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EVERYDAY ELECTRONICS and computer PROJECTS

AUGUST 1984 90p

what is radiation?

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Microwave Alarm System
Kitchen Appliance Timer

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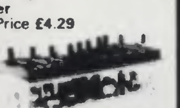
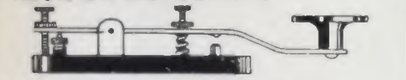


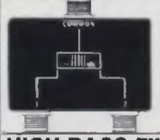
GE 100 MKIII

PRECISION MORSE KEYS



Well designed beginners key. Fully adjustable. Dims: Base 82mm × 45mm. O/No. VP 122. **£1.85**

ANTENNA SWITCH 2 and 3 WAY



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As above but 3 way.
O.No. VP 114 **£4.75**

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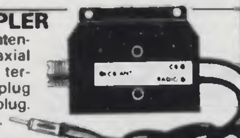

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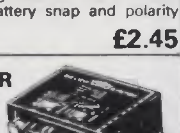

Limits voltage to speaker or to the permissible max., by automatically introducing a resistor in series with speakers. When excessive voltage is reduced the unit resets itself. Electronic voltage-sensing relay circuit. Spring terminals. Cut-off level adjustable from 10W-120W. Full instructions included. Dims: 85 × 74 × 25mm.
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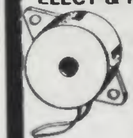
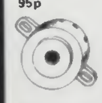
ELECT & PIEZO BUZZERS

PIEZO



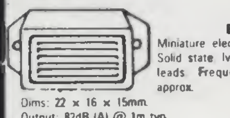
Miniature round piezo electronic buzzer. White plastic. Low consumption.
Frequency: 4kHz approx.
Output: 70dB (A) @ 1, typ
Power: 12Vd.c. 4mA
Dims: 22 (dia.) × 11.5mm.
Fixing Centres: 26.5mm.
O/No. VP 107
95p

PIEZO



Piezo buzzer. White plastic. 90mm leads. For use on a.c mains.
Frequency: 3.5kHz approx.
Output: 85dB (A) @ 1m typ.
Power: 240Va.c. 5mA.
Dims: 32 (dia.) × 14mm.
Fixing centres: 38mm.
O/No. VP 108
£1.15

ELECTRONIC



Miniature electronic buzzers. Solid state. Ivory plastic. 150 leads. Frequency: 500 Hz approx.
Dims: 22 × 16 × 15mm.
Output: 82dB (A) @ 1m typ.
Fixing centres: 26mm.
3V 25mA: O/No. VP 82 — 6V 25mA: VP 83
9V 25mA: O/No. VP 84 — 12V 25mA: VP 86
80p each

SUB-BOX

A neat swivelling disc provides close tolerance substitution resistors of 36 preferred values from 5ohms to 1Kohm. Simply fix clips into circuit and swivel until optimum result is achieved.
O/No. VP 112 **£4.75**

MINIATURE VICE

Miniature plastic and metal vice with strong suction base for portability. Single action to secure or release suction. Plastic jaws with rubber pads 20mm wide, open out to 40mm. Dims: 85 × 65 × 60mm approx.
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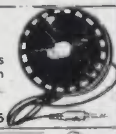

Slim under pillow unit. 8ohms 2" speaker. 1.5m lead with 3.5mm mono jack plug. Black. Dims: 65 (dia.) ×17mm.
O/No. VP 88 **£1.25**

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2m long × 13mm wide	O/No. VP 89	£1.00
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5m long × 16mm wide	O/No. VP 91	£2.00

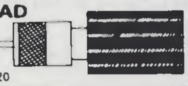
BATTERY TESTER

Tests all types of battery including standard, NICAD, Alkaline etc. Takes all standard sizes including 6V lantern batteries and watch/hearing aid cells. Also tests fuses and lamps by means of internal 9V (PP3) battery. Can also be used to recharge NICAD batteries by means of external 3-12Vd.c. power supply (not included).
Full instructions provided. Dims: 185 × 103 × 30mm (approx.).
O/No. VP 101 **£7.00**

FM MONITOR

FM monitor for 2 metre band. All metal. Attached earphone. PL259/SO239 connectors. 144MHz. 10W maximum. Dims: (Body) 55 × 30 × 23mm.
O/No. VP 120 **£4.20**

DUMMY LOAD



50 ohms. 30W. UHF co-axial plug fitting (PL259).
O/No. VP 121 **£5.20**

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Large telephone pick-up coil for high sensitivity. Suction pad to stick to telephone. 90cm lead to 3.5 jack plug. Connects direct to cassette recorder. Dims: 32 (dia.) × 17mm (body) 36mm (dia.) sucker.
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VP3	200		£1.00
VP4	150	¼ Watt Resistors 100 ohm-1M Mixed	£1.00
VP5	200	Assorted Capacitors All Types	£1.00
VP6	200	Ceramic Caps Miniature – Mixed	£1.00
VP7	100	Mixed Ceramics Disc. 1pf – 56pf	£1.00
VP8	100	Mixed Ceramic Disc. 68pf – .015pf	£1.00
VP9	100	Assorted Polyester/Polystyrene Caps	£1.00
VP10	60	C280 Type Caps Metal Foil Mixed	£1.00
VP11	100	Electrolytics – All Sorts	£1.00
VP12	60	Bead Type Polystyrene Min Caps	£1.00
VP13	50	Silver Mica Caps Ass. 5.6pf – 150pf	£1.00
VP14	50	Silver Mica Caps Ass. 180pf – 4700pf	£1.00
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VP33	200	Sil. Diodes Switching Like IN4148 DO-35	£1.00
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VP35	50	1 Amp IN4000 Series Sil. Diodes Uncoded All Good	£1.00
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TRANSISTOR CLEARANCE

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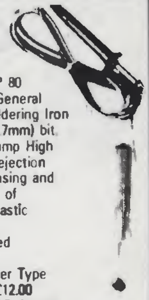

Kit comprises: O/No. VP 80
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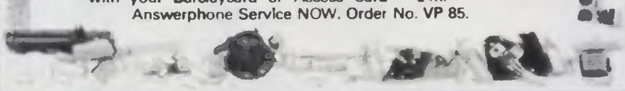

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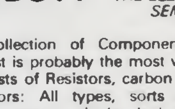

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EVERYDAY ELECTRONICS and computer PROJECTS

VOL. 13 NO. 8 AUGUST 1984

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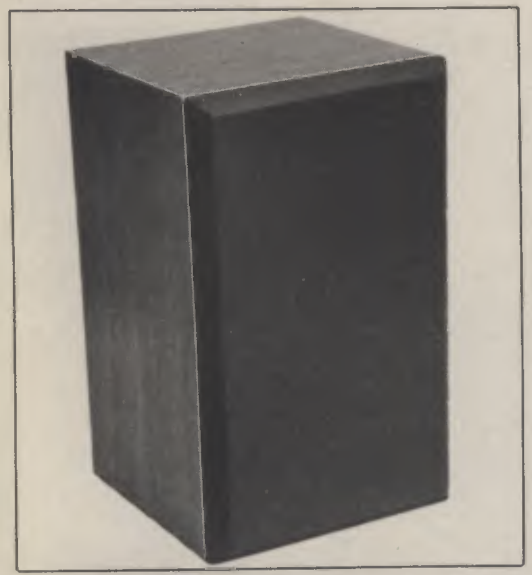

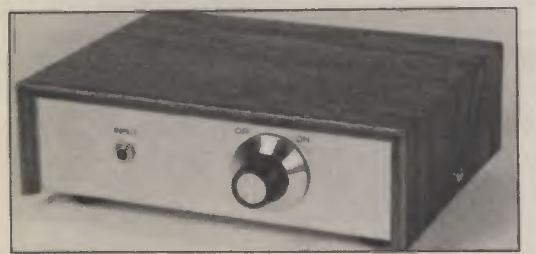

PROJECTS

SERIES

FEATURES

Our September 1984 issue will be published on Friday, August 17. See page 531 for details.

EVERYDAY ELECTRONICS and computer PROJECTS

VOL. 13 NO. 8 AUGUST 1984

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FUNTRONICS

PERHAPS one of the most enjoyable aspects of editing EE is that you never know what the post will bring, or who will phone up to discuss future projects or plans. The high standing and reputation for excellence that EE has achieved over the years, plus total issue sales that are 177 per cent that of our nearest rival, means that all sorts of individuals, companies and educational establishments have been and continue to be, deeply involved with the future of EE.

Just recently the post brought us a new idea for a page entitled *Funtronics*; the artwork came in "out of the blue" from a reader with whom we had had no previous contact. The page submitted was of a very high standard—good to look at, fun, interesting and informative to read. It has plenty of good data, cartoons, puzzles, tables, etc. and must be rated as one of the best innovations in EE ever. Furthermore, the man behind the idea and the artwork has plenty of exciting ideas that we hope will come into the page in the future. To get the flavour of *Funtronics*, see page 531 and don't miss the first one next month. You will not be disappointed!

AROUND THE WORLD

Also popping up in our postbag, and sometimes on the phone, are enquiries and requests from readers around the globe. It is not unusual for us to get phone calls from Scandinavia, Australia or almost anywhere else. Perhaps the most interesting aspect of such correspondence is the similarity in interests of hobbyists in electronics around the world. Obviously not all countries are at the same technical level as the UK, but most hobbyists seem to find ways of getting components and building our projects.

One recent letter from Portugal brought a complaint that we cover projects for computers and few people can yet afford such items. This shows how lucky we are in the UK where most of our readers own a microcomputer or at least have the use of one at work, school, college, evening institute or university. Perhaps we take such things for granted, but in many countries computers are still not widely available at realistic prices.

With every aspect of life being "invaded" by new technology, it will become more and more important to have some understanding of electronics and computing. It will also be necessary for many people, now employed in industries that are being modernised or ones that are becoming outdated, to be retrained. Our series on electronics and computing will provide an excellent grounding for all.

The understanding that can be gained from *Anatomy of the Microcomputer* or our *Teach-In* series could provide the difference necessary to secure a promotion or even employment. We will continue to publish such information so that you can help yourselves!

Mike Kenward

Readers' Enquiries
We cannot undertake to answer readers' letters requesting modifications, designs or information on commercial equipment or subjects not published by us. All letters requiring a personal reply should be accompanied by a stamped self-addressed envelope or international reply coupons.
We cannot undertake to engage in lengthy discussions on the telephone.

Component Supplies
Readers should note that we do not supply electronic components for building the projects featured in EVERYDAY ELECTRONICS, but these requirements can be met by our advertisers.

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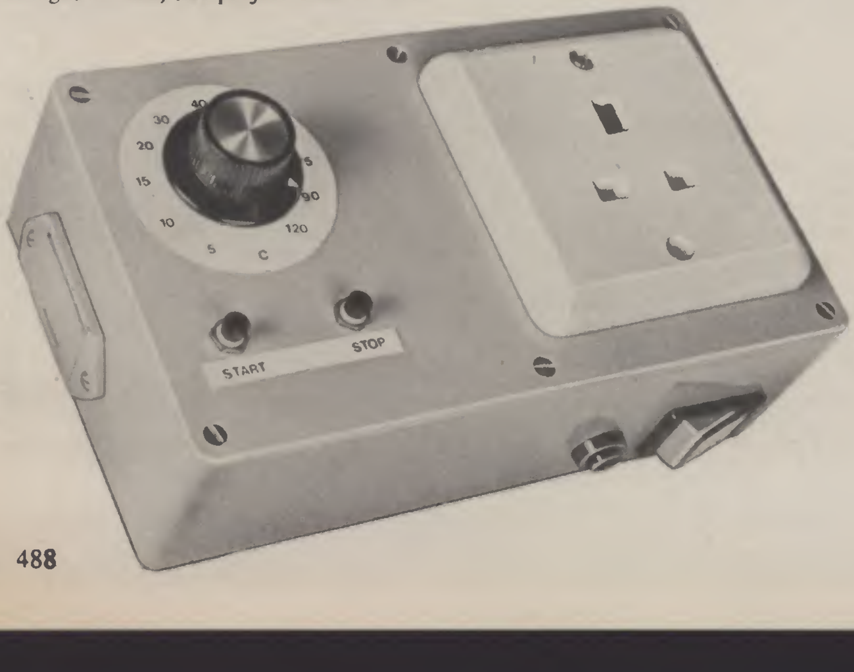
KITCHEN APPLIANCE TIMER

T. R. de Vaux Balbirnie

ELECTRIC food mixers and blenders are common items in every modern kitchen. Although taking much of the hard work out of food preparation, most models have one major drawback. They do not have a built-in timer so a lot of time is wasted "clock watching". This simple project frees the hands of the busy cook by providing a mains power socket which switches on kitchen appliances for a selected time. Although designed principally for food mixers there could be other uses for this project, as an enlarger timer, for example.

The Kitchen Timed Outlet appears as a plastic box which plugs into the mains. A 13-amp socket, rotary switch and two push-button switches are mounted on top. The rotary switch selects the required time interval from a choice of eleven values or "continuous". The push-button switches initiate the process and end it prematurely if need me. Safety features include: a fuse, and a double-pole mains on-off switch with neon indicator.

The electronic part of the circuit is battery-powered for reasons of low cost and simplified construction. Excellent service should be given by the battery since it is totally disconnected from the circuit except while actually timing. The battery may be replaced without removing the lid of the case. Although construction is straightforward, this project does involve making mains connections and readers are advised to seek help if they are unsure of their ability to make a safe job.



CIRCUIT DESCRIPTION

The circuit for the Timed Outlet is shown in Fig. 1. The timing section consists of a 555 timer integrated circuit and associated components. These are connected as a *monostable*. This means that when IC1 is triggered by taking pin 2 low, the output (pin 3) will go high for a time then revert to its original state. The time period is determined by the values of C1 and the "switched resistance" (R1 to R11). In this circuit C1 has a fixed value so timing depends on the value of the switched resistance (R1 to R11). The rotary switch, S1, selects R1 + R2 + R3, etc, to gain the required timing. VR1 is the calibration control whereby the timings are adjusted accurately. This is necessary since the value of C1 is not known precisely due to its range of tolerance.

The output of the 555 is far too small to operate mains equipment and this is where the relays RLA and RLB are necessary. Both these components have normally-open contacts. While IC1 is on, both relay coils will be energised. The contacts of RLB connect the appliance to the mains. Meanwhile, the contacts of RLA short-circuit the "start" switch, S2. Thus, when S2 is pressed for an instant, the i.c. will be triggered by the pulse of charging current to C2 taking pin 2 low. The contacts of RLA then "take over" from S2 in allowing battery current to flow until the end of the timing cycle. Timing may be interrupted at any time by momentary breaking of battery current by means of S3 which is a push-to-break switch.

The reason for using *two* relays instead of just one component with two pairs of contacts, is to keep the battery and mains totally separate. This avoids the possibility of "flash over" from one set of contacts to the other.

D1 is necessary to prevent false triggering which could occur in its absence. No diode need be connected in parallel with either relay coil as would be normal practice, as RLA has a diode already built in which serves RLB also. A diode is important in by-passing the reverse voltage spike which occurs when the magnetic field in a relay core collapses.

MAINS RELAY

The choice of RLB deserves special mention. This component must have at least one pair of normally-open or changeover contacts. Readers who are not using the specified relay must give consideration to *contact current rating, coil operating voltage, coil resistance* and overall physical size.

For mixers and blenders a maximum load figure of 500 watts will be found adequate (that is, about 2 amps on 240V mains). The relay contacts must be rated to this figure at least. Catalogues often specify contact ratings for a *resistive* load; for a motor or other *inductive* load de-rating . is necessary. In practice, a resistiva contact rating of 5 amps will be satisfactory. The coil should operate from as low as 6 volts. Some relays have an 8·4 volt coil which is not suitable, especially as the battery ages. The relay coil should have as high a resistance as possible to minimise drain on the battery.

COMPONENTS

Resistors

R1–4	82kΩ	(4 off)
R7	150kΩ	(1 off)
R5,6,8	180kΩ	(3 off)
R10	220kΩ	(1 off)
R9	270kΩ	(1 off)
R11	470kΩ	(1 off)
R12	10kΩ	

All resistors $\frac{1}{4}$ to $\frac{1}{2}$W ±5%

Potentiometer

VR1 10kΩ miniature preset potentiometer horizontal mounting

Capacitors

C1 47μF electrolytic 10 volt working or higher

C2 100μF 10 volt working or higher

Semiconductors

IC1 NE555V timer

D1 1N4001 silicon

See Shop Talk page 534

Relays

RLA d.i.l. reed relay 5 volt 500 ohm coil with built in diode and one set of N/O contacts

RLB "Open relay" 410-ohm coil: 6 volt operation. N/O or changeover contacts rated at 240V a.c. 5 amps (Maplins "Open Relay" or R.S. type 349–125

Miscellaneous

S1 12-way rotary switch with knob

S2 miniature push-to-make switch

S3 miniature push-to-break switch

S4 mains on/off switch d.p.s.t. with neon indicator—3-amp contacts or higher

FS1 5A fuse and holder

SK1 13-amp mains outlet socket

B1 9V PP3 battery and drawer matrix stripboard, size 16 strips × 40 holes

Approx. cost Guidance only **£10.50**

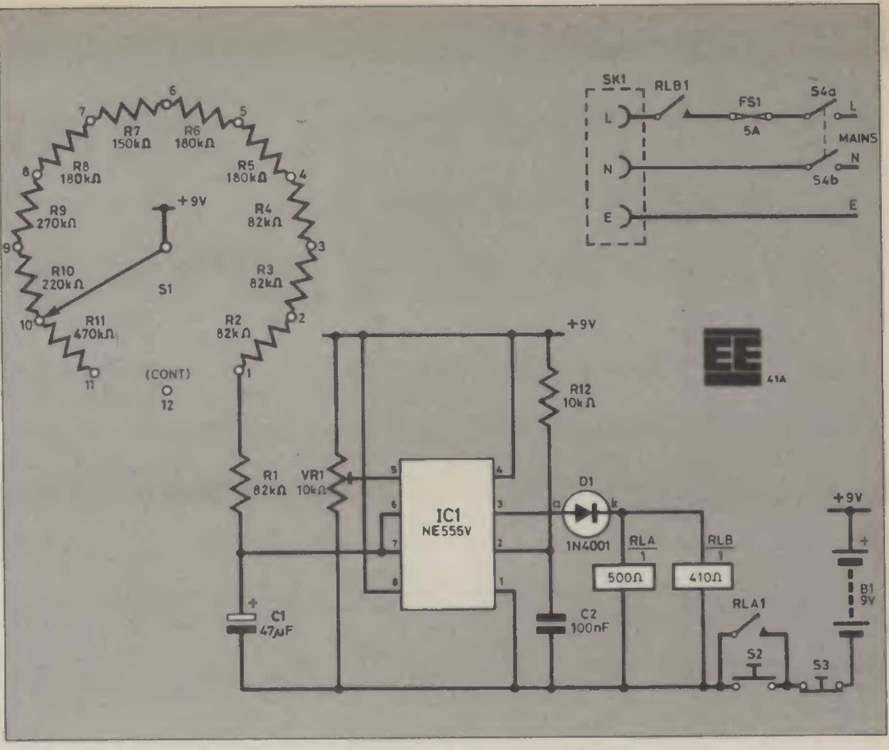


Fig. 1. Circuit diagram of the Kitchen Appliance Timer.

CONSTRUCTION

The wiring diagram is shown in Fig. 2. Prepare the circuit panel using a piece of 0·1in matrix stripboard 16 strips by 40 holes in size. Cut it a little larger then file it to fit tightly into the runners of the plastic box. Solder all components into position but do not insert the 555 into its holder until all construction work has been completed. Solder RLA direct to the panel using minimum heat from the soldering iron to prevent damage. Make the eight interstrip links and all breaks in the copper tracks as indicated. Note that the strips are broken between the pins of IC1 but not between those of RLA. If RLB is not as specified then some modifications will be needed to its

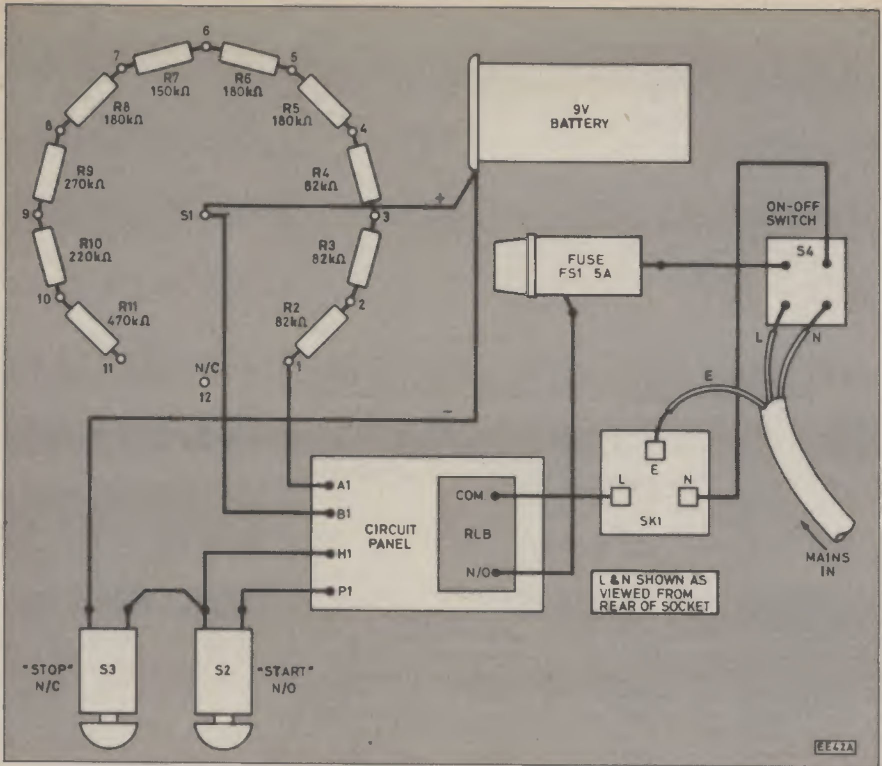
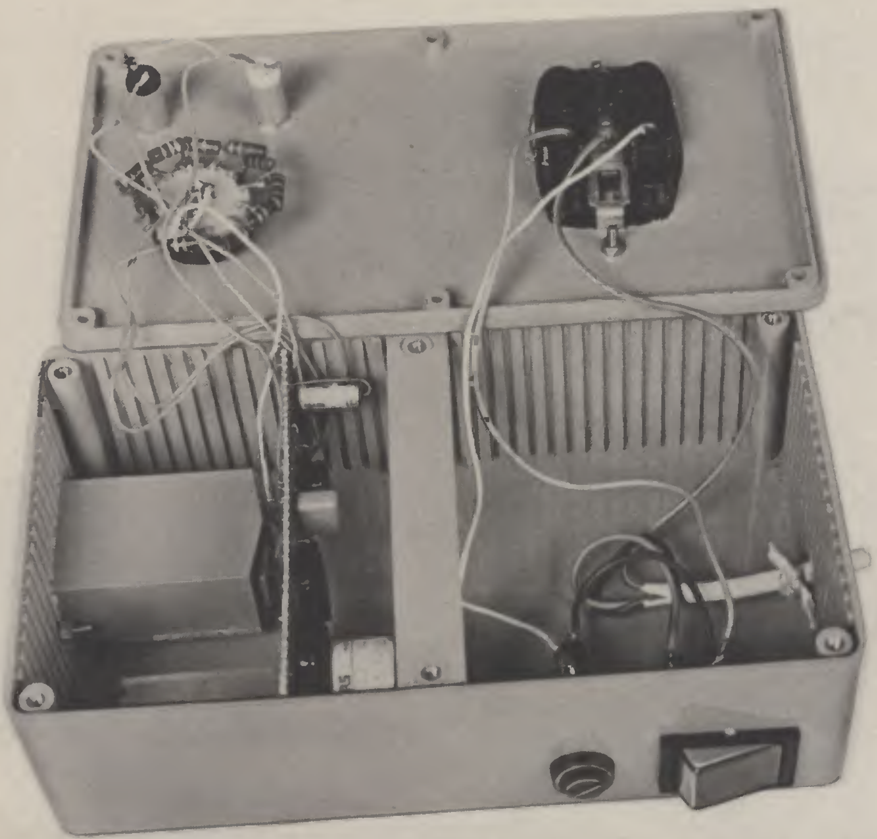


Fig. 2. Wiring details of the Kitchen Appliance Timer.



mounting and connecting details. After soldering the pins of RLB to the copper strips, these strips should then be broken in several places, as indicated, to isolate them from the battery part of the circuit. Carefully-made connections should be made to the normally-open contacts of RLB on the *topside* of the panel using 15 centimetres of 3A stranded wire. A careful check should be made to ensure that no contact connections to RLB make contact with the low voltage side of the panel.

Insert the 555 into its holder then solder 15 centimetres of connecting wires to each of the copper strips A, B, H and P. The rotary switch, S1, may now be prepared by soldering the resistors R2 to R11 around its contacts 1 to 11 (see photograph). Note that R1 is already on the circuit panel and contact 12 has no resistor connected to it as this is the "continuous" setting.

Prepare the case by making holes in the lid for the mains outlet socket and for S1, S2 and S3. Make holes in the side of the box for the mains on-off switch, fuse, inlet lead and battery drawer. All remaining components should be assembled and the wiring completed as in Fig. 2. Make a scale of times for S1 and fit this and the knob in position.

ON NO ACCOUNT MOUNT RLB BY BOLTING IT TO THE CASE. THIS IS BECAUSE THE FRAME OF THE RELAY IS "LIVE" AND THE HEADS OF THE BOLTS WOULD BE "LIVE" TOO.

TESTING

Before operating this project from the mains for the first time, it is essential to test it and adjust VR1 using a battery. To do this, connect the live and neutral pins of a discarded 13A plug to a 6-volt bulb. Plug this into the mains outlet socket to simulate the mixer. Connect the mains inlet wires to the terminals of a 6 or 9-volt battery. Adjust the slider of VR1 to approximately mid-track position. Place a PP3 battery in the drawer and the fuse in its holder. Set the mains switch to "on" and S1 to "15 seconds". Press S2. The lamp should light for a time then go off. VR1 may be adjusted for an accurate 15 seconds. Clockwise rotation of the slider will increase the time. Check operation on other time settings and adjust VR1 for best overall performance. Check the "stop" switch, S3.

When the system is operating correctly, *replace the lid of the case,* plug a mixer into the outlet socket and test the unit on the mains. Never remove the lid of the case while the project is plugged in.

OTHER APPLICATIONS

This timer can be used for any low power operation of mains equipment, such as photographic timers, hi fi or video application. □

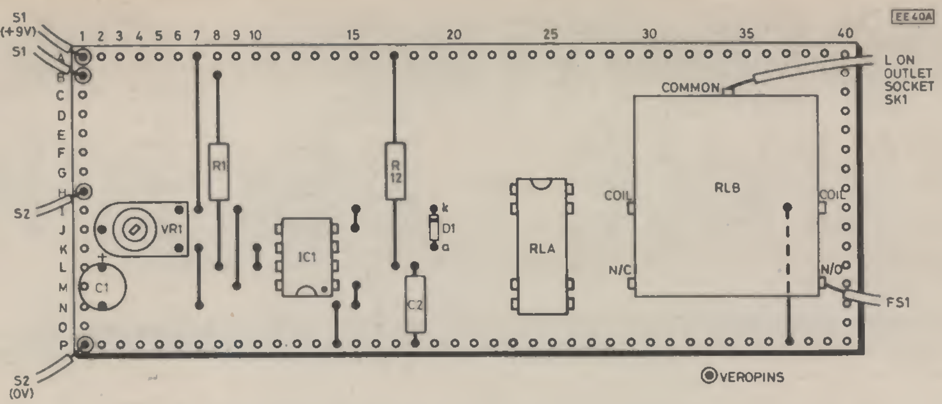


Fig. 3. Component layout of matrix stripboard for Kitchen Appliance Timer.

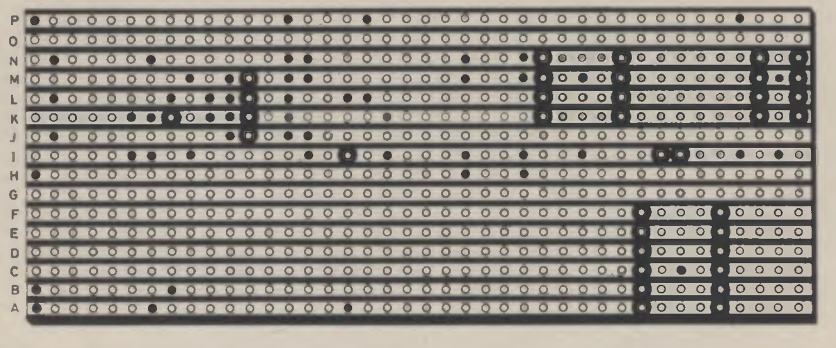
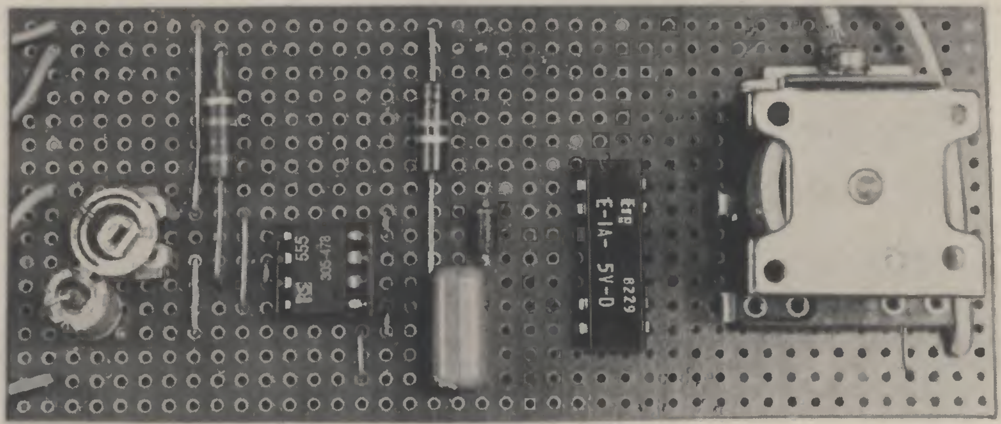


Fig. 4. Drilling details of matrix stripboard for Kitchen Appliance Timer.



TEMPERATURE INTERFACE – BBC MICRO

R.A.PENFOLD

A HOME COMPUTER is ideal for use in many measurement applications since it can be used as a digital readout, or results can be displayed on the monitor or TV screen as a graph or in some similar form. With the aid of a suitable printer it is even possible to produce hard copies of graphs or charts.

This article describes a simple temperature interface for the BBC model B microcomputer, and it makes use of the machine's four channel analogue-to-digital converter. This converter has only a rather limited sampling rate of once every 40ms if all four channels are used, or once every 10ms if only channel 1 is used. However, in an application such as this the response time of the sensor is very slow and the limited sampling rate of the analogue-to-digital converter is of no consequence. The converter is a 12-bit type which gives the system good resolution, and as there are four inputs it is possible to simultaneously use up to four temperature interfaces with the unit.

The interface uses a semiconductor temperature sensor which gives good linearity and accuracy over a wide temperature range of −50 to +150 degrees centigrade.

THERMISTOR SENSOR

Perhaps the most obvious way of providing a temperature interface for the machine is to use a simple thermistor type such as the one outlined in Fig. 1. There are just two components used here; thermistor RTH1 and resistor R1. These are wired as a simple potentiometer connected between the 0V rail and the 1·8 volts reference output of the analogue port. The output of the divider circuit is connected to the channel 1 input of the analogue port. This responds to input voltages of between 0V and 1·8 volts, and the output of the potential divider must therefore be within the correct voltage range.

The specified thermistor is a negative temperature coefficient type, in that its resistance falls as the applied temperature is increased. Thus, increased temperature results in a higher voltage from the circuit, decreased temperature produces a lower output voltage, and it would be reasonably easy to devise software that would convert the values returned from the A/D converter into the correct temperature values. A slight problem with this arrangement is that the linearity is only good over a fairly narrow range of temperatures, and this would complicate the software if a wide temperature coverage was required. Also, a very wide temperature range could not be achieved properly since the voltage changes produced at the extremes of the range would be inadequate.

One final problem is that if several circuits of this type were to be connected to the computer the software for each channel would need to be slightly different in order to compensate for the tolerances of the thermistors and resistors.

Despite these limitations, there are applications where a simple interface of this type will suffice, and where the use of a more sophisticated circuit would just be over complicating matters. With the circuit of Fig. 1 the nominal centre of the temperature range is 25 degrees centigrade, and the value returned from channel 1 of the A/D converter changes by approximately 650 per degree centigrade for temperatures about 20 degrees or so either side of the centre point.

THE LM335Z

The LM335Z is a high quality temperature sensor integrated circuit which is contained in a standard TO-92 plastic encapsulation and looks much like an ordinary plastic cased transistor. The two basic methods of using this device are shown in Fig. 2.

This device can be regarded as a high quality voltage regulator, but the voltage developed across the component depends on its temperature, and is nominally 10 millivolts per degree Kelvin. In terms of degrees centigrade this represents 2·732 volts plus 10 millivolts per degree centigrade (or minus 10 millivolts per degree for temperatures below zero). The circuit of Fig. 2(a) can be used to trim the device for optimum accuracy, but for most purposes the simple method of Fig. 2(b) is adequate. These circuits are not significantly affected by normal supply voltage fluctuations, and it is only necessary to stabilise the supply if there would otherwise be extremely large variations in the supply potential.

BLOCK DIAGRAM

The block diagram of Fig. 3 shows the general arrangement used in the temperature interface. The temperature sensor drives the analogue port of the computer via a buffer amplifier which provides a low output impedance. A variable attenuator is used between the sensor and the buffer stage since the nominal output voltage swing of the sensor is 2 volts (200 degrees × 10

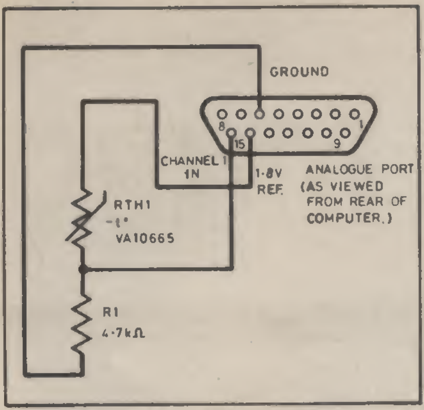


Fig. 1. Simple thermistor circuit.

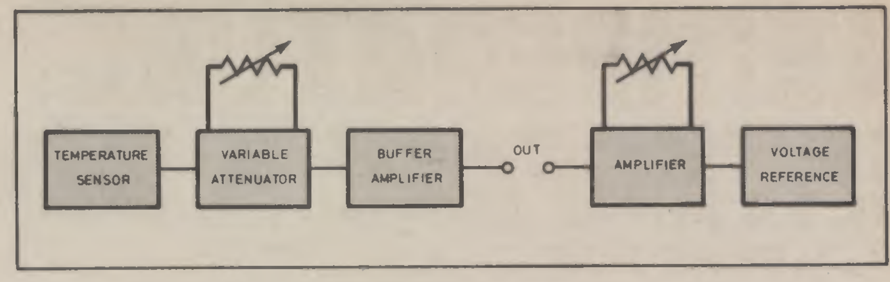


Fig. 3. Block diagram of the Temperature Interface.

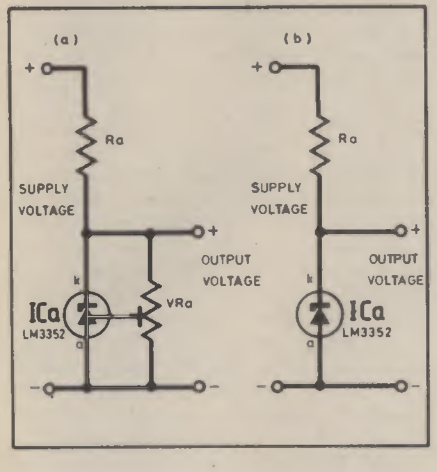


Fig. 2. Basic methods for using the LM335Z.

millivolts = 2000 millivolts or 2 volts) and the computer requires an input voltage swing of 1·8 volts, as explained earlier.

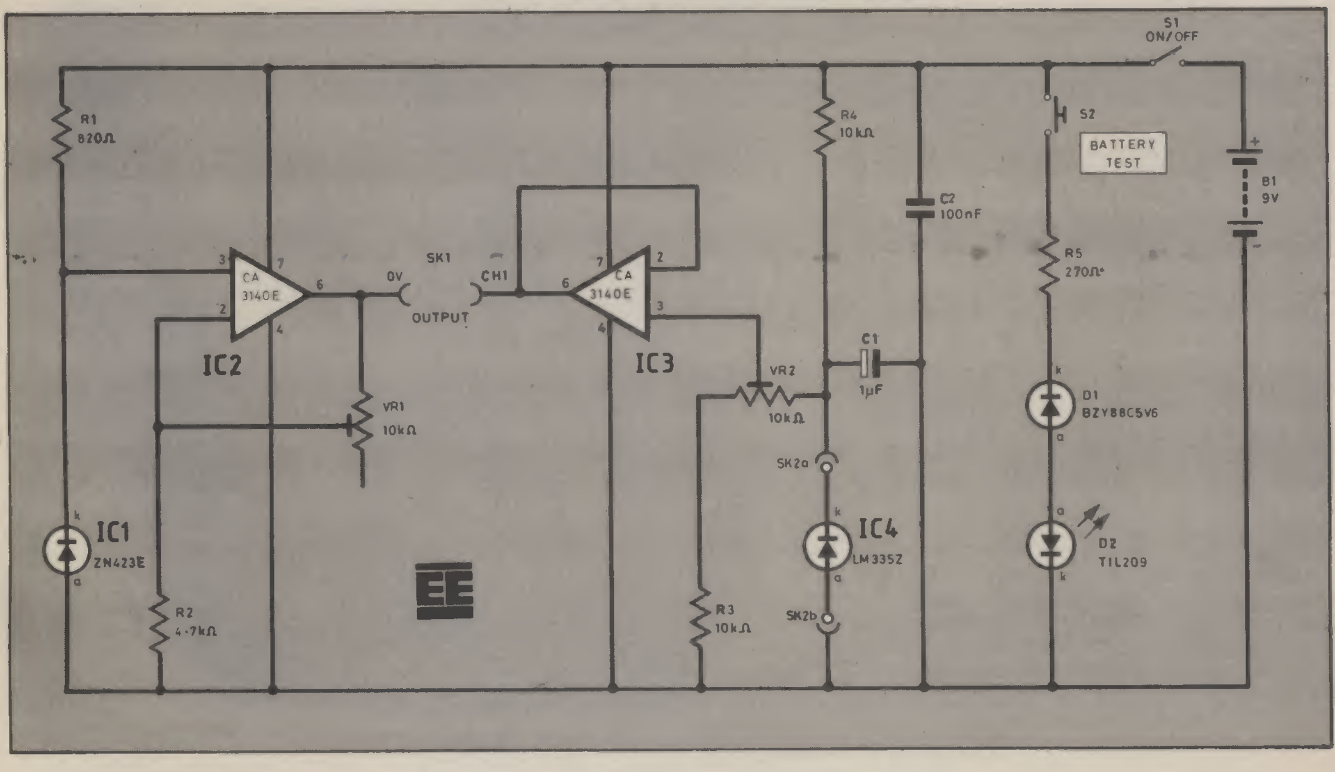
A minimum output voltage of 0 volts is required, but the sensor circuit gives a minimum output potential of about 2·232 volts. Originally a circuit in series with the output which provided a suitable voltage drop was tried, but the bridge circuit was finally adopted as this was found to give better results. With this system a precision voltage regulator is used to provide a 2·232 volts reference level, and when the output to the computer is taken from the output of the sensor and the reference level, rather than between the output of the sensor and the 0V rail. The computer is fed with the potential difference across the two outputs, and with the sensor at its minimum operating temperature the two outputs are at the same potential and the voltage difference is zero. At higher temperatures the sensor produces a higher voltage and a potential is produced across the outputs. This is effectively the same as reducing the output of the sensor by the desired amount, but it must be borne in mind that neither output of the circuit is at its 0V supply potential. The voltage reference is made variable so that it can be adjusted to give precisely the required potential, and it actually consists of a fixed voltage source feeding a variable gain amplifier.

CIRCUIT DESCRIPTION

The full circuit diagram of the temperature interface is shown in Fig. 4.

IC1 is the precision fixed voltage (1·2 volts) reference device, and R1 is its load resistor. The ZN423E requires a current flow of about 10 milliamps in order to operate efficiently and R1 therefore has a fairly low value. If low current consumption is considered important IC1 can be replaced with the more expensive 8069 device and R1 can be increased to 10kΩ in value. Note that this application requires the use of a high quality voltage regulator having temperature compensation, and a simple regulator using a cou-

Fig. 4. Circuit diagram of the Temperature Interface.



ple of forward biased silicon diodes or something of this type would not be adequate.

IC2 is an operational amplifier which is used in the non-inverting mode, and amplifies the potential developed across IC1. The gain of the amplifier can be varied by means of R3 from unity to about three times, giving an output voltage range of about 1·2 volts to 3·6 volts. A CA3140E is used in the IC2 position because this has an output which can swing down to virtually the negative supply potential. Most i.c. operational amplifiers are not quite able to supply the minimum output voltage called for in this circuit.

TEMPERATURE SENSOR

IC4 is the temperature sensor and this will normally need to be located away from the main unit. It is therefore coupled to the rest of the circuit via a twin lead and SK2. C1 helps to filter any mains hum or other electrical noise which is picked up in the connecting cable (which can be several metres long if necessary). R3 and VR2 form the variable attenuator, and IC3 is another CA3140E operational amplifier, but in this case it is used as a straightforward unity gain buffer stage.

BATTERY CHECK

A battery check facility is built into the unit to reduce the risk of misleading readings being obtained due to an inadequate battery voltage. When S2 is operated R5, D1 and D2 are connected across the supply lines. About 7·5 volts must be developed across D1 and D2 before they will conduct, and the supply voltage must therefore be slightly higher than this level before a significant voltage is developed across R5 and the circuit passes a high enough current to cause D2 to light up. If D2 switches on when S2 is operated this indicates that the battery voltage is sufficient.

The current consumption of the circuit is about 14 milliamps, and a PP3 size 9-volt battery is adequate to power the unit provided it will not be used for prolonged periods. If it will be used for long periods of time it would be advisable to use a larger 9-volt battery such as a PP9 size, or rechargeable NiCad cells would probably be the most practical power source if the unit is to be used for many hours at a time.

CONSTRUCTION

PRINTED CIRCUIT BOARD

Provided the unit is to be powered from a small 9-volt battery a plastic case measuring about 120 × 80 × 35mm is large enough to comfortably accommodate all the components. The simple front panel layout of the prototype can be seen from the photographs, but any sensible layout is acceptable.

COMPONENTS

See Shop Talk page 534

Resistors

R1	820Ω
R2	4·7kΩ
R3,4	10kΩ (2 off)
R5	270Ω
VR1,2	10kΩ 15 turn Cermet preset (2 off)

Fixed value types are ¼W ±5%

Capacitors

C1	1μF 63V axial electrolytic
C2	100nF polyester

Semiconductors

D1	BZY88C5V6 5·6V 400mW Zener
D2	TIL209 red l.e.d. or similar (with panel holder)
IC1	ZN423E 1·2V precision regulator
IC2,3	CA3140E MOS op-amps (2 off)
IC4	LM335Z temperature sensor

Miscellaneous

S1	Rotary on/off switch
S2	Push-to-make, release-to-break type
SK1,2	3·5mm jack (2 off)
B1	9-volt PP3 size

Plastic box 120 × 80 × 35mm, printed circuit board, two 8-pin d.i.l. sockets, control knob, battery connector, 15-way D connector, screened lead, two 3·5mm jack plugs, 6BA fixings, Veropins, wire.

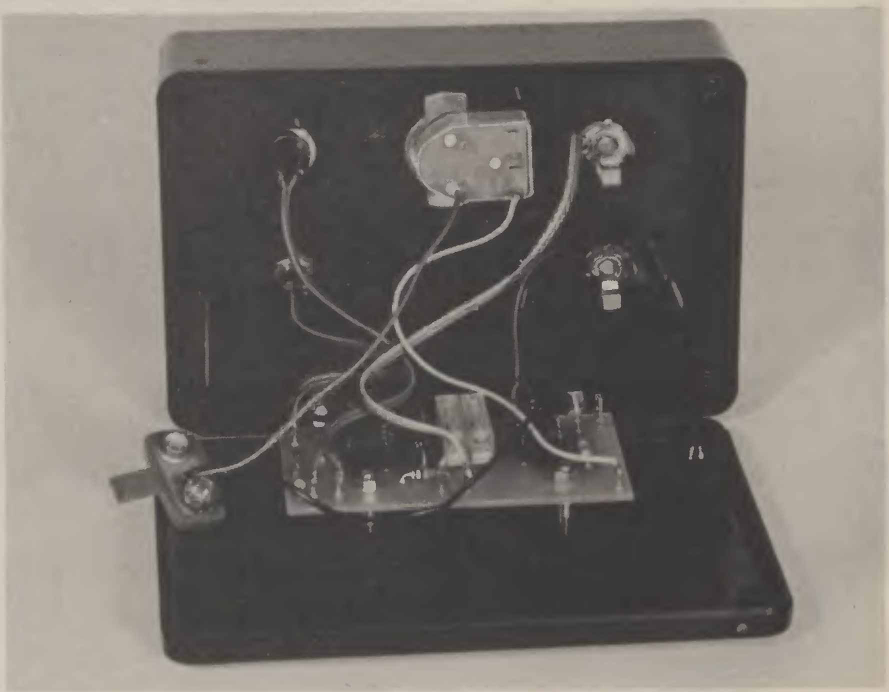
Approx. cost Guidance only **£8.85**

Apart from the LM335Z sensor the small components are all mounted on a printed circuit board which measures 70 × 35mm. The p.c.b. design and the component layout and wiring are shown in Figs. 5 and 6. IC2 and IC3 have MOS input stages and should therefore be mounted in (8 pin) d.i.l. sockets. They should not be fitted in place until the rest of the board is complete, and they should be handled as little as possible once removed from their anti-static packaging.

VR1 and VR2 must be the appropriate Cermet multi-turn trimpots if they are to fit onto the printed circuit properly. The use of ordinary preset resistors is not recommended as fine adjustment of the unit would be very difficult using these, and it is likely that they would not have adequate resolution anyway.

Veropins are fitted to the board at points where connections to off-board components will be made, and then the completed board is mounted on the rear panel of the case using 6BA fixings. The unit is then completed by adding the hard wiring.

The LM335Z temperature sensor is wired to SK2 by way of a twin lead terminated in a 3·5mm jack plug. If the lead is more than about one metre long it is advisable to use screened cable with the outer braiding connected to the barrel of the plug and the inner conductor to the tip. Note that the LM335Z must have its + (cathode) terminal connected to the tip of the plug and its − (anode) terminal connected to the barrel. Also note that IC4 must be an LM335Z temperature sensitive voltage source and not the LM335 which is a temperature sensitive current source and is used in a slightly different way. Use sleeving over the leadout wires of IC4 to prevent them from accidentally short circuiting together, and this component must be



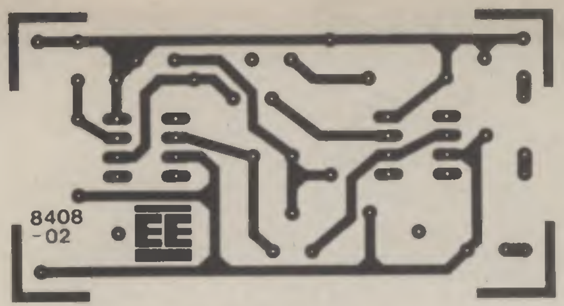


Fig. 5. P.c.b. design.

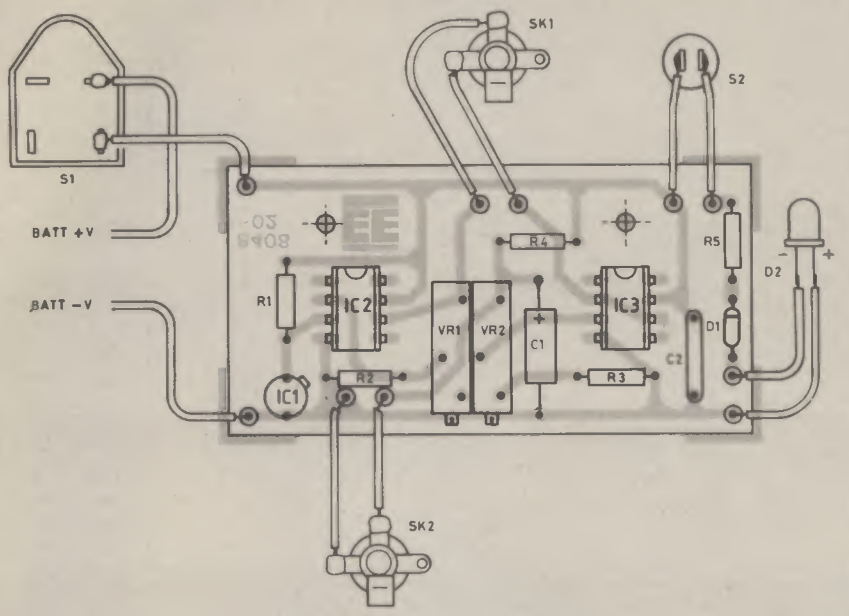


Fig. 6. Component layout.

fitted in a probe of some kind (such as a small test tube) if the unit is to be used to measure the temperature of liquids. Apart from protecting the sensor against corrosion this is also essential to prevent current from flowing from one terminal of the sensor to another through the liquid and giving spurious results.

TESTING AND CALIBRATION

When initially testing and calibrating the unit it is necessary to immerse the sensor in water, but a simple measure such as covering the leadout wires with Bostik Blue Tack is sufficient to temporarily insulate the leadouts during this setting up procedure.

The connection to the computer is made via a screened lead about one or two metres long fitted with a 3·5mm jack plug at one end and a 15-way D type connector at the other. The barrel of the jack connects through to pin 5 of the D plug (analogue ground) and the tip connects to pin 15 of the D plug (channel 1 input). Refer to Fig. 1 of this article or to the "User Guide" for the computer pin numbering of the D connector. If you wish to use any of the other analogue inputs, channels 2, 3 and 4 are at pins 7, 12 and 4, respectively.

ADJUSTMENT

Before connecting the unit to the computer it is advisable to set the output from IC2 at approximately the right voltage. This is just a matter of adjusting VR1 to give about 2·2 volts from pin 6 of IC2 to the negative supply rail. VR2 should be adjusted to give almost maximum output from IC3.

The number returned from a reading of an analogue channel is from 0 to 65520, and presumably the 12-bit output of the converter is fed to the 12 most significant bits of a 16-bit word so that the number obtained is effectively multiplied by sixteen. Anyway, to give suitable scaling the following simple program can be used:

```
10 X%=ADVAL(1)/32
20 Y=X%-500
30 Z=Y/10
40 PRINT Z
```

The first line simply takes the reading from channel 1 of the converter and divides it by 32 to give an integer value of between 0 and 2047. Line 20 deducts 500 from this quantity so that negative numbers are obtained if fairly low values are returned from the converter. Line 30 then divides this result by ten to give an output range of −50 to +154·7 in 0·1 increments, which obviously covers the required −50 to +150 with no significant overflow at either end of the scale. Finally, line 40 prints the result on the screen, and a simple loop could be used to automatically update the reading.

The next step is to adjust the interface so that readings obtained correlate properly with the temperature of the sensor. Probably the easiest way of doing this is to first place the sensor in water kept at 0 degrees centigrade with the aid of ice cubes. VR1 is then adjusted for a reading of 0, but note that noise in the system might cause the reading to fluctuate very slightly (by no more than about plus or minus 0·1 degrees). The sensor is then placed in water at a higher temperature of about 50 degrees centigrade or so, and a thermometer is used to monitor the exact temperature of the water. VR2 is then adjusted to give the correct reading.

This procedure is repeated several times until no further improvement in accuracy can be obtained. Note that it takes at least a few seconds for the sensor to adjust to a large change in temperature, and that any probe assembly in which it is placed will further reduce its response time. Let the reading stabilise properly before adjusting VR1 or VR2.

PROGRAM SUGGESTIONS

Because there are so many possible ways of using the temperature interface, it is not practicable to provide a single program to cover all uses. The programs provided are not intended to be fully-finished stand-alone programs, but rather collections of ideas, to show what can be done. The various procedures and functions can be extracted from these and incorporated into your own programs. However, these programs can be used as they are, if they suit a particular purpose.

The best way of converting the ADVAL reading into a temperature reading is by a defined function. The basic function to produce a centigrade reading is:

```
100 DEF FNtemp(c)
110 LOCAL reading,temp
120 reading=ADVAL(c)/32
130 temp=(reading-500)/10
140 =temp
```

The parameter c is the ADVAL channel number, which can be passed as a constant or a variable, i.e., PRINT FNtemp(1) or temp=FNtemp(channel). You can use one or more of the four available channels as required.

The first listing shows how a three-channel system can be set up to record maximum and minimum readings, in addition to the current reading, separately for the three channels. The readings are displayed in bar-graph form, and also in digital values.

Any particular channel can be updated at any time by pressing the appropriate number key. Lines 50 and 60 deal with out-of-range values.

```
> LIST
   10 REM 3-channel max/min
   20 DIM maxtemp(2):DIM mintemp(2)
   30 DIM initialisation%(2)
   35 MODE 2:PRINT "Channel?"
   40 channel$=GET$:channel=VAL(channel$)
   50 IF channel<1 channel=1
   60 IF channel>3 channel=3
   70 PROCbargraph(FNtemp(channel),mintemp(channel-1),maxtemp(channel-1))
   80 GOTO 40
   90 END
  100 DEF FNtemp(c)
  110 LOCAL reading,temp
  120 reading=ADVAL(c)/32
  130 temp=(reading-500)/10
  140 PROCminmax(c,temp)
  150 =temp
  200 DEF PROCminmax(c,newtemp)
  210 IF initialisation%(c-1)=0 THEN PROCinit(c,newtemp)
  220 IF newtemp>maxtemp(c-1) THEN maxtemp(c-1)=newtemp
  230 IF newtemp<mintemp(c-1) THEN mintemp(c-1)=newtemp
  240 ENDPROC
  300 DEF PROCinit(c,temp)
  310 maxtemp(c-1)=temp
  320 mintemp(c-1)=temp
  330 initialisation%(c-1)=1
  340 ENDPROC
  400 DEF PROCbargraph(now,min,max)
  410 CLS:PROClabels(now,min,max)
  420 MOVE 600,400:DRAW 1200,400
  430 MOVE 600,300:DRAW 600,700
  440 MOVE 700,400:GCOL 0,4
  450 DRAW 700,400+2*min:PLOT 85,800,400:PLOT 85,800,400+2*min
  460 MOVE 900,400:GCOL 0,2
  470 DRAW 900,400+2*now:PLOT 85,1000,400:PLOT 85,1000,400+2*now
  480 MOVE 1100,400:GCOL 0,1
  490 DRAW 1100,400+2*max:PLOT 85,1200,400:PLOT 85,1200,400+2*max
  500 ENDPROC
 1000 DEF PROClabels(now,min,max)
 1010 COLOUR 1:PRINT TAB(1,2)"TEMPERATURE GRAPH"
 1020 COLOUR 4:PRINT TAB(0,14)"MIN":PRINT TAB(0,15);min
 1030 COLOUR 2:PRINT TAB(0,17)"NOW":PRINT TAB(0,18);now
 1040 COLOUR 1:PRINT TAB(0,20)"MAX":PRINT TAB(0,21);max
 1050 COLOUR 7:PRINT TAB(3,30)"CHANNEL";channel
 1055 VDU 23,1,0;0;0;0;
 1060 ENDPROC
```

Listing to record maximum and minimum reading.

```
>MODE 7
> LIST
   10 REM temperature readings
   20 REM at timed intervals
   30 CLS:MODE 1
   40 channel=1
   50 PROCgraticule
   60 PROCtempgraph
   70 STOP
  100 DEF FNtemp
  110 LOCAL reading,temp
  120 reading=ADVAL(channel)/32
  130 temp=(reading-500)/10
  140 =temp
  200 DEF PROCgraticule
  210 GCOL 0,1
  220 MOVE 200,100:DRAW 200,900
  230 MOVE 200,300:DRAW 1200,300
  240 MOVE 200,100:PLOT 21,1200,100
  250 MOVE 1200,500:PLOT 21,200,500
  260 MOVE 200,700:PLOT 21,1200,700
  270 MOVE 1200,900:PLOT 21,200,900
  280 MOVE 1200,100:DRAW 1200,900
  290 PROClabels
  300 ENDPROC
  400 DEF PROClabels
  410 PRINT TAB(3,22)"0"
  420 PRINT TAB(1,28)"-50"
  430 PRINT TAB(1,16)"+50"
  440 PRINT TAB(1,10)"100"
  450 PRINT TAB(1,4)"150"
  460 ENDPROC
  500 DEF PROCtempgraph
  510 MOVE 200,300:GCOL 0,2
  520 FOR X=200 TO 1200 STEP 100
  530 Y=300+4*FNtemp
  540 DRAW X,Y
  550 T=TIME
  560 REPEAT UNTIL TIME=T+1000
  570 NEXT X
  580 ENDPROC
```

Listing to record temperature changes over a period of time.

The maximum and minimum values are stored in two arrays, dimensioned in line 20. Remember, BBC BASIC numbers array elements from 0, so these arrays have three elements. Note also the complications this causes in lines 70, 210–230, and elsewhere. The other array, declared in line 30, is used to "remember" whether a particular channel has been used. On first use, minimum and maximum values are set to the current value, by PROCinit. Thereafter, they are updated as appropriate by PROCminmax.

The rest of this program is fairly straightforward graphics. PROCbargraph has been written using the absolute commands MOVE,DRAW, and PLOT 85, to keep it easily understandable for the inexperienced. It can be slightly shortened by using the relative drawing commands.

Line 1055 keeps things tidy by turning off the cursor. This particular line will only work with O.S. 1.0 onward.

The second listing shows how the computer's TIME function can be used to record temperature changes over a period of time. In this case, the temperatures are recorded as a graph, but they could also be displayed as digital values, or stored in an array or on tape/disc for later analysis.

This program takes 10 readings at 10-second intervals, but much longer intervals and/or more readings are of course quite possible. □

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PRODUCTS
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REMOTE CONTROL FOR SECURITY CAMERAS

A ROTATABLE mounting for closed-circuit TV cameras, or CB or f.m. radio aerials is available from **Semiconductor Supplies** at £49.45 by mail order.

The cast-metal mounting will support equipment weighing up to 100lb, and is weatherproof. Called the 200XL, it is designed to accept a spigot mounting for cameras, but clamps on top of the rotator allow tubular aerial masts to be fitted if required. One complete revolution under remote control takes 65 seconds.

The control box is connected to the rotator by means of ordinary p.v.c.-sleeved cable, and this allows the unit to be controlled at distances of 30 to 40ft. Greater distances are possible by making use of heavy-duty cable.

The control box has a heavy base for precise operation of the control knob, and a follower arrow on the dial indicates the relative position of the rotator unit. When the follower arrow coincides with the direction of the pointer the rotator is in position.

Semiconductor Supplies Ltd., Dept EE, Sutton, Surrey.

ADHESIVE FOR P.C.B. ASSEMBLY

COMPONENTS such as transformers, coils, and edge connectors need to be mechanically secured to a printed circuit board. The Electronics Tak Pak has been specially developed for this purpose and makes a strong, permanent mechanical bond within fifteen seconds.

The adhesive is non-conductive, and designed to remain effective over a temperature range of −100 to +175 degrees Fahrenheit. It will not affect electrical functions or attack insulation.

The Electronics Tak Pak, together with over 3,000 other tools and production aids, can be found in the current **Toolrange** catalogue.

Toolrange Ltd., Dept EE, Upton Road, Reading, Berkshire RG3 4JA.

ULTRA-SLIM STEREO RADIO

THE WORLD'S thinnest and lightest f.m./a.m. personal stereo radio was recently exhibited in London.

Panasonic's RF-07 measures 91mm by 55mm by 3·9mm, and weighs just 38g. Powered by rechargeable Ni-Cad batteries, the RF-07 comes complete with carrying case, stereo earphones and battery charging stand. The retail price for this package has not yet been finally decided, but Panasonic say it is likely to be a three-figure sum.

To achieve such a small size, the local oscillator, mixer, and amplification circuits have had to be redesigned, and an ultra-thin a.m. aerial developed.

The printed wiring board has also been reduced in thickness from 0·5mm to 0·3mm and has been designed as an integral part of the radio's rear panel.

The RF-07 will not be generally available in this country before the end of the year, but further information is available from:

Panasonic UK Ltd., Dept EE, 300-318 Bath Road, Slough, Berkshire SL1 6JB.

TEACH-IN 84

11

A TWELVE-PART HOME STUDY COURSE IN THE PRINCIPLES AND PRACTICE OF ELECTRONIC CIRCUITS. ESSENTIALLY PRACTICAL, EACH PART INCLUDES EXPERIMENTS TO DEMONSTRATE AND PROVE THE THEORY.
USE OF A PROPRIETARY BREADBOARD ELIMINATES NEED FOR SOLDERING AND MAKES ASSEMBLY OF CIRCUITS SIMPLE.
THE IDEAL INTRODUCTION TO THE SUBJECT FOR NEWCOMERS. ALSO A USEFUL REFRESHER COURSE FOR OTHERS.

By GEORGE HYLTON

NEW DEVELOPMENTS

LAST month I mentioned the attractions of designing one's own electronics system. It so happens that many of the practical problems which electronics can help to solve call for techniques and components not yet well established in the consumer field. To give an elementary example, if you indulge in home brewing you may wish to have a temperature controller and instruments for measuring chemical quantities such as acidity. Historically, such things were around for a long time in industry before they began to enter the home.

It often happens that the very latest electronic devices and materials appear first in military equipment. Integrated circuits arrived by this route. The first experiments were made at a British government establishment then the idea was taken up by the Americans. The incentive was the chance of developing lightweight, reliable electronics for use in aircraft, missiles, computers, space vehicles, and so on.

OPTICAL CABLES

The communications industry has always been a breeding-ground for inventions. Readers will be aware that there is a revolution now going on in cable communications, where the transmission of information in the form of electrical signals is being superseded by techniques where the information-carrier is light.

This development of optical cables will produce many useful spin-offs in other spheres. It's quite possible, for instance, that the car driver of the future will turn his headlamps on or off not by a switch which controls the current directly but by one which sends light along glass-fibre to the lamp. On arrival, the light will turn on an opto-electronic current switch. In this way, instead of running heavy copper cables from battery to instrument panel and from instrument panel to headlamps, short direct cables from battery to headlamp will suffice.

In the long run optical cables are bound to be cheaper than copper ones because the raw materials are cheaper. Systems on these lines have already been developed for use in aircraft where the saving of weight makes it economic despite the present high cost of "fibre optics".

The eye of a needle gives some idea of the scale of a typical optical fibre cable.

NOTHING NEW . . .

Oddly enough, the designer can also learn from the past. It may not be absolutely true that there's no new thing under the sun. (The originator of that idea was thinking of the course of nature, not technology.) All the same, most of the new technical developments we see have their roots in past ideas. This means that, buried in the files of the Patent Office (which are open to anybody, by the way) and in old books and magazines there must be a wealth of long-forgotten ideas which came to nothing because of some problem which has now been solved.

Let me give you an example. Alexander Graham Bell, the man who in 1876 made the first successful telephone, also invented an instrument which we today would call a metal detector. Bell called it an induction balance. He used it, on one occasion, to locate an assassin's bullet in the body of an American president.

METAL DETECTORS

The history of metal detectors is instructive. When radio was developed it was realised that the presence of metal near the coil of an LC tuned circuit altered the tuning. The reason is that signal currents in the coil produce an a.c. field which induces voltages in adjacent metal. Currents then flow round and round in the metal (they are called "eddy currents") and in turn create magnetic fields. These oppose and partly cancel the coil's own field. The effect is to alter the inductance.

In radio this can be a nuisance. But in time it was realised that the effect could be put to good military use in searching for buried land mines. In this case the coil (called a search coil) is deliberately shaped so as to create a large "stray field" around itself. If this field links with buried metal the resulting change in inductance can in principle be detected.

BEAT FREQUENCY TECHNIQUE

If World War II designers of metal detectors had made use of Bell's induction balance their efforts would have been more successful. Instead, they went off on a different, more "electronic" tack. (Bell's work was pre-electronic; that is, long before the invention of the radio valve.) They used the search coil as the tuning coil of an oscillator and detected the change in frequency as the coil approached a metal-cased mine. The change is small, perhaps one part in 10,000. If the oscillator operates on 1kHz then the frequency change is only 0·1Hz which is not detectable by ear.

The solution adopted was to work at about 100kHz. A change of one part in 10,000 then gives a frequency shift of 10Hz. This was made audible by "mixing" the 100kHz with a nearby frequency derived from a second oscillator. If the resulting beat frequency is set at 250Hz (which is close to "middle C" on the piano) a shift of 10Hz is audible to anybody with a reasonable sense of pitch.

The beat-frequency oscillator (b.f.o.) type of metal detector still exists. But the vast majority of modern detectors use an induction balance technique, just as Bell's did. They are of course full of transistors and i.c.s and even microcomputers. But the basic principle (Fig. 11.1) is Bell's.

INDUCTION BALANCE

Referring to this diagram, A is the "transmit" coil. It is energised by an oscillator. (Bell used a mechanical oscillator, a trembler switch which chopped up battery current into a mixture of a.c. and d.c.). Coil B is the pick-up coil.

If A and B overlap exactly, large amounts of voltage are induced in B. If A is moved just outside B so there is no overlap some induction still takes place. But the induced voltages are now of the opposite polarity. If there is a small overlap, both effects take place. Opposing voltages are induced in B. At one critical degree of overlap the opposing voltages exactly cancel. There is no pick-up. The induction is balanced.

This fine balance is upset when the coils are brought near metal. Voltage now appears across B, is amplified and detected. By using a high gain tiny amounts of unbalance can be detected. Also, the sensitivity no longer depends on frequency.

CHOICE OF FREQUENCY

The designer can use any frequency he likes. He usually likes rather low frequencies (for example 10kHz) because the effects of iron objects can then easily be distinguished from those of non-ferrous objects.

This is of interest to "treasure hunters" who want to find coins but ignore rusty nails. It is also of medical use. Detectors exist which can find tiny bits of metal in the eye; if iron it may be possible to remove them with a magnet. So, after a century, Bell's induction balance is again finding medical applications.

EXPERIMENT 11.1

METAL DETECTOR EXPERIMENTS

I have gone on about the history of metal detection because it illustrates some important points about how inventions appear, are forgotten and rediscovered. It also illustrates the principle of balance which crops up again and again in electronics and can be a very powerful aid to the designer. But it's high time you did a bit of practical work.

You can use the medium-wave receiver described in Part 9 (Fig. 9.5) as a crude short-range metal detector. Set the reaction control so that the circuit oscillates. Tune to a strong station and adjust to get a pleasant musical beat note. Metal held near the ferrite rod will cause the note to change.

One reason why the detection range is very short is that the ferrite concentrates the magnetic field inside itself. Real-life metal detectors use circular coils with a diameter of 150mm (six inches) or more, and no core.

Even so, the range is still quite short. (For a small object such as a coin it's usually less, in a b.f.o. detector like this, than the diameter of the coil.) This is because the field strength falls off very rapidly as you move away from the coil.

This is a case where the designer is up against a law of nature, which no amount of ingenious circuitry can get round. So even the most sophisticated metal detectors can do little better than find a fairly large coin at a depth of 300mm (one foot).

TRANSDUCERS

When electronic equipment has to interact with the outside world special devices are needed to turn non-electronic quantities into electronic ones, or vice-versa. These devices have the general name, transducers. A microphone is a transducer. It converts sound waves (which are air-pressure variations) into voltages and currents. A loudspeaker, which does the reverse, is a transducer. A gramophone pick-up converts movement into electrical signals. In the world of industry and science many kinds of transducer exist. Any sort of physical quantity: temperature, pressure, vibration, light, nuclear radiation, velocity, chemical properties . . . can be made to yield an electrical signal.

The art of chemical transducer-making has just been extended in a very electronic fashion. It has become possible to replace the gate electrode of a field effect transistor (f.e.t.) with a film of material sensitive to particular chemicals. The current through the f.e.t. is then proportional to the concentration of the chemical.

In principle, f.e.t.s sensitive to almost any chemical substance can be made, including biochemicals. The medical possibilities are exciting. You might use a "biofet", for example, to monitor the insulin level in the bloodstream of a diabetic and automatically turn on a tiny pump to give him a dose if the level falls too low.

EXPERIMENT 11.2

HIGH TEMPERATURE ALARM

In your kit of parts for this *Teach-In* you have the means of making an experiment which illustrates some of the principles of a typical "electronics meets outside world" situation.

People, and the goods they use, are sensitive to temperature and it's important to take remedial action if it gets too hot (or too cold for that matter). There are many ways of producing an electrical signal in response to a rise in temperature. Most thermostats make use of the different rates of thermal expansion of different metals to actuate a contact, when a preset temperature is reached.

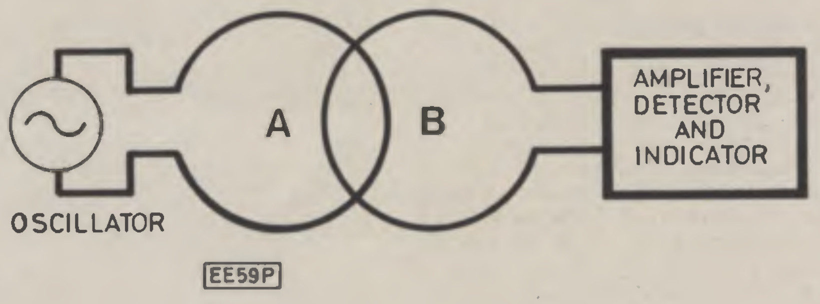
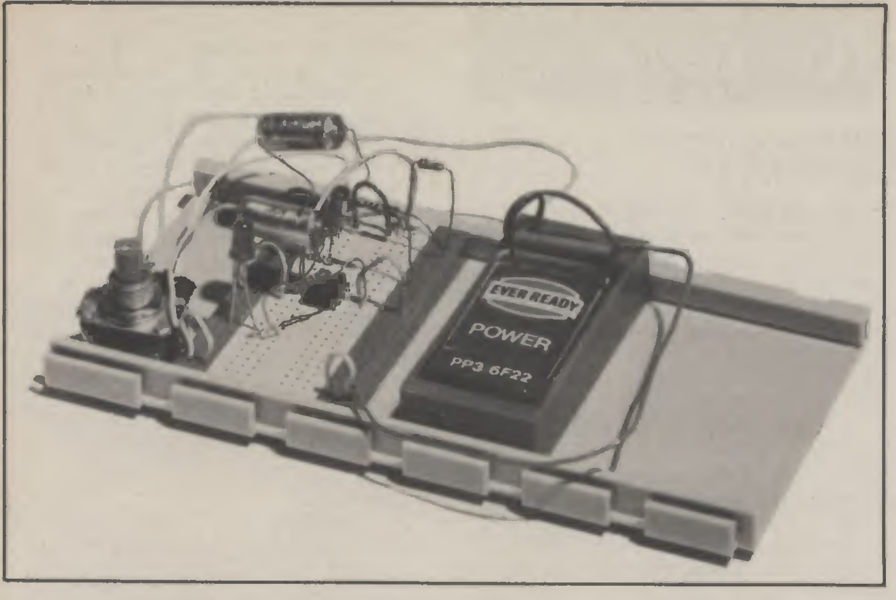


Fig. 11.1. Essentials of an induction-balance metal detector. In practice the coils shown here as single-turn loops usually have many turns.



If VR1 is set so that the l.e.d. just fails to light, then warming TR1 with the fingers will light it, showing that quite a small temperature rise above the set temperature (which is room temperature in the present case) is enough to set off the alarm.

The critical base-emitter voltage of TR1 falls by about 3mV per degree C over a very wide range of temperatures, so if the op-amp is sensitive enough to turn a 3mV input into enough output to sound the alarm, the circuit should be capable of being set up within one degree C.

Possible uses include freezer alarms, which should sound off when the temperature inside a deep-freeze rises substantially above its nominal value (usually about −40 degrees).

Armed with your knowledge of metal detection you might envisage winding a little coil round the stem of a mercury thermometer so that when the thread of mercury enters the coil the change of inductance can be detected.

In our temperature alarm, however, we'll make use of the fact that any ordinary bipolar transistor is sensitive to temperature. Earlier in this *Teach-In* we saw this as a nuisance, which it is, normally. But if you want to detect temperature changes it can be useful.

CIRCUIT OPERATION

In Fig. 11.2, TR1 is the temperature sensor. As the temperature rises, the size of the base-emitter bias voltage needed to turn it on falls. By setting VR1 carefully it can be arranged that TR1 is non-conducting at temperatures below the "too hot" level but conducts at higher temperatures.

Conduction causes a sharp fall in collector voltage because of the high collector load (R2) of 1MΩ.

The op-amp IC1 is used to compare the collector voltage (on pin 2) with a fixed voltage on pin 3. Once the voltage on pin 2 becomes less positive than that on pin 3 the op-amp output goes high (remember that a positive on the inverting terminal, pin 2, gives a negative at the output and vice-versa).

The l.e.d. lights when the output goes high. This, in our case, is the alarm, but clearly the same change in output could be made to ring a bell, turn on a sprinkler, or whatever is needed.

FAIL SAFE

The design as it stands has two obvious defects. One is that the accuracy of temperature setting is affected by the supply voltage. VR1 taps off a bit of the supply voltage to apply the appropriate base-emitter voltage to TR1. If the supply voltage changes then the wrong V_{BE} is applied. One way out of the difficulty might be to use two transistors, one as shown and the other connected in place of R4.

If the transistors were identical then both should apply the same voltage to the op-amp if both were at the same temperature. By exposing TR1 alone to temperature change while insulating the second transistor from change only TR1 could then set off the alarm. Changes in V_{CC} would affect both the transistors equally and not upset the balance of the circuit.

The other obvious defect is that the circuit does not fail safe. If the power supply

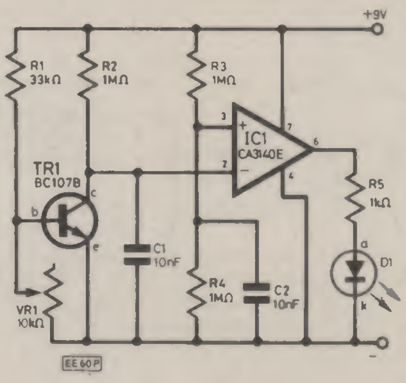


Fig. 11.2. Circuit of Temperature Alarm.

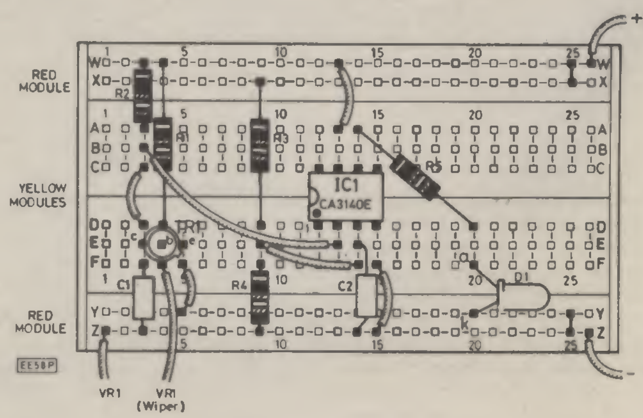


Fig. 11.3. EBBO i.c. board layout for Fig. 11.2.

fails the alarm becomes inoperative. One possible answer would be to operate from a rechargeable battery kept charged by a mains power pack. If the mains failed the circuit would go on operating from its battery (for a time). A mains-failure alarm could draw attention to the problem so that the mains power could be restored before the battery ran out.

IMAGING

Imaging, that is making pictures of things by technical methods, is a rapidly-growing field in which electronics plays a large part. We are all familiar with television. But ordinary TV cameras can't see in the dark. (Some special TV cameras can give pictures in what seems to human eyes to be darkness but is actually not total darkness.)

Even in total darkness images can still be obtained, by using heat. All things in the world contain thermal energy. If they are warmer than their surroundings they radiate heat. If cooler they absorb it. If your eyes could see heat, the warmer objects would look bright and the cooler ones dark. They can't, but cameras which can see heat (or infra-red radiation, which is what heat rays are) can be made.

For military reasons, infra-red imaging has become very important. It enables you to see your enemy at night. As usual, civilian spin-offs from this technology have appeared. There are infra-red intruder alarms and night-watch gear, and infra-red body scanners which enable doctors to see hot spots on the skin which give clues to medical conditions below it.

NUCLEAR MAGNETIC RESONANCE

Images can be obtained in other ways. X-ray scanners linked to powerful computers can give images of sections through the head or body. A more recent development does it without X-rays. When liquids are put in a steady magnetic field their molecules become tuned to radio frequencies. The frequency of tuning depends on the field strength and the nature of the liquid, including what is dissolved in it.

This effect, called nuclear magnetic resonance, NMR for short, enables the body—which is mostly liquid—to be explored with radio waves. By processing the results in a computer images can be made.

For instance, the computer can produce a map of a slice through the body, a map showing where the water is. Since different organs contain different amounts of water the map shows the shapes of the organs. It so happens that NMR is good at seeing the soft tissues of the body, which don't show up well on X-ray pictures.

CHECK YOUR PROGRESS

Questions on *Teach-In 84 Part 11*
Answers next month

Q11.1 A b.f.o. type metal detector is to be fitted with an indicator based on a frequency discriminator which produces a voltage proportional to the beat frequency. This voltage rises linearly from zero to 1V d.c. over the range 0–1kHz. To improve sensitivity, changes in this voltage are amplified 1,000 times by an op-amp. If the output of the op-amp must change by 500mV to produce a clear indication:

(a) What is the minimum detectable frequency change?

(b) If the search oscillator operates at 100kHz, what is then the sensitivity in parts per million?

(c) If changes of temperature of the search coil cause the search frequency to change at a rate of 100 parts per million (p.p.m.) per minute, how often will the user need to re-tune to keep the detector working properly?

ANSWERS TO PART 10

A10.1 High. When any even number of inverters are "cascaded" like this the output and input have the same polarity.

A10.2 (a) 5V; (b) Still 5V approx., because if the gate is CMOS the very high input resistance of CMOS gates makes this type of bias circuit insensitive to resistance changes.

A10.3 Frequency falls to about 160Hz. (In RC oscillators increases in the time constants reduce the frequency, usually in proportion.)

RADAR IMAGES

The very latest integrated circuits and computing techniques are being used to enable aircraft to make very detailed maps of the ground by radar. These new radars transmit bursts of microwave energy and detect their echoes from the ground just like older radars. But by using a technique first developed for quite a different purpose (radio astronomy) much finer detail can now be seen.

In this "synthetic aperture radar" (SAR) objects about the same size as the diameter of the radar "dish" are detectable at long range. Images constructed by computer from SAR information look very like aerial photographs. Features like roads and buildings show clearly. One discovery made by SAR was archaeological. SAR images of tropical forests in Latin America show the remains of ancient irrigation channels, hidden from sight by foliage but still detectable by radar.

SYSTEMS AND CIRCUITS

I've been talking about these new developments because they illustrate a basic point which beginners in electronics can easily overlook. It's this. There are two kinds of electronic engineering. There's circuit design, which occupies a lot of space in magazines like EVERYDAY ELECTRONICS, and there's systems engineering.

Systems engineering looks at a need as it were from a distance, and tries to view it in perspective, mapping out the things which have to be done to make the system work without getting down to details.

For radio, TV, audio and other common areas of electronics this was done long ago and need not be repeated in every article on these subjects. But for new applications of electronics, systems engineering is necessary.

Instead of saying: "I need a circuit for doing this new task" it usually pays to say: "What do I need to know before I can get down to circuits?" The answer to this question may not be an electronic answer at all.

If you are designing an electronically controlled system for cooling a hot room by blowing cold air into it, then long before you get down to electronics you need to establish what airflow speeds and temperatures can be tolerated by the people in the room before reaching the point where they complain of cold draughts. This is not an electronic question, but the answer to it will certainly affect your ultimate design.

It's more than likely that you'll come up against problems which call for a systems-engineering approach, so be prepared. Also, be encouraged. It's very satisfying to come up with something that works because you yourself have made it work, breaking new ground in the process.

Next month: Aids to Design

EVERYDAY news ... from the world of

EXPERIMENT IN SPACE

SCHOOLS BATTLE FOR SPACE ON 1986 SHUTTLE LAUNCH

AN EXCITING and quite unique competition is now open to all secondary school students and apprentices in the UK.

The challenge is to recognise the potential that space offers their future, and to create an experiment that takes into consideration the special environmental conditions in space, in particular vacuum and weightlessness.

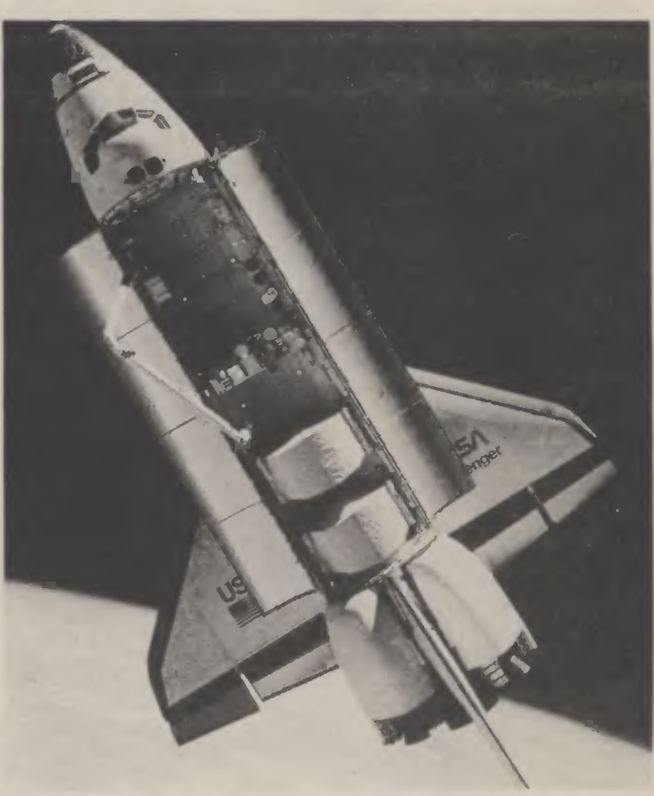
The winning entry will have a reserved spot in the payload bay of the space shuttle due to be launched in early 1986. The simpler the project the better its chances as it must be small and simple enough to be housed in a self-contained cylinder no larger than 502mm diameter, 359mm long with an all up weight restriction of 27·2kg (60lb).

The competition is being run by ITN (Independent Television News), one of Europe's leading space consultants SSI (Space Services International) and NASA (National Aeronautics and Space Administration).

NASA's technological expertise is undoubted and it would be easy for the entrant, in this prestigious company, to get "too technical". Don't forget that (as far as we know) the most basic of Earthbound natural phenomena have never been asked to perform in space.

The ITN-SSI competition will be judged by a panel of experts in the space sciences. Finalists will be asked to construct the winning package from their own resources.

*Full details and conditions can be obtained by sending a large stamped addressed envelope to: **Experiment in Space, ITN, PO Box 4BY, London W1A 4BY.***



The Hitachi H-1 model MSX microcomputer on which will be based the MB-H80 family computer for the UK market.

HITACHI TO LAUNCH HOME COMPUTER

Hitachi is to enter the UK home computer market with the launch this autumn of its MSX product, the Hitachi MB-H80, in good time for the Christmas buying season. MSX is based on the hardware specifications and computer language developed by ASC11 Microsoft of Japan.

Giving preliminary details of the new home computer, Colin Leader of Hitachi Sales (UK) Limited explained that Hitachi was one of the original group of companies to subscribe to the development of hardware to meet the MSX specification in Japan—a success that he expects to be repeated in the UK.

"But we are not just taking the Japanese version of the MB-H80 and bringing it to the UK. We carried out a great deal of research into UK market needs, and enhanced the MB-H80 accordingly, with the result that we now have one of the most powerful and flexible machines in the MSX range.

"The MB-H80 is one of the most sophisticated of the MSX offerings, giving a total of 80K of RAM, made up of 64K user RAM and 16K video RAM controlled by its own video display processor. In addition, the system has 40K of ROM. It features two cartridge slots, allowing expansion up to 576K and the facility to connect the soon to be announced Hitachi MSX disc drives.

"The two joystick ports are sensibly situated on the side of the machine, as is the socket for an ordinary cassette recorder, together with the r.f. output for TV sound and picture. The MB-H80 has a full QWERTY typewriter style keyboard which includes numerics, cursor control and five special function keys."

Current projected price for the Hitachi MB-H80 is less than £200, and it is expected to be popular as a family computer.

electronics

EXPORT BAN

Exports from the UK of spacecraft and launch vehicles, military thermal imaging equipment, and equipment for manufacturing or testing printed circuit boards are now covered by an "Export of Goods" control and an export licence must first be obtained.

The new controls, introduced for strategic and security reasons, are in line with similar controls agreed with the other members of the Western Alliance.

BRITISH FIRM WINS OLYMPICS

Thousands of visitors to Los Angeles, during the July Olympics, will be able to keep right up-to-date with results thanks to a new Teletext decoder from Greendale Electronics of Dronfield, Derbyshire, part of the Crystalate Group of companies.

Greendale have won an order worth £848,000 from Keyfax National Teletext Magazine—the first US company to provide such a service—for several thousand decoders. One hundred of these will be used during the Olympics in prime public locations, such as bank lobbies, hotels, airports and restaurants, to enable customers to access results via a hand-held remote control.

Colin Wemyss, Greendale's managing director said: "We are concentrating on the US market because no-one manufactures ready converted televisions as in the UK. This means cable TV users rely on adaptors for both cable and teletext—and our product meets both needs."

The Olympic's teletext project is called "KTTV's Metrotext" and operated by KTTV, a metromedia television station in Los Angeles. The station will originate a 100-page teletext magazine using the world system technology.

Computer Clinic

Lion Micro, who recently announced the opening of their giant computer store "Micro Systems at Lion House" in Tottenham Court Road, London, have announced that, together with General Computer Systems UK Ltd. (GCS Bus Shop), they will be providing over-the-counter maintenance and repair services in the store.

A team of engineers will provide over-the-counter service on a wide range of micros and other associated peripherals. The service is not only aimed at Lion customers, but at anyone in the London area who has a microcomputer and is without satisfactory service.

Customers hand their micros over the counter and an engineer will, wherever possible, identify and rectify minor faults "on-the-spot" or advise as to the likely time of repair with, of course, an estimate. All repairs are fully guaranteed.

Top Spot for Sinclair

Britain's Sinclair Research continued to dominate the UK personal computer market during the first quarter of 1984, achieving 43 per cent of unit sales—according to independent market research organisation, Audits of Great Britain Ltd. (AGB), who sampled 25,000 households.

Reporting total quarterly unit sales through all outlets of 215,000, up sharply from 129,000 (Q1, 1983). AGB gave second and third places to Commodore (28 per cent), and Acorn (10 per cent). Sinclair's ZX Spectrum remained the most popular model with an individual 36 per cent share, up 2 per cent from fourth quarter 1983.

BRITOIL has chosen the GRiD Compass personal computer for a range of professional staff to use in their day-to-day planning and analytical work.

JAPANESE DISH FOR HALLEY'S COMET

Mitsubishi Electric Corporation recently finished assembling a huge, 64-metres-diameter antenna for observation of the Halley's Comet. When completed in late October this year, it will be Japan's largest deep space probing antenna.

The antenna is being built for the Education Ministry's Institute of Space and Astronautical Science which is in charge of the PLANET-A Project to observe Halley's Comet approaching the sun in 1986. It will be installed in Usuda Town, Nagano Prefecture, for communications with the PLANET-A, a Halley's Comet probe. The comet comes close to the sun every 76 years.

The 70-metres-high gigantic antenna weighing approximately 1,900 tons can horizontally rotate, carried by six platform cars that run on rails. As it is also able to change its vertical angle, the parabolic antenna can be trained in any direction.

To track the deep space probe 180 million kilometres away and receive its very weak, 5-watt radio waves and telemetric data, and give instructions to the probe, Mitsubishi Electric introduced various new technologies to the antenna. These advanced technologies include: homology designing to always hold the parabola's shear down to 1·5 millimetres or less from an ideal parabola; the world's first beam transmission system that reduces noise and enables the use of various frequencies; and a master collimator which ensures high directional accuracy of 0·003 degree.

The antenna will also be used for probing the moon and planets, and astronomical experiment programs to be conducted in cooperation with overseas deep space probe stations.

EXHIBITIONS

"The International Computer Graphics User Show and Conference" is the first of an annual series of shows and conferences in the UK for computer graphics users to be sponsored by the World Computer Graphics Association (WCGA).

The exhibition, aimed at improving productivity and technological advancement by computer graphics, is to take place from 19–21 February, 1985 at London's Barbican Centre.

An exhibition and conference devoted to the use of computers in the hotel industry, HOTECH '84, takes place at the Royal Garden Hotel, London, from October 3–4, 1984.

Car Radio BOOSTER

R.A. PENFOLD

ALTHOUGH primarily intended as a booster amplifier for a car radio to give either 9 watts r.m.s. into an 8-ohm impedance speaker, or about 17 watts r.m.s. into a 4-ohm type, this circuit can be used in any similar application where a fairly high output power is needed using only a 12-volt supply. The booster amplifier is simply connected between the radio (or other high level signal source) and the loudspeaker, and it is therefore very easy to install.

The prototype booster is a negative earth monophonic unit, but as explained in more detail later on in this article, it can easily be built as a stereo and (or) positive earth amplifier.

BRIDGE AMPLIFIER

When using an ordinary transformerless power amplifier and a 12-volt supply, the maximum nominal peak-to-peak voltage swing that can be applied to the speaker is 12 volts. This gives an output power of only about 2·25 watts into an 8-ohm load, or 4·5 watts into a 4-ohm load.

Amplifiers of the type described here use two amplifiers in a bridge circuit to double the maximum output voltage swing available for a given supply voltage, and therefore produce a fourfold increase in maximum output power (bearing in mind that doubling the output voltage also doubles the output current, and thus gives the fourfold boost in output power).

A bridge circuit uses the basic arrangement shown in Fig. 1. One amplifier is fed with the input signal in the normal way, and its output couples to one terminal of the loudspeaker. However, the other loudspeaker terminal does not connect to earth, but is instead connected to the output of the other amplifier of the bridge arrangement. This second amplifier stage has a voltage gain of unity, inverts its input signal, and is fed with the output signal of the first amplifier stage.

Under quiescent conditions both amplifiers have an output voltage of about half the supply voltage, giving no significant voltage across the loudspeaker. If an input signal is applied to the circuit, the output voltage of each amplifier stage changes by an identical amount, but one will be positive going while the other is negative going. Thus if the amplifier is fully driven, when the output of one amplifier stage is fully positive the output of the other stage is fully negative. The loudspeaker is therefore driven with the full supply voltage with one polarity, and then driven with the full supply voltage but with the opposite polarity, giving a peak-to-peak output voltage swing of double the supply voltage.

Of course, a practical amplifier will not give quite this voltage swing at the output as there will inevitably be voltage drops through the output devices, but the maximum output voltage swing is still considerably in excess of the supply voltage, and a very high output power is available

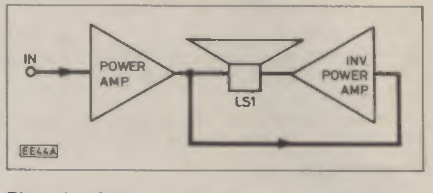


Fig. 1. Schematic diagram of bridge circuit.

for a given speaker impedance and supply potential. There are other ways of obtaining similar or even higher output powers, but these are all more expensive and in general much more complex.

COMPONENTS

Resistors

R1	120kΩ
R2,4,5	560kΩ (3 off)
R3	2·2Ω
R6,7	6·8kΩ (2 off)

All $\frac{1}{3}$ watt ±5%

Capacitors

C1	220nF polyester (C280)
C2	47nF polyester (C280)
C3	330nF polyester (C280)
C4	3·3μF 25V electrolytic
C5	100nF polyester
C6	100μF 25V electrolytic

Semiconductors

IC1,2	TDA2006 (2 off)
D1–4	1N4002 (4 off)

Miscellaneous

S1 Rotary on/off type

Metal case 152 x 114 x 44mm; 0·1in matrix stripboard; 3·5mm jack (SK1); 2-way terminal panel (SK2,3); 20mm chassis mounting fuseholder; 3A quick blow fuse; 2-way connector block; control knob; 18 s.w.g. aluminium for mounting bracket; wire, solder, etc.

Approx. cost Guidance only **£10.00**

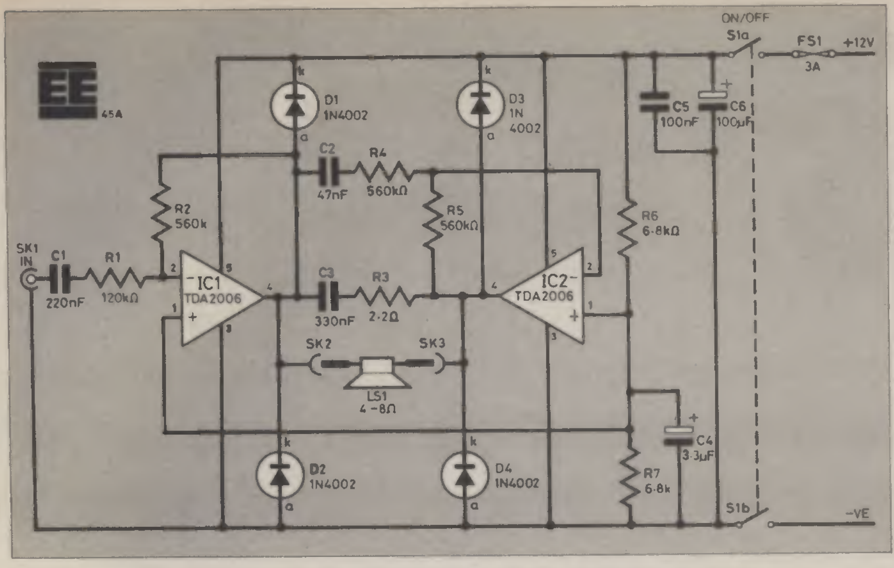


Fig. 2. Circuit diagram of the Car Radio Booster.

THE CIRCUIT

The circuit is based on two TDA2006 audio power amplifier i.c.s, as can be seen by referring to the circuit diagram in Fig. 2. The TDA2006 is a five terminal device which is rather like an operational amplifier, but the output stage is a high power class B type. This device has both output short circuit and thermal shutdown protection circuitry.

Both amplifiers have their non-inverting inputs biased to about half the supply voltage by R6 and R7, with C4 being used to decouple any noise on the supply lines. IC1 is used as an inverting amplifier and has its inverting input biased by R2. R2 together with R1 also sets the closed loop voltage gain of the amplifier, and although the gain is only about 4·5 times, this is more than adequate in this application where an input signal of several volts peak-to-peak will be available. C1 provides d.c. blocking at the input of the unit.

IC2 has purposely been biased in exactly the same way as IC1 so that the two output voltages will be accurately balanced, and only a very small quiescent output current will be fed to the loudspeaker. Input resistor R4 has been given a value which is identical to that of feedback resistor R5 so that the required closed loop voltage gain of unity is obtained. C2 couples the output of IC1 to the input of the second amplifier stage.

PROTECTION AND STABILITY

D1 to D4 are protective diodes, while R3 plus C3 form a Zobel network and aid the stability of the circuit. The unit has only one control, and this is the on/off switch S1. The quiescent current consumption is only about 40mA, but this rises to over 1 amp at full output into 8 ohms, and over 2 amps at full output into 4 ohms. These figures would normally be much less than this on speech and music signals (rather than a sine-wave test signal), but a car battery is well able to supply currents of this order anyway.

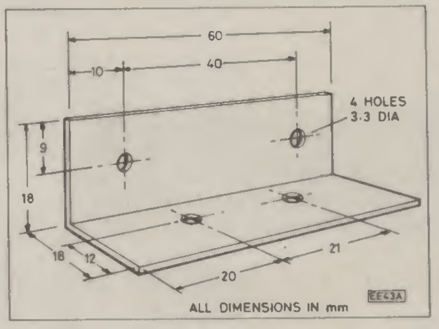


Fig. 3. Dimensions of mounting bracket/heatsink.

CONSTRUCTION starts here

HOUSING DETAILS

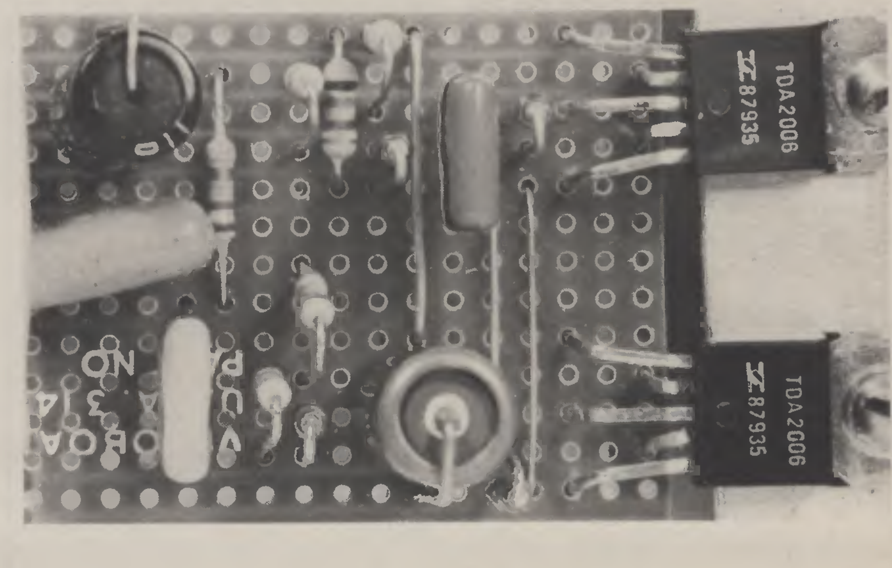
The unit must be housed in a metal case as this is used as the heatsink for the two integrated circuits. An instrument case measuring about 152 × 114 × 44mm was used as the cabinet for the prototype, and this readily accommodates all the components.

The switch and input socket, S1 and SK1 are mounted on the front panel, and SK1 can be a 3·5mm jack or any other 2-way audio connector. The right-hand side of the rear panel (as viewed from the rear) is drilled with a hole to take the power input leads, and this should be fitted with a p.v.c. or rubber grommet. The loudspeaker terminals (SK2 and SK3) are also fitted on this side of the panel.

A mounting bracket/heatsink for the component panel is fitted on the other side of the rear panel, and Fig. 3 gives details of this bracket. It is constructed from 18 s.w.g. aluminium, and it is not advisable to use a thinner guage than this. Thicker material is perfectly suitable, but making the right angled bend in the bracket might then become very difficult. The completed bracket is bolted to the rear panel using M3 or 6BA fixings.

The 20mm fuseholder and a 2-way terminal block are fitted to the base panel of the case in the vacant area between the input socket and the speaker terminals. Reference to the interior photograph of

Photograph showing stripboard layout.



the unit will show the general layout of the unit and help with the positioning of the main components. The connector block, incidentally, is used as a convenient way of connecting the power input leads to the amplifier. It is usually only possible to obtain connector blocks in 12-way lengths, and so it will be necessary to cut a 2-way block from one of these. A sharp knife is sufficient to do this.

STRIPBOARD LAYOUT

Most of the circuitry is fitted onto a 0·1in matrix stripboard which measures 13 copper strips by 18 holes. Details of the component panel, plus all the other wiring of the amplifier, are provided in Fig. 4. Construction of the board is very straightforward as there are no breaks in any of the strips and no mounting holes to be drilled. Make sure that the three link wires are not omitted. C3 and R3 are not mounted on the component panel, but are soldered onto the output terminals, as shown in Fig. 4.

When the component panel and all the point-to-point wiring has been completed, it is only necessary to mount the component panel in order to complete the unit. The panel is mounted by bolting IC1 and IC2 onto the mounting bracket fitted on the rear panel. M3 fixings are suitable here.

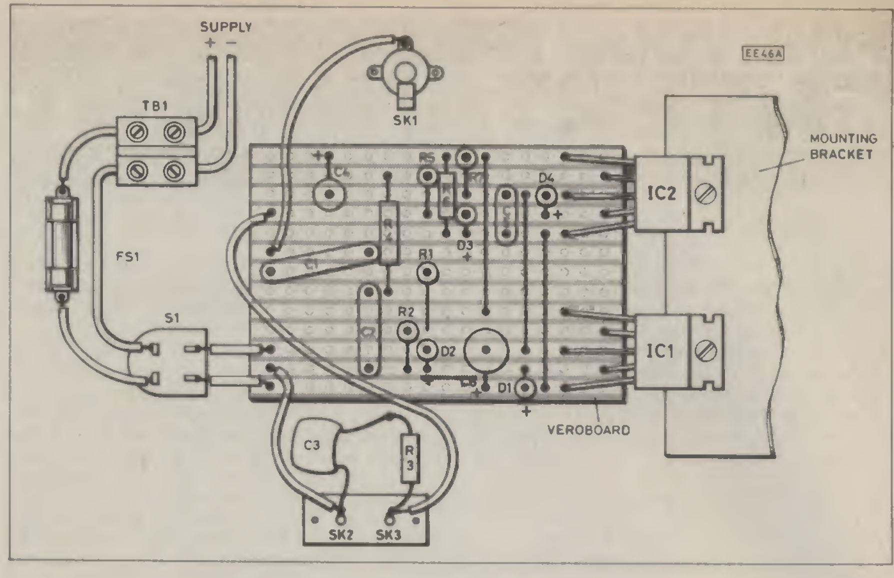


Fig. 4. Stripboard and wiring diagram.

USING THE AMPLIFIER

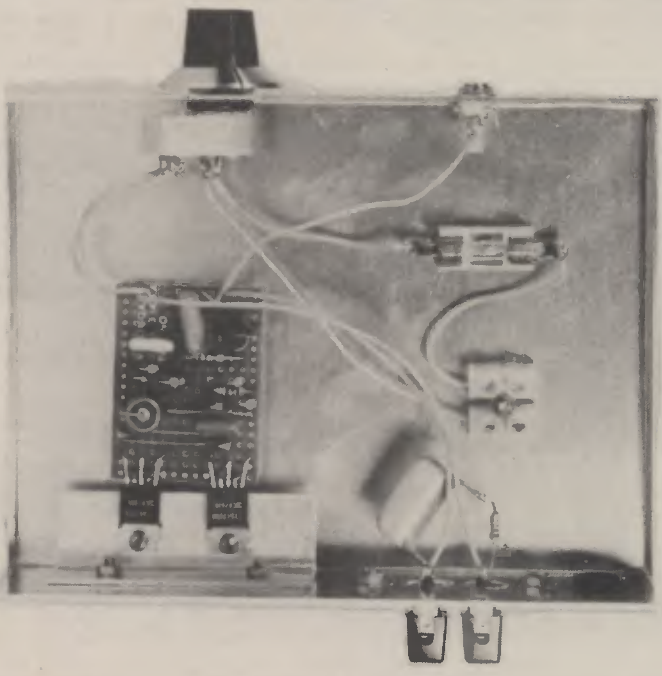
It is a good idea to check all the wiring of any newly constructed project before connecting it to a power supply and switching on, and is especially important in the case of a project of this type which is powered from a low impedance power source which can supply heavy currents.

When quite sure that all is well, connect the amplifier to the 12-volt supply, the output to a loudspeaker of adequate rating, and the output of the radio or cassette unit to the input of the amplifier. The lead carrying the input signal to the amplifier does not need to be screened since it is a low impedance high level signal in the lead. One output lead of the radio or cassette unit will probably be earthed, and this must be the one that connects to the chassis of the amplifier if the unit is to function correctly (reversing these leads will result in the input signal being short circuited). Note that neither speaker lead is at earth potential, and neither lead should be earthed. The TDA2006 i.c.s have output short circuit protection, as was mentioned earlier, and no damage to the unit should occur if one of the output terminals or leads should be accidentally short circuited to earth.

If a positive earth version of the unit is required, IC1 and IC2 must be insulated from the heatsink and case using the usual insulating washers and bushes, since their heat-tabs connect internally to their negative supply leadout wires. FS1 should be wired into the negative supply input lead rather than the positive one, and the chassis should be wired to the positive supply using a lead between the appropriate tags of S1 and SK1.

For a stereo unit it is necessary to build two amplifiers, but these can share a common cause, on/off switch, and supply input connector block. □

See Shop Talk page 534



FOR YOUR ENTERTAINMENT

BY BARRY FOX

Voicebank

There is some interesting technology behind Voicebank, British Telecom's new answering service. According to BT it's aimed at people who don't want to own their own answering machine.

As far as I can see the only real advantage to Voicebank is that it doesn't tie up your phone line. But at what cost!

Voicebank subscribers are allocated an extra phone number which callers must dial to leave a message. As the message is spoken the sound is converted into digital code, by the technique known as delta modulation.

Whereas for PCM (pulse code modulation) the digital bits are arranged in words, for delta modulation (DM) only signal changes up or down are coded. This lets BT record speech with the very low data rate of 32 kilobits a second and still achieve normal telephone speech quality.

The digital code is recorded onto eight Winchester computer hard discs, each with a capacity of 66 megabytes. The discs together hold a total of 40 hours of speech and BT hopes for 5,000 subscribers.

Snag number one is that each subscriber is only allowed seven messages, of up to 25 seconds each. Snag number two is that the messages are only stored for 12 hours. After that they are automatically erased. So you would have to call in twice a day to be sure of getting any messages left.

Service Charge

To simplify things, and avoid this call-in routine, the system can automatically page subscribers by radio when there is a message to be heard. The Winchester discs are under control of Z-80 micros which are hooked into the BT's paging system.

Provided you are within paging range you get a bleep when you have a message. But this is where the cost really mounts up. You pay £45 plus VAT for the Voicebank key pad. Then you pay £35 plus VAT for rental a quarter for Voicebank.

For paging you pay £31.50 plus VAT per quarter for coverage in the London area. The rest of England is divided into 40 zones, which cost an extra £1.50 a zone per quarter.

So, with VAT the full Voicebank and paging service costs the best part of £145 a quarter. This is far more than you would pay for the outright purchase of some telephone answering machines. And these machines will store far more than seven messages of 25 second lengths for as long as you like.

Of course, answering machines go wrong. But no-one, not even BT, can guarantee that the Voicebank micros will never crash.

I use Telecom Gold, the electronic mail service which runs on a similar principle for written messages that you pick up by computer. Quite often the computer is temporarily out of service. If the Voicebank micros go out of service everyone will be in the same boat; they can't pick up their messages.

Frankly I'll be very surprised if Voicebank is a commercial success.

Video Opera

Late in April, *Channel 4 TV* screened "Perfect Lives", described as a video opera in seven parts. If you missed it don't worry, it will doubtless be repeated.

If you didn't miss it you may well be wondering how some of the technical effects were achieved. In fact, although it is unlikely that anyone realised it, there was not a single moment of audio or video signal in the whole three and a half hour performance that had not been artificially processed in one way or another.

I only know because producer Robert Ashley told me. The clever part was that the effects were often so subtle and ordered that they were easily mistaken for reality.

The technology used were digital effects processors, made by British firm Quantel and American firm Ampex. Most pop music promotion films are made using the same technology, but pictures which continually and obviously spin, fold, squeeze, zoom and wipe can be very fatiguing, simply because the effects are so obvious.

Although Robert Ashley talks about the story line of "Perfect Lives" as if it were an episode from any TV soap opera, the story on screen is so obscure as to be virtually invisible. He says he wanted a "repertory effect" which would sustain repeated viewing, like unpeeling the many layers of an onion. He certainly achieved that.

The poetry and jazz dialogue and slightly surreal visuals are either enterprising art or pretentious rubbish, depending on how you look at it. But from a technical point of view "Perfect Lives" was unique.

Ashley hit on the idea of tailoring the picture content so that throughout the entire seven episodes there is consistent colour and contrast level. If the picture is analysed electronically, he says, it shows almost no change in energy content even though the picture images on the screen are continually changing.

For the soundtrack, Ashley used a CBS domestic organ, of the popular semi-automatic type which enables non-musical people to pretend they are playing music. He programmed the CBS organ to play rhythm backing tracks and then added orchestral music over the top. This was overlaid with improvised jazz piano and spoken poetry during the video filming.

It was the video post production work, however, that gave him what he wanted; "a cartoon effect just slightly beyond realism". This took three months in a video studio.

Digital Pictures

The technology of digital picture processing is very new. It dates back only to 1976 when British firm Quantel was first to build a solid state memory store which could freeze a full TV picture in digital code.

While the picture is stored in code it can be altered under computer control, by what is really nothing more than pure mathematics. This technique allows pictures to be changed in shape, viewed from a changing angle, rotated through a full circle, and even turned inside out to create a mirror image.

The processing all happens in real time, but only after laborious preparation of the geometrical transitions through which the picture will pass. This alone took Ashley and his team 300 hours of studio time.

To get all the picture sequences looking superficially similar, he used artificial colouring, often into pastel shades. Almost nothing on screen is seen with an exactly natural colour balance contrast range. But because the processing follows a planned and consistent theme, nothing jars.

Why did it take until 1976 for digital processing to become possible? For a start you need a very rapid action analogue-to-digital converter. Then you need a battery of memory chips capable of holding enough digital bits for a full broadcast quality TV picture.

The black and white or luminance information is sampled at 13·5MHz and two chrominance or colour signals are sampled each at 6·75MHz. The samples are then described in 8-bit words or bytes.

A European TV picture has around 575 active lines (the rest aren't seen on the screen), which means you need a memory store of around 0·5 megabytes for the luminance and the same again for chrominance. This adds up to a total memory store of around 1 megabyte, or 8 megabits, which has to be built up from 64K bit RAMs, each holding 8K bytes.

That's a total of well over 100 64K RAM chips, just to store one picture frame. The store is refreshed at the rate of 25 pictures a second (30 pictures a second for the American NTSC TV standard) and for some effects, like the zooming and picture compression, the sampling rate is continually varied as the picture is processed.

Canal Turn

If you were driving in Holland recently and thought you were on Candid Camera, I can explain. It's all thanks to video.

The flat country is criss-crossed with canals. The road bridges are low so have to be raised, like Tower Bridge, every time a boat comes through.

Until recently every bridge has had its own man in charge, to stop the traffic. Now a subsidiary of Philips has rigged up an optical fibre system which pipes video pictures of a bridge several miles upstream to a central control point. When they see a boat coming, they switch the road traffic lights to red and raise the bridge.

The operators wanted to demonstrate this to the press recently. But there wasn't a boat in sight. So they stopped the traffic and raised the bridge anyway.

Watching on monitors several miles away we could see puzzled car drivers get out of their vehicles and wander in bewilderment as the bridge ahead rose for an invisible boat. The remote operator then played his ace. A microphone in his control cabin is hooked up to hidden loudspeakers. "Get back into your cars. It is dangerous," he bellowed.

On the monitors we watched a gaggle of frightened Dutchmen run back to the safety of their cars. The year is 1984, and in some places Big Brother really is watching on a TV screen.

ANATOMY OF YOUR MICRO

PART TWO

OWEN BISHOP

THE Z80 microprocessor has many features in common with the 6502, but has several more registers. There are also differences in the way we can handle the numbers in these registers. In general, the Z80 is a more powerful microprocessor than the 6502 and has many more op codes. However the 6502 retains its popularity in spite of this. Among the recently introduced micros, we have the Commodore 64 and the BBC microcomputer, both based on the 6502.

The Z80 has two control lines for read and write operations. These are called $\overline{RD}$ and $\overline{WR}$ (Fig. 2.1). Normally these are both at a "high" level, but one or the other is made low by the microprocessor when it wants to read or write data. The Z80 also has another pair of control lines concerned with reading or writing data. These are called the $\overline{MRQ}$ (memory request) and $\overline{IORQ}$ (input/output request). When the Z80 wants to read from or write to memory, it not only makes either the $\overline{RD}$ or $\overline{WR}$ line low, but also the $\overline{MRQ}$ line. This indicates to the memory chips that it is engaged in transferring data between itself and *memory*. Two BASIC statements which cause this to happen are POKE and PEEK. When the Z80 wants to read data from or write data to a peripheral device, such as a telephone modem, it makes $\overline{RD}$ or $\overline{WR}$ low but does not make $\overline{MRQ}$ low. The memory chips will therefore ignore the read or write operation. Instead it makes the $\overline{IORQ}$ line low. This alerts all the peripheral devices and the addressed one responds. The two BASIC statements which bring about this type of operation are IN and OUT. This is not to say that $\overline{IORQ}$ is necessarily used for communicating with peripherals for it is possible to allot some memory addresses to these and treat them as if they were part of memory. This is often done in small machines. The chief advantage of $\overline{IORQ}$ is that it allows all the memory space to be occupied by memory (all 64 kilobytes if you want), and peripherals are addressed independently. This is the usual approach in machines with large memory or where the designers want to cater for maximum memory expansion.

MEMORY MAPS

The memory map of a well-known 6502 based micro is shown in Fig. 2.2. Note the addresses reserved for peripherals (I/O). Unlike the Z80, the 6502 does not have an IORQ line. The rest of memory is divided into two parts, RAM (or random access memory) and ROM (or read-only memory). We will look into these in more detail later but, for the moment, it is sufficient to note that it is possible to both read data from RAM and write data into it. In other words, the contents of RAM can be changed. Also the contents are lost for ever when the power supply is interrupted or switched off. ROM can be read from but cannot be written to (except during manufacture, which we shall deal with later). ROM is permanent; its contents do not disappear when the power supply is discontinued.

ROM is used for storing the programs which the computer needs when first switched on. These include the monitor program which is usually a short program to initialise the system and make the micro ready to receive instructions typed in at the keyboard. It may also include short routines to put a greetings message such as "CBM BASIC V2, 3583 BYTES FREE" on the screen as with VIC-20. Most popular micros have their BASIC interpreter program in ROM. This means that the language is available from the moment the computer is switched on.

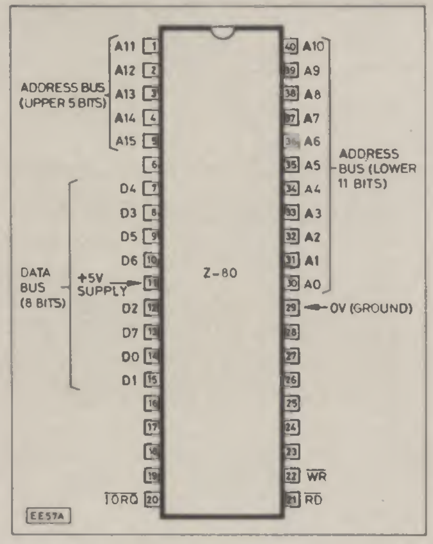


Fig. 2.1. The Z80 microprocessor, showing the connections referred to in the text.

An exception is the Jupiter Ace, which has the FORTH language in ROM, instead of BASIC. The Sord M5 has no resident language (as a language in ROM is called). Instead, the user is provided with a plug-in cartridge containing additional ROM which holds its BASIC. The Sharp MZ-80A and MZ80-B require BASIC to be loaded from tape. The advantage of not having a resident language is that it leaves the user free to choose which language to use with the machine. The required language can then be either plugged in as a cartridge or loaded into RAM from tape or disk. If part of the memory space is already taken up by the ROM for a language you do not want to use, this space is wasted. The language you prefer must then be put into RAM taking up a large part of this and leaving less for program storage. Many computers do not have all their ROM present when you first buy them. The VIC-20, for example, can accept plug-in cartridges containing games programs or utilities. In effect, you are plugging in extra ROM. The BBC micro has empty sockets to take additional ROMs containing programs such as "VIEW", a word processor program.

Another type of ROM which is found in micros is the character generator. This contains the codes used by the micro when putting together the signals used for displaying letters, numerals and other symbols. It may have addresses in memory space, or may be separate, as part of the video circuits.

The other kind of memory, RAM, is mainly used for storing the program that the computer is currently running (or which you are writing). Programs may be put into RAM either by typing them in at the keyboard, by loading them from tape or disk, or by down-loading them from Teletext or Prestel. The greater part of the space used is normally taken up by the program itself, but other areas of RAM need to be set aside for storing the data used by the program. There will be a variable table in which the current values of each variable are stored. If many of the variables are string variables, this may take up a sizeable proportion of available RAM. The contents of arrays are also stored in part of RAM set aside for this purpose.

RESERVED AREAS

Certain parts of RAM are reserved for use by the MPU itself. It needs somewhere to keep important information such as the present position on the screen of the cursor, the name of the most recently pressed key, the colour currently selected as foreground colour. In 6502-based machines, such data is usually stored at the very beginning of RAM (Fig. 2.2). This takes advantage of a simplified addressing mode which can be used with addresses in "zero page" (0 to 255). Another section of RAM may be set aside for storing program lines or text which is on its way from one part of the system to another. Such areas are called buffers. There is nearly always a keyboard buffer (or input buffer) where a program line is stored while it is being entered. When "RETURN" is pressed, this line is then transferred to the end of the program, stored in the main RAM. If you have a disk system, an area of RAM is reserved for materials being sent to the disc or being read from it.

Another section of memory may be taken up for storing the characters which are to appear on the TV or monitor screen. This is often referred to as Video RAM. The amount of memory required for Video RAM depends on a number of factors, including the degree of resolution of the screen image, the number of rows and columns of characters, and the extent to which colours are used. A high-resolution colour display may take several tens of kilobytes of RAM, leaving relatively little for the program. Certain micros, such as the TRS-80 have special Video RAM chips, which are under the control of video circuits. There is thus no conflict between requirements for picture generation and requirements for program storage.

Before leaving memory maps, it is worth noting that the map for a Z80 system is quite different in layout from the one shown in Fig. 2.2. As well as having zero-page storage, which means that the lowest areas of memory must be RAM, the 6502 always reads certain addresses at the very top of memory when it first begins to operate. Here it finds the addresses of the routines to which it must go to initialise the system. Consequently, the top addresses in memory *must* be ROM. It is usual for the whole of the monitor program to be placed at the top. By contrast the Z80 always begins reading its program from address 0, so ROM must occupy the lowest addresses in memory.

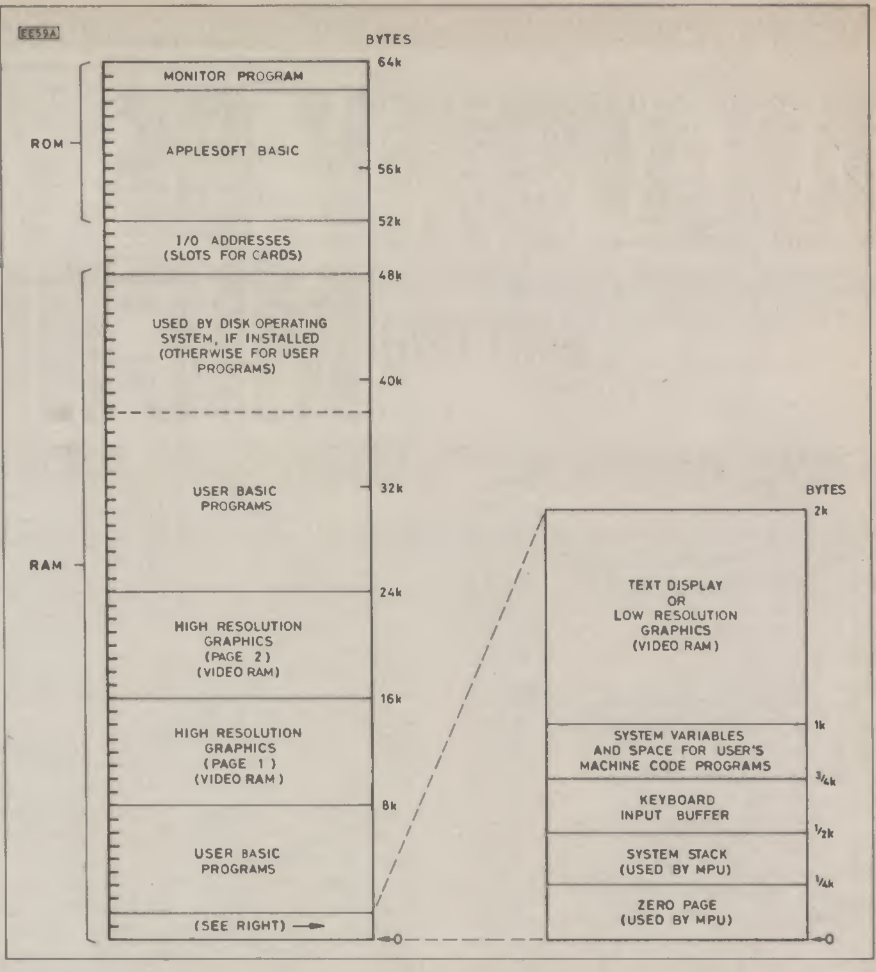
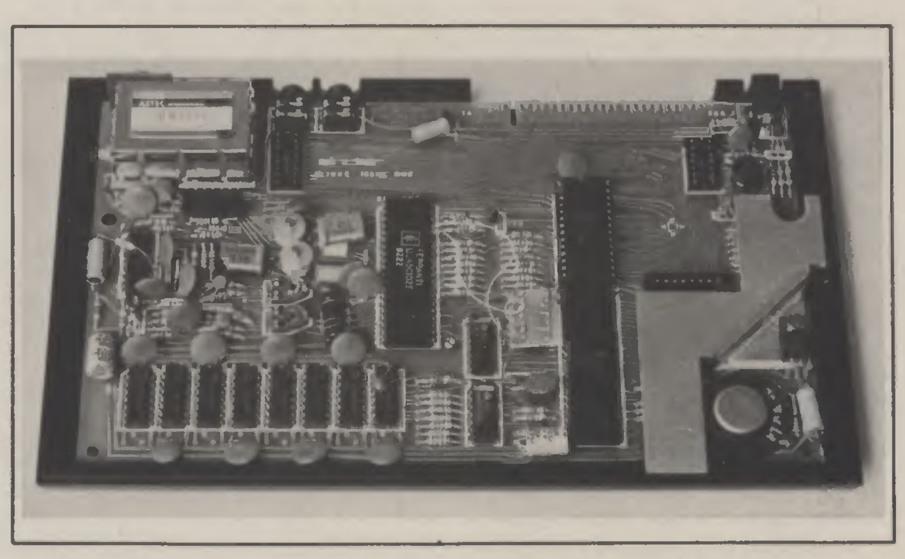


Fig. 2.2. The memory map of a Apple II. Apart from the lower 2K, the whole of RAM is available for BASIC programs, unless part of it is taken over for the Disk Operating System or for High Resolution Graphics. Note the relatively large amount of memory required for high-resolution colour graphics.



Inside the Sinclair ZX Spectrum. The three large chips are the microprocessor, Read-Only Memory, and an Uncommitted Logic Array (ULA). The ULA is a specialised device which takes the place of a large number of discrete logic components. The rest of the circuitry comprises the RAM chips, and the interfacing for the cassette recorder and TV output.

RAM

Two identical RAM i.c.s connected in parallel are shown in Fig. 2.3. This is necessary because each i.c. has only four connections to the data bus. One is connected to the lower four lines (D0 to D3) and the other to the upper four lines (D4 to D7). The other connections to each i.c. are identical, so that they act together to deal with all eight lines (one byte).

There are 10 address bus connections, (the 10 lower lines of the bus). The addresses within the i.c. run:

	Decimal	Binary
From	0	00 0000 0000
To	1023	11 1111 1111

This gives 1024 addresses, which is normally referred to as one kilobyte. Each of these addresses refers to an array of four bistable circuits, the members of which can either be set (giving "1" output) or reset (giving "0" output). Depending on which address is present on the bus, one of these arrays of four bistables is put into connection with the data input/output pins.

The $\overline{WE}$ input determines whether the chip is to be read from (read bistable outputs) or written to (set or reset the bistables). $\overline{WE}$ could be connected directly to the R/$\overline{W}$ of the 6502, so that the write operation is enabled when the R/$\overline{W}$ line is "low". However, we do not want the i.c. to take in data every time R/$\overline{W}$ goes low, for such data might be intended for other sections of memory. This is where the "chip select" input ($\overline{CS}$) is important. The i.c. is incapable of receiving or sending out data except when $\overline{CS}$ is low.

The level on $\overline{CS}$ is determined by the output from an address decoder circuit. This may be made up from a collection of simple logic i.c.s or a special decoder such as that shown in Fig. 2.4. This has three "select" inputs which may be connected to three address lines, as shown. These are the next three above those used for addressing the RAM i.c.s. When all three lines are "low", output "0" goes low, so enabling the pair of RAM i.c.s connected to this line. The effect is that these RAMs have the address range:

	Decimal	Binary
From	0	00000 0000 0000
To	1023	00011 1111 1111

A second pair of RAMs is connected to output "1" of the decoder, which goes low when the input to the decoder is "001". The address of this pair of RAMs is:

	Decimal	Binary
From	1024	00100 0000 0000
To	2047	00111 1111 1111

In each case, the lower 10 bits are decoded within the RAM i.c. covering one kilobyte of memory. The upper three bits are decoded by the decoder, allowing us to use up to eight pairs of RAMs, and covering an address range of eight kilobytes. As Fig. 2.4 shows, the decoder also has some strobe inputs which can in turn be fed from another decoding circuit, so allowing several 8K blocks of memory to be addressed individually.

In many of the smaller machines, it is unnecessary to decode all 16 bits of the address bus. Fourteen lines address 16384 locations (16K) and there may not be need for more. To save cost and complexity, the top two lines may be omitted from the system. Alternatively, they may be reserved for special functions, such as controlling a printer. This makes the design of the computer easier, though it gives problems to those who want to design and build add-on circuits.

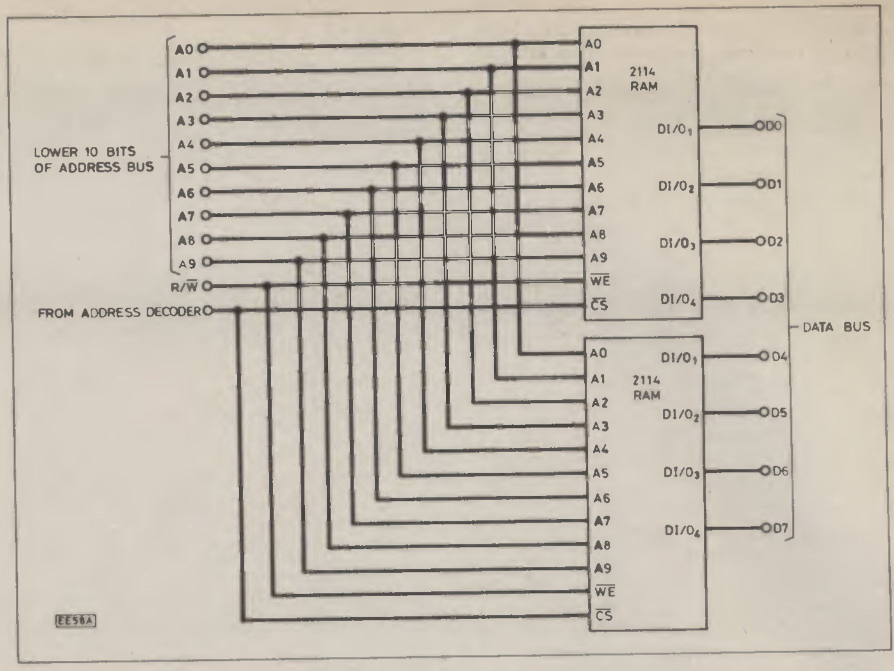


Fig. 2.3. Two 2114 RAM i.c.s wired to store 1 kilobyte of data.

ROM

The most frequently used kind of ROM is that known as a *mask programmed* ROM. It is programmed during manufacture so that addressing any given location always produces the same byte of data from its data bus outputs. The term "mask" refers to the photographic masks used in preparing the chips for etching. These are custom-designed to set each memory location as required. For example, the masks might be designed so that the finished ROM contains a monitor program or a word-processor program, or perhaps the data required for character generation. Designing these ROMs is costly but, once the design has been

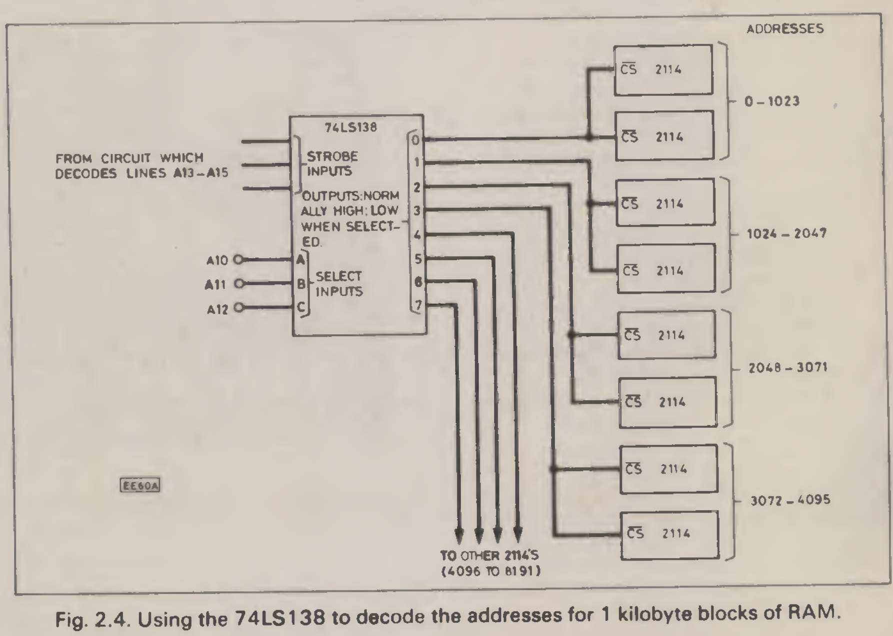


Fig. 2.4. Using the 74LS138 to decode the addresses for 1 kilobyte blocks of RAM.

tested and found correct, it is possible to manufacture such ROMs by the thousand at relatively low cost. This kind of ROM is certainly not for "one-off" applications.

When a system is under development, or when it is known that only a few identical ROMs will ever be required, it is usual to program each ROM chip individually after manufacture. One type of programmable ROM is the *fusible link* ROM. When manufactured, all memory cells give a "1" output. The ROM may then be programmed by addressing each bit in turn (or perhaps eight at a time) and either "blowing" a thin wire link, by passing a high current, or omitting to blow it. Blowing the link makes that location give a "0" output from then on. The work may be done automatically, under computer control. Once such a device has been programmed it cannot be altered.

The erasable programmable ROM (or EPROM) is very popular, not only for dedicated systems for which the expense of mask programming is not justified, but also for systems in development (as many owners of the BBC micro will know). These are programmed by addressing each location in turn, putting the required data on the bus and then applying a programming pulse of short duration but of relatively high voltage, in order to charge the gate of a field effect transistor (Fig. 2.5). The effect of this is to turn the transistor permanently on or off. When, in future, we address the memory cell of which the transistor is a part, the output is "1" or "0" depending on the state of the transistor. Since the gate is electrically insulated, the charge remains on the gate for years, retaining the stored data indefinitely. Reading from the memory does not reduce the charge, for this is a field effect transistor—its action depends solely on the field created by the charge, and does not require any current to flow from the charged gate.

An EPROM can be programmed automatically by an inexpensive device which can be controlled by a home computer. The advantage is that, if it is subsequently necessary to amend the program, it can be completely erased by exposing the chip to ultraviolet radiation. This is the reason that there is a quartz "window" in the package. Ultra violet radiation is an "ionising" radiation; it produces a copious supply of electrical ions in any material on which it falls. These ions cause the charge to be lost from the gates of the transistors. This erases the stored program in a period of a few tens of minutes. The EPROM may then be reprogrammed.

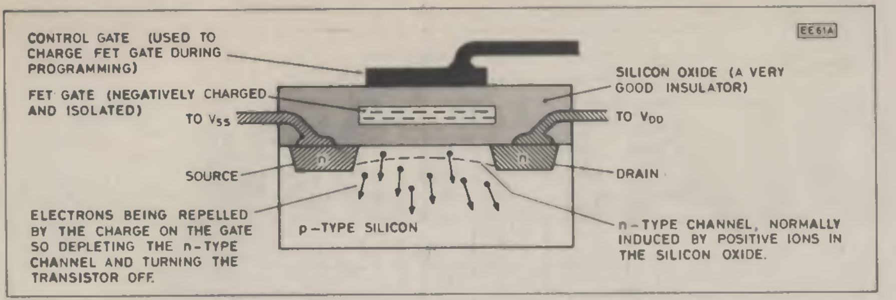


Fig. 2.5. MOSFET with isolated gate, as used in an EPROM.

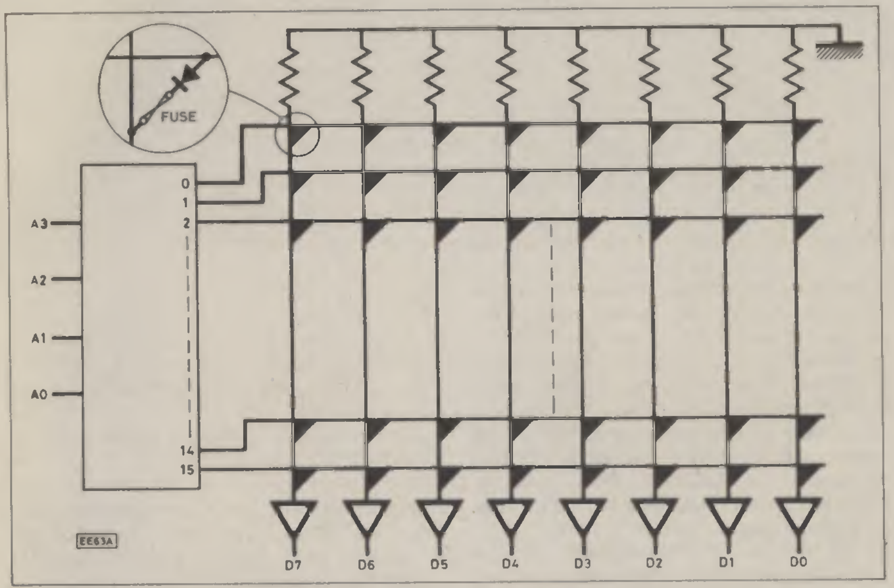


Fig. 2.6a. Unprogrammed 16-byte fusible-link PROM. The address decoder is part of the chip, and as any of the 16 rows is selected (addresses 0000 to 1111), the "1" on the output from the selected row of the address decoder will appear, via the diodes and fusible links as all "1s" on the data bus.

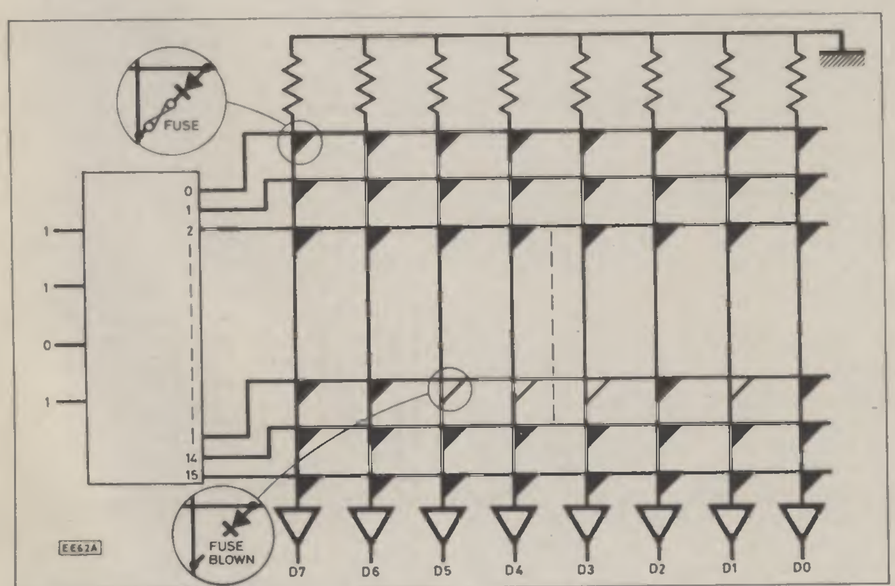
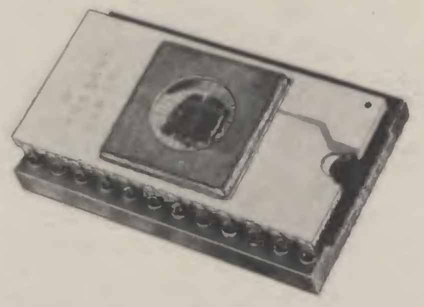


Fig. 2.6b. Programmed FPROM. Address 1101 (thirteen) is shown with fuses blown to give bit pattern 11000101 on the data bus.



A typical UV EPROM, showing the circular quartz window above the memory circuit. When exposed to ultra-violet light, the whole memory is erased.

What is RADIATION?

A. J. BENTLEY

NUCLEAR Power and the "Bomb" are topics of grave public concern. The bright promise of unlimited cheap electricity is dimmed by the spectre of Nagasaki and Hiroshima and by the grim reminder from Three Mile Island. These very real threats are made doubly menacing by the lack of agreement displayed by opposing groups of "experts". Discussions on the subject opened in the news media rapidly degenerate into acrimony over statistics, with no attempt to make clear what it is that is being argued over. I wonder what sort of an answer we would get from a Politician or a General if a TV Interviewer asked: "O.K. so what *is* radiation then?"

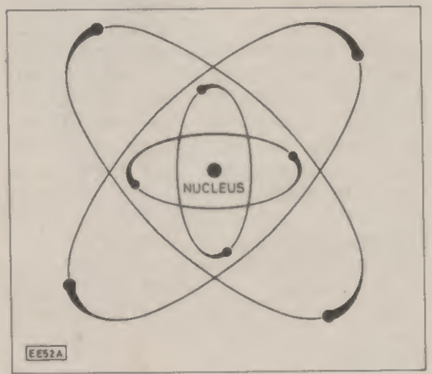


Fig. 1. Classical model of an atom, showing electrons orbiting around a nucleus.

ACTIVE ATOMS

Everything in the world is made of atoms, we have been told. Each atom consists of a central core or nucleus with a collection of orbiting electrons as in Fig. 1. The nucleus has a strong positive electric charge which holds the negatively-charged electrons in orbit. Among the untold numbers of atoms in the universe are certain "rogues" whose nucleus has an ability to "spit", usually only once in its life. This nuclear phlegm is known to us as radiation.

ILLUMINATING DISCOVERY

In order to continue a little more seriously we have to study a bit of history. Around the turn of the century, it was found that certain types of rock were able to fog photographic film even through quite thick wrappings. Apparently this was due to some invisible emmanation from the rock. After much effort scientists were able to purify the substances in these rocks which were responsible for the rays. Some of these "radioactive" materials were found to glow in the dark, especially when mixed with other substances.

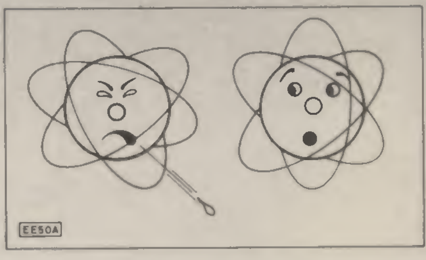
For a while everyone had great fun with the stuff. You could buy luminous paint and luminous watches and even obtain special intimate garments with sewn-in radium to bathe yourself in its invigorating rays. Meanwhile the scientists plodded on with their investigations and found that there were three distinct types of ray, each with different penetrating powers. These were named Alpha, Beta and Gamma rays from the first letters of the Greek alphabet. Gamma rays are the most penetrating and Alpha rays the least. (Fig. 2).

Many more years of investigation revealed the fact that these three types of ray were in fact sprays of tiny particles which had already been discovered under other circumstances; thus the mystery was dispelled quite simply.

ALPHA RAYS

These turned out to be helium gas atoms moving at incredibly high speed. For some unknown reason, many types of atom are able to suddenly split up into two parts, entirely of their own accord. One of these parts is invariably a helium atom, the other part depends on what is left over from the original atom. This residual atom may or may not also be radioactive.

We do not know yet just why some atoms are stable and others are liable to split up in this way. Nor do we know why the result is always a helium atom when



this happens. It is known that the helium atom or alpha particle as it is sometimes called is totally stable, perhaps there is a clue there somewhere.

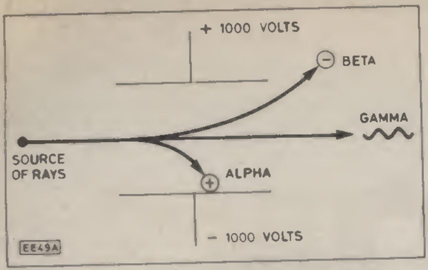
Because the helium atom is moving so fast, it loses its attendent cloud of orbiting electrons (strictly, we should be referring to alpha particles as helium atom nuclei). This means that the particle is positively-charged and can be deflected easily by electric fields. When an alpha particle hits an object it is affected by the local electrostatic field of the surrounding atoms and comes to rest quite quickly. A sheet of paper will stop alpha particles with ease.

BETA RAYS

These are even more easily understood, being nothing more than electrons. They don't come from the orbiting electron cloud but are ejected from the nucleus itself. Sometimes they are antimatter electrons or positrons. This is how antimatter was discovered in fact. Electrons are not so highly charged as alpha particles and being lighter they move rather faster so they are not so easy to stop. Nevertheless, a sheet of metal say 2mm thick will take care of them.

GAMMA RAYS

Gamma rays are a little different from the other two, being short pulses of incredibly high frequency radio waves, even



The effect of an electric field on radiation. The positive alpha particles are attracted to the negative plate, the negative beta particles to the positive plate. The uncharged gamma "particles" go straight through.

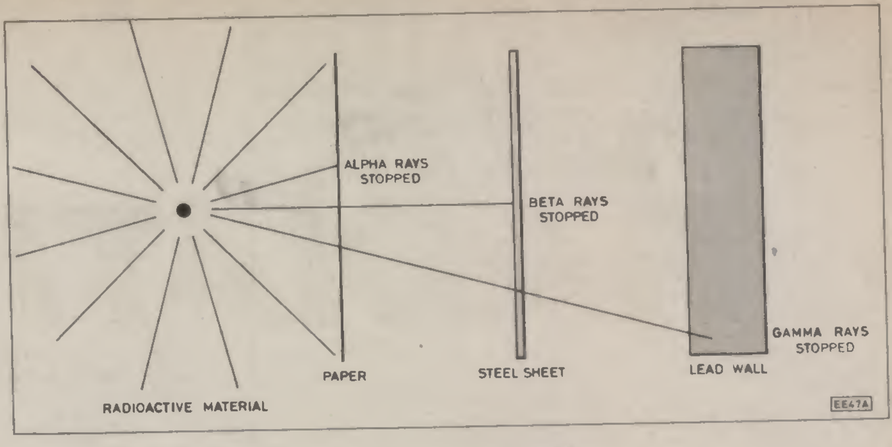
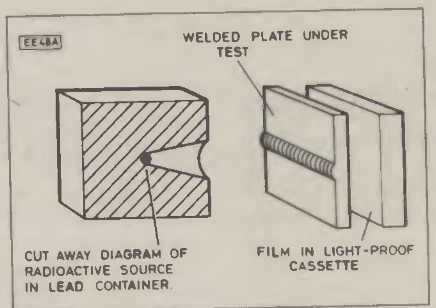


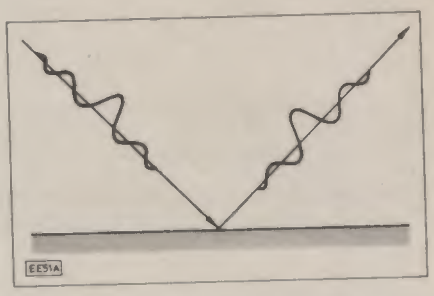
Fig. 2. The penetrating power of radiation.

higher than X-rays or light, having a frequency of over one thousand million million Megahertz. They can penetrate several feet of concrete without slowing down. At such high frequencies, these pulses behave much like particles when they "bounce off" things so it is often convenient to regard them as particles in calculations, in which case they are referred to as "photons".

Radiation then, can be described simply in terms of fragments of material shot out of atomic nuclei with a muzzle velocity close to the speed of light. Pushing the analogy with bullets a little further we can add that the calibre is about one million millionth of a millimetre. You can imagine therefore that each one of these projectiles would do very little damage to the human body, and what damage was done would normally be repaired by the body's own healing mechanism. This is true but unfortunately one particle may just happen to strike one of the d.n.a. molecules in a living cell in exactly the right way to initiate a cancer which may or may not be malignant. If we knew what the chances were of this happening with any one particle we could calculate the probability of a person being killed by a specific dose of radiation. This is the sort of thing the "experts" love to argue over, but the truth is we do not really know. There have not been a sufficient number of deaths from measured amounts of radiation for us to form a conclusion.



Gamma radiography: the first effect of radiation to be discovered is still used in industry to detect faulty welds.



Photons "bouncing". Waves and solid objects both obey the same rule of reflection: angle of incidence equals angle of reflection.

FRIEND OR FOE

The radiation which surrounds us comes from the rocks in the earth and the water in the sea, from dust and gases in the air, even the atoms from which our bodies are made emit radiation. This has always been so since the earth was formed and always will be so. Radioactivity is not some evil man-made thing but a natural consequence of the way the universe is constructed. It is new only in the sense that we have only just become aware of it. As always there are those who wish to use this discovery to kill others, and there are those who wish the knowledge to be lost and forgotten. It must have been the same when the first shivering cave-dweller discovered fire.

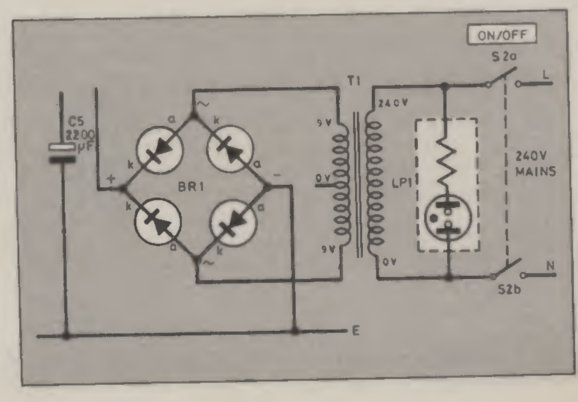
If we compare that first open fire to a modern central heating system, is it too much to hope that we can safely benefit from this find?

NEXT MONTH Fission and Fussion

PLEASE TAKE NOTE

Spectrum Bench Power Supply (July 1984)

The circuit diagram for the Spectrum bench power supply showed the bridge connections short circuited and the diodes reversed. The correct connections are shown in the circuit diagram below. The actual diodes are an integral part of the bridge rectifier.



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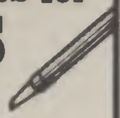

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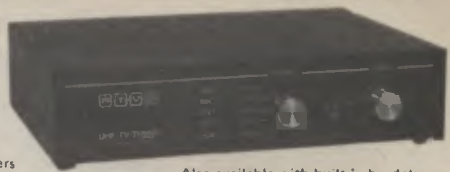

In the cut-throat world of consumer electronics, one of the questions designers apparently ponder over is "Will anyone notice if we save money by chopping this out?" In the domestic TV set, one of the first casualties seems to be the sound quality. Small speakers and no tone controls are common and all this is really quite sad, as the TV companies do their best to transmit the highest quality sound. Given this background a compact and independent TV tuner that connects direct to your Hi-Fi is a must for quality reproduction. The unit is mains-operated.

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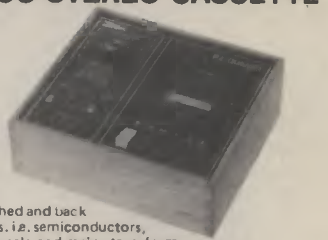

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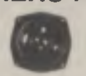

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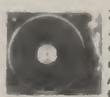

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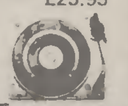

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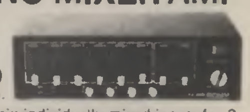

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SQUARE one FOR BEGINNERS

FOR SOME YEARS NOW, CMOS devices have been readily available, and this month *Square One* considers how they work, and also the kind of precautions that need to be taken when handling them.

STRUCTURE AND OPERATION

A conventional transistor works by making use of a small current (to the base) to control a larger one (through the collector load). The transistor may be either n-p-n or p-n-p type, but in either case the material used is normally silicon. The designation n-p-n or p-n-p refers to the structure of the transistor: n-type silicon has a relatively large number of free electrons, while p-type has a shortage. Pure silicon is a semiconductor: its ability to conduct electricity lies between that of a conductor and an insulator. When small quantities of phosphorous are added to pure silicon, the resulting "doped" silicon has an excess of electrons and is called n-type. When, instead, boron is used, the boron attracts electrons from the silicon atoms, creating "holes" in the structure. Silicon doped in this way is called p-type. The charge carriers in p-type silicon—"holes"—are locations that electrons can move to easily.

A field-effect transistor (f.e.t.) also makes use of p- and n-type silicon. The basic arrangement for an "n-channel" device is as shown in Fig. 1. When the f.e.t. is conducting, electrons will flow from n-type silicon at the "source" to n-type silicon at the "drain". In order to do this, they need to pass through the

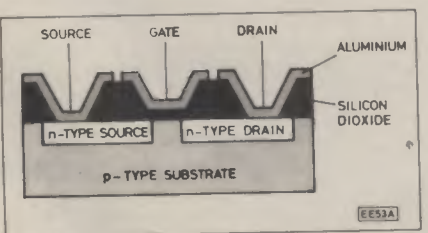


Fig. 1. Basic MOSFET structure.

p-type silicon in between—the substrate. Connections are made to the "source", the "gate" and the "drain"—"source" and "drain" indicate the direction of electron flow. Electrons possess a negative charge, and so the drain terminal is made positive, attracting electrons from the source. This electron flow is controlled by the electric charge on the gate, and this electric charge is related to the voltage on the gate.

Connections are made to metal (usually aluminium) contacts, and in the case of the gate, the metal is insulated from the substrate by a layer of silicon dioxide. Hence there is virtually no current flow possible through the gate; instead, as mentioned above, the voltage on the insulated gate creates an electric field —a positive voltage creating a field that attracts electrons, and a negative voltage repelling them. All this is summed up by the abbreviation MOSFET, standing for Metal-Oxide Semiconductor Field-Effect Transistor.

STANDARD CIRCUITS

When the source is at zero volts and the drain is made positive—say at +12 volts—electrons are attracted to the drain. A smaller positive voltage on the gate—say +5 volts—will repel positive "holes" from the p-type substrate (or, looked at another way, it will attract electrons) and so create a "channel" of n-type silicon between source and drain, as in Fig. 2. Electrons can then pass freely from source to drain.

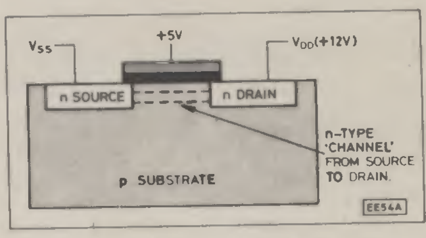


Fig. 2. N-channel MOSFET.

A p-channel device (Fig. 3) works in essentially the same way, except that this time a negative voltage is used to repel electrons from the n-type substrate and so create a conducting channel rich in "holes". The electric current flow is then a flow of "holes" from source to negative drain.

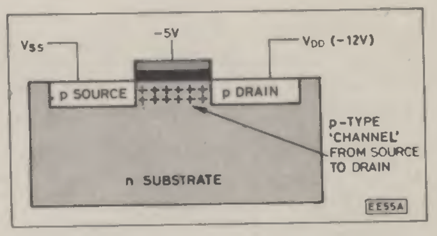


Fig. 3. P-channel MOSFET.

Devices which make use of both p-channel and n-channel f.e.t.s are referred to as CMOS—Complementary Metal-Oxide Semiconductors, and this arrangement offers several advantages. The basic CMOS inverter shown in Fig. 4 works very simply: a high input will make TR2 conduct and turn off TR1. The output will thus be at Vss (ground). A low input will switch off TR2 and switch on TR1 and the output will switch to Vdd (positive). From this inverter, all the usual logic functions can be built up—NAND and NOR gates, flip-flops, registers, as in TTL technology.

The two major advantages of CMOS over TTL are: very low power dissipation; and excellent noise immunity. The low power dissipation is due to the fact that there is only current flow at the input when the device is actually switching. Because the gate is insulated, there is no current flow at any other time. This becomes less advantageous, of course, as the frequency of switching increases. The good noise immunity is a consequence of the fact that CMOS circuits will work over a wide supply voltage range—anywhere from about +3 volts to +15 volts. So if the device is operated from a +12 volts supply, "noise", in the form of transient voltage spikes, has to be of an amplitude greater than +6 volts to affect the circuit.

The major disadvantage of CMOS is its relatively slow speed of switching (though speeds are increasing all the time). This low switching speed is a direct result of the need for the voltage on the gate to set up an electric field; rather like charging a capacitor, this takes time.

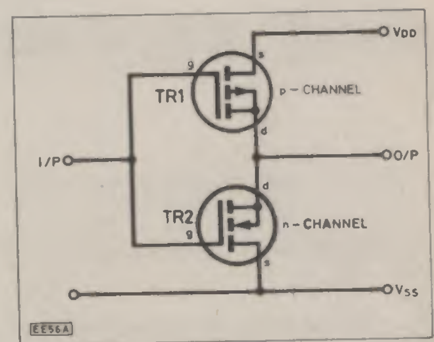


Fig. 4. CMOS inverter circuit.

STATIC SENSITIVITY

The major problem encountered with early CMOS devices was their vulnerability to static electricity. The thin gate insulation will break down at less than 100 volts, and someone walking through a carpeted office can easily acquire a static charge of many thousands of volts. Virtually all CMOS devices now have built-in protection, in the form of diodes to short-out high input voltages before the gate insulation can be damaged, but some care is still necessary when handling them.

Professional workshops and laboratories usually have a "safe-handling area": this is an area in which the workbench is covered in conductive foam, which is in turn connected to ground. The operator wears a wrist-strap made of conductive material, which is also connected to ground. Circuit boards are protected in transit by being packaged in conductive bags (see photo).

For the amateur, the important thing is to keep in mind the fact that CMOS circuits are vulnerable. They are normally sold pushed into a conductive foam pad, and should be left there until actual component insertion; and if possible, the work-area should be at ground potential.

Anti-static packaging for circuits that include static-sensitive devices.

MICROWAVE ALARM SYSTEM

I.F.H.GOULT

Part 3 of the Surveillance series

A CERTAIN mystique is often implied when microwaves are mentioned. This is completely unjustified. Microwave devices are usually very simple, and lend themselves to simple applications. One such application is a motion detector.

The generation of a transmitted wave pattern of specific wavelength and frequency, and the resulting signals received by a receiver have been described in a previous article. Suffice it to say here that reflections from stationary objects result in a received signal at the same frequency as the transmitter. Reflections from a moving object will result in signals having a frequency faster than the transmitted frequency if the object is moving towards the transmitter-receiver system, and slower than the original frequency if the object is moving away from the transceiver. The increase or decrease in frequency will be directly related to the speed to or from the transceiver. This is known as the doppler effect.

If a microwave signal is generated and transmitted in free space having a frequency as recommended by the Home Office for the domestic user of such devices—namely 10·687GHz *(ten thousand, six hundred and eighty-seven million cycles per second)* then the doppler return signal frequency will be 2Hz for a person moving one foot per second to or from the transceiver. Normal walking speed is about 2ft per second. A typical microwave transmitter-receiver is described here.

MICROWAVE DOPPLER MODULE

Typical modules are illustrated in the photograph. The transmitter-receiver will comprise a microwave oscillator and a mixer diode to compare the original oscillator frequency with the received signal frequency.

The simplest form of oscillator is the gunn diode oscillator. A gunn diode is similar to a conventional diode but has gallium arsenide as the semi-conductor material. Such a diode exhibits a "negative resistance" effect over part of its voltage current characteristics. Fig. 1 illustrates this effect.

An electrical oscillator is analogous to the oscillating pendulum of a grandfather clock. The pendulum has to be supplied with energy to overcome the frictional resistance of the bearing on which it hangs, otherwise it would stop. The losses in a circuit are the electrical equivalent of the frictional losses of the clock and no electrical oscillations can be sustained unless these resistive losses are cancelled.

The introduction of the gunn diode working in its negative resistance region into a waveguide cavity will cancel out the resistance losses.

A gunn diode placed one half of the required wavelength from the reflecting wall of the cavity, as illustrated in Fig. 2, will sustain electrical oscillation in the cavity. The tuning screw in the cavity provides fine frequency adjustment.

The electrical pressure pattern is transmitted along the waveguide, which is open at the end to radiate the electrical pressure pattern (oscillating at 10GHz) into free space as a radio wave. The wavelength λ will be approximately 3cm.

This radio wave will be reflected back from any solid surface; coming back to the transmitter source at the same frequency, although delayed slightly in time (less than 1 millionth of a second).

THE RECEIVER

The receiver consists of a mixer diode placed in a suitable position in front of the gunn diode; or in an adjacent waveguide cavity having a hole coupling a small amount of leakage from the transmitter waveguide to the receiver waveguide.

The mixer diode gives an electrical output which contains any difference frequencies between the transmitted and received frequencies. These difference frequencies, which must have been caused by motion, can be amplified and used to trigger an alarm.

BASIC CIRCUIT FOR DOPPLER ALARM

The basic circuit arrangement and circuit diagram recommended by one doppler unit manufacturer are shown in Fig. 3. TR1 and IC1 are low frequency amplifiers.

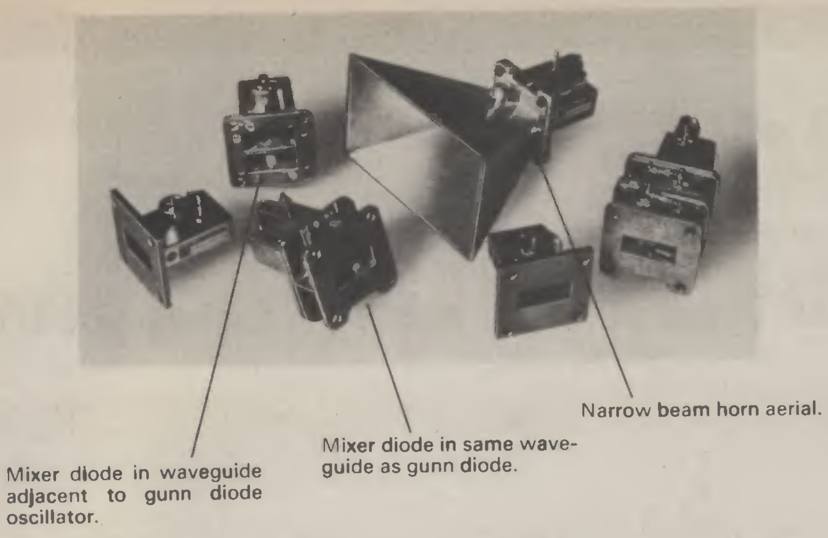
The mixer current will normally be about 400 microamps d.c. due to the coupled signal from the cavity oscillator.

VR1 is set to give a d.c. voltage of about half that of the supply at the collector of TR1. IC1 has 100 per cent negative feedback to d.c. but will amplify low frequency signals.

The amplifier output will be constant for no movement. A signal of a few cycles per second will be amplified by TR1 and IC1, passing through C3 causing TR2 to

SPECIFICATION

Operating frequency	10·687GHz
Mean transmitted power	<10mW
Current consumption in detector mode	1mA approx.
Range	8 metres approx.
No susceptibility to interference from similar units operating locally	



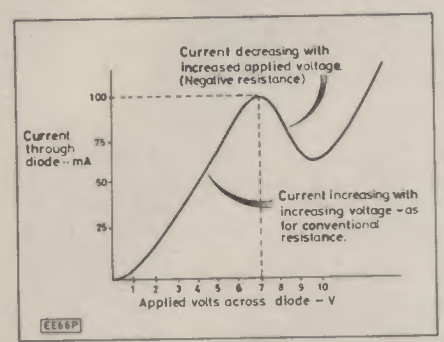


Fig. 1. Typical gunn diode negative resistance characteristics.

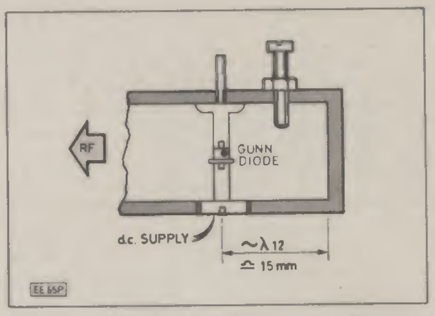


Fig. 2. Waveguide resonant cavity.

conduct during the negative half cycles of the signal. The current through TR4 will progressively charge C4 over several cycles of signal; typically five or six cycles, requiring one or two seconds of continuous movement before the positive potential on C4 is sufficient to switch on transistor TR3.

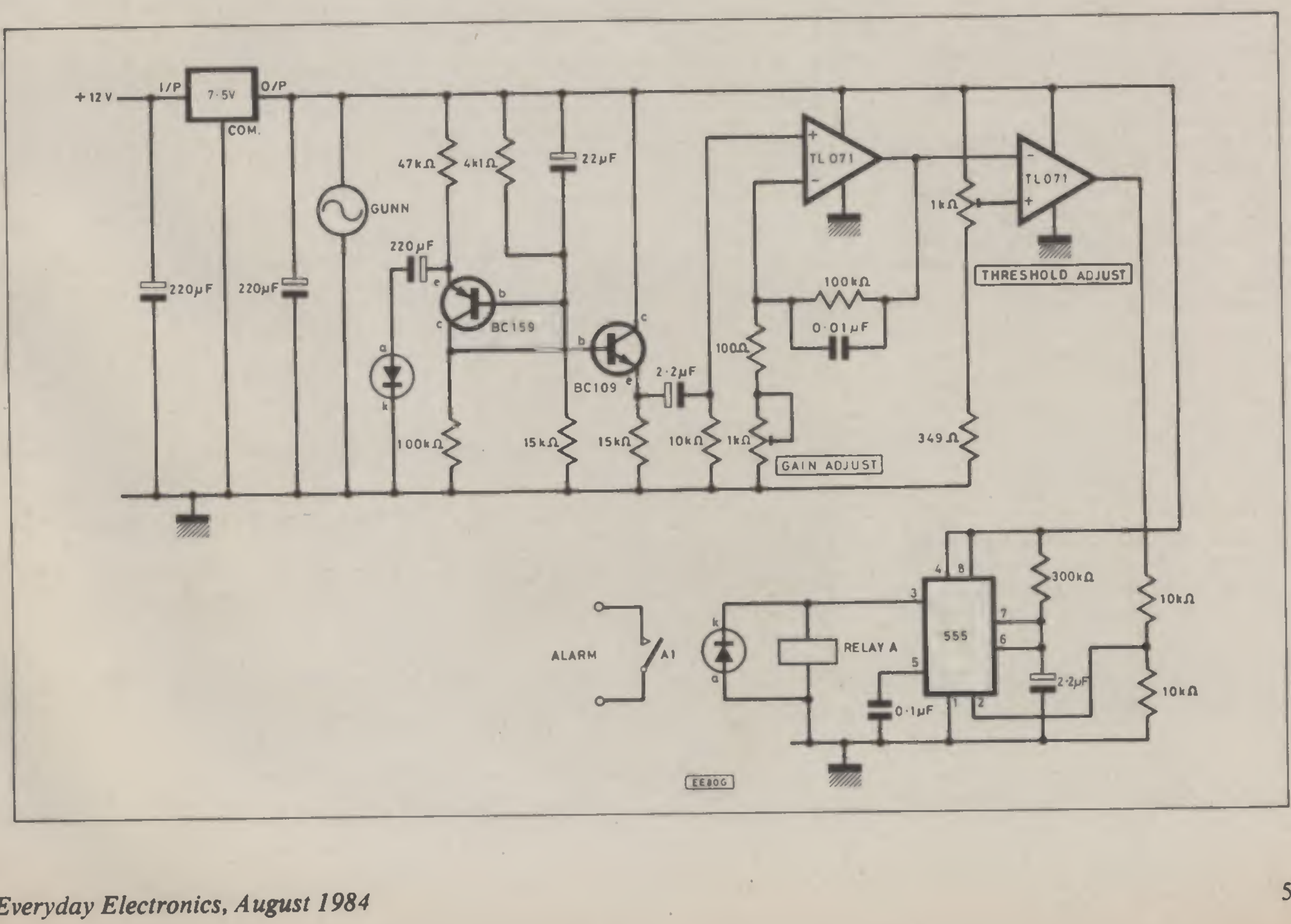
The sensitivity control VR2 sets the signal gain of amplifier IC1 to ensure that the noise level will not trigger the alarm when there is no movement.

The relay has been held on by the positive potential at the collector of TR3 which holds the positive input of IC2 above the –ve (inverting) input. When TR3 conducts the +ve input of IC2 falls below that of the inverting input cutting off the current in TR4. The relay is now de-energised.

The alarm is arranged to operate in the de-energised state in order to cater for the condition when the power supply wires may be cut by an intruder.

A gunn diode operating continuously takes a current of about 100mA to 125mA. This is too much for battery operation. Most microwave dopplers are usually wired systems.

A-BUY-AND-ADAPT PROJECT



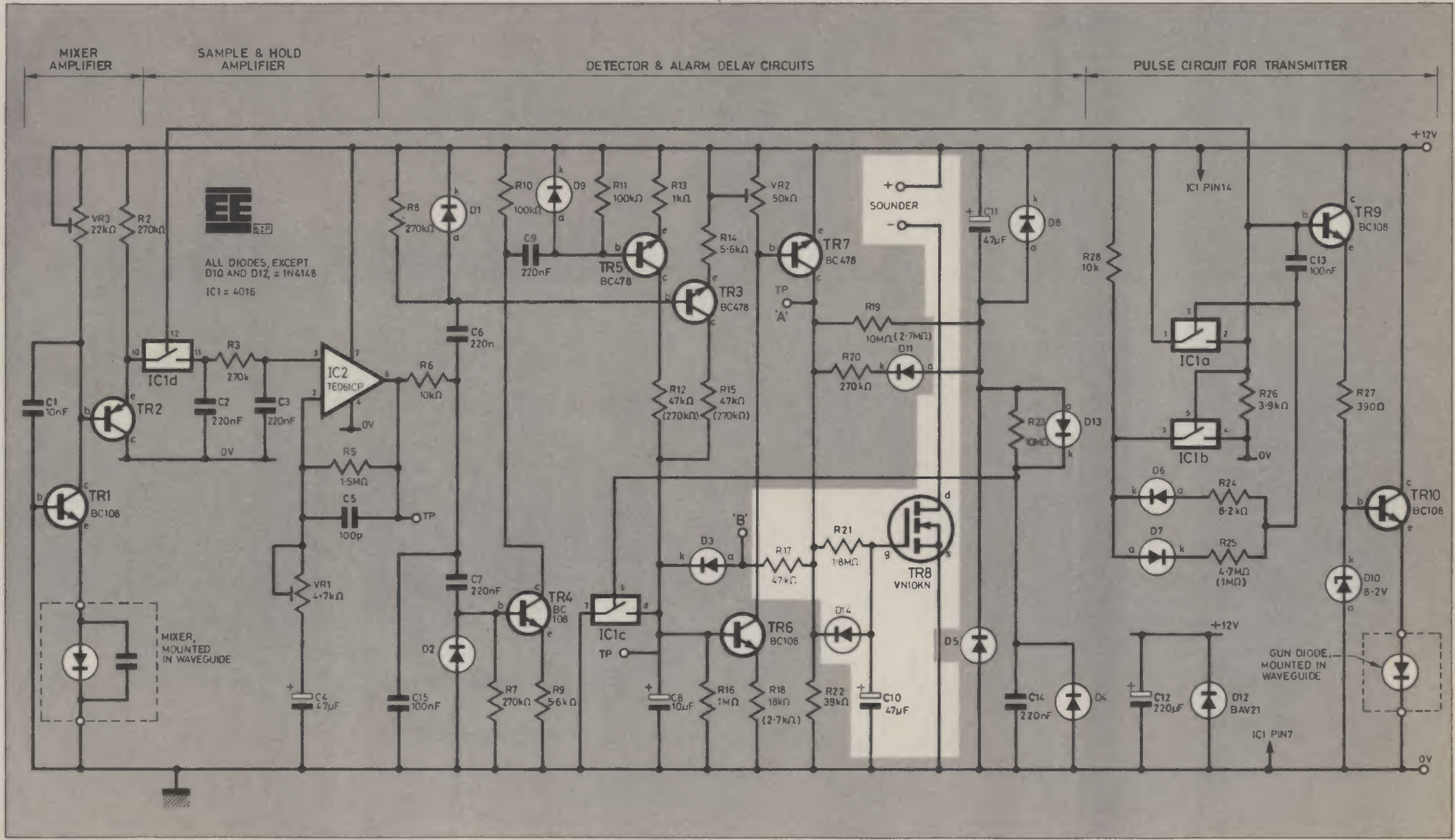


Fig. 4. Circuit diagram of the Microwave Intruder Alarm System as available from Avionic Systems. The non-tinted area shows the components which must be removed by the constructor when incorporating the adaptor kit featured in this article.

SELF-CONTAINED BATTERY UNIT

Fig. 4 illustrates a circuit of a self-contained battery operated unit. Battery power is saved by connecting the switches of IC1 to form a multivibrator which gives a positive pulse output of one millisecond about five times per second. The total current drain is reduced from well over 100 milliamps to about 1 milliamp. This will allow operation for about 1000 hours in the detection mode using eight alkaline type AA cells.

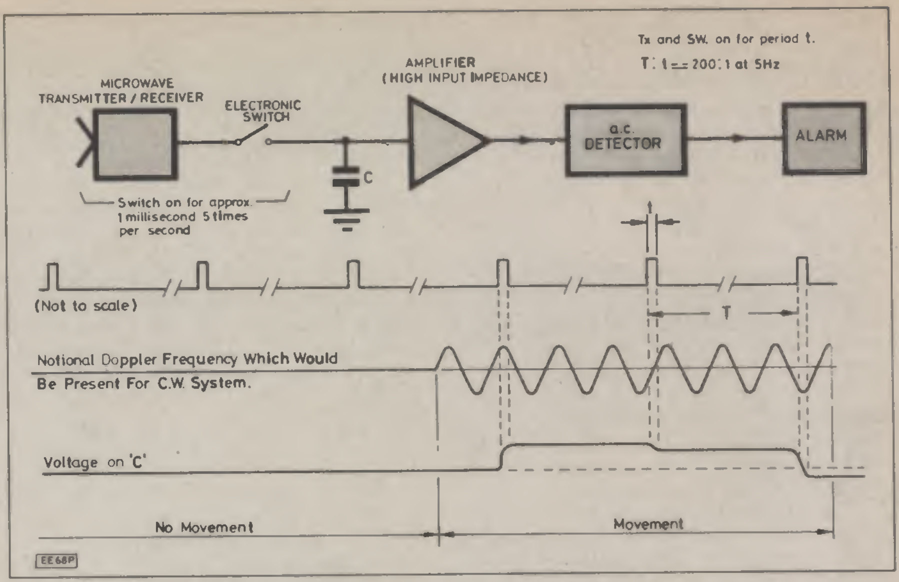
The pulse which switches the gunn diode is also fed to a switch to connect the received signal to C2 during the transmission period. C2 thereby samples the level of the return signal which will remain at a constant potential if there is no movement: but will receive different potentials each time it is switched if there has been movement during the time between transmission pulses.

The amplifier and detectors will only pass the varying potential. TR8 will be latched ON when a varying signal is received to energise the piezo-electric sounder.

When the alarm is on C11 will slowly charge and after about one minute will apply sufficient potential at the input to the switch (pins 6, 8 & 9 of IC1) across C8 causing it to close, discharge C8 and unlatch the alarm to reset the circuit into the detection mode.

This entire self-contained unit can be accommodated into a stylish wood-veneered cabinet which looks very much like a small loudspeaker unit.

The sounder can be replaced by a relay to trigger alternative alarms, lights, etc.



A graphic description of how the circuit works.

OPERATING INSTRUCTIONS

Place unit on firm, steady surface and switch on, using the key provided. Leave the detection area within 30 seconds of switching on. The unit is now set to sound the alarm for any further movement in the area.

If movement is detected there will be a 10-second delay and then the alarm will sound for approximately one minute; after which the unit will reset to its movement detection mode, for example, the alarm will sound again if there is any further movement in the area.

On your return you have 10 to 15 seconds to switch off before the alarm will sound.

Domestic pets in the area will trigger the alarm also, fluorescent lights if switched on should be at least 10ft from the unit.

BATTERY CHECK

A push-button near the "ON/OFF" switch will give a green light indication that the batteries are in good condition. If the light does not glow, replace the batteries. The unit requires eight Duracell 1·5V size AA batteries (Duracell MN 1500). The batteries should give approximately 1000 hours of operation with the unit in the detection mode.

It is necessary to check the unit operation from time-to-time. It should be noted that the current consumption is increased by about thirty times when the alarm is sounding. When testing the alarm the sound should be left on for a *few seconds* only in order to conserve battery life.

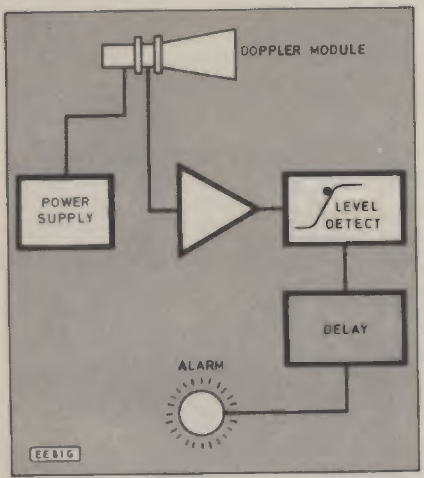
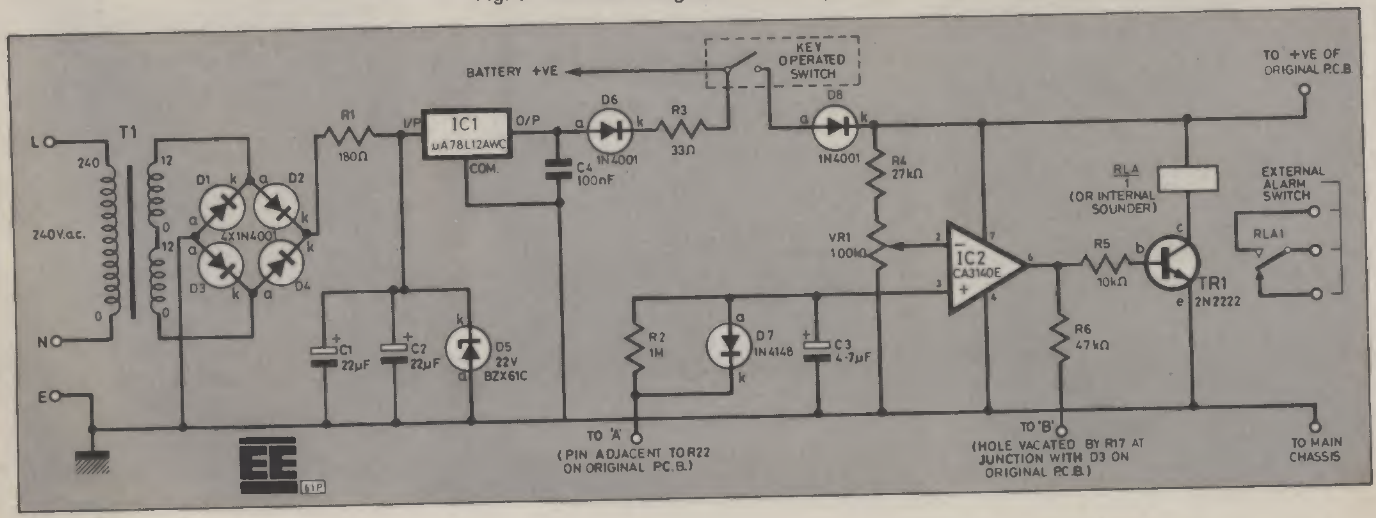


Fig. 5. Block diagram of the doppler module applications system.

Fig. 6. Full circuit diagram of the adaptor kit.



MODIFICATION KIT FOR MICROWAVE ALARM

The self-contained battery unit described in this article, was found to have certain unsatisfactory features. A limited quantity were manufactured, housed in a veneered loudspeaker style cabinet to blend with living-room furniture. The units were never marketed and are now available at cost price to the reader. The modifications listed below overcome the original limitations.

The first operational drawback was battery life. The design target was 1,000 hours using AA style alkaline batteries, but only about half this life was achievable. Thus the modification kit offered adapts the unit to mains operation; with back up Ni-Cad batteries in case of mains failure as an option.

The second problem in the original design was an effect known as "popping" in the gunn diode. This had the effect of giving a momentary kick to the mixer of sufficient level to trigger the alarm, causing false alarms. An additional time delay circuit is introduced by the modification which inhibits the activation of the alarm until continuous movement has been detected over a period of a few seconds.

These modifications take the form of an extra circuit board to add to the microwave unit. The basic microwave alarm unit would not meet with Home Office approval if built by the hobbyist and is not the constructional element of this article. The reader should purchase the alarm from AS(H) at cost price and construct the adaptor board described here.

CIRCUIT DESCRIPTION

Mains transformer T1 and two 12-volt secondary windings: these are connected in series to provide 24V to the bridge rectifier formed by D1 to D2. The ripple is smoothed by R1, C1 and C2. The 22V Zener diode D6 protects the regulator from an excessive input voltage when there is negligible current drain on the circuit. The regulator IC1 provides a constant 12V at its output. This supplies the d.c. supply to the circuits through the ON-OFF key switch on the back of the microwave unit. It will also provide a trickle charge to the Ni-Cad stand-by batteries if fitted. These batteries are optional.

As described earlier, movement detected by the microwave circuit will switch on TR7 in this unit. TR7 collector is connected to point A on the time delay circuit. C3 will start to charge positively at a rate determined by the value of R2 and C3. When the voltage on C3 exceeds that on the slider of VR1 the output of IC3 will change from zero to about 9 volts positive switching on transistor TR1 to operate the relay or sounder.

When the output of IC2 goes positive, current through R6 holds on TR6 until condenser C11 has charged via R19 to switch on the semiconductor switch at pins 8 and 9 of IC1, re-setting the circuit to its stand-by operation.

MODIFICATION INSTRUCTIONS

Remove the back panel of the alarm unit by extracting six Philips head screws. Remove battery cover. Release the battery box by extracting the four wood screws holding it in place.

The purpose of releasing the battery box is to obtain access to the printed circuit board which may now be released from its plastic holding clips. Fit the mains connector to back panel. Before any circuit modifications are carried out it is advisable to protect the microwave gunn and mixer diodes on the microwave module. Connect a one-inch length of wire first to the earth pin on the body of the unit, then to the mixer/gunn diode pin. The earthed wire should be touching the diode connection all the time the soldering iron is applied.

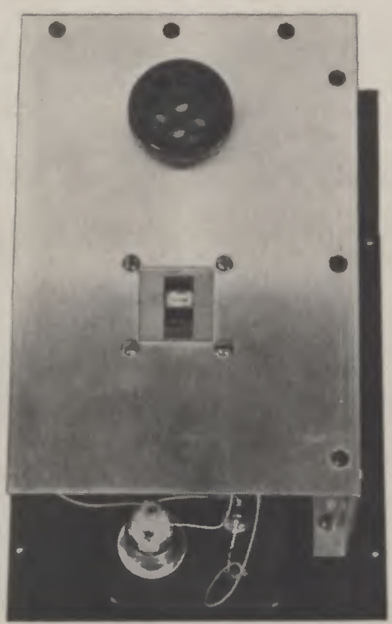
Remove the following components from the circuit board, R17, R21, R18, R25, R12, R15, R19, D14, C10, TR8 (the plastic transistor with the metal heatsink).

Disconnect the sounder wires. Replace R12 and R15 with 270kΩ resistors. Replace R18 with a 2·7kΩ resistor. Replace R19 with a 2·7MΩ resistor. Replace R25 with a 1MΩ resistor.

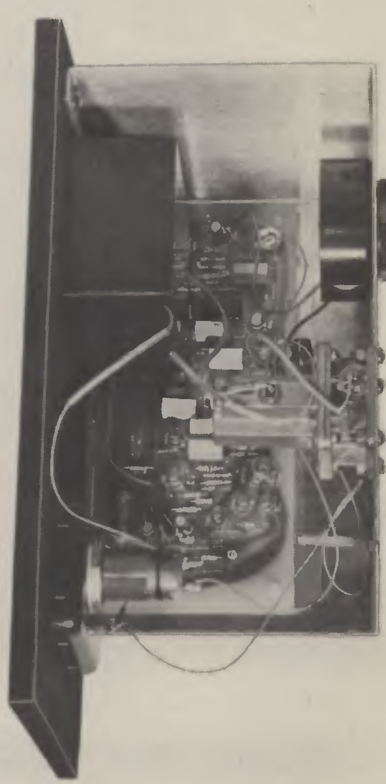
Connect a six-inch length of insulated wire to the position vacated by R17 which connects to diode D3. Connect a six-inch length of insulated wire to TP4 (just above R22).

Drill the chassis ready to accept the bracket assembly, previously made up as illustrated. Fix the made-up and tested time delay circuit board to the bracket assembly, first having connected the wire from D3 on the original p.c.b. to the land provided at (B) and the wire from the pin adjacent to R22 on the original p.c.b. to

THE BASIC INTRUDER ALARM UNIT



View, showing the gunn diode in its resonant cavity, and the audible sounder.



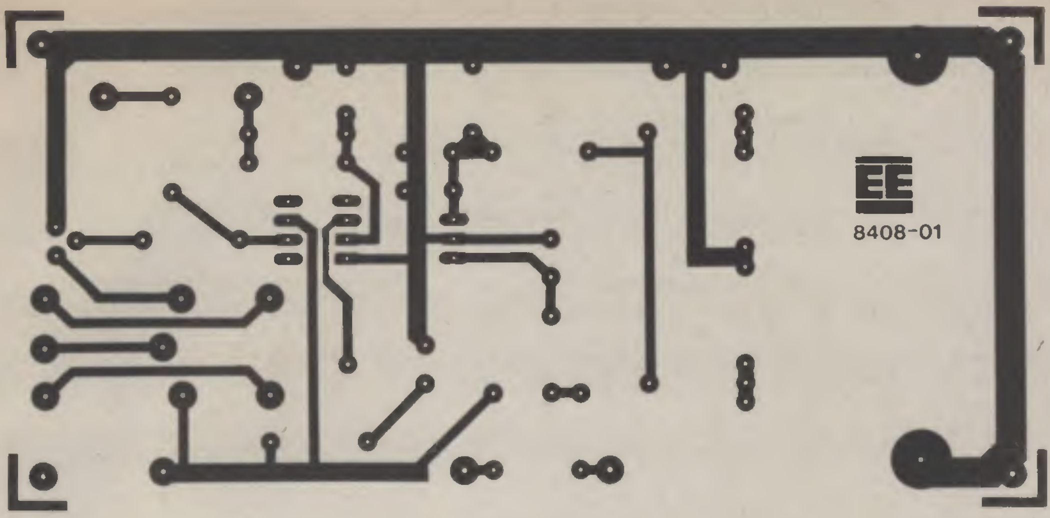


Fig. 7. P.c.b. layout of the adaptor board (actual size). This board is available from the *EE PCB service*, Order code 8408–01.

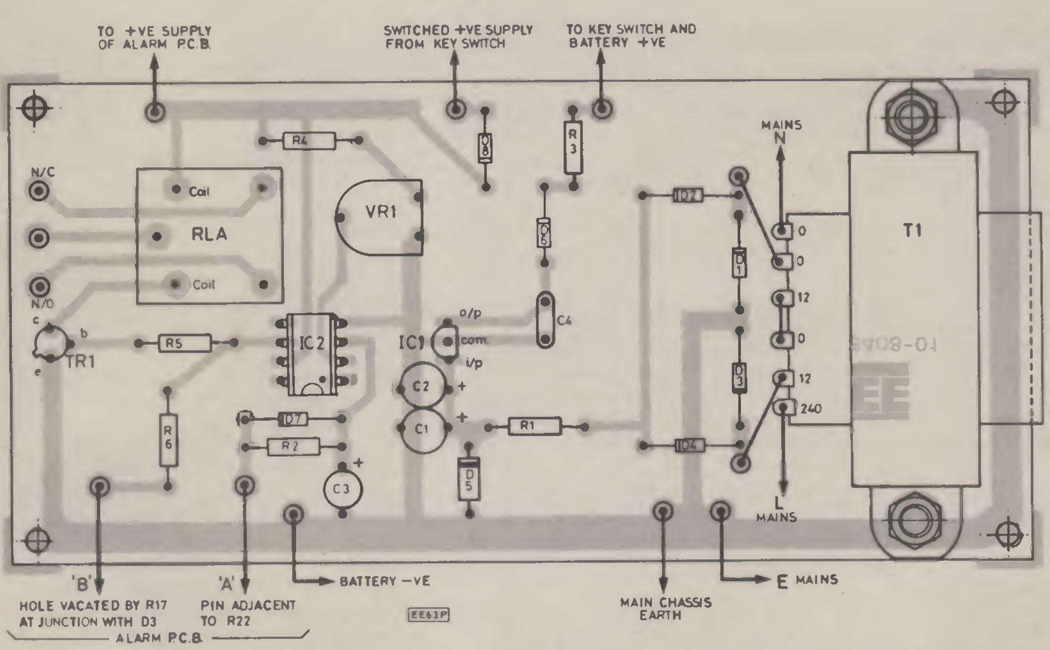


Fig. 8. Component layout of the adaptor board.

COMPONENTS

Approx. cost Guidance only **£7.00**

Resistors

R1	180Ω
R2	1MΩ
R3	33Ω
R4	27kΩ
R5	10kΩ
R6	47kΩ
R12,15	270kΩ (2 off)
R18	2·7kΩ
R19	2·7MΩ
R25	1MΩ

R12,15,18,19,25 for alarm unit p.c.b. replacement

Potentiometers

VR1	100kΩ Maplin WR61P

Capacitors

C1,2	22μ/25V tant. bead Maplin WW73Q (2 off)
C3	4·7μF 16V or 25V tant. bead

Diodes

D1–4,6,8	1N4001 (6 off)
D7	1N4148
D5	BZX61C 22V Zener

Integrated circuits

IC1	12V regulator μA 78L12AWC
IC2	CA3140E

Transistors

TR1	2N2222

See Shop Talk page 534

Miscellaneous

Batteries (optional) Ni-Cad: size AA.
Maplin YG00A (8 off).
Relay: Maplin YX96E.
Mains plug and Socket: Maplin HL15R and HL16S
Transformer: Maplin WB10L

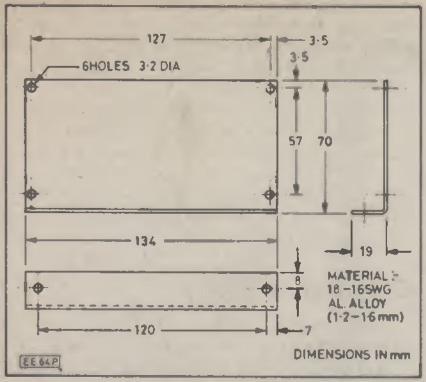


Fig. 9. Mounting bracket for the adaptor p.c.b.

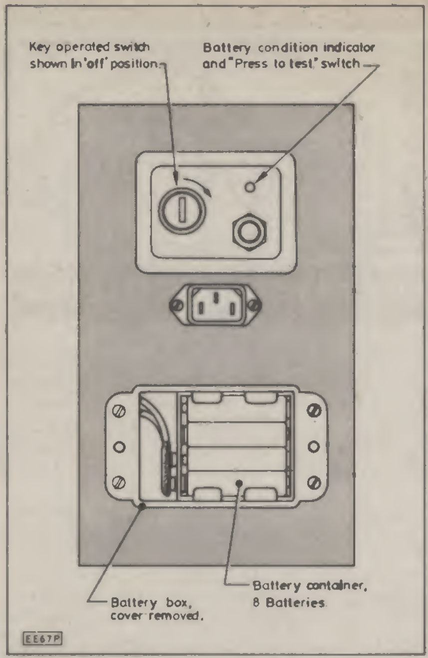


Fig. 10. Rear view of the unit, showing the added mains input socket.

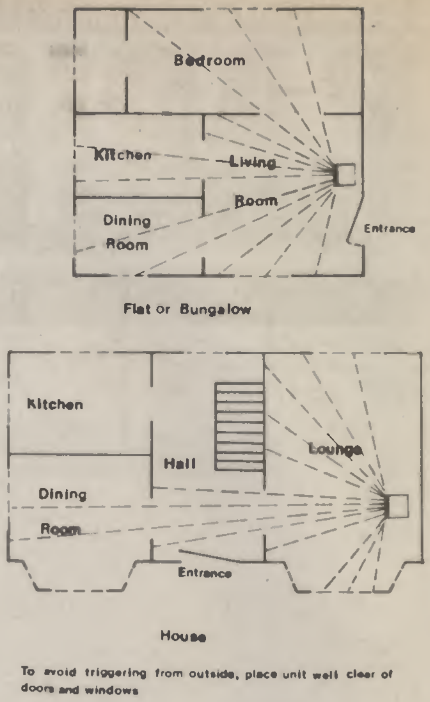


Fig. 11. Locational strategy of the unit.

the land provided at the junction of R2 and D3, point "A". Interconnect the switch and power supply wires as illustrated. Note that the switched supply must be disconnected from the alarm unit circuit board and connected to the new p.c.b. The supply line on the alarm unit p.c.b. is now connected to the +ve diode protected supply line on the new p.c.b. The battery leads may be left in their original positions.

Ensure that the p.c.b. is spaced off the bracket assembly sufficiently to avoid a short from the bracket to the track. Finally fix the bracket assembly to the chassis; check and re-assemble the alarm unit.

For mains operation fit only Ni-Cad batteries for standby operation. These will be on continuous trickle charge so long as the mains is connected.

Remove shorting links from the microwave module, disconnecting the earth pin last. Make sure the earth link is touching the diode connection until the soldering iron is removed.

TESTING

The time delay circuit should be checked independently before fitting to the main unit. Temporarily connect "A" to the zero volt line. Connect the sounder as illustrated. Connect to mains supply from the socket to the transformer input, *ensuring the mains plug is not in*!

Connect to mains supply, voltages at the positive of C1 and C2 should be about 22V d.c. The output at R3 with no batteries connected, should be 12V d.c.—and about 10 volts on the positive supply line when switched on through the key switch. VR1 should be set in the centre of its travel.

Disconnect "A" from earth and connect it to the +ve supply line. Note the time delay before the sounder is energised. Adjust VR1 to give a delay of about five seconds. Always connect "A" to earth for a short time to dump the charge on C3 before re-connecting it to the positive supply line to set the timing.

Complete the fitting of the delay p.c.b. to the chassis. Connect "A" to the pin adjacent to R22 and "B" to D3 using the copper land previously used by R17. Fit eight fully-charged Ni-Cad batteries if battery back-up for mains failure is required. The original p.c.b. was factory set and should need no further adjustment.

The system may now be checked by switching on, allowing one half to one minute for the system to settle down and then moving in the room for about five seconds. The alarm should trigger re-set after one to two minutes. The alarm delay time may be altered by adjustment of VR1, but it should be remembered that the shorter the delay time the more likely are false alarms.

RE-SETTING THE DOPPLER UNIT

As stated in the previous section, the original p.c.b. was factory set. If re-setting, either for interest or because the adjustments have been disturbed, is necessary then adopt the following procedure using an oscilloscope. If no oscilloscope is available an alternative procedure is also described using a high resistance voltmeter. Either disconnect the sounder, or temporarily connect a shorting link across C8. VR2 should be at maximum resistance (fully clockwise).

Connect the oscilloscope probe to the collector of TR1. (C1 provides an accessible point for the oscilloscope probe.) The unit should have open space in front of it for at least 5ft.

Switch on unit and allow one minute to settle. A negative-going pulse will be observed on the oscilloscope. VR3 should be set so that the pulse amplitude is 4V negative relative to the positive supply.

Connect the oscilloscope probe to R6 at output of IC2. The d.c. level on the oscilloscope should be between 6V and 8V d.c. relative to the zero (earth) line. A pulse "spike" will be visible on the oscilloscope trace. This should be less than 1V peak when there is no movement detected by the microwave module. A very slight movement will increase this pulse amplitude.

Connect the oscilloscope probe to the collector of TR4. When there is no movement no pulse should be observed. The slightest movement will create a negative pulse at this point. The sensitivity is adjusted by VR1. VR2 should always be left for maximum resistance (fully clockwise) and no adjustment is necessary. If no oscilloscope is available the pulse level can be set by connecting a high resistance voltmeter to the output of IC2 at R6. VR2 is adjusted to give a d.c. level of 6V to 7V relative to earth. Care must be taken to ensure no movement occurs during this adjustment.

The sensitivity control VR1 is turned clockwise to increase resistance and *reduce* sensitivity to the point where there are no false alarms when there is no movement within the area. □

NOTE

Although this device radiates negligible radio frequency power, in order to operate, it is necessary to possess a Telapproach System Licence as defined in the Wireless Telegraphy Act 1949.

Application forms processed at:
Home Office Accounts Branch,
Tolworth Tower,
Ewell Road,
SURBITON, Surrey KT6 7DS.

RADIO WORLD

BY PAT HAWKER G3VA

In-Car Radio

For many years it has been accepted that listening to music from a car radio or tape cassette while driving does not represent a safety hazard—indeed may soothe a driver whose temper could otherwise be frayed by delays and traffic jams. But there are still doubts about some aspects of listening to more demanding material, such as the use of stereo headphones by drivers or cyclists and the operation of two-way radio telephones.

About 1966 the Ministry of Transport even announced that it proposed to ban the use of a radio transmitter while a car was in motion. However, following strong representations from the radio communications industry and radio amateurs this idea was dropped.

Although some research into the whole question of using radios in cars was carried out in the UK in the 1960s, little effort has been made to investigate this subject in recent years. Some American States now ban the use of stereo headphones by cyclists or drivers.

In the UK it is a clear offence to drive without proper control of the vehicle or to have a television screen within view of the driver (passengers in the back can be viewers). "Proper control" has been held to make it illegal for a driver to use an electric shaver, but does not cover straightforward use of a microphone. In the States there have been a few cases of mobile transmitter power leads short-circuiting and causing fires.

An article by Lydia Taylor, "Facing the Music," in *Care on the Road* (April, 1984) the journal of the Royal Society for the Prevention of Accidents (RoSPA) shows that there is still concern on some aspects of in-car entertainment.

Dr. Ivan Brown, assistant director of the Medical Research Council's Applied Psychology Unit, is quoted as suggesting that sound inputs to a driver's brain that require "mental processing" can allegedly interfere with his visual inputs. In other words, listening to undemanding music presents no hazard but "road safety could be reduced if drivers use their in-car radio/cassette players to do their Open University homework".

There is also the feeling that the control of some equipment involves too much knob-fiddling and the need for the driver to take his eyes off the road. The use of stereo headphones or over-loud speech or music can, it is suggested, impair the driver's monitoring of useful auditory information, for example, from horns outside the vehicle or any warning signs coming from the engine.

There are EEC regulations governing equipment installed in cars intended to ensure that the driver could not be cut by any part of a radio, get his fingers entrapped, or receive an electric shock. Radio/cassette units are expected to be reasonably easy to operate and to have rounded, recessed controls.

European broadcasters are currently investigating a new "radiodata" system which, for example, would automatically tune a radio to a selected programme, etc., without the driver touching any controls, and which might be used in connection with traffic information. But such a system is, operationally, still some way away and is likely to be incorporated only in the more expensive car radios.

There would appear to be few regulations applying specifically to two-way radio, although, for example, the R.S.G.B. does have a list of safety recommendations for mobile operators. With the vast increase in two-way car radios stemming from CB and from the introduction soon of 900MHz cellular radio systems, it is surely time for more detailed research into safety aspects of in-car radio and electronics.

Private Robot, Infantryman

There are many people who regret that such a high proportion of the British and American electronics and communications effort is directed towards what is euphemistically called the Defence Industry. Military communications have advanced a long way from the old wartime sets but it often appears that no sooner has a new system been developed than the same team set about finding an effective way of jamming it, and then a method of countering the jamming, and so on *ad infinitum*.

The electronic equipment fitted in some military aircraft now costs about ten times as much as the basic aircraft; there is also a rule-of-thumb estimate that the cost of maintaining military equipment throughout its operational life can similarly cost ten times as much as the original equipment.

Currently much effort on both sides of the Atlantic is being put into what is called C^3I, tactical radio systems for communications, control, command and intelligence; also in protection of electronic and telecommunications equipment against EMP, the destructive electromagnetic pulse that can follow a high-altitude nuclear explosion; and "stealth" aircraft that would not be detectable by radar or infra-red sensors—not to mention the whole frightful concept of "star wars".

But at least the US Advanced Research Projects Agency is busy working out how to use "artificial intelligence" on the battlefield. One idea is to develop a robot machine that instead of having wheels or tracks would clomp around the battlefield on legs, remotely or self-guided by means of TV eyes and super-computers to form an autonomous land vehicle, a sort of all-electronic infantryman.

Provided they can be fought out entirely by such robots, preferably in the middle of some remote desert, this sounds a sensible way of fighting wars; an activity from which most humans will be only too glad to opt out!

Consumer Risks

The news that RCA is ending manufacture and marketing of their CED video disc players after losing an admitted $500-million (and probably a good deal more if all development costs were included) underlines the risks involved even for major firms in attempting to introduce new technology to the consumer-electronics market. Yet, if the video disc, with its very high technical quality and the lower-cost of discs than tape, had been marketed a few years *before*, instead of after the rival VCR machines, the story might have been very different.

Tape is more expensive, technical quality of the pictures significantly lower, but the VCR has the attractive feature of "record" as well as "playback". That advantage appears to have been decisive in market appeal.

Meanwhile, the City is pondering the financial risks in cable TV, direct broadcasting from satellites, home video networks and the like. It is interesting to note that during 1983 deliveries in the UK of television sets (about 1-million monochrome, 3·5-million colour) was an industry record. The two-set home is becoming the norm and, with home computers and so on, the three-set home is no longer a rarity. But the VCR boom is slowing down with 2·2-million machines delivered in 1983—almost exactly the same figure as for 1982.

30-line Museum Piece

Plessey Radar are to be congratulated on restoring one of the extremely rare 30-line disc £18 Televisors made by Plessey for the original Baird company between 1929 and 1932. This has now been loaned to Douglas Byrne, G3KPO, for his Arreton Wireless Museum on the Isle of Wight. It is believed that this is one of only six still in existence.

But what puzzles me is the fanatic determination of some academics and others to perpetuate the idea that the Baird 30-line system, forced on the BBC by the Post Office and the politicians, ever had any real chance of success.

Apart from the extremely crude pictures, the system had no effective method of providing synchronisation. The disc televisors used a phonic wheel that was expected to lock on to the black edge of the picture, since there were no "blacker-than-black" synchronising signals in the transmitted waveform sent out on the medium-wave band. Effective television had to wait for the coming of v.h.f. and synchronising pulses.

I shall not be popular in Scotland for saying so, but it is stretching credibility to the limit to pretend that Baird was the sole inventor of television! Campbell-Swinton, Zworykin, Blumlein and others deserve an equal share of the credit!

OSCILLATORS

A variety of different types of resistance capacitance feedback oscillators, all having wide use, are described in this short series. Some of the circuits are based on discrete semiconductors, others on familiar i.c.s. In addition to theory of operation, design pointers for particular needs and applications are given. Each part in the series also includes a detailed circuit for a practical project.

Part Three: DIGITAL CMOS DEVICES

By J. R. DAVIES

ALTHOUGH not primarily designed for use as oscillators, digital CMOS inverters, NAND gates and NOR gates can be readily employed in simple RC oscillator circuits. These are dealt with in this chapter. One digital CMOS device, the 4047 monostable/astable multivibrator, is specifically intended to function as an oscillator in its own right and will also be described.

Digital CMOS NAND gates with Schmitt trigger inputs can also be employed as RC oscillators, and this application will be covered in the next part of this series, which describes hysteresis oscillators.

CMOS CIRCUITRY

A basic understanding of the internal functioning of CMOS inverters, NAND gates and NOR gates is desirable before carrying on to their use as oscillators. Fig. 3.1 shows a CMOS inverter comprising a *p*-channel f.e.t. and an *n*-channel f.e.t. When the input voltage on the gate of the *p*-channel f.e.t. is high, that is, at or near the positive rail, this f.e.t. is turned off. If the *p*-channel gate is taken negative of the positive rail, a gate voltage is reached at which the f.e.t. commences to turn on. The *p*-channel f.e.t. is fully turned on when its gate voltage is low, at or near the negative rail.

The *n*-channel f.e.t. has a similar performance with all polarities reversed, and it is turned off when its gate voltage is low. Taking its gate positive causes the *n*-channel f.e.t. to turn on after a certain voltage is reached, and it is turned fully on when its gate voltage is high.

The device functions as an inverter because when the input is high the *p*-channel f.e.t. is turned off and the *n*-channel f.e.t. is turned on, giving a low voltage at the output; and because when the input is low the *n*-channel f.e.t. is turned off and the *p*-channel is turned on, with a high voltage being given at the output. The gate drive current required at the input is negligibly low, being in the order of pA (picoamps, or millionths of microamps) only.

The solid line curve of Fig. 3.2(a) shows a typical input voltage/output voltage transfer characteristic for a CMOS inverter. The supply voltage is 9 volts. When the input gate voltage is low, at zero, the output voltage is high, at 9 volts. Both voltages are with respect to the negative rail.

As the input voltage is taken positive, up to about 2 volts, the output voltage stays high, but after this it commences to go low. The rate of change is small at first, increases to a high rate of change at an input voltage of around 4·6 volts, and then slows again until, at an input voltage of around 7·3 volts, the output is fully low. It stays low as the input voltage continues up to 9 volts.

The two broken line curves in Fig. 3.2(a) show outside limits for the transfer characteristic. The CMOS inverter meets specification if its transfer characteristic is within the two outside limits. As may be seen, a fairly wide spread is permissible but the output is always fully high for input voltages below about 1 volt, and is always fully low for input voltages above about 8 volts.

A typical curve illustrating inverter supply current drawn from the supply for different input voltages is shown in Fig. 3.2(b). At input voltages nearly up to the point at which the typical transfer characteristic of Fig. 3.2(a) starts to go negative,

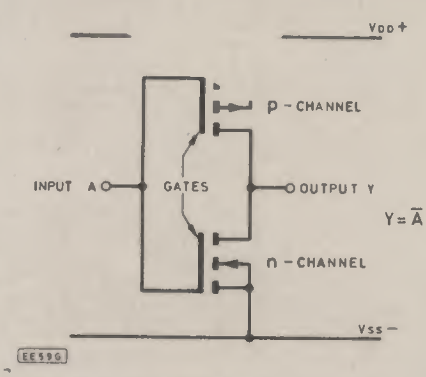


Fig. 3.1. A CMOS inverter. The output is low when the input is high and vice-versa.

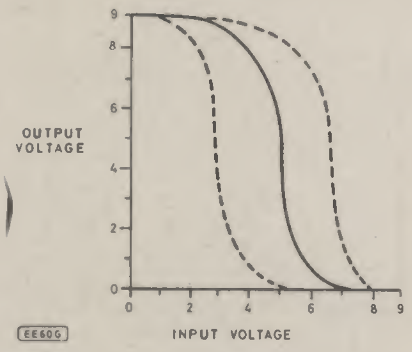


Fig. 3.2(a). The solid line illustrates a typical transfer characteristic for a CMOS inverter with a 9-volt supply. The two broken lines indicate permissible characteristic limits.

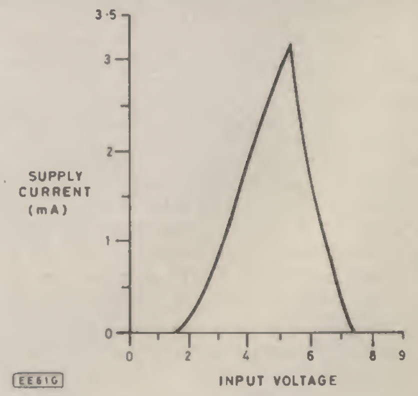


Fig. 3.2(b). Supply current consumption corresponding to the typical transfer characteristic of Fig. 3.2(a).

the current drawn from the supply is too small to be shown on the graph, and can be expected to be of the order of 0·01μA.

As the input voltage increases, causing the transfer characteristic to enter its curved section, supply current increases because both the *p*-channel f.e.t. and the *n*-channel f.e.t. are now turned on. Supply current increases to a maximum of around 3mA near the input voltage point where the transfer characteristic has maximum slope, then falls off to the negligibly low value in the order of 0·01μA for input voltages above some 7·5 volts.

Thus, the supply current drawn by the CMOS inverter can, for nearly all practical purposes, be considered as being negligibly low under quiescent conditions, and it rises to a peak of around 3mA during the transition from one state to the other.

The curves of Fig. 3.2(a) and 3.2(b) are applicable to a supply voltage of 9 volts. They can be scaled up or down, roughly proportionally, for higher or lower supply voltages.

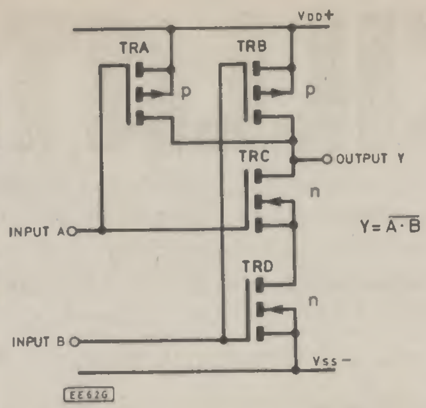
NAND, NOR GATES

Circuit Fig. 3.3 shows a CMOS 2-input NAND gate with its four f.e.t.s identified as TRA to TRD. When both inputs are low, TRA and TRB are turned on, and TRC and TRD are turned off. The output is high. If input A is high and input B is low, TRA is off, TRB is on and TRD is off. TRC cannot turn on because no current is available for it through TRD, and the output is high. Taking input B high with input A low results in TRA being on and TRC being off, so that the output is once more high. The output goes low when both inputs are high because TRA and TRB are then turned off and TRC and TRD are both turned on.

A 2-input NOR gate is shown in Fig. 3.4, and this is virtually the NAND gate turned upside down. When the two inputs are low both the *p*-channel f.e.t.s are turned on and the output is high. If either one or both of the inputs is taken high, either one or both of the *n*-channel f.e.t.s turns on and the output goes low.

A 2-input NAND gate can be used as an inverter by connecting together its two inputs to form a single input. Similarly, a 2-input NOR gate becomes an inverter if its two inputs are connected together. Both configurations are shown in Fig. 3.5. When so connected, the NAND gate and NOR gate exhibit the same transfer characteristic and supply current curves as does the simple inverter.

Inverters are available in a number of CMOS devices, including the 14-pin dual-in-line 4007, whose internal circuitry is illustrated in Fig. 3.6(a). This i.c. has one true inverter with an input at pin 10 and an output at pin 12 and two complementary pairs, and all three sections may be interconnected to produce a number of different logic functions. If the 4007 is connected up as in Fig. 3.6(b) it provides three separate inverters.



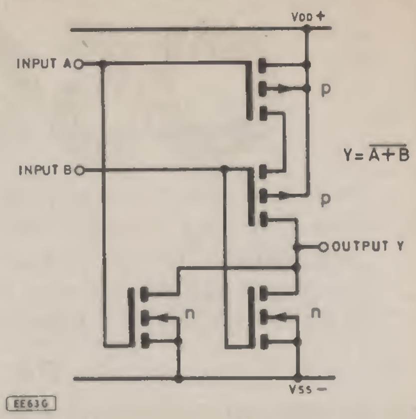


Fig. 3.3 (above left). A CMOS 2-input NAND gate. The output goes low only when both inputs are high.

Fig. 3.4 (above). A 2-input NOR gate. The output is low when either one or both inputs are high.

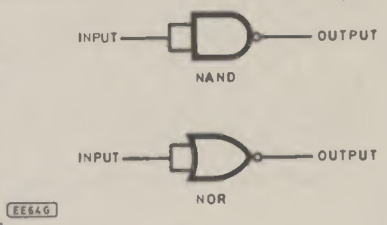


Fig. 3.5 (left). Connecting together the inputs of a NAND gate, or a NOR gate, causes the gate to function as an inverter.

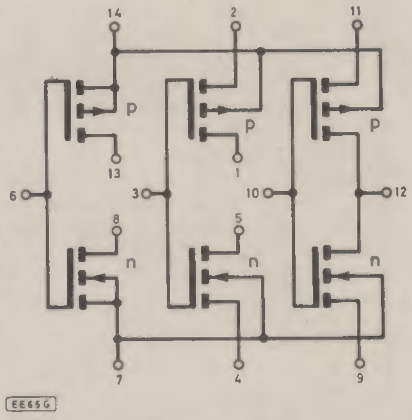


Fig. 3.6(a). The internal circuitry of the 4007.

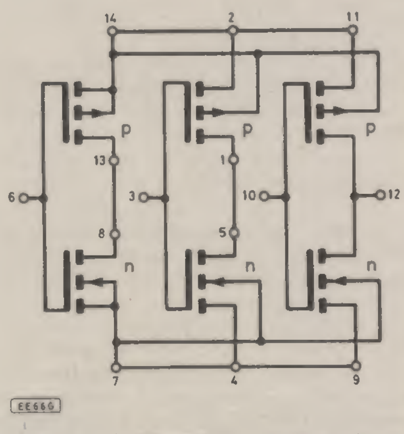


Fig. 3.6(b). The 4007 provides three inverters if its pins are connected as shown here.

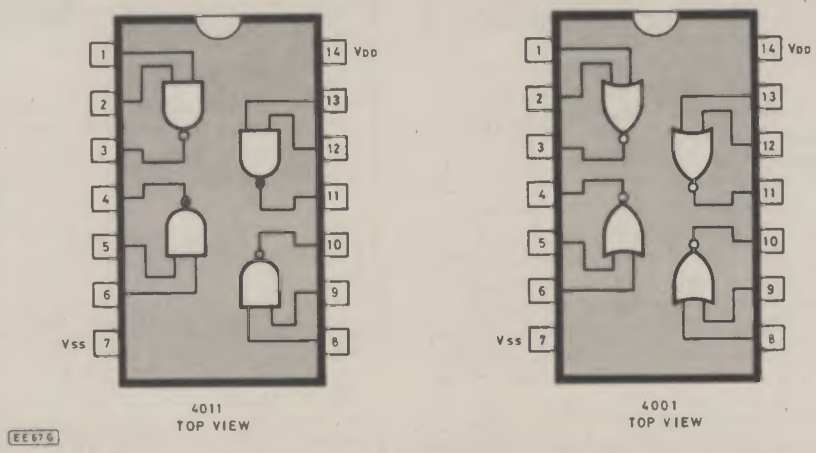


Fig. 3.7. The pin-outs of the 4011 quad NAND gate and the 4001 quad NOR gate.

It has become common practice to use NAND and NOR gates as inverters because these gates are cheap and readily available. Also, if two gates of a quad gate i.c. are connected as inverters and employed in a CMOS oscillator, the two remaining gates can be used for logic circuitry. Two very popular gates for oscillator applications are the quad 2-input NAND gate type 4011 and the quad 2-input NOR gate type 4001. These have the pin-outs shown in Fig. 3.7.

CMOS HANDLING

The current range of digital CMOS devices with the letter "B" immediately following the type number is suitable for supply voltages from 3 to 18 volts with an absolute maximum of 20 volts. (Earlier devices with the letter "A" immediately following the type number had supply ratings of 3 to 12 volts with an absolute maximum of 15 volts.)

The gate insulation in each gate is very thin and can readily breakdown at quite low voltages outside the positive and negative supply rails. The gates are, in consequence, protected by internal diode circuits of the type illustrated in Fig. 3.8. The diodes prevent any gate being taken more than about 0·6 volt higher than the positive rail or more than about 0·6 volt negative of the negative rail.

The diodes do not give full protection against high static voltages, and CMOS devices need to be handled with some care. They should be kept in their conductive packing until required and should be soldered into circuit with an iron having a reliably grounded (earthed) bit.

As we shall next see, the protective diodes play a part in the operation of simple CMOS oscillators.

CMOS OSCILLATOR

What is probably the most commonly encountered digital CMOS oscillator is shown in Fig. 3.9(a). This is illustrated with two NAND gates, and the same results would be given with two NOR gates or two inverters.

At one instant in the oscillator cycle we have the voltage conditions shown in Fig. 3.9(a). The input of gate G1 is low, the output of G1 is high and the output of G2 is low. Capacitor C is therefore charging via R2 with its left-hand plate going positive. Virtually zero current flows through R1 into the input of G1, but this input is still being taken continually positive by left-hand plate of C.

After a time the input of gate G1 goes sufficiently positive for the gate transfer characteristic (see Fig. 3.2(a)) to enter its curved section and the gate output starts to go negative, taking the input of gate G2 similarly negative. After a further period the input of gate G2 also enters the curved section of its transfer characteristic, whereupon there is a chain of linear amplification from the input of gate G1 to the output of gate G2. The circuit then very rapidly changes to its alternate state, with G1 input high, G1 output low and G2 output high. This is shown in Fig. 3.9(b).

Now, at the instant before this rapid changeover capacitor C was charged, with its left-hand plate positive. Immediately after the changeover, which caused G2 output to go high, the left-hand plate of C is actually taken positive of the positive supply rail for the gates, so that at the start of the half-cycle C is discharging via R1 into the protective diodes at G1 input, as well as into the low G1 output via R2. The discharge current into the diodes continues for a small fraction of the half-cycle until the voltage on the left-hand plate of C falls below that at which the protective diodes conduct. The only current from the capacitor which then flows is through R2 into the low output of gate G1.

Capacitor C1 is now charging in the opposite direction and its left-hand plate is going negative whereupon, after a period, the input of G1 reaches the curved section of its transfer characteristic and, later, so does the input of gate G2. Again there is a chain of linear amplification through the two gates, and it causes a rapid transition to the first state, with G1 input low, G1 output high and G2 output low.

This time the left-hand plate of C goes negative of the negative supply rail, and current from the capacitor initially flows via R1 into the protective diodes at G1 input. Shortly after, the only capacitor current which flows is via R2 into G1 output and the circuit is in the same state as it was when we started to examine it.

OSCILLATOR FREQUENCY

The best place in the oscillator circuit to take an output is from the output of gate G2. If both gates have a transfer characteristic in the centre of the permissible spread this output is a square-wave whose voltage swings between the positive and negative supply rails. In practice, different transfer characteristics can cause the duty ratio to lie between some 30 per cent and 70 per cent.

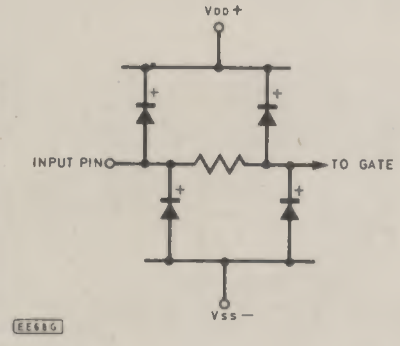


Fig. 3.8. Protection circuit for a CMOS input.

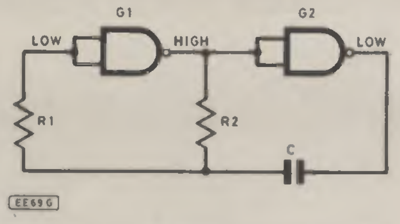


Fig. 3.9(a). Two NAND gates connected as a CMOS RC oscillator. At one instant in the oscillator cycle the gate inputs and outputs will have the voltages indicated.

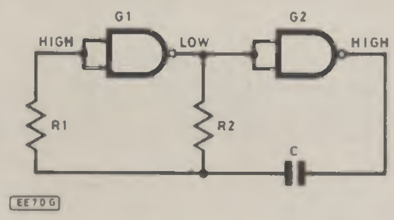


Fig. 3.9(b). The input and output voltages change on the alternate half-cycle.

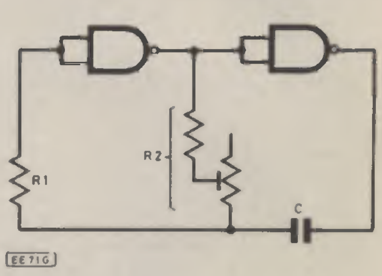


Fig. 3.10. Making R2 partly adjustable to provide a specific oscillator frequency.

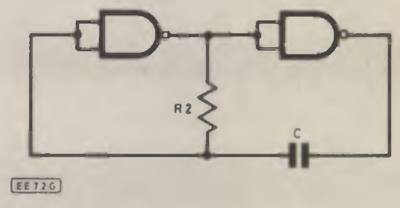
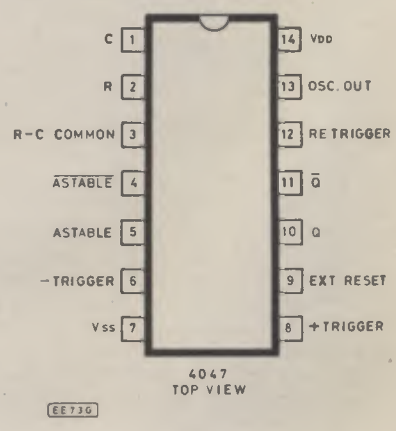


Fig. 3.11. Frequently, the oscillator is employed with R1 omitted.



The transfer characteristic spread also makes it impossible to calculate oscillator frequency precisely, although it is nevertheless a simple matter to arrive at rough approximations.

During the initial part of each half-cycle current from C flows into the protective diodes at the input of G1 whilst, over the whole half-cycle, the capacitor current flows through R2 into the output of gate G1. If R1 is given a value which is equal to, or greater than, R2 it has only a small effect on oscillator frequency, whereupon the major control is exerted by C and R2 only. It is found in practice that the length of each half-cycle is then very approximately equal to the time constant of C and R2.

If, for instance, C is 0·01μF and R2 is 100kΩ (= 0·1MΩ), with R1 having the same or a greater value, the length of each half-cycle calculates as 0·01 × 0·1, or 0·001 second. The length of the total cycle is 0·002 second, the reciprocal of which gives a frequency of 500Hz. So, if we make C 0·01μF and R2 100kΩ, we can expect the oscillator to operate at around 500Hz.

ADJUSTABLE RESISTANCE

Normally, digital CMOS oscillators of the type described here are not required to have accurately determined frequencies, and variation in frequency from one device to the next is quite acceptable. If a fairly precise oscillator frequency is required, R2 can be made largely variable, as in Fig. 3.10, and its resistance can then be adjusted until the desired frequency is obtained. R2 now consists of a fixed and variable resistor in series.

Should the calculated value for R2 at a required frequency be say 200kΩ, the fixed resistor could be 100kΩ and the variable resistor 220kΩ. It should then be possible to arrive at the required frequency by adjusting the variable resistor.

The oscillator circuit is often used with R1 omitted, as in Fig. 3.11. In many cases this tends to significantly increase the frequency because at the start of each half-cycle C rapidly discharges into the protective diodes at G1 input. The circuit of Fig. 3.11 saves a resistor and has the slight disadvantage that the frequency of oscillation may be further removed from the approximate value given by calculating the time constant of C and R2.

Suitable practical values for R2 are between some 2kΩ and 1MΩ, whilst those for C lie between about 0·001μF and 0·5μF. These figures point to maximum and minimum frequencies of about 250kHz and 1Hz, respectively, although oscillator performances may be a little unpredictable at these extremes.

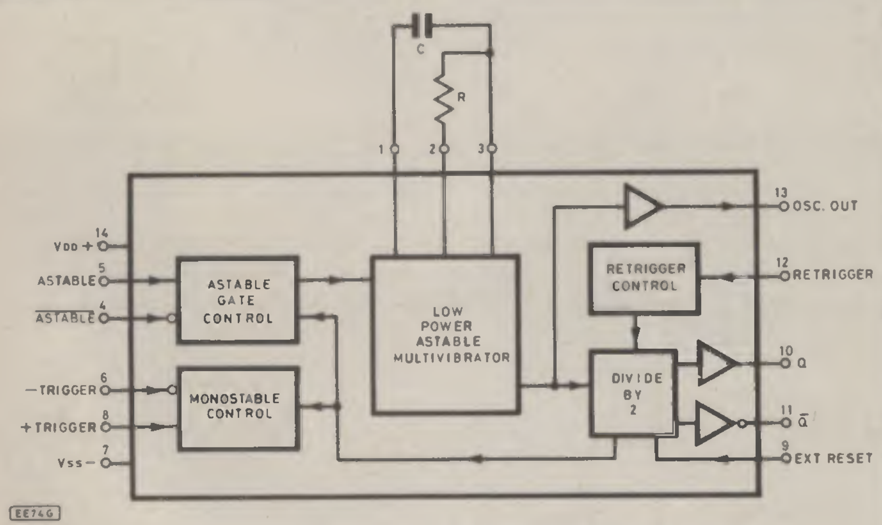


Fig. 3.13 (above). Block diagram illustrating 4047 internal logic circuitry.

Fig. 3.12 (left). The pin allocations of the 4047 monostable/astable multivibrator.

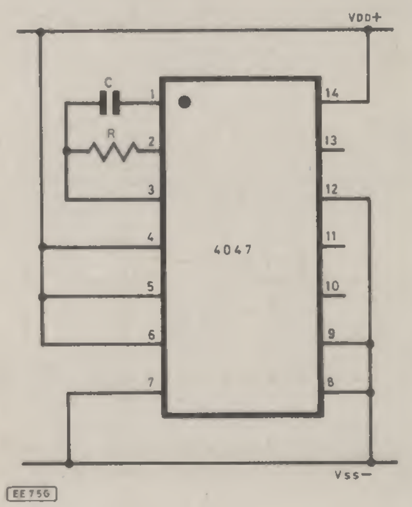


Fig. 3.14 (right). The 4047 connected for continuous astable operation. Outputs are available at pin 13 (oscillator frequency) and at pins 10 and 11 (half oscillator frequency).

CURRENTS

The supply current drawn by the oscillator is relatively high for a circuit incorporating CMOS devices, and at 9 volts can be of the order of 0·3 to 0·7mA, or even higher. The high current is partly explained by the fact that gate G1 is on the curved part of its transfer characteristic for a significant part of each half-cycle. Also, the two gates pass through their current consumption peak twice during each cycle.

The output current capability of the oscillator, when using 4001, 4007, 4011 and similar devices with a 9-volt supply, is in excess of 2mA both when the output is in the high and in the low condition.

THE 4047

The 4047 is a digital CMOS device which is specifically intended to operate as an astable (free-running) or monostable ("one-shot") multivibrator. It tends to be a little more expensive than the two inverters, NAND gates or NOR gates employed in the previous oscillator circuit, but it offers three advantages.

The first of these is that oscillator frequency is defined by manufacturer's specification and can be readily calculated. The second advantage is that the 4047 offers a true 50:50 squarewave output. The third advantage is that, with a suitable choice of external frequency control components, it is capable of running at very low supply current levels.

The i.c. is housed in a 14-pin dual-in-line package having the pin allocations shown in Fig. 3.12. A block diagram illustrating its logic functions is given in Fig. 3.13. The i.c. contains a low power astable multivibrator whose output, after passing through a buffer amplifier, appears at pin 13. The oscillator frequency is controlled by the external capacitor and resistor connecting to pins 1, 2 and 3. The oscillator output also passes to a divide-by-2 circuit which presents a Q output at pin 10 and a not-Q output (bar over the letter signifies "not") at pin 11.

In this series we are interested in the astable operation of the 4047 and the trigger, retrigger and external reset pins are not involved in this function. These pins are returned to the positive or negative rails as indicated in Fig. 3.14, which shows the circuit required for continuous astable running.

Table 3.1: 4047 FREQUENCIES

	0·001µF	0·0033µF	0·01µF	0·033µF	0·1µF	0·33µF	1µF	3·3µF
10kΩ	22·7kHz	6·89kHz	2·27kHz	689Hz	227Hz	68·9Hz	22·7Hz	6·89Hz
27kΩ	8·42kHz	2·55kHz	842Hz	255Hz	84·2Hz	25·5Hz	8·42Hz	2·55Hz
68kΩ	3·34kHz	1·01kHz	334Hz	101Hz	33·4Hz	10·1Hz	3·34Hz	1·01Hz
100kΩ	2·27kHz	689Hz	227Hz	68·9Hz	22·7Hz	6·89Hz	2·27Hz	0·689Hz
270kΩ	842Hz	255Hz	84·2Hz	25·5Hz	8·42Hz	2·55Hz	0·842Hz	0·255Hz
680kΩ	334Hz	101Hz	33·4Hz	10·1Hz	3·34Hz	1·01Hz	0·334Hz	0·101Hz
1MΩ	227Hz	68·9Hz	22·7Hz	6·89Hz	2·27Hz	0·689Hz	0·227Hz	0·0689Hz

An output at oscillator frequency is given at pin 13, and outputs at half oscillator frequency at pins 10 and 11. The output at pin 11 is always opposite in phase to that at pin 10.

The oscillator can be gated by applying control voltages to the astable and not-astable input pins. For astable gating, pin 5 is disconnected from the positive rail and has applied to it an input pulse which swings between the two supply rails, as in Fig. 3.15(a). There are no changes at the other pin connections.

Oscillation is inhibited with pin 5 low, and starts when pin 5 is taken high. When pin 5 is taken low again the oscillation continues until both pin 13 and pin 10 are low, and then stops.

For not-astable gating, pin 5 is taken to the negative rail and the input pulse is applied to pin 4, which is now disconnected from the positive rail, as shown in Fig. 3.15(b). Again, no changes are made at the pins not shown. The oscillator does not run when pin 4 is high and starts when pin 4 is taken low. When pin 4 is taken high again, the oscillation carries on until both pins 13 and 10 are low, and then stops.

WAVEFORMS AND FREQUENCY

The oscillator output at pin 13 is the upper waveform shown in Fig. 3.16. Its duty ratio depends mainly on the transfer characteristic of the internal f.e.t. immediately following pin 3, and is not a guaranteed squarewave. The total time for one cycle is shown as Tosc. Immediately below the oscillator waveform is the divided-by-2 waveform available at pin 10. This waveform changes state on alternate positive-going pulse edges in the oscillator waveform and is, in consequence, a true 50:50 squarewave. The total time of one cycle at pin 10 is designated in the diagram as T_Q.

When the f.e.t. following pin 3 has a transfer characteristic in the centre of its permitted spread, the cycle time is given by

$$T_Q = 4{\cdot}40RC$$

where T_Q is in seconds, and R and C (the external frequency control components) are in megohms and microfarads. If the transfer characteristic goes to its extreme in either direction (to left or right in Fig. 3.2(a)) the cycle time is given by

$$T_Q = 4{\cdot}62RC$$

This time is precisely 5 per cent higher than that given with the transfer characteristic at the centre of its spread.

To calculate cycle time, the approach is to work to the 4·40RC figure (which corresponds to f.e.t.s in the centre of the transfer characteristic spread), accepting that the actual time given will have a tolerance of +5 per cent and −0 per cent.

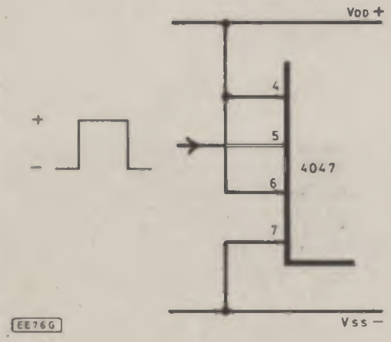
Frequency is the reciprocal of cycle time, so that

$$f = \frac{0{\cdot}227}{RC}$$

where f is in hertz. This is the frequency available at the pin 10 and pin 11 outputs; the pin 13 frequency has twice this value. To take an example, the calculated frequency given by frequency control components of 270kΩ and 0·1µF would be equal to the reciprocal of 4·40 × 0·27 × 0·1, or 8·42Hz to three significant figures. Table 3.1 gives calculated frequencies for different values of R and C.

The recommended range of values for R is 10kΩ to 1MΩ. The value of C should be 100pF or more, with no limit on maximum value. The capacitor must be a non-electrolytic component, and the oscillator works reliably with high values. If, for instance, R in Fig. 3.14 is 1MΩ and C is 10µF, the total cycle length at the pin 10 or pin 11 output calculates as 44 seconds, and this cycle length, within the +5 per cent tolerance, is given in practice.

The current drawn by the 4047 running as an astable multivibrator is largely dependent upon the value of the frequency control resistor, and can be made much smaller than the current consump-



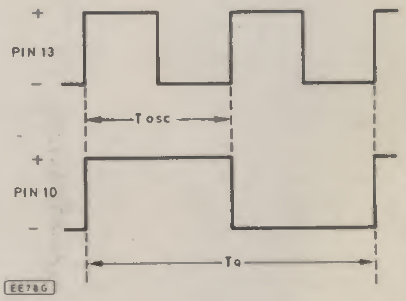


Fig. 3.15(a) (above left). The connections required at pins 4, 5 and 6 for astable gating. The oscillator runs when the input pulse is high.

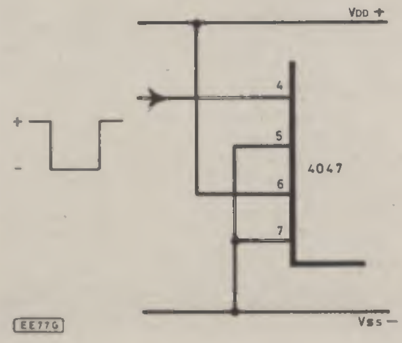


Fig. 3.15(b) (left). With pins 4, 5 and 6 connected as shown here, the oscillator runs when pin 4 is low.

Fig. 3.16 (above). Output waveforms at pin 13 and pin 10. The pin 10 output is a true square wave.

tion of the 2-inverter CMOS oscillator. With R at 1MΩ, a typical current consumption is of the order of 20µA. This increases to around 40µA when R is 100kΩ, and to some 700µA when R is 10kΩ.

All these current figures apply to a supply of 9 volts and a value in C of 0·001µF or more. If low current consumption is important, it is obviously desirable to give R a high value. With a 9-volt supply the output current capability at any of the three output pins is in excess of 2mA for both the high and low conditions.

Like all CMOS devices, the 4047 needs to be handled carefully in order that high static voltages are not applied to any of the pins. However, extra care is needed with the 4047 at its pin 3. To permit larger input voltage swings, this pin has a modified diode protection circuit and is more sensitive to high static voltages than are the other input pins.

STORE SENTINEL

A practical project to protect valuables on display in stores or your home

A very useful practical project incorporating a 4047 and a 4011 has the circuit shown in Fig. 3.17. This is a security unit which protects items on display in a store and it employs the familiar approach of threading a guard wire through the handles or other apertures in the goods. If the guard wire is cut or interrupted an alarm sounds.

DESIGN PRINCIPLES

It is necessary for a unit of this nature to be battery driven in order that it remains operational during power cuts and other cessations in the electricity supply. In the interests of economy it then becomes desirable to design the unit so that it has a very low standing current consumption, say less than half a milliamp. Such a supply current would enable standard dry batteries to be used and these would have a very long life.

Conflicting with the low supply current requirement is the fact that, for robust working, the current flowing in the guard wire should be in the order of several milliamps so that false alarms are not caused due to current leakage between conductors and similar factors.

CIRCUIT DESCRIPTION

These two requirements are reconciled in the circuit of Fig. 3.17 by having a 4047 produce a squarewave which is fed through the guard wire. The current consumption of the 4047 is much less than half a milliamp, but its output current capability is in excess of several milliamps. If the insulation in the guard wire system is good the 4047 supply current will be low. Should the insulation deteriorate for any reason the 4047 will still supply the squarewave, even at leakage currents up to several milliamps, and security will be maintained.

There will, however, be a corresponding increase in battery current. The overall result is that battery current consumption will normally remain low if reasonable care and maintenance is provided, and that the unit will continue to function, with increased battery current, if the guard wire insulation becomes poor.

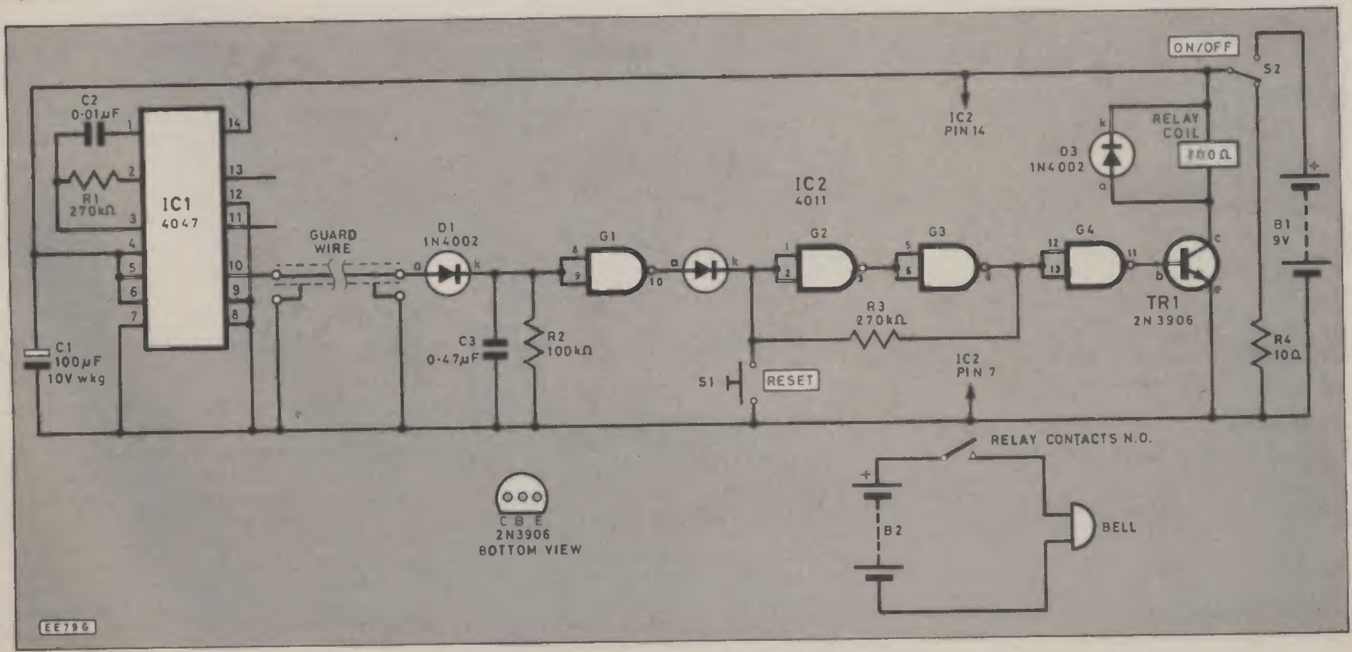
The 4047 produces a squarewave having a frequency of about 84Hz at its pin 10, and this is fed into the guard wire. The wire consists of flexible audio screened cable which leaves the housing in which the unit is assembled, passes through the goods being protected, then returns to the housing to connect to diode D1. This diode rectifies the squarewave and causes C3 to charge.

The time constant of C3 and the parallel resistor R2 is 0·047 second, and the voltage across these two components is about 0·5 volt lower than the peak-to-peak amplitude of the squarewave. If the guard wire is cut, or if its inner and outer conductors are short-circuited, the voltage across C3 rapidly falls to zero. An output short-circuit does not damage the 4047.

LOGIC

The simple logic in the circuit is provided by the four NAND gates of a 4011, all of which are connected as inverters. The first gate, G1, couples to C3 and R2. The voltage at the gate input is nor-

Fig. 3.17. Protection circuit for displayed items in a store. The bell sounds continuously if the guard wire is momentarily opened or short-circuited.



mally high and its output is low. If the guard wire is cut or short-circuited, the gate input goes low and its output goes high.

Gates G2 and G3 form a latch, with the input of G2 and the output of G3 being normally low. The latch maintains this state due to the coupling, through R3, from G3 output back to G2 input. The latch output couples to G4, whose output is normally high. This output connects to the base of the emitter follower, TR1, whereupon no current flows through the relay coil in its emitter circuit.

When the guard wire is cut or short-circuited, G1 output goes high, taking G2 input high via diode D2. The latch now takes up its alternate state with input and output both high, and remains locked in this condition even if G1 output goes low again because D2 is then reverse biased. Thus, it takes only a momentary break or short-circuit in the guard wire to change the latch to its alternate condition, which it then maintains.

When the latch output goes high, the output of gate G4 goes low and TR1 causes the relay to energise. The normally open relay contacts complete the circuit to the alarm bell (or other warning device) and this rings continually until either the unit is switched off or the Reset button is pressed. A separate battery, B2, is used for the bell to keep bell transients away from the electronics.

The high value capacitor, C1, ensures that the initial relay energising current does not affect CMOS operation if B1 should happen to have a high internal resistance. When the on-off switch is turned off, C1 rapidly discharges through current limiting resistor R4. This discharge of C1 is necessary because the voltage across it, due to the low running current of the unit, would otherwise fall slowly, and the CMOS circuitry would remain active for a significant period after it was supposedly turned off.

SETTING-UP

At switch-on it is possible for the CMOS latch to take up the state in which its input and output are high, and the latch can then be brought to its normal state by momentarily pressing the Reset button. If desired, the button can be pressed at the same time as the unit is switched on at S2. There are other means of ensuring that the latch takes up its normal state at switch-on, but the use of a Reset button is the simplest and most reliable since it offers direct control into the circuit.

The relay can be any type having a coil resistance of about 200Ω or more and which reliably energises at less than 9 volts. The three diodes are shown as 1N4002, but they are not critical and any other small silicon diode could be used instead.

HOUSING

Apart from the bell, the whole unit can be housed in a small plastic or metal case. The two ends of the guard wire can connect into the main circuit by way of jack plugs and sockets, phono plugs and sockets, or by any other convenient coaxial plugs and sockets. Coaxial line plugs and sockets can be inserted along the length of the guard wire to ease installation and to allow the insertion of extra lengths of screened wire in the loop.

In the quiescent condition, and assuming no leakage in the guard wire system, the total current drawn from battery B1 is approximately 100μA plus the leakage current in C1. About 60μA of this current is charging current for C3. The electrolytic leakage current in C1 can be expected to be of the order of 10μA. When the guard wire is cut or short-circuited, the main current drawn from B1 is that which flows in the coil of the relay.

Part Four of this series will discuss hysteresis oscillators.

COUNTER INTELLIGENCE

BY PAUL YOUNG

Intelligent Computers

With the modern computer trying to emulate the human brain, a question many of us ask ourselves, is it conceivable that it will ultimately surpass the human brain in matters of intelligence and reasoning?

I was reminded again of this conundrum, by the appearance of a book entitled, "The Fifth Generation," by E. A. Feigenbaum and Pamela McCorduck. Subtitled, "Artificial Intelligence and Japan's Computer Challenge to the World", the authors consider the possibility of reasoning computers. Could Arthur C. Clarke's villainous HAL one day become a reality?

It is not easy to come up with a satisfactory answer. The computer is already able to deal with mathematical problems in seconds, that would take the average mathematician weeks to solve. It can play chess up to the standard of a Grand Master. It can diagnose illness with a higher rate of success than most GPs so one can be forgiven for deciding yes, it will happen.

First we must decide on two points: Will the computer ever be able to give out more than has been put into it? Will it ever be possible to program it with heuristic knowledge?

On a more mundane level, I can think of many reasons why they won't replace us. Taking your average *Homo Sapien*, he has a wage packet (at least the lucky ones do) he (or she) is competitive and wants to keep up with the Jones's. Can you ever imagine the Apricots being worried about not keeping up with the Apples?

Consider the Arts, a computer could compose music at the present moment, but it would only be fit for other computers to listen to. I once read that some genius had worked out that if a group of monkeys were left to scribble for a million years they would write all the Beethoven Symphonies.

By the same token a computer could write them. It seems to me that the fallacy here is, that, the group of monkeys could scribble away for a million years and still not write them.

As for painting, I'm sure any computer worth its software could produce works superior to much that appears at the Royal Academy Summer Exhibition. I don't think writing novels would present much difficulty either, but poetry—could it produce lines like:

> *"Kissing with golden face, the meadows green,*
> *Gilding pale streams with heavenly alchymy"*

describing the sun shining on streams and meadows, I very much doubt it.

One scientist stated, that if a computer were constructed with the mental power of the human brain, it would be the size of Europe!! If they did achieve all this without acquiring top heavy heads, could they one day become Members of Parliament? I don't think so, we couldn't program them to be mendacious enough.

Although I have treated the subject with a certain amount of levity, it is a serious one, and one that we shall be arguing about for many years to come.

Rusty Programme

With Cheltenham very much in the news of late, I was rather amused to read the following: It appears that the BBC Radio Station at York had asked permission to erect a medium-sized relay station at Scarborough. A short time after its completion the BBC was asked by the Home Office to reduce its power by 75 per cent.

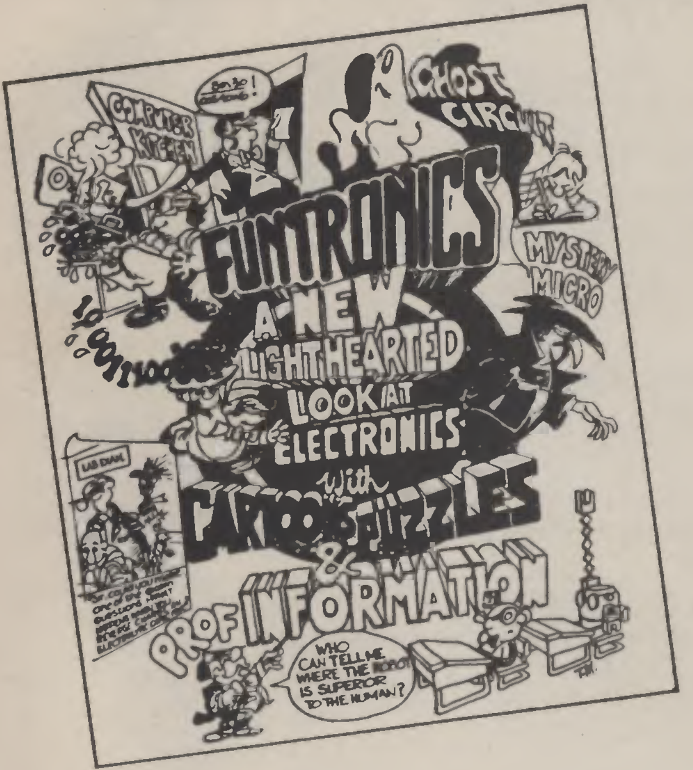
The reason given was National Security. Apparently a listening station nearby, linked to Cheltenham, tunes into the Russian trawlers. Instead of getting the latest news on the size of the herring catches, they were receiving an up to the minute account of the traffic situation in York.

After the BBC Engineers proved that this was impossible, a very embarrassed security man from GCHQ explained why it was happening. Their listening station had never been cleaned since it was built, and consequently suffers from something known as "Dry Rust". This causes the station not only to hear a report of the number of vehicles on the road at Nether Poppleton but also local pop music as well.

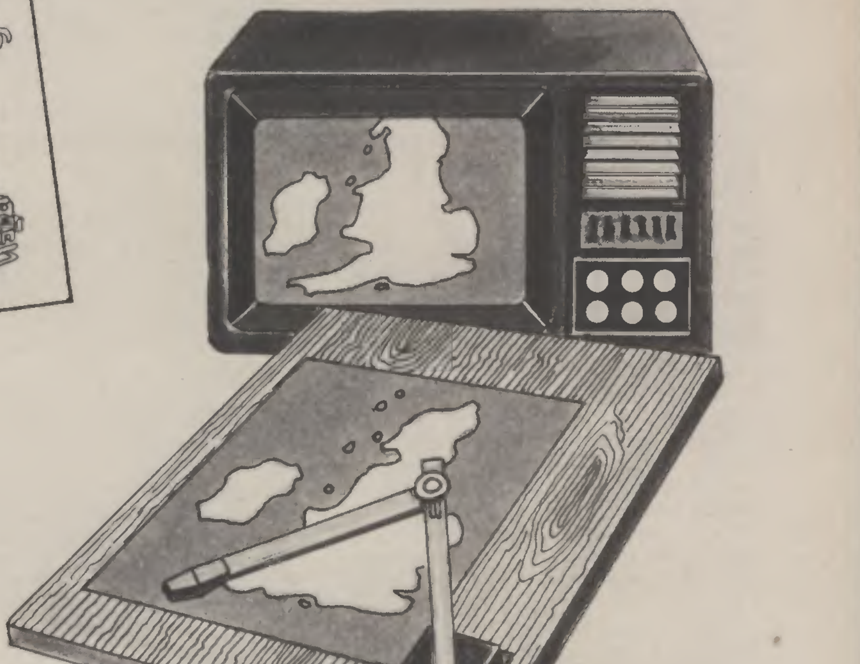
I wonder if this is why I sometimes pick up television on my tape recorder? Perhaps it needs rust-proofing.

Meanwhile the BBC said they would send round engineers to clean the place up with wire brushes, no, not Paul Young's shack, but the listening station. So now we can all sleep soundly in our beds once more.

SEPTEMBER FEATURES...



MICROCOMPUTER DIGITISER



GUITAR HEADPHONE AMPLIFIER

EVERYDAY
ELECTRONICS
and computer PROJECTS

SEPTEMBER 1984 ISSUE ON SALE FRIDAY, AUGUST 17

WASHER FLUID MONITOR

A.R.WINSTANLEY

One of the latest features found on some new high-specification cars is a device which informs the driver when the windscreen washer reservoir is nearly empty, to warn you to replenish it at the earliest opportunity.

The Washer Fluid Monitor is a simple electronic circuit which will tell the motorist by means of a warning lamp that the washer bottle requires re-filling.

The device can be especially useful on long motorway journeys in dirty road conditions; under these circumstances, the screen washers can be in almost continuous use and the Monitor will warn you in good time to pull in at the next stop to re-fill the reservoir. The tell-tale lamp also warns you to economise on screen washer fluid in the meantime!

CIRCUIT DESCRIPTION

The circuit diagram is shown in Fig. 1. Firstly, TR1 and associated components form a simple transistor switch. Two sensor wires are taken from the points shown to the fluid bottle where the two probes dip into the water contained inside. The water, whilst not being a perfect conductor, forms a resistive path between the two probes and thus the base terminal of TR1 is forward biased.

TR1 is therefore permitted to conduct, so the collector terminal goes low, to roughly 0V. In turn, this biases off the base of TR2 and so TR2 is held off by TR1.

Should the water drop to a level below that of the probes, then the base current for TR1 is cut off, switching out that transistor. Base current for TR2 then flows through R4 and so TR2 can switch on. As TR2 switches on the voltage at its collector falls.

A transistor astable multivibrator, comprising TR3 and TR4, forms the collector load for TR2 and the astable is now permitted to oscillate. The astable drives a filament indicator LP1, simple bulbs being more suited, in the author's opinion, to automotive purposes than light-emitting diodes.

The warning lamp will now flash, thereby alerting the driver that the washer fluid level requires topping up.

A capacitor C1 is included to introduce a time delay into the operation of the circuit. This prevents the lamp from flashing for about four or five seconds, so that, should the water level temporarily fall below the pre-determined point as the car corners or travels along uneven surfaces (like the M1!), the delay will inhibit the operation of the warning light for a short period.

None of the component values are critical: the circuit should function quite normally if nearest-value components from the junk box are employed instead. The same applies to the types of transistors used in the circuit.

CONSTRUCTION

VEROBOARD

All the components, with the exception of LP1, are assembled on 0·1in matrix Veroboard of dimensions 16 strips × 29 holes, as shown in Fig. 2.

The Veroboard has been cut to fit inside a plastic Bimbox type 2002 and measuring 100 × 50 × 25mm. It is then possible to mount the board horizontally inside the box by employing four "Bimadaptors" cut to length; these slot into the p.c.b. guides moulded within the case. No mounting hardware is therefore necessary for the circuit board.

Start the assembly by cutting the Veroboard to size, and then making the two breaks in the copper tracks as shown in Fig. 2. The components should be soldered in position. As always, take the usual handling precautions with the transistors and ensure that all the polarised capacitors are inserted the right way round.

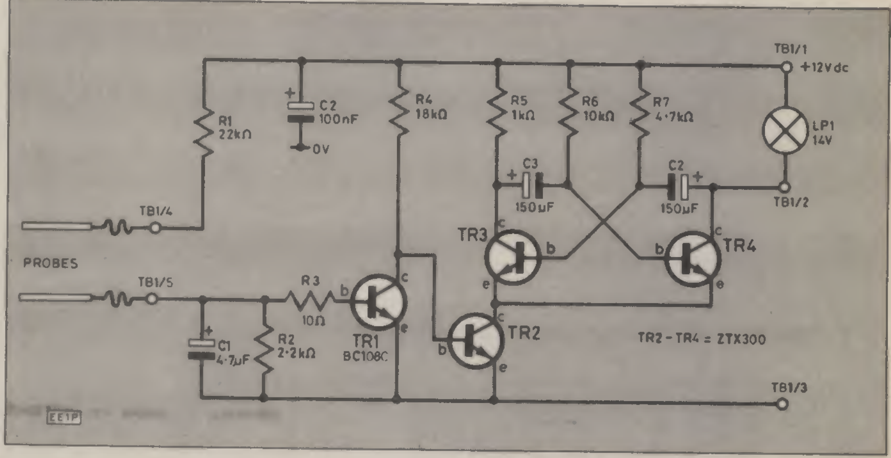
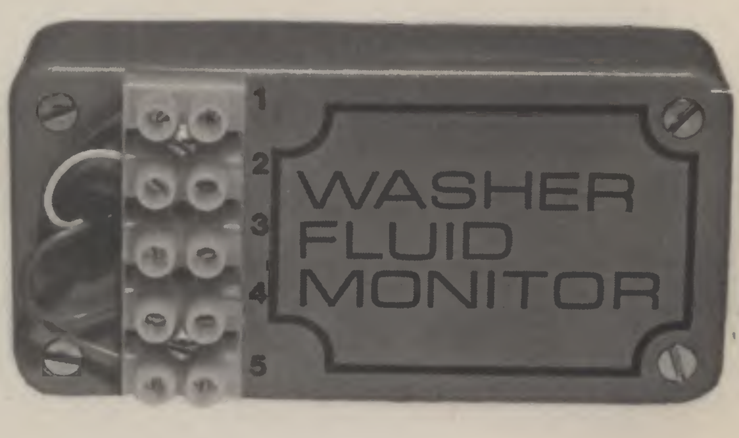


Fig. 1. Circuit diagram of Washer Fluid Monitor



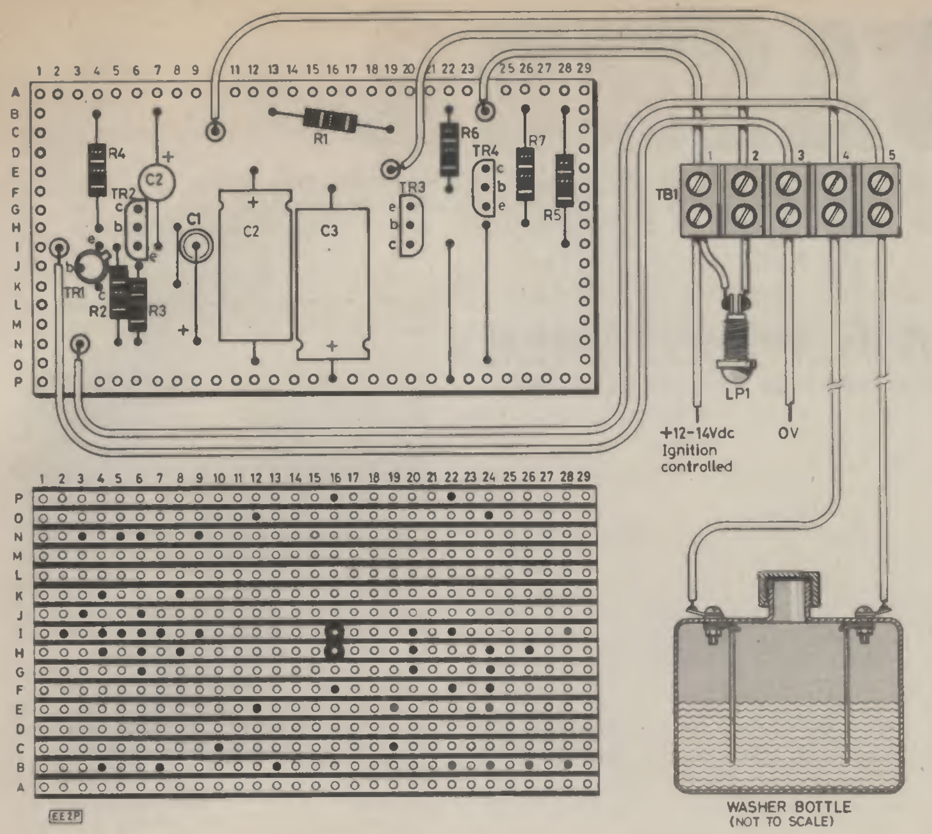


Fig. 2. Veroboard layout, wiring diagram and sensor construction.

COMPONENTS

Resistors
R1 22kΩ
R2 2·2kΩ
R3 10Ω
R4 18kΩ
R5 1kΩ
R6 10kΩ
R7 4·7kΩ
All $\frac{1}{4}$W carbon ±5%

See **Shop Talk** page 534

Capacitors
C1 4·7μF 16V axial lead electrolytic
C2 0·1μF 35V tantalum bead
C3,4 150μF 16V axial lead electrolytic (2 off)

Transistors
TR1 BC108C *npn*
TR2–4 ZTX300 *npn* (3 off)

Miscellaneous
plastic box, Bimbox type 2002 100 x 50 x 25mm; 0·1in matrix Veroboard, 16 strips x 29 holes; (LP1)—14V 40mA filament indicator, amber; (TB1)—5-way screw terminal block; Bimadaptors, cut to suit; gold-plated wire, cut to length (Maplin); 2BA nuts, bolts, washers, solder tags; interconnecting wire; solder.

Approx. cost Guidance only **£6.00**

CONNECTIONS

The connections to the Washer Fluid Monitor are made via a 5-way screw terminal block mounted on the exterior of the case. Flying leads are then passed from the terminal block and through an adjacent hole in the case to the circuit board inside. You can use Veropins where the wires join the component board.

Note that Terminal 1 shares the connections for both the 12V positive input and one leadout to the lamp. The d.c. input should be taken from an ignition-controlled circuit, for example, the radio or similar. LP1 can be mounted in any convenient position on the dashboard, but it will probably be necessary to extend the lamp's leads with hook-up wire.

The completed module is best fitted inside the passenger compartment out of harm's way. The prototype was stuck inside the centre console by using double-sided adhesive foam strip.

SENSOR CONSTRUCTION

The proposed arrangement for incorporating the fluid-level sensor has been designed to be used in conjunction with plastic bottles of the injection-moulded type: the sensor assembly will not be suitable with those "flexible bag" types found on older cars.

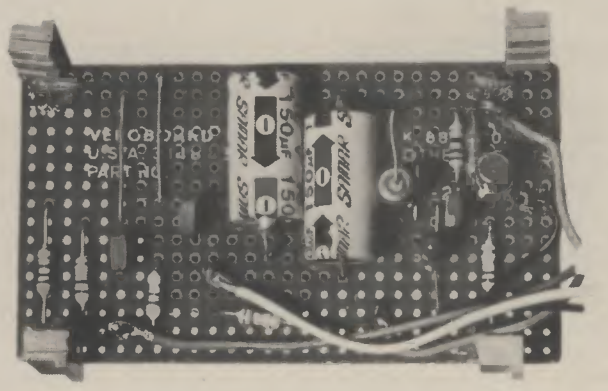
The recommended sensor design is also shown in Fig. 2, and this was used in the author's car with great success. Firstly, empty out the contents of the bottle. Then drill two 2BA clearance holes in the top of the bottle on either side of the re-fill opening.

Two solid-core uninsulated wires are bolted, via a solder tag, to the inside of the bottle so that the wire forms a probe dipping into the water. It should be possible to reach inside the bottle with a finger in order to feed the bolt through the hole made in the washer bottle.

Another solder tag mounted outside on top of the bottle is used to take a connection away from the probe to the Monitor fitted inside the car.

The probe wires used in the prototype set-up were gold-plated since this kind of wire is resistant to corrosion. A suitable source of this wire is indicated in the components list. Being rather thin, the wires should be bent double to introduce an element of rigidity into the probes. Of course, the probes need to be cut to appropriate length, say 25mm to 30mm or so, from the *bottom* of the bottle. When the water drops below the probes, then the warning lamp will flash on the dashboard.

With construction and installation completed, and the washer reservoir still empty, now switch on the ignition to connect the Washer Fluid Monitor to the car's electrical supply: the warning lamp on the dashboard should be flashing. Switch off and then repeat the process after having filled up the bottle with water. This time of course the lamp should remain extinguished. □



SHOP TALK

BY DAVE BARRINGTON

Catalogue

The new 450-page "Electronic Superstore" catalogue from **Verospeed** is their largest edition to date. It now lists over 8000 products, of which 500 are completely new.

Several areas have been expanded and these include, A/D and D/A converters, sealed lead acid batteries, computer peripherals and cleaning kits, drawing aids and a new card frame data-bussing system.

As an indication of the vast amount of information listed in the catalogue it now occupies 300 Megabytes of disc storage. Data stored includes prices and detailed product summaries, together with photos and diagrams.

Altogether, the 450-page catalogue covers a range of products from over 160 suppliers. It is Verospeeds claim that all stock items are available on a "same day despatch" basis.

Copies of the 450-page "Electronic Superstore" catalogue are available from: **Verospeed, Dept EE, Stansted Road, Boyatt Wood Industrial Estate, Eastleigh, Hants SO5 4ZY.**

High Powered

Following their very successful and now widely accepted 100W bi-polar power amplifier module, **BK Electronics** have just launched a follow-up, high specification, range of MOS-FET Power Amplifier models under their OMP brand.

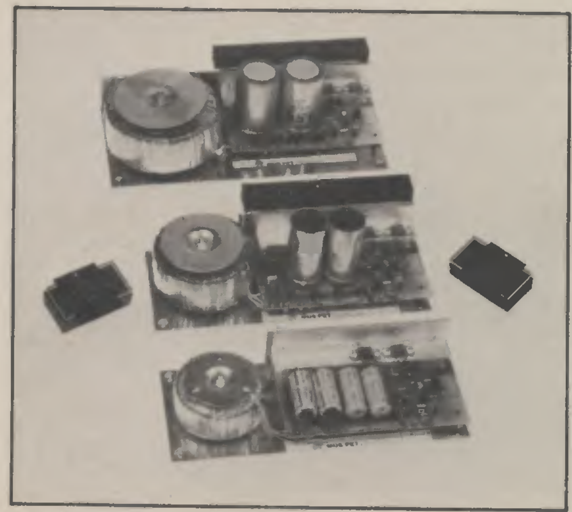
With respective power ratings of 100W, 200W and 300W r.m.s., they are ideal for the designer of instrumental, P.A., disco and hi fi equipment. They are also aimed at the expanding studio and leisure industry.

All models are built on glass-fibre printed circuit boards with aluminium chassis/heatsinks and power supplies, incorporating a toroidal mains transformer. On-board drive circuits are provided to power a compatible eleven segment l.e.d. A Vu-meter is available as an optional extra.

A brief technical specification is as follows: Frequency response: 1Hz to 100kHz; Sensitivity: For maximum output 500mV; Slew rate: 45V/µS; Signal-to-Noise Ratio: 125dB; Total Harmonic Distortion (THD): Full power 0·002 (typical 0·001); Power: Output: Into 4 ohms, 100W, 200W and 300W r.m.s. (dependent on model). Amplifiers with a reduced frequency range are also available.

Prices for the OMP/MF100 to MF300 range from approximately £40 to £80, including VAT. These figures do not include postage and packing.

For more details readers should contact: **B.K. Electronics, Dept EE, Unit 5, Comet Way, Southend-on-Sea, Essex SS2 6TR.**



Tape It

Repairing printed circuit boards and altering prototype layouts is always a tricky undertaking and sometimes it becomes a case of "ditching" the board in frustration and starting again. However, the latest offering from **Copperfoil Enterprises** should help to alleviate some of the above problems.

Taking the form of adhesive-backed copper tape, Copperfoil can easily be cut to length and placed in position on the "baseboard" to make-up the desired circuit.

Tested and approved at 24V 5A d.c., and conforming to BS safety regulations, Copperfoil is available in 4, 4·75, 6 and 8mm widths in 33m rolls. Inclusive prices per 33m roll are: £2.95, £3.35, £3.95 and £4.25 respectively.

For addresses of nearest stockists readers should contact: **Copperfoil Enterprises, Dept EE, 141 Lyndhurst Drive, Hornchurch, Essex RM11 1JP.**

CONSTRUCTIONAL PROJECTS

Microwave Alarm System

As the *Microwave Alarm System* can only be completed by the purchase of the special microwave module, we have been able to convince Avionic Systems that they should offer these units at a discount price. They are prepared to make a special allowance to EE readers and are offering them at below manufactured price.

The microwave alarm unit is being offered at £29 plus £3 post and packing. We understand that this is a saving of £10 on the "bought-in" price.

The unit and the warning sounder can be obtained from **Avionic Systems (Heathrow) Ltd., Dept EE, Viscount Way, London (Heathrow) Airport, Hounslow, Middx. TW6 2JW.**

The remaining components for the "adaptor" should be available from our advertisers.

Seed Propagator

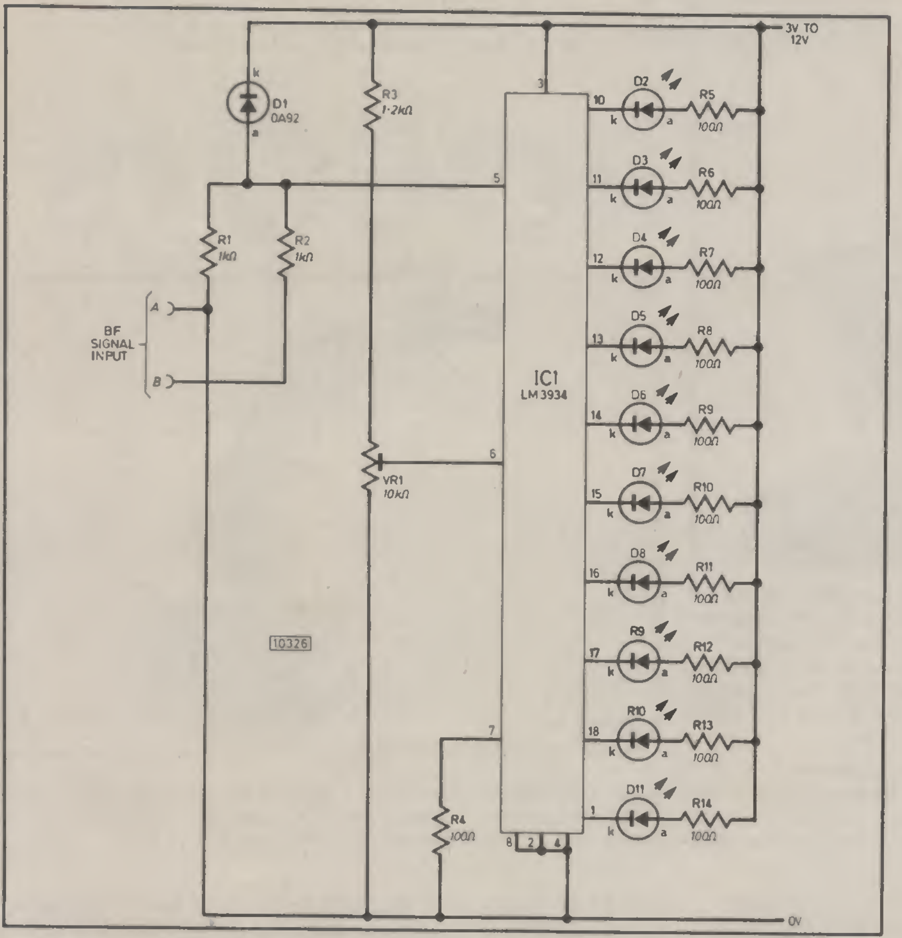
The 1-metre 28 s.w.g. Nichrome wire called for in the *Seed Propagator* project is available from Scientific Wire Co.

This wire is usually sold in 2oz lots and will cost £3.09, including VAT and p&p, from **Scientific Wire Co., Dept EE, Forest Road, London, E17.**

We cannot envisage any component buying problems for the rest of this month's constructional projects.

CIRCUIT EXCHANGE

This is the spot where readers pass on to fellow enthusiasts useful and interesting circuits they have themselves devised. Payment is made for all circuits published in this feature. Contributions should be accompanied by a letter stating that the circuit idea offered is wholly or in significant part the original work of the sender and that it has not been offered for publication elsewhere.



LUMINOUS OUTPUT LEVEL INDICATOR

I DESIGNED this luminous modulator for my stereo hi fi. It replaces the classic galvanometer type of output indicator.

The project is based on the LM3914N integrated circuit which incorporates 10 op-amps. It can sense analogue voltage levels and directly drive 10 l.e.d.s to provide a linear 10-step display. It has its own adjustable reference source that controls the internal 10-step divider chain.

The audio signal is applied to the inverting terminal (–) of each op-amp (pin 5) via resistors R1 and R2 (points A and B). These op-amps are utilised as comparators, that means when the voltage level of the audio signal applied to the inverting terminal is greater than the reference voltage level applied to the non-inverting (+) terminal (pin 6), the l.e.d. will glow. The reference level is adjusted by potentiometer VR1.

The OA92 diode (D1) mounted between pin 5 and the positive line rectifies the waveform of the audio signal, which eliminates the positive component of the BF signal.

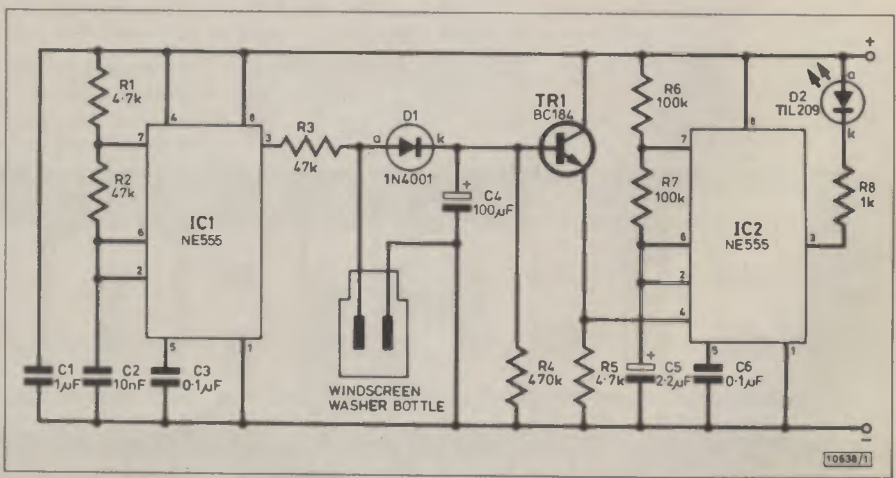
The required power supply is between 3V to 12V. The audio signal is taken from the speaker. For a stereo system, I coupled two circuits together.

Anis Hably,
Beirut,
Lebanon.

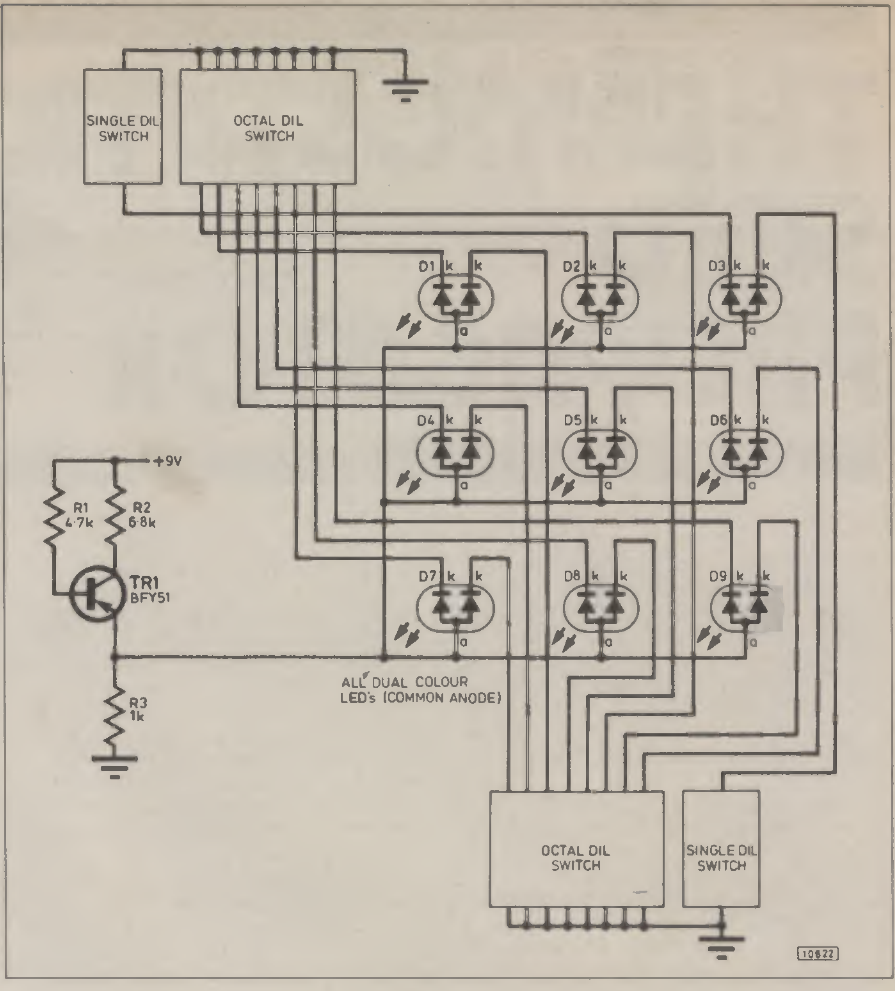
EMPTY WINDSCREEN WASHER INDICATOR

THIS circuit provides early warning of an empty windscreen washer bottle. A varying amplitude voltage is applied across two stainless steel electrodes suspended inside the bottle. The varying voltage is used to help prevent coating of the rods. When there is no water present to short out the rods, diode D1 conducts, thus switching TR1 on. Pin 4 of IC2 goes high causing the l.e.d. D2 to flash. If the rods are shorted out again the charge in C4 results in D2 flashing for a further 15 to 20 seconds. This is necessary as the level of water around the rods will not be constant while the car is running.

R. Ormston,
Southampton,
Hants.



CIRCUIT EXCHANGE



NAUGHTS AND CROSSES

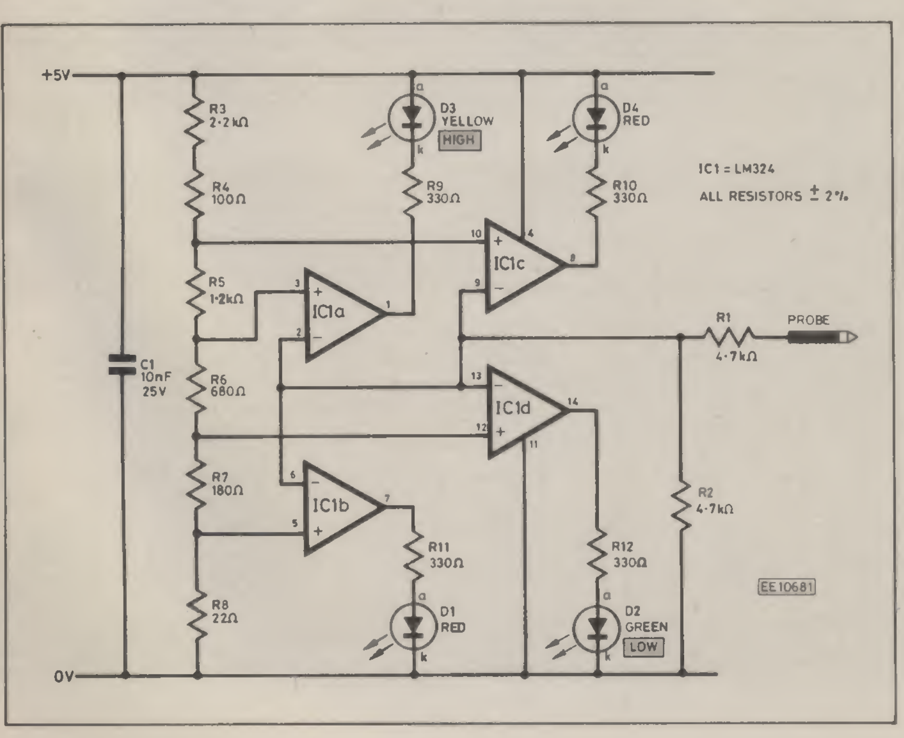
This is a simple electronic naughts and crosses game, ideal for passing the time when travelling. The l.e.d.s are arranged in the normal matrix layout, and are operated by a d.i.l. switch arrangement. All the l.e.d.s are BI-coloured and are supplied via a low voltage current source TR1.

It should be quite easy to construct an attractive little project using this idea. All the components can be mounted on either a stripboard or a p.c.b. which should be mounted inside a suitable box. The l.e.d.s can be brought out to the top of the box and arranged in the standard naughts and crosses, three by three matrix.

Despite being a very simple project, it will provide hours of fun, and can be built by anyone, as all the components are readily available and are quite cheap.

G. McLintock Esq.,
Bishopbriggs,
Glasgow.

INTELLIGENT TTL LOGIC PROBE



The Intelligent Logic Probe, unlike any other probe I know of, can distinguish between a logic 0 and ground, or between logic 1 and Vcc. This is achieved by comparing various reference voltages with the probe voltage.

The power for the circuit is derived from the circuit under test, and the measurement is displayed on four l.e.d.s; green represents logic 0, yellow logic 1 and no l.e.d.s indicates undefined. A green and red indicates short to ground and a yellow and red, short to Vcc.

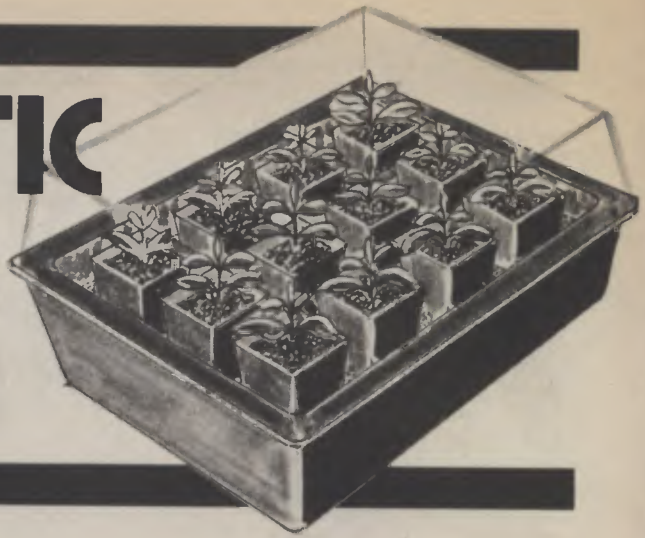
Resistors R1 and R2 act as a potential divider giving a reference of half the probe voltage. Other reference voltages are obtained from the divider chain R3 to R8. To make various comparisons on these references a quad op-amp (LM324) with no feedback is used. Depending on the probe voltage the output of these comparators will be close to Vcc or ground. The outputs are used to drive l.e.d.s via current limiting resistors. This circuit has been tested at a frequency of 15kHz with a square-wave input. However, if a quad comparator such as the LM339 is used then it will probably work at much higher frequencies.

It should be noted that the input impedance of this probe is quite low, and may cause problems if used in circuits with large "fan outs".

D. Kirby,
Walthamstow,
London.

THERMOSTATIC SEED PROPAGATOR

John Lewis



IN SPRING, it is an advantage for the keen gardener to be able to sow seeds in warm, controlled conditions. An electrically heated seed propagator is ideal for this purpose as it avoids the considerable expense of heating the entire greenhouse to a high temperature. It may also be used near a south facing house window where the maximum light may be obtained.

Seed propagators available from garden centres may not be thermostatically controlled and can be quite expensive if this feature is included.

The inexpensive seed propagator described in this article has very good temperature control and provides adequate heating for use in normal conditions.

GENERAL DESCRIPTION

The propagator consists of a modified standard size seed tray which has heating wires covered with sand in its base. A small thermistor senses the sand temperature and an electronic unit controls the 12-volt supply current to the heating element. This element is made from Nichrome wire which is protected by high temperature glass-fibre sleeving.

Square plastic or peat pots are ideal for seed sowing and a number of these can be fitted inside the seed tray, resting on the heated sand. Peat can be packed around the pots to provide extra insulation and a clear plastic cover can be used over the seed tray to help maintain warmth while still allowing light to enter. Sufficient light is important if the plants are to grow well.

The required sand temperature may be set with a variable resistor and an l.e.d. shows when the heating current is switched on. The optimum germination temperature for most seeds is between 18°C and 21°C (65°F and 70°F) and this can be easily achieved with this unit provided that the surrounding temperature is not too low. The unit should be calibrated before use with a thermometer inserted into the sand near the thermistor, a scale can then be drawn under the variable resistor pointer.

CIRCUIT DESCRIPTION

The circuit diagram of the Seed Propagator is shown in Fig. 1.

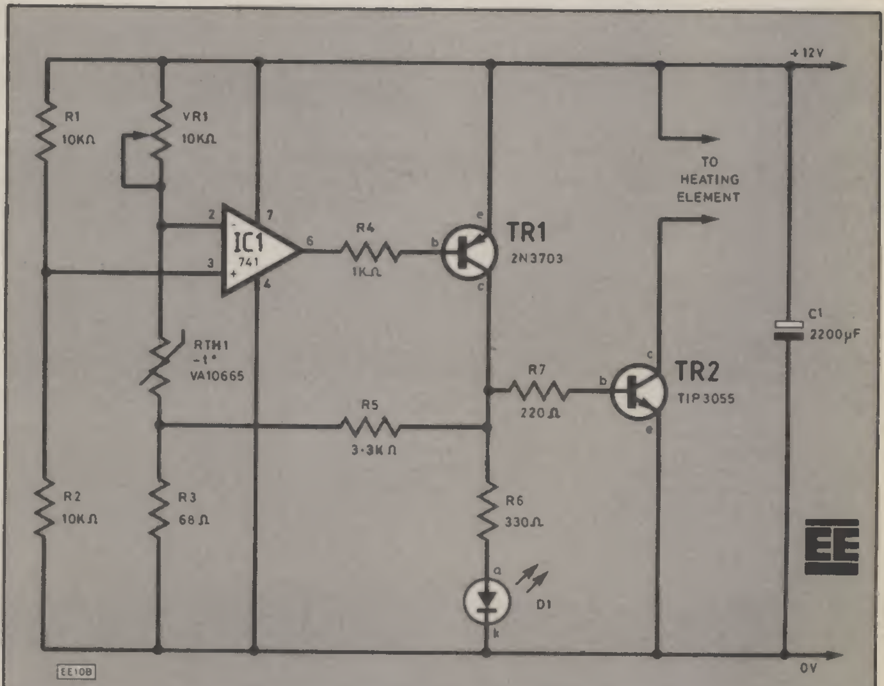
IC1 is a 741 operational amplifier used to compare two voltages. The non-inverting input on pin 3 of the op-amp is held at a reference voltage of about half the supply voltage by the resistors R1 and R2. VR1 is variable and together with thermistor RTH1 and R3 sets the voltage on the inverting input of the op-amp which is pin 2.

If the voltage on pin 2 is greater than the voltage on pin 3, then the op-amp output on pin 6 is at 0 volts and the transistor TR1 is on. The collector of TR1 is then at 12 volts, the l.e.d. is lit and transistor TR2 is also on so current will flow through the heating element.

As RTH1 warms up, its resistance decreases and the voltage on pin 2 will decrease until it is just less than the voltage on pin 3. The op-amp then greatly amplifies this small voltage difference and pin 6 changes rapidly to about 11 volts. TR1 switches off, extinguishes the l.e.d. and switches off TR2. The current through the heating element is therefore rapidly switched off. As the thermistor cools, the operation is reversed. R5 provides a feedback loop which gives about 1°C between the switch-on and switch-off temperatures. This reduces the sensitivity of the circuit to a suitable level and prevents an excessive number of switching operations.

C1 smooths the 12-volt power supply which should be capable of providing about 2 amps. It need not be a regulated supply as the circuit is relatively immune to power supply voltage changes.

Fig. 1. Circuit diagram of the Seed Propagator.



Remember that a mains supply in a greenhouse should be connected through an earth leakage circuit breaker, now referred to as a residual current circuit breaker, this provides a very great deal of protection from electric shocks.

CONSTRUCTION

STRIPBOARD

The circuit is built on 0·1 inch matrix stripboard which is 24 holes wide by 18 strips (Fig. 2 and Fig. 3). The 741 op-amp should be mounted in an 8-way socket which will prevent damage due to overheating when soldering. Care must also be taken when soldering the 2N3703 transistor on the circuit board. The i.c. and the transistor must be correctly inserted into the board as incorrect insertion will cause damage.

A diecast aluminium box about 110 × 60 × 60mm is ideal for containing the circuit board. The variable resistor should be mounted on the box together with the l.e.d. The l.e.d. must be correctly connected, usually the flat side is the negative connection. Note that these devices must never be connected directly across a power supply without a series resistor, this is R6 on the circuit board.

The TIP3055 transistor should be bolted to the inside of the box using an insulated mica washer and a small amount of heatsink compound. The box provides enough heat dissipation and no other heatsink is required unless a plastic or other insulating box is used.

External connections are most conveniently made to a terminal block mounted on the outside of the box (Fig. 4).

HEATING ELEMENT AND SEED TRAY MODIFICATION

The heating element is made from one metre of 28 s.w.g. Nichrome wire which has a resistance of 9·7 ohms. This gives a power of 14·5 watts from a 12-volt supply. Notice that no attempt should be made to run the heating element directly from the mains. The length specified gives a power which is comparable with commercial units of similar size.

To protect the heating wire from corrosion and mechanical damage it must be inside a suitable length of glass-fibre sleeving. Heatsink compound should be smeared over the wire as it is inserted into the sleeving and a liberal amount rubbed over the outside of the sleeving will help to keep moisture out.

COMPONENTS

See Shop Talk page 534

Resistors

R1,2	10kΩ (2 off)
R3	68Ω
R4	1kΩ
R5	3·3kΩ
R6	330Ω
R7	220Ω
VR1	10kΩ linear variable
RTH1	VA1066S thermistor

All resistors are ½W (±10% tolerance)

Capacitors

C1	2200μF 25V axial electrolytic

Semiconductors

D1	light emitting diode (any colour) 0·2in diameter
TR1	2N3703 *pnp* silicon transistor
TR2	TIP3055 *npn* silicon transistor
IC1	741 8-pin d.i.l. operational amplifier

Miscellaneous

Stripboard (0·1in matrix), 24 holes wide × 18 strips; 8-pin d.i.l. socket; l.e.d. clip; 1 metre 28 s.w.g. Nichrome wire; 2 metres 2mm glass-fibre sleeving; heatsink compound, mica washer; diecast aluminium box, 110 × 60 × 60mm; 6-way terminal block; connecting wire, assorted nuts and bolts; knob for variable resistor.
*Residual current circuit breaker.
*See text.

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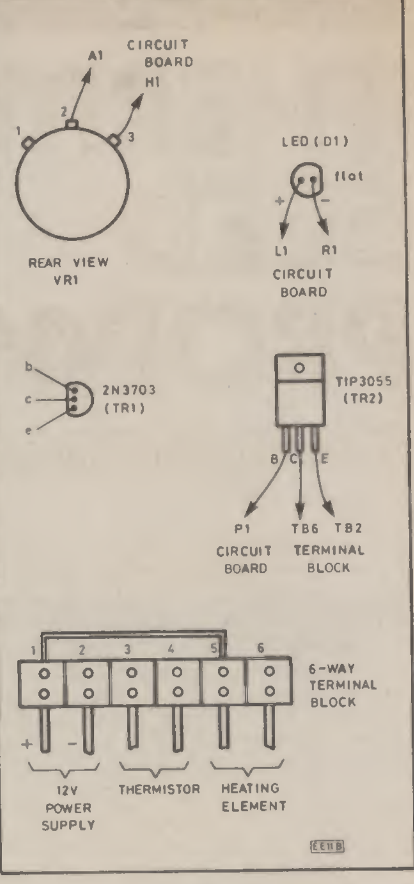

Fig. 4. Wiring details.

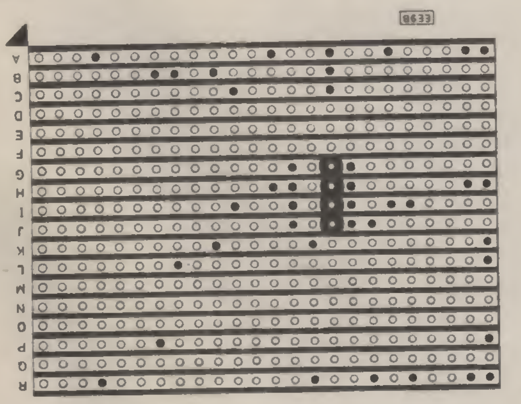

Fig. 2. Stripboard track cutting details.

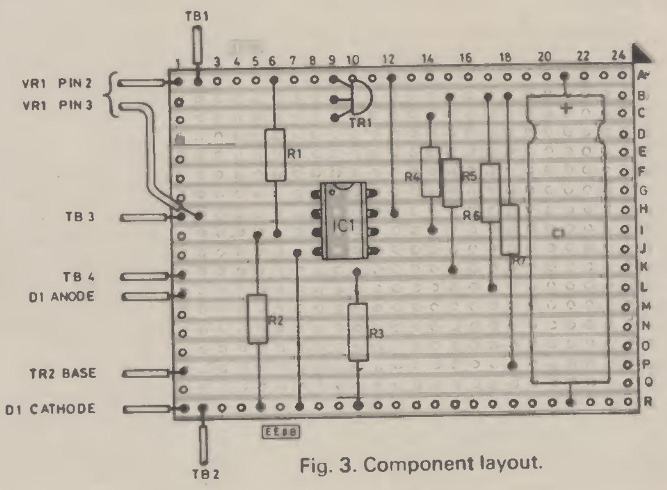

Fig. 3. Component layout.

The seed tray should be a standard full-size tray (350 × 210 × 80mm) made from strong plastic, the drainage holes in its base should be covered with waterproof tape. The heating element should be arranged in a zig-zag pattern on top of a 10mm layer of sand in the base of the tray (Fig. 5). Screw terminals on the side of the tray secure the ends of the heating element, holes for these screw terminals are most easily made with a hot soldering iron rather than with a drill. More sand is then put into the tray to cover the heating element to a depth of about 20mm.

The thermistor is quite delicate and must be protected by being sealed into a plastic pen-top or something similar using epoxy resin or silicone rubber bath sealant. Its leads should also be protected by glass-fibre sleeving, screw terminals on the side of the tray should be provided for connecting these leads. □

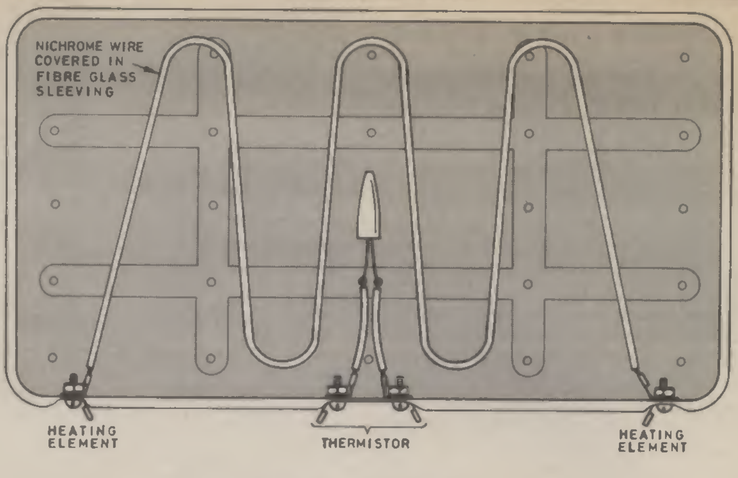

Fig. 5. Seed tray layout.

EE82G

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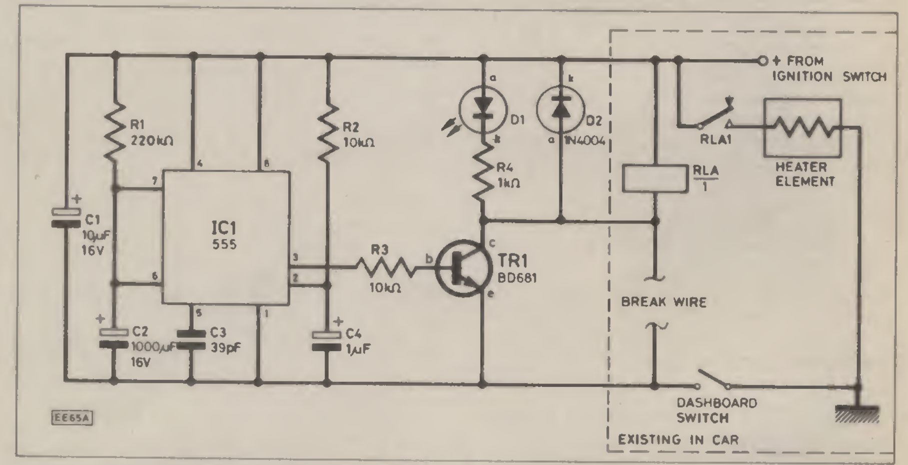
Heated rear screens consume large amounts of energy and if left on too long can deplete the battery power reserve, so much so that the task of cold starting can become impossible.

This simple circuit solves this problem by timing out five minutes after activation of the dashboard switch. This time delay allows sufficient time for the heater to do its job efficiently, and if the heater is needed again during the journey, a simple "off-on" movement of the switch will give another five minutes heating.

The circuit is cheap and easy to build and can easily be installed to most cars. Only three connections to the heater relay are required. An l.e.d. is included to indicate that the heater is on, and the heater can be switched off at any time as normal.

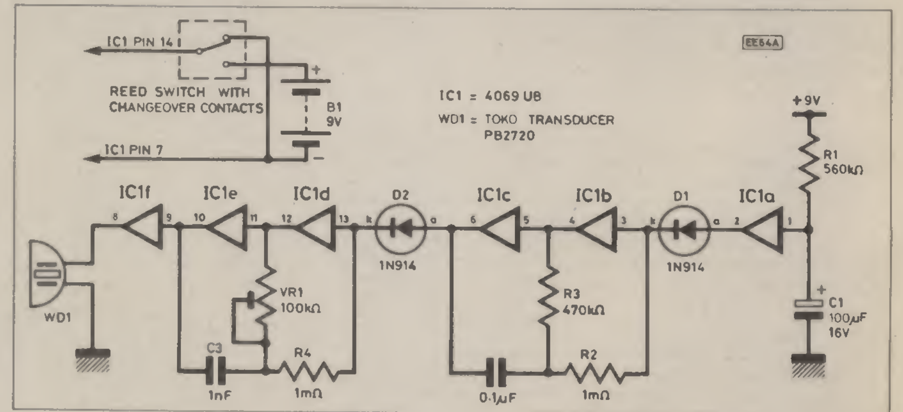


G. R. Cornell,
Chelmsford,
Essex.

TELEPHONE PEN REMINDER

Two RC oscillators form the basis of this telephone pen reminder circuit. After removal of a modified pen from its holder, an alarm will sound after a preset time to remind the user to replace the pen. Only after the pen is replaced will the alarm cease to operate, thus avoiding those times when a pen cannot be found.

The first oscillator, IC1d and e, is tuned by VR1 until WD1 resonates at a frequency of approximately 4·5kHz. The second oscillator, IC1b and c, pulses this tone at approximately 0·3Hz, and the inverter IC1a together with R1 and C1 provide a delay when the circuit is activated.



A small magnet is glued to a cheap pen, making sure that it will operate the change-over contacts on the reed switch. In normal use the pen is placed in its holder so as to operate the reed switch and thus discharge C1. When the pen is removed the contact will close and the circuit will energise when C1 charges to a high logic level. The time delay is set by R1 and with the values shown, will give a delay of approximately 60 seconds.

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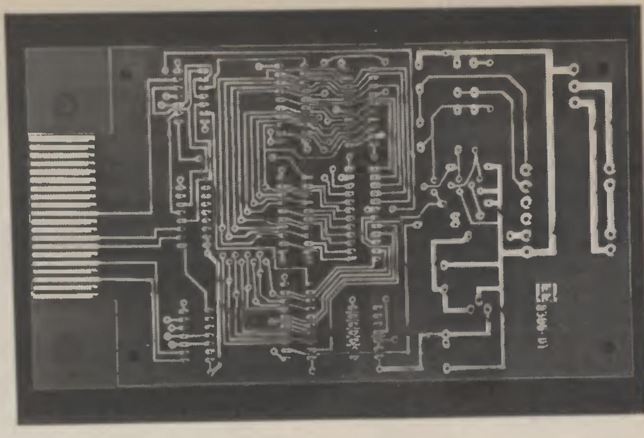

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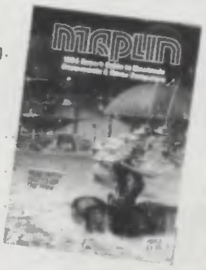

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