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VOL 14 Nº12 DECEMBER '85

EVERYDAY ELECTRONICS and ELECTRONICS MONTHLY

ISSN 0262–3617

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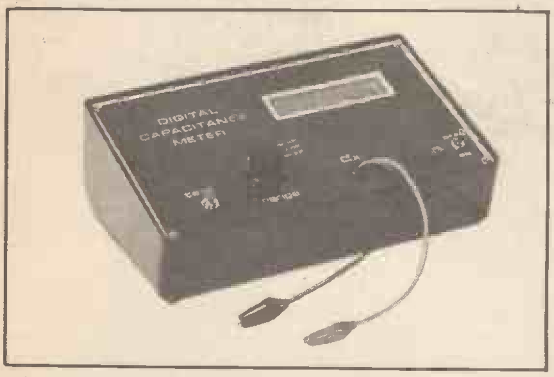

See page 678 for the full story

Projects

Series

Features

Buyers Guide

Our January 1986 issue will be published on Friday, December 6.
See page 675 for details.

OVERSEAS ORDERS

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VOL 14 Nº12 DECEMBER '85

EVERYDAY ELECTRONICS and ELECTRONICS MONTHLY

READERS' ENQUIRIES

We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years old. Letters requiring a personal reply must be accompanied by a **stamped self-addressed envelope or a self-addressed envelope and international reply coupons.**

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Readers should note that we do not supply electronic components for building the projects featured in EVERYDAY ELECTRONICS and ELECTRONICS MONTHLY, but these can be supplied by advertisers.

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. Prices quoted are those current as we go to press.

OLD PROJECTS

We advise readers to check that all parts are still available before commencing any project in a back-dated issue, as we cannot guarantee indefinite availability.

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Annual subscription for delivery direct to any address in the UK: £13.00. Overseas: £15.00. Cheques should be made payable to Everyday Electronics and Electronics Monthly and sent to EE Subscription Dept., Oakfield House, 35 Perrymount Road, Haywards Heath, West Sussex RH16 3DH. Tel. 0444 459188.

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Certain back issues of EVERYDAY ELECTRONICS and ELECTRONICS MONTHLY are available world-wide price £1.25 inclusive of postage and packing per copy. Enquiries with remittance should be sent to Post Sales Department, IPC Magazines Ltd., Lavington House, 25 Lavington Street, London SE1 0PF. In the event of non-availability remittances will be returned.

Binders to hold one volume (12 issues) are available from the above address for £5.50 inclusive of p&p world-wide.

GIFTS

WITH winter now approaching fast the time when indoor hobbies become popular is with us once again. We also begin to think of Christmas and the perennial problem of what to give, or even ask for. This issue carries a guide to some gifts to suit a very wide range of pockets. The guide, together with the Greenweld catalogue which we are pleased to be able to give all readers, should at least set you thinking about presents.

There is of course one gift that lasts a whole year and will provide hours of leisure time interest! I am talking about the magazine you are reading. An annual subscription to EE & EM costs £13 (£15 to overseas addresses) and it can be given to a friend or relation very easily—or why not ask someone to buy a year's supply for you? If you wish to make a present of a subscription, simply send a PO, cheque, credit card number plus expiry date and authorisation signature (Access, Visa, American Express or Diners Club) or international money order to the address on the left, together with a letter showing your name and address plus that of the person to whom the issues should be sent. An issue will drop through their door, anywhere in the world, every month for the next year—a constant reminder of your thoughtfulness!

COMPETITION

It is not often that we run competitions in the magazine but this issue carries one which we have kept simple and tried to make fun. Your response to this free competition will determine the future of similar ideas. If the competition is popular we will carry similar items on a regular basis. We believe companies like West Hyde—who have supplied the 100 meters for prizes this month (thank you West Hyde)—will support us with further items.

SPECIAL OFFERS

Another area we will be getting into is special reader offers; we have a couple planned for the next months and have ideas for more—again, if they are popular. So watch out next month and perhaps, if you have some money at Christmas, we can interest you in some test gear at discount afterwards.

Obviously all our EE & EM editorial offers are backed by the good name of this magazine and by the resources of IPC. We check the products and ensure excellent prices so the value is outstanding.

Mike Kenward

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DIGITAL CAPACITANCE METER

MARK STUART

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

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

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

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

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

DESIGN OBJECTIVES

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

SPECIFICATION

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

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

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

PRINCIPLE OF OPERATION

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

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

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

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

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

CIRCUIT

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

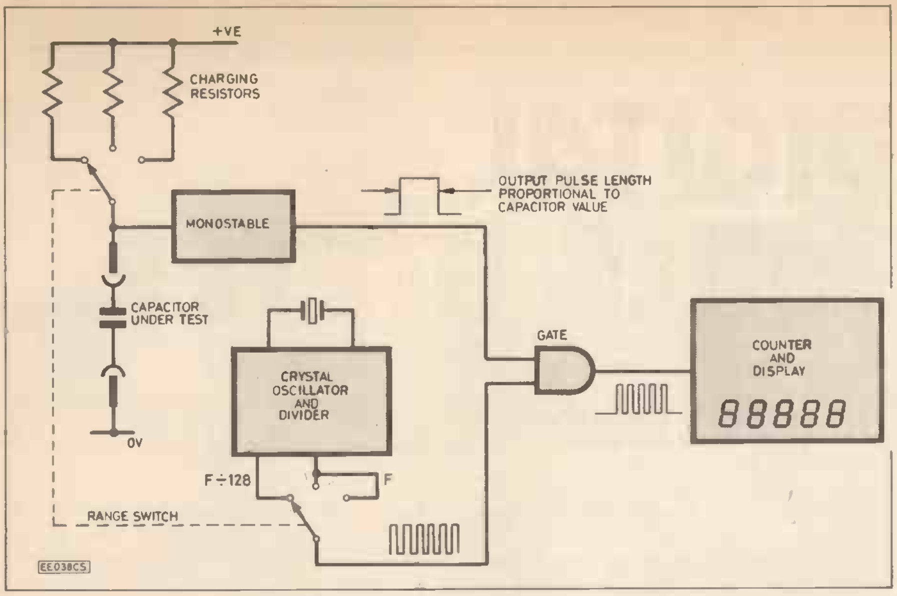


Fig. 1. Block diagram of the Capacitance Meter.

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

CLOCK OSCILLATOR

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

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

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

THE MONOSTABLE

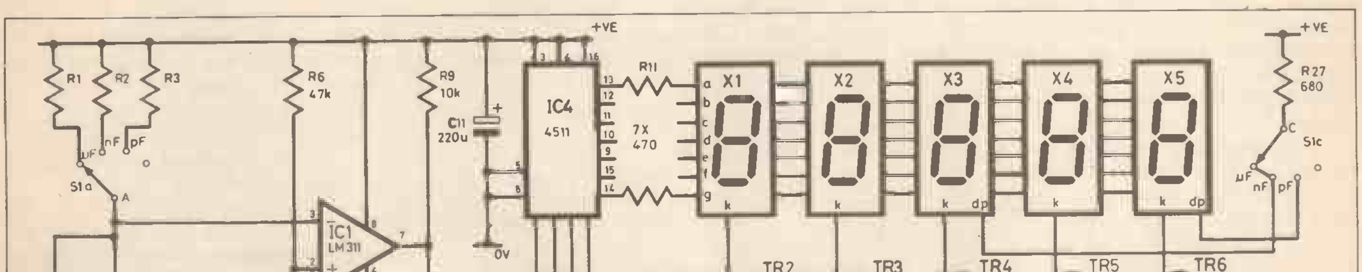
This part of the circuit produces a single output pulse the length of which is determined by the time it takes for the capacitor on test to charge from zero to half supply voltage. It was originally intended to use a 555 i.c. in this part of the circuit, however it was found that pulses shorter than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

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

The circuit operates as follows:

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

Fig. 2. Circuit diagram.



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

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

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

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

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

Table 1. Two-input NAND gate truth table.

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

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

PULSE COUNTER AND DISPLAY

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

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

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

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

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

DISPLAY BLANKING

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

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

CONSTRUCTION

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

COMPONENTS

Resistors

R1	5·515k (5k1 + 47R in series) 1%
R2	40·3k (39k + 1k3 in series) 1%
R3	403k (390k + 13k in series) 1%
R4	2k2
R5	10M
R6,R7	47k 1%
R8	4k7
R9,R10, R23	10k
R11–R17	470 (7 off)
R18–R22	8k2 (5 off)
R24	2M2
R25	330k
R26	100k
R27	680

$\frac{1}{4}$W 5% carbon film unless stated

See Shop Talk page 646

Capacitors

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

Semiconductors

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

Miscellaneous

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

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

A kit of parts is available from **Magenta Electronics Ltd.**, 135 Hunter St., Burton-on-Trent, Staffs., DE14 2ST. ☎ 0283 65435. P.c.b. available from *EE PCB Service*, order code EE512.

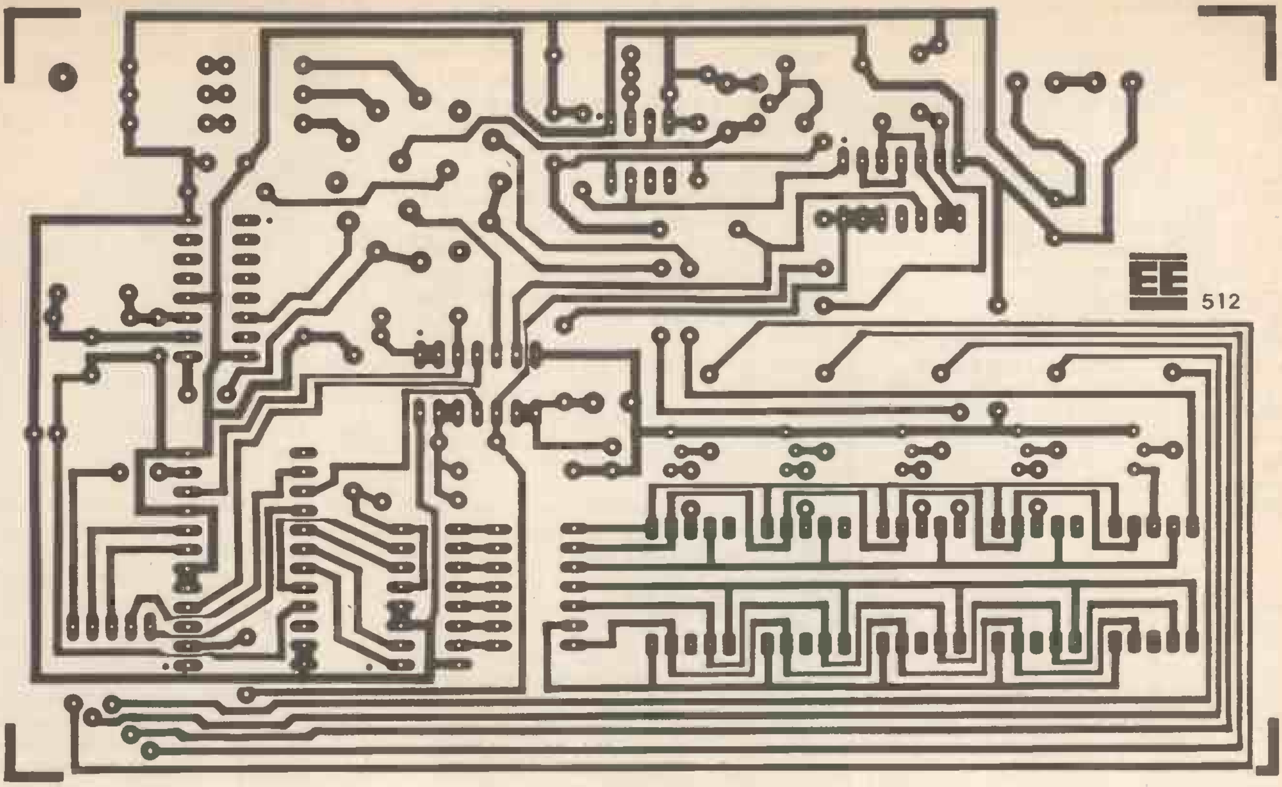


Fig. 3. Printed circuit (actual size).

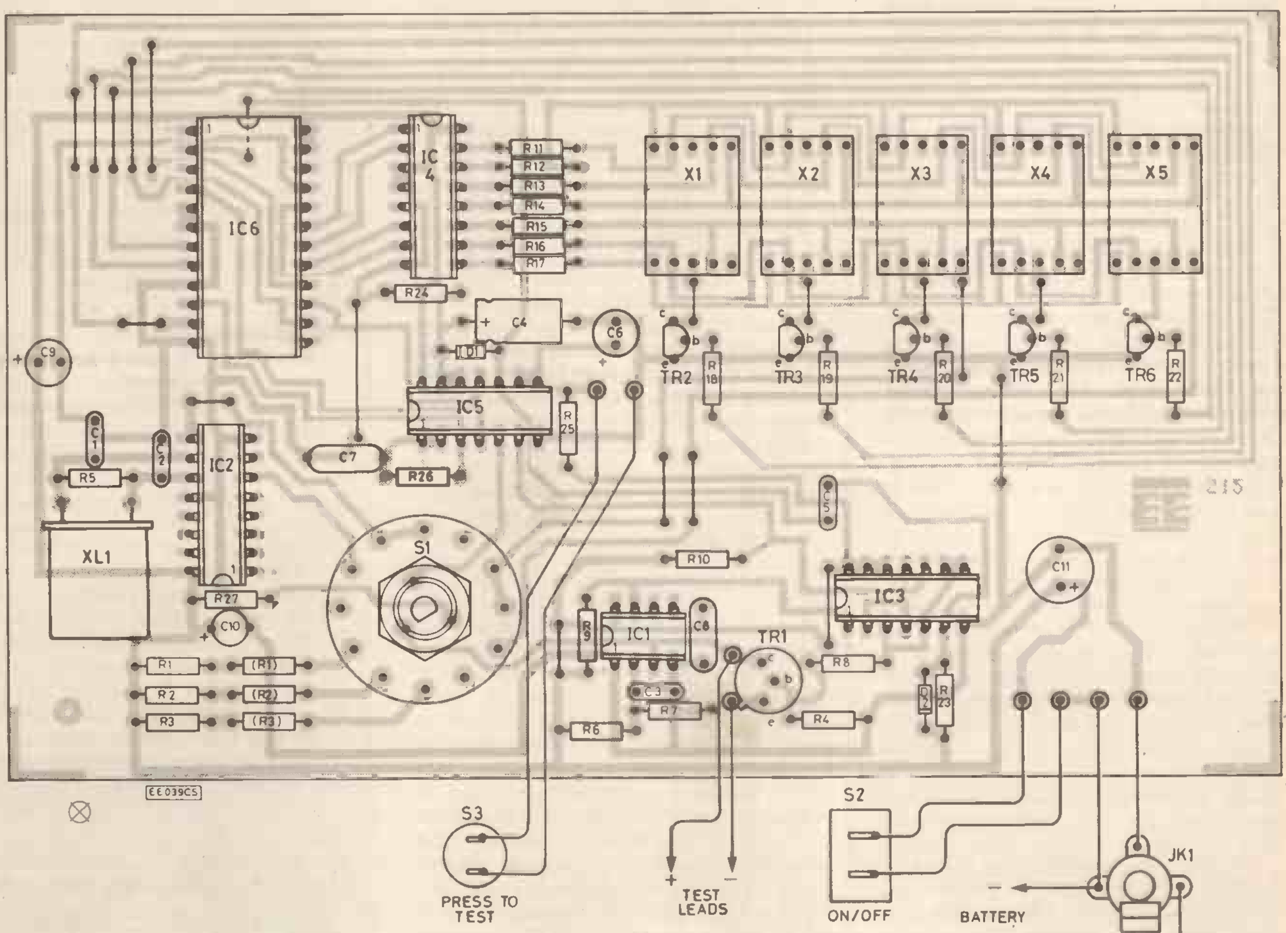


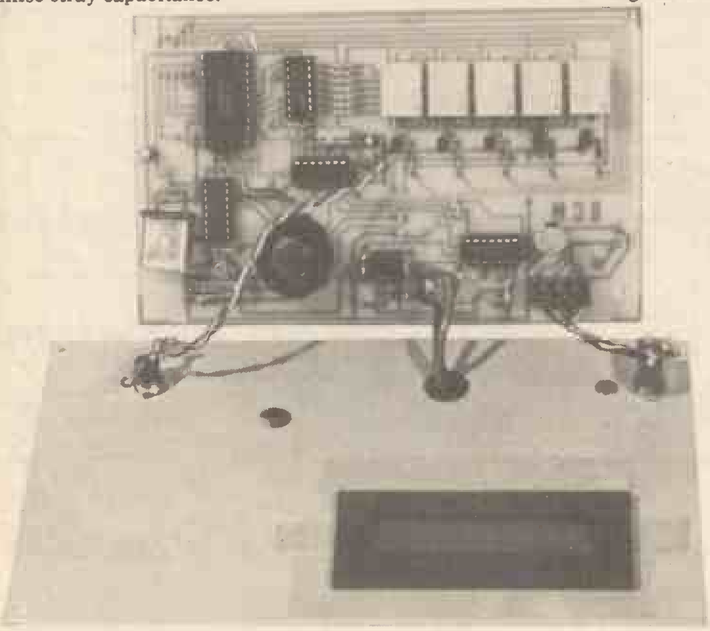
Fig. 4. Component layout and wiring.

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

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

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

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



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

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

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

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

TESTING

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

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

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

USE

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

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

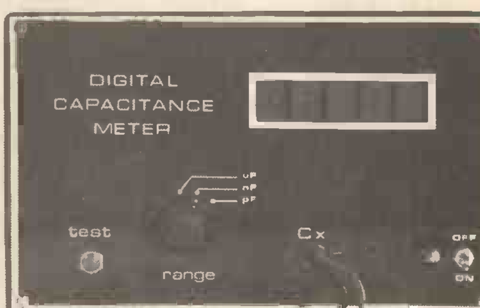
On the pF range the stray capacitance of the leads and printed circuit board tracks will add 20pF or so to the value being measured. This should be subtracted from the value displayed to yield the correct value of the capacitor under test.

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

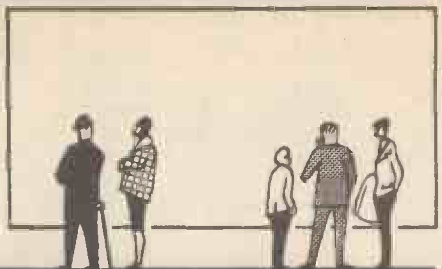
The use of a five digit display means that some values of capacitance are indicated to five digits. For all of these digits to be meaningful the circuit would need to have an accuracy of 0·001 per cent. Since 1 per cent components are used only the first two digits of any displayed value are correct,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

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

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



SHOP TALK



BY RICHARD BARRON

In this month's Shoptalk, we've got a bit of a mixture. There's news of some new products, new services and a special offer.

Supplying Electronics For Education Music Computing And Fun

Magenta Electronics Ltd. has become an established supplier of kits, tools, books and components to hobbyist, particularly through magazines such as *EE* and our sister publication, *Practical Electronics*. For many years now, Magenta have advertised a comprehensive list of *EE* kits, and are still able to supply parts for selected projects from as far back as 1977.

For beginners, the educational kits from Magenta are ideal tools for learning through experiment. Each one includes a book containing logical, and easy, learning steps together with an associated pack of components. Music, computing and fun projects are catered for in much the same way, with a large selection of books and project kits, some of which are designed by Magenta themselves and have been published in *EE*.

Fischertechnik Robots

An exciting new construction kit from **Fischertechnik** is now available from Magenta. It is designed to provide a unique introduction to the fascinating world of robotics. Combining the popular Fischertechnic 'building module' expertise, with the latest computer technology, these kits allow you to design, build and control your own robot models.

Each kit contains two motors, an electro-magnet, eight switches, two potentiometers, 20-core ribbon cable and connectors for interfacing to your computer. Optional interface circuitry is also available for many popular home micros.

Full details of all these products are listed in the Magenta catalogue which is available for £1 inc. VAT & P&P. To keep you up to date, a separate price list is provided at regular intervals, as the catalogue is only updated yearly.

Orders, catalogues and other details are available from: **Magenta Electronics Ltd., Dept. EE, 135 Hunter St., Burton-On-Trent, Staffs., DE14 2ST. ☎ 0283 65435 (Mon-Fri, 9–5).**

Your High Street Technology Store

Tandy Corporation (Branch UK), have over 350 stores and dealers nationwide, selling nearly 3000 different products, from Amplifiers to Zener diodes.

Nowadays, it would seem that Tandy concentrate on consumer electronic products including; hi-fi, video, microwaves and computers. Many of these products carry Tandy's own brand names, such as *Realistic, Archer and Micronta*, all of which have gained 'value for money' reputations.

Maybe not so well known, but of interest to the hobbyist, is Tandy's range of tools, components, kits and test gear. Their component range is not vast by any means, but the convenience of over 300 local stores and dealers makes them a good first choice for those common items such as resistors, capacitors and 'basic' semiconductors which are needed quickly.

Also for the hobbyist and hi-fi enthusiast, Tandy have an excellent range of 'peripheral hardware' such as switches, connectors, plugs, sockets and enclosures. Their range of quality audio plugs and connectors is particularly worth investigating.

Two large, full colour catalogues are produced by Tandy. One covers their complete range of products and the other specialises in computers. The latter is designed to back up their network of Computer Centres which have been developed in recent years.

There are now over sixty dedicated Tandy Computer Centres providing a complete micro service.

Details of the Tandy catalogue or retail stores can be obtained from: **Tandy Corporation (Branch UK), Tameway Tower, Bridge St., Walsall, West Midlands, WS1 1LA.**

Compact Solution

Compact disc (CD) players are becoming a popular medium for hi-fi reproduction, offering a top quality alternative to tape and traditional discs. **Philips Electronics**, a major force behind compact disc technology, have now extended CD applications to the field of computing.

At Philips Research laboratories, at Redhill, in Surrey, engineers saw compact disc read only memory (CDROM) as a logical progression, as music stored on CD was already in digital form-computer language. All that was required was an interface compatible with computers. This achieved, the result is a low-cost, extremely powerful, program storage medium.

Prototype

At present, although Philips have a reliable working prototype, CDROMs are not yet in production. However it looks as if, in the not too distant future, they will be.

Because most of the development investment involved in CD memory has been recovered from the audio market, the price, in theory, should not be too high but, be careful. When they first appear, the price will not become stable until market trends such as supply, demand and software back-up has become established. Also, if you are thinking of buying a standard compact disc player in the near future, and hoping to fit an interface later, you will be disappointed as they probably won't be available.

Super Switch-Super Offer

Superswitch Electric Appliances Ltd., a member of the *MK Electric Group*, have just released a new booklet illustrating a variety of devices for home security and lighting. These include: smoke and intruder alarms, wireless burglar alarms and a range of electronic timers.

Also offered by Superswitch, is a FREE 'In-Car' recharger, worth £7, when you buy a model-4010 rechargeable torch. This is designed to make light work (work light) of car break-downs and emergencies. It retails for around £19 and comes complete with a wall mounting bracket and mains transformer for home use.

Please note however, this offer is only available while stocks last, so buy now to avoid disappointment.

Details of these and other products are available from: **Superswitch Electric Appliances Ltd., 7 Station Trading Estate, Camberley, Surrey GU17 9AH. ☎ (0276) 34556.**

Technology Surfaces

During the early seventies, electronic technology advanced at an incredible rate. The second industrial revolution was just beginning, and whilst many had just become accustomed to transistors as an alternative to valves, integrated circuits loomed.

To many, this signalled the beginning of the end for that inventive and ingenious breed, the electronic hobbyist. This was not to be; indeed, the hobby went from strength to strength as amateurs mastered the art of p.c.b. design and i.c. usage, and at all times remained at the forefront of technology.

Since those early days of small scale integration (a few transistors in one package), manufacturers have striven to cram as many components onto a single chip as possible. There are now i.c. packages containing hundreds of thousands of transistors. Once again, this has been no problem for the hobbyist as all these i.c.s are available in the familiar, standard d.i.l. packages.

"By 1990, almost half of all electronic components used in Europe will be surface mounted devices"

However, the present situation may soon change. In recent years, manufacturers have decided to reduce the size of their i.c. packages to facilitate more efficient and cost-effective production. This has resulted in the ever-increasing availability of small-outline (SO) packages and surface mounted devices (SMDs), a trend certain to continue. According to Dr. Alex Stark of **Mullard Ltd**, Britain's largest electronic component company. "By 1990, nearly half of all the electronic components used in Europe will be surface mounted devices".

What effect this will have on the availability of their d.i.l. counterparts, is difficult to say, but it seems unlikely that they will become obsolete within the next twenty years. The problem is; is this, once again, an early signal to the beginning of the end for the hobbyist? I think not. Hobbyists, like cats, always land on their feet and after all the appearance of SMDs only marks the beginning of their third or fourth life, which leaves five or six to go at.

Before hobbyists are able to adopt surface mounted technology, if indeed they will ever need to, many problems will have to be overcome. The main concern of *Shoptalk* will be the availability of SMDs in small quantities at reasonable prices. Also, as production of SMDs increases it follows that production of standard d.i.l. packages will probably decrease causing the price to rise. At the moment SMDs are rarely available to hobbyists at all and even many industrial suppliers only deal in vast quantities.

As for the hobby itself, some clever and ingenious designers, whether amateurs or professionals, will have to come up with new ideas for utilising surface mounted technology as, at the moment, they are mainly geared up for automatic production methods. In the meantime, *Shoptalk* and *Everyday Electronics* will be keeping a close eye on developments in this area. We will keep you posted!

CONSTRUCTIONAL PROJECTS

Digital Capacitance Meter

A complete kit of parts for the Digital Capacitance Meter is available from Magenta Electronics, Dept. EE, 133 Hunter Street, Burton-on-Trent, Staffs., DE14 2ST. The price is £35.98 and includes VAT but add 60p for P&P per order.

Diode/Transistor Tester (Teach In '86)

Once again, Teach In is proving to be very popular and response from readers and advertisers has been excellent. There are now several advertisers offering complete kits for parts of this series, so no component buying problems are envisaged.

Although it is our policy to print front panel layout designs for each project in the series, it does not prevent constructors from using different cases if they choose. Be careful though, make sure that all the parts will fit into the case with enough room for appropriate panel labelling.

TTL Logic Probe (Building Blocks)

Building Blocks projects continue to be inexpensive, each one being built around a small p.c.b. which is part of a larger board available from the PCB Service.

The board published this month is split into five sections, designed to be carefully cut to produce four separate projects (one project uses two boards). Projects which can be built on these boards include a Single-Chip Alarm, TTL Logic Probe, Computer O/P Port and a Light Effects/Games Unit.

As well as the PCB Service, some advertisers may be selling complete kits for this series and to make them even better value, the boards have been modified to allow cheaper components to be used. In particular, standard chassis mounted pots can be used rather than the p.c.b. mounted types used on the prototypes. Also the boards supplied by the PCB Service have been modified to this end.

The TTL Logic Probe, this month's Building Blocks Project, should present no difficulty as far as the bulk of the components go. However, some readers may prefer to use a different type of case to the one used for the prototype. This is no problem, providing it is large enough to contain all the components. A suitable probe may be made from a stainless steel nail or similar item.

Optical Intensity Transducer

The case used for the Optical Intensity Transducer is the same type used for all the projects in this series. Other than the actual transducer devices, the components are available from a number of advertisers. This months device is a general purpose photodiode similar to the RS 305–462 and is commonly available from many sources.

Please mention EVERYDAY ELECTRONICS when replying to products mentioned on this page and to Classified Ads

FOR YOUR ENTERTAINMENT

BY BARRY FOX

Community Radio

For a while it looked as if the Home Office's handling of Community Radio licensing was a classic case of cock-up. The Home Office takes its technical advice from the DTI's radio department and when one non-technical government department has to mouth the words of engineers from another department, the communications wires can easily get crossed.

But the cock-up theory no longer holds water. It really does begin to look as if the Home Office, and probably the DTI as well, don't want community radio to succeed. They have simply gone through the motions of offering licences to keep critics off their backs.

Consider the facts . . .

The Home Secretary announced on 25 July that he would licence 21 experimental community radio stations in Britain, for a two year experimental period. Five will be in London.

The Home Office said in guidance notes that it wants community stations to offer listeners a broader choice of programming, rather than ape existing BBC and commercial services. Because of the risk of interference on the crowded airwaves, the Home Office has also published a strict technical specification for transmitter power and warns that it will take a particularly serious view if anyone exceeds the permitted power level. Offenders risk losing their licences.

The maximum permissible power on the v.h.f. frequencies made available for community radio will be 10W for small neighbourhood stations or 100W for "community of interest" stations. Anyone reading the Home Office rules would be entitled to expect the licences to cover stereo. The Home Office expects a mix of speech and music programming. As a community of interest the Home Office instances "enthusiasts for a particular kind of music".

To be effective, music transmissions must be in f.m. stereo, like the BBC and commercial stations—and pirates. The licence notes do not specifically exclude stereo, they just make it impossible or at least impractical to transmit!

In accordance with normal f.m. broadcast practice, the carrier signal for community radio will be able to deviate by 75kHz up or down from the allocated frequency. But the transmitted f.m. signal may spread over only a 200kHz band. This is enough for mono, but stereo needs at least 250kHz.

Borderline

The Home Office limits on sidebands are even tighter. In any f.m. transmission there are sideband frequencies which in theory have infinite spread. In practice, they can be reduced in level by filters so that they do not interfere with other stations.

The Home Office insists that at 100kHz away from the main carrier frequency, the sidebands must be at a power of at least 40 decibels below the power of the carrier. Mono radio stations round the world achieve only around 30 decibels at 100kHz; stereo signals have a much wider bandwidth and stronger side bands.

I spoke with Angus McKenzie, a well-known consultant in audio and radio technology, technical specification. "I just cannot see how the community stations will be able to broadcast in stereo and stay within the limits," he says. "Even high-quality mono will be on the borderline."

When I quizzed the Home Office on the point it took them a couple of days to remember that although the notes said nothing about it, they had never intended people to broadcast in stereo. The idea of community radio was born out of pirate radio, much of which is in f.m. stereo. But according to the Home Office: "Stereo was never envisaged because it is only an experiment. We are quite satisfied that our rules allow mono. But we might reconsider if there is any demand."

Do people applying for community licences realise that they will get one for mono only? Says Bevan Jones, Chairman of the Community Radio Association, "Certainly not. It's ridiculous. I expect most stations to be half music. Obviously they will want stereo."

Poles Apart

Prospective licensees dare not push the Home Office too hard. They fear they will not get a licence if they do. Even while the government was supposed to be reconsidering its stance on stereo, the Home Office issued another set of technical notes. And these created another problem.

They specify that transmissions must be vertically polarised.

For vertical polarisation, the transmitter aerial has vertical rods which radiate waves aligned in a vertical plane. These must be picked up by a vertical aerial, such as a vertical rod or "whip" on a portable radio or car. They are largely ignored by a horizontal aerial. Horizontally polarised signals are picked up by horizontal rods. Broadcasters exploit this phenomenon to prevent interference between stations operating on closely related frequencies in the same area. One works with vertical polarisation; the other with horizontal.

The BBC and Independent Broadcasting Authority radio stations currently use mixed or circular polarisation, which can be received on either vertical or horizontal aerials. But until recently the BBC used horizontal polarisation. As a result, many roof aerials in Britain are horizontal and will reject vertical signals. There has been no need for people to spend money on changing their system because a horizontal aerial will receive mixed polarisation signals.

So many roof aerials will treat community radio as an unwanted signal. The Home Office says it is insisting on vertical polarisation "to avoid potential sources of interference". But it does not say what these may be, and a vertical signal will still interfere with the mixed signals put out by the BBC and IBA.

The Community Radio Association is split on the issue. Some members want to broadcast to listeners with hi-fi systems. Bevan Jones says "their reception will be knocked out". Grant Pearson, of Thamesmead Radio, a community station already operating legally on cable in London, does not see it as a problem. He says that mixed aerial systems are "more difficult and expensive to engineer . . . and many stations will be interested mainly in reaching people with portables".

BBC and IBA engineers are watching with bemusement as the Home Office makes life difficult for their competition. "It is a crazy scheme," said one, "the Home Office must want community radio to fail."

War Games

Future wars will be fought, like video games, with the military commanders controlling both conventional and nuclear strikes from a computer keyboard and TV screen.

Chips will compare predictions and display options. But someone somewhere will have to pull the trigger by touching a touch-sensitive screen, keying "ACCEPT" or pressing "ENTER". A war zone, with real bombs dropping, may not prove the easiest place to think things through.

Yesterday, I was running a multi-tasking program called Xchange, written by British software firm Psion. Xchange runs with a clever anti-piracy system, which requires the user to insert a master source disc every time the program is loaded. Although the bulk of files can be copied or installed onto the computer A disc drive, some data has to stay on the master disc which is run in the B drive.

As the program loads the computer juggles A and B, checking matching code numbers. In this way Psion hope that no-one can make an unauthorised copy. But the user can't make a back-up safety copy of the master source disc. If you spill coffee on it, Psion will promptly provide a replacement at nominal cost.

I was running Xchange, and formatting blank discs at the same time. The phone rang, and without thinking I hit "ACCEPT" with the Psion master source disc in the wrong drive. Immediately the computer started to format the source disc, wiping vital data chunks. My own fault? Yes. Stupid? Yes. But it's the kind of thing that happens with computers, especially when you are distracted.

So what happens on the battle-field when the military strike commander has to choose between "ACCEPT" and "ESCAPE", and the field telephone rings, or a bomb drops, or a Harrier jet hovers overhead?

TEACH-IN 86

PART 3 · Michael Tooley BA David Whitfield MA M Sc C Eng MIEE

IN electronics, we often categorise materials as either conductors (e.g. copper or aluminium) or insulators (e.g. mica or polystyrene). There is, however, a third category of material upon which the whole of our modern solid-state technology depends—the semiconductor.

SEMICONDUCTORS

The controlled diffusion of impurities into the crystal lattice structure of materials such as silicon or germanium (which would both be normally classified as insulators in the pure form) allows us to produce materials which are neither conductors nor insulators. These materials are semiconductors and their electrical conductivity is a function of the amount of impurity present. (For the curious, the level of impurity is usually somewhat less than one part in 10^{10}!).

Due to superior characteristics at high temperatures, the majority of modern semiconductors are fabricated from silicon (Si) rather than germanium (Ge). There are still, however, a few applications in which germanium devices may be preferred (as we shall see later) but, for the purpose of our explanation of semiconductor action, we will confine our discussion to silicon, and its atomic structure.

The nucleus of a silicon atom is surrounded by three distinct electron shells. The inner shell contains two electrons, the middle shell contains eight electrons, and the outer shell has four electrons, as shown in Fig. 3.1. Since these four outer (valence) electrons are available for bonding with adjacent atoms, silicon is said to exhibit a valency of four (i.e. it is "tetravalent").

Bearing in mind that the number of protons (+) in the nucleus is exactly equal to the number of orbiting electrons (−), we can simplify the atom as shown in Fig. 3.2. Only the four protons which "balance" the valence electrons are shown.

In pure silicon each one of the four valence electrons is shared between adjacent atoms, as shown in Fig. 3.3. The result is a crystal lattice in which electrons form covalent bonds and, since there are no "free" electrons available to carry charge, the material behaves like a near perfect insulator.

If we now introduce a number of impurity atoms, each having a valency of five (i.e. "pentavalent"), into the regular crystal lattice of silicon atoms it will then contain a number of "free" electrons which are not involved in the bonding process and which are therefore available to take an active role as charge carriers (see Fig. 3.4). It should, however, be noted that the material will still be electrically neutral (i.e. the total number of positive charges will exactly balance the total number of negative charges).

Since the pentavalent element produces a surfeit of electrons, we call it a "donor" impurity. The semiconduc-

Fig. 3.1. Model of a silicon atom.

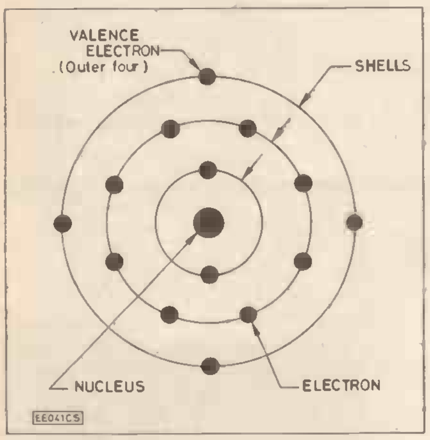


Fig. 3.2. Simplified silicon atom.

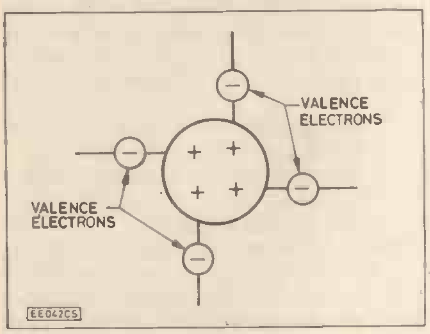


Fig. 3.3. Lattice structure of pure silicon showing covalent bonds.

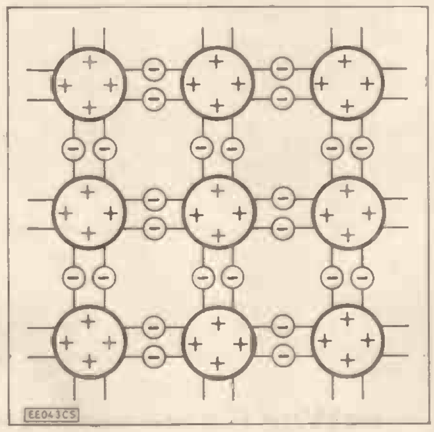
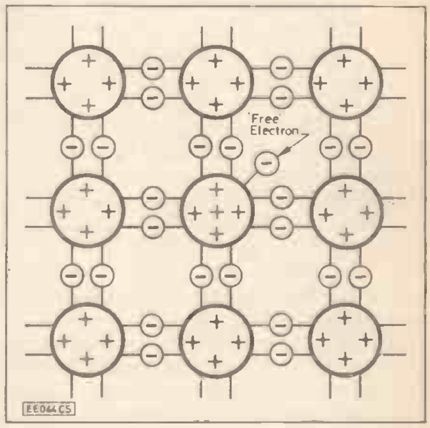


Fig. 3.4. Effect of introducing a pentavalent impurity.



tor material produced is said to be n-type as the majority charge carriers present are negatively charged electrons.

If, on the other hand, we now introduce an impurity element which has a valency of three (i.e. "trivalent") into the regular crystal lattice, we will produce a material which again is electrically neutral but which now has a number of incomplete bonds known as "holes" (see Fig. 3.5). These holes are simply gaps into which electrons can be fitted; as electrons travel within the lattice other holes will be created so we can think of the holes as being mobile positive charge carriers.

Since the trivalent element produces a shortage of electrons we call it an "acceptor" impurity. The semiconductor material is said to be p-

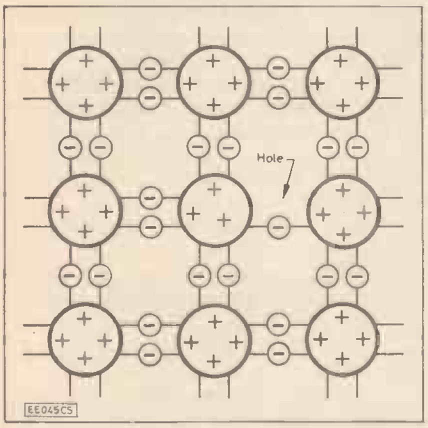


Fig. 3.5. Effect of introducing a trivalent impurity.

type as the majority charge carriers are holes.

The process of introducing impurity elements into pure semiconductor material is known as "doping". Suitable impurities are phosphorous, P, or arsenic, As (both pentavalent) and boron, B, or aluminium, Al (both trivalent).

By means of a sophisticated manufacturing process in which both types of impurity are employed, regions of n-type and p-type material can be produced within the same slice of silicon. The result is called a p-n junction.

THE P-N JUNCTION

When a p-n junction is formed, some of the free electrons within the n-type material diffuse across the junction into the p-type region and recombine with some of the vacant holes. Conversely, some of the holes within the p-type region diffuse across the junction and recombine with free electrons in the n-type region.

This process (illustrated in Fig. 3.6) results in the creation of a region either side of the junction boundary in which no free charge carriers exist (i.e. it contains no free electrons or vacant holes). For this reason it is known as the "depletion region" or "depletion layer".

The process of diffusion across the junction boundary continues until equilibrium is eventually reached. At this point the p-type material has

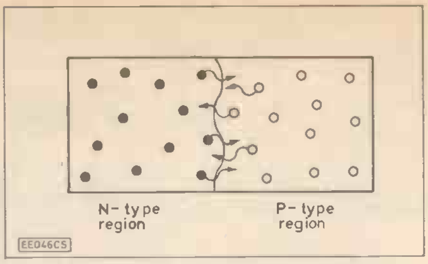


Fig. 3.6. Diffusion of electrons and holes within a p-n junction.

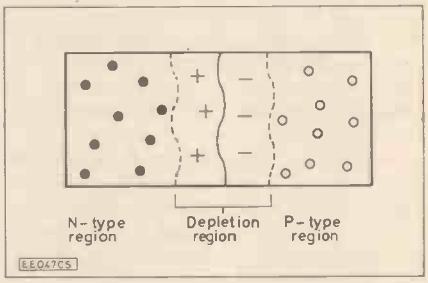


Fig. 3.7. The depletion region.

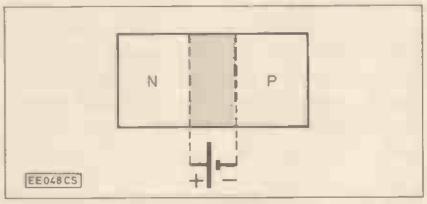


Fig. 3.8. Equivalent potential associated with the depletion region.

acquired a small negative charge and the n-type material has acquired an equally small positive charge, as shown in Fig. 3.7. This difference of charge can be considered as equivalent to a small internal voltage source, as shown in Fig. 3.8.

In order to remove the depletion region it is necessary to apply an external potential to the junction which is exactly equal but of opposite polarity to that which results from the junction's own internal charge, as shown in Fig. 3.9. This potential effectively negates the internal charge imbalance and reduces the width of the depletion region to zero. Thereafter, and with increasing applied potential, charge carriers are able to move across the junction boundary; electrons freely moving from the n-

Fig. 3.9. Forward biased p-n junction.

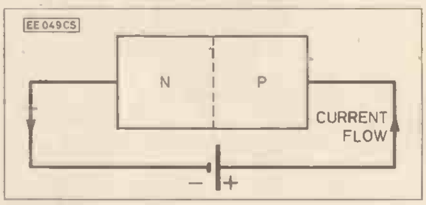
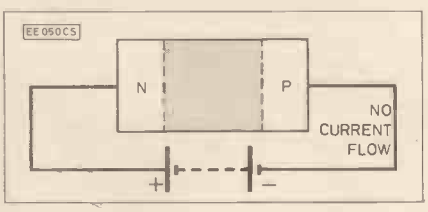


Fig. 3.10. Reverse biased p-n junction.



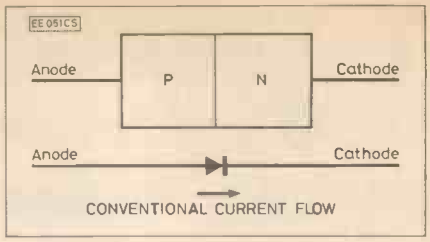


Fig. 3.11. Diode symbol.

type region into the p-type region. This is known as the forward biased condition and an appreciable value of conventional current will flow from the p-type region (anode) to the n-type region (cathode).

If the external potential is applied with the same polarity as that which results from the junction's own internal charge, the depletion region widens and movement of charge carriers across the junction is further inhibited (see Fig. 3.10). The symbol for a diode is shown in Fig. 3.11. Readers should note that the arrow of the symbol shows the direction of conventional current flow.

DIODE CHARACTERISTICS

The properties of any particular diode are best described by means of characteristic graphs showing current plotted against applied voltage. Typical characteristics for low power silicon and germanium diodes are shown in Figs. 3.12 and 3.13 respectively. The following general points should be noted:—

1. For clarity, different scales have been used for the forward and reverse voltage and current axes of both graphs. In particular it should be noted that the forward current has been shown in milliamps whereas the reverse current scale has been shown in microamps.
2. Since the voltage axis is horizontal and the current axis is vertical, the steepness (or slope) of the graph provides an indication of the equivalent resistance of the device. Readers should note that, steepness of the graphs vary according to the applied voltage. The steeper the characteristic the lower the equivalent resistance will be. (Readers seeking further clarification should refer back to Assignment 1.2 in Teach-in Part 1.)

Readers should now devote some time to comparing the characteristics of the two types of diode and should note the following specific points:—

1. Silicon diodes do not start to conduct until the forward voltage reaches approximately 0·6V. Beyond this point the current rises rapidly.
2. Germanium diodes do not start to conduct until the forward voltage reaches approximately 0·2V. The increase of

current beyond this point is somewhat less rapid than for the silicon type.
3. Silicon diodes consume very much less reverse current and can generally withstand very much higher reverse voltages than their germanium counterparts.
4. Silicon diodes have steeper forward characteristics and can generally withstand higher forward currents than their germanium counterparts.

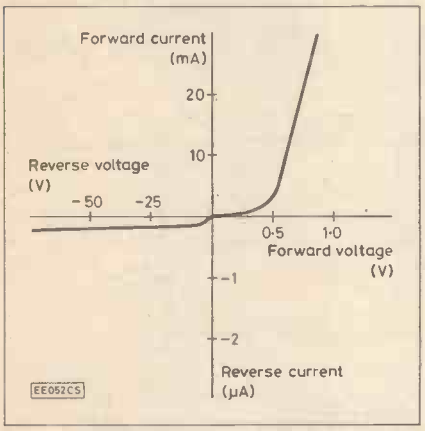


Fig. 3.12. Typical silicon diode characteristic.

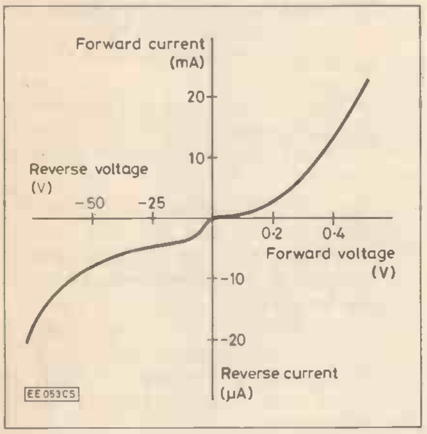


Fig. 3.13. Typical germanium diode characteristic.

Although the significance of the forward voltage drop (0·6V approx. for silicon and 0·2V approx. for germanium) may not at this stage be apparent, readers should bear these values in mind for future reference. As an example of their significance we shall now briefly consider the functioning of a simple diode checker.

SIMPLE DIODE CHECKER

The type and functional state of a diode may be easily checked if we simply measure the voltage drop that appears across it in the forward and reverse biased conditions. A forward voltage drop of between 0·1V and 0·3V would indicate that the device was a functional germanium type whereas an indication of between 0·5V and 0·7V would indicate a functional silicon type.

Since a functional diode should consume negligible current in the reverse biased condition, the reverse voltage drop should be virtually the same as the supply voltage. Any other indication, or deviation from the expected forward biased voltage, would be suspect.

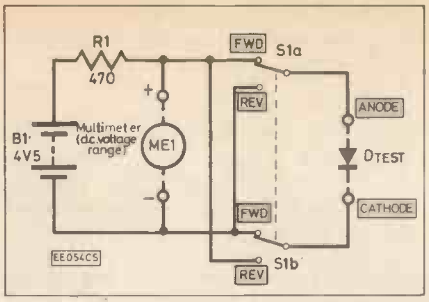


Fig. 3.14. A simple diode checker.

A simple diode checker based on these principles is shown in Fig. 3.14. A forward current of less than 10mA is applied to the diode and the forward and reverse voltage drops are then measured using a multimeter. Some typical indications for the diode checker are given in Table 3.1.

Unfortunately, "in circuit" diode testing is not quite so simple unless one can be certain that the conditions within the circuit remain static and the diode remains in a continuously forward biased state. It is, therefore, usually safer to remove a diode from the circuit before testing it.

Table 3.1. Typical indications produced by the simple diode checker.

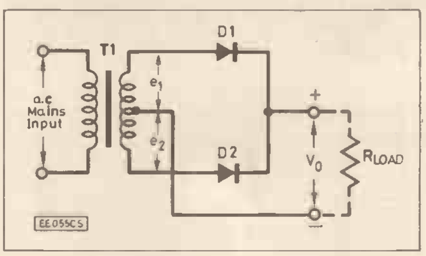
Forward Reading (V)	Reverse Reading (V)	Type of Diode	Comments
0	0	Either	Faulty (Short Circuit)
0·3	4·5	Germanium	O.K.
0·6	4·5	Silicon	O.K.
4·5	4·5	Either	Faulty (Open Circuit)

PEAK REVERSE VOLTAGE

Readers have already seen in Figs. 3.12 and 3.13 how an appreciable reverse voltage may be applied with only negligible reverse current flow. However, if the reverse voltage is increased beyond a certain point, the reverse current rapidly increases and the diode breaks down due to excessive power dissipation. (The power dissipated by the diode being equal to the product of the reverse voltage and the reverse current.)

The maximum reverse voltage which can safely be applied to a diode is known as the "peak reverse voltage", or simply PRV. (Note that some books refer to this as the "peak inverse voltage", or PIV). Germanium diodes have typical PRV ratings in the region 30V to 100V whilst their silicon counterparts have typical PRV ratings of between 50V and 800V.

Fig. 3.15. Bi-phase rectifier arrangement.



THE BI—PHASE RECTIFIER

Readers may recall that we discussed the operation of a rudimentary low voltage power supply in Part One and went on to effect a few improvements to the circuit in Part Two. We shall now develop this theme a little further and incorporate some further enhancements.

The efficiency of our simple power supply can be greatly improved by making use of negative, as well as positive, half cycles of the incoming mains supply. This can be achieved using the "bi-phase" rectifier arrangement shown in Fig. 3.15. Here a split (or "centre-tapped") secondary winding is used.

The alternating voltages at either end of the secondary winding are said to be in "anti-phase"; i.e. when the voltage at one end goes positive with respect to the centre-tap the voltage at the other end goes negative. The two diodes thus conduct alternately, as shown in Fig. 3.16. The net result of all this is that the charge lost by a reservoir capacitor can be replenished at twice the rate (i.e. every 10ms rather than every 20ms when the supply is at 50Hz). This, in turn, leads to more effective smoothing and so the output contains less ripple.

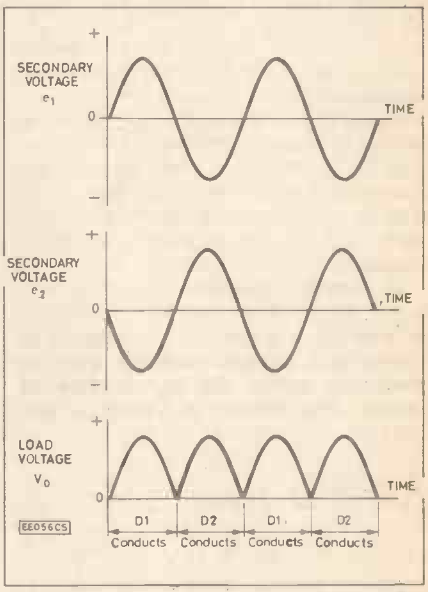


Fig. 3.16. Waveforms for the bi-phase rectifier.

THE BRIDGE RECTIFIER

An alternative to the bi-phase rectifier arrangement is the use of a bridge rectifier, as shown in Fig. 3.17. Here four diodes are used with opposite pairs of diodes conducting on alternate half cycles of the mains input, as shown in Fig. 3.18.

The bridge rectifier arrangement obviates the need for a split secondary winding and often makes use of a specially encapsulated rectifier (in which all four diodes are contained within an epoxy resin block).

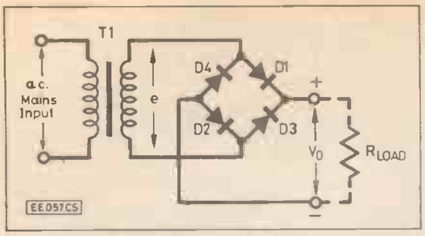


Fig. 3.17. Bridge rectifier arrangement.

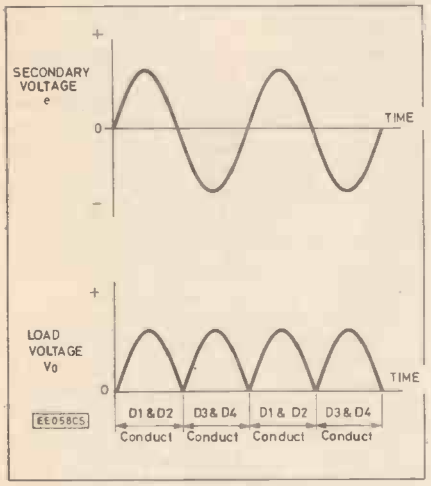


Fig. 3.18. Waveforms for the bridge rectifier.

THE ZENER DIODE

Whereas reverse breakdown is an unpleasant fact of life when designing rectifier circuits it can be quite useful in other areas! Silicon diodes can be manufactured so that they exhibit a controlled reverse breakdown and, provided the current is limited to a safe working value, the diode will not suffer permanent damage. Devices of this type are called zener diodes and they can be purchased with accurate breakdown voltages of between 2·7V and 68V in the same E12 and E24 series used for resistors.

A typical characteristic for a 4·7V zener diode is shown in Fig. 3.19. It should be noted that whereas the forward characteristic is the same as that for a conventional silicon diode, reverse breakdown occurs very much earlier. Once the reverse zener voltage has been exceeded, the voltage drop across the diode remains substantially constant. The zener can thus be used to provide an accurate voltage source; all we need to do is supply an appropriate value of current using a series resistor connected from a higher potential supply.

Fig. 3.19. Typical characteristic for a 4·7V zener diode.

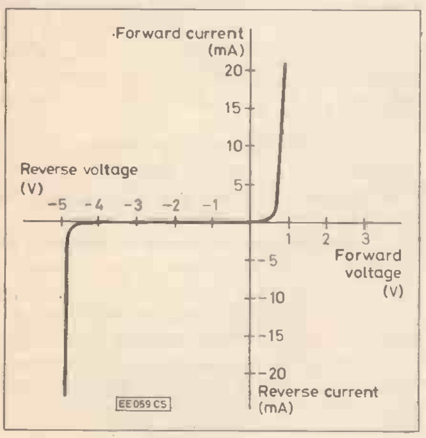


Fig. 3.20 shows a simple zener diode regulator. Provided the load current does not exceed a critical value, the output voltage remains close to the nominal zener voltage regardless of moderate load current and input voltage variations. Finally, Fig. 3.21 shows how our enhanced power supply can be modified to incorporate a regulated output.

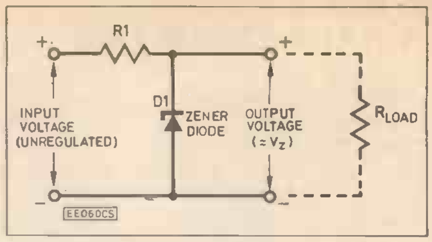


Fig. 3.20. Simple zener diode voltage regulator.

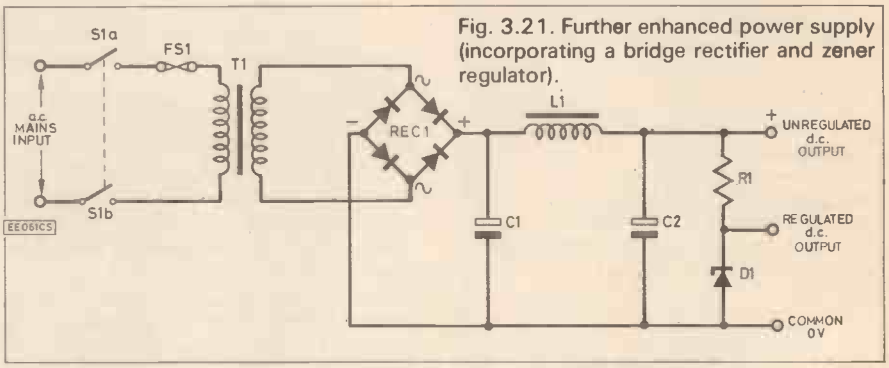


Fig. 3.21. Further enhanced power supply (incorporating a bridge rectifier and zener regulator).

THE TRANSISTOR

Whereas diodes have only one junction, transistors comprise two semiconductor junctions fabricated on a single slice of germanium or silicon. Two varieties are possible; *npn* and *pnp* as shown in Fig. 3.22. In either case, the junctions are formed between the emitter-base and collector-base. This allows us to develop the simple "diode models" of *npn* and *pnp* transistors shown in Fig. 3.23.

The symbols used for *npn* and *pnp* transistors are shown in Fig. 3.24. Readers should take particular note of the direction of the arrow at the emitter which indicates the direction of conventional current flow.

In normal use, the base-emitter junction is forward biased whilst the collector-base junction is reverse biased. Fig. 3.25 shows the biasing arrangement for an *npn* transistor. Electrons present at the emitter will move into the base region where they become "minority carriers". Some electrons will recombine with holes in the base region but, since the base is made very narrow and the collector is positively charged, the greater proportion of electrons leaving the emitter are swept across into the collector region.

The emitter and collector currents are thus almost equal, the difference between them being equal to the base current (i.e. that which results from recombination of electrons and holes within the base region). We can, therefore, establish the following relationship between the currents in a transistor:—

$$I_E = I_B + I_C$$

Typical currents for a small silicon transistor would be:—

$$I_E = 2\text{mA},\ I_C = 1{\cdot}98\text{mA}$$

and

$$I_B = 20\mu\text{A (i.e. } 0{\cdot}02\text{mA)}$$

Fig. 3.22. Basic construction of *npn* and *pnp* transistors.

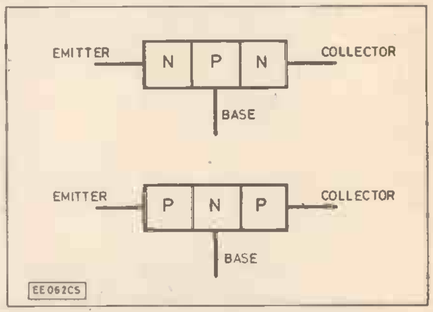


Fig. 3.23. Diode equivalent models for *npn* and *pnp* transistors.

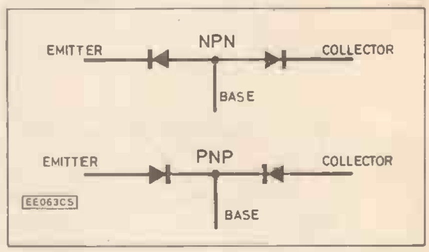


Fig. 3.24. Symbols used for *npn* and *pnp* junction transistors.

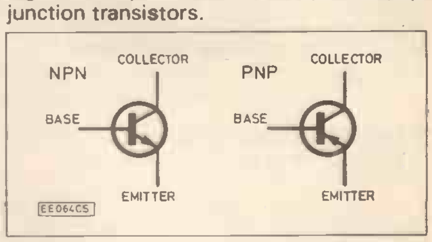
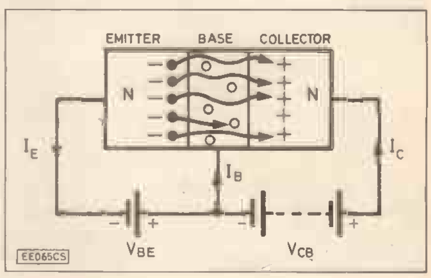


Fig. 3.25. Bias voltages and currents within an *npn* transistor.



TRANSISTOR CHARACTERISTICS

Since transistors have three terminals, their characteristics are somewhat more difficult to show graphically than was the case with diodes. In most cases we can adequately specify a transistor's characteristics using just three graphs:—

(a) the "input characteristic"; I_B plotted against V_{BE} with V_{CE} held constant.
(b) the "transfer characteristic"; I_C plotted against I_B with V_{CE} held constant.
(c) the "output characteristic"; I_C plotted against V_{CE} with I_B held constant.

We have shown a typical set of characteristics for an *npn* silicon transistor in Figs. 3.26 to 3.28. Readers should note that the input characteristic is simply that of a forward biased junction diode and that the transfer characteristic is substantially linear (i.e. doubling the value of base current results in a doubling of the value of collector current, and so on). This latter effect is important since it leads to the concept of "current gain"; a small change in input current at the base of a transistor results in a corresponding, but very much larger, current change at the collector.

Fig. 3.26. Typical input characteristic for a silicon transistor (V_{CE} constant).

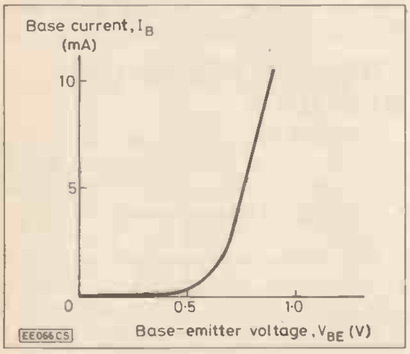


Fig. 3.27. Typical transfer characteristic for a silicon transistor (V_{CE} constant).

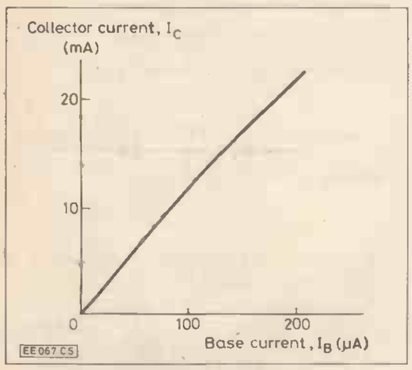
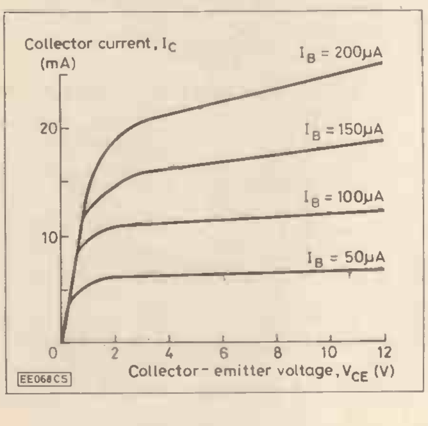


Fig. 3.28. Typical output characteristic for a silicon transistor (I_B constant).



Thus, assuming that we input current to the base of a transistor and take our output current from the collector of the transistor, current gain can be defined as:

$$\text{Current gain} = \frac{\text{Collector current}}{\text{Base current}} = \frac{I_C}{I_B}$$

Typical values for the current gain of small silicon transistors range from around 100 to over 300.

Next month we shall be returning to this topic again, and will show how the output characteristics of a transistor can be used to predict the performance of a transistor amplifier.

PROBLEMS

Difficulty rating (e) easy; (m) moderate.

3.1 Which of the lamps shown in Fig. 3.29 will be illuminated? (e)

3.2 Assuming that all four of the diodes shown in Fig. 3.30 are silicon types, estimate the voltage drop between A and B. Also determine the current in the resistor. (e)

3.3 A transistor operates with collector and base currents of 1·95mA and 50μA respectively. What will the emitter current be? (e)

3.4 Determine the current gain for the transistor in question 3.3. (e)

3.5 A transistor, connected as a simple d.c. amplifier, is to operate a relay which requires a minimum operating current of 60mA. Determine the minimum value of current gain if the circuit is to operate reliably from a base current of 150μA. (m)

The answers to these problems will appear in Teach-In Part 4

ANSWERS TO LAST MONTH'S PROBLEMS

2.1 216kJ
2.2 (a) metal oxide; (b) wirewound; (c) metal oxide
2.3 330nF 10% 250V
2.4 (a) electrolytic; (b) mica; (c) polyester or polystyrene
2.5 800μC
2.6 500nF
2.7 100ms
2.8 A fixed resistor of 10k wired in series with a variable resistor of 100k and a capacitor of 100nF. (Other component values are possible.)
2.9 (a) 63V; (b) 86V
2.10 1·65V

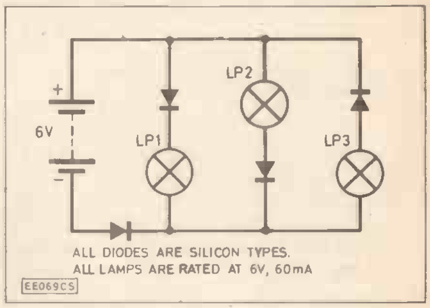


Fig. 3.29. Circuit diagram for Problem 3.1.

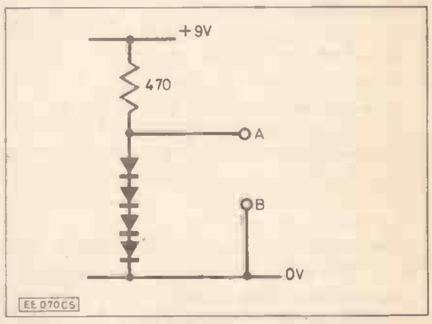


Fig. 3.30. Circuit diagram for Problem 3.2.

Practical Assignments

COMPONENTS

Besides the items used for Parts One and Two, you will need the following components in order to complete the practical assignments described in this part of Teach-In:

Resistors 0·25W, 5%; 100Ω (1); 220Ω (1); 2·7kΩ (1).
Variable resistor 100kΩ
Diodes OA91; 1N4148; BZY88 C3V9; BZY88 C4V7.
Transistors BFY50; 2N3053.

ASSIGNMENT 3.1

Diode Characteristics

This assignment allows readers to derive and compare the forward characteristics of typical germanium and silicon diodes.

PROCEDURE AND RESULTS

Connect the circuit shown in Fig. 3.31 using the wiring diagram shown in Fig. 3.32. The germanium diode (OA91) should be used for the first set of results.

After connecting the circuit, initially set the variable resistor to the extreme anti-clockwise position (corresponding to 0V output). Connect the multimeter (switched to the 50mA d.c. range) in the milliammeter position and ensure that the shorting link is removed. Check that the diode current is zero then reconnect the multimeter in the voltmeter position (switched to the 2·5V d.c. range) and replace the shorting link.

Now adjust the variable resistor for a reading of 0·1V and then repeat the current measurement (this should again be zero!). Increase the voltage in 0·1V steps up to a maximum of 0·5V. At each step, measure and compare the values of current flowing with those printed in Table 3.2.

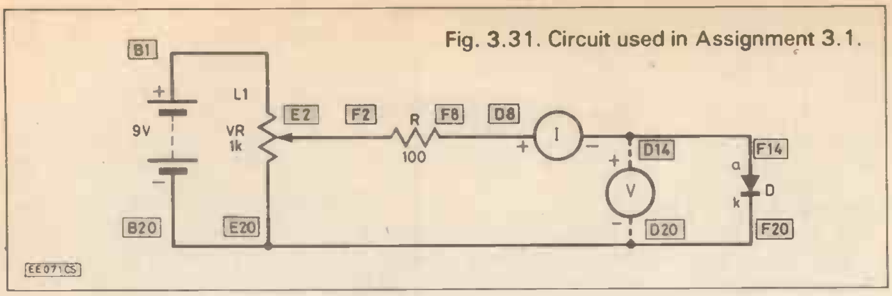
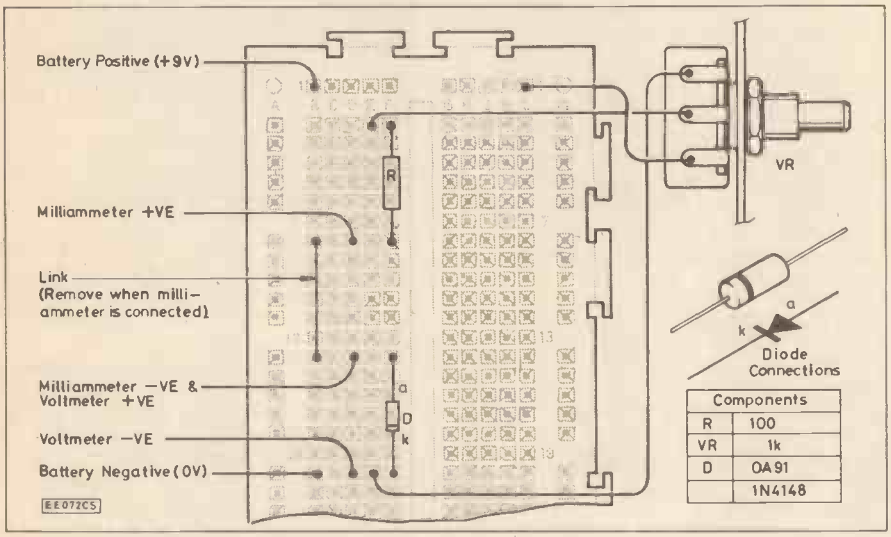


Fig. 3.31. Circuit used in Assignment 3.1.

Fig. 3.32. Wiring diagram for Assignment 3.1.



TR = BFY50	I_B (mA)	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
	I_C (mA)	0	20	38	55	73	90	108	125	145	160	180
TR = 2N3053	I_B (mA)	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
	I_C (mA)											

Table 3.2. Table of results for Assignment 3.1.

Remove the OA91 and replace with the 1N4148. Repeat the foregoing procedure, this time increasing the voltage in 0·1V steps to a maximum of 0·8V. Enter the results in Table 3.2.

Forward Characteristics should then be plotted for each diode and compared with the characteristics shown in Figs. 3.12 and 3.13.

Some of you may be wondering why we have not taken any readings in the reverse biased condition. The currents involved are so small that they would just not produce any indication on the multimeter. If you don't believe it—try it and see!

ASSIGNMENT 3.2

Zener Diode Voltage Regulator

This assignment illustrates the operation of a simple zener diode voltage regulator.

PROCEDURE

Connect the circuit shown in Fig. 3.33 using the wiring diagram shown in Fig. 3.34. The 3·9V zener diode should be used for the first set of results.

Initially set the variable resistor to its extreme anti-clockwise setting (corresponding to 0V output). Connect the voltmeter first to read the input voltage (V_{IN}) and then to read the output voltage (V_{OUT}). (The position of the voltmeter negative lead does not have to be changed during this process).

Compare values of V_{IN} and V_{OUT} with those in Table 3.3 (initially they should both be zero). Then return the voltmeter to the V_{IN} position and increase the setting of VR to obtain input voltages increasing in 1V steps to a maximum of 8V. At each step transfer the voltmeter to the output and measure the value of V_{OUT}. Now finally, exchange the diode for a 4·7V zener and repeat the procedure.

RESULTS

Results should be recorded in Table 3.3, and then plotted graphically showing V_{OUT} (on the vertical axis) plotted against V_{IN} (on the horizontal axis). Readers should note how the output voltage remains substantially constant once the input voltage exceeds the zener value.

ASSIGNMENT 3.3

Transistor Current Gain

This assignment introduces the concept of transistor current gain and also allows readers to compare the transfer characteristics of two common silicon transistors.

PROCEDURE AND RESULTS

Connect the circuit shown in Fig. 3.35 using the wiring diagram shown in Fig. 3.36. Insert the BFY50 transistor taking care to observe the correct polarity.

Initially set the variable resistor to the extreme anti-clockwise position (corresponding to zero base current). Connect the multimeter (switched to

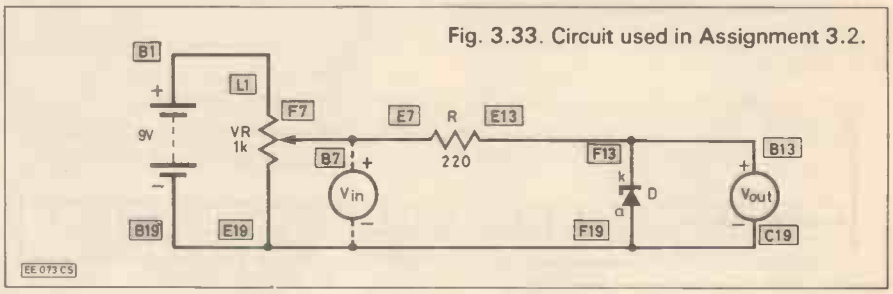
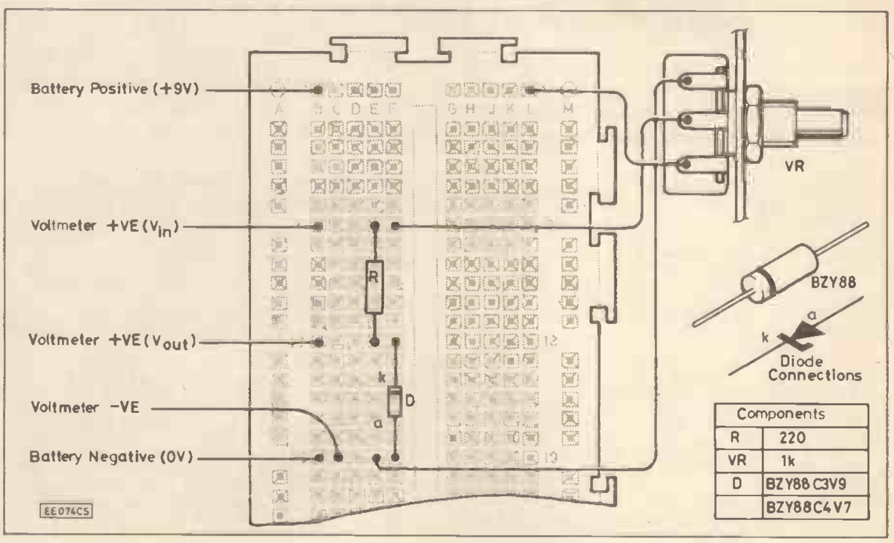


Fig. 3.33. Circuit used in Assignment 3.2.

Fig. 3.34. Wiring diagram for Assignment 3.2.



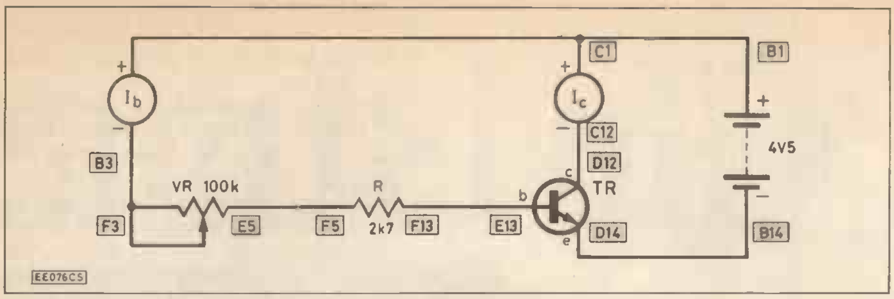


Fig. 3.35. Circuit used in Assignment 3.3.

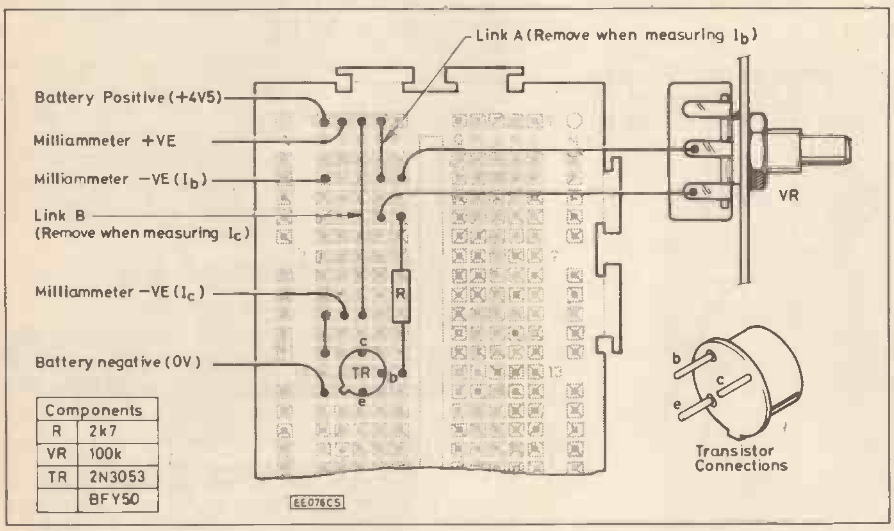


Fig. 3.36. Wiring diagram for Assignment 3.3.

D = OA91	Voltage, V (v)	0	0·1	0·2	0·3	0·4	0·5			
	Current, I (mA)	0	0	0·5	2·5	12	32			
D = 1N4148	Voltage, V (v)	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8
	Current, I (mA)									

Table 3.3. Table of results for Assignment 3.2. (Above).

Table 3.4. Table of results for Assignment 3.3. (Below).

D = BZY88 C3V9	V_{IN} (v)	0	1	2	3	4	5	6	7	8
	V_{OUT} (v)	0	1·0	2·0	2·9	3·5	3·9	3·95	4·05	4·1
D = BZY88 C4V7	V_{IN} (v)	0	1	2	3	4	5	6	7	8
	V_{OUT} (v)									

the 5mA d.c. range) in the base current position and ensure that a link is connected in place of the collector milliammeter. Verify that the base current is zero.

Now connect the multimeter (switched to the 500mA d.c. range) to read the collector current. The link should be transferred so as to replace the base current milliammeter. Check that the collector current is also zero.

Now revert to the original meter position, connecting the multimeter to read base current and changing range accordingly. Replace the collector link and increase the base current in steps of 0·1mA up to a maximum of 1mA. At each step measure and compare the collector current with those in Table 3.4.

Now replace the transistor with a 2N3053 and repeat the entire procedure to obtain a second set of results. Again show these in Table 3.4.

It is important to note that the collector current should not be allowed to exceed 250mA (this corresponds to a collector power dissipation of approximately 1·25W).

Transfer Characteristics should then be plotted for each transfer and compared with those depicted in Fig. 3.28. Finally, readers may like to calculate the current gain for each device using values of collector current of, say, 20mA and 150mA. (Readers should find that the current gain decreases slightly at the higher value of collector current.)

NEXT MONTH you will need the following additional components in order to carry out the practical assignments.

Resistors ($\frac{1}{4}$ Watt, 5% carbon), 2·2Ω (2 off); 470Ω (2 off); 1kΩ (1 off); 2·2kΩ (1 off); 15kΩ (1 off); 47kΩ (1 off), 330k (1 off).
Capacitors (16V, electrolytic), 10μF (2 off); 100μF (1 off). The "radial" type will be easier to use but is not essential—ask when ordering.
Diodes IN4148 (2 off).
Transistors BC108 (1 off); BC461 (1 off); BFY50 (1 off).
Miscellaneous Small 40–80Ω loudspeaker.

THIS MONTH'S TEACH-IN PROJECT IS A DIODE/TRANSISTOR TESTER (PAGE 660)

The most fundamental parts of most circuits today are semiconductor-based. An ability to check transistors and diodes is a very useful addition to any hobbyist's workshop, the Teach-In project this month will allow you to do just that. Besides being able to identify faulty components this unit will allow the sorting and testing of surplus and unmarked devices.

TEACH-IN SOFTWARE NEWS

To complement each published part of the Teach-In series, we have produced an accompanying computer program. The Teach-In Software is available for both the BBC Microcomputer (Model B) and the Sinclair Spectrum (48k) or Spectrum-Plus. The programs are designed to reinforce and consolidate important concepts and principles introduced in the series. The software also allows readers to monitor their progress by means of a series of multi-choice tests, with scores at the end.

Tape 1 (Teach-In parts 1, 2 and 3) is now available for £4.95 (inclusive of VAT and postage) from Everyday Electronics and Electronics Monthly, Westover House, West Quay Road, Poole, Dorset, BH15 1JG.

Please Note. When ordering don't forget to state—BBC or Spectrum. Allow 28 days for delivery.

Christmas

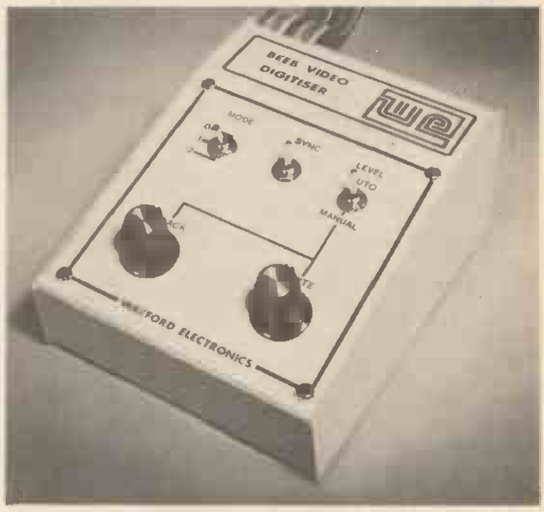
Having problems selecting a suitable gift for the family? Taking advantage of the season of goodwill, we have selected a few special items that have passed through our postbag. We have also included items that we uncovered at various shows during the year and "special buys" from advertisers.

We hope that the next few pages will help solve some of the problems.

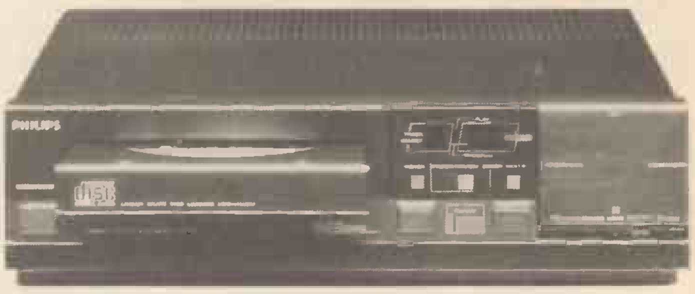
Starting with the most important members of the family —the young, the Robotix range from Milton Bradley enables young people to invent, build, power and control mobiles. The R1000 Basic Set contains a high torque, bi-directional motor, over 50 precision-fit components and a "Commander X" action station—***Milton Bradley Ltd., Dept EE, Spencer House, 23 Shea Road, Richmond upon Thames, Surrey, TW9 1AL. ☎ 01-940 6069.***

For the driver, Systema are marketing a new safety device which could help to prevent accidents.

Called Drive Alert (retailing for around £10.95) it fits behind the driver's ear and sounds a warning at the instant the driver's head nods forward—***Systema (UK) Ltd., Dept EE, 12 Albury Close, Loverock Road, Reading, RG3 1BB. ☎ 073 502223.***

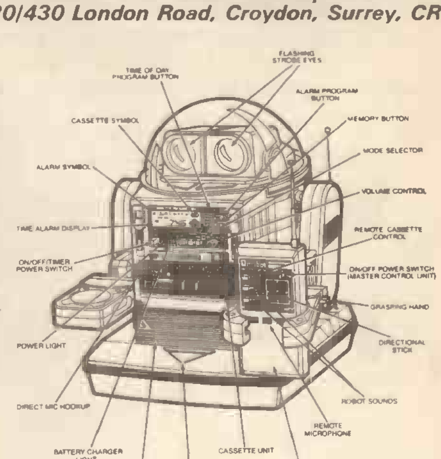


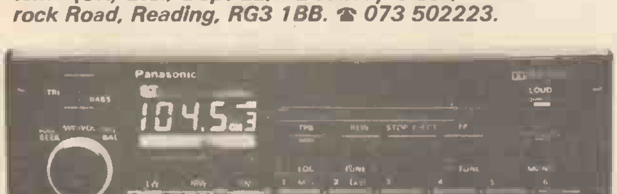
For computer buffs we suggest the Beeb Video Digitiser from Watford Electronics. Using the full graphics capacity of the BBC micro in modes Ø, 1 or 2, the video source may be a camera, video recorder or TV. The unit connects into the User Port and is claimed to scan a complete picture in seconds—***Watford Electronics, Dept EE, 250 Lower High Street, Watford, WD1 2AN. ☎ 0923 37774.***



The biggest talking point at the moment in the audio field is the sudden boom in sales of CD equipment. We have chosen the front loading compact disc machine from Philips. Available for £249, the CD104B features a digital display of track and running time, playback programming for up to 20 tracks and fast music search—***Philips Consumer Electronics, Dept EE, 420/430 London Road, Croydon, Surrey, CR9 3QR.***

A personal programmable robot with a memory, Omnibot from Tomy Toys, leads the way for robot enthusiasts. Use the remote MIC to announce that dinner is ready. Insert a programmed tape and he becomes a "waiter" at the family picnic. Put the robot in tape mode and you can play your favourite music—***Tomy UK Ltd., Dept EE, Wells House, 231 High Street, Sutton, Surrey, SM1 1LD. ☎ 01-661 1547.***





The Panasonic CQ–977 (around £314.95) is a PLL quartz synthesiser electronic tuning f.m. stereo/m.w./l.w. in-car radio/cassette player with auto-reverse and 20W per channel output. Features include: 18 station preset, with instant recall and Dolby B noise reduction—***Panasonic UK Ltd., Dept EE, 300-318 Bath Road, Slough, SL1 6JB. ☎ 0753 34522.***

Gifts Buyers Guide

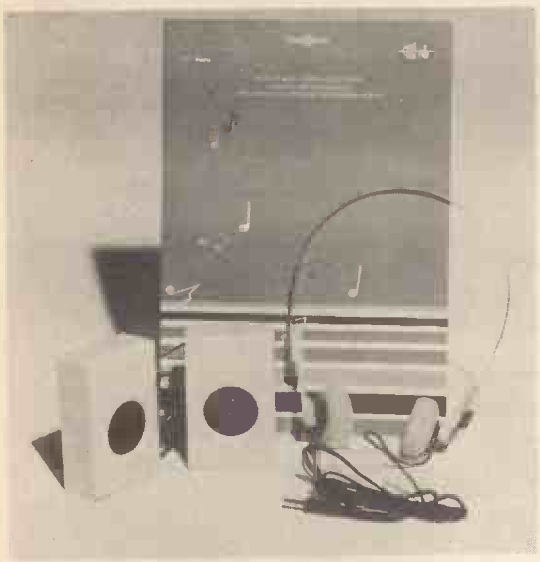
A new complete in-car kit from Sanyo comprises a model FT400LE "Red Sound" stereo radio/cassette player, twin cone speakers, two C90 cassette tapes and a head cleaner tape—***Sanyo Marubeni (UK) Ltd., Dept EE, Sanyo House, Otterspool Way, Watford, Herts, WD2 8JX. ☎ 0923 46363.***

The Ferguson Videostar 3V48 Hi Fi Video Cassette Recorder, at around £550, is claimed to make programming simpler and easier than previous. With most recorders sited close to floor level, it has a unique second display system which faces upwards, making programme setting effortless—***Thorn EMI Ferguson Ltd., Dept EE, Cambridge House, Great Cambridge Road, Enfield, EN1 1UL. ☎ 01-363 5353.***

For newcomers to electronics, a soldering iron would be an invaluable gift which should last for years. The SK5-BP soldering kit from Antex contains an iron stand with sponge, 18W soldering iron with "flexi coil" lead and 3-pin plug and details of how to solder—***Antex (Electronics) Ltd., Dept EE, Mayflower House, Armada Way, Plymouth, Devon. ☎ 0752 667377.***

For the sailing enthusiast we have selected the Casio WW31C. This digital watch combines a compass on the strap and is claimed to be able to withstand 50 metres static water pressure.

The watch, costing £17.95, features a daily alarm, one hundreth second stopwatch and an hour time signal—***Casio Electronics, Dept EE, Unit 6, 1000 North Circular Road, London, NW2 7JD. ☎ 01-450 9131.***



At £6.95 a set of mini speakers and a pair of stereo headphones should go down well with owners of personal radios or "walkmans" and also prove popular in the playroom.

The Altai GH606S pack is available from: ***Greenweld Electronics, Dept EE, 443 Millbrook Road, Southampton, SO1 0HX. ☎ 0703 772501.***

You may not have a hope of beating your local professional, but you will certainly have a laugh with the Bob Hope Golfer from Amazon Industries, price £79.95.

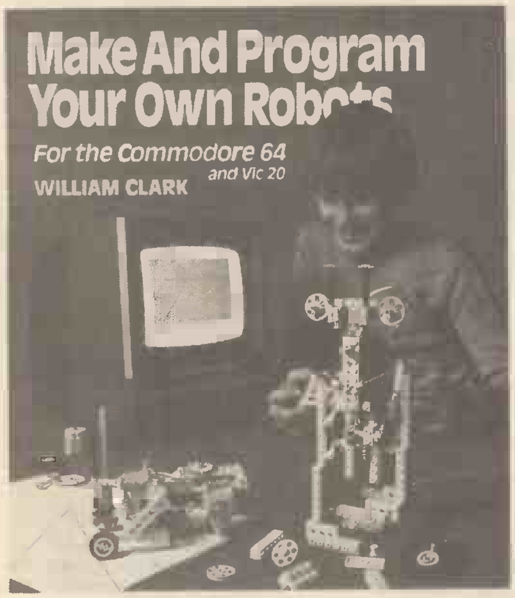
Probably the most novel use of radio control for many years, the golfer allows complete freedom of movement; forward, reverse, left and right, fast to slow. He will swing, drive, putt, chip and slice and, by using a unique tilting device, perform most strokes.

Designed for indoor and outdoor use, the golfer set comes complete with buggy (receiver), radio transmitter, 3 interchangeable clubs, tees, 4 coloured metallic golf balls and 2 golf bags. Three magnetic flag/holes and an illustrated booklet of rules and instructions complete the set—***Amazon Industries Ltd., Dept EE, 4 The Avenue, Blaby, Leicester, LE8 3GW. ☎ 0533 776161.***

For the busy housewife and the "green fingers" member of the family, we offer the Bio-time clock. Originally called the two-potato clock, it can be powered by two indoor plants, oranges, apples or carrots. Great fun for the children's room.

It works like a car battery, with the copper and zinc probes embedded in the plant's soil. The clock also gives date—*The Conservation Catalogue, Dept EE, 11A West Halkin Street, London, SW1X 8JL.* ☎ *01-235 1743.*

Component packs always make useful "stocking fillers" and the latest offering from Marco Trading is worth considering. The resistor pack contains a total of 610 resistors, various values, and costs £5.75. The ceramic capacitor kit contains 125 various value capacitors and costs £4.75—*Marco Trading, Dept EE, The Maltings, High Street, Wem, Shrops, SY4 5EN.* ☎ *0939 32763.*



With many children likely to receive a Lego building kit, we looked around for a suitable gift to complement these excellent kits. The "Make and Program Your Own Robots" by William Clark (£2.95 softback), published by Arrow Books (under their Beaver Books titles) is very well conceived and excellently illustrated.

Editions for Commodore 64 or Spectrum home computers are available and should fit the bill nicely —*Arrow Books Ltd., Dept EE, 17–21 Conway Street, London, W1P 6JD.*

For the busy executive continually on the move, the latest in-car telephone answering system from Elcom Systems may be just the gift, but at a price. The main advantage appears to be that the driver can receive messages whilst still on the move or away from the vehicle —***Elcom Systems Ltd., Dept EE, 19 Station Approach, Fleet, Hants, GU13 8QY.*** ☎ ***02514 28018.***

PLEASE NOTE

We would like to point out that readers buying from the guide are not protected by the Mail Order Protection Scheme unless the company concerned have advertised the product in a display advertisement in this issue.

This rugged action toy (see below) from Bandai begins as a 4-wheel drive pick-up with a working winch. A few quick changes transforms it into a machine robot with winch climbing action. The approximate selling price is £30—***Bandai UK Ltd., Dept EE, 246A High Street, Guildford, Surrey, GU1 3JF.*** ☎ ***0483 63311.***

Bargain Buys . . .

For youngsters and beginners Magenta are offering a book and a set of components to allow learning by experiment. "Adventures with Electronics" uses a breadboard, no soldering. The Component Pack, including breadboard, costs £20.98. The book £3.58—*Magenta Electronics Ltd., Dept EE, 135 Hunter Street, Burton-on-Trent, Staffs, DE14 2ST.* ☎ *0283 65435.*

A complete kit for the beginner is on offer from C.P.L. Electronics for the sum of £35 (p&p £1). It consists of a pocket multimeter; soldering kit; Veroblock breadboard; tools; 160 page book and a selection of components—*C.P.L. Electronics, Dept EE, 8 Southdean Close, Hemlington, Middlesbrough, TS8 9HE.* ☎ *0642 591157.*

Few jobs are more frustrating than the one that needs "three hands". The Gripmate tool produced by Kemplant is a small clamp device that provides up to four extra "hands" able to grip small components, wire and numerous other small items—*Kemplant Ltd., Dept EE, Durfold Wood, Plaistow, Billingshurst, West Sussex, RH14 0PN. ☎ 048 649 344.*

From Cirkit there's a tool kit (40-00007) with soldering iron and various hand tools for around £12. The books are extra. Also a "joggers" stopwatch (40–20001 for £11.50) with lap time and pace maker facilities—*Cirkit, Dept EE, Park Lane, Broxbourne, Herts, EN10 7NQ. ☎ 0992 444111.*

For the games person, the Heber BBC Bridge Companion carries full BBC approval and was put through exhaustive tests before being able to carry the BBC emblem—*Heber Ltd., Dept EE, Belvedere Mill, Chalfond, Stroud, GL6 8NT. ☎ 0453 88 6000.*

CK-5063/Kit from Riscomp comprises: 1 Siren; 2 Ready-assembled p.c.b.s; 1 Key switch; Fixings; Casing. Price: £37.95. Features include stand-alone unit generates a 110dB alarm signal when triggered; Entry/Exit delay incorporated, also three levels of discrimination. Some soldering/assembly reqd., mains operation (catalogue available)—*Riscomp Ltd., 51 Poppy Road, Princes Risborough, Bucks. ☎08444 6326.*

A novel gift for the slimmer or diet conscious person would be the X-cel Diet Calculator (£16) from Systema. This continuous memory machine logs your daily calorie allowance and deducts calories consumed throughout the day. It is supplied with a calorie booklet written by a dietician—*Systema (UK) Ltd., Dept EE, 12 Albury Close, Loverock Road, Reading, RG3 1BB. ☎ 0734 502223.*

The DM105 from Armon is claimed to be a truly pocket-sized digital multimeter. It measures current from 2mA to 2A, in 4 ranges; d.c. volts from 2V to 1000V; a.c. volts 200V to 750V and ohms from 0 to 2000k in four ranges —*Armon Electronics Ltd., Dept EE, Heron House, 109 Wembley Hill Road, Wembley, Middx, HA9 8AG. ☎ 01-902 4321.*

Happy Christmas

PROJECT 3

DIODE/TRANSISTOR TESTER

Michael Tooley BA **David Whitfield** MA MSc CEng MIEE

TRANSISTORS and diodes are essential components in almost every electronic circuit today. A simple but reliable means of checking these components is therefore a valuable addition to any constructor's workshop. It assists in troubleshooting by identifying any faulty components, and allows surplus and unmarked devices to be identified and tested.

The tester to be described is suitable for both silicon and germanium devices. It allows both *npn* and *pnp* transistors, and diodes to be simply and quickly tested.

CIRCUIT OPERATION

The diagram of Fig. 3.1 is too involved to get a clear picture of how each type of test is performed. After looking at the common elements of all of the tests, therefore, we will look separately at how each type of test is performed.

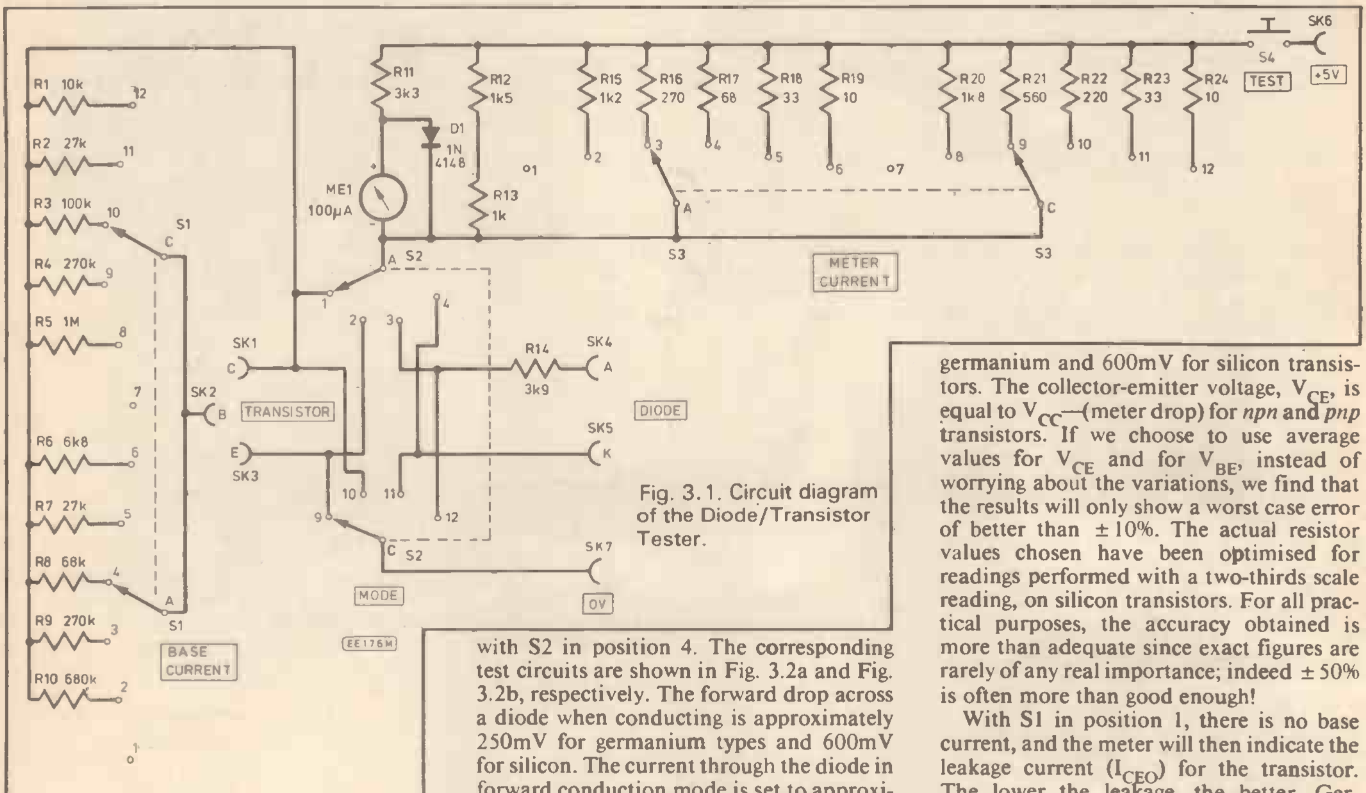


Fig. 3.1. Circuit diagram of the Diode/Transistor Tester.

ME1 is a basic 100μA meter which is protected against severe overload by D1. The sensitivity of the overall meter circuit is set to 300μA by R11, R12 and R13. In this arrangement, full-scale deflection on the meter coincides with a voltage drop across the meter circuit of 500mV. For measurement of higher currents, the additional current is shunted away from the meter by resistors selected by S3. The two poles of the switch are used to select the two resistors (in parallel) for each setting so that readily available values can be used.

The tester operates from a +5V supply, drawing a current of up to 100mA. A suitable supply is readily available from the unit described as the first project in this series, or any other convenient supply may be used. It should be noted that the calibration of the unit assumes that the supply is +5V, and so the accuracy of the supply voltages will affect the accuracy of any readings. S4 is a spring-loaded switch which is pressed whenever you are ready to carry out a test, but it ***should not*** be pressed while changing range. This procedure prevents accidental damage to the meter, and avoids overheating the transistor because it is not possible to accidentally leave it passing a lot of current. The remaining circuitry is selected by S2 depending on the nature of the test to be carried out.

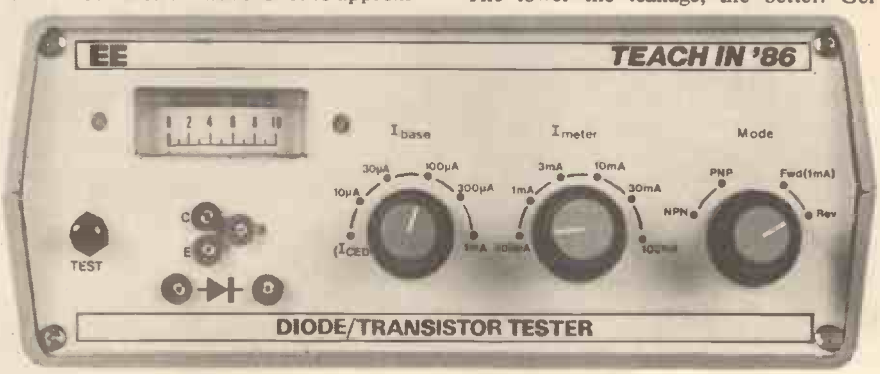
Diode forward conduction is tested with S2 in position 3, and reverse conduction with S2 in position 4. The corresponding test circuits are shown in Fig. 3.2a and Fig. 3.2b, respectively. The forward drop across a diode when conducting is approximately 250mV for germanium types and 600mV for silicon. The current through the diode in forward conduction mode is set to approximately 1mA by the combination of the meter resistance and R14. Hence the meter range switch (S3) should be set to position 2 for this test. In the reverse conduction test, little or no current is expected since the diode is reverse biased.

The test circuits for *npn* (S2 position 1) and *pnp* (S2 position 2) transistors are shown in Fig. 3.3a and Fig. 3.3b, respectively. These circuits show slight differences (to minimise the switching complexity), but as we shall see, these differences are of little practical importance. The base current (I_B) in the transistor under test is set by the resistor selected by S1, according to the following equation:—

$$I_B = \frac{V_{CE} - V_{BE}}{R}$$

V_{BE} is the base-emitter voltage of the transistor, and is approximately 250mV for germanium and 600mV for silicon transistors. The collector-emitter voltage, V_{CE}, is equal to V_{CC}—(meter drop) for *npn* and *pnp* transistors. If we choose to use average values for V_{CE} and for V_{BE}, instead of worrying about the variations, we find that the results will only show a worst case error of better than ±10%. The actual resistor values chosen have been optimised for readings performed with a two-thirds scale reading, on silicon transistors. For all practical purposes, the accuracy obtained is more than adequate since exact figures are rarely of any real importance; indeed ±50% is often more than good enough!

With S1 in position 1, there is no base current, and the meter will then indicate the leakage current (I_{CEO}) for the transistor. The lower the leakage, the better. Ger-



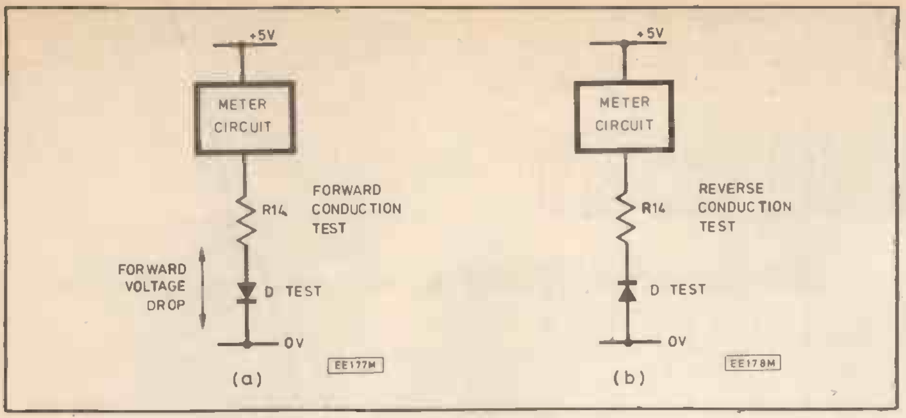


Fig. 3.2. Diode test circuits.

manium transistors usually have a significantly higher leakage current than silicon types. A typical germanium transistor may show a leakage 100µA–2mA, whereas a silicon device will have a negligible leakage. Higher power transistors usually show a higher leakage than small signal types.

With S1 in position 2 to position 6, the gain of the transistor may be measured. If we ignore the leakage current as negligible, the gain of a transistor is given by:—

$$h_{FE} = I_C/I_B$$

If the leakage current is significant when compared with I_C, then this can be taken account of by replacing I_C in the equation by $(I_C - I_{CEO})$. The circuit for *npn* transistors uses the meter to measure collector current (I_C) directly. For *pnp* transistors, on the other hand, the circuit measures emitter current (I_E). However, collector current and emitter current are related by the following equation:—

$$I_E = I_C + I_B$$

In practice, this will make negligible difference, since we find that the gain equation for *pnp* transistors using the meter measuring emitter current now becomes:—

$$(h_{FE} + 1) = I_E/I_B$$

With most transistors, the gain is usually large enough to ignore the "1" in the equation. After all, it is of little practical use to know whether the gain of a BC213 is 349 or 350, given that its gain range is specified as being typically 80 to 400.

In summary, the gain of a transistor is approximately given by:—

Gain=meter current/base current

Where more exact gain figures are required for *pnp* devices, subtract one from the answer above, but this is only likely to be significant for very low gain devices.

Table 3.1. Switch functions.

Switch Position	S1 (I_{BASE})	S2 (Mode)	S3 (I_{METER})
1	0µA	*npn*	300µA
2	10µA	*pnp*	1mA
3	30µA	Diode (Fwd)	3mA
4	100µA	Diode (Rev)	10mA
5	300µA		30mA
6	1mA		100mA

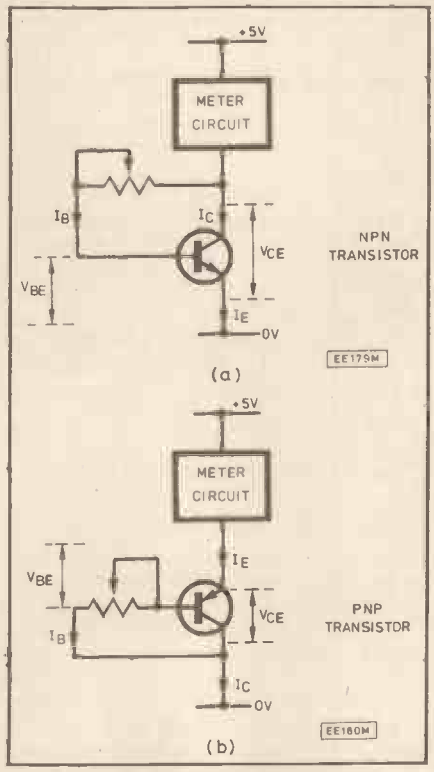


Fig. 3.3. Transistor test circuits.

CONSTRUCTIONAL DETAILS

The transistor and diode tester is built in the same type of case as used for the previous projects in this series. Unlike most of the projects in this series, however, it does not require any circuit board, since all of the components are mounted on the front panel. Indeed, it would actually make the project *more* difficult to build if a circuit board was used!

The first step is to drill the front panel in accordance with the layout in Fig. 3.4. The exact dimensions of cut-out for the meter may differ very slightly, depending on the actual components used. The front panel overlay in Fig. 3.4 (or a photocopy) should then be fixed to the panel. It is suggested that this overlay is protected with self adhesive library film since this will help to maintain the finished appearance of the unit when in use.

The majority of the components in the diode and transistor tester are resistors mounted on the back of S2 and S3. It should be noted that the accuracy of tester is substantially dependent on the resistors used, and 5% types are recommended. There are 10 resistors mounted on each switch, and both sets are arranged in identical fashion; Fig. 3.5 shows the construction in more detail.

First, the resistors should all be mounted on the back of the switch, parallel to each other, and in line with the shaft. One end of each resistor is thus connected to a separate tag on the switch. The circuit diagram (Fig. 3.1) and the overall layout (Fig. 3.6) show the correspondence of resistors to switch tags. When all ten resistors have been soldered to their respective switch tags, their free ends should then all be looped over a ring of copper wire and soldered. The ring should be a length of tinned copper wire (16 s.w.g. or similar is suitable) made into a circular loop of approximately 25mm diameter, with the two ends soldered together.

The meter, sockets, and switches should then be mounted in place on the front panel. The remaining components (R11 to R14 and D1) should then be fitted, and interconnection wiring completed as shown in Fig. 3.6. The meter used in the prototype was a 100µA unit with a movement resistance of 1750Ω. If the meter used has a different movement resistance, the value of R11 should be adjusted accordingly; the total resistance of (meter + R11) should be as close as possible to 5k.

The final step is to drill the rear panel, mount SK6 and SK7, and complete the wiring to the front panel. A final check should be made to ensure the wiring is correct (e.g. by checking that the correct number of connections are made to each switch tag), and the case re-assembled using

COMPONENTS

Resistors

R1	10k
R2,R7	27k (2 off)
R3	100k
R4,R9	270k (2 off)
R5	1M
R6	6k8
R8	68k
R10	680k
R11	3k3
R12	1k5
R13	1k
R14	3k9
R15	1k2
R16	270
R17	68
R18,23	33 (2 off)
R19,24	10 (2 off)
R20	1k8
R21	560
R22	220

All 0·25W 5%

Semiconductor

D1	IN4148

Miscellaneous

SK1–SK5	1mm sockets (5 off)
SK6	4mm socket (red)
SK7	4mm socket (black)
ME1	100µA edgewise meter
S1	2 pole–6 way rotary switch
S2	3 pole–4 way rotary switch
S3	2 pole–6 way rotary switch
S4	Push-to-make switch

knobs with pointers (3 off); stick-on plastic feet (4 off); case (West Hyde Developments type TEK A22)

Approx. cost Guidance only **£16.00**

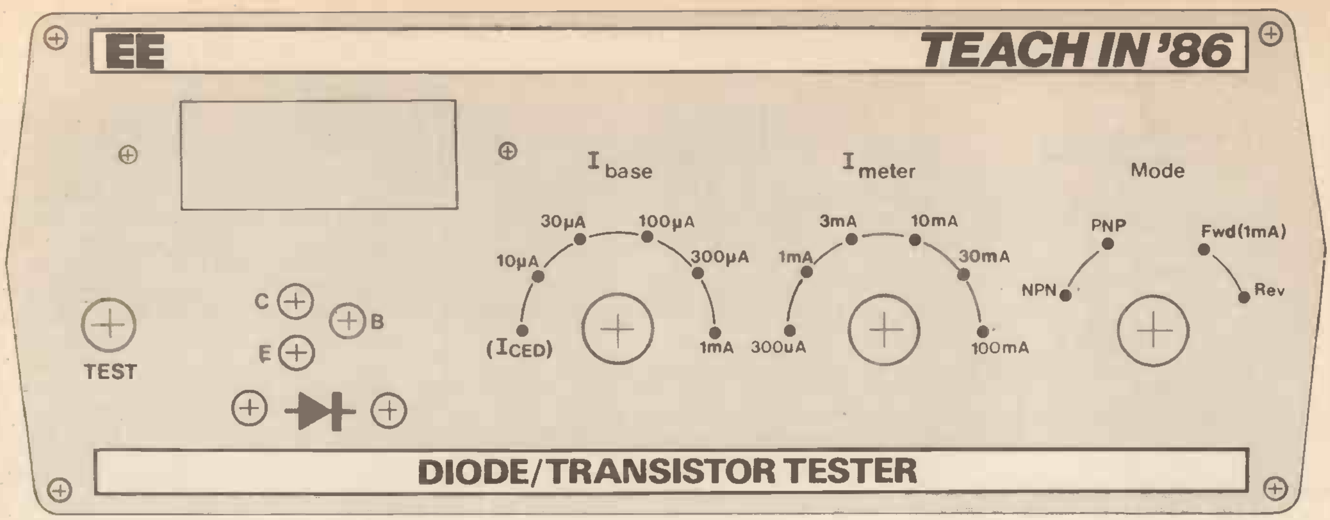


Fig. 3.4. Front panel layout for the Diode/Transistor Tester.

the 8 screws provided. The self-adhesive feet should be fitted, and the unit is then ready for use.

The best way to test the unit is to use it with some known good devices. If there are any unexpected test results, check the wiring and the values of the resistors.

TESTING DIODES

Testing diodes is a question of ensuring that they are effective one-way conductors of current. The diode under test should be connected to SK5 to SK6, and the meter switch set to 1mA. With S2 in the 'diode forward' position, pressing S4 should cause a current of 1mA to flow through the diode, causing approximately full-scale deflection on the meter. Due to the increased forward voltage drop in silicon diodes, they will give a slightly different (about 5% *lower*) meter indication than germanium types. If you have a known example of each type, the unit can even be calibrated to allow germanium and silicon diodes to be identified in this way.

Changing to 'diode reverse' should cause show a *very* small current on the meter. With a silicon diode this will usually be undetectable, even on the 300μA range, while a few germanium types may give a very small deflection.

A normal diode will behave as described above. One of the most common faults to be expected is that a reading of around or a little over 1mA is obtained in both forward and reverse directions. This usually indicates a diode which is short circuit (and hence which should be discarded). However, it could also indicate that the diode is a zener diode rated at less than approximately 4V. A simple test for the latter case is to wire the diode in series with a 1k resistor, and connect the combination across a variable 5V to 10V d.c. supply, with the diode reverse biased. If it is a zener, the voltage measured across the diode (with a suitable meter) should remain substantially constant (at the Zener voltage) as the supply output is varied over the range. The other common fault is where no current is detected in either direction, and this indicates a diode which is open circuit (and hence which should be discarded).

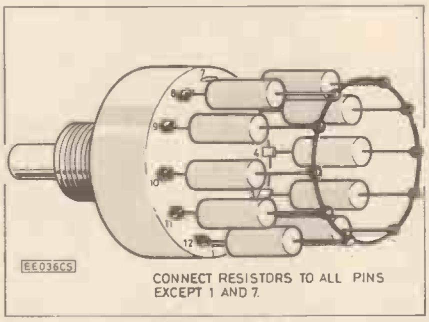


Fig. 3.5. Construction detail for S1–S3.

TESTING TRANSISTORS

The transistor under test should be inserted into SK1-SK3. It is then always best to start with the meter current range set to maximum (100mA) in case the transistor is short circuit in any way. If the type of transistor is unknown, the leakage and gain test should be repeated with the mode switch first in the *npn* position, and then in the *pnp* position. This should not damage the device under test, and the order reflects that *npn* transistors are most common today. The polarity of the device will be indicated by the setting which produces sensible gain figures (typically in the range 40-400). When testing transistors, there are two main measurements to make; leakage and gain, and we shall look at each in turn.

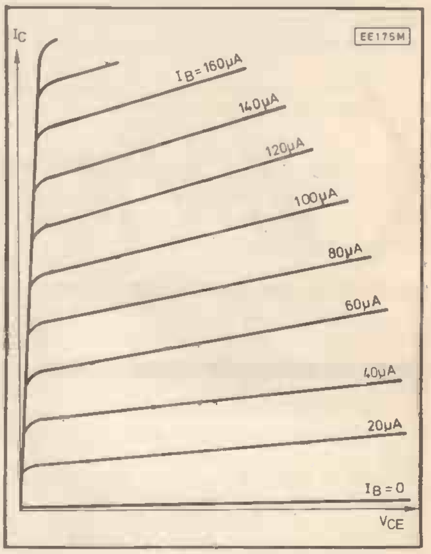


Fig. 3.7. Transistor characteristics.

The value of leakage current is measured with a base current of zero. In the case of a collector-emitter short circuit, which is quite a common fault, there will be a significant current indicated; the device should be discarded. Otherwise, the sensitivity of the meter should be increased (releasing S4 before changing the setting each time) until either a measurable current is obtained or the maximum sensitivity range is reached. The leakage current should give a strong clue as to whether the device is silicon (negligible leakage) or germanium (measurable leakage). Typical leakage for a germanium transistor is 200μA, but values of up to 10 times this may be encountered, particularly for power devices. Any significant leakage in silicon transistors should be treated with suspicion.

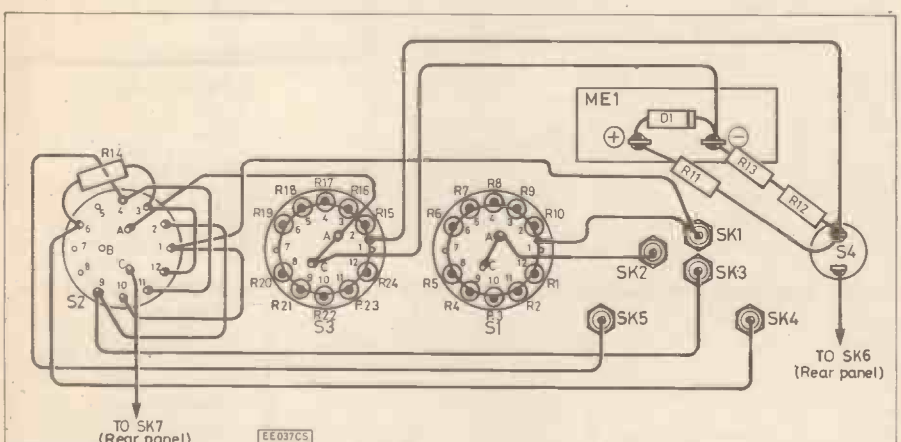
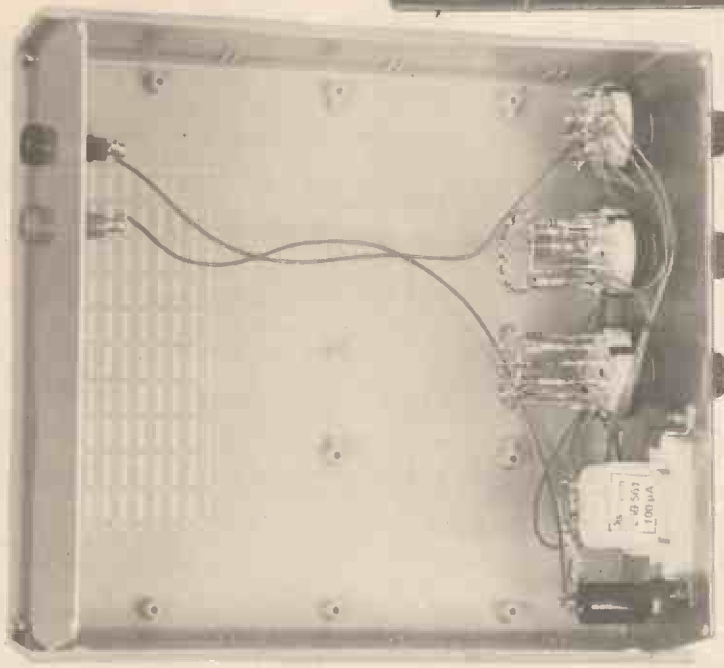


Fig. 3.6. Overall wiring diagram of the Diode/Transistor Tester.

See **Shop Talk** page 646

Photographs illustrating the internal constructional details of the Diode/ Transistor Tester.



When measuring the gain of a transistor, it is worth remembering that the answer may be up to 1000. The procedure should therefore be to start off with the minimum value of base current (10µA), and the meter set to its highest range (100mA). Then progressively change the base current and/ or meter range until a reading of more than approximately half-scale is obtained. The gain is then calculated from the equations shown previously.

With most transistors (particularly lower gain types) it may be possible to measure the gain for more than one value of base current. The measured gains will show some variation. The characteristics of a typical transistor are shown in Fig. 3.7, and these indicate that slight differences in gain figures are to be expected with different values of base current and collector voltage.

NEXT MONTH: Project 4 will be a useful Audio Signal Tracer.

a regular feature for the Spectrum Owner...

by Mike Tooley BA

In the past few months, several readers have written to ask about learning Z80 machine code, the question most often posed being simply: "How can I get started?" This is a topic about which there is a good deal of mystique and, whilst there are numerous books on the topic, my own firmly held conviction is that machine code programming is best learned by actually doing it.

A word of warning is necessary at the outset; don't underestimate the effort required. So, if the thought of numerous late nights (or should I say early mornings!) at the keyboard is daunting, machine code programming is best left well alone!

Writing Good Code

The pre-requisites for successful machine code programming are as follows:

1. A comprehensive list of Z80 instructions (including, for each instruction, the hex code, assembler mnemonic and a brief description of its action).

These are given in a variety of publications (including the "official" Z80 technical manual published by Zilog); however, "Z80 Assembly Language Programming" by Lance Leventhal (Osborne/McGraw-Hill, ISBN 0-931988-21-7) is undoubtedly the best reference text.

2. A piece of software known as an "assembler" or "editor/assembler". This accepts standard Z80 mnemonics placed in a text file (produced by the editor) and, after checking that no errors have crept into the assembly language "source code", it generates ("assembles") the machine language "object code" which is directly executable by the Z80 microprocessor.

My own favourite is Picturesque's "Editor Assembler", though Hi-Soft's "Devpac" and Sinclair's "Zeus" assembler can both be recommended.

3. A "monitor" or "debugger". This piece of software may be supplied with the assembler (as is the case with "Devpac") or may have to be purchased separately and should

```
100 REM Hex code loader
110 REM Everyday Electronics December 1985
120:
130 REM Initialise
140:
150 PAPER 1: BORDER 1: INK 6: CLS
160 POKE 23658,8: REM Caps lock
170 POKE 23609,100: REM Extend pip
180 INPUT £0;AT 0,0;"RAMTOP value? ";ramtop
190 IF ramtop<25200 OR ramtop>65367 THEN  BEEP 0.5,0.5: GO TO 180
200 LET start=ramtop+1
210 LET address=start
490:
500 REM Load memory
510:
520 PRINT  INVERSE 1;"Address","Contents"
530 PRINT "(dec)","(hex)"
540 PRINT
550 INPUT £0;AT 0,0;"Enter byte or <Q> to quit: ";h$
560 IF h$="Q" THEN  GO TO 650
570 PRINT address,h$
580 LET z1=CODE h$(1)
590 IF z1>57 THEN  LET z1=z1-7
600 LET z2=CODE h$(2)
610 IF z2>57 THEN  LET z2=z2-7
620 POKE address,z1*16+z2-816
630 LET address=address+1
640 GO TO 550
650 CLS
660 LET length=address-ramtop-1
670 PRINT AT 0,0; INVERSE 1;"Total = ";length;" bytes"
680 PAUSE 100
690:
700 REM Options
710:
720 CLS
730 PRINT AT 8,4;"Press <E> to EXECUTE code"
740 PRINT AT 9,10;"<P> to PROTECT code"
750 PRINT AT 10,10;"<R> to RESTART"
760 PRINT AT 11,10;"<S> to SAVE code"
770 LET r$=INKEY$
780 IF r$="E" THEN  GO SUB 1000
790 IF r$="P" THEN  CLEAR ramtop: NEW
800 IF r$="R" THEN  GO TO 100
810 IF r$="S" THEN  GO SUB 2000
820 IF r$="" THEN  GO TO 770
830 GO TO 690
990:
1000 REM Execute code
1010:
1020 RANDOMIZE USR start
1030 CLS
1040 PRINT AT 0,0; INVERSE 1;"Code executed"
1050 BEEP 0.5,25
1060 PRINT £0;AT 0,4; FLASH 1;"Press any key to continue"
1070 PAUSE 0
1080 RETURN
1990:
2000 REM Save code
2010:
2020 CLS
2030 INPUT £0;"Filename? ";n$
2040 SAVE n$CODE start,length
2050 RETURN
```

LISTING 1: Hex Code Loader
Note that "£" should be entered as #

at least be capable of:

(a) displaying (in hex) the contents of the CPU registers
(b) displaying (in hex) the contents of a block of memory
(c) disassembling the contents of a block of memory (i.e. performing the reverse of the assembly process)
(d) executing a block of code from a given start address

A useful added facility is that of allowing "breakpoints" to be inserted into the program (these allow the CPU registers to be displayed at crucial stages). A "single step" facility is also useful. This permits execution of one instruction at a time, pausing so that the contents of the CPU registers may be examined.

Finally, one machine code learning aid that I can recommend without hesitation is New Generation Software's "Complete Machine Code Tutor". This comprises a simplified assembler/monitor which may be loaded with a very comprehensive set of demonstration routines. Each routine can be single-stepped, allowing the user to simultaneously display the assembly language source code, the object code, CPU register and memory contents.

Hex Loader

To assist readers who would like to "have a go" but cannot easily afford the initial outlay necessary to acquire an assembler, Listing 1 shows a simple program which allows users to enter instructions and data in hexadecimal form. The code can then be tested and/or saved.

It is, of course, necessary for users to "hand assemble" their instructions before entry. Small routines (of around 50 bytes or less) can be assembled quite easily using this technique and then called from BASIC using statements of the form,

```
RANDOMIZE USR nnnnn
```

where nnnnn is the *decimal* start address of the machine code routine.

Analogue To Digital Converter

Some months ago we described a simple Digital-to-Analogue Converter. This month we shall turn our attention to the opposite problem, converting an analogue input to a digital output suitable for interfacing with the Spectrum.

The complete circuit diagram of the analogue-to-digital converter is shown in Fig. 1. IC3 is a CMOS 8-bit analogue-to-digital converter i.c. which incorporates a tri-state output data latch, thus permitting direct connection to a microcomputer's data bus. This greatly simplifies the interfacing logic.

IC3 contains its own internal clock which operates at a frequency determined by C5 and R1. An external voltage reference is provided by a precision band-gap voltage reference, D2, and scaling of the analogue input is provided by means of a simple attenuator arrangement comprising R4 and R5/VR1. With the values shown, the input resistance of the converter is approximately 1MΩ and a full-scale reading corresponds to an input of 25·5V (i.e. 255 steps of 100mV).

Address decoding is provided by IC1 which, together with IC2c, generates a logic 0 output whenever a decimal address of 191 appears. The output of IC1 is gated with the $\overline{IORQ}$ line within IC2b and then inverted by IC2a in order to provide an active low enable signal for IC3. If desired, the port address can be easily changed to 255 decimal by simply omitting IC2c and linking A6 directly to pin 11 of IC1.

Construction

The analogue-to-digital converter is assembled on a piece of Veroboard measuring approximately 80mm × 100mm. The precise dimensions of the board are uncritical; however, as with other projects, it must have a minimum of 28 tracks aligned in the vertical plane so that a 28-way double-sided edge connector can be mounted along the bottom edge of the board. This connector requires approximately five rows of holes across the full width of the stripboard and is arranged so that the board stands vertically when the connector is mated with the Spectrum.

Before soldering any of the components it is important to allow some clearance for the rear "overhang" of the case. For the Spectrum this gap should correspond to 8 rows of holes (20mm approx.), whilst for the Spectrum Plus the gap should be increased to 12 rows of holes (30mm approx.).

Component layout is generally uncritical although care should be taken to ensure that the supply decoupling capacitors, C1 to C4, are distributed around the board (each preferably associated with an individual integrated circuit supply). Great care should be taken to ensure that all unwanted tracks are cut (including those which link the upper and lower sides of the 28-way connector). A purpose designed "spot-face" cutter may be used for this task or, if such a device is not obtainable, a small sharp drill bit may be used.

COMPONENTS

See Shop Talk page 646

Resistors

R1	33k
R2	270
R3	680
R4	820k
R5	47k

All ¼W ±5%

Potentiometers

VR1	100k

Capacitors

C1,C6	10µ 16V p.c. elect. (2 off)
C2,C3,C4	100n polyester (3 off)
C5	150p

Semiconductors

D1	Red l.e.d.
D2	ZN423
IC1	74LS30
IC2	74LS27
IC3	ADC0804

Miscellaneous

14-pin d.i.l. sockets (2 off); 20-pin d.i.l. socket; 2-pin 2·54mm pitch p.c. mounting connector; 28-way open end double-sided 2·54mm pitch connector (e.g. Vero part number 838–24826A); 2·54mm hole pitch stripboard measuring approx. 80mm × 100mm (minimum 28 strips).

Approx. cost Guidance only **£8.50**

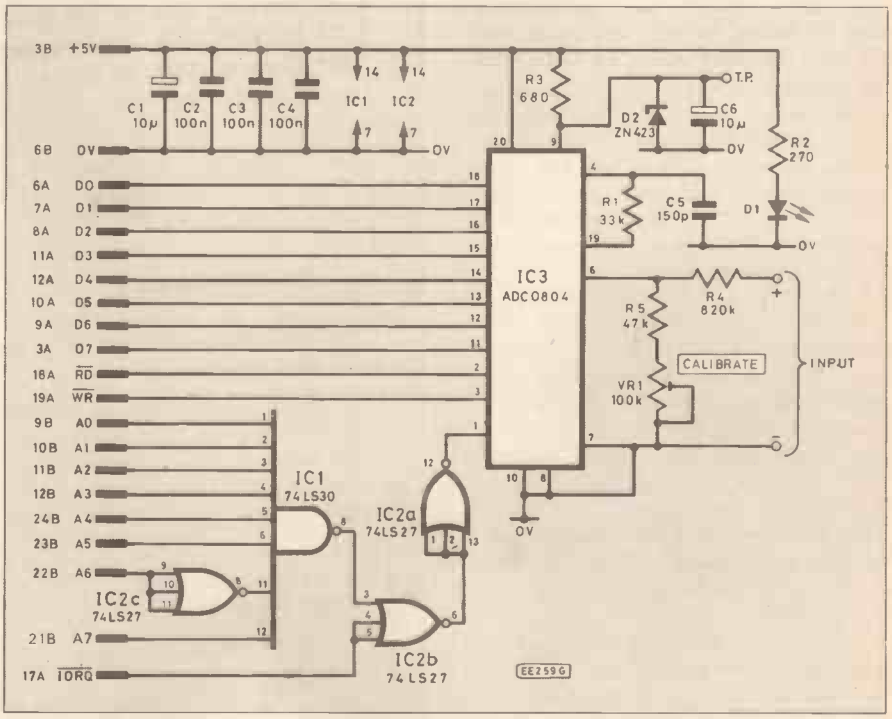


Fig. 1. Complete circuit diagram for the analogue-to-digital converter.

Links on the underside of the board should make use of appropriate lengths of miniature insulated wire (of the type normally used for wire wrapping). Readers requiring further information on the connector should refer to March *On Spec* or send for our latest "Spectrum Update".

When the stripboard wiring is complete, the integrated circuits should be inserted into their sockets (taking care to ensure correct orientation) and the entire board should be carefully checked before connecting to the Spectrum.

Note that the Spectrum should *always* be disconnected from its supply before either connecting or disconnecting any interface module. This point is made repeatedly because the Spectrum may be seriously damaged—the destruction of all the memory chips is not unknown—if this precaution is not observed. If all is well, when power is re-applied, the normal copyright message should appear. If not, disconnect the power, remove the interface and check again.

If you have any comments or suggestions please drop me a line at:
Department of Technology,
Brooklands Technical College,
Heath Road,
WEYBRIDGE, Surrey KT13 8TT

P.S. Don't forget to include a stamped addressed envelope if you would like to receive a copy of our latest "Update"!

NEXT MONTH: The software required for setting-up and driving the analogue-to-digital converter. Also, a few routines for you to enter using our hex Loader.

The Man Behind the Symbol

Nº5 JAMES WATT

by Morgan Bradshaw

THE year is 1755; the place Greenock on the Clyde, and we meet our first British pioneer, not a physicist nor a mathematician engaged in proving any electrical theory but an inventor "extraordinary" James Watt. The man after whom the unit of power is named (see Table 1).

Nineteen-year-old James Watt says goodbye to his family and sets off for London, the hard way, by horseback to look for work. His father, a small merchant, had lost his trade and fortune through bad speculation. Because of this and ill health, Watt had been unable to go to school regularly and was, therefore, largely self taught.

Arriving in London some 12 days later, the young James obtained employment at the instrument works of John Morgan. The work was hard and the pay only eight shillings per week. He lived frugally, dodging the press gangs, but all the time learning. After twelve months he returned home but was forbidden by the Glasgow City Guild to start a business as an instrument maker because he had not served a full apprenticeship.

Watt obtained work with the college of Glasgow in a model making and repair shop. The college asked him to repair their model of Newcomen's engine which had been invented some sixty years earlier and had only been used to pump water out of coal mines.

Having got the model working, Watt was amazed at the great loss of steam from the engine, and he reasoned that he could produce a better version. He made many models and studied the scientific properties of steam, its density and its pressure. In 1765 he made a large scale engine, which was erected at Kinneil near Linlithgow. This gave Watt the opportunity to go into the construction in more detail.

Large scale trials and patent fees took what little money he had, and Watt was forced to agree to Dr John Roebuck founder of the Carron Ironworks, taking two thirds of any profits from the invention in return for bearing costs, but the two partners did not get on well together and after a few years uneasy collaboration they parted.

Once again shortage of money prevented Watt from bringing his invention before the public, but his reputation as a civil engineer was growing, and he was employed to make a survey for the proposed Forth and Clyde canal.

BOULTON AND WATT

In 1768 Watt met Matthew Boulton, a man of considerable vision who could see that steam engines need not be confined to pumping machines and that they had a great future. Boulton, a Birmingham manufacturer, was owner of one of the most modern engineering works in Great Britain. He agreed to take Roebuck's share in the invention and a new and famous partnership was born.

Then in 1769, Watt obtained his first patent. Although his machine produced more power for its size than Newcomen's and used less fuel, it was still only usable as a steam pump.

In 1774 Watt and his family moved to Birmingham. The partnership with Boulton worked well and, free from all business and financial worries, Watt was able to carry on with his experiments. In 1781, he patented his second engine which converted the reciprocating motion of the piston rod into a rotary motion and "drove a wheel round". This opened up new frontiers and was the start of the real steam age, and set Britain on the road as a great manufacturing power.

By 1783 The Boulton and Watt engines were in use everywhere and grateful users were paying royalties on the basis of time and labour saved.

Now wealthy and famous, Watt built Heathfield Hall, a mansion on Handsworth Heath, Staffs, on a forty acre site. He worked constantly in his garrett workshop*. His restless brain invented a sculpture copying machine, a machine for drawing in perspective, and a press for copying manuscripts.

Watt died at Heathfield on August 19 1819 and is buried in the parish church of Handsworth, whilst a memorial stone lies in Westminster Abbey commemorating a truly remarkable man, Inventor and Civil Engineer.

Table 1: The Watt (W)

The Watt might be termed the "horse-power" unit of electronics, in fact 746 watts are equal to 1 HP. The power needed to maintain a current of one ampere (A) through a conductor, and a potential of one volt (V) across its ends is equal to one watt (W).

The unit was first proposed by C. W. Siemens in his presidential address to the British Association in 1889.

Photo: Courtesy Science Museum

** A reproduction of this complete with interesting contents can be seen at the Science Museum, South Kensington, London.*

FREE ENTRY FUN COMPETITION... 100 MULTIMETERS TO BE WON!

Everyday Electronics has got together with **West Hyde Developments Limited** in this festive season to offer you the opportunity of winning an Ishii 301 multimeter. Our prize multimeters have a 40mm anti-parallax mirror scale, 10 switched ranges and the movement uses two jewels for longer life.

West Hyde Developments Limited specialise in supplying instrument cases, sealed enclosures and panelware for housing electronic and electrical equipment. Cases are available in a variety of materials, styles and sizes and there is also a wide range of housings for computer equipment. Add to this items like the prize multimetres, l.e.d.s and switches and you have some idea of the comprehensive range offered by West Hyde.

Their 104 page catalogue, fully detailed with photographs, is available for £2 (redeemable against your first purchase) from: **West Hyde Developments Ltd., 9-10 Park Street Industrial Estate, Aylesbury, Bucks, HP20 1ET**. You could be a winner!

HOW TO ENTER

Shown is a photograph of a typical hi-tech office scene (courtesy of **STC**). Eight possible captions are listed underneath. Simply place the captions in the order you consider they most aptly and amusingly fit the photograph.

Write the key letters of the captions, ***in ink*** in the spaces on your entry coupon, each under its order of choice. For example, if you consider "Wire we all tangled up?" is the best of them all, put C in the first space; the letter of your next choice goes under 2, and so on for all eight.

Complete the coupon with your own full name and address, and post in a sealed envelope to: **EVERYDAY ELECTRONICS WEST HYDE COMPETITION, LONDON SE99 6YP,** to arrive not later than Monday, 6th January, 1986.

RULES

There is no entry fee but each attempt must be on a proper entry coupon cut from *Everyday Electronics* and must bear the entrant's own name and address.

All accepted entries will be examined and the judges will award the prizes to the 100 entrants they consider have shown the greatest skill and judgement in placing the eight captions in order of suitability for the photograph. No entrant may win more than one award. Prizes must be accepted as offered—there can be no alternative awards, cash or otherwise.

In the event of any ties, those tying will take part in a postal eliminating contest to determine the winner(s).

Entries arriving after the closing date will not be considered, and no responsibility can be accepted for entries lost or delayed in the post or elsewhere. Entries received illegible, altered or not complying with the instructions and rules will be disqualified.

The competition is open to all readers in Great Britain, Northern Ireland, the Channel Islands and Isle of Man other than employees (and their families) of IPC Magazines Ltd, West Hyde Developments Limited and the printers of *Everyday Electronics*.

Decisions of the judges, and of the Editor in all other matters affecting the competition, will be final and legally binding. No correspondence will be entered into.

Winners will be notified, and the result will be published later in *Everyday Electronics*.

A. Technology at its best!
B. Crossed lines?
C. Wire we all tangled up?
D. It's B.T. asking if the new 'phone system's O.K.
E. The robot wants to talk to you.
J. Tell Santa, this year I'll settle for a toupee.
K. It's still engaged—must be E.T. phoning home.
L. And a Happy New Year to you too!

IMPORTANT

Before sealing, copy out, on the outside back of the envelope, the eight key letters in the same order as they appear on your completed coupon. *YOUR ENTRY MAY NOT BE CONSIDERED IF THIS IS NOT DONE.* Do not enclose any correspondence or matter other than the coupon.

1	2	3	4	5	6	7	8

In entering this competition, I agree to abide by the rules and to accept the published result as final and legally binding.

NAME ____________________

ADDRESS ____________________

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ELECTRONIC BUILDING BLOCKS

PART FIVE — RICHARD BARRON

Last month, we took a fairly cursory look at the operation of transistor amplifiers and op-amps. Continuing with this theme, we will now highlight some more op-amp circuits which should demonstrate their versatility and thus explain their popularity. Incidentally, readers may have noticed a reduction in the theoretical content of *Building Blocks*; this is intentional as we feel that while running the series at the same time as Teach In '86, some material would be duplicated, obviously a pointless exercise.

DOING SUMS

In addition to basic amplifiers, op-amps are capable of adding, subtracting or comparing voltages. Also functions such as, filtering, integration and differentiating are possible.

The basic summing amplifier is shown in Fig. 1. In this mode, it is connected as an inverting amplifier whose output is proportional to the sum of the input ratios of voltage and resistance, the gain being set by R4. This gives us:

$$V_{out} = -R4\,(V1/R1 + V2/R2 + V3/R3)$$

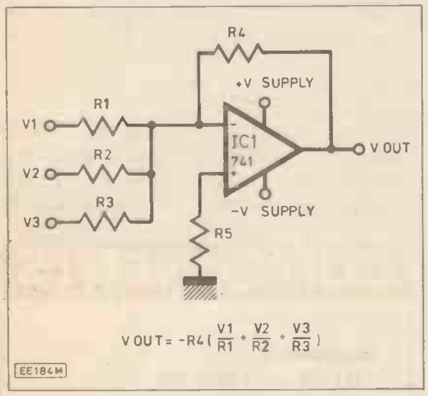


Fig. 1. Inverting summing amplifier.

COMPARISON

By providing additional inputs connected to the non-inverting input of the op-amp, subtraction can be provided. This gives us:

$$V_{out} = V4 + V5 + V6 - V1 - V2 - V3$$

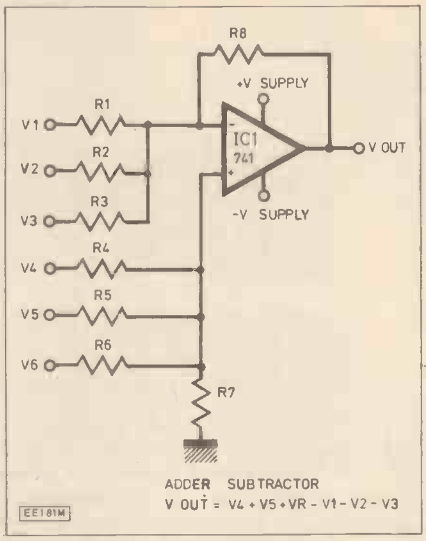


Fig. 2. Adder-Subtractor.

This is shown in Fig. 2 and as can be seen, by keeping the resistance values the same, there is no need to work out proportions.

Because op-amps are high gain devices with directly coupled, differential inputs, they are well suited to comparison applications. In the simplest terms, if no feedback is employed to reduce the gain, the output will either swing high or low, unless the inverting and non-inverting terminals are at exactly the same potential and the amplifier is perfect, ie no offset.

Basically, this means that the output can be easily controlled via the two inputs. If the non-inverting input is at a higher potential than the inverting input, then the output will be close to the positive supply. Alternatively if the non-inverting input is at a lower potential, then the output will go low.

The action of a comparator circuit is illustrated in Fig. 3. In this circuit the output will remain close to the negative supply until the potentiometer, VR1, causes the test voltage, V_{test}, to exceed the reference voltage, V_{ref}.

Comparators are available as standard i.c.s, making it unnecessary to use op-amps unless fast switching is specifically required. Both standard and op-amp comparators can be easily operated from a single rail supply which makes them useful devices for use in digital logic circuits.

LOGIC

The ideas and concepts we have examined so far have, essentially, been concerned with analogue signals. However, much of today's electronic circuitry deals exclusively with logic signals based on the binary system. In these types of circuits only two valid signals are recognised, either 1 or 0 or high or low. These two signals states are represented by voltages which are determined by the logic convention used, the most common being TTL or CMOS.

TTL (transistor-transistor logic) is designed to be operated from a 5V supply and the logic levels remain consistent within this range. CMOS (complementary metal oxide semiconductor) logic may be operated from a 3V to 18V supply and the logic levels are based on a proportion of the supply used ($\frac{1}{3}V_{cc}$ and $\frac{2}{3}V_{cc}$).

Other than this difference, the logical operations of the two types of circuit are very much alike. Therefore, to explain the concepts and practical applications of logic circuits, *Building Blocks* will concentrate mainly on TTL devices.

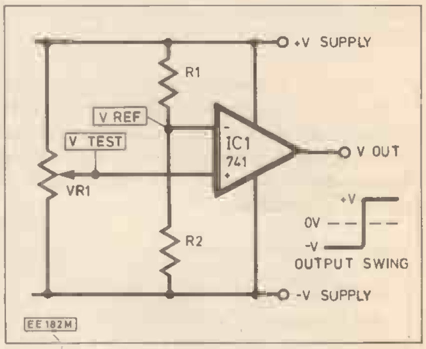


Fig. 3. Comparator test circuit.

NEXT MONTH: Logic circuits and concepts.

TTL LOGIC PROBE

This month's constructional project is a logic probe, a practical piece of test equipment for any TTL circuit. To keep the project simple and inexpensive, but still useful, a compromise was made between price and performance. The result is a single chip circuit and a few associated components.

LEVELS

TTL logic circuits operate from a 5V supply, a high voltage representing a high logic level, and a low voltage, low logic. However, as can be seen from Table 1, a high logic level for a TTL input may differ to a high logic level for a TTL output. This is due to the way in which TTL input and outputs are constructed. In practical terms, this does not present too much of a problem, as in most cases, a high level is higher than the accepted minimum, usually 2·5V.

THE CIRCUIT

The complete circuit diagram of the TTL Logic Probe is shown in Fig. 4. An LM324 i.c. (quad 741 type op-amp) forms the heart of the circuit. Three of the amplifiers are wired as comparators configured to switch at predetermined levels, and one is simply a buffer.

Since there is a slight difference between accepted input and output levels in TTL circuits, it was decided to compromise and set the switching threshold to those shown in Table 2. As can be seen, these thresholds allow indication of; open circuit, high, low, indeterminate and pulsing conditions.

The voltage references for the op-amps are taken from potential dividers supplied from the same 5V supply as used by the logic under test. These references are connected to the inverting inputs of IC1a, IC1c and IC1d. Thus, when the reference voltage is exceeded by the probe voltage, their outputs will go close to 5V.

VOLTAGE DETECTION

IC1a is supplied with a very low reference voltage from the potential divider, R2 and R4. The inverting input is connected to the probe but held at ground potential via a 1M resistor, R3. Therefore, unless the probe is connected to a voltage greater than about 60mV, the output of IC1a will remain low. Also the output of IC1c and IC1d will remain low and as can be seen no l.e.d.s will light thus indicating an open circuit.

Now if the probe is connected to a TTL level voltage, ie between 0V and 5V, the output of IC1b will go high following the output of IC1a. This will allow the low indicator, D2 to light, providing the output of IC1d is low. This condition is satisfied only when the probe voltage is less than about 1V.

If the probe voltage is above 1V but below 2·1V, then the output of IC1d will be high and the output of IC1c, low. This will cause D3 to illuminate, indicating an intermediate logic level.

Table 1. TTL signal levels

Condition	Voltage (V)
Gate input high	>2
Gate input low	0 to 0·8
Gate output high	>2·4
Gate output low	0 to 0·8

Similarly, when the probe voltage exceeds 2·1V, D4 will light indicating a high level. Unfortunately, this cannot be distinguished between a high logic level and a high voltage indication. This should not be too much of a problem, but it should be borne in mind.

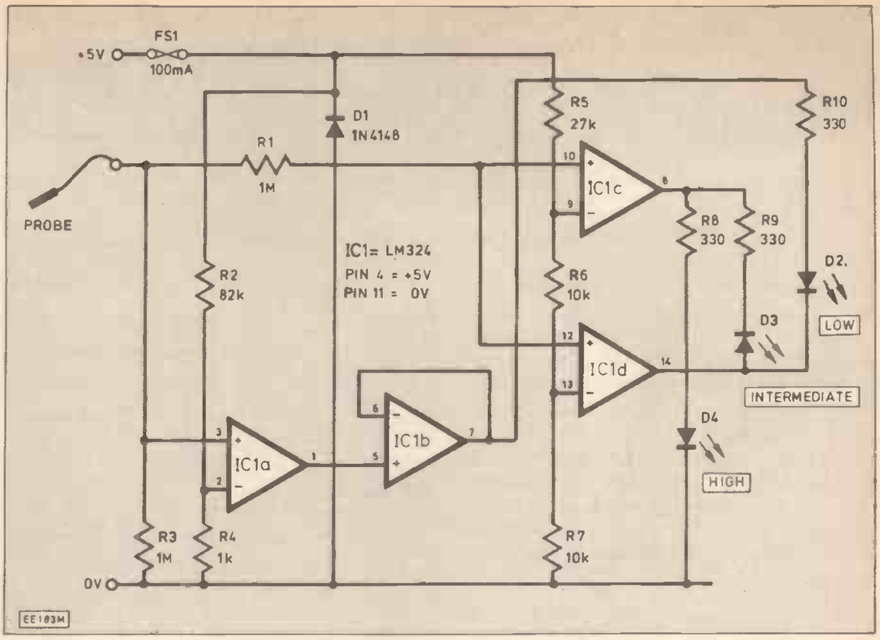


Fig. 4. Circuit of the TTL Logic Probe.

If the circuit under test is pulsing, i.e. alternating between logic levels, then at least two l.e.d.s should appear to be permanently lit, depending on the frequency. In general if the test point is predominantly high, then D4 and D2 will light. If predominantly low then D2 and D3 will light.

CONSTRUCTION AND USE

Once again, construction should be fairly straightforward as all the components, other than the fuse are mounted on a small p.c.b. The p.c.b. is part of a larger board which should be cut into five sections as indicated in Fig. 5. As before, providing several circuits on one p.c.b. makes each project much cheaper.

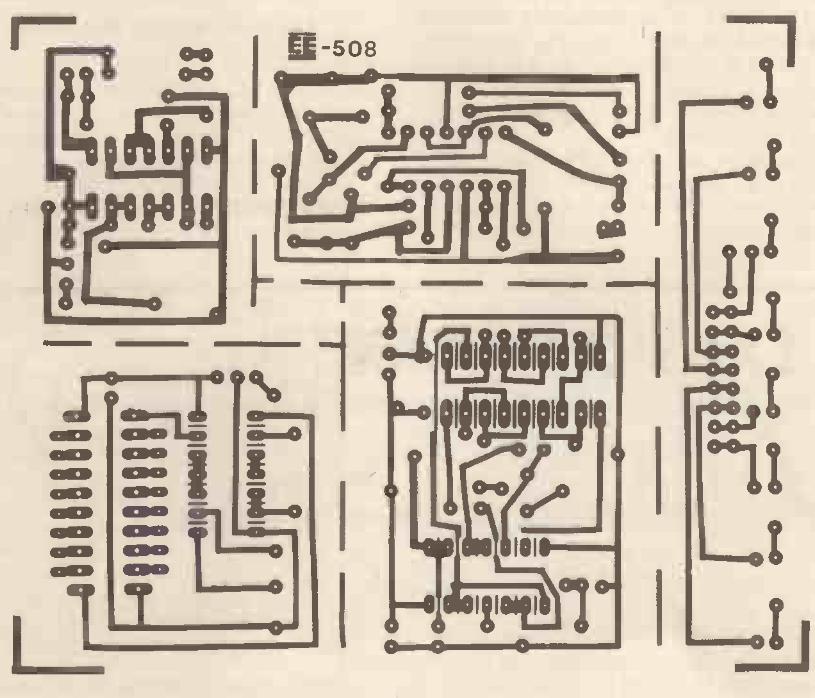
Construction of this project follows that of most other projects with the smaller components such as the resistors and the diodes being mounted first. These are followed by l.e.d.s, the i.c. socket and the terminal pins used for interwiring connection.

For the prototype, a purpose designed case was used and the l.e.d. spacing was designed accordingly. However, should another case be used, the l.e.d.s may be

Table 2. Logic probe indications

Probe Voltage (V)	Indication	Meaning
Open circuit	None	Open circuit
0·06 to 1	D2	Low
>1 to 2·1	D3	Intermediate
>2·1 to 5	D4	High
Pulsing	D2,3 or 3,4	Pulsing

Fig. 5. Building Blocks 5–8 p.c.b.s. Enables a Light Chaser/Game, Logic Probe, Alarm and Computer Port to be built.



COMPONENTS

Resistors
- R1,R3 1M (2 off)
- R2 82k
- R4 1k
- R5 27k
- R6,R7 10k (2 off)
- R8–R10 330 (3 off)

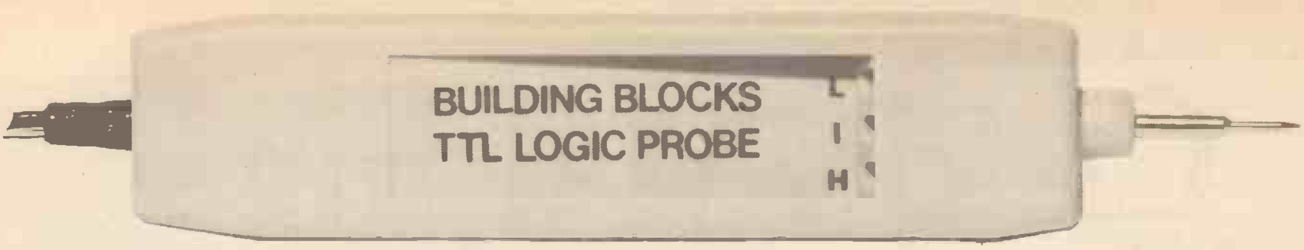
Semiconductors
- D1 1N4148
- D2–D4 miniature l.e.d.s (3 off)
- IC1 LM324 op-amp (quad)

Miscellaneous

Case to suite; probe, if not supplied with case; 100mA fuse and holder; wire; solder; terminal pins, etc.

See Shop Talk page 646

Approx. cost Guidance only £6



See Shop Talk page 646

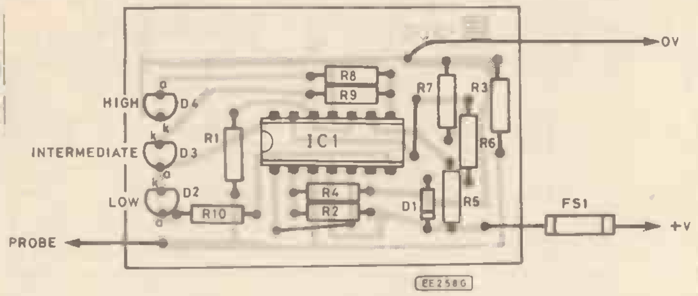


Fig. 6. Component layout of the TTL Logic Probe.

mounted separately using interconnecting wires. The component overlay is shown in Fig. 6 together with the wiring details of the fuse and probe.

To use the logic probe, it is simple. Connect the probe to the power supply of the logic circuit to be tested and start checking various logic levels. If the probe power supply connections are the wrong way round, then the fuse, S1 will blow. The only precaution to take is: *Make sure* not to touch the probe onto any voltage higher than 5V.

NEXT MONTH: A one chip alarm circuit with a variety of applications.

COUNTER INTELLIGENCE

BY PAUL YOUNG

Body Batteries

An interesting programme on the BBC entitled, *Body Matters* set my mind on a train of thought not entirely unconnected with our hobby. Namely this, the medical profession have known for many years that our bodies are activated by small currents of electricity and I suppose most of us became aware of it with the invention of the electronic heart pacer. What I would like to know is, how is it generated, and if it is stored, where is it stored?

I know of a limited number of ways it could be produced and, excluding static, they are, electromagnetically, chemical reaction, heat differential and Piezo crystals. I think the most likely choice would be chemical reaction. The programme still has about four instalments to run, so there is just a possibility that they may tackle this problem.

In the meantime, I am hoping we have a few medicos among our readers because I often wake up in the morning with the distinct impression that my battery is flat. Perhaps they could advise poor old Young how he could obtain a jump start when he feels like this.

Most Popular

If I were asked to name the most popular constructional article, I should unhesitatingly plump for the simple short wave receiver. It began way back about 1950 when a firm called "Johnsons" made one they called "The Globe King". It used a 2V triode valve powered by a 3V cycle battery via a resistor and a ninety volt h.t. battery.

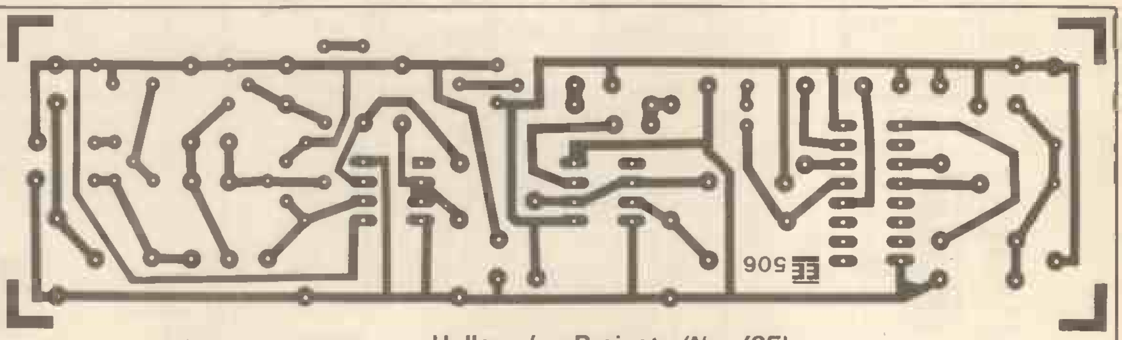
A little later, we produced a similar one which sold well. Then two things happened causing a change in design. The arrival of the transistor and the sharp increase in the price of h.t. batteries. I asked Frank Rayer if he would transistorise the kit, which he did most successfully.

The next problem was the increase in the price of the metal work and I overcame this by putting it into a small plastic box. Alas at that moment the price of the tuning capacitors went through the ceiling making the whole project unviable, rather a sad finale.

Computer Museum

In Boston, Massachusetts, is the world's first computer museum. The museum has grown out of a private collection started by the Digital Equipment Corporation ten years ago and has amongst its collection the original IBM Q7 constructed in 1943. It is about the size of a senior bank manager's house, but it can do no more than the small computers children play with, who talk to each other casually about Bytes and Fractals. Curator Oliver Strimpel, who has a Doctrate in theoretical astrophysics and came from the London Science Museum, says anyone who does not know what a Fractal is, belongs in a museum, as an exhibit. So next time you visit Madame Tussauds you will most likely find Old Young in there, probably in the Chamber of Horrors. I know all our readers know what a Fractal is, but I'm going to remind them anyway. A Fractal is a mathematical entity with an infinite number of transitional states.

PLEASE TAKE NOTE



Simple Reverb ***(Oct. '85)***

Fig. 4, page 530, the arrows at the top of the board should be labelled 1 and 2 (from left to right), the arrow at the bottom should be labelled 5. The component above C5, marked C8, should be marked R8. The preset marked VR1 (right-hand side of board) should be labelled VR5. All textual references to VR7 should read VR3.

Hallowe'en Projects ***(Nov '85)***

The p.c.b. diagram should show the 555 Timer pin 5 unconnected, pin 4 should go to +9V (published circuits are correct). The correct master is shown above. Figs. 4 D1 and D2 anode (a) and cathode (k) annotations should be transposed.

Fig. 3 (Mask), D2 and D3 anode (a) and cathode (k) annotations should be transposed, also C3 right-hand corner should read C8.

TRANSDUCERS

PART 4 OPTICAL INTENSITY MEASUREMENT - AND A SIMPLE LIGHTMETER PROJECT... MIKE FEATHER BSc

THREE basic types of light-sensitive devices are used for the determination of optical intensity. These are described briefly in this article and the use of one of them as a practical optical intensity transducer forms the basis of this month's practical project.

PHOTOVOLTAIC CELLS

These are sometimes referred to as solar cells and they consist of a number of p–n junctions connected in series with each other. One of the regions (n or p) is extremely thin so that the incident light is able to pass through it without a significant loss of energy.

The energy in the light causes the release of charge carriers (holes and electrons) at the junctions and this develops voltages across them. The voltage developed is proportional to the intensity of the light.

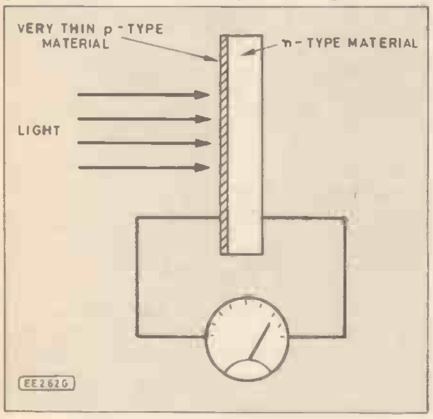


Fig. 4.1. A photovoltaic cell.

Since photovoltaic cells actually generate a voltage from the incident light, they are useful for applications such as camera exposure meters. Fig. 4.1 shows the physical arrangement of this type of photocell.

PHOTOCONDUCTIVE CELLS

This type of photocell uses a material whose electrical conductivity varies with the intensity of the light falling on it.

Cadmium sulphide is normally used in this type of cell and an increase in the light intensity causes a decrease in the resistance; they are often called light dependent resistors (LDR's).

The response of these cells to the spectral colours varies in much the same way as that of the human eye and this makes them useful for lightmeter type applications. The construction of a typical LDR, the ORP12, is shown in Fig. 4.2.

The cadmium sulphide film is deposited on an insulating substrate. Connections are made at each end of the film and the arrangement is encapsulated in epoxy resin with a clear window in order to allow light entry.

The change in resistance with incident light intensity is quite large for the ORP12. Its resistance when dark is about 10M and this falls to around 100 ohms under strong illumination.

The response time of cadmium sulphide cells is rather slow and they are best suited to measuring slowly-changing light levels in applications such as smoke detectors and automatic lighting controllers.

PHOTODIODES AND PHOTOTRANSISTORS

Like photovoltaic cells, photodiodes use a p–n junction which is illuminated by the incident light. Hole-electron pairs are formed and a current flows in the diode.

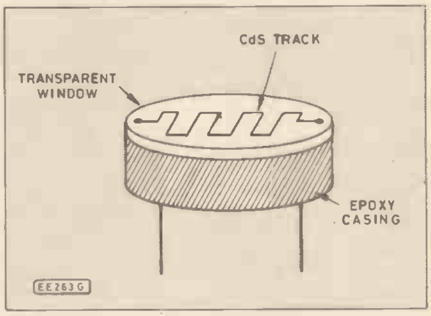


Fig. 4.2. A light-dependent resistor.

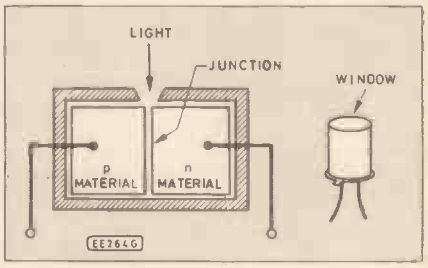


Fig. 4.3. Photodiode structure.

The diode is usually connected so as to be reverse biased and the dark current is therefore very small indeed. As the illumination is increased, the current through the diode rises, the relationship between current and light intensity being very linear. Fig. 4.3 shows the arrangement of p- and n-type regions in a photodiode.

Phototransistors employ the same principle, but the amplifying action of the transistor makes these devices more sensitive. Both photodiodes and phototransistors offer very fast response times; the output of a typical general purpose photodiode increases from 10% to 90% of its final value in only 250ns.

This device is used as the sensor in this month's constructional project—a transducer for optical intensity measurements.

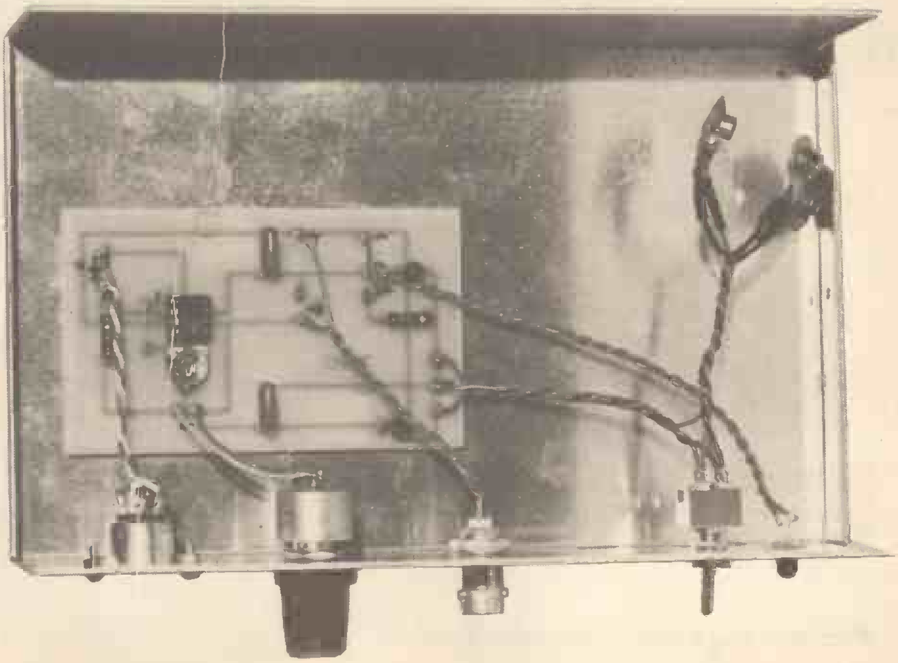
THE CIRCUIT

As described above, the photodiode is connected into the circuit so as to be reverse biased, i.e. its anode is made negative with respect to its cathode: see Fig. 4.4.

Increasing the illumination causes the diode current I_d to increase and this causes a corresponding change in the output voltage of the operational amplifier IC1. The size of the output voltage is determined by the feedback resister R_f and is given by $V_{out} = I_d \times R_f$.

In this application, R1 and VR1 together form the feedback resistor and the output can be adjusted so as to produce 0V to 1V for a fairly wide range of incident light intensity. The calibration of the unit is described following the construction procedure. VR2 is the usual offset null potentiometer and this provides a zero set facility for the unit.

IC2 and IC3 are positive and negative 5V regulators to provide stable supplies for the operational amplifier and the reverse bias voltage for the photodiode; the l.e.d. and its series resistor R2 provide a visual "ON" indication for the unit.



CONSTRUCTION

The circuit is very straightforward and is easily constructed by means of the p.c.b. arrangement shown in Fig. 4.5. Alternatively, a small piece of Veroboard can be used.

Components should be positioned as shown in the overlay diagrams and soldered in carefully. Care should be taken with the orientation of the two voltage regulators; note that the pin-out arrangements of input, output and ground differ for these two devices. Veropins are used for connections to the off-board components and these should be inserted and soldered into the positions indicated. Check the board for dry joints, solder bridges etc.

The completed board is then mounted in a suitable case (see components list) and the connections with off-board components are made as shown in Fig. 4.6, and the photograph.

The 741 operational amplifier can now be inserted into its socket, noting carefully the orientation. Two PP6 batteries were used in the prototype and these should be connected up as shown in Fig. 4.6.

The photodiode is conveniently mounted in a small probe, which may simply be an empty pen-barrel. Connection between this and the main unit is via a length of screened cable and a three-pin DIN plug.

COMPONENTS

See Shop Talk page 646

Resistors
R1 1M
R2 680
¼W ±5% carbon film

Potentiometers
VR1 100k lin. rotary
VR2 10k min. horiz. skeleton

Capacitors
C1, C2 100n polyester (2 off)

Semiconductors
D1 red l.e.d.
D2 general-purpose photodiode
IC1 741 op-amp
IC2 78L05 voltage regulator
IC3 79L05 voltage regulator

Miscellaneous
B1, B2 9V PP6 batteries (2 off)
PL1 3 pin DIN plug
PL2 BNC plug
S1 d.p.d.t. toggle switch
SK1 3 pin DIN socket
SK2 BNC socket

Case—203 × 127 × 51mm; printed circuit board, available from the *EE PCB Service*, order code EE-509; knob for VR1; battery connector clips (2 off); 8-pin i.c. holder; adhesive feet for case.

Approx cost Guidance only £18.50

TESTING AND CALIBRATION

Before dealing with testing and calibration of the unit, it is useful to consider briefly the units used in the measurement of illumination.

Sources of light produce luminous energy and the amount of energy emitted per second is known as the luminous flux, which is measured in lumens.

The actual quantity of light falling on a surface is known as the illuminance and this is measured in lumens per square metre or lux. Bright sunlight produces an illuminance of about 25 000 lux whilst at a distance of 1 metre from a 60 watt lamp, the illuminance has a value of approximately 50 lux.

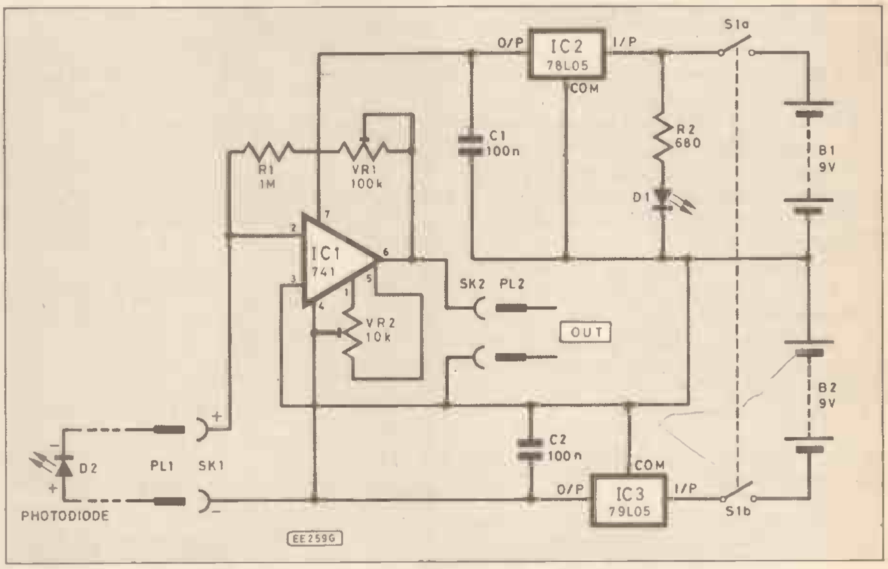


Fig. 4.4. Complete circuit diagram for the Optical Intensity Transducer.

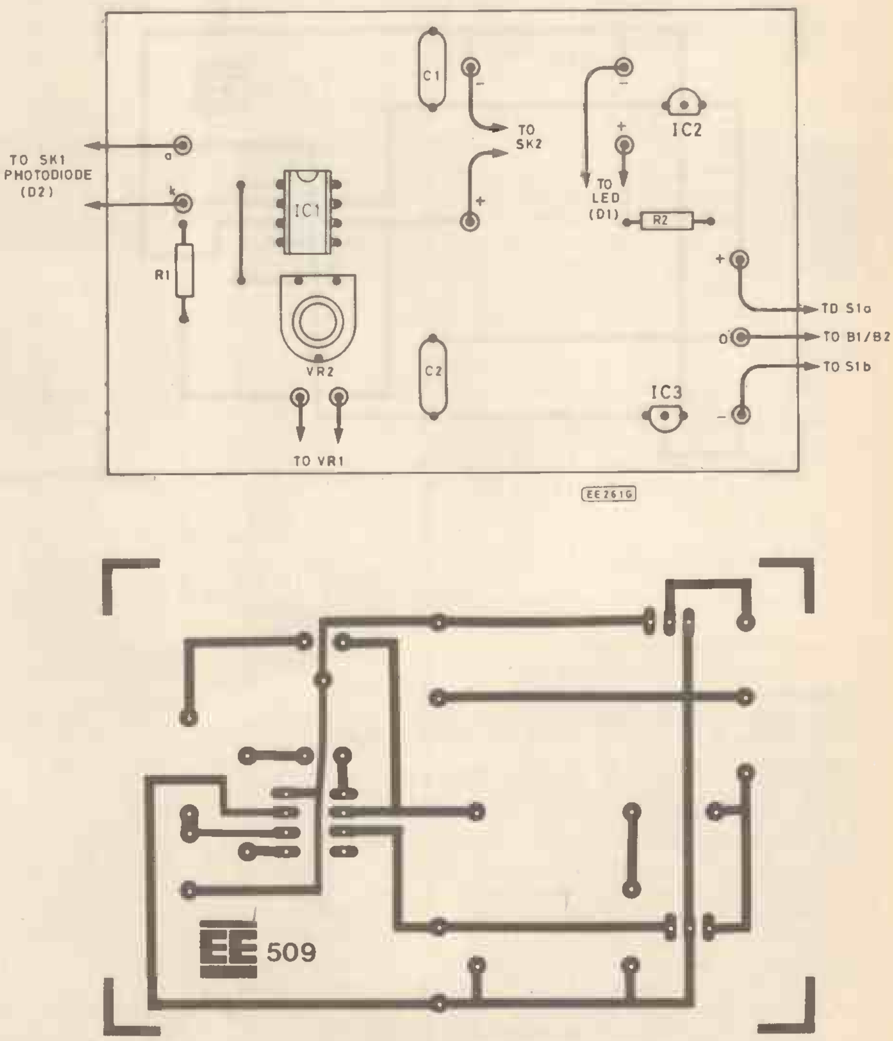


Fig. 4.5. Top, layout of components on the p.c.b., and leadout wires (see also Fig. 4.6). Above, the actual-size p.c.b.

When construction of the main unit and the probe has been completed, all wiring should be checked carefully. The batteries can now be connected and the unit switched on. At this point it is advisable to measure the +5V and −5V power supply lines. The voltages present should not differ appreciably from these values.

Connect up to a 0 to 1V voltmeter (preferably digital) to the output of the unit and cover the window of the photodiode so as to prevent any light from entering. Adjust the offset zero control VR2 until the voltmeter reads zero.

The photodiode can now be uncovered and this should produce an indication on the voltmeter. As it stands, the unit can now be used for comparing the luminous energy of different sources or the illuminace of different surfaces.

Calibration of the unit may be achieved by direct comparison with a conventional lightmeter or exposure meter. The sensitivity control VR1 should be set at a value which will allow the unit to be used within the range of illuminance required.

NEXT MONTH: Frequency measurement transducers.

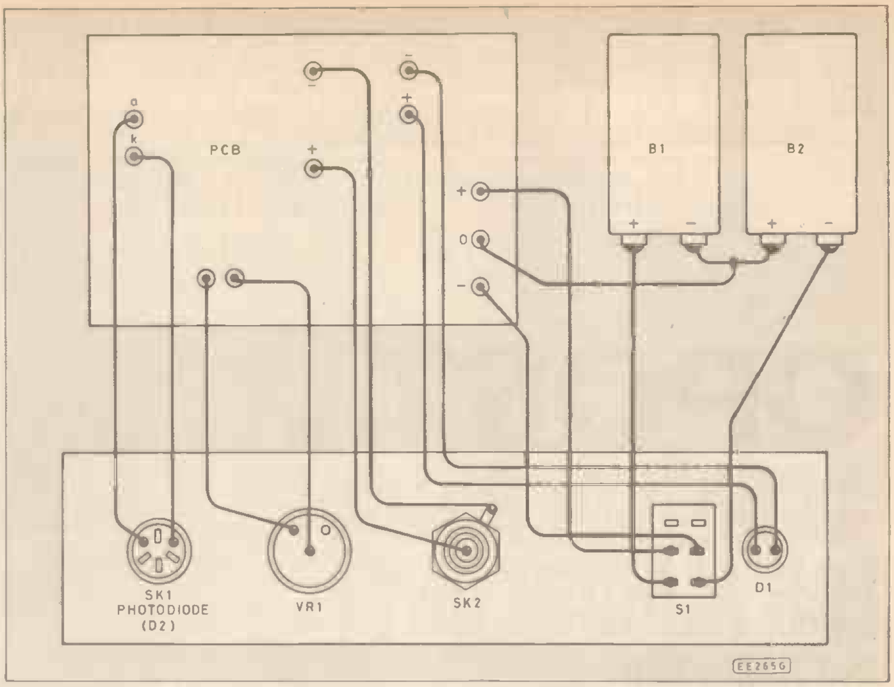


Fig. 4.6. Interwiring details, p.c.b. to front panel.

JANUARY '86 FEATURES...

OPORT...
A CONTROL OUTPUT FOR ALMOST ANY COMPUTER

An opto-coupled output port for an unbelievably low cost. The Oport will allow you to directly control external devices from the screen of your TV set, under computer control. A sensationally original way to achieve computer control—with *no* wiring to the computer itself.

TEACH IN '86 PROJECT...
Audio Signal Tracer

Another useful piece of test gear from Teach In '86. Ideal for trouble shooting audio equipment—or simply proving projects.

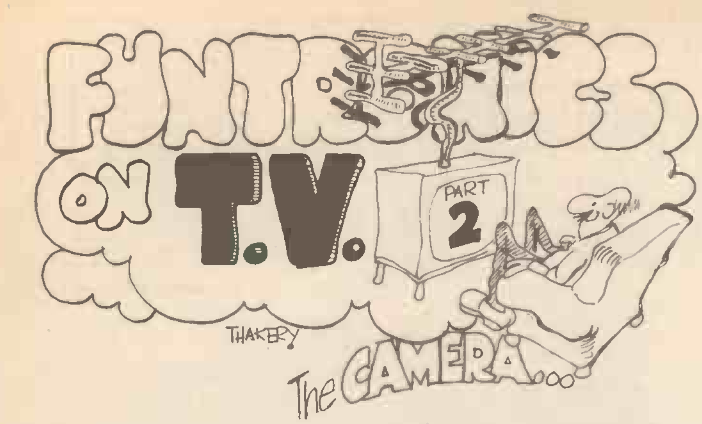
MUSICAL DOORBELL

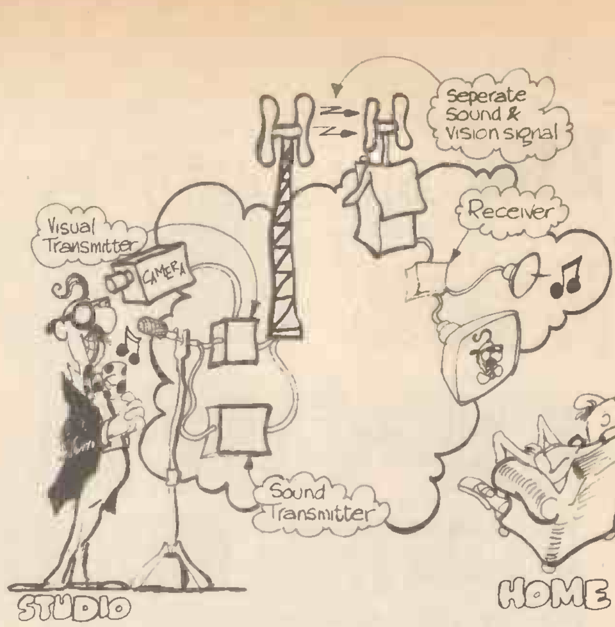
The electronic doorbell is one of the most useful and popular projects in the field of hobby electronics. The circuit uses the AY-3-1350 integrated circuit which provides a total of 25 tunes and three chimes.

EVERYDAY ELECTRONICS and ELECTRONICS MONTHLY

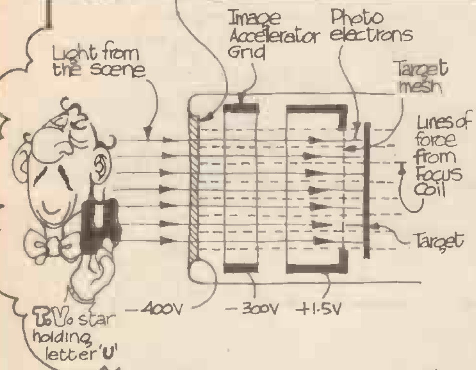
JANUARY 1986 ISSUE ON SALE FRIDAY, DECEMBER 6

FUNTRONICS ON T.V. PART 2





The PHOTO-CATHODE



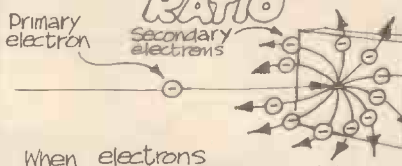
The inside face of the glass-end window of the tube is coated with a mixture of ANTIMONY, CAESIUM, & SILVER which forms a semi-transparent photo-electric surface — this coated window is the photo-cathode.

The number of electrons released from the photo-cathode (caused by the impact of light) are directed towards the TARGET by the potential difference between the -400V on the photo-cathode and the -300V on the Image accelerator and the +1.5V on the TARGET MESH.

The electrons must of course travel in a straight line and this is made possible by passing a direct current through the FOCUS COIL so producing an axial magnetic field with "lines of force" for the electrons to follow.

FUNdamental FACTS

Secondary Emission RATIO



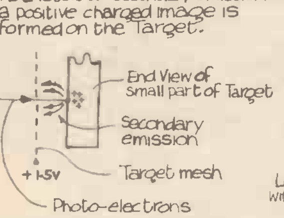
When electrons bombard a conducting material above a certain velocity electrons are emitted from the surface. The bombarding electron is the 'Primary' and the emitting electron is the 'secondary'. The most secondary emissive material used is "caesiated silver."

The number of secondary electrons released for every primary electron is known as the "secondary emission ratio". The diagram shows ten electrons being released by one electron giving a ratio of 10

" I also wish that the 'one over ten' was the 'secondary emission ratio' "

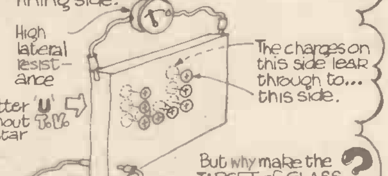
The TARGET

As a result of 'Secondary emission' a positive charged image is formed on the Target.



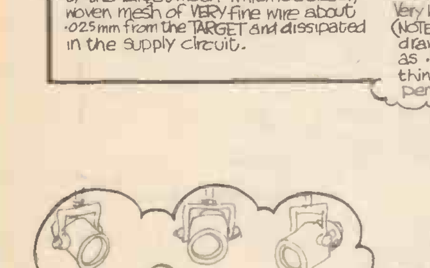
'Secondary emission' means electrons are made free from the Target and, of course, they must NOT return to the target. These are infact collected by the Target mesh which is a closely woven mesh of VERY fine wire about ·025mm from the TARGET and dissipated in the supply circuit.

The TARGET is approximately 50mm × 40mm rectangular in shape and is typically ·125mm thick. The reason for the extreme thinness is to permit the charge image to leak through a very low electrical resistance onto the scanning side.



Very low resistance. (NOTE: Thickness is drawn exaggerated as ·125mm would be thinner than a pencil line)

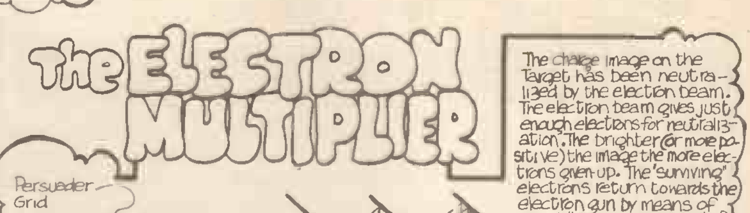
But why make the TARGET of GLASS? Well, the answer is a very simple one! GLASS possesses a high lateral resistance to the movement of electrons and so avoids destroying the whole pattern of the charge image.



"You just DON'T tell our "STAR" he's about to be converted into a mess of positive charges on the back end of a glass plate."

The ELECTRON MULTIPLIER

The charge image on the Target has been neutralised by the electron beam. The electron beam gives just enough electrons for neutralisation. The brighter (or more positive) the image the more electrons given-up. The 'surviving' electrons return towards the electron gun by means of the still positive potential of the decelerator grid and even greater potential of the 'Wall Anode'



As the returning electrons get near the electron gun the Persuader grid diverts them onto the first Dynode (D1) of the electron multiplier and by the process of secondary emission the electrons are multiplied and collected by the ANODE of the electron multiplier.

HOW THE IMAGE ORTHICON TUBE WORKS

1 o The TRANSPARENT PHOTO-CATHODE at one end of the tube has light focused on to it from the scene to be televised. As this happens electrons are emitted from the PHOTO-CATHODES inner surface in numbers corresponding to the tonal composition of the scene.

2 o These electrons are then propelled toward an exceedingly thin glass target on which they produce a positive charge image of the scene by the action of secondary emission. The charge image has still to be reproduced on its photo-cathode side – this is made possible by the thinness of the glass target. The charge image actually "leaks through" the very thin glass.

3 o A low-velocity electron beam then scans this reverse side of the glass target.

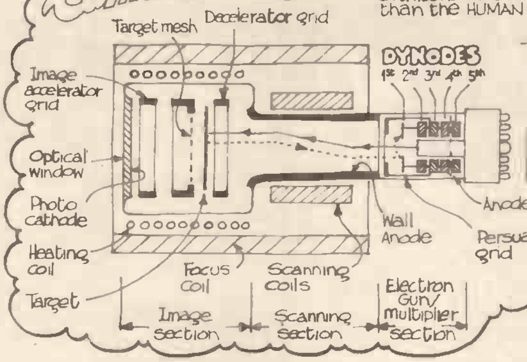
4 o All electrons not given up by the beam as it scans each individual area of charge are reflected back toward the electron gun.

5 o However, before these surplus electrons return to the gun they are deflected towards an electron multiplier assembly which is capable of producing an output signal which is exactly proportional to every variation in the density of the returning electrons.

by Thakery

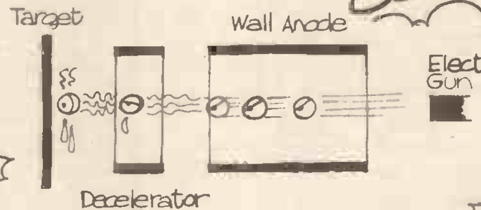
The Image Orthicon Camera Tube

The Image Orthicon is 115mm diameter and about 480mm long and is cylindrical in shape.
Its tube has a sensitivity more than a THOUSAND times greater than its predecessor the Iconoscope, as a matter of fact some Image Orthicons are even more sensitive than the HUMAN eye.



– And unlike the Iconoscope it is suitable for use under almost any lighting conditions.

The SCANNING BEAM



The electron beam in the Image Orthicon overcomes the problem of "Secondary emission" as found in the Iconoscope.

The 'Wall Anode' accelerates the electrons towards the Target and just before reaching the Target the 'Decelerating grid' slows the electrons down hence avoiding the electrons hitting the Target with a force that would cause "secondary emission" and 'Shading signals'.

4-WORD LINK-UP

START ⇩

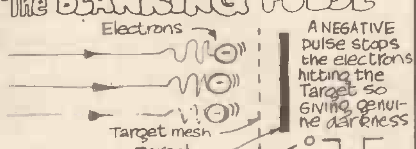
		C	E	L	N	O
		O	T	L	O	S
N	P	H	O	I	C	C
O	A	N	A	E	P	O
I	T	I	N	O	D	E
		M	U	L	L	I

Make a chain of 4-words related to TELEVISION by joining the above letters

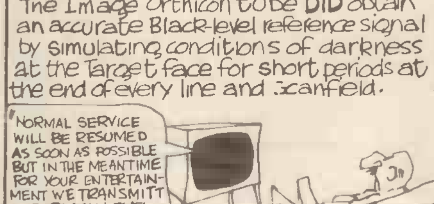
Solutions on page 681

FUNdamental FACTS

The BLANKING PULSE



The Iconoscope never really successfully achieved the Black-level reference voltage from the introduction of a genuinely black object in every scene.
The Image Orthicon tube DID obtain an accurate Black-level reference signal by simulating conditions of darkness at the Target face for short periods at the end of every line and scanfield.



EASY LOOK AT MATHS CALCULUS

The method of calculating called Calculus was discovered in 1666 by Isaac Newton, who called it the 'Method of FLUXIONS'

Calculus deals with changing quantities and with the rates at which they change.

Differential Calculus enables the rates to be calculated from the change in quantity.

Integral calculus can be used to find the quantities themselves from a knowledge of their rate of change

Here's a typical problem easily solved by calculus that would have been solved by trial and error or drawing a graph.

What proportion should a tin's height bear to its diameter so as to use the least amount of tinplate?

HAVE A GO! and look in next episode for solution. Let the volume = 27π cubic inches

NEWS ...from the world of electronics

VIRGIN CHALLENGER'S RACE WITH TIME

A report from Barry Fox on the role played by electronics in the titanic struggle to capture the world water speed record for crossing the Atlantic

At six pm on a hot Thursday evening last August a crowd of engineers, TV and radio reporters, journalists and publicity people were sweating in the Virgin Challenger Mission Control. Virgin's boat *Challenger* was trying to win the Blue Riband for fastest Atlantic crossing by a passenger boat.

They were sweating because it was overcrowded and stuffy in the temporarily converted restaurant above the Virgin Megastore in London's Oxford Street; they were also sweating because the catamaran was nearing the UK, after leaving America on the Monday.

The crowd cheered as the news came up on a TV set in the corner. The *Virgin Challenger* was two hours from the finishing line.

It had been racing at 45 knots across the Atlantic, laden with hi-tech electronics. An hour later all was worry and gloom. The *Challenger* had sunk.

The Virgin boat and control centre relied on an impressive array of communications and computer hardware. Surprisingly the linchpin was a radio link which carried messages by the 50 year old technology of telex, but with modern computer implementation.

By the time the boat hit a piece of flotsam, thought by the crew to be a piece of stray wreckage from the crashed Air India Jumbo, some of its hardware had failed. The technicians' consolation is that no amount of electronics could have averted the disaster.

When the *Virgin Challenger* sank much of her electronics was still working. "I am amazed the electronics stood up to the punishment" navigator Dag Pike told me, "of course some things did go wrong and the pity is that we'll never be able to do a post mortem and find out why for next time."

Communications

But why use telex, instead of ordinary voice radio? The crew believed telex would be more reliable than speech, and for much of the journey it was. Only bad luck shut down the main link.

To provide the telex link for communications, Data General installed a Desktop Model 20 computer, ruggedised for marine use. Twelve sensors round the boat continually monitored engine performance, water and air speed and trim angle. Analogue data from these sensors was fed to the DG computer and stored as digital code every 25 milliseconds.

Every minute a data update appeared on a screen in the cockpit, in jumbo size print to make readout easy. Every five minutes the computer automatically selected a sub-set of the most important readings from the sensors, compiled a telex message and loaded it into a buffer memory.

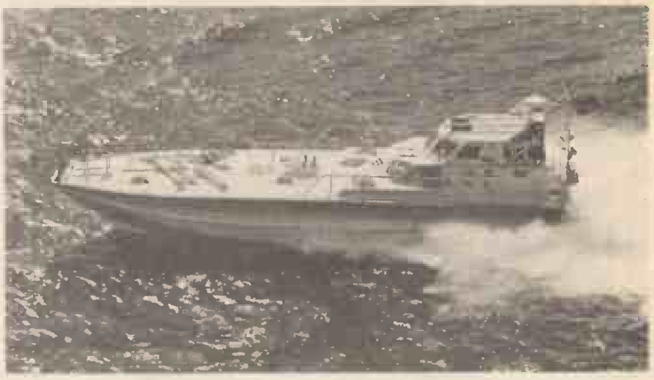
"I'm amazed the electronics stood up to the punishment"

In this way all the sensor data was logged for the future and only the most significant items stored for transmission. When the boat went down, so did all the data which had not already been sent. Unfortunately there was quite a bit of it.

The telexes were sent by marine radio to the Portishead station, at Burnham, on the h.f. band. Lower frequencies were used as the boat got closer. For marine telex-by-radio, the standard 5-bit telex code words are converted to 7-bit ASCII words and transmitted in blocks of three by a modem which converts digital pulses to analogue tones. Transmission is synchronous, with the transmitter and receiver locked together. This allows data to be sent at twice the normal telex rate of 50 baud. Because there are only six radio telex channels in the Atlantic, the *Challenger* used a speech channel in the h.f. band (3MHz–30MHz) for sending telexes. Portishead polled all unread telexes every hour.

The collated data travelled by telex land line from Portishead to the Oxford Street control centre.

The telex link proved its worth early in the trip. For two days messages flowed smoothly, and the control centre received a constant stream of data about fuel consumption, speed and boat behaviour. When the *Challenger* hit an electrical storm on the second night voice communication proved impossible but some telex messages, keyed manually into the computer, got through.



"Anyone like to loan us a satellite channel?"

In the pounding which caused the much-publicised fuel loss, the Racal Decca radar and DG computer terminal kept working even though the shock waves made the pictures on their video screens collapse rhythmically into an oval shape. DG believe this was because the shocks were strong enough to distort the metal framework of the electron guns and coils in the cathode ray tubes.

During the storm the onboard computer failed. The inverter, an electronic circuit which converts the 24V d.c. boat supply to 240V a.c., blew a 20A circuit breaker. It wouldn't re-set.

When the computer failed, the crew switched to voice communications and stayed that way until the end.

Back in London Data General were waiting to get their hands on the gear and see whether anything other than the breaker had failed. Now they never can.

No radar can pick up driftwood or small lumps of submerged ice. "It's all down to Mark One Eyeball" says Pike. By coincidence an airline pilot had told me exactly the same thing a few weeks before when I asked him how jumbos steered clear of small planes flying in their path . . .

Next Time

Already the boat and land crew are planning "next time". Dag Pike would like to see the next boat built round the technology, rather than the technology modified to fit the boat.

"It was so noisy. We couldn't listen for incoming radio calls. And we had no time to sit by a radio and wait. So we had to initiate all calls. Better layout would mean we could work near the radio and listen".

Data General would like to do it again, but this time with a satellite link for communications. "So" says DG "if anyone would like to loan us a satellite channel . . ."

PCB SERVICE

Printed circuit boards for certain constructional projects are now available from the PCB Service, see list. These are fabricated in glass-fibre, and are fully drilled and roller tinned. All prices include VAT and postage and packing. Add £1 per board for overseas airmail. Remittances should be sent to: The PCB Service, Everyday Electronics and Electronics Monthly Editorial Offices, Westover House, West Quay Road, Poole, Dorset BH15 1JG. Cheques should be crossed and made payable to IPC Magazines Ltd.

Please note that when ordering it is important to give project title as well as order code. Please print name and address in Block Caps. Do not send any other correspondence with your order.

Readers are advised to check with prices appearing in the current issue before ordering.

NOTE: Please allow 28 days for delivery. We can only supply boards listed in the latest issue.

PROJECT TITLE	Order Code	Cost
— JULY '83 —		
User Port Input/Output *M.I.T. Part 1*	8307-01	£4.82
User Port Control *M.I.T. Part 1*	8307-02	£5.17
— AUGUST '83 —		
Storage 'Scope Interface, BBC Micro	8308-01	£3.20
Car Intruder Alarm	8308-02	£5.15
High Power Interface *M.I.T. Part 2*	8308-03	£5.08
Pedestrian Crossing Simulation *M.I.T. Pt 2*	8308-04	£3.56
— SEPTEMBER '83 —		
High Speed A-to-D Converter *M.I.T. Pt 3*	8309-01	£4.53
Signal Conditioning Amplifier *M.I.T. Pt 3*	8309-02	£4.48
Stylus Organ	8309-03	£6.84
— OCTOBER '83 —		
D-to-A Converter *M.I.T. Part 4*	8310-01	£5.77
High Power DAC Driver *M.I.T. Part 4*	8310-02	£5.13
— NOVEMBER '83 —		
TTL/Power Interface for Stepper Motor *M.I.T. Part 5*	8311-01	£5.46
Stepper Motor Manual Controller *M.I.T. Part 5*	8311-02	£5.70
Speech Synthesiser for BBC Micro	8311-04	£3.93
— DECEMBER '83 —		
4-Channel High Speed ADC (Analogue) *M.I.T. Part 6*	8312-01	£5.72
4-Channel High Speed ADC (Digital) *M.I.T. Part 6*	8312-02	£5.29
Environmental Data Recorder	8312-04	£7.24
Continuity Tester	8312-08	£3.41
— JANUARY '84 —		
Biological Amplifier *M.I.T. Part 7*	8401-02	£6.27
Temp. Measure & Control for ZX Comprs		
Analogue Thermometer Unit	8401-03	£2.35
Analogue-to-Digital Unit	8401-04	£2.56
Games Scoreboard	8401-06/07	£9.60
— FEBRUARY '84 —		
Oric Port Board *M.I.T. Part 8*	8402-02	£9.56
Negative Ion Generator	8402-03*	£8.95
Temp. Measure & Control for ZX Comprs Relay Driver	8402-04	£3.52
— MARCH '84 —		
Latched Output Port *M.I.T. Part 9*	8403-01	£5.30
Buffered Input Port *M.I.T. Part 9*	8403-02	£4.80
VIC-20 Extension Port Con. *M.I.T. Part 9*	8403-03	£4.42
CBM 64 Extension Port Con. *M.I.T. Part 9*	8403-04	£4.71
Digital Multimeter Add-On for BBC Micro	8403-05	£4.63
— APRIL '84 —		
Multipurpose Interface for Computers	8404-01	£5.72
Data Acquisition "Input" *M.I.T. Part 10*	8404-02	£5.20
Data Acquisition "Output" *M.I.T. Part 10*	8404-03	£5.20
Data Acquisition "PSU" *M.I.T. Part 10*	8404-04	£3.09
A.F. Sweep Generator	8404-06	£3.55
Quasi Stereo Adaptor	8404-07	£3.56
— MAY '84 —		
Simple Loop Burglar Alarm	8405-01	£3.07
Computer Controlled Buggy *M.I.T. Part 11*		
Interface/Motor Drive	8405-02	£5.17
Collision Sensing	8405-03	£3.20
Power Supply	8405-04	£4.93
— JUNE '84 —		
Infra-Red Alarm System	8406-01	£2.55
Spectrum Bench PSU	8406-02	£3.99
Speech Synthesiser *M.I.T. Part 12*	8406-03	£4.85
Train Wait	8406-04	£3.42
— JULY '84 —		
Ultrasonic Alarm System	8407-01	£4.72
Electronic Code Lock		
Main Board	8407-03	£2.70
Keyboard	8407-04	£3.24
— AUGUST '84 —		
Microwave Alarm System	8408-01	£4.36
Temperature Interface—BBC Micro	8408-02	£2.24
— SEPTEMBER '84 —		
Op-Amp Power Supply	8409-01	£3.45
— OCTOBER '84 —		
Micro Memory Synthesiser	8410-01*	£8.20
Drill Speed Controller	8410-04	£1.60
— NOVEMBER '84 —		
BBC Audio Storage Scope Interface	8411-01	£2.90
Proximity Alarm	8411-02	£2.65
— DECEMBER '84 —		
TV Aerial Pre-Amp	8412-01*	£1.60
Digital Multimeter	8412-02/03*	£5.20
Mini Workshop Power Supply	8412-04	£2.78
— JAN '85 —		
Power Lighting Interface	8501-01	£8.23
Games Timer	8501-02	£1.86
Spectrum Amplifier	8501-03	£1.70
— FEB '85 —		
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Transducers Strain Gauge	501	£2.87
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Digital Capacitance Meter	512	£5.22

*Complete set of boards.
M.I.T.—Microcomputer Interfacing Techniques, 12-Part Series.
†Four separate circuits.

Prices for *ELECTRONICS MONTHLY* PCBs are shown below.

PROJECT TITLE		Order Code	Cost
Cymbal Synth	— DEC '84 —	EM/8412/2	£4.86
The Thing		EM/8412/4	£3.18
Speak Board	— JAN '85 —	EM/8501/2	£3.97
Headphone Amp	— FEB '85 —	EM/8502/1	£2.08
Intelligent Nicad Charger		EM/8502/2	£3.50
Anti Phaser		EM/8502/3	£4.56
Logical Lock		EM/8502/4	£3.58
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Courtesy Light Extender	— MAR '85 —	EM/8503/4	£3.29
Disco Light Chaser		EM/8503/5	£8.11
Sound to Light Unit	— APRIL '85 —	EM/8504/1	£4.02
Car Audio Booster		EM/8504/2	£3.12
Short Wave Converter		EM/8504/3	£4.15
Car Burglar Alarm	— MAY '85 —	EM/8505/3	£2.88
Metal Detector	— JUNE '85 —	EM/8506/1	£4.24
Power Supply Module		EM/8506/3	£3.20
Flanger		EM/8506/4	£4.29
El Tom/El Tom+	— JULY '85 —	EM/8507/1	£4.10
El Cymb		EM/8507/2	£4.10
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Real Time Clock		EM/8507/4	£4.62
Intelligent Windscreen Wiper (incl. Terminal Board)	— AUG '85 —	EM/8508/1/2	£4.12
HiFi Intercom (2 boards)		EM/8508/3	£2.92
Plug Power Supply		EM/8508/4	£2.28
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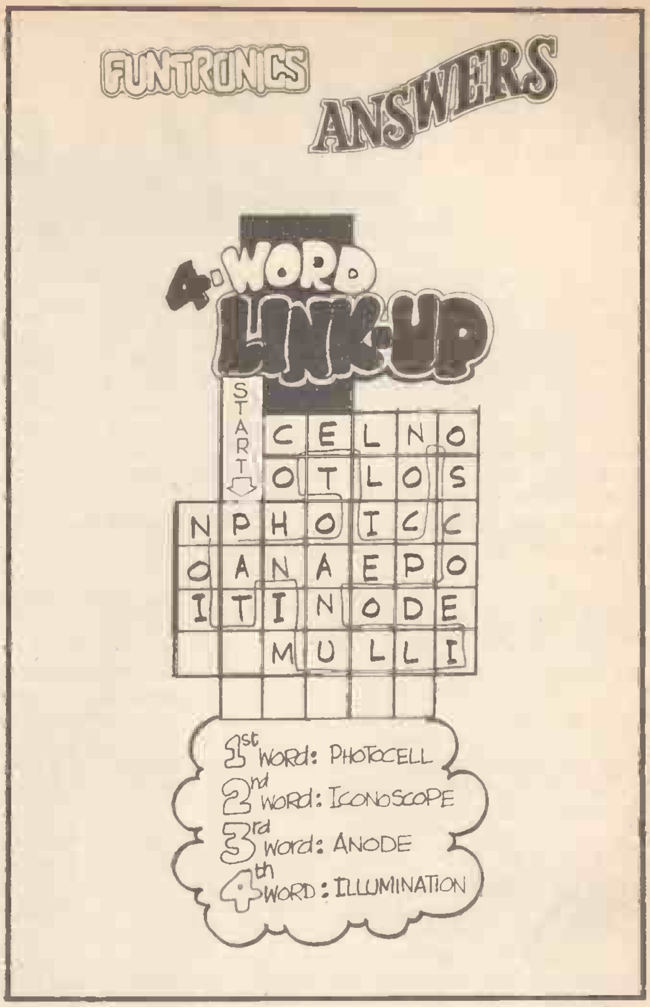


Actually Doing it!!

SO FAR in this series we have been mainly concerned with identifying components and building up circuit boards. However, few projects consist of just a printed circuit board assembly, and in the majority of cases projects are built into cabinets and made as neat and serviceable as possible. Things such as nuts and bolts are every bit as much a part of electronics construction as integrated circuits and other high technology electronic parts. The "nuts and bolts" side of electronics construction is perhaps a little less intimidating for the beginner than the pure electronics aspect, since the items concerned are low-tech and in many cases mundane. It is still something that should be approached with some care and thought though, if the finished article is to achieve a high standard.

Do not worry if finished projects do not look like professionally produced items. In order to compete with ready-made gadgets in this respect it would be necessary for the electronics to take second place, and for the mechanical finishing to be allotted the lion's share of the construction time (and possibly the available funds as well). Most constructors are primarily interested in the electronics, and reasonably aim for no more (and no less) than a neat and functional piece of equipment without the frills of modern ready-made electronic gadgets. This is something that anyone reasonably practical should be able to achieve after learning a few simple skills.

BOARD MOUNTING

The mechanical construction of most projects just boils down to mounting the circuit board inside the case, fitting the controls on the front panel, and then adding a few finishing touches. In this article we will only deal with the basics of board and control mounting, starting with circuit board mounting. The board could simply be bolted in place, and either 6BA or M3 screws are suitable for this purpose. There is a slight problem with this approach, and it is caused by the soldered joints protruding on the underside of the board. This has the effect of causing the board to buckle as the mounting nuts are tightened, since the board in the immediate vicinity of the mounting nuts will be forced against the case, but elsewhere the joints will hold the board slightly clear of the case as shown in Fig. 1(a). Stresses placed on the board will not necessarily cause any damage, but at best it will do nothing for the reliability of the unit, and at worst the board will shatter, making it necessary to remove every component and fit them onto a new circuit board. This problem can be avoided simply by adding an extra nut over each mounting bolt, between the case and the board, as shown in Fig. 1(b).

If the part of the case on which the board is mounted is made of metal, then it is essential to have the board mounted well clear of the casing. Otherwise the connections on the underside of the board will be short circuited through the case. I would recommend the use of spacers no less than about six millimetres in length, fitted in the way shown in Fig. 2(a). There are two types of spacer, the plain and the threaded types. The plain types simply slip over the mounting bolts, whereas the threaded type have to be screwed on like a nut. Where there are several mounting bolts which are well spread out it can be difficult to hold everything in place while the mounting nuts are fitted when using the plain type. Threaded spacers avoid this problem, but the positions of the mounting holes in the case must be drilled very accurately or it could be difficult to fit the board onto the bolts.

An alternative to using nuts, bolts, and spacers is to use the plastic mounting pillars that are now readily available. These just clip into the holes drilled in the case and the board as shown in Fig. 2(b), and the board can be unclipped when required. This may seem like the ideal solution, but the mounting holes have to be precisely the correct diameter if this system is to work well, and by the nature of things the mounting is less reliable that that provided by nuts and bolts. Plastic mounting pillars are also likely to be slightly more expensive. With something like this it is probably best to try both methods to determine which one suits you best overall. Some cases have built in mounting pillars, and a few designs utilize these. The board is mounted on these using self-tapping screws (usually supplied with the case) as shown in Fig. 2(c).

There is actually another and totally different method of board mounting, and one which seems to be gaining in popularity. This is to fit the board into guide rails moulded into the case. This obviously only applies where a plastic case having the moulded guide rails is used, and the circuit board has been designed to fit these rails. The only difficulty with this method is that the board must be accurately cut to size if it is to fit into the rails properly. If you buy a ready-made board there should be no problem, but if you make your own or use stripboard then accurate cutting is essential. Cutting the board marginally too large is not a major blunder, since it can be filed down to size. On the other hand, making the board fractionally too small will result in it tending to slip out of the guide rails, and the only solution might then be to resort to some other method of mounting.

Probably the easiest way of marking the positions of the mounting holes on the case is to use the board itself as a sort of template. In order to produce good drilling accuracy it is a good idea to make indentations at the centres of the required holes using a sharp pointed tool such as a bradawl, and then drill small (about 1·5 millimetre diameter) guide holes before drilling the full-size mounting holes. 3·2 or 3·3 millimetre diameter holes are suitable for M3 and 6BA mounting screws.

If the heads of the board's mounting bolts are on the underside of the case, I would strongly recommend that a set of cabinet feet should be fitted to the case (the small self-adhesive type will suffice). If this is not done there is a danger of the screws scratching any surface on which the project is placed.

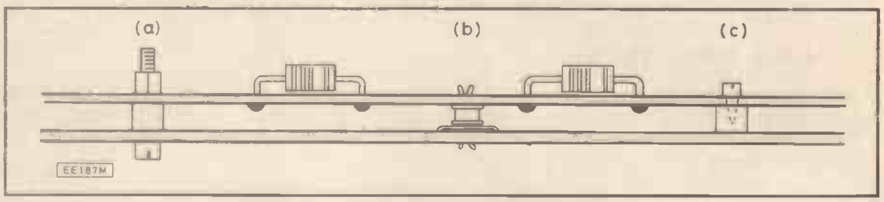
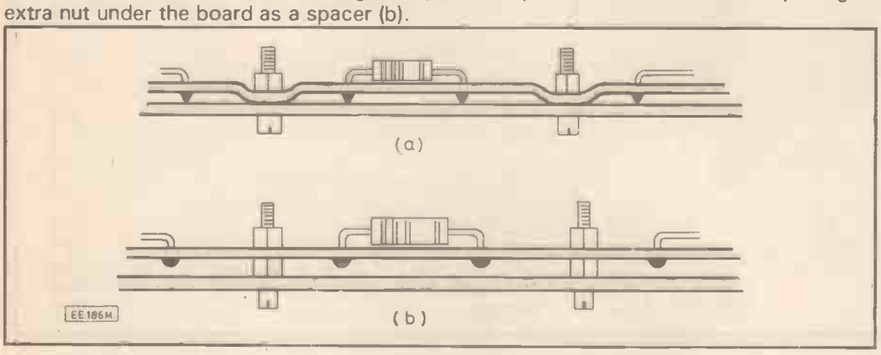


Fig. 2. Various types of spacer materials are available to ensure that the connections are clear of the case. Metal (a), plastic (b), moulded (c).

Fig. 1. Simply bolting a board in place can result in distorting and cracking, a short circuit may also result if a metal case is being used (a). These problems can be avoided by using an extra nut under the board as a spacer (b).



CONTROLS

Usually controls are mounted directly on the front panel. There is a system which uses a dummy front panel to conceal the mounting nuts for the controls, but this was never used widely in home-constructor designs, and is not normally worthwhile these days as most control knobs have a recess to conceal the mounting nut. The standard size of mounting hole for controls is 10 millimetres in diameter.

Robert Penfold

EVERYDAY ELECTRONICS and computer PROJECTS

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3 pin	13p	13p	3.5mm	10p	9p
5 pin	14p	13p	Standard	17p	20p
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1mm	12p	9p	4mm	12p	12p

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PL259 Plug 40p. Reducer 14p.
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Socket with 2m lead . . 125p

SWITCHES

Submin toggle:
SPST 55p. SPDT 60p. DPDT 65p.
Miniature toggle:
SPDT 60p. SPDT centre off 65p.
DPDT 70p. DPDT centre off 75p.
Standard toggle:
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Miniature DPDT slide 14p.
Push to make 15p.
Push to break 22p.
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1P12W, 2P6W, 3P4W, 4P3W 53p
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Spare spool 75p Combs . 6

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2532	380	4164-15	160	6821	140	8156	380
2732 one time programmable	280	41256-15	320	6840	360	8251	350
		Z80A CPU	270	6850	165	8253	370
		Z80A P10	270	6852	240	8255	320
2732	280	Z80A CTC	270	6875	500	8259	400
2764-250	220	Z80A S10	700	6880	100	MC1488	60
2764-BBC	220	Z80A DMA	700	6502	370	MC1489	60

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24 pin	12p	85p
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20 way rainbow ribbon 47p/ft
10 way gery ribbon . . 14P/ft
20 way grey ribbon . . 28p/ft

REGULATORS

78L05	30	79L05	50
78L12	30	79L12	50
78L15	30	79L15	50
7805	40	7905	45
7812	45	7912	45
7815	45	7915	45
LM317K	230	LM723	40
LM317T	90	78H05	550
LM323K	420		

DIODES

		▶1N4001	3
BY127	12	1N4002	5
OA47	10	1N4006	7
OA90	8	1N4007	7
OA91	7	1N5401	12
OA200	8	1N5404	16
OA202	8	1N5406	17
1N914	4	400mW zen	6
▶1N4148	3	1.3W zeners	13

OPTO

3mm red	8	5mm red	8
3mm green	11	5mm green	11
3mm yellow	11	5mm yellow	11

Clips to suit - 3p each.

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2NS777	45	Tri-color Led	30

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FND5000.5" 100 FND5070.5" 100
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HARDWARE

PP3 battery clips . . . 6
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Black pointer control knob 15
Pr Ultrasonic transducers 396
▶6V Electronic buzzer . 70
▶12V Electronic buzzer . 70
▶PB2720 Piezo transducer . 75
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▶64mm 8 ohm speaker . 75
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Electrolytic, radial or axial leads: 0.47/63V, 1/63V, 2.2/63V, 4.7/63V, 10/25V - 7p; 22/25V, 47/25V - 8p; 100/25V - 9p; 220/25V - 14p; 470/25V - 22p; 1000/25V - 30p; 2200/25V - 50p.
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16 way	75	80	80	—
20 way	90	90	95	130
26 way	105	110	115	155
34 way	115	130	130	180
40 way	140	140	145	210
50 way	165	165	170	240
60 way	195	195	200	—

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555CMOS	55	ICL7622	190	LM381	130	MC1496	70	NE5532	160	TL064	105
556CMOS	150	ICL8038	395	LM382	130	MC3302	75	NE5534	105	TL071	32
709	35	ICL8211A	200	LM384	160	MC3340	130	RC4136	65	TL072	55
741	16	ICM7555	55	LM386	85	MF10CN	330	RC4558	45	TL074	105
748	35	ICM7556	150	LM387	90	ML922	415	SL486	240	TL081	28
AY38910	390	LF347	90	LM393	45	ML924	290	SL490	280	TL082	45
AY38912	430	LF351	40	LM710	48	ML925	290	SN76018	150	TL084	90
CA3046	60	LF353	70	LM711	48	ML926	275	SN76477	380	TL170	50
CA3080E	65	LF356	90	LM725	270	ML927	275	SP8629	250	UA2240	130
CA3089	200	LM10C	325	LM733	70	ML928	275	SP0256AL2	425	ULN2003	80
CA3090AQ	375	LM301A	30	LM741	16	ML929	275	Speech data	50	ULN2004	80
CA3130E	75	LM311	45	LM747	60	NE529	225	TBA800	70	XR2206	395
CA3140E	38	LM318	110	LM748	35	NE531	135	TBA810	65	ZN414	75
CA3160	95	LM324	40	LM1458	35	NE544	170	TBA820M	60	ZN423	100
CA3136	100	LM334Z	85	LM2917N8	170	NE555	20	TBA950	220	ZN424P	70
CA3189	260	LM335Z	130	LM3900	50	NE556	46	TCA940	165	ZN425E	340
CA3240E	100	LM339	40	LM3909	85	NE565	95	TDA1008	250	ZN426E	200
ICL7106	680	LM348	60	LM3914	190	NE566	95	TDA1022	270	ZN427E	580

TRANSISTORS

				BC548	5	BFR40	23	2N1613	30	2N3906	10	ZN428E	435
				BC549	10	BFR80	23	2N2218A	45	2N4037	45	ZN459	190
				BC557	10	BFR81	23	2N2219A	28	2N4058	10	ZN1034E	190
AC125	35	BC158	11	BC558	10	BFX29	30	2N2221A	25	2N4060	10	TIP35C	125
AC126	30	BC158	10	BCY70	16	BFX84	30	2N2222A	20	2N4061	10	TIP36A	115
AC127	30	BC159	10	BCY71	16	BFX85	30	2N2368	25	2N4062	10	TIP36C	130
AC128	30	BC160	40	BCY72	16	BFX86	30	2N2369	18	40360	40	TIP41A	45
AC176	25	BC168C	10	BD115	55	BFX87	30	2N2484	27	40361	50	TIP42A	45
AC187	25	BC169C	10	BD131	40	BFX88	30	2N2646	60	40362	50	TIP120	60
AC188	25	BC170	8	BD132	40	BFY50	27	2N2904	28	40408	50	TIP121	60
AD142	120	BC171	10	BD133	50	BFY51	27	2N2904A	28	2N5457	30	TIP122	60
AD161	42	BC172	8	BD135	35	BFY52	27	2N2905	28	2N5458	30	TIP141	110
AD162	42	BC177	16	BD136	35	BFY53	27	2N2905A	28	2N5459	30	TIP142	120
AF124	60	BC178	16	BD137	35	BFY55	30	2N2906	28	2n5485	35	TIP147	120
AF126	50	BC179	18	BD138	35	BFY56	30	2N2906A	28	2N5777	45	TIP2955	70
AF139	40	BC182	10	BD139	35	BRY39	50	2N2907	24	2N697	20	TIP3055	60
AF186	70	BC182L	10	BD140	35	BSX20	22	2N2907A	24	2N698	40	TIS43	40
AF239	55	BC183	10	BD204	110	BSX29	35	2N2926	10	2N706A	20	TIS43	40
BC107	10	BC183L	10	BD206	110	BSY95A	30	2N3053	28	2N708	25	TIS44	45
BC107B	12	BC184	10	BD222	85	BU205	160	2N3054	55	2N918	35	TIS46	45
BC108	10	BC184L	10	BF180	35	BU206	200	2N3055	50	TIP29	35	TIS90	30
BC108B	12	BC212	10	BF182	35	BU208	170	2N3442	120	TIP29A	35	TIS91	30
BC108C	12	BC212L	10	BF184	35	MJ2955	99	2N3702	9	TIP29B	35	VN10KM	65
BC109	10	BC213	10	BF185	25	MJE340	50	2N3703	10	TIP29C	35	VN46AF	94
BC109C	12	BC213L	10	BF194	12	MJE520	50	2N3704	9	TIP30	35	VN66AF	110
BC114	22	BC214	10	BF195	12	MJE521	90	2N3705	10	TIP30A	35	VN88AF	120
BC115	22	BC214L	10	BF196	12	MJE3055	70	2N3706	10	TIP30B	35	ZTX107	11
BC117	22	BC237	7	BF197	12	MPF102	40	2N3707	10	TIP30C	40	ZTX108	11
BC119	35	BC238	7	BF198	15	MPF104	40	2N3708	10	TIP31A	35	ZTX109	11
BC137	40	BC308	10	BF199	18	MPSA05	23	2N3709	10	TIP31B	35	ZTX300	14
BC139	38	BC327	8	BF200	35	MPSA06	25	2N3772	170	TIP31C	40	ZTX301	16
BC140	29	BC328	8	BF244B	35	MPSA12	29	2N3773	195	TIP32A	35	ZTX302	16
BC141	30	BC337	8	BF245	35	MPSA55	30	2N3819	32	TIP32B	38	ZTX304	20
BC142	28	BC338	12	BF256B	45	MPSA56	30	2N3820	50	TIP32C	40	ZTX341	20
BC143	30	BC477	22	BF257	32	MPSU05	55	2N3823	65	TIP33A	65	ZTX500	13
BC147	10	BC478	22	BF258	30	MPSU06	55	2N3866	90	TIP33C	75	ZTX501	18
BC148	10	BC479	22	BF259	30	MPSU55	55	2N3903	10	TIP34A	70	ZTX502	18
BC149	10	BC517	30	BF337	35	MPSU56	55	2N3904	10	TIP34C	80	ZTX503	18
BC157	11	BC547	5	BFR40	35	2N118L	22	2N3905	10	TIP35A	105	ZTX504	25

RESISTORS

Carbon film	1+	25+
¼W 5% 4.7ohm - 10M	2p	1p
½W 5% 4.7ohm - 4M7	3p	2p
Metal film		
¼W 1% 10ohm - 1M	4p	3p

25+ price applies to 25+ per value not mixed.

CRYSTALS

		4.194MHz	150
		4.43MHz	100
100KHz	235	5.008MHz	240
1MHz	275	6.0MHz	140
1.8432M	200	6.144MHz	150
2.0MHz	225	7.0MHz	150
2.4576M	200	8.0MHz	140
3.276M	150	10.0MHz	170
3.579M	95	12.0MHz	170
4.0MHz	140	16.0MHz	200

BOXES

Plastic with lid & screws		Aluminium	
		3 x 2 x 1"	65
		4 x 2¾ x 1½"	95
		4 x 2½ x 2"	95
71x46x22mm	50	6 x 4 x 2"	120
95x71x35mm	86	7 x 5 x 2½"	165
140x90x55mm	140	8 x 6 x 3"	205

TTL

		7412	28	7440	28	7476	40	74107	40	74157	70	74180	90
		7413	38	7442	70	7480	50	74109	50	74160	80	74181	240
		7414	48	7444	105	7483	48	74121	40	74161	80	74182	80
7400	25	7416	38	7446	130	7485	80	74122	50	74162	80	74190	70
7401	28	7417	38	7447	88	7486	38	74123	50	74163	80	74191	75
7402	25	7420	28	7448	88	7489	140	74125	45	74164	110	74192	75
7403	28	7421	50	7450	28	7490	40	74126	45	74165	80	74193	70
7404	25	7422	28	7451	28	7491	70	74132	50	74167	200	74194	75
7405	28	7427	30	7453	28	7492	55	74141	80	74170	170	74195	75
7406	40	7428	30	7454	28	7493	45	74145	75	74173	90	74196	75
7407	40	7430	28	7460	28	7494	80	74147	130	74174	90	74197	75
7408	28	7432	30	7472	35	7495	60	74148	105	74175	80	74198	160
7409	28	7433	38	7473	35	7496	80	74150	135	74176	80	74199	160
7410	28	7437	30	7474	35	7497	150	74153	70	74177	80		
7411	28	7438	35	7475	45	74100	120	74154	135	74179	90		

CMOS

		4016	20	4034	145	4054	70	4081	15	4502	50	4529	55
		4017	35	4036	270	4055	70	4082	15	4503	45	4532	50
		4018	40	4039	270	4059	400	4085	35	4507	45	4534	390
4000	15	4019	30	4040	40	4060	45	4086	50	4508	95	4538	40
4001	15	4020	40	4041	50	4063	75	4089	120	4510	45	4543	40
4002	15	4021	40	4042	30	4066	25	4093	22	4511	50	4549	390
4006	40	4022	40	4043	45	4067	230	4094	55	4512	50	4553	215
4007	15	4023	15	4044	45	4068	18	4095	80	4514	85	4555	35
4008	45	4024	30	4046	48	4069	15	4097	260	4515	85	4556	35
4009	25	4025	18	4047	50	4070	20	4098	50	4516	45	4559	290
4010	25	4026	90	4048	35	4071	18	40106	35	4518	45	4560	110
4011	15	4027	22	4049	23	4072	18	40109	100	4520	45	4584	35
4012	15	4028	35	4050	23	4073	18	40163	75	4521	110	4585	50
4013	24	4029	40	4051	45	4075	18	40173	100	4526	45	4724	140
4014	40	4030	20	4052	45	4076	50	40175	75	4527	35		
4015	40	4031	125	4053	45	4077	30	40193	90	4528	40		

LS TTL

		LS20	20	LS75	30	LS123	45	LS161	55	LS221	70	LS365	40
		LS21	20	LS76	30	LS125	38	LS162	55	LS240	65	LS366	40
		LS22	20	LS78	28	LS126	38	LS163	55	LS241	60	LS367	40
LS00	18	LS26	20	LS83	45	LS132	45	LS164	55	LS242	60	LS368	40
LS01	20	LS27	20	LS85	50	LS136	35	LS165	65	LS243	60	LS373	80
LS02	20	LS30	20	LS86	22	LS138	38	LS166	85	LS244	55	LS374	60
LS03	20	LS32	20	LS90	25	LS139	38	LS170	100	LS245	55	LS375	40
LS04	18	LS37	20	LS92	35	LS145	75	LS173	45	LS247	60	LS377	80
LS05	20	LS38	20	LS93	30	LS147	100	LS174	45	LS251	45	LS378	65
LS08	20	LS40	20	LS95	50	LS148	100	LS175	45	LS257	46	LS390	55
LS09	20	LS42	35	LS96	75	LS151	35	LS190	60	LS258	45	LS393	55
LS10	20	LS47	60	LS107	25	LS153	35	LS191	55	LS259	70	LS399	95
LS11	20	LS48	65	LS109	25	LS154	120	LS192	55	LS266	32	LS541	95
LS12	20	LS51	20	LS112	30	LS155	45	LS193	55	LS273	55	LS670	110
LS13	25	LS55	20	LS113	30	LS157	35	LS195	55	LS279	50		
LS14	35	LS73	33	LS114	30	LS158	35	LS196	55	LS283	60		
LS15	20	LS74	25	LS122	45	LS160	50	LS197	55	LS353	75		

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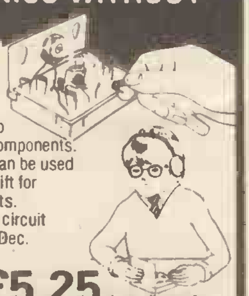

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