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EVERYDAY WITH PRACTICAL ELECTRONICS
INCORPORATING ELECTRONICS MONTHLY
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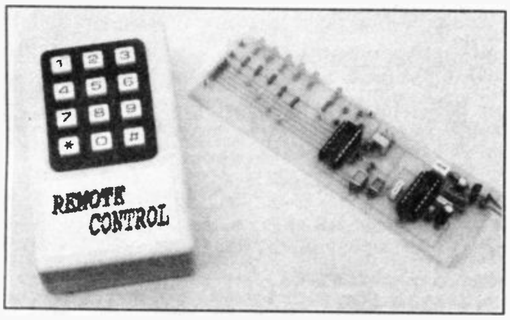
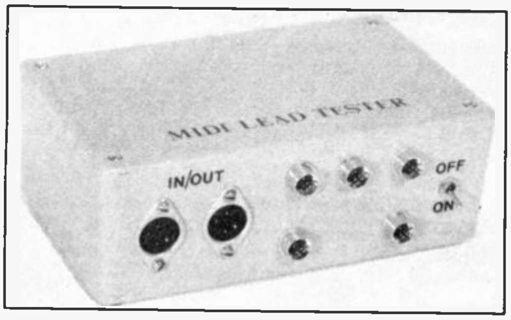
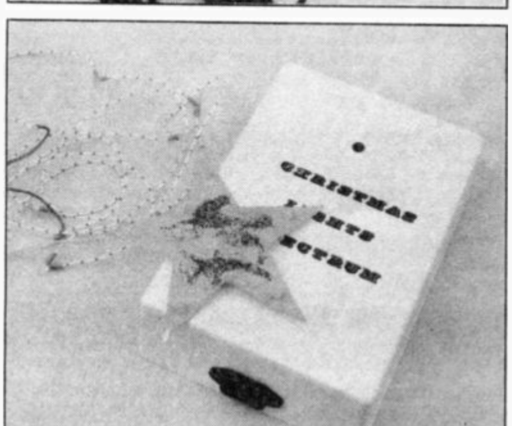
PROJECTS . . . THEORY . . . NEWS . . .
COMMENT . . . POPULAR FEATURES . . .







Projects

Series

Features

Our January '93 issue will be published on Friday, 4 December 1992. See page 771 for details.

SPARKOMATIC 4 x 150 watt CAR AMPLIFIER

The SA3200 is our top of the line 4 Channel Amplifier which is extremely well specified. It is very powerful and versatile and features separate bass and treble controls which gives the user the possibility of reducing bass response to the front speakers and adding treble for better stereo imaging. The bass response can then be increased to the rear speakers which are usually larger and capable of offering better reproduction. The SA3200 features a bridge operation switch which offers the possiblity of using the amplifier in 4, 3 or 2 channel mode. The 3 channel mode is ideal for installations where rear deck speakers are used in combination with a separate subwoofer.

● 4 x 150 Watts max ● 4 x 80 Watts into 4 Ohms at less than 0.5% THD ● 2 x 80 Watts plus 1 x 160 Watts at less than 0.5% THD ● 2 x 160 Watts into 4 Ohms at less than 0.5% THD ● Separate bass and treble controls for front and rear channels ● Separate sensitivity controls for front and rear channels ● 2, 3 or 4 channel operation ● Heavy duty power wires ● Glass blasted aluminium heatsink ● High current capacity

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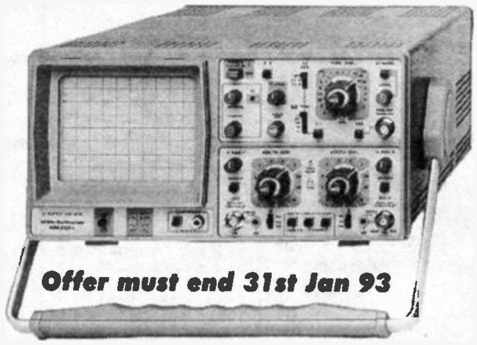

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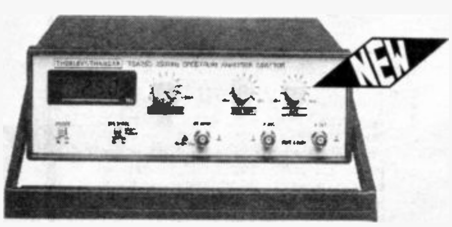

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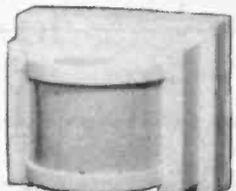

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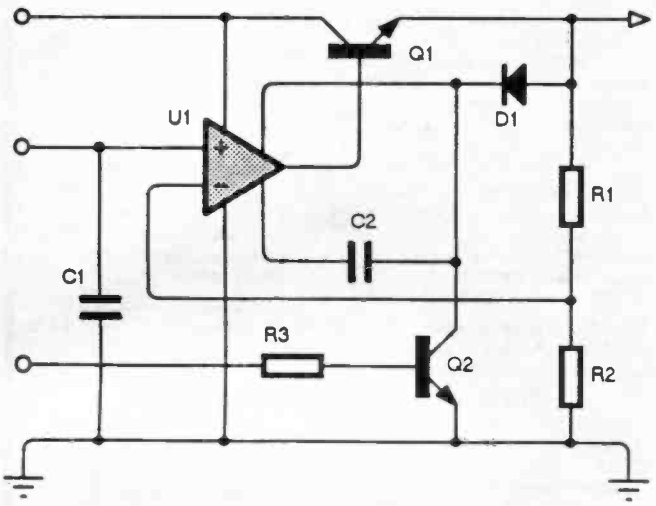

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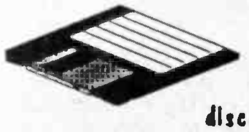

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SUCCESS

Success breeds success as they say and our first combined issue of *Everyday with Practical Electronics* (last month) has certainly been a success, so much so that this issue is even bigger. In an effort to get everything in we have produced our biggest ever issue. Eighty-eight pages of magazine plus sixty-four pages of catalogue. We even had to ask Bull Electrical to accept thinner than normal paper for their catalogue so that we could bind all the pages together and have a big enough cover to fit around it.

In short, we believe this is the best value ever hobby electronics magazine and we will try to keep it going in that direction. Of course our advertisers have recognised the value of our increased circulation and that also means more of their interesting advertisements and a very wide range of products for you to choose from.

TEACH-IN '93

Our new *Teach-In '93* has also kicked off to an excellent start and we have had so many requests for the *Mini Lab* p.c.b. that there has been a delay in sending them out. If you had to wait for yours we are sorry but hopefully, by the time you read this, we will have caught up to our normal seven day turnaround.

Teach-In also upset some readers – see the *Readout* letters page – and we apologise for that. No excuses but the offending mnemonic is widely used in education and was suggested by someone in that profession.

TOPICAL

In view of the recent UK coal mine closures and the subsequent debates and manoeuvres our *Alternative Evergy* series makes interesting reading. This month's part puts the whole field of energy production into perspective and also gives some interesting figures on nuclear pollution, etc.

I certainly have gained some knowledge from the series and found it informative reading. I'm only sorry that we have had to omit a few interesting photos from the last two parts due to lack of space. There were, in fact, so many photographs available of wind farms, solar power stations, etc., that we could easily have filled the whole magazine with them. It just shows how much is going on in this field that many of us are unaware of.

Mike Kenward

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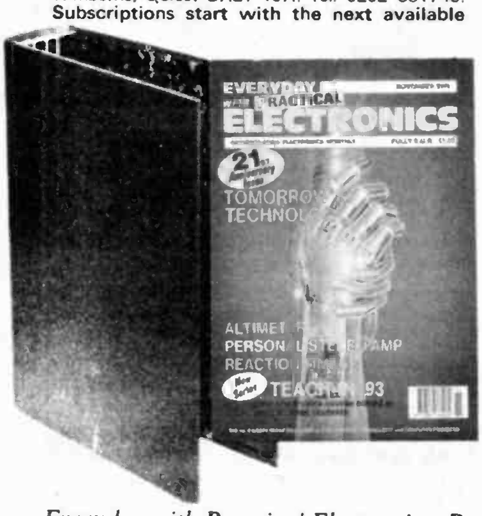

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All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot however guarantee it and we cannot accept legal responsibility for it.

COMPONENT SUPPLIES

We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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Constructional Project

UNIVERSAL INFRA-RED REMOTE CONTROL

CHRIS WALKER

One for the experimenter. Has been designed to be adaptable to almost any control requirement.

HAVING been involved in the design of numerous electronic control and measurement systems, both on a personal level and when assisting Technology students, the author has frequently encountered projects which require the use of a remote control facility.

Some of the applications which spring to mind are: remote control of a free-running robot buggy; security lock systems; remotely controlled garage doors; remote entry of data into a personal computer; remote control of household appliances etc. Needless to say that readers could suggest countless more uses.

Quite often, all the different applications have a common remote control theme running through them, namely the need for a hand-held transmitter unit featuring one or more keys transmitting a short distance (some metres) to a receiver unit which indicates which key on the transmitter has been pressed and activates other parts of the system.

Since the transmitter/receiver remote control sections of the various different systems are all essentially identical, the author thought that it was high time to design a Universal Infra-Red Remote Control unit which could be adapted to a diverse range of uses. This article describes such a "drop-in" unit and applications are limited only by readers' imagination.

SPECIFICATIONS

The entire Versatile Infra-Red Remote Control system is designed around three integrated circuits produced by GEC Plessey Semiconductors. Use of such advanced i.c.s greatly simplifies construction yet results in a flexible and powerful remote control facility.

The handheld Transmitter can feature between *one* and *thirty-two* keys depending on the application requirement. Data may be transmitted at three different rates and will only be decoded by a receiver set to an identical data rate.

It is, therefore, possible to send 32 different codes to three different receivers in one room, a total of *96* code combinations. This powerful feature will probably far exceed the demands of most applications.

Standby transmitter current consumption, when no keys are pressed, is less than one microamp and the PP3 battery should give an extensive working life.

In the Receiver unit, which is operated from a power supply of between 5V and 25V, the infra-red (IR) data picked up from the Transmitter is amplified using a specially designed integrated circuit. The benefits of using a custom amplifier i.c. for this job (rather than discrete transistors) are enormous: apart from simplifying construction, the receiver can reject a large amount of electrical and IR noise. Operation is possible in bright sunlight (important for external use) and also in rooms illuminated with artificial lighting.

The latter often causes a problem because mains-operated incandescent lamps (i.e. light bulbs) generate hugh amounts of infra-red radiation which flickers at a rate of 100Hz. If this flicker was not rejected by the IR amplifier it would swamp the weak IR pulses from the Transmitter unit.

Table 1: Decmal/Binary Codes

Decimal	Binary
0	00000
1	00001
2	00010
3	00011
4	00100
5	00101
6	00110
7	00111
8	01000
9	01001
10	01010
11	01011
12	01100
13	01101
14	01110
15	01111
16	10000
17	10001
18	10010
19	10011
20	10100
21	10101
22	10110
23	10111
24	11000
25	11001
26	11010
27	11011
28	11100
29	11101
30	11110
31	11111

IN CODE

The data output from the Receiver is in the form of a 5-bit binary code, see Table 1. Each output line can either be at 0V (logic 0) or +5V (logic 1) and the code on the output signifies which of the 32 possible keys on the Transmitter has been pressed.

This binary-coded output is ideal if the Receiver is to be interfaced to a computer or other digital device. In addition, there is a Data Ready output which can be used to signal to a computer that a valid transmission code is being received. The 5-bit output from the Receiver is tri-state and can be switched to high impedance (switched off) if necessary.

For more basic applications, this article terminates with a selection of circuits which will decode the binary output to provide individual off/on control of up to 32 appliances. The degree of complexity can be tailored to suit the desired application.

TRANSMITTER CIRCUIT

The circuit diagram for the handheld infra-red Transmitter is shown in Fig. 1.

The 32-switch keypad is wired as an eight-by-four matrix. Fig. 2 shows an example of how five switches can be wired to send codes 1, 2, 4, 8 and 16 (this is a particularly useful set of codes for simple applications as will be seen later).

When a key is pressed, one row of the matrix is connected to one column. IC1 detects which row/column pair are shorted together and transmits the relevant code.

For example, pressing key "1" connects pin 9 on IC1 to pin 12. Pressing key "16" connects pin 5 on IC1 via resistor R1 to +9V. In order to transmit code "26" pin 3 must be shorted to pin 11, and so on. Constructors can build up their own keypads to transmit a particular set of codes needed for their application.

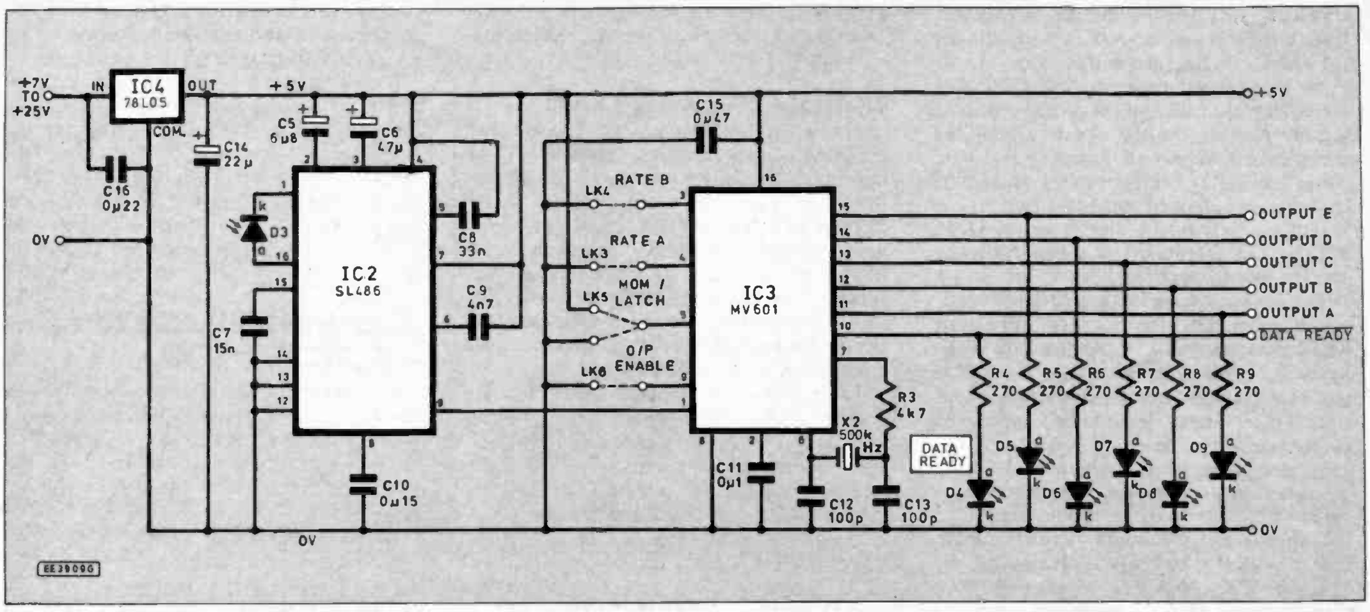


Fig. 4. Complete circuit diagram for the Receiver, including the voltage regulator IC4.

RECEIVER CIRCUIT

The circuit diagram for the Receiver and decoder is shown in Fig. 4. The IR pulses from the Transmitter are picked up by the photodiode D3 and the resulting current pulses through the diode are processed by amplifier IC2.

Capacitors C5 and C6 control the frequency dependent gain of a gyrator circuit within IC2. The gyrator only significantly amplifies the short pulses of infra-red data but ignores continuous background IR such as sunlight or room lighting.

Following the gyrator are three stages of amplification with decoupling capacitors C7, C8 and C9 which *de-sensitise* the amplifiers low frequency infra-red variation such as 100Hz lamp flicker. Capacitor C10 governs the automatic gain control which assists operation under "noisy" conditions.

The processed data emerges from IC2 at pin 9 and is routed directly to the p.p.m. data input (pin 1) of the decoder, IC3.

In likeness to the Transmitter circuit, ceramic resonator X2 and capacitors C12 and C13 form a 500kHz oscillator. Resistor R3 is used as a "damper" to prevent X2 oscillating at harmonics of its fundamental frequency.

The rate inputs A and B (links LK3 and LK4 respectively) should be set to match the Transmitter. Note that, unlike the Transmitter, leaving a link disconnected on the Receiver sets that rate input to a logic 1. Once again, switches may replace all these links if desired.

Once two valid data words have been received the five-bit data is placed on the five output lines (IC3 pins 11 to 15), Output A (least significant bit) to Output E (most significant bit). After a short delay (about 4µs) the Data Ready line (pin 10) drops to logic 0 and stays low as long as valid data is being received. All outputs are compatible with TTL and CMOS logic levels.

OPERATING MODE

When data transmission stops, Data Ready goes high again and the five data outputs will behave in one of two ways.

a) If link LK5 is set to logic 1 (momentary mode), the outputs will all return to 0V.

b) If link LK5 is set to logic 0 (latched mode), the outputs will remain latched to the last valid code received and will not change until a new code is received.

Light emitting diodes D4 and D9 indicate the logic states of the outputs and, although their presence is not essential, it is recommended that they are included as they greatly aid setting-up and fault tracing.

In "latched mode" the data outputs may be reset to 0V at any time by briefly taking IC3 pin 2 to 0V. Capacitor C11 provides a reset pulse during power-up.

The tri-state outputs (A to E) may be put into a high impedance state by taking IC3 pin 9 to a logic 1 level. The ability to isolate the output lines makes it easy to interface them directly to a microprocessor bus where it is important that they do not clash with other devices serving the bus. For "normal" use, link LK6 enables the outputs continuously by tying pin 9 to 0V.

RECEIVER POWER SUPPLY

The power supply requirements for IC3 calls for a well regulated +5V rail and this is supplied by the voltage regulator IC4. The input voltage to IC4 should lie in the range +7V to +25V. Current consumption of the Receiver circuit rises to about 60mA when *all* l.e.d's are switched on.

Capacitors C14 and C15 decouple and stabilise the +5V supply rail and capacitor C16 helps to stabilise IC4. If a clean, regulated 5V source is already available in the main system in which the Receiver is being used then IC4 and C16 may be omitted and the Receiver can be supplied with power directly onto its +5V rail.

CONSTRUCTION - TRANSMITTER

Thanks to the use of dedicated integrated circuits to perform the complex functions of data encoding and decoding and signal processing, the construction of the Transmitter and Receiver sections is very straightforward.

The Transmitter and Receiver printed circuit board (p.c.b.) component layouts, along with the full size copper track patterns, for the Universal Infra-Red Remote Control are shown in Fig. 5 and Fig. 6. These two boards are obtainable, as a pair, from the *EPE PCB Service*, codes 811T and 811R.

Commence construction with the Transmitter p.c.b. Solder all the components to the board, paying attention to the polarity of the electrolytic capacitor C4. Similarly, transistor TR1 must be inserted the correct way round as must the two infra-red diodes D1 and D2 (details given in Fig. 5).

In the prototype unit these two diodes are soldered directly to the p.c.b. and their lenses protrude through the end panel of the plastic case which houses the entire Transmitter. This anchorage helps to support the circuit board within the case.

Use an 18-pin d.i.l. socket for IC1, do *NOT* solder the i.c. directly to the board, and do *NOT* insert the i.c. into its socket until all construction work is complete.

Use p.c.b. terminal pins for all flying lead connections, that is connections to the keypad and to the battery clip for B1. It is also convenient to make the links LK1 and LK2 between terminal pins as they can be changed at a later date.

At this stage, decide which data transmission rate to use (see earlier in text) and solder link LK1 to set the Rate A input of IC1 to **either** +9V (logic 1) **or** 0V (logic 0). Do similar with the Rate B input using link LK2. The links may be replaced with changeover switches if regular alteration of the data rate is anticipated.

KEYPAD CASE

The actual type and size of case used depends on the number of keys to be crammed onto the front panel. Constructors can create their own keypads from discrete switches wired to give the required set of transmission codes or it may be more convenient to buy one of the numerous types of matrix-wired keypads available, ranging from the "telephone style" pad to the "rubber membrane" type which can be customised with your own logos.

The prototype model uses one of the low-cost telephone style keypads, with numeric keys 0 to 9. It should be noted that, because the keypad is only three columns wide, and since it is pre-wired in a matrix fashion, the transmitted codes do not correspond to the numbers on the keys (see Fig. 2).

The "ON" resistance of the keypad switches can be anything up to 20 kilohms, so the switches used do not need to be particularly high quality!

If you possess an oscilloscope or a logic probe, you can test the completed Transmitter circuit by connecting the probe between the 0V line and the "drain (d)" terminal of transistor TR1. You should observe a potential of about 6V which, when a keypad switch is pressed, pulses down to almost 0V showing an inverted version of the type of p.p.m. data illustrated in Fig. 3.

CONSTRUCTION - RECEIVER

The receiver printed circuit board component layout and track pattern is shown in Fig. 6. Once again, assembly of this board is very straightforward and the components can be inserted in any convenient sequence.

Use two 16-pin d.i.l. sockets for IC2 and IC3, the voltage regulator IC4 can be sol-

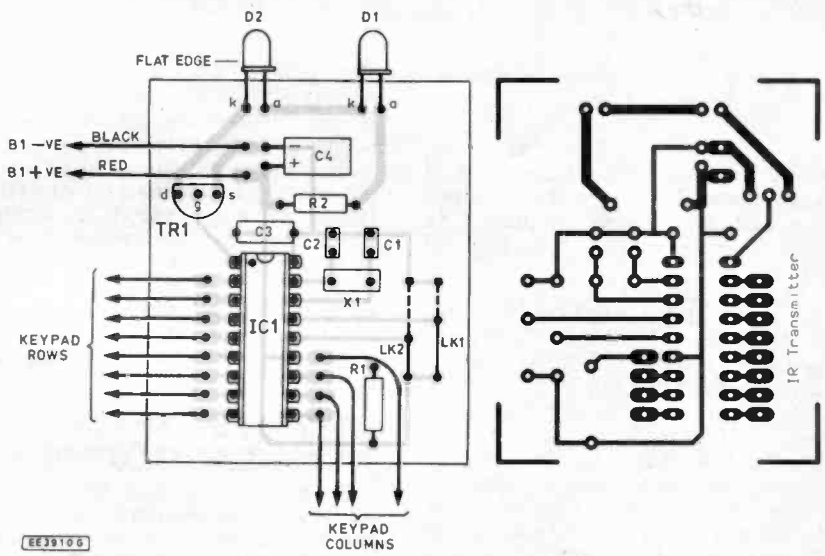
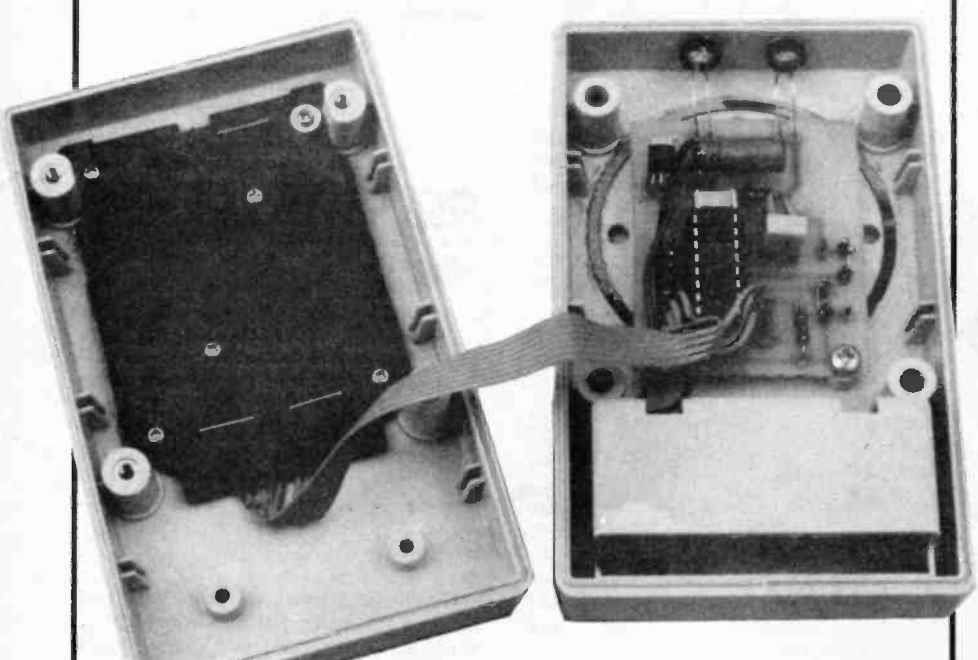


Fig. 5. Printed circuit board component layout, lead-off wiring and full size underside copper foil master pattern for the hand-held transmitter. The completed transmitter, the position of the p.c.b. and the ribbon cable from the board the the keypad can be seen in the photograph below.



COMPONENTS

Transmitter & Receiver

Resistors

R1	10k
R2	1
R3	4k7
R4 to R9	270 (6 off)

All 0·25W 5% carbon (or better)

See SHOP TALK Page

Capacitors

C1, C2, C12, C13	100pF ceramic (4 off)
C3, C11	0µ1 polyester (2 off)
C4	100µ radial elect., 25V
C5	6µ8 tantalum bead, 16V
C6	47µ radial elect., 25V
C7	15n polyester
C8	33n polyester
C9	4n7 polyester
C10	0µ15 polyester
C14	22µ radial elect., 25V
C15	0µ47 polyester
C16	0µ22 polyester

Semiconductors

D1, D2	High power infra-red emitters (2 off)
D3	Infra-red sensitive photodiode
D4	Green l.e.d.
D5 to D9	Red l.e.d. (5 off)
TR1	VN10KN *n*-channel MOSFET
IC1	MV500 transmitter
IC2	SL486 IR amplifier
IC3	MV601 receiver
IC4	78L05 5V 100mA voltage regulator
X1, X2	500kHz ceramic resonator (2 off)

Miscellaneous

B1	9V PP3 battery and clip for transmitter

Single-pole push switches for keypad or ready-made membrane keypad etc.; suitably-sized case for transmitter; 16-pin d.i.l. sockets (2 off); 18-pin d.i.l. socket; terminal pins; connecting wire; solder, etc.

Printed circuit board for Transmitter (811T) and Receiver (811R) available from the *EPE PCB Service* as a pair.

Approx cost guidance only **£32**

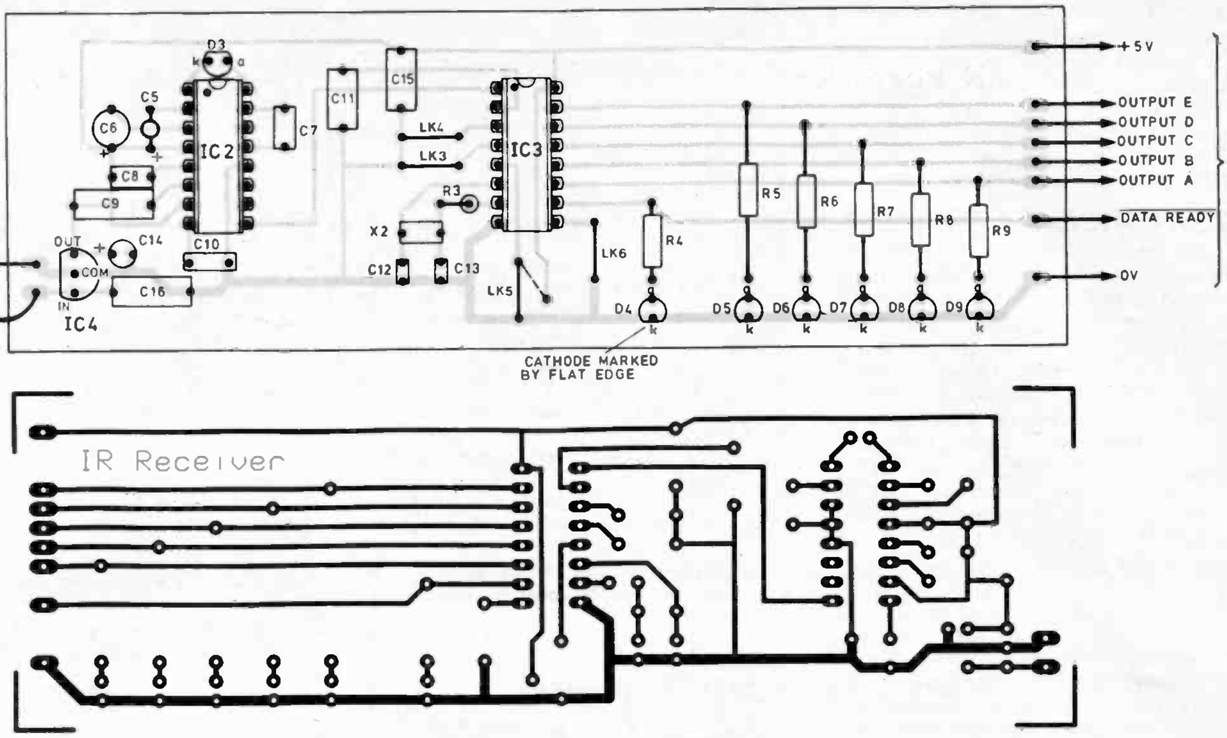


Fig. 6. Receiver and supply regulator printed circuit board component layout, full size underside copper foil master pattern and lead-off wires.

dered directly to the board. The tantalum bead capacitor C5 and the two electrolytic capacitors C6 and C14 must all be inserted the correct way around; pay careful attention to the *plus* or *minus* markings on their cases. Similarly, the six light emitting diodes D4 to D9 have a small flat edge on their case which denotes the cathode (k) lead.

The cathode lead of photodiode D3 needs to be soldered to the track connecting to pin 1 of IC2. Methods of notating the cathode vary on different photodiodes so refer to the manufacturer or supplier for details.

The infra-red amplifier (IC2) is very sensitive and to avoid excessive noise being picked up, the photodiode should be soldered *directly* to the board rather than being linked to the board with flying leads. When used in surroundings which are prone to electrical noise, the entire Receiver p.c.b. may need to be screened inside a metal box containing a small "window" to admit IR light to the photodiode. Screening was not found to be necessary when using the prototype unit.

Insert terminal pins into the p.c.b. for all the off-board connections and for the links LK3 to LK6. The data rate links LK3 and LK4 should be soldered to *match* those set on the Transmitter. On the Receiver p.c.b., leaving a data rate link **disconnected** sets that Rate input to **logic 1**.

Link LK5 should be made between IC3 pin 5 and 0V for **latched** output mode, or pin 5 and +5V for **momentary** mode. Unless the tri-state output feature is required, insert link LK6 to enable the outputs continuously.

TESTING

Before inserting IC2 and IC3 into their sockets, test the voltage regulator on the Receiver p.c.b. by connecting a power supply of between 7V and 25V to the Receiver board. Using a voltmeter, check the p.d. between the 0V and +5V terminal pins adjacent to the Receiver outputs; the reading should be close to 5V.

If the voltage is significantly away from 5V or if voltage regulator IC4 becomes hot, switch off and find your mistake! Do *not* insert the other two i.c.'s until they can be sure of a safe 5V supply.

Remove power whilst inserting IC2 and IC3. When the completed circuit is switched on, only the "Data Ready" l.e.d. (D4) should illuminate. It is worth re-checking the Receiver power supply with the chips now in their sockets; it should still be around 5V.

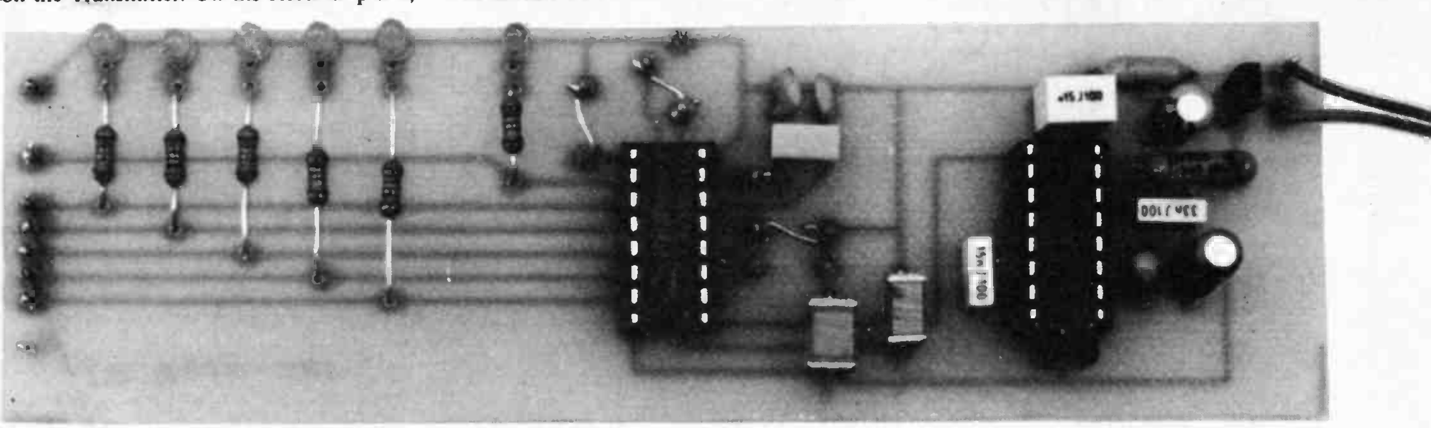
Pressing a key on the Transmitter should cause the Data Ready l.e.d. to extinguish and the five output l.e.d.'s (D5 to D9) to display the binary code of the selected key. Voltage regulator IC4 may become warm when several l.e.d.'s are lit up together; this is normal.

If the Receiver fails to respond to the Transmitter, check for obvious errors such as wrongly inserted i.c.'s or a flat Transmitter battery. Don't forget that the selected data rate on the Transmitter *must match* that on the Receiver. Also, link LK6 must be made for the l.e.d.'s to light.

An oscilloscope connected between the 0V line and IC2 pin 9 should display the received p.p.m. data (see Fig. 3) after amplification. If there appears to be excessive background noise on this signal then screening of the Receiver p.c.b. may be necessary.

OUTPUT CONSIDERATIONS

This completes assembly of the Universal Infra-Red Remote Control. What now follows are some suggestions for using the 5-bit Receiver output to control appliances in various modes. No construc-



tional details are given, but it is hoped that these circuits will give constructors ideas for their own customised designs.

It is suggested that the required output circuit is initially constructed on a prototype board (breadboard) linked to the IR Receiver. When its satisfactory function is assured, it can be built permanently on p.c.b. or stripboard.

CURRENT DRIVER

Each output line from the MV601 decoder (IC3) can supply a current of up to 45mA, 10mA is used to illuminate the output l.e.d., leaving 35mA to drive an external device.

To power any respectable-sized output device, some form of current amplifier is needed. The transistor/relay combination shown in Fig. 7 is the easiest and safest method of achieving this.

Two output drivers are shown, but the arrangement may be repeated for the number of outputs required. The 12V power supply is not exceptionally critical and does not need to be regulated.

The contacts of each relay are used as switches to turn on and off the current to each output device. Low voltage devices can be powered from the 12V supply, or mains-operated devices can be switched provided the relay contacts are rated for such work.

Take great care if you are dealing with mains voltages. Make sure that you fully understand what you are doing; if in doubt, get help from someone with the necessary experience. Mains electricity can kill!

It is possible to independently control up to five appliances directly from the five output lines, A to E. Pressing key "1" on the Transmitter will make output A go high and turn on the relay connected to this output. Similarly, key "2" will make Output B go high; key "4" activates Output C; key "8" activates output D and key "16" activates output E. Wiring details of the five-button keypad for this application are shown in Fig. 2.

Furthermore, if two or more of these five keys are pressed simultaneously then the appropriate lines will still respond.

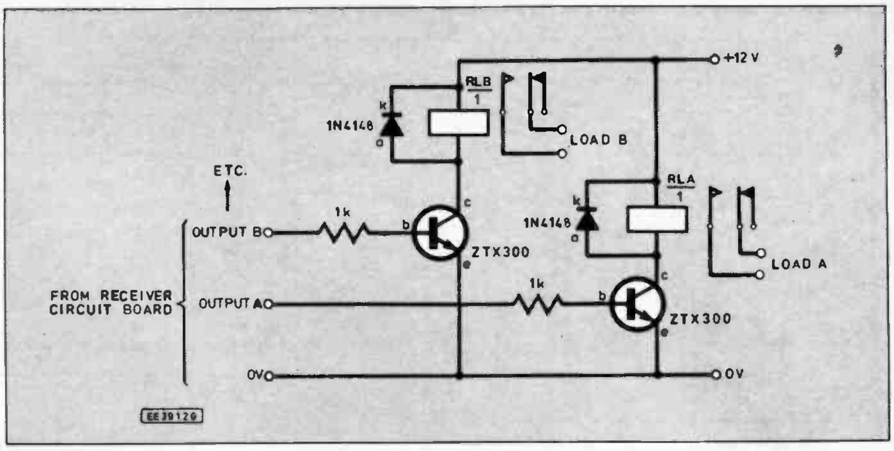


Fig. 7. Suggested transistor/relay output switching circuit diagram.

For example, pressing keys "8" and "2" together will switch on Outputs D and B. Neat, eh !

Depending on the desired application, the outputs may be used in latched or momentary mode.

OUTPUT DECODING

If more than five separate outputs are required then some degree of decoding is required.

The circuit diagram Fig. 8 shows how two 3-to-8 line decoders can be chained together to give sixteen independent outputs. Only one output will go high at any one time depending on which key, from 0 to 15, had been pressed on the Transmitter.

If eight or less outputs are required then only one 74HCT238 i.c. is required. Furthermore, chaining in further 74HCT238 chips will allow all 32 outputs to be decoded. This feat is left as a reader's exercise!

Every output from the decoder i.c.s will need a transistor/relay current switch as shown in Fig. 7 if they are to control external appliances. The 5V power supply for the decoder i.c.s comes from the IR Receiver board.

OUTPUT TOGGLING

It is often convenient to be able to switch an appliance ON with one press of a Transmitter key, and switch it OFF again with another press of the same key. This on-off-on switching is called "toggling" and the circuit of Fig. 9 shows one way of achieving it.

Each box in the circuit is a J-K flip-flop and there are two such flip-flops in each 74LS73 integrated circuit. A separate flip-flop is required for every output to be toggled. The inputs to each flip-flop come either direct from outputs A to E on the IR Receiver p.c.b. (if five or less outputs are required) or from the 74HCT238 decoder i.c.s (if more than five outputs are needed).

The Reset inputs on all the flip-flops are connected together and the 0μ1 capacitor and 4k7 resistor provide a reset pulse at switch-on to put all outputs in the low (off) state. All outputs can be reset at any later time by momentarily pulling the Reset line down to 0V.

The 5V power supply originates from the IR Receiver board. For controlling external appliances, each toggle output will need buffering with the transistor/relay arrangement shown in Fig. 7.

Fig. 8. Using two 3-to-8 decoders to give 16 decoded outputs.

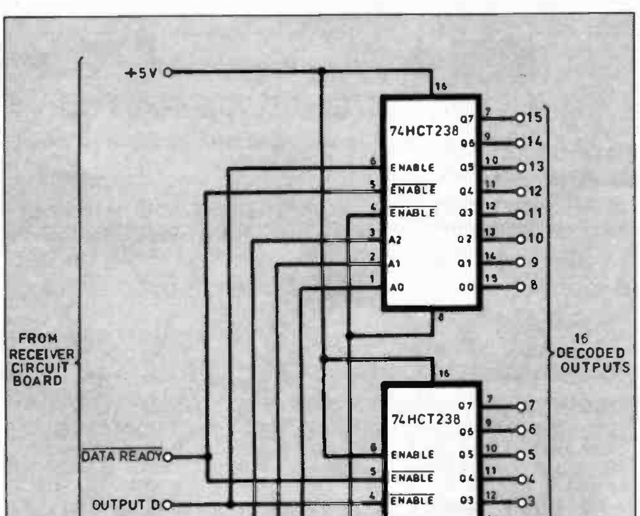
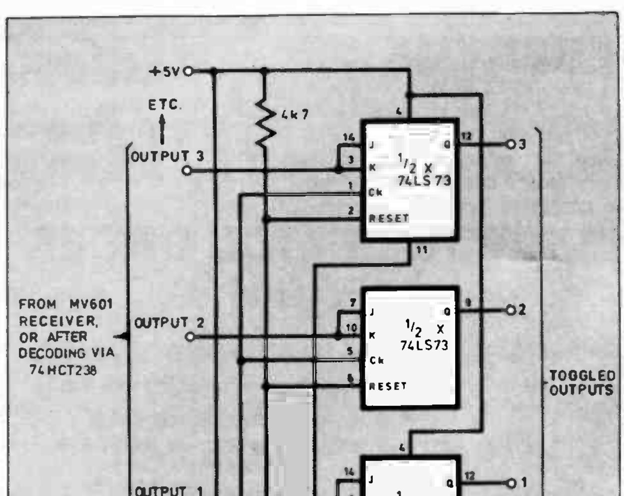


Fig. 9. Circuit diagram to enable on-off "toggling" to be achieved.



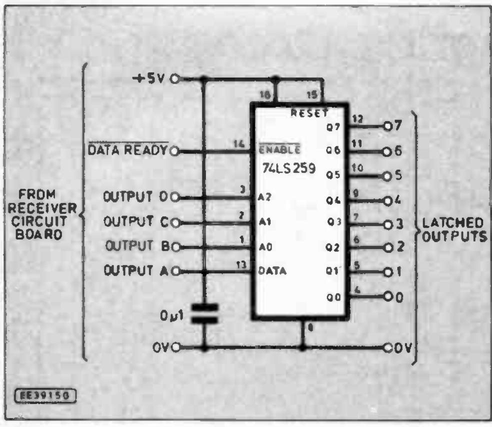


Fig. 10. Circuit to achieve off/on latching outputs.

OFF/ON LATCHING

Up to eight appliances can be latched OFF or ON with a separate OFF and ON key for each using a superb little i.c. known as an addressable latch, see Fig. 10.

The 74LS259 contains eight latches which are individually selected by the binary code on its Address inputs, A_0 to A_2. If a logic 1 is present on its Data input then the addressed latch will switch ON, whilst a logic 0 on the Data input will switch the latch OFF. All outputs may be Reset at any time by momentarily taking pin 15 to 0V.

By using Outputs A to D directly from the IR Receiver p.c.b., 16 keys on the IR Transmitter will give OFF and ON control of the eight outputs from the addressable latch. The functions are:

Key 0	Output 0 OFF
Key 1	Output 0 ON
Key 2	Output 1 OFF
Key 3	Output 1 ON
Key 4	Output 2 OFF
Key 5	Output 2 ON
etc. . .	

The 5V power supply for the latches originates from the IR Receiver board. For controlling external appliances, each latch output will need buffering with the transistor/relay set-up shown in Fig. 7.

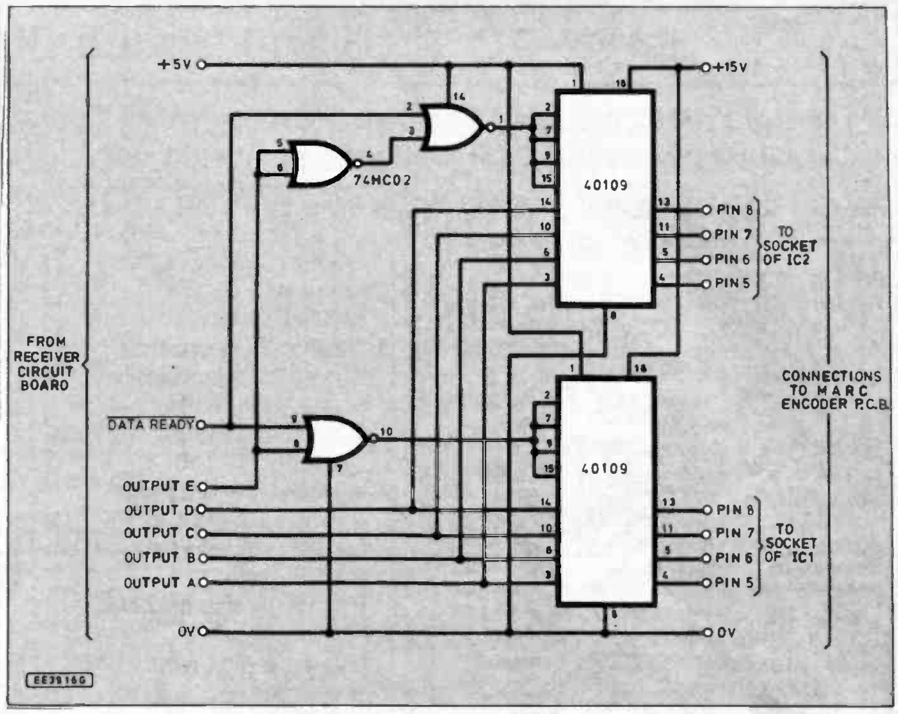


Fig. 11. Circuit diagram to enable the Universal IR Remote Control to be interfaced with the Mains Appliance Remote Control (MARC) *system published in the June/Sept '90 issues.*

MARC

In the June to September 1990 issues of *Everyday Electronics*, the author gave constructional details of a *Mains Appliance Remote Control (MARC)* system.

Unfortunately, since publication, two i.c.s involved with the infra-red remote control section have been discontinued because Plessey, the manufacturer, closed down one of their plants concerned with the manufacture of the ML926 and ML927 decoders.

However, for constructors who are still keen to make the MARC system (and the author's system is still in daily use), it is possible to interface the new Universal IR Remote Control into the existing MARC Encoder unit. The circuit diagram Fig. 11 shows the interfacing technique using two CMOS 40109 logic level shifters and a 74HC02 NOR-gate package.

On the MARC Encoder p.c.b., all components concerned with the infra-red section (up to and including IC1 and IC2) should be removed. The eight outputs from the logic level shifters in Fig. 11 are connected to the sockets of IC1 and IC2 (on the MARC Encoder) as indicated in Fig. 11.

It is necessary to make a 0V and +15V connection to the MARC Encoder p.c.b., but ***no connection*** should be made between +5V on the IR Receiver p.c.b. and +15V on the MARC Encoder p.c.b.

On the new IR Transmitter unit (the old one is now obsolete) keys 1 to 15 select the "Receiver Number" and keys 17 to 31 select the "Function Code". □

Innovations

A roundup of the latest Everyday News from the world of electronics

Keep Your Distance

A SYSTEM that provides an optical or acoustic signal to indicate the distance between vehicles when parking would be a big help, especially to learner drivers. That is only one potential application for the Sharp GP2D02 Distance Sensor. Other conceivable uses include, for example, measurements of fluid levels inside closed vessels, automatic flushing for toilets, control of tools and machining operations for CIM systems, etc.

The Distance Sensor functions as both, a proximity sensor and a distance measurement sensor, and is unaffected by the object colour or reflection ratio. An infra-red l.e.d., a position sensor and a signal-processing circuit are all integrated into a single module which is less than one-eighth the size of conventional components!

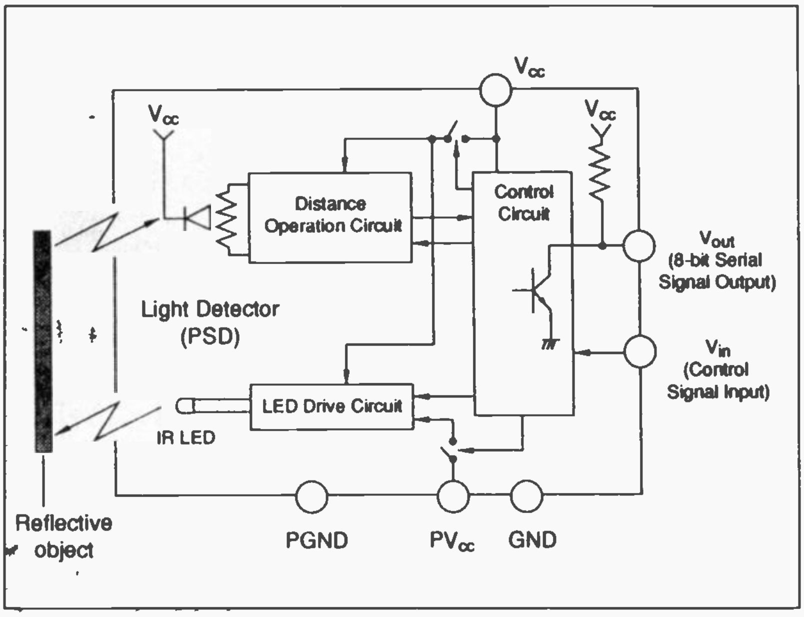
How It Works

The GP2D02 is based upon the principle of using a light-emitting diode to send out high-speed bursts of infra-red light so that objects lying within the beam of light (angle of dispersion ±3°) reflect part of the light back to a unique sensor developed by Sharp.

The relationship between two currents in the position-sensitive detector changes as a function of the angle of reflection, which is determined by the distance between the object and the sensor. This change is monitored at various points, and the signal-processing circuitry uses this information to produce an 8-bit value which is also the average of the various input values.

This method permits a claimed accuracy to within ±10% for distances between 4cm and 30cm (Type 1) or 10cm to 80cm (Type 2). The measurement range can also be varied to meet customer requirements by changing optical components.

The module consumes 7mA in the quick-charge mode and 4·5mA in the standard mode. The sensor switches to a stand-by mode in the absence of reflected light, and current consumption drops to 7μA. The infra-red l.e.d. operates on voltages between 2·7V and 7V and the control circuit on voltages between 2·7V and 3·5V.



HOME AUTOMATION

HOME AUTOMATION is in its early days – about the same stage as the micro computer in the early '80s. It offers a tremendous opportunity for the enthusiast to contribute to progress in the same way as with micro computers.

The current home environment is a mass of discrete systems, lighting, heating, security, audio/visual, just waiting to be linked to provide convenience, security and energy savings. Future home automation standards are under development (Echelon, CEBus) though almost all of today's systems are based on the well established X-10 power line carrier standard.

Smart House Systems offers free advice and an ever expanding range of products from X-10 lighting control modules at £19.95 to the Ener-logic home automation controller at £349.95.

Smart House Systems Ltd, Dept EPE, 3 Buckland Street, Largs, Ayrshire KA30 8PP. Tel: 0475 672589

BUILD YOUR OWN PC

ORGANISERS of *The Christmas Computer Shopper* show, Blenheim, are hosting the UK's first Build Your Own PC competition. The competition will take place during the event from 19 to 22 November.

Schools throughout London have been invited to put together teams for the competition. Each received a copy of the manual in advance and will compete under the guidance of their IT Master to build a PC in the fastest time. The winning team will keep the PC for their school.

21 YEARS COMPETITION

THE little free competition we ran in the news pages of the October '92 issue of EE resulted in a truly underwhelming response. Perhaps there are fewer readers that still have the first issue from 21 years ago than we expected. However, the three (yes three!) entrants each get a free Maplin catalogue and just to thank them all for taking the trouble we have also sent them a magazine binder each.

The correct answers were:

The first Teach-in was written by *Mike Hughes*
The first Shop Talk was written by *Mike Kenward*

(Yes indeed the present Editor, though I have had other jobs in the meantime–Ed.)

Our "lucky" prizewinners are: Mr S. E. Lartice from Enfield; Mr S. Keir from Dundee and Mr S. Carter from Portsmouth.

See the Readout page (page 795) for another "little competition" this month!

Young Radio Amateur of the Year

THE *Young Amateur of the Year* award for 1992 has gone to 17 year old radio buff Martin Saunders (call sign G7JCJ) of Broadstone, Dorset.

Martin was presented with the first prize of £250 by the Radiocommunications Agency's Head of Mobile Radio, Stephen Spivey, at the recent Radio Society of Great Britain's HF Convention at Windsor.

He also received a certificate signed by Michael Heseltine, President of the Board of Trade, to commemorate the presentation, and will be invited to the Agency's Radio Monitoring Centre at Baldock, Hertfordshire, for a conducted tour.

Martin's main interest is in packet radio, which involves transmitting data in packets of information. He assembled his own equipment and has been granted a Notice of Variation to his Amateur Radio Licence to operate a mailbox, a computerised distribution agency which can be accessed by other radio amateurs wishing to hear a message.

He has written a number of articles explaining packet radio and amateur radio generally. He has been appointed Secretary of his local packet group and serves on the forward planning committee of the Flight Refuelling Amateur Radio Society.

His close runner-up was Neil Mothew, aged 16 (call sign G7NGM) of Ashfields, Loughton, Essex, who was also very strong on home construction of radio equipment. Neil will also be invited to Baldock.

THEY'VE GOT THE POWER

A DOUBLING of power is claimed by BK Electronics with the release of their new 1000W MOS-Fet amplifier module. The OMP-MF1000 has taken over from the ever popular OMP/MF450 as the flagship of the OMP module range.

Delivering 1000W r.m.s. into a two ohm load, the OMP/MF1000 is claimed to provide a no compromise on price/power/performance ratio and, as with all of the OMP range, its advanced MOS-Fet circuitry achieves superb sonic clarity with enduring reliability.

The OMP/MF1000 is priced at £259, including VAT, plus £12.50 delivery, and is available from BK Electronics, Dept EPE, Units 1&5 Comet Way, Southend-on-Sea, Essex SS2 6TR. Tel: 0702 527572

AMS6 & Radio Rally

THE All Micro Show and Radio Rally will be held on Saturday, 14 November at Bingley Hall, Staffordshire Show Centre, Stafford.

This is the fourth consecutive year at the Staffordshire Show Centre and the All Micro Show is now established as a major computer and electronics show in the Midlands, ideally timed for the Christmas trade.

Previous shows have attracted a diverse mix of exhibitors ranging across the computing and electronics spectrum, including national PC suppliers, individual user groups, electronics component suppliers, TV and Video sales and spares, Ham Radio, Computer Media etc.

Breach of Security

A RECENT National Computing Centre (NCC) survey estimated that security breaches will cost Britain £1.1 Billion this year. This means that every IT installation in the UK stands to lose on average £22,000 this year due to loss of security. Even this figure may be too low as many incidents are unreported.

Impact On Growth

CLAIMING to be one of the worlds largest dot-matrix printhead repair companies, the American based Impact Printhead Services, opened its UK offices in January 1991.

It has obviously struck a niche in the market. Sales in 1992 have increased by 344 per cent compared with the same period last year.

"We have been staggered by our growth" said Andrew Gadd, UK General Manager, "but when we can save a customer over half the price of a new printhead, and give a one year warranty, it's not really that surprising".

Impact can be contacted at The City Business Centre, Dept EPE, 10 City Business Centre, Brighton Road, Horsham, West Sussex RH13 5BA. Tel: 0403 272627.

APPROVAL FOR CIRKIT

CIRKIT are pleased to announce that they have achieved approval to BS5750, Part 2.

The approval has been awarded as part of the company's on-going commitment to quality and service, meeting the exacting standards of BS5750, Part 2 – with the additional stockists supplement and equivalent to European EN29002 and International IS09002.

As everyone involved in the electronics industry will know, this is not an easy achievement. This coveted award is granted only after a thorough examination of the company's systems and procedures, and reflects the commitment of the entire workforce to a consistantly high level of service.

Cirkit's Quality Manager, Andrea Chapman, responsible for the successful granting of BS5750 approval.

European Customer Service

AN agreement between BT and Olivetti has been signed to ensure round-the-clock maintenance and support for the telecommunications giant's growing number of customers in Europe.

The agreement gives BT's customer support organisation access to Olivetti's established customer service infrastructure *Oliservice* throughout mainland Europe and means that customers can be offered service level agreements which guarantee response times of as little as two hours. The European Customer Service Centre (CSC) in BT's Paris Eurocentre provides multi-lingual support to customers. The CSC, which also houses a network control centre, will now be able to call upon trained Olivetti staff in addition to its pesent resources.

The European Customer Service Centre is also linked to network management centres in London and the US, providing comprehensive service and support.

New Technology Update

Ian Poole reports on techniques for reducing i.c. size, high output l.e.d.s and low voltage logic

ONE of the major thrusts of i.c. technology development is to produce ever smaller structures for use in chips. By doing this more can be packed onto a single i.c. and this in itself brings many benefits. Increased speed and reliability together with reduced costs are just three.

This pressure for size reduction is being applied to the reduction of dynamic RAM sizes as much as anywhere else. However one of the major size restraints is imposed by the small capacitors which are used to store the data in these chips. For the individual cells to be able to reliably store data they must have sufficient capacitance. If the capacitor is too small then insufficient charge will be stored for the data to be detected at a later time.

Capacitors

The main problem for RAM designers is that the amount of capacitance required governs the physical size of the capacitor. To try to overcome this capacitors using a V or trench structure have been used. This gives a larger area for the capacitor whilst taking up no more surface area on the chip itself. Whilst this method is reasonably successful it only provides a limited improvement.

A much more promising approach is now being developed. The key to it has been made possible because researchers have been able to deposit very thin layers of titanium oxide onto the i.c.s. This material has about 20 times the dielectric constant of silicon oxide/silicon nitride which is normally used. Consequently it means that the size of the capacitors can be reduced by about the same ratio.

Apart from the reduction in size, titanium oxide offers a number of other advantages. The most important is that capacitors made with it do not suffer from the same loss of charge that ones made from silicon oxide do. This means that these i.c.s will be more reliable than their silicon oxide counterparts.

Whilst there are several advantages to using titanium oxide there are also some disadvantages. The major one is that the processes needed for handling titanium oxide need to be controlled very stringently. Even so, they are now well advanced and i.c.s using the new process should be seen on the market within the next year.

Bright Lights

Traditionally l.e.d.s have only been used as small indicators. They have not had the power to compete with tungsten lamps. Whilst some high power red and orange l.e.d.s have been manufactured no yellow ones have been available. This is set to change. Toshiba have recently launched a range of high output yellow l.e.d.s which can be used in a number of areas where only tungsten lamps have been used.

To obtain the high light output a totally new structure has been used. This was developed because the l.e.d. itself absorbs a large amount of light, reducing the brightness quite considerably.

To overcome this absorption the new structure uses an indium gallium aluminium phosphide active layer. This layer also includes a reflector consisting of a multi-layer structure to cut the light loss.

By using this structure the light output of the l.e.d.s has been raised to a level which is typically ten times as much as standard yellow l.e.d.s. A figure of six candela at a wavelength of 590nm is quoted. This means that these l.e.d.s will be able to be used in a number of outside applications including roadside displays where previously only the relatively inefficient tungsten lamps have been used.

Low Voltage Logic

Five volts has been a standard voltage rail for digital circuits for as long as most people can remember. It has served well as the supply voltage for virtually all the families of i.c.s since before the power hungry standard 74 family of i.c.s was introduced.

Now technology is advancing and more requests for very low power systems are being placed before system designers. Laptop and notebook computers are two prime examples of the need for power reductions.

By reducing power consumption battery lifetime can be increased in addition to reducing the size of batteries. This is a great advantage because the two main complaints about laptop computers are the short time which these computers can be used on their batteries between charge and the size and weight of the batteries.

To achieve power reduction designers are turning to lower voltage logic as a means of achieving a solution. As a result it now appears that 3·3 volts is becoming an alternative standard to 5 volts for these applications.

A surprising amount of progress is being made. All the major manufacturers of 286, 386, and 486 processor chips are now developing or actually marketing 3.3 volt versions of these chips. In addition to this most of the peripheral chips are now available to operate along side the processors.

For the i.c. manufacturers there are a number of advantages to using 3·3 volts. Having lower supply rails means that some of the internal dimensions of components within the chips can be reduced. The most obvious is that the thickness of the gate insulation layer in the f.e.t.s can be reduced from about 150Å to just 100Å. Gate sizes can also be reduced. Consequently the component sizes in the chip can fall quite significantly.

Redesign

The modifications to enable the i.c.s to operate at lower voltages require some major changes. A full process redesign is needed in addition to any small dimensional reductions.

Many of the circuits have to be changed. This can be very expensive but it has to be undertaken to ensure that the circuit operates correctly and efficiently at the new voltage. Transistor thresholds need to be altered. Also inefficient logic structures need to be replaced by new ones which operate more satisfactorily at the new levels.

Standard techniques do not always provide the best solution. Often new techniques have to be used. One such example is a new process called SIMOX (separation by implantation of oxygen) which can give enormous improvements.

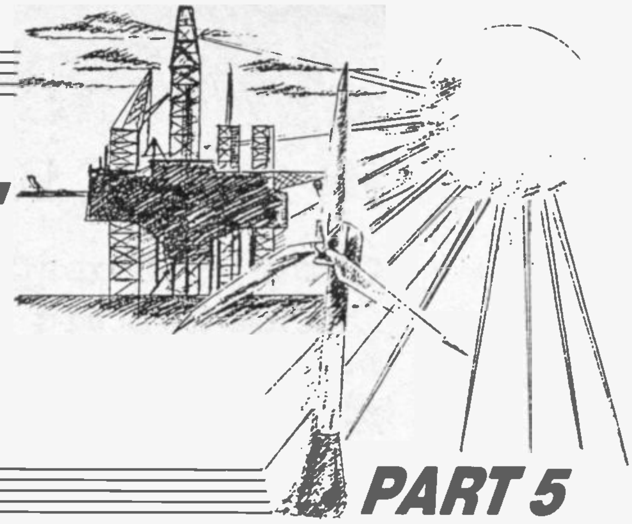
It has been found that transistors fabricated using this process have a much higher drive capability. On top of this they can run 50 per cent faster than transistors fabricated in the normal way. This means that the new transistors can operate just as fast at 3 volts as standard ones do at 5 volts.

With the reduction in size and the use of SIMOX designers now have several options open to them. If all the parameters are optimised for speed then the new 3.3 volt chips can operate faster than their 5 volt counterparts. Alternatively the chip could be designed to give the lowest power consumption, or the smallest chip size whilst keeping the performance the same.

Whatever option is taken by the i.c. designers the new 3.3 volt logic is certainly an exciting development which is likely to have a large presence in the semiconductor market of the near future.

Special Feature

ALTERNATIVE ENERGY



T. R. de VAUX BALBIRNIE — PART 5

Some further Alternative Energy sources.

THIS is the last in a short series about Renewable Energy – that is, sources of power which will last for ever unlike those derived from fossil fuels which will eventually run out. This month we shall look at some remaining renewable energy sources which have the potential for large-scale exploitation in the UK.

These are: energy produced by burning household and industrial waste, landfill gas, biomass and geothermal energy. These methods have been grouped together because they all involve the use of direct or indirect *heat*.

We shall also take the opportunity to look more closely at conventional nuclear power - that is, nuclear fission. Although not itself a source of renewable energy, it also produces heat and will help to put the whole topic of alternative energy into perspective.

WASTE NOT WANT NOT

Currently, 30 million tonnes of waste material per year are disposed of in the UK – that is, around half a tonne for every member of the population. Some 90 per cent of this is disposed of in the 5,000 landfill sites which are scattered around Britain. Using waste to provide energy seems a very attractive idea and one in which the Department of Energy is actively involved through a programme of funding research and development.

Waste material suitable for providing a useful amount of energy may be divided into two groups – *dry organic waste* and *wet waste*. Dry waste may, after suitable preparation, be burned directly. The fairly low technology required and the simplicity of the method are its greatest strengths. A further advantage is that it can reduce vast quantities of waste into a small volume and so simplify its ultimate permanent disposal.

DRY WASTE

Burning dry household and industrial waste involves certain problems. Firstly, the energy content is likely to be much smaller than in a comparable quantity of fossil fuel. Also, there will be a large amount of incombustible matter mixed with it.

Removal of certain types of material is possible such as the ferrous metals using an overhead magnet. However, sorting some of the waste at source would help. Sensible waste management involves *recycling*, whereby the producer of the waste removes certain combustible and non-combustible material such as paper, glass and metals for re-use.

Obtaining heat by burning dry waste in incinerators may be used for space heating, industrial processes close to the site or to produce electricity. This process already saves the equivalent of 100,000 tonnes of coal per year and there is the potential to improve on this. As well as household waste, it is possible to burn certain other types of scrap industrial and agricultural material such as wood.

BURNING RUBBER

One form of dry waste which deserves special mention is scrap tyres. Currently we in the UK dispose of old tyres with an energy content equivalent to 200,000 tonnes of coal each year. Disposal of tyres in landfill sites causes instability so they are often refused. The cost of disposal by other means is then considerable. Burning them under controlled conditions seems an attractive idea and could present a worthwhile energy source in the future.

A further idea is to burn hospital waste. Some is harmless general combustible waste but there is other material which could be dangerous if not disposed of by high-temperature incineration – the so-called *clinical* waste. Separating the two types is difficult and, in practice, the health authority will burn all of it. This involves the use of fuel to reduce it to ash – an energy-hungry process.

The Yorkshire Regional Health Authority alone currently produces 12,000 tonnes of waste per year. Nationwide, Britain produces hospital and similar waste (i.e. from homes for the elderly, etc) to the equivalent energy value of over 400,000 tonnes of coal per year. Several health authorities are now considering self-fuelled on-site incinerators with energy from the waste itself being used for central heating coupled with electricity generators.

In some schemes, the waste is used to produce bulk background power, with conventional (fossil) fuels being used to top-up the output as necessary – in particularly cold weather, for example.

WET WASTE

The use of wet waste and landfill material to generate gas involves a process of *anaerobic digestion*. Here, bacteria decompose organic material in the absence of oxygen to produce *methane* (see Fig. 1). Methane is the same as natural gas obtained from the North Sea reserves and is an excellent fuel.

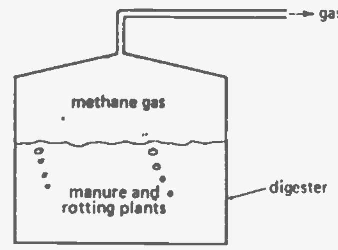


Fig. 1. Production of methane from anaerobic digestion.

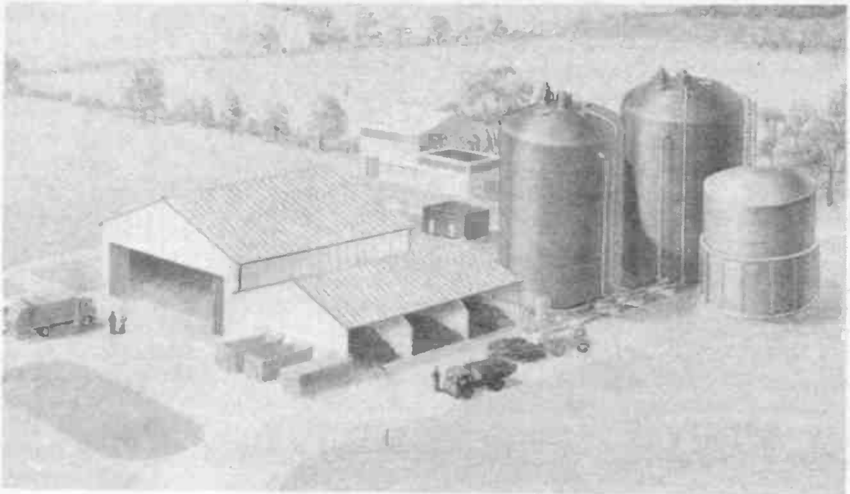
On a small, local scale – for example on a farm – the process may be carried out in a large vessel called a *digester*. Any animal or plant waste (such as chicken-droppings), sewage and certain other material may be treated by simply allowing it to decay in the digester and piping off the gas. This process can yeild approximately 60 per cent methane (but usually nearer 50 per cent) the rest being *carbon dioxide*. This gas mixture may be used for heating or cooking. There may be a future for large-scale digesters for bulk treatment of household waste to produce electricity.

LANDFILL GAS

The UK has been using landfill gas (LFG) since the early 1980's and, together with the United States, is a leader in this technology. There are currently more than 33 large-scale landfill gas extraction schemes in operation in the UK. Burning the gas and using the heat to generate electricity produces some 18MW of power with a total coal saving of 150,000 tonnes per year.

So attractive is this method that it is thought that by the end of the century, the energy contribution from LFG could be equivalent to one million tonnes of coal per year. Apart from the benefits to be gained by using less fossil fuel, it also means that the gas is removed from the site instead of being left to find its way into the atmosphere. This could cause offensive odour blown by the wind over a wide area. Also, since methane is a very flammable gas, there is a danger of explosion if it is allowed to build up in confined spaces.

The rate at which landfill material produces gas depends on several factors such as the exact nature of the waste, the temperature and its moisture content. Typically, on a new site, production begins within a few months of deposition then builds up and maintains a useful output for 15 years or more.



A digester producing methane on a farm.

One tonne of refuse may be expected to yield 135 cubic metres of gas with present technology. However, the theoretical yield is much greater and will, no doubt, increase as the technique for extraction improves. At the moment, the gas is removed by a series of wells drilled into the waste and connected to a pumping system.

Landfill gas may be used simply for local heating or to fuel some industrial process close to the site – to fire brick kilns, for example. Alternatively, the methane may be used to power a *gas turbine* and generator to make electricity. A gas turbine is like a jet aircraft engine – the fuel is burned and the hot gasses produced turn the turbine blades.

In a jet aircraft, *thrust* is produced but here the power is taken from the rotating turbine shaft to turn the generator. The Centrax gas turbine at Meriden fuelled by LFG has a rated output of almost 4MW. The electricity is then sold to the Midland Electricity Board under contract.

It is thought that by the end of the century, the electrical power generated by landfill gas could exceed 175MW (the output of a small coal-fired power station). Research is being funded by the Department of Energy with a view to exploiting this source of power at more sites. Research includes the study of the microbiological process by which the methane is produced. This is because, at the moment, they are not particularly well understood and such knowledge could help to improve the yield.

BIOMASS - ENERGY FOREST

Growing crops for fuel rather than food or manufacture is called *biomass*. In Part 1 of this series (August, 1992 issue), we saw how the Brazilians have turned this idea to good use by making alcohol from sugar. This may then be used as a petrol substitute and used as a fuel for cars. This relieves the pressure on oil from which petrol is obtained. Up to five per cent of alcohol may be blended with petrol with no detrimental effect but more may be used providing certain modifications are made to the engine.

It is interesting to note the large area of land in the UK which over-produces food – currently, one million hectares approximately (almost 2·5 million acres). This land is therefore available for other purposes such as for the production of biofuels. Trees may be grown simply for their fuel value and the Department of Energy is investigating various *energy forestry* schemes in the UK – in particular, in Northern Ireland, Scotland and southern England.

Wood can be used as an industrial fuel and is a renewable energy source so long as the trees are grown at least at the same rate as they are being burned. It is anticipated that by the end of the century, an equivalent saving of one million tonnes of coal will be made using existing sources alone.

By growing wood specifically for the purpose, the saving could be equivalent to at least eight million tonnes of coal per year. Most of this would be used directly for heating purposes simply as a substitute for coal or oil. However, it is also possible to burn it in a more-or-less conventional power station to generate electricity.

Using wood as a fuel has the advantage that sulphur dioxide emission and hence acid rain is much less of a problem than with coal. A further advantage is that much of the technology needed for energy forestry is familiar, well-developed and relatively inexpensive. This, in practice, means that the method is a very attractive one.

GRASPING AT STRAWS

At present, some eight million tonnes of straw are either burnt or ploughed back (incorporated) into the land each year. Straw does have some industrial applications – in the manufacture of fibreboard, for example. It also has some uses on the farm. However, an enormous surplus remains for which there is no particular use. Up to the present time, much of this excess straw has been simply burned in the field. However, this practice was prohibited after the 1992 harvest.

One way of using it is to burn the straw as a fuel under controlled conditions. Some 200,000 tonnes of straw are already used in this way and this is expected to rise to 800,000 tonnes by the end of the century. Unfortunately, straw can cause problems with dust. Also, it is an abrasive material which tends to wear the handling machinery.

Straw must be baled and stored (because it needs to be kept dry). Unfortunately, it has a low density – that is, it has a large volume for a given weight – so storage is expensive. Straw is also expensive to transport again, because of its low density. It may therefore be uneconomic to take it to a distant incinerator. A good way of using it is to burn the straw on the farm where it is produced using whole-bale burners to produce hot water.

Much of the heat may be used locally for domestic heating and for certain other jobs – grain drying and greenhouse heating, for example. Any excess hot water may be sold to local houses, factories, schools, etc. for central heating. The hot water could be sent the relatively short distances involved using feed pipes well-insulated to minimise heat loss.

Woburn Abbey already has a straw-burning scheme in operation which supplies heat for the entire historic home. The aim was to save £20,000 per year on oil, gas and electricity charges. The cost of the straw-burning installation was £150,000 but three boilers needed to be replaced anyway at a cost of £60,000. Also, it was found that further areas of heating could be added to the system.

The straw is handled in 1·2 x 1·2m round bales and delivered to the boiler twice per day from the nearby farm. A straw grater teases the straw out of the bale whereupon it is fed into the boiler. Straw burning is notoriously unpredictable since the material is not one definite substance but varies in composition. In practice, this means that although the plant is under automatic control, a boilerman is needed to solve minor problems as they arise.

COMPACT STRAW

There is some research being carried out with a view to compacting straw into high-density blocks or pellets. This could make transportation to large straw-burning power stations much cheaper. The use of straw as a fuel promises to make a significant contribution to our total energy requirements in the future and the methods will become even more attractive as fuel prices in general rise.

As well as being prominent in the field of wind energy (as we saw in Part 3 of this series – October, 1992 issue) Denmark also leads the way in straw-burning technology. A large number of projects have been set up there over the past few years to heat water and pipe it to private houses and public buildings for use in central heating.

Schemes are also in operation to generate electricity using special furnaces and conventional boilers and turbogenerators. One particular 30MW plant burns 25,000 tonnes of straw per year. Yet other power stations use straw enhanced by coal.

It is important to note that Biomass techniques are *carbon dioxide neutral* – that is, they do not contribute to the greenhouse effect because the carbon dioxide released on burning the crop is the same as the amount absorbed from the atmosphere to perform photosynthesis.

GEOTHERMAL ENERGY

Geothermal energy – often called the energy of *hot rocks* – is heat derived from the interior of the earth. Strictly speaking, geothermal energy is not a form of renewable energy since the heat of the earth is a finite resource - that is, the rocks gradually cool down as heat is extracted from them. However, the reserve of energy is so great that it may be regarded as renewable.

Some estimates put the equivalent heat content of all known hot rocks in the world as high as 50,000,000,000,000,000 tonnes of coal! This could, technically, provide the world with all its energy requirements for several million years.

It seems that there are two reasons why hot rocks exist below the earth's surface. Most of the heat probably derives from the heat of the Earth's core. Also, some of it may come about from the decay of natural radioactive material such as uranium.

Certain forms of geothermal energy are familiar and include volcanoes, hot springs and geysers. It is thought that the energy of volcanoes could not be exploited by present technology – not economically at any rate. However, geysers and hot springs can yield a significant amount of energy.

Geysers work intermittently as cold water flowing deep in the earth's crust becomes suddenly heated by the hot material around it. The water boils violently and bursts out through a crack in the ground. The gushing water and steam may then reach a height of up to 70m. The *Geysir* in Iceland (from which all others are named) sometimes reaches 55m.

Geysers and hot springs are chiefly found in volcanic regions such as Iceland. Here, the water may be used direct for central heating or for warming swimming pools, etc. The pavements of Reykjavic are heated by water derived from hot springs and this keeps them clear of ice.

AQUIFIERS

Aquifiers are deep underground rocks which heat water naturally. In Britain, aquifiers occur some 2km below the surface. These usually provide water at between 60 and 80 degrees (i.e. hot but not boiling). The hot springs at Bath emerging at about 49 degrees C are a good example of such hot water leaking to the surface.

Another example is the Southampton City borehole project which is a joint private sector/local authority district heating scheme. However, there is little prospect of really large-scale development of aquifiers in the UK and the research programme funded by the Department of Energy has been curtailed. Even so, the Department is continuing to fund the monitoring of the Southampton bore-hole project.

HDR TECHNOLOGY

Although Britain is not ideally served, we do have some sites especially in Cornwall where hot granite rocks exist deep below the surface and which may be used as a source of energy. It is thought that a significant proportion of Britain's electricity could be generated this way.

To extract the energy from the hot dry rocks (HDR technology), water is sent down a borehole or natural fissure increased in size by hydraulic fracture – the *injection well*. The water reaches the rocks, boils, and the steam is allowed to return to the surface through the *production well*. This may then be used for simple heating in domestic or industrial processes or used to operate conventional turbogenerators and produce electricity.

To boil water needs a temperature of at least 100 degrees C but, in practice, 200 degrees C is needed to superheat the steam and produce electricity efficiently. Drilling the boreholes is quite difficult due to the depth required – some 6km – and it may involve drilling through some very hard rocks on the way.

Less geologically stable areas than Britain are better suited to exploiting the energy of hot rocks. As well as Iceland already mentioned, countries with better resources include parts of Italy, New Zealand, Japan, Mexico and the United States. These countries all have large-scale geothermal energy programmes already in operation.

THE NUCLEAR ROAD

Nuclear *fission* – that is, the energy technology widely used at present is, like geothermal energy, not strictly a renewable energy source. This is because the process relies on *uranium* and this will eventually run out like the fossil fuels. However, the time scale is much longer.

It is thought that there are sufficient uranium reserves in the world – chiefly in the USA, Canada, Australia, Africa and France – to provide electricity for 1,000 years or more. The fission process produces no carbon dioxide so does not directly contribute to the greenhouse effect and possible global warming. However, there is some *indirect* use of fossil fuels.

Some fossil fuel is needed to build the nuclear plant including the power stations themselves, the re-processing works and storage sites. Some is needed for waste disposal. Yet more fossil fuel energy will be needed for decommissioning purposes when the useful life of the power station is over.

A view of Rosemanowes HRD site showing the well-head structures and the heat exchanger in the background. Crown copyright. Reproduced by permission of the Controller of HMSO.

On the other hand, there are some positive reasons for using uranium rather than the fossil fuels apart from the fact that the latter will eventually run out. The fossil fuels have great importance in their own right as chemicals for the manufacturing industry whereas uranium is a fairly useless material apart from its use in nuclear reactors. Also, uranium is a very concentrated source of energy compared with the others – one tonne providing the same amount of energy as 20,000 tonnes of coal.

Several countries have gone down the nuclear road to generate very significant amounts of their total energy needs this way. Table 1 shows, in descending order, the percentage of total electricity requirement generated using nuclear energy in several countries. The overall figure for Europe is about 30 per cent.

Table 1

Country	% of nuclear energy
France	75
Belgium	61
Sweden	45
Switzerland	42
Spain	38
Finland	35
Germany	34
Japan	28
UK	22
USA	19
Canada	16

Nuclear power production only differs from conventional electricity generation in the source of heat used. This is provided by the fission process carried out in the core of the nuclear reactor (see diagram opposite). There are several different types of reactor used in Britain.

The original design is called a *Magnox* reactor – the first practical one in the world was Calder Hall at Sellafield which was put on stream in 1956 and is generating to this day. The *Advanced Gas-Cooled Reactor* (ARG) followed. The most widely-used type of reactor in the world is in *Pressurised Water Reactor* (PWR) – see opposite. One of these is currently under construction at Sizewell (Sizewell B) in Suffolk and will operate alongside the existing (Sizewell A) Magnox power station.

Whatever type of reactor is used, they all behave in the same basic way – nuclei of uranium atoms are split by bombardment with sub-atomic particles called *neutrons*. This, in turn, releases more neutrons which can cause more splitting of uranium nuclei and a *chain reaction* results (see Fig. 2).

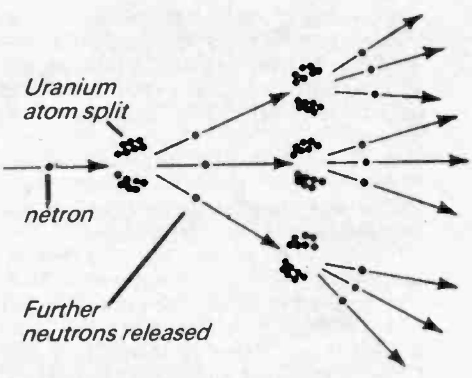
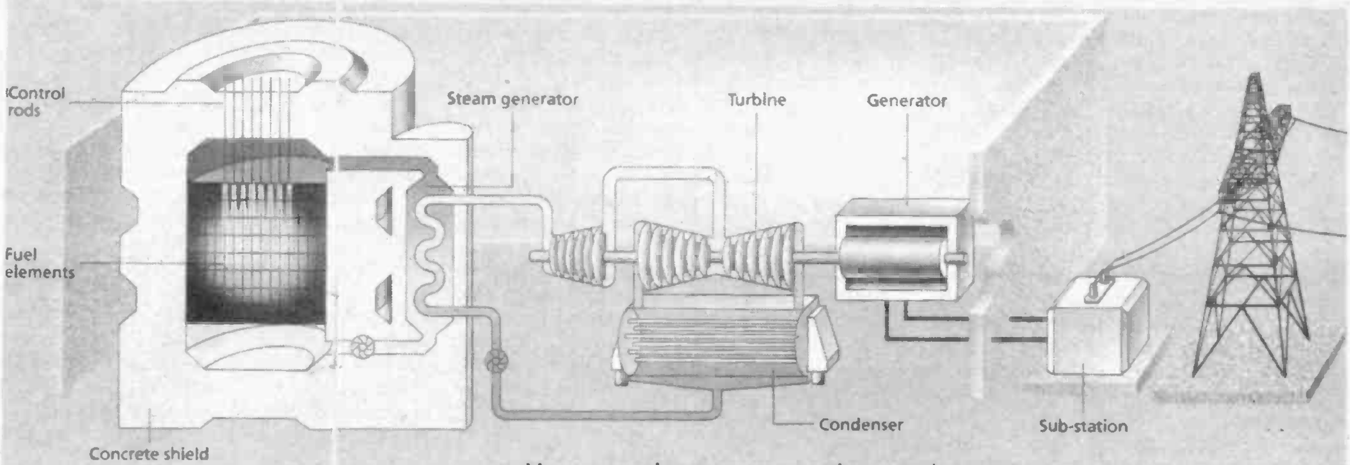


Fig. 2. The fission process.



How a nuclear power station works

This process produces a colossal amount of heat which is transferred to and carried away by a coolant such as water or carbon dioxide gas. This coolant then transfers its heat to water in a heat exchanger and returns for re-heating. The steam produced operates a turbogenerator and hence generates electricity.

Clearly, there must be a way of preventing excessive splitting of uranium nuclei with the ever increasing number of neutrons released. This would cause the system to go out of control. Excess neutrons are therefore absorbed by *control rods* to leave just enough to maintain a chain reaction and provide the amount of heat needed. Control systems ensure that the reactor shuts down completely in the event of any fault developing such as overheating.

WASTE

The nuclear fuel in the reactor gradually becomes less efficient and has to be replaced. In fact, only three per cent of the weight of this material is "waste" – the rest is unused uranium and approximately one per cent of a new material formed in the process called *plutonium* – a decidedly nasty substance both intensely radioactive and highly toxic.

The fuel may be re-processed to remove at least 96 per cent of the uranium and the plutonium. This leaves three per cent of the original material which constitutes highly radioactive liquid waste which has to be stored permanently. The volume of the high level waste produced by the British nuclear industry over the last 30 years or so is about the size of two semi-detached houses. Although this is a very small volume compared with the amount of waste generated by other industries, this material is very dangerous and must be stored carefully.

At present, the storage method used is to keep it in double-walled stainless steel tanks. A more recently-developed method is to reduce it to powder and then melt it permanently into blocks of glass – *vitrification*. This takes up only one-third of the volume of liquid waste and is much easier to store.

The process produces much larger quantities of intermediate-level and low-level waste – liquid and solid. The intermediate-level material is much less dangerous than the high-level variety and may be stored by encasing it in cement inside steel drums. The low-level material is only slightly radioactive and, after some treatment to make it still weaker, the liquid is disposed of in the sea and the solid stored in enormous vaults.

FAST BREEDER

The plutonium obtained from spent uranium fuel rods is itself used as a fuel in a certain type of reactor called a *fast breeder reactor*. This technique increases the energy obtained from the original uranium by a factor of 60 approximately.

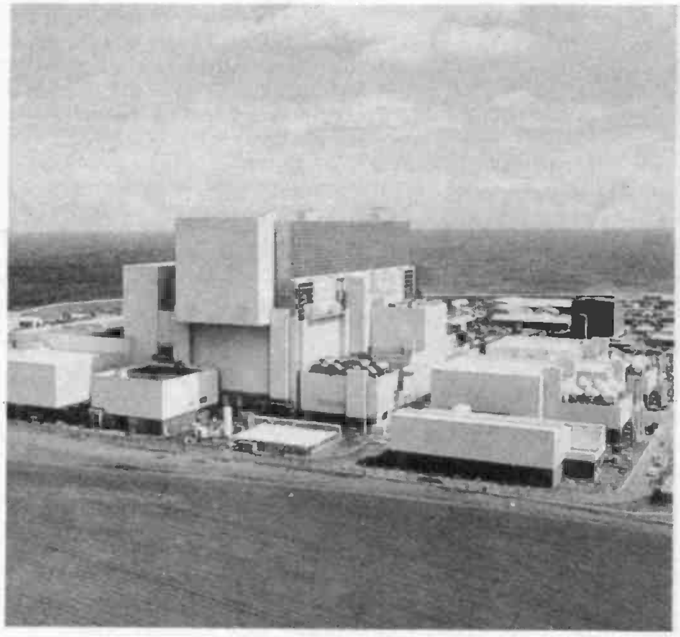
There is public concern about certain safety aspects of nuclear power. One fear – that of danger from direct radiation is unfounded – 87 per cent of the average dose of radiation for a person living in Britain comes from natural sources. Medical uses (such as X-rays) contribute about 12 per cent. Even flying in aircraft increases the radiation does due to cosmic rays entering the earth's atmosphere from space – see Fig. 3. Less than 0·1 per cent comes from the nuclear industry.

Other concerns come from the possibility of an accident resulting in the discharge of radioactive material into the atmosphere such as from the catastrophic event at Chernobyl in the former Soviet Union in 1986. However, this type of reactor was known to have serious design faults and would not be allowed in Britain. Saftey systems were turned off by the staff in a way which could not happen here.

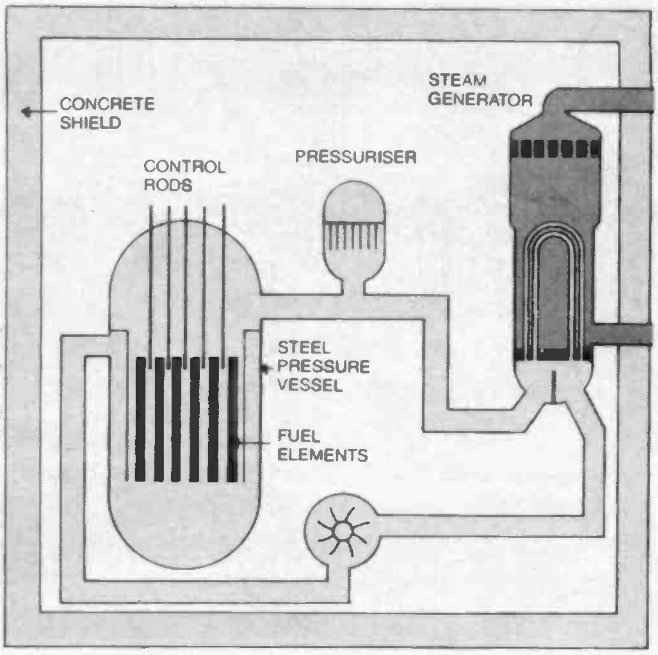
The other concern is that of nuclear waste disposal and the possibility of it entering the environment – perhaps by entering water supplies. British Nuclear Fuels, who manage the waste, go to great lengths to ensure the safety of their waste storage and disposal programme.

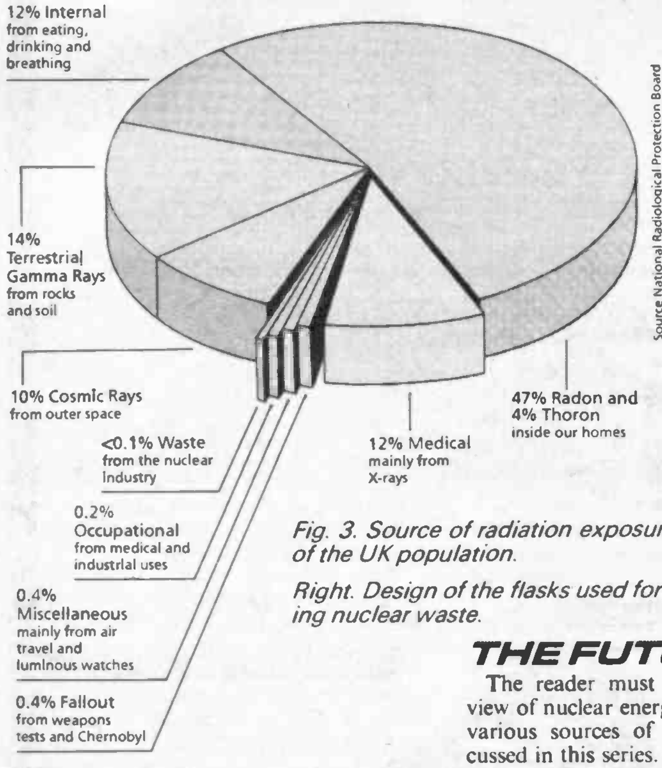
When nuclear material is transported,

An advanced Gas-cooled Reactor at Torness.



Basis of a pressurised water reactor (PWR).





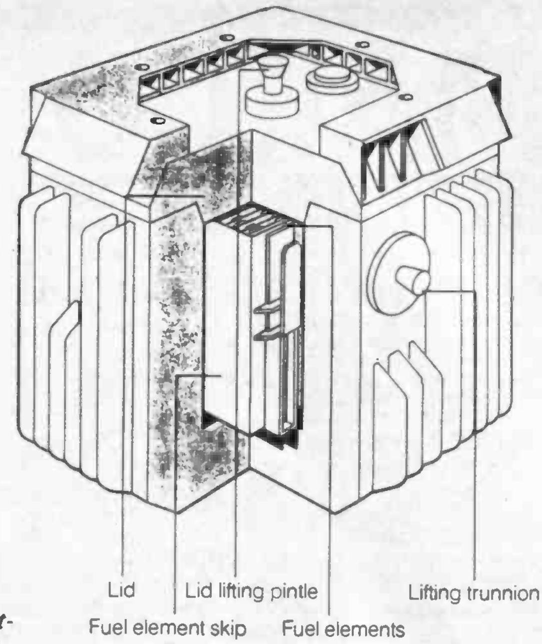


Fig. 3. Source of radiation exposure of the UK population.

Right. Design of the flasks used for transporting nuclear waste.

it is carried in steel or steel and lead *flasks* each weighing up to 110 tonnes (see above). The flasks have undergone a full-scale test involving a collision with a 140 tonne train travelling at 100mph. The locomotive was destroyed but the flask, which was placed in the path of the train in its most vulnerable position, withstood the impact without fracturing.

THE FUTURE

The reader must form his or her own view of nuclear energy balanced against the various sources of renewable energy discussed in this series. There is no doubt that nuclear power will continue to be a large-scale supplier of world electricity needs.

It does seem that several technologies will operate side by side with each making its own contribution to the total energy requirement. It may be that *nuclear fusion* will be the eventual single solution to provide our total energy needs – this topic was discussed in Part 2 of this series (Sept., 1992 issue).

It seems that man will have the energy he requires independently of fossil fuels into the foreseeable future. We will not have to go back to the days when he had to do all the work for himself or use animal power or slaves.

Many familiar techniques which have been developed for the old technology will continue. Perhaps the prophets of doom and gloom who foresaw unspeakable calamity – even the destruction of the Earth itself will be proved wrong after all. With good housekeeping the future is bright. □

We would like to thank British Nuclear Fuels PLC for their permission to reproduce many of the photographs and diagrams used in this article.

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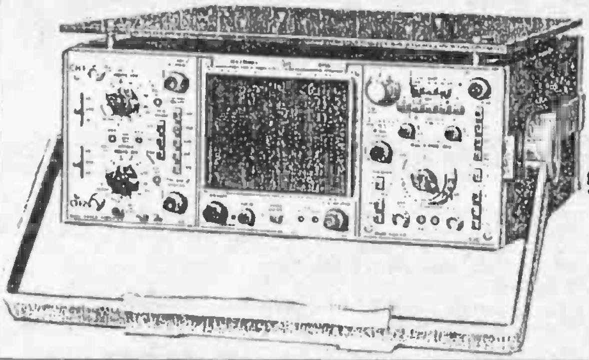

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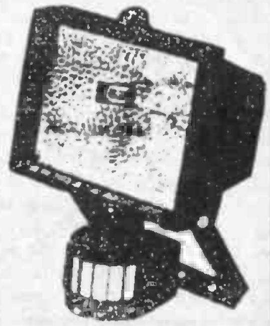

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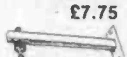

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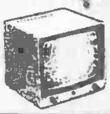

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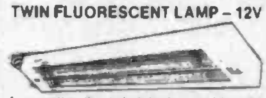

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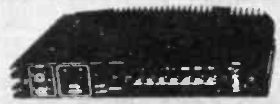

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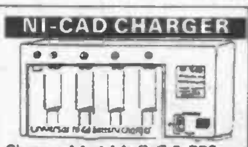

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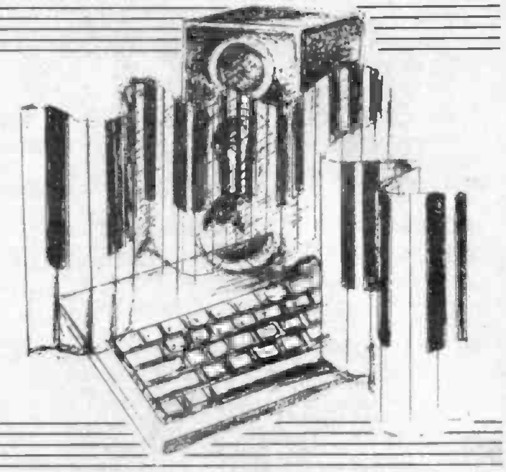


MIDI LEAD TESTER

ROBERT PENFOLD

Now you can check-out your MIDI leads as quick as a flash with this easy-build tester.

MIDI is quite a high-tech means of communicating between units in an electronic music system, but it relies on ordinary plugs, sockets and leads to actually carry the signals. These will function well enough for long periods if left undisturbed. However, in practical systems there is often a lot of plugging-in and unplugging. Also, leads do tend to get kicked and tripped over.

When a MIDI system fails to work properly, unless something in the system is obviously malfunctioning, there are two likely causes. One is that something in the system is simply not set up correctly. The other is that there is a faulty MIDI cable somewhere in the system. Checking for a damaged lead is probably the best starting point.

This unit enables MIDI connecting leads to be quickly checked, and it will show up broken wires/connections or short circuits from one lead to another. In use it is much quicker and easier than using a multimeter or continuity checker. Checking leads with ordinary test equipment is easy enough provided you have four hands (two for the test leads and two for the plugs)!

It should be possible to build this tester for less than the cost of ready made units, some of which seem to be rather crude in comparison.

It can help to greatly speed-up checks on a faulty MIDI system. It can also save a lot of time if non-technical friends with MIDI equipment tend to present you with sets of MIDI leads for testing on your multimeter.

OPERATING METHOD

On the face of it, all the tester has to do is feed five signals down the conductors of the cable, and have five indicators to show whether or not these signals make it to the other end of the cable. This method will indicate any breaks in the conductors, but it will not show any short circuits between conductors. With leads that use moulded plugs it is unusual for short circuits to occur, but with ordinary DIN plugs these can easily arise where multi-strand wires have partially come adrift and frayed.

The tester to be described here has five l.e.d. indicators, one for each pin of the 5-way DIN connectors. These are driven one at a time, so that any short circuits will be indicated by two or more l.e.d.s coming on simultaneously. A break in the cable will, of course, be indicated by one or more l.e.d.s failing to switch on.

MIDI

The block diagram of the MIDI Lead Tester, Fig. 1, shows how this simple scheme of things is implemented in practice. The sequential outputs are provided by a one of five decoder, which is driven by a low frequency clock oscillator.

The decoder has five outputs ("0" to "4") which go high, in sequence, for one clock cycle per output. The decoder cycles continuously, with output "0" going high for one clock cycle after output "4" has had its turn.

Each clock cycle lasts about one fifth of a second, so that things progress at a slow enough rate for the testing of each connector to be clearly seen. On the other hand, the decoder is cycled at a fast enough rate to permit leads to be thoroughly checked in just a few seconds.

The suspect MIDI lead is plugged into the tester, and it should carry the signals to a five l.e.d. display. A faulty lead will scramble the signals in some way, which will be clearly indicated by the l.e.d. display.

In order to use the unit properly you need to know a little about MIDI leads, and the methods of interconnection that they use. This is something that is fully explained at the end of this article.

CIRCUIT OPERATION

The full circuit diagram for the MIDI Lead Tester is shown in Fig. 2. The clock oscillator is based on a low power 555

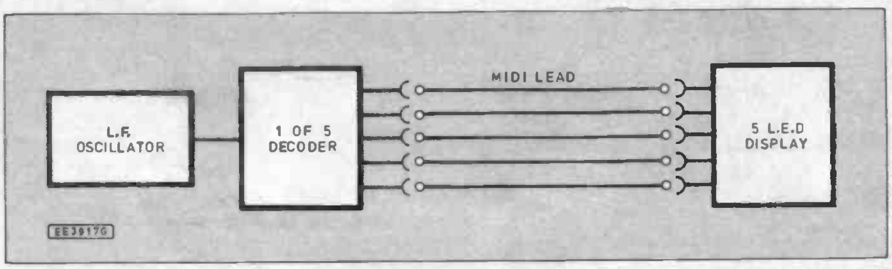
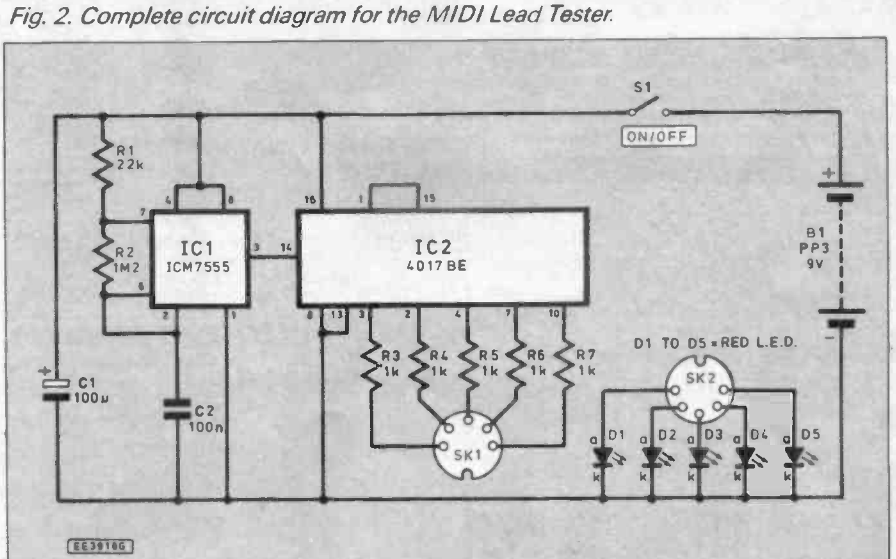


Fig. 1. The MIDI Lead Tester block diagram. To avoid misleading results, the connectors are tested one at a time.

Fig. 2. Complete circuit diagram for the MIDI Lead Tester.



timer (IC1). This is used in the conventional astable circuit, and it oscillates at approximately 5Hz.

A low power version of the 555 is used in order to keep the current consumption of the circuit down to a reasonable level. The circuit will work using an ordinary 555, but it would probably then need a higher capacity battery.

The CMOS 4017BE (1-of-10 decoder), acts as the one-of-five decoder IC2. A five output decoder of this type seems to be unavailable, but eight and ten output types are produced.

In this case a one-of-ten decoder is used, but it has output "5" (pin 1) coupled to its reset input (pin 15). Thus, as output "4" goes low again, and output "5" goes high, the device resets itself to zero and output "0" goes high. This effectively eliminates outputs "5" to "9", and gives the required one-of-five action.

Output socket SK1 is driven from IC2 via separate current limiting resistors (R3 to R7). Apart from limiting the l.e.d. current to a suitable figure, these also ensure that any short circuits in the lead under test cannot cause damage to IC2. The five indicator l.e.d.s (D1 to D5) are simply wired from input socket SK2 to earth (B1-ve).

The current consumption of the unit is well under a milliamp when no l.e.d.s are switched on, and about six milliamps when a l.e.d. is activated. A PP3 size battery is therefore perfectly adequate as the power source.

CONSTRUCTION

The circuit board is a piece of 0·1 inch pitch stripboard which has 39 holes by 15 copper strips. The component layout and details of the underside breaks required in the copper tracks is shown in Fig. 3.

This is not a size in which the board is sold, so it must be cut down from a larger piece using a hacksaw. Cut along rows of holes rather than trying to cut between them. This will probably give some rough

COMPONENTS

Resistors
R1 22k
R2 1M2
R3 to R7 1k (5 off)
All 0·25W 5% carbon film

See SHOP TALK Page

Capacitors
C1 100µ radial elect., 10V
C2 100n polyester

Semiconductors
D1 to D5 Red panel l.e.d.s (5 off)
IC1 ICM7555 CMOS timer, or similar low power 555
IC2 4017BE CMOS 1-of-10 decoder

Miscellaneous
B1 9V battery (PP3 size), with connector
S1 SPST sub-min toggle switch
SK1, SK2 5-way (180 degree) DIN socket (2 off)
Plastic case, , about 148mm x 90mm x 53mm; stripboard, 0·1 in. matrix, size 39 holes by 15 strips; 8-pin d.i.l. holder; 16-pin d.i.l. holder; connecting wire; solder, etc.

Approx cost guidance only **£9**

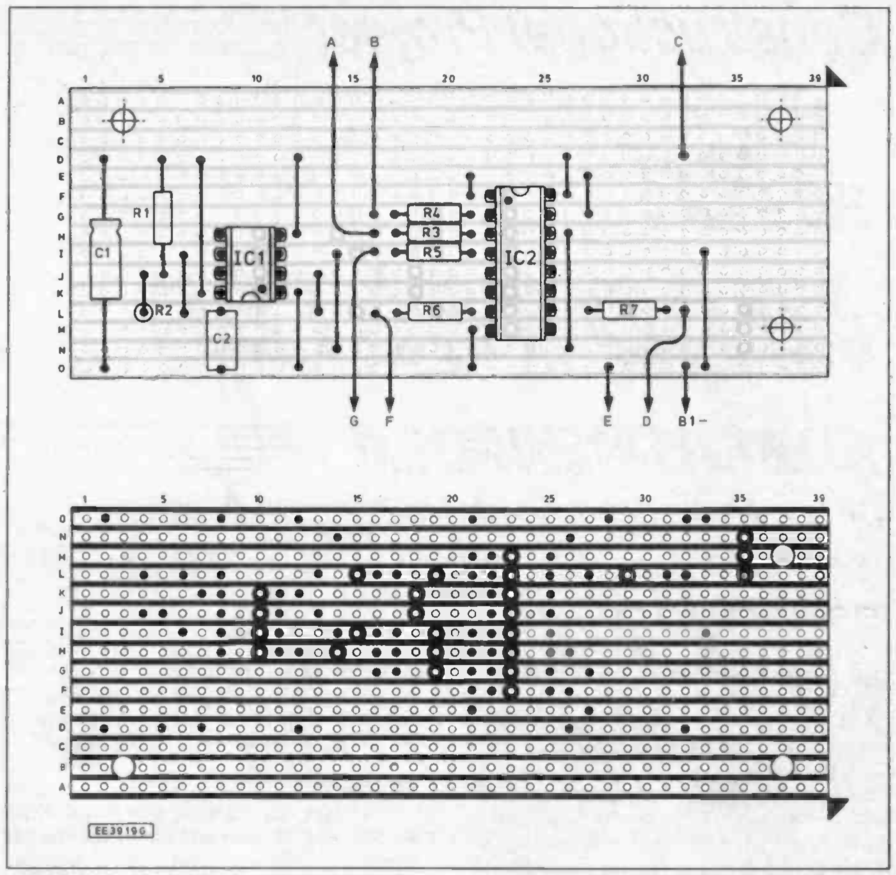
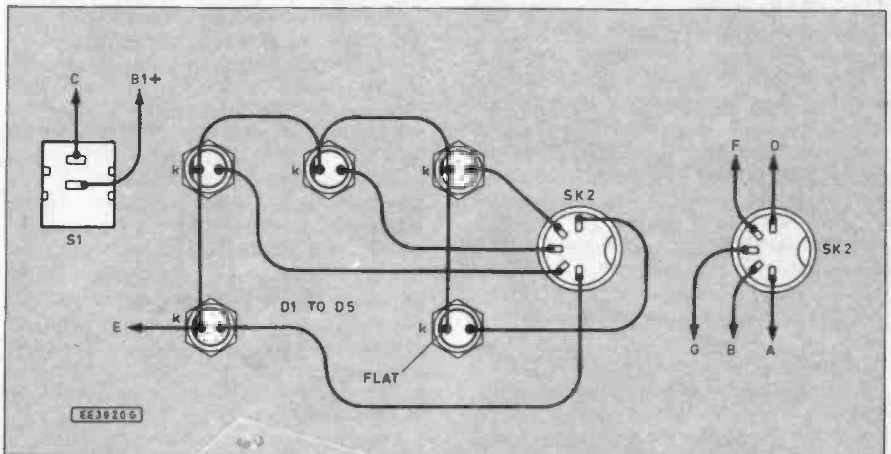
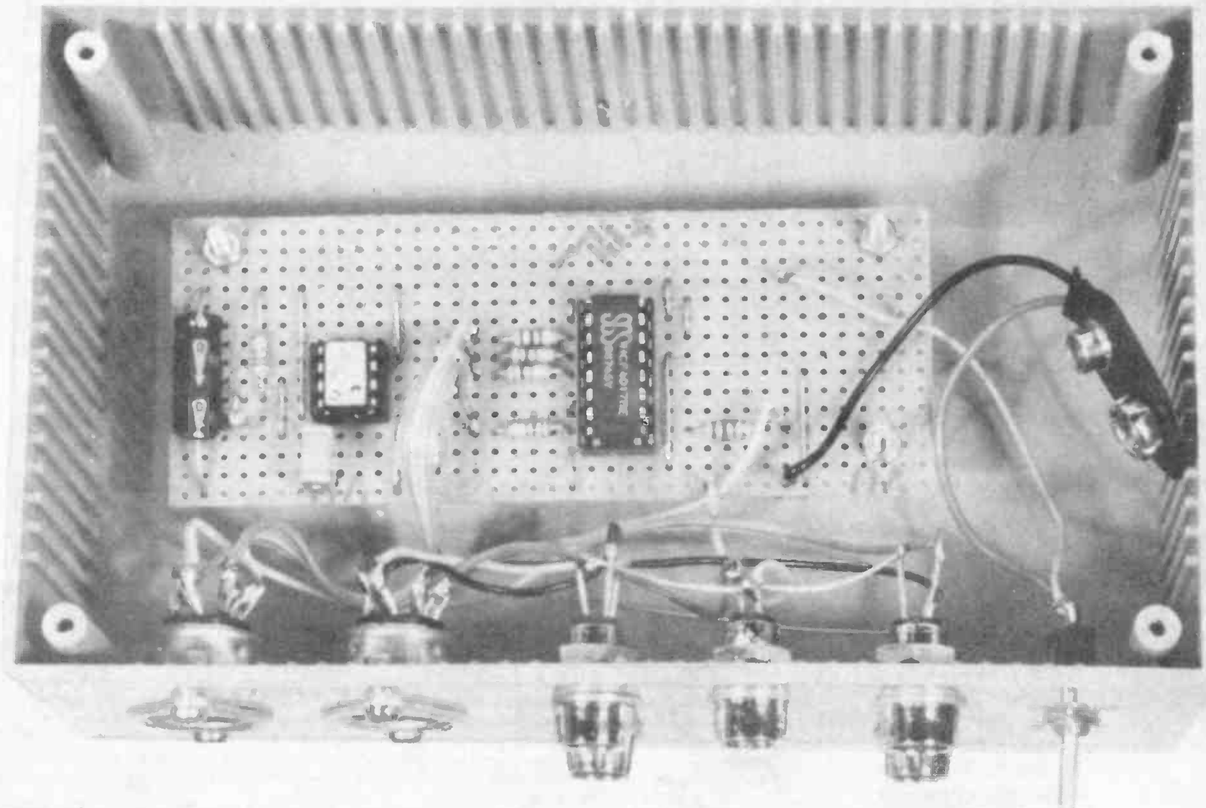


Fig. 3. Stripboard component layout and details of breaks required in the underside copper strips.

Fig. 4. Interwiring to off-board components and leads to circuit board. Use this diagram in conjunction with Fig. 3. above.





Layout of component and wiring inside the case. The battery sits on the bottom of the case to the right of the circuit board.

edges, but these are easily filed flat using a small file. Stripboard is not particularly tough, and it must therefore be worked with reasonable care.

Next drill the three mounting holes (refer to Fig. 3 for details of the board). Use 6BA or M3 fixings which require 3·3 millimetre diameter mounting holes. If you use plastic stand-offs, the size of the mounting holes must be selected to suit the particular stand-offs used. The 25 breaks in the copper strips on the underside of the board should then be made. A special tool for cutting the strips is available, but a hand-held drill bit of about 5 millimetres in diameter will do the job quite well.

The board is now ready for the components and link wires to be fitted. IC2 is a CMOS device which consequently requires the usual anti-static handling precautions. The most important of these is to fit IC2 onto the board via a holder instead of soldering it directly onto the board.

Do not remove IC2 from its anti-static packing and plug it into place until the unit is, in all other respects, finished. Try to handle IC2 as little as possible once it is has been removed from its packing.

The timer i.c., IC1 does not require any special handling precautions, but the use of a holder for this component is still recommended. Note that IC1 has the opposite orientation to IC2.

Fitting the other components and the link wires on the board is quite straightforward. However, be careful to fit the electrolytic capacitor C1 the right way round. Capacitor C2 must be a miniature printed circuit mounting (7·5mm pitch) type if it is to fit into this layout easily.

The link wires can be made from 22s.w.g. tinned copper wire, or the trimmings from the resistor leadout wires will probably be suitable. Fit single-sided solder pins to the board at the points where connections to off-board components will be made. Tin these pins with a generous amount of solder. It should then be easy to make good connections to them.

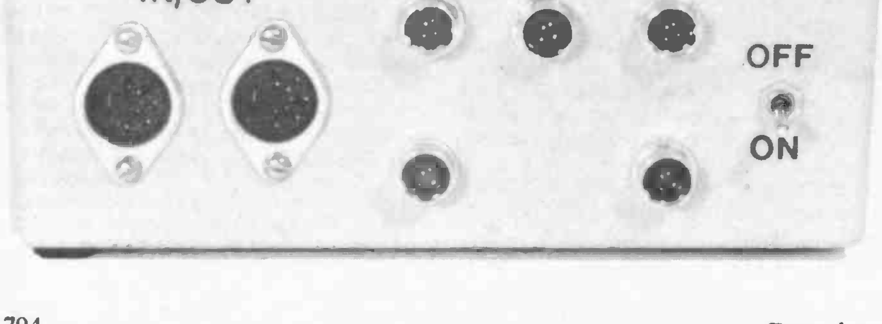
CASE

The prototype is housed in a medium sized plastic box, but this is somewhat larger than is really necessary. The unit should fit into quite a small case without too much difficulty, provided you can find enough front panel space to accommodate the on/off switch, the five l.e.d.s, and the two sockets. From the electronics point of view the layout of the unit is not critical, but try to lay things out sensibly so that the unit is easy to use.

There is a fair amount of point-to-point wiring, and this is shown in Fig. 4. This diagram should be used in conjunction with the circuit board layout, Fig. 3.

For example, point "A" in Fig. 3 connects to point "A" in Fig. 4. The cathode (k) terminal of a l.e.d. is normally indicated by this lead being shorter than the anode (a) lead. There are a few exceptions though, and it might be worthwhile checking this point in the retailer's catalogue before wiring up the l.e.d.s.

The completed MIDI Lead Tester showing layout of components on the front panel.



IN USE

With the Midi Lead Tester unit switched on and no MIDI lead connected, none of the l.e.d.s should come on. If a piece of wire is used to temporarily connect a pin of one socket to the equivalent pin of the other socket, the corresponding panel l.e.d. should flash about once per second. It is a good idea to check all five pairs of pins in this way to check that the unit is fully operational.

A standard MIDI lead has the two pin-2's (the middle pins) interconnected by the screen of the cable. Pins 4 and 5 on one plug are connected to pins 4 and 5 of the other plug via two inner conductors of the cable. Pins 4 and 5 are the ones on either side of pin 2 incidentally. Pins 2 and 3, which are the ones at opposite ends of the arc of pins, should not be connected.

This means that with a standard MIDI lead connected to the unit, only the middle three l.e.d.s of the display should operate. In practice many MIDI leads seem to have all five pins interconnected. One reason for this is that many of the leads which are sold as MIDI types are actually audio cables.

Note that some five-way DIN audio cables have the plugs cross-connected, and are therefore unsuitable for MIDI use.

These can easily be detected using this tester, as with one of these leads the display l.e.d.s will "move" in the wrong direction.

Some MIDI leads supplied with equipment from respectable manufacturers seem to have pins 2 and 3 interconnected. Presumably these leads are purpose made MIDI types, but have pins 2 and 3 connected in case they are utilized in some later MIDI implementation.

Anyway, if the middle three l.e.d.s operate properly, or all five l.e.d.s operate in the correct order, the lead should be usable. It is only if one or more of the middle three l.e.d.s fails to operate, or more than one l.e.d. at a time switches on, that the lead is faulty.

BE FLEXIBLE

If the middle l.e.d. fails to operate, the lead will still carry MIDI information correctly. However, the screening may not be earthed properly, and strong radio interference might be radiated by the cable.

When checking any cables it is always a good idea to flex the leads slightly, and to gently pull the cable away from each plug. A fair percentage of cable problems involve intermitted faults. You can find that a lead passes a test, but fails to operate when it is put back into the system. Flexing and gently tugging the lead will encourage any intermittent problem to occur while the lead is being checked.

The popular Atari ST computer has a non-standard implementation of the MIDI OUT and THRU sockets. These should be separate sockets with the signals carried by pins 4 and 5. Instead, these two functions are combined in a single socket with pins 4 and 5 carrying the OUT signal. Pins 2 and 3 carry the THRU signal.

An ST combined THRU and OUT lead is therefore a twin cable which has a single plug at the ST end. This couples through to the OUT plug in the usual way. However, pins 2 and 3 couple to pins 4 and 5 of the THRU plug. Obviously this tester can check these leads, one section at a time, and can show which is the OUT plug and which is the THRU plug. □

READOUT

OFFENSIVE MNEMONIC

Dear Ed.,

One of my constituents has drawn my attention to the *Teach-In '93* article in the November edition. The article deals with a resistor colour code and suggests a mnemonic to remember the colours.

My constituent found this mnemonic offensive and so do I. I think that, in this day and age, it is totally inappropriate that such mnemonics should be suggested particularly in magazines that will find themselves in schools and colleges.

As a member of the Education Committee of our Regional Council I will be taking this matter further if I do not receive a satisfactory explanation from you. I think it shows a distinct lack of imagination that a mnemonic could not be devised that was unoffensive.

Councillor Des Loughney
Lothian Regional Council

I am sorry that we have offended you with the mnemonic. Your point is taken and on reflection I agree that we should have come up with something different. The published version has been in use in education and the electronics industry for more than 30 years and I must admit we published it without due consideration.

We would like to offer a years subscription to EPE plus a binder (worth £25.95 in total) for the best alternative colour code mnemonic sent in by a reader before December 31st 1992. The winner will be published in EPE.

P.C.B. OR NOT P.C.B.

Recently you published a series of articles on printed circuit boards and it was this that prompted me to write in.

I have been an electronics hobbyist for many years. For a long time, I believed that the p.c.b. was the "best" way of making circuits. Many, if not most, of your readers believe the same. Well, I now think this idea is seriously misguided. Let me explain.

When you see just how widespread the printed circuit is it is easy to imagine that there is some natural law of electronics which demands its use, but this isn't so. In fact they are a recent development, not appearing until the 1940's, and despite their seductive good looks they have a number of serious disadvantages. They are difficult to design, time-consuming to make and impossible to repair (ever *tried* removing a component from a board)?

If all this is so, then why are they used so much? Because they have one big advantage: reliability. For a manufacturer this feature of reliability completely outweighs the disadvantages and this explains how p.c.b.s have taken over.

However, it is important to see this in perspective. The concept of statistical reliability has no meaning for the hobbyist who makes a single copy of a circuit and can fix it if it fails. For him, the disadvantages of the p.c. method, outlined above, can make it a poor choice.

I take the view that for the hobbyist it is a better bet to use matrix board. The recent introduction of wiring pens has made this method of construction rather easy. Additionally, by using the new insulated wires it is possible to implement complex digital circuits where the wiring looks like spaghetti and where using a p.c.b. is out of the question for an amateur.

There is nothing inherently right or wrong about the p.c., only its application. I feel many are using it inappropriately. My advice is just to think before you etch.

B. Clothier
Wallington

We agree with much of what you say, however the biggest advantage of the p.c.b. to the hobbyist, when made from a published design, is the virtual elimination of wiring errors. In our opinion this generally outweighs the cost and/or production time etc. – Ed.

MICROSOFT OK?

Dear Ed.,

I am writing about the item by Barry Fox in *Everyday Electronics* September 1992. Although I have no connection with Microsoft, or to Bill Gates, I feel that Barry has been unfair to them, and showed himself to have a poor grasp of the history of the PC.

Surely the present growth in the marketing of DIY PCs – where you buy components, a motherboard, hard disk, floppy drives, VGA card etc. – shows the (almost) true compatability standard set by the IBM PC. Unfortunately, the standard is now old technology, with local bus and EISA techniques trying to increase speed and performance while still maintaining compatability with the early machines.

Bill Gates business acumen aside, Microsoft did not 'condemn some 70 million people (to using MS-DOS)'. When the original IBM PC was made it was designed to run CP/M-80 – a now seriously outdated operating system. MS-DOS was released as another option which the market chose. It is a consequence of the market's decision *at the time* that 70 million people now use DOS.

The limit of 8-character file names is again a hangover from CP/M. By the way – I work in the real world, with many other people, all of whom use text files, and no one I have asked considers the fact that the operating system places limits on filenames remotely daft.

As for your scornful opinion of Windows 1.0, any software package evolves from the original, through (often) several stages towards the present "best-ever" version. So what if windows is now on 3.1, Wordstar is now in version 7! And DR-DOS a non-Microsoft operating system is on version 6, 1 ahead of MS-DOS. When DOS was originally released, PCs were mainly used by people who knew what they were doing, or at least, knew the dangers involved in delete or format situations. Of course safe format and unerase commands should have been implemented earlier. I for one would have used them many times! However, the extra steps involved in the execution of such commands, or rather in the delete and format commands have in the past added extra time to the execution, and hence were 'undesirable' until of course you needed the files back!

Half way through your column we come to what could be the reason for your violent dislike of Bill Gates and Microsoft – he wouldn't give you an interview. I'd call that a childish attitude.

I use Windows 3.0 at work. I don't like it, but I use it. Although I can see your point about taking quite a while to install Windows 3 itself. Installing applications afterwards is childs play, and while I would also query the times taken to master windows software, certainly many people could learn enough in two and a half hours to use any windows software.

Most windows software packages these days do actually have the necessary PIF files to enable them to run properly.

If I was the ASA I would not take your side, especially since many PC's these days come with windows pre-loaded.

In short, your column was not what I would have expected from a professional electronics and computer journalist. It was inaccurate, ill-informed and biased.

James Ogden
Hemel Hempstead

Everyone is entitled to their opinion – the ASA upheld Barry's complaint – Ed.

Home Base

Jottings of an electronics hobbyist –Terry Pinnell

ROOM FOR IMPROVEMENT

I wonder if I'm unusual in needing so much space for this hobby?

My electronics gets done in what started out a long time ago as a spare bedroom. Recently I started working from home, so this room had to become my office too. Computer, printer, files, stationery and so on, all began to compete for space with what was once the exclusive domain of my electronics paraphernalia.

Something obviously had to go, to the loft to be precise, but deciding what to banish was not easy. Keeping workbench gear like power supply, 'scope, meter, etc, were obvious choices, together with basic component supplies and tools. And my books stayed too. But the bulk of my magazine back-copies now sit on improvised shelves under the rafters. A few months have passed and I'm beginning to regret it though.

I used to look up circuit ideas or design tips, either browsing or, in my earlier more disciplined phase, referring to a card index file of "Circuit References", regularly updated. But the trip to the loft usually proves just too much of a dis-incentive now. Not that it still wouldn't be worth the effort if judged on any objective basis.

Compare the time involved in re-inventing a nifty circuit from scratch on your workbench armed with breadboard and a vague recollection of the article, with say half an hour in the loft – providing of course you ignore the real risk of digressive browsing!

A few years in the future I suppose my dilemma will be resolved by the availability of inexpensive microfiche facilities or something similar. Or perhaps a versatile scanner will allow me to store and classify text and graphics from EPE April '95 straight into my PC, for easy later retrieval.

Another decade on, maybe I'll read the networked monthly issues direct from the screen of my PC, with auxiliary wall-mounted units strategically located in bathroom and bedroom, so indexing and retrieval of old data will be a matter of course. Meanwhile I shall have to either re-prioritise the stuff in this room or reconcile myself to those nuggets of information just gathering dust a few feet above my head.

JUSTIFYING THE JUNK

This maxim of "out of sight, out of mind" also applies to what would probably be unkindly described by non-hobbyists (and maybe some hobbyists!) as my junk collection. I'm a self-confessed hoarder and over the years I've accumulated a pile of unclassifiable bits and pieces. Hardware of all shapes and sizes, strange plugs and sockets, motors, springs, nuts and bolts (separated, all apparently with incompatible threads), solenoids, unidentifiable transistors and i.c.s, electro-mechanical sub-assemblies that once presumably did something useful, and so on – by the box-full.

Most of this stuff once saw the inside of component suppliers and surplus shops throughout the country, with Edgware Road and Tottenham Court Road featuring strongly. It was always clear beyond question to me that at those give-away prices such miscellaneous items were obvious bargains and that I would undoubtedly be using them in many projects. While some of them have certainly been used effectively, at the going rate I reckon another few centuries of constructing will be needed to make an appreciable dent in the remaining stocks.

But another category of my junk bears closer scrutiny. For several years I used to stockpile all sorts of domestic flotsam and jetsam. And much of it has been put to good use. Disposable razors, whose plastic handles can be cut to size for handy spacers; old pens for coil formers; aerosol can tops to hold miniature loudspeakers and so on. And a variety of things have made useful low cost project cases, such as slide photograph holders, square section plastic guttering and tobacco tins by the dozen. Nor does the lowly origin and zero cost of the source materials have to mean a poor quality of finish.

YESTERDAY'S PROJECTS

Finished projects of infrequent use were another obvious candidate for removal to the loft. Out went the meticulously calibrated Accented Beat Metronome, the Random Light Flasher, the Dual Train Controller, the Electromagnetic Pulser, and a score of other devices, each no doubt the focus of my enthusiasm in their time, now long gone.

Even my more recent Electronic Mousetrap was a casualty of the clear-out. After its acclaim in that first week of use a while ago, when it made a successful capture six nights running (the bemused mouse being released by A Kind Human in the mornings) I've been underwhelmed with demand to loan it out.

In fact I probably was not stringent enough. Taking a hard look at the stuff still on my workbench and shelves, I have to say that a lot of it gets too little use to justify being kept down here. I can't remember when I last used such things as my FET Tester, Crystal Calibrator, AC-to-DC Converter, Beat Frequency Oscillator or Mains Detector, to name just a fraction.

Trouble is, if I had a *really* rigorous prune and moved out everything except the hard core essentials, you can be sure that within days something would trigger a renewed burst of enthusiastic experimenting or constructing and down again it would all have to come.

AUTOMATIC LIGHT

I recall the loft lights being left on once for a couple of weeks by mistake; seven bulbs, mainly 150W, so we're talking about a kilowatt. So with the increase in loft-going traffic, I've installed an automatic light (Fig. 1.) It is activated by a microswitch mounted above the trapdoor so that the microswitch is open when the loft ladder is in its horizontal, stowed-away position and closed as soon as it is lowered onto the landing. So the lights go on when anyone goes up and, *more importantly*, go out when they come down.

The unijunction relaxation oscillator TR1 produces sharp pulses at around 400Hz, coupled with complete isolation via the pulse transformer to drive the triac. The transformer was simply a small coil with a core, stripped of its original winding and rewound with two layers of about 40 turns of 34 s.w.g. enamelled wire, with a good layer of insulation tape between

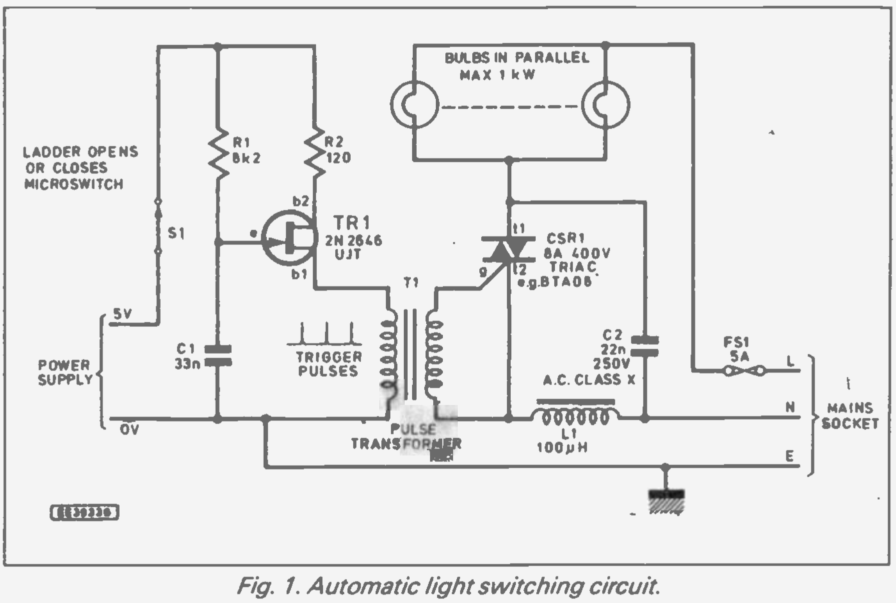


Fig. 1. Automatic light switching circuit.

them. Even for someone as clumsy as me, this is fairly easy because the sort of coils I mean have four legs, making convenient anchor points for the wire. I have dozens of formers from one of my "bargain pack" or surplus purchases. Alternatively a less neat transformer can be wound on a 13mm piece of 6mm diameter ferrite rod.

Together with the 22n capacitor (C2) the choke (L1) forms a filter to minimise r.f. noise. It can be made by winding about 50 turns of 20 s.w.g. enamelled wire onto a 20mm length of 10mm diameter ferrite rod.

The triac should suit your needs. I like a lot of illumination when I'm groping around in our loft, and my string of large bulbs now numbers seven. I therefore used an 8A triac, and chose one with an isolated tab to avoid worrying too much about insulation.

From a tin can that probably started life looking after baked beans, a strip was cut about 150mm long and 20mm wide, doubled up on itself, drilled with a neat hole near one end, then folded into a U-shape and used as a small heatsink for the triac. (Just in case you are wrong about your triac's tab being isolated, if you are curious about how warm the heatsink gets, unplug the mains before touching it!)

The circuit was cased in a tobacco tin, suitably earthed of course and with a 5A mains fuse in the supply. By the way, please don't build this circuit if you are unfamilar with mains wiring – we would hate to loose any readers.

SHOP TALK

with David Barrington

Mini Lab (Teach-In '93)

Before we tackle the components for this month's *Mini Lab* project, we have some welcome news from two of our advertisers.

The first concerns the specified Verobloc. We were surprised to learn that **Maplin** no longer carry this item. However, thanks to the good offices of **Greenweld Electronics**, who do carry stocks, they are making a special offer to readers.

If any reader orders the two "bread-boards" from them (£13·70 plus £2·75 p&p), Greenweld will give them a *Free* low voltage 12V to 24V a.c./d.c. 6W soldering iron whilst stocks last (see their advertisement). *You must request the iron when ordering*. Having seen the iron, its tempting to add a car cigar lighter plug to the leads and keep it in the car tool box for emergency breakdown repairs.

We have received a few comments from readers that ordering the correct components from all the various sources mentioned last month "adds considerably to the cost when each postal charge is taken into account." This point has been taken up and we are pleased to report that **Magenta Electronics** have put together a selection of kits, including a complete package, at prices to suit differing requirements (see their advertisement). The complete kit does not, of course, include the *Micro Lab* demonstration package to be described towards the end of the series.

Back to this month's L.E.D. Voltmeter project. Apart from the toggle switch (covered in last months roundup) and the 10-segment l.e.d. bargraph module, all components should be fairly readily available.

The bargraph module is available from Maplin, code BY65V; Electromail, code 588-027 and Farnell, code MV57164. You can, of course, use individual rectangular l.e.d.s.

The Mini Lab p.c.b. is only available through the EPE PCB Service see page 835. Please remember that in consideration of the effort by both Authors which went into the Mini Lab design, the copper track layout remains Copyright Dytronics 1992.

Universal Infra-red Remote Control

If any constructors have difficulties finding a local source for the transmitter, infra-red amplifier and receiver chips, they are currently listed by **Electromail** (☎ *0536 204555*), codes 658-491, 301-527 and 658-508 respectively.

If you wish to take advantage of the 32-way key switching possibility you will have to use two 16-way membrane keypads. These are available from **Maplin**, code JYO4E. They also supplied the small keypad shown on the model, JMO9K.

The printed circuit boards are available as a pair from our *PCB Service*, code 811T/R.

Combination Switch

Finding the combination switch i.c. for the *Combination switch* project was quite a task. The UA3730 switch i.c. is available from **Maplin**, code UM98G, but was very difficult to find in their "semiconductor listing". The keypad (JMO9K) and other semiconductor devices were obtained from the same source.

The printed circuit board is available from the *PCB Service*, code 812 (see page 835).

Christmas Lights Colour Spectrum

We cannot foresee any component buying problems for anyone wishing to build the *Christmas Lights Colour Spectrum* project. However, you *must* take extreme care when testing the unit as mains voltages are present.

The p.c.b. can be purchased through our *PCB Service*, code 813.

Auto-Switch Add-On

The twin coil d.i.l. relay used in the *Auto-Switch Add-On* prototype was the 5V version from **Electromail** (☎ *0536 204555*) code 351-689 (12V version 351-695). A suitable ultra-miniature switch for the small "pill" box version would be one of the "tactile click effect" ones from **Maplin**, JR89W.

Midi Lead Tester

We do not expect any component buying problems to be encountered when shopping for parts for the *Midi Lead Tester*. The l.e.d.s are widely available in small panel mounting housings.

PLEASE TAKE NOTE
Battery/Mains Inverter – Daughter Board

Please note the annotations in "brackets" on the two i.c.s. in Fig. 2 of the *Battery/Mains Inverter-Daughter Board* have been transposed.

As the two i.c.s. have different pin counts, they can only be inserted on the printed circuit board in one position and should not, we hope, have caused any problems.

Techniques

ACTUALLY DOING IT!

by Robert Penfold

I SUPPOSE that with any hobby there will be some tasks that you enjoy more than others. Probably in common with many electronic project builders, I find the electronics side of the hobby more absorbing and rewarding than the purely mechanical aspects.

One facet of project construction that I definitely do not like much at all is making large cutouts. If you happen to have the perfect equipment for this type of thing, then it is probably enjoyable.

Unfortunately, the perfect equipment is a power fretsaw fitted in a sort of combined stand and work-top. These tend to cost rather more than most electronics hobbyists' annual expenditure on components and tools.

COPING WITH CUTOUTS

There are alternatives to an electric fretsaw, and the obvious one is an ordinary hand fretsaw. One of these fitted with practically any fairly fine-toothed blade will cut quite well through an aluminium or plastic panel. Whatever tool you use, cutting through steel panels is likely to be slow work. Unless you have tools that are really up to this type of thing I would strongly recommend that steel cases are avoided if any large cutouts will be needed.

A fretsaw enables cutouts of any shape to be produced, at the edge and within a panel. In the case of cutouts within a panel a small starting hole must first be drilled somewhere within the perimeter of the required cutout. The blade is then threaded through the hole and fixed into the saw.

Fretsaws are rather unwieldy due to the largeness of their frames. Coping saws have substantially smaller frames and are much easier to use, but cannot reach into the middle of large panels. Where a coping saw has sufficient reach to make the required cutout, it is a better choice.

With either type of saw it is important that the panel is firmly clamped in place, and that you take your time. Rushing things will almost certainly produce poor cutting accuracy and a lot of broken blades.

Even if things are taken slowly and carefully, one or two blades are likely to be broken while making a large cutout. Presumably this is why fretsaw blades are usually sold in packs of a dozen or more!

GETTING THE NEEDLE

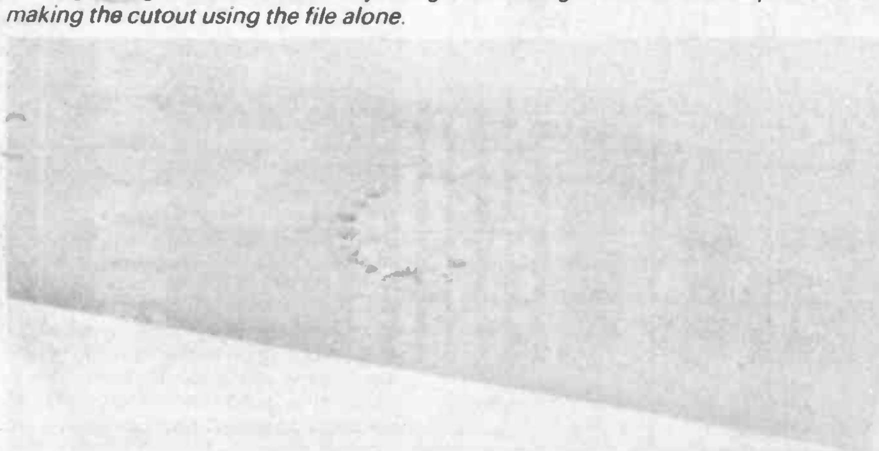
Miniature round files (also known as "needle" files) offer a good alternative to coping and fret saws. They do not provide quite the same degree of precision, but they are adequate for the vast majority of cutouts.

Some of these files fit into a combined handle and frame which is very much like a coping saw. These are quite fast and easy to use, but like a coping saw they cannot reach the parts of a panel that fretsaws and ordinary needle files can reach.

Ordinary needle files are basically just scaled down versions of the full-size products. Unfortunately, in most cases the handles and not just the files themselves are scaled down. This makes them difficult to hold, so that producing large cutouts with one of these files can be a bit awkward and time consuming.

Take things slowly though, or the file may slip out and smash into the panel. This will badly scratch the panel, and could well do the same to you. A needle file probably represents the cheapest means of making cutouts that is reasonably practical, but you need patience when using one of these tools.

Making a ring of holes and then joining them using a needle file is quicker than making the cutout using the file alone.



One way of speeding things up when using a needle file for large cutouts is to drill a series of small and closely spaced holes just inside the perimeter of the required hole – see photograph. The file is then used to join up all the holes, leaving what will be a rather rough cutout.

However, the rough edges can soon be filed out to a neat finish, and there is not much point in trying to make the initial cutout at all neat or tidy. It is really just a matter of making sure that the initial cutout is kept within the perimeter line.

JIGSAWS

These days many household tool kits are equipped with a power jigsaw. For most work in the current context these are too large and cumbersome, although I suppose they may be satisfactory for some project work.

Miniature or "precision" jigsaws are more suitable, and will permit many cutouts to be made quite quickly and easily. Miniature jigsaws do not permit intricate shapes to be cut with quite the same degree of precision as with a fretsaw, but they are adequate for the vast majority of cutouts.

If you have a miniature electric drill for making holes in printed circuit boards, there may be a precision jigsaw attachment available for this drill. An attachment of this type is substantially cheaper than a precision jigsaw, but should be adequate for cutting through thin aluminium and plastic panels.

QUICK NIBBLE

A hand nibbler tool almost certainly represents the quickest means of producing cutouts. These tools vary somewhat in their appearance and design, but they all operate in basically the same fashion. This is a vaguely scissor-like tool which literally nibbles out little rectangles of material.

Results with aluminium are good using one of the better quality nibblers, but I could not recommend them for use with steel. They are usable with some plastics, but will simply shatter *hard* plastics.

There is a knack to using a nibbler, but quite accurate results can be produced after some practise has been gained on some scraps of aluminium sheet. It is not possible to make small and intricate cutouts using these tools as they make much wider cuts than a saw blade. The cut is usually about three or four millimetres wide. They can be used for quite small rectangular holes and the like, but are at their best when large irregular shaped cutouts are needed.

Obviously it is not possible to make cuts with curved edges when using a nibbler, since it has to make a series of short but straight cuts. You can make a pseudo curved cut just within the perimeter of the cutout, and then carefully file this out to precisely the required shape.

Unless you are very skilful, it is best to use a similar approach when using any of the tools mentioned so far. Otherwise it is very easy to stray onto the wrong side of the cutting line here and there, which in some cases will result in an unusable end product.

Nibbler attachments for electric drills are now available. These are relatively expensive though, and are probably a bit "over the top" for most electronic project work. It is probably fair to say that most of the attachments for full-size electric drills are of little use for project construction, where you normally require precision rather than the ability to zip through large work pieces at great speed.

MAKING YOUR MARK

When making any cutout it is important that the perimeter of the required cutout is very clearly marked, so that it can be clearly seen while you are working on the panel. Making a short cut, looking to see how accurate it was, then making another short cut, looking again, and so on, is a sure way to produce some poor quality results. It also gives very slow progress.

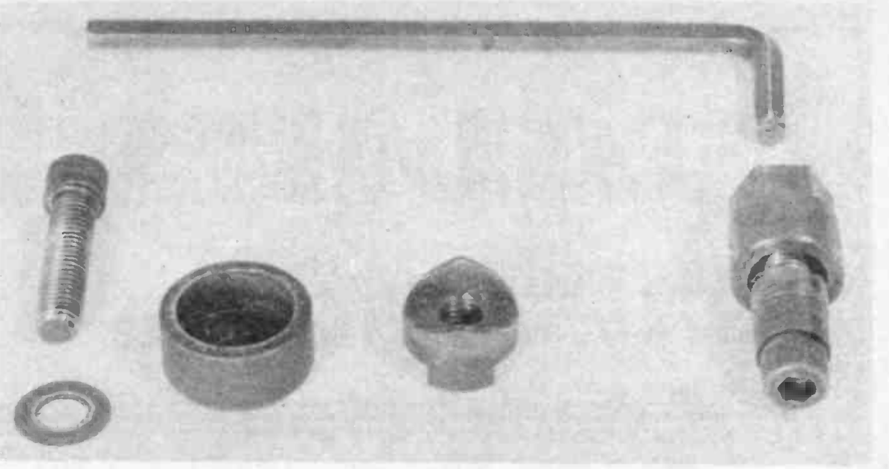
Marking clearly visible lines on most aluminium and plastic panels is not easy. Faint pencil marks or scribed lines may be satisfactory if you have very good eyesight, but are inadequate for many people to see clearly when working on a panel. Some fibre-tipped pens which have spirit based inks will give more distinct lines, but most of these produce quite broad lines which will not give sufficient accuracy.

A commonly used ploy is to fix some paper or thin card over the panel, and to then mark the lines onto this using any pen or pencil that gives a fine dark line. The paper or card needs to be easily removed once the drilling and cutting has been completed.

A few pieces of double-sided adhesive tape are probably the best method of fixing the card in position on the panel. An advantage of this method is that it gives the panel some protection against accidental chips and scratches, particularly if thin card is used.

It is very important to check carefully that the marking-out of the panel has been done correctly, particularly with larger projects where mistakes are more easily made (and potentially more expensive to fix). Placing each front panel component over its respective place on the panel *before* starting any drilling or cutting should highlight any discrepencies. If there is a hole too many, a hole missing, a cutout marked too large, not enough space reserved for a component, or anything of this type, the mistake will become obvious once everything is placed in position on the panel.

Once a mistake has been made it can be very difficult to correct it. If a hole has been omitted, then it will probably be possible to accommodate it somewhere on the panel. The panel layout might look a bit odd though, and the finished unit might not be very easy to use.



The constituent parts of a chassis punch plus an allen key (top) and assembled punch (right).

Holes or cutouts that are made too small can be enlarged fairly easily, although with a large cutout a lot of time consuming filing may be required. An extra hole or accidental damage to a panel can be covered over with a veneer, such as a self-adhesive brush aluminium effect veneer.

With cutouts that have been made too large there is no easy solution. It might be possible to make a cutout of the right size in a small aluminium panel and then glue this in place behind the incorrect cutout.

However, if a major mistake is made it is best to discard the panel and start again from scratch. It is much better to proceed carefully and get it right first time.

ROUNDING OFF

Where large round holes are required there are some quite quick ways of producing them. Chassis punches have been mentioned more than once before in *"Actually Doing It"* over the years, but it is worthwhile mentioning them again.

This seems to be a type of tool which is largely unknown outside the field of electronics, but a chassis punch is useful whenever a large (up to about 30 to 35mm in diameter) circular hole is needed in thin sheet metal. They also work quite well with softish plastics incidentally.

A chassis punch is basically a large nut and bolt – see photograph. A hole for the bolt must first be drilled, and the nut and bolt are then fixed in place.

The "nut" is actually a circular cutting blade of the appropriate diameter, and an allen key is used to tighten the bolt to the point where the blade is forced right through the panel. There is a large cap beneath the head of the bolt, and the blade goes up into this, together with the washer-like piece of metal that is punched out of the panel.

This may seem like a rather crude way of making holes, but it is quite fast and produces far neater results than any other method I have encountered. The holes produced are invariably clean and burr-free. It is a system which is not restricted to round holes, and practically any shape could be punched out using an apposite cutting blade and cap.

In practice these tools are only widely available in the standard round form, although there are rectangular types available from a few sources (e.g. RS outlets). These are designed to make the cutouts for particular switches, etc.

The main drawback of chassis punches is that good quality ones are quite expensive. I find that 12·5mm and 16mm diameter ones are very useful for making mounting holes for jack sockets, DIN sockets, toggle switches, panel neons, etc. It is only worthwhile buying a larger size if you have a specific purpose for it.

The cheap way of making large round holes is to use a reamer. This is a long tapered tool having about five cutting blades along its full length. There is a hole drilled through the top (thick) end of the tool, and a metal bar which acts as a handle is placed through this.

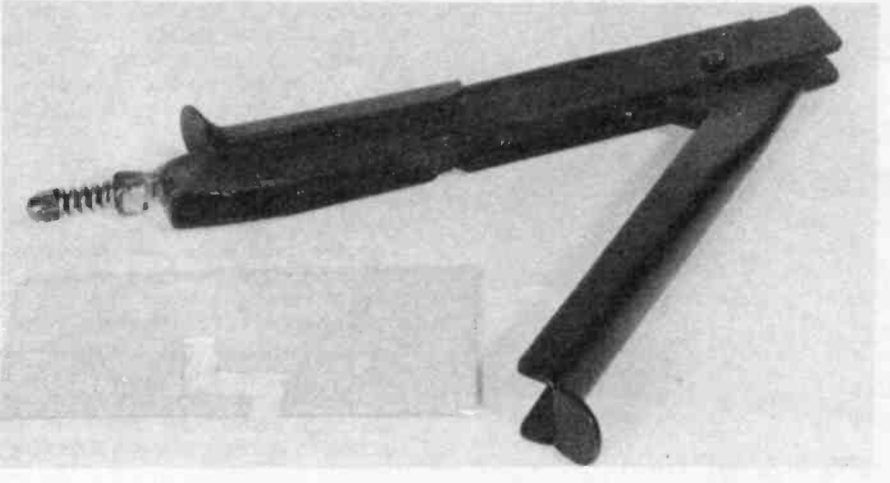
The basic idea is to first drill a relatively small hole, and to then widen this out to the required size using the reamer. Simply place the reamer in the hole and rotate it until the hole has been increased to the appropriate size.

Some reamers are for small holes from around 3mm to 12mm diameter. The ones which cover larger sizes from about 12mm to 30mm are probably the more useful though.

Enlarging holes to diameters of 20mm or more can take a fair amount of effort, but reamers are very much an economy way of doing things. You need to proceed carefully with these tools as it is easy to slightly overdo things.

Reamers produce holes that are far from burr-free, and you need to allow for the fact that the de-burring process will slightly enlarge the hole. There are special de-burring tools available, but when working on aluminium and plastics simply trimming away the burrs with the blade of a penknife seems to be the quickest and easiest method.

A nibbler provides a quick means of making large irregular shaped cutouts.



Teach-In '93

with Alan Winstanley
and Keith Dye B.Eng(Tech)AMIEE

Part 2

Teach-In '93 continues a tradition of offering an interesting and thorough tutorial series aimed specifically at the novice or complete beginner in electronics. The series is designed to support those undertaking either GCSE Electronics or GCE Advanced Levels, and starts with fundamental principles to give the student a solid foundation before proceeding onto further topics.

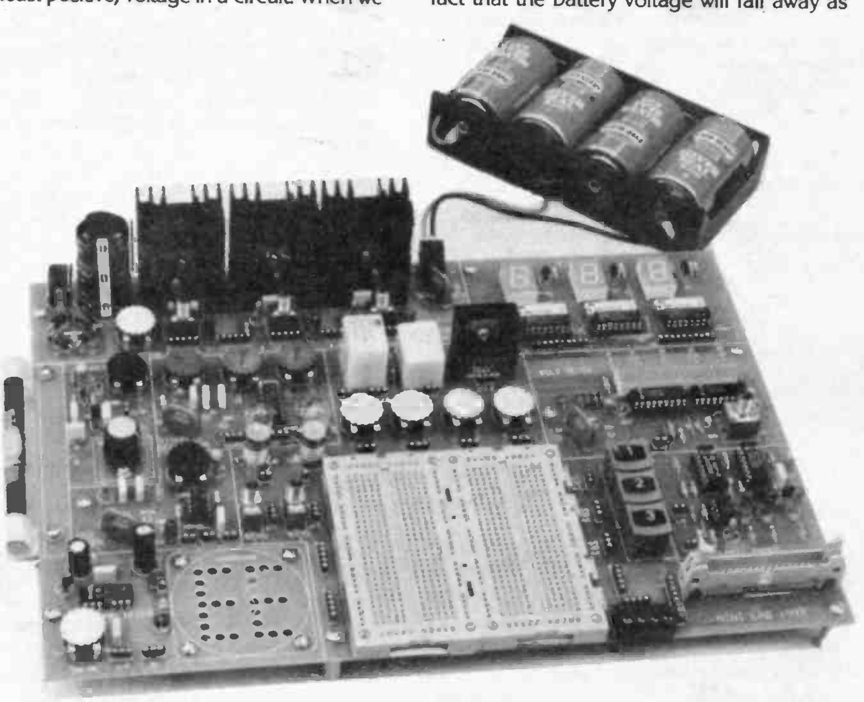
IN ACCORDANCE with the recommendations contained in the various GCSE Electronics Syllabuses, which themselves comply with the National Criteria for Science, no attempt is made to explain the "physics" behind any electronic components. Instead, we are much more interested in what they look like and *how to use them*, rather than what makes them work in the way they do. Many text books on electronics start with the very dry theory of atoms, electrons and semiconductor physics, much of which in our opinion may deter the less able candidate: apart from being of academic interest only, it can also be a bit boring!

We invited a highly-qualified and experienced Moderator and GCE A Level Examiner to join us and the text incorporates his very valuable suggestions to enable *Teach-In* to have maximum appeal to those candidates undertaking GCSE or GCE examinations and coursework. *Teach-In* we hope will also appeal to the experienced *Everyday with Practical Electronics* reader who might like to brush up on his or her theory.

IN PART ONE we introduced the fundamental rules which concern voltage, current and resistance, and we performed several demonstrations on the *Mini Lab* which for now, continues to be powered by batteries. We start this month with more basic theory and then we will use the *Mini Lab* to help demonstrate more electronic principles.

We now know that electric current flows from the most positive to the most negative (or least positive) voltage in a circuit. When we use a 6V battery pack, *conventional* current flows out of the positive terminal, through the circuit and back into the negative terminal of the battery. Remember also that it's more accurate to talk of the "0V" terminal of a battery rather than the –6V terminal.

If we were to draw a graph of the output of our 6V battery pack, perhaps connected to a simple load like a filament bulb or a resistor, when we plot the output voltage V_o against time, it might look like Fig. 2.1. Ignoring the fact that the battery voltage will fall away as the battery starts to age or flatten, the voltage level is reasonably constant with time.



However, many types of electrical signals actually vary with time. Fig. 2.2 is a very simple system consisting of a battery pack and a push switch in series with a bulb. The adjacent graph plots the possible states of the output voltage and clearly there are two possible conditions: *on* or *off*. The graph actually shows a *waveform* called a **square wave**, although the "squares" could be fairly brief "blips" or on the other hand, very long **pulses**. The time period "t" is the time taken for one complete cycle to occur.

In fact, you've just seen your first **digital** signal. These have only two states, being on and off or "high" and "low" or "one" and "zero". Digital signals are the language of "logic" circuits and microprocessors and we investigate them in great depth in Part Six.

Fig. 2.3 shows a potentiometer (pot for short) connected across a 6V battery and the output voltage is present at the wiper of the pot. By rotating the spindle of the pot., you can vary the output voltage V_o accordingly. The resultant graph plot would be a wavy line, and how large the peaks and **dips** are depends on how much you rotate the spindle of the variable resistor.

Clearly there is no consistency in the waveform, and its shape can vary considerably. It's certainly nothing like the distinctive on/off digital waveform we saw earlier. This type of varying waveform is called an **analogue** signal and they are simply wavy lines which have varying states.

ALTERNATING CURRENT

We mentioned last month how the current which flows out of a battery is classed as "direct current" (or d.c. for short) because it can only flow one way. Alternating current (a.c.) signals are different because they flow *forwards and backwards* and not simply in one direction. This could be simulated as in the circuit diagram and waveform shown in Fig. 2.4.

This time we have added a second 6V battery B2 in series to form 12V d.c. total, and this is connected across a potentiometer. However, we have made a connection in between the batteries, which forms a "centre tap". Consider this "tap" as 0V (zero volts), and therefore think of the battery terminal voltages as shown, with +6V wired to one end of the pot. and therefore –6V connected to the other end. The p.d. across each battery is still 6V as normal, and the overall p.d. across the potentiometer is still 12 volts (the difference between +6V and –6V).

Now, if we consider the output voltage between 0V and the potentiometer wiper, we have a situation where with the wiper at "A", the potential at the output *with respect to 0V* will be +6 Volts.

If we move the wiper to the other end of the track ("C"), the output voltage *with respect to 0V* becomes –6V. In other words, you can actually have an output voltage which is *below 0V*. With the wiper at the centre "B", the output voltage will be balanced at 0V, because the 12V p.d. of the batteries is divided in two by the potentiometer, i.e. "A" will be at +6V, "B" will be at 0V and "C" will be at –6V.

It's difficult to measure the output voltage at the pot. wiper (with respect to our 0V centre tap) with a test meter unless you have a special centre-zero voltmeter which can swing between plus and minus, with zero in the middle: you would then see the output action clearly. Alternatively, a digital multimeter will automatically change polarity to indicate both positive and negative voltages on its digital display, so you could see the output voltage swing above or below 0V.

By rotating the spindle of the potentiometer, we could generate a varying analogue signal which could be positive or negative of 0V. A graph of the results might look something like that shown in Fig. 2.4. Unlike the waveforms shown earlier, notice this time how it is possible for the waveform to dip into the negative region, below 0V, depending on how you move the control.

It's not unusual for a circuit to require both positive and negative supply "rails" – an arrangement called a "split supply" – though the vast majority of the *Teach-In* demonstration circuits will use a straightforward positive rail together with a 0V rail. We will look at power supplies in more detail next month.

SINE WAVES

If you were able to rotate the potentiometer spindle at a perfectly timed regular interval from one limit to the other, the output voltage would appear like the undulating waveform of Fig. 2.5 which depicts a sine wave.

We can usually measure a d.c. voltage simply in terms of its voltage with reference to the 0V rail, but how can we define a waveform like a sine wave? And how can you actually *measure* a waveform like a sine wave?

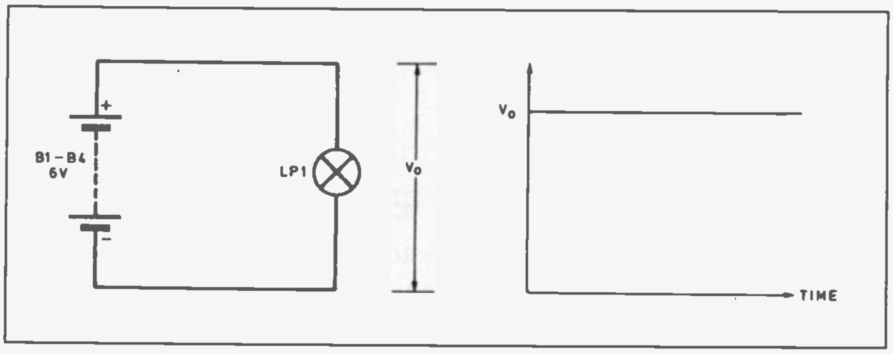


Fig. 2.1. Graph showing the output voltage versus time of a simple circuit. V_0 remains constant with time.

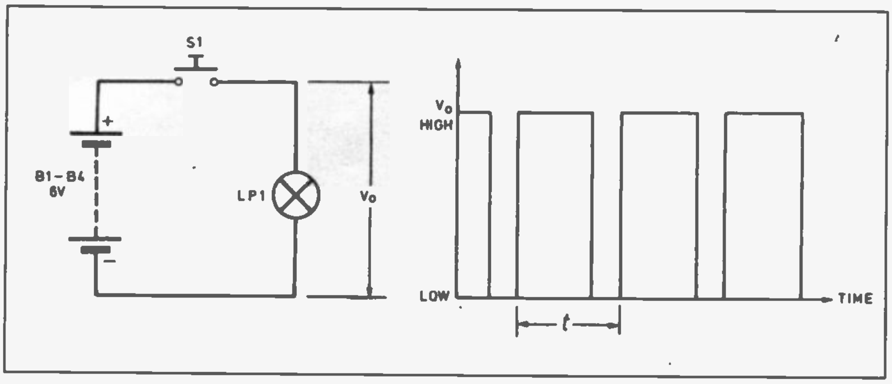


Fig. 2.2. A simple switching system producing a square wave consisting of two states – "high" and "low" or "on" and "off".

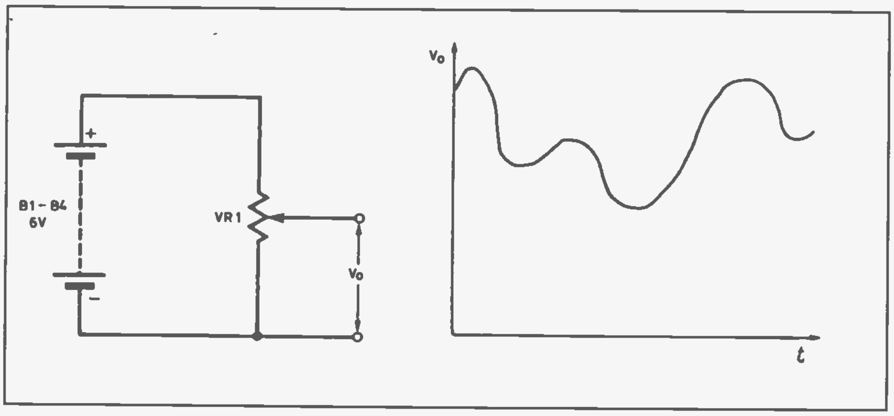
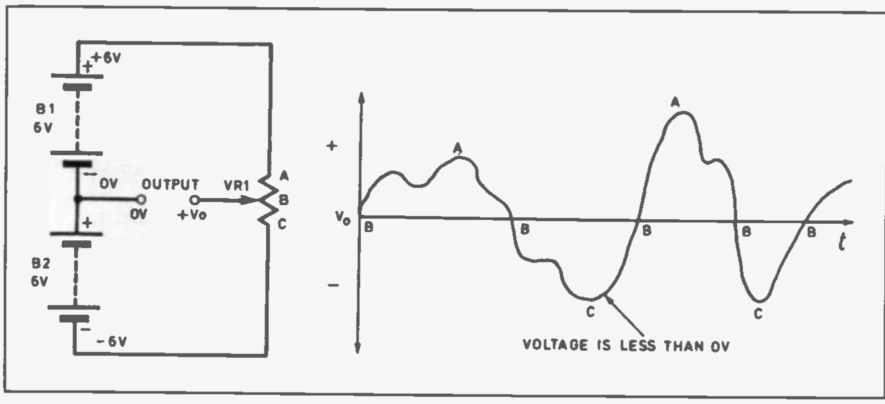


Fig. 2.3. This simple potentiometer circuit will produce an analogue *waveform such as that shown in the graph.*



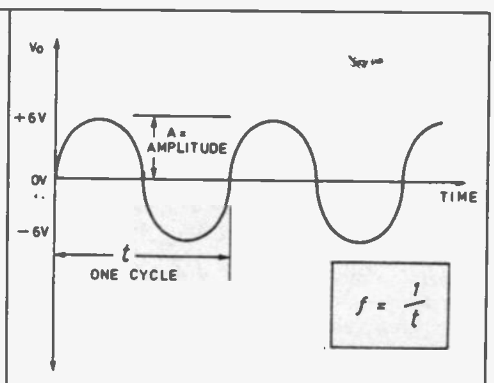


Fig. 2.4. Simulation of an alternating waveform. The output voltage V_0 could be considered as swinging between +6V and –6V with respect to 0V.

Fig. 2.5. A sine wave. The frequency of the waveform is given by the formula $f = 1/t$ where t is the time for a complete cycle, in seconds. Frequency is measured in Hertz.

Several parameters are shown in the sine wave of Fig. 2.5 which will help us to define its characteristics. The first is how high the peaks rise with respect to 0V: this is termed **the amplitude** of the sinewave. In our simple example, the amplitude A is 6 volts.

Another important parameter is how frequently the sine waves repeat themselves. The **frequency** would be determined by how quickly you can rotate the spindle back and forth between the two end stops of the potentiometer: the quicker you can do this every second, the higher the frequency.

The unit of measurement of frequency is the **Hertz** (abbreviated simply to "Hz."). It's defined as **the number of complete cycles which occur per second**. One cycle is equivalent to one complete sine wave in this example, as shown in the diagram. The formula used to calculate frequency is:-

f = 1/t Hertz
where f is the frequency (cycles per second) in Hertz, and **t** is the period, or time taken in seconds for one complete cycle.

So for example if one complete sine wave cycle takes two seconds, the waveform frequency is 0.5Hz, i.e. half a cycle every second. If the period is 25mS (0.025S), the frequency is 40Hz. Similarly a more rapid sine wave might have a frequency of say 10Hz and working backwards from the above formula, we could state if we needed to that the time period t for the wave is 0.1 seconds.

The Hertz can be quite a cumbersome unit to deal with and, like the Ohm, we often add a prefix to save writing many zeros when dealing with high frequencies.

The symbol "kHz" is the symbol for kilohertz, or thousands of cycles per second. 25kHz equals 25,000 cycles per second. MHz is the abbreviation for megahertz, or millions of cycles per second. If you own a hi-fi system or car radio, you might have a digital tuner which informs you of the frequency of the radio station you're tuned to. Look at the digital display for the "kHz" and "MHz" symbols on the a.m. and f.m. wavebands.

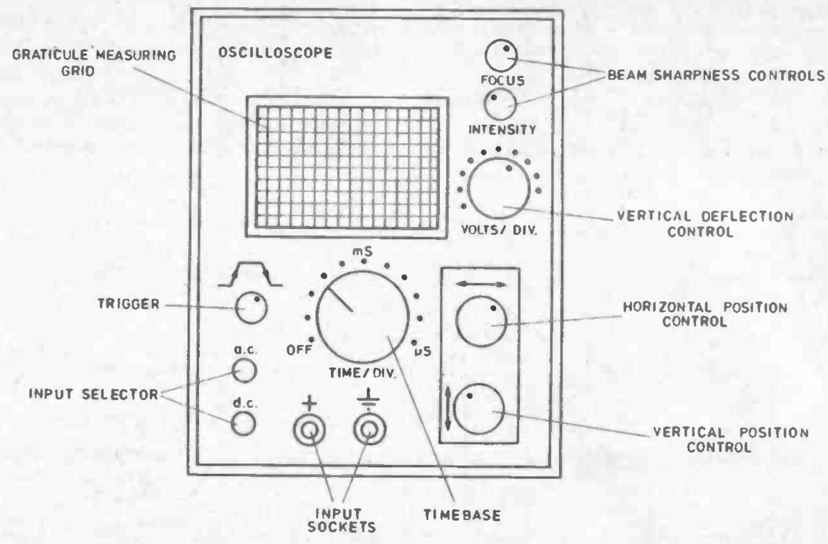
The formula for frequency holds true for any repetitive waveform such as a square wave: if we know the time taken for one complete cycle ("t" in Fig. 2.2) then we can work out the frequency of the waveform.

THE OSCILLOSCOPE

The cathode-ray oscilloscope (C.R.O.) is one of the most versatile pieces of test equipment you can buy. The basic operation of the C.R.O. is described in a separate section; even if you don't possess one, you should still be familiar with their capabilities and basic controls.

An oscilloscope actually plots a graph of voltage against time, just like the graphs of the waveforms we saw earlier. The graph takes the form of a trace on the screen which mimics what is happening in the circuit under test. If we know the *time-base* and *vertical deflection* settings (q.v.) of the C.R.O., then we can make some meaningful measurements on the waveform which appears on the display. Fig. 2.6 shows a real sine wave which we observed with a C.R.O. and then plotted on a computer printer. The *graticule* grid is also shown. (The sine wave is actually taken from the *Mini Lab* Signal Generator described in future parts.)

The **amplitude** of the sine wave is easily calculated. The vertical deflection has been set at 500mV per division, and we can see that the measurement "A" is 2.5 divisions.



THE OSCILLOSCOPE

In order to actually "see" what is going on in a circuit, a *cathode ray oscilloscope* (C.R.O.) is invaluable, though they are expensive pieces of equipment which only the keen enthusiast might buy. The diagram above illustrates the controls of a simple C.R.O.

An oscilloscope contains a *cathode ray tube* like a small round television tube. A fine *beam* of electrons strikes the *phosphors* coated inside the face of the tube making them glow temporarily, perhaps bright blue or green. Two factors control the path of the beam: the *vertical deflection* on the screen which is directly proportional to the voltage connected to the C.R.O.'s input terminals; secondly, a *timebase* which causes the beam to repeatedly traverse from left to right at an accurate rate.

Superimposed on the screen is a precise measuring grid called a *graticule* which may be calibrated in centimetres or simply in "divisions". If the vertical deflection switch is set to, say, two volts per division then a 6V d.c. input will cause the beam to deflect upwards by three divisions on the graticule.

The time-base control is calibrated in fractions of a second per division, and if the time-base was set at, say, 25mS (25 milliseconds) per division then the beam will traverse the screen left to right at precisely that rate. A timebase can easily operate at microseconds (millionths of a second) per division if necessary.

A *trigger* control locks a waveform on the screen so that the waveform shape "freezes" to enable us to observe it. The trigger control determines the level at which the beam will start its sweep, and whether it's triggered on the positive-going or negative-going slope of a waveform.

Also, it's possible to use a switch to select either d.c. or a.c. inputs: in a.c. mode, a small capacitor is inserted in series with the input signal and it removes any d.c. voltages superimposed on the signal, so that we can simply observe the a.c. "wobble". In d.c. mode, the input signal passes straight through to the C.R.O. (This topic is discussed in Part Four when we look at a.c. coupling.)

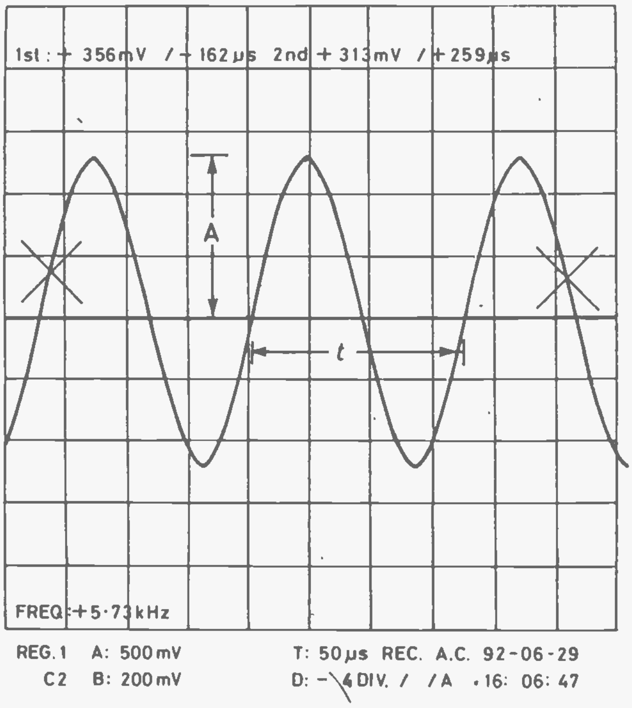
SETTING UP

After switching on and letting the instrument warm up, firstly centralise the electron beam on the screen with no input voltage present: do this by turning off the time-base completely and adjust the *horizontal and vertical position controls* to manually move the dot of light to the centre of the graticule. Adjust the *focus* and *intensity* controls to obtain a pin-sharp dot of light.

Then turn on the time base and adjust it to make the beam sweep across the screen. Because no input voltage is present, the line now being traced is effectively a 0V reference line. Fig. 2.3 showed how you could obtain a varying voltage from a 6V battery – a circuit like this could be connected to the input of the 'scope. Note the beam's deflection with reference to the graticule so that you can measure the voltage on the screen: it's the distance between your 0V reference line and the beam's new position with the input signal connected. In effect you are using the C.R.O. as a simple voltmeter.

Unlike moving coil multimeters, oscilloscopes don't appreciably load the circuit under test, so they are very accurate. However the major advantage of a C.R.O. over a multimeter is that we are actually able to see the *shapes* of waveforms on the cathode-ray tube. An example is given in the main text of how to utilise a C.R.O. to measure the frequency and amplitude of a waveform like a sinewave.

The *Mini Lab* will in due course sprout a compact waveform generator capable of producing three different types of waveform. This will be of especial interest to those readers who own, or have access to, an oscilloscope. However, we continue on the basis that it is *not* compulsory to possess an oscilloscope in order to follow *Teach-In*. For the purposes of GCSE/ A Level Electronics, though, you should be familiar with the basic operation of the C.R.O. – so try to have a go on one if you can.



$f = 1/t$ = 1/175µS = 5·7kHz

Fig. 2.6 (left). A real sine wave shown on an oscilloscope graticule. The frequency can be calculated as shown: compare against the actual digital frequency readout on this oscilloscope.

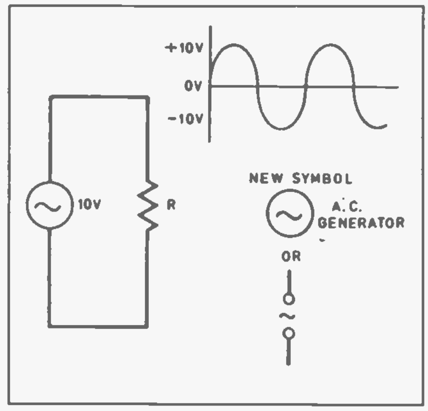


Fig. 2.7 (above right). An alternating waveform connected across a resistor. The voltage has a peak value of 10V, and swings back to 0V before reversing the other way.

The amplitude is therefore 1.25 volts. The **peak-to-peak amplitude** is equivalent to 2A, i.e. 2.5 volts.

The **frequency** can be calculated by measuring the time taken for one complete cycle of the sine wave to occur, and then applying our formula f = 1/t. We set the time-base at 50µS per division. One complete cycle covers 3.5 squares as represented by "t" on the diagram, which is equivalent to a period of 175µS. Hence, the frequency of this waveform is 1/175 µS or 5.7kHz. (Indeed, the built-in digital frequency meter display on our C.R.O. screen confirmed this as you can see.)

We now analyse sine waves in a little more detail. Again, we deliberately avoid any intensive mathematics as *Teach-In* is more interested in the results rather than how we arrived at them. Also, for the next section, it's not necessary to own an oscilloscope in order to progress through the text.

A.C. AND POWER

We already know from Part One that a resistor will dissipate power when a there is a voltage drop across it. When a simple d.c. voltage is applied, the resistor will become warmer, though you might not physically notice it, depending on circuit values.

Fig. 2.7 shows an a.c. voltage source applied across a resistor. Unlike a d.c. voltage supply, there is no longer a constant voltage across the resistor. Instead, a peak voltage is applied which actually drops to zero before the current switches the other way through the resistor, which heats up at a varying rate as the voltage across it rises and falls.

In fact, the resistor averages out the power dissipation when an a.c. current flows through it. If the a.c. has a peak voltage of, say, 10V, this cannot produce as great a heating effect in the resistor as a *d.c. voltage* of 10V would: the a.c. peak voltage of 10V only appears across the resistor for a fraction of the time (twice per cycle) – for the rest of the period, it's less than 10V. Compare this against 10V d.c. which would appear across the resistor *all the time*.

It's actually possible to calculate *effective values* for a.c. sine waves which would give the same heating effect in the resistor as a particular d.c. value. We can do this by considering the **root-mean-square** or **r.m.s.** values of the sine wave. Without detailing the mathematics behind it to any extent, the formula:

r.m.s. equivalent = peak value ÷ 1.414
($1.414 = \sqrt{2}$ = the square root of 2)

can be applied to both the a.c. peak voltage and peak current. Multiplying V r.m.s. and I r.m.s. together (because P = I × V) in an a.c. circuit would give the same value of power dissipation in Watts as multiplying V d.c. and I d.c. would, in an equivalent d.c. circuit.

In Fig. 2.8, a sine wave of 10V *peak value* is plotted – this has an equivalent value of 7.07V (i.e. 10V a.c. / 1.414). Hence 7.07V a.c. r.m.s. would cause the same heating effect in a resistor as a d.c. voltage of 7.07V.

When we talk about a.c. values, we nearly always mean the r.m.s. equivalent, not the peak value. The peak value has little use except when we specify the ratings of some components, when we might be interested in how high a voltage or current is likely to be applied. We then have to ensure that the component will be able to withstand these peak values. Note that the formula given above for calculating r.m.s. values applies *only* to sine waves – not a square wave for instance.

In the domestic mains power supply, the output is a sine wave which is stated as being 240V a.c. In actual fact, it's 240V r.m.s. and using the above formula in reverse, the peak value of the sine wave is 339V (240V × 1.414). Therefore, the 240V r.m.s. a.c. voltage from a mains outlet gives the same heating effect in a resistor (like an electric fire element) as a d.c. – and equally lethal – level of 240V d.c. would. But the insulation still has to withstand the peak value of 339 volts.

We can always apply the power dissipation formula (P = I × V) and also Ohm's Law (R = V/I) in a.c. circuits provided that we are referring to r.m.s. values, not peak or peak-to-peak figures. If your multimeter (either digital or moving-coil) has an a.c. voltage scale, this will actually read in r.m.s. volts, not the peak voltage.

THE DIODE

Let's turn to the *Mini Lab* for some practical work. We continue to use batteries as our source of power, so ensure that the "EXT BATT" option is selected in the power supply area of your *Mini Lab*.

Fig. 2.9(a) is a simple circuit diagram which shows a d.c. voltage supply and a filament bulb, together with a new symbol. D1 is a component in the class of *semiconductors* and is called a **diode**, and to demonstrate this device you will require a 1N4001 diode from your supplier. This is a simple two-wire device, generally with one end of the body painted with a white band. Build this circuit as shown in Fig. 2.9(b), using the breadboard section to connect the diode D1, and note the condition of the bulb below:

	CONDITION OF THE BULB:
DIODE CONNECTED AS IN FIG. 2.9(b)	
DIODE REVERSED	

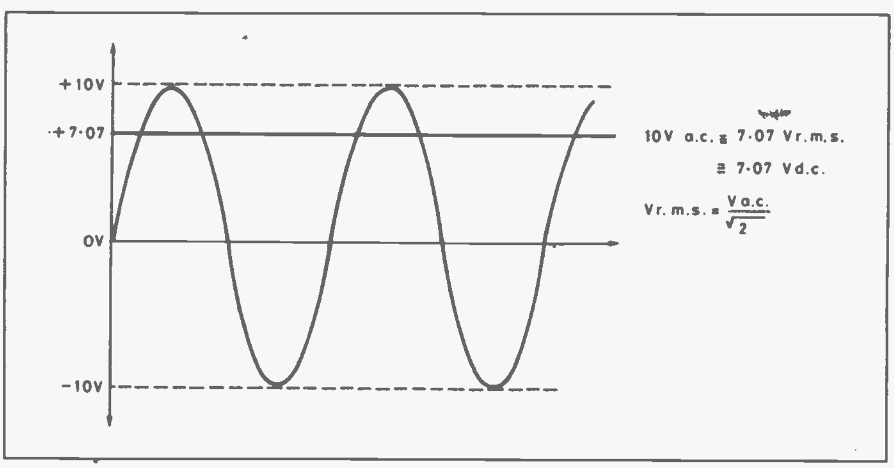


Fig. 2.8. A 10V a.c. (peak value) waveform would have an effective value of 7·07V in d.c. terms, or 7·07V r.m.s. When we refer to a.c. values, we nearly always mean the root-mean-square value rather than the peak figure.

What happens when you reverse the diode? Connect it the other way round again and confirm. The bulb will only illuminate when the diode is connected one way round. Which way round? The diode is a "uni-directional" device, and will only permit current to flow one way. It blocks current in the other direction, as its circuit symbol indeed suggests.

(Note: some Examinations Boards have slightly differing but equally correct symbols from ours for diodes and also a few other components. You may lose marks for using a symbol which is not approved by your Examining Board, whilst other Authorities may not object provided you are consistent throughout your work. Please consult your tutor if you have any doubts in this respect.)

With the bulb illuminated, use your multimeter to measure the voltage across the diode (meter + terminal connected to +6V). Your meter should be set to a low d.c. volts range, say 1V f.s.d.; record your measurement below:

VOLTAGE ACROSS THE CONDUCTING DIODE: Volts

Your answer will be in the region of 0.6V to 0.7V. When the diode permits current to flow (the bulb lights up), it is said to be **forward biased**. Conversely, when it blocks current (the bulb is extinguished) it is **reverse biased**. A voltage of about 0.7V always appears across a *silicon* diode (like the very common 1N4001) when it is forward biased, and this is called the **forward voltage**.

In fact the *anode* of the diode must be 0.7V more positive than the *cathode* before the diode can become forward biased and allow current to flow through it. See Fig. 2.10 which summarises the function of the diode.

Fig. 2.11 shows the *characteristic curve* for a typical silicon diode. The plotted line shows how the forward current through a diode can only rise once the forward voltage of the diode exceeds 0.7V. When it is reverse biased, hardly any current flows at all so it doesn't conduct.

DIODE SPECIFICATIONS

Diodes have electrical ratings, and the main parameters we are normally interested in are these:-

- V_f Forward Voltage,
- I_f Forward Current, the maximum current which can flow through the diode when it is conducting
- PIV Peak Inverse Voltage, the maximum reverse voltage allowed before the device is damaged

The data for our humble 1N4001 diode states that it's a 50PIV 1A device. A forward voltage of 0.7V roughly is fairly standard amongst all silicon diodes and therefore you won't often see it quoted in any published data. You might also see the symbol V_{rrm} instead of PIV. Have a look in some suppliers' catalogues to see if you can spot the ratings of diodes. Also check out their shapes and sizes, and compare the cost. Note how the prices increase for diodes which can carry more current (up to

GCSE QUESTION

This month's question is taken from the Midland Examining Group GCSE Electronics (1751) 1989 Paper 1. We acknowledge their co-operation with thanks. Here's an opportunity to apply your knowledge of light-emitting diodes and series resistors in this straightforward question.

The answers are the work of the authors and do not necessarily constitute the only correct solution.

1 The circuit shown in Fig. 1 has an LED connected in parallel with a buzzer to a 9 V power supply. A 1.2 kΩ resistor is connected in series with the LED. A switch is connected in series with the buzzer.

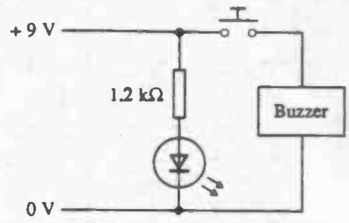


Fig. 1

(*a*) Fill in this Table. It shows what the LED and buzzer do when the switch is open and closed. [4]

Switch	LED (dark or light)	Buzzer (silent or buzzing)
Open		
Closed		

(*b*) Fig. 2 shows the coloured bands on the 1.2 kΩ resistor. If the resistor has a tolerance of 10%, name the colours of the bands on Fig. 2. [4]

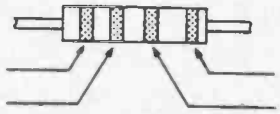


Fig. 2

(*c*) The potential difference across the LED is 1.8 V. Calculate the potential difference across the 1.2 kΩ resistor. [2]

....................V

(*d*) Calculate the current going through the LED. [3]

....

....

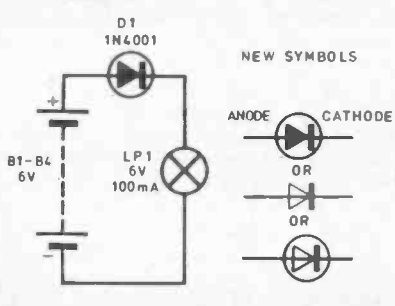


Fig. 2.9(a). Illustrating a diode in a simple circuit. Various symbols, as shown, are used by Examination Boards.

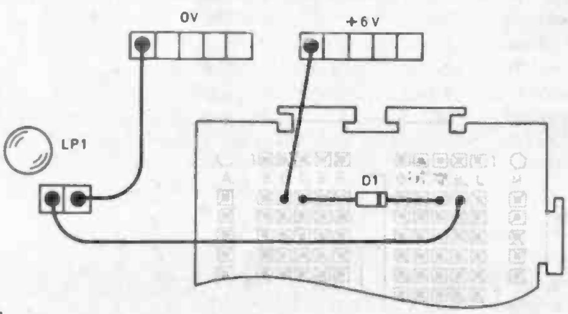


Fig. 2.9(b) Assembling the diode circuit on the Mini Lab. Reverse the diode and see what happens.

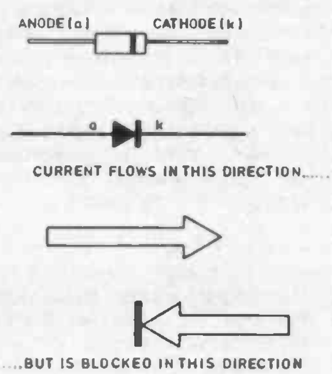


Fig. 2.10. Function of the diode.

3

(*e*) The graph of Fig. 3 shows how the current through the buzzer depends on the potential difference across it. Use it to find out how much current goes through the buzzer when the switch is pressed. [2]

The current through the buzzer is ....

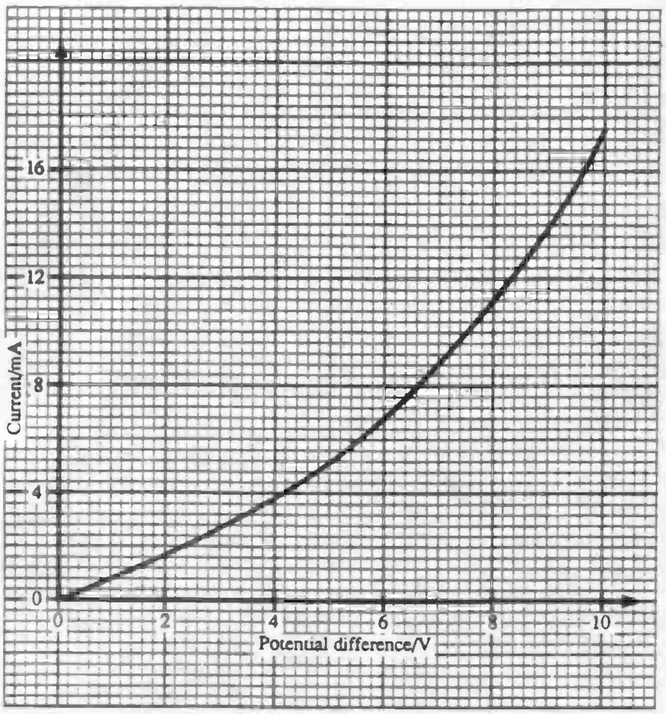


Fig. 3

(*f*) Sketch on the graph of Fig. 3 how you would expect the current through the LED to change with the potential difference across it. Assume that the LED is forward biased. [3]

(*g*) The 1.2 kΩ resistor in Fig. 1 is replaced with a 4.7 kΩ resistor. Describe and explain what effect this would have on (i) the LED, and (ii) the buzzer. [4]

(i) the LED: *change* ....

reason ....

(ii) the buzzer: *change* ....

reason ....

many tens of amps) or which have a higher PIV.

Apart from silicon diodes you may comes across devices fabricated from another material called "germanium" (not to be confused with "geranium" which is a flower!). These differ from silicon types in several respects: they have a forward voltage of typically 0.2V, and their current-carrying capabilities are vastly inferior to silicon types. A typical germanium device such as the OA91 may have an I_f rating of only 50mA. These sensitive low-power devices are classed as "signal" diodes in radio circuits for instance, where they work with audio or radio-frequency waveforms.

DIODES AND RELAYS

One major headache of using relays is the fact that they are based around an *electromagnet*, which is basically a coil wound onto an iron core. Coils in electronic circuits can have a major drawback: when you switch a coil **off**, the magnetic field around the coil collapses back into it, causing a large back **e.m.f.** to be generated. This takes the form of an often massive reverse electric pulse which can cause havoc with delicate electronic components such as transistors.

The *Mini Lab* incorporates a relay on the circuit board, and Fig. 2.12(a) illustrates a basic switching system where a push-operated switch S1 supplies power to the coil of the relay RLA. Closing S1 will supply power to the relay which operates, and in turn illuminates the bulb LP1. At this time, point "A" is actually at +6V with respect to point "B" which is at 0V.

It's similar to the circuits which were demonstrated last month when we discussed the relay. However there is one important difference, which is the inclusion of a diode D1 across the relay coil. When S1 is closed, D1 is

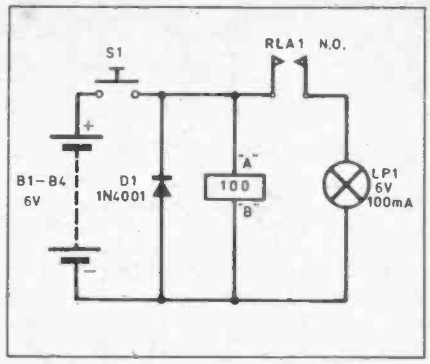


Fig. 2.12(a). A simple relay circuit which will drive LP1 once the switch S1 is closed. The diode D1 is used to short out any reverse-voltage pulse ("back e.m.f.") which is generated when the relay is de-energised.

reverse-biased because its cathode is at a voltage of +6V whilst the anode is at 0V.

Therefore under normal circumstances, D1 does nothing at all because it cannot conduct. However, when S1 is opened again, a reverse voltage (back e.m.f.) appears temporarily across its coil, such that point "B" is very much more positive than point "A". Now, the diode is instantly forward biased. It thus conducts and shorts out the back e.m.f. pulse generated by the coil.

Without the diode, the back e.m.f. which is created by the "implosion" of the relay's magnetic field will probably damage other components in the circuit. You will *always* find a reverse-connected diode across relay coils when they are used in electronic circuits. It's essential!

Fig. 2.12(b) shows an oscillogram of this actual effect which we captured using advanced test equipment. We connected a relay identical to that on the *Mini Lab* in an arrangement similar to that in Fig. 2.12(a),

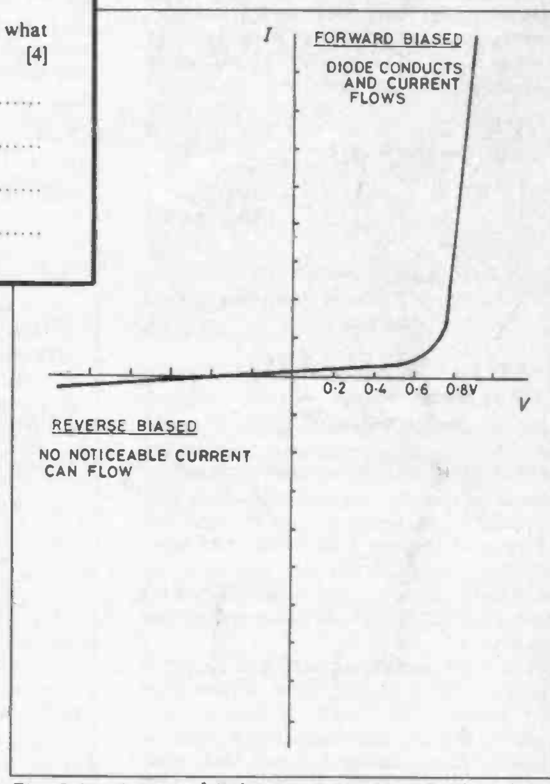


Fig. 2.11. A typical "characteristic curve" of a silicon diode, which will only start to conduct once the voltage across it exceeds approximately 0·6V – the anode must be 0·6V more positive than the cathode. In the opposite direction, no current can flow (apart from a tiny "leakage" current).

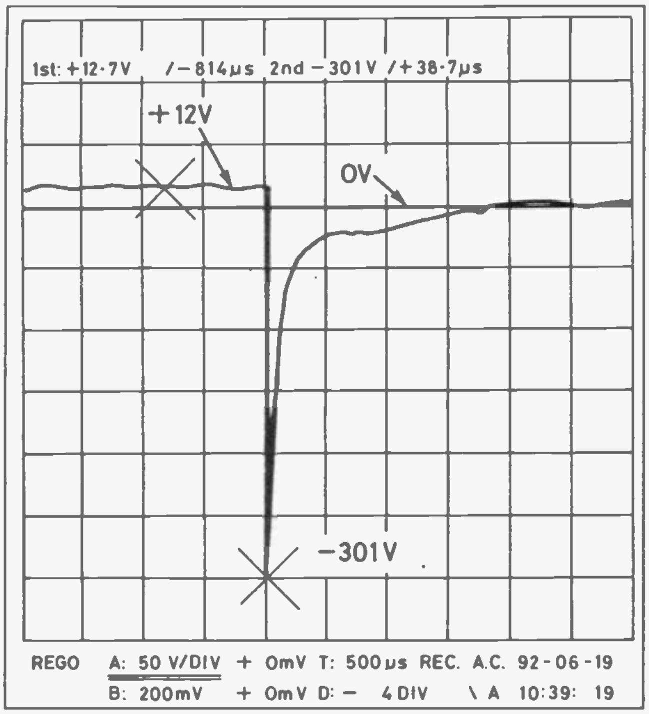


Fig. 2.12(b). Oscillograph of the back e.m.f. generated by a relay coil.

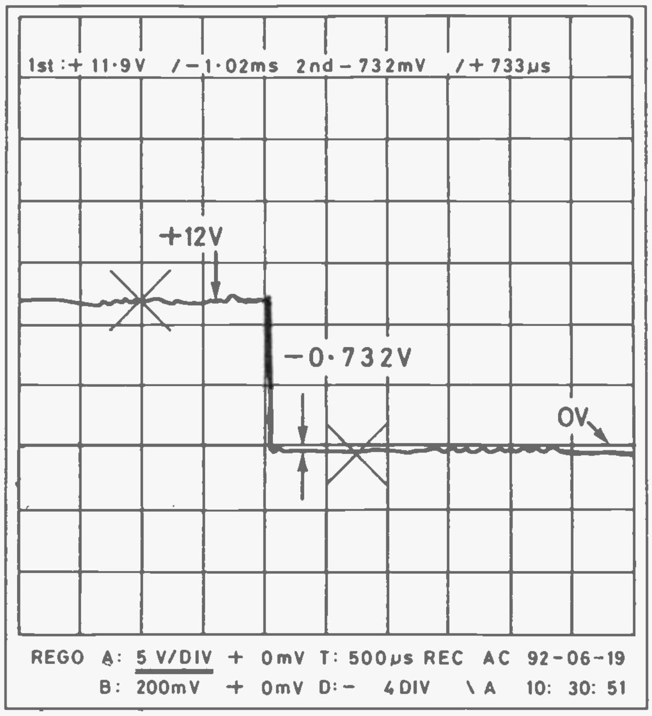


Fig. 2.12(c). The result of including a reverse biassed diode across the relay coil.

both with and without the diode. Our oscilloscope recorded the back e.m.f. pulse which was generated when the relay was switched off: as you can see, the peak reverse voltage was measured at an incredible –301 volts! Fig. 2.12(c) shows the result of including a diode to "shunt" the back e.m.f. which is now all but eliminated.

There is a location on the *Mini Lab*, adjacent to the general-purpose relay, where a suitable diode (e.g. 1N4001) can be permanently soldered into position to protect your test circuits from back e.m.f. You can solder it into place now, if you wish, taking care not to overheat it as semiconductors can be damaged by excessive soldering times. Once the diode is in place, it becomes *imperative* that you connect the relay coil correctly so that the diode is normally reverse biased.

Other important applications of diodes are shown next month when we utilise the unidirectional effect in power supplies to form a "rectifier". We also look at an interesting version of the rectifier called a "thyristor" which only conducts when you input a suitable control signal.

LIGHT-EMITTING DIODES

Diodes contain a special "junction" manufactured from either silicon or germanium, which has been carefully treated to transform it into a semi-conducting material with certain operating characteristics. However, manufacturers have created a whole class of light-emitting diodes which are invaluable as solid-state indicators in electronics. They don't have a filament like a bulb, and in normal use last forever.

A typical light-emitting diode (l.e.d.) is shown in Fig. 2.13, and these devices have two lead-outs designated anode (a) and cathode (k) like a normal diode, and by forward-biasing the l.e.d., it will emit light. You can buy them in red (cheapest and most common), green, yellow, orange and even blue (unusual and very expensive). A whole host of shapes and sizes is available – look through the "Opto-Electronics" section of a good catalogue to see.

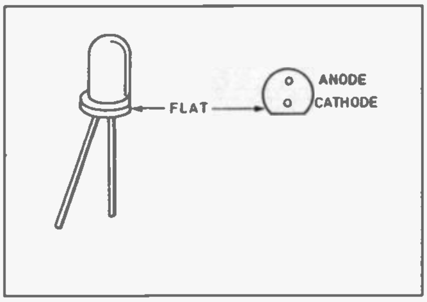


Fig. 2.13. A typical light-emitting diode, with pin-out connections. Usually, the flat notch is nearest the cathode, *Sometimes, one lead is longer than the other, in order to identify anode and cathode – check the manufacturer's data.*

There are some important operating conditions to observe, or an l.e.d. could be damaged. Firstly, they hate reverse voltages, and are likely to be destroyed by anything over 5V PIV or even less – so connect them the right way round, forward biased! Secondly, they have a typical forward voltage of about 1.8V. It's essential that you don't test them by connecting them directly across a 6V battery (for example), because you will exceed their V_f rating and destroy them.

Light-emitting diodes always have their lead-outs identified somehow so that you know which is which. Generally you see a flat mark on the base of the resin body adjacent to the *cathode*. Other times, the anode and

GCSE QUESTION (see previous page) ANSWERS

(a) With the switch *open*, 9V is applied to the l.e.d. and series resistor but not the buzzer. Hence the l.e.d. is alight and the buzzer is silent. With the switch *closed*, 9V is now applied to the buzzer, so the l.e.d. is alight and the buzzer sounds. The switch has nothing to do with the state of the light-emitting diode – it's a red (l.e.d.) herring!

(b) From the Resistor Colour Code, the digits required are 12 and the multiplier to obtain 1.2k (1200 ohms) is x100. Hence the coloured bands are **Brown (1), Red** (2), **Red** (x100) and finally **Silver** (10%). The Resistor Code, by the way, was given with the Paper.

(c) If 1·8V appears across the l.e.d. (forward voltage), the rest of the supply voltage appears across the resistor, so the answer is 9V – 1·8V = **7·2V.**

(d) Hmmm ... the current flowing through the l.e.d. must be the same as that flowing through the series limiting resistor: use Ohm's Law I = V / R so the current is 7·2 / 1200 = **6mA**. No marks were lost if you wrote 0·006A instead, or even 6/1000 Amps.

(e) The p.d. across the buzzer when the switch is closed is 9V. Therefore, read from 9V on the Voltage scale upwards to intersect the curved line: read across to obtain an answer of **14mA**. Interestingly, the Examiners commented that many candidates could not read the graph, a fundamental skill required in electronics.

(f) A constant 1·8V will appear across the l.e.d. once it's forward biased. Until then, no current can flow. The graph rises steeply when the l.e.d. starts to conduct, when we know from (e) that 14mA will flow through it with 1·8V across it.

(g) (i) The l.e.d. will **dim**. Increasing the resistance reduces the current flowing through the l.e.d. to (I = V / R) 1·5mA.

(ii) There is **no change** with the buzzer, because its supply voltage remains at 9V. Its operation has nothing whatsoever to do with the l.e.d. series resistor – another red herring to test you!

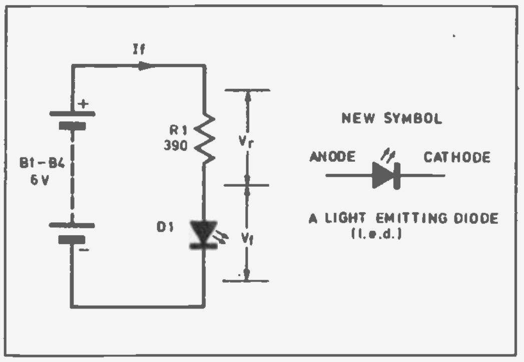


Fig. 2.14(a). *A light-emitting diode (l.e.d.) operated in series with a limiting resistor R1.*

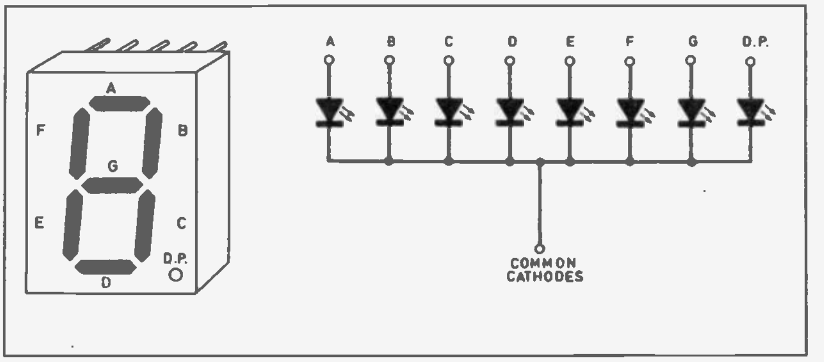


Fig. 2.15. *A seven-segment light-emitting diode digital display. Either common-anode or common-cathode types are available. CC-type is shown (right).*

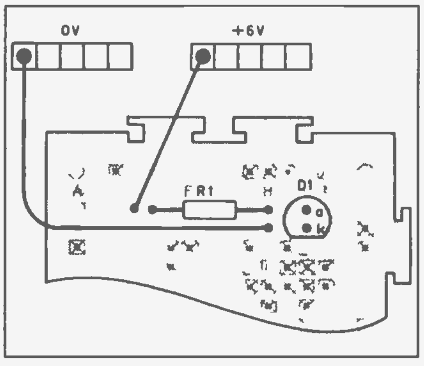


Fig. 2.14(b). *Connecting an l.e.d. with a series resistor to the* 6V Mini Lab *supply.*

cathode are denote by different lengths of the lead: check the supplier's data if in doubt.

Nearly always you will want to drive an l.e.d. from a voltage higher than the maximum permissible forward voltage, such as the +5V rail which is extremely common in digital circuits. You have to ensure that when it's illuminated, only the forward voltage value appears across the l.e.d., nothing greater. Anything less, and the l.e.d. simply doesn't light; too much, and it spells death to the l.e.d.!

It is also necessary to consider the *current flowing through the device.* Light-emitting diodes have a maximum forward current (I_f) rating which is usually expressed in milliamps. We have to limit the current so that this current is not exceeded. 50mA might be typical, but you can obtain a respectable light output from an l.e.d. when as little as 10-20mA, or even less, flows through it.

Thus when operating a light-emitting diode from a (d.c.) voltage, we generally have to reduce this voltage so that only the forward voltage of the l.e.d. appears across it – the rest of the voltage has to be wasted somewhere – and we have to limit the current flowing through the l.e.d. as well.

Fig. 2.14(a) is a simple circuit to demonstrate the light-emitting diode. For this section, you will need any general-purpose l.e.d., say 5mm diameter so that it isn't too fiddly to handle: they cost about 20p.

The basic specification for a typical l.e.d. is as follows:–

Type: RS 590-446
Colour: red
Diameter: 5mm
I_f (maximum) : 30mA
I_f (typical) : 10mA
V_f : 2V typical
V_{rev} max : 3V
Viewing angle : 30 degrees.
The values shown are typical of other types of l.e.d.

For our demonstration we will operate the l.e.d. from our 6V battery pack, and because the typical forward voltage for this l.e.d. is 2V, we have to lose 4V before we can drive the l.e.d. safely. Additionally, we have to ensure that the forward current (I_f) is limited to no more than 30mA – though let's choose 10mA which from experience is adequate to give a reasonable output of light. A lower current simply reduces the brightness.

SERIES RESISTOR

For the l.e.d. to operate reliably, we have to employ a **series limiting resistor** so that 4V will appear across the resistor, *and* the current flowing through the l.e.d (and therefore through the series resistor) will be limited to 10mA. It's really easy to calculate the resistor value using Ohm's Law (see Part One):

$$R = V / I = 4 / 0.01 = 400 \text{ ohms.}$$

Remembering that resistors are produced in a range of preferred values, the one nearest to 400 ohms is actually 390 ohms. To double check the current which will flow using a 390 ohm type, use I = V/R to obtain an answer of 10.2mA – quite acceptable.

The final consideration is the power dissipated by the resistor. You can use either $P = V^2/R$ or $P = I^2R$ which will give about 0.04 Watts (40mW), so a standard 0.25W 5% resistor will easily be more than adequate.

The power dissipated by the l.e.d., incidentally, will be a mere 20mW ($P = IV$). Thus they are very energy-efficient devices and ideal for operating with low-power circuits – compare against our 6V filament bulb used in Part One, which draws some 100mA of current and dissipates 600mW of power, though the bulb is of course much brighter.

Now use a 390 ohm resistor and an l.e.d. to build the circuit of Fig 2.14 on the *Mini Lab*, as shown in Fig. 2.14(b). Note particularly the polarity of the l.e.d. which in accordance with our standard practice is shown from an *aerial* (bird's eye) viewpoint in this diagram.

You may wish to try other colours in this circuit to assess the effect, and the red device can be exchanged for any other colour, size or shape of l.e.d. if you have any. Simply remember to observe the polarity.

OTHER TYPES

Check out a catalogue for *bi-colour* types. These glow either red *or* green, depending which way round you connect them. They're great fun to play with. Also look for *flashing* types, which are designed to run from a stable +5V supply and incorporate a miniaturised circuit to make the l.e.d. flash continually. You might see *constant-current* light-emitting diodes which don't need a series resistor: they adjust automatically to ensure that a safe forward current flows. They're ideal for use with varying voltages.

Our final look at light-emitting diodes is the *seven-segment* display, see Fig. 2.15. The bars of the display are actually elongated light-emitting diodes; and by activating various segments, different numbers can be displayed. Each segment is denoted by a letter *A-G* as shown, and a decimal point is generally included too.

Rather than have seven cathodes and seven anodes – 14 connections in all – it's normal to connect either all the anodes or all the cathodes together and connect them to one voltage (e.g. the supply rail), and activate the other ends of the segments as needed to form a display. Hence, you can buy either "common anode" or "common cathode" devices to specify which segment terminals are all connected together. The *Mini Lab* will require three seven-segment displays in due course.

The very first digital watches introduced in the mid 1970's used seven-segment light-emitting diode displays under a magnifying lens; they didn't display the time constantly (you had to press a button) and compared against modern liquid-crystal displays (l.c.d.s) they consumed batteries at a frightening rate!

CAPACITANCE

The following topic utilises the Mini Lab L.E.D. Voltmeter, which is the first of the modules to be assembled on the Mini Lab *printed circuit board. The constructional details for the L.E.D. Voltmeter are given separately. Don't worry if you don't fully understand how the module works: the main thing for now is to assemble it!*

Capacitors are components which have the "capacity" (literally) to store electric charge. The circuit symbols for three common types of capacitor are shown in Fig. 2.16 – we will look at each type in due course. The symbol is actually a good representation of a capacitor's construction,

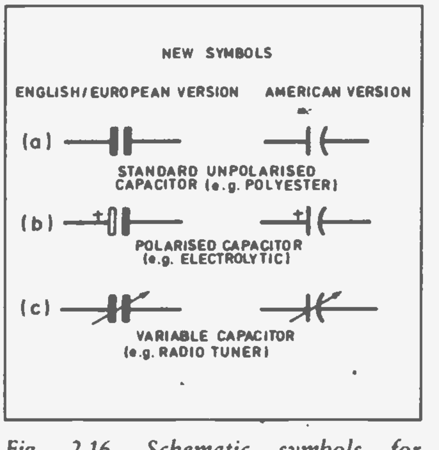


Fig. 2.16. *Schematic symbols for capacitors. The American versions are also shown, as these often appear in component manufacturers' data sheets for American-made semiconductors.*

ADVANCED LEVEL

In order not to encroach upon the Physics syllabus, our treatment of Capacitance is deliberately simplified, and only outlines the principles which are of interest to the electronics enthusiast. Physics students must remember that in electronics, by convention we treat charge as positive but in real life, electrons have a *negative* charge.

The basic property of a capacitor is described by the formula C = Q/V where C is the capacitance in Farads, Q is the charge in **Coulombs** stored on the capacitor and V is the potential difference created across the device. In an ideal capacitor, when a voltage is applied to it a charge of +Q Coulombs is gained by one plate and so -Q is lost by the other.

The *nett* charge is zero because in mathematical terms +Q and -Q cancel out, yet the capacitor stores *electrical energy* in the form of an electric field between the plates. In electronics, when we talk of the charge on a capacitor, we actually mean the charge of magnitude Q on just one of the plates.

When capacitors are placed in parallel, the p.d. across them remains the same (just like it does with two resistors in parallel) but the total charge is increased. If both capacitors were identical, the total charge would be doubled. The formula for any number of capacitors in parallel is:

$$C_{total} = C1 + C2 \ldots etc$$

For capacitors placed in series across a potential difference, the applied voltage is now split up across the capacitors. If two identical capacitors are placed in series across a potential difference, half of the voltage appears across each capacitor. The formula for capacitors in series is:

$$1/C_{total} = 1/C1 + 1/C2 \ldots etc$$

You might have spotted that these formulae are the opposite of those for resistors in series and parallel.

Apart from their use as energy-storage devices, capacitors have another important characteristic when used with a.c. waveforms: their "resistance" can vary depending on the frequency of the applied waveform. The term "impedance" is used when we mean "a.c. resistance" and the impedance Z (in Ohms) of a capacitor of C Farads at a particular frequency f is:

$$Z = 1/(2\pi f.C)$$

Their properties make them useful as frequency-dependent *filters* when we want to reduce (or "attenuate") a particular fre-

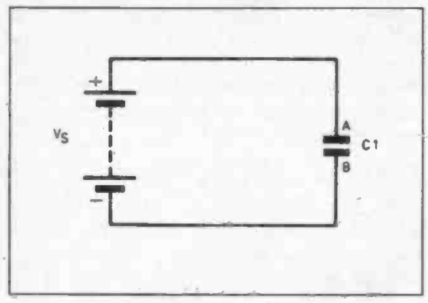
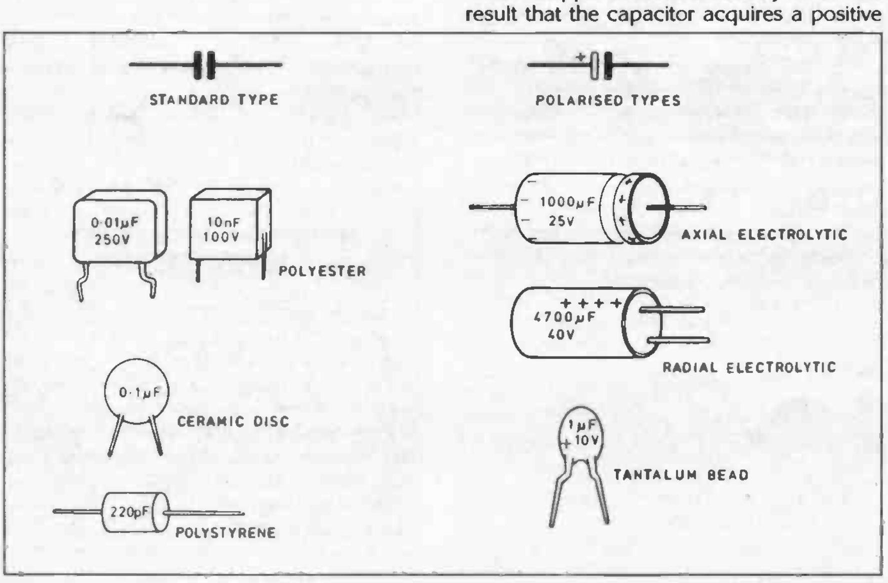


Fig. 2.17. A capacitor C1 connected to a hypothetical d.c. voltage V_S.

Fig. 2.18 (below). Some typical capacitor types. It is VITAL that polarised types, especially electrolytics, are connected the right way round. Capacitors are classified by the dielectric material.



which consists of two relatively large "plates" (often several inches square) separated by an insulating layer called the "dielectric".

The dielectric acts like a break in the circuit, and you would be right in thinking that the dielectric layer prevents current from flowing *through* the capacitor. We have already discussed how some materials (insulators) are very poor at conducting electric current. So what use is a component which simply stops current flowing in a circuit? Read on!

Fig. 2.17 is a hypothetical arrangement consisting of a capacitor C1 connected across a d.c. supply voltage V_S. When the circuit is made, a *charge* flows out of the positive terminal of the battery onto the plate marked "A" and a compensating equal charge is lost from plate "B" (remember we talk in old-fashioned "conventional current terms" and not "real life electron flow" which is the exact opposite – see last month).

This happens instantaneously with the result that the capacitor acquires a positive charge on plate "A" and a negative charge on "B" so a potential difference equal to V_s is then present across the plates. Whilst a current has not passed through the capacitor itself, there has been a flow of electrons on each side of the component, which often gives the false impression in a circuit that a current did indeed flow through the dielectric. Refer to the "Advanced Level" section for further information on capacitance.

The unit of measurement of capacitance is the **Farad** (symbol F). Very large capacitors (say 1 to 3F) are used as memory back-up devices in car radios or hi-fi digital tuners, but in general terms the Farad is such a large unit that we mainly use the following:

MicroFarad	1µF	= 10^{-6}F
NanoFarad	1nF	= 10^{-9}F
PicoFarad	1pF	= 10^{-12}F

Different types of capacitor are available which utilise different dielectric materials. We generally classify a capacitor by what the dielectric is made of; probably the most common type suitable for general purpose use is the plastic *polyester* capacitor which ranges from say 10nF to 0.47µF or more. Tiny capacitances of, say 220pF or less might have a *polystyrene* dielectric.

For larger capacitances, e.g. 1µF to 4,700µF or more, it's generally necessary to utilise a *polarised* device called an *electrolytic capacitor*. The symbol for this is shown in Fig. 2.16(b) and it will be seen that it has a positive symbol. The real problem with electrolytics is that they have an extremely large manufacturing tolerance, typically –20 per cent to +50 per cent of their stated capacitance value.

WARNING

Because of their construction and contents, it is essential that electrolytic capacitors are always connected the right way round in a circuit, otherwise damage or personal injury could result. Therefore, *always* connect the + terminal to the most positive voltage in the circuit. Never ever mess about with electrolytic capacitors.

In theory the capacitor in Fig. 2.17 would retain its charge indefinitely, once the battery was removed. However electrolytics are notoriously bad for having an exceptionally high *leakage current*, because the dielectric they use is far from being a perfect insulator. Some of the charge leaks away through the component – smaller tantalum bead capacitors are an improvement in terms of size and performance (they are also polarised like electrolytics), and for smaller capacitances polyester types are better still in terms of tolerance, leakage and physical size.

Capacitors also have a *voltage rating* and the user must always ensure that the voltage across the capacitor does not exceed this value – especially electrolytic types. It is however permissible to use a component with a *higher* rating than one specified in a circuit.

Fig. 2.18 depicts some common capacitors. Note that an electrolytic type generally has a ring crimped into its body: this signifies the positive (+) end: the "can" is always connected to the negative terminal. Again, have a look through a mail order catalogue and compare size, type and price.

TIME CONSTANT

Fig. 2.19(a) shows a 1000µF 16V electrolytic capacitor in series with a 27k resistor, connected across the 6V battery pack. The battery also powers the L.E.D.

Voltmeter through a ready-made internal connection on the *Mini Lab*. Build this circuit on the Veroblock as shown in Fig. 2.19(b), ensuring the electrolytic capacitor is connected the right way round. Use the largest electrolytic capacitor you have available – certainly 470µF or more. The resistor should be roughly the value shown.

Before switching on the battery pack, set the range of the L.E.D. Voltmeter to 5V d.c. using its on-board selector plug. The meter is now going to be used to display the charging up action of a capacitor: we have included the 27k resistor in series to "slow down" the capacitor charging current to enable us to monitor the charging time. As the voltage across the capacitor increases due to its charging action, the L.E.D. Voltmeter display will gradually advance. You will find it best to use the "DOT" mode.

You need a stopwatch or a clock with a seconds hand. As soon as you switch on the 6V supply, start the clock and watch the display of the voltmeter: every time the l.e.d. display advances, try to note down the elapsed time in seconds. Continue until the display is static.

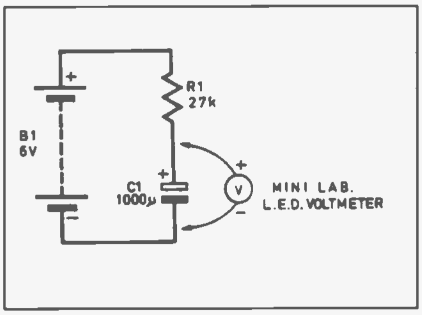


Fig. 2.19(a). A large electrolytic capacitor is charged through a resistor R1. The L.E.D. Voltmeter shows the gradual increase of potential across C1 as it charges.

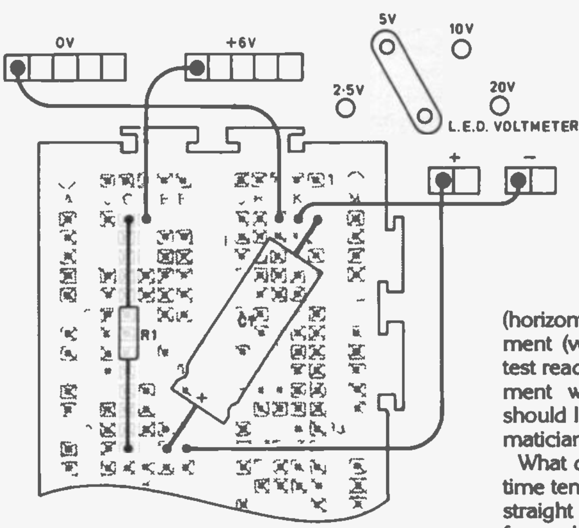


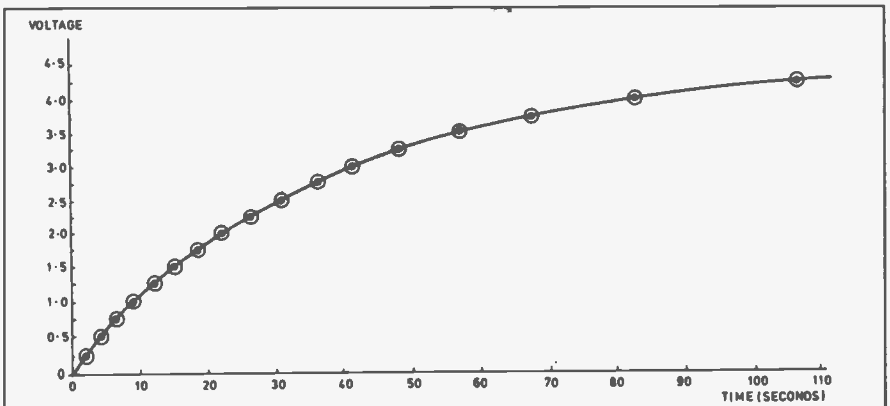
Fig. 2.19(b). Utilising the Mini Lab *L.E.D. Voltmeter to monitor the rising voltage of a charging capacitor. Use any electrolytic capacitor you have available, preferably 470µF or more.*

A great alternative suggested by our G.C.S.E. Advisor is to use a cassette recorder to tape your test readings as follows: set the tape machine recording and start the experiment. Either speak the time in seconds, or say "now" every time an l.e.d. lights, until no further change is noticed on the l.e.d. scale. Play back the tape and using the stopwatch, note down the elapsed time.

You will finish with a string of numbers, each one representing the elapsed time when the next l.e.d. in the display lights. With the L.E.D. Voltmeter module set to 5V, each l.e.d. step is equivalent to 250mV (5V divided by 20 l.e.d.s), *so the time taken for the next l.e.d. to light represents an increase of 250mV across the charging capacitor.*

If you want to start the experiment again, you must ensure that the capacitor is fully discharged. In this instance it's acceptable to short it out with a temporary link wire – or why not use one of the convenient n/o push switches? **In general you should not do this with larger capacitors or when higher voltages exist across a capacitor, as electrolytics are high-energy devices.**

Using your results, plot a simple graph of voltage against elapsed time for your charging capacitor. Just plot the elapsed time



TEST RESULTS

VOLTAGE PER L.E.D VOLTMETER	0·25	0·5	0·75	1·0	1·25	1·5	1·75	2·0	2·25	2·5	2·75	3·0	3·25	3·5	3·75	4·0	4·25
ELAPSED TIME (SECONDS)	2	4	7	9	12	15	18	22	26	30	36	41	48	57	68	83	107

Fig. 2.20. Plot of an exponential charging curve, using the results obtained from the circuit of Fig. 2.19.

(horizontally) against each 250mV increment (vertically). Fig. 2.20 shows our own test readings when we performed the experiment with our *Mini Lab* – your result should look roughly the same, what mathematicians call an "exponential curve".

What does the graph show? The charging time tends to tail off in a curve rather than a straight line. It takes progressively longer for each 250mV step to be reached, so a capacitor does not charge in a linear fashion through a resistor. The **Time Constant** of a resistor/capacitor network (like the one we've just used), is equal to:

RC Time Constant (seconds)
= R (ohms) × C (Farads)

The RC time constant for the 27k/1000µF network works out as 27 seconds. Introducing some useful rules of thumb:-

RC = time taken (seconds) for a capacitor to charge up to 63 per cent of its final value, or discharge down through a resistor to 37 per cent of its final value.

5RC = approximately the time it takes to *fully* charge or discharge a capacitor through a resistor.

Whenever you see "RC" mentioned in a formula or circuit containing a resistor and capacitor, you know that somewhere the capacitor is charging and/or discharging through that resistor. It's actually possible to make a capacitor charge up linearly through a "constant current source" – useful if you want to generate a uniform "ramp" waveform instead of a curve.

You can also experiment by *discharging* a capacitor through a resistor. Use one of the push switches to charge up an electrolytic capacitor from the 6V battery, then release the button to start the experiment and discharge it through the resistor, monitoring the voltage across the RC combination with the L.E.D. Voltmeter. Fig. 2.21 shows a

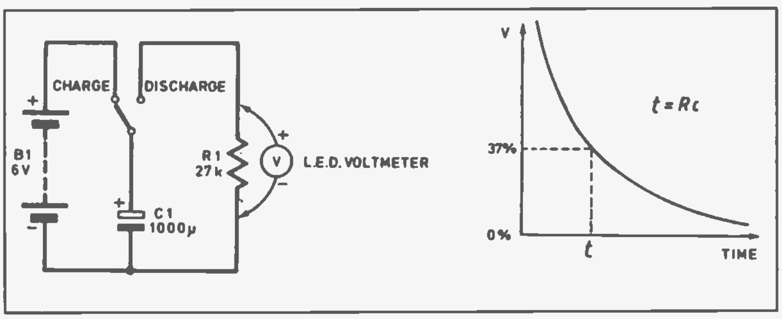


Fig. 2.21. Suggested circuit to observe the discharge action of a capacitor, use the L.E.D. Voltmeter to obtain results as before, then plot a discharge curve.

simple circuit to do this – see if you can work out the interwiring yourself, then take your results (the l.e.d. display moves backwards this time) and plot a discharge graph. Experiment with different values of resistors and capacitors.

Next month, we take a look at power supplies where your *Mini Lab* becomes mains powered – it will then *really* look like it means business! We also examine the extremely important area of safety in electronics, so there's something for everyone!

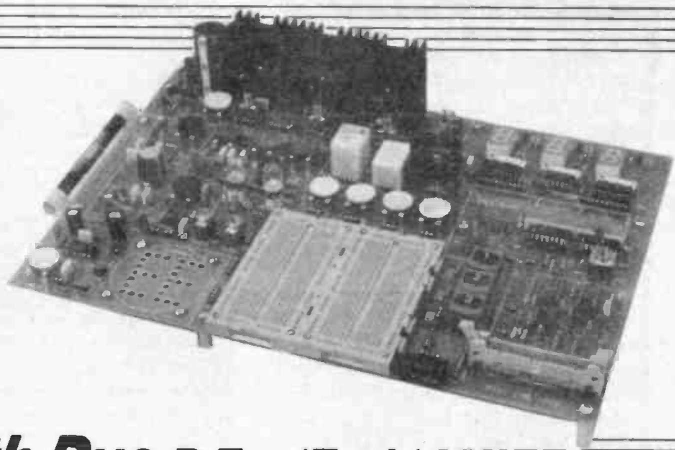
MINI LAB KITS

Magenta Electronics have advised us that they are now spplying kits of parts for the *Teach-In '93* series. They can supply kits for each part (part 1 with the p.c.b.) or a complete kit for the series.

Greenweld Electronics are also offering the two breadboards for the *Mini Lab* at a special price with a free soldering iron.

See the relevant advertisement and *Shop Talk* for more details.

Teach-In Project



MINI LAB

Alan Winstanley & Keith Dye B.Eng(Tech)AMIEE

The Everyday with Practical Electronics Mini Lab has been created to accompany Teach-In '93, and enables the reader to assemble demonstration circuits by following the clear instructions and diagrams contained in the main text, with every chance of it working first time. The Mini Lab is an exciting learning aid which brings electronics to life in an enjoyable and interesting way: you will both see, and hear, the electron in action.

THE first module to be constructed on your *Mini Lab* printed circuit board (described in detail last month) is a complete voltmeter which uses a row of 20 light-emitting diodes (l.e.d.s) for a scale. It reads up to 2·5V, 5V, 10V or 20V full-scale deflection (f.s.d.). The circuit diagram is shown in Fig. 1: if you are a novice in electronics, don't worry if the circuit diagram doesn't make too much sense – the important thing for now is to build the module successfully.

Space does not permit us to examine the mode of operation in great detail, though the components used will be familiar to experienced readers. Two LM3914N integrated circuits are used, and are connected to form a 20-step l.e.d. bargraph. The 1·25V internal reference voltages of both devices are connected in series to form an accurate 2·5V reference. The LM3914 I.c.s then compare the input voltage against this and illuminate (or "enable") the appropriate number of light-emitting diodes.

An attenuator system of close-tolerance resistors (R1 to R6) is selectable so that the f.s.d. of the module can be determined by linking with a shorting plug the appropriate sockets mounted on the *Mini Lab*. The values have been selected so that when the maximum f.s.d. voltage is presented to the L.E.D. Voltmeter, only 2·5V maximum actually appears at the inputs of IC1 and IC2. On the 2·5V setting, the input voltage is applied directly to the inputs of the l.e.d. drivers.

The meter has a sensitivity of 80,000 o.p.v. (ohms per volt) which is much better than many moving coil multimeters. The i.c.s are protected against overloads up to 35V and reverse input voltages down to –35V d.c. For further information, the manufacturers (National Semiconductor) of the LM3914 produce an informative Data Sheet which should be consulted.

S1 is a p.c.b.-mounted switch which controls the "mode" pins of the i.c.s and selects either moving dot or bargraph mode – the former is preferable for battery operation in order to minimise battery drain.

The design will be more than accurate enough for our purposes, and it also adds interest to demonstrations whilst freeing your multimeter to make other measurements. A printed scale is incorporated in the silk-screen printing of the printed circuit board, so you will have no problems interpreting readings.

CONSTRUCTION

The L.E.D. Voltmeter is assembled on the relevant section of the *Mini Lab* printed circuit board, which is fully silk-screen printed to help with component positioning. Solder in all parts as shown in Fig. 2 starting with the

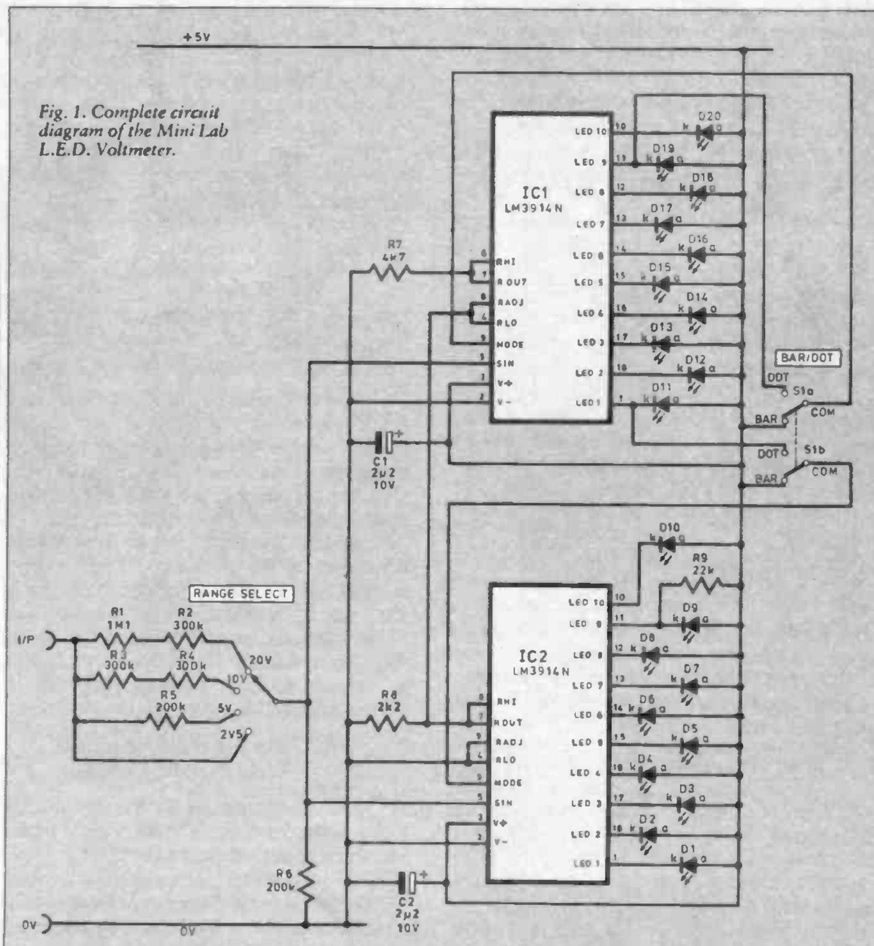


Fig. 1. Complete circuit diagram of the Mini Lab L.E.D. Voltmeter.

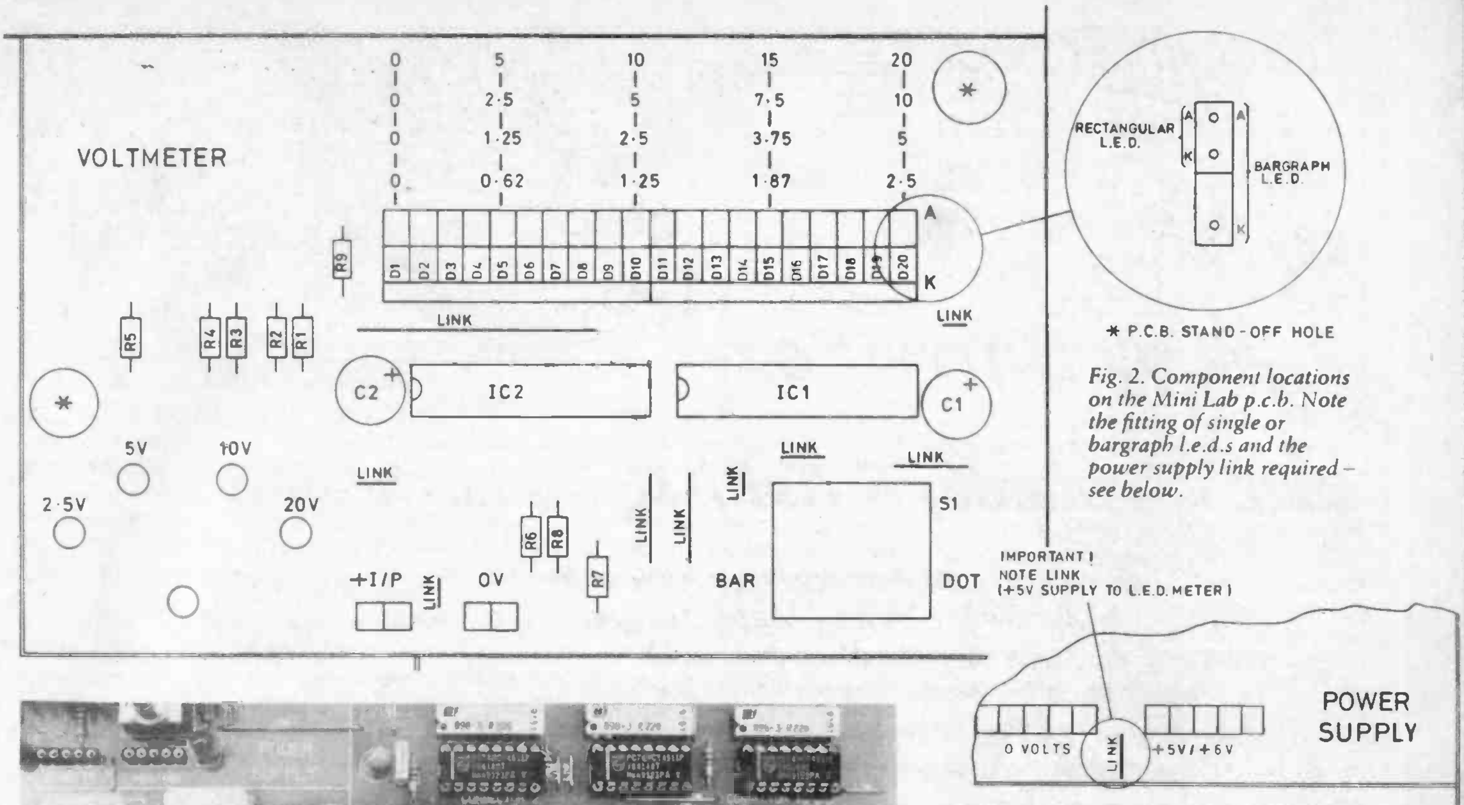
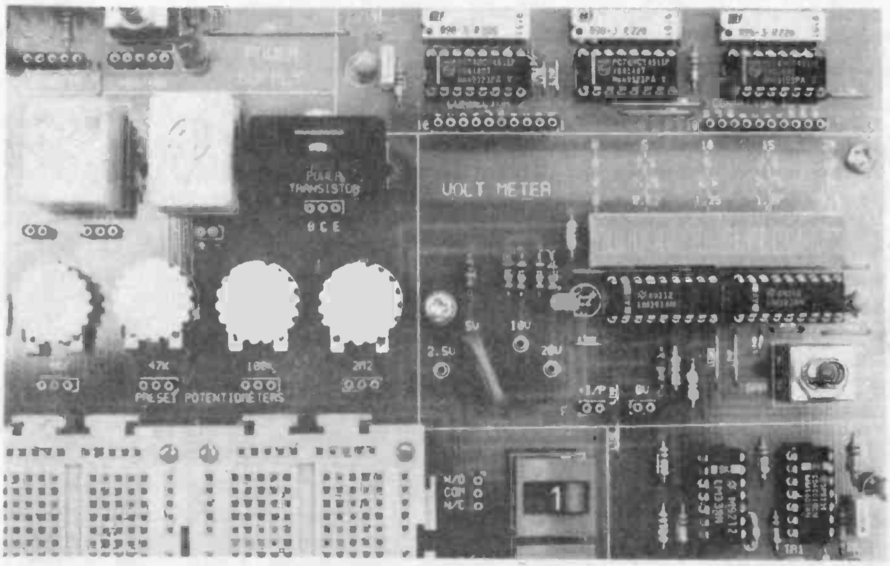


Fig. 2. Component locations on the Mini Lab p.c.b. Note the fitting of single or bargraph l.e.d.s and the power supply link required – see below.



jumper link wires which can be made from tinned copper wire.

It is best to use i.c. sockets if you are unaccustomed to soldering integrated circuits, so that thermal damage is avoided. In any event, do not overheat any joints or you may damage the p.c.b. and lift off the copper track. A fine-tipped soldering iron is best – take your time! Then insert the two integrated circuits carefully into their sockets, *observing polarity or you will damage the devices.*

Separate l.e.d.s can be used for the indicators, and to help when reading the scale, each 5th l.e.d. can be green coloured, the remainder being standard red devices. Rectangular types are best, and you *must* ensure that the l.e.d.s are soldered in the right way round, fitting them so that they are flush against the board.

Alternatively, a much neater effect is produced by utilising two 10-segment l.e.d. bargraph modules, although unlike separate l.e.d.s (the p.c.b. is designed to accept either) it will not be possible to include different coloured bars as "milestone" indicators. Either solder the bargraphs directly to the board or use dual-in-line sockets to carry them.

IN USE

The Voltmeter is powered by the 6V battery pack during the early stages of *Teach-In* after which mains operation is introduced and it is then powered from the 5V rail of the Mains Power Supply. External battery or Mains operation is selected with an on-board selector plug near the Power Supply section of the p.c.b., with the L.E.D. Voltmeter being powered from the appropriate source.

A set of turned-pin sockets are used for the + and – inputs to the L.E.D. Voltmeter, and these can quickly be connected using jumper wires to the Veroblock breadboard when required, in order to make a measurement. The 0V rail connects by the p.c.b. to the other modules (e.g. the Mains Power Supply), so often it will not be necessary to link a jumper wire to the 0V input socket – this connection is ready-made by the board.

Choose the required range of the Voltmeter using the selector plug to link the two appropriate sockets on the printed circuit board. In the demonstration circuits of *Teach-In* , you are always advised which f.s.d. is required for any experiments. Generally, you can also select either dot or bargraph mode, whichever you find easiest to read.

To test your completed L.E.D. Voltmeter module, choose 10V f.s.d. and switch on the 6V battery pack. Then use one of the on-board preset resistors (e.g. 47k) to apply a varying voltage to the input terminals of the Voltmeter (see Fig. 2.3 in the main tutorial). The relevant number of light-emitting diodes will illuminate when you rotate the preset control. Also test the Dot/ Bar selector, after which your L.E.D. Voltmeter is ready for use. □

Next Month: Power supply.

Mini Lab Components

See **SHOP TALK** Page

Resistors

R1	1M1 1%
R2 to R4	300k 1% (3 off)
R5, R6	200k 1% (2 off)
R7	4k7
R8	2k2
R9	22k

All 0·25W 5% except where shown

Capacitors

C1, C2 2μ2 35V tantalum bead (2 off)

Semiconductors

IC1, IC2 LM3914N l.e.d. bargraph driver i.c. (2 off)

D1 to D20 EITHER: 10 segment l.e.d. bargraph module (2 off),
OR: D1 to D4, D6 to D9, D11 to D14, D16 to D19: Red rectangular l.e.d. (16 off)
D5, D10, D15, D20: Green rectangular l.e.d. (4 off)

Miscellaneous

S1 d.p.d.t. toggle switch (C&K Z200 series)

P.C.B. mounting "jacks" (5 off); p.c.b. 0·5 inch insulated shorting link plug; turned pin s.i.l. sockets (4 off); 18-pin d.i.l. i.c. sockets (2 off); s.i.l. sockets for l.e.d. arrays, if required (4 of); wire, solder etc.

Note as detailed last month the Mini Lab p.c.b. is available from the EPE PCB Service, order code MINI LAB.

Price £13 Approx

FOX REPORT

by Barry Fox

On The Cards

Looking at the piles of discarded payphone cards littering the street near a public call box recently, someone asked why the cards cannot be re-cycled and whether any other country re-cycles them.

British Telecom now has 100,000 payphones, of which 21,000 are card phones. BT sells 25 million cards a year and they cannot be re-cycled because the credit units are stored in the card as an optical hologram. The card reader literally burns along a track as it uses up the credits.

If you look carefully at the top (green) surface of a BT phone card you will see a strip, stetching the length of the card with parallel markings, like rungs of a ladder. These are the credit units.

The object of using this type of card (made by Continental company Landis and Gyr) is to prevent fraud. The disadvantage of BT's system is that if the card surface becomes scuffed, the optical reader cannot read the track. Tip: Keep BT cards in a plastic holder.

Folklore

There have been all kinds of rumours and folklore stories about clever ways of rejuvenating BT cards. One theory was that you could put the cards in a freezer overnight to restore their value. Another was that you could cover the card surface with nail varnish to stop the laser destroying the track.

Needless to say British Telecom describes both tricks as "complete nonsense". But I have not yet met anyone with first-hand experience of reviving a card and I am not going to risk trying myself because it would of course be fraud and illegal to do so. Common sense suggests it is indeed impossible.

In theory cards, like credit cards, which have a magnetic strip can be recycled. But in practice the strips are unlikely to be sufficietly robust for resused cards to be reliable.

In any case the criminal fraternity has come up with several ways of copying the information on a magnetic strip card, either by heat transfer or the kind of card readers and encoders which large companies use for their own security cards. This is why magnetic cash cards will only work when the user keys in a secret PIN, or personal identification number.

It thus comes as quite a shock to find that Mercury, which went into card phones later than BT, adopted a magnetic card. Although there is no obvious magnetic strip on the surface, magnetic material hidden under the surface works just like the surface strip on a credit card.

How then does Mercury stop people cloning cards? No company wants to talk about security matters, but those in the know believe that Mercury uses a central monitoring system.

All the payphones are connected to a computer, which cross checks the serial number of the payphone card with a record of its last use. This is what causes the delay when some calls are made through a Mercury payphone, even though dialling is by speedy touch tone. The computer is checking its records.

If the computer finds that the card has suddenly accumulated value, instead of lost value, then the system rejects it.

The disadvantage of any magnetic system is that data can be erased if the card is brought near a powerful magnetic field. There was for years a folklore story that sealskin wallets erased credit cards. In reality it was the magnetic catch on the wallet which was erasing the data.

Smartcards

In France telephone cards are Smartcards, credit cards with a built-in computer chip and memory. Technically this is expensive overkill, but France has for years been subsidizing the use of Smartcards in an effort to make the French invention a way of life. Although it would be easy to re-cycle Smartcards, and make good financial sense, I checked with France Telecom, and they tell me that cards are not re-cycled.

The Smartcard system may be hi-tech, but it falls flat on its face in practice. Recently I tried to make a call from a French airport. I had no card and there was nowhere to buy one. I tried for half an hour to make a reverse-cahrges "collect" call, but never did get to speak to a human operator.

Charge It

For the first time British Telecom is feeling the real bite of competition from Mercury. If you are moving house, or planning to install a second phone line, or have a fault on your line, it pays to know how to turn this to your advantage.

Recently I needed a second line installed in a London flat. BT charged £163.75 (including VAT) to do the work, even though there were plenty of BT lines already running into the block.

Just after I paid, I received a press release from British Telecom quoting Michael Hepher, BT's Group Managing Director. He was puffing about BT "making it easier to get on the phone". Hepher quoted BT's line connection charge of £163.75 as a "maximum". "Very few customers are asked to pay the maximum connection charge" he went on.

I asked BT why I had been charged the "maximum" when there were already plenty of spare lines and the extra work done was minimal. Various BT people then came up with various excuses which boiled down to one practical fact. You only avoid paying BT's "maximum" connection charge if a full telephone service has previously been installed and disconnected, so that the only work involved is re-connection at the exchange.

While I was wasting time and money writing letters to BT, something else happened. The local cable TV service "passed" the premises, and offered me either a cable TV or Mercury telephone line connection, or both, for a flat fee of £30. Also, the cable company reminded, long distance calls on Mercury are cheaper.

Sunday Special

Incidentally this is doubtless why BT is now advertising the "Sunday Special", long distance calls at local rate on Sunday afternoons in November and December. Mercury and the cable companies now have to change their publicity adverts to "cheaper calls except on Sundays during November and December", which is hardly a catchy slogan.

BT's "present" also hits everyone with one of Mercury's "smart boxes", which supposedly route calls by the cheapest route. On Sundays this winter they no longer will. If you have one of these boxes you may well save money by disconnecting it on Sundays.

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A similar unit to the above but relying on the courtesy light operation and the well known volt drop detection system.

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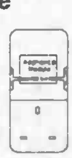

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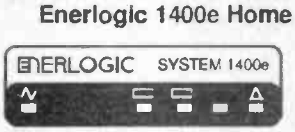

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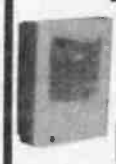

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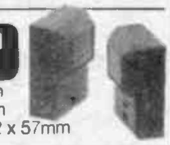

The IR1470 consists of a separate transmitter and receiver providing a beam of up to 50ft which, when interrupted, operates a relay in the receiver which in turn may be used to control external equipment. The system requires only 65mA from a12V supply. Size:(each unit) 82 x 52 x 57mm

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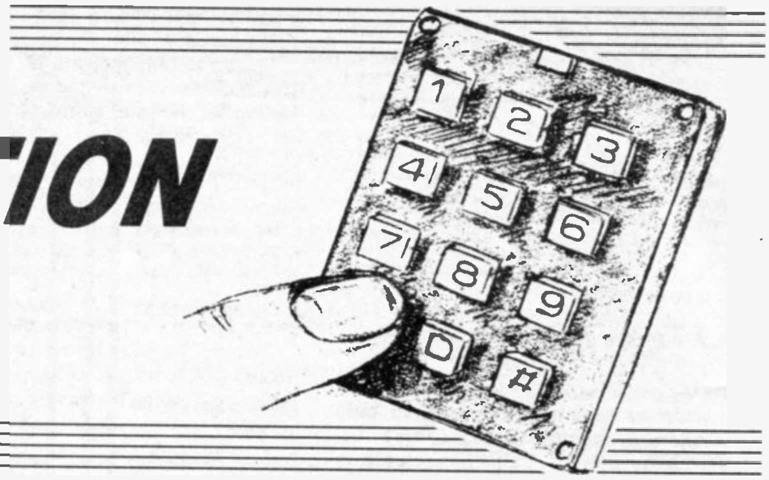
COMBINATION SWITCH



MAX HORSEY

A versatile project which can be used as a home security lock or alarm control switch. Personal "password" is held in memory and may be reprogrammed at any time

THE Combination Switch or Combination Lock is a versatile project which may be used to unlock a door or switch off an alarm etc. The user's password is held in memory, which is protected by a back-up battery in case of power cuts.

The password may be re-programmed by the user at any time, and up to 12 digits can be stored. If the wrong password is entered more than 3 times, a siren output is activated for a minute or so.

There is also provision for a switch input so that the siren sounds if the switch is closed before the correct password has been entered. This may be used to detect a door or window being forced. The project may be fully integrated with an alarm system if required.

The outputs are via transistors and a relay as follows:

- **Solenoid Output** (up to 3A) – to unlock a door.
- **Relay** – to turn on or off an alarm or any other equipment.
- **Siren** (up to 3A) – which sounds for a limited time if the wrong password is entered three times, or if the door is forced.
- **Small buzzer** – to indicate correct operation.

The constructor may select one or more of these output options.

OPTIONAL BACK-UP BATTERY

A power cut would cause the loss of the user's password in memory, resulting in the entry password defaulting to 0. This problem may be overcome by the use of a back-up battery. It is not intended that this battery should allow the project to function normally (a much larger 12V battery across the whole circuit would be needed), but the battery suggested will provide enough power to keep the memory of the i.c. active.

The supply suggested is three AA cells, which may be non-rechargeable (dry) cells, or re-chargeable Ni-Cad cells. In the latter case, resistor R_X should be fitted to trickle charge the cells.

Warning: Do **not** fit R_X if non-rechargeable cells are employed.

HOW IT WORKS

The essential features of the Combination Switch are shown in Fig. 1. At the heart of the circuit is IC1, a coded "security lock" chip type UA3730. Data is entered with an inexpensive matrix keypad, and all the complex functions are performed by IC1. A 5V supply is required, but since most solenoids and sirens require 12V, a regulator (IC2) is used to power IC1.

The voltage at pin 14 allows a small piezo buzzer to sound each time a key is pressed, and to indicate other functions. When the correct password is entered pin 17 goes low (i.e. 0V) for two seconds. The current available is amplified by a Darlington pair.

Also, each time the correct password is entered pin 16 toggles – in other words it changes from low to high, or high to low. A single transistor and relay are used here to switch on or off an alarm etc.

The output at pin 15 goes low for one minute to activate the siren via a Darlington amplifier, if the wrong password is entered more than three times.

OPERATING THE SYSTEM

Each time a key is pressed, the small buzzer WD1 will sound. The password is entered by pressing the correct keys, followed by the button marked "#". When first switched on the password is 0.

The password may be re-programmed as follows:

1. Enter the existing password. (Do not press "#")
2. Press *
3. Key in the new password – any combination up to 12 digits.
4. Press *

The "security" IC1 is now programmed with your new password.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Combination Switch is shown in Fig. 2. The 12V power supply is delivered via diode D9 which prevents damage if the supply is accidentally connected the wrong way round. Capacitor C4 decouples the supply, and 12V is available for the transistors, solenoid, relay and siren.

The 12V supply is reduced to 5V by the regulator IC2. This is a 78L05 i.c. which provides a very stable 5V output at up to 100 mA. Diode D2 prevents current returning to the regulator from the back-up battery in the event of a power failure, and capacitor C3 provides further supply decoupling.

The 5V supply from IC2 is applied to pin 9 of IC1. Diode D1 allows current to flow from the back-up battery to IC1 during a power failure, but prevents current flowing into the battery from the circuit during normal operation.

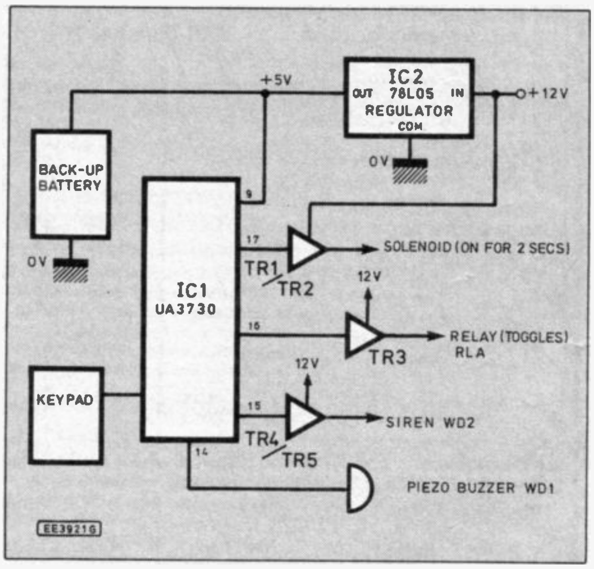


Fig. 1. Block diagram for the Combination Switch.

Optional resistor R_X should be fitted ***only*** if re-chargeable cells are employed. R_X allows a trickle charging current to flow when power is restored.

The suggest value of 100 ohms for R_X provides a trickle charge current of about 3mA. If the power supply is frequently disconnected, R_X could be reduced to 56 ohms. Note that R_X **MUST NOT** be included if dry-cells are used, because there is a risk of the cells exploding.

INPUTS

The keypad is connected to IC1 via pins 5, 6, 7, 8, 10 and 11. The matrix arrangement of the switch contacts reduces the number of connecting wires and pins required.

Switch S1 is optional, and when closed, causes the siren WD2 to be triggered. S1 could be used on a door or window or as an under-carpet pressure mat (or all three if wired in parallel), to trigger the siren if entry is forced without first entering the correct password.

OUTPUTS

Output pin 17 is "active low". In other words the pin is normally open circuit, but after the correct password is keyed in, pin 17 is internally connected to 0V. Pin 17 is connected via current limiting resistor R3 to the base of TR1.

Transistors TR1 and TR2 form a *pnp* Darlington pair. When pin 17 is open circuit, no current flows from the base of TR1, and both transistors are turned off. When pin 17 switches to 0V, current flows from the base of TR1, and both TR1 and TR2 turn on.

Assuming that the gain of TR1 is about 150, and the gain of the power transistor TR2 is 50, the total gain will be 150 × 50, i.e. 7500. Thus a current of 3A supplied to the solenoid requires only 0·4mA from the base of TR1. The circuit more than meets this requirement.

As mentioned earlier, output pin 16 toggles whenever the correct password is entered. In other words pin 16 changes from open circuit to low, then changes back again at the next correct entry.

The use of a relay here ensures that the project can be used to control any type of device from an alarm system to unauthorised use of a Hi-Fi unit! Transistor TR3 is employed to increase the current available from pin 16 to that required by the relay coil.

The output at pin 15 switches from open circuit to low when an incorrect password is entered more than three times. It is used to drive a siren via the Darlington pair TR4 and TR5. This operates in exactly the same way as with pin 17.

Diodes D6, D7 and D8 remove any high voltage spikes which tend to be produced by electro-magnetic devices such as solenoids and relays.

COMPONENTS

Resistors

R1	12k	
R2	4k7	
R3-R5	2k2 (3 off)	
Rx	100 (see text)	

All 0·25W 5% carbon film

See SHOP TALK Page

Capacitors

C1	270p ceramic plate
C2	1µ radial elect., 63V
C3	0µ1, disc ceramic
C4	1000µ, axial electrolytic 16V or more

Semiconductors

D1, D2, D9	1N4001 1A 50V rec. diode (3 off)
D3-D8	1N4148 signal diode (6 off)
IC1	UA3730 combination switch i.c.
IC2	78L05 5V 100mA voltage regulator
TR1, TR3, TR4	BC214L silicon *pnp* transistor (3 off)
TR2, TR5	TIP42A silicon *pnp* power transistor (2 off)

Miscellaneous

WD1	Piezoelectric sounder
WD2	12V high power siren
RLA	12V 180 ohm coil or more, with changeover contacts (see text)
S1	Door or window micro-switch (see text)

Keypad, 12-key 4 by 3 X/Y matrix; plastics case (main unit), size 150mm x 100mm x 60mm; small plastic case (relay housing), size 76mm x 50mm x 38mm; 12V solenoid or lock mechanism (see text); 18-pin d.i.l. socket; self-adhesive p.c.b. stand-off (2 off); back-up battery holder (for 3 AA cells), with battery clip; dry or rechargeable AA battery (3 off) – see text; multi-coloured connecting wire; 7-way "rainbow" ribbon cable (see text); double-sided sticky pads; solder, etc.

Printed circuit board available from *PCB Service*, code 812.

Note: you may not require all these parts – see "Options" section.

Approx cost guidance only **£32**

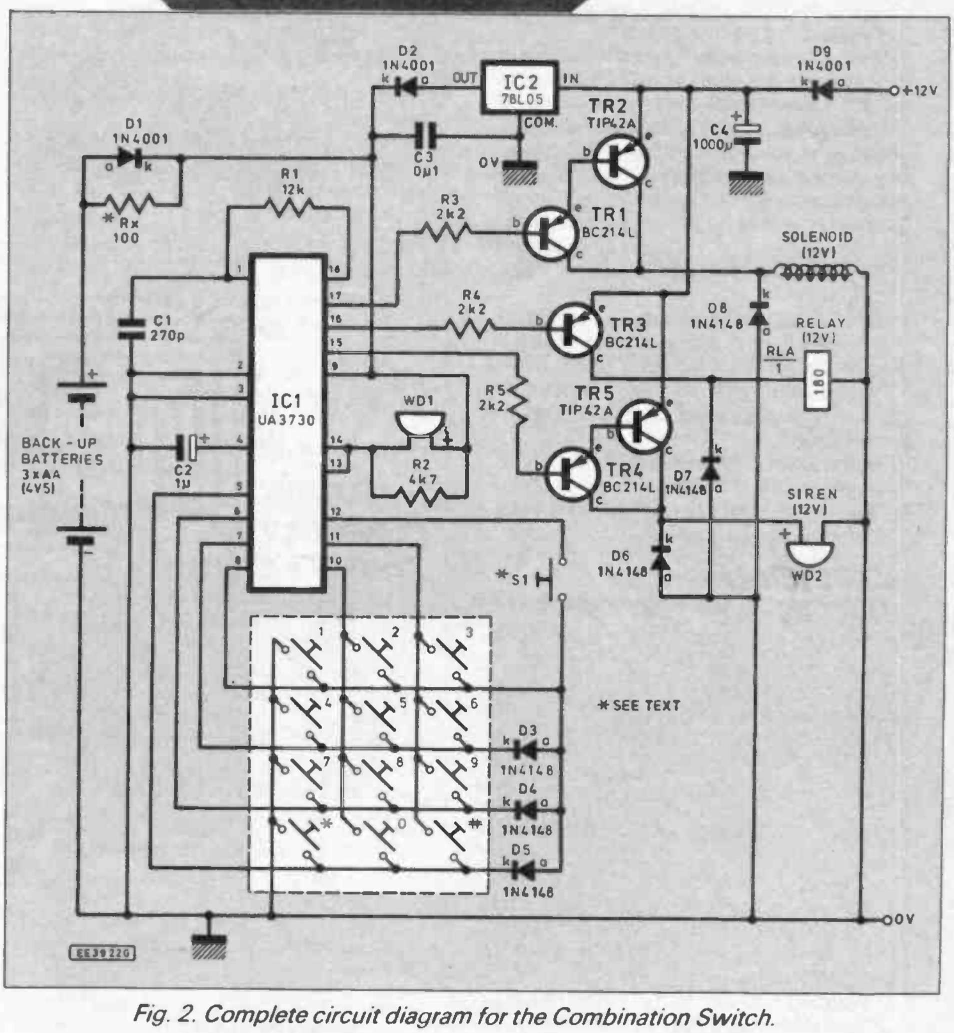


Fig. 2. Complete circuit diagram for the Combination Switch.

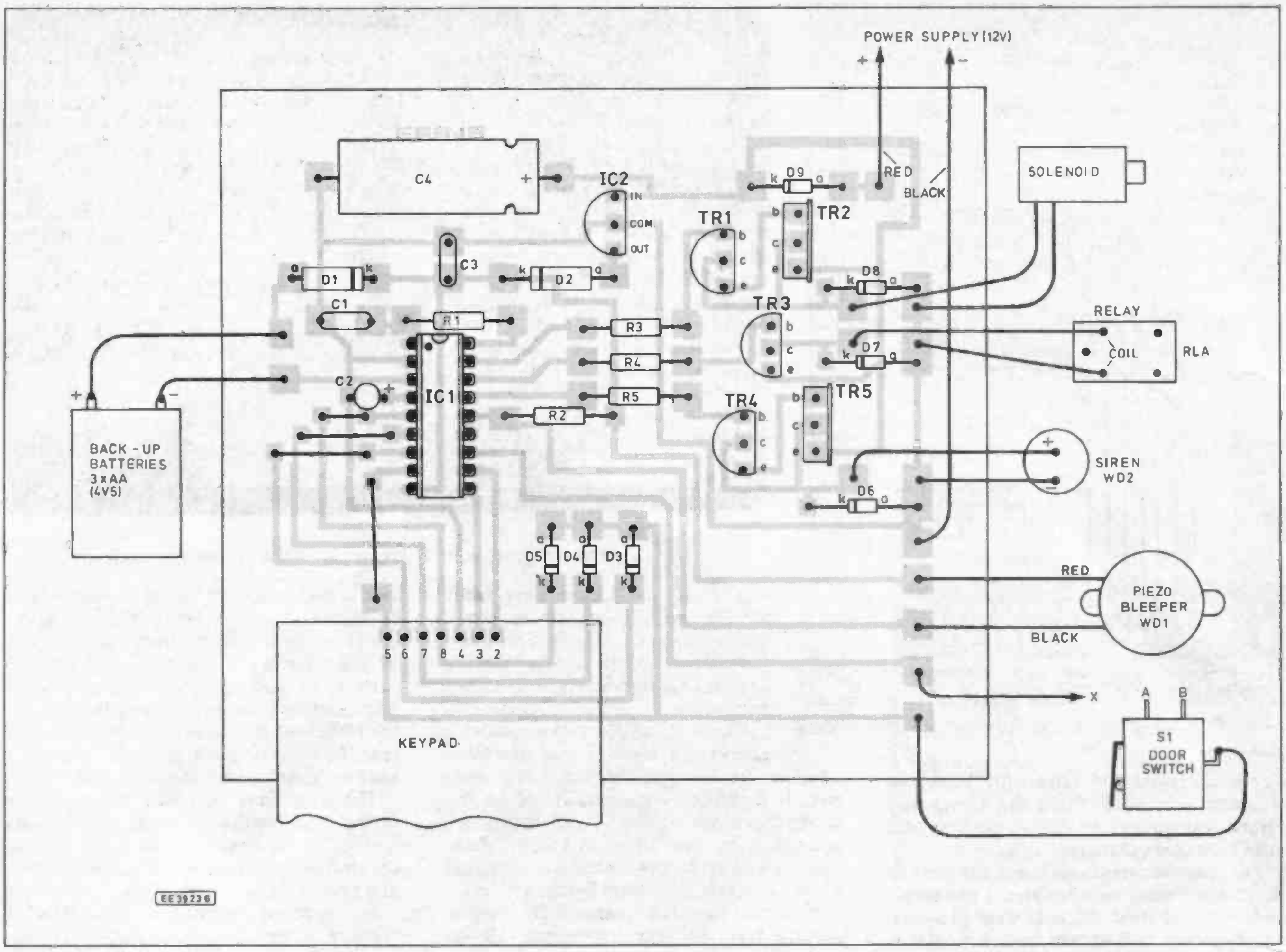


Fig. 3a. Printed circuit board component layout and wiring to off-board components. Wiring from the keypad is shown in Fig. 4.

OPTIONS

The solenoid, relay and siren are all optional, and you may not require all three. If you omit any of these devices, certain other components can also be left out as follows:

Solenoid not fitted:	Omit R3, TR1, TR2, D8
Relay not fitted:	Omit R4, TR3, D7
Siren not fitted:	Omit R5, TR4, TR5, D6

CONSTRUCTION

All the discrete components for the Combination Switch are mounted on a small printed circuit board (p.c.b.) which is fixed to the rear of the case lid. The memory back-up battery, sounders and relay are mounted on the base of the case

The printed circuit board component layout and full size copper foil master pattern is shown in Fig. 3. This board is available from the *PCB Service*, code 812.

Before soldering any components on the p.c.b., the final layout inside the case must be decided on. Remember, the p.c.b. is mounted on the back of the case lid and should be taken into account when setting out the off-board components, making sure they do not "short-out" on the p.c.b.

The best positioning of components can be found by laying the battery back-up holder in one corner of the case, the keyboard buzzer and siren down one side and the relay in the remaining corner – see photograph. If the mains supply is to be controlled by the relay, it should be covered or housed inside an additional small plastic case (inside the main case) for added safety.

Begin construction of the board with the i.c. socket, checking that the notch is towards the top of the p.c.b. Do not fit IC1 into the socket at this stage.

Next solder in the wire links using bare solid wire. Fit the resistors, with a careful check on their values. Diodes D1 to D9 may now be fitted, checking whether they are 1N4001 or 1N4148 types, and also checking that the black or silver cathode

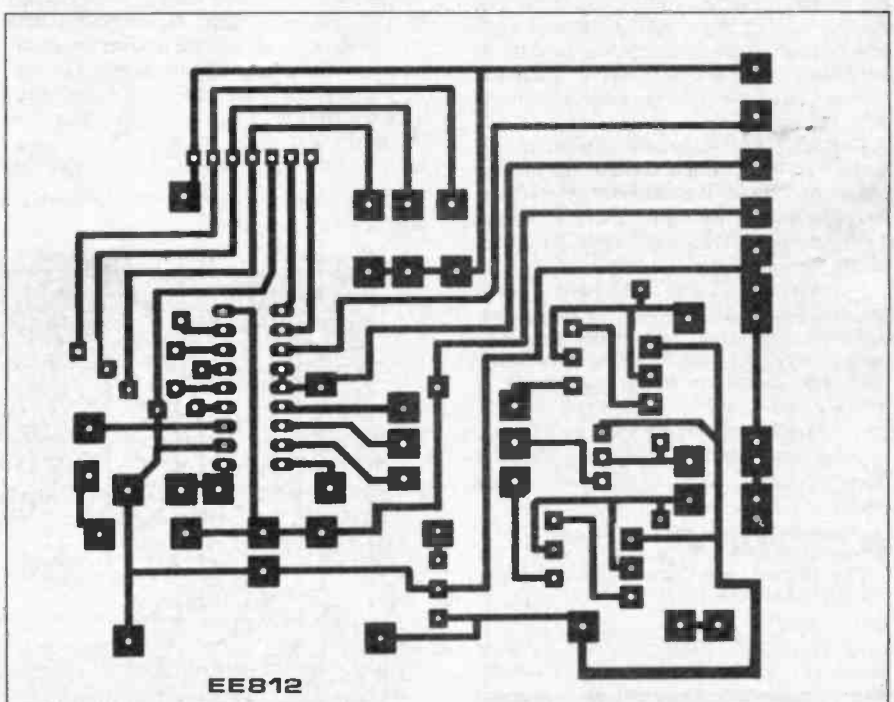


Fig. 3b. Full size copper foil master pattern for the Combination Switch.

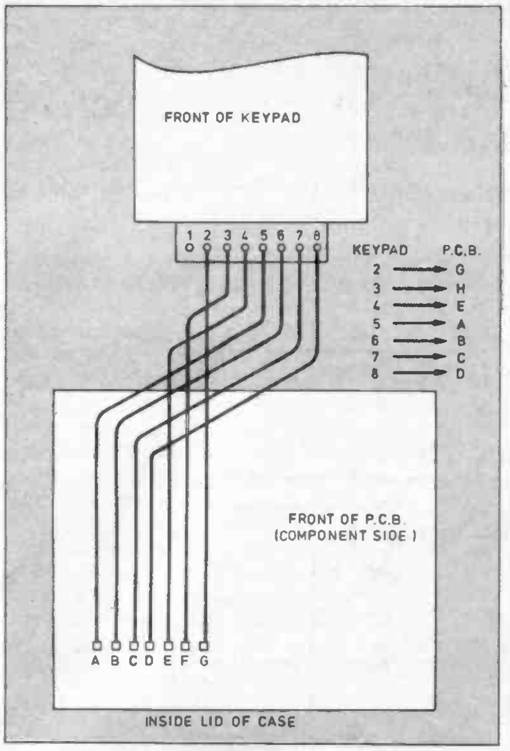
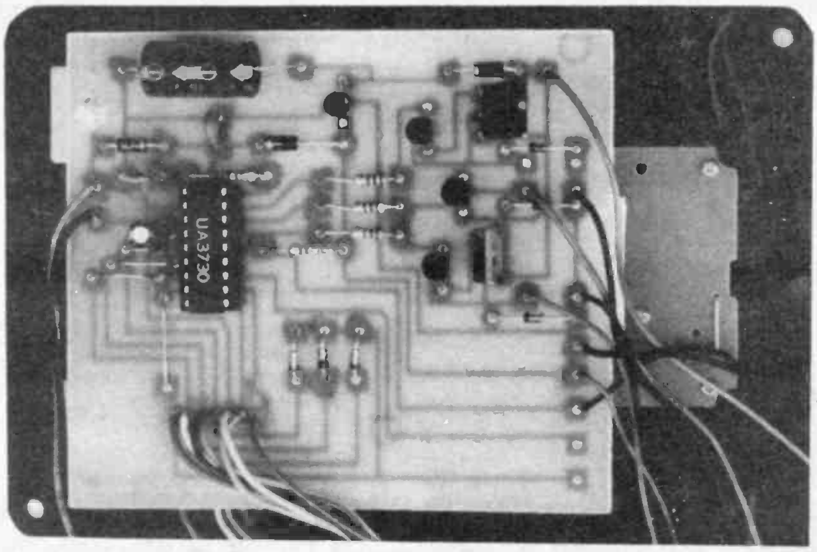


Fig. 4. Wiring from the keypad to the circuit board.



The completed circuit board mounted on the rear of the case lid.

(k) bands at one end agree with the layout diagram. Any diode fitted the wrong way round will prevent the circuit working and may even cause damage.

No provision has been made for resistor R_X, since it must *only* be fitted if **re-chargeable** cells are used. If pads were provided for R_X, there is a danger that it would be fitted accidentally, and if dry cells are then employed there is a risk of the cells exploding. Consequently, R_X must be soldered to the pads used for diode D1 on the *copper* side of the p.c.b. if re-chargeable cells are to be used.

The small capacitors, C1 and C3, may be fitted either way round, but the larger electrolytic capacitors must be fitted with the correct polarity, noting carefully that the negative side is usually marked with small minus signs and arrows. Just to be confusing, the *positive* lead of axial (lie down) capacitors nearly always emerges from the *black* end.

Regulator IC2 looks like a transistor, so check the code, which should include the characters 78L05. It must be fitted with the flat side facing the right. TR1, TR3 and TR4 are also fitted with their flat sides facing the right.

Transistors TR2 and TR5 have a metal tab, and, looking from above, this tab must be on the right-hand side. A heatsink may be attached to these tabs if required; however, this was not found necessary in the prototype circuit. The transistor body can become surprisingly hot before any damage results, and in this circuit both the current required and the "on time" is quite small.

KEYPAD

The keypad may now be fitted on the outside of the case lid. But before doing this, suitable lengths of multi-coloured leads or 7-way "rainbow" ribbon cable should be soldered to the key contacts. These leads/cable should be threaded through a suitable "window" cutout in the lid so that the opposite ends can be soldered to the board, as shown in Fig. 4.

If using leads, use long wires (which can be bunched up later), and a variety of colours if possible. Note that from the underside of the keypad, the numbers 1, 2, etc. read backwards.

Solder in all the other insulated connecting leads noting the convention: red for positive, black for negative. It is difficult to generalise about the connections for the solenoid etc. since individual circumstances will vary. These devices could be connected via terminal blocks to retain maximum flexibility.

Note that the small buzzer WD1 *must* be a **piezo** type; an ordinary buzzer will not work. Wires may be connected to the back-up battery holder, but do not load the cells at this stage.

Finally, IC1 may now be inserted into its socket, checking that the notch or dot is towards the top of the p.c.b., regardless of which way round you fitted the socket.

CASE

Assuming that the circuit is to be housed in a conventional case, the keypad is best connected to the p.c.b. via flexible insulated leads. The photographs show how the battery box, relay (and small plastic case if required), siren and buzzer are positioned in the main part of the case, with the p.c.b. mounted on the inside of the lid. The key pad is fixed with self-adhesive sticky pads to the outside of the lid or if the cutout in the case matches the keypad exactly, it may be glued in place.

Begin by drilling all the necessary holes, and a slot for the keypad connecting pins. In the prototype the siren was fitted inside the case, but in practice it might be connected via long leads to the side of a wall etc.

The relay may be glued into position. If the relay switch contacts are to control mains equipment, take great care to prevent the mains coming into contact with any part of the low voltage wiring.

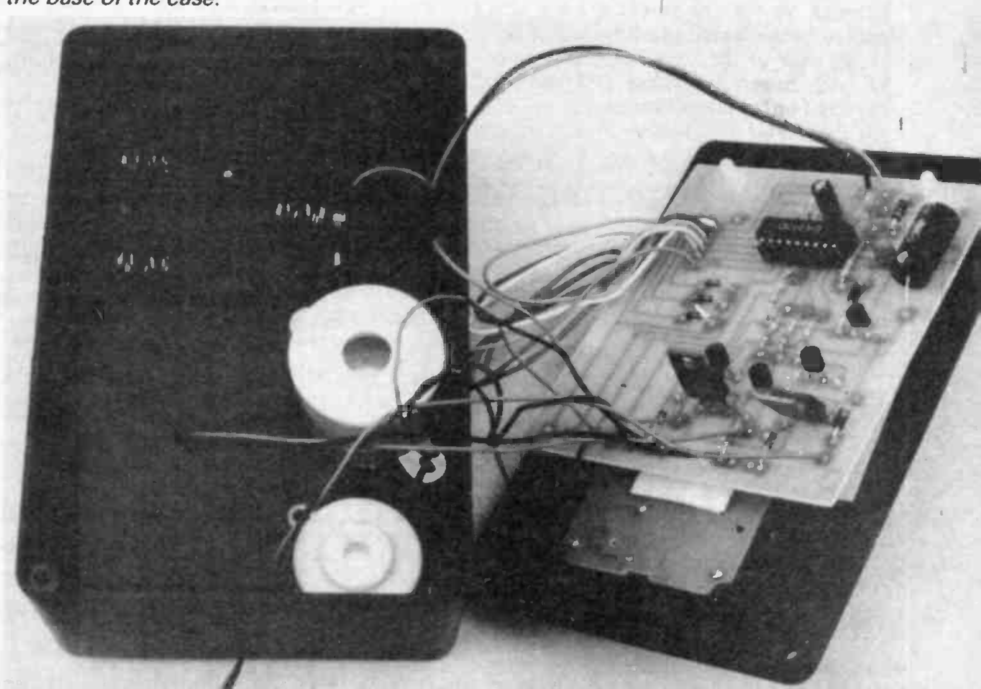
A wise safety precaution is to house the relay in a separate small plastic box inside the main case. This guards against electric shock in the event of internal parts such as batteries becoming loose and falling against live contacts.

The battery box, siren and buzzer may be secured with glue or double sided sticky pads. The p.c.b. may be fixed to the lid of the case using self-adhesive p.c.b. supports, taking care to position it in such a way that the lid will close easily.

TESTING

When the main power supply has been connected, press a key, and check that the piezo buzzer WD1 sounds. If it does not, disconnect the power supply and check for obvious faults such as either IC1, WD1 or

The back-up battery holder, keypad piezo buzzer, siren and relay box mounted in the base of the case.



The completed unit showing positioning of the keypad.

any diode the wrong way round. Double check the connections between the keypad and the circuit particularly if flexible wires have been used.

Re-connect the power supply and if WD1 still fails to sound, using a voltmeter (multimeter set to d.c. volts) attach the negative lead to 0V on the board (the negative end of C4 is a convenient place to clip a lead), and use the positive voltmeter lead as a probe. Touch the positive end of C4 with the probe; a reading of between 11V and 12V should result.

Check the following results:

Voltage regulator IC2
- Input = 12V (approx)
- Common = 0V
- Output = 5V

Combination switch IC1
- Pin 2 = 0V
- Pin 3 = 0V
- Pin 9 = 4V to 5V
- Pin 14 = 4V to 5V, dropping slightly if any key is pressed.
- Pin 13 = as pin 14

If the pin 14 test is satisfactory, the buzzer WD1 must be at fault.

If WD1 is operating correctly, try inputting the password 0, followed by the button marked*. The solenoid should operate for two seconds and the relay should toggle. Try entering the wrong password three times. The siren should operate.

If any or all of these tests fail, establish whether the i.c. or the transistors are at fault, by taking voltmeter readings as follows:

Connect the positive lead of the voltmeter to 12V positive (the positive end of C4 is a handy connecting point), and use the *negative* voltmeter lead as the probe.

The voltmeter readings (not the actual voltages relative to 0V), should be as follows:

IC1 pin 17 changes from 0V approx. to 12V approx. for two seconds on correct password.

Pin 16 toggles between 0V and 12V approx. at each correct password.

Pin 15 changes from 0V approx. to 12V approx. for one minute if three wrong passwords are entered.

Failure to obtain these readings indicates that IC1 is not working correctly, or not connected properly, otherwise one or more of the transistors or associated components must be at fault.

FINAL SETTING UP

If all is well and the circuit is working correctly, try changing the password as described at the beginning of the article.

The back-up battery may now be connected. If the 12V power supply is disconnected the password should still be retained by IC1.

The optional door switch S1 must be normally open for correct operation of the circuit. When the contacts of S1 close, the siren is triggered for one minute. This trigger could be used to set off a conventional alarm system if preferred.

A number of options are possible; for example, switch S1 could be an under-carpet pressure mat, or a lever-operated microswitch (as shown in Fig. 3).

If a microswitch is used, then the lead marked X (see Fig. 3) must be connected to contact *A* for correct operation if the switch is positioned such that it is pressed when the door or window is closed. S1 could also be used in this way to detect somebody tampering with the case of the project.

SOLENOID

An inexpensive solenoid will provide a small amount of movement, and a degree of mechanical skill is required to enable it to operate a lock successfully. For something over £10 an electric door catch release can be purchased. The solenoid only operates for two seconds since its purpose is to release the door, not open it! □

INTERFACE

Robert Penfold

As POINTED out in last month's *Interface* article, it is not essential to have a special driver circuit in order to control a stepper motor. Control can be provided by driving the four solenoids from four latching digital outputs of a parallel port, via relay driver style circuits. This table shows the output states needed in order to drive a four phase stepper motor correctly.

Step Number	Q1	Q2	Q3	Q4
1	L	H	L	H
2	H	L	L	H
3	H	L	H	L
4	L	H	H	L
5	L	H	L	H

Of course, step 5 just takes things back to the beginning of the sequence, and for continuous rotation steps 1 to 4 are just repeated over and over again. For continuous rotation in the opposite direction the sequence is reversed (i.e. repeat steps 5 to 2 over and over again).

You will notice that Q1 is always at the opposite state to Q2, and that Q3 is always at the opposite state to Q4. This permits simplified control with each pair of solenoids being driven from one digital output line. One solenoid in each pair is driven in-phase, while the other is driven out-of-phase via an inverter stage.

The basic scheme of things is shown in Fig. 1. An identical circuit (controlled by a different output line) is needed to drive the motor's other two solenoids. The inverter can be any TTL or CMOS type powered from a 5 volt supply, or a 4000 series CMOS inverter powered from the 12 volt motor supply. Alternate toggling of the two digital outputs steps the motor to give continuous rotation.

SAA1027

Although driving a stepper motor without a special interface device is clearly not particularly difficult, most users seem to prefer the convenience of a proper interface circuit. The hardware is much more costly, but the software side of things is more straightforward.

The standard stepper motor driver chip is the SAA1027, which is not a particularly modern device, and it is out-performed by some more recent chips. For the amateur user it is still probably the best choice though, as it is relatively cheap, has a perfectly adequate level of performance, and it is readily available. It is very easy to use, as can be seen from the basic SAA1027 stepper motor driver circuit of Fig.2.

On the output side of the circuit there is no need for discrete protection diodes as protection circuitry is incorporated in the SAA1027. The supply voltage can be anything from 9.5 to 18 volts, but most small stepper motors seem to be designed for 12 volt operation. The maximum permissible output current is 500 milliamps, which means that the resistance of each solenoid should be 24 ohms or more for operation on a 12 volt supply. In practice most stepper motors seem to have coil resistances of a round 100 ohms or more, and are therefore perfectly suitable for use with this circuit.

The circuit is controlled via three input lines, one of which is the "Clock" input. Each input pulse on this line shifts the motor one step, and it is on high to low transitions that the outputs of IC1 change state. With the motor connected to the circuit correctly, taking the "Direction" input low gives clockwise rotation of the motor - taking it high gives counter clockwise rotation.

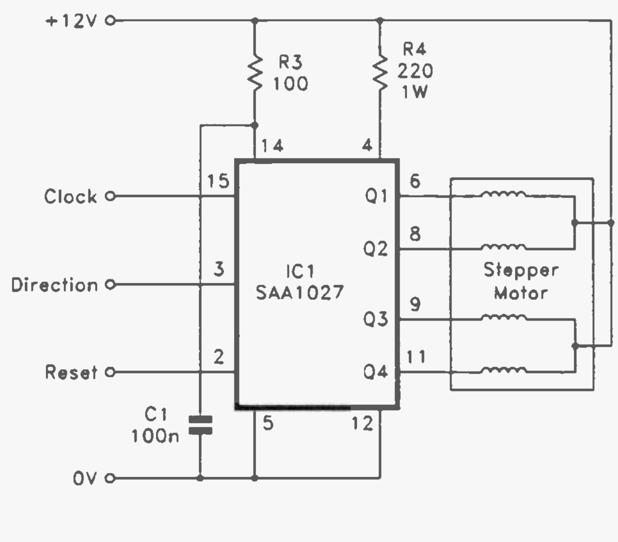


Fig. 2. The SAA7027 driver circuit.

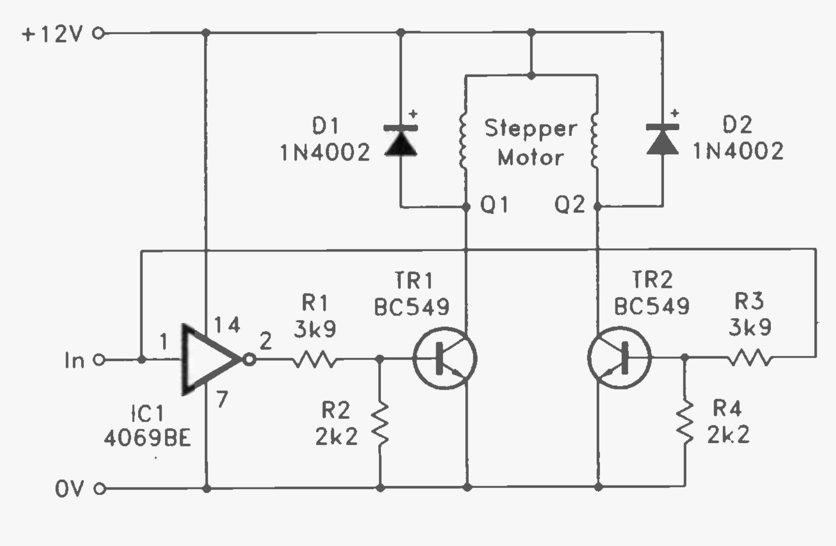


Fig. 1. Driving two stepper motor solenoids from a single output.

Pulsing the "Reset" input low simply takes the outputs back to their initial state (i.e. step 1/5 in the table provided previously). This does not mean that the motor will be taken back to its starting position. To permit this the software must include a counter which is incremented each time the motor is stepped in one direction, and decremented whenever it is stepped in the opposite direction.

The counter will then indicate how many steps the motor must be moved, and in which direction, in order to return it to the starting position. It is then quite easy to implement a software routine which can read the counter and step the motor back to its starting point. In some applications the "Reset" input will not be needed, and it is then simply connected to the +12 volt supply line.

Level Shifting

One slight problem when using the SAA1027 is that its inputs are not designed to operate using normal 5 volt logic levels. Logic 1 is at a potential of around 12 volts, not 5 volts. There should be no difficulty in controlling the SAA1027 from a CMOS control circuit having a 12 volt supply, but with 5 volt logic control circuits a level shifter will be needed at each input.

There are several ways of providing this simple level shifting, including circuits based on operational amplifiers and open collector TTL chips. In this case a very high operating speed is not essential, and simple transistor level shifters are perfectly adequate. Fig. 3 shows the circuit diagram for a simple level shifter of this type. Of course, one of these circuits is needed at each input of the SAA1027.

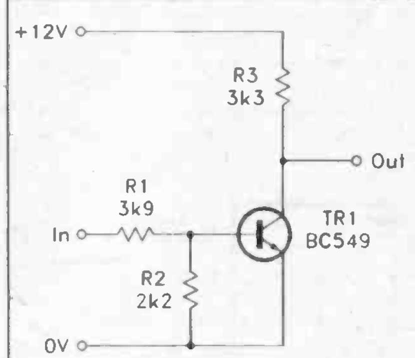


Fig. 3. Simple level shifter circuit. Note that this provides an inversion.

Note that there is an inversion through each level shifter. Therefore, with these circuits added a high level on the "Direction" input gives clockwise rotation, pulsing the "Reset" input high resets the circuit, and the motor is stepped as the "Clock" input is taken through a low to high transition.

Comio V.1.00

Comio is a set of C callable functions which form a buffered serial i/o communications library. It is an interesting product, both for what it does and how it is presented.

Intended for IBM PC computers and compatibles, Comio is supplied as a set of source code files in C and 8086 assembly language. No object files are supplied, so you need both a C compiler and an assembler to use it. It was written using Microsoft's Quick C with Quick Assembler package (something the author has used extensively), but it should also be usable with the full professional Microsoft C and Macro Assembler (MASM).

The assembly language file is supplied in two versions, one of which uses the simplified segment directives (.MODEL, .CODE etc.) and the macro features of Quick Assembler and MASM 5.1 and 6.0. The other is plain vanilla 8086 assembly language, and should be usable with other assemblers. The C code is ANSI compatible. Most current C compilers meet this standard.

The product implements a fully buffered, instant return communications system. When a program written using Comio sends data to a port, the functions return immediately, so the program can continue operation while the Comio functions deal with transmitting the data in the background. Buffered read functions are also provided.

Functions

The full set of functions includes opening and closing routines, functions to read and write single bytes, and to read and write multiple bytes (block or null-terminated string), functions to check for completion of read write operations, and error handling functions. There are also functions to check the validity of ports and file pointers, and a number of other "utility" functions. In all, 23 functions are provided.

The ports can be fully configured for Baud rate, parity etc. in the opening function, and the closing function makes sure your program tidies up after itself. The memory for the buffers is not allocated until communications are opened, and it is freed on closure. This means memory is not occupied if the communications facilities in a program are not used. The buffer sizes can be from 19 to 66519 bytes. The two serial ports, COM1 and COM2, can be used concurrently for read or write.

The manual is extensive. It runs to 77 A4-size pages in a channel binder, is well-written, and includes a full description of all the functions, plus background information and descriptions of the example programs. You should not find yourself foundering, short of some vital information, with this manual. The example programs are interesting, but you will, of course, need something for them to communicate with to explore them fully.

The most obvious uses for this product are perhaps to write a printer driver or a communications system between two computers, but other uses are possible, including control and robotics. The serial ports have, perhaps, been under-used in these areas, but Comio could help to change this. Being supplied in source code, it may also interest students of programming, who may be interested to see how a device driver is implemented.

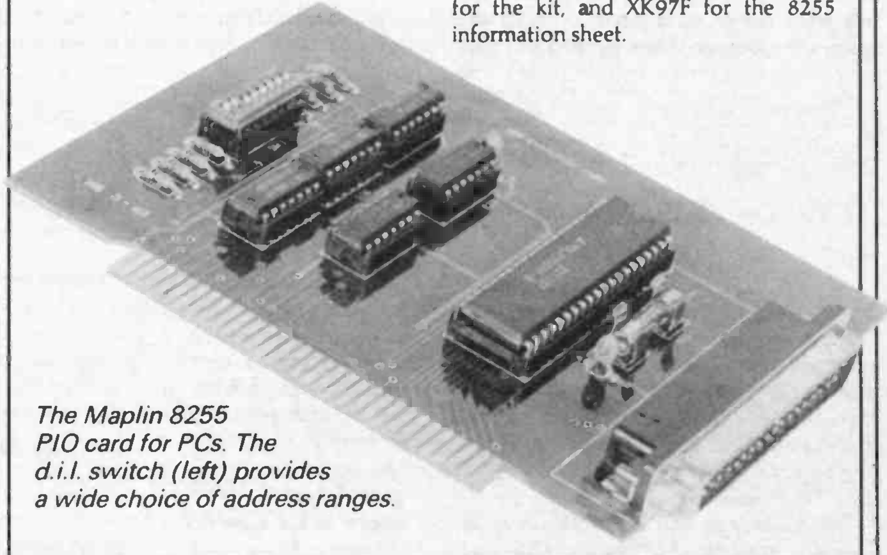
Comio is remarkably inexpensive at £34.00 including VAT. It is supplied direct by Micro SciTech Ltd., Dept EPE, 2 Coxford Drove, Maybush, Southampton, SO1 6FD, Telephone/Fax 0703 784578.

Inexpensive PIO

On more than one occasion I have bemoaned the lack of low cost prototype cards etc. for the PCs. The situation is now slightly better than it was two or three years ago. Maplin sell three useful prototyping cards at reasonable prices, and there are some useful products available from R. Bartlett which are often advertised in *Everyday with Practical Electronics*. Recently I have been trying out the Maplin 8255 PIO card for the PCs.

This is a kit for a straightforward 8255 PIO card which gives 24 input/output lines. These, plus the supply lines, are made available on a 37 way D connector. The address range occupied by the card can be altered via a bank of d.i.p. switches so that conflicts with other hardware can be avoided. The printed circuit board is a good quality through-plated type. Everything fits together properly and the finished unit worked first time.

Even with the recently increased price of £21-95 (plus 80p if you require the 8255 data sheet) this kit still represents very good value for money, and is one of the cheapest ways of connecting a PC to relay drivers, D/A converters, etc. The Maplin order codes are LP12N for the kit, and XK97F for the 8255 information sheet.



The Maplin 8255 PIO card for PCs. The d.i.l. switch (left) provides a wide choice of address ranges.

CHRISTMAS LIGHTS COLOUR SPECTRUM

BY MARK DANIELS

Drives up to 30 l.e.d.s and produces a steadily changing colour sequence from red to orange, yellow and green to yellow, etc.

THERE have been many designs published for Christmas lighting effects units, a number of which have been add on units for conventional filament lamp sets, producing various flashing, sequencing or shimmering effects. Other designs have made use of more modern, semi conductor lamps, or l.e.d.s as they are better known.

Using single colour l.e.d.s a conventional string of lights can be made which may then be driven by suitably designed electronics to produce one or more of the effects outlined above. If, however, two l.e.d. dies of different colours are encapsulated in a single colourless, translucent package a broad range of the light spectrum may be produced simply by driving the two dies at various current ratios.

The two colours best used for this are Red and Green. Being two of the primary colours they can, between them, produce a wide variety of other colours including yellow and orange of various shades. The third primary colour is, of course, blue, but is not readily available in a bi-colour package.

OBTAINING THE SPECTRUM

There are two possible ways of connecting a red and a green l.e.d. in a single package, each with its own advantages and disadvantages. The simplest way, as depicted in Fig. 1a, is to connect them in a common cathode (k) (or common anode (a)) configuration, with three connection leads. This has the advantage of allowing both l.e.d.s to be lit simultaneously providing a continuous spectrum by driving them over a range of current ratios.

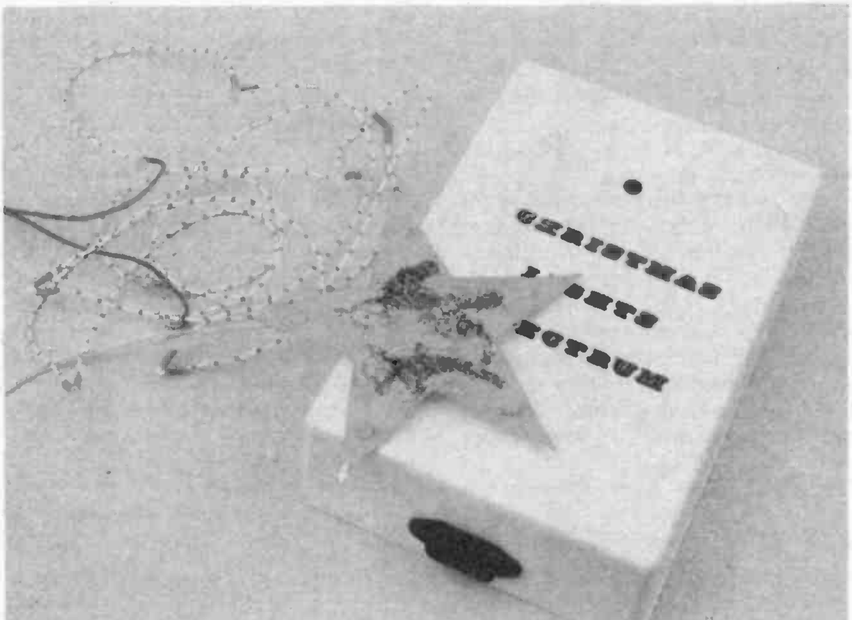
The alternative is to connect them in inverse parallel (Fig.1b) such that connection to a d.c. supply will cause either one or the other of the diodes to emit light (but not both together) depending upon the polarity of the supply. This has the advantage of requiring only two connecting leads.

It would appear at first glance that the only way a wide colour spectrum may be obtained is by using the "tri-colour" l.e.d. with its three connecting leads. This is, indeed, a possibility and may be realised with fairly simple drive circuitry.

Further investigation reveals that parallel connection of the devices using three-core connecting wire is necessary to produce a chain of lamps and that each individual l.e.d. requires its own current limiting resistor. This does not make it easy to produce an attractive chain of Christmas lights.

The two pin "bi-colour" device appears, at first glance, to be even more awkward to use in this application than its multi-pin cousin, since it is not possible to light both the green and red l.e.d.s simultaneously due to their conflicting polarity requirements. It does however eliminate the above connection problems, as simple series connection of the devices is now possible.

The fact that the red and green l.e.d.s may not be on together is not a particularly serious problem as the response of the human eye is fairly slow. If we



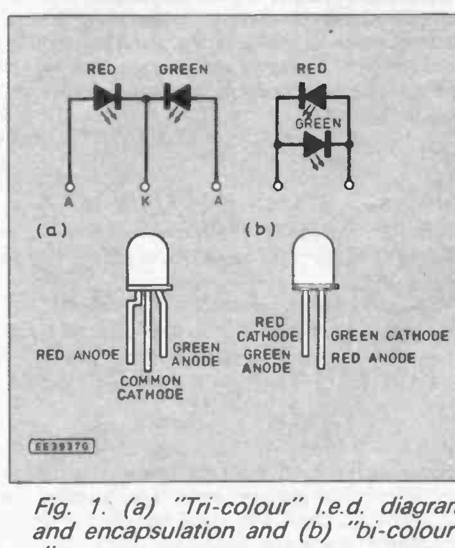


Fig. 1. (a) "Tri-colour" l.e.d. diagram and encapsulation and (b) "bi-colour" diagrams.

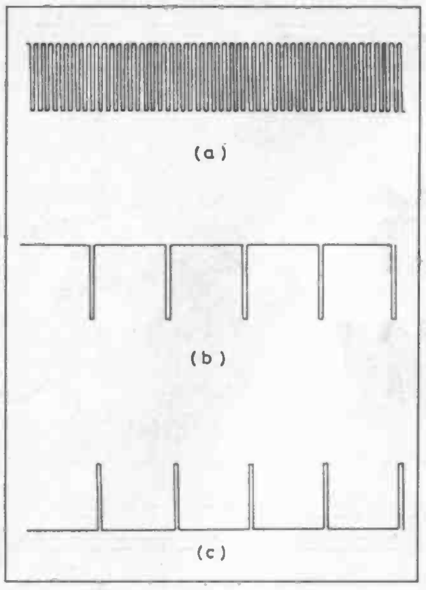


Fig. 2. Output waveform produced by the unit.

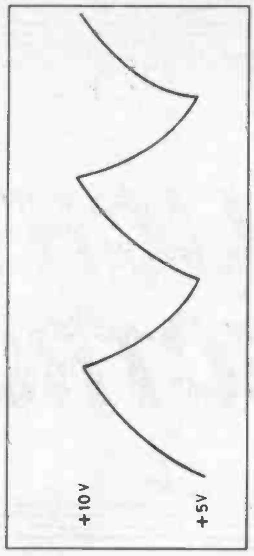


Fig. 4. Non-linear triangular waveshape produced across C4 by IC1.

switch between the two colours sufficiently rapidly (more than about 25 times per second) the brain will perceive the result of the two colours being mixed together to produce yellow or orange, depending on the intensity ratio.

This allows us to use an alternating current supply which lights alternately one, then the other of the two colours. A symmetrical square waveform as depicted in Fig. 2a will light the red and green for equal lengths of time in each cycle producing yellow light. Using the asymmetrical waveforms of Fig. 2b and Fig. 2c will produce nearly pure red or pure green light.

CIRCUIT DESCRIPTION

The complete circuit diagram for the control board of the Christmas Lights Colour Spectrum is given in Fig. 3. The circuit is powered from the mains via a conventional stabilised power supply comprising transformer, T1, rectifier diodes, D1 to D4 and electrolytic smoothing capacitor, C1. Zener diodes, D5 and D6 with current limiting resistor, R1 regulate the supply providing 15 volt and 30 volt supply rails.

A 555 timer, IC1, is employed here in its astable mode to provide the low frequency timing waveform, which has a period of approximately ten seconds. The non-linear triangular waveform produced across capacitor C4 by IC1 (see Fig. 4) is buffered by transistor TR1 and provides a modulating input to the control voltage pin (9) of IC2, a phase locked loop.

V.C.O.

In this application only the voltage controlled oscillator section (v.c.o.) of the 4046 is used. A 5·4V Zener diode is connected internally across pins 8 and 15 of IC2 which is used in conjunction with Zener diode D8 and resistor R6 to provide a stabilised supply above the normal zero volt rail. This allows the triangular waveform produced by IC1 to sweep the complete control voltage range of the v.c.o.

The variable frequency output of IC2 is used to repeatedly trigger a short period monostable, IC3, the pulse length of which may be adjusted by preset VR1. At the highest output frequency of IC2, each pulse produced by IC3 is very nearly equal to one output cycle of the v.c.o. and thus produces an almost continuous positive voltage, as in Fig. 2b.

As the frequency of the v.c.o. reduces, the time interval between the pulses from IC3 increases and a point is reached when thee time between pulses is equal to the duration of the pulses, shown in Fig. 2a. At this point the red and green l.e.d.s are on for equal time intervals and will produce light of a yellowish colour. Reducing the frequency of the v.c.o. still further, to its minimum, will give the longest intervals between pulses and the effect of the pulses is almost negligable.

BRIDGE AMPLIFIER

The output at pin 10 of IC3 is a low level signal of approximately five volts peak and capable of providing only a few milliamps of current and thus requires amplification to provide a useful output. A dual op-amp IC4 is connected as a bridge amplifier to provide dual complementary outputs of 60 volts peak-to-peak from the single input.

The high current output stage comprises two complementary followers, consisting of pairs of *npn/pnp* transistors, TR2 to TR5, connected in a bridge arrangement. This gives an output current capability approaching 200mA with the specified transistors, allowing at least three chains of l.e.d.s to be driven.

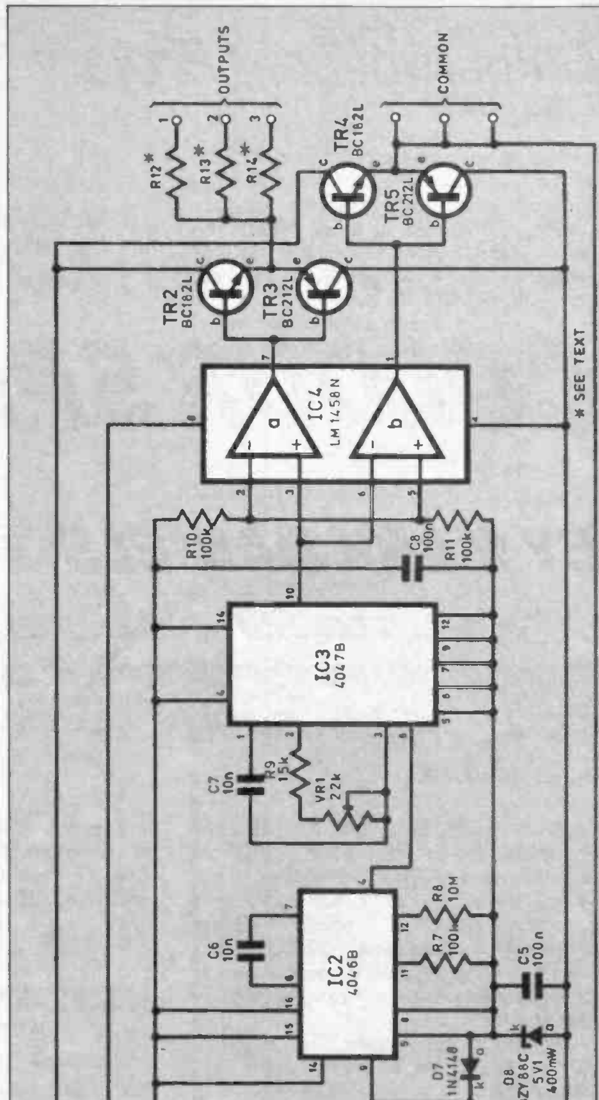


Fig. 3. Complete circuit diagram of the Christmas Lights Colour Spectrum.

Resistors, R12 to R14 are the current limiting resistors for the l.e.d.s and are selected to give a current through the chains of l.e.d.s of around 20mA. Table 1 gives suitable values of resistor for up to *ten* l.e.d.s per chain, which is considered to be a sensible limit, although under ideal conditions twelve is possible, but the resistor will have to be selected by trial and error.

ALTERNATIVE CURRENT LIMITING

With large numbers of l.e.d.s in a chain (see Fig. 5), the current difference between the red and green dies can become very significant due to the somewhat higher forward volt drop of the green die and the low voltage dropped across the current limiting resistor. This can be overcome to a certain extent by shunting the resistor. R_L with a diode and second resistor. R_G in series (see Fig. 6) to allow the current through the green dies to be increased without increasing the current through the red ones.

The value of resistor, R_G will have to be determined by experiment. A suitable starting point would be to make R_G equal to R_L.

If the red brightness increases (rather than the green) when this circuit is connected, merely turn the diode round to obtain the correct result.

The circuit of Fig. 6 replaces one of the resistors, R12 to R14 in the main circuit of Fig. 3 and may be repeated for each chain where a relative brightness problem is apparent.

COMPONENTS

Resistors

R1	120
R2	5k6 1% metal film
R3	18k 1% metal film
R4	10k
R5	1M
R6	1k5
R7, R10, R11	100k (3 off)
R8	10M
R9	15k
R12, R13, R14	See Text and Table 1

0.25W 5% carbon film, unless stated

See SHOP TALK Page

Potentiometer

VR1	22k sub-min horz. preset, lin

Capacitors

C1	1000µ axial elect., 50V
C2	47µ radial elect., 25V
C3	100n polyester 5mm
C4	10µ tantalum bead, 25V
C5, C8	100n polyester (2 off)
C6, C7	10n polyester (2 off)

Semiconductors

D1 to D4	1N4002 1A 100V rec. diode (4 off)
D5, D6	BZX85 15V 1·3W Zener (2 off)
D7	1N4148 signal diode
D8	BZY88C5V1 400mW Zener
D9, D10 etc	Bi-colour two pin l.e.d.s, as many off as required
TR1	BC184L *npn* silicon
TR2, TR4	BC182L *npn* silicon (2 off)
TR3, TR5	BC212L *pnp* silicon (2 off)
IC1	555 timer i.c.
IC2	4046B phase-locked loop
IC3	4047B CMOS multivibrator
IC4	LM1458N dual op.amp

Miscellaneous

T1	6VA mains transformer: 240V a.c. primary; 12V-0V-12V secondary

Plastic case, size 220mm x 150mm x 65mm; 8-pin d.i.l. socket (2 off); 14-pin d.i.l. socket; 16-pin d.i.l. socket; miniature d.c. power-in connectors (3 off); 3-core mains cable; connecting wire; rubber grommet; solder tag; M3 x 12mm screws and nuts; solder, etc.

Approx cost guidance only **£20** *inc. 10 l.e.d.s.*

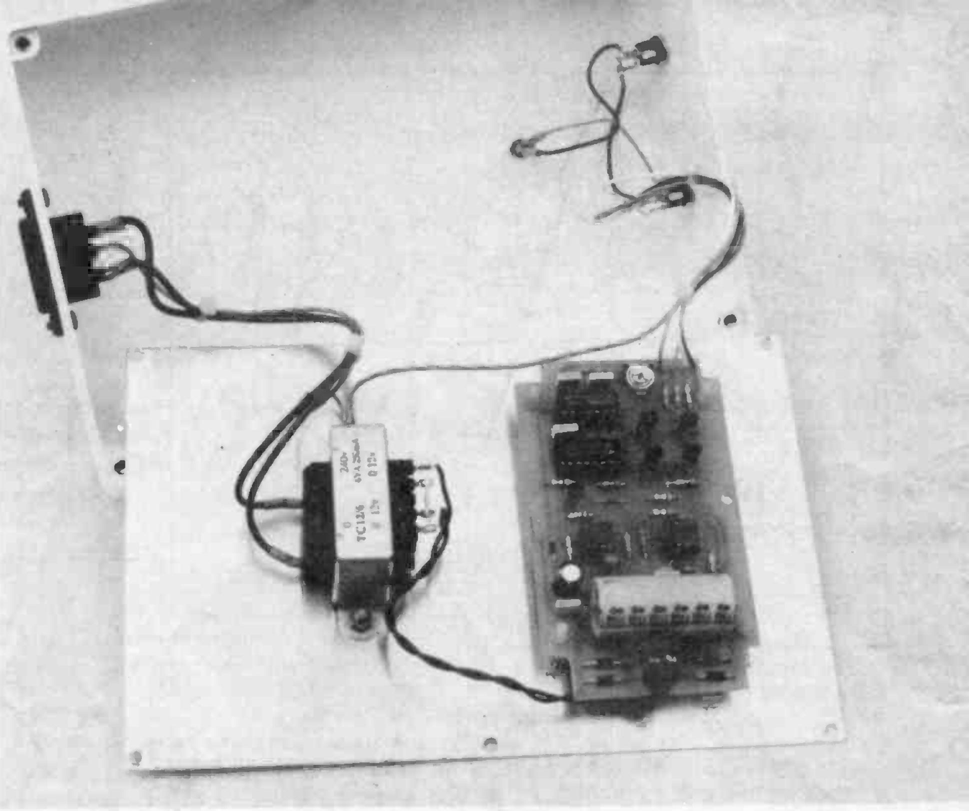


Table 1. Suggested Current Limiting Resistor Values

No. of l.e.d.s	Approx value for R12, R13 or R14	Red l.e.d. Current (mA)	Green l.e.d. Current (mA)
1	1k2	21.7	21.5
2	1k2	20.0	19.7
3	1k	22.0	21.4
4	1k	20.0	19.2
5	820	21.9	20.7
6	820	19.5	18.0
7	680	20.6	18.5
8	560	21.4	18.6
9	470	21.3	17.4
10	330	24.2	18.2

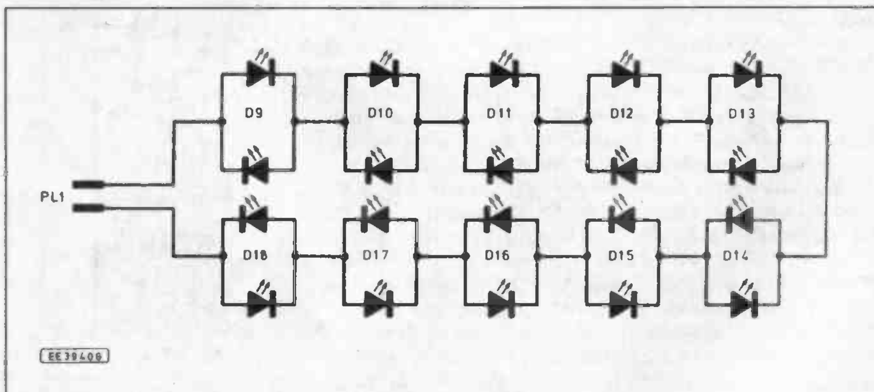


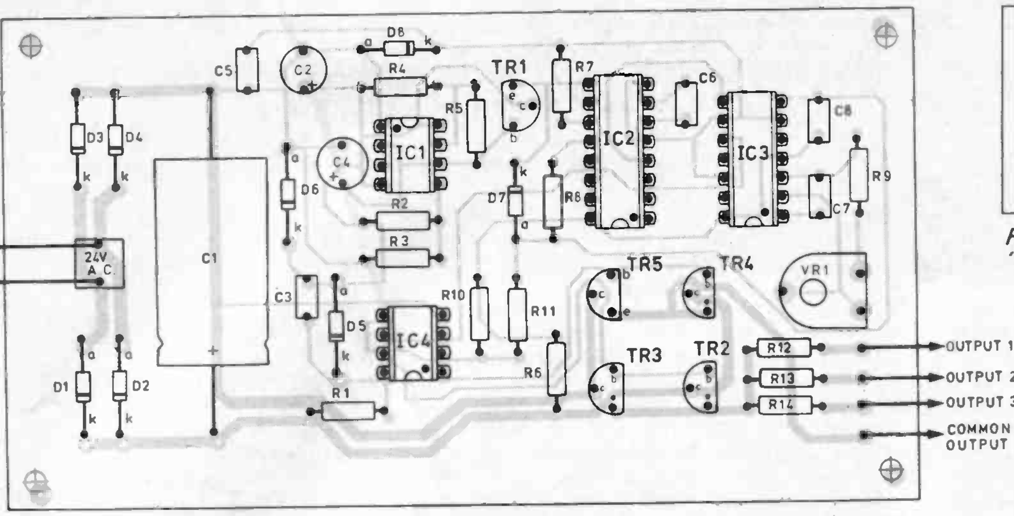
Fig. 5. Circuit diagram of a 10 l.e.d. light chain.

CONSTRUCTION

The majority of the components are assembled on a single sided glass-fibre printed circuit board. This board is available from the *EPE PCB Service*, code 813. The component layout and full size copper foil master pattern is shown in Fig. 7.

Before commencing assembly of the printed circuit board decide how many l.e.d.s are going to be used in each chain and then, from Table 1, select the appropriate value of resistor for each of R12 to R14. If it is intended that a large number of l.e.d.s (e.g. eight or more) are to be used in one or more of the chains then it may be desirable to use the alternative method of current limiting, described above, for each such chain.

For ease of assembly it is recommended



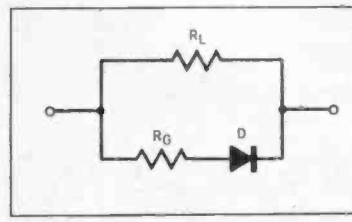
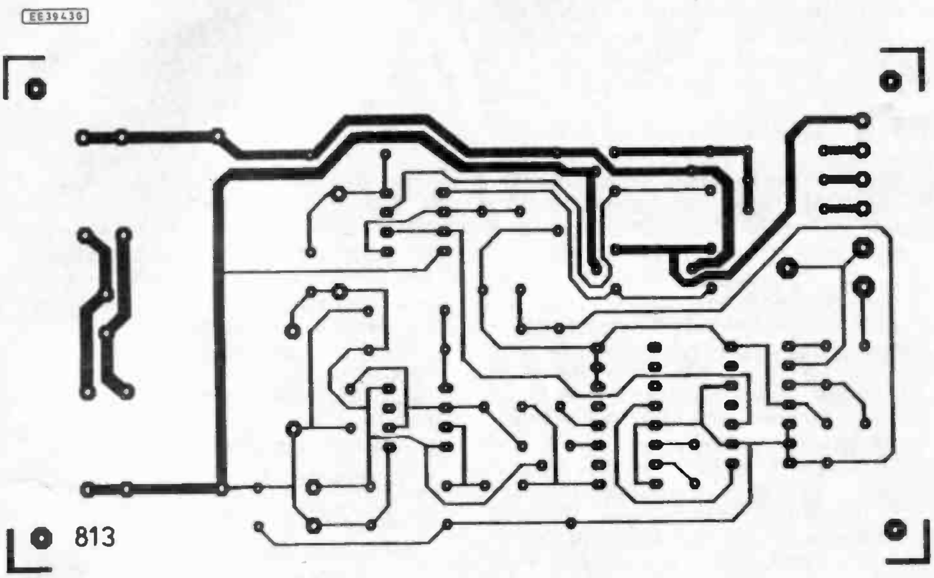
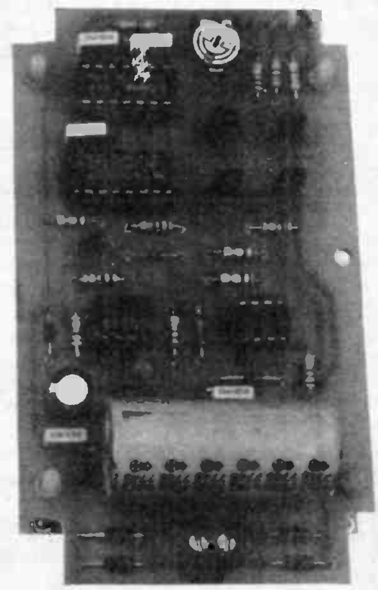


Fig. 6 (above). Alternative "biassed" current limiting circuit.

Fig. 7 (left). P.C.B. layout and wiring for the Christmas Lights Colour Spectrum.





that the components are fitted in the following order: i.c. sockets, resistors, small capacitors, semiconductors (other than the i.c.s) and finally the large power supply smoothing capacitor, C1. Check carefully the orientation of semiconductors and the tantalum and electrolytic capacitors, as a mistake here could result in the affected components being destroyed or the completed circuit malfunctioning. A p.c.b. mounting screw terminal block was used on the prototype for the a.c. input and, if used, should also be fitted at this stage.

It is suggested that the i.c.s be fitted in their sockets after the board has been mounted in the case. Care should be taken in handling IC2 and IC3 since these are both CMOS devices and may easily be damaged by exposure to static electricity.

MAIN UNIT ASSEMBLY

The assembled printed circuit board (p.c.b.), mains transformer and output sockets are all fitted in a plastic case for safety. A suggested case layout is shown in Fig. 8, with the majority of the parts fitted to the case lid. If the recommended case is used there will be plenty of room to get everything in without it being cramped.

Using the p.c.b. as a template, drill four 3mm mounting holes in the case lid and fit a plastic p.c.b. support pillar to each hole using suitable size self-tapping screws. The board can now be mounted on top of these

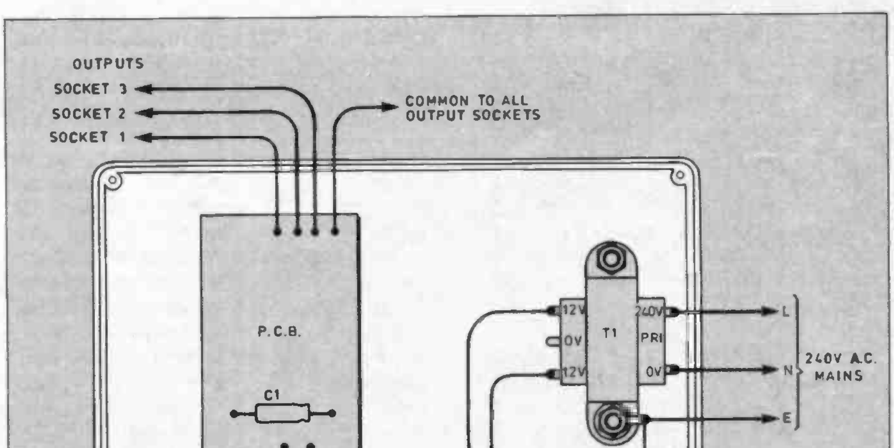


Fig. 8. Case layout and interwiring of T1 and the sockets.

pillars with four more screws after all external connections have been made to it, ensuring that the pillars are long enough not to allow the points of the screws to contact each other.

The mains transformer is mounted adjacent to the p.c.b. using two M3 × 12mm machine screws and nuts, an "Earth" solder tag being placed under one of the nuts for the mains earth (E) wire connection. Make the a.c. connections from the two ends of the transformer secondary winding to the p.c.b. using 7/0.2 wire. No connection is made to the centre tap of the winding.

If the transformer used has two separate 12 volt secondaries then these will need to be connected in series in accordance with any instructions supplied with the device. In the abscence of any data determine which connections go to each secondary by using a meter or a lamp and then connect them in series (i.e. one end of the first winding to one end of the second winding) and check for voltage across the two free ends. If there is no output then reverse the connections to only *one* of the windings.

Decide how many chains of lights are going to be connected to the unit and fit a d.c. power socket to the main part of the box for each light chain. Up to three may be fitted without modifying the circuit. On the prototype unit only two sockets were fitted and the third output was used to drive a bi-colour indicator l.e.d. fitted to the top of the case to show when the unit is operational.

Drill a hole in one end of the box and fit it with a grommet for the mains lead. Thread a length of three core mains flex through the grommet and secure it internally with a cable tie. Make the mains connections directly to transformer T1 primary and connect the Earth lead to the solder tag fastened under the transformer mounting screw.

LIGHT CHAINS

It is important to ensure that all the l.e.d.s in a single set are from the same manufacturing batch to guarantee intensity and colour matching of the devices. The l.e.d.s may be made up into conventional strings or mounted on decorative card cut into stars or other traditional Christmas designs.

The connection details for a string of ten l.e.d.s is shown in Fig. 9a. Note that in this diagram all the l.e.d.s are connected with the same polarity and will therefore follow the same colour sequence as each other. Connecting alternate devices the opposite way round, as in Fig. 9b, will cause every other l.e.d. to follow the reverse colour sequence to its neighbours.

Use thin single core stranded connecting wire, of an appropriate colour, e.g. green to match the Christmas tree, for making up the light cains. Cut the leads on each l.e.d. short and solder the wires to the l.e.d.s to connect them in series.

The connections on the finished set may be given some protection by coating them with "Araldite" or hot glue from a glue gun. Finally run a long wire from each end of the chain and connect to a miniature d.c. power plug to fit the socket(s) on the main unit

An alternative method is to fix the l.e.d.s to a card star or other decoration, fold the pins over to secure them in place and make connections on the back of the card where they will not be seen and then glue a piece of paper over the wiring.

TESTING

Fit a mains plug, fused at 3 amps or less, to the end of the mains cable and give all the wiring a final check. If the i.c.s have not already been fitted now is the time to fit them, observing the handling instructions given earlier.

Temporarily assemble the case (closing the lid), connect a string of lights to one of the output sockets and plug the unit into the mains. If all is well the lights should come on and, after a few seconds, start changing colour, eventually reaching the opposite primary colour to which they started at. The sequence then reverses and is repeated indefinitely.

If all appears o.k. preset VR1 may be adjusted to obtain the best result. This adjustment allows the widest range of colours to be selected and also enables any "jittering" at the ends of the spectrum to be smoothed out.

The "jittering" is caused by the monostable, IC3 failing to retrigger, due to it not having finished its current timing cycle before the next trigger pulse arrives. This does prevent absolutely pure red and green from being obtained, but in practice the differences are virtually unnoticeable.

FAULT FINDING

If the Christmas Lights Colour Spectrum fails to work immediately at switch-on do not despair as the fault may turn out to be something quite simple. Check first for anything obvious such as a failed fuse in the plug or bad connections, dry joints, solder splashes bridging copper tracks, or semiconductors inserted the wrong way round, etc.

If the unit still does not work then the fault may lie in malfunctioning components. With the circuit diagram at hand check power supply voltages first, across transformer T1 secondary, across capacitor C1 and across the Zener diodes. Then check for power to all the i.c.s and the collectors of the transistors.

The voltage across TR1 emitter (e) and pin 1 of IC1 should be steadily changing over a period of several seconds, between approximately 5V and 10V or 11V (see Fig. 4). If it remains fixed at a steady potential try replacing IC1 with a known working device (this is made much simpler if i.c. sockets were used when constructing the board). If this does not cure the fault then replace transistor TR1.

CHECKING THE V.C.O.

With the control voltage on pin 9 of IC2 sweeping up and down in the correct manner a variable frequency square wave should be present at pin 4 of the i.c. Check for this with an oscilloscope, if one is available or use a loudspeaker with a one kilohm resistor in series with it across pins 9 and 10 of IC2 and listen for a note which changes pitch over a few seconds. The note will become inaudible as the frequency falls below the lower frequency response of the ear.

If IC2 fails to produce the correct output check the values and location of C6, R7 and R8 before replacing it. Also check the orientation of diode D7, as this protects the i.c. from negative input voltages as capacitor C4 initially charges from zero volts on the first cycle of IC1.

The output from IC3 is best checked by connecting a bi-colour l.e.d. and a one kilohm series resistor across pin 10 and pin 11 of the i.c. (pin 11 is the complementary output to pin 10). The result if the unit is functioning correctly up to this stage will be the same as the expected output from a fully functional unit. C7, VR1 and R9 are the components associated with IC3 and should be checked before suspecting the i.c.

The dual op.amp IC4 should only really need checking for its power supply rails (30 volts) and outputs across pin 1 and pin 7, which may be checked in a similar manner to the outputs of IC3, but increase the resistor to 4k7.

If everything is working up to this stage and the unit is still causing problems the fault will most likely be in one or more of the output transistors, TR2 to TR5. □

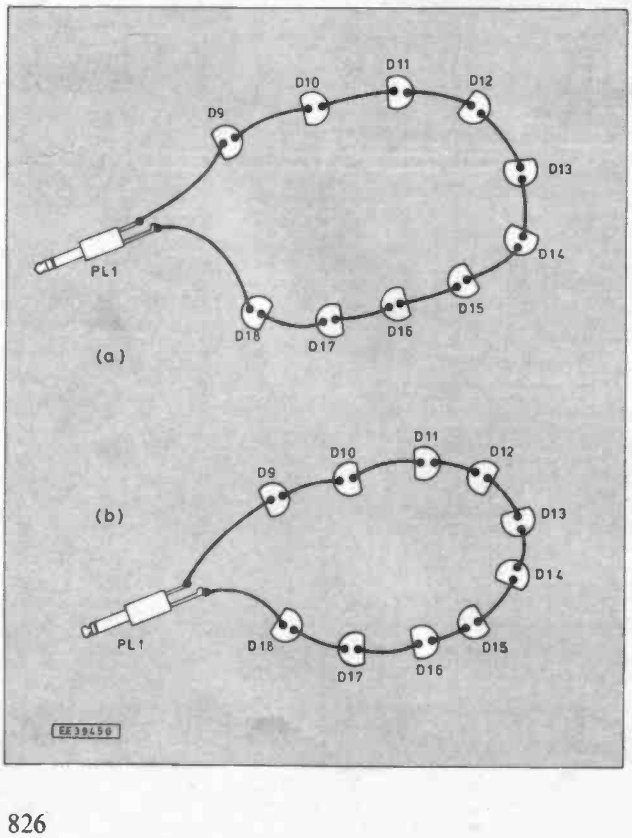
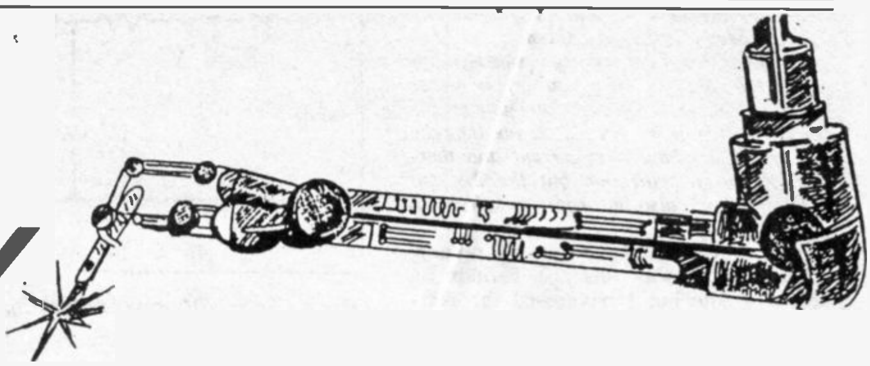


Fig. 9. (a) Connection details for an l.e.d. where all "lamps" follow the same colour pattern. (b) Alternative connection where alternate l.e.d.s follow an opposite colour pattern. The alternative current limiting circuit is not required with this type of display.

WARNING

Due to mains voltage being present, extreme care should be exercised when carrying out work on the unit. In all cases the mains plug must be removed

CIRCUIT SURGERY



MIKE TOOLEY B.A.

Once again, welcome to Circuit Surgery, our regular clinic for readers' problems. In this month's Surgery we take a look at reliable regulator design and attempt to explain some of the mysteries of "safe area protection". For the test equipment enthusiast, we describe several probes which can be used to extend the performance of signal tracing equipment. We end this month's instalment with a "round-up" of hints and tips sent in by readers.

Probing around

A letter from ***J. Ryan*** has prompted me to give some thought to the use of various types of signal-tracing probes. Mr Ryan has asked for some clarification concerning the probe which was designed for use with the *Audiotest* signal tracer which appeared in *Everyday Electronics*, March 1978 (issue NOT available).

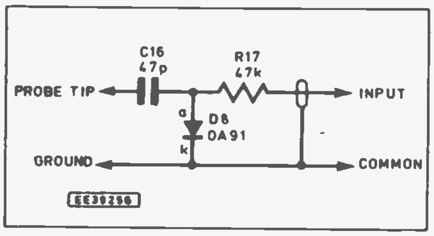


Fig. 1 Audiotest r.f. probe

The Audiotest Probe (see Fig. 1) provides a simple means of demodulating amplitude modulated (a.m.) radio signals, allowing the audio frequency signal information to be recovered and then amplified within the Audiotest itself. The probe was linked to the Audiotest by means of a short length of single-core coaxial cable (the outer braid of the cable being connected to earth/common).

I must confess to using an almost identical home-constructed probe in my own workshop and have found it to be invaluable when fault-finding on radio equipment. Other signal tracing probes which I have found useful include an "infinite impedance" probe (Fig. 2) and a "wideband" probe (Fig. 3). Both can be constructed on a small piece of matrix board and housed, together with a PP3 battery, within a small probe case (e.g. Maplin JX57M).

Taken to task

E. Fielder of Southampton has taken me to task over the position of the fuses in Mr Taylor's high current power supply (*Circuit Surgery*, October 1992). For those who may have missed it, Mr Taylor's power supply had fuses fitted in *both* the line (L) and neutral (N) supply connections.

As Mr Fielder rightly surmises, if the fuse in the neutral rail was to become open-circuit the remainder of the mains input circuit although apparently dead would still be live. This is a point worth noting and, if nothing else, should re-inforce the importance of disconnecting ***any*** item of mains powered equipment ***before*** delving inside.

There is, however, some justification for Mr Taylor's use of a fuse in both line and neutral. Firstly, one cannot always rely on the line and neutral being correctly wired and secondly the neutral fuse could provide protection against the excessive current which might flow if the neutral end of the mains transformer primary was to become shorted to the transformer core (presumably earthed).

Depending upon the *actual* potential of the mains neutral connection (rarely is this exactly 0V) a considerable current may circulate when the neutral and supply earth connections are shorted together. Clearly the correct position of mains fuses (not to mention switches) is a topic for some debate and other readers' views and experiences on this topic would be most welcome.

Safe power supplies

Regular reader ***Kevin Davies*** writes:

"I have a worrying problem concerning three-terminal voltage regulators. A friend recently asked if I could run his 6V camcorder from a 12V battery temporarily until a purpose designed power supply was available.

I suggested a 7805 type voltage regulator, voltage boosted to 6.2V with two diodes in the common terminal. However, when I went to buy one from a local TV repair shop, the engineer suggested that it was unwise to use this method without over-voltage protection since these regulators commonly fail and go short-circuit. This would clearly damage the camcorder by applying the full 12V.

Fig. 2 (below). Infinite impedance probe

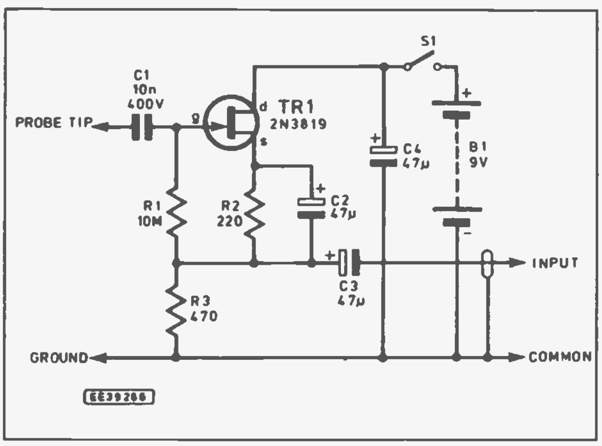
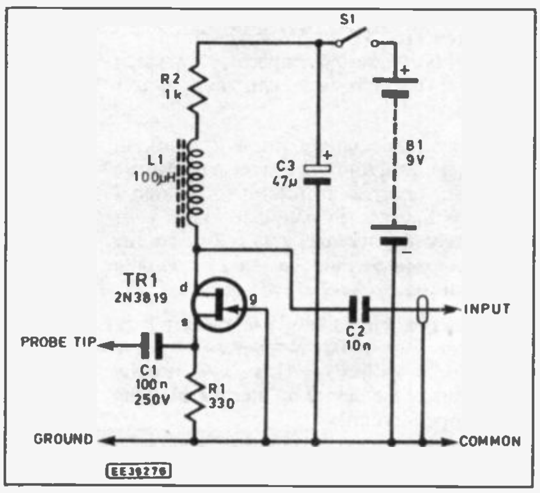


Fig. 3 (right). Wideband (low-impedance) probe



This is both puzzling and worrying since many other items of expensive equipment seems to use these regulators without any special over-voltage protection. Is it true that these regulators do go short-circuit when they fail? Also would you please explain what Safe Area Protection means since I notice in the RS Catalogue that the 1A regulators have over-current and thermal shutdown protection but the 2A and 3A regulators also incorporate safe area protection."

Well, Kevin, it really is difficult to know where to start with this one. Perhaps its tempting fate but I have used three-terminal voltage regulators in numerous circuits and not had even a single failure (but perhaps I have been lucky).

In any event, I decided to find out just what it takes to make one of these regulators go short-circuit by applying the output of a high-current 13V d.c. supply (via a 5A fuse for protection) to a 7805 mounted on a 4°C/W heatsink. The camcorder load was simulated using a 20 ohm 5W resistor. An intermittent short-circuit applied to the output did not produce any adverse effects; the output voltage merely fell to 0V when the short-circuit was applied and then immediately returned to 6·2V when the short was removed.

Heartened by this, I applied a short-circuit for 60 seconds. The output voltage fell to 0V and the regulator quickly became very hot. Happily, the output voltage rose again (a little more slowly than before) to 6·2V when the short-circuit was removed. This test was repeated several times, again with no adverse effects.

I then resolved to leave the short-circuit in place permanently (or for as long as was necessary to cause the regulator to fail). After approximately ten minutes (with the heatsink running extremely hot), the output voltage suddenly rose to 9·8V signifying the point at which the regulator failed. Even so, it is worth noting that it did not go completely short-circuit.

I am not sure what this proves other than demonstrating that three-terminal regulators can (and do) fail internally and produce excessive output voltages. That said, it is worth emphasising that prudent design can be instrumental in significantly reducing the chance of regulator failure.

Points to bear in mind when designing a "safe" supply include:

1. Check that the regulator is correctly rated.
2. Keep regulator dissipation to an acceptable level by avoiding an excessive difference between input and output voltages. For most regulators a difference of 3V to 5V is all that is required. A series-connected low-value wirewound resistor can help in this respect.
3. Fit an adequately rated heatsink in order to avoid excessive temperature rise. As a rule of thumb (or should I say finger?), if you can place your finger on the heatsink close to the device and count to ten this usually indicates that all is well.
4. Insert a silicon diode in the input in order to avoid inadvertent reverse supply polarity. This will usually destroy the device by literally blowing it open-circuit!
5. Fit electrolytic capacitors of 47µF to 100µF with adequate voltage ratings at the input and output. These can help to prevent momentary voltage surges.
6. Fit ceramic 100nF capacitors at the input and output to prevent high-frequency instability and noise spikes.
7. In exceptional cases, consider fitting an external "crow-bar" and input fuse to provide "last-ditch" protection.

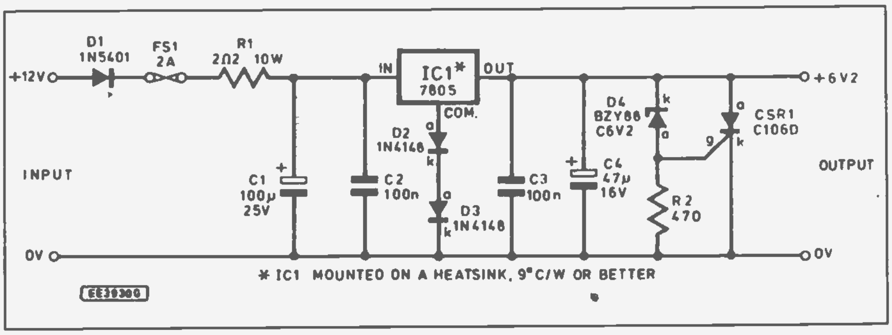


Fig. 4 "Safe" 6V power supply suitable for a camcorder

A representative circuit incorporating all of the above features is shown in Fig. 4.

Kevin's second point relating to "Safe Operating Area Protection" is somewhat more general. One can reasonably expect a semiconductor device to cope with either a high current or a high voltage. However, some devices (including power transistors, regulators and power hybrids) are required to withstand high current and high voltage *simultaneously* during normal operation.

The ability of a device to tolerate such conditions is normally shown by means of a graph showing the region in which the manufacturer considers that the device can be used reliably. It is worth noting that the situation is a little more complicated when the device in question is intended for use in pulsed or switching applications. Here, there may be several graphs relating to different conditions of duty cycle or pulse duration.

A typical safe operating area graph for a power transistor is shown in Fig. 5. Modern power integrated circuits can incorporate voltage and current sensing circuitry which ensures that the device in question operates within the safe area.

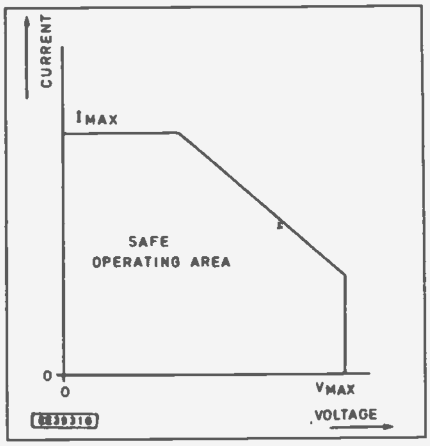


Fig. 5 Typical safe operating area graph for a power semiconductor

Next month: We shall be describing a range extender which will permit low-level audio meaurements on a basic multi-range d.c. meter. In the meantime, if you have any comments or suggestions for inclusion in *Circuit Surgery*, please drop me a line at: Faculty of Technology, Brooklands College, Heath Road, Weybridge, Surrey, KT13 8TT. Please note that I *cannot* undertake to reply to individual queries from readers however I will do my best to answer all questions from readers through the medium of this column.

Hints and tips

One of the nice things about writing this column is that readers often include hints and tips in their letters. These are usually borne out of considerable experience and many are worthy of a wider audience. Hence, we end this instalment of *Circuit Surgery* with a quick round-up of those which have arrived in my post bag during the last six months:

J. Holt recommends sorting unmarked transistors into *npn* and *pnp* groups and marking the TO18 and TO5 cases with a small spot of enamel paint; red for *pnp* and blue for *npn* (does anyone else remember the "red spot" transistors of the 1950's?).

Andrew Wilkinson suggests that empty egg boxes make excellent storage "bins" for small components when building projects. Andrew also suggests storing nuts and bolts in see-through glass jars (rather than in drawers where they can't be seen).

Finally, ***Jeremy Field*** has found a novel use for unmarked plastic transistors, the base-emitter junction of which can be used as a Zener diode. Transistors of the "BC548/BC212 variety" can be used (whether they be *pnp* or *npn*) as shown in Fig. 6. The "Zener voltage" produced will normally be in the range 7V to 10V (around 8·5V being the most common).

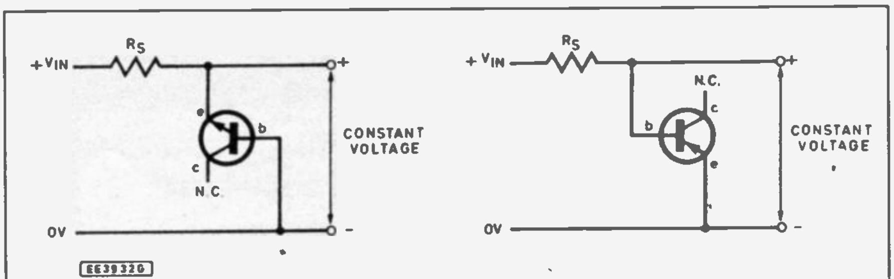


Fig. 6 Jeremy Field's "Zener diode" equivalent

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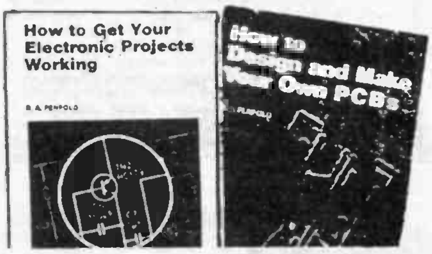

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Testing and Test Gear

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The topics covered in this book include: The broadcast bands and their characteristics; The amateur bands and their characteristics; The propagation of radio signals; Simple aerials; Making an earth connection; Short wave crystal set; Simple t.r.f. receivers; Single sideband reception; Direct conversion receiver.
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A. Pickford
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There are a large number of amateur communications satellites in orbit around the world, traversing the globe continuously and they can be tracked and their signals received with relatively inexpensive equipment. This equipment can be connected to a home computer such as the BBC Micro or IBM compatible PCs, for the decoding of received signals.
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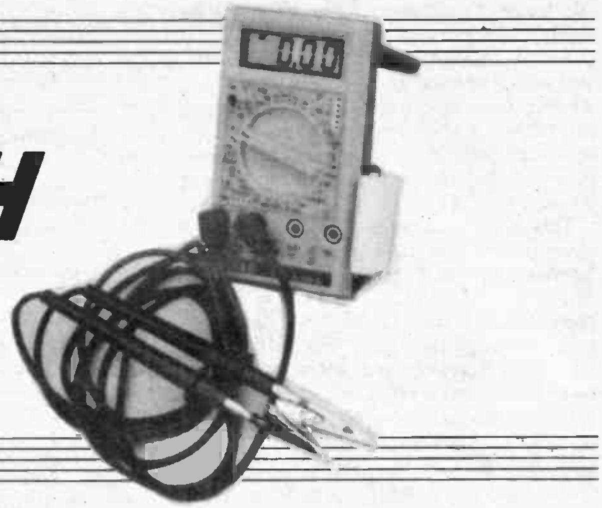


AUTO-SWITCH ADD-ON

KEN TAYLOR

Prolong the operating life of your battery operated equipment with one of these two low-cost add-ons

HERE'S a simple device that should reduce your battery costs if you – or your family – often forget to switch off toys, radios, test equipment, or other battery operated items. It will do as much for saving PP3 type battery costs as the *Dry Cell Recharger* (Sept '91 – for back issues) did for single cells.

You may remember that the one common battery type that couldn't be recharged was the PP3 and it was advised that devices using 9 volt batteries shouldn't be purchased. But this battery is being used in more and more toys and equipment and if you want one of these there is little you can do.

This problem came to prominence when the author decided to purchase one of the small Digital Volt Meters – DVM's – on the market. Some have an *auto switch-off* facility but the one selected didn't have this. With the most conscientious intentions it was found difficult to remember to always return the rotary switch to the OFF position after each use and some hours or even days later the meter would be found to be still switched on. Something was needed urgently.

REQUIREMENT

For the DVM, a unit was required which was small enough that it could easily be attached to the meter, take a negligible extra current to the five milliamps taken by the meter and provide times of about two to 10 minutes. When it switched the unit off it should ideally also switch itself off and cease to take any current.

For radios, toys and other battery operated equipment, the switching current might be as high as 500 milliamps and the maximum time up to one hour. The voltages of these devices will also vary and the unit should cater for a range of about 5V to 12V. The unit should be small enough to be built into these larger devices.

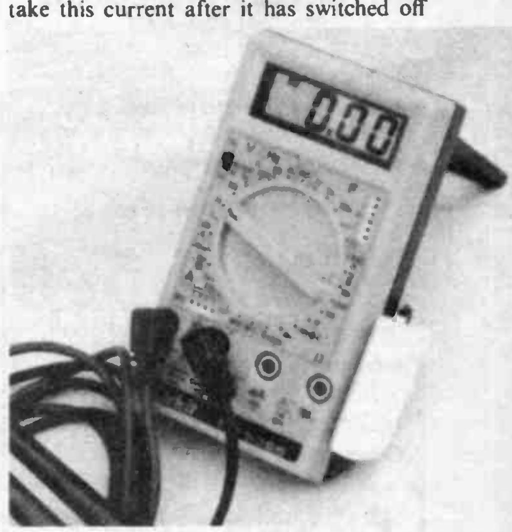
SIMPLE VERSION

The simplest version of the Auto-Switch Add-On Unit circuit, designed to operate the DVM, is shown in Fig. 1. Because the meter needs such a small current it was decided that a circuit using just a CMOS timer might meet the requirements.

However, a look at the timer specification revealed the first problem. The timer output in common with many i.c.s is capable of sinking a much higher current than it can source, therefore the circuit should connect the negative lead of the DVM to the timer so that it will be switched on when the timer output is low. But in the monostable mode the timer output is normally low and goes high when timed out.

This circuit reverses the sequence being low whilst timing and going high when it has timed-out. So you will find the circuit slightly different to the one you would normally expect. Also there is a single push-button switch S1 to both reset and start the timing cycle.

There is no doubt that this circuit fulfils some of the requirements and would certainly pay for itself in battery saving for *low current* devices; but it also has some serious failings. Although while timing it only takes 170 microamps, it continues to take this current after it has switched off



COMPONENTS

Simple Version (Fig. 1)

See SHOP TALK Page

Resistors
R1, R2 1M (2 off)
All 0·25W 5% carbon film

Potentiometer
VR1 1M enclosed vertical min. preset, lin.

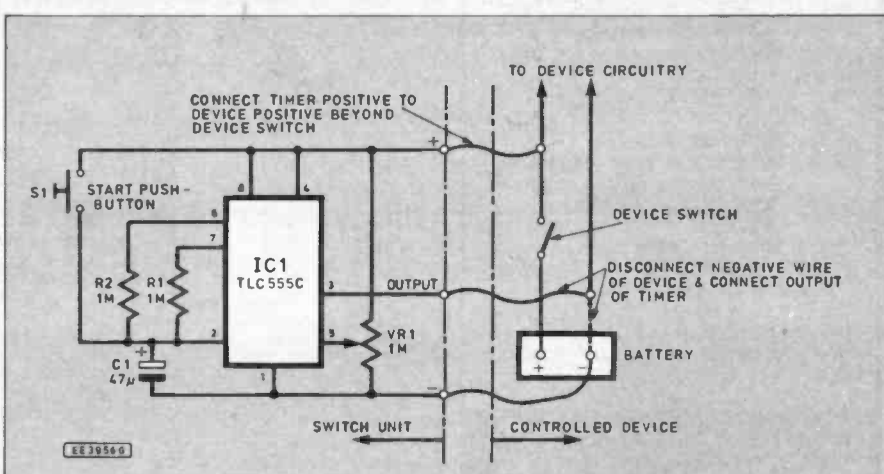
Capacitor
C1 47µ sub-min. radial elect., 16V or more

Semiconductor
IC1 TLC555C CMOS timer i.c.

Miscellaneous
Miniature pushbutton switch; 8-pin d.i.l. socket; stripboard, 0·1in. matrix (size as required); connecting wire; solder, etc.

Approx cost guidance only **£3**

Fig. 1. Circuit diagram for the Simple Auto-Switch Add-On for low current devices.



the device. This current drain will continue until the device itself is switched off.

Another undesirable feature of this circuit is the internal resistance of the timer. At five milliamps there is a voltage drop of 0·072V (see Table 1) which doesn't look too bad. But this gives an internal resistance of 14·4 ohms that at 100 milliamps would drop 1·4V.

This drop on a supply of 9V could be quite serious and at lower voltages would be unacceptable. It could also give rise to distortion in an audio device unless decoupling measures were taken.

So although the circuit Fig. 1 could be useful in certain circumstances further improvements were necessary. These would keep all the good points, such as the low operating current, of the simple circuit but removing the undesirable features of internal resistance and lack of switch-off.

IMPROVED CIRCUIT

One method of solving the problem with the first circuit would be to use a relay. But a normal relay requires too much current even if the "holding" current is reduced to a minimum.

A while ago the author produced a reed relay which by mounting a permanent magnet in a suitable position would latch ON when the coil current assisted the magnet and unlatch when the direction of the current was reversed. This type of relay needs no holding current and therefore would be ideally suitable for this application.

However, it was found to be very difficult to achieve reliable operation and so enquiries were made of the major suppliers to find a commercial equivalent. The relays that were obtained were found to operate on the same reed switch principle but they also had an improvement. They had two coils one for on and one for off and this greatly simplifies the switching.

The final circuit diagram for the Auto-Switch Add-On is shown in Fig. 2. Because the relay unlatches at the end of the timing period when the timer output goes low, the circuit looks more like the one you would expect for a 555 timer.

The timer IC1 is initiated by the Start pushbutton switch S1 which latches the relay by energising the start coil winding across pin 8 and pin 9. This closes the two relay contacts pins 12/16 and pins 1/5. The closing of the relay contacts at pin 12 and pin 16 completes the battery positive supply to the "equipment" or device switch.

Providing the device switch is ON the timer output goes high and the timer starts to time-out. At the end of this period the output goes low and energises the unlatch winding across pin 7 and pin 10. This opens both sets of contacts and the device being powered *and* the timer are switched off. Similarly all current ceases if the device switch is turned off; but then at switch-on the timer will restart without the button being pressed.

According to the specification for the timers no supply decoupling capacitor is needed. Despite this it has sometimes been found necessary when operating at five volts to fit one, shown dotted (C3) in Fig. 2, otherwise the relay drops out when the pressbutton switch is released.

There are 5V and 12V versions of the twin coil, latched relays available, covering the range 4V to 18V. This is virtually the same as a low current timer and defines the operating range of the unit.

The five volt relay should be used in a circuit with a voltage of 4V to 8V and the 12 volt relay for voltages of from 8V to 18V. While the lower voltage relay does not seem reliable below 4V the 12V one has worked reliably down to six volts this is well below the voltage at which a 9V battery would be replaced. The maximum switch rating for both of these relays is 1A which should cater for most requirements.

MAKING TIME

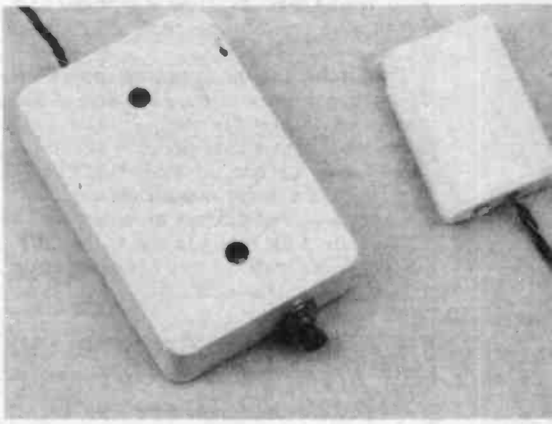
There are two readily obtainable low current timers, ICM7555 and TLC555C. Both give the same time delay but differ slightly in some of the other parameters.

Table 1 compares these two types but basically the TLC555 is best for the simple circuit because it has the lowest internal resistance and the ICM7555 is best for the relay circuit, having a slightly lower operating current. There is very little difference in the price and both have the same operating voltage range.

Table 1: Operating Data for the Low Current Timers

		ICM 7555	TLC 555C
Operating voltage	Max Min	18 volts 2 volts	18 volts 2 volts
Operating cuttent at 9 volts (in Fig. 1 Circuit)		0·12mA	0·17mA
Output current (Sink)	Max	100mA	100mA
Volt drop at 5mA (Sink)		0·117 volts	0·072 volts
Internal resistance		23 ohms	14·4 ohms

Completed relay version (left) and a smaller version (right).



COMPONENTS

Relay Version (Fig. 2)

See SHOP TALK Page

Resistors
R1 1M
R2 2M2
All 0·25W 5% carbon film

Potentiometer
VR1 1M sub-min. enclosed horizontal preset, lin.

Capacitors
C1 220µ sub-min. radial elect., 16V or more
C2 10n ceramic
C3 47µ sub-min. radial elect., 16V or more
C4 0µ47 sub-min. radial elect., 16V or more

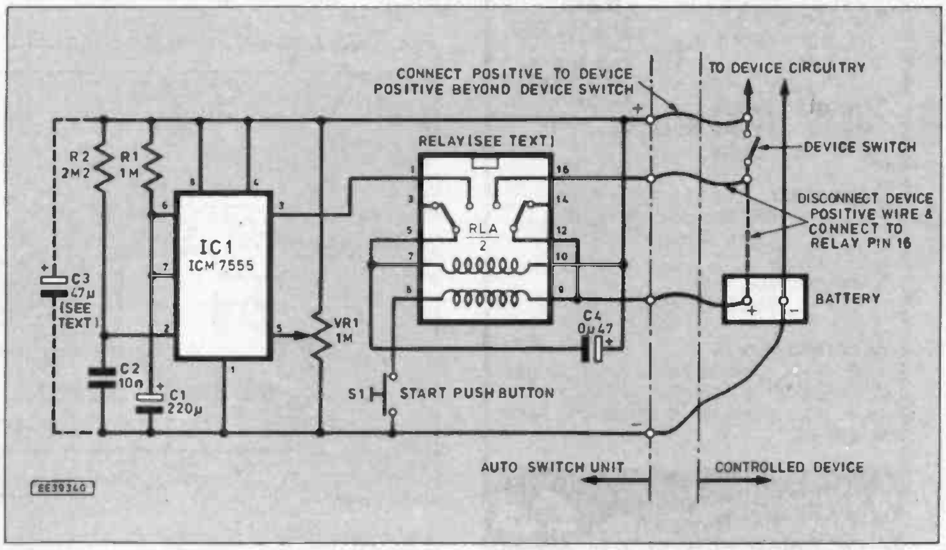
Semiconductor
IC1 ICM7555 CMOS timer i.c.

Miscellaneous
RLA 5V or 12V, twin coil (167 or 960 ohm), d.i.l. latching relay with double-pole changeover contacts
S1 Min. pushbutton switch, press-to-make non-locking

Plastics case, size 75mm x 50mm x 25mm; stripboard 0·1in. matrix, size 18 strips x 24 holes; 8-pin d.i.l. socket; 16-pin d.i.l. socket; connecting wire; solder, etc.

Approx cost guidance only **£8**

Fig. 2. Circuit diagram for the improved relay version of the Auto-Switch Add-On.



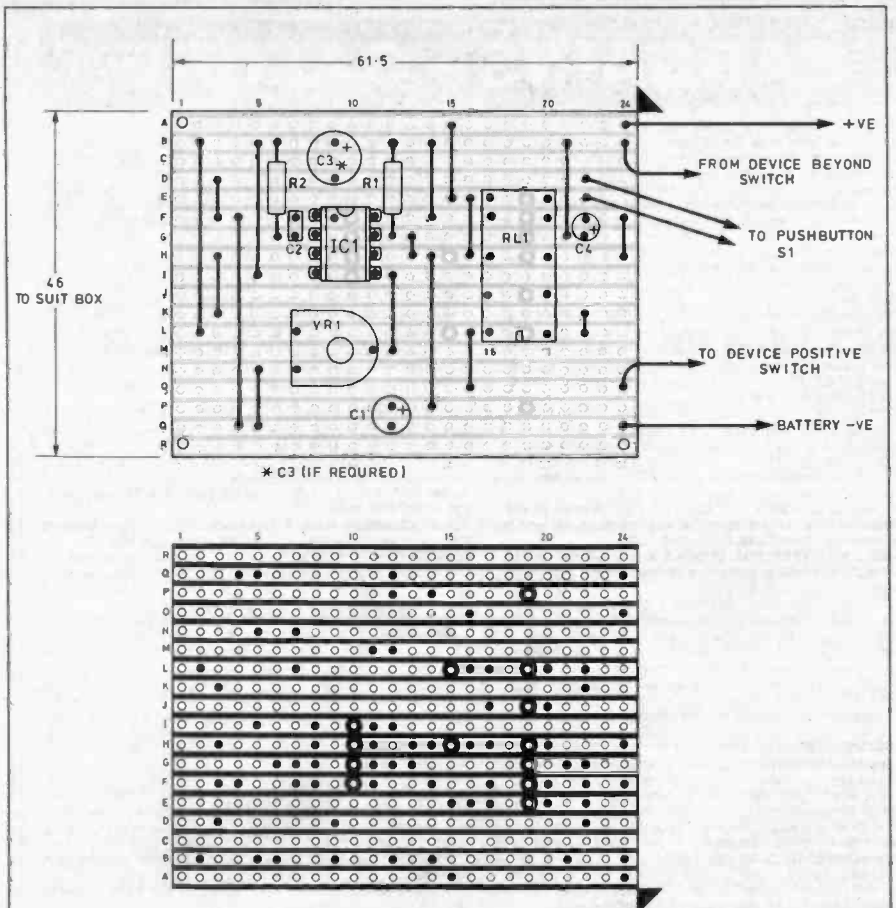


Fig. 3. Stripboard component layout and underside copper break details.

CONSTRUCTION

No construction details or layout is given for the Simple Auto-Switch Add-On circuit (Fig. 1) as this unit will probably be tailored to suit the device to be powered. The problem with the relay version was to find a suitable container.

If there is plenty of room inside the case of the device to be controlled, or if a box is acceptable, the Relay version can be constructed on a piece of stripboard, size 18 strips x 24 holes. The stripboard component layout and details of the breaks in the underside copper tracks is shown in Fig. 3.

The unit which was designed for operation with the DVM was also built on a small piece of off-cut stripboard, size 14 strips by 4 holes, and was designed to fit into a "Hermesetas" sweetener box – see photographs. This was ideally suited as it was just large enough and has an opening gap at the front providing access to the time adjustment potentiometer. The copper strips on the board are cut *between* the two centre holes, along its length, to form a miniature "tagboard".

This is an example of what can be done to pack the components into the space available. Most of the components are small and in this unit the timer i.c. was fitted into a wire-wrap type socket which was soldered well clear of the stripboard to provide space underneath for the resistors and the 10nF capacitor C2.

At the time it was constructed a push-button switch small enough to fit the box couldn't be found and one salvaged from the front p.c.b. of an old Betamax video was used. However, this type of sub-miniature switch is now available if you need it. (See *Shop Talk*). This unit is attached to the DVM with double-sided adhesive tape.

While it is not essential, both the timer IC1 and the relay RLA are fitted into d.i.l. sockets, enabling the soldering to be finished before the main components are fitted. This also enables the relay to be changed very easily if the unit is required to operate at a different voltage.

IN-CIRCUIT

To fit the Auto-Switch to a piece of equipment it is only necessary to disconnect the equipment positive wire from the battery and connect it to board location *O*24 (pin 16 of the relay RLA). The positive (relay pins 9 and 12) and "ground" (–V) leads from stripboard points *A*24 and *Q*24 are then connected directly to the equipment battery.

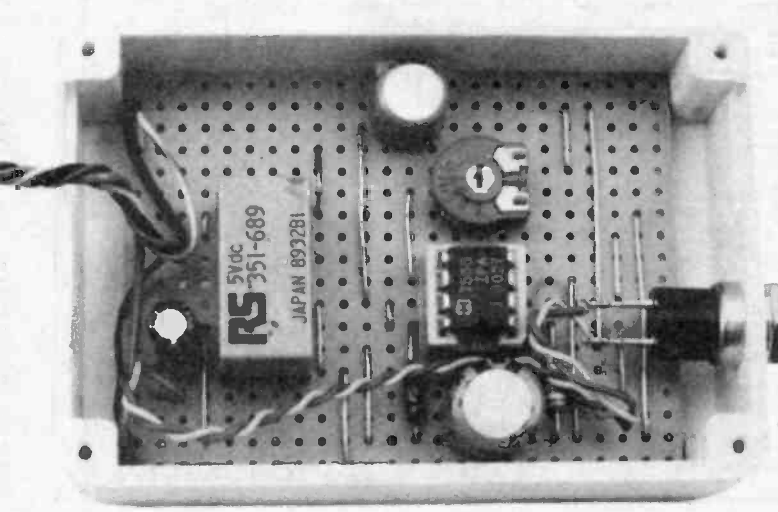
A connection is made from the *circuit side* of the device/equipment On/Off switch to pin 10 of the relay at board point *B*24. This is not usually a problem. It is only necessary to search the device p.c.b. with a voltmeter until a contact is found where the full battery voltage is present, checking that this voltage is controlled by the device switch.

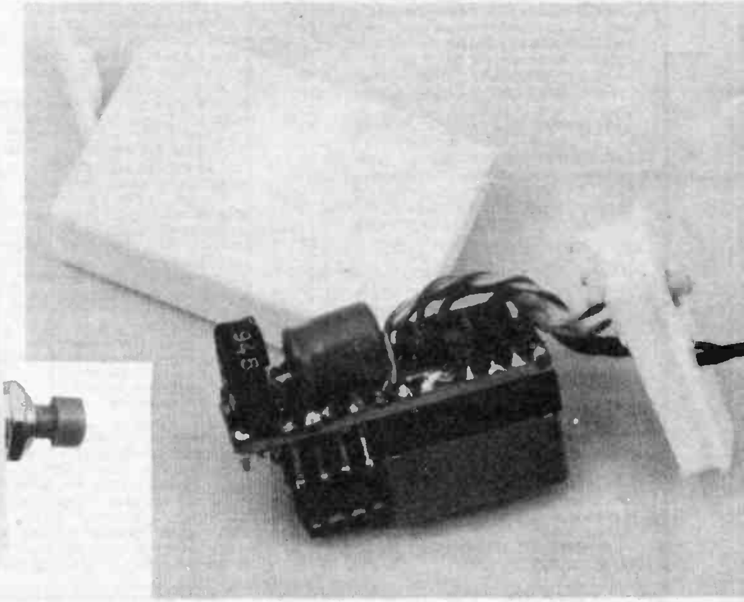
Often this will be pin 14 or pin 16 of an i.c. or the positive connection of an electrolytic capacitor. However, if it is not possible to make this connection, relay pin 16 can be joined to pin 10 and the timer will still work satisfactorily. The advantage of wiring the timer through the device switch is that when the device is switched off all current ceases: even the small current drain taken by the timer.

The component values shown in the circuits of Fig. 1 and Fig. 2 give approximate times of one to ten minutes. This is a useful range for equipment such as the DVM which in use has been found to be best with a time of about four minutes.

Those who have used the 555 timers before, will know that the timing is directly proportional to the value of the capacitor C1 and/or resistor R1. Therefore to double the time either the resistor value or the capacitor value should be doubled. □

Two versions of the Auto-Switch Add-On. To enable the smaller version to fit into the tiny box, some of the components are mounted underneath a wire-wrap d.i.l. socket.





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REPORTING AMATEUR RADIO

Tony Smith G4FAI

NEW MORSE TEST

To obtain an amateur "A" licence one needs to pass a 12 words per minute Morse test, as well as the *Radio Amateurs' Examination*, and for many years the test has simply required candidates to send and receive plain language text and, separately, to send and receive groups of figures.

When the new Novice licence was introduced last year, with an "A" version requiring a 5 w.p.m. Morse ability, the Novice test had a new format. This required candidates to send and receive typical exchanges between amateurs, as in real-life contacts, including mixed text and figures and the use of regularly used abbreviations, Q-codes and procedural signals.

This style of test has proved so successful in preparing Novices to go on the air that it will also be used for the full 12 w.p.m. test as from 1 January 1993. Those who have been studying for the old test can still take it until 31 March 1993 but after that the new test will become compulsory.

Under the old system, many successful candidates were hardly better prepared to use Morse on the air than when they began to learn the code and, not surprisingly, most picked up their microphones and forgot all about Morse as soon as they got their licence. It is hoped that the new-style test will encourage more newcomers to try the code since they will at least be familiar with the basics of CW communication when they first get their licence.

As reported previously, it is not absolutely necessary to learn Morse to become a radio amateur. The "B" licence, whether Full or Novice, permits operation on the v.h.f. and u.h.f. bands without a Morse test and this is a popular way of coming into the hobby. This approach leaves open the option of taking the test later to extend operation into the h.f. bands.

BUY BUT DON'T USE!

Radio scanners are increasing in popularity, providing reception over v.h.f. and u.h.f. frequencies together with control facilities well beyond those of older-style shortwave receivers. World band radios have some of the facilities of scanners and between them these two types of microprocessor equipped receiver provide an impressive means of listening to the entire spectrum of radio transmissions while some scanners are now available which cover the whole range in one set.

However, while such sets may be legally purchased by the general public, it is *not legal* to listen to *everything* that can be heard on them. Anyone can listen to licensed radio broadcast stations, to radio amateurs and standard frequency transmissions but licenses, mostly not available to the public, are required to listen to other transmissions.

It seems to be a feature of the law in this country that while certain things may not be done legally, it is perfectly legal to obtain the means of doing them. Before CB was legalised there was no problem in obtaining illegal rigs.

Surveillance bugs are widely advertised today even though licences cannot be obtained for them. Non-BABT approved modems and other telephone equipment can be bought although it is not legal to use them, and there are many situations where the good citizen can be quite unaware that the *use* of the latest "goodie" he has just purchased could put him on the wrong side of the law.

NEW BOOK

These musings have been brought on by the publication of a new book by the prolific Ian Poole who has produced an excellent introduction to yet another aspect of hobby radio. *An Introduction to Scanners and Scanning* covers the whole gamut of this activity although the author does make a point of referring to the legal position in the first chapter, including the fact that prosecutions have taken place for illegal listening.

For those thinking of obtaining a scanner or a world band radio this handy book (152 pages, 178mm + 108mm) will tell them about radio waves and how they travel; the types of transmissions they will be able to hear legally, and what they may not listen to without a licence; what facilities they will find on a typical scanner; what specifications to look for when choosing a set; and aerials suitable for different ranges of frequency.

There are some useful notes on listening to broadcast stations on the long, medium, shortwave and v.h.f. bands. A chapter on amateur radio provides a helpful summary of amateur activities from h.f. to u.h.f. plus some notes on procedure and jargon which will help a newcomer make sense of what he hears.

A similar chapter provides information about Citizen's Band Radio, including its background, informal procedures, and frequency bands. I was surprised to note that a CB licence is required to *listen* to CB transmissions. Three useful appendices provide a glossary of receiver terminology; a list of ITU callsign prefix allocations; and an amateur prefix list.

Covering a wide range of subjects and containing a lot of factual information, this book provides a helpful introduction to both world band listening and scanning over the v.h.f. and u.h.f. range. Its style makes it particularly suitable for the beginner and it will also provide a useful reference facility for the more experienced. Written by I.D. Poole, G3YWX, the book is published by Bernard Babani (publishing) Ltd at £4.95, and is obtainable from the *EPE Direct Book Service*, code BP311.

Incidentally, a Radiocommunications Agency Information Sheet, *RA 169 Receive Only – Scanners etc*, provides official advice on scanner use. This can be obtained free of charge by telephoning *071-215 2072* (24-hour answerphone service).

NO AMATEUR!

A specific example of illegal listening on legal equipment occurred recently in the case of the "radio ham" who recorded a cellular telephone conversation allegedly involving a member of the Royal Family, and sold the recording to a popular newspaper.

This was another of those instances, which I mentioned last month, when the term "ham" is applied indiscriminately by the press to anyone interested in radio whether they are licensed radio amateurs or not; and on this occasion there were some very critical remarks about radio amateurs in some of the papers together with ill-informed assumptions about activities outside the terms of the amateur licence.

It appears however that the person who made the recording was not a licensed amateur at all but a shortwave listener who at one time operated on CB before giving it up because he didn't like the language he heard.

The *W5YI Report*, an amateur radio newsletter published in the USA, telephoned this person who, according to their report, acknowledged that he had made the recording on January 4, 1990. He said that the 23 minute tape, subsequently heard by thousands of callers to a British Telecom 0898 number, was really two tapes spliced together to make one conversation. The other part was from a phone call intercepted by "a lady" on New Year's Day 1989. He knew that the recording was illegal and the paper had gone back on their agreement with him not to release his name.

It seems a pity that amateur radio, with its great tradition and background of public service, should have become involved in all this. At a recent Strategy Conference the Radio Society of Great Britain received a recommendation that it should adopt a professional approach to public relations. If it did that, perhaps there would be fewer inaccurate and harmful references in the media to amateur radio and to what it actually does.

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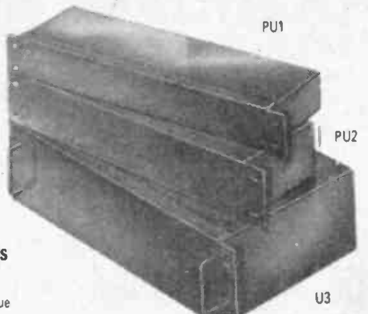

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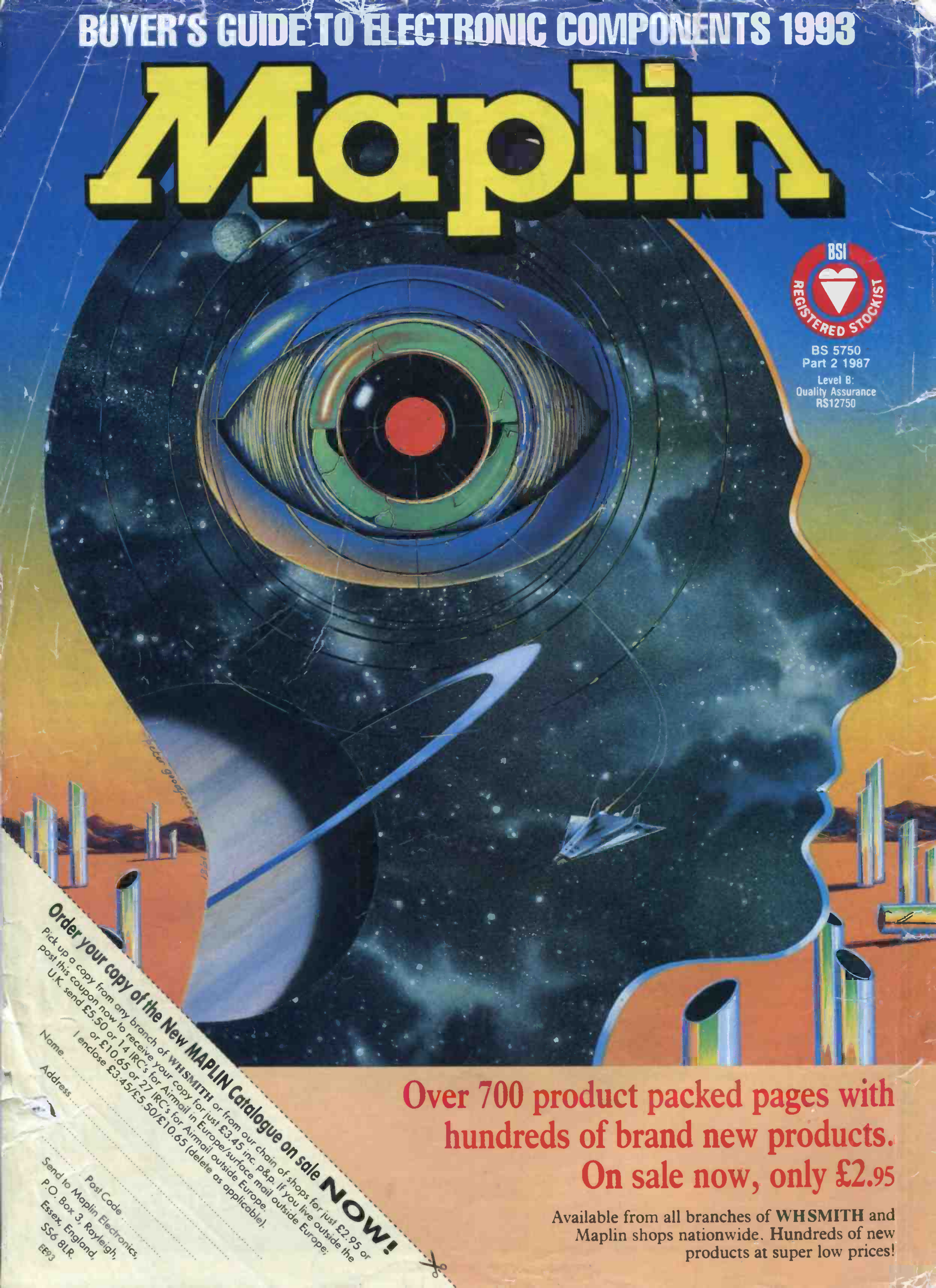
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