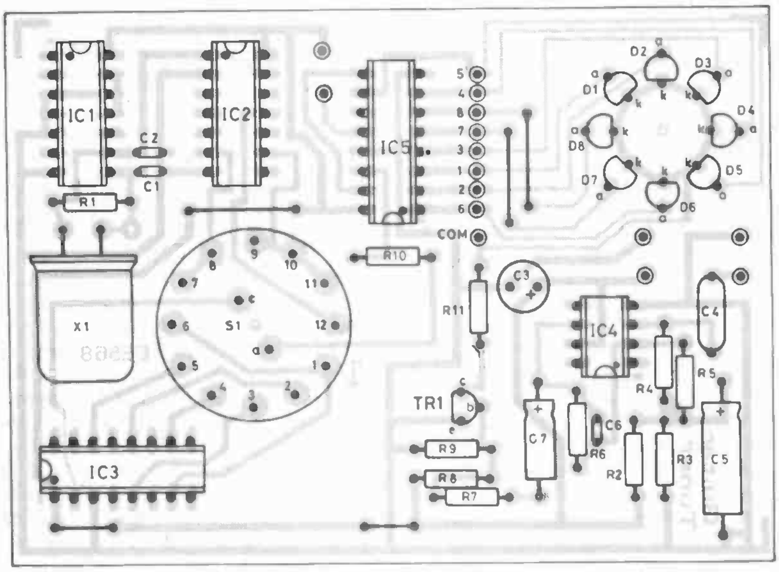
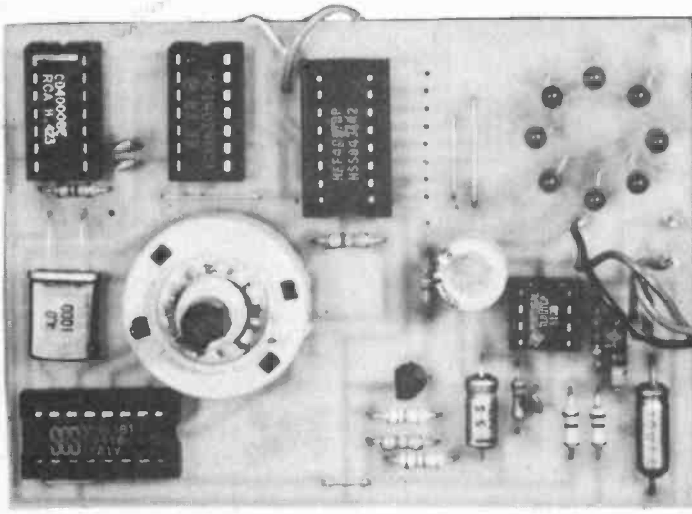


Fig. 3. Printed circuit board component layout. The numbers to the side of IC5 are the order of the outputs if the l.e.d.s are mounted off the p.c.b.



The completed board with the display l.e.d.s forming a circle.

CONSTRUCTION

The circuit is built on a single printed circuit board. Fig. 2 shows the p.c.b. track patterns and Fig. 3 the component layout.

S1 and the l.e.d.s can be mounted on the board as shown or may be mounted remotely if a different style of case layout is preferred. A set of connection points are provided for remotely mounted components.

Assemble the circuit in the usual order: small components, wire links and i.c. sockets first followed by larger components and wiring. TR1 must be the standard BC184 type and **not a BC184L** (which has the collector connected to the middle lead). Capacitors C3, C5 and C7 must be fitted with the correct polarity as shown. The l.e.d.s have a small flat at the point where the leads are attached which identifies the cathode.

In the prototype the l.e.d.s were all mounted directly on the board and the case front drilled appropriately. It is easier to do this if the l.e.d.s are first pushed into close fitting holes drilled for them in the case front and the printed circuit board fitted over the leads so that they all pass through the correct holes. The leads can then all be soldered and the board removed complete with the l.e.d.s. which will be in perfect alignment.

If a standard switch is used for S1 the letters and numbers shown are moulded on the switch body. The board is designed so that the switch can be mounted directly on it. Alternatively it can be mounted elsewhere and connected by wiring. The type of switch specified will need its tag ends removed for p.c.b. mounting.

CRYSTAL

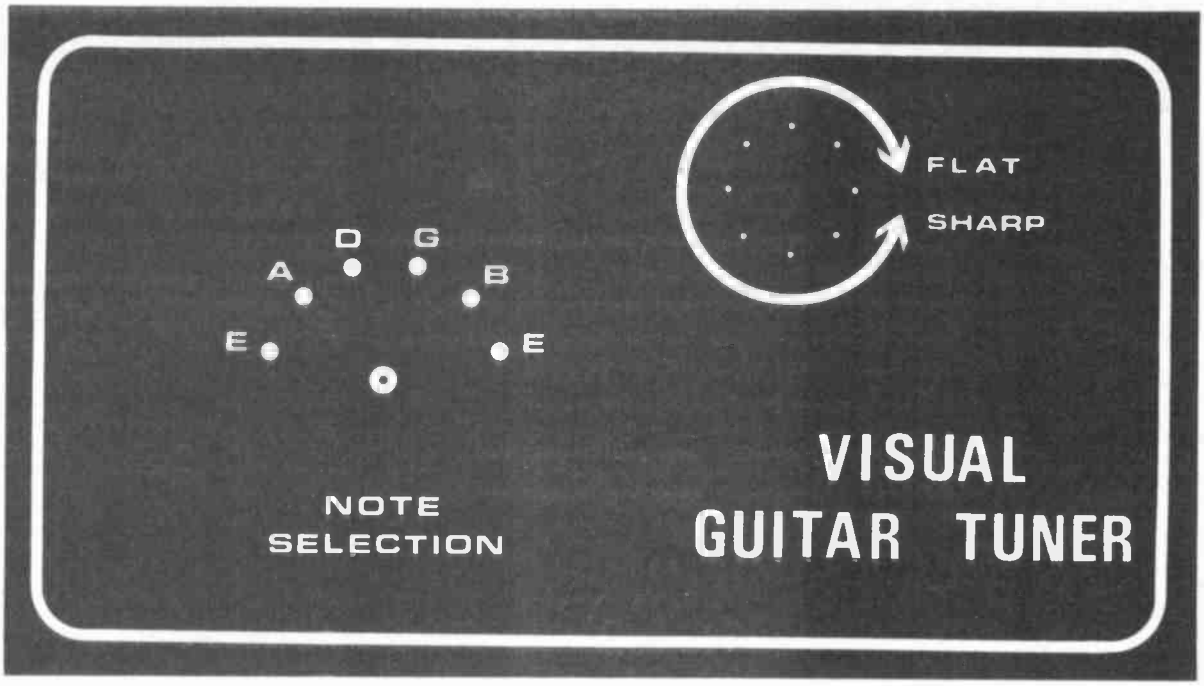
The crystal X1 should have its leads supported whilst they are bent, so that the glass seal is not broken. A small double-sided sticky pad can be used to hold the crystal firmly down on the board. Wiring simply involves the connection of S2 and WD1, a battery clip and the input socket SK1. Use flexible connecting wire and take care to connect SK1 exactly as shown in Fig. 4 so that the switch section works correctly. Other types of switched socket can be used if they have the correct switching arrangement.

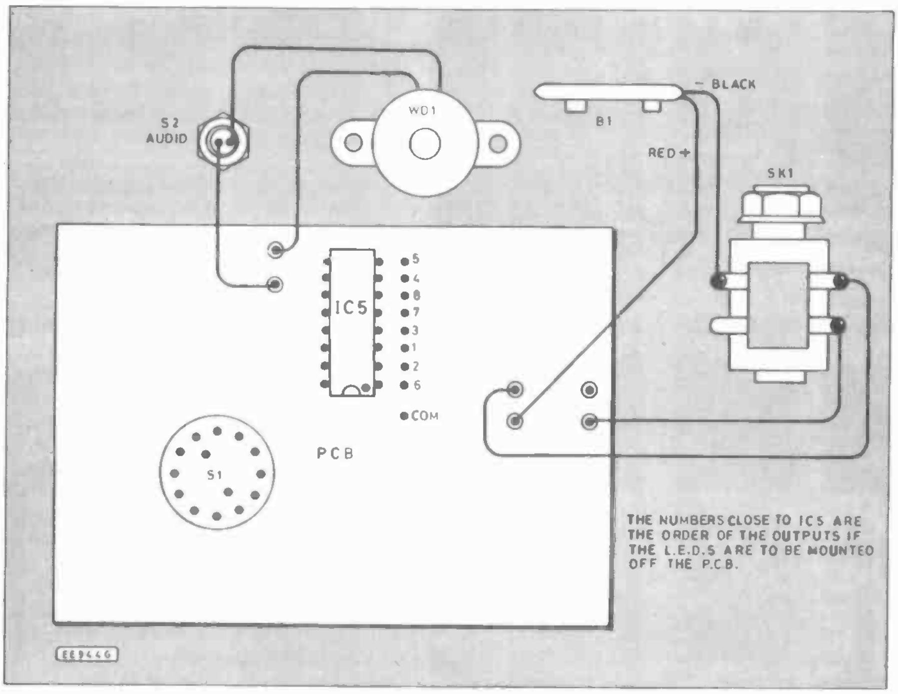
The board can be mounted by means of the fixing nut of S1 if this is fitted to the board. If S1 is mounted off the board it will be necessary to drill some fixing holes and mount the board using spacers or long screws fitted with extra nuts. The front panel of the prototype was marked as shown in Fig. 5. If the specified case and layout are used this panel layout can be photocopied, covered with plastic film, and used as a label. Details for drilling the front panel are shown in Fig. 6.

TESTING AND USE

Insert all i.c.s, switch on and check that the l.e.d.s do not light. Press S2 and check that a rough sounding note is produced. Keep S2 pressed and rotate S1 to obtain all six of the set notes. If everything is correct so far it remains only to inject a signal and see if the lights behave as described. A signal generator can be used as the source to simplify fault finding (if any is required).

If none of the l.e.d.s light there could be a fault in the signal path or IC5. Short circuit





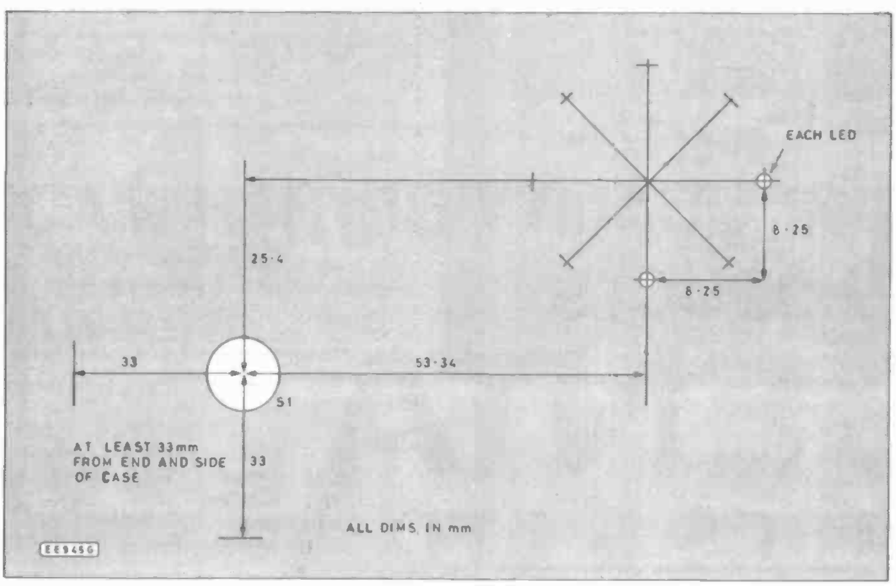


Fig. 5 (above). Full size front panel legend for the tuner. This diagram may be photocopied and fixed on the case to give a neat finish.

Fig. 4 (left). Interwiring details to the off-board components.

Fig. 6 (bottom left). Front panel drilling details for the note selection switch and the display l.e.d.s.

collector-emitter of TR1 and all l.e.d.s will light if IC5 is working and is receiving the correct signals. If only one l.e.d. lights, check that S1a is correctly wired.

If all l.e.d.s light when TR1 is shorted out but refuse to light when a signal is connected it is likely that either IC4 or TR1 is at fault. Check that both are inserted the right way round and that C7 and C5 are also the right way round. If a multimeter is available check that the output of IC4 (pin 6) is at exactly half of the supply voltage.

If these checks are correct but the circuit still refuses to work there could be a fault in the wiring of SK1 or in one of the capacitors C4, C5, C6, and C7 which would prevent the signal from getting through to TR1. As there is very little wiring it is likely that the circuit will work first time. Remember that 99 per cent of faults are due to poor soldering—dry joints, bridges, short-circuits—or incorrectly fitted components. If you cannot see anything wrong, ask a friend to look. It's surprising how easy it is not to see one's own errors!

As the circuit is crystal controlled, temperature stability and accuracy are excellent and no setting up is required at all. Battery drain is about 30mA when operating, most of this being used by IC3 and the l.e.d.s. A PP3 should have a good life provided the jack plug is removed when tuning is complete. A failing battery will be shown by the display getting dimmer but accuracy will not be affected.

The type of display used is a very effective way of comparing two frequencies and probably has a wide range of other applications where a clear simple indication of frequency difference is needed. The author would be delighted to hear of readers' suggestions which could possibly be used as the basis of other projects. □

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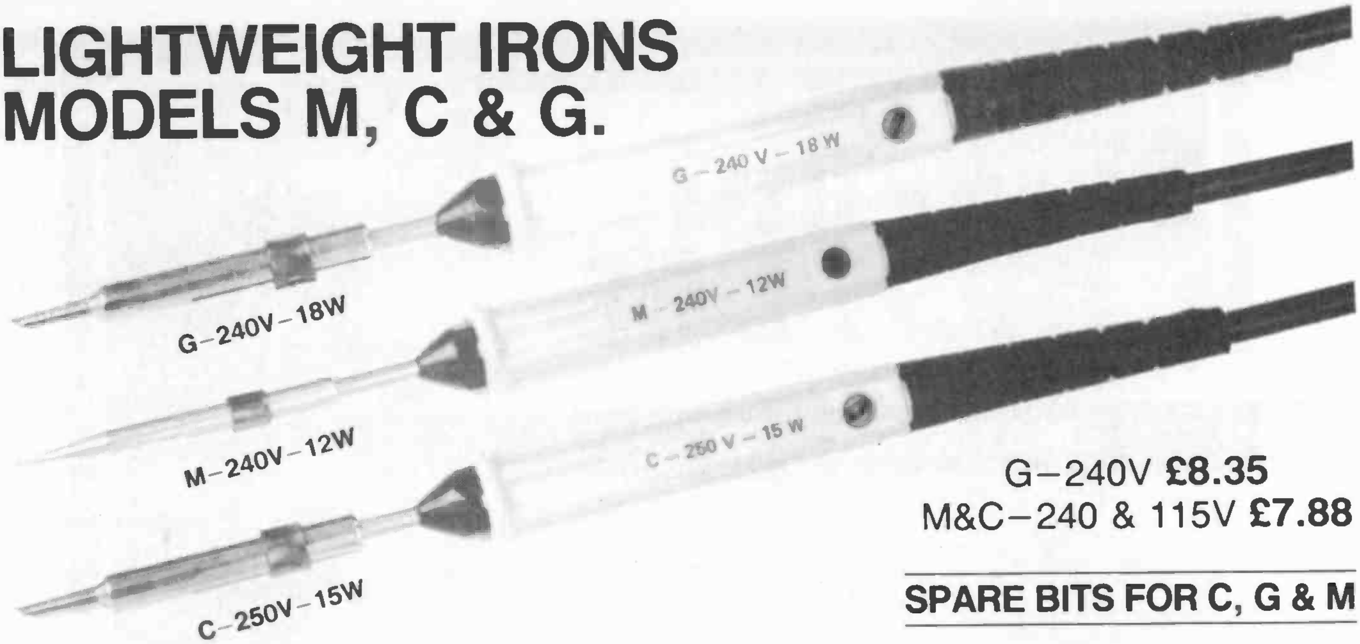

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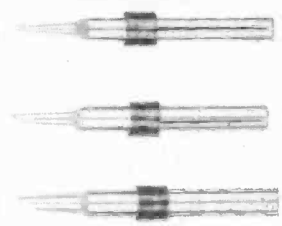

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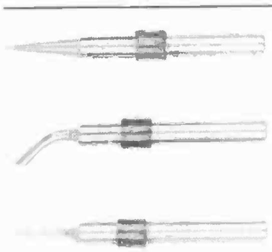

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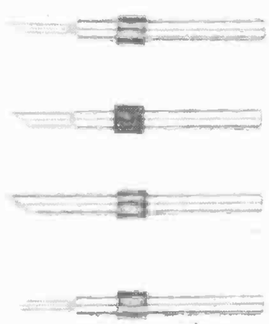

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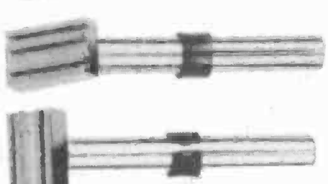
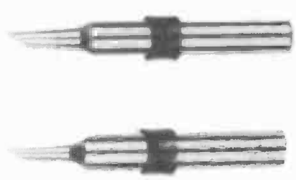


14a
14b
52



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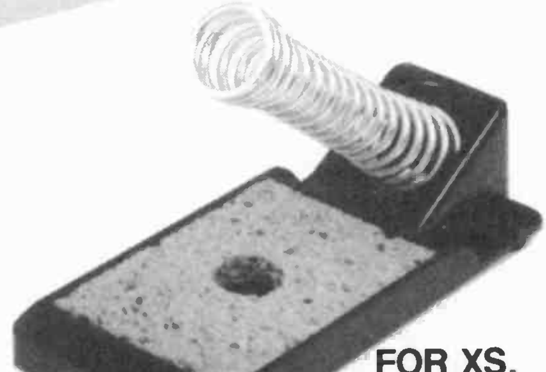

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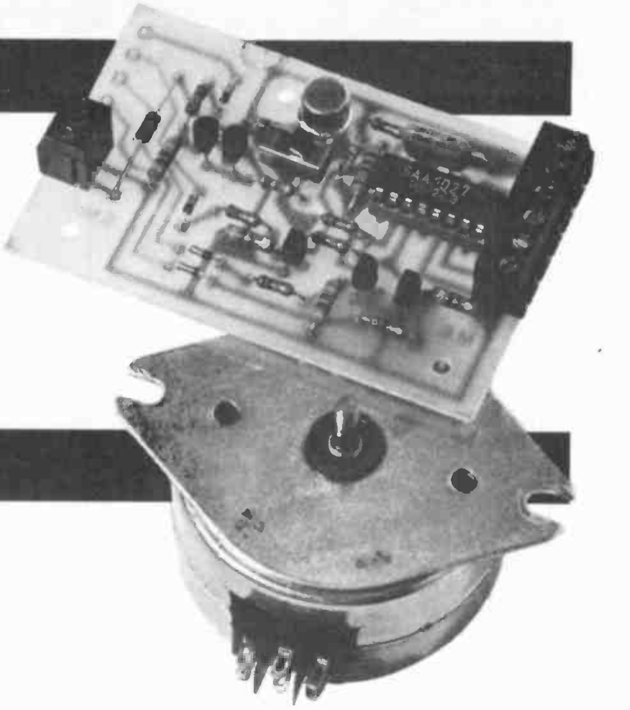
STEPPING MOTORS



MARK STUART

STEPPING motors provide a very simple means of producing precise controlled movement from digital input signals. For this reason their use has become more and more common in all kinds of computer controlled mechanisms.

CONSTRUCTION AND USE

To explain the operation of a stepping motor a very basic 4-step per revolution model is shown in Fig. 1. This model has a smooth cylindrical rotor which is magnetised with a single pair of magnetic poles. There are two pairs of stator poles set at 90° to each other. Each stator is wound with a coil through which current may be passed in either direction to produce a magnetic field between the poles.

This type of motor where the rotor is a smooth magnetised cylinder and the stators are not permanently magnetised is known as a permanent magnet stepping motor. There is another type of motor construction known as variable reluctance, and a third type which combines the characteristics of the previous two types and is aptly called the hybrid.

The windings shown on the stators of Fig. 1 are centre tapped. The centre taps are connected to one side of the power supply and the remaining ends of the coils are returned to the other side of the supply via four switches. This method of winding is called unipolar because it allows all four windings to be switched to the same supply. This method is particularly suited to simple drive circuitry. For example the four switches could be replaced by transistors which can be driven directly from a computer output port. A particularly useful integrated circuit, the SAA1027, is designed to drive unipolar stepping motors directly.

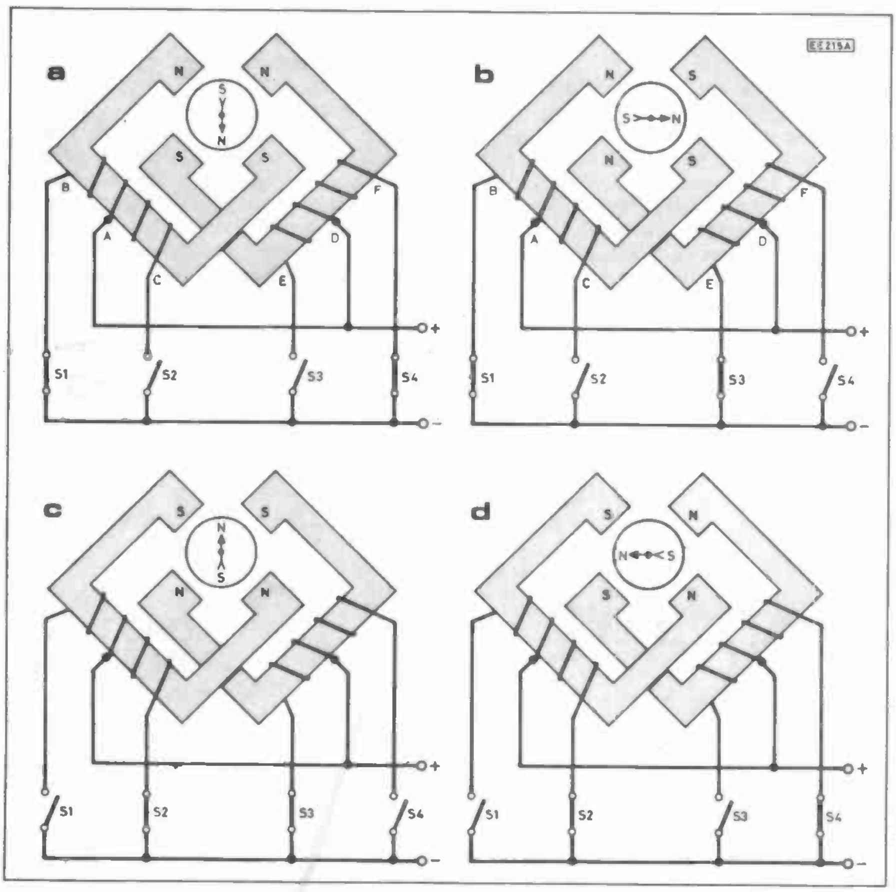


Fig. 1. Basic operation of a 4-step per revolution stepping motor.

Fig. 1a shows the motor in the first position. S1 and S4 are closed, current flows in windings AB and DF magnetising the stators as shown. The stators attract the opposite poles of the rotor which aligns itself as shown.

The second position is shown in Fig. 1b. This time current flows in winding DE instead of DF so that the magnetic polarity of the stator is reversed. The rotor now aligns itself in the second step position. Step 3 and step 4 follow in a similar way as shown in Fig. 1c and 1d respectively.

The switching sequence of the windings is shown in Table 1. Reversing the sequence of switching results in the motor stepping in the opposite direction.

This much simplified model produces steps at 90 degree intervals which are not practical for real applications.

Standard commercial permanent magnet (PM) stepping motors are made with 15 degree or 7·5 degree steps, giving 24 or 48 steps per revolution. The finer steps are achieved by magnetising the rotor with several pole-pairs and using multi pole stators. The maximum number of steps per revolution is limited by the number of pole pairs with which the rotor can be magnetised. This depends on the rotor material (usually a type of ferrite) and the circumference of the rotor. A very large rotor could be produced with a correspondingly large number of pole-pairs but then the mechanical inertia would be so high that the motor acceleration would be severely limited. The practical maximum for this type of motor seems to be 48 steps per revolution.

ID35 MOTOR

The ID35 motor uses the type of construction shown in Fig. 2. The rotor is magnetised as shown with twelve pairs of magnetic poles around its circumference. In all 24 pairs of stator poles are required. These are provided by two identical sets of 12 pairs, one set of which is offset from the other by one quarter of the pole pitch as shown. Each set of 12 pole pairs is constructed from two pressings which resemble large locking washers assembled each side of a coil former so that their teeth interlock. Current passing through the coil magnetises the two pressings with opposite magnetic poles so that the teeth appear as twelve pairs of poles around the rotor (Fig. 2b).

The actual ID35 motor pressings are more complicated than the simplified drawing in Fig. 2 shows. The two outer pressings form the casing of the motor and are drilled to hold the motor bearings. The alignment of the whole assembly is critical so do not be tempted to take one to pieces—it will not fit back together properly.

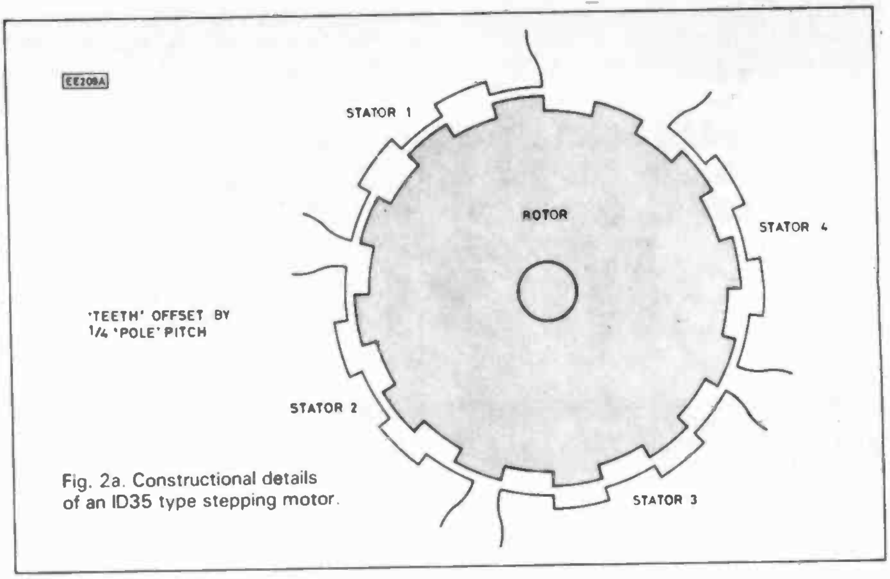


Fig. 2a. Constructional details of an ID35 type stepping motor.

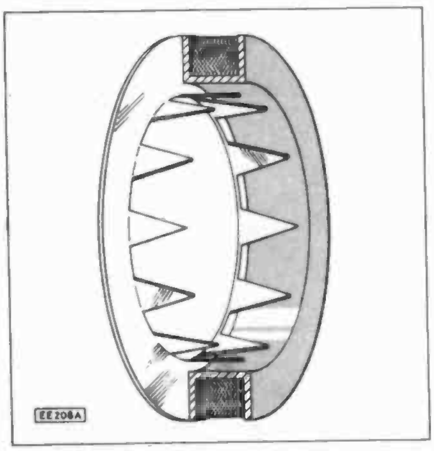


Fig. 2b. Motor assembly.

The permanent magnet motors being of simple construction are at the low cost end of the market.

VARIABLE RELUCTANCE MOTORS

Variable reluctance (VR) motors have an unmagnetised cog shaped iron rotor which is attracted to sets of toothed stator poles magnetised by current flowing in windings around them. These motors have practically no torque when the windings are not energised (the detent torque) and can be useful in applications where freewheeling manual operation and motorised operation of a mechanism are required. A good example of this is the paper feed mechanism on a strip chart recorder where paper is pulled through manually between recordings.

HYBRID MOTORS

The Hybrid stepping motor uses a cog shaped rotor and toothed stator poles as in the VR type, but also has a permanent magnetic field supplied by a magnet fitted to either the stator or rotor. The teeth on the stator poles are offset from each other by a small amount as shown in Fig. 3. As each set of poles is energised the rotor turns so that its teeth line up with them. By energising pairs of poles in the appropriate sequence as with the permanent magnet motors rotation in either direction is achieved. The step angle of hybrid (and VR) motors is not limited by the magnetic materials in the same way as the permanent magnet motor so that much smaller steps angles can be achieved.

Step angles 0·9, 1·8, 1·875 and 3·75 degrees are common yielding 400, 200, 192 and 96 steps per revolution.

VARIATIONS

The motors discussed so far are the most common types encountered. Many variations exist offering better performance or lighter weight and so on. Motors may have two, three, four or even five sets of windings and power outputs vary from milliwatts to a maximum of about 1 kilowatt. For very high power outputs an hydraulic motor has been linked to a stepping motor. The stepping motor operates a set of valves which control the hydraulic fluid to the main motor which follows the stepping motor exactly. Power outputs of up to 150kW are available using this technique. At the other end of the scale is the motor driving the hands of the analogue quartz watch. This must be the most common application of stepping motors.

Table 1. Step sequence.

		S_1	S_2	S_3	S_4
CLOCKWISE ↓	1	ON	OFF	OFF	ON
	2	ON	OFF	ON	OFF
	3	OFF	ON	ON	OFF
	4	OFF	ON	OFF	ON
	1	ON	OFF	OFF	ON

MOTOR SPECIFICATIONS

The full specification of a stepping motor covers a very wide range of mechanical and electrical parameters. Table 2 shows the main parameters for three types of motor. The maximum stepping rate and power output can only be obtained when the motors are driven from the correct power source. The higher power motors employ very sophisticated drive circuits which provide a high voltage current limited supply to the windings. The high voltage forces the current in the windings to rise very quickly. Once the current reaches the maximum rating the current limiting circuit comes into action and prevents the current rising further. This arrangement gives the maximum speed and power output from the motor. Such techniques could be applied to the smaller motors but the complexity and

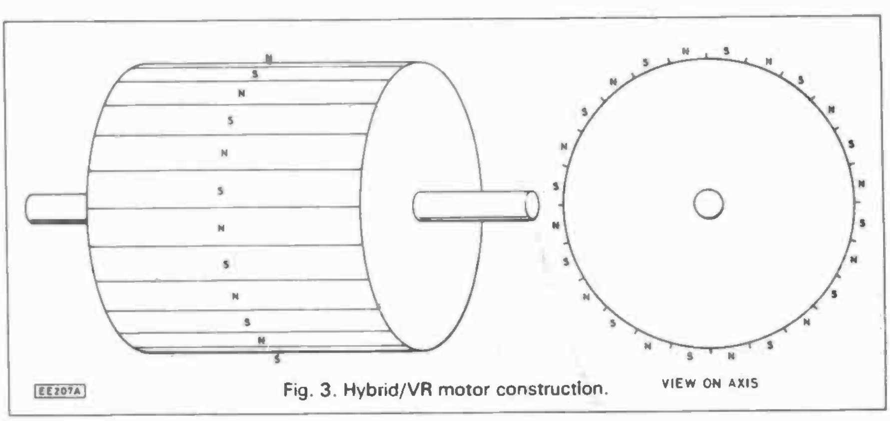


Fig. 3. Hybrid/VR motor construction.

cost of the circuitry are not really justified. It is usually cheaper to use a larger motor.

One interesting feature shown in Table 2 is that the largest motor is capable of better acceleration and top speed than the smaller motors. It is also more efficient.

Stepping motors have been around for a very long time in one form or another. The advent of cheap decoder i.c.s, and power transistors has already given a major boost to their use. The arrival of low cost computers with the need for simple accurate mechanisms in such things as disc drives, printers and plotters must have presented an enormous new market.

The relentless spread of automation into all aspects of life must mean that the future of the stepping motor is guaranteed.

	Step Angle	Holding Torque	Resistance Per Phase (Ohms)	Max Pull In Rate	Max Pull Out Rate	Inductance Per Phase	Rotor Inertia	Max Power Output	Current Per Phase
PHILIPS ID35 35014	7·5°	85mNm	47	130	130	400mH	45gm cm²	1 watt	240mA
PHILIPS HR23	1·8°	450mNm	4·3	300	7000	14mH	100gm cm²	10 watts @ 2000 step/sec	1A
SIGMA SERIES 21	1·8°	4860mNm	0·3	800	20,000	1·65mH	3530gm cm²	275 watts @ 6000 step/sec	9·2A

Table 2. Stepping motor specifications.

STEPPER MOTOR INTERFACE

THIS interface was designed to enable 4-phase unipolar stepping motors of the ID31/35 type to be driven from four output lines of any computer user port.

The computer connections shown in this article are for the BBC Model B. They can easily be varied to suit most other computers provided at least four output lines are available.

In order to keep the programming as simple as possible a special stepping motor decoder/driver i.c. is used. This i.c. takes clock pulses from the computer and produces the correct switching sequence on its outputs to drive directly the four stepping motor coils. A second i.c. input selects the direction of motor rotation by reversing the output switching sequence.

Two additional inputs are provided. One sets the motor in the nearest phase 1 position and inhibits the clock and direction inputs. The other input allows the motor current to be switched between high and low levels, this allows dissipation to be minimised when the motor is stationary whilst still allowing full power during rotation. These last two inputs may be ignored in simpler applications simply by leaving them disconnected. The interface then only requires two output lines to run.

CIRCUIT OPERATION

Fig. 4 shows the full interface circuit diagram. The four motor coils are driven directly from pins 6, 8, 9 and 11 of IC1. Up to 450mA is available for each coil. The output current is controlled by the current fed into pin 4. This current is used to bias the output transistors. The relationship between the output current limit and the bias current is approximately 4 to 1 except at outputs below about 50mA when control becomes very critical.

The bias current is set via R14 and R15. When the output current control input is held low (logic 0) TR6 is turned off and so

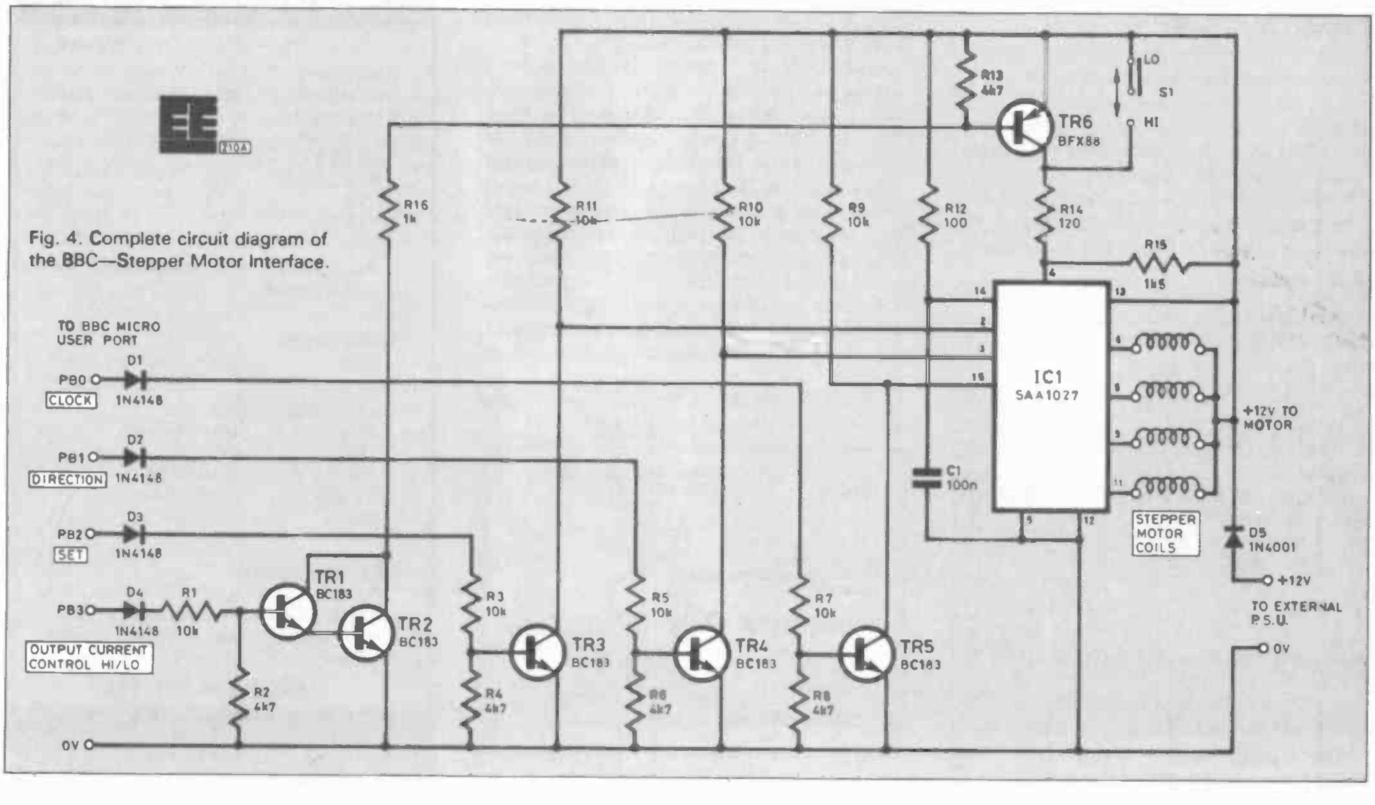


Fig. 4. Complete circuit diagram of the BBC—Stepper Motor Interface.

the supply is removed from R14. The only bias current is thus supplied via R15. The value of R15 is selected to give about 10mA of bias current. This sets the output current limit to about 50mA. Setting the output current control input high (logic 1) turns on TR6 and provides bias current via R14 in addition to that via R15. The output current limit now becomes 400mA, and values of R14 and R15 may be adjusted if required to suit the particular motor and operating conditions. SW1 bypasses TR6 and sets the output current permanently high. This setting allows the interface to be used with the current control input left open circuit so saving one output port line.

The clock, direction, and set functions are all provided by IC1 and are selected by the voltage levels on pins 15, 3 and 2 respectively. It is not possible to drive the i.c. directly from the computer output port because the inputs require a logic high level exceeding 7·5 volts. Transistors TR3, TR4 and TR5 along with their associated components perform the necessary level shifting operation. The component values are chosen so that the transistors are turned on by 2·4 volts from the computer. The pull-up resistors R9, 10 and 11 take the inputs of IC1 up to 12V when the transistors are turned off. When the transistors are turned on they pull the i.c. pins right down to zero volts.

The output current control input has a similar circuit to the other three inputs but instead of a single transistor two are used. These two transistors are connected as a Darlington pair which has a much higher current gain than a single transistor. This is necessary to provide the higher drive current required by TR6. Diodes D1–D4 are fitted to prevent the interface from feeding current back into the computer port when the computer is switched off.

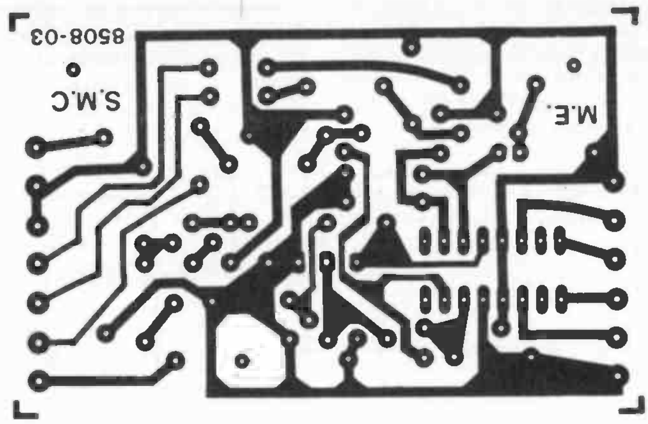


Fig. 5. P.c.b. design for the Stepper Motor Interface.

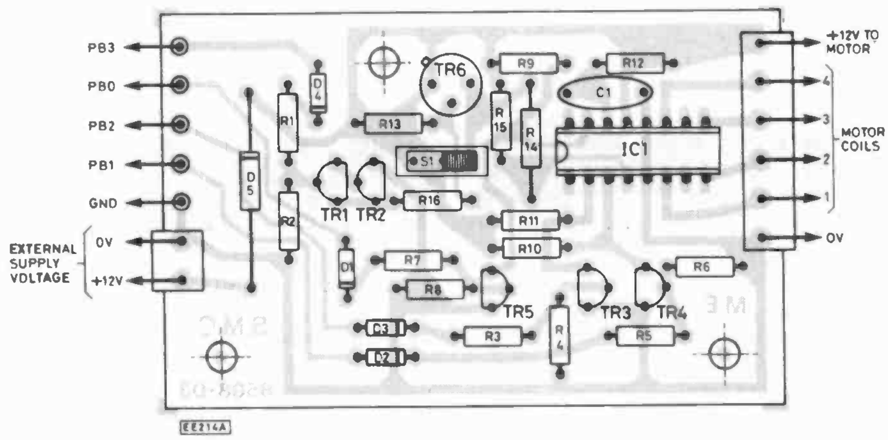


Fig. 6. Component layout for the Stepper Motor Interface.

CONSTRUCTION

The interface is built on a single printed circuit board. (See Fig. 5.) Start by fitting the smaller components. Take care with the polarity of the diodes. The cathode end of the 1N4148 types is indicated by a broad band marked on the body. The larger 1N4001 diode has its cathode marked by a silver band. All of the resistors and the capacitor C1 can be fitted either way round.

Next fit the socket for IC1 (taking care to fit the socket the correct way round) and the transistors. Finally fit S1 (either way round) and the terminal blocks. Note that the terminal blocks have a dovetail arrangement which enables a 6-way strip to be made up by sliding shorter ones together.

Having completed the board assembly the ribbon cable should now be connected to the appropriate computer connector. For the BBC I/O port a 20 pin IDC socket is required. Fig. 7 shows the correct assembly of the socket viewed from the end nearest to pin 1. Note the position of the polarising bump and the way that the cable is folded back over the socket before the retaining clip is fitted. For those unfamiliar with IDC sockets the important thing to remember is that the cable insulation does NOT need stripping. The connections are made by pressing the insulated cable down over specially shaped tines which pierce the insulation and make very good contact with the conductors inside.

The cable is connected to the printed circuit as shown in Fig. 6. The lead numbers are counted across the cable starting from pin 1. The required leads should be separated from the ribbon cable, stripped and tinned so that they can be fed down through the p.c.b. from the component side and soldered to the pads on the track side. The ground connection is available on several pins of the BBC. Pin 7 is probably the most convenient. Ensure that the unused leads are cut cleanly and do not have any stray wire ends that might cause short circuits.

Finally insert the i.c. into its socket—take care to get it the right way round.

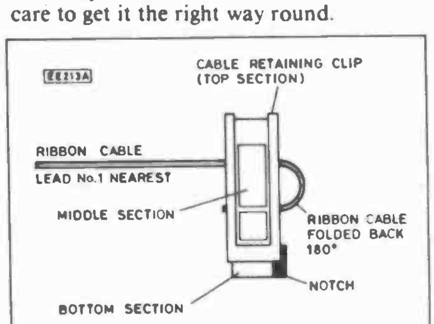


Fig. 7. IDC socket assembly.

COMPONENTS

Resistors

R1,R3,R5, R7,R9–R11	10K (7 off)
R2,R4,R6, R8,R13	4K7 (5 off)
R12	100
R14	120 ½W
R15	1K5
R16	1K

All resistors ¼W 5% carbon film unless stated

Capacitors

C1	100n polyester 16V

Semiconductors

TR1–TR5	BC183 (5 off)
TR6	BFX88
IC1	SAA1027
D1–D4	1N4148 (4 off)
D5	1N4005

Miscellaneous

S.p.d.t. p.c.b. mounting switch, i.c. socket, p.c.b. terminal blocks, p.c.b., IDC socket to suit computer, ribbon cable.

MAGENTA KIT 464

POWER SUPPLY

The interface requires a 12V supply capable of supplying up to 800mA. The supply need not be regulated as the i.c. will take up to 20V safely. A simple circuit is shown in Fig. 8. This circuit can be built in any suitable small case. Take care to keep the mains wiring separated from the secondary wiring and use insulating sleeving on all of the mains connections. The transformer must be a split bobbin type with plenty of insulation between primary and secondary. The core of the transformer should be connected to earth using a solder tag under one of the fixing screws.

TESTING AND USE

Connect a suitable motor to the output terminals, set S1 to the HIGH position and connect a 12V supply. Do not connect the computer at this stage. Check that the motor is energised and locked into one step. It should now be possible to move the motor one step each time the clock lead is touched onto the +12V supply. If all is well disconnect the 12V supply, connect the interface to the computer user port and reconnect the supply.

The four computer port lines operate as follows:

PB0 This line provides the clock pulses which step the motor. Each time the level changes from logic 1 to 0 the motor moves 1 step.

PB1 Sets the direction of motor rotation. Logic 0 gives clockwise movement, logic 1 anticlockwise. If this is inconvenient it is possible to reverse the directions by interchanging the motor connections.

PB2 This is the SET input which locks the motor into the nearest step 0 position when it is held at a logic 1. In this condition the direction inputs are ignored.

PB3 The current control input when S1 is set to 'low'. This input allows the computer to set the output current. Logic 1 gives High. Logic 0 gives Low.

A full truth table is shown in Table 3.

The simplest program that will run the motor is one which alternately writes 8 and 9 to the port. The speed of rotation of the motor is limited to a maximum of 130 steps per second before the torque falls to zero. This means that a delay loop of around 10 milliseconds will need to be incorporated into the program. As the speed is lowered the torque increases rapidly—at 50 steps per second the torque is 90% of the maximum.

The inertia of the motor and its load influence the rate at which the motor can begin stepping from a standstill. With high inertia loads it is necessary to ramp up and ramp down the speed when accelerating and decelerating. The maximum rate of speed increase and decrease must be found by trial and error. It depends on both the inertial and frictional content of the load.

PB1 = L		PB2 = L			PB1 = H				
PB0	Q1	Q2	Q3	Q4	PB0	Q1	Q2	Q3	Q4
0	L	H	L	H	0	L	H	L	H
1	H	L	L	H	1	L	H	H	L
2	H	L	H	L	2	H	L	H	L
3	L	H	H	L	3	H	L	L	H
4	L	H	L	H	4	L	H	L	H

Table 3. Stepping motor truth table.

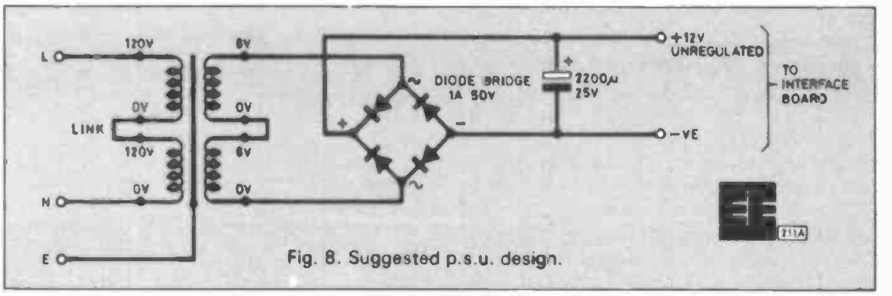


Fig. 8. Suggested p.s.u. design.

BBC COMPUTER PROGRAM LISTING

A simple programme to demonstrate the driving of a stepping motor from the interface is provided. The program includes simple instructions for operation.

Line 10 sets up the port and displays the instructions. The computer asks for the number of steps and direction. Maximum speed is set in lines 160 and 200 which are small FOR-NEXT type delay loops. Acceleration is represented by variable A%, which is used in lines 150 and 190 to provide a steadily decreasing delay loop over 40 pulses. A% can be varied in line 120—a higher number gives a slower acceleration.

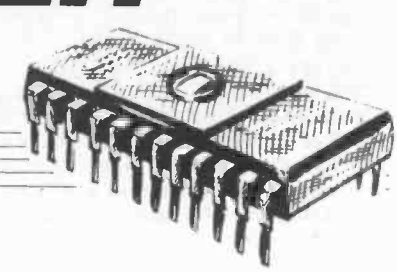
The delay in lines 160 and 200 can be varied by changing the number of loops initially set at 3, e.g. change to "FOR E%=0 TO 10:NEXT" to lengthen the delay.

Although only intended for demonstration purposes the program may be varied as required or embedded in larger programs to provide the motor control function. □

```
 10 MODE7:?&FE62=15:VOU 23;8202;0;0;0;
 20 ENVELOPE1,1,0,0,0,100,5,100,10,-1,-1,-1,110,100:PROCINSTRUCTIONS:CLS
 30 INPUT TAB(0,1);"Number of steps."S$
 40 IF S$=0 THEN VOU7:PROCCLEAR:GOTO30
 50 PROCSOUND:PROCCLEAR
 60 INPUT TAB(0,1);"Clockwise/Anticlockwise (C or A)."O$
 70 IF O$="A" OR O$="C" THEN 80 ELSE VOU7:PROCCLEAR:GOTO60
 80 CAO$="AN ANTICLOCKWISE":O$=0:IF O$="C" THEN O$=2:CAO$="A CLOCKWISE"
 90 PROCSOUND:PROCCLEAR
100 PROCSETUP
110 M$=9+O$
120 A$=20:FOR B$=1 TO S$
130 ?&FE60=M$
140 IF A$=0 THEN 160
150 FOR E$=1 TO A$:NEXT E$
160 FOR E$=0 TO 3:NEXT E$
170 ?&FE60=(M$-1)
180 IF A$=0 THEN 200
190 FOR E$=1 TO A$:NEXT E$:A$=A$-.5
200 FOR E$=0 TO 3:NEXT E$
210 NEXT B$
220 PRINT TAB(0,9);"LAST MOVE:";TAB(0,20);SPC(40)
230 SOUND 1,1,33,2:SOUND 2,1,53,2:SOUND 3,1,69,2:GOTO 30
240 DEF PROCSOUND:SOUND 1,1,33,2:SOUND 2,1,49,2:SOUND 3,1,61,2:ENDPROC
250 DEF PROCCLEAR:PRINT TAB(0,0);SPC(120):ENDPROC
260 DEF PROCINSTRUCTIONS:CLS
270 PRINT" STEPPER MOTOR DEMONSTRATION PROGRAM"
280 PRINT" ___________________________________"
290 PRINT';"When prompted, enter the data required."'
300 PRINT"Any invalid data will be ignored by the"'
310 PRINT"program and you will be asked to enter"'
320 PRINT"it again."''
330 PRINT"If your stepper motor is connected to"'
340 PRINT"the controller board in the wrong order,"
350 PRINT"it will not be damaged, nor cause any"'
360 PRINT"damage whatsoever to the board. It will"'
370 PRINT"simply either rotate in the opposite"'
380 PRINT"direction or struggle to rotate at all."'
390 PRINT"  * * TAP THE RETURN KEY TO BEGIN * *";
400 A$=GET$:IF ASC A$=13 ENDPROC ELSE 400
410 ENDPROC
420 DEF PROCSETUP:CLS:PRINT TAB(0,10)
430 PRINT;"ROTATE ";S$;" STEPS IN ";CAO$
440 PRINT'"DIRECTION"
450 PRINT TAB(0,20);"*** PRESS RETURN KEY TO DRIVE MOTOR ***";TAB(0,9);SPC(10)
460 A$=GET$:IF ASC A$=13 ENDPROC ELSE 460
```

Constructional Project

EPROM ERASER



MARK STUART

Safe, low-cost unit capable of erasing up to four EPROM's simultaneously in less than twenty minutes. Could also be used to drive some fluorescent tubes from 12V supply.

MANY projects have been published in the last few years for EPROM programmers. These have been designed for use with various different computers, and each one has had particular features such as speed of programming, simple hardware, elaborate software, ability to program a wide range of i.c.'s etc. In each case, it has been assumed that a source of blank EPROMS was available, and yet, a good EPROM *ERASER* project has been elusive.

To redress the balance, this article describes an EPROM eraser which should cover most needs. It is capable of erasing up to four EPROMS at once in less than 20 minutes. It operates from 12 volts d.c. and was designed specifically for use in schools where mains voltages are not allowed–it is ultra-safe. The advantages go further than this, however, because the use of a high frequency inverter circuit results in longer lamp life and higher efficiency.

WHAT IS AN EPROM

The letters EPROM stand for Eraseable/Programmable Read Only Memory. The fact that these are Read-Only Memories means that the computer in which they are used cannot store information in them, but can only read from them. In practice EPROMS are used to hold permanent information such as the computer "operating system" that enables it to read the keyboard and print on the screen before other programs are loaded. In the case of the BBC computer, sockets are available to enable EPROMS to be fitted which contain special programs.

EPROMS are supplied "blank" by the manufacturers and are programmed by applying the information to be stored along with a pulse of 12.5, 21 or 25 volts depending upon the type. There are various ways of applying the information and the voltage pulses so that faster programming can take place. This is probably why so many people have been attracted to the design of EPROM programming hardware and, more particulary, software.

During programming, each data "bit" is set to a 0 or 1 by trapping (or not) a tiny amount of electrical charge in the gate region of a field effect transistor (f.e.t.). The trapped charge cannot escape because it is completely surrounded with insulating silicon dioxide.

ERASING

To erase the EPROM is necessary to remove the trapped charge. This cannot be done by applying voltages to the pins, or by any other direct electrical method. It is achieved instead by making the silicon dioxide act like a photo conductive cell. Applying ultra-violet radiation of the correct (short-wave) type directly to the surface of the silicon chip causes the silicon dioide to become very slightly conductive, so allowing the trapped charge to leak away. This, of course, is the reason for the familiar "window" in the middle of EPROMS which allows the ultraviolet radiation to penetrate to the surface of the silicon.

The special short-wave ultra-violet radiation which (for the technically minded) has a wavelength of 2537 Angstrom units, is produced by a special type of tube, similar to a flourescent lighting tube, but without the white flourescent coating. The tube has a combination of mercury vapour and inert gas filling, and is made from a special "glass" that allows short-wave ultra-violet to pass. Ordinary tubes, and those used to expose photo-resist in printed circuit boards have little, if any, effect. A fully erased EPROM has all its bits set to "1" and so will read FF or 255 when in circuit. This seems "upside down", but has little practical significance.

CIRCUIT

The circuit diagram is shown in Fig. 1. A single transistor is used in a self-oscillating circuit to produce 120 volts peak to peak at 25kHz. The tube is driven from this high voltage via the current limiting inductor L1. An incoming 12V d.c. supply passes via D1, which protects against reverse polarity, and on to decoupling capacitor C4.

The current consumed by the circuit is just under 400mA so only a modest power supply is required. As the circuit draws current in large pulses at 25kHz the value of C4 needs to be quite large to maintain a clean supply rail. The important part of the circuit is T1, this is a tuned transformer with a step-up ratio of just under 6 to 1. The primary winding is of 9 turns and is connected between the supply and the collector of TR1. The secondary winding of 52 turns is wound on from the primary for convenience and is tuned by C2 to 25kHz. TR1 is made to oscillate by means of positive feedback supplied from the winding on T1 via C3, R3, and R2. Resistor R1 supplies a small base current to start the oscillator at switch-on.

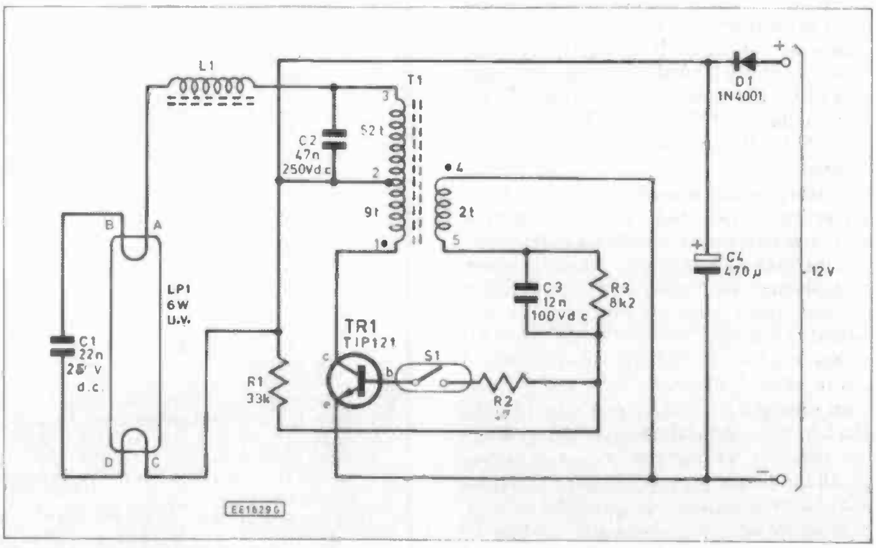


Fig. 1. Complete circuit diagram for the EPROM Eraser.

The short-wave ultra-violet radiation from the tube is harmful. To prevent possible exposure whilst changing EPROMS a simple interlock circuit is provided by a reed switch (S1) and a magnet. Only when the EPROM tray is slid into position can a magnet get close to the reed switch and close it. At first it was thought ideal to put the reed switch in the 12V supply line. The high initial surge current needed to charge C4 rules out this approach, however, because reed switches are unable to handle large currents and the switch would soon fail. By fitting the reed switch in series with the base of TR1 it is possible to switch the circuit on and off by means of a current in the region of 1mA.

This type of oscillator circuit is simple and reliable provided the correct values are used for all of the components. The values of C3 and R3 are particularly important as they determine the correct level of base drive for TR1. Over, or under driving TR1 results in reduced efficiency.

INDUCTOR

As mentioned before, the output from T1 is almost a sine wave of 120 volts peak to peak. This cannot be directly connected to the tube because of the nature of all gas discharge lamps. At low voltage the gas inside is not conductive and the tube behaves like an open circuit. At higher voltages the gas and vapour in the tube become ionised and the tube becomes a good conductor—so good that it will draw excessive current and destroy itself unless the current is limited by some external means. In this circuit the same principle is adopted as that used in domestic flourescent lights—a series connected inductor—or choke.

It is easier to use a series resistor instead of a choke, but the power loss in a resistor would be very high. At 25kHz a suitable inductor can be very small and simple to wind, so offering an easy, efficient means of current limiting.

The final component in the circuit, C1, is a very important one. In order to get the tube to "strike" it is necessary to apply a high voltage across the ends, and to heat the filaments at each end of the tube. The filaments (which are connected between the two pins at each end) are heated by a current passing from L1 via the filament AB, through C1 and then via filament CD back to T1.

At 25kHz the impendance of C1 is a few hundred ohms, and so it passes current reasonably well, however this is helped further by the fact that C1 and L1 together form a series tuned circuit that resonates close to 25kHz. The effect of this is to substantially increase the filament current and at the same time step up the peak voltage applied to the tube. As soon as the filaments are hot, the tube strikes, the voltage across it falls to around 20 volts r.m.s, and the resonant effect of L1 and C1 is damped by the effective resistance of the conducting tube. The current in C1 now becomes insignificant and all the power from L2 is delivered to the tube. This type of starting circuit is known as "semi-resonant start" and is employed on the more expensive types of domestic light fittings.

CONSTRUCTION

A lot of attention was paid to the "mechanical" aspects of the design to ensure a very high level of safety. **It is recommended that the case and type of construction used is followed closely as a substantial amount of care has been taken to get this right.**

The construction can be divided into two parts. One is the assembly of the printed circuit board and the tube into the "top" part of the case. The other is the mechanical slide arrangement which is fitted inside the "bottom" of the case. Those who recognise the type of case will appreciate that *it is being used upside down* in this application.

The details of construction of the slide arrangement which is built on the case lid are shown in Fig. 2 The material used in the prototype was 1.6mm thick printed circuit board material, but any type of insulating board is suitable, such as Paxolin, s.r.b.f. or s.r.b.p. material. Begin by cutting strips as shown in Fig. 2. These are cut slightly shorter than the case lid so that they clear the internal p.c.b. guides moulded into the case.

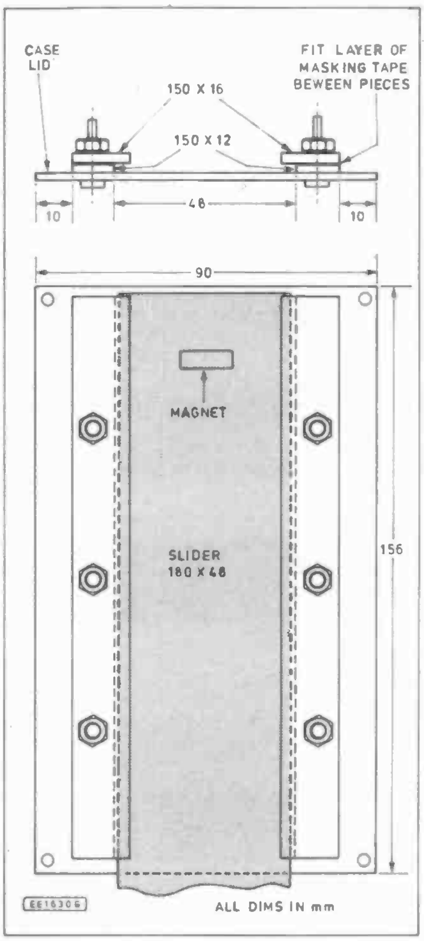


Fig. 2. Suggested method of slide construction.

Next cut a piece 180mm long×48mm wide for the slider which will carry the EPROMs and the magnet to operate the interlock reed switch S1.

The long edges of the slider and the inside edges of the two 150×12mm pieces should be smoothed with fine abrasive paper to ensure a smooth sliding action when assembly is complete. At this stage the slides should be fitted to the inside of the case lid. This is best done by fitting one side first, and then using the 180×48mm slider as a spacing guide to position the strips on the other side. A layer of masking tape or similar material between the two strips on each side will ensure ade-

COMPONENTS

Resistors

R1	33k
R2	47
R3	8k2

All ¼W carbon film

Capacitors

C1	22n 250V d.c. polyester
C2	47n 250V d.c. polyester
C3	12n 100V d.c. polyester
C4	470µ radial elec. 16V

Semiconductors

D1	1N4001
TR1	TIP121 Darlington power transistor

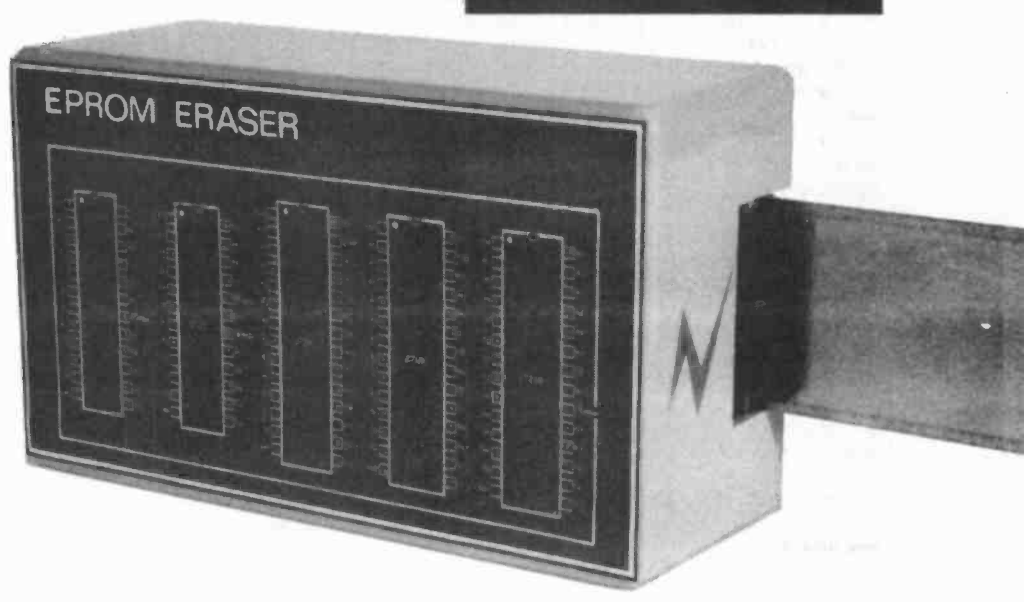
Miscellaneous

T1	Transformer core+28 s.w.g. wire
L1	Choke core+32 s.w.g. wire

(L1 and T1 are available as a pack of cores, formers, and wire from Magenta)

Printed circuit board; material for slides, slider and tube mount; nuts and screws 7×M3 screws nuts and washers; 2×M3×25mm Nylon screws with nuts and washers; wire; glass reed switch; magnet; two 2-way terminal blocks to fit tube; tube, 6in. 4W short-wave U.V.; conductive foam; case; wooden block.

MAGENTA KIT 790



quate clearance for the slider to move easily.

To ease assembly it is useful to fit the whole thing together using strips of double-sided adhesive tape. The fixing holes can then be drilled whilst everything is in place, thus their correct alignment is ensured. Three sets of M3 screws, nuts and washers are sufficient to fix the slides permanently in position. Take care to position these as shown in Fig. 2 away from where the tube mounting boards are to be fitted.

TUBE MOUNTING

The next step in assembly is to make and fit the boards which hold the tube. Two boards are used as shown in Fig. 3, one at each end, fitted into the internal case slots. At one end, the board is the printed circuit (which should not have any components fitted at this stage). The board at the other end is a plain piece of Paxolin or other insulating board which is cut to the same size and has a matching hole 16mm in diameter. This piece is easier to make if the printed circuit board is used as a template. A rectangular cut-out in the plain board is also required, for the EPROMS to slide under, and a small notch must be cut in one corner to allow the two wires from the end of the tube to pass.

Check that the tube fits correctly and that the lid can be fitted (minus the slider). The tube mountings are held in place by the lid and two pieces of foam rubber stuck to the slides in the correct position will hold the tube mountings more firmly, and stop rattles.

The final cutting job is to make a rectangular cut-out in the end of the case for the slider to pass through. This should be 50mm×22mm as shown in Fig. 4. To protect the case and simplify marking-out, the case end should be covered with masking tape. The cut-out can then be made, and filed smooth before removing the masking tape.

A small hole is needed at the other end of the case to allow the power supply wires to pass through to the board. A 4mm diameter hole is adequate, positioned as shown in Fig. 4. Finally check the whole assembly with the tube and slider in position and make any adjustments necessary before moving to the next stage.

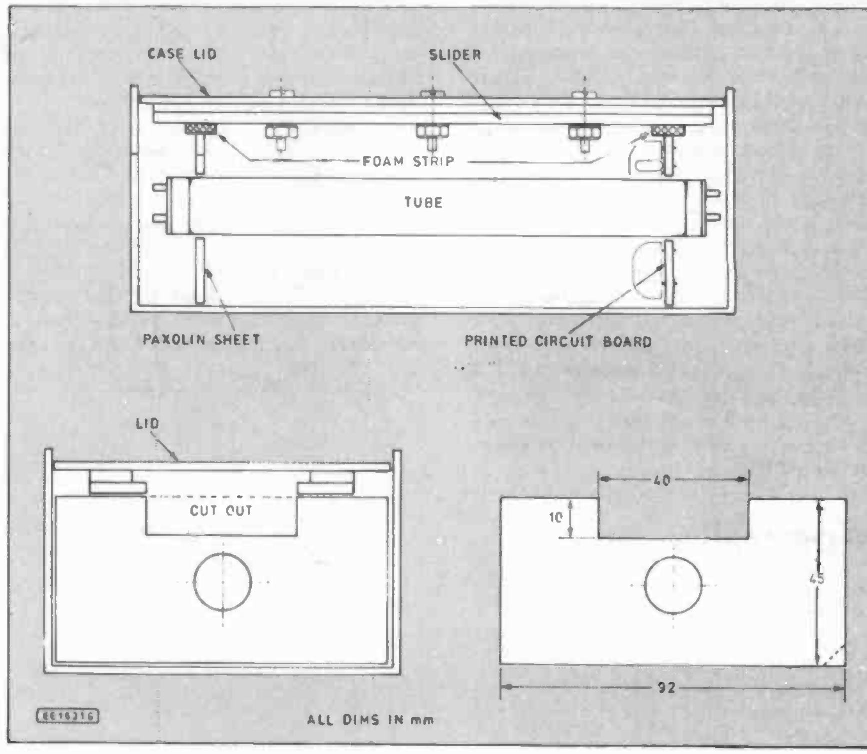


Fig. 3. Suggested arrangement for mounting the tube inside the plastic case.

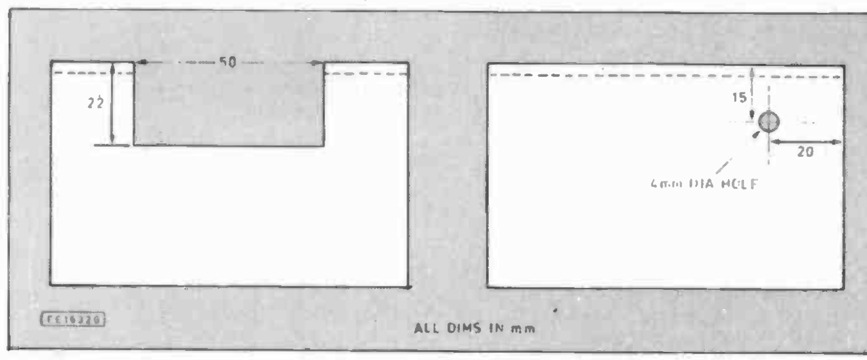
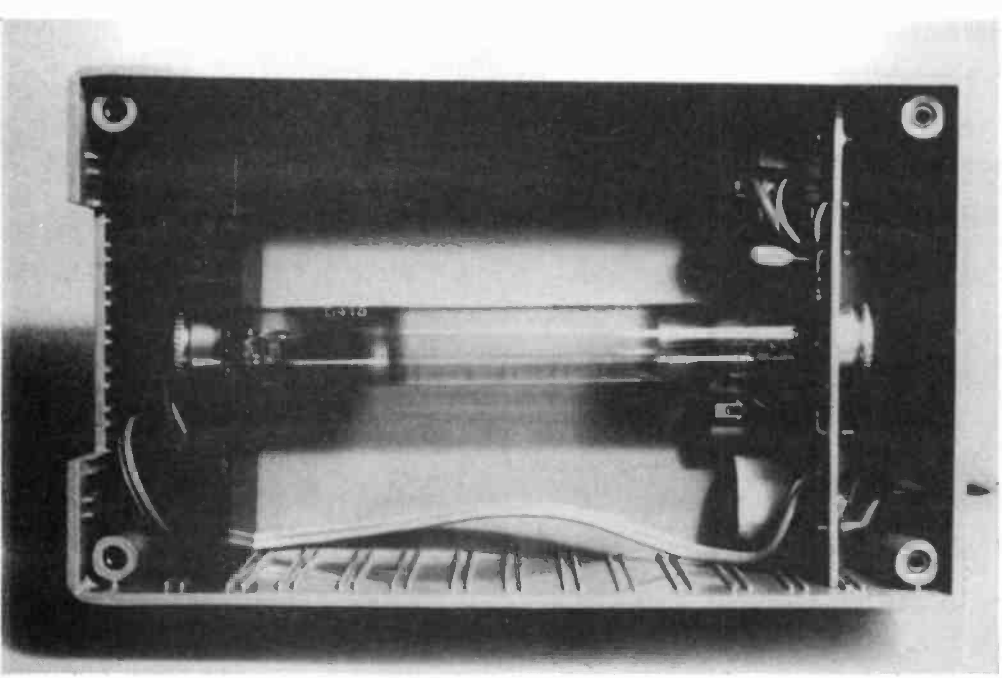


Fig. 4. Dimensions, cutting and drilling details for the ends of the case. Note that the slider cutout is the opposite end to the p.c.b.



The circuit board and tube mounted inside the case.

COIL ASSEMBLY

This type of inverter circuit is very dependent upon correct coil construction, and so every care should be taken at this stage. The choke L1 is wound from 32 s.w.g. enammelled copper wire on a single or multi-section coil former. 145 turns are required and are easily accomodated within the 18mm diameter ferrite pot cores specified.

Winding is simplified by using a "mandrel" which fits inside the coil former and allows it to be held easily. A ball-point pen case was found to be ideal when winding the prototype coils.

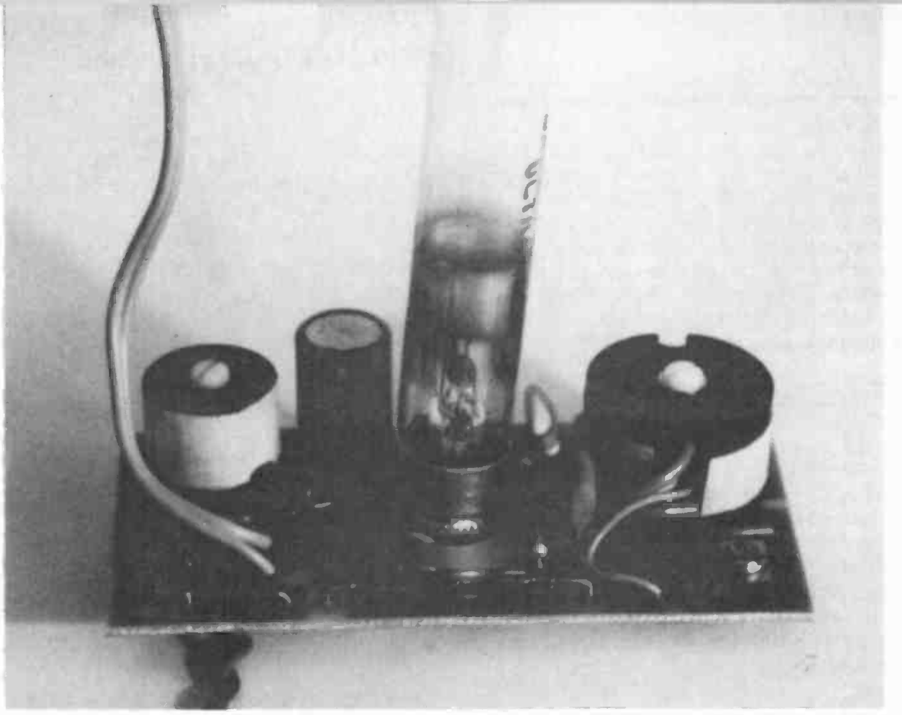
Wind the choke by building up the wire evenly across the former. There is no need to wind the coil in layers—in fact this is practically impossible by hand. All that is needed is an even spread of wire across the former. The start and finish of the winding must be brought out through the same gap in the ferrite core. A layer of insulation or masking tape over the completed coil will keep everything in place. Fit the two core halves around the coil, making sure that nothing is trapped between them and fix them together with a layer of type.

Next wind the step-up transformer T1. The main winding is made from 28 s.w.g. enamelled wire. Fig. 5 shows the winding in detail. Before begining, cut some lengths of masking tape the same width as the coil former sections and 10cm long. Start winding from the edge of the former with terminal number 1 and wind a single layer of nine turns. Cover this winding with a layer of tape and bring out a loop for about 80 cms through the same slot in the former as the start. Fit a second layer of tape, loop the wire back into the former and continue winding in the same direction until a further 52 turns have been added. If the specified two section former is used, wind 20 turns in the first section, and 32 in the second section. Tape over both sections and leave approximately 80mm of wire free at the end—this is terminal number 3.

FEEDBACK WINDING

The feedback winding is made from 1/0.6 or 7/0.2 insulated connecting wire wound as shown in Fig. 5b. The position of the winding is not important, but the vital thing is to get the direction right, and to label the ends correctly. The black dots next to wires 1 and 4 on the circuit diagram indicate the starts of each winding. Provided the windings are then made in the same direction everything else should follow automatically.

Secure the feedback winding with tape and fit the two halves of the 25mm pot core assemblies. As with the choke, ensure that the two halves are in close contact with nothing trapped between them, and that all five coil connections are brought out through the same gap in the cores. Tape the two halves together and prepare the three enamelled wire leads for assembly to the board.



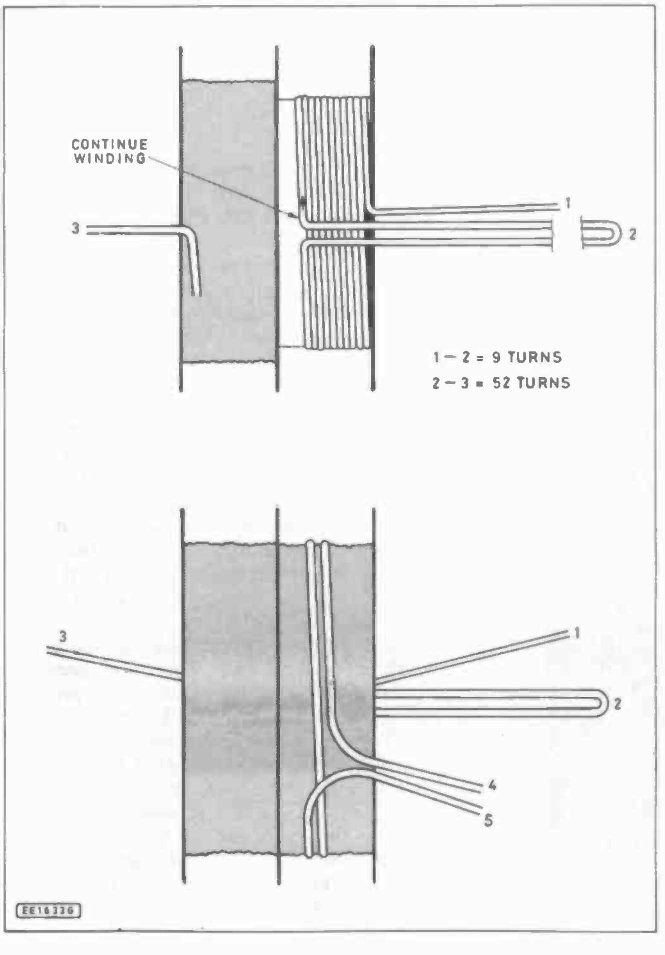
Close-up of the circuit board showing the reed switch S1 mounted on the front edge of the board. This board is available through the EE PCB Service, code EE620.

The type of enamel used on the wire is a self-fluxing solderable type, but it can still take some time to melt away and allow the wire to be tinned. In case of difficulty, drawing the wire through a small folded piece of fine abrasive paper works wonders and strips the enamel very easily. Note that connection number 2 is in the form of two wires, which should be twisted together after tinning. Fit a short length of insulating sleeving over each of the three leads, and the coil is ready for fitting to the board.

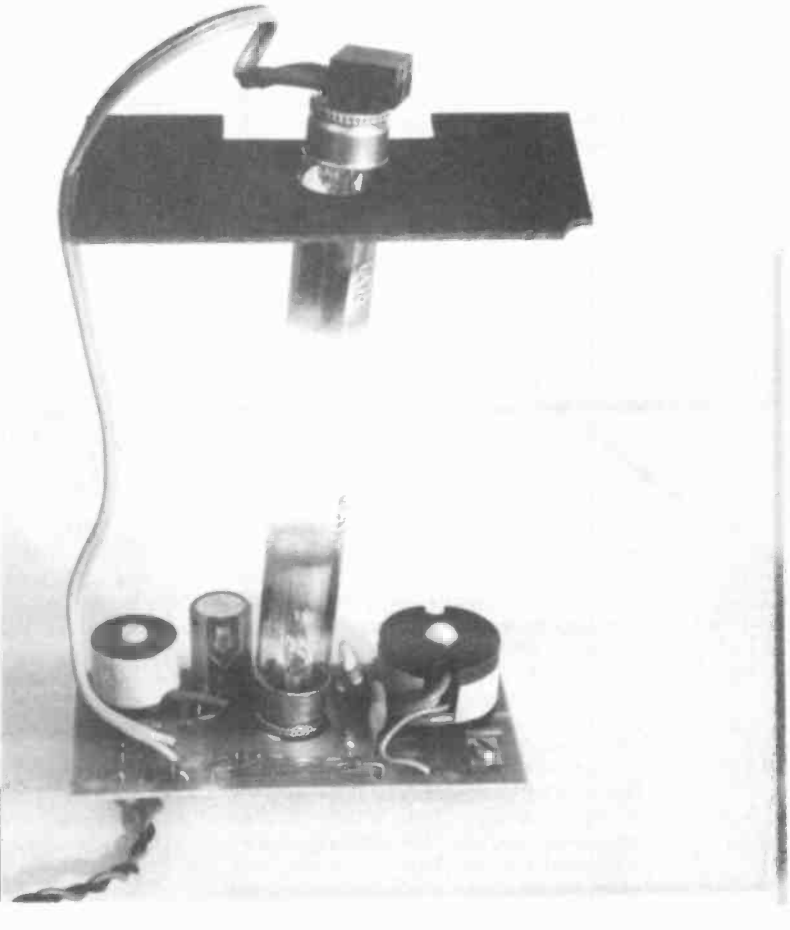
P.C.B. ASSEMBLY

There are very few components on the board, and assembly is simple. Refer to Fig. 6 for the component layout, and to Fig. 7 for the track pattern. Diode D1, and capacitor C4 are the only polarity conscious parts, so take care when fitting these. The wires to the power supply should be fitted to the rear of the board, as should the two tube wires which connect to the near end of the tube. A length of twin cable 220mm long to reach to the opposite end of the tube should be fitted

Fig. 5. Step-up transformer T1 winding details.



The completed circuit board, with the u.v. tube, prior to sliding it into the case side runners.



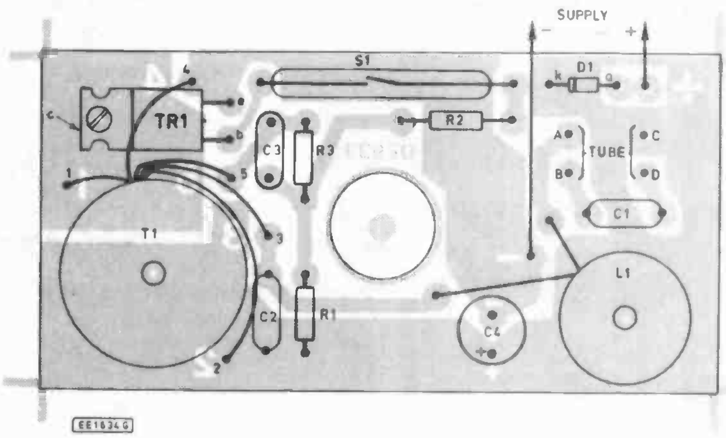


Fig. 6. Printed circuit board component layout. The centre of the board is cut out to take the u.v. tube.

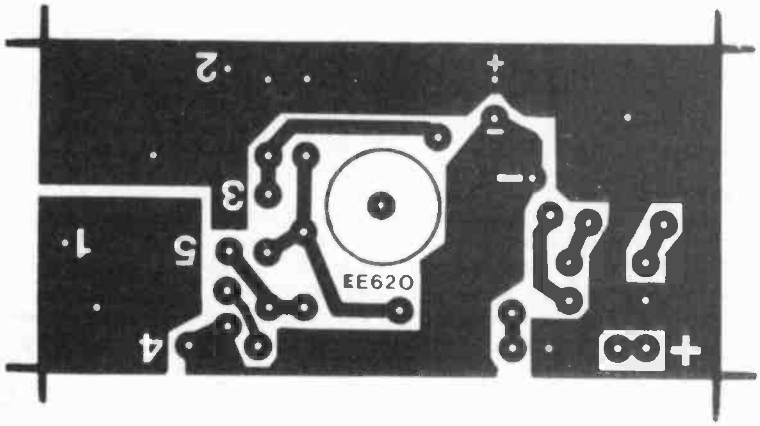


Fig. 7. Full size copper foil master pattern for the EPROM Eraser p.c.b.

on the component side. The power transistor TR1 is mounted on the board by means of an M3 fixing screw through the tab. This mounting also provides the collector connection, so do not use an insulating set. The actual collector lead—the centre one—can be removed from the transistor or bent out of the way.

The reed switch, which is mounted directly to the board, must have it's leads bent at 90° **This must be done very carefully,** as it is easy to fracture the glass envelope. The best method is to support each lead with a pair of pliers between the envelope and the point where the bend is made, then use another pair of pliers to make the actual bend.

The connections to L1 can be made either way round, but the five connections to T1 must be made exactly as shown. To make this easy the board has been marked on the track pattern with the corresponding wire numbers. The two coils are fixed to the board using M3×25mm nylon screws. **Metal screws must not be used** because current will be induced into them, and there will be considerable circuit losses. Metal nuts and washers can be used, as these are outside the cores.

The connections to the tube are made by means of two-way 90° p.c.b. terminal blocks. The wires are soldered onto these and the joints sleeved with 25mm lengths of close fitting p.v.c. sleeving. The terminals fit perfectly onto the tube pins and can be held firmly in place by gently tightening the screws. The tube can be fitted either way round.

TESTING

As there are no adjustments to make it is likely that the circuit will work first time, and all will be well. The most likely source of trouble is T1 and its connections, which can easily be mixed up. The circuit board can be tested before the tube is fitted to check the functioning of the oscillator. Tape the magnet to the reed switch and apply 12 volts. The current should be around 50mA, and a meter set to a.c. volts should read approximately 40V (which corresponds to 120V peak-to-peak) across C2.

If all is well so far, fit the tube, assemble the whole unit and attach the magnet to the slider so that it is directly under the reed switch when it is pushed fully home. Remove the slider and connect a 12V supply via a meter set to read 0 to 1 amp. Push the slider into place and the current should rise to approximately 350mA, fluctuating slightly as the tube strikes. To check correct operation, the tube can be viewed briefly through a piece of glass. **The short-wave ultra-violet radiation is harmful to skin and eyes, and so direct exposure should be avoided.**

Once correct operation has been obtained, assembly should be completed by fitting a small block of wood or other opaque insulating material to the slider so that it completely closes the case cut-out when the slider is in position. This, along with the reed switch ensures that it is impossible to view the tube, even by peering into the slot. A piece of black anti-static foam attached to the slider over its centre 100mm is ideal for holding the EPROMS whilst erasing.

OPERATION

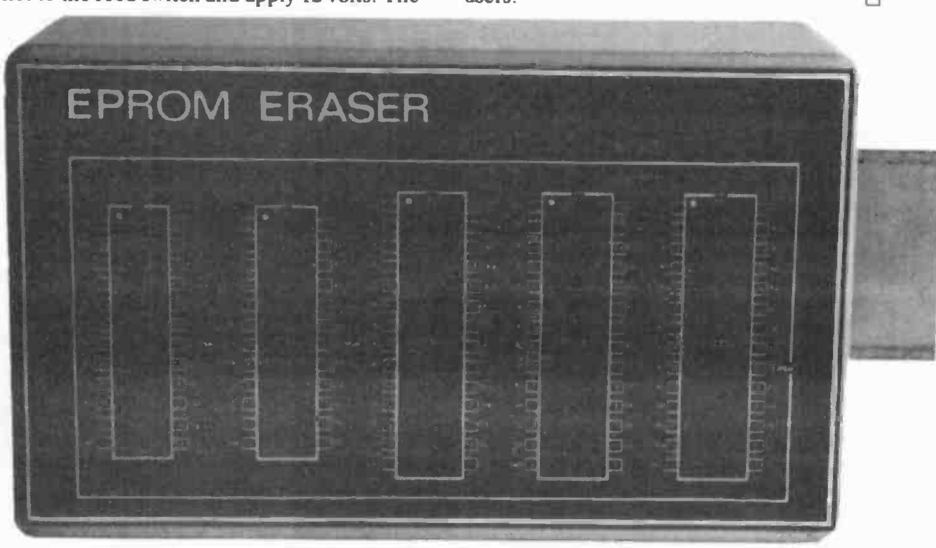
With a tube of this type running at full power it is normal to allow 20 minutes to erase EPROMS at 25mm from the tube. In this eraser the distance is slightly shorter, and the tube is slightly under-run, so the time should be about the same. With a new tube faster erase times are possible.

To test the operation, put a programmed EPROM into the eraser, and check it at two minute intervals. Once the EPROM is erased. (All locations read FF) record the time and then erase further for three times as long again. This ensures full erasure in all circumstances.

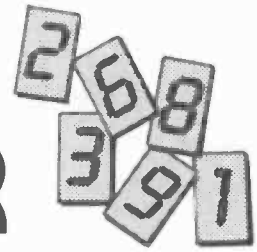
The level of radiation along the tube is not uniform and falls off towards each end. It may be possible to erase 4, 5 or 6 EPROMS in a row depending on the condition of the tube. A few tests will soon show the practical limits.

SAFETY

As already stated, safety was a major factor in this design. The highest voltage present at any time is 60V (120V peak-to-peak) and this is from a relatively high impedance source. In addition, construction is such that contact is impossible during use. The reed switch interlock makes contact with the tube radiation impossible. These factors make the eraser particulaly suitable for educational users. □



200 MHz DIGITAL FREQUENCY METER



MARK STUART

Easy to use—easy to construct—0 to 10MHz and 10–200MHz ranges

THIS project was designed to provide a simple easy to use digital frequency meter without sacrificing accuracy or frequency range. Throughout the design particular attention was paid to keeping the cost down and the construction simple. The resulting instrument is compact and extremely convenient to use. Among its more obvious applications are checking C.B. and amateur radio transmitter frequencies, calibrating signal generators and providing accurate frequency readings when used in conjunction with a function generator when measuring audio amplifier frequency responses, etc.

The unit was designed to be powered from a small plug-in transformer but can also be powered from a 12V car battery or four HP7 cells for portable use.

SPECIFICATION

The circuit uses eight 0·56 inch red seven segment l.e.d. displays to give a large bright clear read-out. Two frequencies ranges cover 0–10MHz and 10–200MHz. The display is automatically up-dated at one second intervals giving resolution down to 1Hz on the 10MHz range and 100Hz on the 200MHz range. Between readings the display holds the previous reading, providing a stable continuous read-out.

Accuracy of the frequency readings depends upon the internal 10MHz crystal. A standard commercial quality crystal is used, giving 0·002 per cent initial accuracy with a possible thermal drift up to 0·003 per cent per degree Celsius. If required the initial error can be trimmed out by reference to the 200kHz BBC Radio 4 carrier frequency so that very accurate measurements can be made especially if the meter is kept at or near room temperature.

Power requirements are approximately 100mA at five volts. An internal voltage regulator permits external d.c. supplies from 9V to 16V to be used as an alternative to the plug-in 9V transformer specified. When portable operation is required four standard or re-chargeable small cells can be used to give several hours of operation.

CIRCUIT

The circuit diagram of the complete unit is shown in Fig. 1. The heart of the circuit is IC2 which provides all of the timing, counting, and display decoding functions. This remarkable i.c. provides direct drive to the entire eight digit display eliminating the need for current limiting resistors digit driving transistors and so on. There are a number of versions of this i.c. (the ICM7216), **it is important that only the ICM7216D is used** in this circuit—the others will not work at all.

A crystal oscillator is also built into IC2 and this is connected to the 10MHz crystal XL1 at pins 25 and 26. Resistor R7 provides d.c. bias for the oscillator and capacitors C15 and C16 provide the correct loading to suit the crystal. Where maximum accuracy is required the frequency of the crystal can be fine tuned over a small range by varying the value of C15.

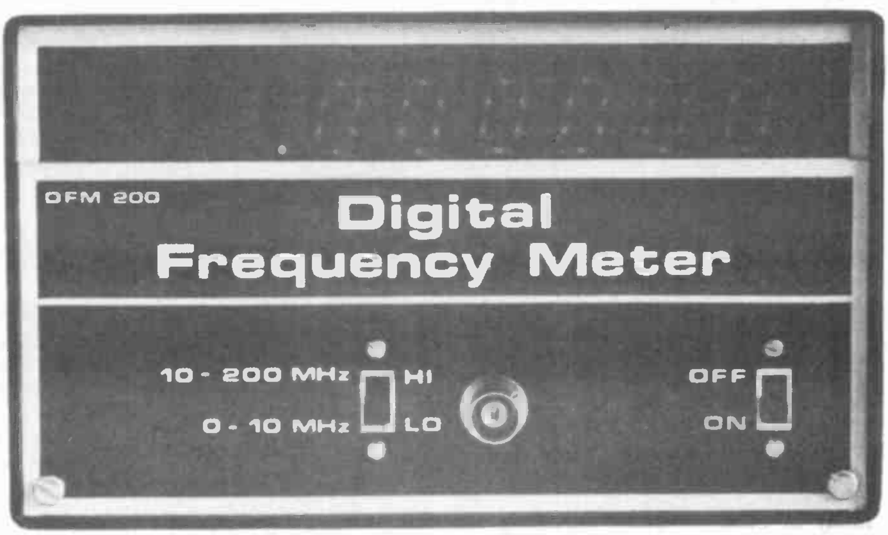
To minimise the number of connections and so keep down the number of pins needed on the i.c. the display is "multiplexed". This means that each digit is lit for 12·5 per cent of the time. To do this each one of the eight digit driver lines is activated in turn by taking it from +5V down to 0V. For each digit the segment drivers are fed with the particular code to light the number required. The whole process takes place at 500Hz so that there is no perceptible flicker and all eight displays appear to be lit continuously.

The position of the decimal point in the display is selected by connecting pin 13 of IC2 to the digit drive output where the decimal point is required. In this application the decimal point is required after X7 for the 10MHz range and after X5 for the 200MHz range. Switching between the two is carried out by IC6c and IC6d which are analogue gates controlled from the range switch S2. When S2 is in the 10MHz position the +5V supply is connected to the control input of IC6c via S2b. This turns on the analogue gate and connects pin 13 of IC2 to the X7 digit drive line. The control input of IC6d is held at 0V via R2 ensuring that the X5 digit drive line is disconnected. On the 200MHz range the situation is reversed so that the X7 line is disconnected and X5 line is connected. S2b also provides gate control voltages for IC6a and IC6b which select which input stage is used to provide the signal to be counted by IC2.

There are two other pins on IC2 which are linked to the digit select lines. Pin 1 provides various functions such as display test, and blank display, by connecting it either to the X8 or line X4. In this application pin 1 is linked to the X3 line to select "external decimal point" mode. This allows the decimal point to be positioned by linking pin 13 to the digit drive outputs as already described.

Pin 14 of IC2 is the "range" input which is used to select whether the input signal is counted for 0·01sec, 0·1sec, 1sec, or 10sec by connecting it respectively to digit drive

Front panel layout and legend for the 200MHz Digital Frequency Meter.



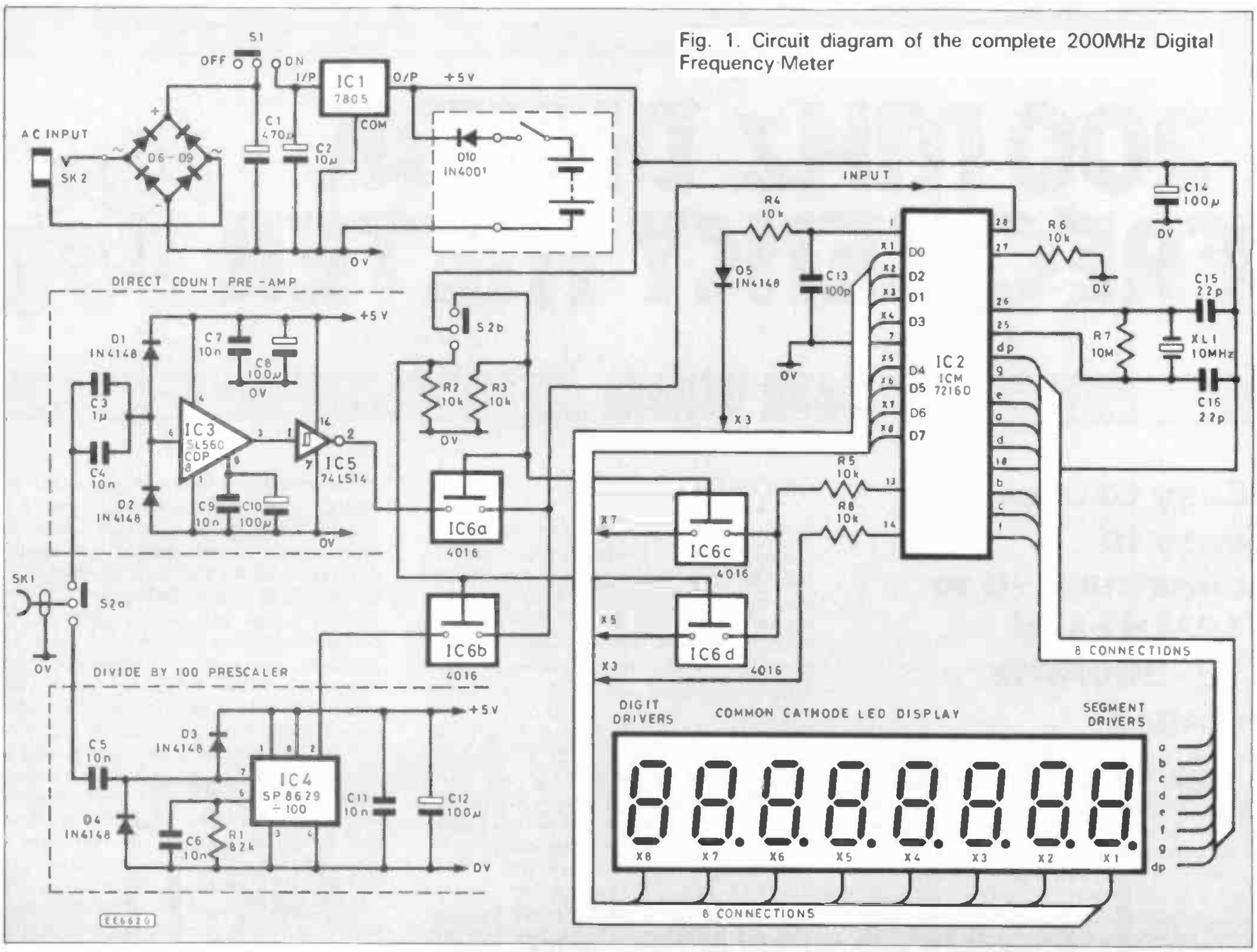


Fig. 1. Circuit diagram of the complete 200MHz Digital Frequency Meter

lines X1, X2, X3, or X4. The one second setting is most suitable for the present circuit as it gives a full eight digit display for 10MHz. On the 200MHz position it would be possible to gain an extra digit by selecting the ten second range, however a ten second wait between readings is too long for most practical purposes and so a common one second period is used.

INPUT STAGES

The input circuits of the meter are completely different for the two frequency ranges. On the 10MHz range the signal is first amplified by IC3 and then squared by IC5 before being passed to IC2. IC3 contains a very high speed three transistor amplifier with a gain of 25 at frequencies up to well over 100MHz. IC5 is a schmitt trigger i.c. which is used to square up the output of IC3 so that low frequency sine waves can be counted correctly. Without IC5 the circuit would work perfectly at high frequencies but would not count low frequency sine wave inputs at all. This is because the input voltage to IC2 must change at a rate faster than 25V per microsecond to trigger the input counting circuits.

The input is coupled to IC3 by means of C3 and C4. Two capacitors are used because the larger value capacitor will not be as effective at high frequencies because of its construction. The smaller ceramic disc capacitor freely passes the high frequencies whilst not being as effective at low frequencies. Together the two capacitors are effective over the necessary wide band of frequencies.

Diodes D1 and D2 are incorporated to

COMPONENTS

MAGENTA KIT 563

Resistors

R1	82k
R2 to R6,R8,R9	10k (7 off)
R7	10M
All 5% carbon film ¼W	

Capacitors

C1	470µ axial elect. 25V
C2	10µ radial elect. 25V
C3	1µ min 100V layer type
C4 to C7,C9,C11	10n disc ceramic (6 off)
C8,C10,C12,C14	100µ min radial elect. 6·3V (4 off)
C13	100p ceramic
C15,C16	22p ceramic (2 off)

Semiconductors

D1–D4	1N4148 (4 off)
D6–D9	50V 1A diode bridge
D10	1N4001
X1 to X8	Seven segment display 0·56 inch common cathode type HDSP 5303 (8 off)
IC1	7805 voltage regulator
IC2	ICM7216D (see text)
IC3	SL560CDP8
IC4	SP8629
IC5	74LS14
IC6	4016 CMOS

Miscellaneous

S1,S2	d.p.d.t. miniature slide switches (2 off)
XL1	10MHz HC18U wire ended crystal
SK1	50 ohm BNC socket, bulkhead mounting type
SK2	3·5mm jack socket
L1	100µH choke

Perspex for display window; p.c.b.; wire; screws and nuts; 9V a.c. plug in power supply (see text); two 14-pin and one 28-pin i.c. mounting sockets; case approx 160 × 95 × 60mm.

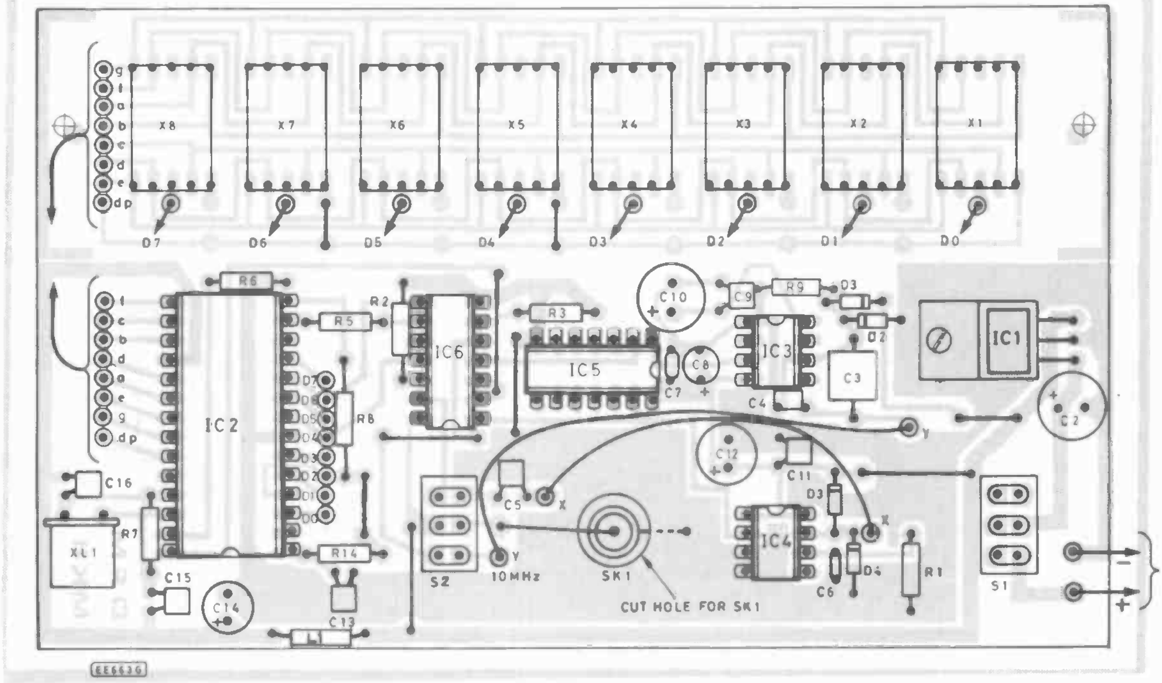


Fig. 2. Component layout on the p.c.b.

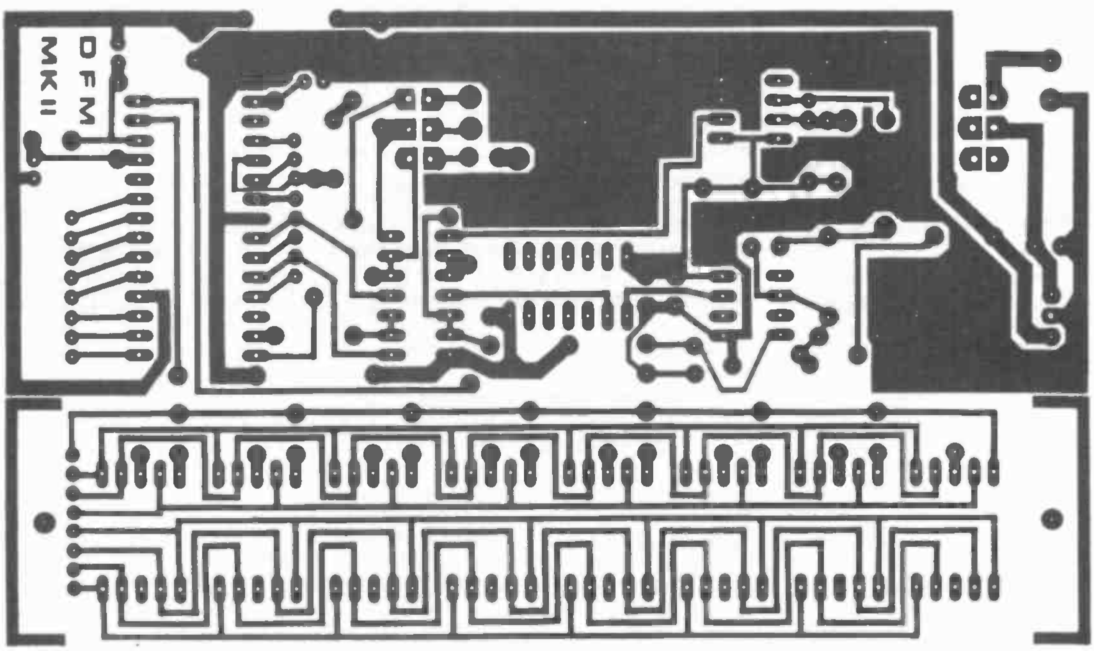


Fig. 3. Track pattern for the p.c.b. (full size).

protect the input circuits from excessive input voltages, and capacitors C7, C8, C9 and C10 provide decoupling of the power supply and the input stages of IC3. Two capacitors are again used in each case to cover the wide frequency range.

On the 200MHz range a prescaler i.c. is used to divide the incoming frequency by 100 so that it is reduced to a value that can be handled comfortably by IC2 which has an upper frequency limit of 10MHz. The necessary adjustment to the display so that it reads correctly is achieved by moving the decimal point from X7 to X5.

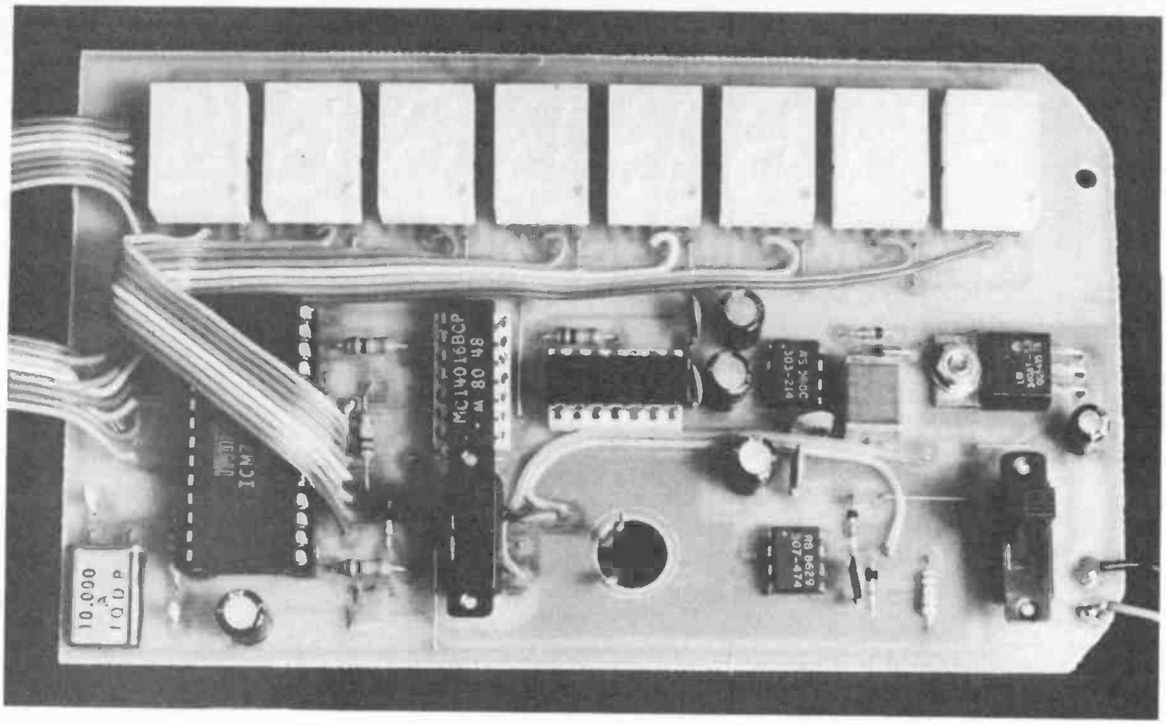
As well as the divider circuit, IC4 also contains a pre-amplifier and so no further signal amplification is required. Only a single input coupling capacitor is required on this channel as frequencies below 10MHz are of no interest. Diodes D3 and D4 are fitted to protect the circuit from excessive input signals. The input to IC4 is a differential amplifier circuit which like an op-amp i.c. has inverting and a non-inverting terminals. Pin 6 of the i.c. which is the inverting input is decoupled by C6 and given a small offset bias by means of R1. This introduces a small signal cut off effect which prevents circuit noise from causing spurious counting. The selection of R1 is a compromise between sensitivity and false triggering. Reducing its value will decrease the sensitivity if random counting is found to be a problem.

The power supply section of the circuit is completely straightforward. An i.c. voltage regulator provides five volts output for any input from 9V to 16V. For mains operation a simple plug-in 9V a.c. transformer followed by a diode bridge and smoothing capacitor is used. When portable operation is required a small battery holder containing four 1·5V HP7 cells can be used and will give several hours of operation.

CONSTRUCTION

The circuit is built on a single printed circuit board. Fig. 2 shows the component layout and Fig. 3 the track pattern. As parts of the circuit are operating at very high frequencies **it is essential that the layout shown is used.** Even simple changes to the input stages could result in instability and oscillation which would make the instrument completely unusable. The final layout shown is completely stable and reliable and there should be no difficulty at all in producing a sound stable instrument.

To simplify board layout and to save space the displays have been wired to IC2 using short lengths of ribbon cable. The cable should be connected to the board directly by stripping and twisting approximately 5mm of each wire, passing it through the board, and soldering on the track side. This method is simpler and neater than



using wiring pins which are only really necessary when the wires are going to be disconnected and reconnected several times.

The display layout has been done so that if required the display section of the board can be cut off and mounted at an angle or remotely if required to allow various types of case to be used.

In the prototype the board is kept in one piece and mounted to the front panel by means of the two switches S1 and S2. The input socket SK1 is mounted directly on the front panel and fitted with two short lengths of tinned wire which are soldered directly to the printed circuit board tracks after the board is fitted in position.

ICs 3 and 4 should be fitted directly to the board to avoid introducing the extra capacitance of sockets. The other i.c.s can be fitted in standard low profile sockets. The crystal XL1 should have its leads bent carefully at 90 deg and be fixed to the board with a small piece of double sided adhesive tape. Take care not to stress the glass seal when bending the leads as this can severely reduce the reliability and stability of the crystal. The displays are fitted directly to the board as sockets are not readily available and soldercon pins are very difficult to use properly. Make sure the displays are mounted the right way up by means of the manufacturer's type number which is printed on the top of each digit.

Switches S1 and S2 have tags which are too big to mount directly on the board. The switches should first be fitted with short lengths of tinned wire which can then pass easily into the board and be soldered in position. Make sure when doing this that the switches are fitted squarely and as close to the board as possible.

The voltage regulator IC1 is fitted with its tab flat against the board. As this is a 1A device it is not necessary to provide any heatsinking unless continuous operation from more than 12 volts d.c. is anticipated in which case a small strip of aluminium should suffice.

To keep the mechanical assembly of the counter as simple as possible the front panel is made in two parts. The top part is the display window made from a piece of transparent red perspex 3mm thick. The bottom part is made from the case front panel simply by cutting a strip from the top edge. The two panels are joined in the middle by means of a thin film of adhesive where the perspex panel overlaps the metal panel. The edge of the perspex can be "tidied up" if required by fixing a thin strip of black plastic tape on the front surface.

Power is provided by a plug-in power supply delivering 9V a.c. This is connected to the counter via a 3·5mm jack plug and socket. A small diode bridge mounted on the socket and smoothing capacitor (C1) provide the necessary 9V d.c. which feeds the 5V regulator on the board (Fig. 4). A 12V car battery can also be used as an external power supply. It can be connected via the diode bridge and smoothing capacitor as these will have no effect on the d.c. supply.

If an internal battery supply is required this is connected to the 0V and +5V rails via diode D7 which will prevent the battery from being damaged if an external supply is accidentally connected. A separate on-off switch can be fitted or alternatively the unused section of the on-off switch is available. Fig. 5 shows the mechanical construction of the unit and p.c.b. mounting.

TESTING

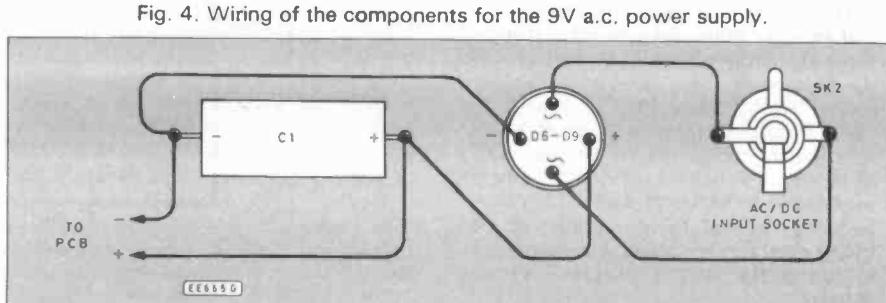
Once the circuit board has been completed it should be very carefully inspected for dry joints, solder bridges and reversed components. When everything looks correct, connect the power and check that the displays to the right of the decimal point show zeros. Check that operating S2 moves the decimal point from X7 to X5. If a multimeter is available the current taken by the circuit can be measured. A figure of around 100mA is correct.

If all these checks are correct the only thing that remains is to connect an input signal and check that the display gives stable accurate readings from known frequencies. The initial accuracy of the instrument is determined by the counter crystal XL1. For most purposes this will be adequate without trimming, however if desired it is possible to vary the crystal frequency slightly by altering the value of C15. This should be done whilst a known frequency standard is connected to the counter input. If required C15 can be replaced with a small high quality 33 picofarad trimmer capacitor and the frequency set up exactly.

USE

Use of the frequency meter is quite straightforward. Provided there is a sufficiently high input signal level the display should give stable readings from a variety of sources. When low level, low frequency sine wave inputs are used the display may vary from reading to reading due to circuit noise on the input. This effect is due to the very wide bandwidth of the amplifier which is necessary to enable 10MHz readings to be made. It is a normal characteristic of digital frequency meters and is overcome by either increasing the input signal amplitude or by using a square wave of the same frequency.

Fig. 4. Wiring of the components for the 9V a.c. power supply.



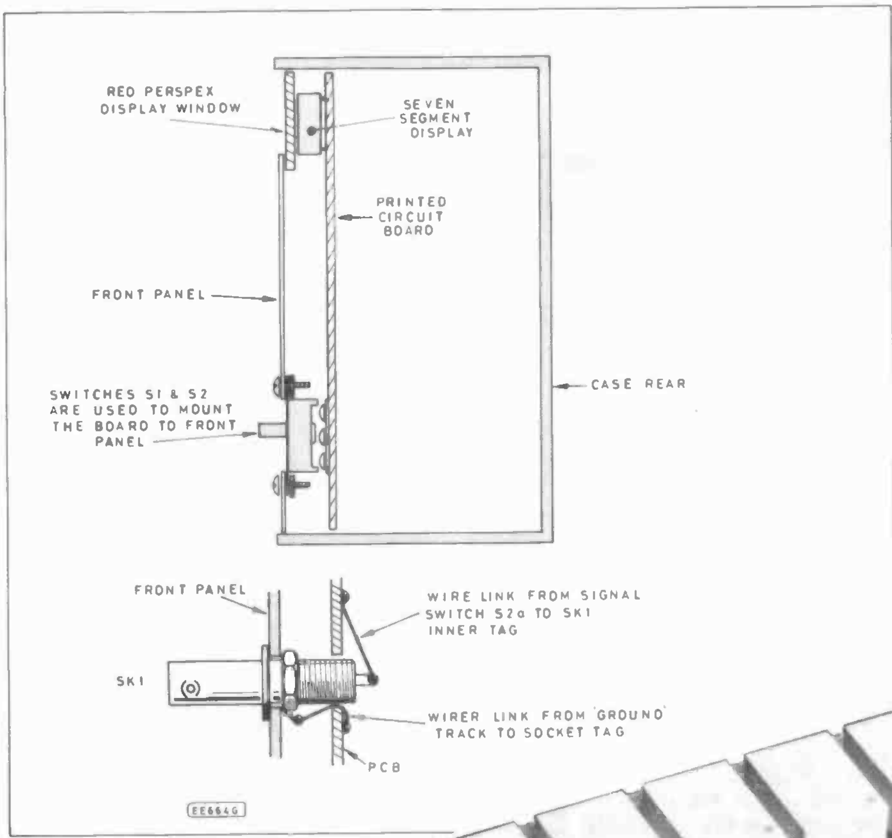
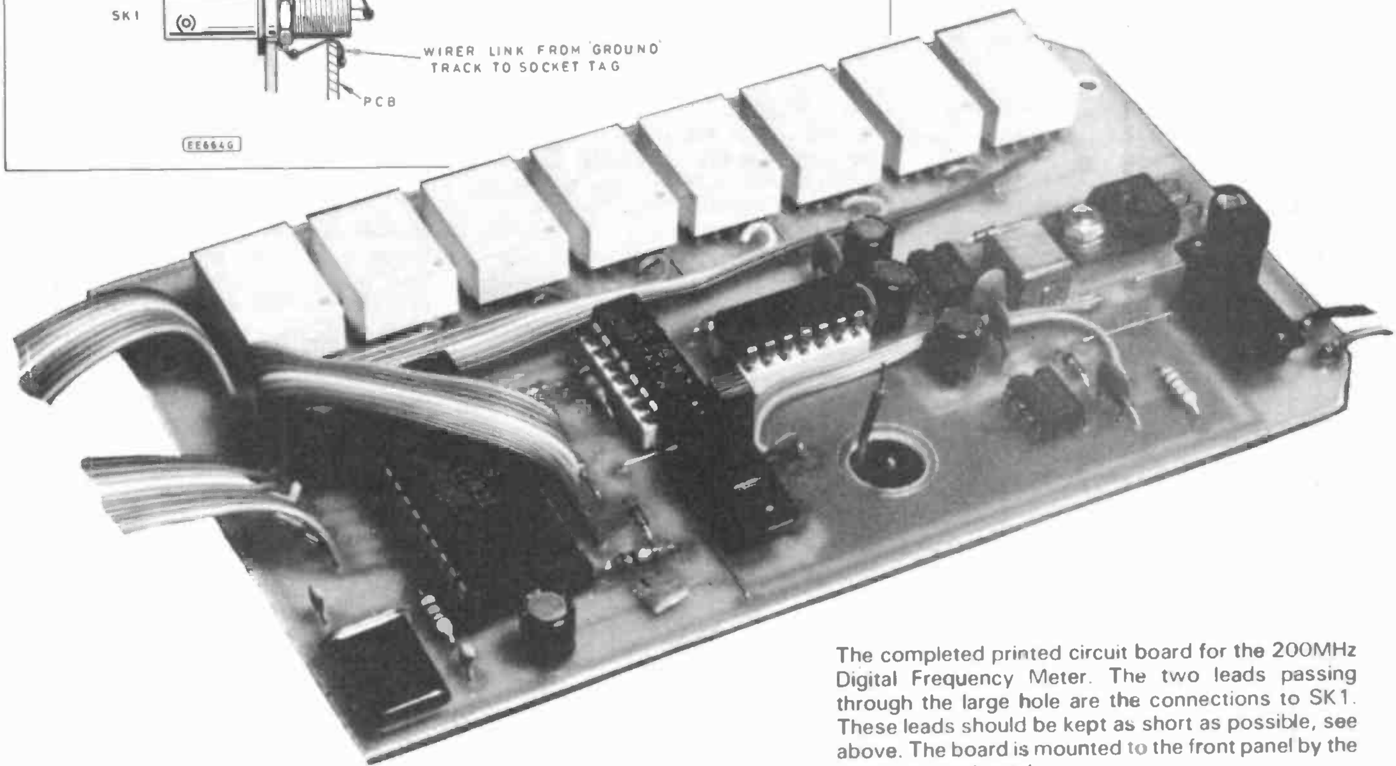


Fig. 5. Switches S1 and S2 are used to mount the p.c.b. to the case. Note that spacers may be required between these switches and the front panel. In this format it is simply necessary to trim the top section off the front panel of the case and replace it with a piece of red tinted perspex to form a display window. Also shown are the connections to SK1; these should be kept as short as possible and soldered to the p.c.b. once it is mounted.



The completed printed circuit board for the 200MHz Digital Frequency Meter. The two leads passing through the large hole are the connections to SK1. These leads should be kept as short as possible, see above. The board is mounted to the front panel by the switch mounting tabs.

Most signal generators (such as the *Function Generator*) have a constant amplitude square-wave output which can be connected to the digital frequency meter whilst the other sine wave or triangular wave outputs are used as inputs to the circuit being tested. A typical arrangement for plotting the frequency response of an amplifier is shown in Fig. 6.

To check the operating frequency of C.B. and amateur radio transmitters it is necessary only to connect a short length of wire to the input socket and be within about 10 metres of the transmitter antenna. Note that the digital frequency meter should never be connected directly to transmitters of any type as the input would be badly overloaded by the large signal. The upper frequency limit of the circuit is determined by the prescaler i.c. which is guaranteed to be 150MHz and typically exceeds 200MHz. □

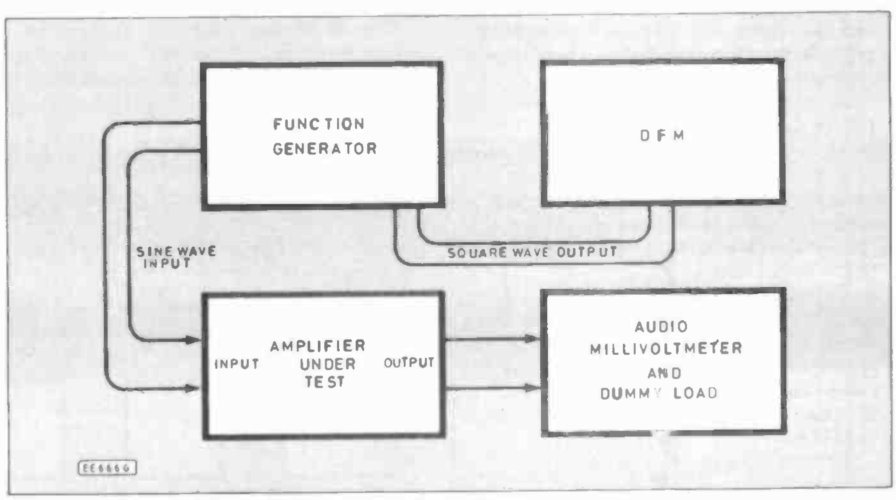
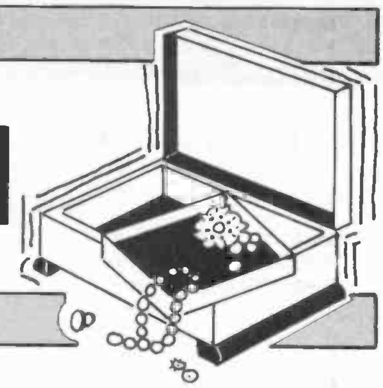


Fig. 6. A typical arrangement for checking amplifier frequency response.

INFRA RED ALARM



MARK STUART

Multipurpose detector that uses the power of an invisible beam

THIS circuit was designed as a multipurpose movement detector able to form the basis of all sorts of burglar alarms and automatic controllers. It will work either as a single interrupted beam alarm over substantial distances, or will directly detect moving objects or persons by measuring changes in the level of reflected infra red over shorter distances. The output of the device is a set of mains-rated changeover relay contacts which operate as soon as an object is detected, and remain operated for a pre-settable time between one second and one hour.

As the relay contacts are mains voltage rated and are capable of carrying up to 6A they can be used to control a wide variety of things such as automatic garage door opening mechanisms, central heating systems, room lighting, extractor fans, alarm bells, tape-recorders, and cameras. There must be hundreds of other applications in agriculture, industry and commerce for this versatile detector.

PRINCIPLES OF OPERATION

A block diagram of the system is shown in Fig. 1. A pulsed beam of infra red radiation is produced by feeding a high efficiency l.e.d. (TX1) with 500mA pulses from a pulse generator circuit with a 1:100 mark—space ratio.

This radiation is detected by an infra red photodiode (RX1) which produces a very small pulse output which is amplified by a high gain pulse amplifier and passed to a synchronous detector circuit. The synchronous detector produces a d.c. output voltage which is proportional to the incoming pulse level and hence proportional to the level of infra red radiation received.

This level is capacitively coupled to the next stage which is a "window comparator". Provided the input level is steady or varies only slightly the output of the window comparator remains low (at logic 0). If the level increases or decreases beyond the set limits (or window) the output changes state from low to high level.

The following stage is a latch circuit which detects the low to high transition on its input and starts the timer circuit. As the timer starts it operates the relay driver and so energises the relay. The timer now operates for the set time regardless of what happens to the beam.

At the end of the set time the timer releases the relay and resets the latch circuit. The circuit then resumes its original stable state until a disturbance of the infra red beam is again detected.

The time delay is produced by a low frequency clock oscillator followed by a 12-stage binary divider. Any of these outputs can be used to provide the reset pulse so that the time delay can be pre-set to be 2, 4, 8, etc up to 2048 clock cycles. With a clock frequency of 0·5Hz this gives a maximum delay of approximately 1 hour.

CIRCUIT DESCRIPTION

The project is constructed in two separate parts. A power supply and relay unit which carries mains voltage circuits, and the detector head unit which is connected to the other unit via a three-core cable and carries only low voltage circuits.

This arrangement ensures complete safety in those applications where the detector head is to be mounted outside and exposed to weather, because the separate mains circuits can be installed indoors. It is also possible to use more than one detector head with a single power supply unit to extend the area covered.

The circuit diagram of the detector section of the Infra Red Alarm is shown in Fig. 2. IC1a is a standard Schmitt-trigger oscillator in which capacitor C2 is repeatedly charged through diode D1 and resistor R2 and discharged via R1.

As resistor R2 is 100 times smaller than R1 the capacitor charge time is 100 times less than the discharge time and so a pulse waveform with a mark-space ratio of 1 to 100 is produced at the output of IC1a (pin 3). The pulses are approximately five milliseconds apart and 50 microseconds long.

Transistor TR6 is turned on during each pulse by a base current of 10mA from IC1a through resistor R3. A minimum current gain of 50 ensures that 500mA pulses are available to drive the infra red emitting diode TX1 via series limiting resistor R4. As the pulses are very short the average supply current is only 5mA.

Decoupling capacitors C1, C8 and C11 and careful p.c.b. track routeing ensure that the high pulse currents can be handled without producing supply voltage "spikes". Poor layout and inadequate decoupling can cause severe circuit interaction problems in circuits of this type and it is recommended that the layout shown is adhered to as it is completely trouble free.

The pulse output from IC1a is also connected to the gating input (pin 5) of IC2. This forms part of the synchronous detector circuit which will be described later.

The reflected infra red beam is detected by photodiode RX1. This is a large area device with a lensed front and a built in visible light filter. This prevents pulsing light sources such as fluorescent tubes, discharge lamps, and television screens from causing interference.

Ordinary tungsten filament bulbs emit a considerable amount of infra red radiation but the thermal inertia of the filament is such that only a low level of pulsing occurs as the filament heats and cools during each half cycle of the mains. This is not generally a problem but it is advisable to keep such lamps out of the direct field of view of the photodiode.

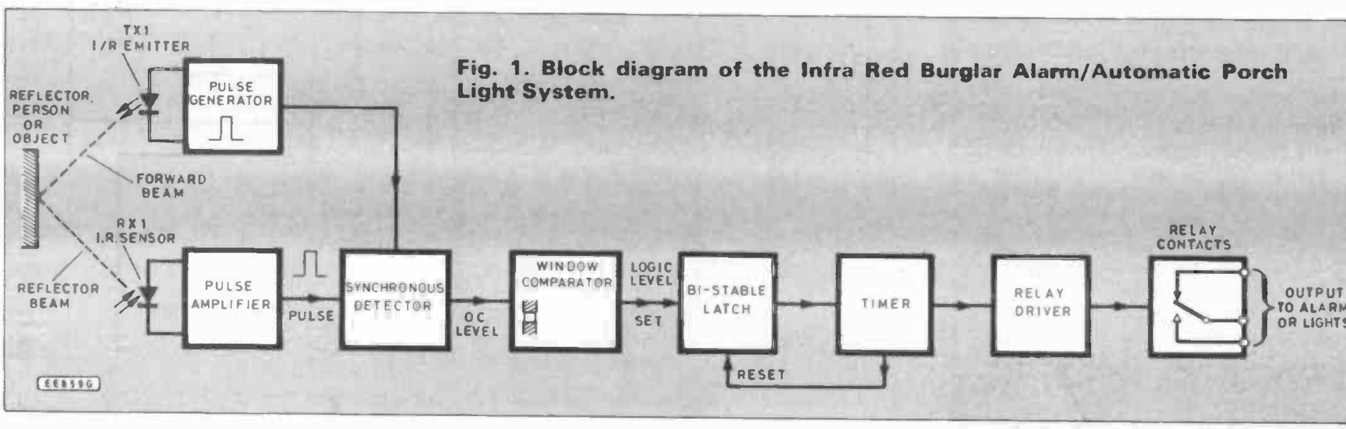


Fig. 1. Block diagram of the Infra Red Burglar Alarm/Automatic Porch Light System.

COMPONENTS

MAGENTA KIT 700

Resistors

R1,R23,R24	100k (3 off)
R2,R3,R13, R19,R27	1k (5 off)
R4	15
R5,7	47k (2 off)
R6	2M2
R8,R11,R14, R22,R26	10k (5 off)
R9	680
R10	470k
R12,R15, R18,R25	1M (4 off)
R16,R17	470 (2 off)
R20	3k3
R21	220k

All 0·25W 5% carbon

Capacitors

C1	100µ radial 16V
C2,C14	470n polyester (small 100V type) C280
C3,C8	10µ radial 16V
C4,C5	10n polyester
C6	220n polyester 100V
C7	0·47µ tantalum 35V
C9	47µ radial 16V
C10	1µ radial 16V
C11	220µ radial 16V
C12	4µ7 axial 16V
C13	2200µ radial 16V

Semiconductors

IC1	4093 Quad 2-input NAND Schmitt
IC2	4016 4-pole 1-way analogue switch
IC3	LM324 Quad op. amp
IC4	4040 12-stage binary counter
IC5	78L05 voltage regulator
D1,D3,D4, D5,D6	IN4148 signal diode (5 off)
D2,D10	BZY88 C4V7 Zener diode (2 off)
D7,D8,D9	IN4001 1A 50V diode (3 off)
TR1,TR3, TR4	BC184 *npn* silicon (3 off)
TR2	BC212 *pnp* silicon
TR5,TR6	BFY51 *npn* silicon (2 off)
TX1	CQW13R. I.R. l.e.d.
RX1	MIR10L pin photodiode

Miscellaneous

T1, 0–9V 0-9V p.c.b. 6VA transformer; i.c. sockets, 14-pin (3 off) 16-pin (1 off); 3-way p.c.b. terminal block (3 off); RLA1 12V relay s.p.d.t; cable entry clamp; screws and nuts; cable; wire and cases; printed circuit boards,

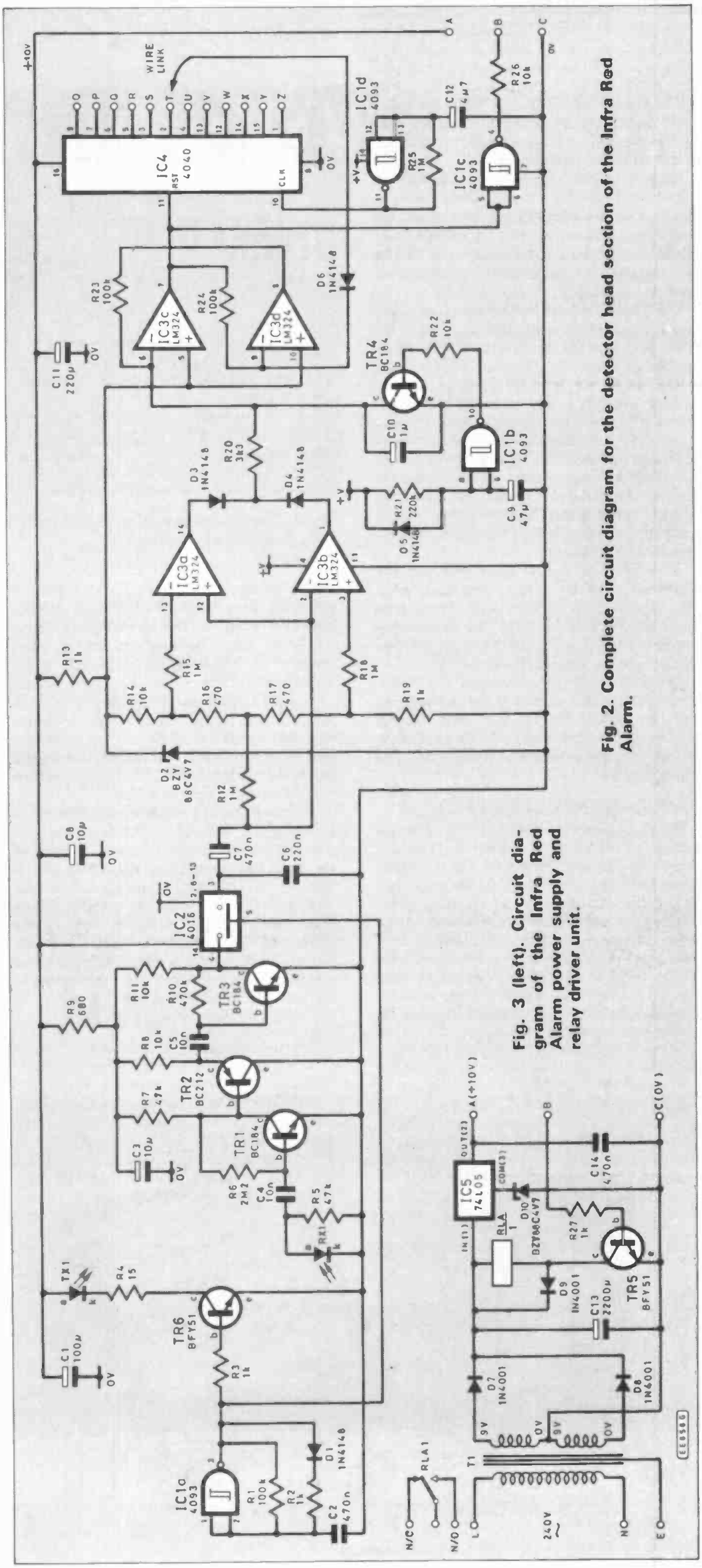


Fig. 2. Complete circuit diagram for the detector head section of the Infra Red Alarm.

Fig. 3 (left). Circuit diagram of the Infra Red Alarm power supply and relay driver unit.

PULSE AMPLIFIER

The output from the photodiode is a low level pulse waveform which is coupled via capacitor C4 to the three-stage pulse amplifier made up from transistor TR1, TR2 and TR3. Transistors TR1 and TR3 are standard common emitter amplifier stages with bias and negative feedback via resistors R6 and R10 respectively.

Each stage provides a substantial voltage gain. Transistor TR2 is an emitter-follower stage which has a high impedance input and low impedance output but no voltage gain. Its function is to match the output of TR1 to the input of TR3 and so optimize the gain of each.

The power supply to the sensitive pulse amplifier stages is decoupled by resistor R9 and capacitor C3 to ensure a very clean supply rail. At the collector of TR3 the output waveform is in the form of positive pulses. The amplitude of which is proportional to the strength of the received beam.

To detect changes in the received beam level it is first necessary to convert the pulse level into a steady voltage which represents the received pulse level. There are a number of ways of doing this. The simplest way is to use a diode to rectify the pulses and charge a smoothing capacitor.

This method would work but has the drawback that the voltage output will only fall slowly even if the beam level falls quickly. This is because the smoothing capacitor (*C*) charges via the diode (*D*) but discharges via a parallel resistor (*R*).

Using a lower value resistor for *R* improves the speed at which the voltage can fall but as the voltage also falls further between pulses the result is a large amount of ripple in the output and a lower average signal level.

SYNCHRONOUS DETECTOR

The synchronous detector circuit overcomes all of these problems by using a switch in place of the diode. The switch is closed during each pulse and the capacitor charges almost instantly to the peak pulse voltage. As the switch is bi-directional the capacitor can also discharge instantly to a new lower peak pulse level as the signal level drops. In between pulses the switch is open circuit and so the capacitor level remains constant and there is no output ripple at all.

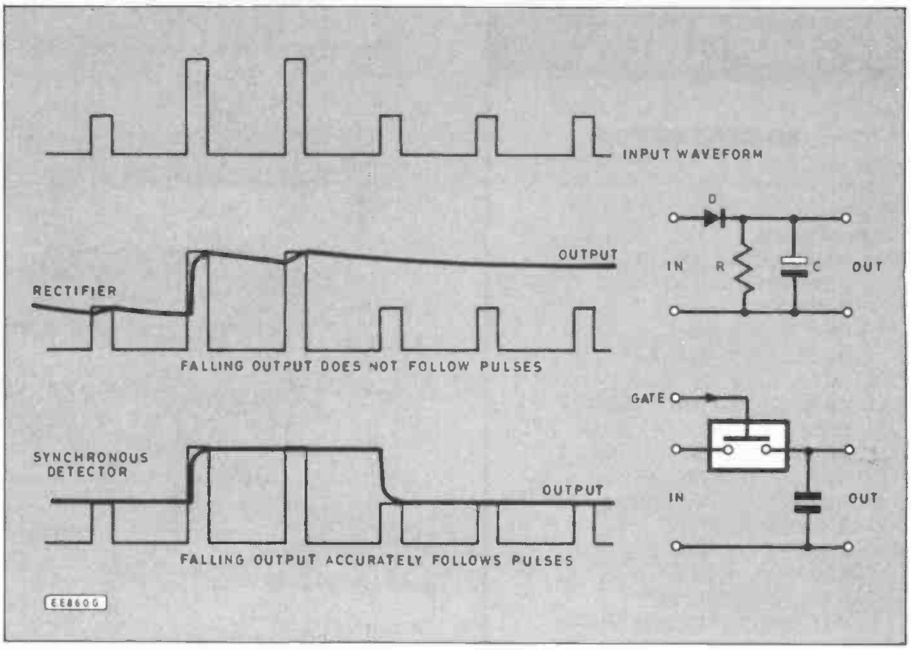


Fig. 4. The comparison of the two types of detection circuits, rectifier and synchronous, with idealised waveforms.

The comparison of the two types of detection with idealised circuit waveforms is shown in Fig. 4. The synchronous detector is so called because the switch must operate in synchronism with the pulse waveform. In this circuit the switch is part of a 4016 CMOS bi-directional switch i.c. and is turned on and off by a "gating" pulse derived from IC1a. As IC1a is the oscillator that drives the infra red emitter circuit the gating pulses are automatically in synchronism with the received pulses.

The output of the synchronous detector is a steady d.c. voltage across capacitor C6. Any fluctuation in this voltage is a result of the infra red beam being disturbed and is passed, via coupling capacitor C7, to the inputs of IC3a and IC3b. IC3a and IC3b are standard op-amp i.c.s which amplify the difference in voltage between their two inputs. As their gain is very high only a few millivolts difference between the inputs is sufficient to make the output "swing" from 0V to the positive supply voltage.

The inputs of the op-amps that are not connected to the signal are connected to constant voltage bias points on the resistive potential divider chain consisting of resistors R14, R16, R17 and R19. This divider chain is fed from a 4·7V stabilised supply provided by resistor R13 and Zener diode D2.

WINDOW COMPARATOR

The voltages on pin 13 of IC3a and pin 3 of IC3b are 800mV and 400mV respectively. At the junction of resistors R16 and R17 the voltage is 600mV and this is used to provide the d.c. bias via R12 for the other inputs of IC3a and IC3b.

These d.c. conditions are such that the non-inverting (+) input of IC3b is at 400mV which is 200mV lower than the 600mV at its inverting input. This means that the output of IC3b will be held at or very close to 0V.

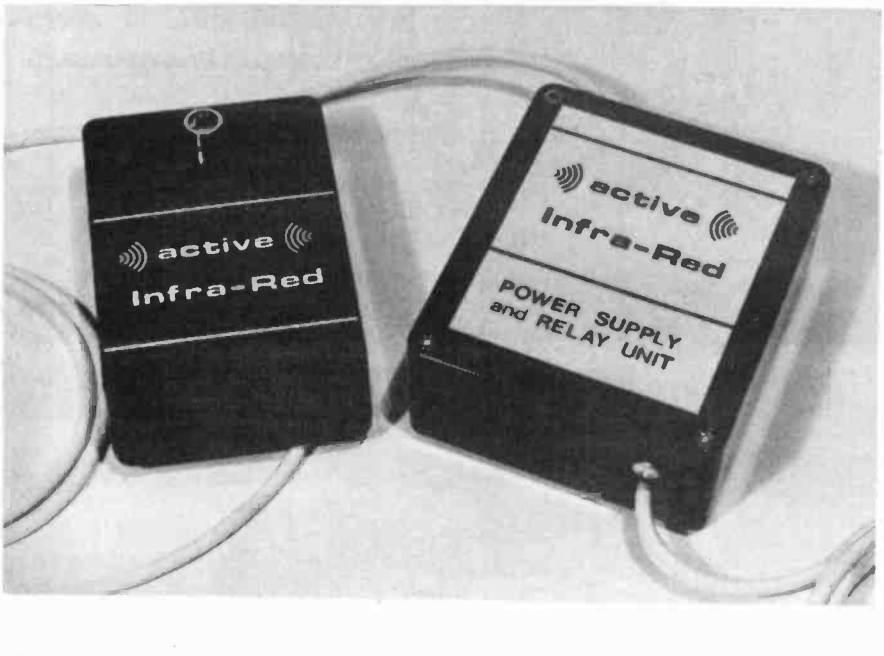
The d.c. conditions of IC3a are also such that the non-inverting input is 200mV lower than its inverting input as these are at 600mV and 800mV respectively. The output of IC3a is therefore also close to 0V.

Fluctuations in the voltage across capacitor C6 are passed via C7 and are added to the 600mV d.c. bias. Provided the fluctuations are less than 200mV in either direction nothing happens. Once this level is exceeded however pin 12 of IC3a may rise above 800mV or pin 2 of IC3b may fall below 400mV.

In each case the effect is to reverse the polarity of the voltage between the inverting and non-inverting inputs of the amplifiers so that the non-inverting input is at a higher voltage than the inverting input. The result of this is that the output swings positive from 0V up to almost the full positive supply voltage.

This type of circuit is known as a "Window Comparator". The "window" is the gap between 400mV and 800mV within which the input signal may be, without changing the state of the output. If the input signal falls outside the "window" below 400mV or above 800mV the output changes state.

Diodes D3 and D4 are connected to couple a positive output voltage from either



of the outputs of IC3a and IC3b through resistor R20 to the bi-stable latch circuit made up from IC3c and IC3d. These are a pair of cross-coupled amplifiers which work in a similar way to cross-coupled logic gates.

The non-inverting inputs of both amplifiers are connected to 4·7V at the junction of resistors R13, R14 and diode D2. The inverting outputs are cross-coupled via resistors R23 and R24. The circuit can rest in two stable states with either the output of IC3c high (positive) or output of IC3d high.

Normally the circuit resets with the output of IC3c held high. This holds the Reset pin of IC4 high which sets all the outputs low. When the beam is disturbed a positive output signal from the "window" comparator passes to pin 6 of IC3c. This forces the output of IC3c to change from high to low.

Pin 9 of IC3d is pulled low via R24 forcing its output to change from low to high. Feedback through resistor R23 now completes the latching operation of the circuit by holding pin 6 of IC3c high even after the original positive signal from the window comparator is removed.

BINARY COUNTER

The circuit is now stable in this state until pin 9 of IC3d is pulled high via diode D6. This happens when the selected output of the binary counter IC4 changes state. The speed at which this happens is determined by the low frequency clock oscillator consisting of IC1d, R25 and C12. This is a standard Schmitt trigger oscillator (similar to IC1a) producing an output of approximately 0·5Hz.

There are twelve stages in IC4 which change state in a binary sequence after 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048 clock cycles respectively. These are lettered O–Z in ascending order.

Whichever of these pins is used its voltage level changes from low to high after the appropriate number of clock cycles. When this happens, pin 9 of IC3d is pulled high via D6 and the bi-stable latch circuit returns to its original state with IC3c output held high and IC4 reset so that all its outputs are forced low.

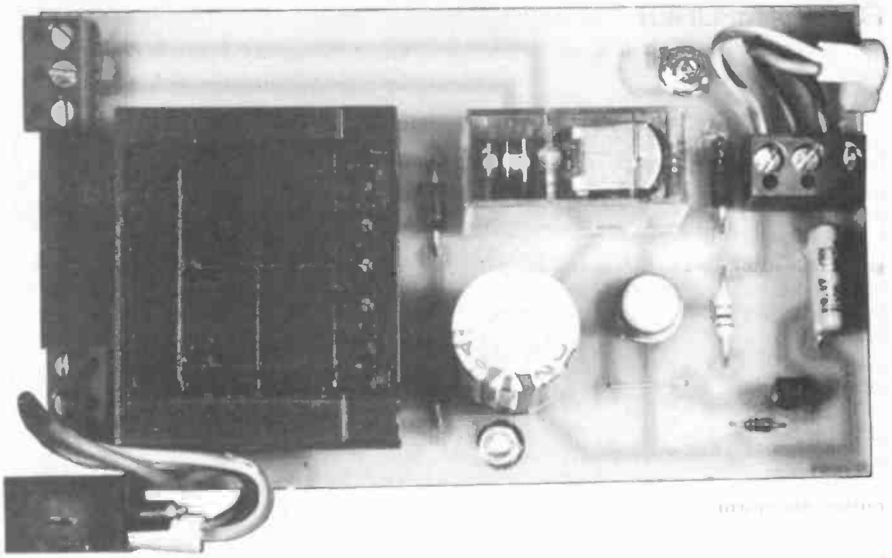
Drive to the ouput relay is provided by IC1c which inverts the level from IC3c so that terminal B is pulled positive for the full time period whenever the circuit is triggered.

The remaining components of the detection circuit are to ensure that the circuit does not trigger when first switched on. Transistor TR4 is turned on by IC1b for approximately 10 seconds after switch-on, whilst capacitor C9 charges from zero up to approximately half of the supply voltage. This effectively short-circuits capacitor C10 and sets the bi-stable circuit in the correct state.

After 10 seconds the voltage across C9 exceeds half of the supply voltage and the output of IC1d falls from high to low, TR4 is turned off, and these components play no further part.

POWER SUPPLY

The power supply and relay driver circuit is shown in Fig. 3. A small centre tapped mains transformer T1 provides approximately 12V via rectifier diodes D7 and D8 across smoothing capacitor C13. A 5V regulator IC5 is used along with a 4·7V Zener diode to give a regulated 10V supply for the detector circuit. Connections to the detector are via a three-core lead linking the three points A, B, and C.



The relay RLA is driven from terminal B on the sensor head via transistor TR5 which provides the necessary current gain. A set of changeover mains rated 6A contacts on the relay are terminated by a three-way terminal block on the circuit board.

These contacts can be wired directly to mains lighting or motor control circuits or may be fitted into a burglar alarm loop systems etc.

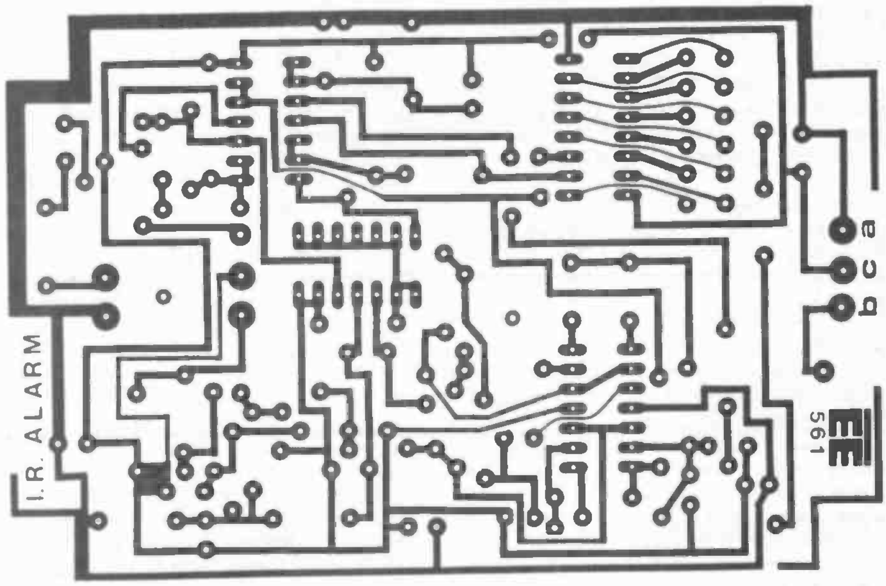


Fig. 5. Full size printed circuit master pattern for the Infra Red Alarm—Detection Head.

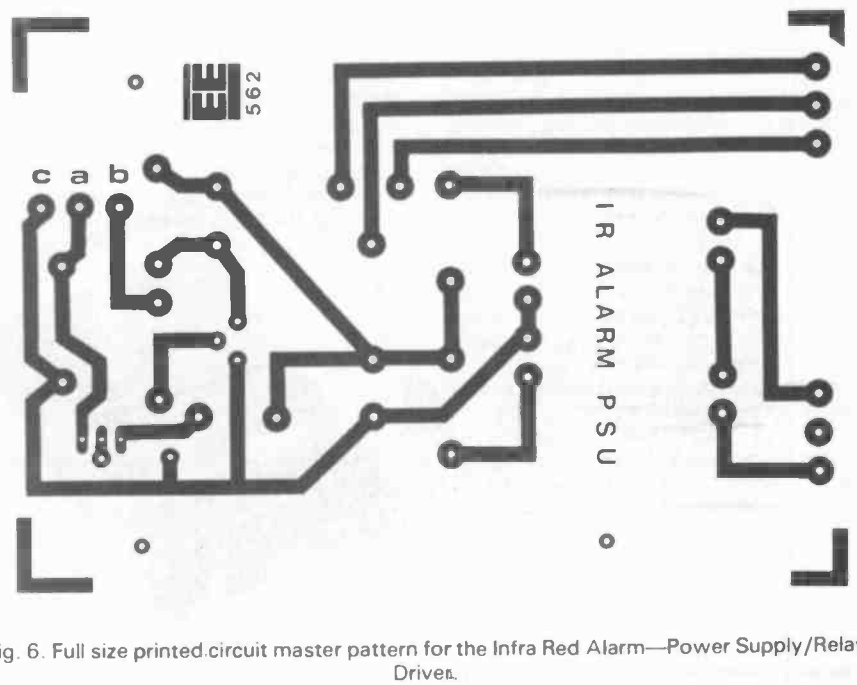


Fig. 6. Full size printed circuit master pattern for the Infra Red Alarm—Power Supply/Relay Driver.

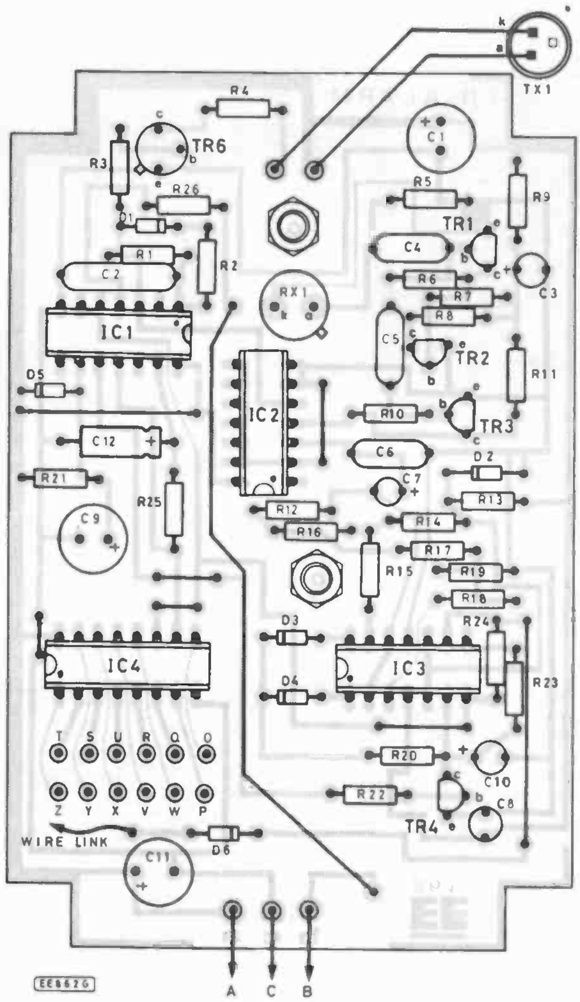


Fig. 7. Printed circuit board component layout for the detector circuit.

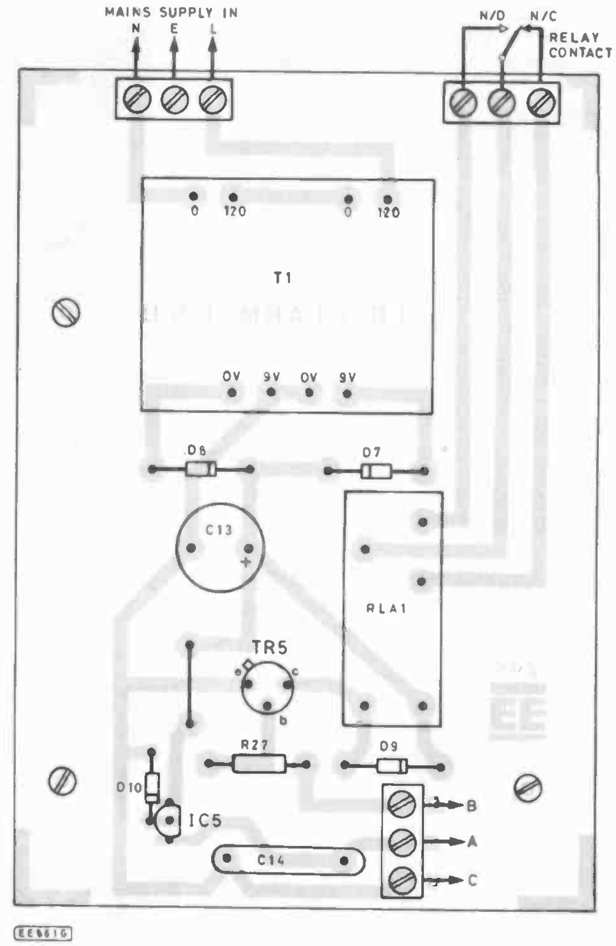


Fig. 8. Printed circuit board component layout for the p.s.u. and relay driver.

CONSTRUCTION

The detector circuit and the power supply are built on separate printed circuit boards. Full size foil patterns and component layouts for the boards are shown in Figs. 5, 7 and Figs. 6, 8. Except for the infra red emitter TX1 all of the components are board mounted.

Begin construction by referring to Fig. 7 and assembling the detector head. After inspecting the printed circuit board drill out the two fixing holes to 3mm and if necessary cut the corner notches. The board can then be used as a template to drill the holes for the fixing screws in the case.

The prototype board was mounted on the case lid with the corners notched for the case and mounting screws and pillars. Alternative arrangement may be used if desired. It is possible to mount the emitter at some distance from the board by the use of screened cable. With simple lenses, up to 50 metres' separation is possible.

Fit the short wire links, resistors, and the diodes to the board first, followed by i.c. sockets, transistors and capacitors. Check carefully that diode, transistor, and capacitor polarities and types are correctly identified and fitted. The photodiode should be fitted flush with the board and of course the right way round as indicated by the small tab.

The long wire link from terminal B to the hole near resistor R2 should be made using solid core insulated wire. A further link from near capacitor C11 to one of the timer output pins should be made with similar wire and it is recommended that this is set to the *Q* position at first so that testing does not take too long.

Two holes are required in the case, one for the emitter and the other for a window for the detector. In the prototype an 8mm diameter hole was drilled exactly opposite the detector and a thin clear plastic window was glued to the inside. The emitter has a lens and bezel which enables it to be mounted in the panel about 20 millimetres away from the detector window and connected to the board using a twisted pair of multi strand wire. Ensure that the polarity of the emitter is correct; the anode (a) is the short lead.

The power supply board should be assembled next. First inspect the board and drill out the two 3mm mounting holes. As with the detector head use the board as a template to drill the bottom of the power supply case with mounting holes. (See Figs. 6, 8.)

Fit all the components, small ones first, and take care to correctly identify their type and polarity. Most mains transformers are varnish impregnated and their tags are frequently covered with the stuff. It not only smokes and smells when soldering but also makes it difficult to make good connections. A careful scrape of each transformer pin before assembly will eliminate these problems and save time in the long run.

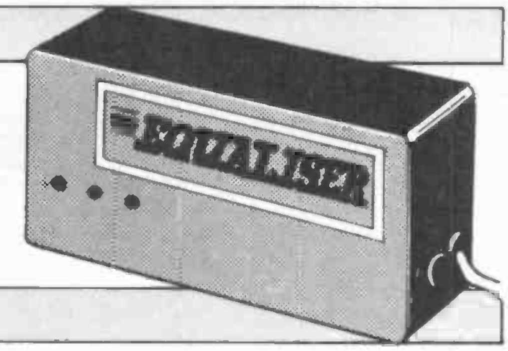
Once the board is complete it should be assembled into a suitable case and fitted with a mains lead via a proper mains cable retaining clamp or bush. The specified case has internal p.c.b. guide slots which can be removed with a sharp wood chisel if they are in the way. Fitting the lids and the interconnecting cable is all that remains of construction and should be completed after testing.

TESTING

The mains power supply unit should be tested first. Fit three wires to the output terminals A, B and C and bring these out of the case through a suitable grommet.

Continued on page 68

E.E. EQUALISER



ANDY FLIND

You can have a fresh start if you call in the Equaliser

An ioniser is a device for injecting a stream of negative ions into the surrounding air. The reason for doing so is based on the discovery that rural areas, where the air is supposedly "Fresh", have far higher concentrations of natural negative ions in the air than urban places; ergo, if the ion levels in our living rooms are artificially increased, we should become healthier, or at least feel better! There is still much debate regarding this, but commercially produced ionisers are now freely available and many users swear by them.

The author's personal experience is that ionised air does indeed seem "fresher", odours are reduced to some extent, and a room with an ioniser is generally a more pleasant place to inhabit. Whilst prices of commercial models remain at their present level however, home construction makes good sense.

Readers of long standing may recall an earlier design by the present author. This was produced at a time when there was still some mystique surrounding the subject and incorporated one or two features that have since proved unnecessary, resulting in extra expense and complexity.

A negative ion is simply an atom to which an extra electron has been added, giving it a net negative charge. To produce them in air all that is necessary is a high negative voltage, in excess of 4kV, applied to some sharp points.

Once ionised, the air will be repelled from the points (since like charges repel, remember those pith balls from the school lab?) so an actual "wind" of negative ions will be created. The aim of this design is to raise the required voltage as simply and cheaply as possible.

COMPONENTS

Resistors

R1 to R8 2M2 high voltage resistor (3500Vd.c.) (8 off)

Capacitors

C1 to C30 0·01µ 1000V d.c. disc ceramic (30 off)

Semiconductors

D1 to D30 IN4007 (30 off)

MAGENTA KIT 707

Miscellaneous

ABS Box 150 × 80 × 50mm, 20mm fuseholder and 100mA quickblow fuse, pins (3 off), 5A twin mains lead and plug,

It is essential that the correct working voltage resistors and capacitors are used.

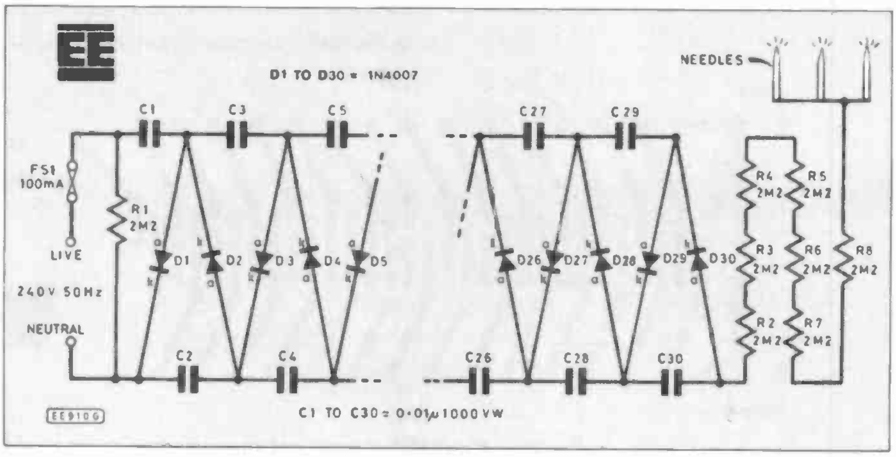


Fig. 1. Complete circuit diagram for the EE Equaliser air ioniser.

DESIGN

A number of ioniser designs have been published in recent years using various methods of raising the voltage, though all of them end with a circuit known as the "Cockroft–Walton Multiplier", a ladder-like string of diodes and capacitors used for pumping the output voltage up to the final level required. Commercially made units usually start with a transformer to raise the mains voltage to 1kV or so, then continue with around five multiplier stages built with 5kV rated components. This is impractical for home constructors since both the transformer and the 5kV rated parts would be difficult to obtain.

Another approach employs a 12V power supply feeding an oscillator running at several kHz. This in turn drives a ferrite-cored transformer followed by the multiplier. The claimed benefit is that the higher frequency permits the use of smaller capacitors, but unless battery operation is required this is heavily outweighed by the disadvantages. These are greater complexity for a start, then low efficiency, since the 1N4007 diodes normally used have very poor recovery characteristics above a couple of kHz. Finally, such circuits tend to generate lots of nasty r.f. harmonics, rather difficult to keep from the house wiring if they're mains operated.

A multiplier circuit run directly from the 240V 50Hz mains has much to recommend it, so long as some basic safety precautions are properly observed. Cheap, simple and noise free, it also has greatly improved reliability, an important consideration in an item intended to be operated continuously for literally years.

CIRCUIT

The basis of the EE Equaliser circuit, Fig. 1, is a thirty-stage multiplier, using 1000V diodes and 1000V disc ceramic capacitors. A 100mA fuse is provided in the supply, as a safety precaution against the unlikely event of catastrophic failure of several chain components. R1 has little effect during normal operation, but when the unit is disconnected it ensures the discharge of any stored voltage that might cause a shock to be received from the plug. In theory the multiplier produces over 20kV, but it's regulation is fairly poor and the impedance so high that even the tiny ionising current drawn from it pulls the output down to around 5kV; ideal for ion generation.

Safety is a major consideration with a circuit of this type, of course, and this is ensured by the chain of resistors between the output and the ion emitters. These are *special high-voltage rated* types; ***on no account should they be omitted or replaced by a single resistor*** of a higher value, which may not have an adequate voltage rating. The "ion emitters" are ordinary needlework pins positioned so that they project just above the surface of the unit's case.

CLEANLINESS

Constructors should ensure both their hands and the board are clean before starting to build the board, as losses through natural skin oils, etc. on the surface can significantly reduce the ion output.

Note that the edge of the board is undercut where the emitters are positioned; if this hasn't been provided it can be done with a small file. The edge should be smoothed here too, with some fine emery paper.

CONSTRUCTION

Construction could hardly be simpler, though the compact layout calls for careful use of a soldering iron with a small tip. The component layout and p.c.b. master pattern is shown in Fig. 2 and Fig. 3.

Since all the resistors, capacitors and diodes are of the same type it would be difficult to get it wrong! The diodes are

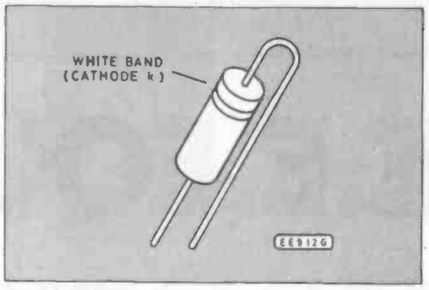


Fig. 4. Preforming the diodes, cathode (band) at top of the bend, prior to inserting on the board.

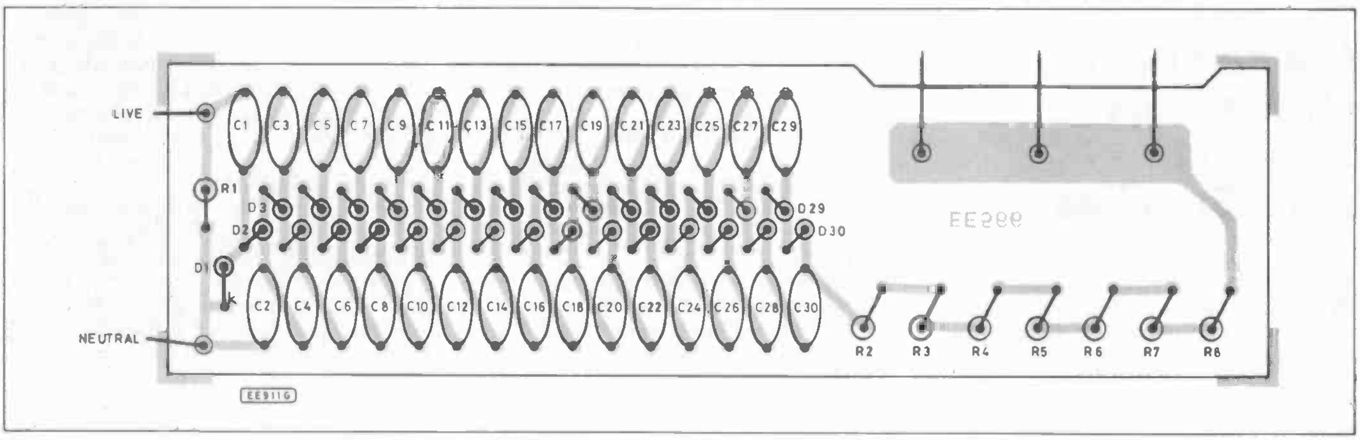


Fig. 2. Printed circuit board component layout.

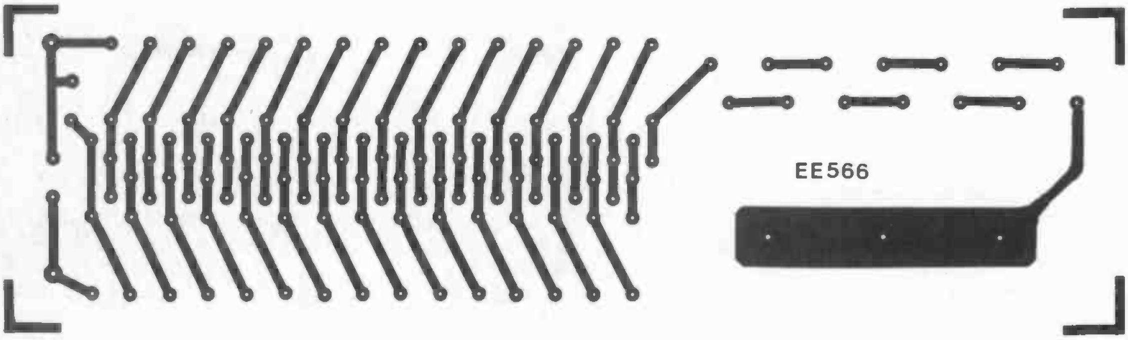
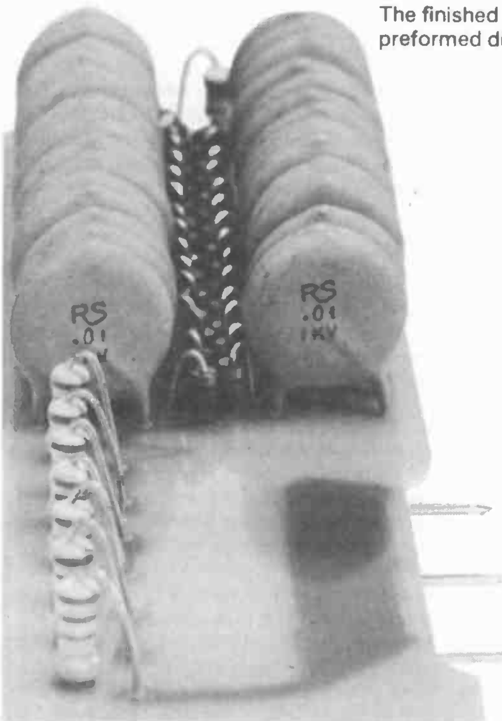


Fig. 3. Full size printed circuit board master pattern.

The finished board showing the preformed diodes.



The completed unit showing the tips of the "ion" emitter pins.

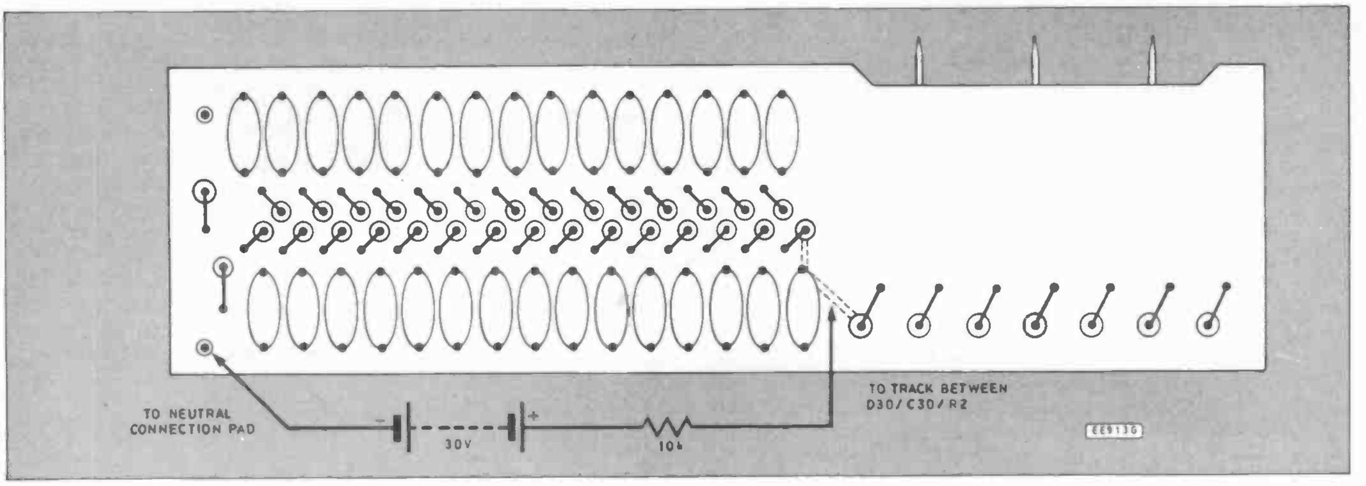


Fig. 5. Low voltage set-up for testing the board. Check voltage drop across each diode.

polarity-conscious of course; start by bending them all to the shape shown in Fig. 4 with the cathode (band) at the top, then they will all be correct when fitted to the board. Solder these in first, then fit the capacitors, then the resistors.

Because ions are emitted from sharp points, the solder joints should be smooth and rounded, especially towards the output end of the board. The easiest way to achieve this is to solder the components in place tion as shown in Fig. 5. Silicon diodes exhibit a voltage drop of about 0·6V in the forward direction, so the drop across the chain will be of the order of 16V to 18V. The remainder will appear across the resistor, which thus limits the current to one or two milliamps. It's now a simple matter to check that the appropriate voltage is appearing across each diode; faults in either components or construction will be immediately apparent.

emitter points end up nearly central. Try it in position and mark the position of the points, so that holes, about 4mm dia., can be accurately drilled for them. A suitable cord-grip should be fitted to the mains lead.

Cable entry and fuse are on the copper side of the board, as there's more room here. The Neutral is connected directly to the board, the Live goes via the fuse. Ensure the connections are the right way round, as a peak-to-peak mains ripple superimposed

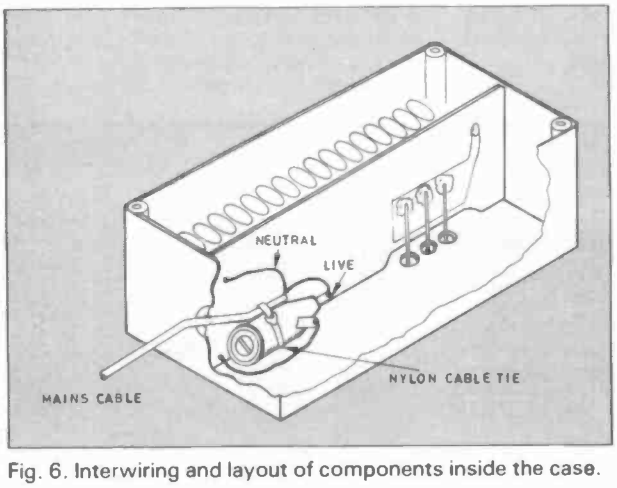
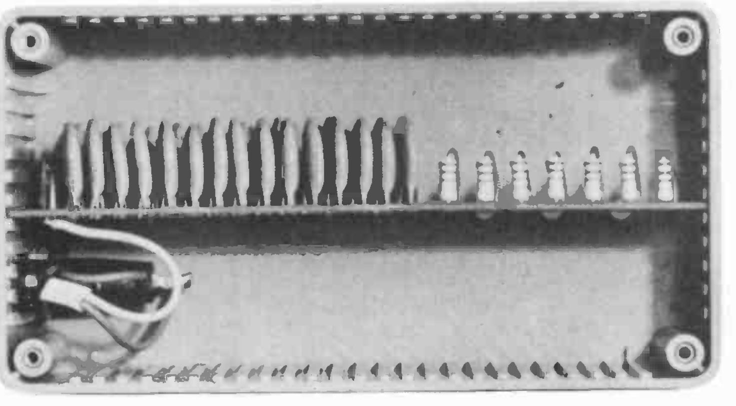


Fig. 6. Interwiring and layout of components inside the case.



The printed circuit boad slotted into the case of the ioniser.

with the leads projecting vertically from the board, crop them, remove all the sharp bits with a large flat file, then run over them all again with the iron and some extra solder to achieve the smooth rounded joints required.

The emitter points are made from ordinary pins. Cut these to length so that, when the points are positioned to project 1mm or so above the top of the case, the bottoms are within the area of the mounting pad. The easiest method of fitting is to stick them into something, cardboard perhaps, at the correct spacing, and prop them in place whilst soldering is carried out. Once again the joints should be made smooth and rounded.

TESTING

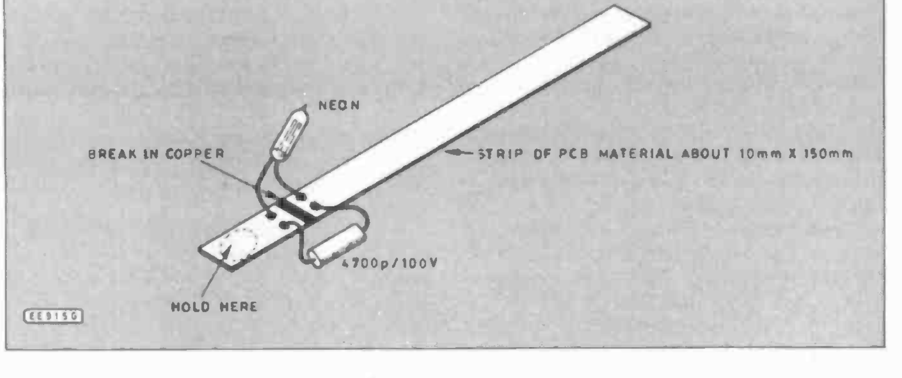
The board should be tested next. ***Live testing should never be attempted owing to the obvious dangers involved***, but an excellent low-voltage check is quite easy to carry out. A d.c. supply of around thirty volts (three 9V batteries will suffice) should be connected across the diode chain with a series resistor of 10k or so, in the forward direc-

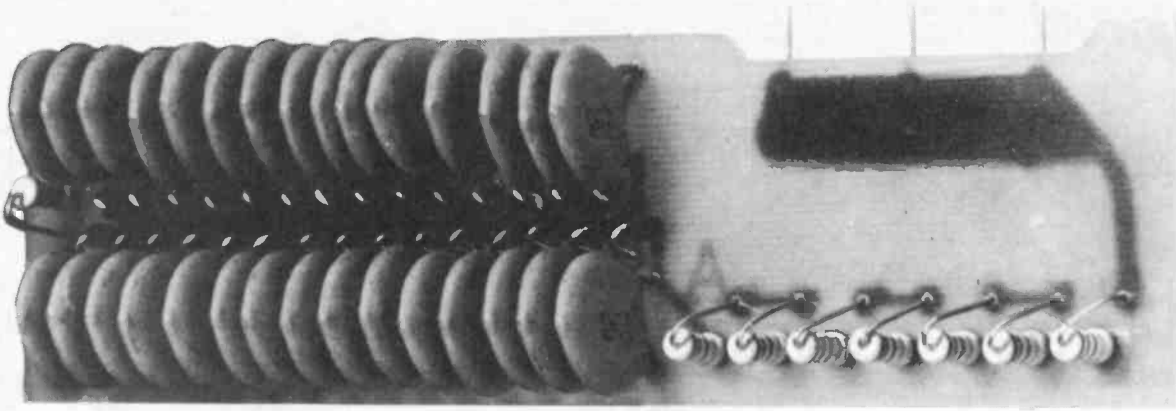
ASSEMBLY

Final assembly is just as simple. The board is designed to fit into the moulded slots in the specified case as shown in Fig. 6, slightly to one side of centre, so that the

on the output voltage is not to be recommended, even though it wouldn't prevent it from working. A small piece of foam plastic suffices to hold the board firmly in place when the base is screwed home; on the prototype pieces of draught excluder strip were used.

Fig. 7. Neon test/demonstration indicator.





OPERATION

Fifteen seconds or so after the ioniser is plugged in, it should be possible to hear a very faint "rushing" noise from the emitters. The impedance of the multiplier is such that it takes this long to build up to full voltage. It may be possible to feel a slight coldness against a hand held some 5–10cm above it, due to the "ion wind" of ionised air being repelled from the emitters.

A body or object placed too close seems to raise the potential difference and may cause the production of ozone, which has a distinct smell like arcing motor brushes: these tests may cause this. In normal use though, this unit will not produce ozone. If your body is well insulated, holding your hand over it for a few seconds will cause a charge to accumulate. Subsequent touching of an earthed object will produce a faint discharge, similar to static.

TEST WAND

The most effective test can be carried out if desired with the indicator shown in Fig. 7, made from a piece of scrap p.c.b. This is a simple neon relaxation oscillator; ions picked up from the air charge the capacitor until the striking voltage of the neon is reached, when it will flash. Simply hold the device between thumb and forefinger with the other end close to the emitters. The neon should begin to flash some fifteen centimetres away and the rate will increase rapidly as the distance is reduced.

The ioniser will probably cause your air to seem fresher and cleaner, especially if used in a small "stuffy" room. It may help to clear odours such as tobacco smoke; it certainly does this in the author's home. Whether it confers any health benefit is open to conjecture, though the cost of this design is certainly low enough to encourage trial!

One unwanted effect that should be noted is that airborne dust and dirt particles become charged and promptly stick to the nearest neutral object. Over a period of months this can amount to a surprising amount of dirt, which seems to ingrain itself right into the surface and becomes difficult to clean off. Ionisers, therefore, should not be operated for long periods in close proximity to expensive decorations. □

Continued from page 64

Fit the case lid and connect up the mains supply. If all is well it should be possible to make the relay click in and out by connecting terminals A and B, and there should be a voltage between 9·5V and 10·5V between terminals A and C. If not, switch off, remove the mains plug, inspect the board again and correct any faults.

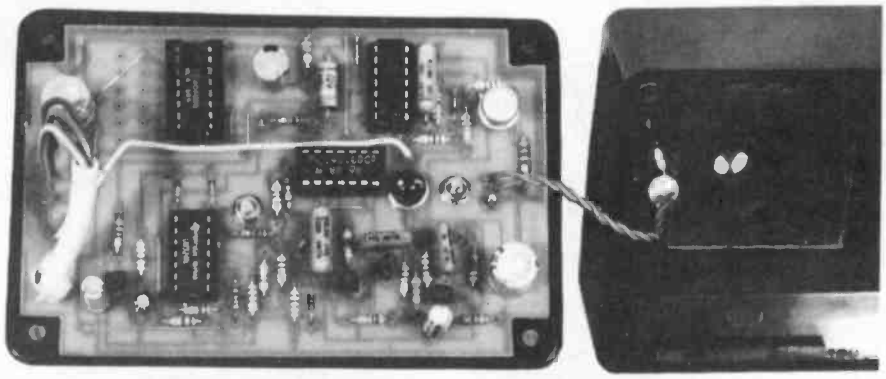
It may be necessary to check voltage whilst the mains is on. If so, keep the board fastened in the box, use a multimeter with well insulated probes and **keep clear of the mains end of the board**. Voltage readings can be taken across the various component leads on top of the board.

Once the power supply is working correctly, switch off, connect the three wires to the detector head, and insert the four i.c.s. Switch on again and check that the relay is not operating and that the supply voltage is still correct.

By moving a hand between or in front of the emitter and sensor it should be possible to operate the relay. Once the relay is operated move away and wait for 10 seconds or so for the relay to release. If this happens—well done—everything is working OK. If not, check and double check.

It is possible to check for correct voltages around IC3 and IC4, IC1b and IC1c and to check that IC1d pin 11 is pulsing up and down about every two seconds by using a simple multimeter on the 10V d.c. range. Check also for 4·7V across Zener diode D2 and approximately 9V across C3. The collector of TR6 should read almost +10V and the collector of TR3 +1·5V to 2V measured with respect to 0V (terminal C).

It is hard to go much further without more sophisticated equipment but bear in mind that 99 per cent of circuit problems are due to connections, soldering, and incorrectly fitted components. Faulty components and correctly wired circuits that don't work are rare so check your work very carefully.



The completed detector board mounted on the case lid.

APPLICATIONS

As mentioned earlier there are endless ways in which this circuit can be used. The infra red emitter can be removed from the detector head case and mounted opposite to form a broken-beam type alarm. Considerable range should be achieved in this way which could be extended even further by the use of cheap plastic lenses carefully positioned.

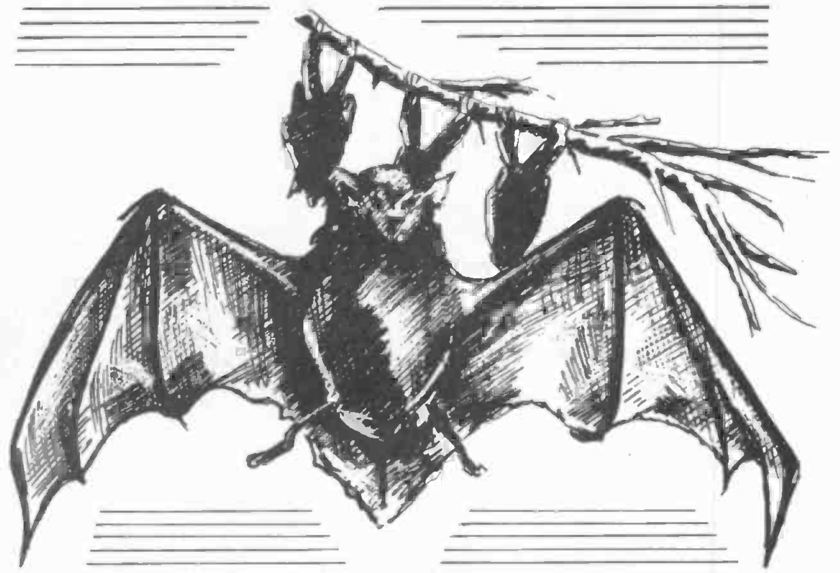
Various forms of reflector can be used if the standard arrangement is used with the emitter and detector side by side. Reflective tapes, discs and adhesive pads are fairly easy to obtain from motor cycle or car accessory shops.

If the detector head is to be used outside it should be protected from direct sunlight and rain and sealed with a strip of adhesive tape around the join between the case and the lid. As mentioned earlier, more detector heads can be used with a single power supply and relay unit by wiring them in parallel to terminals A, B and C.

The time delay is set by making the appropriate link to IC4. Intermediate times if required can be obtained by altering the values of resistor R25 and capacitor C12. If the unit is to be used as a burglar alarm sensor then a short time delay should be selected.

With the emitter and sensor mounted side by side the circuit works extremely well as a proximity detector just by measuring the increased amount of infra red reflected from the object or person. This mode of operation is extremely effective for porch light operation and as an indoor intruder detector. □

BAT DETECTOR



R. A. PENFOLD

Explore the fascinating world of bats and unravel some of their mysteries with this low cost instrument

A STEADY stream of readers' suggestions for projects is received in the offices of *EE*, and one idea which seems to crop up fairly regularly is for a "bat detector". In other words, a unit that will effectively extend human hearing so that the ultrasonic sounds produced by bats, or any other sounds at similarly high frequencies, can be heard.

Apparently units of this type do have practical applications in such diverse fields of interest as nature study and the detection of gas leaks. The unit described here may well be suitable for serious applications, but it was really only designed for its interest value.

It it surprising how much ultrasonic sound there is in the average house. Some quite loud sounds such as moving furniture around seem to have little or no ultrasonic content. Other sounds seem to contain little audio frequency content, but have quite significant ultrasonic levels. Dropping a pin or some other small object onto a hard surface produces little audio frequency sound, but seems to be readily detectable using this unit.

DETECTION METHODS

Detecting ultrasonic soundwaves is not very difficult technically, and the *Breaking Glass Alarm* in the September 1988 issue of *Everyday Electronics* is a basic detector of this type. Processing the received signal to give a useful audio frequency output signal is a little more difficult.

Some means of reducing the frequency of the received soundwaves is clearly needed, but the method used must not affect the relative amplitudes of the signals or otherwise severely distort the signal. What is needed is a system that not only gives some form of audio output, but one which also gives the sort of sound that you would hear if your ears could detect the ultrasonic input frequencies unaided.

One obvious approach is to use some form of frequency division systems. Dividing input frequencies by (say) five, would effectively extend the 20Hz to 20kHz audio frequency range to a 100Hz to 100kHz range. Bats apparently operate at around 35kHz to 80kHz or so, and this should enable them to be detected.

Unfortunately, the only reasonably simple frequency divider circuits are digital types which only deal in pulse signals. Using one of these would give a very distorted and crude form of output signal.

HETERODYNE APPROACH

The other obvious approach, and the one adopted in this design, is to utilize the heterodyne principle. This is the same effect that is used in most radio receivers and television sets.

In these applications it is used to convert a signal at a high radio frequency to one at a lower radio frequency. Here the frequencies involved are much lower, but the principle of operation is exactly the same. Heterodyning mixes two signals to generate an output signal that contains new frequencies, plus the input frequencies.

By using a balanced or double balanced mixer it is possible to remove one or both of the input signals from the output. In this case both the input frequencies will be at ultrasonic frequencies, and failing to remove them will not necessarily prevent the unit from functioning properly. However, there is some advantage in removing both input frequencies in that this avoids problems with these signals overloading or otherwise having adverse effects on the output stages of the unit.

SUM AND DIFFERENCE

The new frequencies produced by the heterodyning technique are the sum and difference frequencies. As a simple example we will assume that a bat is using a frequency of 60kHz for its "RADAR". If we heterodyne this with the 55kHz output from an audio frequency oscillator, the *sum frequency* is 115kHz (60kHz + 55kHz = 115kHz), and the *difference frequency* is 5kHz (60kHz−55kHz=5kHz). The sum frequency is of no interest as it is at an even higher frequency that the input signal, but the difference frequency provides the desired effect with the input signal being brought down to an audio frequency output.

In effect, the heterodyning technique reduces all the input frequencies by an amount which is equal to the frequency of the signal with which they are mixed. By using a suitable oscillator frequency it is therefore possible to bring a signal at any frequency down into the audio range.

The relative strengths of the input frequency components is reflected in the relative strengths of the output components that they generate. The output signal consequently reflects the nature of the input signal. A single input tone will give a single output tone—a noise input signal will produce a noise signal from the output.

FREQUENCY RANGE

This system does have its limitations, and one of these is that a single oscillator frequency will not provide coverage of the full ultrasonic range. This is simply because

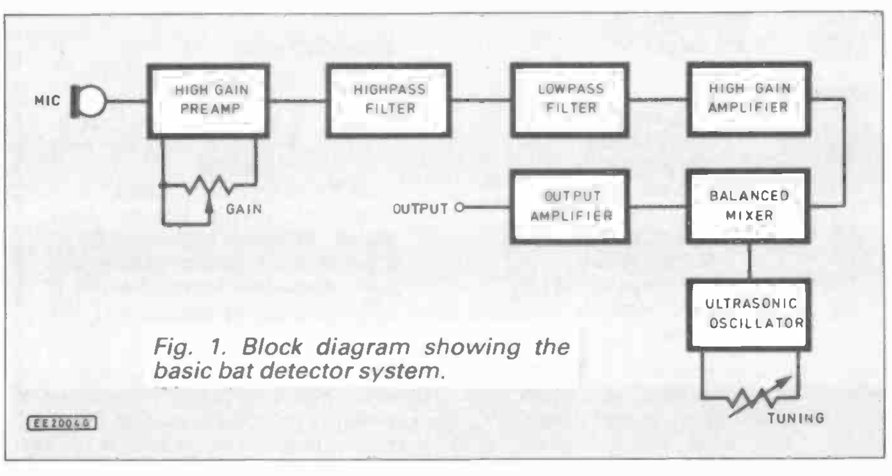


Fig. 1. Block diagram showing the basic bat detector system.

the ultrasonic range covers a much wider span of frequencies than the audio frequency range. With this method you can only cover 20kHz chunks of the ultrasonic spectrum.

Another problem is that signals at frequencies below the oscillator frequency can also produce an output at audio frequencies. In our previous example a signal at 60kHz was reduced to 5kHz using an oscillator frequency of 55kHz. An input signal at 50kHz would also give a 5kHz audio output signal (55kHz − 50kHz = 5kHz).

Having the oscillator above the signal frequencies inverts the audio output signal. The lower the input frequency, the higher the output frequency.

In practice these problems do not seriously detract from the effectiveness of the unit. For best results the oscillator should be set at something approaching the lowest frequency that gives a good audio output signal. The audio output signal should then give a good idea of the type of input signal that is being received.

BASIC SETUP

The block diagram of Fig. 1 shows the basic setup used in the Bat Detector. A microphone detects the ultrasonic soundwaves and converts them into corresponding electrical signals.

There is a slight problem here in that ordinary microphones are only designed to operate efficiently over the audio frequency range. Most have responses that fall away rapidly above 20kHz, and some do not even operate well to the upper limit of the audio range.

We opted for a 40kHz ultrasonic transducer of the type used in remote control units, burglar alarms, etc. Although these have peak efficiency at a frequency of about 40kHz, they seem to work reasonably well from the upper part of the audio range to a frequency of around 80kHz.

Their frequency response is far from flat, but they provide reasonable sensitivity and quite good results overall. Of course, if you can find an ordinary miocrophone that works well at frequencies well into the ultrasonic range, then it should work perfectly well with this unit.

Whatever type of microphone is used, its output is unlikely to be anything other than very weak. A high gain preamplifier stage is therefore used to boost the input signal.

A gain control permits the gain of the unit to be backed off if a strong input signal causes overloading. This is followed by highpass and lowpass filters.

HIGHPASS FILTER

The highpass filter is important as it severely attenuates any audio frequency output signals from the microphone. This helps to keep any audio frequency breakthrough to the output down to an insignificant level. When using a fairly low oscillator frequency it also avoids having audio frequency input signals reacting with the oscillator to produce further audio frequency signals at the ouptut.

The lowpass filtering might seem to be unnecessary, since the response of the microphone is unlikely to provide any significant output at frequencies beyond about 80kHz. It is not signals from the microphone that are likely to be troublesome, a more likely cause of difficulties is stray pick-up of radio frequency (r.f.) signals.

These r.f. signals could cause breakthrough in demodulated form at the output of the unit, or they could react with harmonics of the oscillator signal to produce heterodyne "whistles" on the output signal. The lowpass filtering eliminates both these possibilities.

Even after being boosted by the preamplifier the signal is still quite weak, and a further high gain amplifier stage is used to raise it to a more useful level. The signal is then applied to one input of a balanced mixer. The other input is fed from a variable frequency oscillator.

A dual balanced mixer is used, and both input signals are suppressed at its output. This avoids the need for any complex filtering at the output of the mixer, and a simple passive lowpass filter is all that is needed in order to prevent high frequencies on the output (the sum signal) signal from producing any problems. An output amplifier provides a certain amount of additional voltage gain, but its main purpose is to provide buffering so that a crystal earphone or medium impedance headphones can be driven from the output of the unit.

COMPONENTS

Resistors

R1, R13	1M (2 off)
R2, R8, R12, R14	2k2 (4 off)
R3, R26	390 (2 off)
R4, R15, R16, R22, R23	4k7 (5 off)
R5	2k7
R6, R7	68k (2 off)
R9, R10, R11	1k (3 off)
R17	18k
R18, R24	10k (2 off)
R19, R25	100k (2 off)
R20	5k6
R21	270

All 0.25 watt 5% carbon

Potentiometers

VR1	4k7 rotary, log
VR2	47k rotary, lin.

Capacitors

C1, C19, C20, C21	100μ radial elec. 10V (4 off)
C2, C3, C10 C12, C13	10n polyester (5 off)
C4, C5, C5, C11	1n polyester (4 off)
C7	3n3 polyester
C8, C16	4n7 polyester (2 off)
C9	330p ceramic plate
C14	2μ2 radial elec. 63V
C15	10μ radial elec. 25V
C17	2n2 polyester d25V
C18	4μ7 radial elec. 63V

Semiconductors

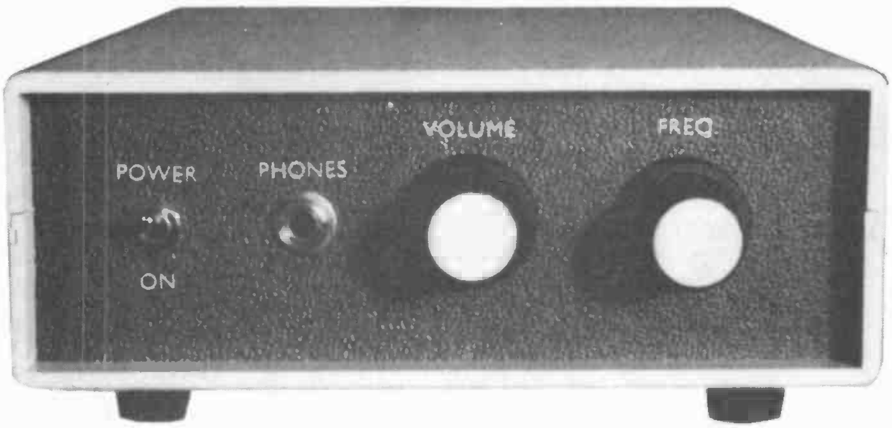
TR1, TR2, TR3, TR4	BC549 *npn* silicon (4 off)
IC1	LF353 dual op. amp
IC2	SL1640C double balanced mixer
IC3	μA741C op. amp

Miscellaneous

MIC1	40kHz ultrasonic transducer (see text)
S1	s.p.s.t miniature toggle
B1	9V (e.g. 6×HP7 size cells in holder)
JK1	3.5mm jack socket

Printed circuit board; case, about 125mm×190mm×45mm; 8 pin d.i.l. i.c. holder (3 off); battery connector; control knob (2 off); connecting wire; pins; solder, etc.

MAGENTA KIT 814



CIRCUIT DESCRIPTION

The full circuit diagram for the Bat Detector appears in Fig.2.

The output from Mic.1 is fed to the input of a high gain common emitter amplifier based on transistor TR1. This has its output fed to potentiometer VR1 which is connected as a volume control style variable attenuator.

The output of the amplifier is fed, via the wiper of VR1, to the input of the highpass filter which is a three stage (18dB per octave) active type which has transistor TR2 as the buffer amplifier. The cutoff frequency of this stage is approximately 30kHz.

Transistor TR3 is used as the basis of the lowpass filter, which is again a three stage type. This has a cutoff frequency at about 100kHz. The second high gain amplifier stage is another common emitter amplifier (TR4).

The dual balanced mixer, IC2, is a device which is primarily intended for use as an s.s.b. (single side-band) modulator/demodulator and other communications applications. However, it works equally well in its current role, where the only real difference is that it is operating with relatively low input frequencies.

The SL1640C used in the IC2 position is not a particularly cheap device, but it provides a high level of performance. It also has the advantage of achieving accurate balancing without the need for any setting up. It requires a six volt supply, and this is derived from the main 9V supply via dropper resistor R21 and decoupling capacitor C15.

The local oscillator signal is generated by a standard operational amplifier square/triangular oscillator circuit. IC1a functions as the Miller integrator while IC1b provides the trigger function. In this case it is the triangular waveform (with its relatively low harmonic content) that is required.

The frequency response limitations of IC1 seem to round the waveform slightly, which gives an even lower harmonic content. There is still a significant harmonic content on the output signal, but is not large enough to prevent the unit from working properly.

Using a high quality sinewave generator as the local oscillator seems to give no noticeable improvement in performance. Potentiometer VR2 is the frequency control, and this gives a frequency coverage from just over 20kHz to a little under 100kHz.

The audio output of IC2 is processed by a two stage passive lowpass filter (R22—C16—R23—C17) which attenuates any high frequency components on the output signal (which will primarily be the sum signal). IC3 is a simple inverting mode amplifier, and this provides a voltage gain of about 20dB (ten times). It also provides a certain amount of current gain so that medium impedance headphones can be driven from the output.

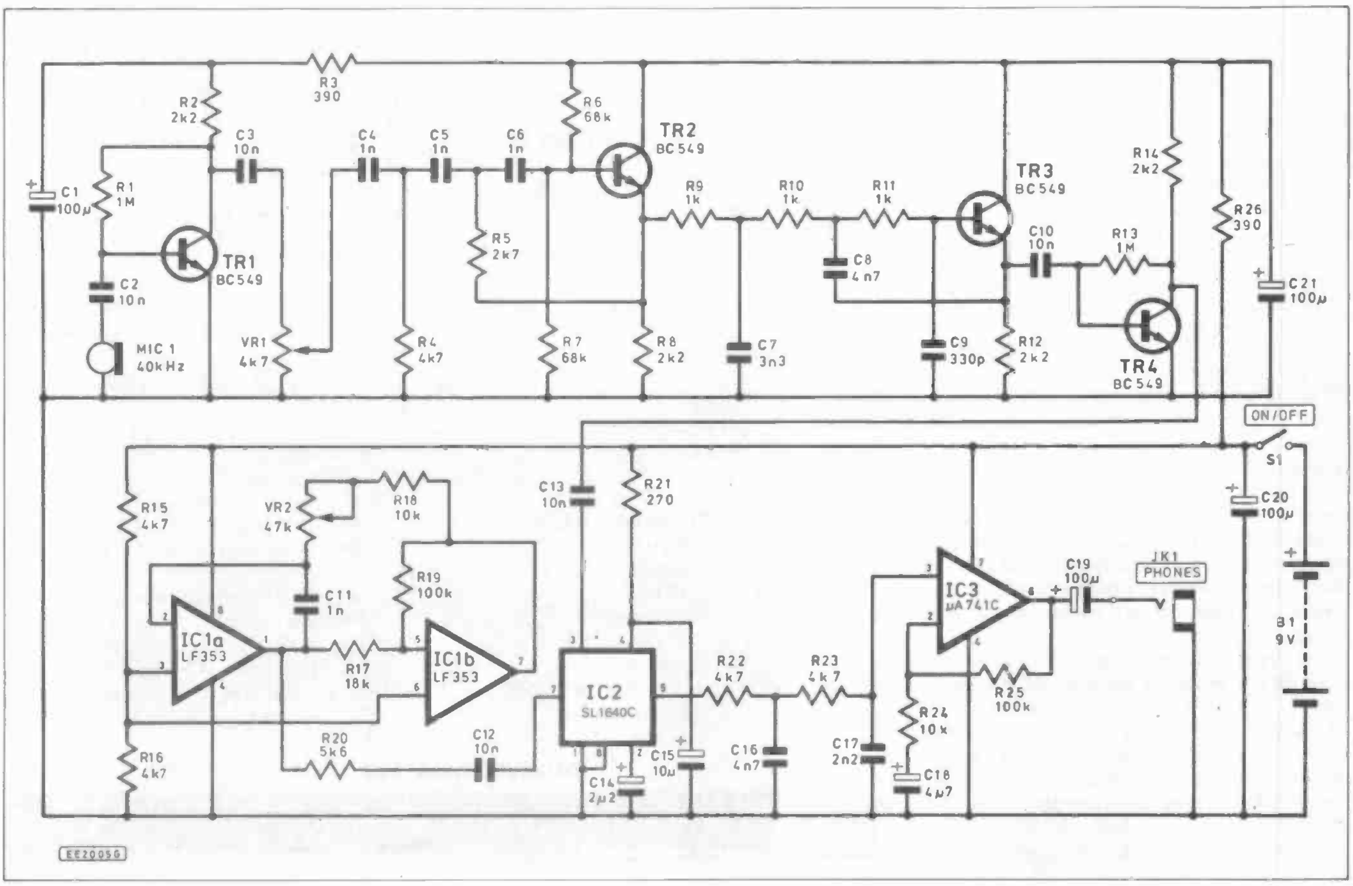
Power is obtained from a 9V battery, and the current consumption is about 10 milliamps or so. For economic operation a fairly high capacity battery is required, such as six HP7 size cells in a plastic battery holder.

CONSTRUCTION

The component layout and full size copper foil master pattern for the Bat Detector is shown in Fig.3.

None of the semiconductors are static sensitive devices, but the SL1640C used for

Fig. 2. Complete circuit diagram for the Bat Detector. The battery B1 is made up from six HP7 type cells.



IC2 is sufficiently expensive to warrant a socket anyway. In fact it is recommended that i.c. sockets be used for all three integrated circuits.

Do not overlook the single link wire between transistor TR4 and resistor R25. This can be made from 22 s.w.g. tinned copper wire, or a piece of wire trimmed from a resistor leadout should suffice.

Construction of the board is not particularly difficult, but it does demand that the proper miniature components are used. In particular, the electrolytic capacitors must be radial (vertical mounting) components, and the polyester capacitors must be printed circuit mounting types having a lead spacing of 7.5 millimetres. Other types could be very difficult to fit into the layout. At this stage only single-sided pins are fitted to the board at the positions where connections to off-board components will eventually be made.

CASE

There are a number of plastic boxes that are suitable as the housing for this project. The prototype model used a low-profile case having removable front and rear panels. The headphone socket and controls being mounted on the front panel, with the microphone fitted on the rear panel.

A 3.5 millimetre jack socket was used for JK1, but this can be changed for any type of socket that will match the plug on the particular earpiece or headphones you will be using with the unit. For medium impedance headphones a 3.5 millimetre stereo jack socket will usually be needed.

Mounting ultrasonic transducers can be difficult as there is not usually any built-in mounting of any description. It is usually a matter of drilling two small holes to accommodate their terminals, and then gluing them in position on the front surface of the panel. A good quality gap-filling adhesive is required, and an epoxy resin type is ideal.

The printed circuit board is mounted on the base panel of the case using 6BA mounting bolts and spacers, or plastic stand-offs. Mount it well towards the front of the case so that there is sufficient space for the battery at the rear of the unit.

The board is wired to the off-board components using multi-strand p.v.c. insulated connecting wire. Details of this wiring is shown in Fig.3.

With many ultrasonic transducers one terminal connects to the component's case, and with a component of this type it is this terminal that should connect to the negative supply rail. Connection to the battery holder is via an ordinary PP3 style battery clip.

IN USE

Either a crystal earphone or medium impedance headphones (the type sold as replacements for personal stereo units) can be driven from the output of the Bat Detector. If headphones are used they should be connected in series (ignore the chassis terminal of the socket and make the connections to the other two tags).

With the unit switched on and the "volume" control VR1 well advanced there should be a certain amount of background "hiss", but ordinary noises should not be picked up and reproduced through the headphones. Obviously some ultrasonic sounds are needed in order to test the unit, and bats are not the only source of these.

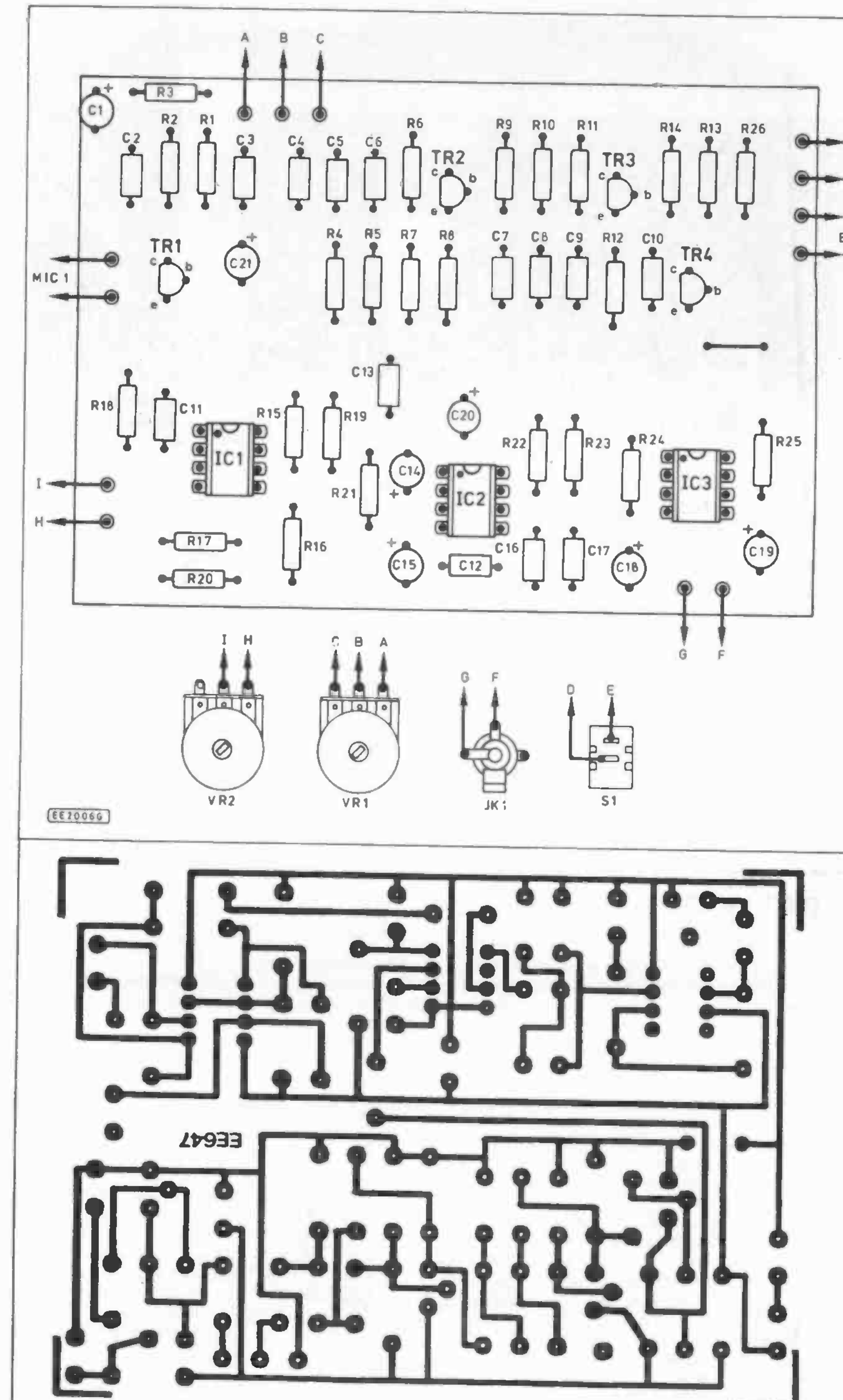
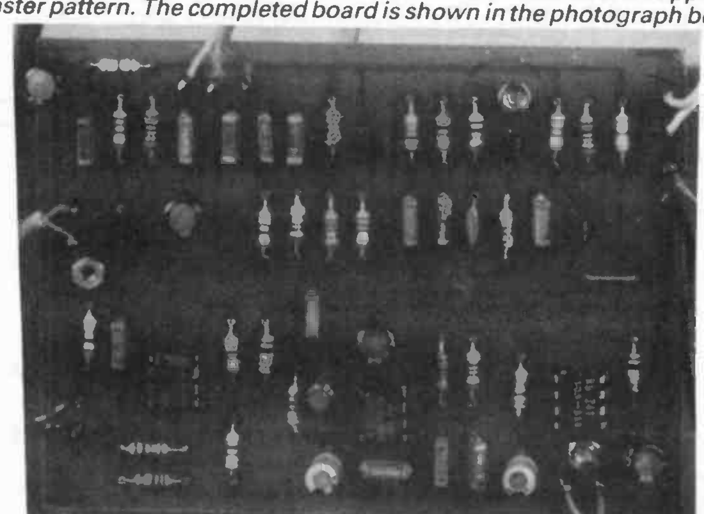
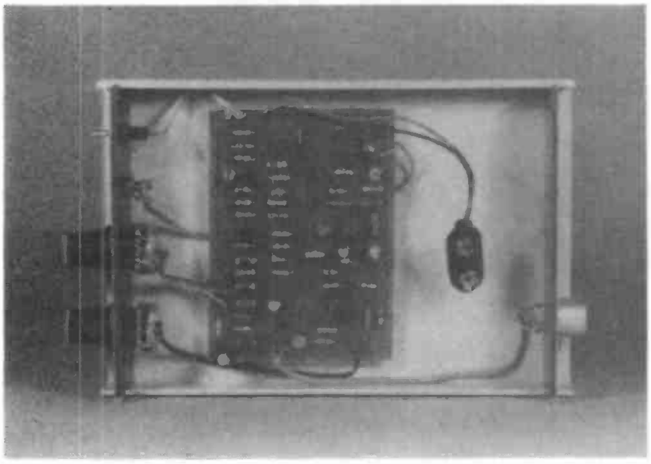
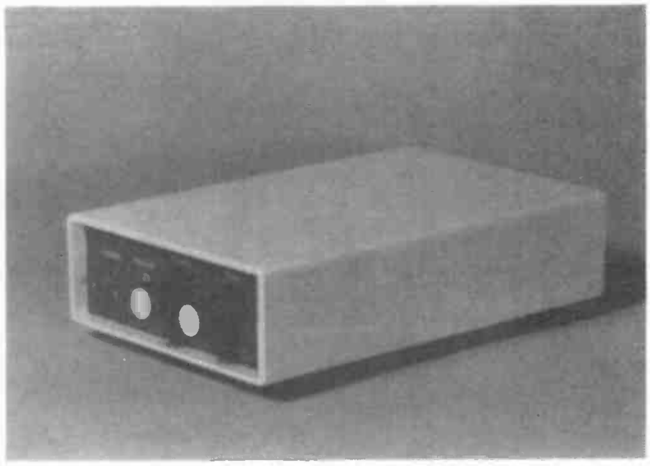


Fig. 3. Component layout and full size printed circuit board copper foil master pattern. The completed board is shown in the photograph below.





Completed unit showing wiring to ultrasonic "sensor" (Mic 1). Leave plenty of room for the batteries.



Layout of front panel controls.

An ultrasonic remote control transmitter will provide a test signal, but there are much more simple methods that will suffice. Simply rubbing your fingers together about 300 millimetres in front of the transducer should produce a noise sound from the headphones.

Adjustment of the "frequency" control VR2 should have some effect on the pitch of this noise. Dropping a pin, small needle, or very short pieces of wire onto a table-top should also produce a signal that can be readily detected by the unit.

With suitable adjustment of VR2 the sound from the headphones may well sound very similar to the audio frequency sound of the pin (or whatever) dropping. A little experimentation should soon find some other sources of ultrasonic sound.

When using the detector bear in mind that ultrasonic sound waves tend to highly directional. The unit will probably be insensitive to sounds unless the transducer is aimed at the source reasonably accurately.

Also bear in mind that the unit covers less than the full ultrasonic range at any one setting of VR2. Some adjustment of this control may be needed before an ultrasonic sound will give an audible output from the unit.

Avoid using the unit very near television sets, computer monitors, or other apparatus that generates electrical signals in the ultrasonic range. If the unit is used very close to equipment of this type it is almost inevitable that it will pick up a certain amount of interference from them. □

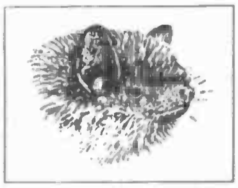
BAT WATCH

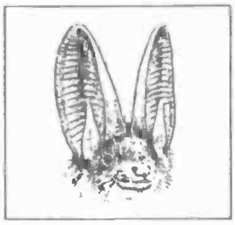
Under the Wildlife and Countryside Act 1981 *it is illegal for anyone without a licence to intentionally kill, injure or handle a bat of any species in Great Britain; to possess a bat, whether alive or dead (unless obtained legally); or to disturb a bat when roosting.*

Ringing or marking bats or photographing them (except when in flight outdoors) requires a licence from the Nature Conservancy Council. It is also an offence to sell or offer for sale any bat, whether alive or dead, without a licence.

The law does allow you to tend a disabled bat in order to release it when it has recovered, or to kill a seriously disabled bat which has no reasonable chance of recovery.

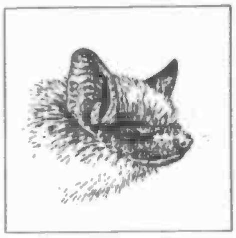
***Pipistrelle* ▶**
40-50kHz
Location:
Throughout
Gt Britain & Ireland
Habitat:
Buildings—Trees

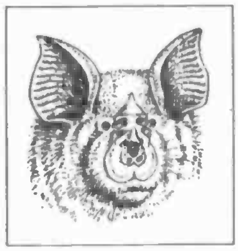




◀ *Brown Long-eared*
35-60kHz
Location:
Throughout
Gt. Britain & Ireland
Habitat:
Buildings—Trees

***Serotine* ▶**
20-60kHz
Location:
S. Britain
Habitat:
Buildings





◀ *Greater/Lesser Horseshoe*
80-110kHz
Location:
S/W England, Wales, North to Yorkshire
Habitat:
Buildings—Caves

Habits

Only very basic information is available about bats and until recently their study had been confined to a handful of sites where local interest had stimulated further investigations.

But why do we want to know about bats? For a start, there is much in common between bats and humans. Both are warm-blooded mammals with a high parental care for their "children" and also like living together with others of their own species.

Bats are relatively intelligent, with good eyesight and hearing, preferring clean dry places in which to roost—particularly houses. In most cases, it is their liking for houses that brings them into contact with humans and can cause conflict, even though they are completely harmless.

Bats change their roost sites seasonally and are inquisitive creatures, constantly investigating potential roosts. It is not understood why they choose a particular site, but temperature seems to play an important part. Their summer roosts would have been mainly hollow trees, but these are now a very rare feature of the countryside.

As social creatures they tend to gather in groups, the size of which varies—about 30 to 40 Horseshoe Bats to a roof but up to hundreds if it's the common Pipistrelle species. Whatever their numbers they do no damage, they will not gnaw the rafters nor do they build nests like birds.

Senses

Bats are not blind but have good eyesight which is used mostly for navigation. Their most highly developed sense is that of hearing. They use a form of sonar for obstacle avoidance and for locating food. High-frequency sounds are emitted which enable bats to "see" or discriminate fine detail even in complete darkness, but their range is limited to a few metres. This is why bats have a twisting turning flight as they only notice insects or obstacles when close to them.

Unlike most other mammals, bats do not have a steady body temperature. In flight, their body temperature of 42°C and pulse rate of 1000 per minute are much higher than man's 37°C and 75 per minute. After landing, their temperature rapidly falls 10 degrees for digestion and later falls to the surrounding temperature, helping to conserve energy.

Feeding

British bats all feed on insects caught in flight or picked off water, the ground or foliage. During summer, they consume vast numbers, many of which are crop pests. One pipistrelle may eat up to 3,500 insects each night.

Because few insects are available in winter, bats put on about one third extra weight during autumn and then hibernate from October to April. Body temperatures approximate their surroundings, which may be down to zero.

In very cold weather, they may be seen moving to alternative hiberation sites with a more suitable temperature. Bats should never be disturbed during hibernation as if this happens they use up vital energy reserves and may die.

FOR FURTHER INFORMATION CONTACT:

Nature Conservancy Council,
Northminster House, Peterborough, PE1 1UA.
Tel: 0733 40345

or your local bat group

Fauna and Flora Preservation Society,
c/o Zoological Society of London, Regent's Park,
London NW1 4RY. Tel: 01-387-9670

Mammal Society, Baltic Exchange Buildings,
21 Bury Street, London EC3A 5AU.
Tel: 01-283-1266

ACOUSTIC PROBE

A.J. FLIND

A relatively simple diagnostic tool which can provide excellent results on everything from watches to car engines

HOW MANY times have you raised your car's bonnet to investigate some new and worrying noise, only to be faced with a bewildering array of whirring and clattering machinery amongst which it is quite impossible to identify the offending sound? It might be tappets tapping, big ends on their way out, or simply a noisy alternator bearing.

On one memorable occasion a qualified mechanic identified a noise in the author's car as "big ends" and would have stripped the engine, had a more experienced colleague not chanced to hear it and identify a faulty water pump. To pinpoint such noises, some kind of "stethoscope" is invaluable. Sometimes a skilled mechanic will use a long screwdriver for the purpose, but this is not very satisfactory, and for the amateur not entirely safe. One can get one's ears caught in the fan belt that way!

An electronic "stethoscope", easily built by any electronics enthusiast, is a far better solution. This can easily be applied to any part of the engine, the volume adjusted, and of course full-size padded headphones will help block out some of the general racket in favour of the sound being traced. The accuracy of such a tool can be surprising; in a test with the prototype it was found that not only could the alternator of a friend's car be identified as the source, but there was no doubt whatsoever about which bearing was faulty.

Of course the instrument is not limited just to automotive applications. It can be used for almost any mechanical noise location, from clockwork to cental heating systems. It is sensitive enough to pick up the tick of the author's watch, an analogue quartz model with a tiny stepping motor. Finally, for those who live in terraced accommodation and enjoy listening to the neighbours fighting, it beats a glass pressed to the wall hands down!

CIRCUIT

In principle this project is very simple. All that is required is a microphone on the end of a rod (probe), and a high-gain amplifier. The "microphone" is rather special, and will be described in detail later.

The full circuit of the Acoustic Probe appears in Fig. 1, and operates as follows. Since the microphone is a crystal device with high output impedance, it is buffered by the source follower f.e.t. TR1. The output from this goes to amplifier TR2 which, in the configuration shown, provides a voltage gain of about thirty five. The gain is actually set by the ratio of R5 to R6, less a bit for losses, and can be altered if desired by changing the value of R6. Increasing the gain here will raise the circuit noise level a little though.

The output from TR2 is buffered by emitter follower TR3, and then fed, via volume control VR1, to output amplifier IC1. The positive supply for the preamplifier stages of the circuit are decoupled from supply variations by R8 and C1.

The amplifier i.c. is the well-known TBA820M audio chip. This is available in a compact 8-pin d.i.l. package, has ample power

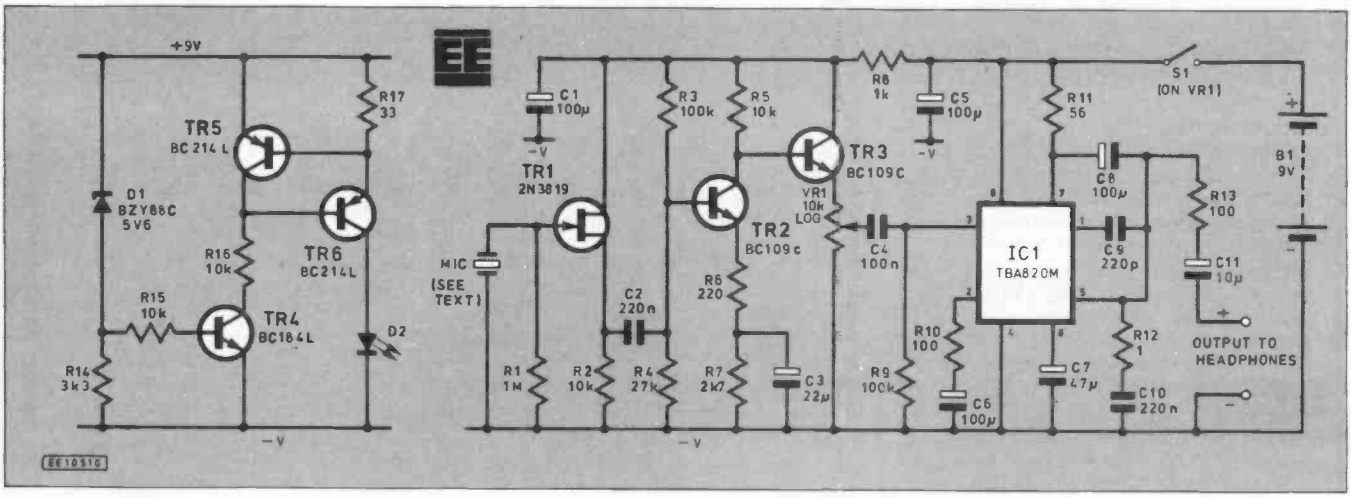
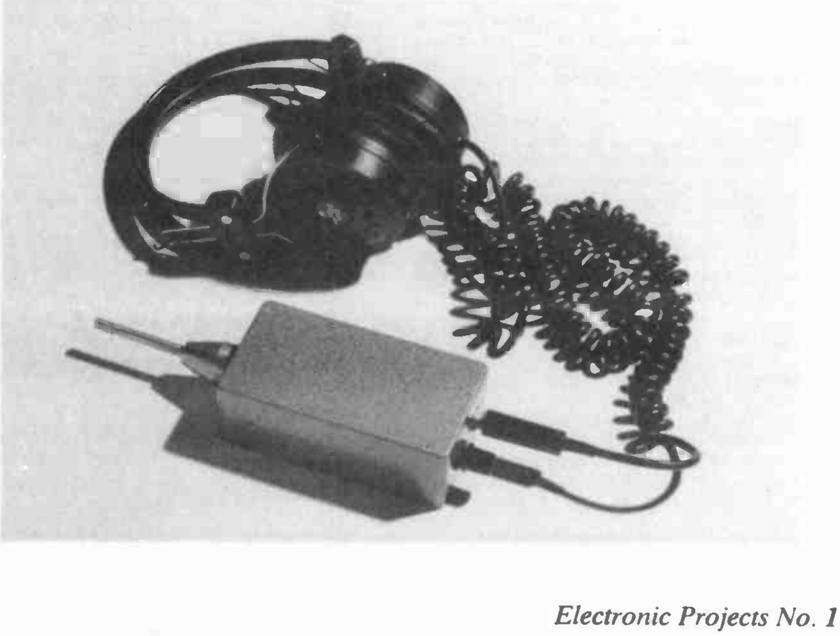


Fig. 1. Complete circuit diagram of the Acoustic Probe.



COMPONENTS

Resistors
R1, 1M
R2, R5, R15, R16 10k (4 off)
R3, R9 100k (2 off)
R4 27k
R6 220
R7 2k7
R8 1k
R10 100
R11 56
R12 1
R13 100 (see text)
R14 3k3
R17 33

Potentiometer
VR1 10k log carbon with switch (S1)

Capacitors
C1, C5, C6, C8 100μ axial elect. 10V (4 off)
C2, C10 220n polyester layer (2 off)
C3 22μ axial elect. 25V
C4 100n polyester layer
C7 47μ axial elect 16V
C9 220p ceramic plate
C11 10μ axial elect. 25V

Semiconductors
D1 BZY88C5V6 400mW 5.6V Zener diode
D2 red l.e.d. 3mm type.
TR1 2N3819 f.e.t.
TR2, TR3 BC109C silicon *npn* (2 off)
TR4 BC184L silicon *npn*
TR5, TR6 BC214L silicon *pnp* (2 off)
IC1 TBA820M i.c. power amplifier

Miscellaneous
Printed circuit board; 8 pin d.i.l. i.c. holder; case, diecast alloy box, 120×65×40mm; PP3 battery and connector; knob; standard stereo jack socket; 27mm piezo transducer element; assorted hardware for transducer — see text; connecting wire, etc.

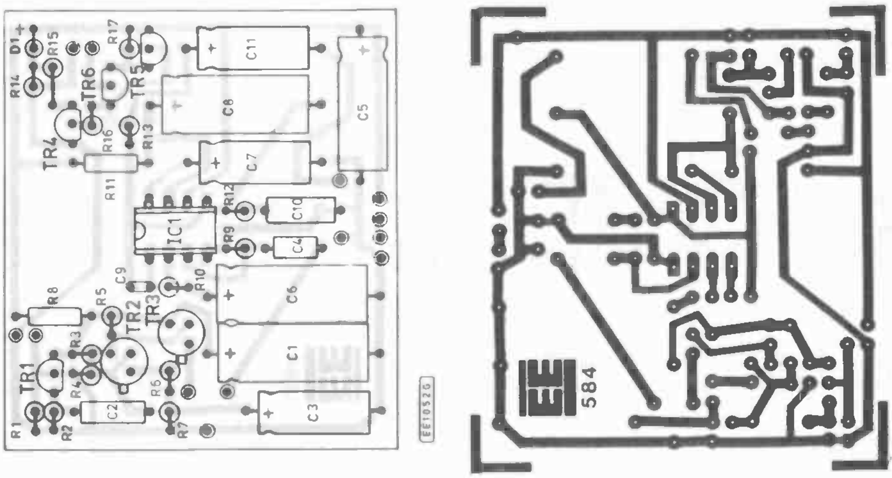


Fig. 2. Printed circuit full size master pattern and component layout

for driving ordinary stereo headphones, and can operate from as little as three volts with a typical quiescent drain of only four milliamps, making it ideal for operation from a single PP3 battery supply. About the only drawback is that its recommended circuit uses rather a lot of electrolytic capacitors, which take up most of the space on the p.c.b.

The voltage gain of this stage is about twenty but it can be adjusted slightly if required, by alteration of R10. To ensure stability the "Zobell" network, R12 and C10, has been included. The value of C11 may seem rather small to readers used to audio work, but it proved perfectly adequate in this design as headphones are the only load and the frequencies of interest are normally quite high. The resulting reduction of output current at low frequencies also helps to maintain stability.

The output is taken to a stereo socket wired so as to connect the two phones in parallel. R13 sets the maximum output, the value shown may need some adjustment to suit the headphones actually used.

An indicator l.e.d. is useful, to show that the unit is switched on and the battery is healthy. This goes a little further than usual in that l.e.d. D2 is supplied with a constant current by TR5 and TR6, which are in turn biased from TR4, which receives base current from Zener D1. So long as the supply voltage is high enough for current flow through D1 and the base-emitter junction of TR4, D2 glows with constant brightness. Once the voltage falls below this critical point it goes out quite sharply. It will probably flicker with strong input signals when battery replacement is due.

CONSTRUCTION

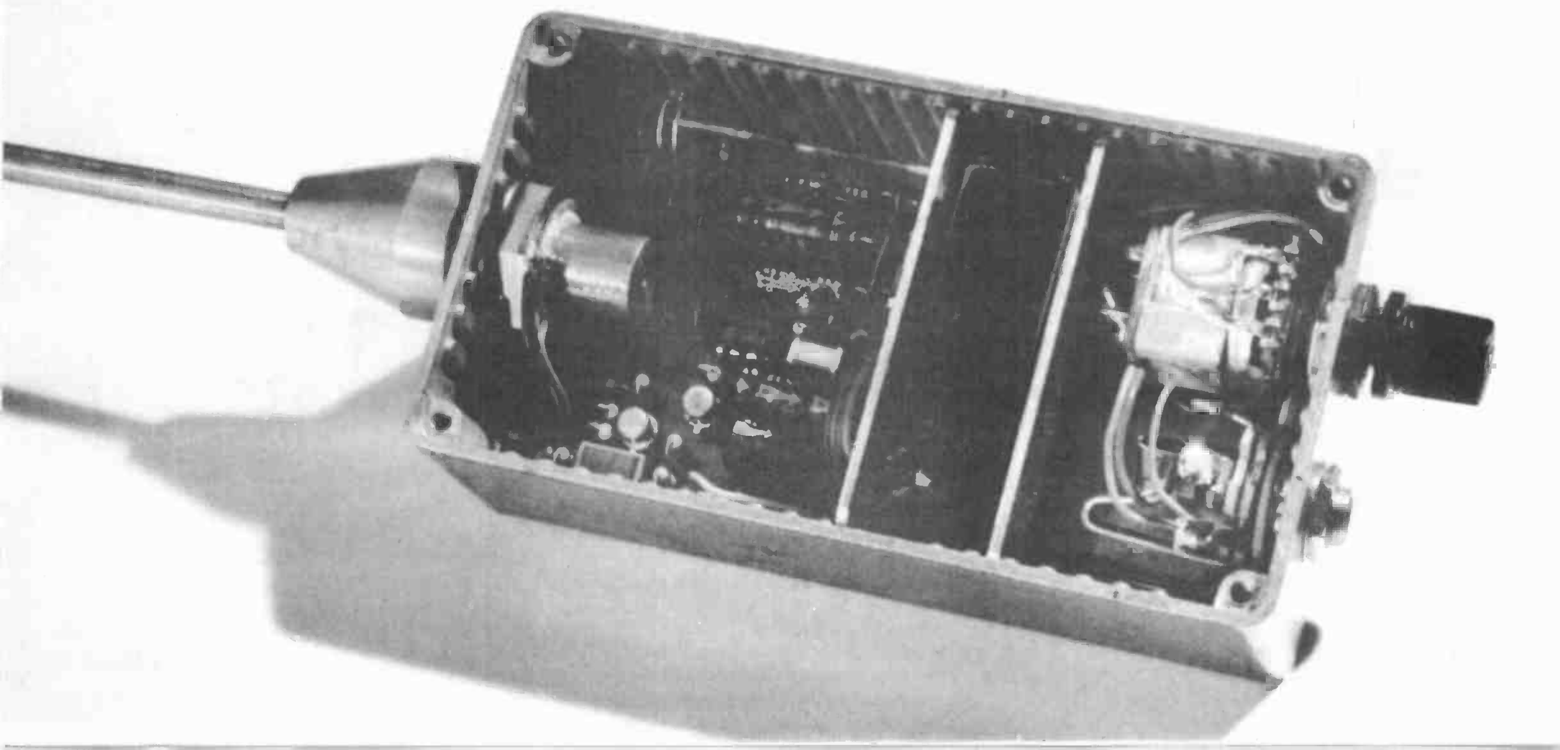
The construction of this project is straightforward, provided a little care is taken to obtain neat results with the upright mounted resistors. The small printed circuit board is available from the *EE* PCB Service, code EE584 (see page 628).

The positioning of all components can be seen in the overlay drawing, Fig. 2. Take care with the orientation of the transistors, D1 and the electrolytics. C2, C4 and C10 are the small, silver coloured polyester layer type.

Capacitors C2 and C10 may present problems in that there appears to be more than one size of this value; an order recently received contained two with different pin spacings. The p.c.b. has been designed to accept either. Though omitted in the prototype, a d.i.l. socket is strongly recommended for IC1. It can be a great help if any trouble-shooting becomes necessary.

TESTING

The board should, of course, be tested before installation. The total current drain should be about 26mA, of which about 18mA will be taken by the l.e.d. If the supply voltage is gradually reduced, this will extinguish fairly rapidly at about 5 to 5.5V. If the initial current



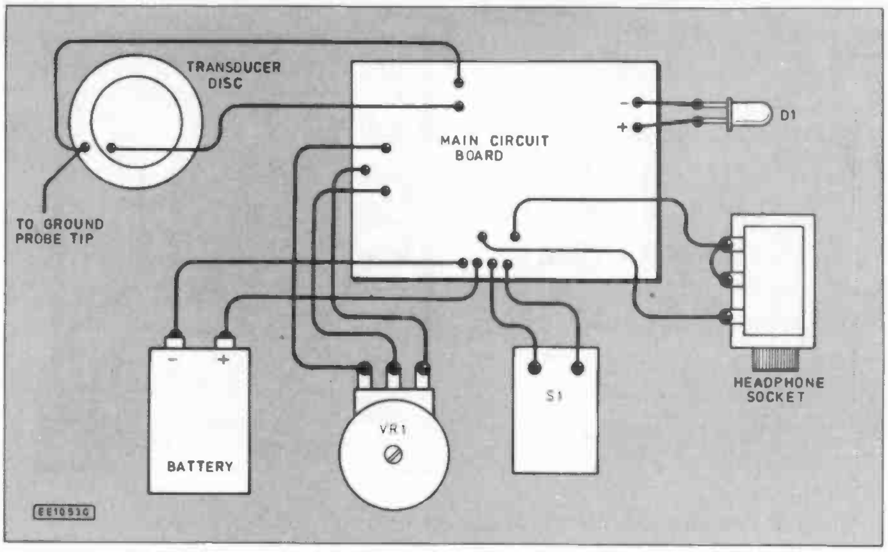


Fig. 3. Interwiring of the case mounted components and the p.c.b. VRI is shown from the front, SI is mounted on the back of VRI.

drain seems about right, the headphones and volume control can be temporarily connected and a quick functional check, if satisfactory, will be enough.

This is also a good time to decide whether the value of R13 needs any alteration to suit the headphones to be used. If there seems to be a problem however, some figures which may be useful are as follows; all were taken with exactly nine volts supply. TR1 source voltage will of course depend on the individual f.e.t. as these have a wide production spread, but it should be between 1 and 5 volts. Try another f.e.t. if it is outside these limits. TR2 emitter will be about 1V, this can be measured across C3, the drop across R6 being very small. TR2 collector (its metal case!) should be at about 4.4V, TR3 emitter about 3.8V. The output of IC5 (pin 5) will be about half supply, nominally 4.5V. The voltage across C1, the positive supply for the preamp stages, should be about 8V. These voltages are all intended purely as a guide for trouble-shooting.

CASE

As the circuit has a high input impedance and gain and may be used in areas where a fair amount of electrical interference may be present, a diecast metal case is specified to provide effective screening. The general layout of components in this can be seen from the photograph.

The l.e.d. is soldered directly to the p.c.b. with leads about 25mm long, allowing it to be bent over and pushed straight into a suitable hole drilled in the side of the case. A drop of "Araldite" will secure it firmly.

The board is sited at one end of the box, secured (and insulated) with double-sided sticky foam pad. The switch/volume control and the headphone socket are fitted at the other end, and between them the battery is held in a compartment formed by two small aluminium plates that fit the case slots. Plastic, such as surplus p.c.b. would do just as well. Some plastic foam prevents the battery from rattling.

The wiring passes beneath the foam and plates; ribbon cable is best as it is neat and lies flat. All the interconnections are shown in Fig. 3.

MICROPHONE

The microphone, as mentioned, is special. Any small microphone insert could be used for the job but would probably prove rather delicate. For vibration sensing something rather more robust is needed, so a vibration transducer was made with a "piezo transducer" element, the sort of thing normally used to provide bleeps in calculators, watches, etc. Being essentially crystal transducers these work just as well in reverse, as microphone elements, if properly mounted. A 27mm bare transducer "disc", readily available at very low cost from most major suppliers, was mounted as shown in the drawing of Fig. 4.

Although the prototype has components that were made in a lathe, early experiments used transducers made from bits of brass bolts with methods available in any reasonably equipped home workshop, so construction should not be too difficult. In essence the bolt is screwed down fairly tightly through a grommet fitted into the end of the case, the piezo element has its larger diameter side glued to the head of the bolt with Araldite, and a small weight is glued to the other side to provide something for the vibration to work against.

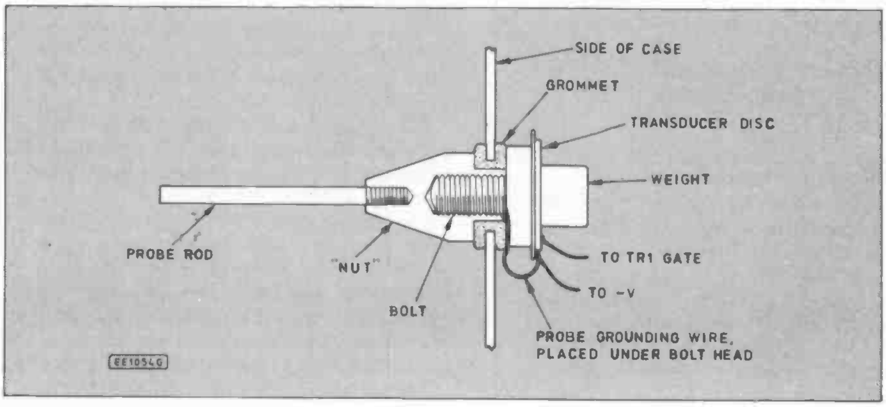
The head of the bolt needs to be flat and smooth; this could be achieved by rubbing it on emery paper placed on a flat surface. The weight is by no means critical and could be the head off another bolt, or a suitable nut, etc. The assembly can be so rigid in the grommet that it seems almost immobile, yet it is amazing how it will transmit sound from the tip whilst attenuating noise from the case. A "probe" can be attached by drilling a blind hole in the bolt, tapping it and fitting a threaded rod. Several rods of various lengths might prove useful.

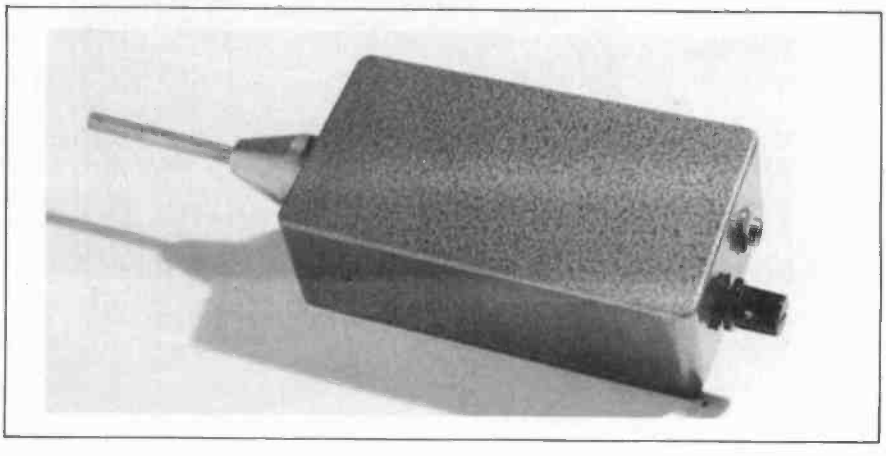
Note how the connections are made to the element, they are soldered directly to the disc surface. The earthy (negative rail) wire should go to the side glued to the bolt, and an extra wire from here is tucked between the grommet and the bolt to ensure contact. The metal case should also be grounded; in the prototype this was achieved through the metal jack socket. In the case of an all-plastic socket separate earthing to circuit negative should be provided.

The time taken to construct this transducer is well worthwhile. It is very sensitive and more robust than anything that could be achieved with a conventional microphone, and the results are excellent. The frequency response spans the complete audio spectrum; when placed against a loudspeaker surprisingly good sound can be heard. It's certainly more than adequate for the intended purpose.

A commercially produced stethoscope similar to this project is available. Constructors might be interested to know that it is priced around £300 . . . ! In fairness, there is a de-luxe model with an extra feature — an output jack for tape recording! This, the makers claim, can be used to record the sounds of industrial machinery for replay through a telephone, or for comparison at some time later. Perhaps these days it might also be used for computer analysis; at any rate it would be easy to add the facility to this project □

Fig. 4. Construction details for the "microphone".





MAINS TESTER AND FUSE FINDER

MARK STUART

How safe is your mains wiring? Locate that blown fuse! You can do both with this audio / visual tester

THE IDEA for this project came about whilst trying to find which fuse in the fusebox was connected to which set of sockets in the house. There are two "traditional" ways of doing this. One way is to remove a fuse, and then search the house for "dead" sockets. The other way is to connect a lamp to one socket and remove fuses one at a time. An observer posted next to the lamp is asked to shout when it goes out.

Both methods work. The first method is tedious, especially if the fusebox is positioned (as usual) in the most inaccessible corner of the house. The second method is better, but needs two people and has been known to put considerable stress on marital harmony.

DESIGN CONSIDERATIONS

It was decided that the ideal "gadget" would be one that could be plugged into a mains socket and would emit a loud easily recognized sound when the supply was disconnected. In addition it would be helpful (and safer) to incorporate an indicator lamp to give visual confirmation that the supply was disconnected.

This could be done by fitting just one lamp between the live and neutral connections. By adding two further lamps, however, it is possible not only to indicate whether power is on or off, but also to check the connections of live, neutral, and earth wires to the socket.

The final design has proved to be a very useful tool for checking sockets and finding fuses, and has also been used as a mains failure indicator when trying to track down spurious tripping of an ELCB (now known as RCCB).

CIRCUIT DESCRIPTION

The complete circuit diagram is shown in Fig. 1. Three neon lamps LP 1-3 are fitted to indicate that power is connected and that the three leads to the sockets are correctly fitted. Normally there will be mains voltage between *L* and *N*, and between *L* and *E*, lighting LP2 and LP3. Lamp LP1 will not light because normally the neutral wire is earthed at the local distribution transformer.

If the wiring to the socket is faulty the correct combination of lamps will not light. By checking which lamps are on or off it is possible to determine the nature of the fault. The interpretation of the fault indications is dealt with later in the section headed 'IN USE'.

The audible signal is produced by a ceramic resonator, WD1, driven by IC1. IC1 is a quadruple two input NAND Schmitt trigger i.c. The first section, IC1a, is used as a gated low frequency oscillator. Power for the oscillator is provided from battery B1 via S1.

The positive side of the supply is connected to the mains neutral. When mains voltage is present a small amount of mains current passes through capacitor C1. On positive half cycles, the Zener diode D1 is forward biassed and acts like a normal diode, clamping the voltage at point *A* in Fig. 1 at +0·6V with respect to point *B*. On negative half cycles of the mains D1 is reverse biassed and will not conduct until point *A* is at −10V (the Zener diode breakdown voltage) with respect to point *B*.

Diode D2 conducts during the negative half cycles so that the smoothing capacitor C2 is charged to −10V. The voltage on point *C* of Fig. 1 is a steady −10V with respect to point *B*.

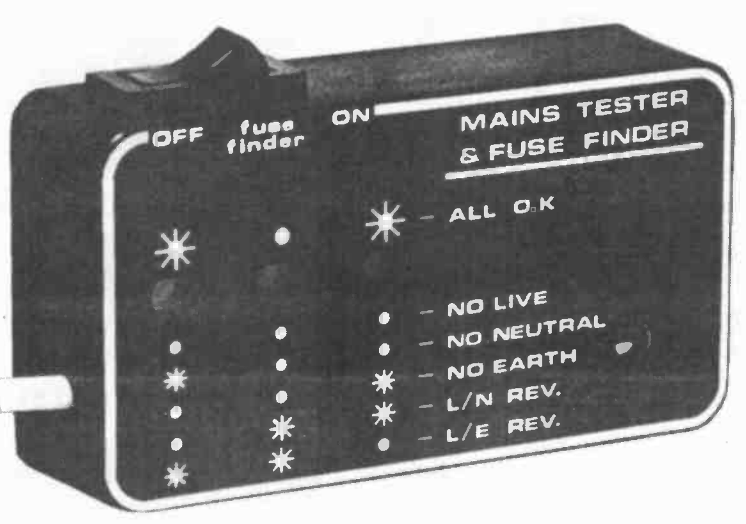
This voltage is passed via potential divider resistors R8 and R7 to one of the inputs of IC1a holding it low. As IC1 is a NAND gate a logic low on any of the inputs forces the output to a high state. IC1b is connected as an inverter so that its output is held low. This in turn holds down one of the inputs of IC1c so that its output is forced high. IC1d is connected as an inverter and so its output is held low. In this condition all of the sections of IC1 are held in steady status and there is no audio output.

When the mains voltage is disconnected C2 discharges via R7 and R8 and the voltage on the input of IC1a changes from low to high. The voltage on the other input of IC1a is also high because C3 has charged via R9. With both inputs high the output of IC1a is held low.

Capacitor C3 now discharges via R9 and the voltage on the associated input of IC1a begins to fall. After a time this voltage falls to the lower input threshold voltage of IC1a. At this point the output switches from low to high and C3 begins to charge via R9.

When the voltage across C3 rises to the upper input threshold of IC1a, the output switches from high back to low. C3 now begins to discharge through R9 again and the cycle repeats.

This simple oscillator action is only possible with Schmitt trigger type inverting gates, because it depends upon the output switching rapidly between low and high states. Normal gates will simply settle with their outputs at around half the supply voltage and not oscillate at all. The ease with which these simple oscillators can be put together makes the 4093 one of the author's favourite chips.



OUTPUT

The output of IC1a is a squarewave of about 2Hz which is inverted by IC1b and passed to one of the inputs of IC1c. IC1c is another oscillator circuit similar to IC1a but operating at about 2·5kHz. It is turned on during positive half cycles of the low frequency input from IC1b. IC1d inverts the input of IC1c and drives the ceramic resonator WD1.

The resulting output is a piercing beep-beep-beep sound whenever S1 is on and the mains off. The current consumption is very low, a single PP3 will probably last for a year or more of typical intermittent use.

CONSTRUCTION

As the whole circuit is connected to the mains it is **essential that it is housed in a totally insulated enclosure.** The plastic box specified is ideal and fits comfortably into a pocket. All of the components are fitted on a single printed circuit board. Fig. 2 shows the copper foil pattern and Fig. 3 the component layout.

Before mounting any components it is a good idea to use the board as a template to cut out the three holes in the bottom of the case through which the lamps are viewed. Figs. 4 and 5 show the layout of the components in the case and the method of assembly.

The holes for the neons should be about 8mm diameter. An additional hole or set of holes is needed for the ceramic resonator WD1. These holes should be drilled so that they do not line up with the hole in the resonator. A circle of 6 holes 3mm diameter is ideal. The metallised top plate of the resonator is connected to the mains so it is important that the holes do not align. Fig. 5b shows a suitable pattern.

The resonator WD1 is mounted on the bottom of the case by means of four strips of double sided adhesive sponge tape 1·6mm thick. These are first stuck to the case to form a square around the six holes and then WD1 is pressed into place. This arrangement ensures that there is sufficient air gap for the sound to travel efficiently.

A strip of 2 or 3mm thick clear or amber Perspex 12mm wide × 50mm long should be glued to the bottom of the case so that it covers the three holes through which the

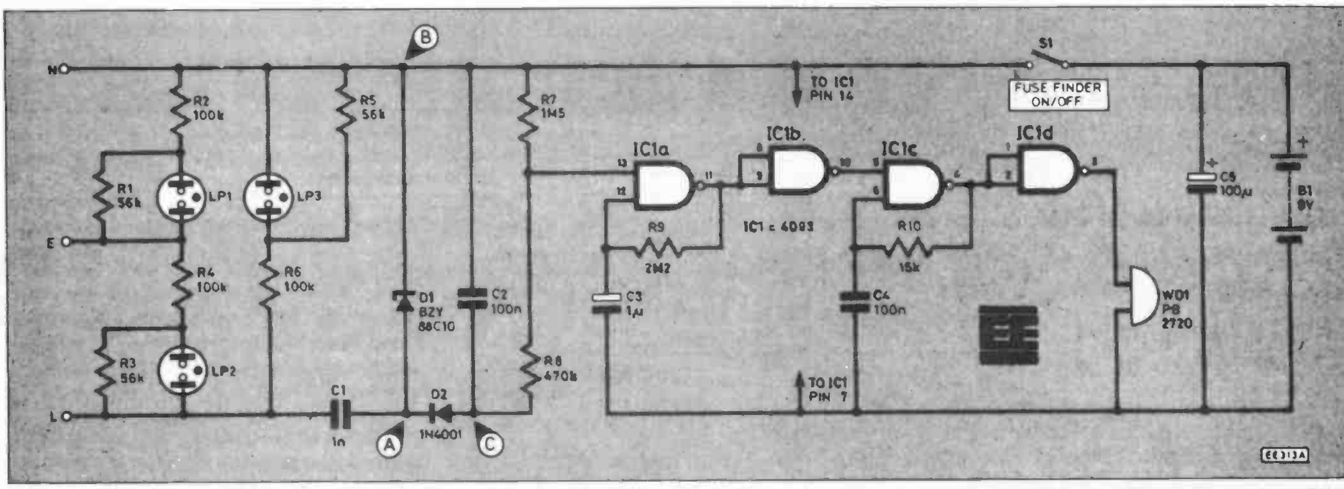


Fig. 1. Complete circuit diagram for the Mains Tester and Fuse Finder.

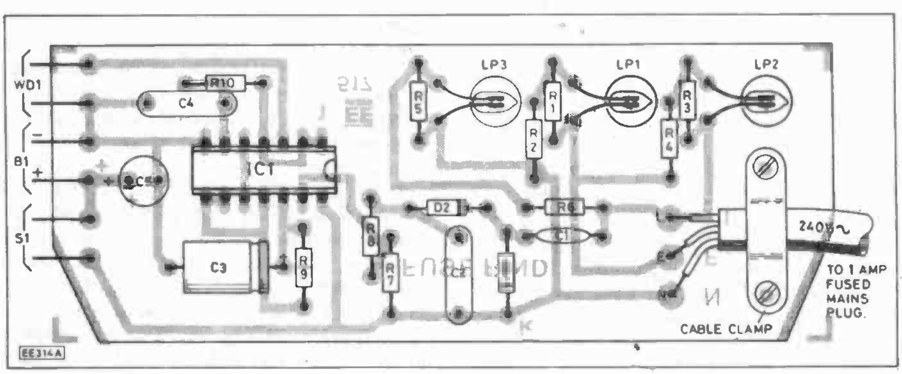


Fig. 2. Layout of components on the printed circuit board.

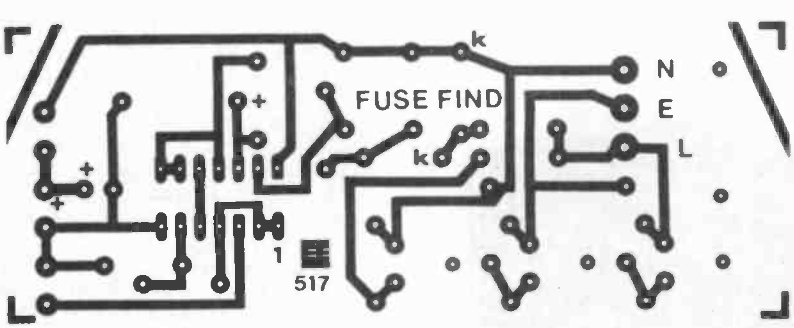


Fig. 3. Full size printed circuit master.

COMPONENTS

Resistors

R1,3,5	56k
R2,4,6	100 (3 off)
R7	1M5
R8	470k
R9	2M2
R10	15k

All ¼W ±5% carbon film

Capacitors

C1	1n disc ceramic 750V
C2,4	100n polyester (C368) (2 off)
C3	1µf axial elec. 16V
C5	100µf radial elec. 16V

Semiconductors

IC1	4093 CMOS quad 2-input NAND Schmitt trigger
D1	BZY88C10 10V Zener
D2	1N4001 silicon

Miscellaneous

WD1	PB2720 ceramic resonator
LP1-LP3	Miniature mains neons, 4mm high brightness type, 3 off
S1	SPST rocker switch

B1, 9V PP3; battery clip; connecting wire; Veropins; cable clamp and screws; 2A 3-core mains cable; printed circuit board; 14-pin i.c. socket; case; double-sided adhesive foam tape; clear or amber Perspex.

MAGENTA KIT 512

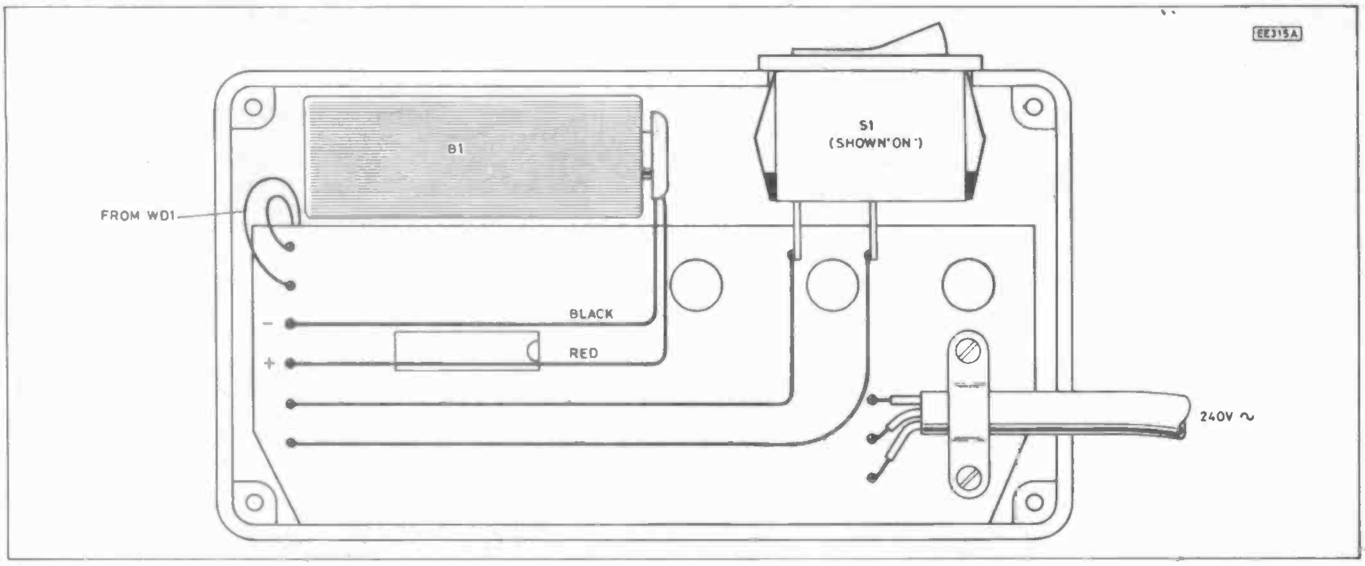


Fig. 4. Layout of components inside the case and interwiring details. Note the "wings" on S1 for holding the switch firmly in position.

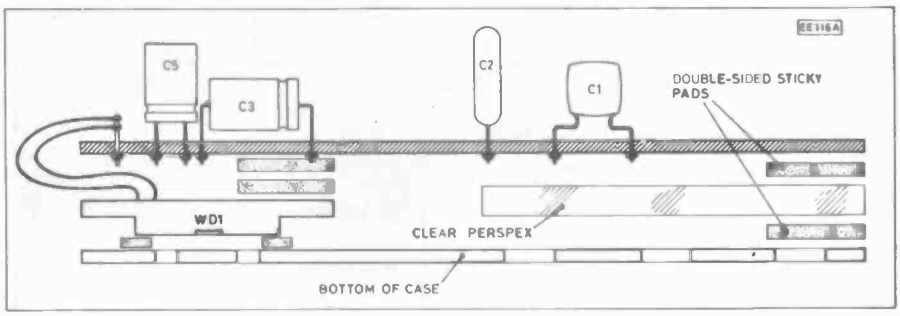


Fig. 5a. Arrangement for mounting the printed circuit board in the case.

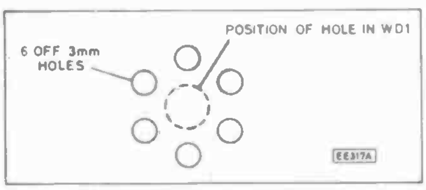
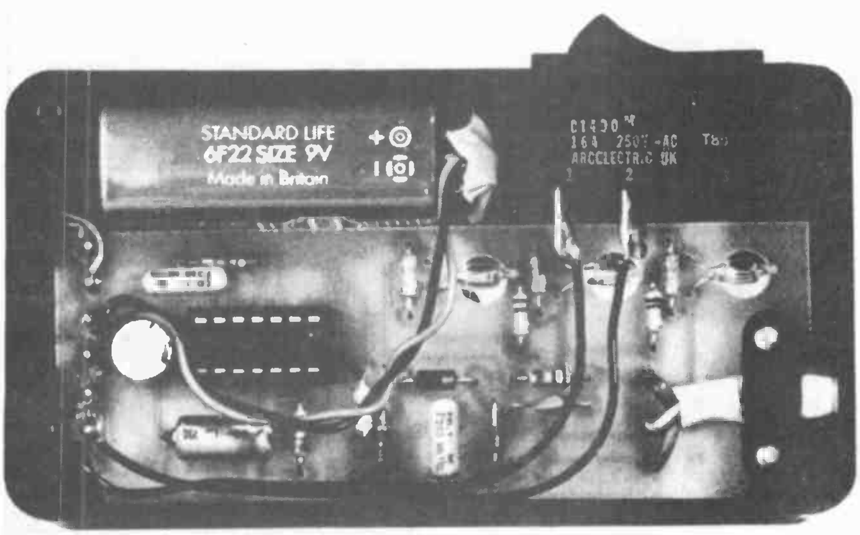


Fig. 5b. Suggested pattern of holes to be drilled in the case over the sound transducer.

The completed tester showing the cutouts in the board for the neon indicators. Note the "strain" clamp for the mains lead.



neons LP1-LP3 are viewed. The mains cable enters the case through a hole drilled in one end. This hole should be a close fit around the cable to prevent accidental access to the internal live parts.

The switch S1 requires a rectangular notch to be cut in the side of the case. Refer to Fig. 4 and position the switch as shown. The switch specified has a pair of "wings" which snap into position to hold it in place. Take care to cut the hole exactly the right size otherwise the switch will wobble.

CIRCUIT BOARD

When the case cutting is complete the printed circuit board should be assembled. Begin by fixing six single sided "solder pins" for the connections to B1, WD1 and S1.

These pins are inserted from the foil side of the board and must be pressed in so that their splined section passes into the board. This operation can require considerable force. Once the pins are fully home, solder them on the foil side in the usual way.

Continue by fitting all of the other board mounted components, starting with the smaller low profile ones such as diodes and resistors. A socket should be used for IC1. Note that D1, D2, C3, C5 and IC1 must all be fitted the right way round. The other components fit either way. The miniature neons must be positioned so that they lie centrally over the large holes in the board.

When all the components have been fixed, the mains lead should be connected to the board and fixed with a "saddle" type cable clamp. At this stage the board should be loosely fitted to the case, the connections made to WD1, B1 and S1, and tested for correct operation.

When all is well the board should be fixed in position using double sided adhesive foam pads. The battery can be fixed in the same way, as it will not require changing very often.

TESTING

The correct operation of the oscillator section can be tested, without connecting the mains, simply by fitting a battery and closing S1. A loud 2kHz tone interrupted at about 2Hz should be produced after a delay of around 2 seconds. The beep is produced

Continued on page 87

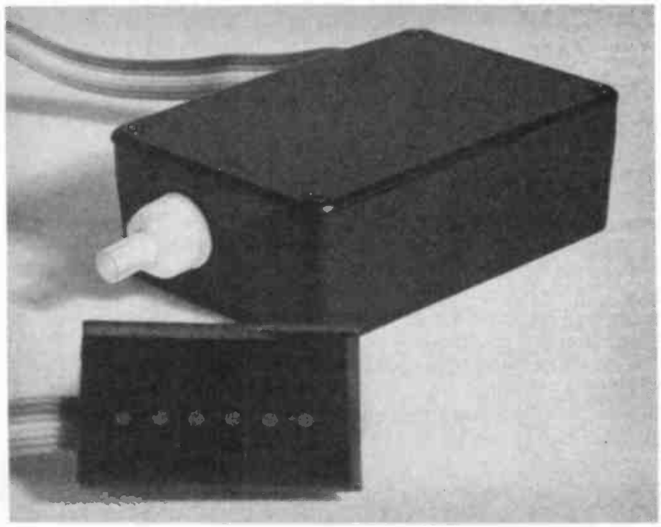
LIGHT RIDER

DISCO LIGHTS . . . LAPEL BADGE . . . CHASER LIGHT

Three projects that will certainly test the creative eye of the experimenter. You could even create your own version of "Kit" of *TV Knight Rider* fame.

LAPEL BADGE

MARK STUART



THE Lapel Badge project was started to give a 10 year old something different to amaze his friends at the school disco. A row of six red l.e.d.s are arranged to be lit in order from left to right and then back from right to left continually, completing two full cycles every second. Each l.e.d. in turn is switched on and then switched off followed by the next one along the line and so on.

If the l.e.d.s are switched on and off abruptly the display appears to flicker unpleasantly. This is completely eliminated by connecting capacitors across the l.e.d.s so that each one fades gradually. The result is a tail of three or four l.e.d.s of decreasing brightness which appears to follow the leading light.

Reasonable battery life is achieved by the use of a new breed of low current l.e.d.s designed to operate at 2mA with plenty of brightness. The badge is clearly visible in normal daylight and appears to be extremely bright at night.

CIRCUIT DESCRIPTION

The circuit diagram for the Lapel Badge is shown in Fig. 1. There are many ways of switching the l.e.d.s in the necessary manner but this circuit has a certain simplicity and cunning which may impress even the best engineers.

The dual 3-input NOR gate IC1a and IC1b form a simple two gate oscillator which runs at about 16Hz. The inverter section of the device is not used in this circuit design.

Very briefly capacitor C1 charges first in one direction and then in the other direction, via resistor R2, as the outputs of IC1a and IC1b change state. Oscillation is maintained by positive feedback through resistor R1 to the input of IC1a, which ensures that the output of IC1a switches over each time the capacitor charges.

The output from IC1b is a square wave which is used to clock the Decade Counter/Divider, IC2. Ten outputs are available from IC2 which change from low to high one by one in turn each time the i.c. receives a clock pulse. Only one output can be high at a time, so on each clock pulse the output that was high becomes low as the next output changes from low to high and so on.

If the light emitting diodes were connected to all ten outputs and the i.c. clocked, a single illuminated l.e.d. would appear to move along from left to right. After ten pulses the far right l.e.d. would go out and the display would appear to jump back to the left end as the cycle began to repeat.

Switching the l.e.d.s from left to right and then back from right to left is more complicated and is achieved by means of the diodes D1 to D10. These are connected so that the l.e.d.s light in the order shown in Table 1.

Table 1 shows that above six clock pulses the l.e.d.s (D12 to D15) are lit in reverse sequence via diodes D9, D7, D5 and D3. The two l.e.d.s at the ends of the display are lit once each cycle and all the others twice, once in one "direction" and then in the other. Resistors R4 to R9 limit the current

Fig. 1. Complete circuit diagram for the Lapel Badge.

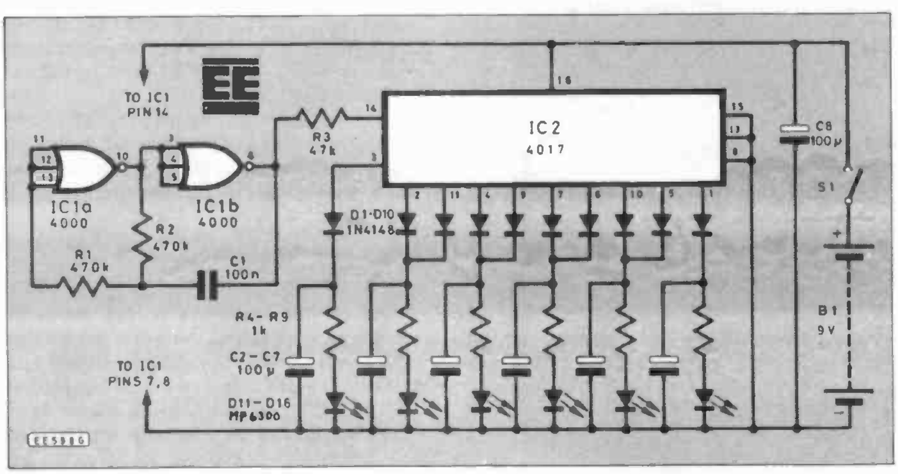


Table 1: Display Switching Sequence

IC count	IC pin high	Diode conducting	(D11–D16) l.e.d. lit
0	3	D1	D11
1	2	D2	D12
2	4	D4	D13
3	7	D6	D14
4	10	D8	D15
5	1	D10	D16
6	5	D9	D15
7	6	D7	D14
8	9	D5	D13
9	11	D3	D12
0	3	D1	D11

in each l.e.d. to about 5mA with a fresh battery.

The electrolytic capacitors C2 to C7 improve the visual effect enormously by discharging gradually through the l.e.d.s and resistors after the i.c. output has turned off. This gives a slow fade-out to each l.e.d. and produces the desired "tail" of decaying light which appears to follow the leading light. As the capacitors are charged directly from the outputs of IC2 their charge time is relatively short and so each l.e.d. appears to turn on instantaneously.

CONSTRUCTION

The circuit for the Lapel Badge is built on two printed circuit boards; the main board and the display board.

The circuit is built in two parts. The small display board carries the six l.e.d.s and is connected by a short length of ribbon cable to the rest of the circuit which is housed in a small plastic box.

An area of track on the display board is provided so that a small safety pin can be soldered on to it to allow the badge to be attached to clothing. The plastic box is carried invisibly in a convenient pocket.

The component layout of the Main Board is shown in Fig. 2. To make sure that the battery will fit into the specified case it is essential to use modern miniature components in all positions and to mount them as close to the board as possible. A socket may be used for IC1 if required but not for IC2, as it fits underneath the battery.

COMPONENTS

LAPEL BADGE

Resistors

R1,R2	470k (2 off)
R3	47k
R4–R9	1k (6 off)

All ¼W carbon ± 10%

Capacitors

C1	100n poly. C368
C2–C8	100µ radial miniature elec. 10V (Size critical) (7 off)

Semiconductors

IC1	CD4000 Dual 3-input NOR gate + inverter
IC2	CD4017 Decade Counter/Divider
D1–D10	1N4148 (10 off)
D11–D16	MP 6300, high efficiency Red l.e.d.s (6 off)

Miscellaneous

S1 s.p.s.t. push-on/push-off switch

PP3 battery and clips; 7-way ribbon cable; case, 71mm × 46mm × 22mm; 14-pin i.c. socket; red Perspex, 25mm × 38mm; small safety pin; printed circuit boards

MAGENTA KIT 561

Construction is quite straightforward. Ensure that the diodes, capacitors and i.c.s are all fitted the right way round. The leads from C8 should be protected with insulated sleeving and left as long as possible. Remember to fit IC1 before connecting C8.

When all components are in place turn over the board and crop all the leads as close as possible to the tracks to ensure that the board can sit as low down in the case as possible.

DISPLAY BOARD

Turning to the Display Board, the component layout is also given in Fig. 2. The six special low current l.e.d.s are fitted so that their domed lenses pass from the track side of the board into close fitting holes. Their two leads are soldered where they lie flat on the adjacent copper tracks. Note that the polarity is indicated by the thickness of the leads, the thick lead being the cathode (k). Also take care not to overheat the l.e.d.s whilst soldering as the plastic used for all l.e.d.s is particularly susceptible to melting and causing the leads to come adrift inside.

INTERWIRING

Interwiring between the main and display boards is also shown in Fig. 2. The necessary cross overs in the ribbon cable should be made close to the main board inside the case. The leads at the badge end are connected directly to the copper tracks on the rear of the board.

In the prototype a small saddle of sleeved wire was soldered over the ribbon cable to reduce the stress on the connections. Alternatively a good adhesive may be used. There is plenty of room for individual interpretation of the badge part of the project, but check that it works in standard form first before trying anything too clever.

The connections for the ribbon cable, battery and switch leads are made to the main board by passing a small stripped length of each wire through its hole in the top side of the board and soldering to the copper track on the underside.

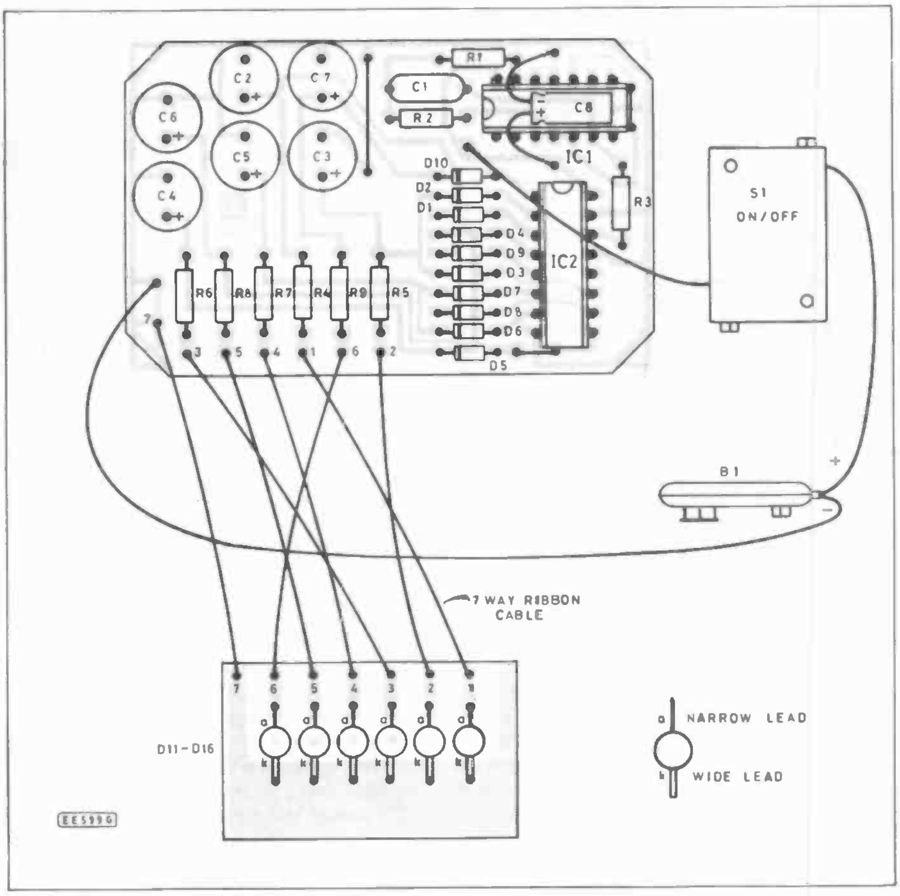
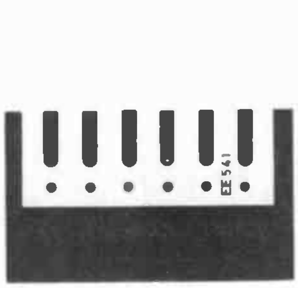
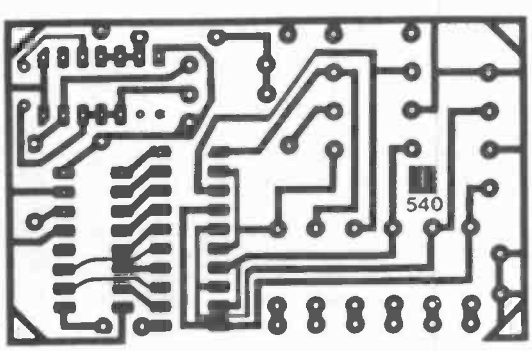


Fig. 2. Component layout for main board, display board and interwiring between the two boards. Full size p.c.b. masters are shown below.





The layout of the parts in the plastic case is shown in Fig. 3. As everything is such a tight fit there is no need to fix the board or battery, but small sticky pads may be used if required. A hole must be drilled for S1 and a shallow notch cut in the edge of the case so that the ribbon cable can pass out under the lid.

TESTING

There is very little to be said about testing since the circuit is either on or off. The main things to check are that the component values and polarities are correct and that there are no errors in the wiring.

The current consumption is about 15mA with a fresh battery. As the battery voltage falls the brightness of the l.e.d.s will decrease but the circuit will continue to function correctly right down to about 5V. The current consumption will fall as the voltage drops, prolonging the life of the battery.

For special applications the values of resistors R4 to R9 can be increased or decreased to give a dimmer or brighter display. For a very bright display it is possible to use two 5mm "ultra-bright" l.e.d.s in series in each position, set the resistor values to 330 ohms, and use a 12V supply.

The circuit is quite happy up to 18V and so can be used in a car without problems. Ideally a small resistor (100 ohms) should be connected in series with each electrolytic capacitor to limit the peak current in IC2.

The stepping speed is set by R2 and C1 either or both of which can be changed as required. If a variable speed control is required this can be achieved by replacing R2 with a 470k "reverse" log potentiometer. □

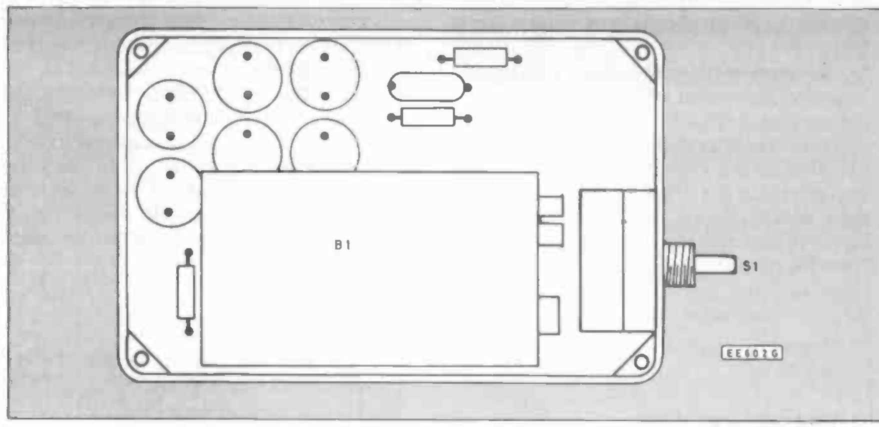
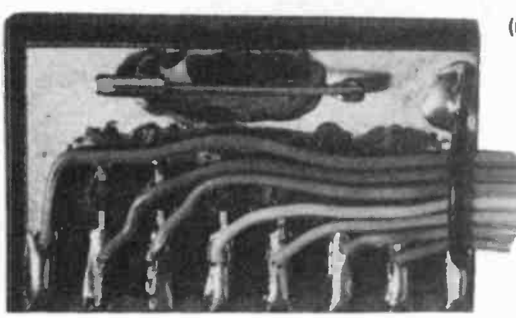
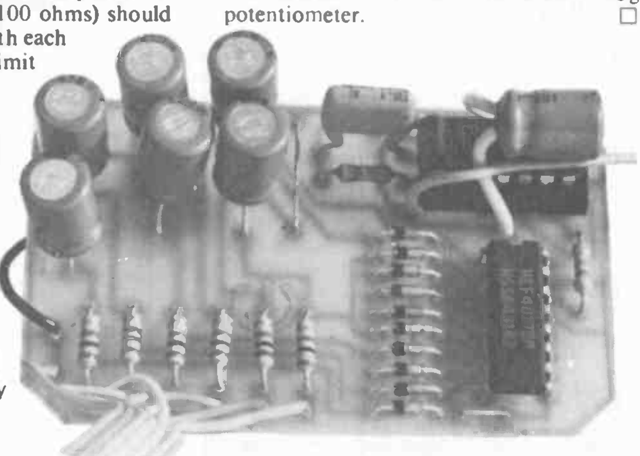


Fig. 3. Layout of components inside the small plastic case.



(left) The completed "badge", with safety pin.



(right) The completed main driver and switching board.

DISCO LIGHTS

MARK STUART

THE EXTENSION of the Lapel Badge circuit to give a high power mains voltage display is a simple idea. The result when connected to a bank of bulbs arranged in rows, crosses, stars or concentric circles is very effective indeed.

Each of the 6 original l.e.d. outputs has been adapted to drive a 5A special sensitive gate triac. Without heatsinking each triac will be able to switch banks of small lamps totalling over 500 watts. As only one bank is switched on at any time the mains supply current is not excessive. To enhance the range of effects a variable Speed Control has been added.

CIRCUIT DESCRIPTION

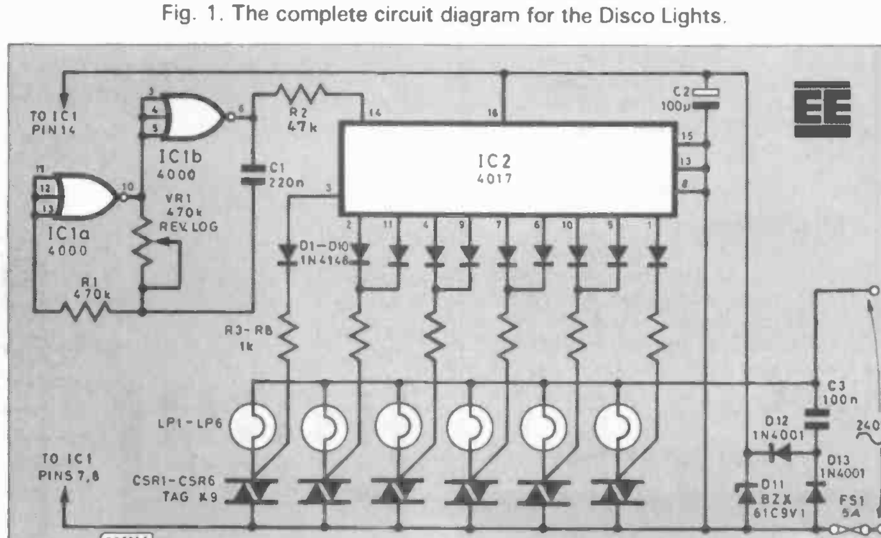
The circuit diagram for the Disco Light Rider is shown in Fig. 1. Each of the outputs of IC2 is fed to the gate terminal of a triac which switches mains voltage. Special sensitive gate triacs, CSR1 to CSR6, are required so that they can be driven directly from IC2 without problems.

The power for IC1 and IC2 is derived directly from the mains via a series capacitor dropper C3. This method is very effective for small currents (10mA in this case) and is very efficient as there is negligible power dissipation in the capacitor. In contrast a resistor carrying 10mA would be dissipating 2·5W.

The operation of this type of circuit is quite simple to understand. The capacitor C3 passes the a.c. mains voltage signal to diodes D11, D12 and D13. During negative half cycles of the mains, current flows via D13 into C3 and during positive half cycles current flows via D11 and D12. As D11 is a Zener diode the voltage across it must exceed its rating (in this case 9·1V) before it can conduct. The result is a series of half-wave 9·1V positive pulses which are smoothed by capacitor C2 to drive the rest of the circuit.

The main disadvantage of this type of circuit is that a short circuit fault in the capacitor C3 will apply the full mains supply voltage with catastrophic results. For this reason a special mains suppressor

Fig. 1. The complete circuit diagram for the Disco Lights.



COMPONENTS

DISCO LIGHTS

Resistors

R1	470k
R2	47k
R3–R8	1k (6 off)

All ¼W carbon ± 10%

Potentiometer

VR1	470k reverse log.

Capacitors

C1	220n miniature polyester C368
C2	100µ 25V radial electrolytic
C3	100n 250V a.c. suppressor type

Semiconductors

IC1	4000 Dual 3-input NOR gate + inverter
IC2	4017 Decade Counter/Divider
D1 to D10	1N4148 (10 off)
D11	BZX61C 9V1 Zener
D12,D13	1N4001 (2 off)
CSR1–CSR6	TAG K9 Triacs (sensitive gate) (6 off)

Miscellaneous

TB1	10-way 2A terminal block
FS1	5A 20mm quick-blow fuse
LP1–LP6	Mains lamps, colours and shape to choice (see text) (6 off)

14-pin i.c. socket; 16-pin i.c. socket; p.c.b. mounting fuse-holder; case, Plastic 145mm × 95mm × 55mm minimum; screw fit knob; wire; printed circuit board

MAGENTA KIT 560

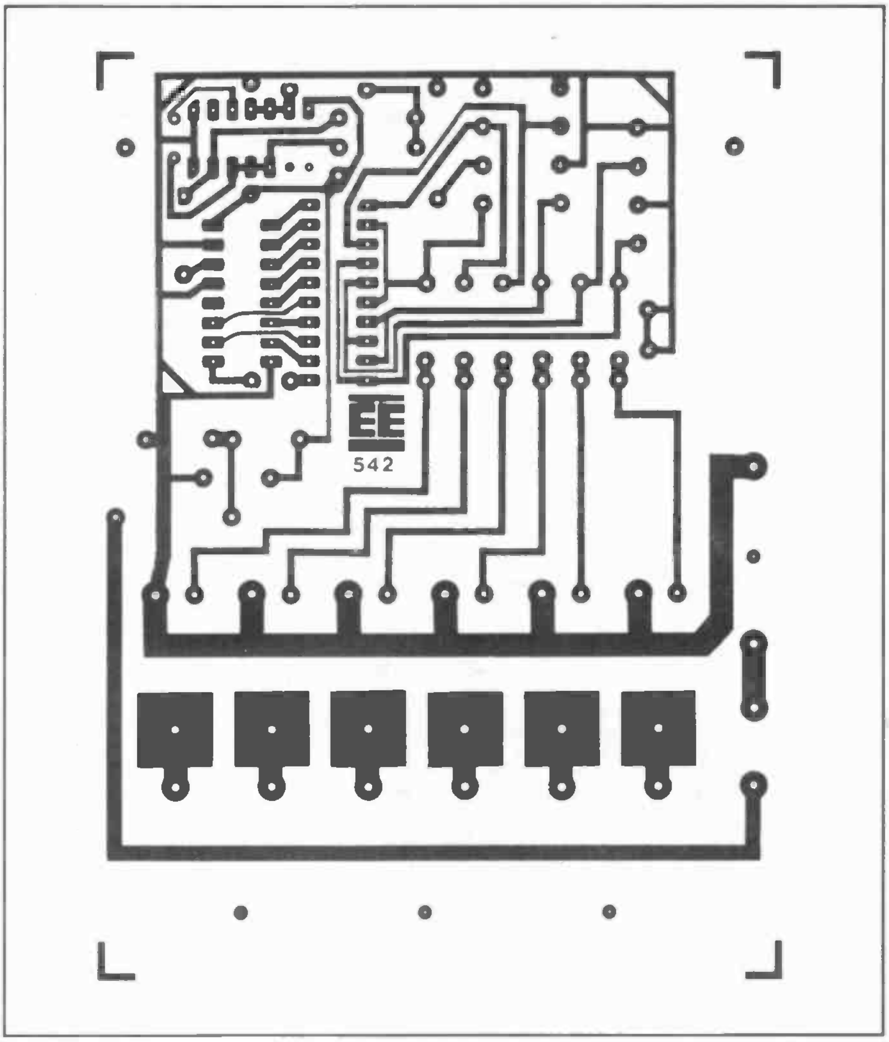


Fig. 2. Full size printed circuit master pattern for the Disco Lights.

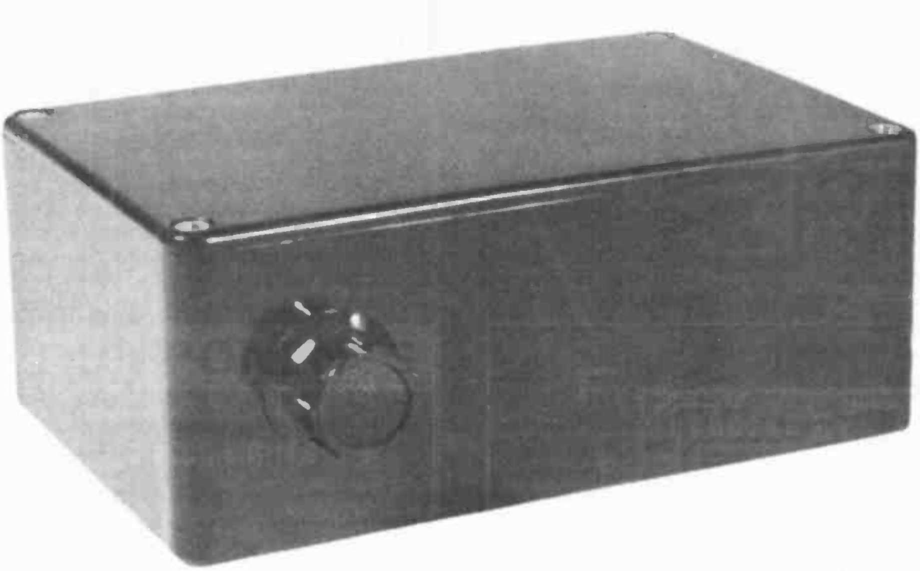
capacitor is specified. Provided this is used the chances of a breakdown are very small indeed.

A second disadvantage is that the whole of the circuit is connected directly to the mains supply. This is not a problem in sound-to-light effects and similar circuits which are already connected to the mains in any case.

The big advantage is that a bulky heavy and expensive mains transformer is not needed.

CONSTRUCTION

Because of the mains voltages present in the Disco "Light Rider", constructors should be very careful when building this unit. It is advised that only persons experienced in mains circuits should tackle this project and extra care should be exercised when testing and checking the circuit.



To keep cost to a minimum the circuit is built on a single printed circuit board housed in a plain plastic box.

The component layout and p.c.b. master pattern (full size) is shown in Figs. 2 and 3. As the tabs on the triacs are connected to the MT2 terminal the mounting screws have been used to make the connection to the board and the MT2 leads removed.

A standard 2A terminal block is used to make all of the connections from the mains and to the lamps. All six banks of lamps share a common mains neutral connection. To keep the board layout simple the connections for the lamp do not follow in a strict order and so a little wire-crossing is needed when the connections are made.

The Speed Control potentiometer VR1 (which should have a plastic insulated spindle) must be mounted on a bracket from the board so that its insulated spindle

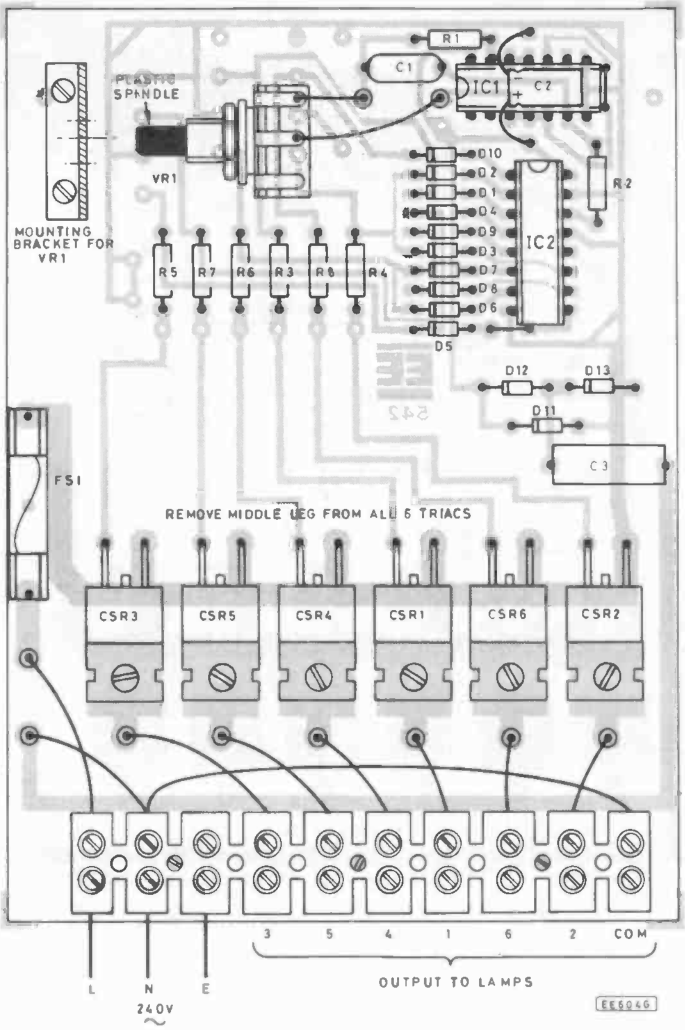


Fig. 3. Component layout and interwiring for the Disco Lights. Note that this board must be housed in a PLASTIC case.

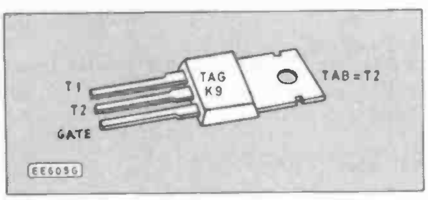
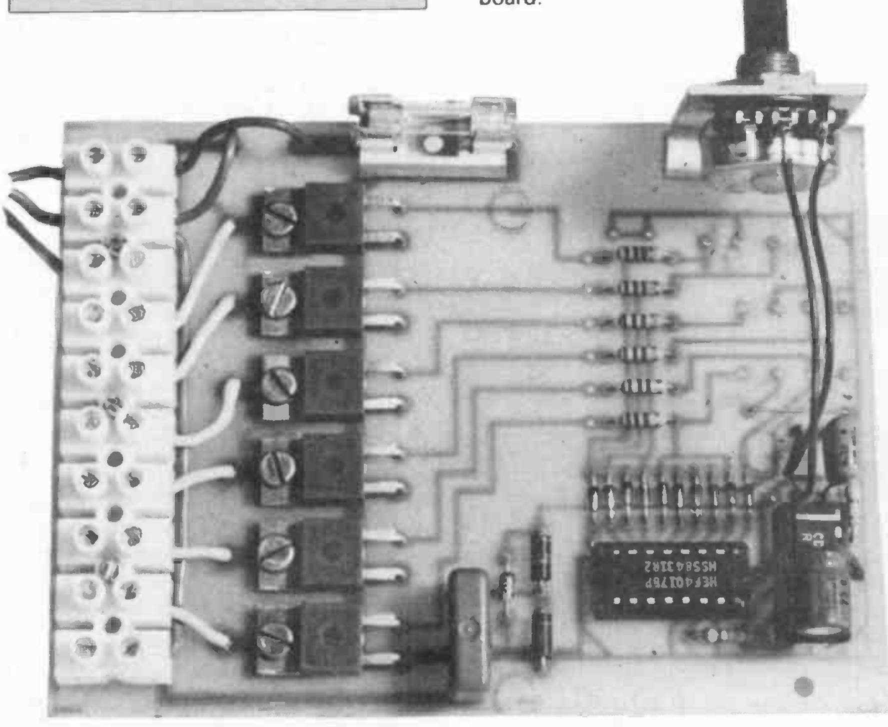


Fig. 4. Pinning details for the thyristors CSR1–CSR6. Note the T2 lead is cut short and the "tab" used for this connection.

The completed disco lights board.



passes through a close fitting hole in the case. This is to ensure that even with the control knob removed it is impossible to touch any part of the circuit that may be live. A "reverse log" potentiometer is specified because this gives a very smooth control of speed over a wide range.

Only two connections are made to the board as shown in Fig. 3 and the assembly of the rest of the board is straightforward. Take particular care with the three diodes D11 to D13 to ensure their correct polarity.

Once the board is complete it should be tested at low voltage and then fitted into a plastic case before testing at mains voltage. The incoming and outgoing leads should be fed through close fitting grommets and should have strain relief clamps fitted just inside the case to restrain them and prevent them from being pulled out accidentally. The board should be mounted on sticky pads or with nylon nuts and screws so that there are no exposed metal parts to become live.

TESTING

Ideally the circuit should be tested first at *low* voltage. This can be done by applying 9V d.c. across diode D13 with the negative side connected to its anode. With the Speed Control set at minimum it should be possible to see the triac gates pulsing in turn by using a multimeter set to a low d.c. voltage range. The voltage on each gate should pulse up to 1·2V approximately.

A separate 6–12V a.c. source and a number of low voltage bulbs can be used to check full operation of the triacs. Keep the 9V d.c. supply connected and connect the a.c. supply to the *L* and *N* terminals. Connect the bulbs to each output and they should be turned on and off in the correct order. Check that the Speed Control works, and the circuit is ready for testing at mains voltage.

Before testing at mains voltage the board must be fitted into a suitable all plastic case. Disconnect the low voltage supply and take ***extreme care*** when making measurements. With the mains connected *all* parts of the circuit should be considered to be *"live"*. Use a good multimeter with insulated test probes. Apply the mains to the circuit; if the power supply section is producing 9V across diode D11 all is well and all that remains to be done is a quick test with six mains lamps.

IN USE

Once the unit is working satisfactorily it can be connected to whatever type of display is required. Remember to use cable rated at mains voltage for the interconnections. Combinations of shapes, colours and lamp types can be arranged to produce exactly the effect required.

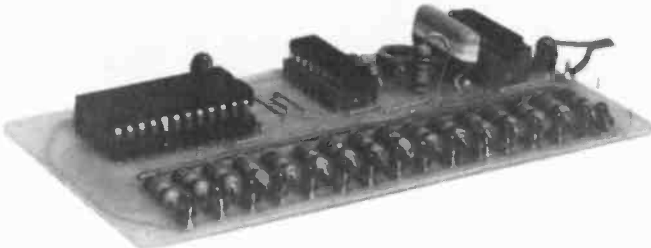
Unlike l.e.d.s it is not possible to turn the triacs off slowly simply by using capacitors. Instead the thermal inertia of the lamp filaments is relied upon to produce a gradual fade out. At slow speed setting the fade is relatively fast and so the lamps will appear to switch abruptly but at higher speeds the fade becomes significant and a very pleasant smooth effect is achieved.

At very high speed settings the frequency of the oscillator approaches mains frequency. This gives rise to a number of very strange effects. Some of which are quite interesting. If preferred the upper range of speed can be limited by connecting a 22k resistor in series with VR1.

□

CHASER LIGHT

G.R. HAYNES



THIS project simulates the red light which sweeps to and fro on the front of "Kit" the computerised car in the TV series *Knight Rider*.

Although designed primarily with novelty in mind and not for mounting on car bonnets, there are useful applications for this circuit.

It could, for example, be used to add that little bit extra to home-made robots, be they kit or self-designed. Or, the l.e.d.s could be arranged in different patterns using different colours to produce interesting displays.

The circuit is not limited to driving l.e.d.s however. If a suitable interface is used any type of lamp can be driven, making the circuit suitable for "disco lights" etc.

The number of outputs required is selectable up to a maximum of 16 by a single wire link. The prototype used all 16 outputs. The speed of the display is adjustable from dead slow to a blur by an on-board preset potentiometer.

A feature of the circuit is the ability to disable the display without removing the power to it. For instance, when a robot is "idle" preventing unnecessary drain on the battery.

Since the circuit uses CMOS i.c.s it will operate over a wide supply range (3V–15V) and is very economical on battery power.

PRINCIPLE OF OPERATION

A simplified block diagram of the circuit is shown in Fig. 1. For normal operation Disable is low. When high however the oscillator is stopped and all l.e.d.s are turned off.

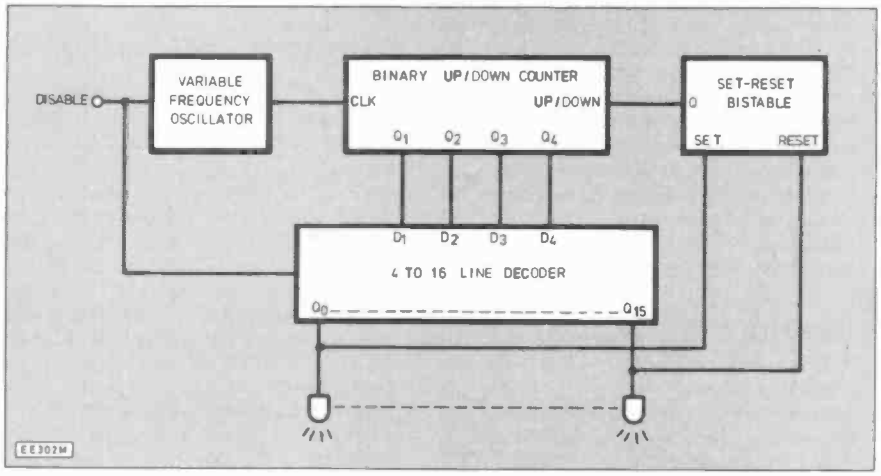


Fig. 1. Block diagram of the Chaser Light system.

The Variable Frequency Oscillator produces pulses which are counted by a Binary Up/Down counter. The direction in which the pulses are counted is controlled by the logic level applied to the counters Up/Down input. When "high" it counts up, when "low" it counts down. The Up/Down input is fed from the output Q of a Set-Reset Bistable. Q goes high when the Set input is pulsed high and low when the Reset input is pulsed high.

The counters output appears as a binary code weighted Q1 = 1, Q2 = 2, Q3 = 4, Q4 = 8 and is fed to the inputs of a 4 to 16 Line Decoder which selects one of its 16 possible outputs according to the binary code at its input e.g., code 0101 will select Q5 and code 1111 will select Q15. The selected output goes high causing the l.e.d. connected to it to light. All other outputs remain low and therefore all other l.e.d.s are off.

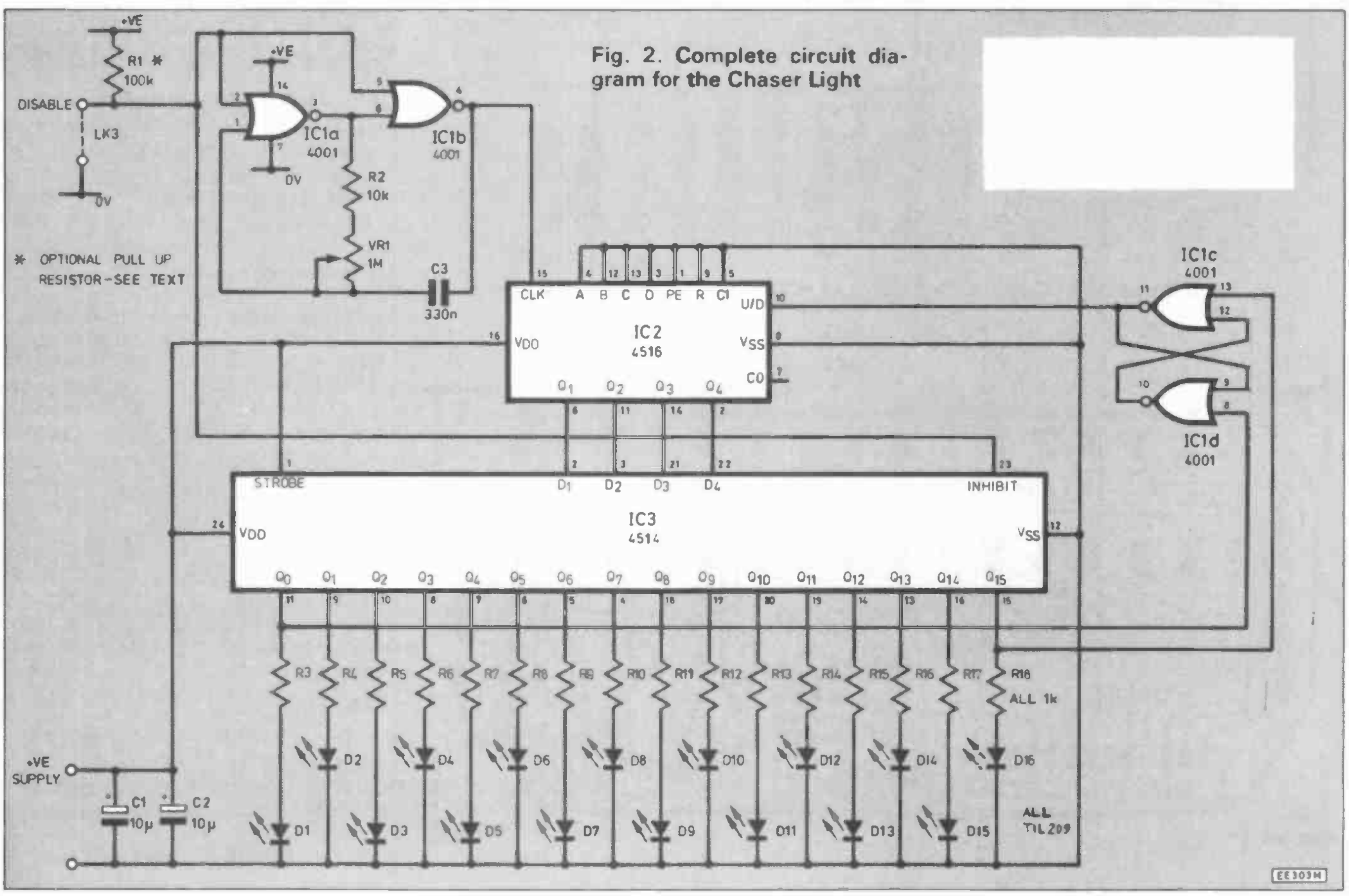


Fig. 2. Complete circuit diagram for the Chaser Light

Consider that the bistable is in the Set state, i.e. Q is high and the counter is counting up. Each time it receives a clock pulse from the oscillator it adds one to its count, the count is decoded and the selected output goes high lighting the l.e.d. connected to it. This continues until eventually Q15 goes high, at this point the bistable is reset and its output Q goes low.

The counter now begins to subtract one from its count each time it receives a clock pulse. As before the count is decoded and the selected output lights an l.e.d. This continues until eventually Q0 goes high, the bistable is set and the counter begins to count up once more. The result is a display that produces a light that sweeps to and fro.

By altering the point at which the bistable is reset the number of lights required can be changed e.g. if ten lights are required Q9 is used to reset the bistable.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Chaser Light is shown in Fig. 2. Having discussed the circuit's operation all that remains is to describe its finer details.

The prototype was powered from a 9V PP3 battery but the circuit will work equally well in the range 3V to 15V. If a different supply voltage is to be used then the value of l.e.d. current limit resistors R3 to R18 will have to be changed.

The current required by an l.e.d. for satisfactory illumination is usually in the range 5mA to 10mA and the forward voltage is about 2V. On the prototype an l.e.d. current of 7mA was used.

The value of the current limit resistors can be calculated by the following formula:

$$R \text{ limit} = \frac{V \text{supply} - V_F}{I \text{ l.e.d.}}$$

e.g., for the prototype

$$R \text{ limit} = \frac{9V - 2V}{7mA} = 1k \text{ ohms}$$

The supply is decoupled by capacitors C1 and C2.

The Variable Frequency Oscillator is formed by two NOR gates IC1a and IC1b C3, R2 and VR1 set the oscillator frequency. Preset potentiometer VR1 allows adjustment of the frequency and hence the speed of the display. The oscillator output is fed to the CLK input (pin 15) of IC2, a Binary Up/Down Counter which counts the pulses the oscillator produces.

Preset inputs A, B, C, D, Preset Enable (PE), Reset and Carry In (pins 4, 12, 13, 3, 1 9, 5) of IC2 are all unused and are tied permanently low. Carry Out (pin 7) is not required and is left unconnected.

The UP/DOWN input (pin 10) of IC2 determines the direction of count and is controlled by a bistable formed by two NOR gates IC1c and IC1d. Pin 11 of IC1c acts as the Bistable output, pin 13 of IC1c acts as the Reset input and pin 8 of IC1d as the Set input.

The counters binary output appears at Q1 to Q4 (pins 6, 11, 14, 2) and is fed to the inputs D1 to D4 (pins 2, 3, 21, 22) of IC3, a 4 to 16 Line Decoder. As explained previously IC3 decodes the binary input to select one of its 16 possible outputs. The selected output goes high and drives an l.e.d. (D1 to D16) via a current limiting resistor R3–R18).

Output Q0 (pin 11) is also connected to the Set input of the bistable such that when the count is at 0000, i.e. at its minimum, the bistable is set, its output is forced high and the counter is made to count up. Q15 (pin 15) of IC3 is conencted to the Reset input of the bistable such that when the count is at its maximum, i.e. 1111, the bistable is reset and the counter is forced to count down.

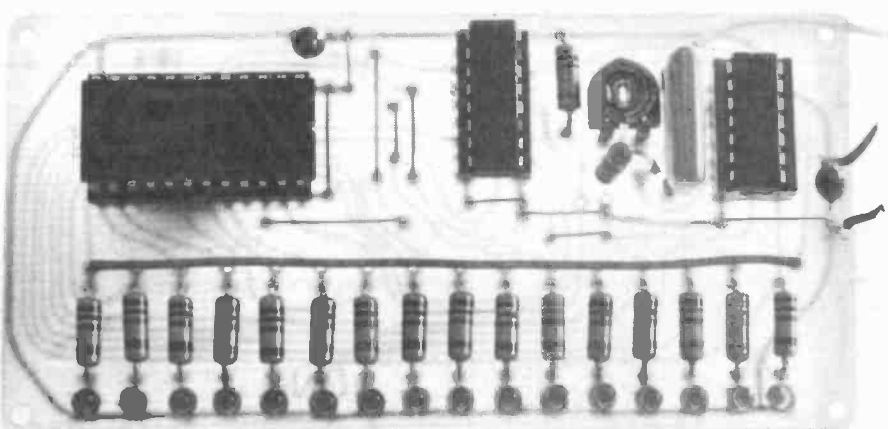
The data latching facility of IC3 is not required and so Strobe (pin 1) is tied permanently high. The Inhibit, pin 23, is connected to the Disable input as are the NOR gates IC1a and IC1b which form the oscillator. When the Disable is taken low the circuit works normally. However, when left unconnected the Disable input is pulled high by resistor R1 stopping the oscillator and forcing the outputs of IC3 low switching off all l.e.d.s.

The Disable input was designed to be driven by an external transistor which when turned on pulls Disable low and when turned off allows Disable to be pulled high by R1.

CONSTRUCTION

All the components are mounted on a single printed circuit board as detailed in Figs. 3 and 4.

Before commencing construction you must first decide whether you want to use the "Disable" facility or not. If you do then resistor R1 is included and link LK3 is omitted, if not then R1 is omitted and LK3 is included. Secondly, you must decide how many outputs you require. This will determine the number of l.e.d.s and current limit resistors used and also the position of link LK1.



Completed Chaser Light showing the bank of l.e.d.s mounted directly on the board.

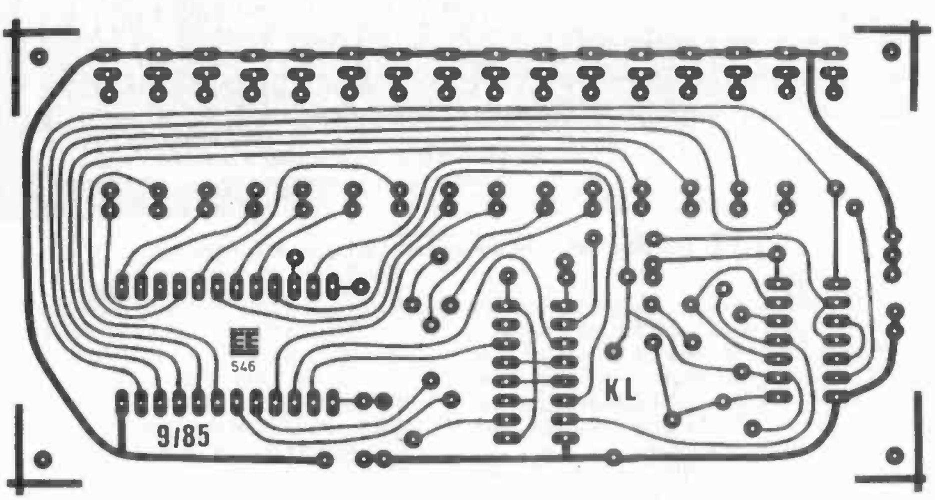


Fig. 3. Full size printed circuit master pattern for the Chaser Light.

COMPONENTS

CHASER LIGHT

Resistors

R1	100k (see text)
R2	10k
R3–R18	1k (16 off)

All ¼W carbon ±5%

Potentiometers

VR1	1M lin. Miniature horizontal preset

Capacitors

C1,C2	10µ tantalum 25V (2 off)
C3	330n polyester

Semiconductors

IC1	4001B CMOS NOR gate
IC2	4516B CMOS Binary Up/Down Counter
IC3	4514B CMOS 4 to 16 Line Decoder
D1–D16	TIL209 or similar (16 off)

Miscellaneous

PP3 9V battery and battery clips (if required); 14-pin, 16-pin and 24-pin i.c. sockets; printed circuit board,

MAGENTA KIT 559

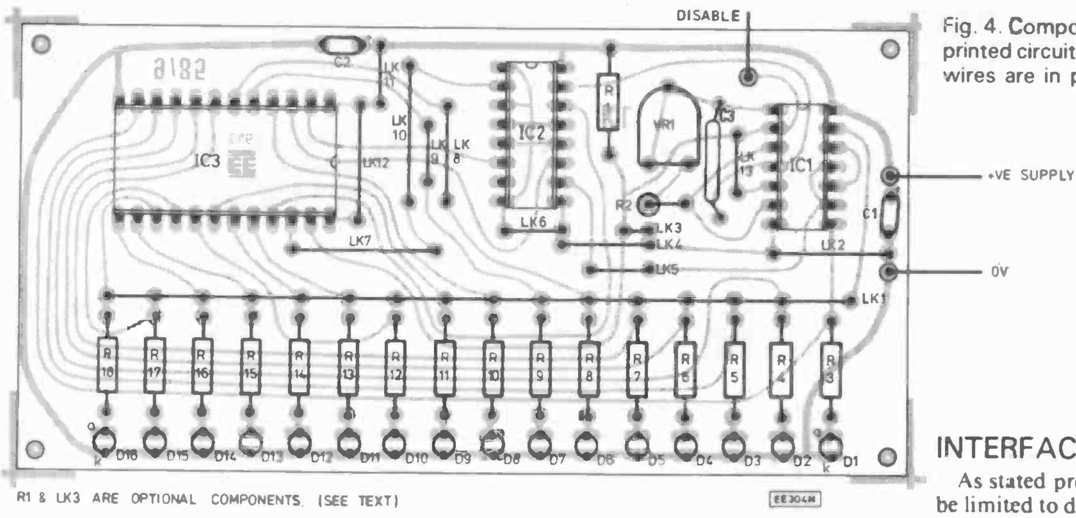


Fig. 4. Component layout and wiring to the printed circuit board. Make sure that all link wires are in position before testing.

Begin construction by fitting wire links LK1 to LK12 observing the conditions stated above for LK1 and LK3. Next fit the i.c. sockets, preset, resistors and capacitors ensuring correct polarity for capacitors C1 and C2.

Next fit the l.e.d.s again ensuring correct polarity, designated by a "flat" against the cathode (k) connection. The l.e.d.s need not necessarily be mounted on the p.c.b. but this will depend upon the application.

Finally, connect wires for the power supply and the Disable input (if required) and insert IC1, IC2 and IC3 taking care to get them the right way round.

TESTING

Set VR1 to mid-position and connect the unit to a suitable power source. If LK3 is not fitted connect "Disable" to 0V. The display should now be working. Adjust preset potentiometer VR1 to change its speed.

If the circuit fails to work switch off and thoroughly check the board for mistakes especially the orientation of l.e.d.s, capacitors and i.c.s.

Once the board is working correctly it is ready for its intended purpose. Final assembly will depend upon the application but holes are provided for mounting the p.c.b.

INTERFACING

As stated previously the circuit need not be limited to driving l.e.d.s. With a suitable interface any type of lamp may be driven including mains lamps.

For low voltage lamps I would suggest the use of a ULN2801 octal (8 pin a package) Darlington Driver Array which will drive loads of up to 50V at 500mA. Outputs may be paralleled to increase current capability.

Interfacing to mains lamps must only be undertaken by the experienced reader because of the obvious dangers involved. The January 1985 edition of *Everyday Electronics and Computer Projects* describes a *"Power Lighting Interface"* for home computers which is ideal.

The interface will need to be driven by ULN2801s because the 15mA l.e.d. current required by the opto-isolators used in the project is beyond the capability of CMOS. □

Continued from page 79

by IC1 and its associated components so this is the area to check if problems arise. It should be possible to stop oscillation by linking pins 7 and 13 of IC1.

Take extreme care when carrying out the following tests. The remaining tests are performed with the mains connected so must be done with great care. With a battery connected and S1 closed, check that the circuit stops beeping when the mains is connected, and re-starts when the mains is disconnected. Problems here will probably be due to either D1 or D2 being fitted the wrong way round.

Finally, check the operation of the three neon lamps. With a normal supply connected LP2 and LP3 should be on and LP1 off. Reverse the live and neutral connections and then LP1 and LP3 should be on and LP2 off. These tests ensure that all of the neons are working. The next step is to simulate all of the mains fault conditions one by one and check for the correct indication.

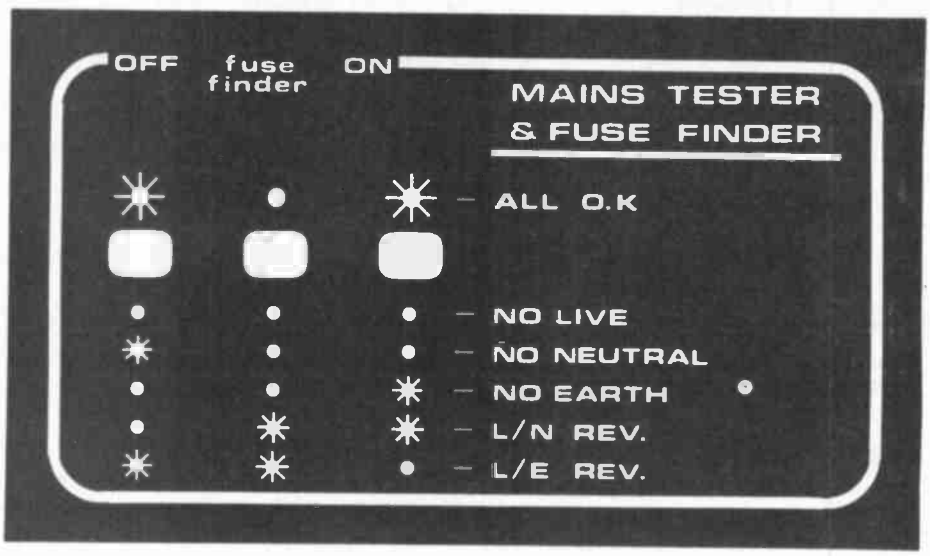


Fig. 6. Full size master of the front panel layout and lettering.

IN USE

The use of the fuse finder section of the circuit requires little explanation. The unit is switched on and plugged in to the circuit under test. As soon as the fuse feeding the circuit is removed, the beeping sound will be heard. It is surprising how far away interrupted high frequency sounds can be heard and recognised, even in the presence of considerable background noise.

The three neon lamps are able to indicate a wide range of fault conditions. In principle each neon indicates the voltage between each pair of the incoming wires. The series and parallel resistors R1-R6 are chosen so that above 200V the neons will light and below 150V they will not.

If the earth lead is disconnected LP3 will have 250V across it and will light. The other two neons are effectively in series between the live and neutral leads and so the supply is divided equally, giving 125V to each neon, which is not enough to light them.

The various other fault conditions and their associated indications are shown on the front panel label drawing in Fig. 6. The one condition that the unit does not indicate is reversed neutral and earth connections. Fortunately this is an unusual fault. □

MUSICAL DOORBELL

MARK STUART

The electronic doorbell is one of the most useful and popular projects in the field of hobby electronics. This circuit uses the AY-3-1350 integrated circuit which provides a total of 25 tunes and three chimes.

THE selection of a particular tune for the doorbell is made by the setting of two rotary switches connected to IC1, the AY-3-1350. The tunes are divided into five banks of five as shown in Table 1. Chimes are selected in a different manner depending upon the connection of the doorbell push switch. Up to three separate bell pushes may be connected, each producing a different tune or chime. Power is supplied by a single PP3 nine volt battery. Current drain is zero except when a chime or tune is being played, so a very long battery life can be expected.

CIRCUIT

The circuit diagram is shown in Fig. 1; IC1 provides all of the main functions of the circuit. The tune select switch S1 and bank select switch S2 connect directly to the i.c. Resistor R1 and capacitor C1 provide a brief negative reset pulse to ensure that IC1 starts correctly when power is applied. The timing components R2, VR1 and C2 are used by the internal oscillator on IC1 to determined the pitch of the notes. Adjustment of VR1 allows the pitch of the tunes to be varied to suit the user.

Power is applied to the i.c. via TR1. Normally when the "bell" is silent and none of the pushes pressed TR1 is turned off. Closing any of the bell pushes will turn on TR1 via R5 and D1 or D2 depending on which "push" is pressed.

When TR1 is turned on power is applied to IC1 via the shunt regulator circuit R4 and Zener diode D4. Feedback from IC1 via R6 maintains base current in TR1 so that it remains turned on even though the bell pushes are released. This feedback stops when the i.c. has completed the tune. At the point TR1 is turned off the power is removed from IC1 and the circuit assumes the quiescent state.

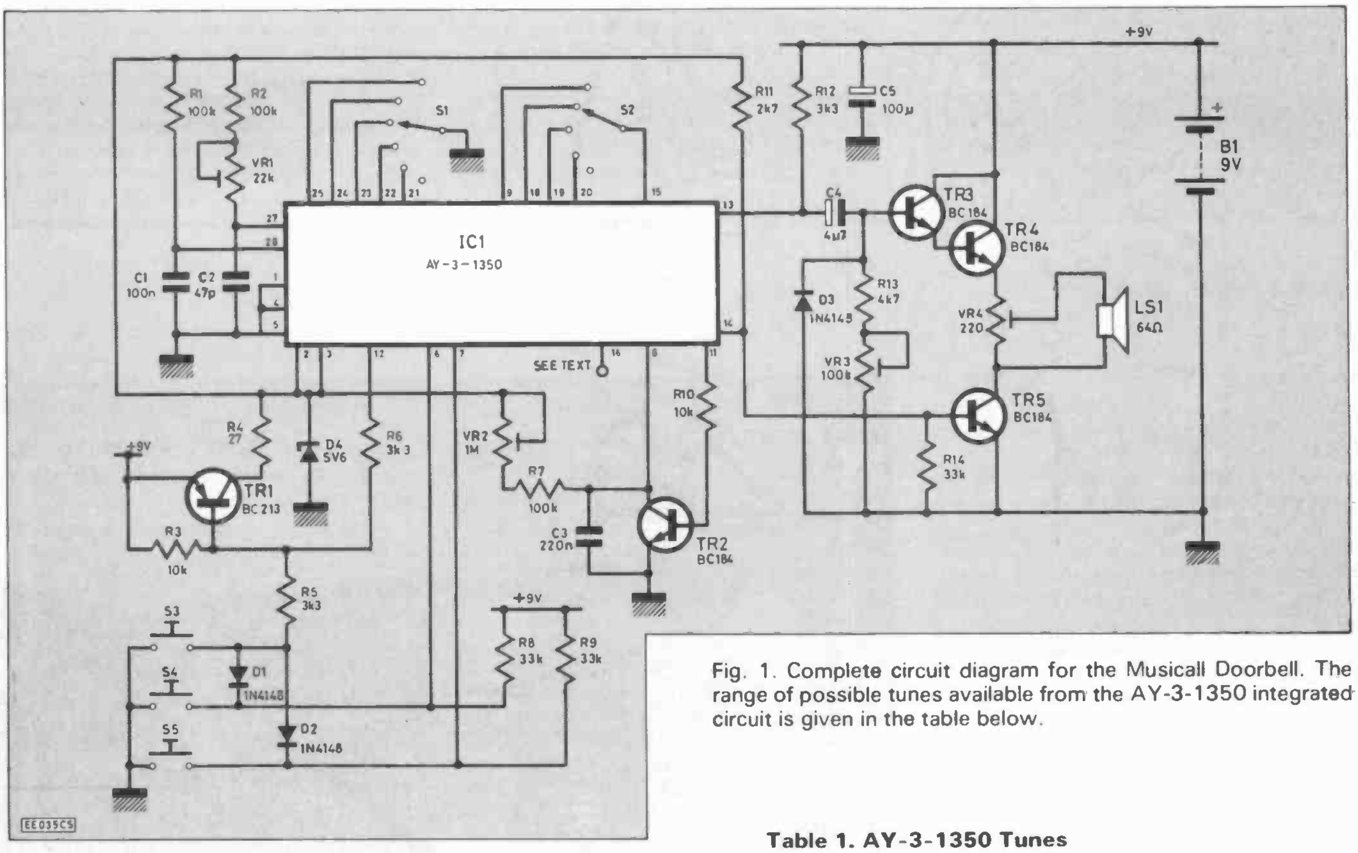


Fig. 1. Complete circuit diagram for the Musicall Doorbell. The range of possible tunes available from the AY-3-1350 integrated circuit is given in the table below.

Table 1. AY-3-1350 Tunes

A0	Toreador	A2	America, America	A4	Hell's Bells
B0	William Tell	B2	Deutschland Leid	B4	Jingle Bells
C0	Hallelujah Chorus	C2	Wedding March	C4	La Vie en Rose
D0	Star Spangled Banner	D2	Beethoven's 5th	D4	Star Wars
E0	Yankee Doodle	E2	Augustine	E4	Beethoven's 9th
A1	John Brown's Body	A3	O Sole Mio	Chime X	Westminster Chime
B1	Clementine	B3	Santa Lucia	Chime Y	Simple Chime
C1	God Save the Queen	C3	The End	Chime Z	Descending Octave Chime
D1	Colonel Bogey	D3	Blue Danube		
E1	Marseillaise	E3	Brahms' Lullaby		

COMPONENTS

Resistors

R1,R7	100k (2 off)
R2	2k2
R3,R10	10k (2 off)
R4	27
R5,R6,R12	3k3 (3 off)
R8,R9,R14	33k (3 off)
R11	2k7
R13	4k7

All ¼W ±5% carbon film

Potentiometers

VR1	22k
VR2	1M
VR3	100k
VR4	220

All miniature horizontal presets

Capacitors

C1	100n polyester
C2	47p ceramic
C3	220n polyester
C4	4µ7 25V radial elect.
C5	100u 16V radial elect.

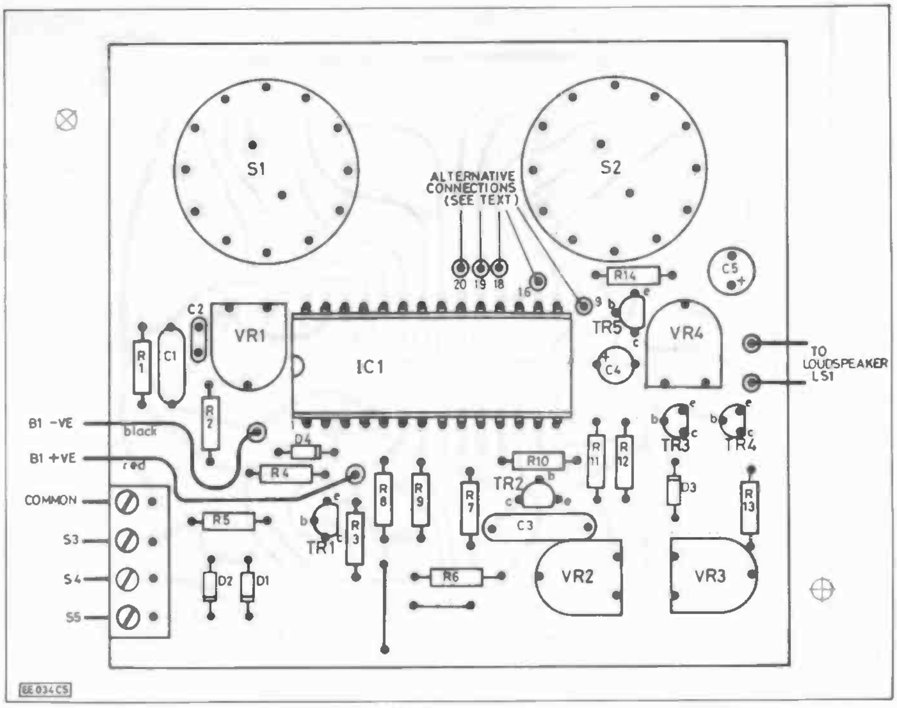


Fig. 3. Printed circuit board component layout and wiring details.

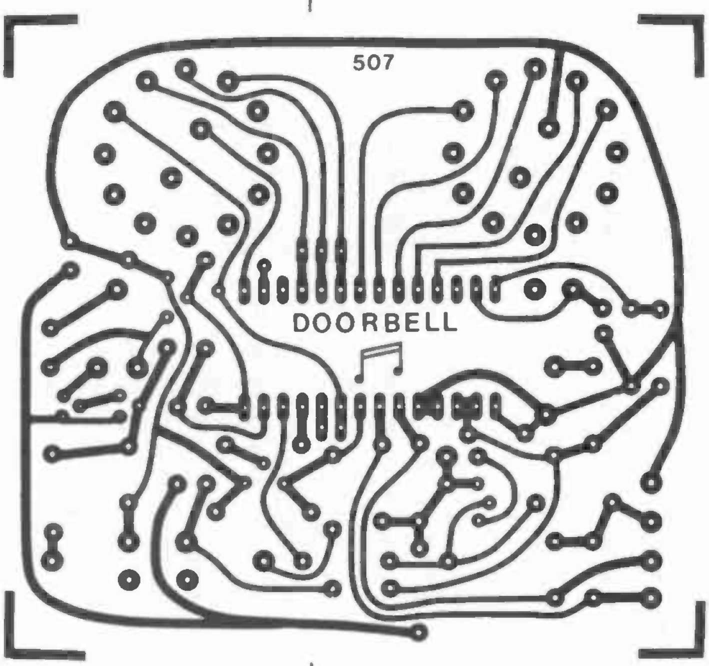


Fig. 2. Full size printed circuit master.

Semiconductors

D1–D3	1N4148 (3 off)
D4	5V6 400mW Zener
TR1	BC213
TR2–TR5	BC184 (4 off)
IC1	AY-3-1350

Miscellaneous

B1	9V PP3 battery
LS1	64 ohm speaker (approx. 65mm diam.)
S1,S2	Two pole six way rotary switches (2 off)
S3–S5	Door mounting bell pushes, single pole push to make—number as required

Four way p.c.b. mounting terminal block; 28 pin i.c. socket; PP3 clips; two knobs; p.b.c.; plastic case approx 160×96×53mm; grommet, wire etc.

MAGENTA KIT 497

The audio output from IC1 is a square wave which appears on pin 14 and drives the loudspeaker via TR5. Transistors TR3 and TR4 are driven by a positive going pulse which is derived from IC1 via the pulse forming network C4, R13, VR3 and D3. Each time a new note is played the voltage on pin 13 of IC1 switches from negative to positive. This change is coupled via C4 to the base of TR3 which also turns on TR4 providing almost the full supply voltage to the loudspeaker. During the note C4 gradually charges via R13 and VR3 and the voltage on TR3 base falls towards zero.

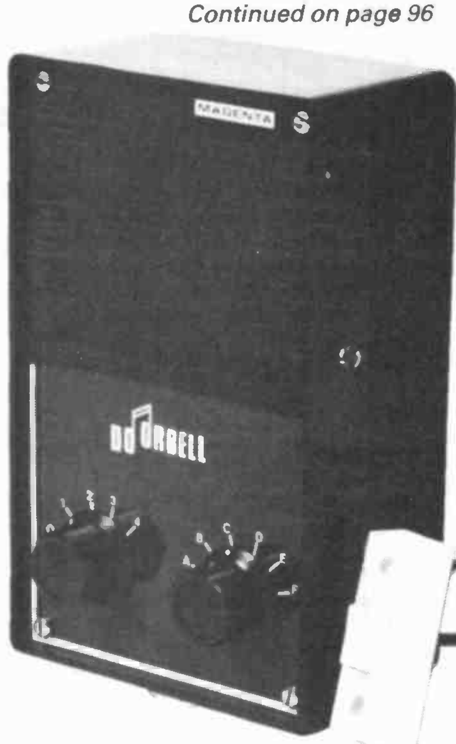
This falling voltage is coupled via TR3 and TR4 to the loudspeaker supply causing the output voltage to decay and giving the characteristic envelope to the sound. At the end of the note the voltage on pin 13 falls to zero and C4 is quickly discharged via D3 ready for the next note.

The volume is set by VR4 which is a simple high level volume control. The speed of playback of the tunes can be adjusted independently of the pitch by means of VR2 and R7 as the note is played. The voltage on C3 is monitored by pin eight of IC1 which detects when it has charged to a fixed threshold level. When this level is reached the note is ended and the circuit is ready for the next note. VR2 adjusts the charge current flowing into C3 and so determines the time taken to reach the threshold, therefore it sets the tempo.

CONSTRUCTION

The circuit is constructed on a single printed circuit board, Fig. 3 shows the component overlay. Begin construction of the board by fitting Veropins at the points where the battery clip and loudspeaker connections are to be made. Also fit five pins at the points marked "alternative connections" in Fig. 3.

Continued on page 96



FUNCTION GENERATOR

MARK STUART

A FUNCTION generator is a very useful piece of test equipment. The one described here was designed to provide signals suitable for testing as wide a range of circuits as possible. The designer has used the prototype for some months and found it to be invaluable. The generator has been used with audio circuits, digital logic circuits, and computer peripherals such as A-to-D converters.

It was initially intended that the circuit should be powered from two PP3 batteries, it soon became clear that the amount of use the generator was getting justified the addition of a simple mains adaptor. A commercial plug-in type of adaptor would be suitable but 20 volt versions are not readily available. Instead a simple supply was designed and the generator was fitted with a power socket that automatically disconnects the batteries when the adaptor is connected.

CIRCUIT

The circuit diagram is shown in Fig. 1. The circuit is based upon the excellent XR2206 monolithic function generator i.c. This is a very useful integrated circuit. It is capable of generating a whole range of signals over a frequency range of 0·01Hz to 1MHz. In this application many of its features are ignored in the interests of simplicity. The signals used are sine, square, and triangular waves. A schematic diagram of the i.c. is shown in Fig. 2.

The frequency of oscillation is set by the value of VR4 and one of the timing capacitors C5–C8 selected by the frequency range control S2. The oscillator works by repeatedly charging and discharging the timing capacitor with a constant current set by the resistance connected to pin 7 of the i.c. A set of transistors known as 'current switches' are used to switch the direction of the current so that the capacitor is alternately charged and discharged. Charging a capacitor with a constant current produces a linear change of voltage with time so that the output voltage waveform across the timing capacitor is triangular. An amplifier within the i.c. (part of the block labelled Multiplier and Sine Shaper) takes the triangular waveform and presents it at the output (pin 2). The gain of this amplifier stage depends on

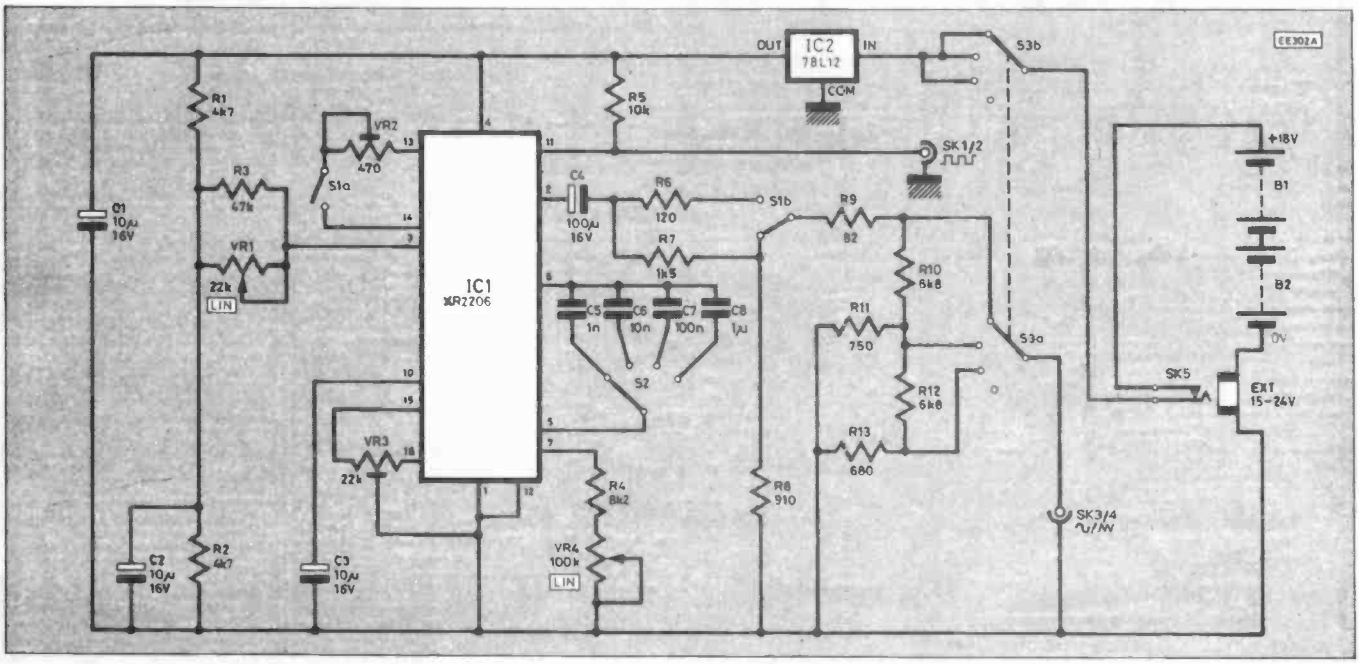


Fig. 1. Circuit diagram.

Makes waves from 0·01Hz to 1MHz in sine, square and triangle

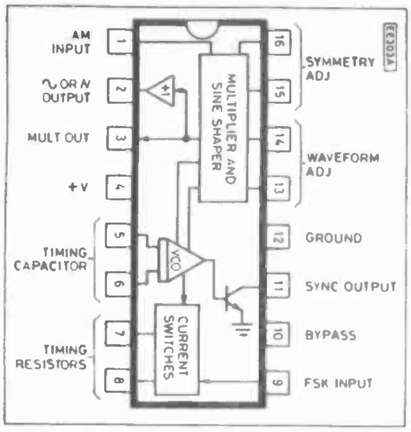


Fig. 2. Block diagram of IC1.

the resistance connected to pin 3 of the i.c. The output level control, VR1 sets this resistance value whilst the associated components R1, R2, R3 and C2 provide the correct d.c. voltage conditions.

The Multiplier and Sine Shaper block also contains a number of additional stages which allow the triangular input waveform to be altered. Presets VR2 and VR3 set the characteristics of these stages, and when correctly set the triangular waveform peaks are evenly rounded so that the output is a low distortion sine wave. The ideal setting of VR2 and VR3 results in a sine wave with only 0·5 per cent distortion. Switching between triangle and sine waves is done by S1a. S1b is necessary to adjust the output signal level because the sine wave output voltage is less than half of the triangular wave. R7 and R8 reduce the level of the triangular wave to that of the sine wave.

The output signal from S1b passes to the switched attenuator network made up of resistors R9–13 and S3a. This arrangement provides one of the nicest aspects of this function generator—a constant output impedance. The values of the resistors are chosen so that the signal level is changed in three steps of 10 to 1 giving 0–1 volt, 0–100mV, and 0–10mV outputs whilst the output impedance stays constant at 600 Ohms.

Many circuits give a voltage gain which is influenced by the source resistance of the input signal, being able to rely on the generator as a constant 600 Ohm source enables such circuits to be checked without difficulty. It is also useful to be able to

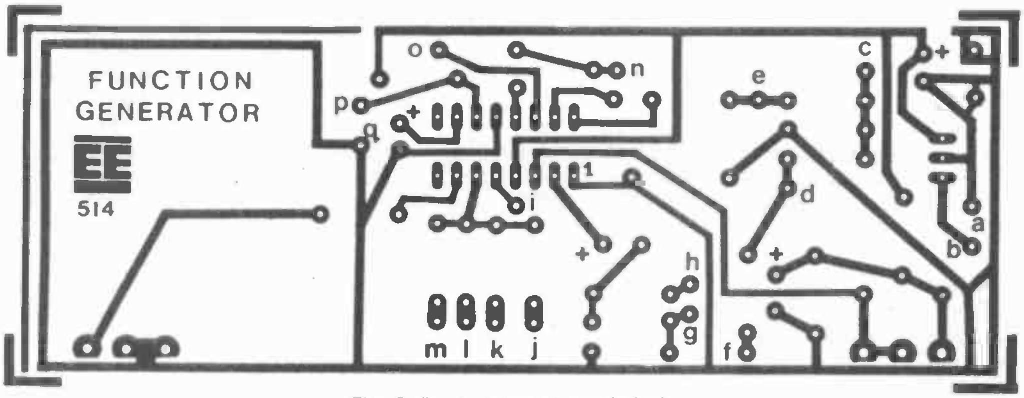


Fig. 3. P.c.b. layout (actual size).

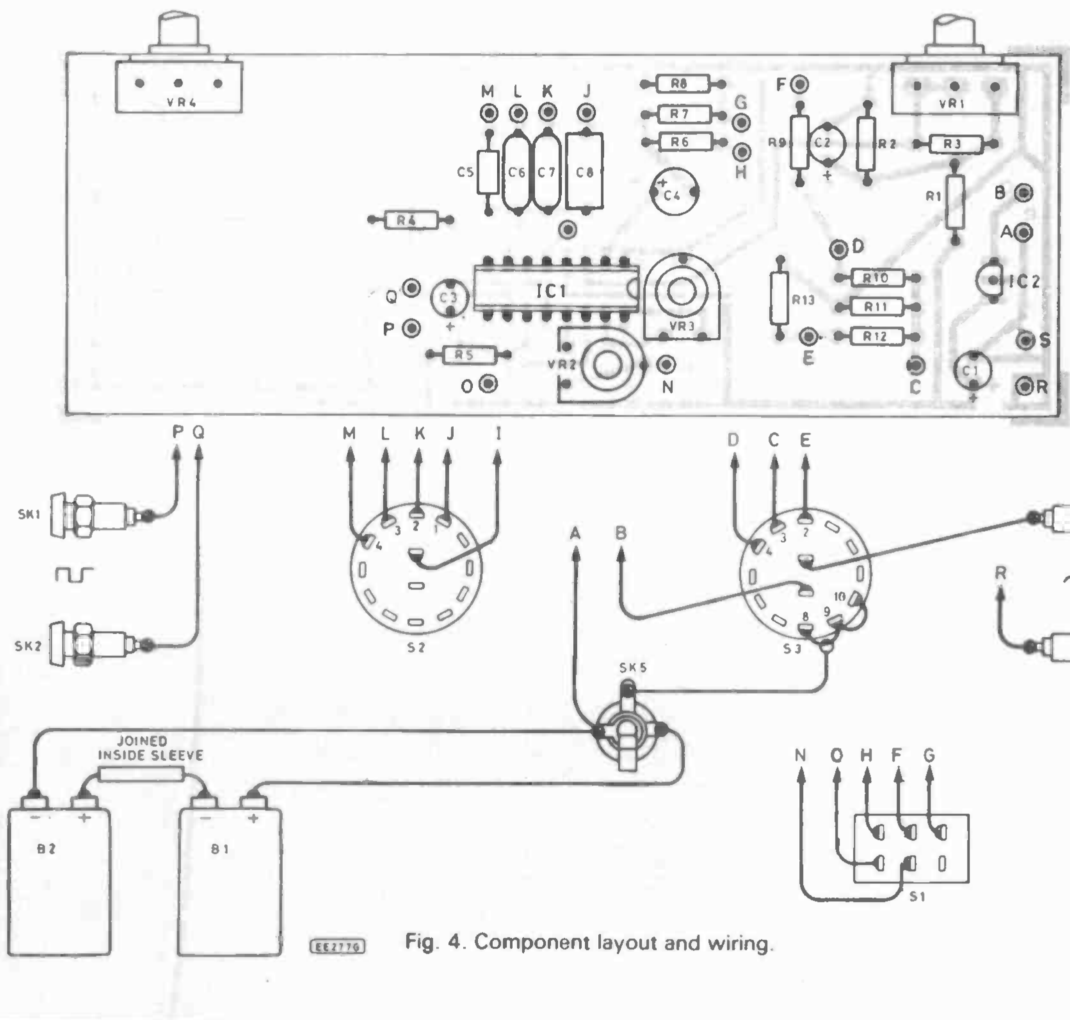


Fig. 4. Component layout and wiring.

COMPONENTS

MAGENTA KIT 503

Resistors

R1,2	4k7 (2 off)
R3	47k
R4	8k2
R5	10k
R6	120
R7	1k5
R8	910
R9	82
R10,12	6k8 (2 off)
R11	750
R13	680

All resistors ¼W 5% Carbon film

Potentiometers

VR1	22k lin. potentiometer
VR4	100k lin. potentiometer
VR2	470 preset
VR3	22k preset

Capacitors

C1,2,3	10µ 16V electrolytic (3 off)
C4	100µ 16V electrolytic
C5	1n polystyrene
C6	10n polyester
C7	100n polyester
C8	1µ multilayer

Semiconductors

IC1	XR2206 function generator
IC2	78L12 voltage regulator

Miscellaneous

Printed circuit board (No 514), 16-pin i.c. socket, 7/0·2 connecting wire, 2 pole 6-way rotary switches (2 off), DPDT toggle switch, 4mm sockets (2 off red & 2 off black), PP3 clips (2 off), 3·5mm jack socket, K9 marker knobs (4 off), suitable case with sloping front—plastic with metal panel—approx 160 × 95 × 55mm, sleeving, etc.

External power supply

D1,2	1N4001 (2 off)
C1	680µ 40V electrolytic
T1	16-0-16 3VA transformer
PL1	3·5mm jack plug

Printed circuit board (No. 515)
Mains cable 2 Amp
Screened wire
Plastic case approx. 80 × 60 × 40mm.
Feet, grommets, etc.

connect series or parallel resistors to the output to simulate different source impedances. For example 47k Ohms for a magnetic pick up cartridge, or 30 Ohms for a low impedance microphone. In these situations it is important to be able to trust the function generator so that the output impedance can be set up by adding series and parallel resistors to the 600 Ohms of the generator. The power on/off function is provided by S3b which is part of the output level control. This arrangement saves space and the cost of a separate switch. IC2 provides a regulator 12V supply for IC1. Any supply giving 15V to 24V at 50mA will be suitable. For occasional portable use two PP3 batteries will give 10 hours continuous operation.

An 'open' collector transistor switched by the oscillator section of the i.c. provides the square wave output. Resistor R5 is a 'pull up' resistor so that a 12V peak to peak square wave appears on SK1. The availability of an open collector transistor output is very useful because it enables TTL and most other logic families to be directly connected. Having a separate square wave output is also very useful for providing a synchronisation signal to an oscilloscope when making tests with very low level signals in noisy circuits. Often the signal being viewed is incapable of synchronising the oscilloscope. Connecting the square wave output to the 'external sync' terminal of the oscilloscope will give rock solid synchronisation regardless of the signal input.

CONSTRUCTION

All of the active circuitry is built on a single printed circuit board. Quite a lot of connections are made to the board from the range switches and output sockets etc. These points are all identified by letters etched onto the track side of the board. This is shown in Figs. 3 and 4, the printed circuit board component overlay. To simplify the wiring it is recommended that double sided 0·1 inch wiring pins are fitted at each of these locations. The pins should be fitted from the track side of the board and pressed fully home so that their splined sections pass through the board material. This can take considerable force and a vice, hammer, or one of the pin insertion tools should be used to do the job properly. Fig. 4 shows the correct way to fit the pins before soldering them. When the pins have been fitted and soldered the rest of the board can be assembled. With the exception of C1–4 and the i.c.s all components can be fitted either way round. A socket should be used for IC1 as it is quite expensive. Mount the two controls VR1 and VR4 last.

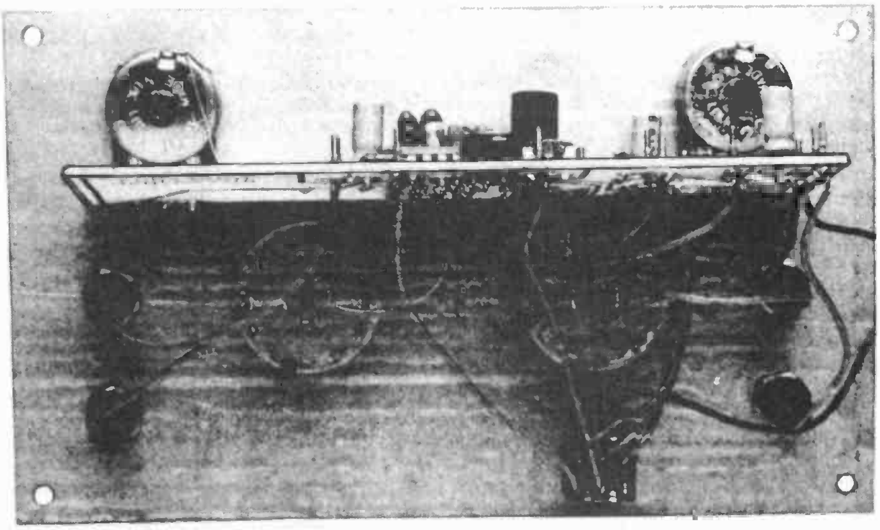
INTERWIRING

The next stage in assembly is to mount the board, switches S1–3, and sockets SK1/2 and SK3/4 onto the front panel. If the recommended case is used the front panel should be laid out as shown in photograph on page 67. When the appropriate size holes have been drilled put one serrated washer on to each of the potentiometers and switches, and fit them to the panel with a single nut on the top of each. Check that S1 and S2 are positioned with their numbering as shown in Fig. 4. A similar approach should be adopted when fitting S1 which is supplied with two nuts and a serrated washer. First fit one nut and the serrated washer to the switch, mount the switch to the panel with a single nut. The position of the first nut can be adjusted to give the best appearance to the finished panel. The fitting of SK1/2 and SK3/4 is quite straightforward.

Wiring is simply a matter of making point to point connections from the bottom of the board to the components as shown in Fig. 4. Use 7/0·2 or similar thin connecting wire and keep the connections fairly short. Don't be tempted to 'tidy up' the wiring as this will increase cross coupling between the various signals and lead to increased distortion.

The battery clips and power sockets SK5 should be connected as shown. Mount the socket in the side or rear of the case as preferred but *not* on the metal front panel.

Wiring of front panel to the printed circuit board.



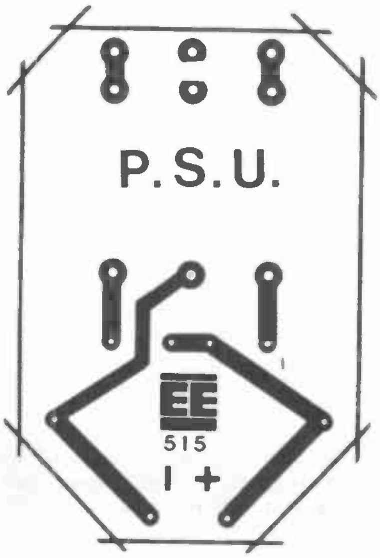


Fig. 6. Power Supply Unit p.c.b. (actual size).

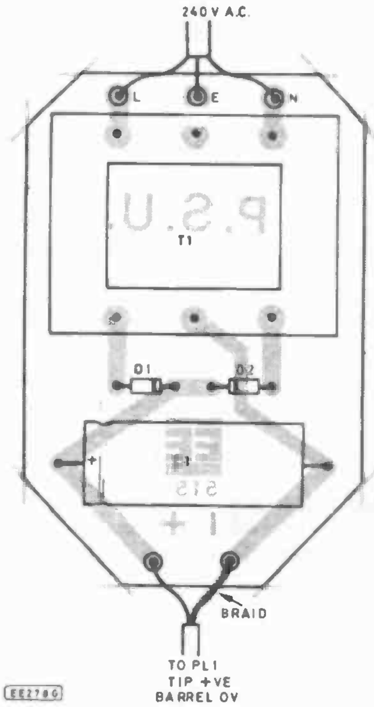
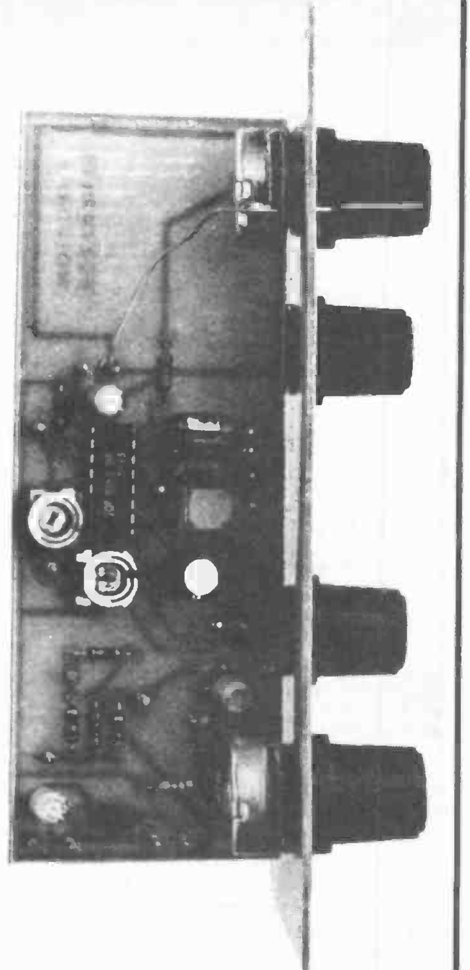


Fig. 7. Power Supply Unit component layout.



Plan view of the Function Generator.

A final connection from the metal body of VR4 to point 'q' on the top of the board should be made to ensure that the front panel is connected to the circuit 0V rail for screening purposes. When mounting the assembled panel into the case it may be necessary to gently bend the board up a small amount on the potentiometer pins to clear the back of the case.

SETTING UP AND TESTING

When assembly is complete and has been fully visually inspected carefully fit IC1 the correct way round, connect a suitable source of 15V to 24V to the circuit and switch on. If possible check the supply current which should be around 14 to 24mA. Connect the sine/triangle output to an audio amplifier or a set of high impedance headphones, and set S2 to the 1KHz range. Set VR2 and VR3 to mid position. An audible tone should be present, adjustable in pitch by VR4, and volume by S3 and VR1. If you are lucky enough to have an oscilloscope you can set up VR2 and VR3 for a symmetrical sine wave. Adjust VR3 first and then VR2 and remember that a good sine wave has quite sharp peaks. There is a tendency to overdo the rounding of the peaks in the waveform. If an oscilloscope is not available then these adjustments should be done by ear. Set the output waveform switch to sine and with VR3 at mid point adjust VR2 for minimum audible distortion or harshness. Finally adjust VR3 to further minimise any distortion. These settings should give quite good results as the ear is notoriously sensitive to distortion.

Check all the settings of VR1, VR4, S1, 2 and 3, to ensure that they are functioning correctly and finally check that a harsh sounding signal is available on SK1. Further use of an oscilloscope could be made to check the output amplitude and frequency ranges etc., although provided the assembly is correct these things will look after themselves.

POWER SUPPLY ADAPTOR

As mentioned earlier a small mains adaptor was built to power the function generator during prolonged bench use.

Fig. 5 shows the simple circuit diagram of this supply. A small 3VA 16-0-16V split bobbin transformer. The circuit is built on a compact printed circuit board that fits neatly inside a small plastic box. A metal box is not recommended, however if one is used ***it must have a mains earth connection made to it.***

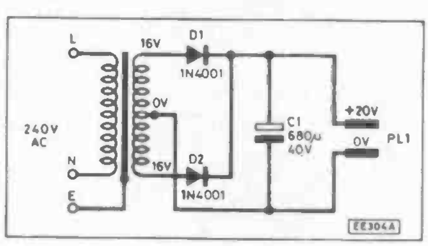
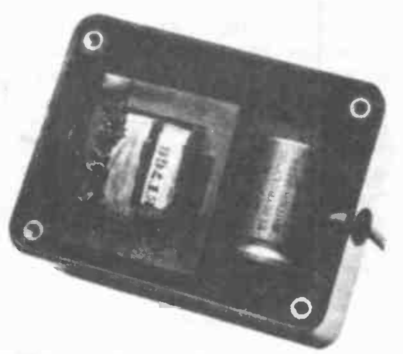


Fig. 5. Circuit diagram of the mains power pack.



The mains lead and output lead are passed through grommets at each end of the case. Fit a plastic cable tie to each lead to prevent them from being pulled out of the case. Take great care to separate the mains connections and use a good quality transformer. It is not usual to earth the ground lines of function generators because of creating hum loops and interference, so extra care is needed during construction of the power supply. The power connector to the generator is made via a 3·5mm jack plug connected so that the tip is positive. Figs. 6 and 7 show the component layout on the printed circuit board and the connections to the plug. □

TILT ALARM

I.P. KEMP

Protects cases, doors, car boots, roof racks, tool or jewel boxes etc.

THIS simple Tilt Alarm was designed to be portable and easy to operate. It can be used in any situation where an attempted theft involves tilting something.

The initial idea was that it could be attached to the handle on the inside of a hotel room door but there are many other applications. The lids of suitcases or camera cases are suitable places as are garage doors, tail gates and car boots. It is also suitable for protecting items fitted to a roof rack. The list of possible applications seems to be unlimited. The unit is small enough to be built into a jewel box (or tool box).

The alarm is particularly suitable for use in situations where it is left unattended for long periods. A two-minute alarm time-out prevents the battery being exhausted, and the possible annoyance of neighbours, in the event of a false alarm (or an abandoned theft attempt).

After the time-out the alarm resets and will respond again when tilted. The alarm is set by removing a "key" made from a miniature jack plug. This method is cheap and easy and offers good security. An opportunist thief will be totally unprepared for an alarm of any kind and certainly won't hang around trying to turn it off.

CIRCUIT DESCRIPTION

The complete circuit diagram of the Tilt Alarm is shown in Fig. 1. The "tilt" is detected by S1 which is a mercury tilt switch. This is a simple glass bulb containing a blob of mercury which is free to move around if the bulb is tilted. Two wires which pass into the bulb at one end are short circuited when the mercury blob bridges them and open circuited when it does not.

In this application the tilt switch is positioned so that the mercury blob is normally away from the two wires but falls to bridge them when disturbed. The alarm circuit must, therefore, detect when the tilt switch changes from open circuit to short circuit.

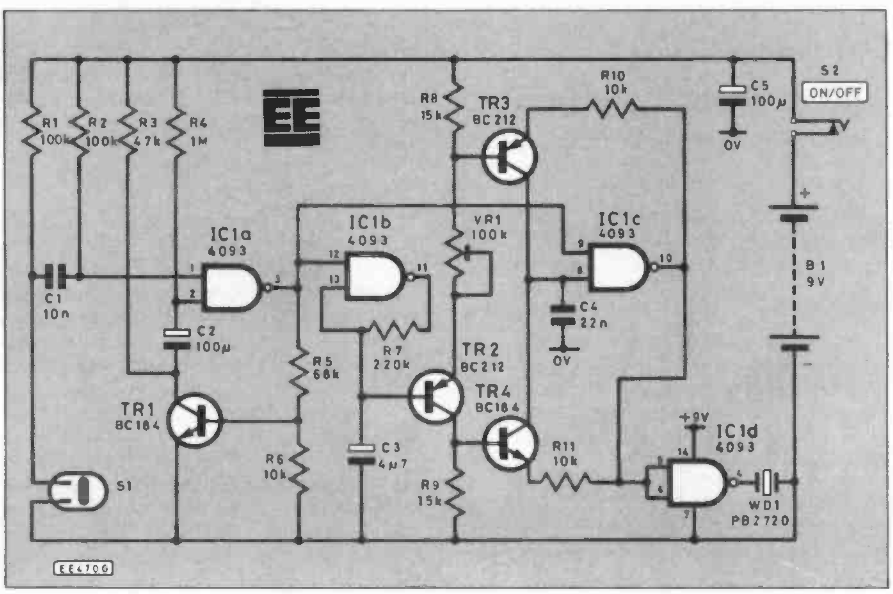
The closing of the tilt switch is detected by IC1a. Normally both inputs to IC1a are held high. A truth table for all four NAND gates of IC1 is given in Table 1.

Table 1. Truth Table for Two Input NAND Gate

INPUT 1	INPUT 2	OUTPUT
H	H	L
H	L	H
L	H	H
L	L	H

H — High or Logic 1
L — Low or Logic 0

Fig. 1. Complete circuit diagram of the Tilt Alarm.



With its two inputs held high the output of IC1a will be low. Transistor TR1 will not receive any base bias current via resistor R5 and so will be turned off. The collector of TR1 will be held at the positive supply voltage via R3. IC1a also feeds one input each of IC1b and IC1c.

From Table 1 it can be seen that holding either of the inputs of these gates low forces the outputs to remain in the high state regardless of the other inputs. The alarm stays quietly in this state until the tilt switch is disturbed and switches from open to short circuit. When this happens the input of IC1a is briefly pulled low via capacitor C1.

With one of its inputs low the output of IC1a switches from low to high, turning on TR1 via R5. As TR1 turns on its collector voltage falls from the positive supply voltage to almost zero. This fall in voltage is passed via capacitor C2 and pulls the other input of IC1a from high to low. The low on this input of IC1a now takes over and holds the output in the high state regardless of the state of the other input.

IC1a would remain latched in this state except for the effect of resistor R4, via which C2 gradually charges. After approximately 100 seconds the voltage on the positive end of capacitor C2 has risen sufficiently to take the input of IC1a from the low state to the high state. The other input of IC1a is already held in the high state via R2 and so with both inputs high the output of IC1a switches from high to low and turns off TR1.

The collector of TR1 rises to supply voltage and the circuit settles down once again with both inputs of IC1a in the high state and its output in the low state. Even if S1 remains closed the circuit action will be unaltered because capacitor C1 and resistor R1 only allows the input of IC1a to be pulled down for a few milliseconds.

The circuit will be re-triggered next time S1 changes from open circuit to short circuit and the whole 100-second cycle will repeat. The 100-second time period is set by the values of C2 and R4. These values can be reduced for shorter periods but should not be increased much because the small charge current and the high leakage current of big electrolytic capacitors will give unpredictable results.

ALARM TONE GENERATOR

IC1b and IC1c form a frequency modulated audio generator which produces a particularly penetrating sound when used with miniature piezo-acoustic transducers because it excites their natural resonances.

In the quiescent state the output of IC1a is low and holds one input each of IC1b and IC1c low. In this state the outputs of IC1b and IC1c are high and they cannot oscillate.

When the alarm is triggered the output of IC1a and the inputs of IC1b and IC1c connected to it become high. From the truth table of Table 1 it can be seen that when one of the inputs of a gate is high, the output is always the opposite of the other input. I.e. the gate can be treated as a simple inverter.

The gates in IC1 are not just "straight" CMOS NAND gates. They also have a Schmitt trigger action. Schmitt trigger gates have a built in hysteresis effect so that the output switches sharply between states even if the input changes slowly.

This feature enables the gates to function and oscillators with the addition of just one resistor and one capacitor. IC1b is connected as such an oscillator and operates as follows:

Initially assume that the input of IC1b is low and its output is therefore high. Capacitor C3 will be charged via R7 until the voltage across it rises to a voltage known as the upper input threshold voltage of IC1. At this point the output switches from high to low and C3 now begins to discharge via R7.

The hysteresis of the Schmitt trigger gate means that the output will not switch from low to high until the input voltage has fallen to a lower voltage known as the "lower input threshold". At this point the output switches from low to high, C3 begins to charge via R7 again, and the cycle repeats.

The output from the i.c. is a square wave as it switches backwards and forwards between states. The voltage across C3 is a gently rising and falling triangular waveform. This waveform is used to modulate the frequency of a second similar oscillator formed around IC1c.

VOLTAGE CONTROLLED OSCILLATOR

In the second oscillator C4 is the capacitor which is charged and discharged via two transistors TR3 and TR4 instead of a single resistor. By varying the base bias voltage on the two transistors it is possible to alter the amount of current that they pass and hence the rate at which C4 is charged and discharged.

To understand how this circuit works assume the base of TR2 is held at half of the supply voltage. The emitter of TR2 will be above half of the supply voltage by 0·6V (the base—emitter voltage of TR2).

Preset potentiometer VR1 sets up the current that flows via resistors R8, R9 and transistor TR2 and would normally be adjusted so that there was 1·6V across R8 and R9, (the base current of TR2, TR3 and TR4 is insignificant, so the current in R8 is practically identical to that in R9, about 105 microamps in this case).

When the output of IC1c is high it almost reaches the supply voltage and so the voltage across TR3 and resistor R10 is 1·6V. Allowing 0·6V for the base-emitter junction of TR3 this leaves 1V across R10 giving a current of 100 microamps passing through TR3 to charge C4. When the output of IC1c is low TR3 is turned off and TR4 turned on. As there is 1·6V across R9 there will be 1V across R11 and so the discharge current of capacitor C4 will also be 100 microamps.

The base voltage of TR2 is varied by the low frequency triangular waveform across capacitor C3. This causes the voltages across R8 and R9 to vary and so alters the charge and discharge currents of C4 and the frequency of oscillation.

The values are chosen so that the output of IC1c is a square wave which sweeps up and down between 2kHz and 3kHz at a rate of 2Hz. IC1d is a simple buffer stage which isolates IC1c from the loading effect of the output transducer WD1.

The alarm is turned on by removing the plug from the miniature switched jack socket S2. The socket is wired so that the alarm will keep sounding even if a nail or other (conducting) object is used to attempt to foil it. The choice of a 2·5mm jack socket ensures that matchsticks cannot be inserted.

COMPONENTS

MAGENTA KIT 544

Resistors

R1,R2	100k (2 off)
R3	47k
R4	1M
R5	68k
R6,R10, R11	10k (3 off)
R7	220k
R8,R9	15k (2 off)

All ½W 5% carbon film

Potentiometers

VR1	100k Miniature Horizontal Preset

Capacitors

C1	10n polyester C368
C2,C5	100µ elec. radial 10V (2 off)
C3	4·7µ elec. radial 10V
C4	22n polyester C368

Semiconductors

IC1	4093 *CMOS*
TR1,TR4	BC184 *npn* silicon (2 off)
TR2,TR3	BC212 *pnp* silicon (2 off)

Miscellaneous

S1	Mercury tilt switch, type MGT2
S2	2·5mm switched jack socket
WD1	PB2720 piezo-electric resonator
B1	PP3 9V battery and clip

2·5mm plastic jack plug; case; sticky pads; 14-pin i.c. socket; printed circuit board,

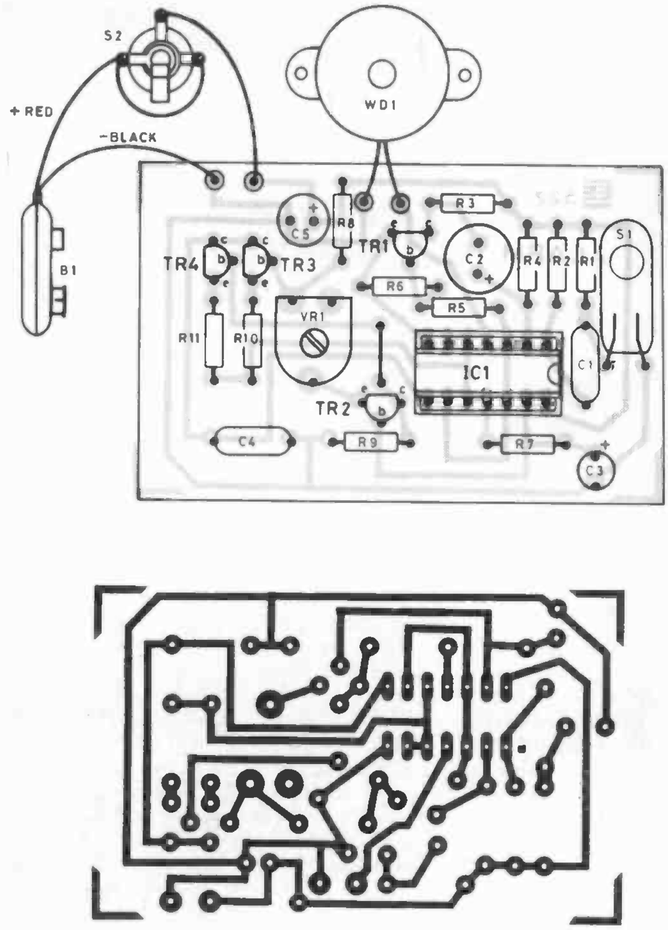


Fig. 2. Component layout and wiring.

CONSTRUCTION

The alarm is built on a single small printed circuit board. The component layout and wiring is shown full size in Fig. 2. A socket is recommended for IC1 as it aids trouble shooting enormously if the i.c. can be removed when making checks. The electrolytic capacitors C2, C3 and C5 must be fitted the right way round as must the transistors and the i.c. Take care not to confuse the two types of transistor.

The tilt switch can be mounted on the board as shown but may also be fitted remotely on wire leads. The main thing is to get the switch set at the correct angle so that it is normally open but closes on an attempted theft. The operation of the switch can be checked easily by watching the mercury blob fall from end to end.

The prototype was built in a plastic case measuring 60×110×30mm. Sticky pads are used to mount the board, transducer and battery.

TESTING

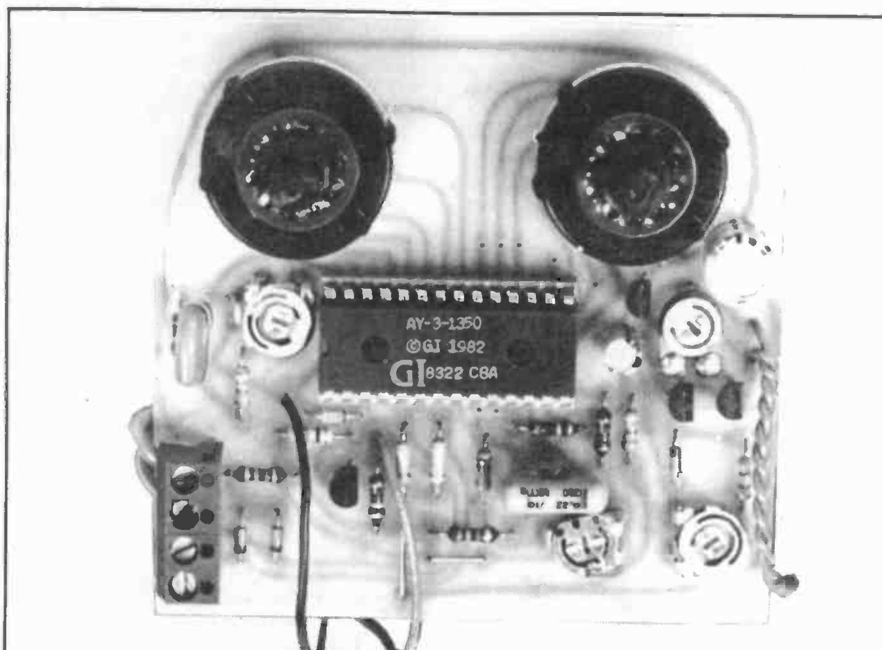
When the alarm is complete check that S2 is working correctly so that power is only supplied to the circuit when the plug is removed. Insert the jack plug, connect a battery and set the position of S1 so that it is open circuit. Remove the plug and check that the alarm is silent. As soon as S1 is tilted to the short circuit position the alarm should sound. Tilting S1 to the open position should have no effect and the alarm should continue to sound for between 60 and 120 seconds. The frequency range of the alarm sound should be set by VR1 for the most penetrating effect. Resonances in WD1 are influenced by its mounting method so the setting of VR1 should be done with the alarm in as near to its final form as possible.

IN USE

The alarm can be fixed to the object to be protected by using double-sided tape, Blutak, Velchro strips or any other appropriate method. Battery drain is negligible when the alarm is not sounding and small even when it is. A PP3 battery will probably last for a year's "normal" use.

Although a tilt switch is used in the design it is also quite possible to use any other sensor that changes from open circuit to closed circuit when disturbed. Pressure mats and micro switches wired in parallel with S1 could be used to give additional protection. □

Continued from page 89



The completed circuit board ready for inserting in a suitable case.

Next fit the resistors, presets, diodes and capacitors in that order. Be sure to observe polarity when fitting the diodes. Then fit a 28 pin low profile socket for IC1 and fit the transistors with their flat sides correctly orientated as shown. Note that TR1 is different from the others. The rotary switches should now be fitted, these may be the type with tags that have loops in the ends for direct wiring, cut off the loops leaving only the straight parts which will pass through the board.

The bell push connections are made to four board mounting terminal blocks. A single common connection serves all three pushes. Finally connect the battery clip and loudspeaker and insert IC1 taking care to get it the right way round. The board is now ready for testing.

TESTING

Set all the presets to mid position and connect a suitable battery. If all is well the current drain should be zero. Now temporarily link S3 and the common terminals via a push to make switch and check that one of the tunes is played each time the switch is pressed. Go through the various positions of S1 and S2 and check that the tunes correspond to Table 1. The action of the presets is self explanatory. Make a brief check that they are all working before setting them up to your own liking.

The operation of S4 and S5 should now be checked: S4 will play the descending octave chime for all settings of the switches, S5 will play any of the tunes A0, B0, C0, D0 and E0 depending upon the setting of S1, regardless of the setting of S2. When S1 is in the F position the three chimes are available—X from S3; Y from S4; and Z from S5. The alternative links shown on the board allow the tunes from several different banks to be selected for S5 as shown in Table 2.

Table 2. Alternative tune links

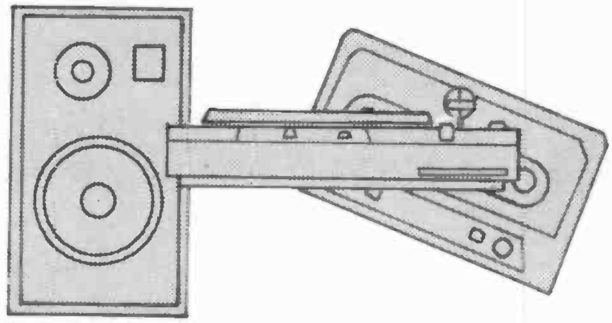
LINK PIN 16 TO	S5 TUNES
No other pin	A0–E0
PIN 20	A1–E1
PIN 19	A2–E2
PIN 18	A3–E3
PIN 9	A4–E4

FINAL ASSEMBLY

Once everything is working correctly the board can be mounted inside the front panel of a suitable case by means of the bushes on S1 and S2. The speaker should be glued in position over a pattern of holes or a large hole covered with speaker fabric.

The unit may be linked to the doorbell push switch (or switches) by ordinary twin "figure 8" wire or similar. □

10W AUDIO AMPLIFIER



MARK STUART

A versatile design which will accept a wide variety of inputs and provides mixing facilities

THIS AMPLIFIER was designed to be extremely versatile and useful. It provides 10 watts r.m.s. sine wave output power (20 watts PEAK) into 8 ohms and will accept a wide variety of inputs.

There are two "flat" inputs; one with 47k input impedance is for dynamic and electret microphones, guitar pick-ups and other low signal sources. The other input has a 1megohm impedance and accepts signals at standard "line" levels between 100mV and 1 volt.

Another completely independent input is provided with full disc RIAA equalisation for use with moving magnet pick-up cartridges. This channel has a separate level control from the "flat" channel and so signals from the two can be mixed without interaction to blend announcements with music for example. A master volume control allows the overall output level to be adjusted without affecting the relative levels of the two channels.

HOW IT WORKS

A block diagram of the amplifier is shown in Fig. 1. Two input sockets wired in parallel are provided on the disc input so that stereo signals will automatically be combined for mono reproduction. The mixer stage incorporates a "soft limiter" action which can be used to provide overdrive effects when used with electric guitars or to improve the intelligibility of speech from those individuals who insist on shouting into the microphone regardless of the fact that the amplifier is giving its all.

The beauty of soft limiting is that the behaviour of the amplifier under overload is smooth and controlled. In fact a degree of soft limiting adds a compression effect which improves the effective "speech power" without introducing harshness.

Soft limiting is introduced by reducing the master volume setting and increasing the flat channel input volume setting to compensate. The relative levels of these two controls affect the degree of limiting that is applied. At "normal' control settings limiting does not occur until the full power output is being delivered and the power amplifier begins to clip.

The power supply to the amplifier incorporates an i.c. voltage regulator. This component is often omitted in audio amplifier designs to keep down the cost. Its inclusion in this design gives two very worthwhile benefits. The first is that the output hum level is practically inaudible even at maximum settings of all controls. The second benefit is that the power supply transformer and rectifiers are fully protected from output short-circuit conditions. The ability to withstand abuse without problems is essential for an amplifier which will be used as a "workhorse" in a wide variety of situations.

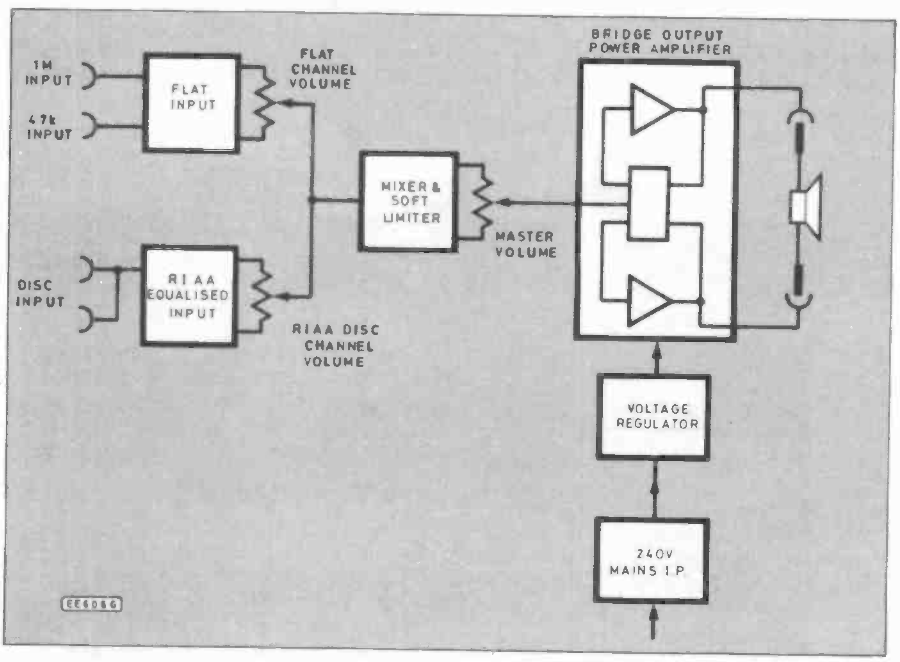


Fig. 1. Block diagram of the 10W Audio Amplifier.

POWER AMPLIFIER

The circuit of the amplifier is shown in Fig. 2. The power amplifier section appears

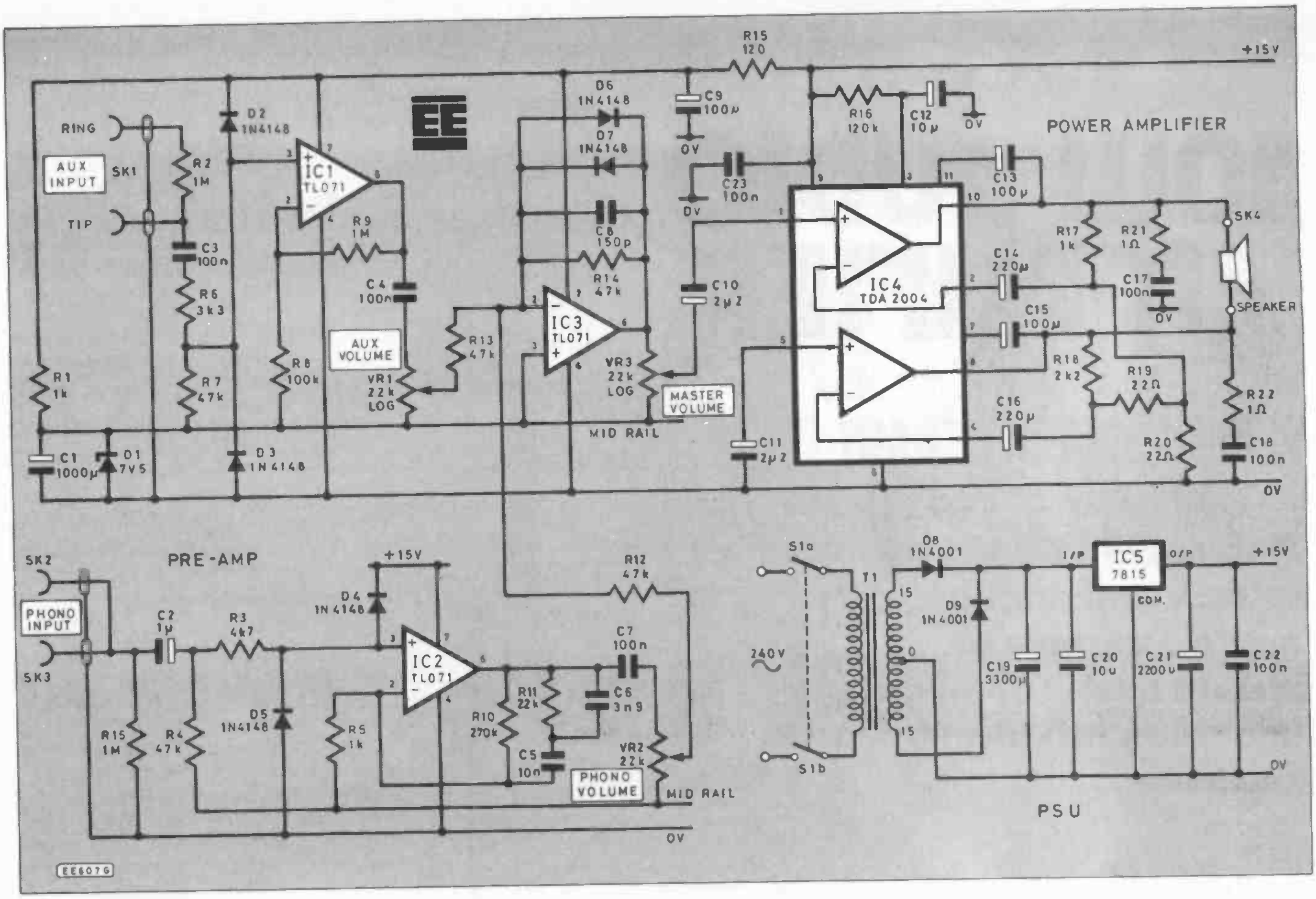


Fig. 2. Complete circuit diagram of the 10W Audio Amplifier.

very simple because all of the work is done by a single TDA2004 class B dual audio power amplifier i.c. This i.c. contains two identical power amplifier stages which have been connected in this circuit as a full bridge amplifier.

The feedback network of resistors R17, R18, R19, R20, and capacitors C14, C16 is arranged so that the output of the lower amplifier is exactly the opposite to that of the upper amplifier. The loudspeaker is connected between the two outputs so that the maximum voltage swing across it is twice that of each single stage.

At maximum output each stage can deliver 13V peak-to-peak giving 26V across the loudspeaker. With a sine wave output this corresponds to 9V r.m.s. which gives just over 10 watts into 8 ohms or 20 watts peak.

The supply to IC4 is decoupled by C23, R16 and C12. Other components around IC4 are: R21, C17, R22 and C18, which prevent high frequency instability; C13 and C15, which provide bootstrapping to increase the available output voltage swing and the input coupling capacitors C10 and C11. One big advantage of the full bridge amplifier is that the two outputs are at the same d.c. voltage and so a large output coupling capacitor is not required.

POWER SUPPLY

The power supply is based on a good quality mains transformer with separate primary and secondary bobbins; this is used to reduce mains borne interference to an absolute minimum.

A standard centre tapped transformer arrangement with two diodes (D8, D9) and a smoothing capacitor (C19) provides the rough d.c. supply which feeds the 15V regulator IC5. From IC5 the stable 15V rail is decoupled by C21 before passing to the power amplifier circuit.

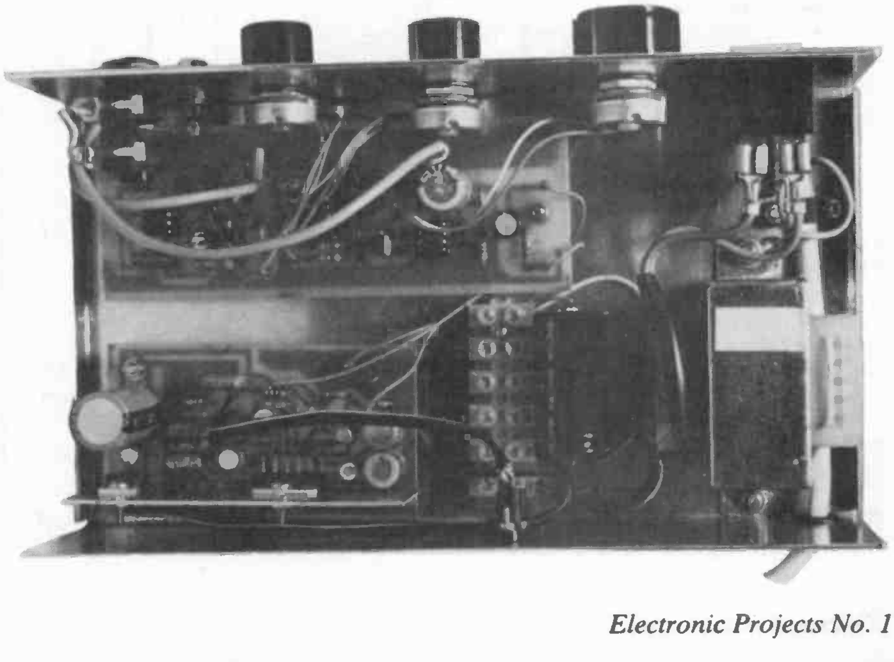
Capacitors C20 and C22 are connected close to IC5 and prevent high frequency instability due to lead inductances. The output ripple voltage from IC5 is less than 10mV even when the amplifier is delivering its full output.

PREAMPLIFIER

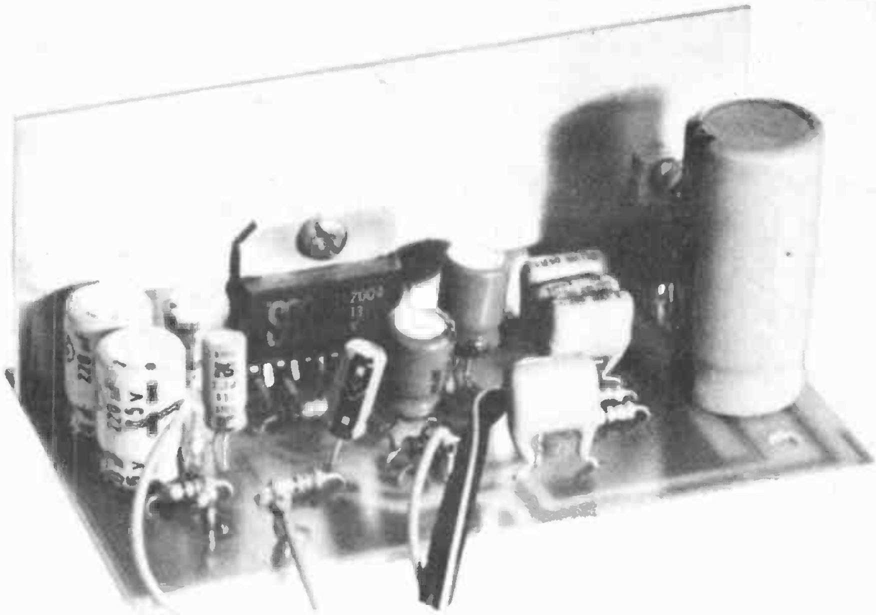
In the preamplifier section three low noise op-amps are used to provide the two input channels and mixer amplifier. The mid-rail voltage of 7·5V which is required for correct biasing of these stages is provided from the main 15V supply by resistor R1 and Zener diode D1 and decoupled by capacitor C1.

The "flat" frequency response channel gain is provided by IC1, which is configured as a non-inverting amplifier. Two input levels are obtained by means of resistors R2 and R7 which also define the input impedances.

Inputs are connected via a stereo jack socket SK1 which is wired so that the high sensitivity 47k input is connected to the plug *tip*, and the low sensitivity one megohm input is connected to the plug *ring*. The



S. MUTCH



sleeve of the jack plug is the common ground connection.

When a mono jack plug is inserted it automatically connects to the 47k high sensitivity input, which is the one required by guitars, microphones, etc. Diodes D2 and D3 along with series resistor R6 have been added to protect the amplifier from excessive input signals.

Static charges, mains pick-up, and the output signals from other amplifiers are all potential hazards to P.A. systems of this type. The combination of a series resistor to limit the current and shunt diodes which direct excess voltages safely into the supply rails should eliminate the danger from all but lightning strikes!

The output from IC1 passes to the flat channel volume control VR1 via C4. From the slider of VR1 the signal passes to the mixer amplifier stage where it is combined with the signal from the RIAA equalised phono channel.

RIAA INPUT STAGE

The RIAA disc equalising section of the circuit is built around the TL071 low-noise BI-FET op-amp IC2, see Fig. 2. It is connected in a similar arrangement to IC1 but the feedback network which consists of R5, R10, R11, C6 and C5 is calculated to give the necessary equalisation for a standard moving magnet disc pick-up.

Overload protection is provided by resistor R3 and diodes D4, D5. The output passes to the phono volume control VR2 and then on via resistor R12 to the mixer stage.

MIXER STAGE

Signals from VR1 and VR2 pass via R13 and R12 respectively to the inverting inputs of IC3, the mixer stage. Feedback around this stage is provided by R14 and C8 for low and medium level signals. At higher levels diodes D6 and D7 begin to conduct and provide progressively higher amounts of feedback as the signal level increases.

This progressive feedback gives the stage

COMPONENTS

Resistors

R1,R5,R17	1k (3 off)	R11	22k
R2,R9	1M (2 off)	R15	120
R3	4k7	R16	120k
R4,R7,R12, R13,R14	47k (5 off)	R18	2k2
R6	3k3	R19, R20	22
R8	100k	R21,R22	1
R10	270k		

Potentiometers

VR1,VR2,VR3	22k log. (3 off)

MAGENTA KIT 562

Capacitors

C1	1000µ radial elect. 16V
C2	1µ radial elec. 16V
C3,C4,C7,C17, C18,C22,C23	100n polyester (7 off)
C5	10n polyester
C6	3n9 polyester
C8	150p ceramic
C9,C13,C15	100µ radial elect. 25V (3 off)
C10,C11	2µ2 radial elect. 63V (2 off)
C12,C20	10µ radial elec. 16V (2 off)
C14,C16	220µ radial elec. 25V (2 off)
C19	3300µ or 2200µ axial elc. 35V
C21	2200µ radial elec. 16V

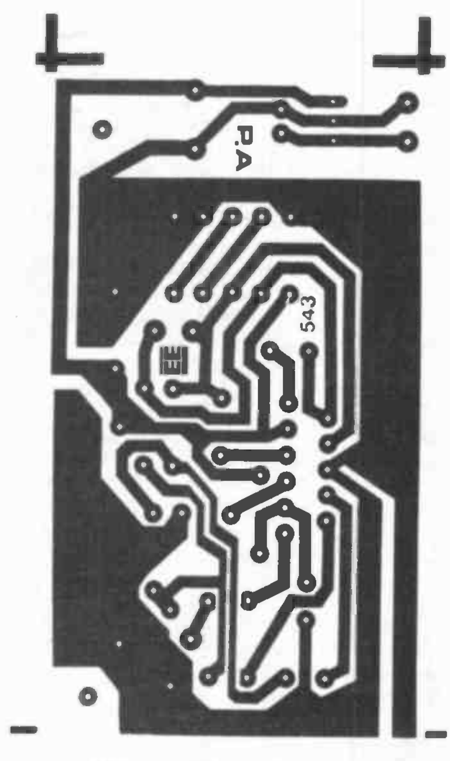
Semiconductors

IC1,IC2,IC3	TL071 low-noise BI-FET op-amp (3 off)
IC4	TDA2004 dual audio power amp
IC5	7815 +15V voltage regulator
D1	BZY88C7V5 Zener
D2-D7	IN4148 (6 off)
D8,D9	IN4001 (2 off)

Miscellaneous

T1	18V/A transformer, 240V primary, 15V-0V-15V secondary (see text)
S1	d.p.s.t. mains rocker switch
SK1	¼in stereo jack socket
SK2,SK3	metal panel mounting phono sockets (2 off)
SK4	DIN loudspeaker socket

Metal case, 230mm × 130mm × 60mm; 8-pin i.c. sockets (3 off); 6-way 2A terminal block; aluminium heatsink, approx. 102mm × 38mm; mains cable "saddle" clamp; connecting wire and soldering pins, etc.; printed circuit boards,



Main amplifier p.c.b. master.

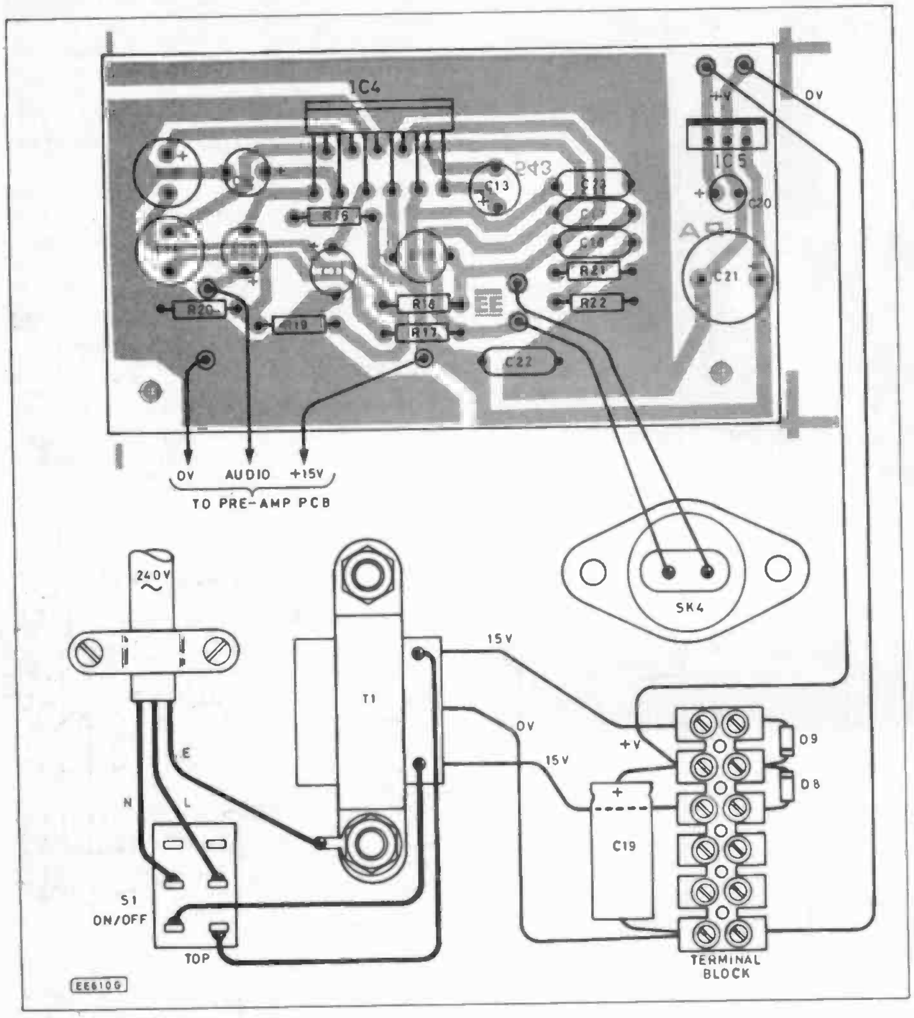
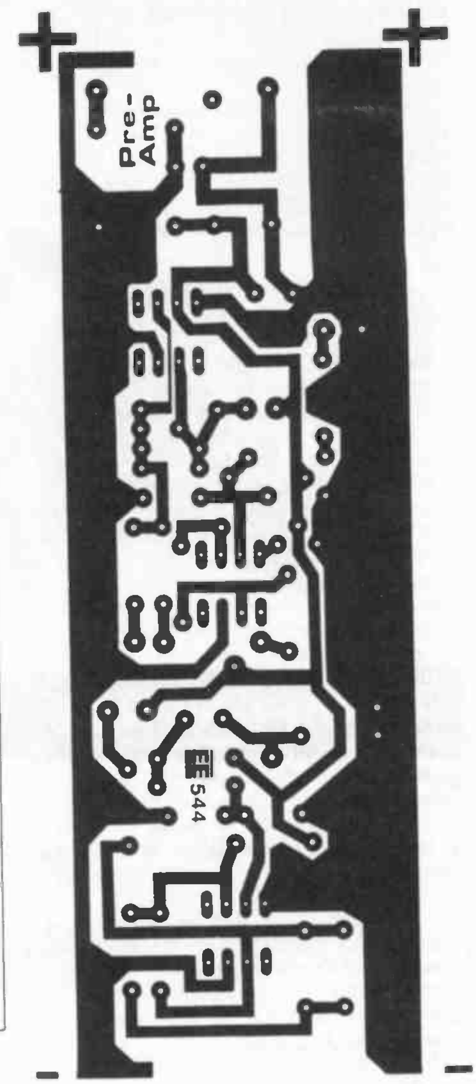
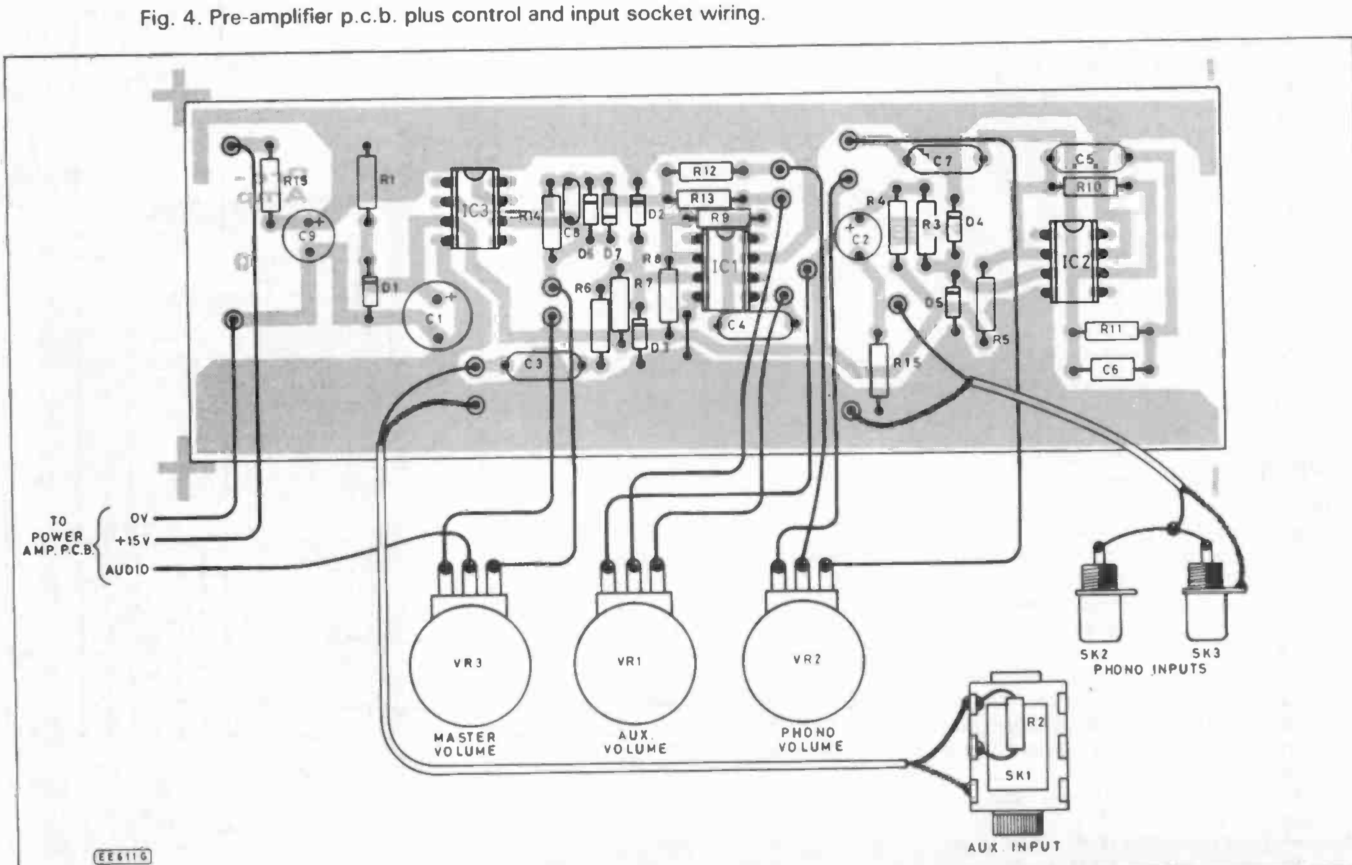


Fig. 3. Power amplifier p.c.b. and power supply component wiring.



Pre-amplifier p.c.b. master.

Fig. 4. Pre-amplifier p.c.b. plus control and input socket wiring.



the soft limiting characteristic which has been discussed earlier. Capacitor C8 gives the mixer response a gentle high frequency roll off.

The use of an inverting amplifier as a mixer stage ensures that interaction between the settings of VR1 and VR2 is completely eliminated. From the mixer stage the signal passes via the master volume control to the power amplifier.

CONSTRUCTION

Individual printed circuit boards are used for the power amplifier and the preamplifier. Figs. 3 and 4 show the printed circuit master patterns (full size) and component layout of the two boards.

Before inserting any components into the boards it is suggested that the case is drilled and the sockets, potentiometers, mains switch, mains transformer, power supply terminal block and mains cable are fitted. The printed boards can be used as templates to mark out their fixing holes and can be temporarily fitted to ensure that the layout of the components in the case is correct.

It is advised that the layout used in the prototype is adhered to as this gives the best routeing of signal wires and ensures that the mains wiring is safely separated from all other connections. The transformer recommended is one with fully insulated wire leads. This means that the mains connections can be made by insulated spade connectors to the on-off switch.

It is also essential that there is a good mains earth connection to the case for reasons of safety and to eliminate mains hum. A solder tag fitted tightly under one of the transformer mounting bolts makes the best mains earthing point.

Also important for safety is the use of a suitable grommet where the mains cable enters the case and a saddle clamp or similar device near to the switch to ensure that the mains lead cannot work loose and make dangerous contact with other parts of the circuit. ***Attention to these safety aspects is vital to the construction of all types of mains powered projects.***

To simplify the cutting of the front panel a dimensional drawing of the case specified is given in Fig. 5. The speaker output socket SK4 is fitted to the rear panel of the case.

Diodes D8 and D9 and the smoothing capacitor C19 have been deliberately kept away from the rest of the circuit and are mounted on a screw terminal block fitted to the bottom of the case. A small double-sided adhesive pad should be used to secure C19 to the case.

CIRCUIT BOARDS

Begin assembling the boards by fitting wiring pins in all of the appropriate places. The pins must be pressed into the board material from the track side so that they are a tight fit and then soldered. Considerable force may be needed to push the pins fully home, a vice or small hammer may be used (with care) if necessary.

Construction of the boards is straight forward. Observe polarity of the diodes and electrolytic capacitors and fit i.c. sockets for the three pre-amp i.c.s.

A small piece of aluminium is used as a heatsink for IC4 and IC5. This heatsink does not need insulating from either of the i.c. tabs, but it **MUST NOT** contact the

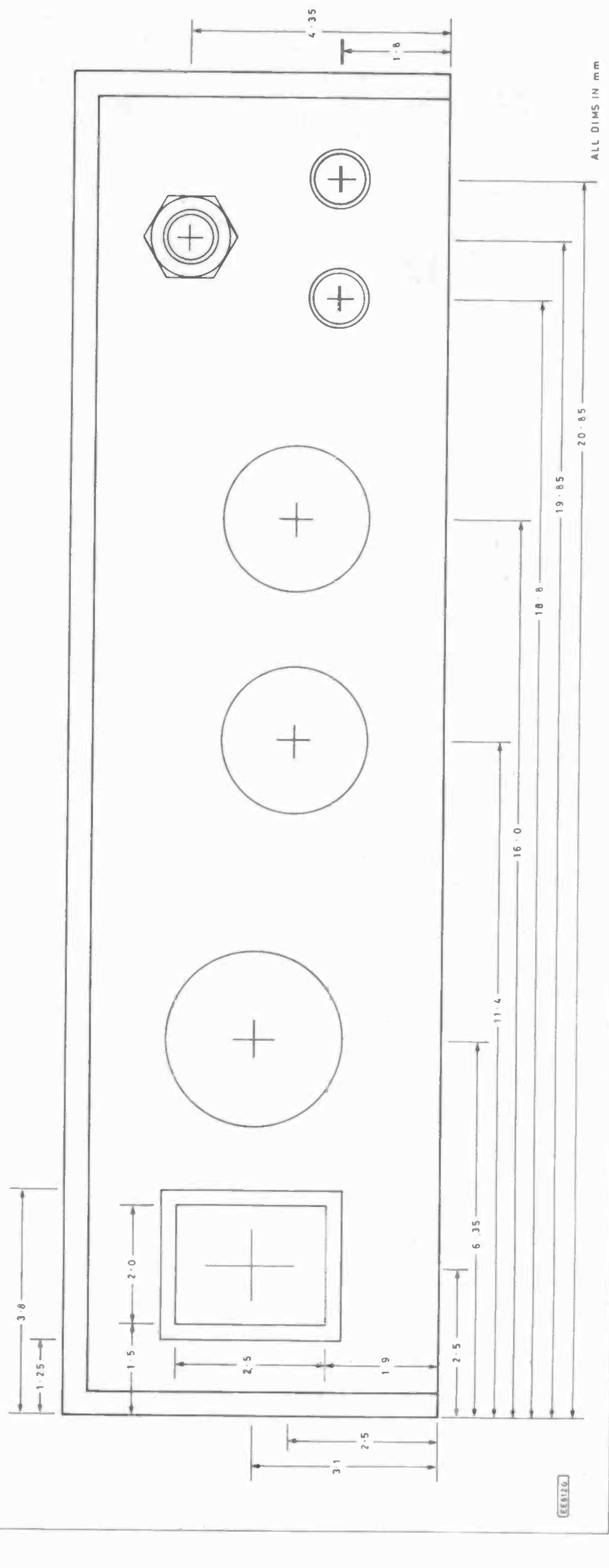
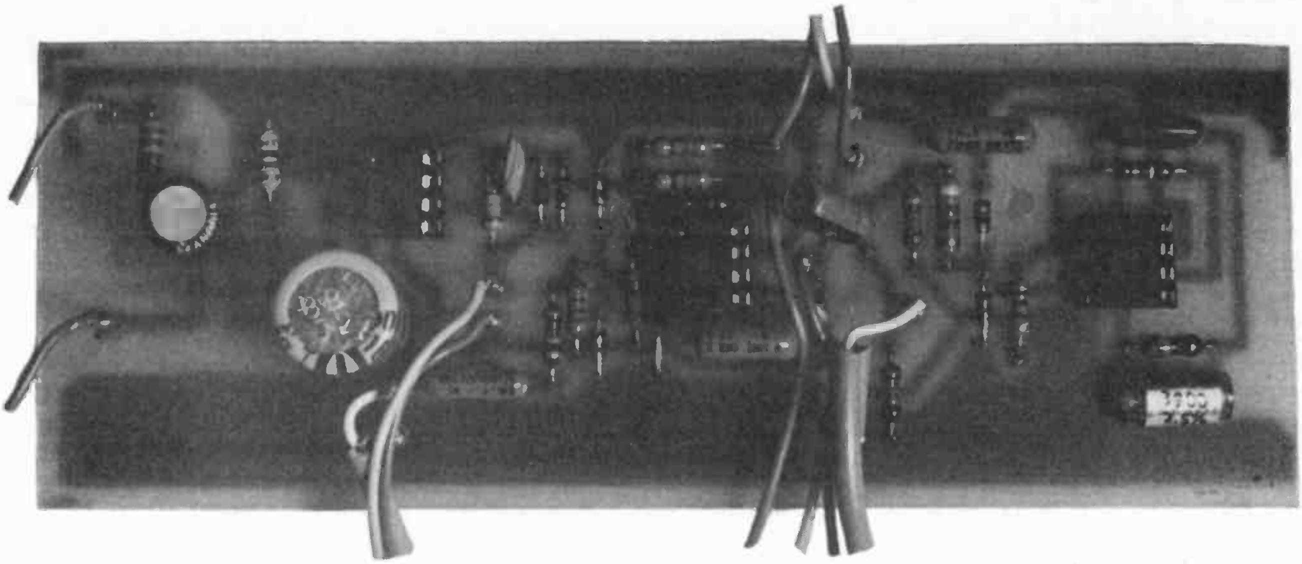


Fig. 5. Hole positions for drilling the specified case front panel.



case. The reason for this is that power supply currents flowing in the case can appear as input signals by means of so called "earth loops", resulting in severe distortion and instability.

Earth loops are completely overcome by ensuring that the power supply is connected to the case at just one point. In this amplifier a single connection is made to the case via a solder tag on the input socket SK3.

When the two boards have been assembled they can be mounted in the case ready for wiring.

WIRING

Wiring details to the boards and case mounted components are given in Figs. 3 and 4. The wiring between the pre-amp board and the three controls and input sockets should be carried out first. Use 7/0·2 or similar stranded wire and keep the three wires to each control separate from the other wires. Leave sufficient wire to enable the board to be lifted and turned over for testing.

The connections to the input sockets are made using single screened cable. Note that R2 is fitted directly on to the tags of SK1. Complete the wiring by making the connection between the two boards, and to the speaker socket and power supply.

When everything is complete check that the mains wiring is secure and well separated from the other wiring and that the power amplifier heatsink cannot touch the case. The amplifier is now complete and ready for testing.

TESTING

To test the amplifier it is necessary to have the power connected whilst the case lid is removed. Provided the mains connections have all been carefully insulated this should be possible with complete safety. Before applying power look over the mains wiring and ensure that there are no bare connections.

Begin testing by using an ohmmeter to check for continuity between the mains lead, earth wire and the case. Next, disconnect the positive supply wire (+V) from the power supply terminal block, and switch on the amplifier. Check that the voltage across capacitor C19 is about 28V and of the correct polarity. Switch off again and discharge C19 using a resistor (between 100 ohms and 1k).

If a multimeter with a current range of 250mA or greater is available connect this between the positive terminal of C19 and the +V wire to the power amplifier. Switch on and check that after an initial surge the current steadies at between 80mA and 120mA.

A higher current reading indicates possible reversed capacitors or diodes or faulty wiring. In this event the best policy is a thorough check of everything. The use of an i.c. voltage regulator (IC5) means that the fault current will be limited automatically and so damage is unlikely to occur even if a fault is present.

When the current reading is correct take the meter out of circuit and reconnect the +V wire directly to the power supply terminal block. A set of voltage checks can now be made and will reveal any obvious errors.

All voltages should be measured with respect to the negative supply rail (case) and be within 0·5V of the value given. First check that the output of IC5 is delivering 15V. The two terminals of the speaker socket should both be at half supply (7·5V).

Next check that the pre-amp board mid-rail voltage on the cathode of D1 is 7·5V. The same voltage should appear on pin 6 of all three pre-amp i.c.s. If all the voltages are correct it is likely that the whole circuit is functioning correctly and all that remains is to do a few audio signal tests.

The simplest audio signal test is to connect a speaker, turn up all three controls to mid setting and touch each input terminal in turn. There should be the familiar loud mains buzz, adjustable in volume by the appropriate controls. The RIAA equalised channel should give a deeper sounding buzz because of the built-in low frequency emphasis.

If all of these tests are satisfactory, switch off, fit the case lid and try using a few appropriate audio signal sources. The effect of the soft limiter is brought in by turning up the input control and turning down the master volume control. Using an electric guitar as a source it should be possible to get a smooth overdrive and sustain effect.

For use with sources where soft limiting is not required use lower settings of the input controls and turn up the master control to compensate. A few minutes experimenting will show how controllable the effect is and how it can be eliminated completely if required.

VARIATIONS

Although the amplifier as it stands can cope with most input signals, by changing a few component values its gain can be changed to suit other applications.

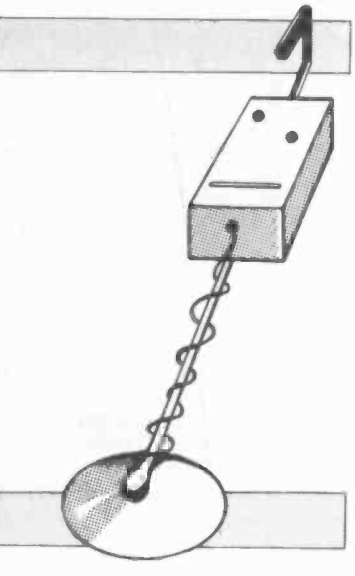
The soft limiting effect can be eliminated completely by removing diodes D6 and D7 and the overall gain of the mixer stage can be increased by increasing the value of resistor R14. A value of 470k will give a ten fold increase in gain.

Similarly the gain of the "flat" channel amplifier IC1 can be increased by reducing the value of resistor R8. A 10k resistor will give a ten fold increase in gain. Changing the values the other way will give gain reductions.

The input impedances of the "flat" channel are set by resistors R7 and R2. These may be changed to anything between zero and 2M2 without altering the gain of IC1. The value of resistor R6 will need to be reduced, if very low (below 4k7) input impedances are required, the potential divider effect of R2 and R7 must be taken into account when the input is connected via R2. There is plenty of room for experiment with these values for specific applications without any problems of stability or noise, so the user is encouraged to make what adjustments seem desirable.

No matter what the final use is, the amplifier will soon become an indispensible piece of equipment, much sought after by friends. So take good care of it! □

E.E. BUCCANEER INDUCTION BALANCE METAL DETECTOR



ANDY FLIND

An induction balance metal detector. Providing good sensitivity with ease of use and construction

ALTHOUGH the "boom" passed a few years ago, metal detecting remains a popular hobby, with some tens of thousands of enthusiasts in Britain alone. At least one magazine is devoted to the pastime, and many areas have clubs which organize outings and rallies. for most users the enjoyment lies in the interest of their finds, though the odd spectacular discovery still occasionally makes the headlines.

In 1987 a hoard of ancient Church treasures valued at £5 million was unearthed. Good metal detectors are expensive however, even a simple one is far from cheap and may not be very satisfactory to use. Luckily, it's not too difficult to build a detector effective enough for serious use; both the interest of construction and the saving in cost can be considerable.

TYPE

Of the many types of metal detector, the best known are Beat Frequency Operation, Pulse Induction, and Induction Balance. The first, though simple, is rather insensitive and now practically obsolete. The second can be extremely powerful and has the advantage (for amateur constructors) of simple coil construction. However, it is very sensitive to the minute scraps of iron found on many sites, making it tedious to use. The third, I.B. for short, has many different forms. Complicated (and expensive) models can reject iron, foil and false signals caused by the ground whilst some can almost distinguish what has been detected. Simpler versions cannot do all these things, but it is still possible to obtain good sensitivity whilst rejecting iron.

BLOCK DIAGRAM

The block diagram of such a detector is shown in Fig. 1. The "search head" contains two coils. One of these, the transmitter or "Tx" coil, is driven by an oscillator, setting up an alternating magnetic field. The receiving or "Rx" coil is positioned so that it partially overlaps the Tx. By adjusting the amount of overlap a point can be found where the voltages induced in the Rx coil "null", or cancel out so that little or no electrical output is produced. A metal object entering the field causes an imbalance, resulting in a signal.

In a simple I.B. circuit the rise in amplitude is used to signal the metal's presence, so the following stages consist of amplification, accurate conversion to "peak value" (a d.c. signal), further amplification, and a means of presenting the final output as an audible tone of increasing volume. An adjustable d.c. offset control is used to adjust the initial sound threshold, this being known as "tuning".

SENSITIVITY

In this type of circuit more sensitivity is obtained if the coils are, in fact, slightly offset from null. If this offset is in the direction of "too far apart", iron and other permeable objects cause an initial reduction in amplitude, whilst conductive ones produce an immediate rise. In this way some iron rejection can be built in.

Simple detectors are notorious for great sensitivity to foil, or silver paper, because they often use fairly high search frequencies, where large "skin effect" currents are induced in the foil. The low search frequency used by the Buccaneer, around 20kHz, helps to reduce this problem to some extent.

CIRCUIT DESCRIPTION

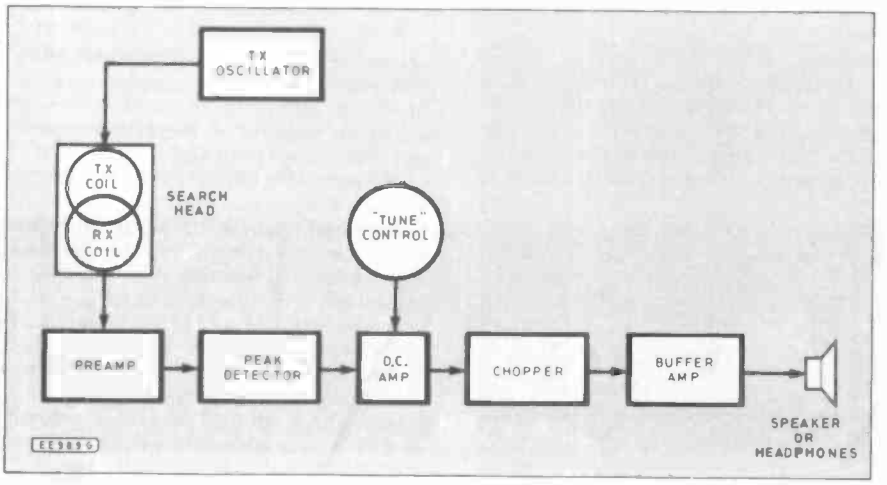
The full circuit diagram of the *EE* Buccaneer appears in Fig. 2. The oscillator, based on IC1 and transistors TR1 and TR2, may appear a little strange. It is required to produce a reasonable amount of transmitted power with moderate battery consumption, whilst being very stable with varying temperature. The transistors supply the power, being driven into saturation they provide a squarewave drive of almost rail-to-rail amplitude. R6 controls the power sent to the coil.

Impedance matching for the best possible efficiency from the resonant coil circuit is achieved by tapping the capacitance instead of the coil, as this simplifies coil construction. Feedback is sensed by IC1 which drives the transistors. Finally, again for efficiency, the coil is wound with thicker (28 s.w.g.) wire than usual to obtain a good "Q" factor.

Moving to the receiving section, this again begins with a tuned coil, set to the same frequency as the transmitter. At first sight it would seem that a high "Q" factor here would also improve the sensitivity but in practice, it was found difficult to tune the two circuits accurately enough and the resulting detector was badly affected by signals from the ground ("ground effect"). The Rx coil is therefore damped a little by R7 to increase the bandwidth, and the drop in amplitude is made good by gain from TR3.

The circuit must now detect the peak value of the amplified signal and convert

Fig. 1. Block diagram of the induction balance metal detector.



this to a d.c. level. This cannot be done with a simple diode as changes in temperature would cause constant, annoying drift; overcoming this leads, as can be seen, to some complexity. The circuit is best explained with the help of the simplified drawing Fig. 3.

The maximum positive voltage reaching TR1 base consists of the reference voltage plus the peak positive value of the signal from C1. If this exceeds the voltage at TR2 base (from C2), TR1 will conduct, in doing so it will turn on TR3 which will raise C2's voltage until it matches the input. So long as transistors TR1 and TR2 are similar in type and closely coupled thermally, the effects of temperature on their base-emitter junctions will cancel, having no effect on the output. Their emitters should be fed by a current source, shown here as a simple resistor.

TRANSISTOR ARRAY

In the complete circuit, all the *npn* transistors in this section are contained in a CA3046 integrated array. The numbers refer to the pins on the chip, which contains the emitter-coupled pair TR4 and TR5, ideal for this application, plus three extra transistors. Two, TR8 and TR9, are configured as a current source for the emitters, whilst the third is amplifier TR3. Because the operating conditions of TR4 and TR5 should be closely matched, and TR4 is "off" most of the time, TR6 has been added to take most of the current-carrying work away from TR5.

The input is applied through C11, the adjustable reference is supplied by VR1 and VR2, respectively "coarse" and "fine" tuning controls, and the output appears as a

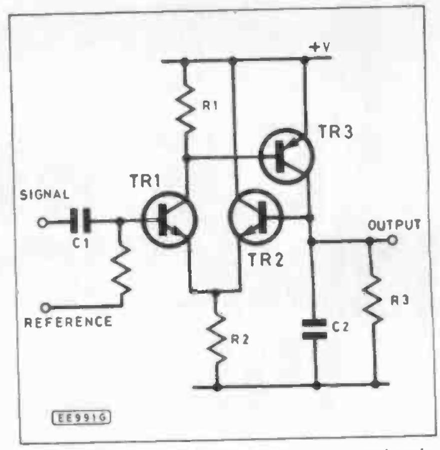


Fig. 3. The simplified peak detector circuit.

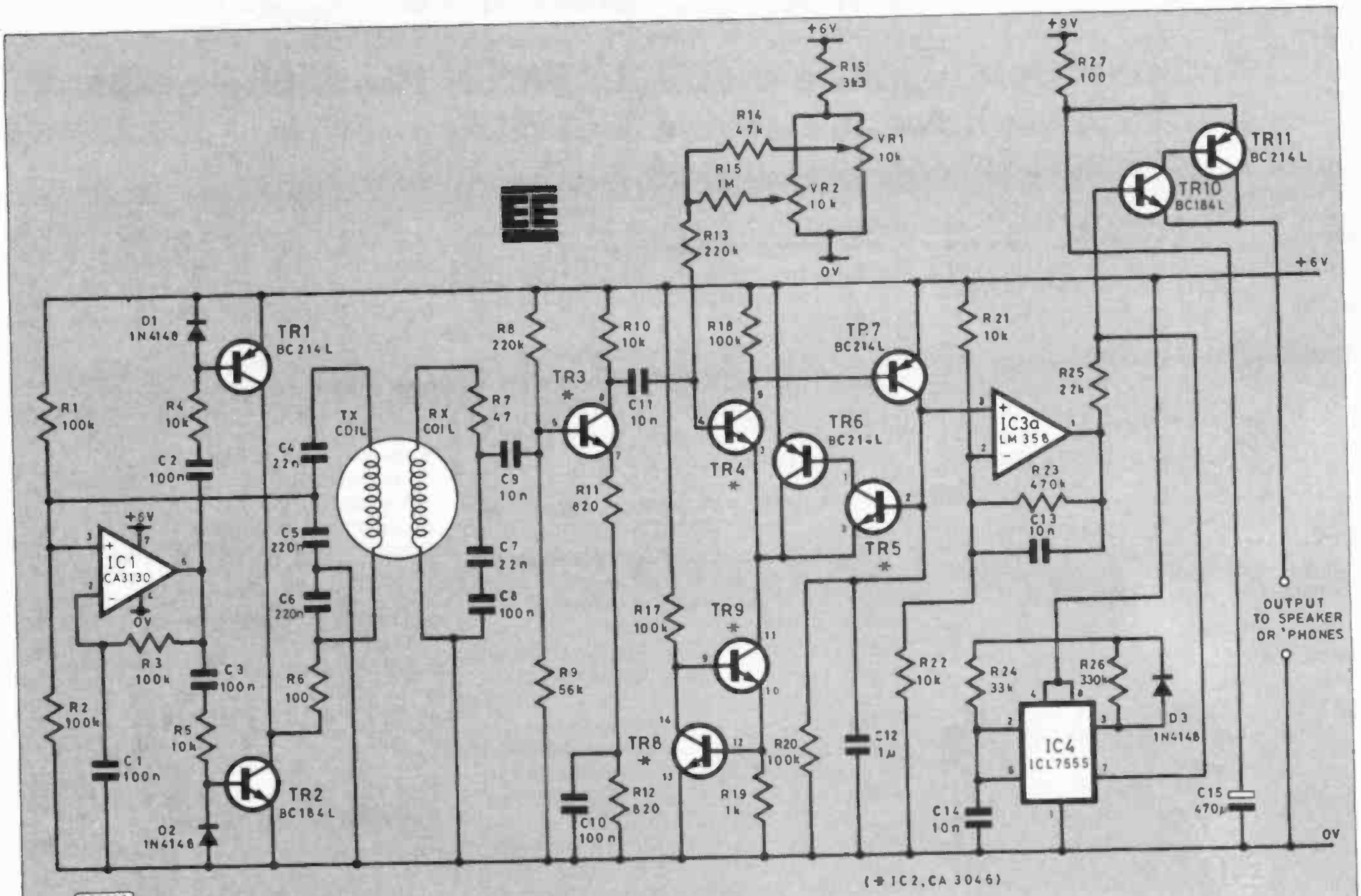
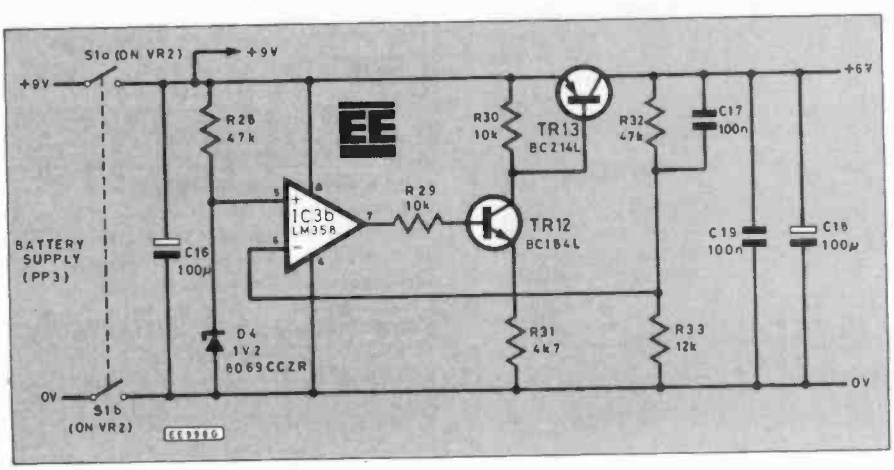
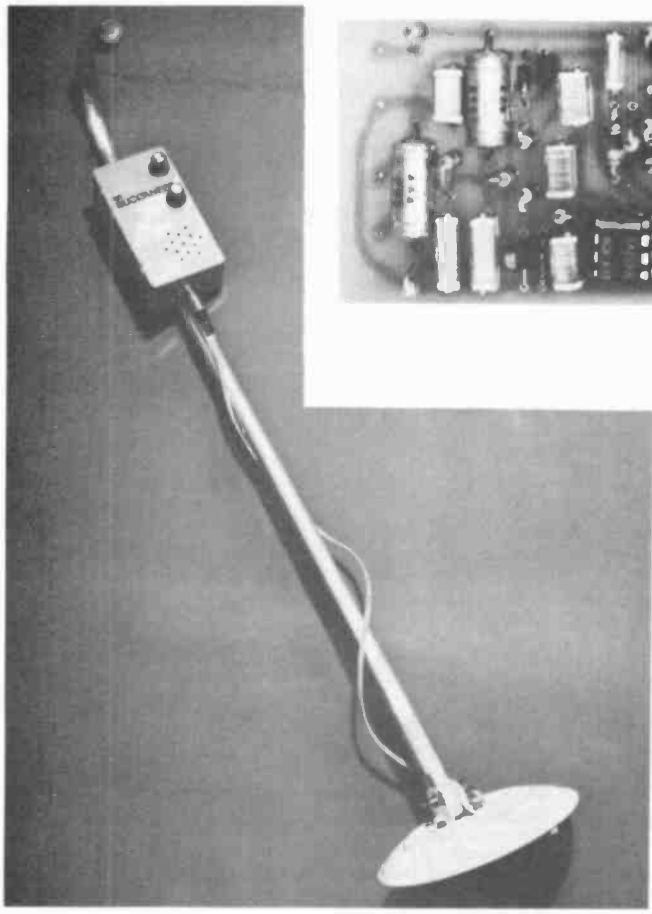


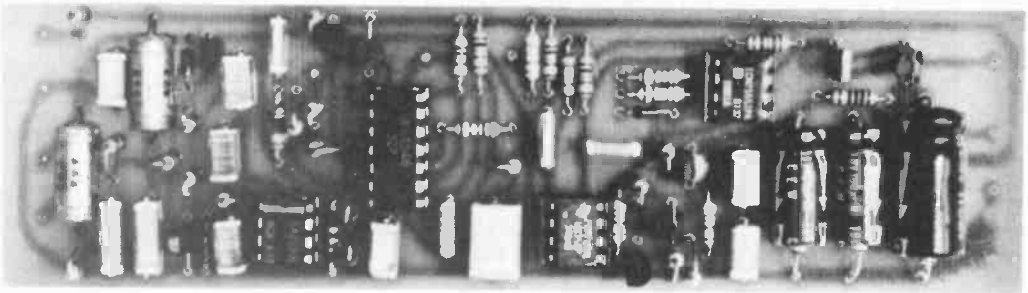
Fig. 2. Complete circuit diagram for the *EE* Buccaneer Metal Detector. The power supply section is shown below.



voltage on C12. The stability obtained with this admittedly rather complex arrangement has proved quite outstanding, enabling the detector to outperform almost any other design of its type.

The remaining circuitry is quite straightforward. IC3a provides d.c. gain, the output being initially set (by VR1 and VR2) just above zero, and rising to nearly six volts on a strong signal. It is necessary only to chop it up and buffer it to make it audible. Chopping is done by IC4, a 7555 low-power timer connected as an oscillator. Pin 7 of this chip is the output of the transistor intended for discharging the timing capacitor, this being switched on when the "output" (pin three) is low. Here it is used to pull the voltage from R25 low.





Component layout on the completed printed circuit board.

(Left) The completed metal detector showing the control box and the search coil arrangement.

Small speakers produce the most efficient loud noises when fed with short pulses, so the mark-space ratio of IC4 is arranged to convert the output into this form. Transistors TR10 and TR11 do the buffering, after which the output will drive speaker or headphones.

SUPPLY

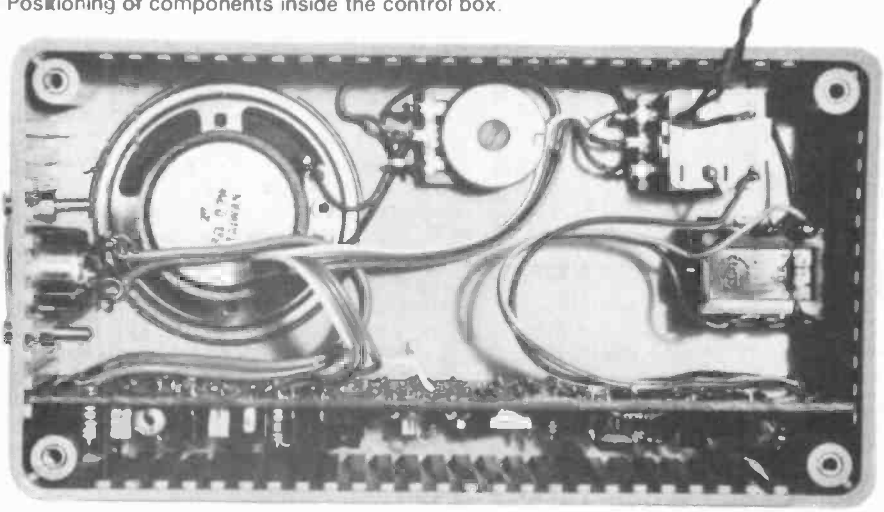
For good stability a well regulated supply is essential. With only nine volts to start with, dropping below seven as the battery ages, the two volts differential required by most integrated regulators is unacceptable so the supply circuit shown was developed. This uses a 1·2V bandgap reference. IC3b compares this with a divided portion of the output from TR13, intended to be six volts, and drives the transistors as necessary. This circuit works with a differential, or "drop-out" down to 0·1V

CONSTRUCTION

Board construction for this project is straightforward providing some simple precautions are observed. Firstly, since the layout is fairly compact, a fine-tipped iron and reasonable soldering skill are required. The polycarbonate capacitors are the compact layer type supplied as "poly layer". C4 and C7 are both one per cent tolerance, this being important for matching the tuned circuits. Transistors TR2 and TR6 emitter leads are bent to clear underlying tracks on the board, do this carefully before fitting them.

The bandgap device D4 may be supplied in a three-lead package identical to the transistors, or a slightly smaller two-lead version. The latter can be fitted using the lower two holes in the p.c.b., with the flat on the same side as before. Use sockets for all four integrated circuits as this simplifies testing and, where necessary, trouble shooting. It also provides protection for IC4, a rather static-sensitive device in the author's experience. The printed circuit board component layout is shown in Fig. 4 and the p.c.b. track pattern in Fig. 5. The board construction should be completed, but at this stage none of the i.c.'s should be plugged in as this will be done during testing.

Positioning of components inside the control box.



CONTROL BOX

Before testing the board, the control box should be assembled as it will be found useful for much of the test procedure. As clearances in the box are small, precise drilling details are given in Fig. 6 to ensure it all fits. The speaker "grille" is a pattern of holes, there being scope for some personal artistry here! Assembly consists of fitting sockets, pots VR1 and VR2, and gluing the speaker into place. An impact adhesive such as "Evostick" is suitable for this purpose. Wiring is shown in Fig. 7.

The headphone socket connections face outwards, with the volume reducing resistor soldered to them so that it can be easily selected to suit the 'phones to be used. Its value will have to be found by experiment, a suggested starting point is around 200 to 300 ohms. A switched socket is required to turn off the speaker when 'phones are in use. It doesn't matter if they're connected in series or parallel, but there should be no possibility of short-circuiting the output as the plug is inserted and removed, as this can cause output transistor destruction. Socket wiring details shown in Fig. 8 are for the most common types. Connect the controls and the switch to the board, but leave the other connections for the time being.

TESTING

About the worst misfortune that can befall a constructor testing a new project is that some drastic fault causes heavy current drain and damages expensive components. A current limiter of some kind can prevent this. It may be that a limited bench supply is available but, if not, a few pence invested in the simple device shown in Fig. 9 is well worth while. This is placed in series with the positive supply and will normally have very little effect, but if a fault is present, it will limit the current to about 25 milliamps.

Most of the circuit can be checked out as follows. With just controls and switch wired to the board, apply power through the limiter. Monitor the current taken with a meter. After an initial surge as electrolytics charge, the drain should drop to a very low value, about 0·2mA. Switch off, plug in IC3, and try again. This time the current should settle to about 1·8mA. Check the voltage across C18, which should be close to six volts as the regulator is now working.

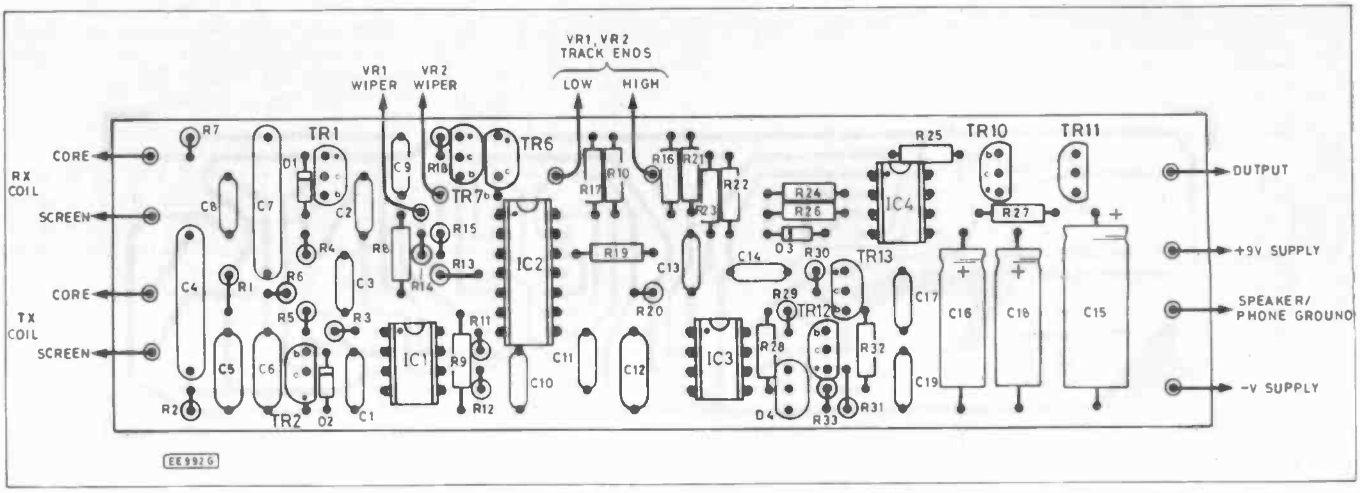


Fig. 4. Component layout on the printed circuit board.

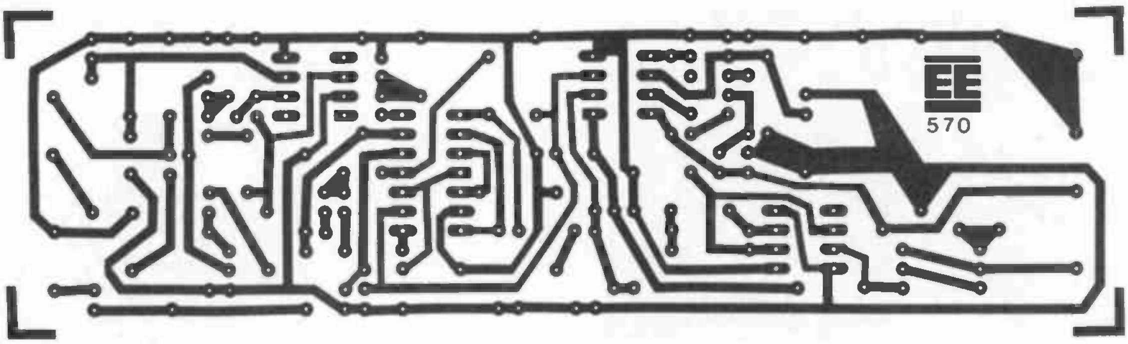


Fig. 5. Full size printed circuit board foil master pattern.

COMPONENTS

Resistors

R1,R2,R3,R17,R18, R20	100k (6 off)	R15	1M
R4,R5,R10,R21,R22, R29,R30	10k (7 off)	R16	3k3
R6,R27	100 (2 off)	R19	1k
R7	47	R23	470k
R8,R13	220k (2 off)	R24	33k
R9	56k	R25	22k
R11,R12	820 (2 off)	R26	330k
R14,R28,R32	47k (2 off)	R31	4k7
		R33	12k

All 0.6 watt 1% type

Potentiometers

VR1	10k lin. carbon
VR2	10k lin. carbon with switch

Capacitors

C1,C2,C3,C8,C10, C17,C19	100n polyester layer (7 off)
C4,C7	22n 1% polystyrene (2 off)
C5,C6	220n polyester layer (2 off)
C9,C11,C13,C14	10n polyester layer (4 off)
C12	1µ polyester layer
C15	470µ axial elect. 10V
C16,C18	100µ axial elect. 10V (2 off)

Semiconductors

IC1	CA3130 C-MOS op-amp
IC2	CA3046 transistor array
IC3	LM358 dual op-amp
IC4	ICM7555 C-MOS 555 timer
TR1,TR6,TR7,TR11, TR13	BC214L silicon *pnp* (5 off)
TR2,TR10,TR12	BC184L silicon *npn* (3 off)
D1,D2,D3	IN4148 silicon diode (3 off)
D4	8069CCZR 1·2 volt Voltage Reference

Miscellaneous

Printed circuit board, d.i.l. sockets 8-pin (3 off); d.i.l. socket 14-pin; case, ABS box 150×80×50mm; control knobs (2 off); PP3 battery container with clip; DIN plug and chassis socket, 5-pin 240 degree; switched stereo jack socket; 8 ohm loudspeaker, 50mm diameter; 28 s.w.g. (0.375mm) enamelled copper wire; 2 metres twin individually screened cable; hardware; plastic plate, plastic bracket, PTFE tape, cooking foil, fibreglass repair kit, tubing for handle etc., see text.

MAGENTA KIT 719

Plug in IC2 (with power off; always switch off when working on the board) and check that drain rises to two or three milliamps. Check the voltage across C12, the 1µ polyester. This should be variable from zero to about four volts with the setting of coarse control VR1. If so, check the voltage on pin seven of IC4's socket which should rise sharply from zero to within a volt or so of main supply at some point on VR1's range. If all seems well, connect the speaker, fit IC4 and switch on again, this time without the current limiter.

Adjustment of VR1 should turn a loud tone on and off. Try making it just audible, using both controls. At this point, place a finger on the Rx coil input connection; this should increase the volume, due to injection of stray a.c. pickup from mains wiring etc. Everything bar the oscillator, which needs the Tx coil, has now been tested so fit IC1 and complete connections to the box. When the coils are connected the complete circuit will draw around 12 to 14 milliamps, plus whatever is required to generate the sound when an object is detected.

SEARCH HEAD

Search head construction is next. Although this can be built in many ways, the method to be described has served well for several designs, producing a neat, pivoting waterproof head. The one slight disadvantage is weight, due to the resin used. The hardware consists of a rigid melamine plastic plate (flexible types are not suitable) 190mm in diameter. The prototype used a brand called "Style", the best place to find these plates being caravan equipment stockists.

The inside of the plate should be roughened with emery paper so that resin will stick firmly to it. To the plate is screwed a pair of L-shaped plastic brackets, cut from a fixing intended for square section rainwater "downspouting". This can be obtained from builders' merchants; whilst there buy a reel of PTFE plumbers' jointing tape. The stem fits between the brackets and is held by a threaded rod with a wingnut at each end, allowing the head to be tilted to the required angle and tightened by the user. A hole is drilled to allow entry of the "figure of eight" screened twin cable to the coils.

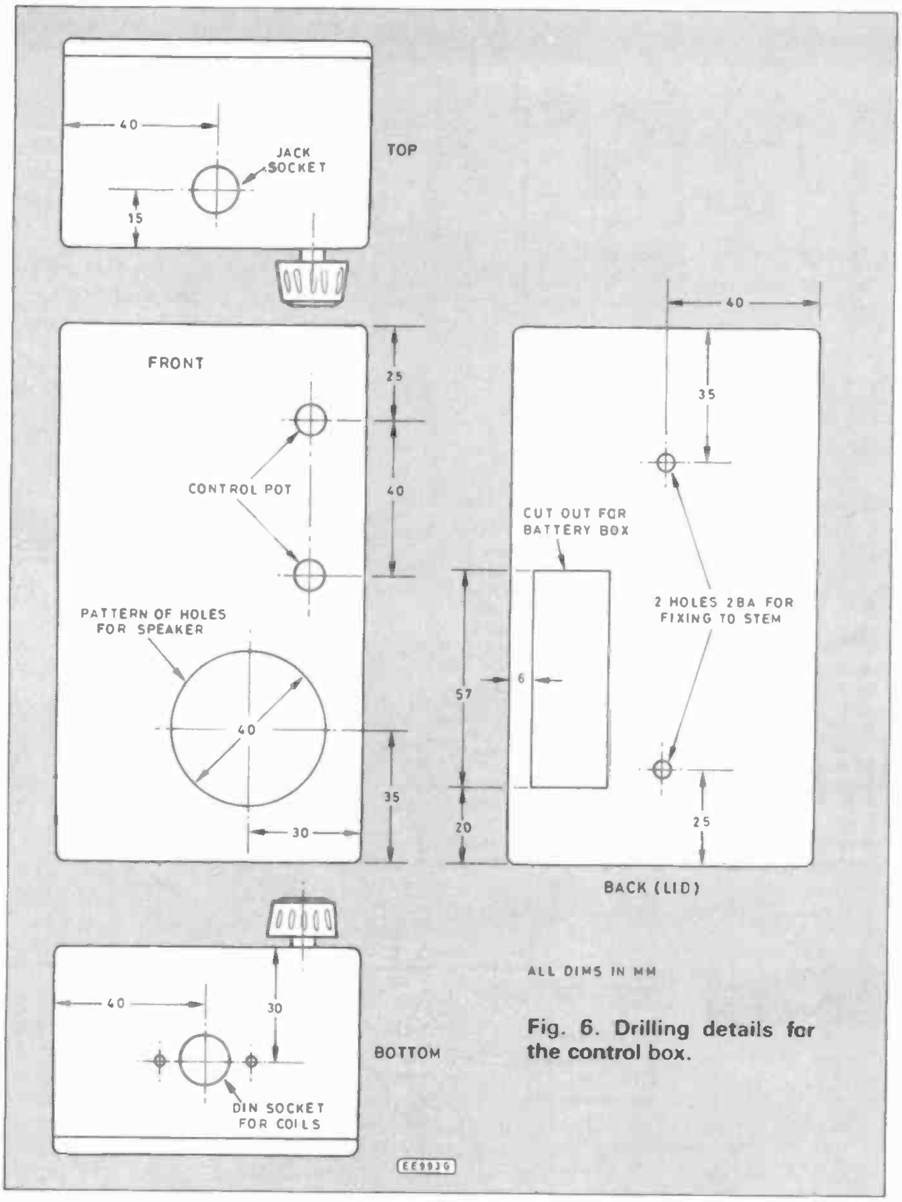


Fig. 6. Drilling details for the control box.

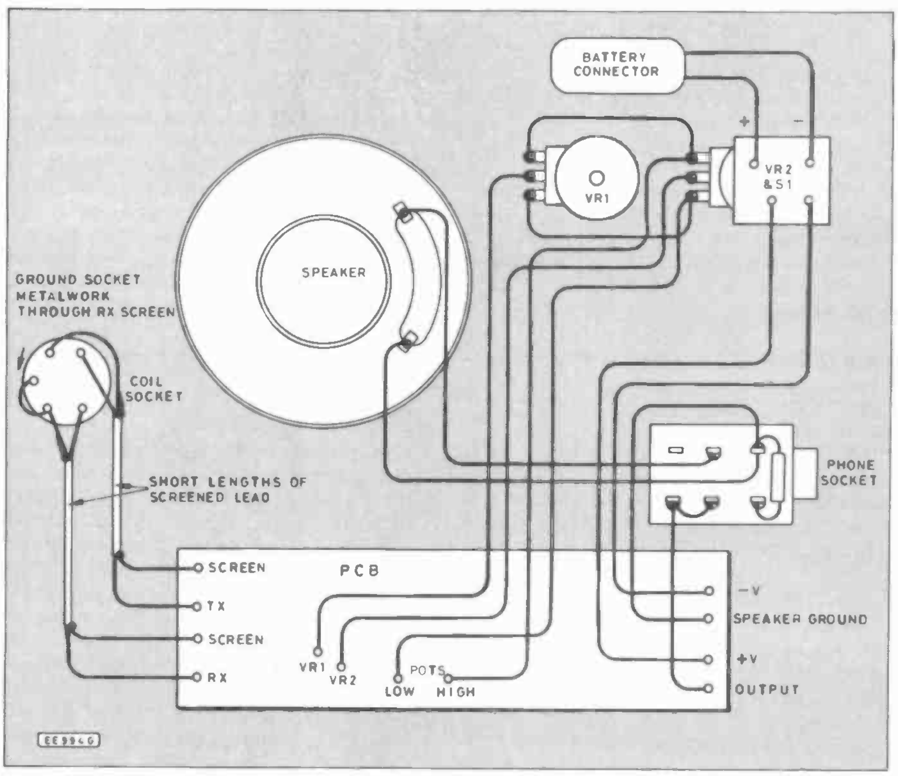
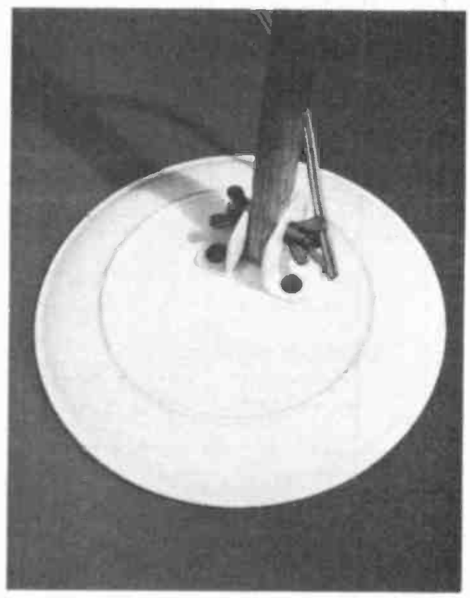


Fig. 7. Interwiring details for the off-board components mounted inside the control box.



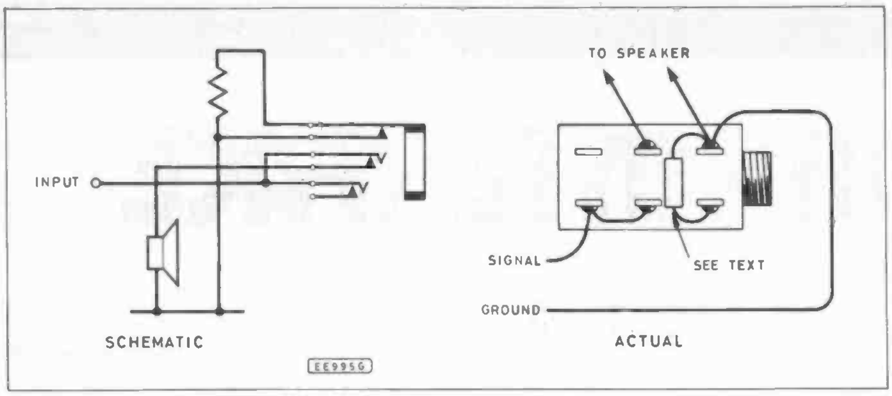


Fig. 8. Headphone socket circuit and wiring arrangement.

Coil warning starts with a sheet of paper taped to a soft board. A 110mm diameter circle is marked out and pins stuck around it at five to ten millimetre intervals, sloping outwards slightly. 100 turns of 28s.w.g. enamelled copper wire are wound around the circle (don't use a different gauge as performance may be affected). Winding is easier if the wire is first passed through the tube from a ballpoint pen, it can then be "written" into place. The wound coil is secured with temporary twists of wire and removed from the board. A binding of PTFE tape is applied, the wire ties being removed in the process. Bunching of the wire may prove a slight problem as "full circle" is approached, an initial looser binding of PTFE will help here. PTFE is used as it's impervious to the resin used later for potting. The coil can now be bent into something approaching its final shape, a sort of lopsided oval as shown in Fig. 10.

With the coil tightly bound and insulated, a "Faraday" electrostatic shield is added. Thin, stranded hookup wire is stripped to a length of about three inches, the strands are then divided into two and wound around the coil in each direction starting near the connections. This provides a sound connection to the cooking foil which is now cut into 10mm wide strips and wrapped around the coil. A gap of about 10mm is left at some point to prevent the shield forming a closed turn around the circumference of the coil. Finally, the coil is again bound and insulated with more PTFE. The two coils are identical, the second being made in exactly the same way.

SETTING UP THE HEAD

"Fastglas" resin is used to pot the coils into the head. Motoring accessory shops can supply a small kit containing resin, hardener, a measuring beaker and glass matting. A brush and cellulose thinners to clean it with are also needed. The approximate coil process should proceed in several stages, fixing a little more of the coils at each step, mixing about 30cc of resin at a time.

If the coil is potted in solid resin it will be very heavy, so the larger gaps should be filled with something light and bulky. Expanded polystyrene cannot be used as alas, resin attacks it. In the past the author has used soft Balsa wood, but corrugated cardboard was tried for this design and appears just as effective. A covering of the glass matting is applied with the final coat of resin for a neat, tough finish.

The stem may be wood, plastic pipe, or metal. Aluminium tubing is best, and can be bent to shape with a pipe-bending tool or possibly a bending spring. Copper tubing would probably be as good, though heavier. If a metal stem is used, the last 150mm or so should be made from wood dowel glued to the tubing with Araldite, to prevent the metal being placed hard against the most sensitive area of the head. As a finishing touch, a bicycle handlebar grip makes a neat handle.

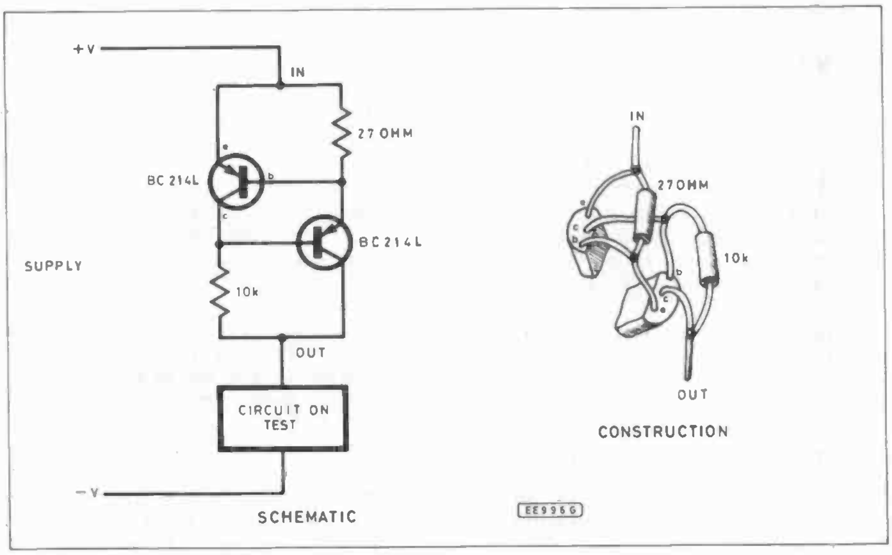


Fig. 9. Test circuit for current limiter.

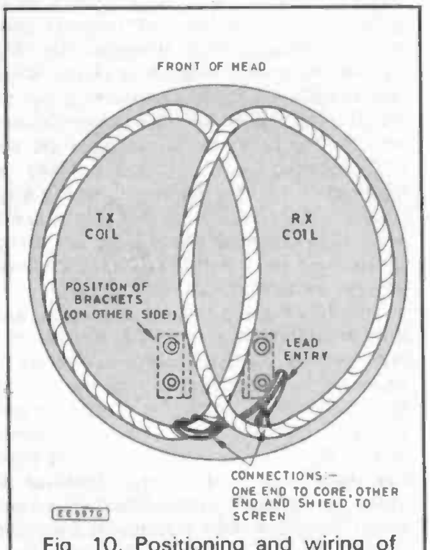


Fig. 10. Positioning and wiring of coils in the search head.

positions can be seen from Fig. 10. They should be connected by their lead to the circuit, with a meter arranged to read the voltage across C12. The sound can be silenced either by disconnecting the speaker or by inserting a spare plug into the headphone socket. VR1 should be turned right down. If the overlap of the coils is adjusted very carefully, a point will be found where the meter dips very sharply. This is the "null", or balance point, close to the final coil position. The coils should be clamped here, clothes pegs are useful for this, whilst their outer edges are fixed in place with some resin.

When the resin has set the pegs can be removed, and the central parts of the coils carefully adjusted to find the position giving lowest output. If the meter falls to zero, an adjustment of VR1 will cause it to read again. This should all be done well away from any metal of course, save for the screws in the assembly itself. When the lowest output has been found, move the coils in the direction of "too far apart" until the voltage on C12 has risen by about half a volt; this will give the detector greater sensitivity and enable it to reject most iron. Having set the coils to the correct point they can be fixed with more resin. In practice the

IN USE

Detectors of this type are capable of surprising results. Simple, rapid operation means that on many sites users may find as much as those with powerful discriminators, since most buried objects are not, in fact at very great depths. As a guide to sensitivity, "in air" the prototype will just detect a 2p coin at about 200mm, by 150mm the signal is clear, and at 100mm it's really singing out. These figures will not apply "in the ground", where depth will depend largely upon the mineralisation present. On many sites false signals will be caused by "ground effect".

Most inland areas, especially those where man's presence has been concentrated, contain ferrous particles which cause a negative response with this detector. Salt-wet beaches are conductive and will usually produce a positive output. Good detecting consists of keeping the tuning adjusted as near the threshold as possible, holding the head at a constant height *close* to the ground, and searching slowly and methodically. Finally, most really successful treasure hunters engage in a lot of research before they venture out, studying old newspaper reports, ancient tithe maps and the like at their local libraries.

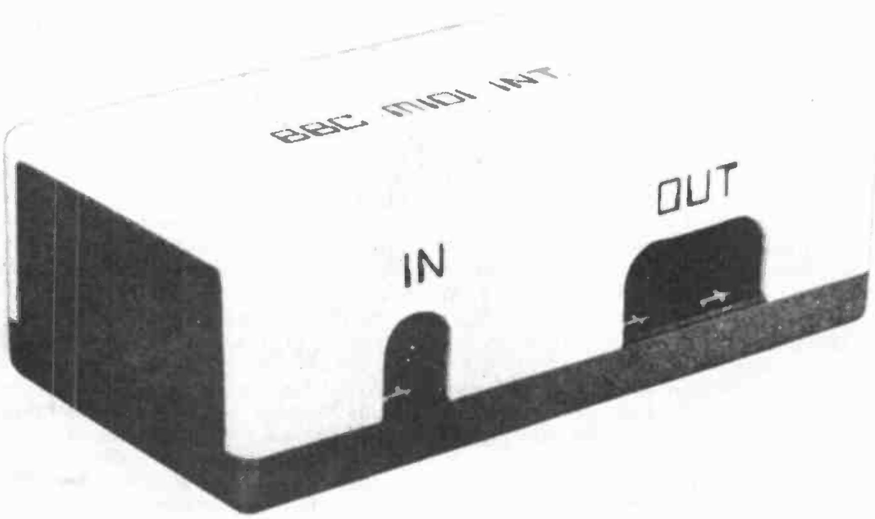
BBC MIDI INTERFACE

R.A.PENFOLD

This Musical Instruments Digital Interface will link a BBC Micro to a keyboard or synthesiser

MIDI is a term which will probably be familiar to any readers who have an interest in electronic music making, and it is a form of interface which is appearing on an increasing range of instruments from portable keyboards to expensive synthesisers. For the record, MIDI stands for "Musical Instruments Digital Interface", and it is a computer style serial interface. It enables two or more instruments to be connected together, and unlike the old CV/gate system, it enables complex systems to be put together using a minimum of connecting wires. One instrument acts as the controller for the system, or a special sequencer can be used to control the system.

An attractive feature of the MIDI system is that a home computer fitted with a suitable interface can act as the sequencer, and an extremely good one at that. Even with a long sequencer program loaded, the average home computer will still have sufficient memory left to accommodate several thousand notes. A home computer also gives great versatility since any desired feature (within reason) can be added using suitable software.



BBC

As yet there are few computers which have a built-in MIDI interface, and due to its rather specialised nature this could remain the case (although MIDI ports can also function as high speed serial interfaces for communication between two computers). As it is basically just a standard serial interface it is not difficult to add a MIDI port to most computers, and this article describes an add-on MIDI interface for the BBC model B computer.

The BBC machine is a good choice for an application of this type as it is easy to interface to add-ons, it has a fast BASIC which enables several channels to be sequenced with good synchronisation, and the built-in assembler is available for applications that require the extra operating speed of assembly language routines.

MIDI BASICS

MIDI is a two way asynchronous serial interface which is similar to the RS232C and RS423 serial systems often used with home computers. As we shall see shortly, the MIDI system is sufficiently different from these two forms of interface to prevent either of them from being used in a MIDI set-up. The MIDI word format is one start bit, eight data bits, one stop bit, and no parity, which is about the most common one these days. The baud rate is very high at 31·25k baud, but it is necessarily so as significant delays must be avoided when sequencing several channels. The highest standard RS232C and RS423 baud rate is 19·2k baud, which is one reason for the incompatibility between MIDI equipment and standard serial interfaces. Although 31·25k baud appears at first sight to be a rather odd choice, it is a practical one which enables a suitable clock signal to be derived from a 1MHz crystal oscillator (1MHz divided by 32 equals 31250).

With RS232C and RS423 serial systems the signal levels are around +3V to 12V and −3V to 12V. The MIDI system has an opto-isolator at each input to avoid problems with earth and hum loops, and consequently ordinary 0V to 5V output logic levels are all that is required. Alternatively, open collector outputs to drive the l.e.d.s in the opto-isolators can be used.

Most MIDI equipped musical instruments can have practically any parameter set via the MIDI interface, but the instruction codes for many facilities are non-standard and can be found in the instruction manual concerned. However, there is a standard format used for gating notes on and off so that there is compatibility between any two MIDI instruments at a fundamental level at least. Bytes are sent in groups of three, one group to switch a note on, and another to switch it off.

BYTES

Taking the triggering of a note first, the first byte breaks down into two four bit nibbles. The most significant of these contains the "trigger a note" header code which is 1001 in binary (144 in decimal). The least significant nibble contains the MIDI channel number, and this is in the range 0 to 15, but note that MIDI channels are normally numbered 1 to 16 and not 0 to 15. To select (say) MIDI channel 8, a channel value of 7 would therefore be used.

The second byte is the note value and must be in the range 1 to 127. Notes increment in semitones and a value of 60 gives middle C. This gives a very wide pitch range of well over ten octaves. Bear in mind though, that although the MIDI system accommodates this pitch range, not all MIDI equipped instruments can do so. The manual for each instrument should specify the pitch range available via the MIDI interface (which might actually be wider than can be achieved via the keyboard). Of course, with something like a percussion synthesiser only on/off gating is required, and the note value (which must always be sent) is ignored.

The third byte is the velocity value, and is again in the range 1 to 127. A value of 1 represents a key that is played as gently as possible, incrementing to a key struck as hard as possible at a value of 127. Not all instruments have touch sensitivity, and it is actually a feaure which is absent from the majority of instruments. However, in order to maintain compatibility between touch sensitive and non-touch sensitive instruments this byte must always be sent. Non-touch sensitive instruments normally send a dummy value of 127.

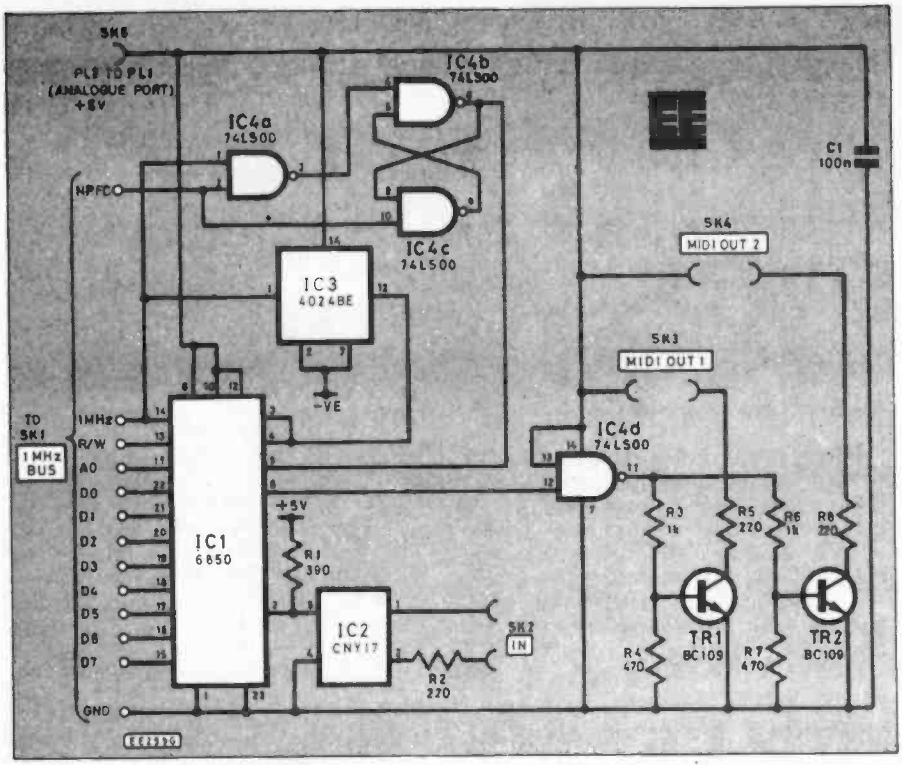


Fig. 1. Complete circuit diagram of the BBC MIDI Interface.

The system used to switch a note off again is virtually identical to the one used for triggering. In fact the second and third bytes perform the same function as before. On the face of it there is no point in including the note value, but in serial control systems things are usually arranged so that a certain number of bytes are transmitted in each control sequence, and the note value is transmitted merely to make up the three byte block. The least significant nibble of the first byte is also as before, and contains the channel value. The header code in the most significant nibble is different though, and is 1000 in binary (128 in decimal).

MODES

MIDI interfacing can be a little confusing at first as there are three operating modes, and the system will probably not perform as intended unless every component in it is set to the right mode. The most important mode is "Omni", which is one that every piece of MIDI equipment has, and the one which the equipment defaults to at switch-on. In this mode the receiving device will respond to all commands regardless of which channel they are directed to. This mode ensures a basic level of compatibility between all pieces of MIDI equipment, and it is adequate for monophonic sequencing of a single instrument, or where two or more instruments must play in unison. Polyphonic sequencing of a suitable synthesiser is possible, but exactly how the received notes are assigned to the channels of the instrument depends on the design of the instrument. Whatever the system of internal assignment, homophonic operation (all channels having the same voice) is all that is likely to be possible.

The "Poly" mode gives slightly greater versatility by enabling each instrument in the system to have its own channel number, and commands can therefore be directed to just one instrument in a multi-component set-up. However, this still effectively limits each instrument to homophonic operation. The "Mono" mode is the most sophisticated one, and it gives individual access to each channel of an instrument. With a suitable instrument this permits polyphonic sequencing with each channel having a different voice.

Only a few fundamentals of MIDI software have been covered here, but this is all that you need to know in order to understand how sequencing via a MIDI interface can be achieved. Other features can be controlled via the MIDI interface of most instruments, but the codes and system used are not universal in many cases, and it is a matter of consulting the handbook for each instrument to see just what can be achieved, and how.

CIRCUIT OPERATION

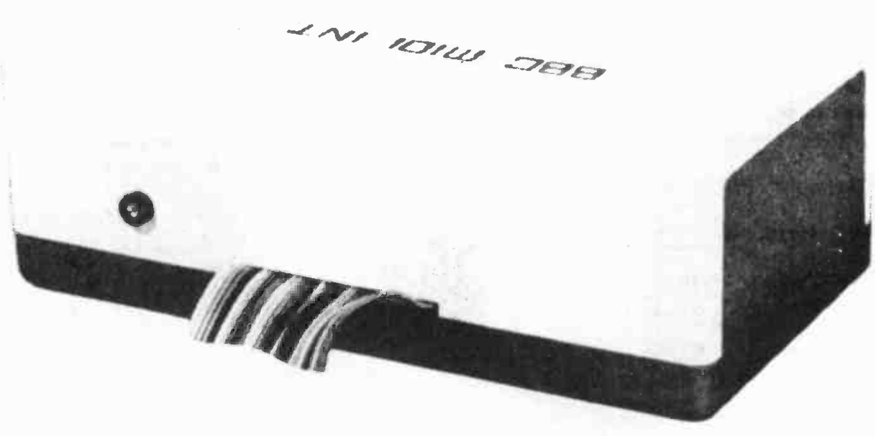
The full circuit diagram of the interface is provided in Fig. 1. Most simple BBC add-ons connect to the analogue and (or) user port, but in this case where 8 bit bi-directional operation is required the 1MHz Bus represents the best option.

Most normal serial interface devices can be used as the basis of a MIDI interface, and the only exceptions are the few devices which can not handle the fairly high baud rate involved. The obvious choice for a 6502 computer is the inexpensive and 6502 bus compatible 6850 ACIA (Asynchronous Communications Interface Adaptor), which is the device used here (IC1). The data bus of IC1, plus the clock and R/W lines simply connect to the corresponding lines of the 1MHz Bus. There is no reset terminal on IC1 as the 6850 uses a software reset. IC1 has two read registers and two write types, and it consequently occupies two addresses in the memory map. Address line A0 is used to drive the single register select input of IC1.

The 6850 can operate with the transmitter and receiver clocks at 1, 16 or 64 times the required baud rate. In practice this device is not normally operated in the mode where the clock frequency is identical to the baud rate, as the internal receiver synchronisation circuit will not function in this mode and an external synchronisation circuit would be required. In this case the 1MHz clock signal is divided by two jn IC3, and the 500kHz output is connected to the receiver and transmitter clock inputs of IC1. With IC1 operated in the X16 mode this gives the required 31·25k baud rate.

There are two decoded address outputs on the 1MHz Bus; NPFC and NPFD. These pulse low when any address in page &FC or &FD respectively is accessed. In theory one of these lines could be connected direct to the negative chip select input of IC1, but in practice this might not give good results due to noise on the page select outputs. In this application a missed byte of information would almost certainly cause the system to crash, and good reliability in the interface is essential. The problem is due to the BBC computer having a 2MHz clock for normal operation, but a change to 1MHz when input/output circuits are accessed. A simple circuit is all that is needed to rectify the problem, and in this circuit three of the NAND gates in IC4 are used to provide a "clean" version of NPFC to IC1. This places the control and status registers at address &FC00, and the receive/transmit registers at address &FC01. Note though that only partial address decoding is used, and that the interface appears at "echoes" throughout page &FC. This page is therefore unavailable for other add-ons when the MIDI interface is connected.

IC2 is the opto-isolator at the MIDI input. R1 is the collector load resistor for the transistor at the output of IC2 while R2



COMPONENTS

MAGENTA KIT 513

Resistors

R1	390
R2,5,8	220 (3 off)
R3,6	1k (2 off)
R4,7	470 (2 off)

All $\frac{1}{4}$W 5% carbon film

Capacitors

C1	100n ceramic

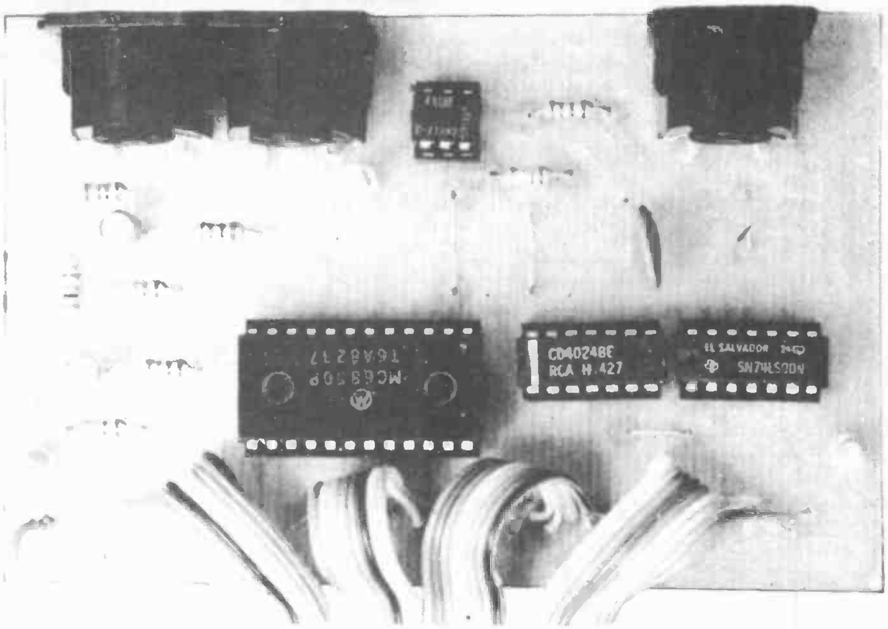
Semiconductors

IC1	MC6850P ASCIA
IC2	CNY17 high efficiency opto-isolator
IC3	4024BE CMOS binary counter
IC4	74LS00 TTL quad 2 input NAND gate
TR1,2	BC109 silicon npn (2 off)

Miscellaneous

SK1	34 way IDC header socket and cable
SK2,3,4	5 way 180 degree DIN printed circuit mounting sockets (3 off)
SK5	1mm socket
PL1	15 way D plug
PL2	1mm plug

Printed circuit board; Plastic case 150×80×50mm; two 14-pin DIL i.c. holders; 6-pin d.i.l. i.c. holder; 24-pin d.i.l. i.c. holder; wire; fixings; solder; etc.



provides current limiting at the input. IC4d is used to invert the output from IC1, and the inverted signal is then coupled to a couple of switching transistors which provide the unit with twin MIDI outputs.

Most MIDI instruments have three interface sockets, "IN", "OUT", and "THRU". The "THRU" socket merely provides a buffered version of the signal applied to the input. A MIDI system is normally "chained" together in the manner shown in Fig. 2(a), but if two of the instruments lack a "THRU" socket this is not possible. The method of connection shown in Fig. 2(b), with the second MIDI output of the interface being brought into operation, must then be utilized. If the second output is not required, simply omit R6, R7, R8, TR2, and SK4.

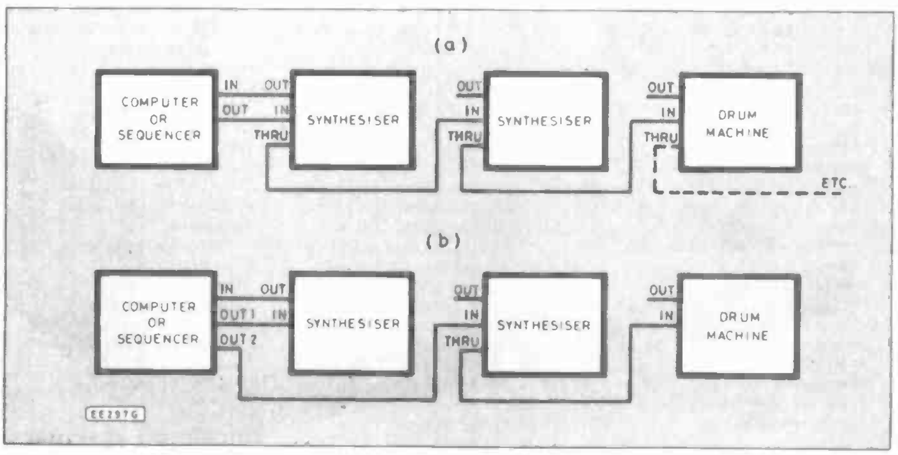
An unexpected omission from the BBC computer's 1MHz Bus is any form of power supply output. The +5V supply for the interface is therefore taken from the analogue port.

CONSTRUCTION

Refer to Fig. 3 for details of the printed circuit board. IC1 and IC3 are both MOS devices and accordingly require the standard antistatic handling precautions to be observed. The standard connector for MIDI interfaces is a 5 way (180 degree) DIN type, and here printed circuit mounting sockets are used. Make sure that these are pushed right down onto the board before soldering them into place, and use plenty of solder. There are four link wires on the board which should not be overlooked. Also, note that IC1 and IC2 have the opposite orientation to IC3 and IC4.

The board is connected to the 1MHz Bus of the computer via a piece of 34 ribbon cable up to about one metre long and fitted with a 34 way IDC header socket. Be careful to connect the free end of the cable to the board the right way around. Fig. 4 gives connection details for both the 1MHz Bus and the analogue port (note that the diagram on page 499 of the BBC computer's "User Guide" shows the 1MHz Bus connector incorrectly, and it is Fig. 4 rather than this which should be followed). An insulated lead about one metre long is used to connect PL1 to the board.

Fig. 2(a). The normal "chained" MIDI set-up. (b) A series-parallel combination can be used if there are inadequate "Thru" sockets for the "chained."



The unit can be left as an open board or, like the prototype, it can be fitted into a case having outside dimensions of about 150 by 80 by 50 millimetres. The board is mounted on the base panel of the case using 6BA fixings, including $\frac{1}{4}$ inch spacers. Cutouts to accommodate the sockets are then made in one side of the case, which then effectively becomes the front panel. An exit slot for the 34 way ribbon cable is filed in the rear panel of the case, and the +5V lead to the analogue port can also be taken through this. However, a neater solution is to connect the +5V terminal of the circuit board to a 1mm socket mounted on the rear panel of the case, and to terminate the lead from the analogue port in a 1mm plug which connects to this socket.

TESTING

As this project connects to the computer's buses, albeit via buffers in most cases, it is essential to connect it to the computer prior to switch-on. Once switched on the computer should give the normal "beep" and screen display, and you should switch off at once and recheck everything if there is any sign of abnormal operation. The interface is connected to the synthesiser (or whatever) using a standard five way DIN to five way DIN lead. If you are making up your own connecting leads bear in mind that only pins 4 and 5 actually carry connections; pin 2 at each output is earthed, and this connects to the outer braiding of the cable to provide screening and prevent radio frequency interference from being radiated.

SOFTWARE

The 6850 needs only very simple driving software. First the device must be reset by writing a value of three to the control register (i.e. ?&FC00 = 3), after which the word format and baud rate are selected by writing the correct value to the control register. In this case a value of 21 is required (i.e. ?&FC00 = 21). Data to be transmitted is then written to address

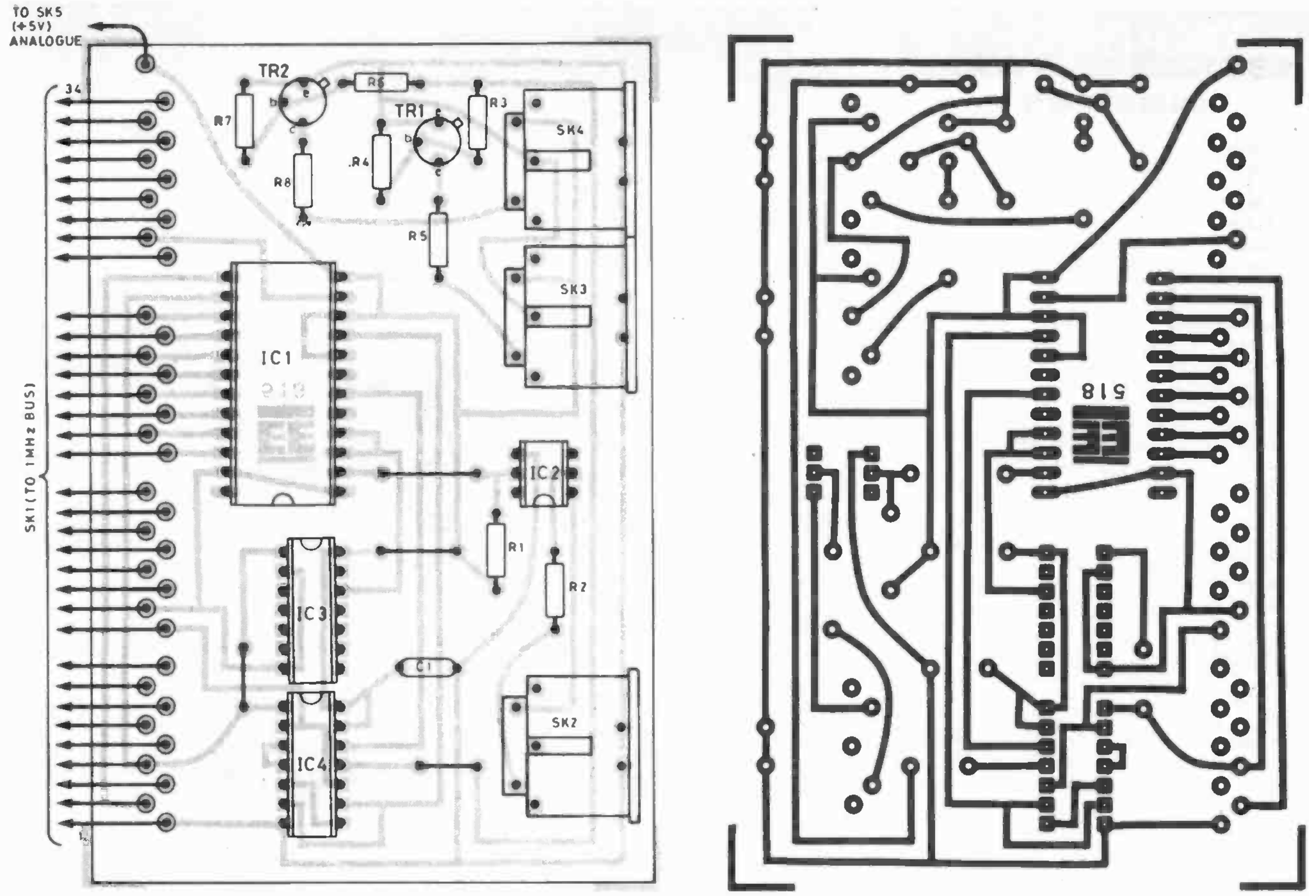


Fig. 3. Printed circuit board layout and construction.

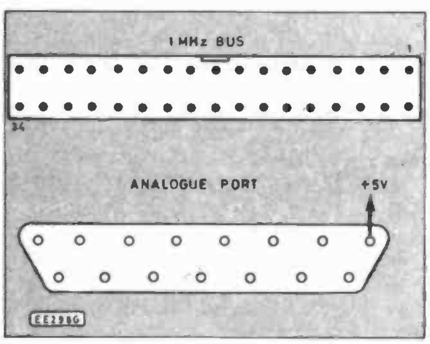


Fig. 4. Connections to the 1MHz Bus and Analogue Port.

&FC01. Using assembly language it is possible to write data to the interface faster than it can be transmitted. This must be avoided by reading the "transmitter register empty" bit at bit 1 of the status register and using a software loop to provide the necessary hold-off. This bit goes high when the register is empty and ready to receive fresh data.

Data is read from the receive register at address &FC01, but to avoid multiple readings of each byte data should only be read when the "receive data register full" bit of the status register (bit 0) is set to 1. The MIDI system does not include any handshake lines to control the rate at which data flows, and any device which receives data must be able to keep up with the very rapid rate at which it is transmitted at times. In practice this means that the interface can only be read properly using machine code or assembly language.

As a quick test of the unit you can try connecting one of the outputs direct to the input socket. After writing the two values to the status register, as described previously, you should find that any value written to ?&FC01 can be read back from that address, but only if the link from the output to the input is maintained.

USE

The accompanying listing is for a simple real-time sequencer that is suitable for recording and backing of up to four parts. The normal way of using a sequencer of this type is to record a backing, and to then have the computer play this while the user plays the melody line. Most MIDI instruments will accept input simultaneously from the keyboard and the MIDI interface.

In theory there is no limit to the number of notes that can be played simultaneously using this sequencer program, which records notes in five byte blocks of memory (three bytes from the synthesiser, plus two from the computer's timer). In practice though, using more than four part harmonies might produce data from the instrument at a faster rate than the computer can handle it, despite the extensive use of assembly language routines in the program. It might be possible to streamline the program to handle more than four notes at a time reliably, and it should be possible to add refinements such as rhythm correction and the ability to vary the playback speed. As it stands the program uses a 5k block of memory which gives a storage capacity of 512 notes, but this could obviously be boosted considerably if required. The program is largely self explanatory in use.

Step-time sequencing can be achieved relatively easily, and the high operating speed of BBC BASIC avoids the need to resort to assembly language unless a large number of channels are to be controlled. □

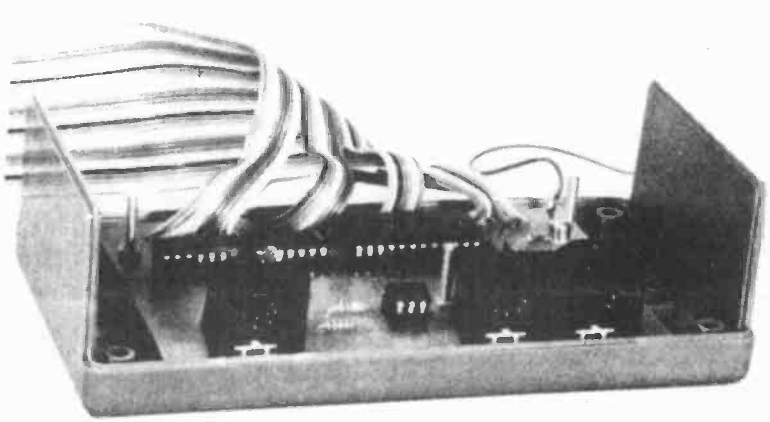
BBC MIDI SOFTWARE

```
10REM MIDI INTERFACE
20REM REAL TIME RECORD/
30REM PLAYBACK PROGRAM
40REM VERSION 2.1 JWP 8/85
50MODE 7
60
70
80DIM CODE 1023
90DIM STORE 5119
100DIM CLOCK 4
110
120
130?&72=STORE MOD 256
140?&73=STORE DIV 256
150notecountl=&74
160notecounth=&75
170pointer=&70
180pointerh=&71
190OSWORD=&FFF1
200OSBYTE=&FFF4
210midi=&FC01
220status=&FC00
230
240
250FOR I%=0 TO 2 STEP 2
260P%=CODE
270[
280OPT I%
290.firstnote
300LDA #0
310STA CLOCK
320STA CLOCK+1
330STA CLOCK+2
340STA CLOCK+3
350STA CLOCK+4
360STA notecountl
370STA notecounth
380LDA &72
390STA &70
400LDA &73
410STA &71
420.start
430LDA status
440AND #1
450BEQ start
460LDA #2
470LDX #CLOCK MOD 256
480LDY #CLOCK.DIV 256
490JSR OSWORD
500
510
520.getnote
530LDX #0
540LDY #0
550LDA midi
560STA (pointer),Y
570JSR increment
580.note
590LDA status
600AND #1
610BEQ note
620LDA midi
630STA (pointer),Y
640JSR increment
650.tail
660LDA status
```

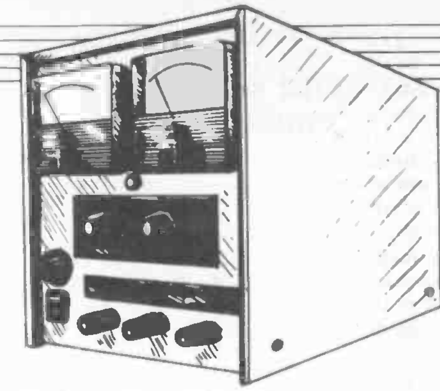
continued

BBC MIDI SOFTWARE continued

```
670AND #1
680BEQ tail
690LDA midi
700STA (pointer),Y
710JSR increment
720JSR addnote
730JSR timing
740.next
750LDA #255
760CMP &78
770BEQ tobasic
780LDA status
790AND #1
800BEQ next
810JMP getnote
820
830
840.increment
850INC &70
860BNE nocarry
870INC &71
880.nocarry
890RTS
900
910
920.key
930PHA
940LDA #255
950STA &78
960PLA
970RTS
980
990
1000.timing
1010LDA #1
1020LDX #CLOCK MOD 256
1030LDY #CLOCK DIV 256
1040JSR OSWORD
1050LDY #0
1060LDA CLOCK
1070STA (pointer),Y
1080JSR increment
1090LDA CLOCK+1
1100STA (pointer),Y
1110JSR increment
1120RTS
1130
1140
1150.addnote
1160INC notecountl
1170BNE nohi
1180INC notecounth
1190LDA notecounth
1200CMP #4
1210BNE nohi
1220BRK
1230EQUB 100
1240EQUS "Note store full "
1250BRK
1260.nohi
1270RTS
1280
1290
1300.tobasic
1310BRK
1320EQUB 102
1330EQUS"Key pressed"
1340BRK
1350
1360
1370.wait
1380LDA #&91
1390LDX #0
1400LDY #0
1410JSR OSBYTE
1420BCC tobasic
1430LDX #CLOCK MOD 256
1440LDY #CLOCK DIV 256
1450LDA #1
1460JSR OSWORD
1470LDY #4
1480LDA CLOCK+1
1490CMP (pointer),Y
1500BEQ lobyte
1510BCS outwait
1520BCC wait
1530.lobyte
1540DEY
1550LDA CLOCK
1560CMP (pointer),Y
1570BCC wait
1580.outwait
1590RTS
1600
1610
1620.firstplay
1630LDA #0
1640STA CLOCK
1650STA CLOCK+1
1660STA CLOCK+2
1670STA CLOCK+3
1680STA CLOCK+4
1690LDA &72
1700STA &70
1710LDA &73
1720STA &71
1730LDA &74
1740STA &76
1750LDA &75
1760STA &77
1770LDA #2
1780LDX #CLOCK MOD 256
1790LDY #CLOCK DIV 256
1800JSR OSWORD
1810JSR nextnote
1820.playnote
1830JSR wait
1840LDA status
1850AND #2
1860BEQ playnote
1870LDY #0
1880LDA (pointer),Y
1890STA midi
1900JSR increment
1910.noteval
1920LDA status
1930AND #2
1940BEQ noteval
1950LDA (pointer),Y
1960STA midi
1970JSR increment
1980.thirdval
1990LDA status
2000AND #2
2010BEQ thirdval
2020LDA (pointer),Y
2030STA midi
2040JSR increment
2050JSR increment
2060JSR increment
2070JSR nextnote
2080JMP playnote
2090
2100
2110.nextnote
2120DEC &76
2130LDA &76
2140CMP #255
2150BNE nextout
2160DEC &77
2170LDA &77
2180CMP #255
2190BNE nextout
2200BRK
2210EQUB 101
2220EQUS "All notes played"
2230BRK
2240.nextout
2250RTS
2260]
2270NEXT I%
2280
2290
2300ON ERROR GOTO 2510
2310
2320
2330CLS
2340?status=3
2350?status=21
2360?&220=key MOD 256:?&221=key DIV 256
2370PRINTTAB(5,5);"Press R to record"
2380PRINTTAB(5,7);"Press P to playback"
2390PRINTTAB(5,9);"Press any key to sto
p recording/"'TAB(5);"playing back, exce
pt ESCAPE."
2400PRINTTAB(5,12);"Press ESCAPE to qui
t program."
2410
2420
2430REPEAT
2440K=GET
2450K=K AND 223
2460IF K=82 THEN PROCrecord
2470IF K=80 THEN PROCplay
2480UNTIL FALSE
2490
2500
2510IF ERR=17 THEN STOP
2520*FX13,2
2530?&78=0
2540IF ERR=100 THEN PROCnotes:GOTO 2430
2550IF ERR=101 THEN PROCclearline:GOTO
2430
2560IF ERR=102 AND K=82 THEN PROCnotes:
GOTO 2430
2570IF ERR=102 AND K=80 THEN PROCclearl
ine:GOTO 2430
2580REPORT:PRINT " at line ";ERL
2590PRINT "PRESS ANY KEY"
2600REPEAT UNTIL GET
2610GOTO 2330
2620
2630
2640DEF PROCrecord
2650*FX14,2
2660PRINTTAB(5,20);"Recording..."
2670?status=3
2680?status=21
2690CALL firstnote
2700ENDPROC
2710
2720
2730DEF PROCplay
2740IF ?&75=0 AND ?&74=0 THEN PROCempty
:ENDPROC
2750PRINTTAB(5,20)"Playing..."
2760CALL firstplay
2770ENDPROC
2780
2790
2800DEF PROCnotes
2810notecount=(256*?&75+?&74)
2820PRINTTAB(5,20);notecount;" Events s
tored."
2830*FX21,0
2840PRINTTAB(5,21);"Press any key"
2850REPEAT UNTIL GET
2860PROCclearline
2870ENDPROC
2880
2890
2900DEF PROCclearline
2910PRINTTAB(5,20);SPC(20)
2920PRINTTAB(5,21);SPC(20)
2930VDU 31,5,20
2940ENDPROC
2950
2960
2970DEF PROCempty
2980PRINTTAB(5,20)"Nothing recorded."
2990PRINTTAB(5,21)"Press any key."
3000REPEAT UNTIL GET
3010PROCclearline
3020ENDPROC
>
```



Constructional Project



VARIABLE BENCH POWER SUPPLY

MARK STUART

Fully controllable from 0 to 24V, up to 2.5A output. Current limit control allows maximum output current to be set anywhere between zero and maximum.

THE power supply to be described here was designed to be capable of a wide variety of jobs. Its high output voltage of 0 to 25V and output current capability of 2.5A are far better than the more usual bench power supplied with their 12V and 1A ratings.

Output voltage is fully variable right down to zero (unlike a lot of i.c. regulators which stop at 1.5V) and a "Current Limit" control allows the maximum output current to be set anywhere between zero and maximum. The current limit feature has two particular uses. One is to protect circuitry under test from being damaged due to faulty construction – a real delight for electronics experimenters. The other use is in the constant current charging of NiCad batteries.

Its uses in the school science lab are too numerous to list in full, but such uses as electrolysis, electroplating, polystyrene cutting, and the like come to mind as well as the more obvious uses for driving model motors, computer interfaces and robots. Two large meters continuously display Voltage and Current leaving the user in absolutely no doubt about what is being provided.

Ripple and noise in the output are at a very low level and the output voltage change in response to load current changes and fluctuating mains voltage is very small. A supply of this type can never be cheap, the cost of transformer, case, heatsink and above all the meters soon add up, but the amount of use that such a project gets justifies the initial cost and the two meters are very worthwhile features. This is a project that will be used almost every day and will soon become indispensable.

CIRCUIT CONSIDERATIONS

A number of options are available when designing a supply of this type. Variable voltage i.c. regulators are available but all seem to have some disadvantages. The circuit finally chosen uses a simple high power device to handle the output, controlled by a low power integrator circuit which does all the "intelligent" work.

A power MOSFET was chosen as the output device because they are rugged, that is, able to withstand voltage and current surges, and also because the insulated gate requires negligible drive current. This second feature is very useful because it enables a simple small-signal transistor to be used as the output driver.

To understand how the circuit works the various sections of it are shown separately in Fig. 1a to Fig. 1d. The final complete circuit diagram for the Variable Bench Power Supply is shown in Fig. 2.

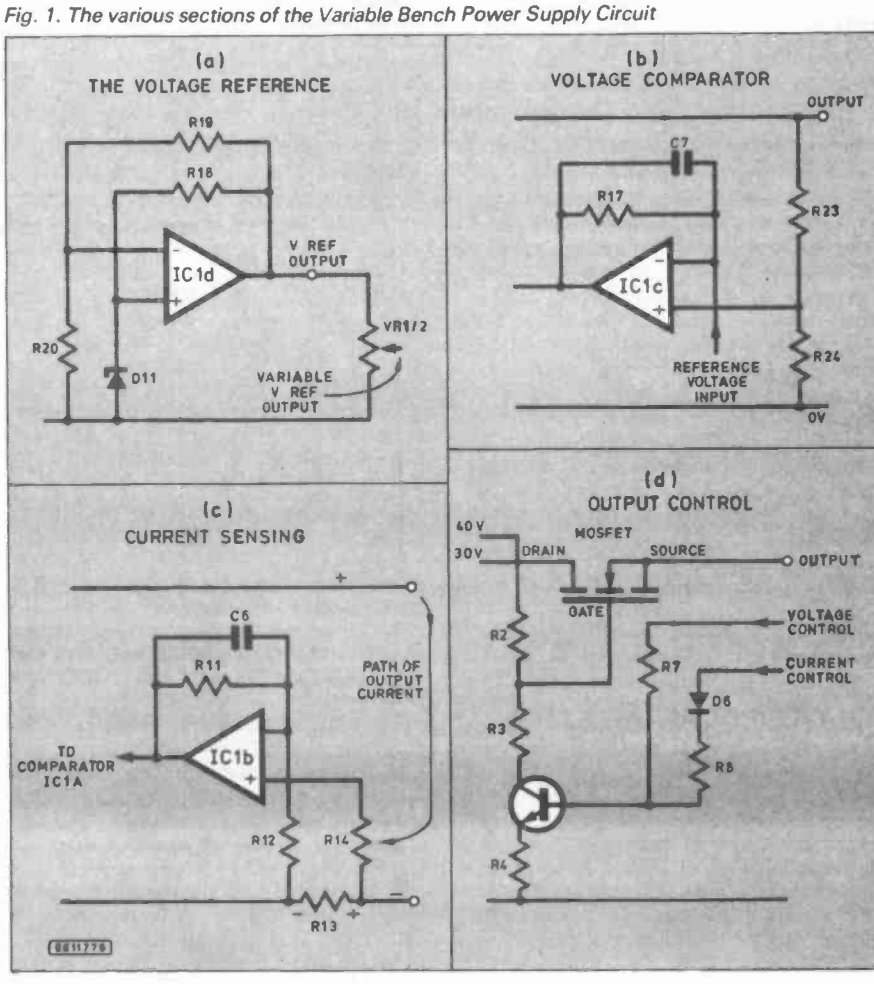
REFERENCE VOLTAGE

The first thing that a power supply control circuit needs is some sort of "reference voltage". This is used to set the output voltage and needs to be stable and noise-free if the power supply output is to be clean.

Fig. 1a shows the voltage reference section of the circuit. Zener diode D11 is the primary reference source. A 5.6 volt Zener diode has been chosen because these have the lowest variation with temperature (temperature co-efficient) of all Zener values. Above and below this voltage the stability is not so good.

To get the best performance from a Zener diode it is best to drive it with a constant current. This is achieved very neatly by IC1d and the associated resistors.

Fig. 1. The various sections of the Variable Bench Power Supply Circuit



Upon switch-on there is a low voltage across D11 which therefore does not conduct and acts like a very high value resistor. The pairs of components resistor R18, diode D11 and resistors R19, R20 are two potential dividers driven from the output of IC1d.

At low voltages, with D11 not conducting more of the output voltage from IC1d is connected to the non-inverting input (+) than to the inverting input (−). The net effect is overall positive feedback that pushes up the output of IC1d. At a certain point the voltage across diode D11 will reach 5.6V and it will begin to conduct. The non-inverting input of IC1d is now held at 5.6V.

The output of IC1d still continues to rise until the inverting input which is fed from the output via resistors R19 and R20 also reaches 5.6V. When this occurs the circuit stabilises

IC1c is connected as a high gain amplifier that amplifies the difference between its two (inverting, and non-inverting) inputs. If the tapped off voltage from the output exceeds the voltage from VR2 slider, the output of IC1c is driven positive. This rising voltage acts on the output control circuit (Fig. 1d) in such a way that the output voltage is reduced.

If the output falls so that the voltage tapped off from the output becomes less than that from VR2 slider, the opposite things happen and the power supply voltage increases. In this way the circuit stabilises itself so that the two inputs of IC1c are kept equal. Any tendency for the output voltage to vary due to loading or mains voltage changes is instantly corrected as IC1c re-balances its inputs and sends a signal to the output control circuits.

to be set anywhere between zero and a maximum of 2.5A.

OUTPUT CONTROL

The control of the output of the power supply is dealt with by the power MOSFET device transistor TR2 which is driven by transistor TR1. This particular type of MOSFET is an *N*-CHANNEL ENHANCEMENT type. This means that its gate (g) terminal must be at a voltage more positive than its source (s) in order for it to conduct.

For this particular device the minimum voltage required to start conduction is 3V, and up to 9V are required to give an output current of 3A. At maximum output, the voltage of transistor TR2 must be able to rise to 25+9

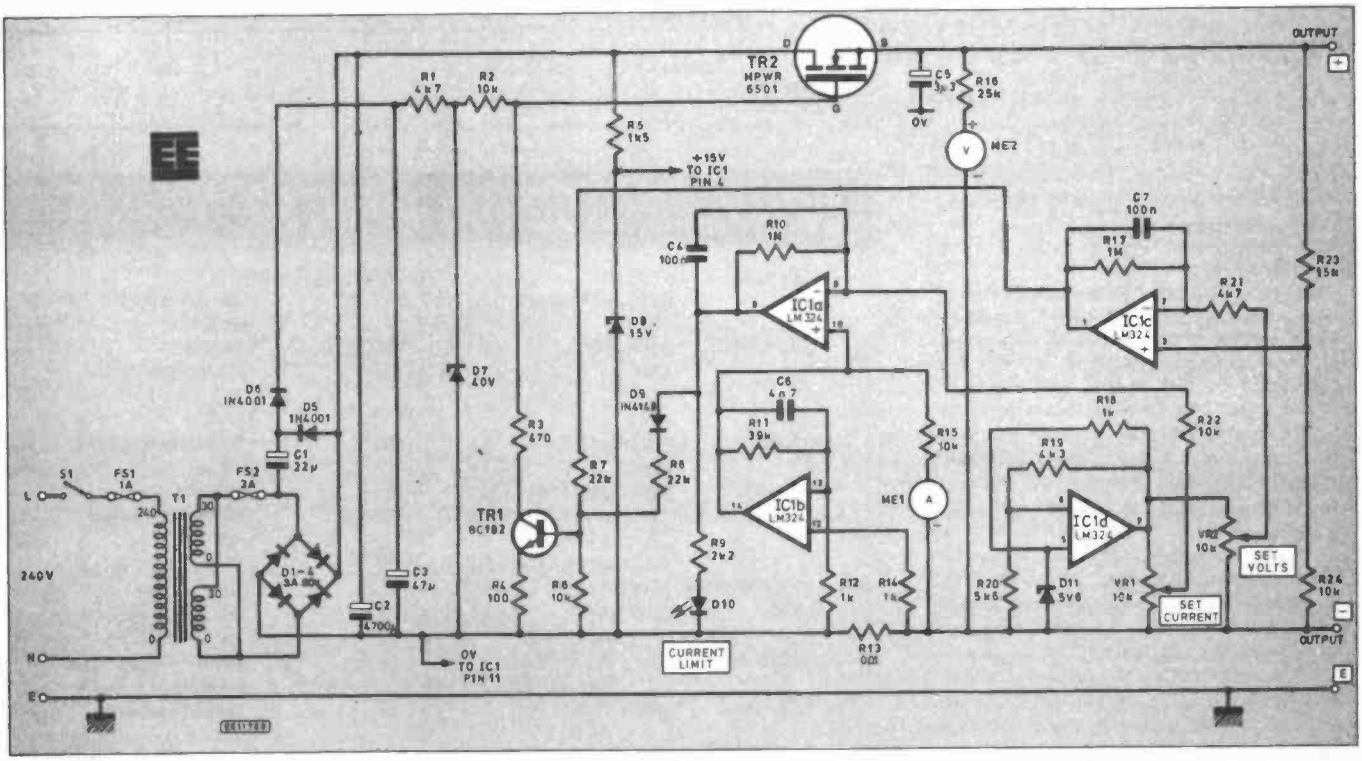


Fig. 2. Complete circuit diagram for the Variable Bench Power Supply. The operation of this circuit is best understood by referring to Fig. 1.

with the output voltage set by the Zener diode voltage and the ratio R19+R20/R20. The values chosen here give an output of 10 volts from IC1d. The current through D11 is fixed by the output which is at 10V and the Zener diode at 5.6V which leaves 4.4V across resistor R18 giving a current of 4.4mA.

The important thing is that all of these values are set up by diode D11. The power supply input and output voltages have no effect whatsoever.

The stable reference voltage from IC1d is fed to the two control potentiometers VR1 and VR2. The output from each of these is a voltage which varies between zero and 10V as the control is rotated clockwise.

VOLTAGE COMPARATOR

This voltage is used by the next stage of the circuit, the "voltage comparator", which is shown in Fig. 1b. A proportion of the power supply output voltage is tapped off by resistors R23 and R24 and fed to one input of IC1c. The other input of IC1c is fed from the slider (or wiper contact) of potentiometer VR2. The values of resistors R23 and R24 are selected so that at 25V output the voltage at their junction is 10V.

CURRENT SENSING

Output current control is carried out by IC1b, the "current sensing" circuit. Resistor R13 in Fig. 1c is connected in series with the power supply negative line. All of the output current flows through this resistor producing a voltage drop across it. This is used by IC1b, via resistors R12 and R14, and amplified to produce a voltage which varies from 0 to 10V as the current increases from zero to 1.5A

This voltage is used to drive the output current meter which is connected via R15 to give full scale deflection (f.s.d.) at 10V. The voltage is also fed to a second voltage comparator circuit (IC1a) and compared with the voltage from the slider of the Set Current control VR1.

Operation of this circuit is the same for current as Fig. 1b is for voltage. Its output is fed to the output control circuit via diode D9 and resistor R8, and also to the current limit indicator l.e.d. D10.

Whenever the output current attempts to exceed the value set by VR1, the output of IC1a rises, diode D10 is lit, and the output control circuit operates to reduce the drive to transistor TR2 and hold the current steady. Varying VR1 from zero to maximum allows the current limit

volts. This is provided, via resistor R2, from a 40V Zener regulated supply derived from the transformer by a voltage doubling circuit.

It is necessary to use a voltage doubler because the rectified transformer output voltage across the mains smoothing capacitor C2 is only 30V at full load. Driver transistor TR1 controls the gate voltage of TR2 via R3.

As the base of the TR1 is made positive it is turned on and the gate voltage of TR2 is pulled down lowering the output voltage. Signals from the voltage and current sensing circuits are both connected to TR1 base and so control the output.

Diode D9 is fitted in the current control circuit so that there is no interaction between this and the voltage control as long as the output current remains below the circuit limit setting. Once the circuit is in current limit mode D9 conducts and current control takes over from voltage control.

All the details of the circuit have already been explained individually. In Fig. 2 they are shown as a whole with a few additional (essential) components such as fuses, a mains transformer, smoothing capacitors, and voltage regulating Zener diodes.

Incoming mains to the transformer T1 passes via the power on/off switch and a 1A fuse in a panel fuseholder. Most transformers nowadays are wound with two equal secondary windings which can be series or parallel connected to give a choice of outputs.

Transformers with two 15V or two 30V secondaries may be used. In the first case connected in series and in the second connected in parallel.

From the transformer secondary the output passes via a 3A fuse to the bridge rectifier, D1-D4, and on to smoothing capacitor C2. This is the main supply which passes to the drain terminal (d) of TR2 and on to the output. Power to IC1 is derived from this supply via resistor R5 and is regulated to 15V by means of Zener diode D8.

A high voltage supply is produced from the transformer by coupling an additional a.c. output from the secondary via capacitor C1 which is rectified by diodes D5 and D6 and added to the main positive supply. The result is a voltage of almost 80V across capacitor C3 which is reduced to 40V by resistor R1 and Zener diode D7. Forty volt Zener diodes are not always easy to obtain so provision is made on the p.c.b. for two 20V Zener diodes in series. Output voltage is displayed by means of a 1mA panel meter connected as a voltmeter reading 0-25 volts with a series resistor R16.

CONSTRUCTION

Most of the components are mounted on a single printed circuit board. The component layout and full size printed circuit board foil master pattern is shown in Fig. 3.

The board is mounted by means of the two potentiometers VR1 and VR2 which are direct p.c.b. mounting types. Other potentiometers may be used and can be wired "off board" to suit other case layouts.

Before fitting any components to the board eleven Veropins should be pressed firmly into the positions shown for external connections and soldered. Begin component insertion by fitting the low profile components such as diodes and resistors, and a socket for IC1.

Take particular care with the diodes to identify each type and its polarity because they all look very similar. Transistor TR1 should be fitted with its flat surface as shown, and must NOT be one of the types with "L" suffix as these have a completely different pin-out.

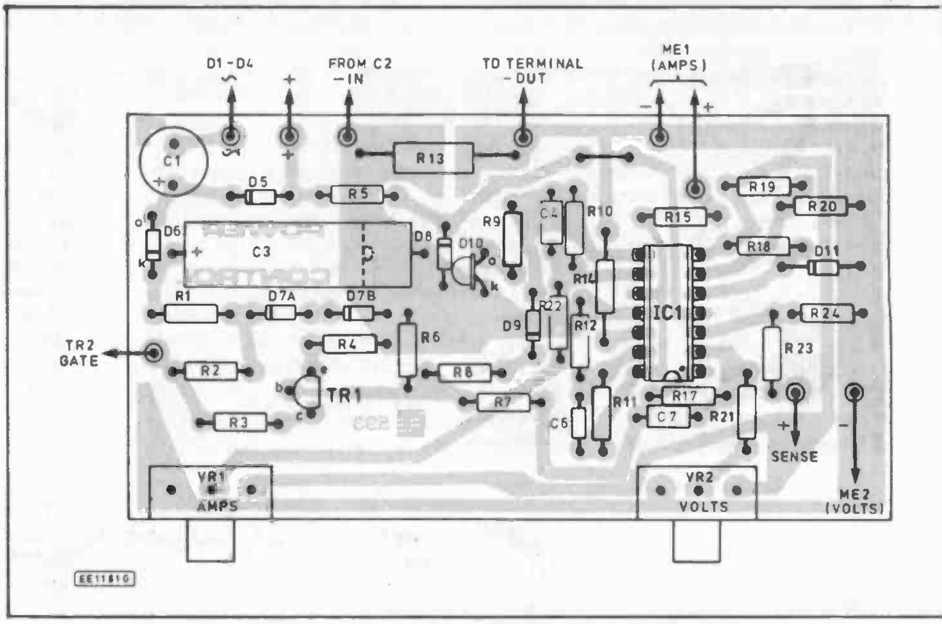
Capacitors C1 and C3 are polarised so must be fitted the right way round. Note that two holes are provided for C3 to enable different sized items to be accommodated. When the board assembly is complete, inspect the underside for solder bridges etc. Provided everything looks in order, the next stage is the wiring.

ASSEMBLY AND WIRING

A full wiring and assembly drawing is shown in Fig. 4. Fig. 5 shows details of the insulation of TR2 from its heatsink and the mounting of a toroidal type transformer is shown in Fig. 6.

Take great care with the mains wiring to fully insulate *every* joint with a good length of sleeving and to make all connections mechanically good before soldering them. A mains cable entry clamp is used to secure the cable firmly and prevent it from being pushed, twisted or pulled from the case. An additional "p" clip near to the front of the case is also needed to keep the cable in position. The mains Earth connection is made to a solder tag on the bottom of the case and brought out to a terminal on the front panel.

The rest of the wiring is quite straightforward but the wiring between the transformer, rectifier, capacitor C2, TR2, the board and the output terminals must be done



COMPONENTS

Resistors

R1	4k7 ½W carbon film
R2, R6, R22	10k (3 off)
R3	470
R4	100
R5	1k5
R7, R8	22k (2 off)
R9	2k2
R10, R17	1M 0.25W 1% metal film (2 off)
R11	39k 0.25W 1% metal film
R12, R14, R18	1k (3 off)
R13	0Ω1 2.5W wirewound
R15, R24	10k 0.25W 1% metal film (2 off)
R16	25k 0.25W 1% metal film (made from 10k + 15k in series)
R19	4k3 0.25W 1% metal film
R20	5k6 0.25W 1% metal film
R21	4k7
R23	15k 0.25W 1% metal film

All 0.25W 5% carbon film, except where stated

Potentiometers

VR1, VR2	10k lin. (2 off)

Capacitors

C1	22µ radial elec. 63V
C2	2,500µ + 2,500µ tag-ended elec. 63V
C3	47µ axial elec. 100V
C4, C7	100n min. polyester (0.3in pitch) 100V
C5	3.3µ axial elec 40V
C6	4n7 Mylar or polyester 63V

Semiconductors

D1-D4	3A 50V bridge rectifier
D5, D6	1N4001
D7	40V 500mW Zener diode (or 2 × 20V in series)
D8	15V 500mW Zener diode
D9	1N4148
D10	3mm low current red l.e.d.
D11	5V6 500mW Zener diode
TR1	BC182 *npn* silicon
TR2	HPWR 6501 MOSFET (*N*-channel)
IC1	LM324 Quad op. amp.

MAGENTA KIT 769

Miscellaneous

S1	s.p.s.t. miniature rocker switch
T1	120V/A Toroidal mains transformer – primary 240V mains, sec. two 30V windings (see text)
ME1,ME2	1mA 65 ohm, moving coil panel meter (2 off)

Printed circuit board; heatsinks; insulating kit (TO3); knobs (2 off); screw terminals, 1 red, 1 black, 1 green; capacitor clip; wire, mains and low voltage; fuse, primary 1A 1¼in with panel holder, secondary 3A 20mm with chassis holder; case; feet for case; nuts, screws, etc.

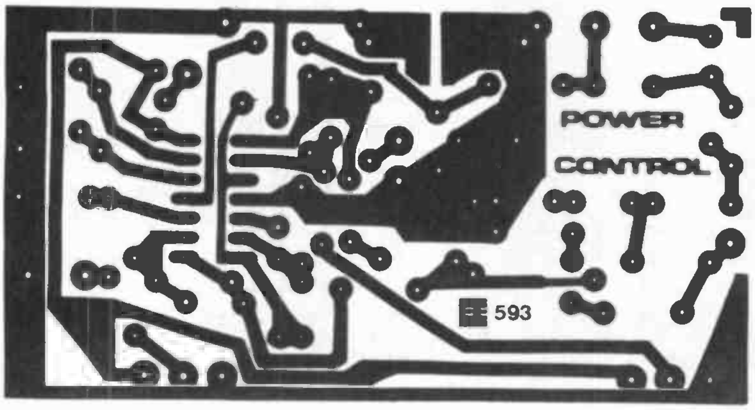
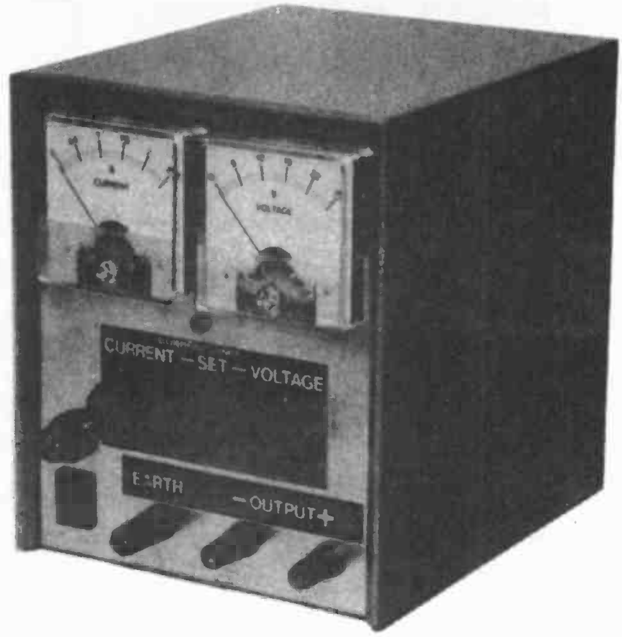


Fig. 3. Full size foil master pattern and component layout.



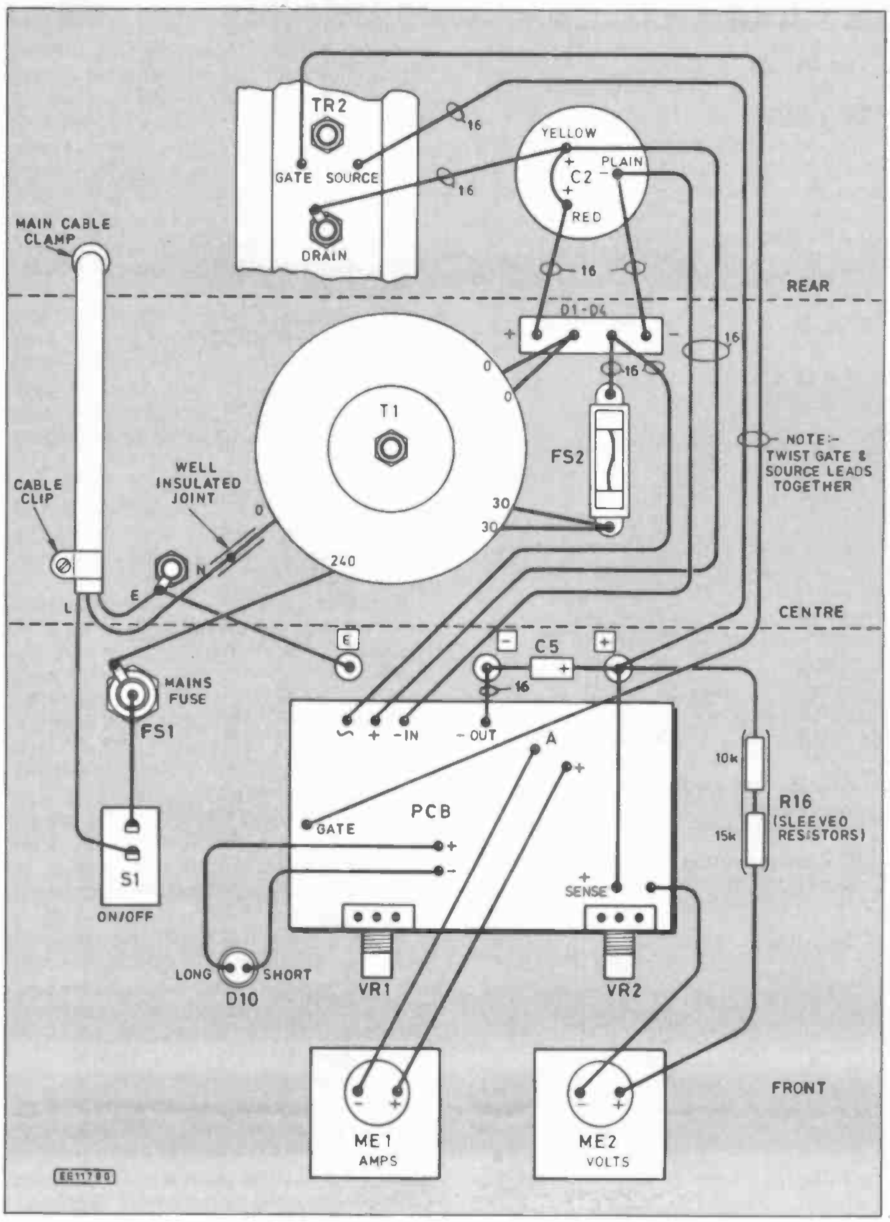


Fig. 4. Full wiring and assembly details to the circuit board, transformer and case mounted components. Heavy duty wires which carry the full output current are indicated by the number 16.

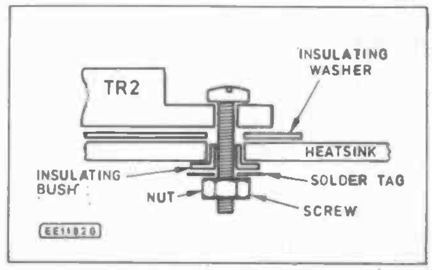


Fig. 5. Details of mounting the MOSFET device on the heatsink.

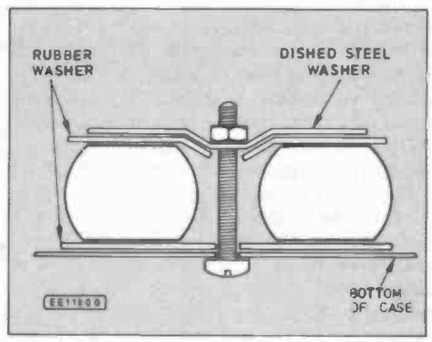


Fig. 6. Method of mounting the toroidal transformer in the case.

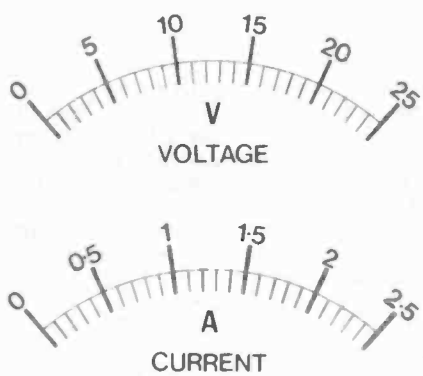
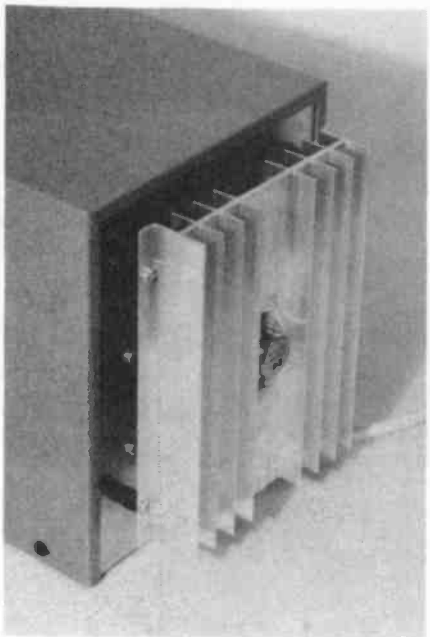
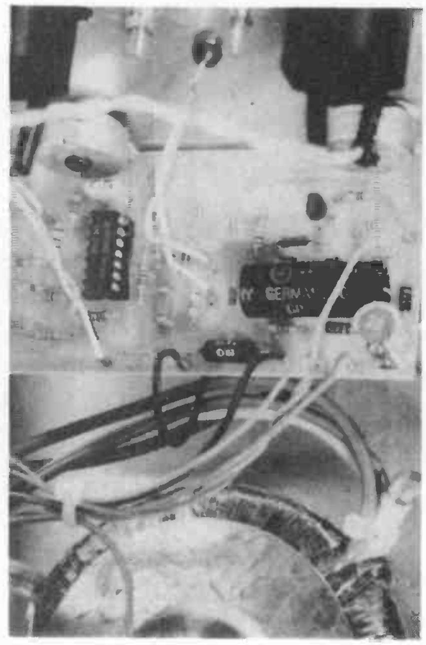


Fig. 7. Full size Voltage and Amps scales for the power supply





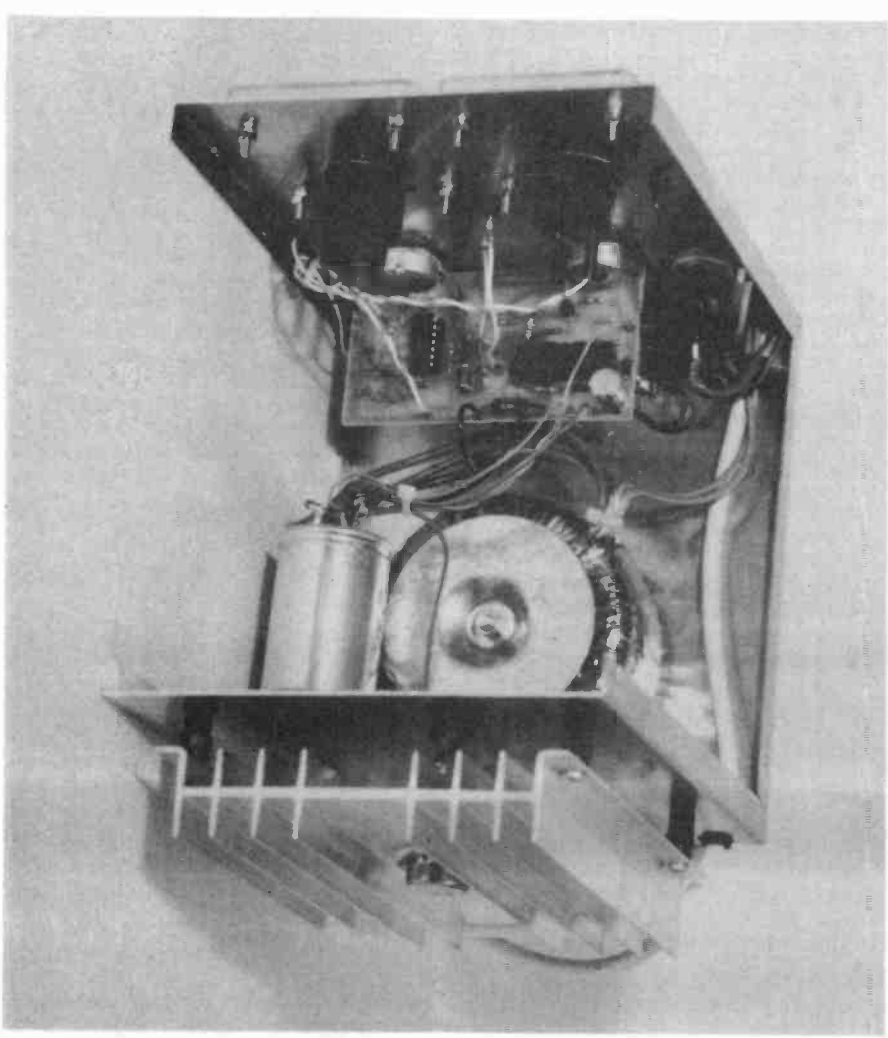
exactly as shown to keep ripple currents to a minimum.

Some wires carry the full output current, and so should be thicker than others. These wires have been marked with a circle and the number 16 to indicate that at least 16/0.2 wire should be used. All other connections may be made using 7/0.2 wire.

The leads to the gate and source of TR2 should be twisted together. When mounting TR2 to the heatsink it is necessary to use thermal compound on *both* sides of the insulating washer to ensure good heat transfer.

TESTING

Commence testing by first checking and double checking everything; make sure the mains wiring is correctly insulated and switch on. If the fuse does not blow it is possible that everything is working correctly.



Set VR1 halfway, vary VR2 and see if the voltage reading on the output meter is varying. If it is, well done. If not, the next step is to check a few voltages around the circuit.

There should be 40V across C2 and 80V across C3. If these are not correct check the voltage across diode D4 which should be 40V and across D8 which should be 15V. If any of these are low it is likely that they have been fitted the wrong way round, or that IC1 is reversed. As these are standard power supply circuits it should be fairly simple to trace any faults here.

The next thing to check is the voltage across Zener diode D11 which should be 5.6V and then the output of IC1d (pin 7) which should be 10V. If things are still not right then it could be TR1 which is at fault.

Check the base voltage and collector voltages of transistor TR1. If the base voltage is less than 0.6V the collector voltage should be high. TR2 is unlikely to be at fault, but if its drain and gate are at high voltages and the source is very low or zero it is faulty.

After these tests it is really rather more of a detective job to find faults, but remember that 99 out of 100 faults are due to bad soldering or wiring.

OPERATION

Once the Voltage control is working correctly, connect a load (100 ohm resistor) across the output and check that the current reading increases as the voltage increases. At 25V a 100 ohm resistor should take 250mA.

Now reduce the current limit setting so that the current reading falls and note that the voltage reading also falls.The current limit l.e.d. should light at the point where the current just begins to reduce. Decrease the voltage setting and the circuit will resume voltage control as the l.e.d. goes out.

When testing a suspect (or newly built) circuit use the Voltage and Current limit controls to prevent excess power from being taken in the event of a fault. Start with both controls at zero and gradually increase them little by little until the expected circuit working current is reached.

If the controls are now advanced further and the current does not increase, then all is well. If the current continues to increase above the expected level then it is probably necessary to do some fault finding.

To charge NiCad batteries set the voltage to twice the total voltage of the batteries to be charged, and set the charge current using the current limit control. Note that you *must* remember to switch off after the correct time has expired to fully charge the batteries, especially when charging at higher rates. ***Failure to do this can result in the battery being damaged and at worst exploding.***

In some circumstances the heatsink can get very hot. This is especially so when a *High* current is being delivered at a *Low* voltage. In this instance TR2 is carrying the high current and is dropping most of the voltage as well.

At 2A and 25V this can be so much as 50 watts. Just think how hot a 60 watt light bulb gets and you get some idea of the heat dissipation requirement. For moderate durations this sort of power can be tolerated, but prolonged use at this level is not recommended.

When *full* current and voltage are being used, the power transistor has just a few volts across it and so is perfectly happy, and at medium output levels power is divided between the load and the power transistor which only generates moderate heat.

If continuous use at high currents and low voltages is anticipated a larger heatsink would be a good idea. □

Constructional Project

PET SCARER

MARK STUART

Keep pets/pests away from newly sown areas, fruit etc. Designed to operate over long periods, this easy to build unit gives a pulsed output.

THIS project was designed to deter a variety of animals from their irritating irrigation pastimes in newly-sown areas of the garden. It also should offer some degree of protection later in the year to young shoots and fruit. Exactly which animals are most susceptible to the high power ultrasound has not been established, but favourable reports were received when a lower power project was published some years ago.

The circuit described here uses a 40kHz ultrasonic transducer which is pulsed at two second intervals with 100V. A very efficient circuit is used so that the total average current consumption is only 15mA at 9V. This makes battery power a possibility, especially if C or D re-chargeable cells are used.

Alternatively, an old car battery will give weeks of operation from a single charge (ideal for allotments) and (at 12V) give a higher output. For continuous use in the garden a plug-in double-insulated 9V a.c. power supply is available which is capable of operating over 50 metres of low cost twin cable.

CIRCUIT DESCRIPTION

The full circuit diagram for the *Pet Scarer* is shown in Fig. 1. A quad 2-input OR gate IC1 does all the complicated work, whilst transistor TR1 provides the output power.

A 40kHz crystal oscillator, producing a square wave output, is formed by IC1c and associated components. This is a standard circuit with resistor R4 providing d.c. bias and setting the gate in a "linear" mode so that it works as an amplifier.

Feedback takes place via resistor R5 and crystal X1 at the resonant frequency of the crystal so that the circuit oscillates. Capacitors C2 and C3 ensure that the feedback is in the correct phase for oscillation and also eliminate the tendency of some i.c.s to ignore the crystal and cheerfully oscillate at 10MHz or more.

From the oscillator the square wave passes via R6, C4 and R7. The effect of this network is to produce a series of short negative-going pulses at 40kHz which are fed to one input of IC1d.

A low frequency oscillator is formed by IC1a, IC1b, and associated components. This oscillator works as follows: Assume that the input to IC1a is low. As it is an inverter, its output will be high, and so the output of IC1b will be low.

Capacitor C1 will charge via resistor R2 and R3/D1 so that the voltage at the junction of resistors R1 and R2 begins to rise. Resistor R1 couples this rise to IC1a input.

After a time the voltage at IC1a input rises to the point where it is taken as a logic 1 instead of a logic 0 and so the output of IC1a goes low. This drives the output of IC1b high (1). This change is coupled back to the input of IC1a via capacitor C1 and resistor R1 forcing the input of IC1a even higher.

This regenerative effect makes the circuit switch over rapidly to a state which is the opposite of the starting condition.

COMPONENTS

MAGENTA KIT 812

Resistors

R1	2M2
R2	3M3
R3	1M
R4	10M
R5, R7	10k (2 off)
R6, R8	470 (2 off)

All ¼W carbon film.

Capacitors

C1	1µ 0.6in. pitch 100V
C2	22p ceramic plate 50V
C3	1n ceramic plate 50V
C4, C5	1n mylar 50V (2 off)
C6	22n 100V C344 5%
C7	100µ radial elec. 16V

Semiconductors

D1, D4	1N4148 (2 off)
D2	BY407A
D3	1N4001
D5	3mm standard red l.e.d.
TR1	ZTX451 *npn* silicon
IC1	4001B CMOS quad 2-input NOR gate

Miscellaneous:

X1	40kHz sub miniature crystal
X2	40kHz Ceramic Ultrasonic Transmitter
L1	45 turns of 28s.w.g. enamelled wire on N22 ferrite core assembly

Printed circuit board; case, Magenta B1; 14-pin i.c. socket; grommet for X2; M3 nylon screw with metal nut; flexible connecting wire 7/0.2, 0.5 metres; 1.5mm sleeving, 100mm.

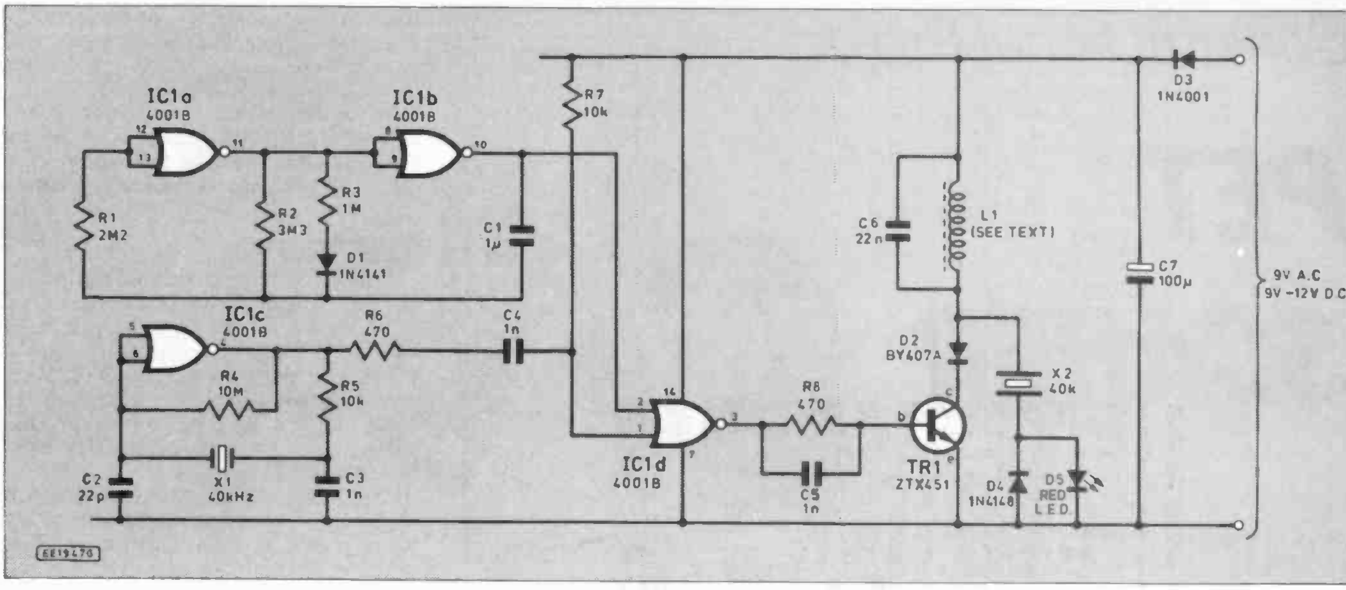


Fig. 1. Complete circuit diagram of the Pet Scarer.

Capacitor C1 now discharges via resistor R2 (diode D1 is reverse biased, blocking the path via resistor R3) and the voltage at the junction of resistors R1 and R2 falls until it reaches the point where IC1a input is taken as a logic 0. The circuit then switches over to the original state and the cycle repeats.

The output of IC1b is a square wave of unequal mark/space ratio due to C1 charging via R2 and R3 and discharging more slowly through resistor R2 only. The periods when the output is high are longer than when it is low. With the component values given these times are two seconds and one second respectively.

Two signals are applied to the inputs of IC1d. A truth table for this two-input NOR gate is shown in Table 1.

Table 1.
Truth Table for 2-input NOR

Input 1	Input 2	Output
0	0	1
0	1	0
1	0	0
1	1	0

With either input held high the output of the gate is forced low. For the two seconds that IC1b output is held high, therefore, the output of IC1d stays low regardless of the other input's state.

During the one second that IC1b output is low, the output of IC1d is an inverted form of the 40kHz signal on its other input. As this is a train of negative going pulses, the output is a train of 40kHz positive pulses. The final result is one second bursts of 40kHz pulses repeated at two second intervals.

OUTPUT DRIVE

The pulse waveform from IC1d drives the output transistor TR1 via resistor R8 and capacitor C5. Resistor R8 limits the maximum base current to a level that does not overload IC1d, capacitor C5 speeds up the pulse edges to give clean sharp switching of TR1.

The collector load of TR1 is a tuned circuit consisting of capacitor C6 and coil L1 in parallel which resonates at 40kHz. The effect of this circuit when driven from the pulsed output of transistor TR1 is to provide a greatly magnified voltage swing of over 100V peak-to-peak which is connected directly to the ultrasonic transducer X2.

The operation of this tuned circuit is analogous to a pendulum which executes large swings when given short pushes. The important thing is that the pushes must be timed to match exactly the pendulum swing. In the case of this circuit the "pushes" take the form of precisely timed pulses of current from TR1, and the "pendulum" which consists of L1 and C1 is tuned to match the pulse rate.

The capacitance of the ultrasonic transducer X2 also influences the tuned circuit and this can vary substantially from unit to unit. To prevent this from causing problems, the value of capacitor C6 is chosen to be much larger than that of the transducer so that it dominates and reduces the effect of X2 to insignificant proportions.

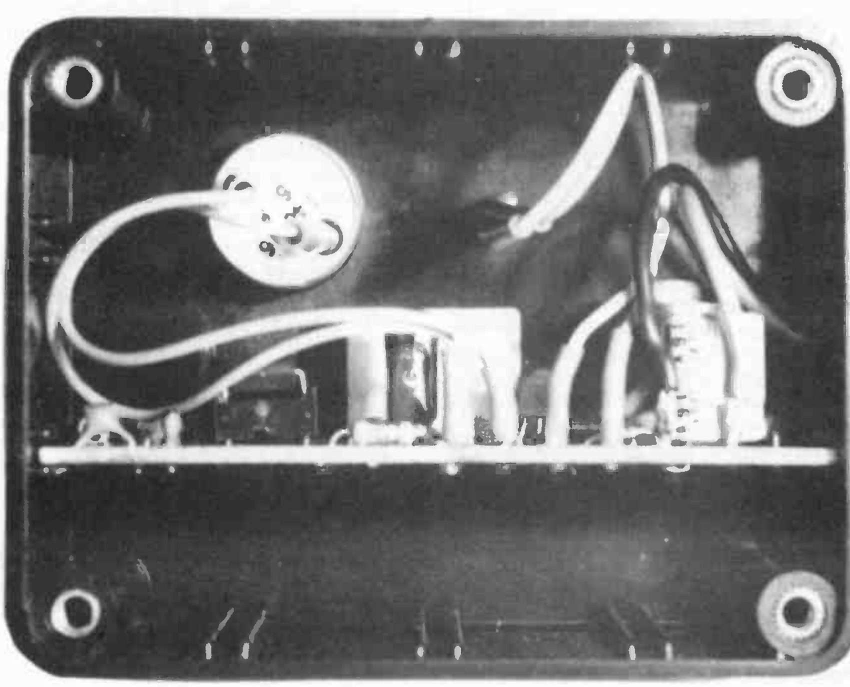
To give an accurate indication of correct operation, an l.e.d. (D5) is connected in series with the transducer and is lit only by the 40kHz current passing through it. A failure in any part of the circuit will put out the light, unlike a simple "power on" l.e.d. which would merely indicate battery condition. The brightness of the l.e.d. also gives some indication of the output power level. Diode D4 is necessary to by-pass the l.e.d. in the reverse direction.

Diode D2 is a very important part of the circuit. It allows the voltage at the lower end of L1 to swing freely below the negative supply rail. Without the diode, TR1 collector/base junction would become forward biased and effectively clamp the negative voltage swing.

Finally, the two power supply components capacitor C7 and diode D3 provide decoupling and polarity protection when d.c. supplies are used, and rectification and smoothing when used with a.c.

CONSTRUCTION

A single printed circuit board holds all of



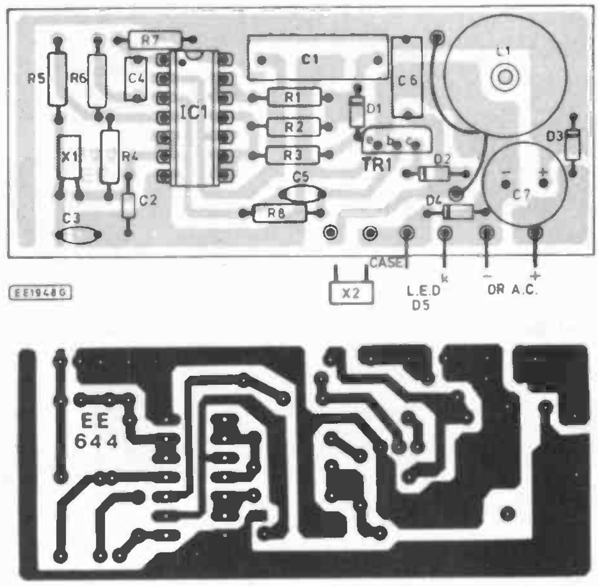


Fig. 2. P.C.B. layout and wiring for the Pet Scarer.

the components, except the ultrasonic transducer and l.e.d.

The size of the board fits exactly into guide slots in the specified case, or can be mounted in an alternative case using screws, nuts and spacers. The leads to the transducer can be extended up to 10 metres without causing any problems, allowing the "electronics" to be kept indoors or in a shed if required. This should not be necessary though if the case is well sealed, and sheltered.

The inductor coil L1 should be wound first with 45 turns of 28s.w.g. enamelled wire. Either a single or multi-section bobbin can be used as there is plenty of winding space available. If a three section bobbin is used, wind 15 turns in each section before moving on to the next. A single section bobbin can be "scramble wound" as there is nothing to be gained by neat layer winding. In either case it is important to bring both ends of the winding out at the same side of the bobbin so that 45 FULL turns are completed.

A layer of p.v.c. tape should be put over the finished winding to protect it and hold the turns in place. Leave 50mm wire ends and "tin" solder 10mm of each wire. If solderable (or self-fluxing) enamelled wire is used this should be easy, although the soldering iron must be held on the wire for some time to start the enamel melting. Other types of enamel will need scraping away to expose the bare copper before soldering. This is best done by folding a piece of emery paper over the wire.

The two core halves should be fitted over the coil with their gaps aligned and fixed together and to the p.c.b. by means of a nylon M3 screw and a metal nut which must **NOT** be over tightened. A metal screw passing through the cores must not be used as it would introduce enormous losses. The core types specified **MUST** be used as the inductance of the final assembly is critical.

CIRCUIT BOARD

The printed circuit board (p.c.b.) component layout is shown in Fig. 2 together with a full size copper foil master pattern. Assembly is straightforward with only crystal X1 requiring special care as it has delicate leads and a glass seal. It is best to leave the leads full length and to fix the crystal to the board with a dab of flexible "impact" adhesive.

A socket should be used for IC1 as it can be a great aid in fault finding to be able to remove the i.c. and make resistance checks. The diodes are marked with a band to indicate the cathode (k) end, and transistor TR1 is shaped so that its polarity can be easily identified. Capacitor C7 has its negative lead indicated by markings on its case.

The l.e.d. D5 should be mounted into a tight fitting hole in the case and its leads left full length. Two 100mm lengths of flexible wire should be attached to the ends of the l.e.d. leads, and fitted with 1.5mm sleeving to cover the full uninsulated length.

Mounting of the ultrasonic transducer X2 to the case is made easy by means of a tight fitting grommet. Varnish, rubber bath sealant or flexible adhesive can be used to make perfect seals around the l.e.d. transducer, and grommet on the inside of the case. Be careful though as some compounds have solvents which will damage the case, and "melt" the l.e.d.

Wires to the power source should be brought out through a small hole in the end of the case which will be the bottom when the unit is working, and sealed as before.

TESTING

If all is well the l.e.d. should flash and the circuit current consumption should be 50mA during the flashes, and practically zero in between. Giving an average of 15mA assuming a 9V supply. On 12V the current consumption will be higher and the l.e.d. brighter. As the circuit is very efficient, transistor TR1 should stay completely cold.

The circuit can be checked in stages if found to be faulty. The output of IC1b can be read with a multimeter as it pulses slowly at three second intervals. The output of IC1c is a 40kHz square wave and will read as half supply voltage on a multimeter d.c. voltage range. The output of IC1d is a series of 40kHz pulses which will read as half supply voltage pulses on and off at three second intervals.

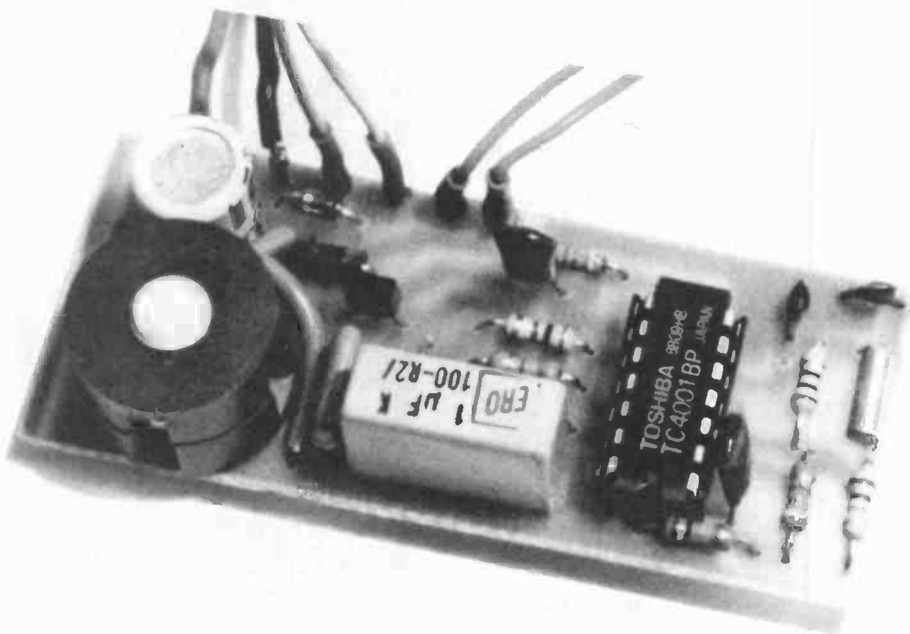
The base of transistor TR1 should read slightly positive during pulses and zero in between. TR1 collector will read approximately 20V and the anode of diode D2 will be at the supply voltage.

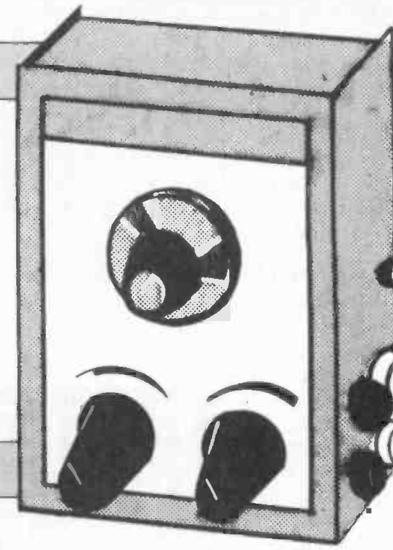
For those with an oscilloscope the circuit waveform can be read easily, making fault finding a simple task.

IN USE

Once the circuit is operating normally, the case should be closed and weatherproofed by the use of insulating tape around the lid and over the lid screws. It is recommended that the unit is fitted to a stake in the garden and sheltered from direct rainfall by a flat piece of wood nailed to the top of the stake. Other methods may of course be tried, with such hardware as plastic drink bottles and p.v.c. rainwater pipes offering interesting possibilities.

If a mains transformer is used as the power source, it is essential to use a good quality type with double insulation. Plug-in adaptors are particularly good as they are manufactured to high safety standards. The 9V d.c. adaptor specified is ideal □





AUDIO SIGNAL GENERATOR

MARK STUART

A low cost, versatile audio signal generator providing up to 6V output.

THIS simple low cost audio generator is extremely useful to have around. The output is a sine wave of up to six volts peak to peak and the frequency can be varied from 33Hz up to 33kHz. Two output sockets give variable outputs of 0-60mV, and 0-6 volts. A third socket gives a constant six volts output which can drive loads as low as eight ohms directly at up to 0.5 watts. This high power output level is ideal for checking loudspeakers and associated wiring. The compact construction makes the unit perfect for the tool box or pocket.

CIRCUIT

The circuit diagram of the oscillator is shown in Fig. 1. A single audio amplifier i.c. the LM386N-1 does everything. The frequency of oscillation is set by the dual variable control VR2a and VR2b, in conjunction with whichever pair of capacitors is selected by S1b and S1c. Capacitors C1 and C4 give the low frequency range of 33Hz to 330Hz, C2 and C5 give 330Hz to 3.3kHz, and C3 and C6 give 3.3kHz to 33kHz.

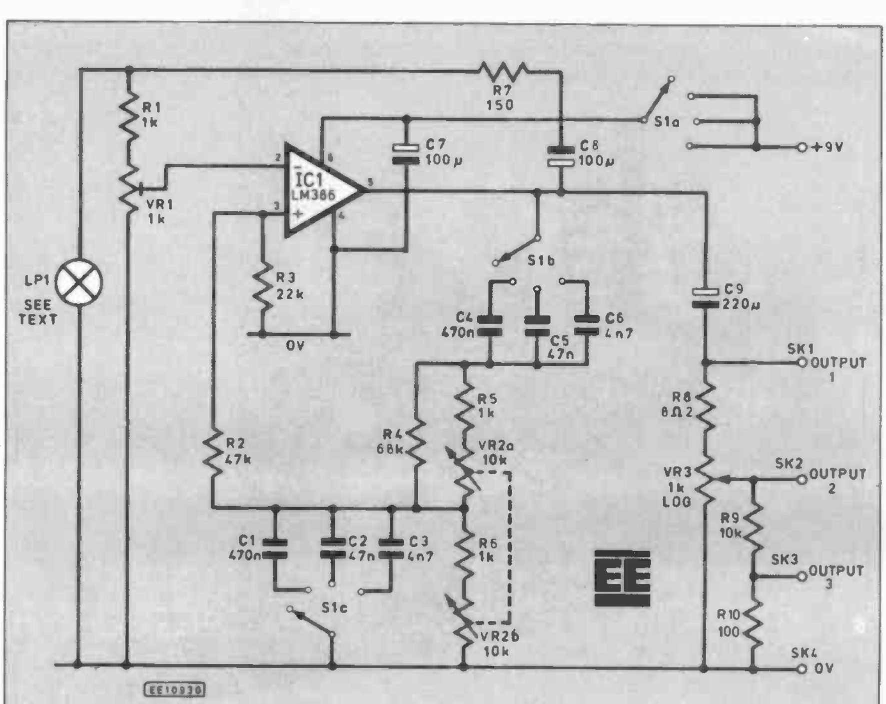
The components together form a frequency selective network known as a Wein Bridge. At the frequency of oscillation the circuit has its maximum voltage "gain" of one third. Above or below this frequency the "gain" falls away. Unlike the sort of tuned circuits used in radio receivers which can have very sharp peaks, this circuit has only a gentle "hump" in its frequency response. Its big advantage is that it does not use inductors (which would be very large for low frequencies) and that the frequency can be varied by changing just the two resistor values. Feedback via this network is passed from the output of IC1 (pin five) to its non-inverting input (pin three) via R2 and R3. If the amplifier gain is exactly three the losses of the feedback network are made up and the whole circuit will oscillate as required. The problem in a practical circuit is that a gain of exactly three is impossible to achieve. If the gain is only slightly less than three the circuit will never oscillate and if the gain is slightly more than three the oscillations will go on increasing in level until the amplifier is driven into clipping and the output is no longer a sine wave.

What is needed is a means of measuring the output level and increasing or decreasing the gain as the output voltage falls or rises. Many elaborate circuits have been designed to do this, some of which are very sophisticated and are used in top class audio measuring instruments. One of the most common methods is to use a pair of diodes or Zener diodes in the feedback network to introduce a controlled form of clipping and to set the gain to slightly over three. This method introduces a small amount of distortion but is quite adequate for some applications.

THERMISTOR

An alternative is to use a thermistor which is driven by some of the output signal and as a result increases in temperature and changes resistance. This change in resistance is arranged to affect the feedback signal so that if the output rises and the thermistor gets hotter the gain is automatically reduced and vice-versa. In this way the gain is constantly controlled and sets itself to exactly three. Low distortion and

Fig. 1. Complete circuit diagram of the Audio Signal Generator.



simple circuitry are the merits of this method, the only drawback being the cost of the thermistor. As this has to be heated by a very small signal it has to be physically small and contained inside an evacuated glass envelope. The RA53 type usually used costs around £6.00 which is rather expensive when a simple, cheap circuit is required. In this circuit the thermistor method has been used but instead of a standard thermistor a small cheap filament lamp is employed.

LAMP CHARACTERISTICS

It is generally known that the resistance of a filament lamp changes as it heats and cools. What is probably less well known is exactly how much. To get some idea of the figures involved a small bulb of 12 volts 60mA rating was tested. The voltage across it was varied and the current measured at different voltages from 25 millivolts upwards. The resulting curve is plotted in Fig. 2. A normal resistor would produce a straight line as shown by the dotted line for a 200 ohm resistor. The shape of the curve shows that initially the current increases rapidly for only a small increase in voltage but gradually increases less and less as the voltage gets higher.

At very low current and voltage (1mA,25mV) the slope of the curve shows the resistance to be around 25 ohms. At higher currents the effective resistance rises becoming 355 ohms at 12 volts. This has very interesting implications from the point of view of switch-on surges. In this case a 60mA bulb will actually look like a 25 ohm resistor at switch-on and will draw a current of 500mA. If the power supply can only provide 250mA then a voltage dip will occur which could result in numerous undesirable circuit effects. If it is assumed that all bulbs behave similarly it indicates that a car headlight bulb rated at 48 watts or four amps will draw an initial surge current at switch-on of around 35 amps! The headlamp switch must therefore be able to handle regular 70 amp current surges.

Getting back to the original purpose of all this, it is clear that the bulb filament can be used in the same way as a thermistor to control the gain of the oscillator circuit. The bulb resistance increases as the power in it increases and this must be arranged so that it causes a decrease of circuit gain.

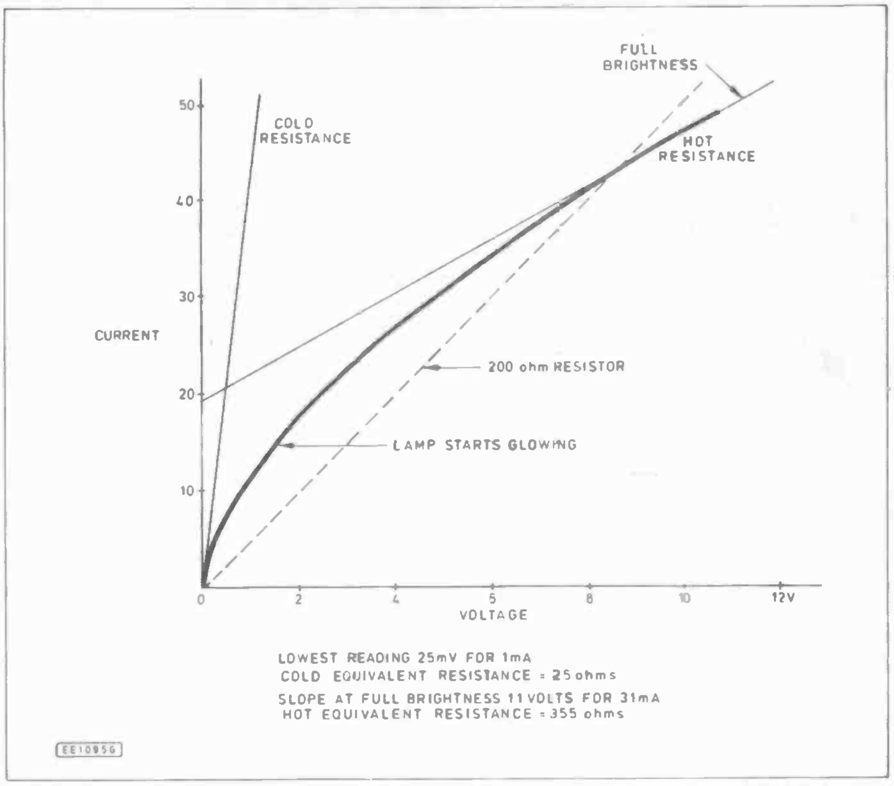


Fig. 2. Lamp resistance variation.

COMPONENTS

Resistors

R1,R5,R6	1k (3 off)
R2	47k
R3	22k
R4	68k
R7	150
R8	8Ω2
R9	10k
R10	100

Potentiometers

VR1	1k min. horizontal preset
VR2	10k dual reverse log.
VR3	1k log.

Capacitors

C1,C4	470n 100V min. polyester 10%
C2,C5	47n polyester 10%
C3,C6	4n7 polystrene 5%
C7,C8	100μ radial elect. 16V
C9	220μ radial elect. 16V

Semiconductors

IC1	LM386N-1 amplifier

Miscellaneous

LP1, 12V 60mA min. wire ended lamp.

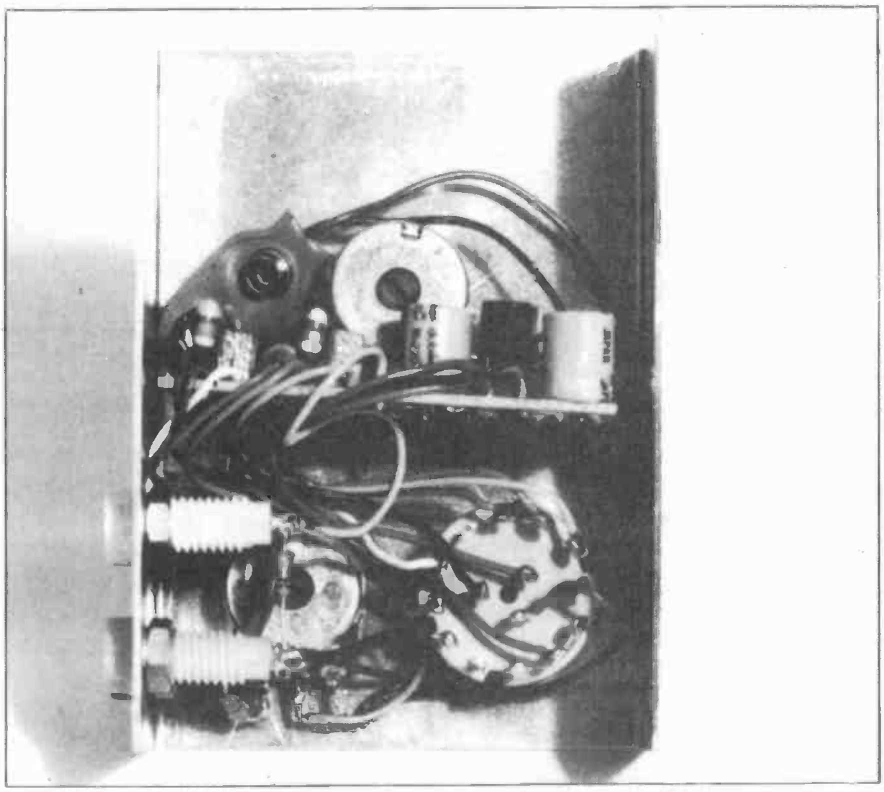
S1, 3pole 4way rotary switch.

SK1 to SK4, 4mm panel sockets.

Knobs, 2 miniature, 1 with metal skirt; i.c. socket, 8 pin; PP3 battery clip; p.c.b., metal case – size 75 × 100 × 40mm; wire; case feet.

SECOND FEEDBACK LOOP

The arrangement shown in Fig. 1 achieves the necessary control by introducing a second feedback loop around IC1. This loop is from the output to the inverting input so is negative feedback. The output signal is coupled via C8 and R7 to the lamp LP1. The voltage across the



lamp is tapped off via R1 and VR1 and fed to pin two of IC1. Operation is as follows: Initially when the circuit is switched on LP1 is cold and so has a very low resistance. Any feedback via R7 is therefore shunted away and has little effect. Without negative feedback the circuit has high gain and so oscillation commences and builds up.

As LP1 is heated by the increasing output signal, its resistance increases and so the voltage across it also increases. This causes more negative feedback to be applied to the circuit which reduces its gain. This stabilises the oscillations at a level which then can be pre-set by means of VR1. The result is a good stable sine wave output of 6V peak to peak.

Although the final circuit is very simple the actual design of the negative feedback stabilisation loop is quite difficult. The thermal inertia of the lamp puts a delay into the circuit which can cause the stabilisation to overshoot. This means that the output level can have a tendency to bounce up and down as the frequency is varied. Careful design is necessary to reduce this effect to a minimum.

OUTPUTS

Three outputs are available from the circuit. One is straight from the i.c. output via C9, and is capable of driving a speaker at up to 0.5 watts. The second output is variable by means of VR3 from zero to six volts. R8 protects this output from short circuits. The third output is divided by 100 by R9 and R10 and so is suitable for use with sensitive input circuits.

POWER

The circuit can be powered either by 9 or 12 volts. A PP3 battery will give adequate power for intermittent use. A mains adaptor should be used if the unit is in use for longer periods for example during bench testing. A section of S1 (S1a) is used as the on-off switch.

CONSTRUCTION

The whole circuit is built on a small printed circuit board which is shown in Fig. 3, the copper track pattern is also shown. Assemble the board as shown taking care to get C7, C8 and C9 the right way round. A socket should be used for IC1. The board should be fitted with flexible wire leads for the connections to VR3 and S1. These leads are best fitted directly to the board by stripping approximately 6mm of insulation and passing the bare ends through from the component side and soldering on the track side.

Refer to the wiring diagram of Fig. 5 for all of the necessary off-board connections. Switch S1 has all of its tags numbered or lettered for ease of identification. If different switches are used it may be necessary to make changes to this. The lamp LP1 should be secured to the board with a small blob of adhesive. **It is important that the correct lamp is used for the stabilisation circuit.**

SETTING UP

The circuit only requires adjustment of VR1 to be up and ready to use. Fortunately this adjustment is quite simple. Ensure that a fresh battery is fitted, select the lowest frequency range and set the dial to give approximately 50Hz. Connect a multimeter set to a.c. volts between 0V and "Output 1". Adjust VR1 to give a reading of 2.1 volts, and that's it. The calibration of VR2 can be done by borrowing a frequency meter or oscilloscope, or in a slightly more primitive way by comparison with musical instruments.

The scale and panel label shown in the photographs can be copied, stuck on and protected by self adhesive transparent film. □

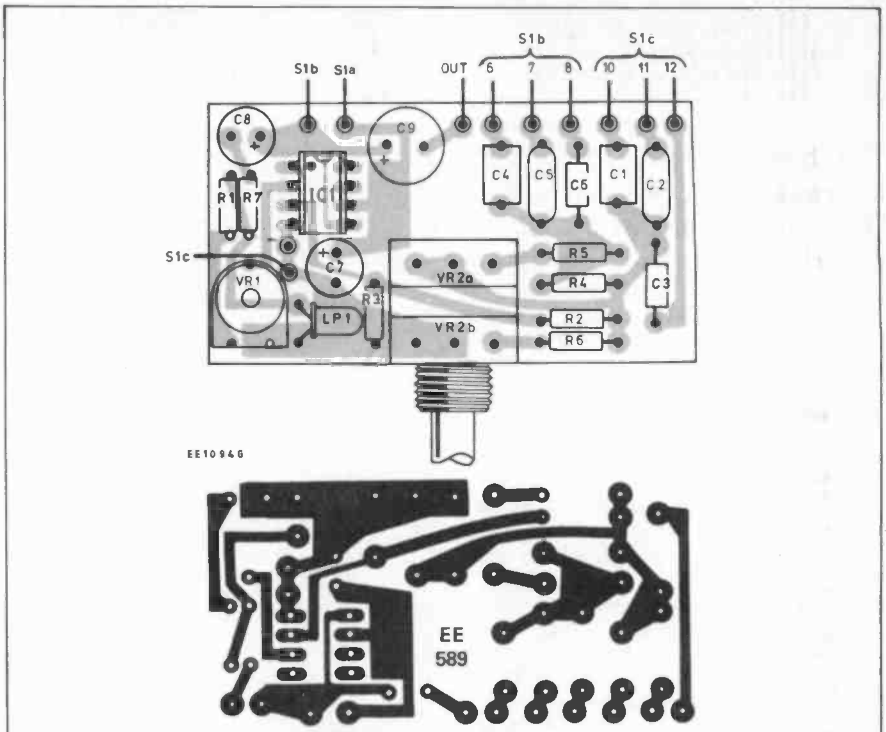


Fig. 3. Printed circuit board layout and wiring.

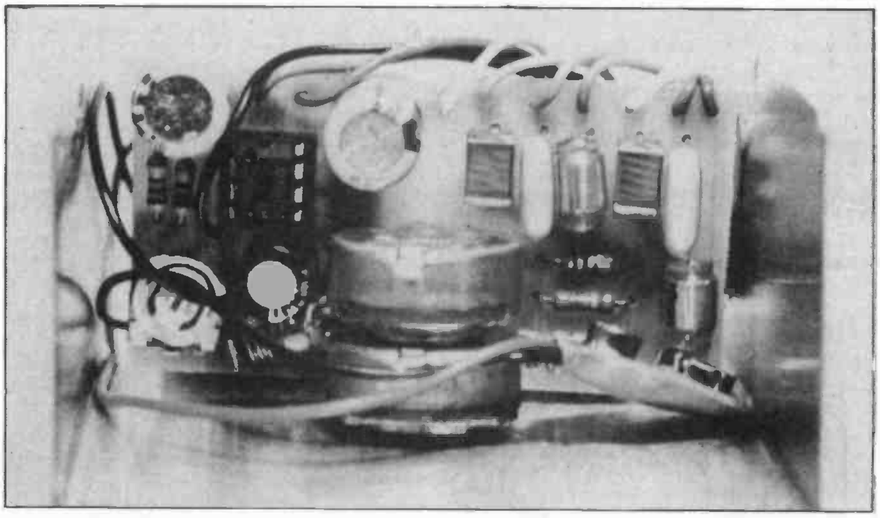
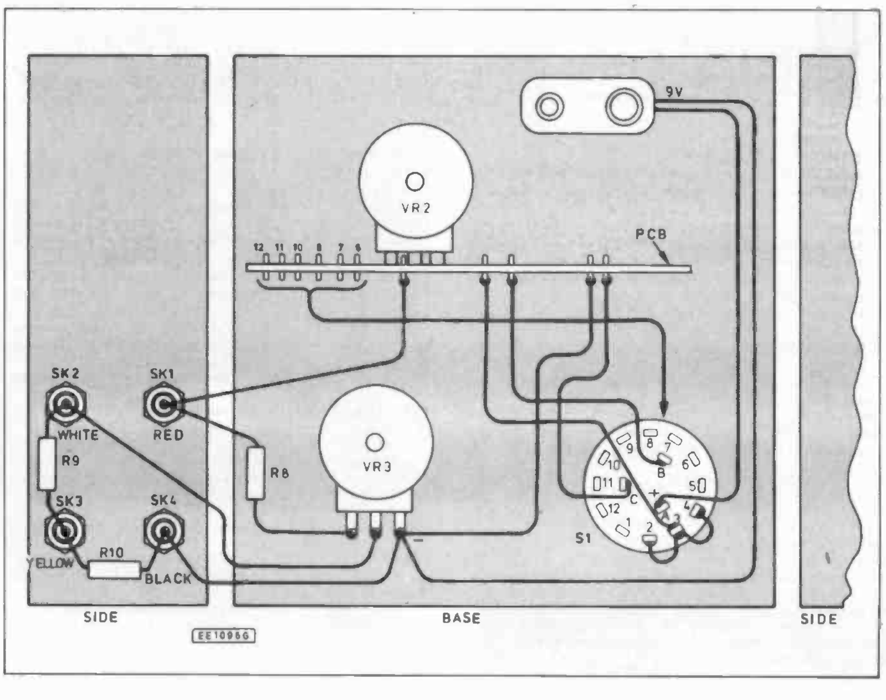


Fig. 4. Interwiring details.



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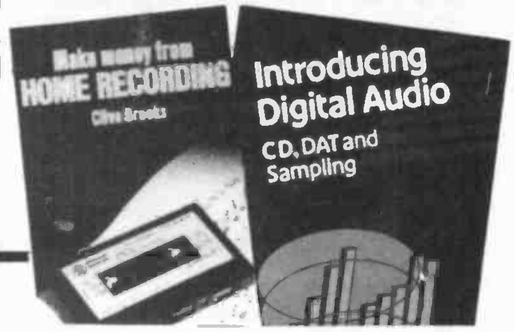

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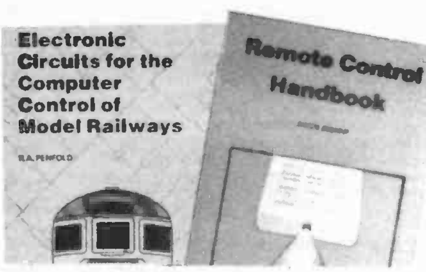

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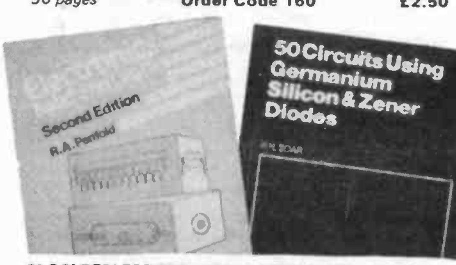

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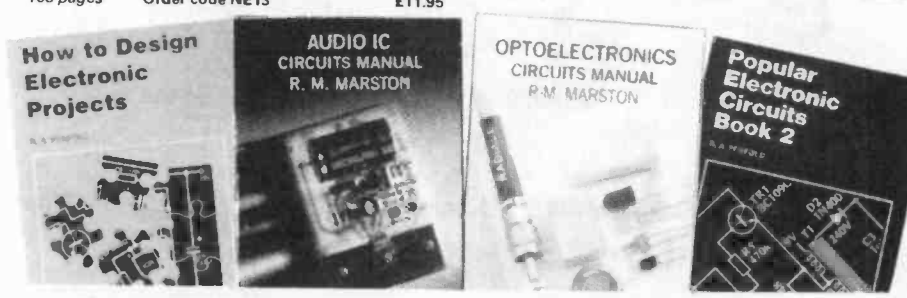

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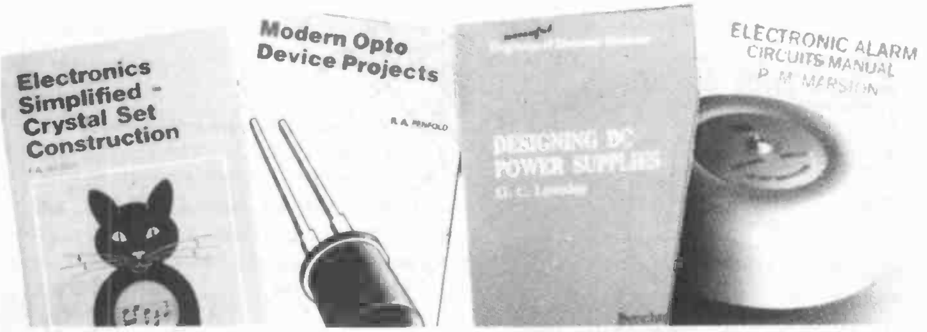

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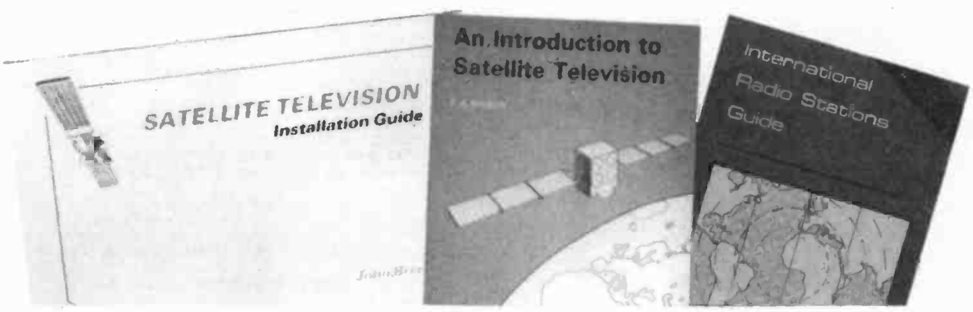

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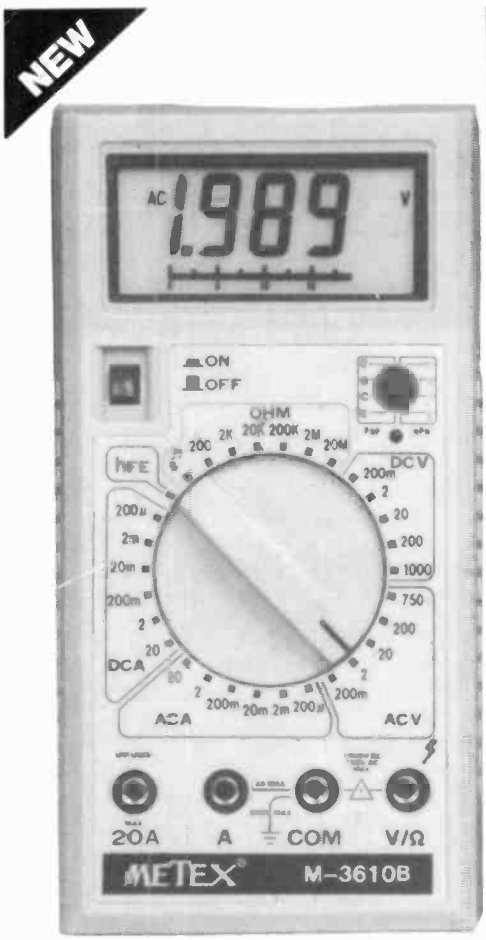

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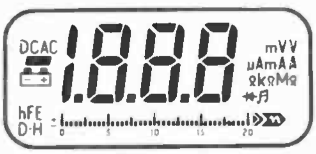

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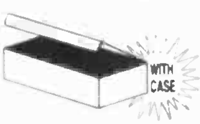

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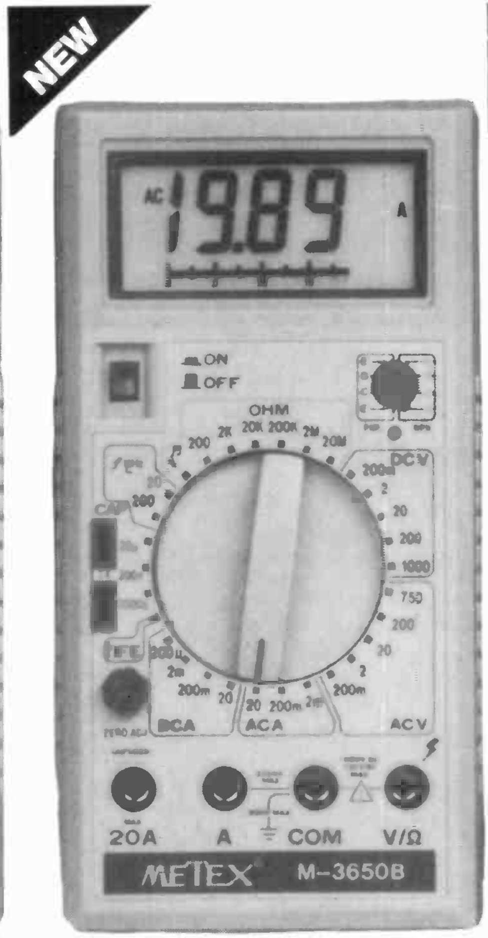

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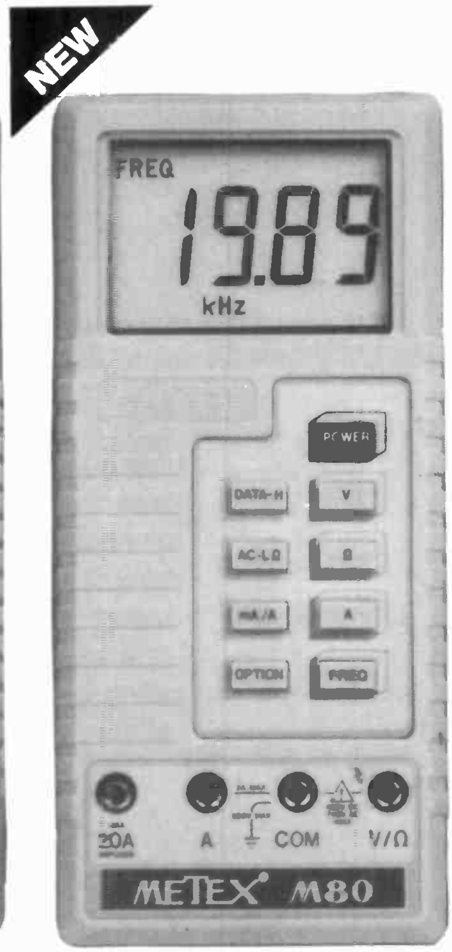

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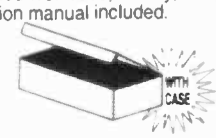

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Specification

Vertical Deflection

Operating modes: Channel I or Ch. II separate, Channel I and II: alternate or chopped. (Chopper frequency approx. 0.5 MHz).
Sum or **difference** of Ch. I and Ch. II, (with invert buttons for both Channels).
X-Y Mode: via Channel I and Channel II.
Frequency range: 2x DC to 20 MHz (−3 dB).
Risetime: approx. 17.5 ns. Overshoot: ≤1 %.
Deflection coefficients: 12 calibrated steps from 5 mV/div. to 20 V/div in 1-2-5 sequence, variable 1:2.5 to min. **2 mV/cm**.
Accuracy in calibrated position: ±3 %.
Input impedance: 1 MΩ II 30 pF.
Input coupling: DC-AC-GD (Ground).
Input voltage: max. 400 V (DC + peak AC).

Trigger System

With **automatic** from 10 Hz-40 MHz, normal with level control from DC-40 MHz.
Threshold internal ≥5 mm, external ≥0.3 V.
Slope: positive or negative.
LED indication for trigger action.
Sources: Ch. I, Ch. II, line, external.
Coupling: **AC** (≥10 Hz - 10 MHz), **DC** (0 - 10 MHz, **LF** (0 - ≤1 kHz), **HF** (≥1,5 kHz - 40 MHz).
Active TV-Sync-Separator for line and frame.

Horizontal Deflection

Time coefficients: 18 calibrated steps from 0.5 µs/div. to 0.2 s/div. in 1-2-5 sequence, variable 1:2.5 to min. 0.2 µs/div., accuracy in calibrated position: ±3 %.
with **X-Magnifier x 10** (±5%) to ≈ **20 ns/div.**
Hold-Off time: variable to approx. 10:1.
Bandwidth X-Amplifier: DC-2.5 MHz (−3 dB).
Input X-Amplifier via Channel II, sensitivity see Ch. II specification.
X-Y phase shift: <3° below 120 kHz.

Component Tester

Test voltage: max. 8.5 V_{rms} (open circuit).
Test current: max. 24 mA_{rms} (shorted).
Test frequency: 50 - 60 Hz (line frequency).
Test connection: 2 banana jacks 4 mm Ø.
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Cathode-ray tube: D14-364 P43/123, **8 x 10 div.**, rectangular screen, intern. graticule, quick heating.
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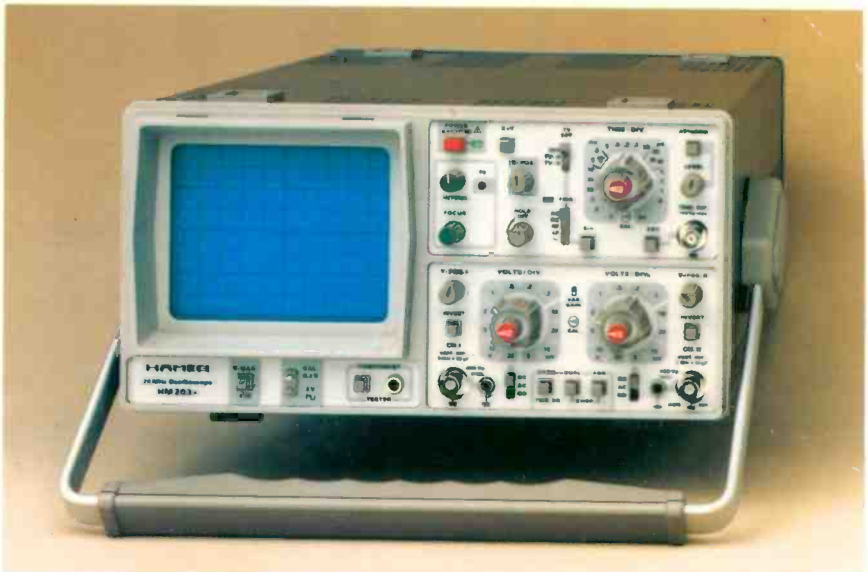
Line voltage: 110, 125, 220, 240 V~ ±10%.
Power consumption: ≈ 37 Watt, 50/60/400 Hz.
Protective system: Safety Class I (IEC 348).
Weight: approx. 7.5 kg. Colour: techno-brown.
Cabinet: **W** 285, **H** 145, **D** 380 mm.
Lockable tilt handle.

Subject to change without notice.



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