EVERYDAY ELECTRONICS

JANUARY 1988

INCORPORATING ELECTRONICS MONTHLY

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The Magazine for Electronic & Computer Projects

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1 – 5 13 amp ring main junction boxes
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38 – 10 compression trimmers
41 – 6 Rocker Switches 10 amp mains SPST
43 – 5 Rocker Switches 10 amp SPDT Centre Off
44 – 4 Rocker Switches 10 amp DPDT
45 – 1 24 hour time switch mains operated (s.h.)
46 – 1 6 hour clock timeswitch
48 – 2 6V operated reed switch relays
49 – 10 neon valves – make good night lights
50 – 2 x 12V DC or 24V AC, 4 CD relays
51 – 1 x 12V 2C O very sensitive relay
52 – 1 12V 4C relay
55 – 1 locking mechanism with 2 keys
56 – Miniature Uniselector with circuit for electric jigsaw
57 – 5 Dolls' House switches
60 – 5 ferrite rods 4" x 5/16" diameter aerials
61 – 4 ferrite slab aerials with L & M wave coils
62 – 4 200 ohm earpieces
63 – 1 Mullard thyristor trigger module
64 – 10 assorted knobs ¼ spindles
65 – 5 different themostats, mainly bi metal
66 – Magnetic brake – stops rotation instantly
67 – Low pressure 3 level switch
69 – 2 25 watt pots 8 ohm
70 – 2 25 watt pots 1000 ohm
71 – 4 wire wound pots – 18, 33, 50 and 100 ohm
73 – 4 3 watt wire wound pots 50 ohm
77 – 1 time reminder adjustable 1-60 mins
78 – 5.5 amp stud rectifiers 400V
85 – 1 mains shaded pole motor ¾" stack – ¼ shaft
86 – 2 5" ali fan blades fit ¼" shaft
87 – 2 3" plastic fan blades fit ¼" shaft
88 – Mains motor suitable for above blades
89 – 1 mains motor with gearbox 1 rev per 24 hours
91 – 2 mains motors with gearbox 16 rpm
93 – 4 11 pin moulded bases for relays
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95 – 4 skirted B9A valve bases
96 – 1 thermostat for fridge
98 – 1 motorised stud switch (s.h.)
101 – 1 2½ hours delay switch
103 – 1 6v mains power supply unit
104 – 1 4½V mains power supply unit
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107 – 1 5" speaker size radio cabinet with handle
109 – 10¼" spindle type volume controls
110 – 10 slider type volume controls
112 – 1 heating pad 200 watts mains
114 – 1 1W amplifier Mullard 1172
115 – 1 Wall mounting thermostat 24V
118 – 1 Teak effect extension 5" speaker cabinet
120 – 2 p.c.b. with 2 amp full wave and 17 other recs
122 – 10 mtrs twin screened flex white p.v.c. outer
132 – 2 plastic boxes with windows, ideal for interrupted beam switch etc
155 – 3 varicap push button tuners with knobs
188 – 1 plastic box, sloping metal front, 16 x 95mm, average depth 45mm
241 – 1 car door speaker (very flat) 6½" 15 ohm made for Radiomobile
243 – 2 speakers 6" x 4" 15 ohm 5 watt made for Radiomobile
266 – 2 mains transformer 9V ½ A secondary split primary so OK also for 115V
267 – 1 mains transformers 15V 1A secondary p.c.b. mounting
330 – 2 6V 0.6V mains transformer .3a p.c.b. mounting
350 – 40 double pole leaf switches
365 – 1 7uf 660V 50hz metal cased condenser
453 – 2 2¼ in 60 ohm loudspeakers
454 – 2 2¼ in 8 ohm loudspeakers
463 – 1 mains operated relay with 2 sets c/o contacts
464 – 2 packets resin filler/sealer with cures
465 – 3 5A round 3 pin plugs will fit item 193
466 – 4 7 segment l.e.d. displays
470 – 4 pc boards for stripping, lots of valuable parts
480 – 1 3A double pole magnetic trip, saves repairing fuses
498 – 4 1000uf 25V axial electrolytic capacitors
504 – 1 Audax PM 8" speaker 15 ohm 5 watt rating
515 – 100 4BA 1½" cheesehead plated screws and 100 4BA nuts
541 – 1 pair stereo tape head as in cassette recorder/players
546 – 1 bridge rectifier 600V international rectifier ref 3SB100
548 – 2 battery operated relays (3-6v) each with 5A c/o contacts 2 pairs
553 – 2 lithium 3V batteries (everlasting shelf life)

TELEPHONE BITS

Master socket (has surge arrestor – ringing condenser etc) and takes B.T. plug	£3.95
Extension socket	£2.95
Dual adaptors (2 from one socket)	£3.95
Cord terminating with B.T. plug 3 metres	£1
Kit for converting old entry terminal box to new B.T. master socket, complete with 4 core cable, cable clips and 2 B.T. extension sockets	£11.50
100 mtrs 4 core telephone cable	£8.50

COMPACT FLOPPY DISC DRIVE EME-101

The EME-101 drives a 3" disc of the new standard which despite its small size provides a capacity of 500k per disc, which is equivalent to the 3½" and 5¼" discs. We supply the Dperators Manual and other information showing how to use this with popular computers: BBC, Spectrum, Amstrad etc. All at a special snip price of £27.50 including post and VAT. Data available separately £2, refundable if you purchase the drive.

MULLARD UNILEX AMPLIFIERS

We are probably the only firm in the country with these now in stock. Although only four watts per channel, these give superb reproduction. We now offer the 4 Mullard modules – i.e. Mains power unit (EP9002) Pre amp module (EP9001) and two amplifier modules (EP9000) all for £6.00 plus £2 postage. For prices of modules bought separately see TWD PDUNDERS.

CAR STARTER/CHARGER KIT

Flat Battery! Don't worry you will start your car in a few minutes with this unit – 250 watt transformer 20 amp rectifiers, case and all parts with data case £17.50 post £2.

THIS MONTH'S SNIP

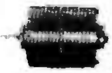
is a 2½kW tangential heater, metal box to contain it and 3 level switch to control it. Special price £7.50 post paid.

Ex-Electricity Board. Guaranteed 12 months.

VENNER TIME SWITCH

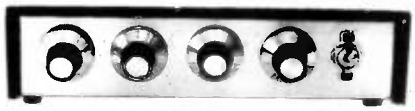
Mains operated with 20 amp switch, one on and one off per 24 hrs. repeats daily automatically correcting for the lengthening or shortening day. An expensive time switch but you can have it for only £2.95 without case, metal case – £2.95. adaptor kit to convert this into a normal 24hr time switch but with the added advantage of up to 12 on/offs per 24hrs. This makes an ideal controller for the immersion heater. Price of adaptor kit is £2.30

12 volt MOTORS BY SMITHS



Made for use in cars, etc. these are very powerful and easily reversible. Size 3½" long by 3" dia. They have a good length of ¼" spindle – 1/10 hp £3.45
1/8 hp £5.75. 1/6 hp £7.50

SOUND TO LIGHT UNIT



Complete kit of parts for a three channel sound to light unit controlling over 2000 watts of lighting. Use this at home if you wish but it is plenty rugged enough for disco work. The unit is housed in an attractive two tone metal case and has controls for each channel, and a master on/off. The audio input and output are by ¼" sockets and three panel mounting fuse holders provide thyristor protection. A four pin plug and socket facilitate ease of connecting lamps. Special price is £14.95 in kit form.

9" MONITOR

Ideal to work with computer or video camera uses Philips black and white tube ref M24/306W. Which tube is implosion and X-Ray radiation protected. VDU is brand new and has a time base and EHT circuitry. Requires only a 16V dc supply to set it going. It's made up in a lacquered metal framework but has open sides so should be cased. The VDU comes complete with circuit diagram and has been line tested and has our six months guarantee. Offered at a lot less than some firms are asking for the tube alone, only £16 plus £5 post.

LIGHT BOX

This when completed measures approximately 15" x 14". The light source is the Philips fluorescent 'W' tube. Above the light a sheet of fibreglass and through this should be sufficient light to enable you to follow the circuit on fibreglass PCBs. Price for the complete kit, that is the box, choke, starter, tube and switch, and fibreglass is £5 plus £2 post, order ref 5P69.

TANGENTIAL HEATERS

We again have very good stocks of these quiet runnng instant heat units. They require only a simple case, or could easily be fitted into the bottom of a kitchen unit or book case etc. At present we have stocks of 1.2kw, 2kw, 2.5kw, and 3kw. Prices are £5 each for the first 3, and £6.95 for the 3k. Add post £1.50 per heater if not collecting.
CONTROL SWITCH enabling full heat, half heat or cold blow, with connection diagram, 50p for 2kw, 75p for 3kw.

FANS & BLOWERS

5" £5 + £1.25 post. 6" £6 + £1.50 post
4" x 4" Muffin equipment cooling fan 115V £2.00
4" x 4" Muffin equipment cooling fan 230/240V £5.00
9" Extractor or blower 115V supplied with 230 to 115V adaptor £9.50 + £2 post.
All above are ex computers but guaranteed 12 months.
10" x 3" Tangential Blower. New. Very quiet – supplied with 230 to 115V adaptor on use two in series to give long blow £2.00 + £1.50 post or £4.00 + £2.00 post for two

TELEPHONE LEAD

3 mtrs long terminating one end with new BT, flat plug and the other end with 4 correctly coloured coded wires to fit to phone or appliance. Replaces the lead on old phone making it suitable for new BT socket. Price £1 ref BD552 or 3 for £2 ref 2P164.

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Generates approx. 10 times more IDNS than the ETI and similar circuits. Will refresh your home, office, shop, work room etc. Makes you feel better and work harder – a complete mains operated kit, case included. £11.50 + £3 P&P.

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NEW ITEMS

Some of the many described in our current list which you will receive with your parcel.

£2 POUNDERS*

2P122 – 1 30a rotary switch, surface mounting with pointer knob
2P123 – 1 25a rotary switch, surface mounting, cover engraved, high, medium low and off
2P124 – 1 28kv .001 mfd block condensor
2P129 – 1 10rpm motor 115V so supplied with adaptor for 230V
2P131 – 1 Crouzet motor 230V fits the Crouzet gearbox
2P132 – 1 ceiling heat-stat for fire warning or protection
2P133 – 1 Circuit breaker 20a, Crabtree ref C50
2P134 – 1 9V 500mA psu, plugs into 13a socket
2P135 – 10m 10 conductor intercom cable
2P136 – 1 2½ kw element made for tangential blowers
2P137 – 1 Thermo couple, stainless steel tipped for measuring internal heat
2P138 – 1 Mains transformer 20V-0-20V 1a upright mounting
2P141 – 1 rechargeable battery D size (4 AH) solder tag ended
2P142 – 10m 4 pair intercom cable White PVC outer
2P144 – 1 mains operated relay with 4 x 8a c/o contacts
2P146 – 1 7,800 uf 150C d.c. smoothing capacitor
2P148 – 1 Technical information on 3" FDD refundable if you buy fdd
2P149 – 5 diff battery operated model motors
2P150 – 1 PSU chassis with all components for 24V 2A d.c. unwired
2P151 – 1 Metal box 14½ x 14 x 4 with lid add £2.00 post
2P152 – 1 Motor start capacitor 80uf 250V
2P153 – 1 Two station Intercom unused but line reject
2P154a – 1 Nicad charger – plug into 13a socket 5.2V .7UA output
2P154b – 1 Nicad charger – plug into 13a socket 6V .9VA output
2P155 – 1 Mains transformer giving 16, 17, 18 & 20V 60W
2P158 – 1 Dven thermostat with temp calibrated knob
2P159 – 1 9V 500ma cased with mains lead and output lead
2P160 – 1 13a plug adaptor fused takes 3 x 3a plugs
2P161 – 1 6" diagonal side cutters
2P162 – 1 Stereo Matrix PCB mounting deemphasis K35
2P163 – 1 AC Working capacitor 12uf 660V AC or 1500V dc
2P164 – 3 Phone leeds 3 mtrs long tags one end B.T. plug other end

£3 POUNDERS*

3P7 – 1 DC voltage, doubler or halver for 12V to 24V 12 to 6V 24 to 12V
3P8 – 1 24hr time switch Sangemo, new condition Guaranteed 1 year
3P9 – 12V 500mA psu plugs in 13a socket regulated
3P10 – 1 Mains transformer 60V 2A with 6.3 pilot light winding, upright mounting, fully shrouded plus £1 post
3P13 – 1 Noise filter to fit in mains lead of appliance up to 25a
3P15 – 1 waterproof case will take 150 watt transformer
3P16 – 1 signal box, 3 lamps on face plate of metal box size 5½ x 3½
3P17 – 1 choke and starter to work 8" fluorescent tube at 125W
3P18 – 1 22V 3a mains transformer with bridge rect fitted on top panel
3P20 – 1 0-5a ammeter 3½ ac/dc ex equipment
3P21 – 1 power factor correction condenser 35uf 350ac
3P22 – 1 200va – auto transformer 230 to 115V torroidal encapsulated £1.50 post
3P24 – 1 3" floppy disc for Amstred etc.
3P25 – 1 7" Electricians pliers

£4 POUNDERS*

4P12 – 50m low loss co-ax 75ohm + £1 post
4P13 – 3 Horstmann time and set switches 15amp
4P14 – 1 150w mains transformer "c" core 43V 3.5A secondary
4P15 – 1 powerful motor 2" stack fitted with gearbox final speed 60rpm mains opereted, could operate door opener etc.
4P17 – 1 Uniselector 3 pole 25W, 50V coil standard size
4P18 – 1 Volt meter with digital display (DIGIVISDR)

COMPUTERS

ACORN ELECTRON – ZX SPECTRUM PLUS – ZX SPECTRUM 128 – COMMODORE 64 – COMMODORE C16 – ALL IN STOCK AT TIME OF GOING TO PRESS
Phone for details

£5 POUNDERS*

5P86 – 1 Transformer upright mounting 230/240V primary 2 x 100 1a secondary
5P88 – 1 Transformer in waterproof metel box 24V 5A add £2 post
5P89 – 1 4 bank heating element each 2kw ideal convactor heater
5P90 – 1 18" long tangential blower with motor at one end
5P91 – 1 14" blower, motor in middle
5P92 – 10m Audio co-ax double screened 75ohm super low loss for TV
5P93 – 1 6" Alarm bell 24V dc or ac
5P94 – 1 Current transformer 14V out with 1a dc input
5P96 – 1 Vintage photo cell
5P97 – 1 Impedance matching transformer 0-4-5-8-160 ohm 100 add £1.50 post
5P98a – 1 0-90a ammeter for mounting outside control panel
5P98b – 1 0-180a ammeter for mounting outside control panel
5P99 – 1 Mains operated blower centrifugal output size app. 5" x 1½"
5P100 – 1 Mains splitter 45a switch 3 x 15a fused circuits
5P101 – 1 Model motor 1 rpm from 6V reversible

£7 POUNDERS*

7P1 – 1 Instant heat solder gun – mains with renewable tip and job light

£8 POUNDERS*

8P1 – 1 Charger transformer 10a upright mounting 230/240 primary 16v 10a secondary
8P2 – 1 6" underdome alarmbell suitable for a fire alarm or burgler alarm mains operated.
8P3 – 1 heat sink big powerful so ideal for power transmitter
8P6 – 1 24hr time switch – 2 on offs 16a c/o contects 3" x 3" x 1½"
8P7 – 1 Silent sentinel invisible ray kit
8P8 – 1 Papst fan 3½ x 3½ x 1½ 230V metal bodied

£10 POUNDERS*

10P14 – 1 100a time switch 1 on/off per 24hr extra triggers £1 per pair
10P15 – 1 Max demand meter 230 ac mains
10P16 – 1 powerful air mover 2 small type blowers with motor in middle
10P18 – 1 mains operated klaxon
10P19 – 1 12V alarm bell really loud, mains operated, in iron case + £5 post
10P22 – 1 sensitive volt meter relay
10P23 – 1 fruit machine heart 3 fruit wheels each stepper motor operated add £3 post
10P24 – 1 big panel meter face size 4¾ x 2½ 200uA movement scaled 1-10
10P30 – 1 instrument psu on pcb has 4 outputs .12V/.5V 6A/12V .5A/5V .5A
10P31 – 1 7 day time switch 16a c/o contects sep switches for each day
10P32 – 1 68 rpm 1/6th hp motor reversible

£15 POUNDERS*

15P1 – 1 kit for 115W hi fi amp
15P2 – 1 kit for psu to supply one or two 15P1 amps
15P3 – 1 time switch battery or mains operated – 16a c/o contacts, 7 day programmable has 36hr reserve

LIGHT CHASER KIT motor driven switch bank with connection diagram, used in connection with 4 sets of xmas lights makes a very eye catching display for home, shop or disco, only £5 ref 5P56.

VOL 17 No.1 JANUARY '88

EVERYDAY ELECTRONICS

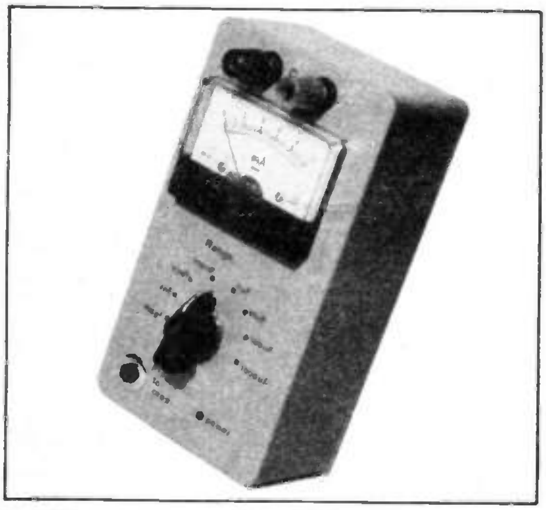
INCORPORATING ELECTRONICS MONTHLY

ABC

The Magazine for Electronic & Computer Projects

ISSN 0262-3617

PROJECTS . . . THEORY . . . NEWS . . .
COMMENT . . . POPULAR FEATURES . . .



Seasonal Greetings To All Our Readers

Our February 1988 Issue will be published on Friday, 8 January 1988. See page 45 for details.

Projects

Series

Features

SPECIAL OFFERS

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EVERYDAY ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

The Magazine for Electronic & Computer Projects

VOL 17 No. 1 **January '88**

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INGENUITY

The electronics around us – the electronics we all take for granted are becoming more and more ingenious and complex every day. This month's feature on The Digital Satellite Revolution will give some idea of the ingenuity that British Telecom International is employing to make international communications more efficient and to improve quality. The complexity of operation and of course the electronics employed are quite staggering.

Those readers who are getting to grips with microprocessors for the first time, throughout our City and Guilds Certificate course, will no doubt by now have realised just how ingenious a microprocessor is. Bear in mind that such components have been around for 14 years and again you have some understanding of the present level of technology.

All this high tech is based on an understanding of current flow and component operation – every engineer involved in design and development had to start at this level at some time. For many of them, that start in electronics came from magazines like *EE* and, for a quite a few, that start was not very many years ago.

TRAINING AND EDUCATION

We are proud of our reputation in the area of training and education, it is obvious that many readers have gained from articles and series we have published. Our Electronics Teach-In book is now aiding about 20,000 more readers (see page 3 for details of this book).

We will look at possible future developments in a related area of technology next month. The London to Sydney in Three Hours article looks at the Hermes, HOTOL, and NASP space projects and considers a possible Soviet Shuttle. Could we be taking day trips to Australia in thirty years? Come to that, will you be involved in the development of such a space craft?

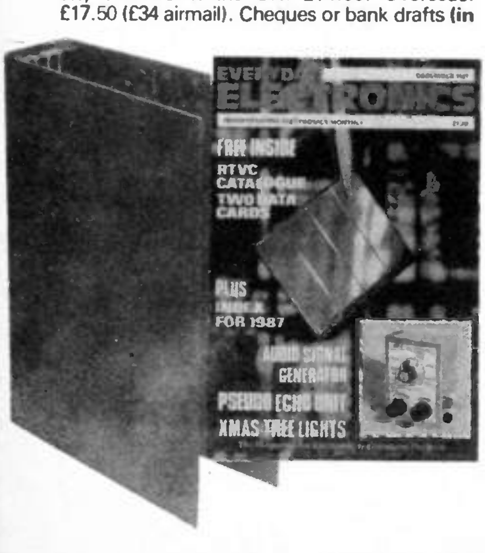
TIMES PAST

Just about the same time as the microprocessor was being developed, a component supply company was formed in the UK. Fifteen years ago Nazir Jessa established Watford Electronics – he held a dinner to celebrate the fact recently. In that 15 years Watford has grown from a part time job for Nazir into a multimillion pound turn-over company. The interesting thing is that when Watford was launched the founder knew virtually nothing about electronics. That has of course changed but it does show that you can make a fortune from selling high tech without understanding how it works. There will always be room for salesmen.

Mike Kenward

SUBSCRIPTIONS

Annual subscriptions for delivery direct to any address in the UK: £14.50. Overseas: £17.50 (£34 airmail). Cheques or bank drafts **(in £ sterling only)** payable to Everyday Electronics and sent to EE Subscriptions Dept., 6 Church Street, Wimborne, Dorset BH21 1JH. **Subscriptions can only start with the next available issue.** For back numbers see below.



BACK ISSUES & BINDERS

Certain back issues of EVERYDAY ELECTRONICS are available price £1.50 (£2.00 overseas surface mail) inclusive of postage and packing per copy. Enquiries with remittance, made payable to Everyday Electronics, should be sent to Post Sales Department, Everyday Electronics, 6 Church Street, Wimborne, Dorset BH21 1JH. In the event of non-availability remittance will be returned. *Please allow 28 days for delivery.* **(We have sold out of Sept. Oct. & Nov. 85, April, May & Dec 86, & Jan 87.)**

Binders to hold one volume (12 issues) are available from the above address for £4.95 (£9.00 overseas surface mail) inclusive of p&p. *Please allow 28 days for delivery.*

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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.**

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

COMPONENT SUPPLIES

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

OLD PROJECTS

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

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Although the proprietors and staff of EVERYDAY ELECTRONICS take reasonable precautions to protect the interests of readers by ensuring as far as practicable that advertisements are *bona fide*, the magazine and its Publishers cannot give any undertakings in respect of statements or claims made by advertisers, whether these advertisements are printed as part of the magazine, or are in the form of inserts.

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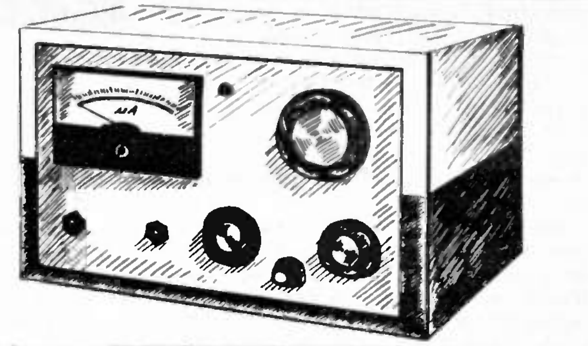
TRANSMITTERS

We would like to advise readers that certain items of radio transmitting equipment which may be advertised in our pages cannot be legally used in the U.K. Readers should check the law before using any transmitting equipment as a fine, confiscation of equipment and/or imprisonment can result from illegal use.

The law relating to this subject varies from country to country; overseas readers should check local laws.

Constructional Project

BENCH AMPLIFIER



ANDY FLIND

A simple high input impedance test amplifier for the workbench

ALMOST all electronic enthusiasts occasionally find themselves dealing with audio circuits. From hi-fi equipment design to experiments with the analogue areas of Midi interface, or perhaps a circuit that alerts the user with an audible signal, or maybe just repairing a friend's cassette player, the applications of audio signals seem endless.

Often they are just that, electronic signals, and whilst the well-equipped workshop will have an oscilloscope, a device for actually listening to them would be a very welcome facility. Usually some sort of amplifier is available, in the author's case a channel of the workshop stereo was sometimes pressed into service, but this often proved less than satisfactory. A custom workbench amplifier, designed specifically for the task, needs special features not normally provided.

BOMB PROOF

To start with, like most test equipment it should have a high input impedance to minimise loading of the circuit on trial. A megohm would be adequate, though most general purpose amplifiers have much lower input impedances than this. Next, a wide range of input sensitivities is needed to cope with all the signal levels likely to be encountered, from millivolts to several volts r.m.s.

It should be "bomb-proof", in that gross overloading should not cause damage. Some sort of noise limiting is desirable to prevent overloads damaging the speaker (and the ears!), and this might be adjustable. Visual indication of input level would be useful.

For most applications the unit should be mains-powered for economy but battery operation is sometimes necessary, either for portability or for "floating" it at some potential other than earth, so switchable supplies would be an advantage. Finally, whilst amplifiers of this type usually have small, cheap speakers, these give a poor impression of the sound quality to be expected from the finished circuit. A large, effective speaker giving good sound quality is desirable.

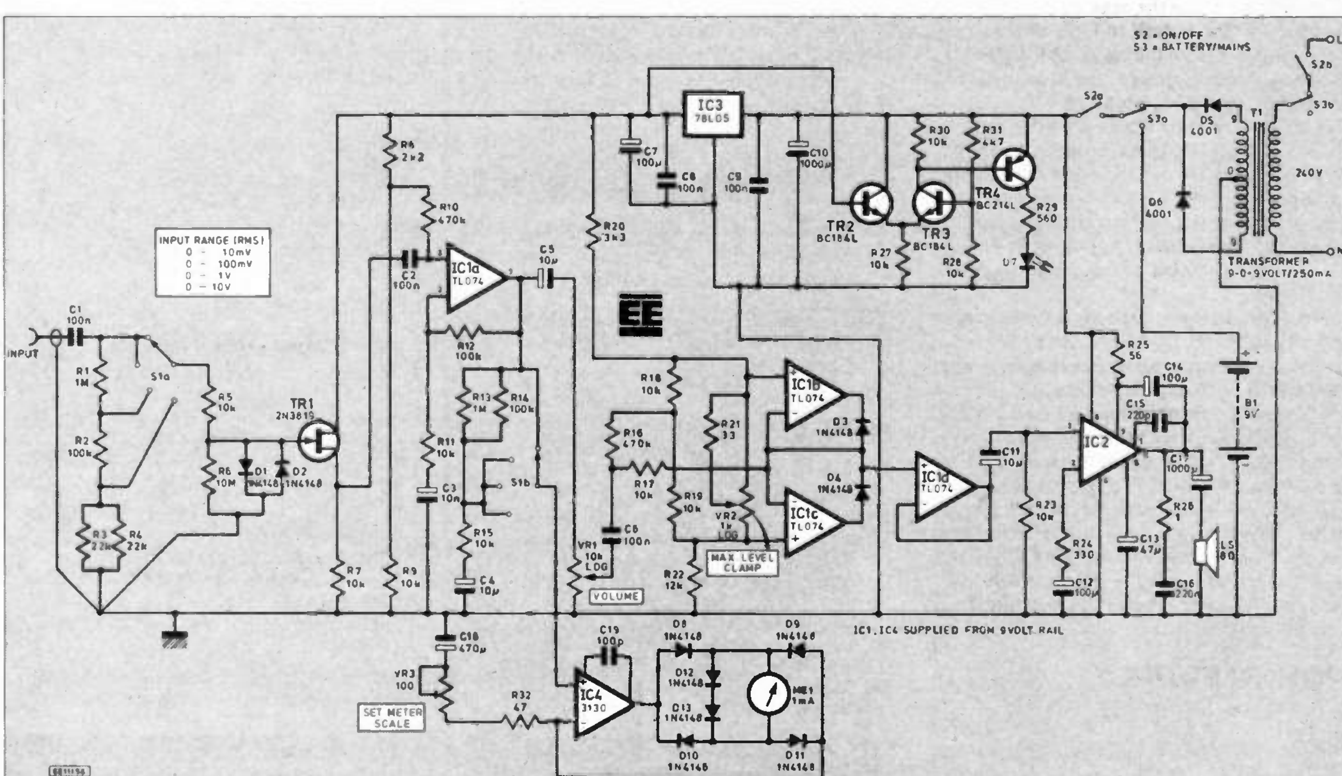
CIRCUIT DIAGRAM

The way in which these various objectives have been achieved is best explained with the help of the full circuit diagram, Fig. 1. The high input impedance is given by TR1, a f.e.t. connected as a source follower.

The desired one Megohm is easily obtained though careful screening is required, this will be described in detail in the construction. Transistor TR1 is not intended to handle signals greater than 100mV r.m.s., but in the case of really severe overloads it will be protected by diodes D1 and D2 in conjunction with resistor R5.

IC1a provides a voltage gain of ten before passing the signal through capacitor C5 to VR1, the Volume control. From here it goes through C6 and R17 to IC1d, which buffers

Fig. 1. Complete circuit diagram for the Bench Amplifier.



and transfers it via C11 to the output amplifier IC2 which drives the speaker. The working points for IC1a and IC1d are set to about 4V, roughly half the full supply voltage.

The use of 1000μF capacitors for C10 and C17, with suitable coupling values elsewhere, extend the low frequency response to about 30Hz, below audio threshold. This is the main audio signal path, which is quite straightforward, but some additional features have been added *en route*.

Input level is indicated by a simple meter amplifier formed with IC4 and associated components. This has a basic sensitivity of 100mV r.m.s. for full scale, adjustable with resistor R32 and preset potentiometer VR3. Diodes D12 and D13 protect the meter from overload.

INPUT SENSITIVITY

The input sensitivity is switched as follows. On the most sensitive range, 10mV full scale, the signal goes straight to TR1 whilst the meter is connected directly to IC1a output. An input of 10mV thus gives full scale on the meter but, although just 1mV gives clearly audible sound, the full 10mV is required for maximum audio output.

On the next range, 100mV, the input is again fed directly to TR1 but the meter input is attenuated by a factor of ten. Although 100mV is now required for full meter scale, full audio output can be obtained with any input above ten per cent of this range.

This also applies to the next two ranges, 1V and 10V r.m.s., which are obtained by input attenuation before TR1. Although this may at first appear an odd way to obtain the most sensitive range, it's not at all intrusive in use and it avoids the instability and noise problems that would occur if all ranges were obtained through input attenuation and extra gain.

NOISE LIMITER

The noise limiter, built around IC1b and IC1c, acts on the signal path between VR1 and IC1d. An adjustable voltage of 10mV to 300mV is developed across VR2, the lower limit being set by resistor R21. This corresponds (approximately!) to the peak-to-peak value of signals from about 4mV to 100mV r.m.s.

The voltages from the ends of VR2 are fed to the non-inverting inputs of the two amplifiers, whilst the mid-point, obtained with resistors R18 and R19, is superimposed on the signal by resistor R16 and taken to the inverting inputs. Starting with IC1b, so long as the positive peak value of the signal is less than half the voltage across VR2, the non-inverting input remains positive of the inverting, its output stays high, diode D3 is reverse biased and the signal path is unaffected.

However, if it rises above this, the output falls and diode D3 conducts to clamp the signal level at the selected maximum value. IC1c does the same thing to negative peaks.

This method of noise limiting isn't perfect, the main disadvantage being "squaring" of the signal. Square waves sound much noisier than pure sines, as is readily apparent if a sine is applied to the input and increased until limiting begins. However, it's much more effective than simple "soft" diode limiting for really severe overloads, and the truly horrible distortion generated will warn the user quite unmistakably that the limiter is active.

POWER SUPPLY

Power supplies for the circuit consist of a simple mains supply or a 9V battery, selected by switch S3. The 5V regulator, IC3, prevents supply voltage fluctuations from reaching sensitive parts of the circuit and also provides a

COMPONENTS

Resistors

R1,R13	1M (2 off)	R20	3k3
R2,R12,R14	100k (3 off)	R21	33
R3,R4	22k (2 off)	R22	12k
R5,R7,R9,R11, R15,R17,R18, R19,R23,R27, R28,R30	10k (12 off)	R24	330
R6	10M	R25	56
R8	2k2	R26	1
R10,R16	470k	R29	560
		R31	4k7
		R32	47

All 0.6W 1 per cent metal film type

Shop Talk

See page 40

Potentiometer

VR1	10k carbon log
VR2	1k carbon log
VR3	100 submin horizontal preset

Capacitors

C1,C2,C6,C8,C9	100n polyester layer (5 off)
C3,C4,C5,C11	10μ axial 24V (4 off)
C7,C12,C14	100μ axial 35V (3 off)
C10,C17	1000μ axial 16V (2 off)
C13	47μ axial 16V
C15	220p polystyrene
C16	220n polyester layer
C18	470μ axial 16V
C19	100p ceramic plate

Semiconductors

D1,D2,D3,D4,D8,D9,D10,D11, D12,D13	IN4148 (10 off)
D5,D6	IN4001 (2 off)
D7	3mm high brightness, red l.e.d.
TR1	2N3819 f.e.t.
TR2,TR3	BC184L *npn* silicon (2 off)
TR4	BC214 *pnp* silicon
IC1	TL074 quad low-noise J-fet op-amp
IC2	TBA820M power amp
IC3	78L05 5V 100mA positive regulator
IC4	3130 CMOS op-amp

Miscellaneous

Case, Verobox type 203, 205 × 140 × 110mm; Printed circuit board, available from *EE PCB Service*, code 591; Knobs, (3 off); 8-pin DIL sockets (2 off). 14-pin DIL socket; Speaker, 6" × 4" elliptical; Meter, 1mA FSD; Transformer, 9-0-9V 250mA; Switch, 3-pole 4-way rotary; Switches, miniature 2-pole 2-way, 240V a.c. rated. BNC chassis socket; Mains chassis plug, 3-pin low current type P429 (and free socket to suit); Battery holder to take 6 × AA cells; Tagstrip; Ribbon cable; Screened cable; Aluminium sheet.

Approx. cost Guidance only **£30.50 excl. case**

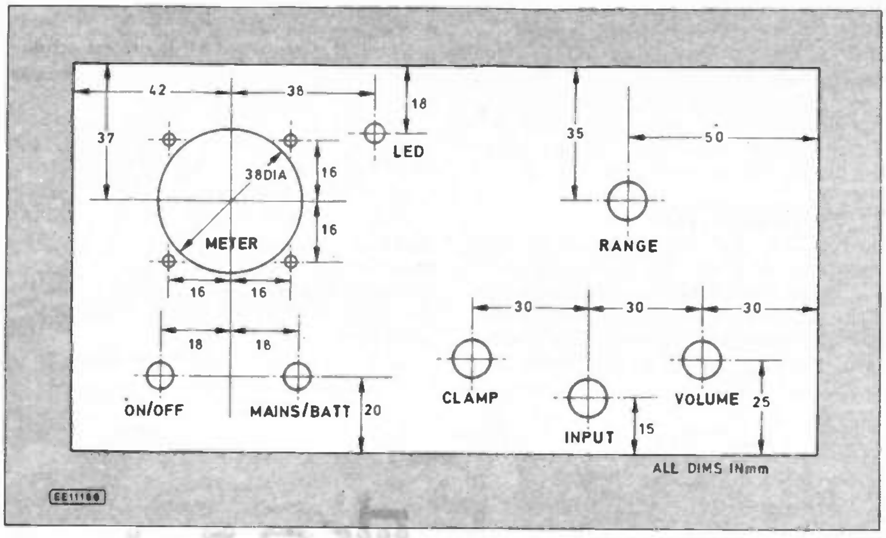


Fig.2. Details and dimensions of the front panel drilling.

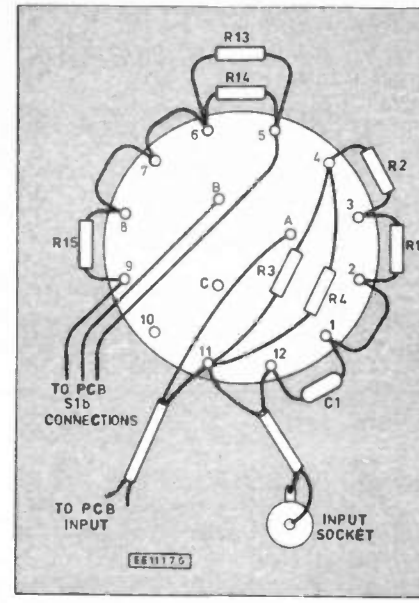


Fig.3. Interwiring to the range switch S1. The unused tags are used as anchor points for the range resistors.

reference for the supply monitor, TR2 to TR4. These transistors are arranged so that the l.e.d. is normally lit, but extinguish it sharply around 7.5V, warning of impending supply failure if batteries are in use.

CONSTRUCTION

Construction of this project should not present any difficulty so long as a few points are noted. Although it's not essential to stick to the case and layout given, it would be advisable for constructors not experienced in the problems of *"earth loops"* and strays as hum pick-up can be quite severe.

The suggested arrangement includes a metal front panel, a metal plate beneath the printed circuit board, and screening over the input stage, all of which are earthed to a *common* point. Care has been taken to place the mains transformer and all output signal paths well away from the input, including that for the meter, where the switching of IC4's output between diode forward potentials can induce a small but unpleasant harmonic into the signal.

CASE DETAILS

Construction should start with the hardware and control wiring. Testing of the board is easier if the controls, etc, are to hand, and the sight of the finished front panel will inspire completion!

A plate cut from thin sheet aluminium covers the bottom of the case, from just behind the front pillars all the way to the back, where cut-outs are made to clear the rear pillars. The plate is eventually screwed to the four larger mountings with self-tappers so holes can be drilled for these. A sheet of paper cut to the shape of the plate and laid in place has the hole positions traced in pencil, this then serves as a drilling template.

The p.c.b. is positioned about 15mm from the front edge of the plate, with transistor TR1 towards the volume control side. Two 6BA screws form mounting pillars, the p.c.b. can be used to mark and drill these. They are secured with single full nuts which also act as spacers to keep the p.c.b. clear of the plate.

The screw nearest TR1 should be about 25-30mm long as it also carries a screening plate and earthing tags. The "L" shape of this plate and its position should be apparent from the photographs; it guards the input circuitry from stray electrostatic fields.

The transformer and battery pack fit behind the board, the transformer being furthest away from the input end. When mounting this, make sure adequate clearance is left for the mains plug, mounted on the back panel as far as possible from the input.

Front panel layout and lettering.

A small tagstrip next to the transformer supports diodes D5 and D6. On the prototype, a short length of cable trunking, into which the battery pack clips firmly, was screwed to the plate.

Precise dimensions for drilling the front panel are given in Fig. 2 to ensure that everything fits properly. It can be marked out with a soft pencil, which will rub out later as if on paper.

A BNC input socket is recommended as the improvement this gives over co-axial or phono types is well worth the small extra cost. It also looks more professional!

The speaker is the largest that will fit, a 4in×6in elliptical mounted in the lid. Its connections face the meter end, away from the input.

A neat pattern of holes drilled in the plastic forms the "grille", and is secured with four "L" shaped steel brackets and self-tappers. To allow it to lie flat against the surface, it is necessary to trim away some of the lid mouldings with a sharp knife.

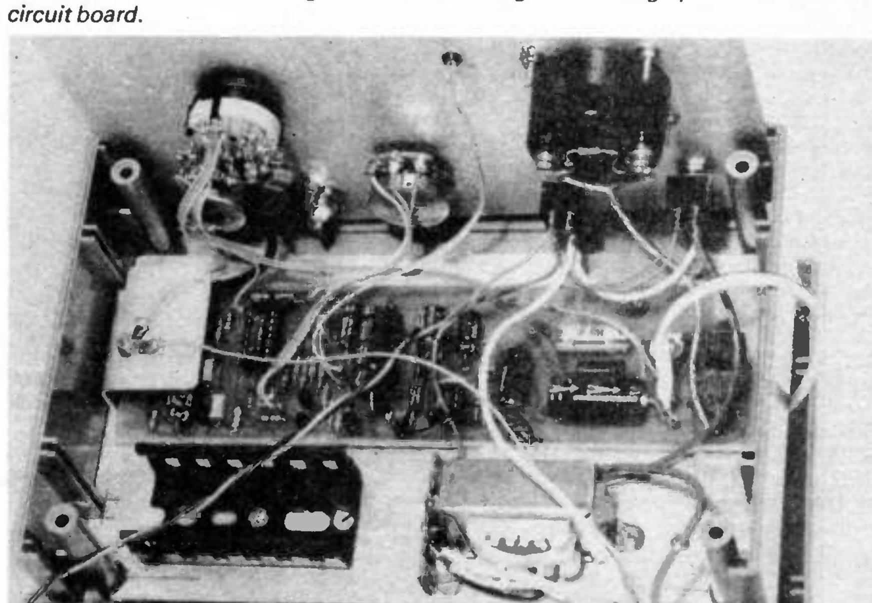
The range switch, S1 is a standard 3-pole 4-way type. Since only two poles are required, tags of the third can be used to mount some of the range and input components. Resistors R1 to R4, R13 to R15 and capacitor C1 are all attached to this switch as shown in Fig. 3.

To keep the input wiring as short as possible the input socket is wired directly to S1a, note that the front panel is also "earthed" via the screen of this lead. Connections to S1b are made through a piece of ribbon cable. This and the screened lead from S1a should be about 40cms long at this stage, to facilitate p.c.b. testing.

CIRCUIT BOARD

Following this work, construction of the p.c.b. should provide a pleasant interlude! The track pattern is shown in Fig. 4; the bit of track

Close-up of the internal wiring and view of the large "screening" plate beneath the circuit board.



around TR1 and R5 that appears to go nowhere is in fact a guard line shielding the input. The printed circuit board for this project is available from the *EE* PCB Service, code 591.

The component layout shown in Fig. 5 is fairly straightforward, the only point to watch is orientation of polarised components, the diodes, electrolytics and transistors. There is no pattern to these – some are one way up, some the other, so care must be taken to fit them correctly.

Both testing and final wiring into the case are simplified if 0.1mm "solderpins" are used for external connections. Insertion of these can require some force so they should be fitted before the components.

DIL sockets are recommended for IC1, IC2 and IC4, these make testing and trouble shooting easier. On the prototype, IC4 failed during final assembly, probably due to static. It was a simple matter to plug in a replacement, but the hassle that would have resulted had it been soldered can well be imagined.

BOARD TESTING

Testing of the circuit board should commence *without* IC1, IC2 and IC4 being in circuit. Apply a source of 9V to the appropriate points, preferably from a current-limited supply although this isn't essential. The supply current will surge briefly as the decouplers charge, notably capacitor C10, but should then settle to just a few milliamps.

Check that regulated 5V is present across capacitor C7. If so, connect up l.e.d. D7, which should light (and raise the consumption a bit!). If the facility is available, reduce the supply voltage gradually until D7 extinguishes, which should happen between 7V and 7.5V.

Check the voltage at the source of TR1 with respect to negative supply. An easy place to find this is the top end of capacitor C2. An exact value cannot be given as f.e.t. characteristics vary widely, but if it is outside the limits of 1V to 4V, change TR1 and try again.

When all seems satisfactory, temporarily

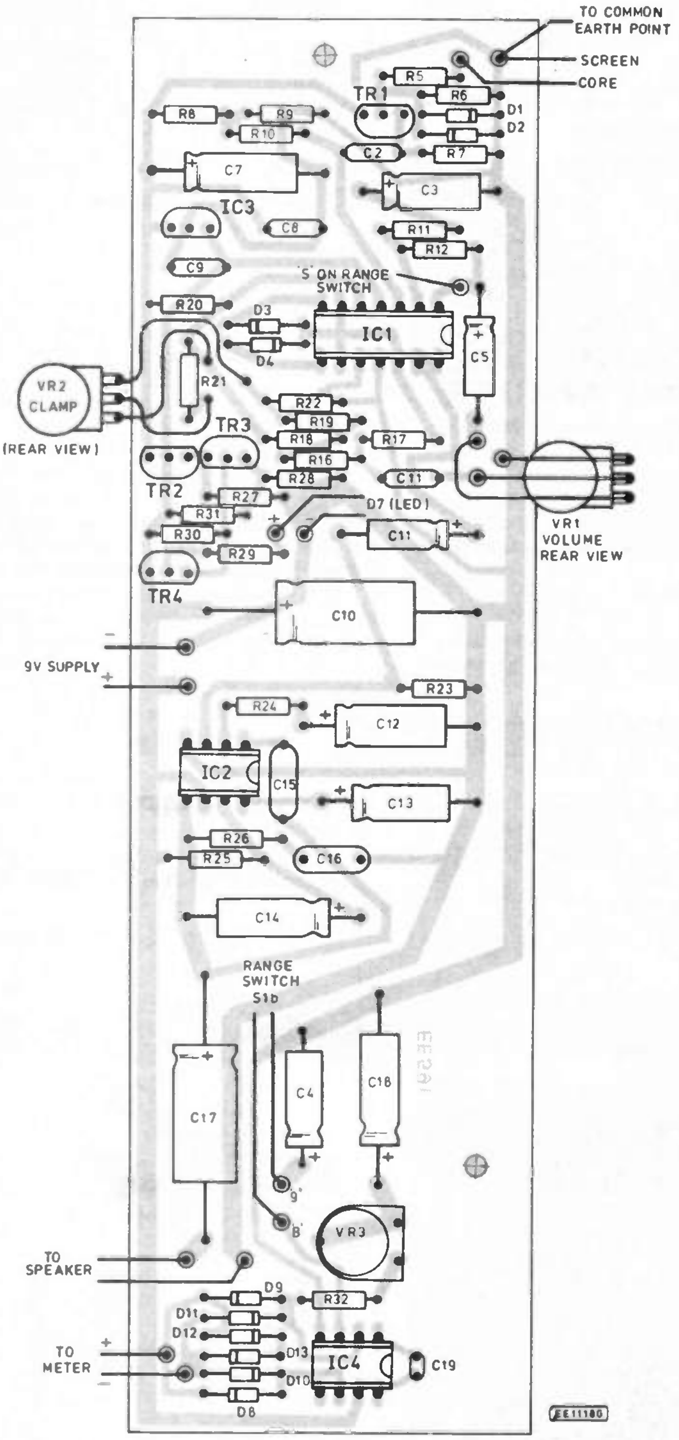


Fig.5. Printed circuit board component layout and wiring details for the case mounted components.

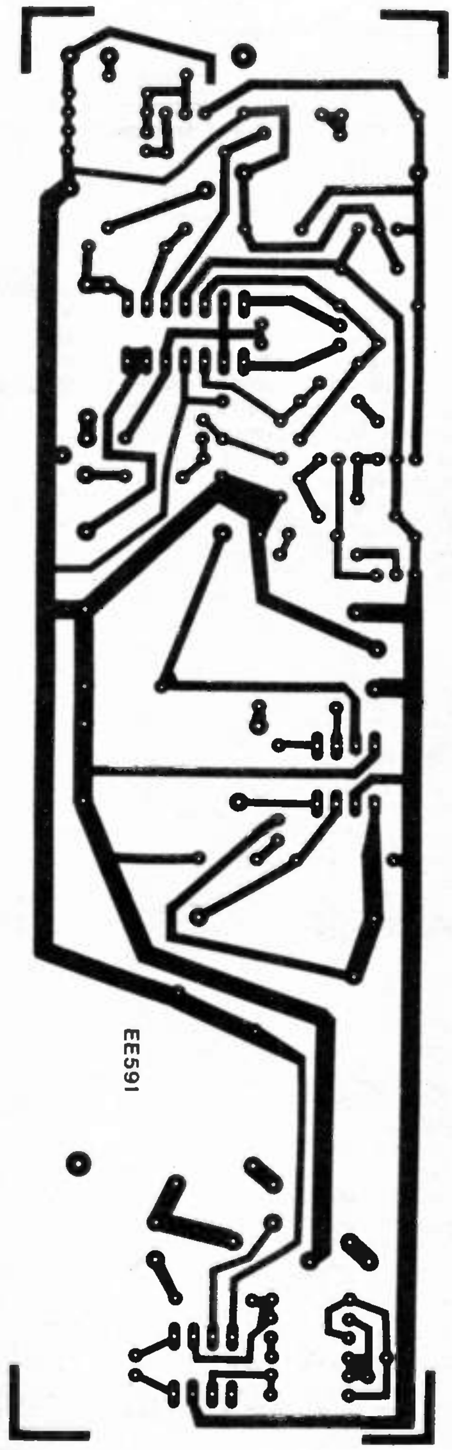
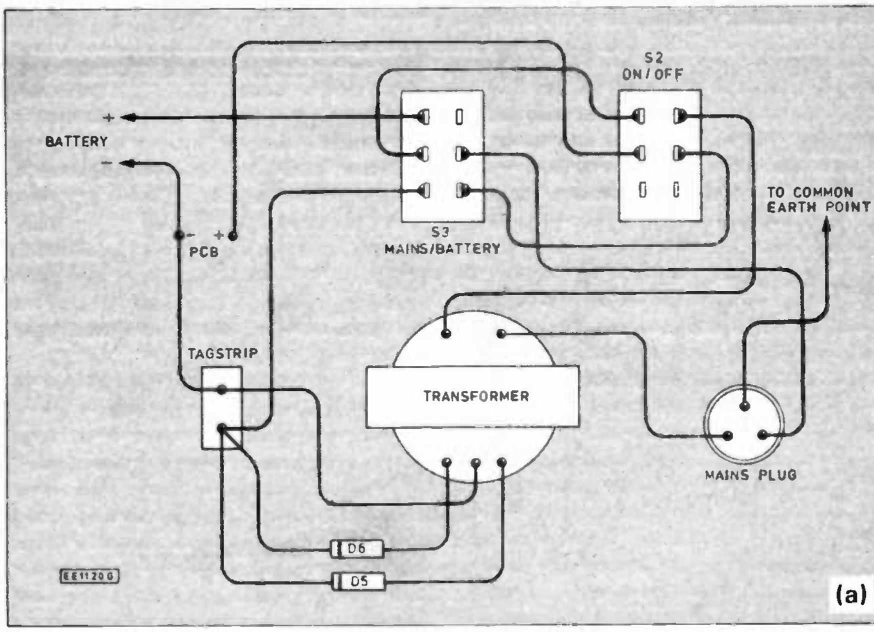


Fig.4. Full size printed circuit master foil pattern. This board is available from the EE PCB Service, *code EE591.*



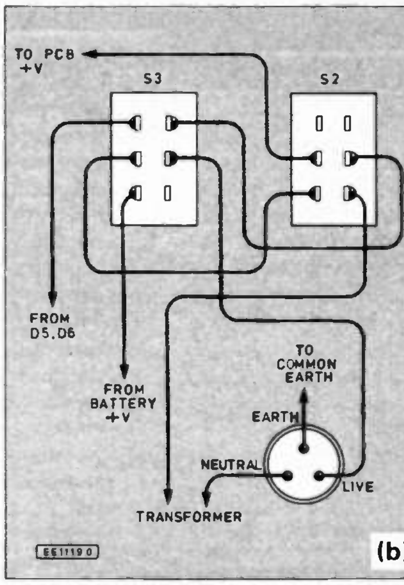


Fig.6. (a) Switch connections, centre and upper tags connected when toggle is down. (b) Alternative connections where switch centre and lower tags are connected when toggle is down.

connect the leads from S1a, S1b, VR1 and VR2, plug in IC1 (with the power off, of course), then power up again and check the four outputs of this chip. These are the four corner pins. IC1a, pin 1, should show about 4V d.c., as should IC1d, pin 14. IC1b, pin 7, should be about 8V and IC1c, pin 8, about 1V.

Meter amplifier IC4 can now be tested. (As a matter of interest, for sharp-eyed readers who have noticed that the prototype is fitted with a 100μA movement, this is in fact shunted with a 470 ohm resistor to convert it to 1mA which proved a better choice for this circuit.) To continue, set preset potentiometer VR3 to about mid-scale, plug in IC4 and power up. On switching on, the meter will probably drive to full scale and then quickly settle back.

With the input circuitry unscreened there will probably be a fair amount of hum pick-up which will cause a reading; if it's too much select a less sensitive range with S1. Touching the input should increase the reading. If it does, this stage is probably working correctly.

Connect up the speaker and plug in IC2. Varying degrees of hum should be obtainable, depending on Range switch and Volume control settings. If it's loud, backing off the "Clamp" control VR2 should produce an audible change in the quality of the sound and perhaps a drop in its volume, though this won't be all that apparent on a messy low frequency signal. This completes p.c.b. testing.

INTERWIRING

The board can now be fitted into the case and permanently connected to the controls and internal power supplies. Most of the wiring is self explanatory, but the following notes may help.

Concerning the mains/battery and on/off switching, miniature switches are used but these MUST be rated for 240V a.c. operation. The contacts on 2-pole changeover types are nearly always arranged as shown, but in some types "on" means centre and upper tags connected, in others its centre to lower. As mains voltage is involved, connections for both types are shown in detail in Fig. 6.

Check which type you have with a meter and follow the appropriate diagram carefully. Take care not to touch live parts when testing with mains power operation.

Diodes D5 and D6 are attached to the tagstrip by one end only, the others being attached directly to the transformer leads. These connections should be sleeved; "heatshrink" is ideal. The transformer centre tap goes to the other tag on the strip, completing the mains supply.

The screened lead from S1a is cut to length and soldered to the input before the shield is fitted. Also, 5cm of wire with a 6BA solder tag is soldered to the "ground" input connection along with the screen.

The shield can now be fitted with two nuts, beneath the top one of which goes the above solder tag, plus another for the earth lead from the mains plug. All the case metalwork is thus earthed at the same point, effectively avoiding loops.

Of course, the transformer is in contact with the plate, but on the prototype this hasn't caused problems. It could be insulated and connected to the same point should this prove necessary.

CALIBRATION

The only adjustment necessary is calibration of the meter. Meters, it must be said, ain't what they used to be. They cost the same, they look the same, but the movements are often just moulded plastic and metal stampings, not the all-metal construction they once were.

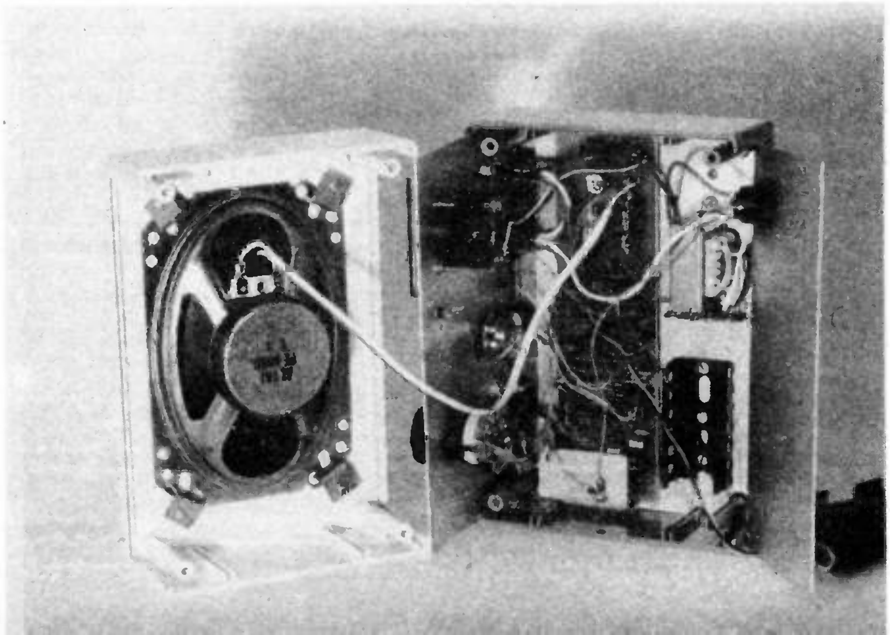
The accuracy is generally less than the 2 per cent f.s.d. claimed, in places a lot less. In particular there is sometimes a sudden severe loss of accuracy at f.s.d., so calibration at about 50 per cent scale is recommended as the best compromise.

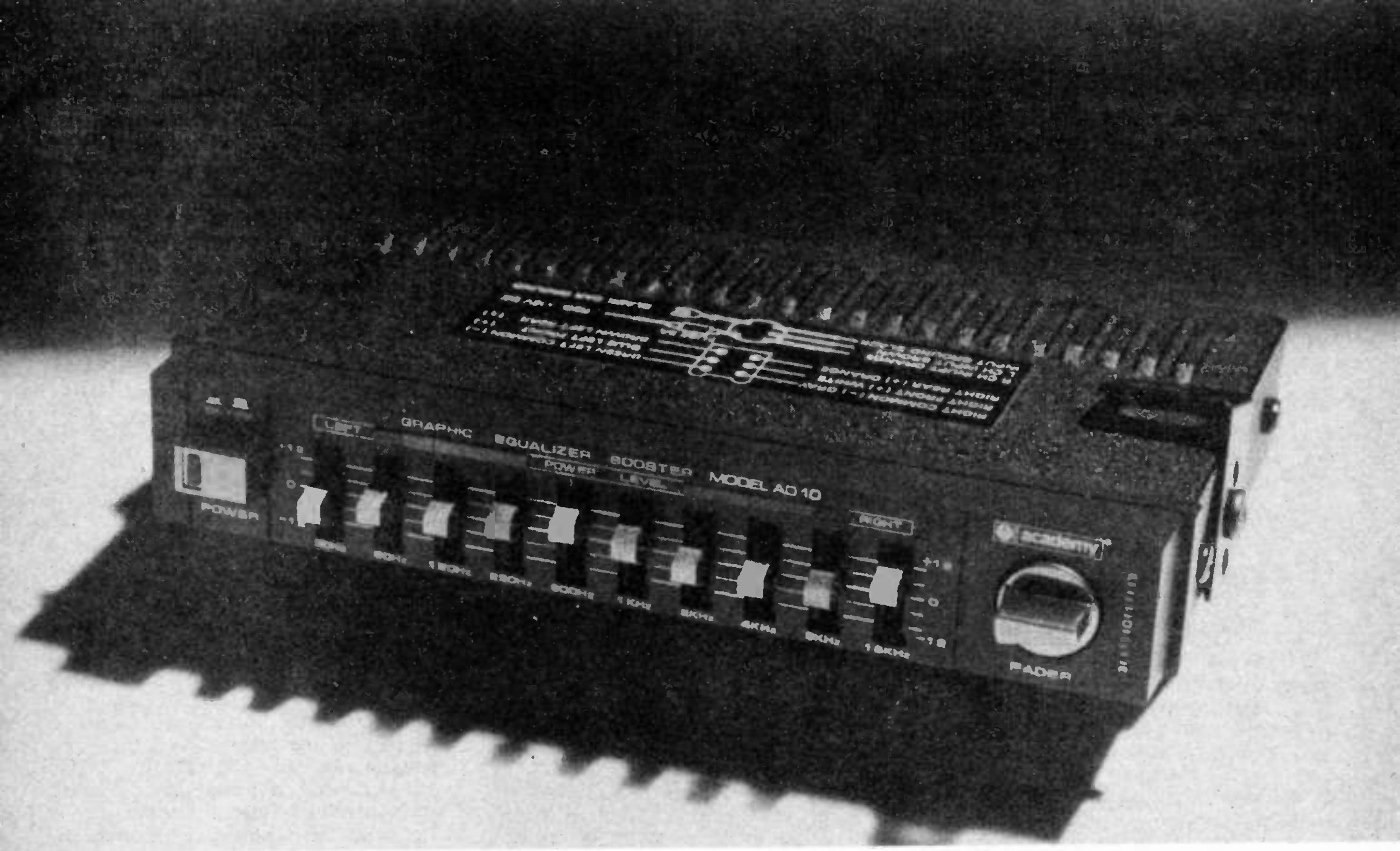
Simply inject an input of about half-scale on any range (a transformer giving 5V to 6V into the 10V range will do!) monitor it with a good meter and adjust preset VR3 until the readings correspond. Although intended as a rough and ready guide to input level, the circuit is capable of surprising accuracy, probably to 1 per cent with a good movement should this be available.

This amplifier should quickly prove invaluable in most workshops. The ease with which signals can be tracked and their quality assessed will simplify many tasks, both in design and repair. The meter provides an immediate reading of signal level and can be used to check gain, attenuation, etc.

Although not tried on the prototype, it would probably be possible to make a test lead incorporating a diode demodulator probe, allowing checks of amplitude modulated signals such as the i.f. stages of a.m. radio receivers. This would increase its usefulness even further. □

The completed amplifier showing the speaker mounted in the top of the case and the small L-shaped input screening plate together with the "earthing" solder tags.





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Constructional Project

QUIZMASTER

W. HUNTER

No more arguments! You will always be in control if you build this low cost quiz controller.

RECENTLY a member of one of the local youth clubs asked the author to design a quiz controller similar to those used in television quiz shows. The club was about to begin running a series of quizzes where four contestants would compete to answer a series of general knowledge questions. The quiz controller was required to indicate which of the contestants pressed their answer button first.

The device was to be simple to use, inexpensive, reliable, and battery operated. The latter was required because the device might have to be used in locations where a mains socket would be unavailable. Several designs were looked at, but the one described here was the simplest and least expensive reliable design that was tried.

CIRCUIT DESCRIPTION

The circuit diagram for the Quizmaster is shown in Fig.1, consists of four identical sections each dealing with one push button. At switch on, six volts is applied to the circuit through the toggle switch S1, and through the Reset switch S2.

The gates of the thyristors are all tied to the zero volt line through the resistors R3, R5, R7 and R9, and so the thyristors are held off. If push button S3 is pressed, current is fed through resistor R2, Zener diode D5 and switch S3 to the gate of the thyristor CSR1 and it is turned on. Current flows from the supply line through resistor R1, light emitting diode D1 and thyristor CSR1 to the zero volt line, and thus lights D1.

INHIBITOR

Resistor R1 fulfills two functions, it limits the current flowing through the l.e.d. whose thyristor is turned on, and it provides a voltage drop on the common supply line which feeds power to each of the channels. This drop reduces the voltage on the common line by about four volts, so that it sits at around two volts instead of six.

If any other contestant's button is pressed now, the gate of their thyristor will be connected to this common supply line, but because the voltage is reduced to about one third of its previous value, there will be insufficient current to turn their thyristor on. Thus the first thyristor to "fire" inhibits all the others from firing and so only one l.e.d. can light.

Originally the circuit had only resistors feeding the thyristor gates from the common supply line, but on test it was found that the gate sensitivity of the thyristors varied so much that it was not possible to choose a resistor value that would work reliably with every thyristor. The gates of some thyristors were found to be so sensitive that they would still turn on with the current supplied from the reduced common supply rail through the 47k gate resistor.

If this resistor was increased in value sufficiently, this problem could be prevented, but less sensitive thysistors would not then trigger with this resistor value even on the full supply. It would have been possible to tailor the value of each gate resistor to suit the sensitivity of the gate, but it was felt that this was not

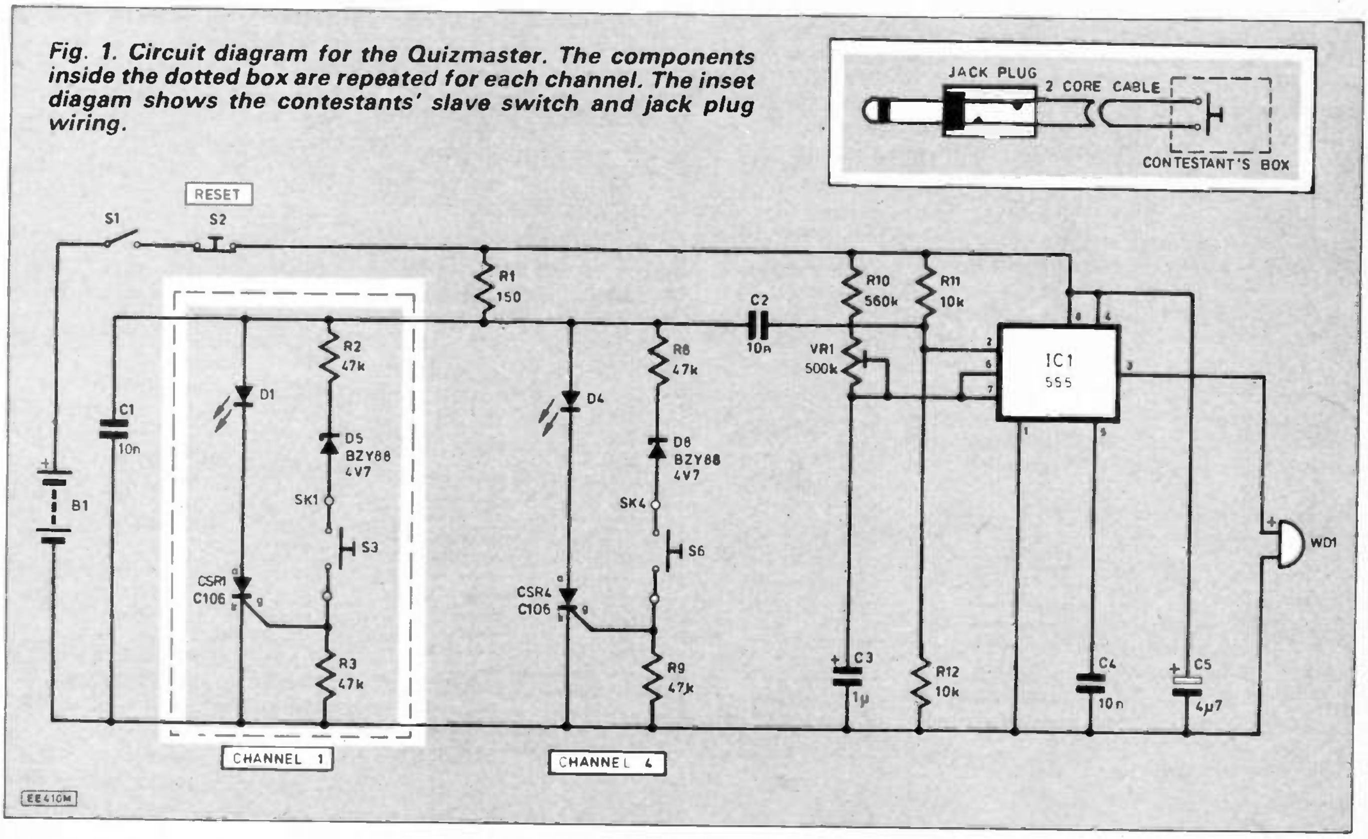


Fig. 1. Circuit diagram for the Quizmaster. The components inside the dotted box are repeated for each channel. The inset diagam shows the contestants' slave switch and jack plug wiring.

really solving the problem and any drift in the component values or supply voltage could cause the circuit to become unreliable. Also if a thyristor ever required changing, then the resistor value would probably have to be modified too.

Because of these factors, Zener diodes were added to eliminate the above problems. These are 4.7V Zeners, so that when the common supply line drops to around two volts, there is insufficient voltage to cause the Zeners to conduct, and therefore no current flows into the gate of the thyristors and the thyristors are not turned on.

TURN ON

It may seem possible for two thyristors to turn on if two "slave" buttons were pressed at exactly the same time, but in practice one channel always wins and inhibits the others. This was tested by wiring a two-pole toggle switch to two of the channels and repeatedly switching on and off. It was found that it was impossible to get two channels on at once.

It was also found that during this test, it could be either of the two channels which would come on, thus showing that the poles of the toggle switch closed at virtually the same time. The test was repeated for many permutations of channels and the circuit was found to perform faultlessly.

The thyristor which turns on is latched into the conducting state by virtue of the current flowing through it, and so the l.e.d. will remain lit even if the contestant releases his button. Indeed, it will remain lit until the "master" Reset switch interrupts the supply to the circuit allowing the current flowing through the thyristor to fall to zero.

Capacitor C1 is required to limit the rate of rise of voltage on the common supply line when power is first applied, or when the Reset button is released. It is a characteristic of a thyristor that if the voltage across it rises too quickly, the thyristor will turn on, C1 prevents this.

When any channel turns on, the negative going voltage level on the common supply line is transmitted through capacitor C2 and triggers the CMOS 555 timer. This is wired as a monostable with a period of a second or so and its output drives an audible warning device, WD1, to indicate that a contestant has pressed his button. The period of the monostable can be adjusted by preset VR1 to a value that suits the user.

The audible warning device is driven by a monostable so that the duration of the bleep is fixed and is not dependent on the length of time that the contestant holds his button down. As well as ensuring that the bleep sounds long enough to be noticed, this also ensures that the duration is not too long so as to conserve battery life.

With the values given for VR1 and C3 the duration of the bleep can be varied over a fairly wide range. If desired, the duration of the 555 can be calculated from $T = 0.64CR$, (where C is the value of capacitor C3 in Farads and R is the value of resistor R10 plus preset VR1 in Ohms) and a fixed resistor wired in place of the variable one.

The thyristors carry very little current and so could be very low power devices, but the designer used C106 thyristors in the prototype because although they are fairly high power devices they were found to be amongst the cheapest available. Other thyristors could be substituted, but the gate resistors may need to be adjusted if the substitute has a very different gate current.

CONSTRUCTION

The Master Control circuit can be built on a piece of 0.1in matrix stripboard, size 14 strips × 37 holes. The component layout and underside view showing breaks in the copper strips is shown in Fig.2.

The circuit board is fixed to the bottom of the box using self-adhesive printed circuit guides. The unit can be housed in any suitable case, the author's model being built in a plastic case with a sloping front panel whose dimensions are 161mm × 96mm × 39mm. A sloping box was used as this gives good visibility of the l.e.d.s for the operator, and does not slide away when the Reset button is pressed.

Each of the contestant's "slave" push-buttons is housed in a small plastic box measuring 72mm × 50mm × 25mm and is connected to the main box by an 8 metre length of two-core flex. The flex enters the contestants

COMPONENTS

Resistors

R1	150
R2 – R9	47k (8 off)
R10	560k
R11, R12	10k (2 off)
All 0.25W carbon	

Potentiometer

VR1	500k miniature skeleton preset, horizontal.

Capacitors

C1, C2, C4	10n polyester layer
C3	1µ tant. 35V
C5	4µ7 elec. 63V

Semiconductors

D1 – D4	Green l.e.d.
D5 – D8	BZY88 4V7
CSR1 – CSR4	C106 Thyristor
IC1	CMOS 555 Timer

Switches

S1	s.p.s.t. miniature toggle
S2	s.p. push button (push-to-break)
S3 – S6	s.p. push button (push-to-make)

Miscellaneous

WD1 6V solid-state buzzer; JK1-JK4 jack plugs (3.5mm), 4 off; SK1-SK4 jack sockets (3.5mm), 4 off; sloping front case, 161mm × 96mm × 39mm; small plastic box, 72mm × 50mm × 25mm (4 off); B1, 4 × AA cells; battery holder; stripboard, 36 holes by 14 strips (240mm × 90mm); connecting wire and solder, etc.

Approx. cost Guidance only £12 (excl. cases)

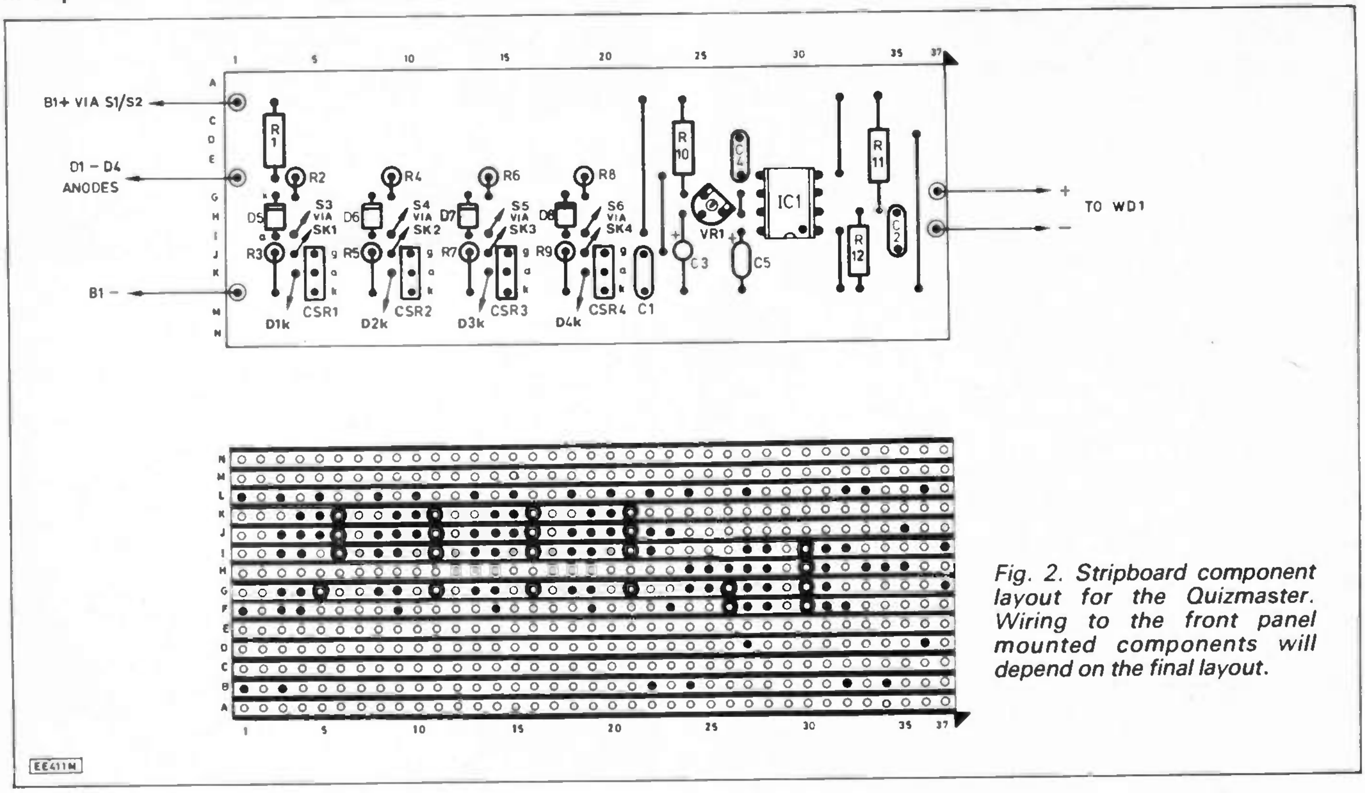


Fig. 2. Stripboard component layout for the Quizmaster. Wiring to the front panel mounted components will depend on the final layout.

box through a small grommet and is anchored inside the box with a P-clip to prevent it being pulled free.

The other end of the flex is terminated in a miniature jack plug. The contestants boxes could be wired directly into the main box, but because of the long wires required on the boxes, they would tangle very easily and the extra cost of the jack plugs and sockets is money well spent. The battery B1 is made up of four AA type cells which are housed in a battery holder and this along with the jack sockets is mounted on the back panel of the control case, see Fig. 3.

FRONT PANEL

The layout details of the "Master" front panel and back of the case is shown in Fig. 3. The final layout will depend on components used, but once it has been completed, the front panel should be labelled with instant lettering or something similar and then sprayed with a coat of clear protective lacquer. It is also advisable to label the jack socket positions on the rear panel with the appropriate channel numbers so that there is no confusion when the unit is in use.

When all the wiring is completed, it only remains to insert the batteries, plug in the contestants boxes, and test the unit. Because of the simplicity of the circuit, it should prove to be very reliable, the weakest part being the wires which connect to the contestants slave units. But if these are not abused, they should give years of trouble free use.

The power consumption of the unit when "idling" is very low, being mainly the quiescent current of the CMOS 555, which is well below 100μA at 6V and the current through the resistors R11 and R12 which is about 300μA. This current rises to a few tens of milliamps when the bleeper and l.e.d.s are on, but even so the batteries should last for a very long time before requiring replacement.

The unit as described is for four contestants, but it could be extended to cover any number by merely adding the components shown inside the dotted lines in the circuit diagram. Obviously a larger case and stripboard would also be required. □

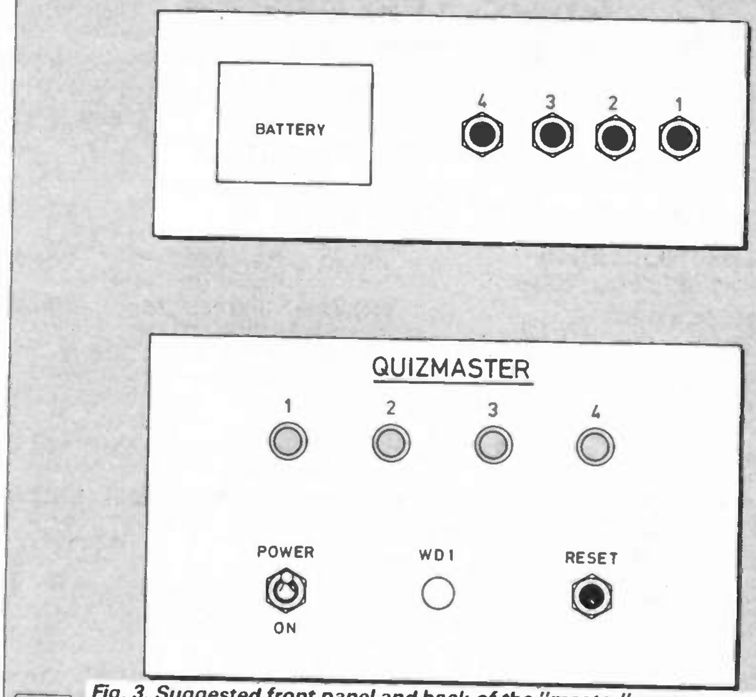


Fig. 3. Suggested front panel and back of the "master" case component layout and labelling. The grille for the buzzer WD1 can be made by drilling a series of small holes or a single larger hole in the sloping panel.

City and Guilds C+G

INTRODUCING MICROPROCESSORS

MIKE TOOLEY B.A.

Part 3

MICROPROCESSORS

In Part 2 we examined the internal architecture and external control signals of a hypothetical microprocessor. In this part we shall explain the process of fetching, decoding and executing the sequence of instructions which constitutes a program. We shall also introduce readers to some of the facilities offered by a typical system monitor.

LEARNING OBJECTIVES

The general learning objectives for part three of *Introducing Microprocessors* are that readers should be able to:

(a) Understand and use a subset of the instruction set of any common 8-bit microprocesor (2.2)

(b) Describe, using appropriate diagrams, the microprocessor instruction fetch/execute cycle (2.3)

(c) Understand the facilities provided by a monitor program (2.4)

(Note: City and Guilds module document reference numbers are shown in brackets).

The specific objectives for this part are as follows:

2.2 INSTRUCTION SETS

2.2.1 Explain what is meant by the terms instruction and instruction set.

2.2.2 Explain the form in which instructions are stored and presented to the microprocessor for execution.

2.2.3 Categorise instructions in the following groups:

data transfer

arithmetic and logical

test, branch and control

2.2.4 Explain the following modes of addressing:

implied

immediate

absolute.

2.2.5 Examine a subset of the instruction set of any common 8-bit microprocessor and identify the types of instruction for data movement (transfer), control, and arithmetic.

2.3 FETCH-EXECUTE CYCLE

2.3.1 Explain each stage of the fetch-execute cycle.

2.3.2 Explain the function of the Program Counter, Instruction Register and Instruction Decoder during the fetch-execute cycle.

2.3.3 Draw a timing diagram showing the state of the read, write (or read/write), and bus lines at each stage of the fetch-execute cycle for a representative 8-bit microprocessor.

2.3.4 Draw a timing diagram to show the movement of data during each stage of the fetch-execute cycle.

2.4 MONITOR PROGRAMS

2.4.1 Use a monitor program.

INSTRUCTIONS AND INSTRUCTION SETS

The individual commands contained within a microprocessor program are called instructions. Clearly, if a microprocessor is to be capable of performing a variety of operations, a range of different instructions must be available. Some of these will be concerned with moving data from place to place and are aptly known as "data-transfer" instructions. Others are used to perform "arithmetic and logic" functions. A third type of instruction is needed to control the overall flow of the program. Such instructions form part of the "test, branch and control" group.

The microprocessor keeps track of its progress through a series of instructions by regularly updating its Instruction Pointer (or Program Counter). This sixteen bit register effectively points to the address of the next instruction to be fetched in the sequence of execution.

A simple IMP program (expressed in hexadecimal format) might take the form:

3E
01 } First instruction (two bytes)
06
02 } Second instruction (two bytes)
80 Third instruction (one byte)

The five byte program contains three instructions. The first two take up two bytes each whilst the last instruction only requires a single byte. The hexadecimal representation is compact but not very explicit and readers might be forgiven for wondering what the program actually does. Furthermore, writing anything other than the shortest of programs in hexadecimal format is clearly going to be a rather tedious process!

In practice we make use of a mnemonic shorthand for writing our instructions rather than resorting to hexadecimal code. However, even programming in hexadecimal is one step removed from the binary codes that the microprocessor actually requires (readers may be unaware that the first generation of computer programmers actually wrote their code in binary!).

As far as the microprocessor is concerned, each instruction comprises an individual binary code (the operation code) which may be followed by one or more further bytes (which constitute an operand). The operand qualifies the instruction in some way and typically may be used to form an address at which data is to be stored or from which data is to be fetched. Clearly, if we are dealing with an operand which is used to denote a 16-bit address, it will require two bytes. IMP knows how many bytes to take as an operand since it is implicit in the operation code which it will have previously decoded.

Assembly language

We have already stated that IMP responds to instructions presented in binary form and that a form of shorthand is used to simplify the task of writing a program. This shorthand is known as "assembly language" and it provides us with a means of expressing our programs in terms of a set of mnemonics.

Assembly language is a low-level language which is (relatively) easy for humans to learn and remember and which can quite easily be translated into the binary code required by a microprocessor. The function of translating mnemonic assembly code into binary code is performed by a utility program known as an "assembler". Some assemblers produce intermediate programs in hexadecimal format which are then translated into binary code for final loading into program memory.

Unfortunately, each microprocessor family has its own dialect of assembly language. This makes it difficult (if not impossible) to transfer programs written in assembly language from one microprocessor to another. High level languages, such as BASIC or PASCAL, are much more "portable" since, with a few changes, they can usually be modified to run on a wide variety of machines.

Happily, IMP's assembly language is reasonably conventional. The following instructions (and their hexadecimal equivalents) constitute a small subset of IMP's instruction set. For convenience we have divided these instructions into the three major groups associated with "data transfer", "arithmetic and logic", and "test, branch, and control"

Function	Instruction	
	Mnemonic form	Hexadecimal form
Data transfer		
Immediate data to accumulator	LD A,n	3E xx
Immediate data to B register	LD B,n	06 xx
Memory to accumulator	LD A,(nn)	3A ll hh
Accumulator to memory	LD (nn),A	32 ll hh
Accumulator to register B	LD B,A	47
Register B to accumulator	LD A,B	78
Immediate data to HL register pair	LD HL,nn	21
Memory (pointed to by HL register) to accumulator	LD A,(HL)	7E
Accumulator to memory (pointed by HL register)	LD (HL),A	77
Arithmetic and logic		
Add register A to register B	ADD B	80
Subract register B from register A	SUB B	90
Increment register A	INC A	3C
Increment register B	INC B	04
Increment register HL	INC HL	23
Decrement register A	DEC A	3D
Decrement register B	DEC B	05
Decrement register HL	DEC HL	2B
Test, branch and control		
Jump unconditionally to specified IP address	JP nn	C3 ll hh
Jump to specified IP address if zero flag is set	JP Z,nn	CA ll hh
Jump to specified IP address if zero flag is reset	JP NZ,nn	C2 ll hh

Notes

(a) Mnemonics are used as follows:
  LD = LoaD
  ADD = ADD
  SUB = SUBtract
  INC = INCrement
  DEC = DECrement
  JP = JumP
  Z = Zero
  NZ = Non-Zero

(b) n and xx represents an immediate data byte (values ranging from 00H to FFH)

(c) nn represents a two byte address (values ranging from 0000H to FFFFH)

(d) ll represents the low byte of an address (values ranging from 00H to FFH)

(e) hh represents the high byte of an address (values ranging from 00H to FFH)

Readers should note that the general format used for IMP's data transfer instructions involves a destination followed by a source and that these are separated by a comma. As an example, the instruction LD A,B specifies A as the destination and B as the source. It is also important to note that the load instructions do NOT involve the destruction of the source byte; data is effectively copied from source to destination where it replaces whatever was there before the instruction was executed.

Finally, the meaning of the brackets shown in instructions such as LD A,(HL) are taken to mean "address pointed to by" or "memory location given by". Thus LD A,(HL) means "load the accumulator with the data found at the address pointed to by the HL register pair". This may sound a little wordy but, in order to avoid confusion, it is important to be quite precise.

Addressing modes

The different ways of locating the data to be used by a microprocessor instruction are referred to as "addressing modes". Three commonly used addressing modes are known as "implied", "immediate", and "absolute".

In the "implied" addressing mode another register pair is used to hold the address of the location being accessed. In IMP's case, the instruction LD A,(HL) is an example of this mode. In the "immediate" mode of addressing the data to be used is contained within the instruction itself (i.e. the data in question immediately follows the operation code). The instruction LD A,n is an example drawn from IMP's instruction set. In the "absolute" mode of addressing, the address at which the data is located forms part of the instruction. This mode is exemplified by IMP's LD A,(nn) instruction.

A number of other (more complex) addressing modes exist. These, however, are not really appropriate to an introductory level module and will be left for readers to explore in the event that they continue with studies at a higher level. For the moment, it is merely necessary for readers to be able to recognise and distinguish between the three modes previously mentioned. The following table summarises these modes of addressing and includes examples from IMP's instruction set:

Addresing mode	Data located . . .	Example
Implied	. . at an address pointed to by other CPU registers	LD A,(HL)
Absolute	. . at an address specified in the instruction	LD A,(nn)
Immediate	. . in the instruction itself	LD A,n

Problem 3.1

(a) IMP encounters the hexadecimal values 3E and 00 which appear as successive bytes in a program instruction. What action do they produce?

(b) IMP is performing the assembly language instruction SUB B. If the A register contains the 14H before the instruction was performed and 0AH after the instruction is executed, determine the contents of register B.

(c) A single-byte IMP instruction expressed in binary (MSB first) takes the form 00101011. What action does the instruction perform?

(d) It is necessary to load the HL register pair with 3C02H. What IMP assembly language instruction is required?

(e) What hexadecimal code is used to represent the instruction in (d)?

(f) What addressing mode is used in the instruction LD A,FFH?

(g) To which group or class of instructions does the instruction LD A,(HL) belong?

THE FETCH-EXECUTE CYCLE

The operation of a microprocessor is based upon a continuous sequence of events each of which is known as a "fetch-execute" cycle. The fetch-execute cycle involves the following stages:

(a) Fetching the instruction from memory and placing it in the microprocessor's Instruction Register.

(b) Decoding the instruction (using the Instruction Decoder) and determining what subsequent action is required.

(c) If necessary, fetching more data.

(d) Executing the instruction.

This process is illustrated by the flowchart shown in Fig. 3.1.

Timing diagrams

Timing diagrams show the relationship between control signals and the data and addresses which appears on the microprocessor buses. Fig. 3.2 shows a typical timing diagram which illustrates the sequence of events when IMP performs the instruction LD A,3F. This fetch-execute sequence occupies just two complete machine cycles. During the first machine cycle, IMP fetches the operation code and decodes it. On the second machine cycle, IMP fetches the data byte (3FH) and copies it into the accumulator.

Read and write operations

When performing memory read or write operations IMP performs different tasks on the first and second half-cycle of the clock. During the first half cycle of the clock signal (i.e. when the clock line is high) IMP Places a valid memory address on the address bus and selects either a read or write operation by taking the R/$\overline{W}$ line high or low respectively. Data exchanges then take place during the second half of the clock cycle (i.e. when the clock line goes low), the direction of data movement (i.e. to or from IMP) being determined by the previously set condition on the R/$\overline{W}$ line.

A read cycle (Fig. 3.3) can be used to transfer a byte of data from an address in ROM, RAM, or I/O to one of the IMP's internal registers. A write cycle (Fig. 3.3b), on the other hand, is used to transfer a byte of data from one of the IMP's internal registers to either RAM or I/O. Note that, whilst it is possible to undertake a write operation to an address in ROM there is little point in doing so as this would, by definition, have no effect on the contents of the address location in question.

Example 1

Now, let's consider a simple example. Suppose that we wish to add together two bytes of data stored in RAM as part of IMP's program. This task will involve three instructions. The first will load the first operand (in this case a byte of immediate data) into the accumulator (A). The second will load the second byte of data into the B register. Finally, the third instruction will add the contents of the A and B registers and deposit the result back into the accumulator.

Fig. 3.1 Flowchart for the fetch-execute cycle

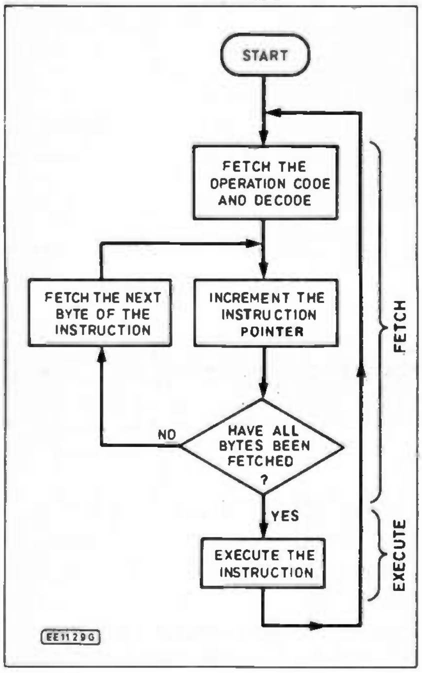
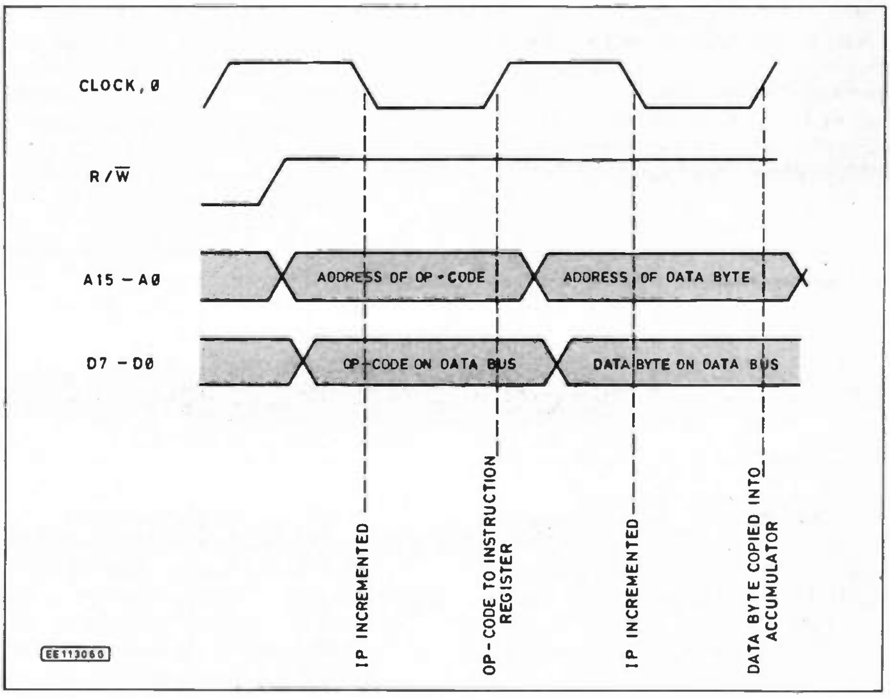


Fig. 3.2 Simplified timing diagram for a typical fetch-execute cycle



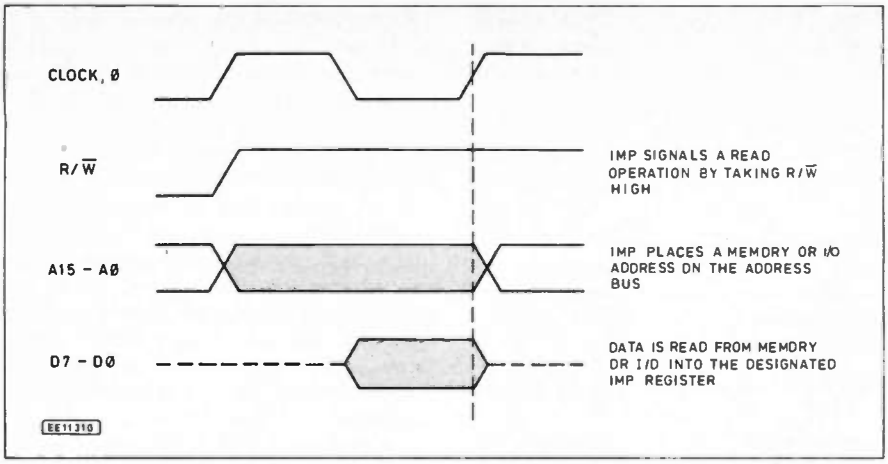
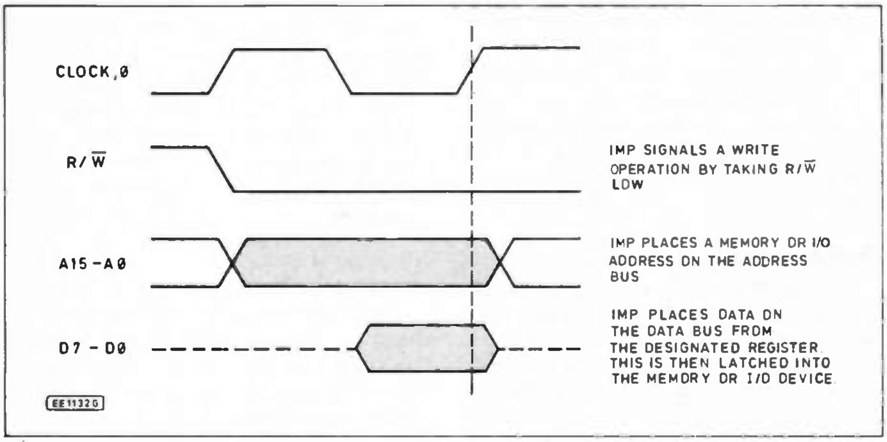


Fig. 3.3a Simplified timing diagram for a read cycle

Fig. 3.3b Simplified timing diagram for a write cycle



We shall assume that the program starts at a hexadecimal address of 1000. Written in assembly language mnemonics, the program looks like this:

LD A,01
LD B,02
ADD A,B

The hexadecimal representation of the program is as follows:

3E 01 First instruction
06 02 Second instruction
80 Third instruction

Readers will probably have spotted that this program is identical to that which we introduced earlier! Note how each of the two load instructions is followed by the respective data to be loaded. Within IMP's memory, the program will thus take the form:

Address (hex)	Byte (hex)	Function
1000	3E	Operation code for LD A,n
1001	01	Immediate data byte
1002	06	Operation code for LD B,n
1003	02	Immediate data byte
1004	80	Operation code for ADD A,B

At the start of the program, the Instruction Pointer will be set to 1000H whilst, at the end, it will have reached 1005H. Execution of the program involves the following steps:

1. Fetching and decoding the first instruction (see Fig. 3.4a).

   IMP places the contents of its Instruction Pointer (1000H) onto the address bus and takes the R/$\overline{W}$ line high. The byte returned on the data bus (3EH) is read during the second half of the clock cycle and passed into the instruction register.
2. Executing the first instruction (see Fig. 3.4b).

   IMP executes the first instruction which involves copying the next byte (i.e. that which follows the operation code, 3EH) into the accumulator. IMP also updates the Instruction Pointer so that it points to the address of the next instruction byte at 1002H.
3. Fetching and decoding the second instruction (see Fig. 3.4c)

   IMP places the contents of its Instruction Pointer (1002H) onto the address bus and takes the R/$\overline{W}$ line high. The byte returned on the data bus (06H) is read during the second half of the clock cycle and passed into the instruction register.
4. Executing the second instruction (see Fig. 3.4d).

   IMP executes the second instruction which involves copying the next byte (i.e. that which follows the operation code, 06H) into the B register. IMP also updates the Instruction Pointer so that it points to the address of the next instruction byte at 1004H.

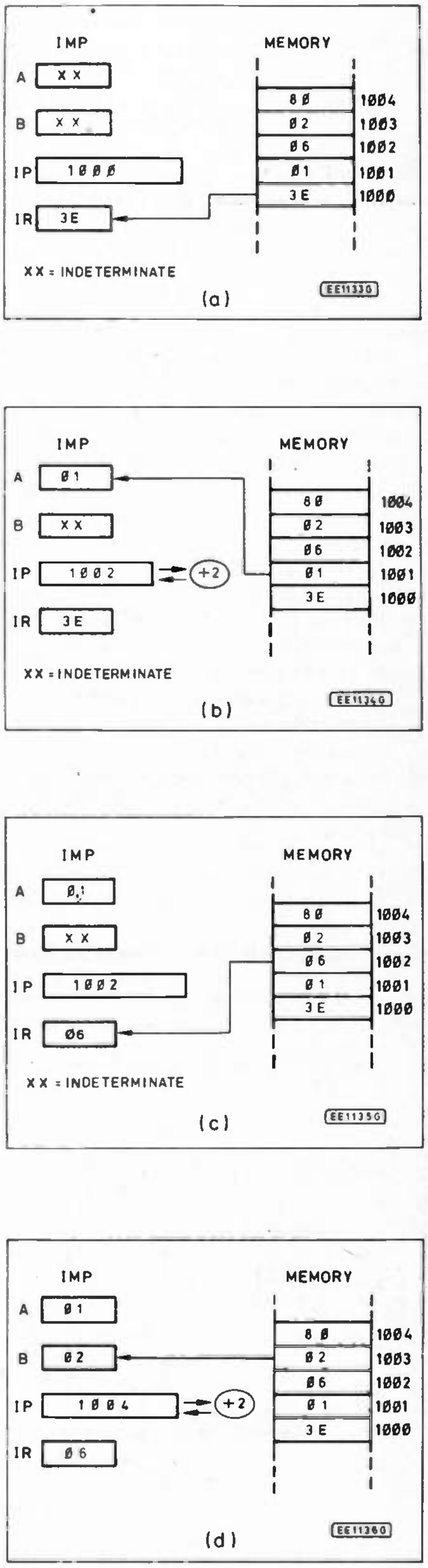


Fig. 3.4 Flow of data between IMP and memory in Example 1 (continued overleaf)

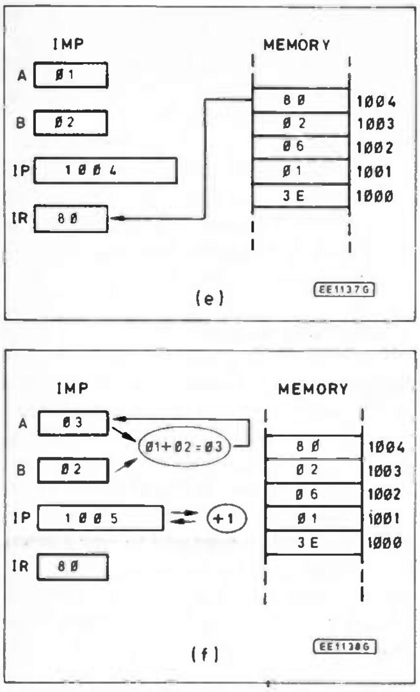


Fig. 3.4. (continued) Flow of data between IMP and memory in Example 1

5. Fetching the third instruction (see Fig. 3.4e).

   IMP places the contents of its Instruction Pointer (1004H) onto the address bus and takes the R/$\overline{W}$ line high. The byte returned on the data bus (80H) is read during the second half of the clock cycle and passed into the instruction register.
6. Executing the third instruction (see Fig. 3.4f).

   IMP executes the third instruction which involves passing the contents of the A and B registers into the ALU and adding the two bytes together. The result is then passed back into the accumulator (replacing the byte that was originally present). Also note that the byte present in the B register has remained unchanged. IMP also updates the Instruction Pointer so that it points to the address of the next instruction byte at 1005H.

Example 2

Now, as a further example, suppose that we wish to copy a byte of data from an address in ROM (G04EH) to an address in RAM (2AB0H). This task would obviously involve two instructions; a read operation followed by a write operation. We shall again assume that the program again starts at a hexadecimal address of 1000H. The program would be written in assembly language as follows:

LD A,(C04EH)
LD (2AB0),A

The hexadecimal machine code corresponding to these two instructions is given below:

3A 4E C0
32 B0 2A

The program thus comprises six bytes. Each operation code byte is followed by a two byte address (in low-byte/high-byte order). Within IMP's memory, the program will thus take the form:

Address (hex)	Byte (hex)	Function
1000	3A	Operation code for LD A,(nn)
1001	4E	Low byte of address operand
1002	C0	High byte of address operand
1003	32	Operation code for LD (nn),A
1004	B0	Low byte of address operand
1005	2A	High byte of address operand

At the start of the program, the Instruction Pointer will be set to 1000H whilst, at the end, it will have reached 1006H. The execution of the program involves the following four steps:

1. Fetching and decoding the first instruction (see Fig. 3.5a).

   IMP places the contents of its Instruction Pointer onto the address bus and takes the R/$\overline{W}$ line high. The byte returned on the data bus (3AH) is read during the second half of the clock cycle and passed into the instruction register.
2. Executing the first instruction (see Fig. 3.5b).

   IMP executes the first instruction which involves reading the next two bytes (4EH and C0H) and using them to form an address (C04EH) which is then placed on the address bus. The data present at C04EH is then copied into the accumulator during a further read operation. IMP again updates the Instruction Pointer so that it ends up pointing to the address of the next instruction byte at 1003H.
3. Fetching the second instruction (see Fig. 3.5c).

   IMP places the contents of its Instruction Pointer (1003H) onto the address bus and takes the R/$\overline{W}$ line high. The byte returned on the data bus (32H) is read during the second half of the clock cycle and

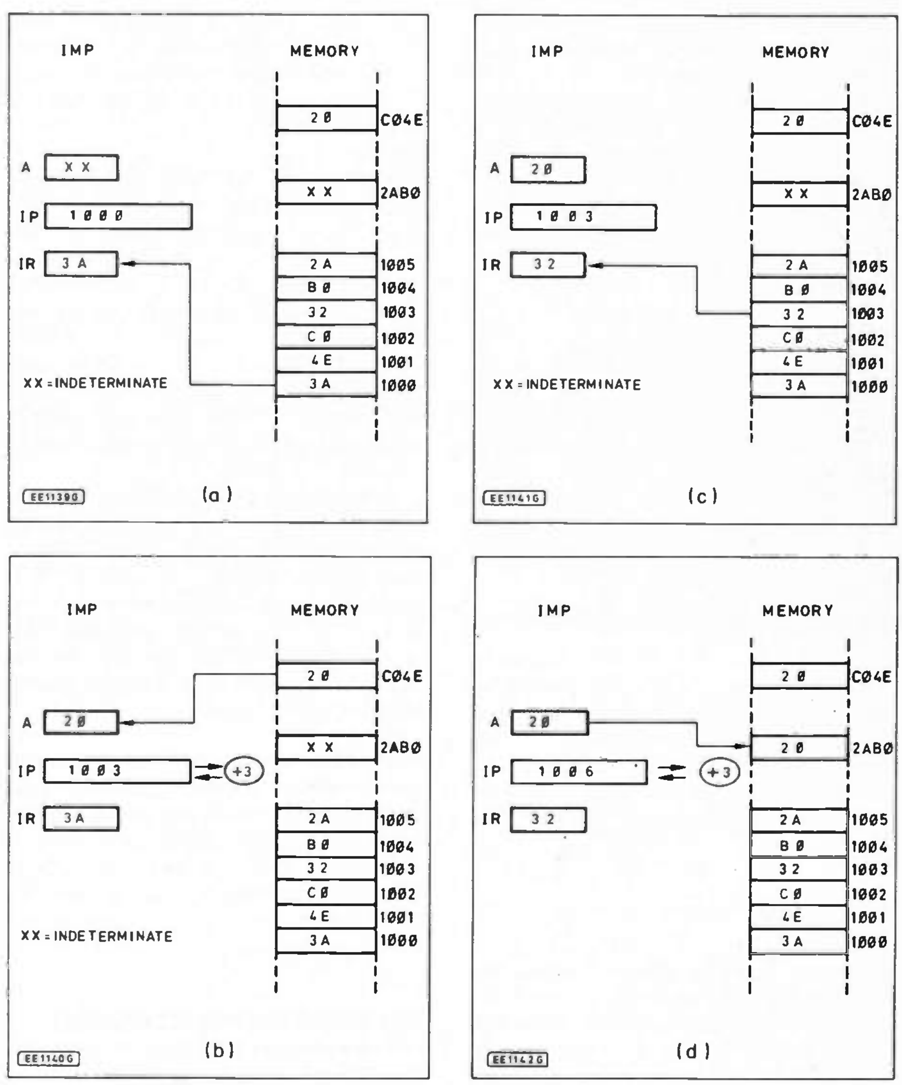


Fig. 3.5 Flow of data between IMP and memory in Example 2

MACHINE CYCLE	M1	M2	M3	M4
TYPE OF CYCLE	MEMORY READ (OP-CODE FETCH)	MEMORY READ	MEMORY READ	MEMORY WRITE (EXECUTE)
ADDRESS BUS	IP (LOCATION OF OP-CODE BYTE)	IP+1 (LOCATION OF SECOND INSTRUCTION BYTE)	IP+2 (LOCATION OF THIRD INSTRUCTION BYTE)	ADDRESS ASSEMBLED FROM DATA READ DURING M2 & M3
DATA BUS				

Fig. 3.6 Table for Problem 3.2

passed into the instruction register.

4. Executing the second instruction (see Fig. 3.5d).

   IMP executes the second instruction which involves reading the next two bytes (B0H and 2AH) and using them to form an address (2AB0H) which is then placed on the address bus. The data present in the accumulator is then written to address 2AB0H during a final write operation. IMP also updates its Instruction Pointer so that it ends up pointing to the address of the next instruction byte at 1006H.

Readers should now be getting a "feel" for the way in which IMP operates. In particular, the following should be noted:

(a) instructions may comprise one, two, three (or more) bytes.
(b) instructions comprise an operation code which may be followed by a further byte or bytes which constitutes an operand.
(c) instructions may involve further read and/or write operations, not just fetching (i.e. reading) the instruction itself.

Problem 3.2

Fig. 3.6 shows the sequence of operations which occur during the fetch-execute cycle associated with the instruction LD (2E00),A. Given that the accumulator contains 7FH immediately before the instruction is executed, complete the table showing the byte present on the data bus at each stage of the fetch-execute cycle.

Problem 3.3

Write simple assembly language programs (using only the given subset of IMP's instruction set) which will:

(a) add 1 to the data stored in memory location 3E00H,
(b) exchange the data bytes present at memory locations 3E00H and 3E01H.

MONITOR PROGRAMS

Monitor programs provide us with a variety of useful facilities which can not only aid our understanding of the operation of a microprocessor but also allow us to enter, test and debug simple programs. A typical monitor program comprises about 2K of code and provides the user with the means to:

(a) display the contents of a given block of memory in hexadecimal and ASCII (see note 1) format
(b) modify or edit hexadecimal bytes in memory
(c) display the contents of the CPU registers
(d) modify the contents of the CPU registers
(e) disassemble a given block of memory into assembly language mnemonics
(f) insert breakpoints (see note 2) into a program
(g) execute a program from a given start address until a breakpoint is encountered
(h) trace the execution of a program with a continuous display of the CPU registers and memory contents as each instruction is executed

Notes:

1. ASCII stands for "American Standard Code for Information Interchange". The ASCII code is commonly used for representing alphanumeric characters (i.e. letters, numbers and punctuation) within a microprocessor system. Each character is represented by a single byte (i.e. 8 bits). Since the standard ASCII code uses seven bits, the leading (i.e. most significant) bit is either ignored or used to distinguish special graphic characters or tokenised keywords.
2. A breakpoint is a code (usually a single byte) inserted into a program during testing or debugging which, when encountered during the course of a program, suspends execution and returns control to the monitor program. This facility allows the user to examine the state of the system when a certain point is reached in the program.

NEXT MONTH: we shall explain how the system monitor is used. We shall also pause to review parts one to three of the course and prepare readers for the first assessment and first practical assignment. We shall also attempt to deal with points which readers have raised in our first *Readers Forum*.

BACKGROUND READING

The following background reading is suggested for this month:

(a) Chapter 3 (Software and Programming) of **Beginner's Guide to Microprocessors** by E.A. Parr (a Newnes Technical Book published by Heinemann-Newnes) ISBN 0 408 00579 3. Available from the *EE Book Service* – see page 60.
(b) Chapter 3 (Microprocessor Instruction Sets) of **Microelectronic Systems 2** by R. Vears (published by William Heinemann Ltd) ISBN 0 434 92194 7. Available from the *EE Book Service* – see page 60.

CORRESPONDENCE

Comments and queries from readers are welcome and should be sent directly to the author at the following address: Department of Technology, Brooklands Technical College, Heath Road, Weybridge, Surrey KT13 8TT.

Please include a stamped addressed envelope (and be prepared to wait a little!) if you require an individual reply. General queries will be dealt with in *Readers Forum* which will appear in Parts Four and Nine of the series.

MODULE DOCUMENTATION

Readers requiring their own copy of the module documentation should send a cheque or postal order for £10 to the following address, clearly stating "Everyday Electronics – Introductory Microprocessors 726-303" in an accompanying letter (do not forget to include your name and address!): Publications Department, City and Guilds, 76 Portland Place, London W1N 4AA.

GLOSSARY FOR PART THREE

Address modes
The various methods of specifying an address as part of an instruction.

Assembler program
A program which translates assembly language statements into the binary code machine code which is directly executable by the microprocessor.

Assembly language
Assembly language is a machine-oriented low-level programming language as distinct from human-oriented high-level languages. An assembly language program is normally written as a series of statements using mnemonics. It is then translated into machine code by an assembler program.

Decrement
Programming instruction which decreases the contents of a register or storage location.

Execute (cycle)
The last part of the fetch-execute cycle during which the operation specified by the instruction is actually performed.

Fetch (cycle)
The first part of the fetch-execute cycle during which the instruction is fetched from program memory. The first part of the instruction to be fetched is the operation code.

Increment
Programming instruction which increases the contents of a register or storage location.

Instruction cycle
The total group of instructions that can be executed by a given microprocessor. This information provides the programmer with the basic information necessary to produce a working program.

Machine language
Binary coded language (often represented in hexadecimal) that is directly understood by the

microprocessor. All other programming languages must be translated into binary code before they can be executed by the microprocessor.

Mnemonic code
Mnemonic codes are a form of shorthand which helps the programmer remember the function of a particular microprocessor instruction.

Operation code (op-code)
The first part of a machine-language instruction which specifies the operation to be performed.

MACHINE CYCLE	M1	M2	M3	M4
TYPE OF CYCLE	MEMORY READ (OP-CODE FETCH)	MEMORY READ	MEMORY READ	MEMORY WRITE (EXECUTE)
ADDRESS BUS	IP (LOCATION OF OP-CODE BYTE)	IP+1 (LOCATION OF SECOND INSTRUCTION BYTE)	IP+2 (LOCATION OF THIRD INSTRUCTION BYTE)	ADDRESS ASSEMBLED FROM DATA READ DURING M2 & M3
DATA BUS	32 (OP-CODE)	ØØ (LOW BYTE OF ADDRESS OPERAND)	2E (HIGH BYTE OF ADDRESS OPERAND)	7F (BYTE FROM ACCUMULATOR)

Fig. 3.7 Answer to Problem 3.2

ANSWERS TO PROBLEMS

3.1 (a) load the accumulator with immediate data of 00H
(b) 0AH
(c) DEC HL
(d) LD HL,3C02
(e) 21 02 3C
(f) immediate
(g) data transfer

3.2 See Fig. 3.7

3.3 (a) Any of the following would be acceptable:

LD A,(3E00)
LD B,1
ADD A,B
LD (3E00),A

or **LD A,(3E00)**
INC A
LD (3E00),A

or **LD HL,3E00**
LD A,(HL)
INC A
LD (HL),A

or **LD HL,3E00**
LD B,1
LD A,(HL)
ADD A,B
LD (HL),A

3.4 One possible solution would be:

LD A,(3E00)
LD B,A
LD A,(3E01)
LD (3E00),A
LD A,B
LD (3E01),A

PLEASE NOTE

We apologise for a couple of errors which unfortunately appeared in Part 1. We actually managed to miss out Table 3 completely (the Editor did the make up!); however a similar table was published on Data Card 2 – Powers of 16 – given in last month's issue.

Under Addition (page 597) the second paragraph set an example and we then added two completely different numbers – please disregard the second paragraph.

Finally, the answer to Problem 1.14(a) should have been 00000101, the MSB was wrong.

SPECIAL OFFER...

Made by Altai these two special price items would make excellent Christmas gifts.

SB7 Headphones

High quality lightweight stereo headphones. Black adjustable headband with coloured earpieces. Packed in attractive display box.

Impedance: 32Ω
Response: 30-12,000Hz
Power: 100mW
Lead: .... 1.8m Straight Screened
Plug: .... 6.35mm Stereo
Weight: 140g

Available in white or yellow – please state preference when ordering.

SB12 Headphones + Speakers

Combination pack of "Walkman" type player units consisting of stereo headphones and a pair of micro speakers with leads, in a variety of colours. Packed on clear plastic display card.

Speakers
Impedance: 8Ω
Rating: 0.5W
Dimensions: .... 87 × 55 × 29mm

Headphones
Impedance: 32Ω
Response: 20-20,000Hz
Power: 100mW

Available in blue, yellow or green – please state preference when ordering.

Please supply

Quantity		Value
	SB7 Headphones @ £3.95	
	SB12 Headphones + speakers @ £3.50	

Overseas readers please add £1 for postage — Total £

Please make cheques payable to Greenweld Electronic Components

BLOCK CAPITALS PLEASE

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OFFER CLOSES Friday, January 29, 1988

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Post to: *EE* Offer, Greenweld Electronic Components
443 Millbrook Road, Southampton SO1 OHX

Robot Roundup

NIGEL CLARK

DRAINPIPES do not readily come to mind when considering the latest developments in new technology. Useful and necessary they might be but they are hardly things which set the hearts of roboticists racing. Yet 2½ inch drainpiping is an essential component in a system being offered to schools by a new company, Tribotics, which was set up recently by a group of people who had previously been involved in supplying vision systems to industry.

They saw that robots were getting very expensive, thought that the developments were becoming very complex and decided to find out if schools were getting what they required for the teaching of technological subjects.

Tribotics thought that there might be a particularly pressing need following the introduction of the new GCSE syllabuses last September. Their investigations involved asking local schools in the Oxfordshire area what equipment they would like to assist in the teaching of some of the technical subjects.

"The demand was for something fairly large and robust yet inexpensive, to be used in the teaching of control technology," said Bob Vidler, one of the directors. "A number of teachers said that the existing kits were too small and the bigger robot arms were too expensive." He added that they had also wanted to demystify the subject as they felt many people were being put off technology because it was being made unnecessarily complicated.

As a result Tribotics came up with a series of kits which can be used for a variety of subjects. They considered that to concentrate on the teaching of control technology would have been too limiting. Choosing robotics allowed them to cover a number of subjects, including control.

There are two basic d.c. motor units, one powering a hinge for joints and the other a rotating tube for powering items like a conveyor; potentiometers provide feedback.

The drainpiping provides the other main building block.

"We realised that we would need some sort of tube to build the machines and decided on drainpiping because it was cheap and easy to obtain if any had to be replaced," said Vidler.

Prices begin at £75 plus V.A.T. for the starter unit which includes one motor, a hinge and tee connector. The starter kit, the next stage up, has sufficient pieces for a three-axis arm with a lifting capacity of 1kg at full stretch.

There is an extra gripper, with an ingenious design, which can be added to the arm. The closing mechanism is provided by inflating a balloon, giving a clamping power of between 3lb and 5lb. An elastic band re-opens the three fingers.

The kits also include a SCARA arm, conveyor, carousel and, at the top of range, a two-legged device for £650 plus V.A.T. When asked if it could walk Vidler said that depended on the correct instructions being given to ensure that the various limbs moved in a sequence which prevented the machine falling over as it moved.

CONTROL

All the devices can be controlled by the company's own communications box which can be connected to any micro with an 8-bit parallel output. Interfaces are available for 6502-based and Z80-based machines. No specific software is available but instructions can be given in normal Basic.

It is planned to develop the system to provide simple building blocks for use in industry. The company is also looking at requests for a smaller version with which children in primary schools could work. Vidler said that the conveyor system had attracted a lot of interest from the younger schools. However he was not sure that smaller kits to the same design could be produced for the same price.

Other developments include the provision of a light sensor and a RAM camera vision system. It is hoped to have them available by the spring of next year.

The Tribotics kits were the highlight, from the robotics point of view, of the Design and Technology Education Exhibition in October. Otherwise the exhibition, which celebrated its tenth anniversary by moving to the National Exhibition Centre in Birmingham from the Wembley Conference Centre, London, was rather lacklustre.

Many suppliers did not attend including Feedback Instruments, LJ Electronics, TecEquipment and Clwyd Technics. And those which did take space had little new to show.

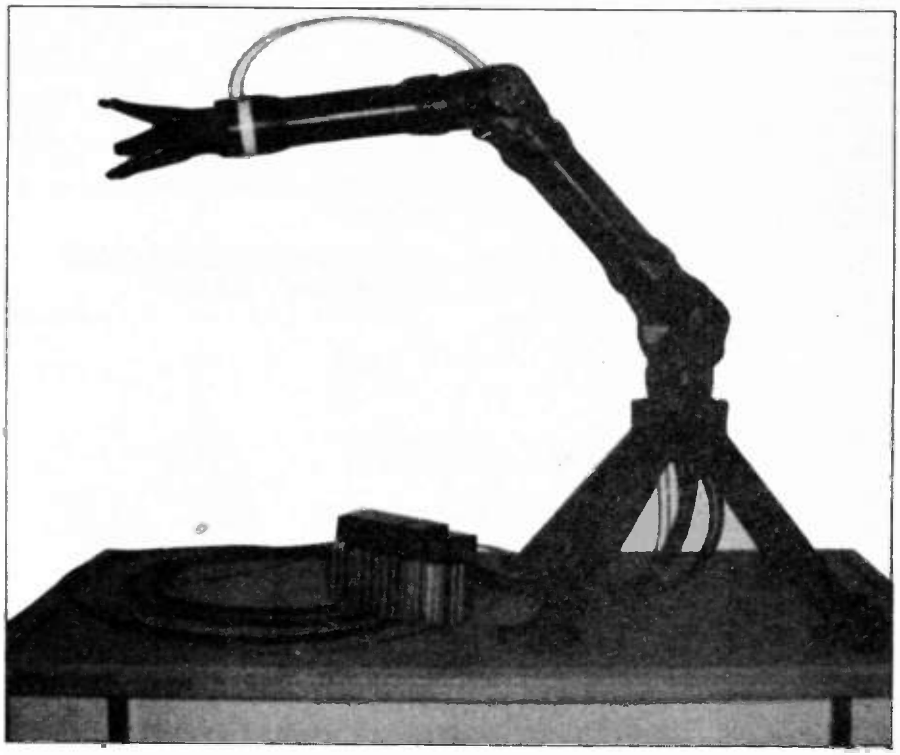
Cybernetic Applications put on its usual good show with its four robots working together in its workcell. Intriguingly there was a model gantry crane at the back of the stand. It was without electronics or a gripper and no detailed explanation of what it would become. But it is clearly something to watch out for in the future.

As foreshadowed in this column in November the show was used to launch the Plawcotech kit and the Shesto Armtech 2000 and its accessories. Plawcotech is the technical expansion of the Plawco wire frame construction system. The basic pack for about £17 includes a d.c. motor, three types of gear, pulleys, belts, friction drive components, wheels and axles as well as metal components which give the models greater sturdiness than is possible with the plastics rods and connectors of the basic Plawco kits.

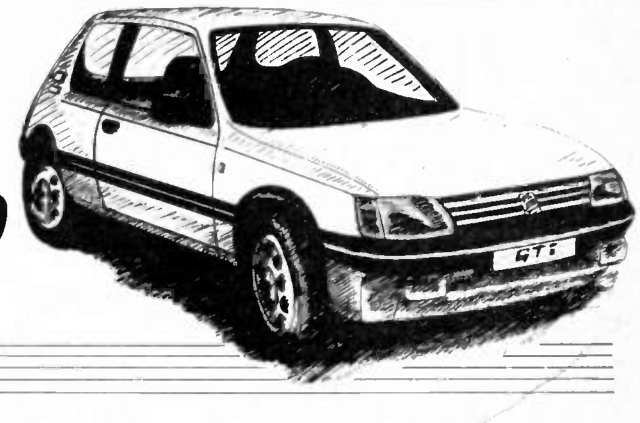
There is also a larger collection containing both the mechanical and the usual Plawco parts for about £50. Computer control of the models is not available at the moment. But the company says that the parts are compatible with other kits on the market which do have interfaces available for a variety of micros.

As expected the Shesto accessories included a conveyor, carousel, linear slide base and vacuum gripper. There was also an Armtech 2000 Plus — looking remarkably like an Armdroid — with a built-in interface for FMS accessories and costing £45 more than the basic Armtech's £450.

However there was no sign of Research Development Associates, the company formed to take over the production of the Alfred robot arms and which said it would be relaunching the machine at the show.



Constructional Project



GTi CAR COMPUTER

STEVE COUSINS

This easily fitted car computer is designed to operate in any type of petrol or diesel engined car.

THE Outrider GTI car computer design will fit any type of diesel or petrol engined car including fuel injection vehicles. Fuel injection vehicles are of special interest both because of the trend away from carburettored engines and the fact that car computers have traditionally not been available as high street add-ons to GTI vehicles. Fuel injection itself has many advantages stemming from the more precise delivery of fuel to the cylinders leading in turn to greater efficiency of combustion. This improved efficiency is then available to the driver as either lower fuel consumption or higher performance.

COST AND SAVINGS

The reason for conventional car computers not being available for fuel injection vehicles is that fuel is delivered to the injectors off a circulating fuel system in which fuel is pumped from the tank and back to the tank again via the injection unit. Inserting a single flow meter is unsuitable for measuring flows in such systems. Instead manufacturers have taken a signal directly from the injector itself, measuring for example the time the injectors are open. But in these cases the car computers have to have tailor-made adaptors for each model of injector. This kind of bespoke engineering comes expensive and the prices we were quoted this month indicate this: £233 for a car computer on Vauxhall injection cars to £362 on BMW.

Car computers have justified these kinds of prices partly on high-tech image and partly on efficiency grounds. There is certainly plenty to be saved on fuel. The average motorist drives 9000 miles each year while the average company car does 18000 miles in the same period. Assuming 30 m.p.g. this means consuming 300 or 600 gallons of fuel respectively at a cost of around £500 or £1000 per year.

The Outrider GTI car computer has been developed after the first wave of car computer novelties, and we are able to build on their experience. We have concentrated on achieving a high standard of design so that the Outrider will be simple and safe to use whilst driving, easy to fit to the car and easy to refit if you change cars. But most important of all we have developed a high quality digital m.p.g. readout which is stable under continuous driving conditions, such as on a motorway, yet is also responsive to acceleration and responsive too when easing off the accelerator pedal. It is not necessary to fit sensors to the accelerator incidentally!

When the car is stationary other features of the computer can be accessed. For example, the computer will predict the gallons of fuel required for a trip before you travel. To do this simply enter into the computer the distance you expect to travel and view the appropriate functions. Precisely how data is entered is dealt with later, but it is worth noting at this stage that, as a safety measure, data can only be entered into the computer when the car is stationary.

BUSINESS TRAVEL AND COMPANY CARS

Many of us have to record our mileage in order to reclaim expenses from our employers. The trip distance key is invaluable for this as it is easy to underestimate the true length of trips when claiming expenses. Self-employed people and company managers may also benefit from knowing the cost of car operation for particular business trips.

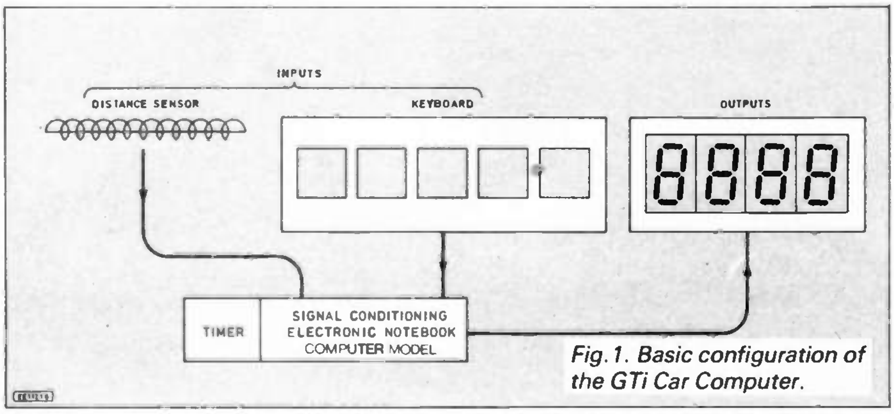


Fig. 1. Basic configuration of the GTi Car Computer.

HOW THE COMPUTER WORKS

The overall configuration of the computer is shown in Fig. 1. Distance travelled is detected by a sensor coil located behind the speedometer. Fuel consumption information is calibrated on the computer via the computer keyboard. This is done by entering into the computer's electronic notebook the volume of fuel purchased between tank fill-ups and the distance travelled. The latter is indicated by the computer and is used to calculate a reference m.p.g. as a starting point for the computer model of fuel consumption.

The distance sensor controls the dynamic behaviour of the computer outputs in conjunction with the crystal oscillator which provides a time source. Together the distance and time inputs are used to determine distance travelled, cold starts, vehicle speed, vehicle acceleration and vehicle braking. These factors are used in the computer model to determine instantaneous m.p.g. using the reference m.p.g. to calibrate the model itself. Readers will recognise this kinetic method of calculating instantaneous m.p.g. as being very similar to the approach taken in the standard EEC driving cycle for new cars. Here m.p.g.s are given according to the speed at which they are driven (56m.p.h. and 75m.p.h.) and for an urban driving cycle involving acceleration and braking.

There are advantages to this kinetic method of determining instantaneous m.p.g. Flow meters in the fuel line can be inaccurate or expensive and there is always a slight additional risk of a petrol leak if a meter is introduced into the fuel line. In non-fuel injection cars fuel flows reflect the characteristics of the carburettor float chamber as well as driver behaviour and the combination can be confusing to the driver particularly during motorway driving. By contrast the kinetic method can give a high quality signal to the driver.

Trip m.p.g. is the average of the instantaneous values over the period since the tip data were reset to zero. Fuel consumed on trip is also calculated from the trip average m.p.g. figure.

Provided that the power supply to the computer is maintained, all trip and calibration data are retained when the computer display is off and the car is not in use.

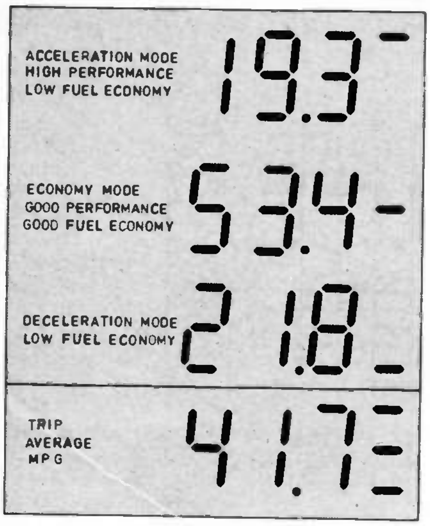


Fig.2. The hybrid display system used.

THE M.P.G. READOUT

There has been considerable debate about whether a digital or analogue readout is best for car instrumentation in general and for the m.p.g. display in particular. The Outrider display (Fig.2) is something of a hybrid using three of the seven-segment l.e.d.s to display digital m.p.g. while the fourth l.e.d. is effectively an analogue display summarising how the car is being driven. This horizontal bar can be usefully positioned at the edge of the driver's vision when the driver is at the wheel and looking straight ahead.

MAIN BOARD

The heart of the circuit is a Motorola 6803 single chip microcomputer (Fig.3). This chip contains the processor, 128 bytes of RAM, a programmable timer and 13 input/output lines. The program for the microcomputer resides in a 2K byte EPROM. A 74LS373 is used to latch the low order address lines from the 8 bit multiplexed address/data bus. Timing information is derived from the 3.579545MHz crystal. This part is commonly available as it is used in colour t.v. sets.

KEYBOARD AND DISPLAY

Each of the four l.e.d. digits and the function indicator l.e.d.s are controlled by a transistor driven from one of five output lines of the 6803. Rapid scanning of the digits synchronising with the data which is held in the 74LS374 latch, to switch segments on or off gives the impression of all digits being on simultaneously but with great economy in wiring and components.

The 7-segment l.e.d.s were selected for both their appearance and their high brightness. The latter is particularly important for car instruments which must be readable in all light conditions.

The five digit lines are also used to scan the five input keys, which have a common line of input to the processor. The processor detects a key press when this line goes high.

The Outrider contains calibration and trip information which must not be lost when the ignition is switched off. 64 bytes of the 6803 memory can be retained even when the processor is turned off, through the Vcc standby pin. This pin is connected directly to the 5V regulator which is in turn connected directly to the 12V car battery. The power to the rest of the circuit is switched by a transistor which is turned on either by the ignition or an output line from the 6803. This enables the 6803 to hold the power on to enter a defined power down sequence.

TRANSDUCER

The transducer is a high inductance coil mounted as close as possible to the rotating magnet found in all conventional speedometers. Normally it is sufficient to place the coil tight up against the back of the speedometer case and mounted at right angles to the axis of the drive cable. Exceptionally it could be necessary to drill through the speedometer side or back and locate the transducer internally although we have not known this to be necessary on any car to date.

Each time a pole of the speedometer magnet passes the sensor coil a voltage is induced which is then converted to a digital signal by a Schmitt trigger on the main circuit board. The wires connecting the sensor coil to the main board are twisted to remove any electrical noise problems coming from the car's ignition circuit, Fig.4.

PRINTED CIRCUIT BOARDS

The main p.c.b. is fairly complicated and double sided. If you are building up your own boards then all holes are to be drilled to 0.8mm except for specific instances. On the main board the IN4003 diodes and the voltage regulator require 1mm and the variable resistor 1.5mm. The 0V, +12V and ignition

THE COMPUTER OUTPUTS

The keys display these functions

Keys	Functions
DIST	Distance travelled on trip
FUEL	Fuel used on trip
MPG	Instantaneous m.p.g. (above 20 m.p.h.) Trip average m.p.g. (below 20 m.p.h.)
SPEED	Instantaneous m.p.h. (above 20 m.p.h.) Trip average m.p.h. (below 20 m.p.h.)
SET	Display brightness

COMPONENTS

Resistors

R1,R5	270 (2 off)
R2,R11	3k3 (2 off)
R3	22/2W
R4,R9,R15	10k (3 off)
R6	470
R7,R14,R20 to 24	1k (7 off)
R8	12k
R10, R16	220k (2 off)
R12	620k
R13	2k2
R17	22k
R18	6k8
R19	100k
R25	4k7

Potentiometers

VR1	10k 0.1W skeleton vertical, preset

Capacitors

C1	1000μ elect. 40V
C2,C8,C9,C10	47n (4 off)
C3,C5	47μ elect. 16V (2 off)
C4	470n elect. 16V
C6,C7	22p (2 off)
C11	10n

Semiconductors

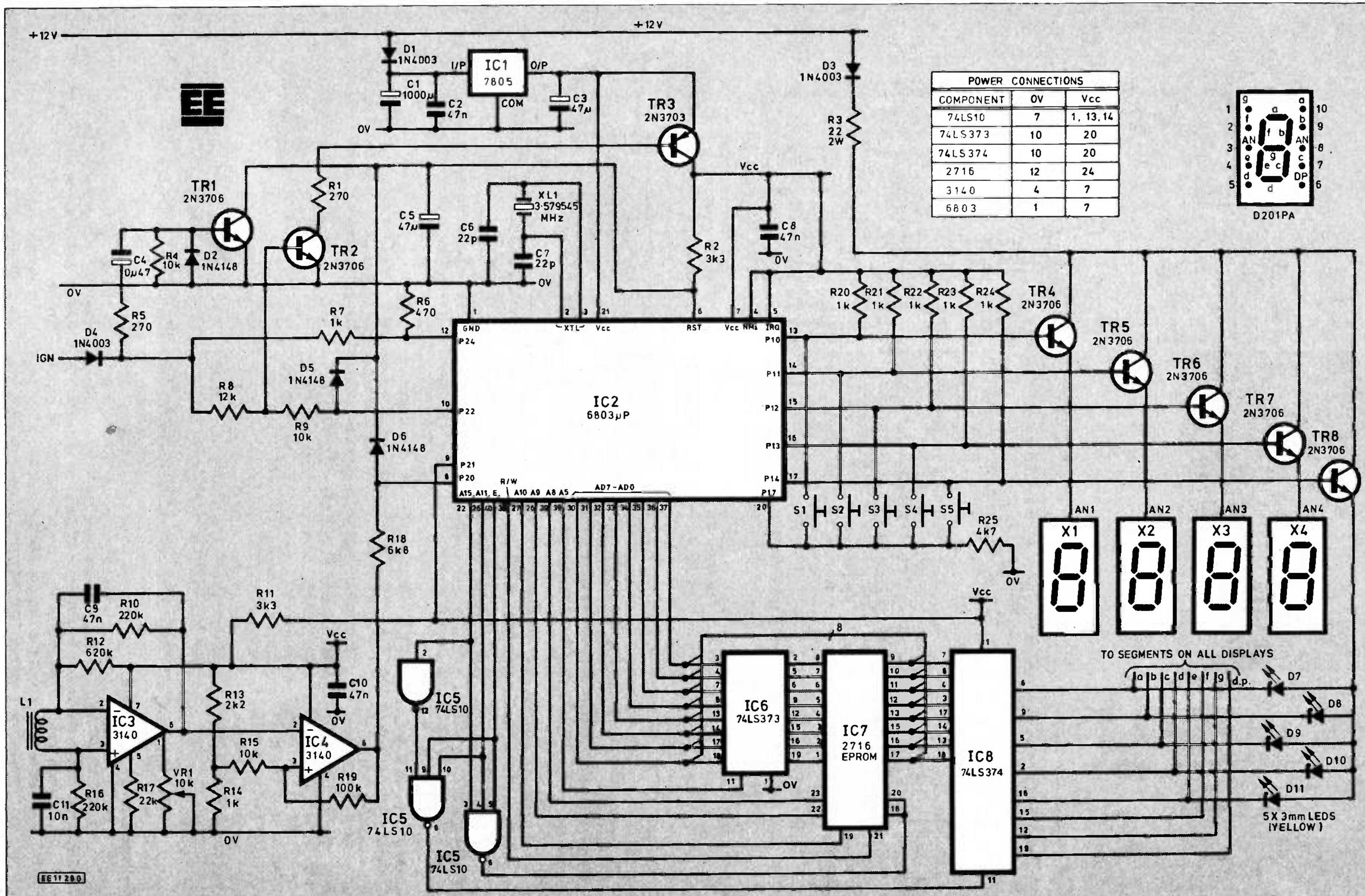
IC1	7805 regulator (T0220)
IC2	6803 μP
IC3,IC4	3140 op. amp. (2 off)
IC5	74LS10
IC6	74LS373
IC7	2716 EPROM
IC8	74LS374
X1 to X4	D201PA 7-seg. display (4 off)
TR1,TR2,TR4 to TR8	2N3706 (7 off)
TR3	2N3703
D1,D3,D4	1N4003 (3 off)
D2,D5,D6	1N4148 (3 off)
D7 to D11	3mm yellow l.e.d. (5 off)

Miscellaneous

S1 to S5	REKN 1A push switch (5 off)
XTAL	3.579545MHz

Sockets for i.c.s; sensor coil and clip; wire; p.c.b.s (see Shop Talk); heat sink; red filter; case

Approx. cost Guidance only £65



COMPONENT	0V	Vcc
74LS10	7	1, 13, 14
74LS373	10	20
74LS374	10	20
2716	12	24
3140	4	7
6803	1	7

Fig.3. Circuit diagram of the GTi Car Computer.

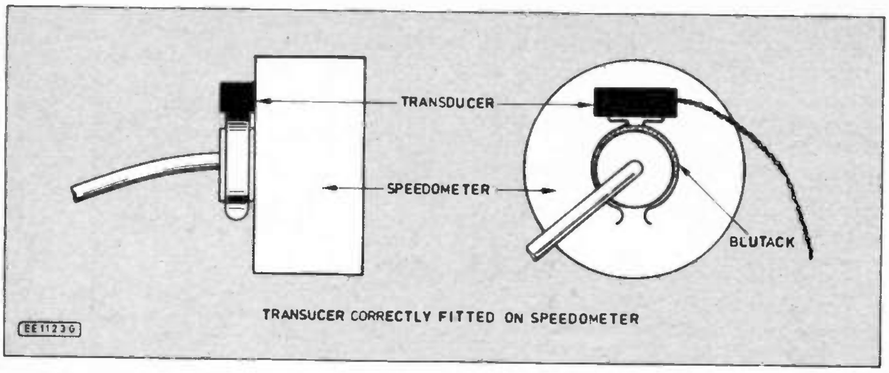
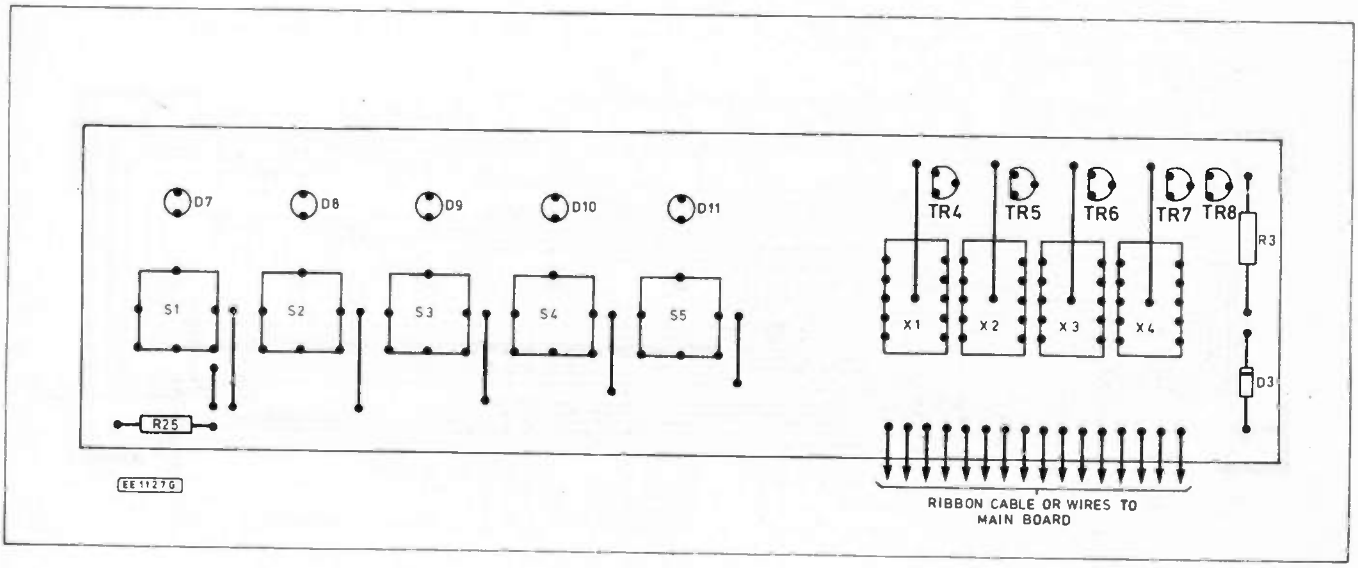
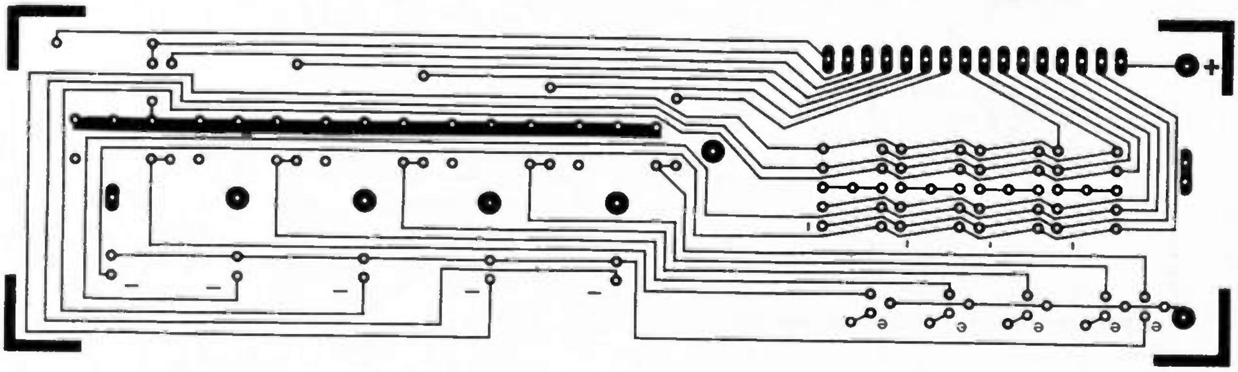
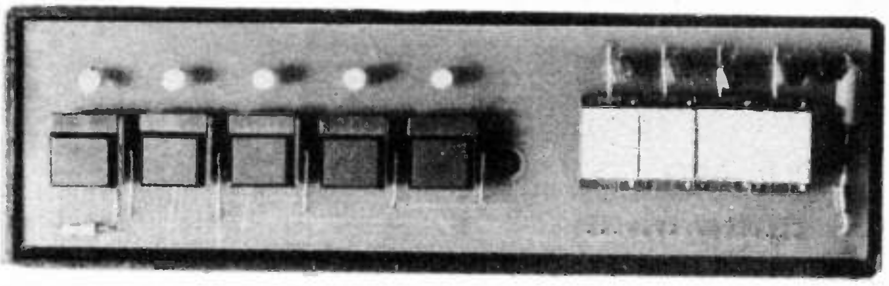


Fig.4. Distance sensor fitting to the speedometer.

Fig.5. Front panel p.c.b. construction.







connections also require 1mm. On the front panel the two locating lugs on each of the five switches require 1mm holes; the upper lug goes into the 5mm pad at the top of the switch position on the p.c.b. and the lower lug into the vacant small pad directly below this on the 5V rail. The case-front has a locating lug which requires a 3.5mm hole in the p.c.b. and a pad is provided between the switches and the 7-segment l.e.d.s for this purpose.

CONSTRUCTION – FRONT PANEL

The front panel is a single sided p.c.b. (Fig.5). Put in the 10 wire links first. The five function indicator l.e.d.s come next. The shorter lead on the l.e.d. is the cathode and should be inserted into the p.c.b. hole adjacent to the negative sign. A 5mm gap should be left between the board and the base of each l.e.d. This will allow the l.e.d.s to protrude into the holes provided in the case-front.

Before soldering the 7-segment displays inspect the p.c.b. for any bridges between adjacent tracks. Take extra care when soldering these particular components on. The 7-segment l.e.d.s can be placed in sockets which are soldered to the board, or soldered direct into the board themselves. The appearance of the computer when finished is enhanced if these l.e.d.s are soldered direct to the board. The other components can now be fitted but check that the five switches are correctly mounted with the location lugs in the board. The connecting wires from the front panel to the main board should remain on the rear of the front for soldering i.e. the connector wires should not wrap round onto the component side of the front panel, see Fig.9. But do not at this stage connect the front panel p.c.b. to the main board.

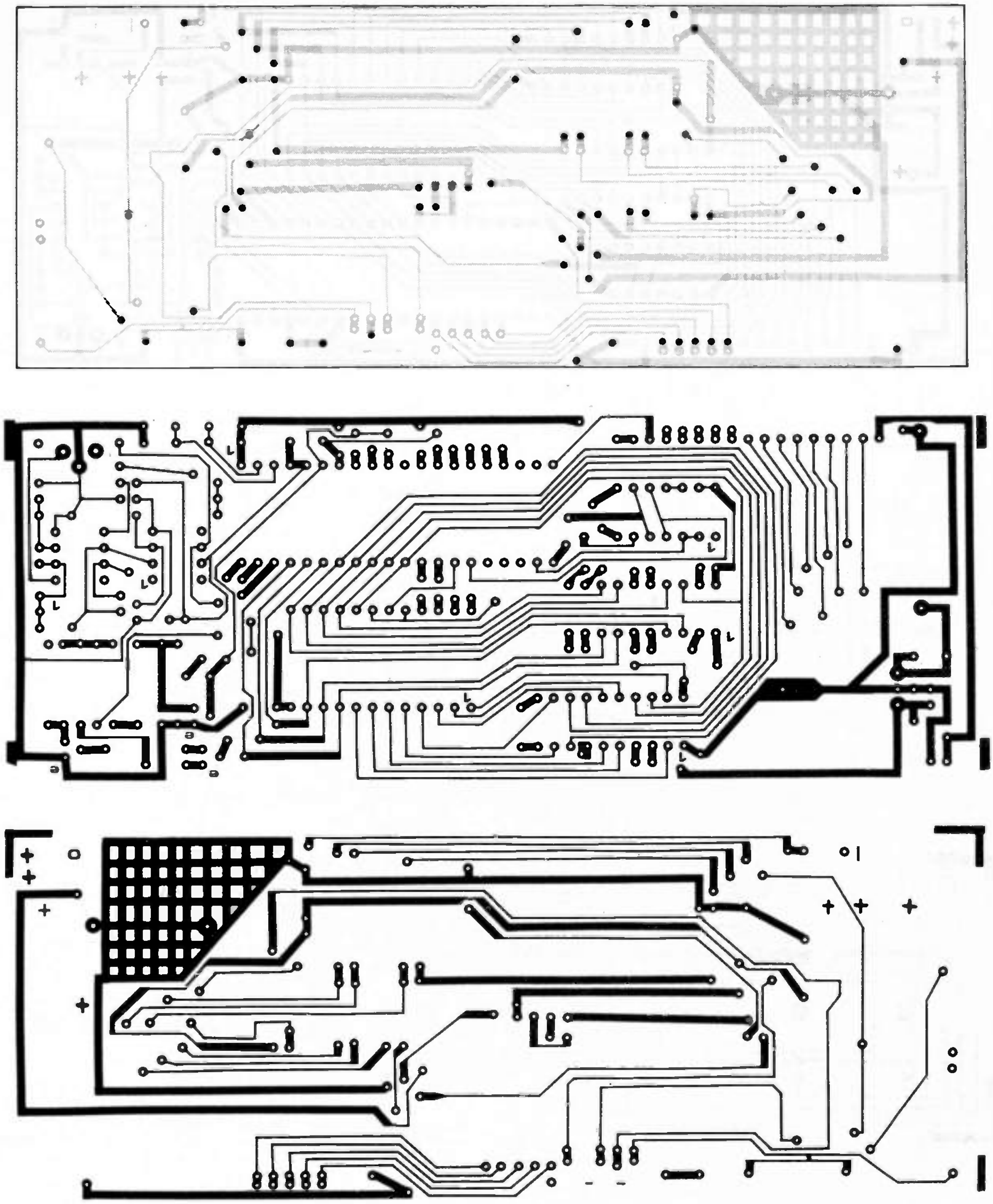


Fig.6. Through hole connections and details of the layout of the main, double sided p.c.b.

MAIN BOARD

To asemble the main double sided board do not solder on components but begin by soldering the connections required between the two sides. There are 70 of these illustrated as single "black dots" in Fig.6. Next fit those components which require soldering on the *top* of the board (Fig.7). They are as follows:

3k3 – pull-up resistor on pin 1 374 (R11)
3k3 – pull-up resistor on the reset line (R2)
6k8 – resistor into pin 8 of the 6803 (R13)
2k2 – into the + 5V rail, potential divider in sensor circuit (R13)
470 – pull-down resistor on pin 12 of the 6803 (R6)
diodes, anode on pins 10,8 of 6803 (D5, D6).

Next, fit the resistors R20-R24. These should be inserted in the holes next to IC2 leaving about 3mm gap between the components and the p.c.b. These can now be soldered to the p.c.b. *top and underside*. The lead from the top of R24 should be bent back along the top leads of R20 to R23 and down into the hole next to R20, see Fig.8. The tops of the resitors can now be soldered. The variable resistor is mounted vertically. Do not connect to the front panel yet.

CASE ASSEMBLY

Bend forward the heat sink vanes so that the main board fits snugly into the bottom runners of the case. Place the assembled front panel in position too. In the main case there are two slots on each side which retain the case-front in position. These should be visible when both boards are in position and any obstructions trimmed off if this is required. Now solder the sensor and power leads to the underside of the main board, first passing these through the hole in the back of the case.

We do not advise frequent opening and closing of the case so therefore do the bench tests (next section) before completing the assembly. Solder the connections between the two boards – these connection wires should not be pinched by the boards when the case is closed, i.e. it should close easily, see Fig.9. Again check that the slots in the case are visible with the boards in position.

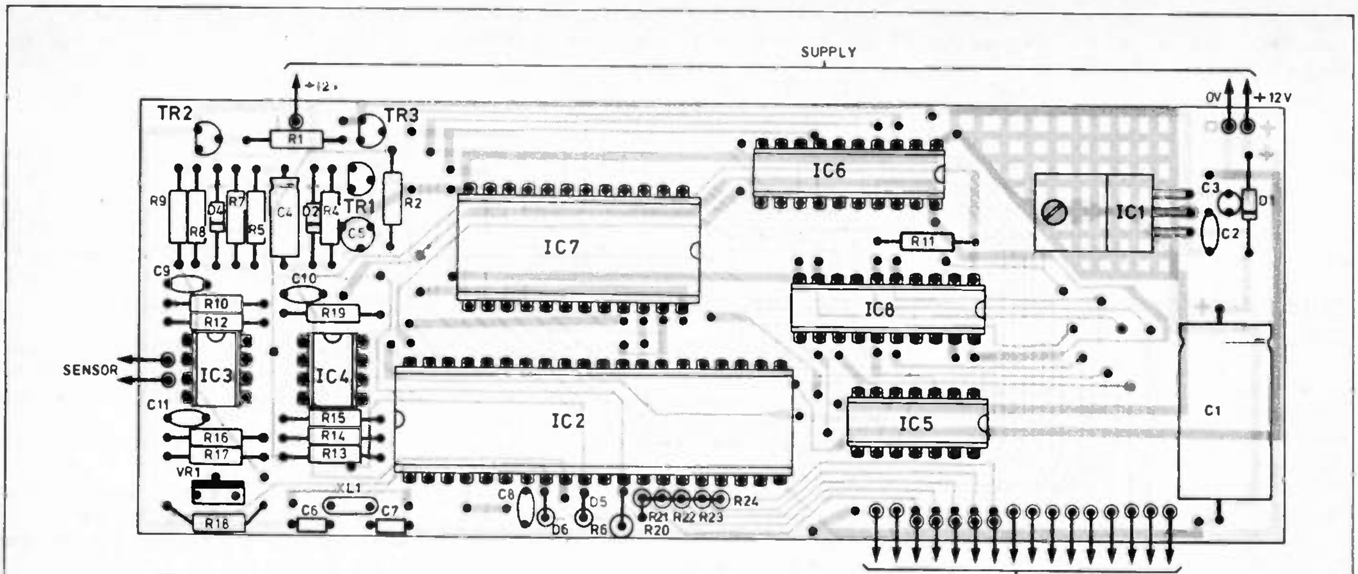
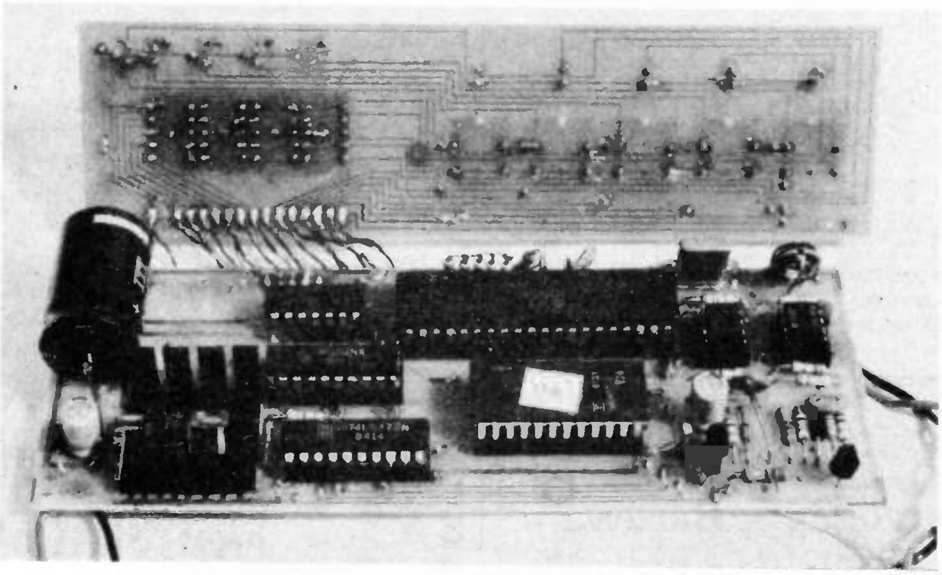


Fig.7. Layout and winning of the main p.c.b.



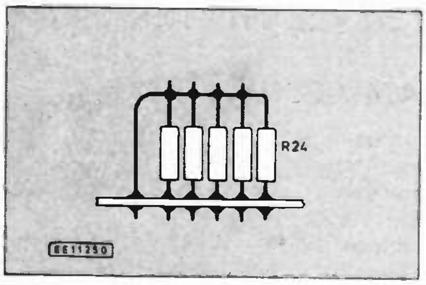
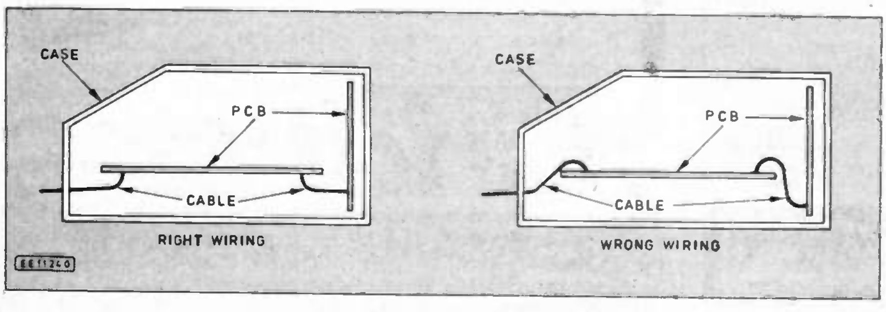


Fig.8. Wiring of R20 to R24.

Fig.9. Connections to the p.c.b.s. in the case.



SET-UP AND TEST

You should check the operation of the Outrider GTI before final assembly. Here are some guidelines:
With the 12V connected, but with the ignition line open circuit, check that there is 5V on the ouptput of the regulator and *V*cc standby (pin 21 6803), and that *V*cc and reset are low (pins 6 and 7). The Outrider should draw a current of about 400mA with the display on and 300mA with the display immediately off which is reduced to 10mA after 15 minutes. If you have an oscilloscope or access to one the crystal frequency should be clearly seen on pins 2 and 3 of the 6803.

The keyboard/display strobes (pins 13 to 17) on IC2 have a cycle period of 1.8ms. The cycle starts with all lines going high for the first 0.3ms. The remaining 1.5ms are divided into five slots in each of which one strobe line goes high.

The variable resistor (10k pot.) should be adjusted until 1.5V is given on pin 6 of the op. amp. (IC3) directly connected to the sensor. Care should be taken to set this voltage when the system has warmed up. To test the operation of the distance sensor hold the coil close to a mains transformer. A 50Hz signal should appear on pin 8 of the 6803. With the default calibration of the computer a 50Hz signal corresponds to a speed of around 180 m.p.h. which is outside the range of normal operation of the m.p.g. function. However, the distance function will work normally with this signal.

INSTALLATION

Begin by choosing where you are going to mount the computer. It is very important to place it where you can read the display without taking your eyes from the road. Therefore the computer should be placed on top of the dashboard or high in the dashboard area. To mount the computer low in the dashboard can be dangerous.

When fitting the distance sensor do use Blutak or similar product, *not* sticky tape. Blutak absorbs vibrations and keeps the sensor very firmly positioned which is essential to proper signal detection from the speedometer, see Fig.4.

There are just three electrical connections to be made between the computer and your car, these are the OV, + 12V permanent and + 12V when ignition on. The computer is designed for fitting to negative earthed vehicles only. Use a test light to identify the required connection points on the car. Each of these connections should be firm clean connections. The existing terminals and connectors on the car battery should also be in good condition. For positive earth cars write in for circuit modifications.

DATA ENTRY AND CALIBRATION

Pressing each of the four function keys, distance, fuel, m.p.g. and speed causes the appropriate digital readout to be displayed. To enter data as is needed for calibration the car must be stationary. The SET key is used in conjunction with the desired function key in the following ways:

depress the set key for 2 seconds and SET is displayed

depress the set key for 4 seconds and CAL is displayed.

While either SET or CAL is displayed press the function key that you wish to tell the computer about, e.g. Fuel. Now any number between 00.00 and 99.99 can be entered as follows. Each of the four left-hand keys rolls a separate digit on the display. "roll-up" your desired number then press the SET key to finish.

This is the sequence keys you will press to enter data

SET FUNCTION NUMBER SET (2 secs)

Remember the car must be stationary and the SET key pressed for two seconds.

Data entries are as follows for each function key:

SET DIST 0000 SET – Resets all trip data to zero, e.g. fuel used on trip, distance travelled on trip and cost of trip

SET DIST NUMBER SET – Predicts the fuel required and cost of a trip a NUMBER miles long

Set fuel, set m.p.g. and set speed have no function.

Calibrate the computer as follows: The calibration mode CAL is obtained by pressing the SET key for four seconds. Begin calibration by entering.

CAL DIST 0001 SET

Now go for a drive. Drive for one mile and note the number which is displayed on the computer. Suppose this number were 1530, then enter this number (which is the number of pulses per mile detected by your distance transducer on the back of the speedometer) thus.

CAL DIST 1530 SET

That completes the distance calibration.

The next function is m.p.g. You should enter an estimate of what the average fuel consumption of your vehicle is, in miles per gallon. Accuracy is not important here as the computer will compute this figure for itself once it is fitted and a tank of petrol has been used. Suppose your estimate m.p.g. is 35, then,

CAL MPG 35.00 SET

That provides initial m.p.g. calibration.

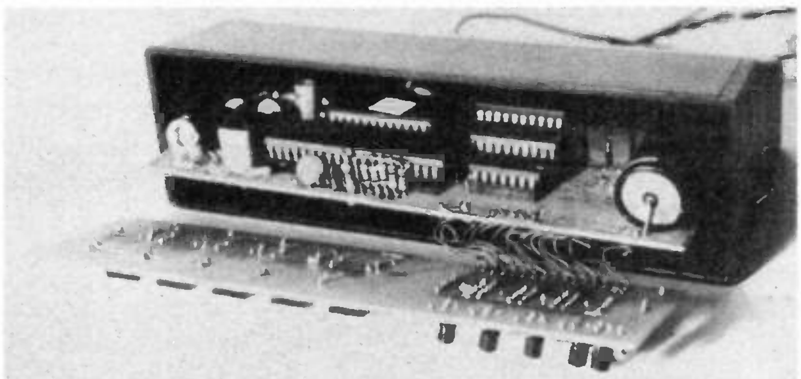
The next function to calibrate is fuel. Fill the tank completely and reset the trip distance to zero and do not reset distance again until calibrate fuel is completed. Drive and use approximately a tank of fuel then refill the tank completely. Enter the number of gallons used between fill-ups, say 10.43 galls,

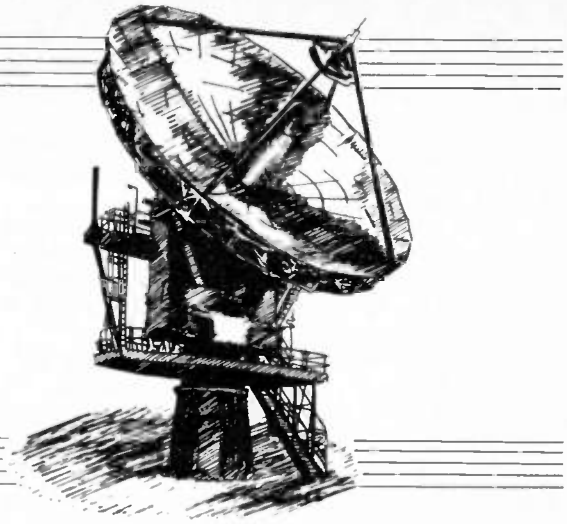
CAL FUEL 10.43 SET

The computer will now calculate a new reference m.p.g. which may be viewed by pressing CAL MPG and then SET to return to normal again.

Calibrate speed has no function. That completes all calibration.

The Outrider GTI computer kit or part kit is available from Mark Space Enterprises – see *Shop Talk* page 40 for details. The computer design is protected by Patent GB 2 127 545 B. □





DIGITAL SATELLITE

JOHN WROE*

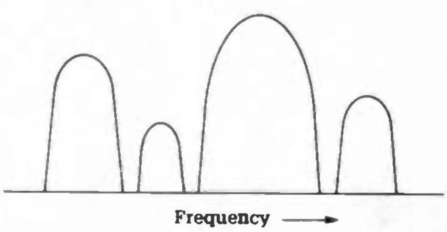
British Telecom International are now using a variety of high tech methods to increase the traffic and improve quality of satellite communications.

THIS article is about a revolution in British Telecom International's telephone services via satellite. BTI provides these services using its large satellite antennas at Goonhilly and Madley, BTIs second satellite earth station near Hereford. BTI has routes to about 110 countries and have over 10,000 circuits.

About 8 per cent of the satellite circuits are leased circuits, but the main telephony service is the simple dialled telephone call, calls for business, calls for pleasure, and a growing number of calls to machines.

Most of this traffic has, since the beginning of satellite communications in the 1960's, been carried using an analogue technique known as frequency modulation. Several 10's or 100's of channels are carried on a single carrier which is separated from other carriers by being transmitted at a different frequency. Since those early days the technology has not changed dramatically. Until now.

Frequency Division Multiple Access

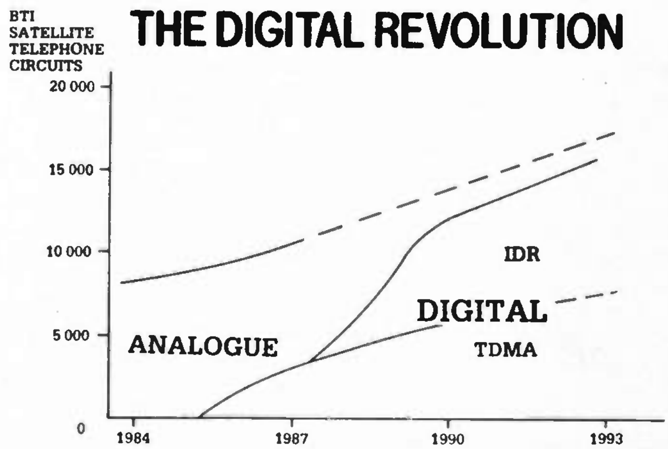


Analogue transmission using Frequency Modulation

Now we are witnessing the digital revolution – a wholesale change to digital technology which is affecting the entire global telecommunications network. By the early 1990's our international satellite network will be almost totally digital. This revolution is fuelled by two major advantages afforded by digital transmission. The first of these important factors is improved quality.

Digital transmission improves quality because it becomes easier to control transmission impairments in a digital environment. Once the voice signal has been digitally encoded, it can be protected against noticeable degradation until after it has been decoded back into analogue form. As this digital encoding and decoding is brought nearer and nearer to the customer, often in his local exchange or even in his own company PABX, the opportunities for noise and crosstalk to affect the customer are reduced. Furthermore, distance becomes of no significance – calls half way round the world will sound as clear as a call to the next office.

THE DIGITAL REVOLUTION



Digital transmission also helps us in our drive to improve efficiency of operation. The digital techniques which I am about to describe allow more traffic to be carried through the same satellite capacity than was possible using analogue frequency modulation.

TDMA

One of the digital transmission systems used is known as TDMA. This stands for Time Division Multiple Access.

BTI ACHIEVEMENTS WITH TDMA

OCTOBER 1985	Start of TDMA service on Atlantic MP2 satellite – first commercial operation of TDMA in INTELSAT network
JANUARY 1986	Start of TDMA service on Indian ocean primary satellite. World's first all-digital ISC-to-ISC link (London Keybridge to Oyama Japan) enters service via TDMA
MAY 1986	Start of TDMA service on EUTELSAT network
SEPTEMBER 1986	Start of TDMA service via Goonhilly Aerial 6 on Atlantic Primary satellite

With TDMA, instead of the transmissions from different stations being separated from each other by transmitting them at different frequencies, they are transmitted at different times. The digital information is transmitted in short bursts in a prearranged sequence every two milliseconds. At any one instant, only one burst is passing through the satellite transponder.

This leads to a major advantage of TDMA. Since the amplifier in the satellite transponder has to cope with only one signal at a time, higher powers can then be used for the transmission back to earth without intermodulation in the amplifier causing interference to other signals.

The signals have to be carefully timed such that, when they arrive at the satellite, they do not collide and interfere with each other. Instead they interleave and reach the satellite one at a time. The timing has to be extremely accurate – the gap between bursts is only one microsecond. Let me put that in context.

First I should explain that a signal takes about 120 milliseconds to get from an earth station to the satellite. So if a burst is transmitted from a particular station every two milliseconds, there will be about 60 bursts "in transit". Furthermore the various earth stations are different distances from the satellite.

The guard time allowed between the bursts I said was only one microsecond, and at the speed of light that corresponds to a distance of only 300 metres. You can see that the timing of each burst is critical.

The task is made even more difficult by the fact that the satellite, though geostationary, can move by as much as 300km each day. It makes the police displays with motorcycles criss-crossing in front of each other look tame indeed.

British Telecom International, together with COMSAT in the United States, established the first commercial traffic using TDMA in the INTELSAT system in October 1985. BTI now has four TDMA terminals in operation, two over the Atlantic, one in the Indian Ocean region, and one in the European EUTELSAT network. The latest of the terminals is installed at Goonhilly and operates via Aerial 6.

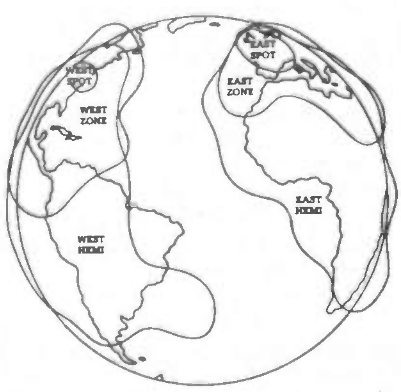
A major milestone was the introduction of BTIs second TDMA terminal at the Madley earth station, in January 1986. A digital service to Japan was introduced facilitating what is believed to be the world's first intercontinental all-digital link between the digital international exchanges at Oyama in Japan and Keybridge in London.

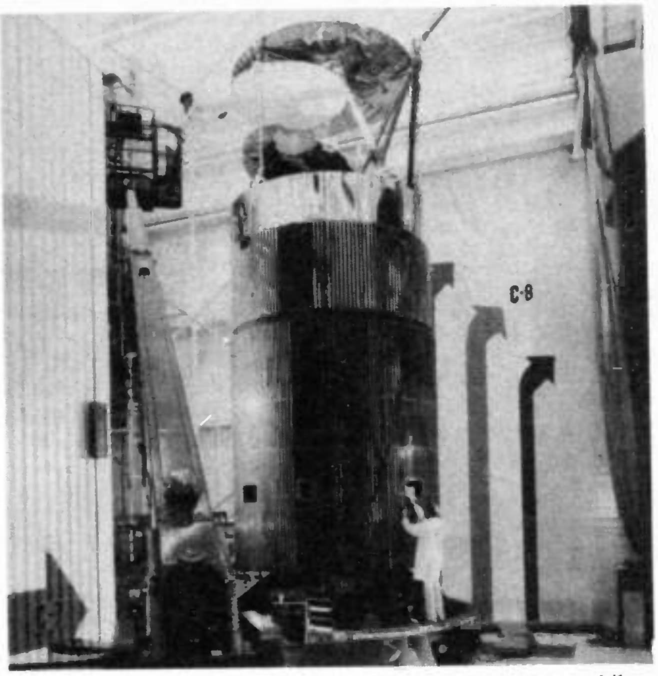
TDMA now provides BTI with service to 20 countries and is carrying over 30 per cent of the satellite telephony traffic.

LOOKING FORWARD

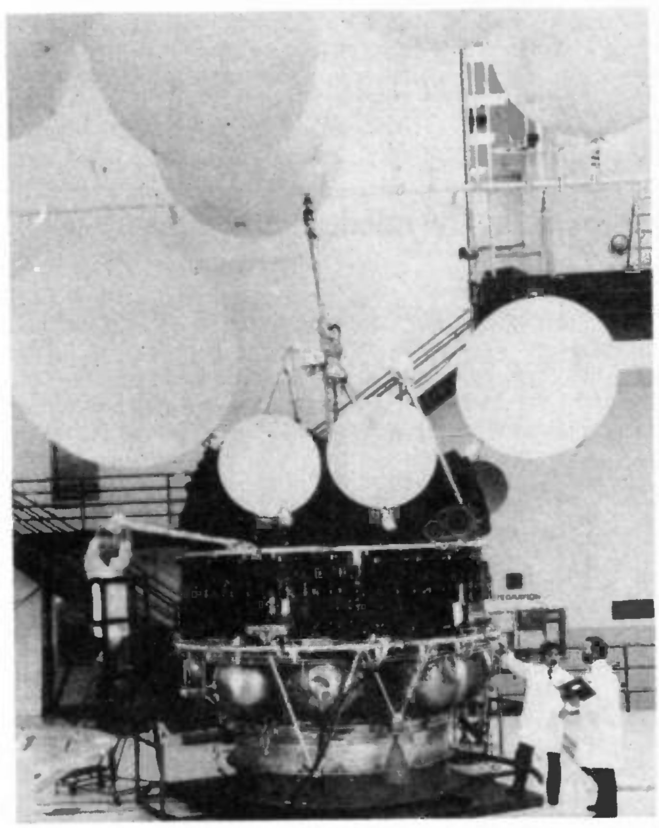
The next generation of INTELSAT satellites, the INTELSAT VI series, will allow a further advancement. Current satellites transmit and receive with various different beams, their signals are directed to particular parts of the earth's surface as hemi, zone and spot beams. Unfortunately the interconnection between these beams has to be static and since the amount of traffic in each beam will not fill an integer number of transponders, this represents a constraint on efficiency.

INTELSAT V Atlantic Ocean beam coverages





Four stories high – The prototype of Intelsat VI, the world's largest commercial communications satellite, undergoes its final series of tests at the Space Simulation Laboratory of Hughes Aircraft Company in El Segundo, California. During more than 30 months of developmental tests, the 40-foot-high prototype, acted as a guinea pig for engineers building the five Intelsat VI flight spacecraft. Operated by the International Telecommunications Satellite Organization, each Intelsat VI will be able to simultaneously carry 120,000 telephone calls and three television channels, making it the world's highest capacity commercial satellite. The first in the series is scheduled to be launched on an Ariane rocket in 1989.



Need a lift? – In the weightlessness of space, the antennas of Intelsat VI will be able to unfold on their own, but during earthly tests the two larger antennas need a lift to defy gravity. Engineers at Hughes Aircraft Company in El Segundo, California, turn to helium-filled balloons to do just that. Intelsat VI, shown without its solar-cell skin, is the world's largest commercial communications satellite.

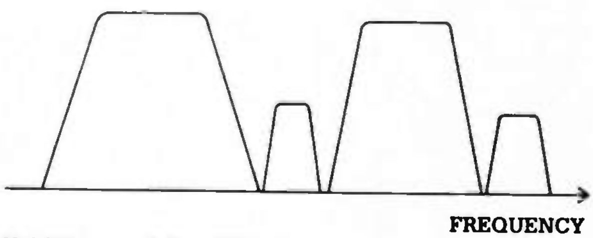
The INTELSAT VI satellite has on-board a fast acting switch matrix which will route bursts coming up in one beam to various different down links. Similarly, a single downlink can have traffic routed from various different uplinks. The switching is dynamic and has to be synchronised to the operation of the TDMA network. Thus it switches in-between bursts from different earth stations and provides improved-connectivity through the satellite. The result is a further improvement in utilisation of the valuable resource which the satellite represents.

IDR

The other main digital transmission system which is to be used via satellite is known as Intermediate Data Rate (or IDR) Carriers. In this case the signals are once again separated by frequency as they were for the original frequency modulated carriers, however the IDR carriers use digital modulation (four phase Phase Shift Keying) and a sophisticated error correcting system to achieve an efficiency of operation which still exceeds that of the frequency modulation systems.

Intermediate Data Rate

DIGITAL CARRIERS

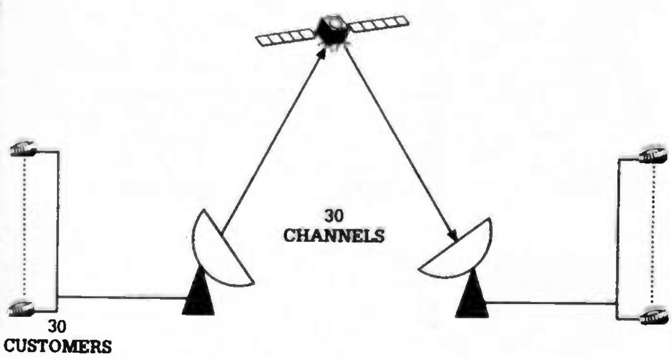


Modulation: 4 phase shift keyed
Error Correction: soft decision 3/4 rate punctured VITERBI

IDR does not attain quite the same high efficiency s TDMA but it provides a simpler alternative for those many smaller countries for whom the expense of a TDMA terminal cannot be justified.

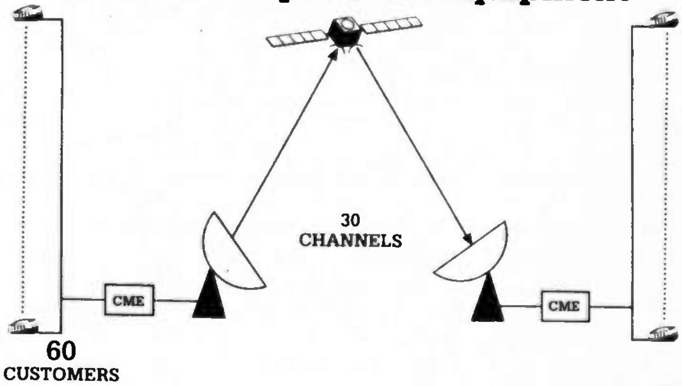
CME

Whilst these digital transmission systems are, in themselves, more efficient than their analogue predecessors, they also permit use of digital speech processing techniques which can provide a dramatic further increase in efficiency. These techniques are termed "Channel Multiplication".



Imagine this situation where the transmission system provides 30 circuits between two countries – so permitting 30 telephone conversations. By adding channel multiplication equipment, we can at least double the effective capacity to 60 circuits. How do we do it?

Circuit Multiplication Equipment



If you listen to a telephone channel in one direction, you will hear that there are natural pauses in the speech while the customer is listening to the other party. So for more than 50 per cent of the time our valuable transmission capacity is carrying silence! What a waste!

HELLO   YES IT'S ME   HOW ARE YOU?

60% is silence!

While that customer is silent, why not use his transmission channel to carry snippets of speech from another customer? We could switch each customer onto the transmission channel only while he is speaking, like this:

Speaker 1

HELLO   YES IT'S ME   HOW ARE YOU?

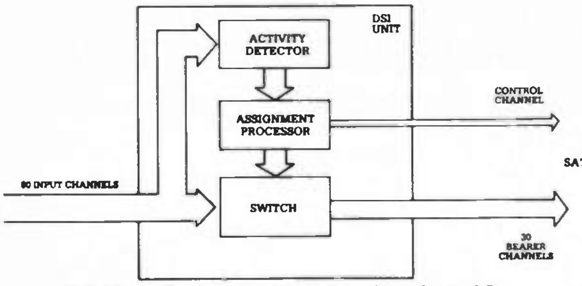
Speaker 2

TONIGHT THEN?   YES DARLING

Of course, we cannot expect our two customers here to time their conversation so conveniently, but if we have a large number of circuits it does become possible to carry them on a pool of transmission channels, or bearer channels, numbering less than half the number of transmission channels. For example 60 conversations could be carried over just 30 bearer channels in each direction, a channel multiplication of two.

The Digital Speech Interpretation equipment has to detect activity on each input channel and then assign the active channels to a pool of bearer channels over the satellite. When an input channel becomes silent, the equipment will assign the bearer channel to another input channel which has become active. The equipment has to send control messages to the receiving equipment so that the right bearer channels can be connected to the right circuits and hence to the right listener!

Digital Speech Interpolation



Digital Speech Interpolation gives a gain of from 2 up to 2.5

This may seem a fanciful way of increasing network efficiency . . . in fact it is in service and operating on over 30 per cent of BTI satellite telephony traffic. It operates so well that the customer does not even notice!

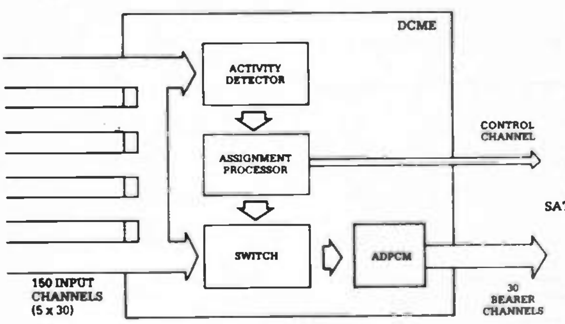
LRE

Another method of improving our tranmission efficiency is known as Low Rate Encoding (LRE). Speech is normally encoded for digital transmission using PCM – pulse code modulation – and requires 64,000 bits per second to provide telephone quality.

International standards are now being established which permit transmission of speech, with comparable quality using only 32,000 bits per second, half the bit rate of normal PCM. The techniques is known as ADPCM – Adaptive Differential Pulse Code Modulation. By converting the speech coding to ADPCM it is possible to halve the transmission capacity required for a given number of circuits. This provides a circuit multiplication of two.

Equipment which combines both techniques – DSI and LRE – is being developed and will be in service next year in BTI's network. The gains achieved using these techniques multiply together – two and a half for DSI and two for LRE – to give an overall gain of five.

Digital Circuit Multiplication Equipment



DCME, combining DSI and LRE, gives a gain of about 5 (2 x 2.5)

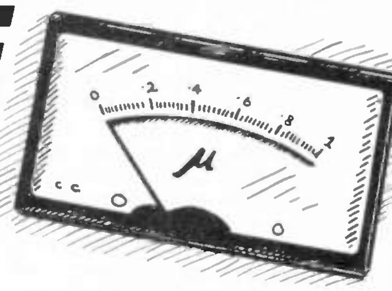
CONCLUSION

The use of techniques such as I have described is leading to much improved efficiency of utilisation of the satellites currently in orbit. This means that the continuing rapid growth in demand for international telephone traffic can be accommodated without increasing the number of satellites. Hence BTI are avoiding the need to build additional antennas and are keeping down the cost to the customer.

The use of digital techniques is not only bringing economic advantages. They simultaneously bring improved and more consistent quality. The introduction of digital transmission systems and circuit multiplication equipment and the abolition of the old analogue regime, is nothing short of revolutionary.☐

***John Wroe is Head of Digital Systems BTI.**

CAPACITANCE METER



ANDY FLIND

An easy-to-use test meter that will check values from 100p to 1000μF. Invaluable for checking unmarked capacitors

RESISTORS are easy to check. Every electronic workshop has (or should have!) a Multimeter, which will measure resistance directly on suitable ranges. This is only right, considering that the resistor is the most frequently used component in many circuits.

The next most common item is the capacitor however, and by contrast, it is generally quite difficult to check the value of one of these. The generally accepted method is with a capacitance bridge but few hobbyists seem to possess one. Probably because a good bridge is expensive.

Also, a certain amount of experience is often required to operate it. Obviously, a need exists for a simple,, inexpensive capacitance measuring instrument.

The Capacitance Meter described here is as simple to use as a voltmeter. The capacitor is placed across the terminals, a suitable range selected, and the value can be read on pressing a button. Should it be out of range the meter will read zero or full scale, indicating the direction of range switching needed.

Despite its simplicity it offers ranges from 100pF to 1000μF, greater than most previous designs. At one extreme it can measure the few picofarads between tracks on stripboard, at the other the actual value of a 470μF electrolytic can be indicated. Despite their enormous tolerance factors these still appear as "timing" capacitors in some projects!

HOW IT WORKS

Although simple to use, the instrument's operation is moderately complex and requires some explanation. The block diagram for the Capacitance Meter is shown in Fig. 1.

The capacitor being checked, *Cx*, is connected as the timing element in a simple oscillator circuit built around a 555 timer. The latest version of this is used, the TLC555 produced with "linCMOS" technology. This is faster than the CMOS ICM7555 and in the author's experience less electrically fragile, yet it retains CMOS characteristics; low consumption, high input impedance and an output that switches all the way to the supply rails.

During positive half-cycles of oscillation, capacitor *C* is charged through resistor *R*. Whilst the output is negative this capacitor is discharged through the timer's own discharge transistor. The maximum voltage reached across *C* therefore depends on the length of the charge periods, which in turn depend upon the value of *Cx*.

The rate of rise of voltage across *C* is in fact

Fig.2. Complete circuit diagram for the Capacitance Meter.

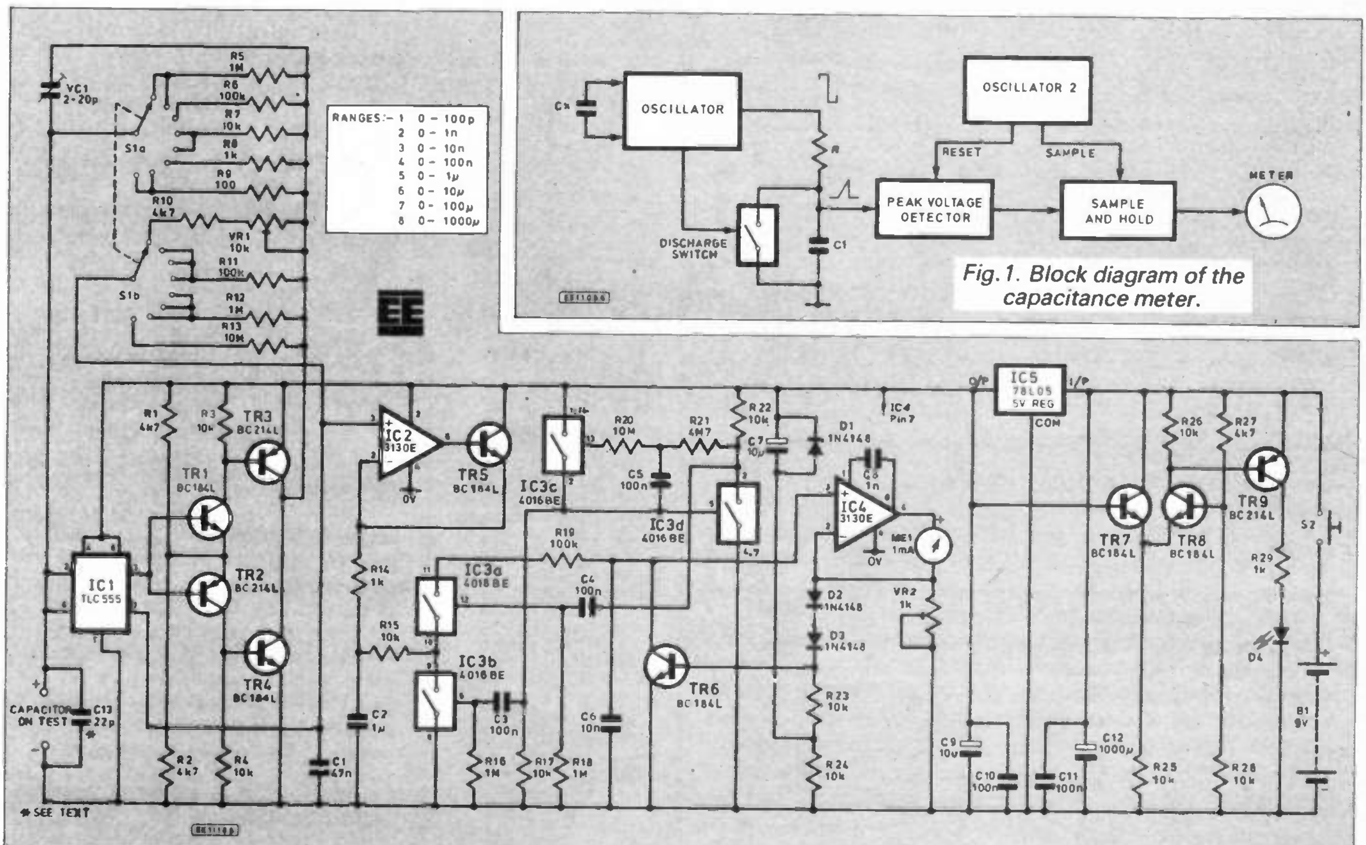


Fig. 1. Block diagram of the capacitance meter.

exponential, but as full scale corresponds to only about a fifth of the supply voltage the voltage reached is practically linear with time. The maximum value is detected, and with suitable values of *C* and *R* gives a direct indication of the value of *Cx*.

Where *Cx* is above, say, 100µF the frequency of oscillation is low, a few hertz at most. Greater speed would require too much current for the intended battery operation.

A low frequency rules out any form of "averaging" output circuit though, as this would take an unreasonably long time to settle. Instead, a sample-hold technique is used. The peak detector follows the voltage on *C* as it rises, then remains at the maximum value reached.

A second oscillator drives circuitry that periodically reads and stores the detected voltage before resetting it. The meter indicates the currently stored voltage. The frequency at which this happens is about 1Hz; the meter can be seen "stepping" and should reach a stable reading within two or three cycles, regardless of the range in use.

CIRCUIT DESCRIPTION

The full circuit diagram for the Capacitance Meter appears in Fig. 2. The oscillator follows the simplest possible arrangement, *Cx*, the capacitor "under test" being connected between ground and IC1 pins 2 and 6, with a single feedback resistor from the output, the value of which is selected by "Range" switch S1a.

The lowest resistor value required for the 100µF and 1000µF ranges, is 100 ohms. IC1's output cannot provide enough current for this so transistors TR1 to TR4 buffer it. The coupled collectors of TR3, TR4 follow pin 3, but provide greater current.

Whilst positive, they also charge capacitor C1 through the resistor selected by S1b. Whilst they are negative C1 is discharged rapidly through IC1 pin 7, behind which lurks the chip's "discharge" transistor.

If the voltage on C1 exceeds that on capacitor C2, IC2, through TR5, pulls C2 up to match it. Initially there is a discharge path across C2 so it will retain the highest voltage reached.

Sample-holding is implemented through IC3, a CMOS 4016B "quad analogue switch". Switches IC3c and IC3d are connected as an astable oscillator, the frequency being set by capacitor C5 and resistor R21 to about 1Hz.

There are two outputs, appearing across resistors R17 and R22, which go positive alternately. As they do so, they pulse the two remaining switches IC3a and IC3b for brief periods set by R18,C4 and R16,C3. When IC3a is closed, the voltage on capacitor C2 is transferred to capacitor C6; when IC3b closes resistor R15 leaks some charge from C2. Between each "read" and "discharge" pulse there is plenty of time for C2 to regain the peak value from C1, at even the slowest operating speed.

A simple voltage-to-current arrangement, for displaying the voltage from capacitor C6 on the meter, is made up by the components around IC4. Transistor TR6 is a clamp circuit for limiting the maximum input.

In the course of design it was found that on powering up, the meter drove hard to full scale. The cause seemed to be some form of breakthrough occurring in IC3 as the supply voltage first appeared across this chip. As push-button operation was intended, and the sight of the meter being overdriven each time was disconcerting, a cure was provided by capacitor C7, which operates the clamp briefly as power is applied.

A stable supply voltage is necessary, this being provided by the 5V regulator IC5. Transistors TR7 to TR9 compare the battery voltage against the regulated supply and drive l.e.d. D4. So long as the battery is healthy the l.e.d. is lit, but it extinguishes sharply at around 7.5V.

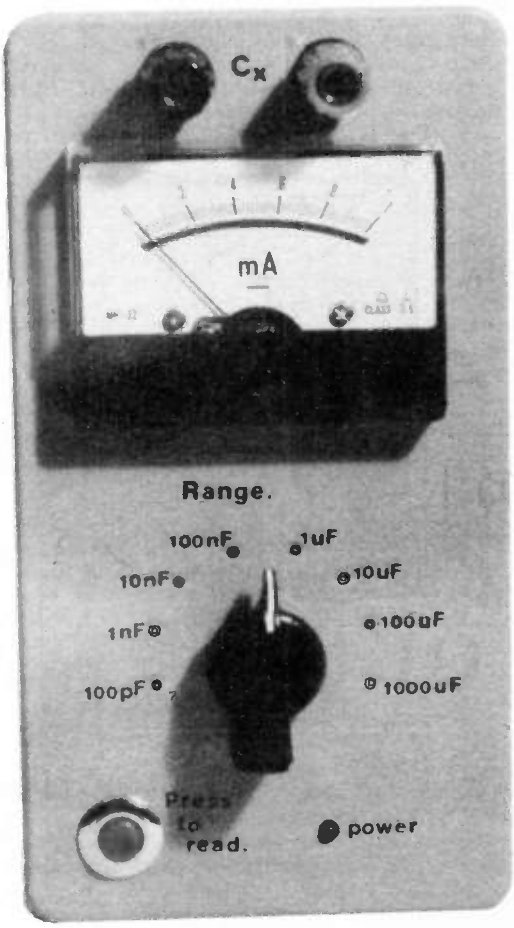
LOW VALUES

The difficulty of measuring large capacitors has been mentioned but at the other end, the 0 to 100pF scale presents its own problems. This is likely to be very useful to radio enthusiasts, so it should be as accurate as possible.

During breadboarding, it was found that the meter would not zero on this range due to stray input capacitance, probably including that of IC1. The solution was the use of the variable capacitor VC1, which can be adjusted to neutralize the strays. When the complete instrument was assembled however, the imbalance had swung the other way.

The range-switch wiring was contributing too much neutralising capacitance on its own. A 22pF polystyrene capacitor was placed directly across the input, which allowed zero adjustment with VC1 as before.

There remains some non-linearity across this range though, about five per cent of scale, which is probably unavoidable in a simple meter of this type. Options for dealing with this will be described in the setting-up procedure.



COMPONENTS

Resistors

R1,R2, R10,R27	4k7 (4 off)
R3,R4,R7, R15,R17,R22, R23,R24,R25, R26,R28	10k (11 off)
R5,R12,R16, R18	1M (4 off)
R6,R11,R19	100k (3 off)
R8,R14,R29	1k (3 off)
R9	100
R13,R20	10M (2 off)
R21	4M7

All 0.6W
1% metal film

Shop Talk
See page 40

Potentiometers

VR1	10k Cermet skeleton preset, horizontal
VR2	1k Cermet preset

Capacitors

C1	47n polyester layer
C2	1µ polyester layer
C3,C4,C5, C10,C11	100n polyester layer (5 off)
C6	10n polyester layer
C7,C9	10µ axial elect. 25V (2 off)
C8	1n ceramic
C12	1000µ axial elec. 10V
C13	22p polystyrene, to fit across input (see text)
VC1	2-20p trimmer

Assorted 1% values for calibration; 10n, 100p, values below 100p, see text.

Semiconductors

D1,D2,D3	IN4148 (3 off)
D4	3mm Hi-bright, red l.e.d.
TR1,TR4,TR5, TR6,TR7,TR8	BC184L *npn* silicon (6 off)
TR2,TR3,TR9	BC214L *pnp* silicon (3 off)
IC1	TLC555 linCMOS timer
IC2,IC4	3130 CMOS op-amp (2 off)
IC3	4016B CMOS quad analogue switch
IC5	78LO5 5V 100mA voltage regulator

Miscellaneous

Case, ABS plastic box 150mm × 80mm × 50mm; printed circuit board, available from the *EE* PCB Service, code EE590; ic sockets, 8-pin (3 off), 14-pin (1 off); S1, "Maka-Switch" miniature shaft assembly and "Make-Wafer", 2-pole 9-way; S2, push-button switch – "press to make"; ME1, 1mA f.s.d. meter; red and black terminal posts; multicoloured ribbon cable; PP3 battery and connector; Pointer knob.

Approx. cost Guidance only **£24**

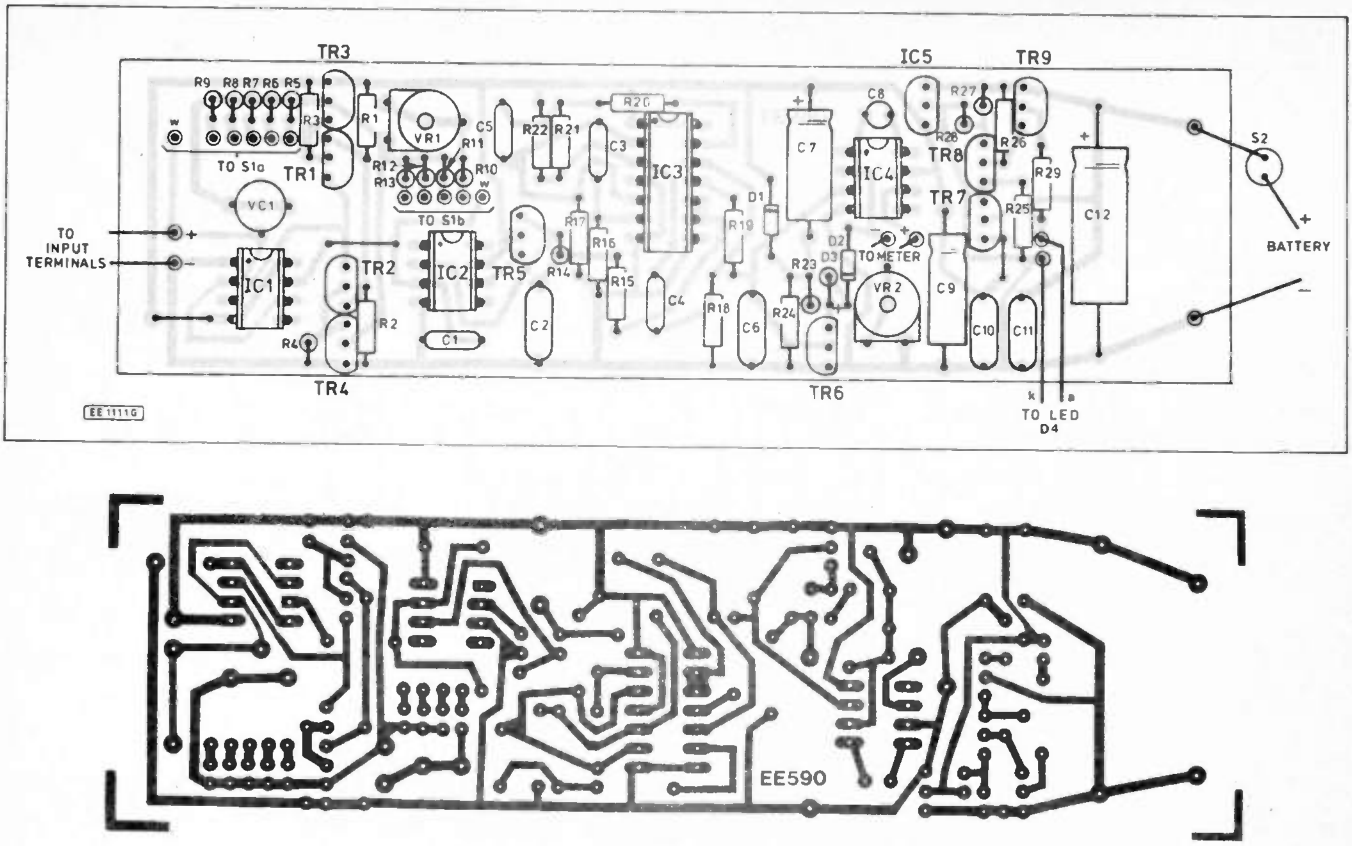


Fig.3. Printed circuit board component layout, interwiring details to case mounted components and full size underside copper foil master pattern. This board is available from the EE PCB Service, *code EE590.*

CONSTRUCTION

Before commencing construction, care should be taken to see that the board is clean. Parts of this circuit operate at very high impedance where leakage can cause substantial errors, so it's worth giving it a wipe with a solvent cleaner and washing one's hands before assembly to prevent any risk of contamination by skin oils, etc.

All the components including the range selection resistors, are assembled on a single printed circuit board. The component layout and full size copper foil master pattern being shown in Fig. 3.

In some places components are quite closely packed, so care and a fine-tipped iron are called for. In general it's best to fit components in order of physical height, as this makes for easier handling and less problems keeping them in place whilst soldering. "Height order" for this project begins with three links, followed by fifteen horizontally mounted resistors.

Sockets are recommended for IC1 to IC4 as this both protects them and aids testing. These ICs should not be plugged in yet. The two variable resistors VR1 and VR3 were "cermets" on the prototype; these are recommended, but standard sub-miniature types can be used, the board is designed to accommodate either.

When the board is assembled, some testing can be carried out before fitting in the case and wiring to the range switch. A long lead should be connected to the "meter" points (it can be shortened later) and the light emitting diode D4 fitted on about 8cm of lead.

Ribbon cable is suggested for all connections, for neatness and reliability. Temporary leads can be soldered to the battery points for testing.

If the board is now powered with just the l.e.d. connected, this should light. Following an initial surge as the electrolytics charge, the consumption should be around 11mA, most of which will be drawn by the l.e.d.

A potential of 5V should appear across capacitor C9, indicating correct operation of IC5. If the facility is available (bench power supply, etc), the supply voltage can be reduced until the l.e.d. extinguishes, this should happen at about 7 to 7.5V.

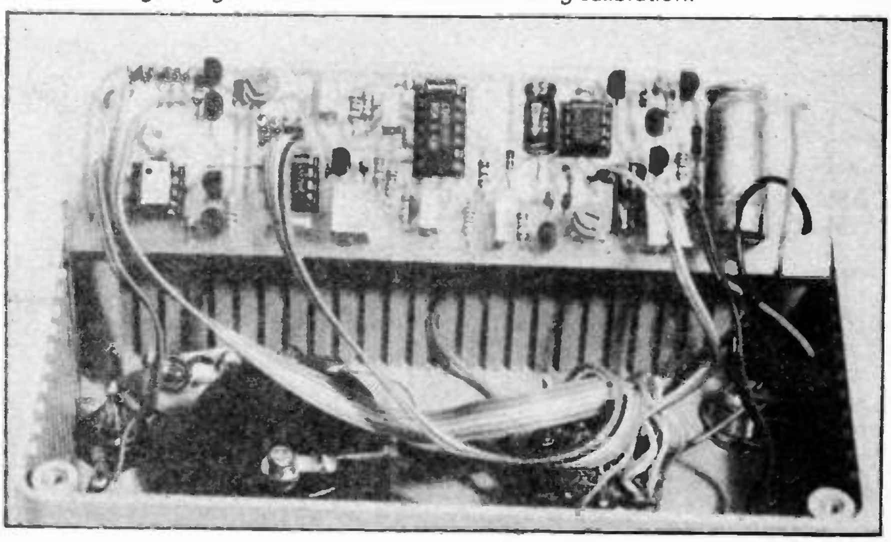
If all appears well, the meter can be connected and IC4 plugged in. With potentiometer VR2 set mid-way, as the board is powered the meter will probably "twitch".

The meter circuit's input can be accessed through pin 11 on IC3's socket (fourth one up, right-hand side). If this is touched with one hand, touching positive supply with the other should cause the meter to rise, possibly to the stop, whilst touching negative should cause it to fall. It should hold at random points when the input is open circuit, reading whatever voltage is retained by C6.

If this test is successful, IC3 can be plugged in and the board powered again. This time the meter should read zero but a very slight pulsing may be visible at about 1Hz, which may increase when the top of capacitor C2 is touched.

Touching the positive supply with the other hand at the same time should cause the meter to rise but it should return to zero when released, in steps at about 1Hz. Next, IC2 can be inserted, after which touching the right-hand side of capacitor C1 with one hand and *positive* supply with the other should cause the meter reading to rise, and C1 with *negative* a fall to zero.

The completed meter with the board removed. All wiring passes under the board and should be long enough to allow it to be removed during calibration.



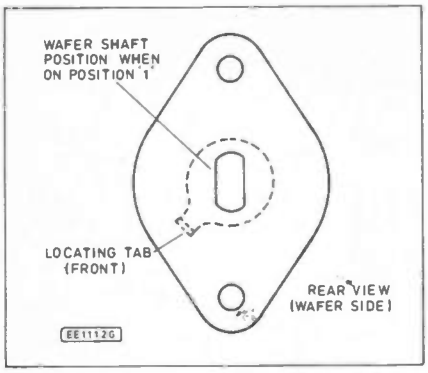


Fig.4. Position of the range switch shaft assembly prior to fitting the contact wafer.

RANGE SWITCH

Further testing requires the use of the range switch, so assembly and wiring of S1 should be completed. The ranges provided on the meter require more than one component value to be switchable, so a 2-pole 8-way switch is needed. A "miniature Maka-switch" assembly is used as a suitable wafer is available.

The correct assembly and wiring of this is not obvious, so it will be described in detail. The parts required are a "Shaft Assembly" and a "2-pole 9-way" wafer, preferably "break-before-make". A point to note is that the wafer contacts are delicate and may catch and bend if the rotor is carelessly turned before assembly. Whilst they can be straightened again, a watch-maker's skill is called for!

The first step is to remove the fixing nut, lock washer and locating tab from the shaft assembly bush. Adjust the stop to No. 8 and replace the other components with the locating tab facing forwards. Cut the shaft to suit the knob and check that there are indeed eight positions.

Rotate the switch spindle anticlockwise (to position 1), then turn over so that the wafer side is uppermost and the locating tab is lower left, as shown in Fig. 4. Next take the wafer, which has contacts and a rotating centre on each side. It will be seen that one of the moving poles is in one piece, with a single wiping contact, whilst the other is in two parts with two wipers.

With this latter side facing away from the switch, turn carefully to the position shown in Fig. 5 and fit to the shaft. When wired as shown, the assembly will now provide the two 8-way switches required.

Two separate lengths of multicoloured ribbon cable with five and six-ways are used to connect the board to the switch, one for each section. These should be 18cm long, and are soldered first to the board, then to the switch.

On the prototype this was done before assembly into the case, the switch being held in a small vice. The links between contacts are made from insulated wire to avoid risk of shorts.

CASE

Detailed case drilling dimensions are given in Fig. 6 as some of the internal clearances are small. The board and other components are mounted in the case as shown in the photographs, all connections save those to the power supply being made with ribbon cable. The wiring to the circuit board is shown in Fig. 3.

All the wiring passes under the board and the use of ribbon cable makes it easier to lie flat. It should all be long enough to allow the board to be pulled out for access beside the case during calibration.

Red and black input terminals are provided for *C*x ("capacitor under test"), with the black

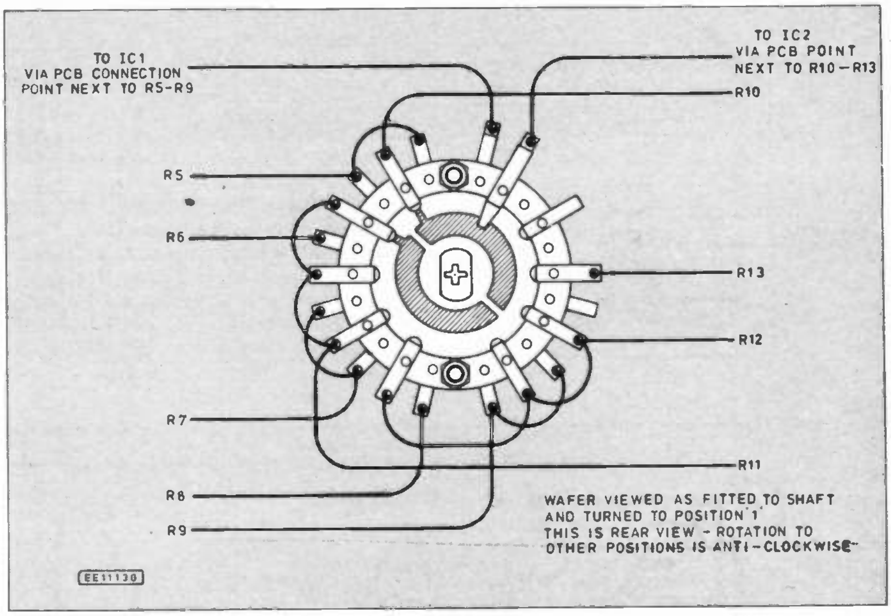


Fig.5. Interwiring details for the range switch S1. The switch should be wired to the circuit board using 6-way and 5-way multicoloured ribbon cable.

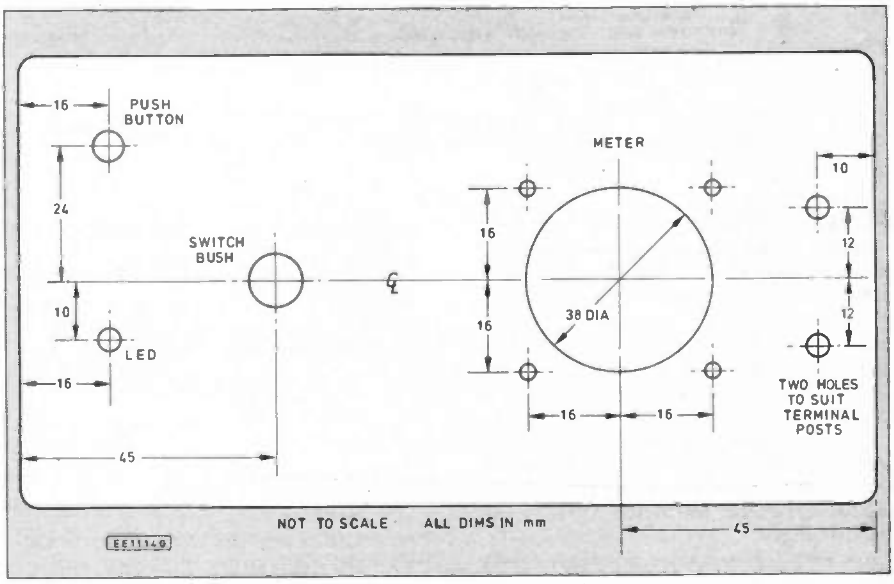
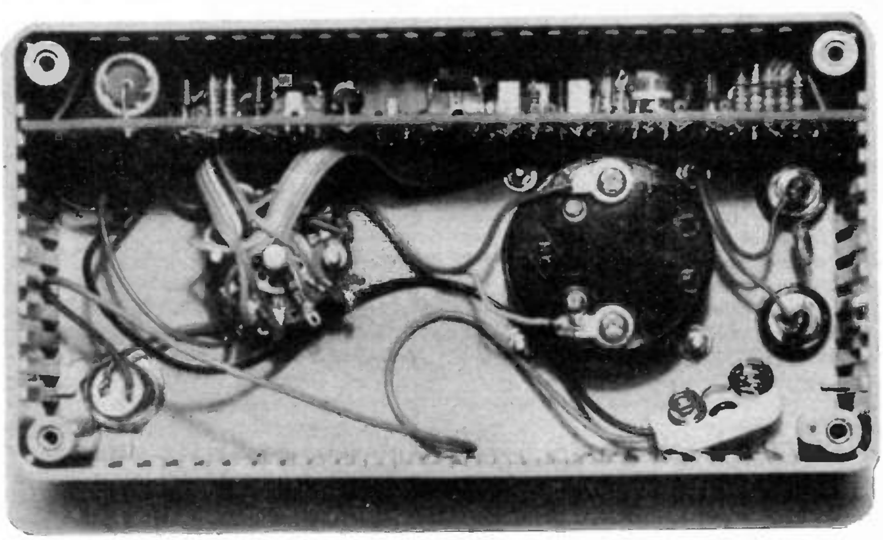
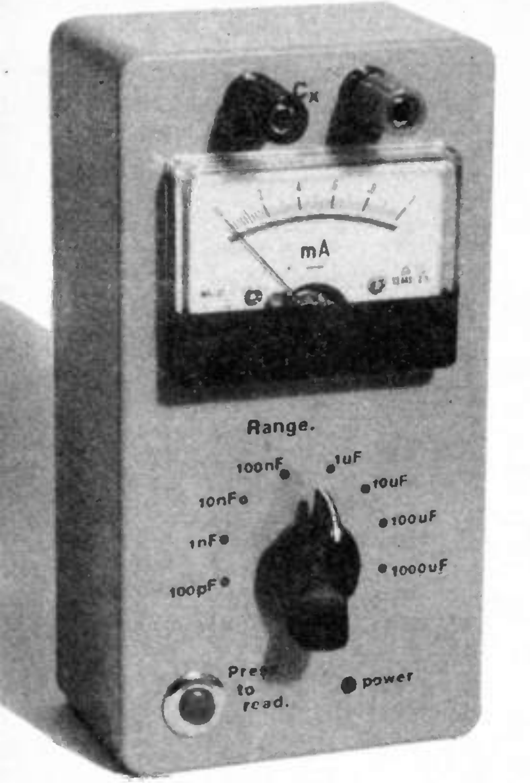


Fig.6. Case drilling details. The circuit board and other components are mounted in the case as shown in the photograph below.





being connected to the negative supply side of the input, indicating polarity for electrolytic testing. A 22pF polystyrene capacitor (C13) should be connected directly across them.

CALIBRATION

For calibration only, bypass the push-button so that the supply is on continuously whilst the battery is fitted. A simple short across the button terminals will accomplish this.

Calibration is carried out with suitable test capacitors, 1 per cent silvered mica or polystyrene types being ideal. Begin by connecting a 10nF capacitor across the terminals and switching to the 10nF range. Adjust VR2 for a full scale reading.

This is the only calibration needed for all ranges save 100pF. For this, first connect a 100pF capacitor and adjust VR1 for full scale. Then connect a 10pF and adjust VC1 for 10 per cent scale. Then connect a 10pF and adjust VC1 for 10 per cent scale. Repeat this procedure until the reading is correct at both points.

When calibrated in this way the prototype exhibited some non-linearity on this range, from 20 per cent to 90 per cent the readings were a little high. If the lower adjustment was carried out at 22pF instead of 10pF the accuracy improved, but below 22pF the readings became so inaccurate that the ability to indicate values below 10pF was virtually lost.

A slightly better solution was to adjust for "best compromise", but best of all is to calibrate as before, then, with the help of suitable values of silvered mica, mark the cardinal points for this range separately on the meter scale. Quite outstanding accuracy for such a simple meter can be obtained in this way.

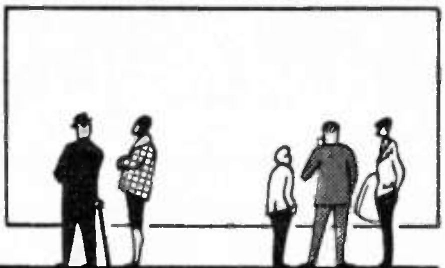
CONCLUSION

This instrument should prove invaluable in any workshop. It's far quicker and simpler to use than a bridge, and quite accurate enough for most purposes.

The true value of large electrolytics can be easily checked, useful where tolerances can be as much as −20 per cent to +50 per cent. At the other end of the scale, the capacitance between adjacent stripboard copper tracks, ribbon wires and the cores and screens of shielded cables can be measured.

In between it will cope with all those capacitors whose markings are ambiguous or have rubbed off, and with trimmers of uncertain origin and span. Even the effects of temperature on ceramics can be observed. In short, most constructors will soon wonder how they ever managed without it. □

SHOP TALK



BY DAVID BARRINGTON

Catalogue Received

With so many new lines in the latest 176-page **Cirkit** catalogue it is difficult to select one particular product for special mention. However, just to mention two items that caught the eye there is a printed circuit board "workstation" that is claimed to remove most of the mess from making your own p.c.b.s and under the "Kits & Modules" section is a new mobile CB rig.

The Uniden 400 is claimed to be the first CB kit in the UK to be designed and approved to the new CEPT regulations. Designed for the 27MHz CB band, the 400 is a 40 channel, synthesized controlled, f.m. transceiver suitable for mobile operation.

The new edition has been completely restyled and the pages certainly seem better visually and easy to follow. The only minor criticism is that devices would be easier to locate and make the "semiconductor index" easy to follow if it was in alphanumeric order.

With over £200 in prizes to be won, the top prize in this year's, easy to enter competition is a Thandar 600MHz Frequency Counter valued at £156.25, including VAT. Second prize is a digital multimeter and third, fourth and fifth prizes are a Cirkit 2000 digital timeswitch. Five runners-up will each receive a component pack containing an assortment of components.

The Winter 1987/8 edition catalogue lists well over 3,000 product lines and still only costs the reader £1.20 from most large newsagent stores. It also contains redeemable discount vouchers with values from £1 to £4, usuable on orders over £15, £30, £45 and £60 respectively.

GTi Car Computer

At first sight some readers may feel that the **GTi Car Computer** may be beyond their expertise, but don't be put off, with the use of a double-sided printed circuit main board the construction of this excellent project should be within most constructors capabilities, provided the instructions are followed carefully.

Obviously, with a project of this nature some of the components used are "specials" and arrangements have been made with **Mark Space Enterprises** to supply these in kit form. A kit comprising those parts not generally available, i.e. case, front panel label and switches (5 off), p.c.b.s, four seven-segment displays, sensor coil and a programmed ROM is available for the sum of £34.50.

A complete kit (£64.50, inclusive of p&p) for the *GTi Car Computer* may be purchased from **Mark Space Enterprises, Dept EE, 11 Church Green Road, Bletchley, Milton Keynes MK3 6BJ.**

Bench Amplifier

Although it is quite in order to use lower spec' resistors in the *Bench Amplifier,* we strongly advise constructors to use the one per cent metal film types recommended. Metal film resistors are carried by most component stockists and though slightly more expensive than carbon types the final performance well justifies the outlay.

When purchasing the BC184L transistor remember to specify the **L** type as pin connections for this device vary. The printed circuit board is available from the *EE PCB Service*, code EE591.

Capacitance Meter

All the components required to build the *Capacitance Meter* appear to be fairly standard devices and we do not expect readers to experience any buying difficulties. The cermet presets, the "Maka-Switch" assemblies and the ribbon cable is now extensively stocked by component suppliers.

The linCMOS low power timer, type TLC555, is a pin-for-pin replacement for the ubiquitous 555 timer, but requires only about one fiftieth of the supply current and has an extremely low trigger, threshold and reset current. The operating voltage ranges from 2V to 18V. This device is currently stocked by **Maplin**, order code RA76H (TLC555CP) and **Cirkit**, stock code 61-15550.

Light-up, Squeak-up, Shut-up

The switch S1 used in the prototype *Light-up, Squeak-up, Shut-up* project is an old spare biased-off key type switch. You can, of course, use any of the common biased-off push-button switches in this circuit.

Having been almost spiked on the prototype probe "needles" several times, it is probably a wise precaution to keep the probe points inbedded in a piece of polystyrene or in some flower arranging "oasis" when not in use.

Transistor Curve Tracer

All of the components required to build the *Transistor Curve Tracer,* described in this month's *BBC Micro* feature, seem to be available as "off-the-shelf" items.

A suitable printed circuit board for this project is available from the *EE PCB Service,* code 592. The use of a four-pole three-way rotary switch was chosen as this item was in the "spare box" and is also readily available from component suppliers.

The 8-bit D/A converter chip type ZN426E should be available through most of our component suppliers. If readers do experience difficulty in locating this device it is currently listed by **Greenweld, Maplin, Omega** and **Xen.**

We cannot foresee any component buying problems for the *Quizmaster* project or the *Reaction Timer* – this month's *Exploring Electronics* project.

...Beeb...Beeb...Beeb...Bee

... Transistor testing ... Transistor Curve Tracer Interface ...

PROGRESSING from last month's article dealing with basic transistor testing using the BBC micro, in this month's *BEEB Micro* article we will consider basic transistor curve tracing. Detailed data on transistors tends to have large numbers of graphs showing a variety of curve types, and I would guess that virtually all of these could be produced using the BBC micro plus a reasonably simple interface.

Some transistor graphs are of more academic significance than practical importance, and are probably not worth bothering about. Others are of little academic value, but are of *great* practical help.

The simple curve tracer interface that is described here is in this second category. It is rather too rough and ready to be of great scientific value, but it clearly shows whether the device under test is functioning properly.

It can also provide current gain measurement. It is in fact a slight development of the interface described in the previous *BEEB Micro* article.

Base Response

The basic action of a transistor is to produce a current flow in its collector circuit that is proportional to the current fed into its base circuit. However, the collector current is much larger than the input current to the base, and the transistor therefore provides amplification.

Most transistor testers, including the one described in the previous article, provide a small base current to the test device, and then measure the resultant collector current. With suitable calibration this gives a direct readout in terms of current gain.

This is not a totally reliable way of doing things, and a plausible current gain reading does not necessarily indicate that the transistor under test is fully serviceable. The main risk is that the device will have a high leakage level (i.e. a high current flow with no base current applied). This could give the impression that the base current is producing a suitable collector current, whereas it might be purely the leakage current. The test transistor might even have zero again! Misleading results of this type can be avoided by first checking each device with its base lead left unconnected, so that a high leakage current will be brought to light.

If a high leakage level is detected, connecting the base terminal might produce a significant increase in current which would indicate that the device does have a reasonable current gain. Even so, silicon transistors should have very low leakage currents (usually well under one microamp), and most circuits are designed on the assumption that the leakage level is so low that it can be ignored. A device that has a high leakage current is unlikely to be of much use in practice.

A few transistors that exhibit low leakage levels have been encountered and when tested at a spot current seem to offer a reasonable level of gain. But despite this, when tried in a circuit results were far from good.

This is generally the result of damage due to excessive voltages or heat, and the problem seems to be a lack of linearity in the input/output current characteristic. This can produce what is more of a switching action than a linear characteristic, but the most common problem is the collector current failing to rise significantly once a certain base current is reached.

The certain way of testing the gain characteristic of a transistor is to feed it with a wide range of base currents, noting the resultant collector current for each one. This kind of testing can be a bit tedious to carry out manually, but it is the sort of thing that a computer can carry out very rapidly, giving the results either in tabular or graph form. Fig. 1 shows the basic arrangement needed to carry out this type of testing using the BBC computer.

Reading the current flow in the collector circuit presents few difficulties since the analogue port provides inputs that can easily be used to measure current. The only slight problem is in accommodating both *npn* and *pnp* transistors.

The *pnp* typed can directly drive the analogue port, but a current mirror is needed in order to provide a suitable output signal from *npn* transistors. A mode switch gives either direct connection or switches in the current mirror, and it also connects the emitter terminal to the appropriate supply rail for the type of transistor being tested. This part of the interface is actually identical to the design described in the previous article.

Where this interface differs from its predecessor is in the method of driving the base terminal. In the original design the base was connected to the appropriate supply rail via one pole of the mode switch and a series resistor, so that it received a fixed current.

In this case there is no *npn/pnp* switching in the base circuit. This could be incorporated in the interface, but the alternative of software switching offers a zero cost solution. The base is fed via a current limiting resistor, but this is fed from the output of an amplifier, which is in turn fed from the output of an 8-bit digital-to-analogue converter (DAC). The converter is driven from the user port.

The output voltage from the amplifier (in millivolts) is equal to the value fed to the user port multiplied by twenty, and values from 0 to 250 therefore produce an output that varies from 0 to 5V in 20 millivolt steps. An important point to note here is that the circuit is powered from the +5V supply of the computer, and that the output of the amplifier can be varied from one supply rail potential to the other.

For *npn* transistors outputting values from 0

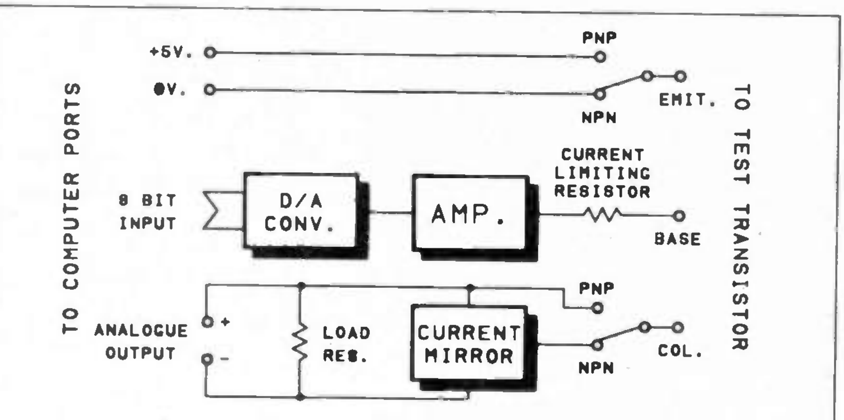


Fig. 1. Block diagram showing general arrangement used in the Transistor Curve Tracer

COMPONENTS

Resistors

R1	390
R2,R3	22k 1% (2 off)
R4	8k2
R5	43k
R6	220k
R7	180

All 0.25W 5% carbon, except where stated

See Shop Talk page 40

Capacitor

C1	1µ radial elec. 63V

Semiconductors

TR1,TR2	BC559 *npn* silicon
IC1	ZN426E 8-bit D/A convertor
IC2	CA3140E MOSFET input Op. Amp.

Miscellaneous

S1	4-pole 3-way rotary switch
S2	d.p.d.t. slide switch

Printed circuit board, available from *EE PCB Service*, code 592; sockets, ribbon cable; connecting wire, pointer knobs, etc.

Approx. cost Guidance only £10

to 250 gives a steady rise in base current. For *pnp* devices, which have the emitter connected to the +5V rail, it is values from 250 down to 0 that provide a steady increase in base current. It is this factor that enables software *npn*/*pnp* switching to be used in the base circuit.

Although it was stated that a steady increase in the base current is produced, this is not strictly true. The input characteristic of a transistor is much like that of a forward biased silicon diode.

In other words, about 0.5V or so is needed before there is any significant current flow. The resistance into the base then becomes quite low, and the current flow is largely determined by the value of the current limiting resistor, and the margin by which the input voltage exceeds the forward threshold voltage of the base.

What this means in practice is that about the first fifty values have no effect, and (with a functioning device) produce zero output current. This could be largely overcome in software by using a starting value of about fifty for *npn* transistors, or around two hundred for *pnp* types, but in practice it is probably not worthwhile doing this. As you know what to expect this lack of output will not be interpreted as a fault in the test device, and it is interesting to see that some transistors have significantly higher turn-on threshold voltages than others.

TRANSISTOR CURVE TRACER

The full circuit diagram for the Transistor Curve Tracer Interface is shown in Fig.2, but this will not be described in detail. The right-hand section of the circuit is the same as the equivalent part in the Transistor Checker described last month, and the rest of the circuit is based on a Ferranti ZN426E Digital to Analogue Converter which has also been covered in a previous article.

A suggested component layout and full size printed circuit foil master pattern is shown in Fig.3. This board is available from the *EE PCB Service*, code 592.

One aspect of the circuit that is worthy of mention is that IC2 is powered from the +12V supply and not the +5V line that is used to power the other parts of the circuit. The CA3140E specified for IC2 has an output stage that will operate at voltages virtually right down to the 0 volt supply rail voltage. This obviates the need for a negative supply rail.

However, IC2's output stage does not operate at voltages within about 2V of the positive supply rail though. Thus, in order to achieve the required maximum output potential of 5V, IC2 must have a positive supply of about 7V or more.

Provided the computer is not being used to power a disc drive or drives, the +12V supply can be obtained from the power port. Alternatively, the circuit of Fig. 4 can be used to provide a supply of just under 8V from the 5V output of the user or analogue port. This circuit may well prove to be cheaper (and easier) than obtaining a plug and lead for the power port!

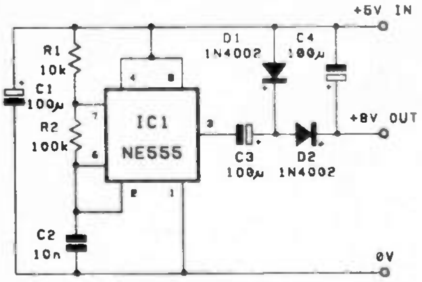


Fig.4. Circuit diagram to provide a +8V supply for IC2.

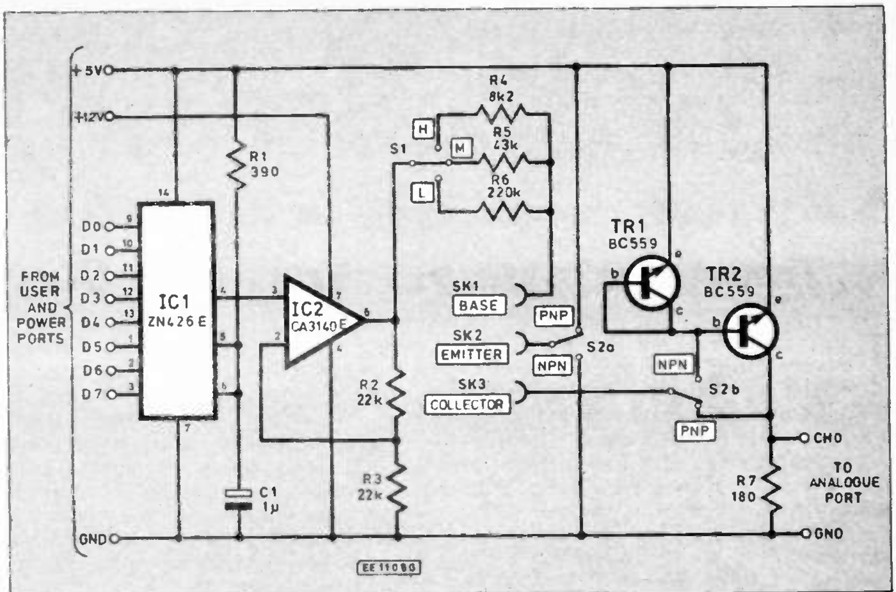
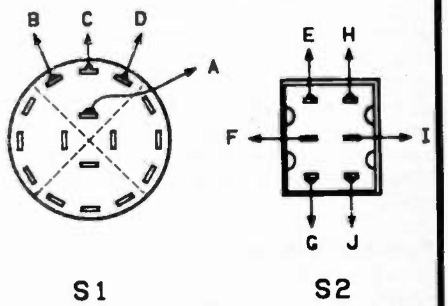
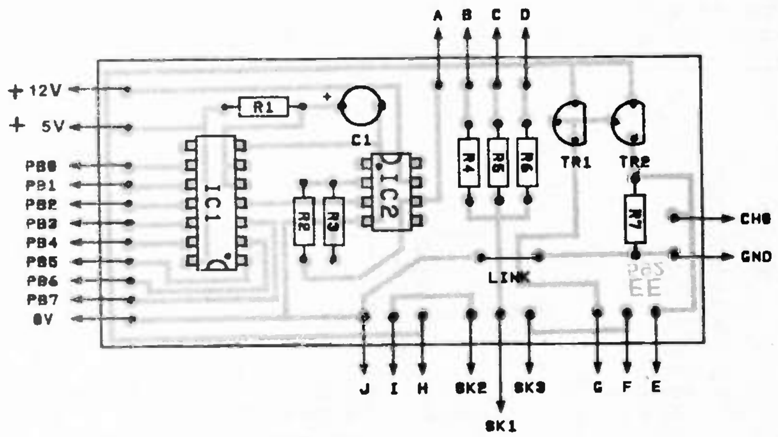


Fig.2. Complete circuit diagram for the Transistor Curve Tracer Interface. An alternative power supply for IC2 is shown in Fig.4.

BBC MICRO
TRANSISTOR CURVE TRACER INTERFACE





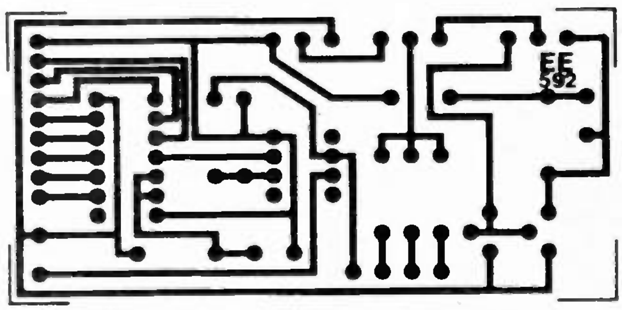


Fig.3. Suggested printed circuit board component layout and full size underside master foil pattern. The leads terminated with letters are wired to corresponding points on the switches shown above.

This board is available from the *EE PCB service*, code 592 (see page 62).

current intensities, with resistors R4, R5, and R6 giving maximum base currents of about 500μA, 100μA, 20μA respectively. It is a matter of selecting the resistor that gives the greatest vertical deflection on the graph without any readings going off-scale, and this can only be done by trial and error. One final point about the circuit is that resistors R2 and R3 should have a tolerance of one per cent.

Software

The accompanying listing is for a basic curve tracer programme, and it clearly demonstrates that using a computer to plot graphs does not necessarily mean resorting to massive programs. The program is largely self explanatory in operation and in use, but note that an upper case "N" is needed to select the *npn* mode and produce a graph (any other key will select the *pnp* mode). There is plenty of scope for adding "frills" to the program, such as calibration marks on the *X* and *Y* scales, and possibly a table of results including calculated gain values.

Curve tracer is perhaps not a very apt name for this particular gadget as with most transistors the line produced is virtually straight. All transistors tend to have relatively low current gains at low collector currents, and the classic response from a unit of this type is an initial curve leading into an almost straight line.

A steep slope and a high final value indicates high gain. A straight line means that the test device has perfect linearity (which will not happen in practice) while a pronounced curve indicates that the device will generate relative large amounts of distortion.

Some transistors do produce what are far from straight lines, but these are generally types that are only intended for switching applications, or some other specialist application. Any pronounced kinks or other severe irregularities in the graph indicate that test device is faulty (or that you have selected the wrong operating mode on the interface).

If you have a VMOS transistor to hand you may care to try connecting this to the unit. These are voltage rather than current operated, and what the unit will actually plot is input voltage versus output current (the setting of S1 will be irrelevant incidentally). The drain, gate, and source of a field effect transistor (f.e.t.) are equivalent to the collector, base, and emitter (respectively) of a bipolar type. VMOS transistors have enormous power gains, and the slope of a graph will probably be quite steep. Do NOT try testing j.f.e.t. devices (2N3819 etc.) with the unit as it is totally unsuitable for operation with these.

Another experiment worth trying is to feed the base of the component under test direct from the output of IC2. The system will then plot base — emitter voltage versus collector current. The rapid turn on as the forward threshold voltage is reached should be clearly shown, with an almost vertical trace.

SOFTWARE

```
 10 REM Curve Tracer Program
 20 MODE 1
 30 MOVE 276,950
 40 DRAW 276,96
 50 DRAW 1280,96
 60 VDU24,280;100;1279;950;
 70 REM sets graphics window
 80 VDU29,280;100;
 90 REM sets graphics origin
100 PRINTTAB(20,30)"Input Current >"
110 PRINTTAB(5,12)"^"
120 PRINTTAB(2,13)"Output"
130 PRINTTAB(1,14)"Current"
140 ?&FE62=255
150 REPEAT
160 PRINTTAB(0,0) "Press 'N' for NPN or 'P' for PNP ";
170 type$=GET$
180  PRINT type$;
190 CLG
200 MOVE 0,0
210 FOR Y=0 TO 250 STEP 1
220 IF type$="N" THEN OV=Y ELSE OV=250-Y
230 ?&FE60=OV
240 IV=ADVAL(1)
250 DRAW Y*4,IV/80
260 NEXT Y
270 UNTIL FALSE
>
```

NEXT MONTH

LONDON TO SYDNEY IN

THREE HOURS

Hermes, HOTOL, NASP and a possible Soviet Shuttle? You have probably read all about them in the news recently — we take a look at what the future may hold without getting involved in the politics. A day trip to Australia!

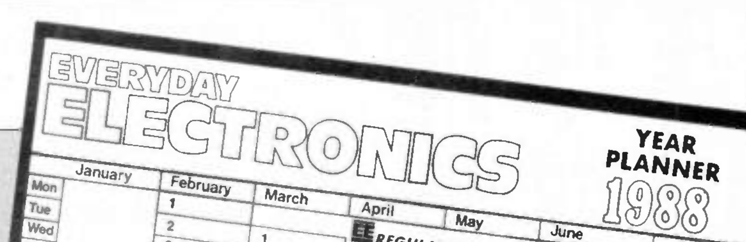
ONE VALVE RECEIVER

Ever felt like a change from anonymous plastic packages and printed circuit boards? Fancy a radio with a nice warm glowing valve on a metal case — something that you can "see" is working? Then this project is for you.

EMERGENCY LIGHT UNIT

Just the job for winter power cuts, this project will provide up to 12 hours of automatically controlled light in the event of mains failure. Two different versions are described, each providing emergency lighting from rechargeable cells.

FREE! with every issue



1988 YEAR PLANNER

EVERYDAY ELECTRONICS

FEBRUARY ISSUE ON SALE FRIDAY JANUARY 8TH

exploring electronics

OWEN BISHOP

This series is designed to explain the workings of electronic components and circuits by involving the reader in experimenting with them. There will not be masses of theory or formulae but straightforward explanations and circuits to build and experiment with.

Part 19
High Speed Logic

CIRCUITS built using integrated circuits have several advantages over circuits built from separate transistors, resistors and other components. They occupy less space, they are simpler to assemble and often cost less too. Another advantage is that most i.c.s are designed to operate at high speed.

All of these advantages explain why the arrival of low-cost home computers depended upon the availability of i.c.s. This month we have two projects that depend upon the high speed operation of i.c.s. The i.c.s used are not the fastest available but, even so, are more than adequate for the purpose.

PROJECT ONE
REACTION TIMER

The circuit diagram shown in Fig. 19.1 allows you to measure your reaction time to the nearest tenth of a second. This is really the same circuit as the Christmas Lights described last month – an oscillator followed by a counting chain.

The difference here is that this circuit is stopped and started under the control of a bistable. In the non-running state the bistable holds the reset input of the 555 timer (IC2) low, so it does not oscillate.

The 7493 binary counter IC3 is first reset by pressing switch S3. All lamps go out. Now your friend presses the "start" button (S1). Instantly the bistable changes state. The reset of the 555 goes high and it begins to produce 10 pulses a second. These are counted by the 7493.

At the same time as counting begins, the light emitting diode (l.e.d.) D6 comes on. You should be watching for this and ***as soon as you see it come on,*** you press the "Stop" button (S2). When you press this, the state of the bistable is reversed, the counter stops counting and D6 goes out.

The count indicated by l.e.d.s D1 to D5 tell you how many tenths of a second elapsed between the instant when your

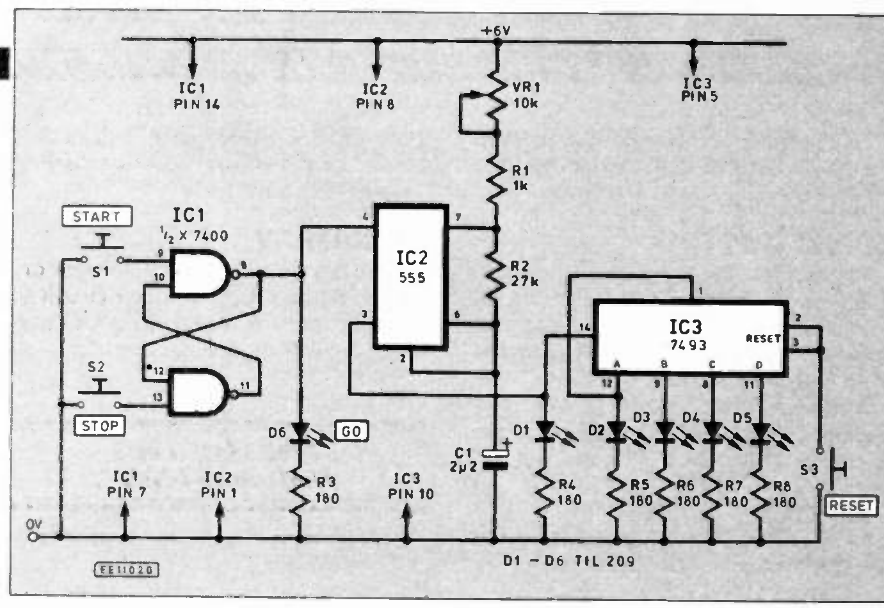
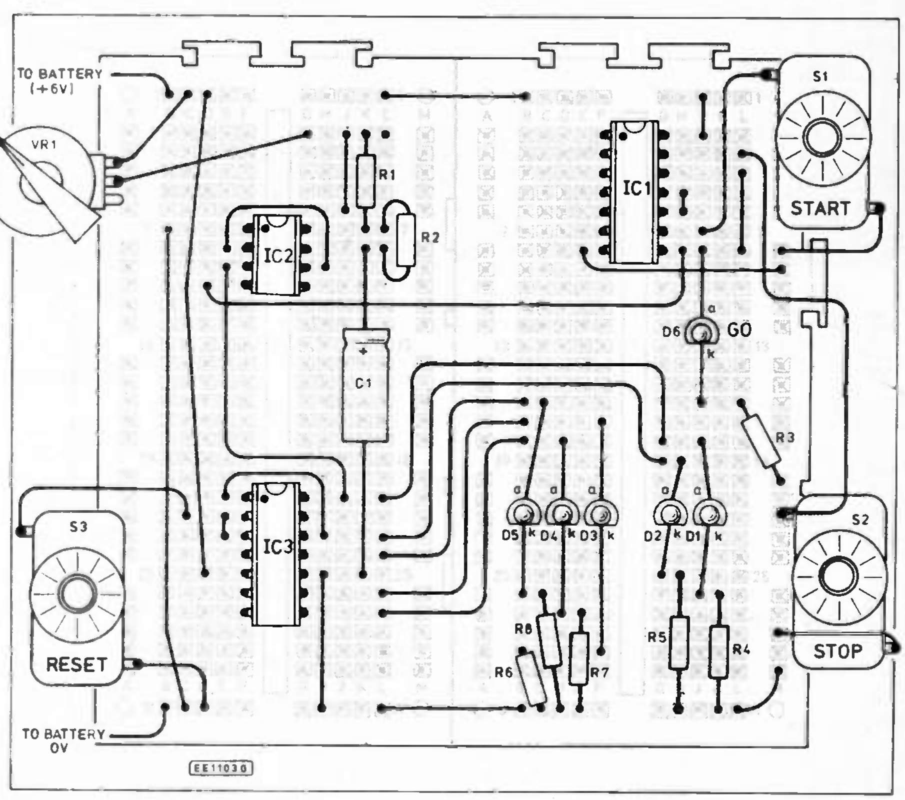
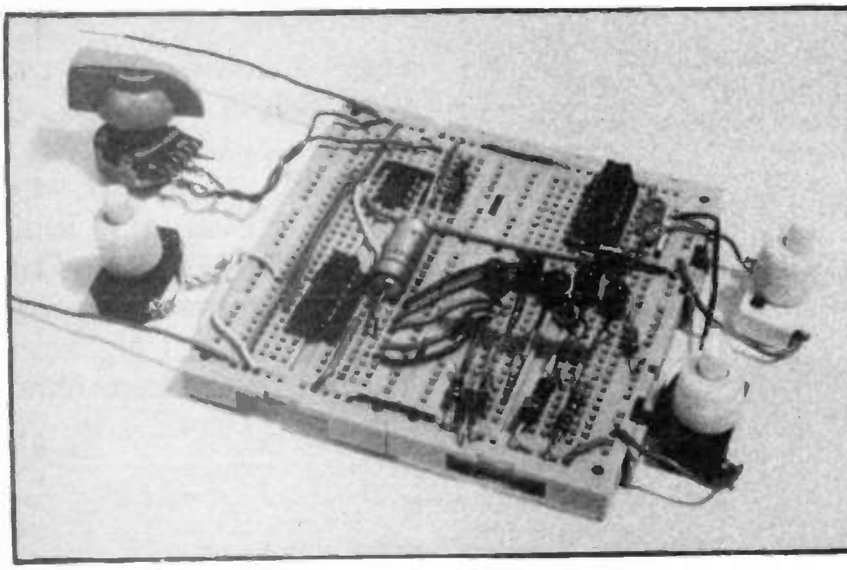


Fig. 19.1. Circuit diagram for the Reaction Timer using the 555 timer i.c.
Fig. 19.2. Demonstration breadboard component layout for the Reaction Timer.





friend pressed the Start button and the instant you pressed the "Stop" button. This is a measure of your reaction time.

CONSTRUCTION

The demonstration breadboard component layout for the Reaction Timer is shown in Fig. 19.2. If possible, place the start button out of sight, so that you can not tell when your friend is about to press it. When the circuit is assembled, let it run steadily and watch the final l.e.d. of the sequence. This should go out every 3.2 seconds.

You will need to adjust potentiometer VR1 to make the 555 timer run at the correct frequency. The easiest way is to watch the fifth l.e.d. as it goes out. Measure how long it takes to go out 10 times, this should be 32 seconds exactly. Then you know that the count indicated on the l.e.d.s is your reaction time in tenths of a second.

VARIATION

Here is a problem for you to work on. How can you adapt the timer circuit so that it can be used as a lap-timer for races, for example with model racing cars?

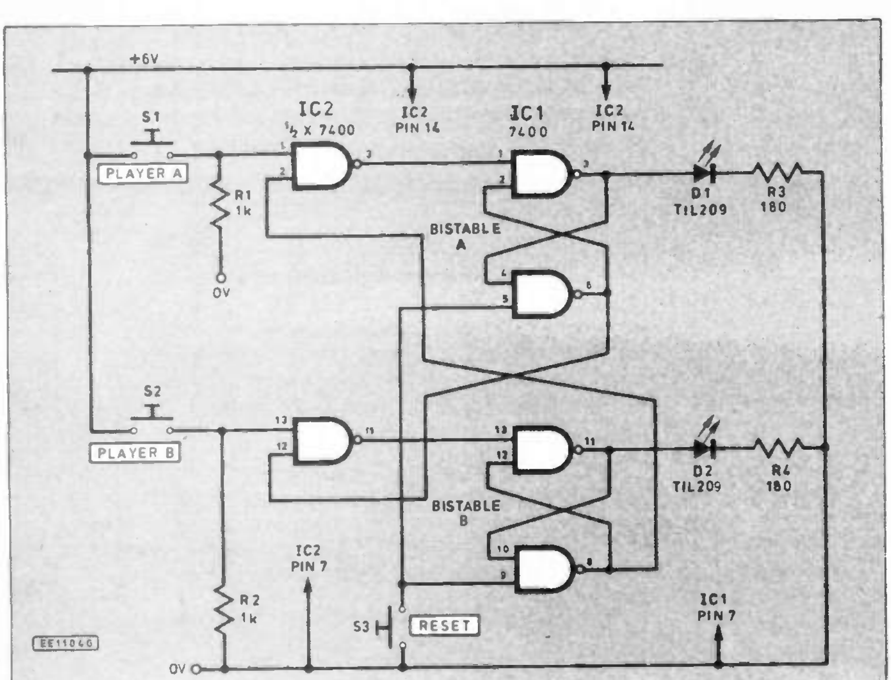
PROJECT TWO
WHO WAS FIRST?

It is all to easy to disagree about who did something first. With the circuit diagram shown in Fig. 19.3 there can be no argument – even when one person is only 25 seconds before the other. Since a nano second is only a thousand-millionth of a second, most close ties can be decided easily.

The circuit (Fig. 19.3) is triggered by push-buttons operated by two players – perhaps they are playing "Snap" or some other game in which it is necessary to know who was first. It could instead be triggered by two phototransistor light sensors and be used in deciding which model car was first to cross the finishing line.

For each player there is a bistable, which operates an l.e.d. When the circuit is reset (press S3) and ready for action, both l.e.d.s are out.

Fig. 19.3. Circuit diagram for a simple Who Was First? project using the 7400 quad 2-input NAND gate i.c.s.



COMPONENTS

REACTION TIMER

Resistors

R1	10k
R2	27k
R3-R8	180 (6 off)

All 0.25W 5% carbon

Potentiometer

VR1	10k linear, carbon track potentiometer

Capacitors

C1	2μ2 electrolytic

Semiconductors

D1-D6	TIL 209 (or similar) l.e.d. (6 off)
IC1	7400 quad 2-input NAND gate
IC2	555 timer
IC3	7493 4-bit binary counter

Miscellaneous

S1-S3	Push-to-make or push-button switch (3 off)

Breadboard (2 off, or 1 large); connecting wire; knob for VR1 and 5V to 6V supply.

WHO WAS FIRST?

Shop Talk
See page 40

Resistors

R1,R2	1k (2 off)
R3,R4	180 (2 off)

Semiconductors

D1,D2	TIL209 (or similar) l.e.d. (2 off)
ICI-IC2	7400 quad 2-input NAND gate (2 off)

Miscellaneous

S1-S3	Push-to-make push-button switch (3 off)

Breadboard (e.g. Verobloc); connecting wire and 5V to 6V supply.

Approx. cost Guidance only **£9 each**

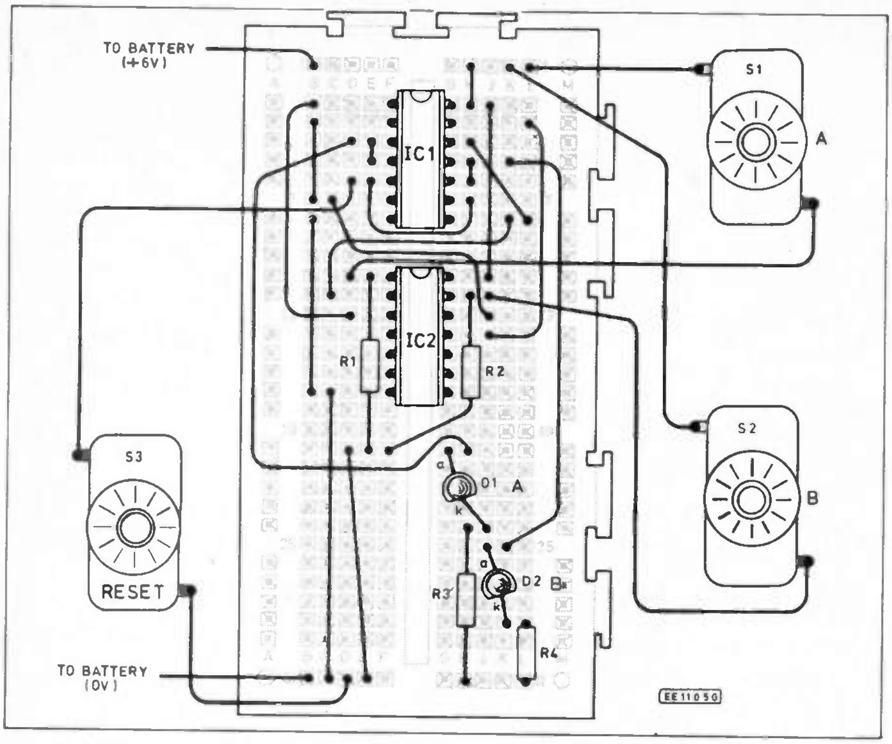


Fig. 19.4. Demonstration breadboard component layout for the Who Was First? circuit

Between each push-button and the corresponding bistable is a NAND gate. One input to the gate comes from the player's push-button. The other input comes from the bistable *of the opposing player*.

Each bistable feeds a "high" input to the NAND gates, so that if the other input is made high, by pressing the button, the output of the gate goes low. This triggers the bistable.

Suppose that player *A* changes state and the lamp comes on, to indicate the winner. At the same time a "low" input is fed to the NAND gate belonging to player *B*. Now it makes no difference if *B* presses the button or not. The output of that NAND gate is bound to be "high" whatever *B* does and it is impossible for B's bistable to be triggered.

If *B* had pressed the button first, then the opposite would apply and *A* would be unable to trigger the bistable. So the lamp lights for whoever was first, and stays lit until the whole circuit is reset.

The demonstration breadboard component layout for the Who Was First? circuit is shown in Fig.19.4. Commence construction by inserting all the link wires followed by the on-board components. Finally insert the switch and battery leads.

Next month: Doing sums by logic.

...REPORTING AMATEUR RADIO...

TONY SMITH G4FAI

A NATIONAL SOCIETY

The first legislation putting radio transmission under some form of control was the *Wireless Telegraphy Act of 1904*, which granted licences for "wireless experimentation" under very restrictive conditions. From that time governmental control of radio communication has steadily increased, and today individual governments are frequently bound by international agreements when allocating or controlling the radio frequency spectrum on a national basis.

So much of amateur radio can affect, or be affected by, the activities of others that it became obvious, even in the early days, that there was a need for an organisation to represent and support the needs of amateurs in dealing with officialdom, and this was not long in coming.

The organisation for radio amateurs in the UK today is the Radio Society of Great Britain, which has its origins in the London Wireless Club founded in 1913. It was not the first club to be formed but shortly after its formation its representatives met the Secretary of the Post Office to protest about a recent decision of the Postmaster General to introduce a licence fee of one guinea (£1.05) for all wireless experimenters.

At the same time a letter was published from the secretaries of the Derby, Birmingham and London Wireless Clubs on the same subject, suggesting a reduction in the fee to 5/- (25p) or 7/6d (37½p), and inviting other clubs to join the campaign.

UNSUCCESSFUL

It would be nice to report that what must have been the first attempt by British amateurs to protect their interests by joint action was a success, but it was not. The PMG regretted that he could not see his way to reducing the fee, but he did accept an offer by the London club to make arrangements for certifying the qualifications of applicants for licenses, "provided those submitting the testimonials possess an expert knowledge of wireless telegraphy and are qualified to give such testimonials."

By November 1913 there were 162 members of the re-named Wireless Society of London, including many names which subsequently became famous in the history of radio communication. The society suspended its activities in 1915, resuming in 1919.

Many local societies then sought affiliation to it as London was increasingly representing the views of all amateurs, particularly in pressing for the re-introduction of the amateur licence which the government seemed reluctant to agree to following the end of the war. An affiliation conference was held in 1920, where a representative of the Post Office announced that licences would shortly be re-issued, and the first post-war callsigns were heard on the air shortly after.

INTERNATIONAL NEEDS

In 1922, the Society, becoming ever more involved in national affairs became the Radio Society of Great Britain. Two years later saw an international meeting in Paris to which all known national societies were invited to send delegates. Following this the International Amateur Radio Union (IARU) was set up to represent the interests of radio amateurs at international level.

The first Congress of the IARU, apart from making detailed arrangements for its own constitution, discussed the then current transatlantic amateur radio tests, the question of wavebands for amateur use, the adoption of an international language for amateur contacts and the use of special letters in call-signs to indicate the country from which the amateur was transmitting.

Those early delegates could not have visualised, however, just how complex and how extensive the matters to be dealt with by the IARU and its member societies would become.

The RSGB today has well over 35,000 members, and an annual turnover in excess of £1,000,000. It publishes a monthly journal, *Radio Communication;* it publishes and sells authoritative books on amateur radio subjects, and provides a daily reference service from its headquarters to assist members in a wide variety of matters connected with the hobby.

It negotiates with the Department of Trade and Industry, which is the radio licensing authority for the UK, and works with the City & Guilds of London Institute which is responsible for setting the Radio Amateurs' Examination. At the beginning of 1987 it took over responsibility for administering the Amateur Morse test on behalf of the DTI.

VOLUNTEERS

There is a small hardworking headquarters staff, but a vast amount of the work of the RSGB is carried out by volunteer members of the society, acting as office holders, members of the Council, or its various committees. They co-ordinate or provide a wide range of services or activities ranging from advice on aerials (in terms of the requirements of the Town & Country Planning Acts) and television interference, to provision of the QSL bureau.

Contests are organised; exhibitions and rallies arranged; slow Morse and news bulletins are broadcast; the amateur bands are monitored for unauthorised transmissions; propagation conditions are forecast; beacons and repeaters are operated under the aegis of the Society.

Apart from amateur transmissions, the radio bands are fully occupied by other services including government, military, aviation, shipping, commercial and broadcast stations, each with their allotted segments of the spectrum. The pressure to obtain more space at the expense of others is enormous and there is need for constant vigilance to ensure that far from being pushed aside and deprived of its hard-earned frequencies amateur radio itself has the opportunity to expand.

This happened in 1979 when a world administrative radio conference agreed to allocate additional bands to amateurs. But this could not have happened if the RSGB, together with societies from other countries, had not carried out an enormous amount of preparatory work and persuaded their respective governments to support their proposals at the conference.

International amateur radio could not survive today without the existence of its 124 national societies working together through the IARU in a common cause. The Radio Society of Great Britain celebrates its 75th anniversary in 1988. It has a lot to celebrate and a number of special events and activities are being arranged. I hope to tell you about some of these as we go through the year.

FREE LEAFLETS

If you would like to find out more about what the RSGB does it has two free leaflets, *Amateur Radio – an introduction*, and *The RSGB and the Radio Amateur*, which are well worth reading. The Society's address is: **Dept EE, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JW.**

LEARNING MORSE

A new book, *The Secret of Learning Morse Code*, by Mark Francis, GØGBY, is intended specifically to help amateurs learn the code and pass the official Morse test. The interesting thing is that it is not written by an "old hand" passing on the benefit of his years of experience to newcomers, but by someone who only passed the test himself in October 1986.

He received so much help and advice from other amateurs that he felt he should record and publish it for the benefit of others. The result is a well-written comprehensive discussion of just about every aspect of learning Morse code, sending and receiving it competently, and passing the test itself.

As I have mentioned before, international regulations require amateurs to pass a Morse test before they can operate on the bands 1.8Hz to 28MHz, with the result that many amateurs take the trouble to learn Morse, whether they intend to use the code of not, in order to obtain an A licence.

Mark Francis's book is a major addition to the range of publications already available to help with the learning process. Its strength lies in its understanding of those aspects of learning Morse which cause difficulties for beginners, and in the anxieties which they experience in contemplation of being examined in the subject. Published by Spa Publishing Ltd, it costs £4.95 from most amateur radio shops, or £5.85 post paid from **Waters & Stanton, Dept EE, 18-20 Main Road, Hockley, Essex.**

Actually Doing it!!

JUST about every hobby, technical or otherwise, seems to have at least its fair share of jargon and abbreviations. Electronics certainly has more than its fare share, which is perhaps inevitable for such a technical subject. Jargon and abbreviations can be rather bewildering for the uninitiated, but they act as an invaluable short-hand for those with some experience of the subject.

Some electronic abbreviations have become standard parts of the English language, with l.e.d. (or just plain "led") being a good example of this. Others are at the other extreme, and are highly technical and theoretical in nature. In this article we will look at some of those in the middle ground. In particular, we will consider those which the beginner is likely to encounter fairly early on, and where the complete meaning of the abbreviations is considerably less than obvious.

SWITCHING TERMS

When first taking up electronics I found some of the abbreviations used to describe switches rather confusing, and many beginners would seem to be puzzled by the terminology. Even when you have learned that s.p.d.t. stands for "single pole double throw", this is not necessarily of much help.

Taking the most simple types of switch first, there are four basic varieties, as follows:

s.p.s.t. single pole single throw (Fig.1c)
s.p.d.t. single pole double throw (Fig.1a)
d.p.s.t. double pole single throw (Fig.1d)
d.p.d.t. double pole double throw (Fig.1b)

Fig.1 shows the circuit symbols for these switches, and Fig.2 shows the standard contact arrangements for each type. All the switches I have encountered in recent years conform to these contact arrangements, but I obviously cannot guarantee that every switch will do so. If you are ever in any doubt about the contact arrangement of any switch, remember that a few checks with a continuity tester will soon sort things out.

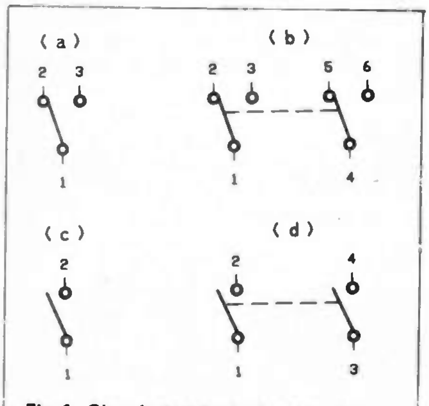


Fig.1. Circuit symbols for the four basic types of switch.

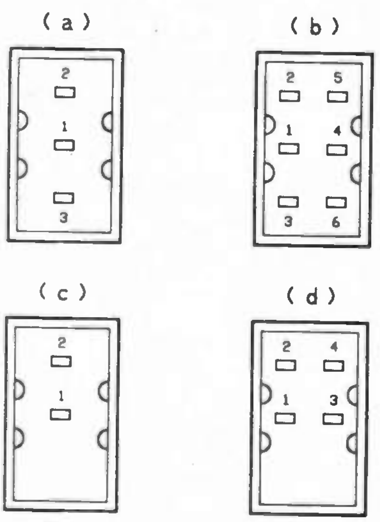


Fig.2. The standard contact arrangement for the four basic types of switch.

POLES

The single pole switches have a single set of contacts, whereas the double pole types have two, and are effectively two switches operated via a single lever. The "pole" incidentally, is the terminal of the switch at which the moving contact pivots. Single throw contacts are two contact types that provide a basic on/off action. The double throw type have three terminals and provide a change-over action. In other words, the pole is connected to one or other of the other terminals. The term "change-over" or "C.O." is often used instead of "double throw", particularly when describing relay contacts rather than manually operated switches.

Switches of the type described above are mostly of the toggle or slider variety, the main exception being d.p.s.t. rotary types intended for mains on/off switching. There are a few more complex toggle and slider types, including "biased" and "centre off" types. The "biased" types are spring loaded so that they return to a particular setting when released, and the "centre off" variety are double throw switches where the pole(s) do not connect to any of the other contacts when they are in the middle one of three positions. There are more exotic types, but with these the retailer's catalogue must be consulted in order to find full details of the contact arrangement.

A useful point to bear in mind is that a double pole switch can be used in place of a single pole type if one section is ignored, and a double throw switch can be used in place of a single throw type if one of the contacts (but not the "pole") is ignored. A d.p.d.t. type can therefore replace the other three types. This can be helpful if you have (say) a d.p.d.t. switch in the spares box and urgently need a d.p.s.t. switch to complete a project. Also, some retailers only stock s.p.s.t. and d.p.d.t. types, and expect the constructor to use the d.p.d.t. type where an s.p.d.t. or d.p.s.t. switch is called for.

ROTARY SWITCHES

Where more complex switching than d.p.d.t. contacts are required a rotary switch is the most common solution. These are generally described as having "x" number of poles and "y" number of ways. A six way two pole switch would often just be referred to as a 6w 2p type. In the past it often needed a quick check with a continuity tester to determine the contact arrangement of these switches. All the types I have obtained recently have had the poles marked "A", "B", "C", etc., and the other contacts marked with numbers from "1" to "12" to indicate their sequence. Taking our 6w 2p example, when adjusted in a fully anti-clockwise direction pole "A" connects to terminal "1", and pole "B" connects to terminal "7". Clicking the switch one position in a clockwise direction results in "A" connecting to "2", and "B" connecting to "8", and so on.

These rotary switches are available in "break before make" and "make before break" versions. Components lists do not usually stipulate one type or the other, and either type should then be entirely satisfactory. The difference is that with the "break before make" type, as the switch is moved from one position to the next, the pole is disconnected from one contact before it connects to the other.

With the "make before break" switches, during the switch-over the two terminals become momentarily shorted together via the pole. If a components list does specify one type or the other, be sure to obtain the right type. There can be problems with momentary short circuits on the supply lines and the like if the wrong type is used. This could seriously shorten the life of the switch, and might not do some other components in the project much good either!

RELAYS

When dealing with relay contacts you are likely to encounter the abbreviations "N.C." and "N.O.". These stand for "normally closed" and "normally open" respectively. A relay is merely a switch that is operated by an electro-magnet. A pair of normally closed contacts are closed (on) when the relay is not activated, whereas normally open contacts are open (off) when the relay is not energised.

The layout of relay terminals is frequently less logical than that of most switches. Some relays actually include a layout diagram on the cover, and retailer's catalogues are also a useful source for this kind of information. Otherwise it is again a matter of checking with a continuity tester to determine the method of connection.

Most projects are based on printed circuit boards these days, and relays are generally printed circuit mounting types. These are unlikely to give any difficulties, since they plug into the board and will almost certainly only fit one way round. This assumes that you use the specified component and not some near equivalent. With relays I would definitely not recommend the use of anything other than the specified component, since physical differences between relays make it difficult to fit even very similar substitute devices.

PC MOUNTING

A lot of components are described as "PC mounting", or even just as "PC" components. The "PC" in this context simply stands for "printed circuit", and it indicates that the component is only intended for use with printed circuit boards. With something like a relay or transformer it means that the component is a reasonably small type with pins on the underside to fit the board rather than having a bracket for chassis mounting plus tags for hard-wired connections.

When applied to smaller components such as capacitors it generally indicates that they are some form of vertical mounting type of small physical size, possibly with pins instead of true leadout wires. When used to describe electrolytic capacitors it means the type having both leadout wires emanating from the same end of the device. These are also known as "radial" electrolytics (the tubular type with a leadout wire protruding from each end are "axial" components).

The trend amongst commercially produced equipment to have as many of the components as possible mounted on the printed circuit board is gradually spreading to home constructor designs. Switches, potentiometers, and sockets designed for printed circuit mounting now appear in component catalogues, and in projects.

It is often possible to use ordinary panel mounted components where printed circuit mounted types have been specified, and to hard-wire them to the board. The finished result is likely to be somewhat less neat though, and while printed circuit mounting components generally guarantee correct connection, mistakes can easily occur when wiring in off-board components. If a project is designed to take printed circuit mounting sockets, switches, etc., then I would advise the use of these components.

LEDs

Just about everyone knows that "l.e.d." stands for "light emitting diode", but "c.c." and "c.a." are much less well known. These are types of l.e.d. display, and they stand for "common cathode" and "common anode" respectively. Something you have to keep in mind when dealing with l.e.d.s is that, unlike filament bulbs etc., they will only light up if they are fed with a voltage of the correct polarity.

Seven segment l.e.d. displays do not have all sixteen terminals available, but instead have a "common" terminal which connects to one side of every segment, plus individual pins for the other connection to each segment. Common anode displays have the common terminal connected to the positive supply rail, and they are mostly used with TTL integrated circuits. With common cathode displays the common terminal connects to the negative supply rail, and these devices are much used with CMOS and other non-TTL based circuits.

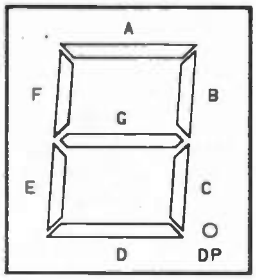


Fig.3. The system of segment identification used for seven segment displays.

Using a common cathode display instead of a common anode type (or vice versa) stands no chance of success. Apart from the fact that the drive signals will have the wrong polarity, the pin functions for the two types of display are not the same either.

When dealing with seven segment l.e.d. displays you may come across references to something like an "A" segment or a "B" segment. These letters do not stand for anything, and the convention has the segments identified by letters from "A" to "G", as in Fig.3. Of course, the "DP" segment is the decimal point segment.

ICs

Integrated circuits are commonly referred to as just "i.c.s". The TTL type are logic devices having the 74*** type numbers. In this context TTL stands for "transistor transistor logic". This may seem a rather odd name for the devices, but the "transistor transistor" part refers to the fact that the output has a transistor switch with a transistor load. Originally there were other logic families with similar names such as "RTL" (resistor transistor logic) and "DTL" (diode transistor logic), but these devices are now all obsolete. There are a number of improved TTL families, as listed below:

LS	Low power Schottky
ALS	Advanced low power Schottky
HC	High-speed CMOS
S	Schottky
H	High-speed
L	Low-power

These are designed for higher speed and (or) lower power consumption than the standard types. Unless you know what you are doing, I would recommend that precisely the specified TTL device should be used, and not an equivalent device from another TTL family. CMOS, incidentally, stands for "complementary metal oxide silicon", and is the type of transistor used in these integrated circuits.

D.I.L. integrated circuits are types in a "dual in-line" package. In other words, devices of the type which have two rows of pins, which is the vast majority of integrated circuits. The pins in each row are spaced 0.1 inches (25.4 millimetres) apart. The rows are 0.3 inches apart (76.2 millimetres) for the smaller types, and 0.6 inches (152.4 millimetres) for components with twenty-four pins or more. There are a few q.i.l. (quad in-line) devices which have the pins in a sort of staggered arrangement that effectively gives four rows. There are also some s.i.l. (single in-line) types (mainly power devices) which have a single row of pins.

Do not be confused if you see other types of components described as s.i.l. or d.i.l. types. There are now many types of component available in s.i.l. and d.i.l. encapsulations, including relays, resistor networks, switches, plugs, and sockets.

Robert Penfold

New Book

Title: Practical Digital Electronics Handbook
Author: Mike Tooley
Pages: 208
Format: 216 × 138mm
Illustrated: 100 line drawings
ISBN: 1 870775 00 7
Price: £6.95

We are pleased to bring you this new book; published in association with PC Publishing it has been reprinted and updated from the *Digital Trouble Shooting* series published in EE.

The vast majority of modern electronic systems rely heavily on the application of digital electronics, and the *Practical Digital Electronics Handbook* aims to provide readers with a practically based introduction to this subject. The book will prove invaluable to anyone involved with the design, manufacture or servicing of digital circuitry, as well as to those wishing to update their knowledge of modern digital devices and techniques.

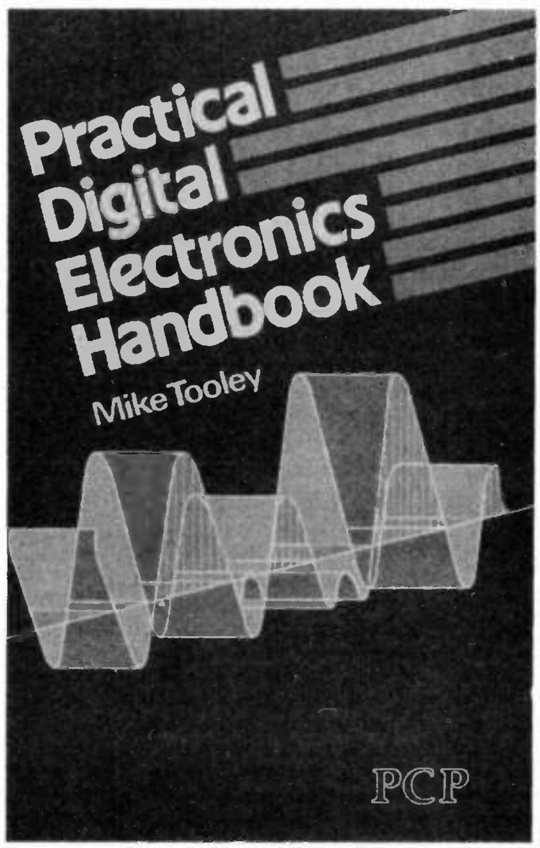
The book introduces digital circuits, logic gates, bistables and timers, as well as microprocessors, memory and input/output devices, before looking at the RS-232C interface and the IEEE-488 and IEEE-1000 microprocessor buses.

A special feature of the book is the section on digital test gear projects, and the practical emphasis is continued with appendices on test equipment and useful reference data.

Contents:

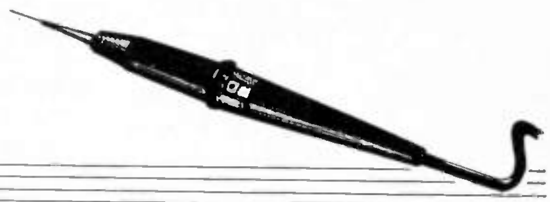
Introduction to integrated circuits; Basic logic gates; Monostable and bistable devices; Timers; Microprocessors; Memories; Input and output devices; Interfaces; Microprocessor buses; Appendix 1: Data; Appendix 2: Digital test gear projects; Tools and test equipment, Regulated bench power supply, Logic probe, Logic pulser, Versatile pulse generator, Digital IC tester, Current tracer, Audio logic tracer, RS-232C breakout box, Versatile digital counter/frequency meter. Appendix 3 The oscilloscope; Appendix 4 Suggested reading; Appendix 5 Further study.

The book is available through the *EE Book Service* — see page 60.



Constructional Project

LIGHT UP, SQUEAK UP, SHUT UP



D. KING

A simple continuity/junction tester with timed switch-off to prolong battery life

THE traditional advice offered to a person required to make a speech is, "Stand up, speak up, shut up", and this was in my mind when a PP3 battery was found "dead" in my continuity tester that had been switched on, used briefly and . . . not switched off.

Over the years the intercom, test amplifiers and other battery-operated gear have at various times all been left switched on for much too long in between sessions in the workshop so that the resulting inconvenience, cost and the accusing look on my wife's face as I steal the batteries from *her* radio made me think of the following approach to the problem.

Supply Voltage	Load Voltage	4011 Quad Two Input NAND	4049 Hex Inverter	4069 Hex Inverter
		All inputs paralleled; all outputs paralleled **Available load current (mA)**		
3	2.5	2	3	3
6	5.5	4	12	8
9	8.5	8	15	7
12	11.5	10	18	3
15	14.5	10	24	2

Table 1

BASIC CIRCUIT

A circuit is needed to allow the on-off switch to be replaced by a push-button type, momentarily-on and a simple, cheap timer to give automatic switch-off or power-down after a fixed, pre-determined time suited to the apparatus. A test is often performed in a few seconds, sometimes only once a day. The timing depends upon a charged capacitor discharging slowly via a resistor and reaching about 50 per cent of the starting voltage after some 70 per cent of the time-constant of the C-R combination.

If the capacitance is C (Farads) and the resistor is R (Ohms) then the time-constant t (in seconds) is given by $t = C \times R$ while if C and R are in units of microfarads and megohms respectively, the time t is again in seconds. Thus a 1μ capacitor in parallel with a 10M resistor has a time-constant of 10 seconds, a 16μ would produce a 160 second time-constant with the same resistor, and so on.

Now CMOS logic gates consume virtually no current from the supply when the gate inputs are fully logic "1" or "0" and the gate is not feeding a load. A CMOS i.c. may, therefore, be connected across an un-switched supply voltage with no resulting battery drain, waiting for input states to be changed and perhaps to then feed a current via the gate(s) output to a load.

Tests were made on three cheap and common i.c.s, the 4011, 4069 and the 4049, to determine the output current available at a voltage no more than 0.5V below the supply voltage; results are given in Table 1. From this table it will be seen that it is quite possible to

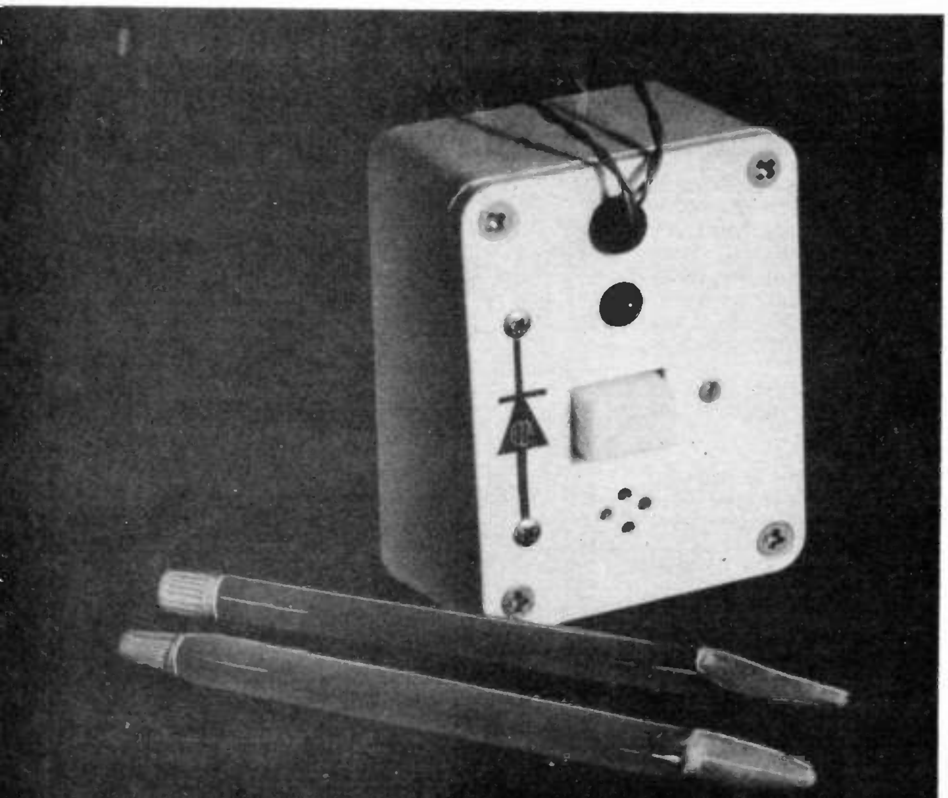
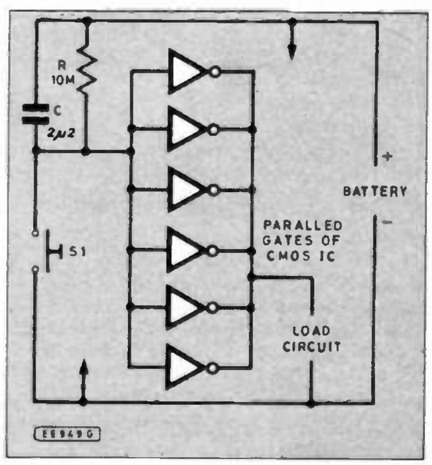


Fig. 1. An inverter switching a low current load.



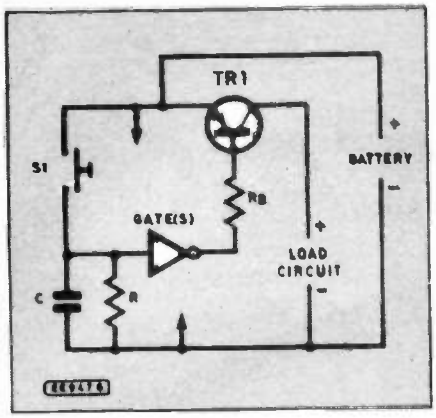


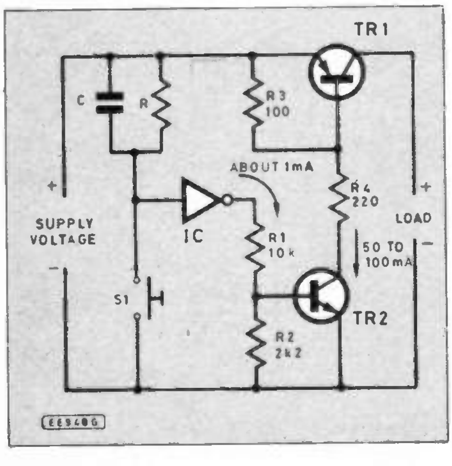
Fig. 2. Using a transistor to increase available current.

operate a low-current load as in Fig. 1 where upon pressing the "on" button C is charged to full supply voltage, taking the inputs to "0" and with, say, a 2.2μ capacitor, and 10M resistor after about 70 per cent of 22 seconds the inputs are changing to "1" so that the load will be fed by the logic "1" voltage for some 15 seconds and then, within half a second or so, the circuit goes to sleep and, taking no battery current, waits until needed again. Fifteen seconds does not sound a very long time but is ample for the continuity/junction tester described later. The additional expense of the CMOS i.c. is only about 30p, while the use of a biased switch or a push-switch in place of the normal s.p.s.t. type adds enormously to battery life. It also increases the life of your partner's radio and of yourself!

If the current available from even the 4049 is insufficient, more current is provided with less voltage difference between the battery supply and the load voltage by a saturated transistor connected as shown in Fig. 2. With a typical minimum current gain, h_{FE}, of 100 a 2mA feed from the i.c. gate can switch on up to 200mA with only some 0.2V dropped across the transistor. As C discharges and the gate input voltage falls, the output goes high to "1", there is less than the required 0.6V between base and emitter to cause conduction and the transistor turns off to leak a mere microamp or so.

If you should wish to switch on the negative side of the supply, then use an *npn* transistor in an inverted version of Fig. 2 circuit. If even more load current is needed then Fig. 3 will enable an ampere or more to be switched. The values of components in Fig. 3 are for a suggested supply voltage of 12V; it is unlikely that you will manage to obtain an ampere from a PP3 or even from a PP6 battery!

Fig. 3. Using two transistors to switch up to 1A.



TIMING

Timing with an electrolyte capacitor is a rather hit-or-miss affair, due to the unknown leakage current of electrolytics and, of course, to the rather loose tolerance or accuracy of the chosen value of capacitance. The simple answer to these questions is to *try* a capacitor for its performance in a timing circuit; do make sure to use a resistor for discharge, do not rely upon the leakage to take the capacitor to a true discharged state reliably and repeatedly. Several electrolytic capacitors, both old and new, were tried with success for the production of long on times of 30 to 40 minutes.

CONTINUITY TESTER

The times continuity and junction tester circuit is shown in Fig. 4. It looks quite impressive at first sight but requires only two i.c.s and about ten other components. IC1, R1 and C1 form the timed voltage supply to IC2. IC2 a and b are in a standard astable oscillator circuit, producing about 5Hz. Anti-phase outputs are taken to parallel connected gates 2c and 2d, 2e and 2f to provide an alternating voltage feeding the two probes. A diode junction is thus repeatedly tested in each direction for "easy conduction" via the probes, the conventional direction of current being identified by a flashing l.e.d. in the probe at the cathode or "sharp end" of the junction under test.

For the probes, two discarded felt-tip or ball-point pen bodies are shaped as shown in Fig. 5, the l.e.d. is soldered to the silicon diode and the pin as shown, the l.e.d. is angled away from the pen tip to allow easy viewing and the end is then tidied up with a suitable resin-putty that will hold the pin in place solidly. Be careful about the polarity of the two diodes and make two identical probes, using flexible or multi-strand wiring to connect the probes to the tester circuit.

Since the current to the oscillator and test probes flows via R4, there is a small volt drop across R4 when a pulse of current flows through the probes and the device or circuit under test. A piezo electric sounder (X1) across

COMPONENTS

Resistors

R1	10M
R2	220k
R3	2M2
R4	330
R5	680
R6	100

¼W±10% carbon

Capacitors

C1	2μ2	(value depends on timing required – see text)
C2	100n	

Semiconductors

D1, D2, D5	red l.e.d.s (3 off)
D3, D4	1N4001 silicon diodes (2 off)
IC1, IC2	4069s, CMOS Hex Inverters (2 off)

Miscellaneous

S1 Push-to-make or spring-biased toggle switched

WD1 piezo electric sounder RS 249-794 used by author

Stripboard 0.1in. matrix, 20 strips by 30 holes; terminal pins to fit stripboard; 9V PP3 battery; discarded pen bodies (see text); two pins; plastic case 50 × 75 × 33mm approx.

Approx. cost Guidance only £5.50

R4 is thus energised when either of the probe l.e.d.s light up and so there is both a "squawk and flash" when continuity is found by the probes. Also, even when the probes are not in use, the circuit operation produces a noise from the sounder as the oscillator circuit charges and discharges C2, the sound dying away as C1 discharges. Resistor R4 and the sounder may be

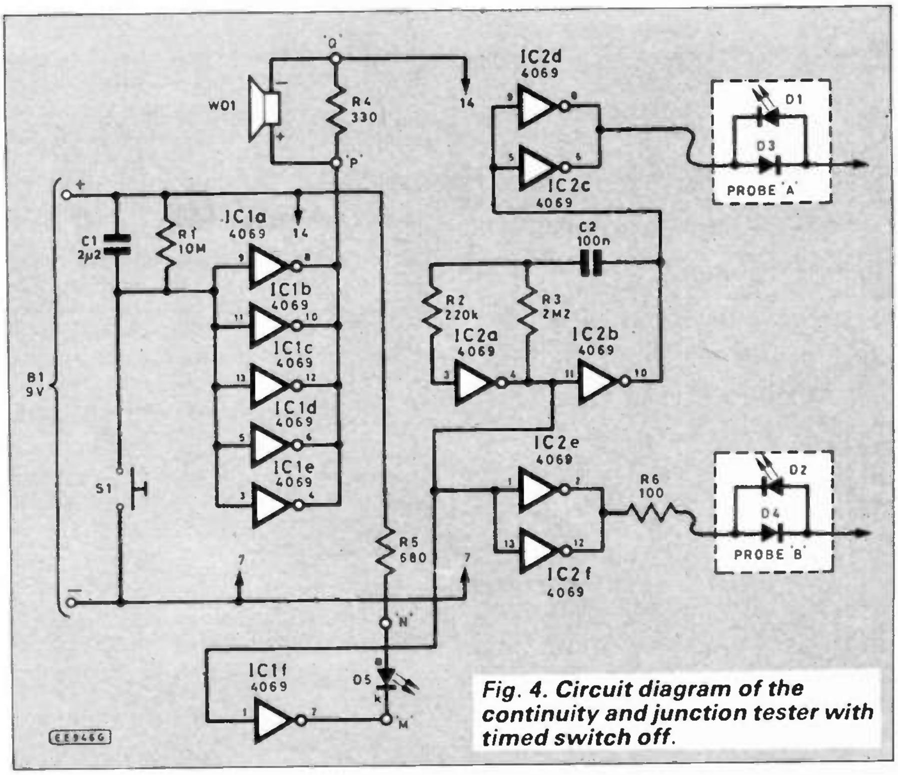
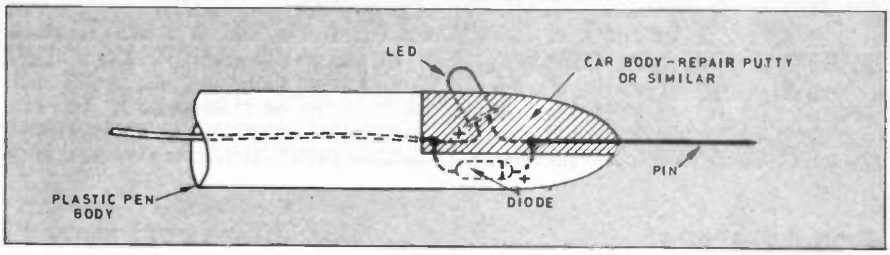


Fig. 4. Circuit diagram of the continuity and junction tester with timed switch off.

Fig. 5. (right). Construction of the two probes.



omitted from the circuit if wished but they have been found to add to the versatility of the whole apparatus.

CONSTRUCTION

A layout for Veroboard is shown in Fig. 6. Due to the paralleled gates there are a number of link wires but currents are very small and even one strand from flexible wire is adequate, as well as being easily drawn tight, straight and neat during soldering. I.C. holders are recommended since CMOS i.c.s can sometimes be damaged during the assembly process. Fit the i.c.s into their holders (with due care for pin numbering) after the circuit has been completed. Check carefully for missing track-breaks, track-breaks that may have the smallest sliver of copper remaining across the gap and solder blobs or splashes between tracks.

The Veroboard sits nicely in the bottom of the plastic case, the PP3 battery being secured by a double-sided sticky pad to the top of the board as shown in the layout diagram. These sticky pads are *very* useful for all sorts of little, light-duty jobs like this in electronics where drilled holes and nuts/bolts would otherwise be an untidy necessity. Make sure that your particular switch and sounder will fit under the lid of the box without colliding with the other parts inside and also will fit your hand/fingers to make the operation easy – neatness and symmetrical layout come second in importance to the demands of operator ease of use. Note that the sounder recommended is polarised, so connect it the right way round; the l.e.d.s also.

IN USE

Is the box a gimmick? Definitely not; one has been in use for years testing diodes and transistors for polarity and open/short circuits, wiring and p.c.b.s for continuity. Build one yourself, use it and cut down the profits of the battery manufacturers! □

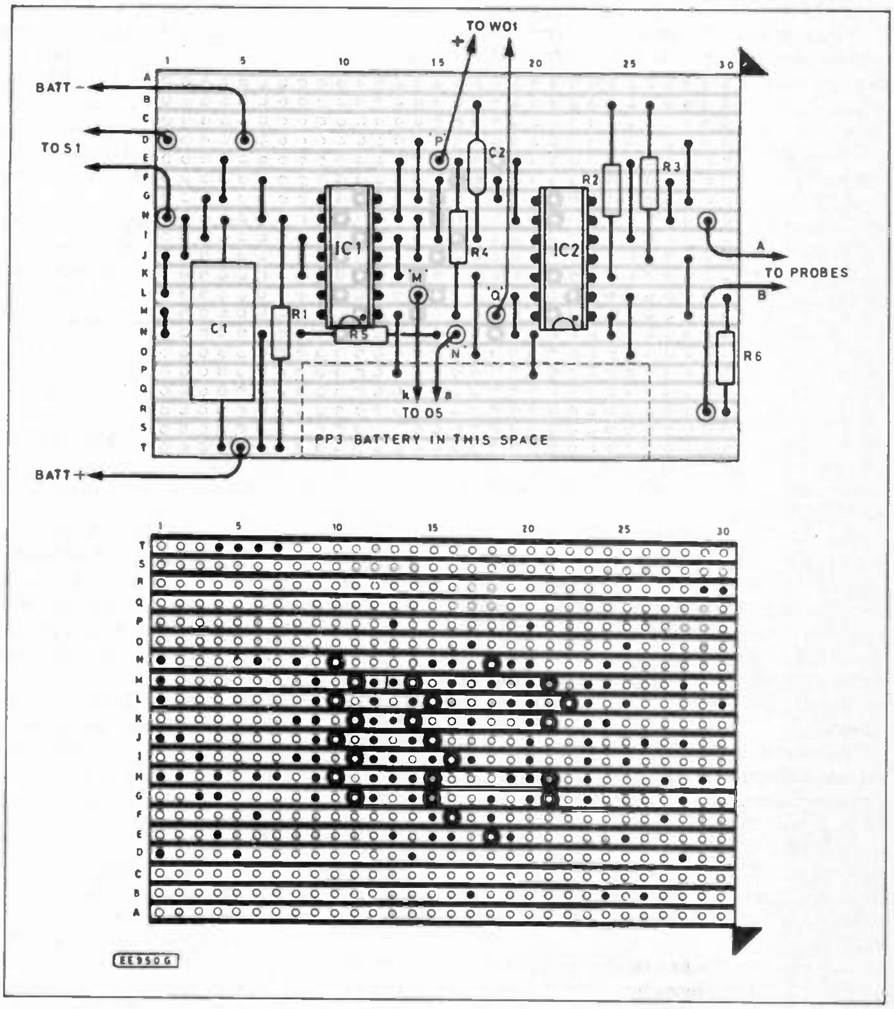
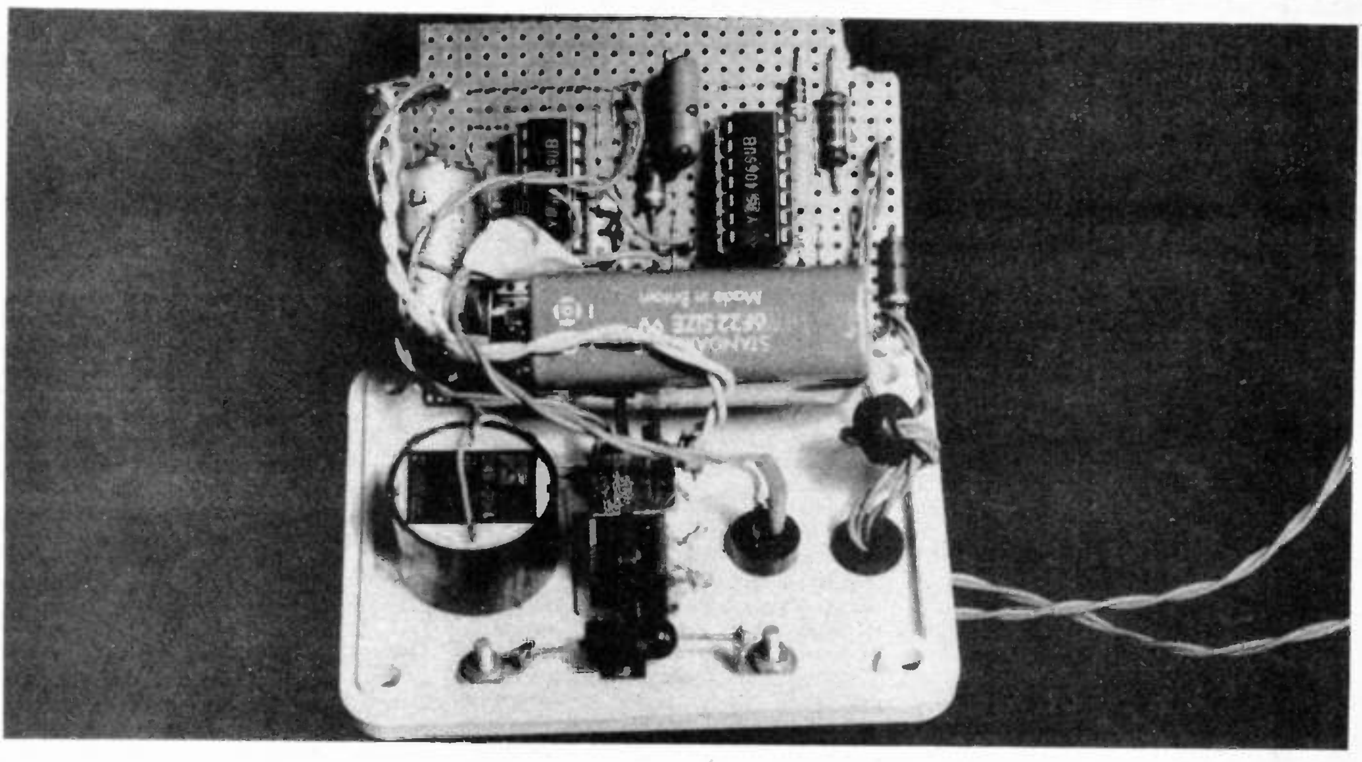


Fig. 6. Layout and wiring of the tester on Veroboard.



FOR YOUR ENTERTAINMENT

BY BARRY FOX

Digital Exchange

Held in the unlikely – but surprisingly ideal – surroundings of the restaurant and reception area at London Zoo, the *Digital Information Exchange* has now become an annual event sponsored by Sony and HHB, the professional audio hire and sales company. The aim of DIE is to bring together a wide range of people who are working with compact disc and digital sound so that they can exchange information and know-how.

Delegates range from colourfully clad young studio engineers to grey men in suits using digital technology for unspecified secret research in anonymous government departments. Last year I went as a spectator and picked up some interesting first hand information.

For instance not a lot of people know that the maintenance manuals for a Boeing 747 aircraft, weigh as much as the aircraft itself. But the same data can be stored on a handful of CD ROM discs . . .

Alan Parsons is well known as a music and record producer, who records his own work but never performs live. Musicians, says Parsons, should program their synthesizers or drum machines at home or at rehearsal, instead of wasting valuable studio time. "Thousands of hours of studio time have been wasted trying to recreate the feel of an original demo," he warns.

The record companies, says Parsons, have an odd attitude towards digital recording. "If this album does well," they tell the artist, "we'll do your next one in digital."

Each year at the DIE there is a surprising absence of any record company representatives. "It indicates their general attitude to new technology," noted Alan Parsons.

He thinks that in future studios will gang two 24-track digital machines together, to give the equivalent of one 48-track recorder. The Mitsubishi system, which is incompatible with Sony's, and its main rival, is a 32-track format.

"32 tracks is not enough," says Parsons. "But a pair of machines giving 64 tracks is too much for most studio mixing desks to handle."

Memory Lane

Those with long memories may recall that it was Alan Parsons who worked on the original Beatles recordings which were made at Abbey Road on four-track machines. They sounded pretty good and sold pretty well. Times, attitudes and priorities change.

Parsons also notes that although it is possible to cut and splice digital studio tape, with a razor blade and sticky tape, it is impractical. "You need a dust free room," he says. "So it's much better to edit electronically. The video industry threw out razor blades long ago. Also with electronic editing you can retain the original version because the tape is never actually cut."

Parsons is clearly now fully committed to digital recording. He wonders why the record companies don't buy digital equipment. Instead they spend a fortune hiring it. "At Abbey Road it takes two hours before an analogue session to line up the recorder, checking azimuth, bias, Dolby level and so on. With digital the only day to day check is on level in and level out. After that you just leave the level adjustments alone. You switch on, check a 1kHz tone across all tracks and are ready to go."

An interesting point made by Parsons is that originally at Abbey Road the engineers used to monitor sessions off-tape. As the musicians played onto tape, the engineer would listen to a replay of the actual recording a fraction of a second later.

But the advent of noise reduction, like Dolby and DBX, made this impractical because the extra cost of a decoder for each encoder was too high for EMI. So they went back to monitoring the live sound and thus were never quite sure what was going down onto tape until it was played back afterwards. "With digital," says Parsons, "we can't monitor off tape, but we can monitor the sound from the digital processor which gives a good idea of what's being recorded."

David Smith works with the Editel digital editing studio in New York, and gave DIE delegates some interesting insights into how the market for CD is going across the Atlantic. Quite simply the end of vinyl looks far closer than anyone expected. The famous Schwann catalogue, which lists all available recorded material, is now 75 per cent CD, and may cease vinyl listings altogether.

The Metropolitan Opera in New York has bought its own digital 24-track recorder. Bruce Springsteen bought two Sony PCM 1630 digital processors, three 1610 Sony processors and four U-Matic recorders. He paid for them as a tax loss but then used them for the boxed set re-issue of five CDs.

Springsteen took all the analogue multi-track masters and dubbed them onto digital multi-track tape. He then re-mixed down into stereo onto the 1630 machines and edited digitally, with level adjustments and equalization, before dubbing onto U-Matic tape for CD mastering.

It took him three months of rented studio time to re-mix all 40 songs. In New York, it costs the equivalent of around £140 an hour to rent any studio, plus a premium of around £300 or £400 a day for the use of digital equipment. But of course Springsteen's investment has already paid off many times over, thanks to sales of the boxed sets.

Audiofile

Some studios are now using "hard" or Winchester discs to record digital sound for editing. AMS of Burnley makes the Audiofile disc recorder. Each disc drive is actually a stack of eight 5.25in discs in a tight vertical sandwich.

This eight pack disc drive has a total capacity of 380 megabytes. When "formatted", so that the digital information on the disc is labelled and thus easily found, this capacity reduces to 320 megabytes + equivalent to 2,560 megabits.

The Audiofile converts analogue sound into digital code of CD quality or better, by sampling at up to 50kHz and coding in 16-bit words. Although the error rate in data stored on disc is very low, one error in 10^{12} bits, some extra error correction is needed.

With this, and labelling, each megabyte of disc capacity stores around 10 seconds of audio. So the 320 megabyte disc pack holds around one hour of CD quality mono. The AMS Audiofile has two disc packs, so can store either one hour of stereo or two hours of mono.

Like all Winchesters, the disc is an aluminium platter, coated with nickel cobalt magnetic alloy. The disc rotates at 3600rpm, with data packed at a density of around 20,000 bits per inch and streamed on and off disc at 10 megabits per second.

As with all Winchester discs, there is no contact between the head and disc surface – the head flies on a very thin cushion of air. Thus there is no wear of either head or disc. So there is no loss of quality, or buildup of digital errors, through repeated plays during editing.

The head can find any part of the disc in under 50 milliseconds, and usually 30 milliseconds, which is 0.03 of a second and virtually instantaneous. In practice this search delay is slightly extended because the Audiofile has a solid state memory buffer, capable of holding about one second of sound.

This is necessary because Winchester hard discs were designed to store computer data, which runs in bursts, rather than audio data, which runs as a continuous stream. The buffer bridges the gaps between bursts.

In the first six months of production AMS have sold 50 Audiofile units. Because the system is big and bulky, there is no real possibility of using it as a portable recorder.

The drill is to go out and record onto tape, and then dump the recording from tape onto disc for editing. But the instant access makes it ideal not just for sound effects, but for storing large quantities of speech.

The aircraft industry is now experimenting with hard disc recorders for flight simulators, to give pilots running sound effects. And one secret police body in Eastern Europe wanted to buy an Audiofile, for who knows what reason.

a regular feature for the Spectrum Owner...

by Mike Tooley BA

LAST month we described yet another application for the Z80-CTC Counter/Timer Interface described in October's *On Spec*. This month, by popular request, I shall attempt to dispell some of the mystery concerning interrupts and interrupt handling. We shall round off this instalment by taking a look at a pair of useful utilities currently on offer from Picturesque. We begin by agonising over a decision which must confront many of us confirmed Spectrum addicts.

Is The Battle Over?

With the battle for the Christmas home computer market nearing its conclusion, people at Amstrad must be awaiting news of how well the Spectrum+3 has faired against its arch rivals. Whether Amstrad's recent price cut for the +3 will have been instrumental in outwitting competition from Atari's ST range remains the burning question for those with interests in the home computer scene.

Having identified Atari's machine as the +3's arch rival, I must come clean and admit to having been a user of the ST ever since it first arrived in the UK. Furthermore, it should be clear to anyone who can sift through the hype of advertising copy that the +3 is a vastly inferior machine. Why then should I, or anyone else for that matter, consider purchasing a +3?

It is a fact of life that, for many people planning to purchase a home computer, superiority of performance and technical specification is a less important consideration than that of the availability of a huge range of software at modest cost. With the +3 in mind it is unfortunate that, in order to exploit this huge software base, one has to resort to running in 48K mode. This means abandoning many of the features which make the +3 so attractive!

Since the future of a machine is so dependent on the availability of software, one can only hope that software houses show continued faith in the Spectrum line by modifying existing software packages to exploit the new features of the machine. The long term success of the +3 will surely depend on software support more than anything else. Should this not be forthcoming, and given its current £200 price tag, I would give absolutely nothing for its chances in the 1988 Christmas stakes regardless of how well it performs this year!

Interrupts (and how to manage them!)

There appears to be a good deal of mystique surrounding the subject of interrupts and interrupt handling. Interrupts are simply signals generated by external devices when they wish to gain the attention of the Spectrum's Z80 central processing unit (CPU). Readers may be blissfully unaware that an interrupt is generated every 20ms (i.e. 50 times a second) within the Spectrum as part of the process of updating the video signal fed to a TV or monitor.

Interrupts can be extremely useful when adding external hardware to the Spectrum since they allow an external chip (such as the Z80-CTC which we met in October *EE*) to indicate that a certain condition exists. The CPU can then decide what action it should take.

It can, if it has been programmed accordingly, ignore the interrupt and carry on with a current task which takes precedence. Alternatively, the Z80 may wish to suspend its current task (retaining sufficient information so that it can later resume the task) and then execute an "interrupt service routine" appropriate to the interrupting device.

The Spectrum has two interrupt inputs. One of these is described as "non-maskable" (i.e. the Z80 has to obey an interrupt signal appearing on this line) whilst the other is "maskable" (i.e. the programmer can configure his or her program to ignore or respond to interrupts at will.

The non-maskable interrupt is clearly more versatile than its maskable counterpart which, in a typical Z80 system, would be used to implement some form of "break" facility. (Note that, due to an unfortunate programming error in the Spectrum's ROM, this does not work correctly in all versions of the Spectrum other than the +3!)

The Spectrum's Z80 microprocessor provides three different Interrupt Modes. In normal operation (i.e. using BASIC) the Spectrum operates in Mode 1. This mode is rather limited since it only allows for a single response to an interrupt signal.

It was provided for use in what can best be described as a "minimum system" (i.e. a microcomputer which supports minimal external hardware). The other two modes (Mode 0 and Mode 2) both allow for several interrupt routines to cope with interrupts from different external devices, each with its own customised service routine.

Interrupt Service Routines

Interrupt service routines operate in a similar fashion to that associated with the subroutines with which most readers will already be familiar.

An interrupt service routine is stored away from the main body of code and simply called when an interrupt occurs. There is, however, no need for a CALL instruction since interrupts may occur at virtually any point in the execution of the main program (provided they have not been disabled or "masked").

The response to an interrupt *must* be automatic; the CPU must suspend its current task and save the return address so that the program can be resumed at the point at which it was left. Thereafter, the programmer is responsible for preserving the state of any other registers which may be changed during execution of the interrupt service routine and restoring them so that the main program may be resumed at the point at which it was left.

Interrupt Modes

As stated earlier, the Z80 has three different interrupt modes. The programmer can select a desired mode by means of the IM instruction. Interrupts can be enabled or disabled by means of the EI and DI instructions respectively.

Interrupt Mode 0 was incorporated merely to retain compatibility with the interrupt mechanism implemented on the 8080 microprocessor. In Mode 0, the CPU uses the data passed by an interrupting device to determine the address at which the interrupt service routine can be found.

The data byte (one of eight possible vectors) is placed on the bus in response to an interrupt acknowledgement generated by the CPU and is directly equivalent to a single-byte ReSTart (RST) instruction. The values of the data byte (together with its equivalent RST instruction and destination address) are given in the following table:

Data Byte (opcode)	Equivalent RST Instruction	Destination Address
C7	RST 0H	0000H
CF	RST 8H	0008H
D7	RST 10H	0010H
DF	RST 18H	0018H
E7	RST 20H	0020H
EF	RST 28H	0028H
F7	RST 30H	0030H
FF	RST 38H	0038H

RST 0 is equivalent to a hardware CPU RESET and thus is of little use. The programmer is thus able to implement seven different interrupt service routines in Mode 0. Note that it is not necessary to have the complete service routine present in Page Zero since code can be easily vectored to another address by means of one, or more, JumP (JP) instructions.

Mode 1, as normally used on the Spectrum, is rather more limited as it only offers a single interrupt service routine which should be located at 0038H or jumped to from this address. A Mode 1 interrupt is equivalent to an RST 38H instruction and no data is passed by the interrupting device.

The last of the Z80's interrupt modes (Mode 2) offers programmers a great deal of flexibility and allows for a maximum of 128 different interrupt service routines. When the interrupt request is accepted, the CPU disables further interrupts (so that the interrupt service routine cannot itself be interrupted) and saves the Program Counter in the stack.

The CPU then reads the data passed on the bus by the interrupting device in response to the interrupt acknowledgement and uses this to form the address of a pointer to the required interrupt service routine. Execution continues from the start address of the particular interrupt service routine.

The first few lines of code within the interrupt service routine *must* be used to preserve the contents of all CPU registers which may be affected by the routine. Register contents may be preserved in the stack or may be preserved in the alternate register set.

After completing execution of the main body of the interrupt service routine, the routine restores any registers that were saved and then enables interrupts (using an EI instruction). The routine then closes with a RETI (RETurn from interrupt) instruction.

In Practice

Having spent some time dealing with the technicalities of interrupt handling it is high time we put something into practice by describing a little routine which readers can test out for themselves. This, after all, is the fun side of programming!

The demonstration routine makes use of the Spectrum's normal video interrupt which occurs every 20ms and thus avoids the need for any external hardware. When this interrupt occurs, our demonstration routine will be executed along with the usual jump to ROM location 38 hex. or 56 dec..

We shall, of course, need to initialise the Spectrum into Mode 2, set up a skeleton vector table, and place an appropriate byte in the Interrupt Register. This is how it is done:

The interrupt code is loaded into the Spectrum's printer buffer (starting at address 5B00 hex. or 23296 dec.). Provided, one is not making use of a ZX-type printer, this is a "safe" place for storing short code modules!

In this simple example we shall only be using a single interrupt service routine and thus will only require a single address in the Mode 2 interrupt vector table. This address will be represented by the label VECT and will be equivalent to BFFF hex. or 49151 dec. (the data bus will return a byte of FF hex. in the absence of any external hardware device).

This address was chosen for no particular reason other than the fact that it was clear of both the short BASIC demonstration program and did not conflict with addresses used by the SP-DOS operating system. In practice, a higher address above RAMTOP would be advisable.

Lines 30 and 40 set up the address of the interrupt service routine CHK (5B05 hex. or 23311 dec.) in its position at the top of the vector table. The high byte of VECT (BF hex.) must be loaded into the Interrupt (I) register but note that we must disable interrupts whilst carrying out this task and re-enable them when it is completed. This is accomplished in lines 50 to 90.

The interrupt service routine CHK starts at address 5B0F hex. or 23311 dec. and starts by disabling any further interrupts (we should avoid the possibility of interrupting the interrupt service routine!). Since the routine makes use of the AF and BC register pairs, these must be preserved by pushing them onto the stack.

Lines 140 to 170 read the key row associated with keys 8, 9 and 0 (i.e. the keys which correspond to a standard Sinclair joystick) and then output the value returned to the screen border. Finally, the values previously pushed onto the stack are popped back again, interrupts are enabled, and the program jumps back into the Spectrum's ROM at address 0038 hex. or 56 dec. in order to complete the normal interrupt process.

Readers having access to an assembler may wish to enter the code given in assembly language mnemonic form shown in Fig. 1. Alternatively, readers can make use of the Machine Code Loader published in the *Update*.

Alternatively, a BASIC loader and simple BASIC demonstration program is shown in Fig. 2. The demonstration program given in Fig. 3 is designed for use when the code has been entered and located in memory using an assembler.

Readers should run one or other of the demonstration programs (depending upon whether or not an assembler has been used to generate the interrupt service code) and then examine the effect of pressing the 8, 9 and 0 keys (or making equivalent movements on a Sinclair compatible joystick). The border colours should be seen to change as the program runs. Furthermore, when the program completes, the interrupt service routine will still be in place and the 8, 9 and 0 keys will continue to produce the same colourful if somewhat disconcerting effect!

For the benefit of readers wishing to learn more about interrupt handling, a somewhat more complex demonstration interrupt service routine has been included in the current *On Spec Update*. This piece of code can be used to clear the screen whenever the "true video" key is depressed. In effect, the "true video" key behaves as a CLS (clear screen) key, even when a program is running!

Code Machine

Like most "serious users" of the Spectrum, I am always on the look-out for new utilities and software tools which can simplify the task of program development. I was, therefore, interested to learn that Picturesque had produced a successor to the popular EDITAS and MONITOR packages in the shape of CODE MACHINE.

Unlike some packages which I have mentioned in this column, there is nothing

```
*HISOFT GENS3 ASSEMBLER*
48K ZX SPECTRUM / SPDOS

Copyright (C) HISOFT 1984
All rights reserved

Pass 1 errors: 00

5B00              10          ORG   #5B00
BFFF              20 VECT     EQU   #BFFF
5B00 210F5B       30 START    LD    HL,CHK
5B03 22FFBF       40          LD    (VECT),HL
5B06 F3           50          DI
5B07 3EBF         60          LD    A,#BF
5B09 ED47         70          LD    I,A
5B0B ED5E         80          IM    2
5B0D FB           90          EI
5B0E C9          100          RET
5B0F F3          110 CHK      DI
5B10 F5          120          PUSH  AF
5B11 C5          130          PUSH  BC
5B12 0EFE        140          LD    C,254
5B14 06EF        150          LD    B,239
5B16 ED78        160          IN    A,(C)
5B18 D3FE        170          OUT   (254),A
5B1A C1          180          POP   BC
5B1B F1          190          POP   AF
5B1C FB          200          EI
5B1D C33800      210          JP    #38

Pass 2 errors: 00

CHK     5B0F     START    5B00
VECT    BFFF

Table used:   46  from   129
```

Fig.1. Interrupt code in assembly language format

SOFTWARE

Fig.2. BASIC interrupt code loader and demonstration program

```
 10 REM Install interrupt code
 20 FOR i=23296 TO 23327
 30 READ x
 40 POKE i,x
 50 NEXT i
 60 DATA 33,15,91,34,255,191
 61 DATA 243,62,191,237,71,237
 62 DATA 94,251,201,243,245,197
 63 DATA 14,254,6,239,237,120
 64 DATA 211,254,193,241,251
 65 DATA 195,56,0
 80 REM Initialise handler
 90 RANDOMIZE USR 23296
100 REM Test loop
110 FOR i=1 TO 10000
120 PRINT AT 0,0;i
130 NEXT i
140 STOP
```

Fig.3. BASIC demonstration program for use with previously assembled code

```
 10 REM Initialise handler
 20 RANDOMIZE USR 23296
100 REM Test loop
110 FOR i=1 TO 10000
120 PRINT AT 0,0;i
130 NEXT i
140 STOP
```

particularly new or revolutionary about Picturesque's latest offering; it is simply an updated and re-packaged version of EDITAS and MONITOR.

CODE MACHINE comprises an editor and assembler (EDITAS Version 3.1) together with a monitor (MONITOR Version 3.1). These programs are supplied on two sides of a cassette tape but Picturesque supply instructions for customising the programs for your own use (including a wide range of printer options). I found it convenient to place customised versions on one side of a cassette tape to simplify loading one after the other.

MONITOR comprises approximately 7K of machine code and users are prompted to specify a load address. This, however, can be defaulted in which case the program is located at the highest possible address (usually 57778 dec.).

After loading, the program prompts the user with the entry point for the monitor which should be noted down for future reference. Thereafter, access from BASIC is by a command or statement of the form:

RANDOMIZE USR 57778

The monitor offers a comprehensive range of facilities including a particularly pleasing trace facility. The assembler, EDITAS, can usefully be made co-resident with the monitor. Assuming that it is loaded immediately below the MONITOR, access to the assembler from BASIC can be achieved by a command or statement of the form:

RANDOMIZE USR 51565

Again, it is important to make a note of the entry address supplied by the program when loading is complete.

EDITAS is a fairly conventional Z80 assembler but, unlike Hisoft's DEVPAC, it does not support macros. For many purposes this does not present too much of a handicap, indeed, the over enthusiastic use of macro expansions can often result in programs becoming excessively long.

Modular assembly of code is, however, possible using either cassette or microdrive and up to ten code modules (each with the same filename) can be assembled in turn to produce one long object code file. A comprehensive range of cassette, microdrive, RS-232 and network commands is available for saving, loading and verifying text and object code files.

Assembler commands make use of a variety of the BASIC keywords printed on the Spectrum's keytops. Unfortunately, this poses problems for +2 and +3 users since it forces the user to make numerous references to the handbook. Things are much simpler for 48K and + users.

CODE MACHINE is supplied with a useful 61-page manual. The software is very competitively priced and can be recommended as a straightforward and effective development aid. So, if you do not already possess EDITAS and MONITOR, it is well worth considering this package. **Picturesque is at 6, Corkscrew Hill, West Wickham, Kent BR4 9BB.**

If you would like a copy of our *On Spec Update*, please drop me a line enclosing a large (at least 250mm × 300mm!) stamped addressed envelope.

Mike Tooley, Department of Technology, Brooklands Technical College, Heath Road, Weybridge, Surrey KT13 8TT.

Next Month: We shall be delving into the system of memory "paging" used on 128K versions of the Spectrum.

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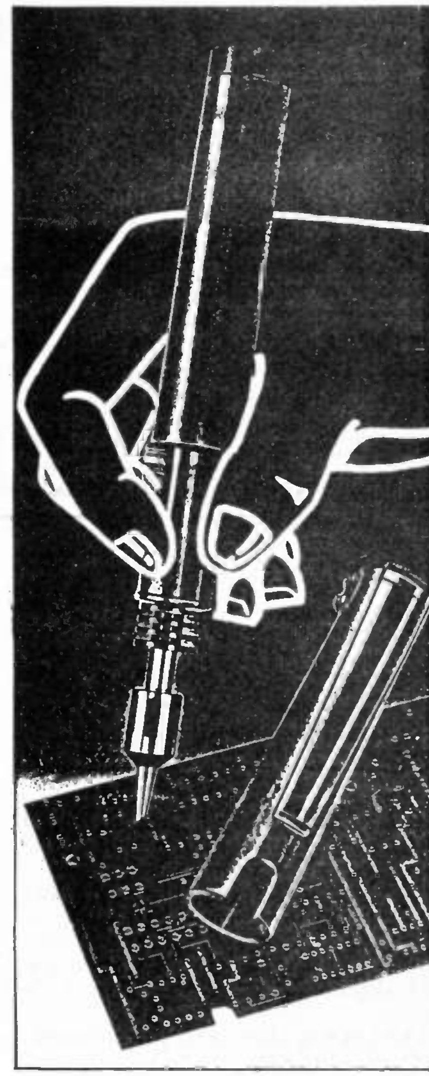

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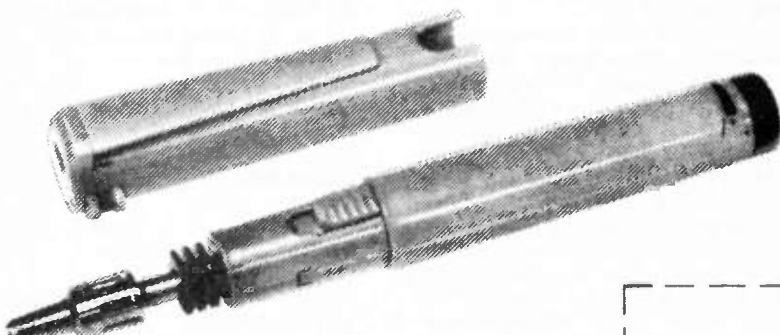

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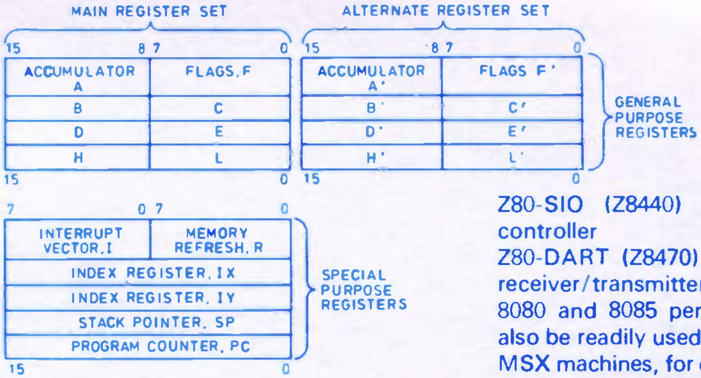
The Z80 Microprocessor

Developed by Zilog as a successor to the Intel's popular 8080 microprocessor, the Z80 is arguably the most powerful of the popular 8-bit microprocessors. The Z80 is found in a diverse range of applications, from industrial process control to popular home computers (such as the Spectrum and Japanese MSX machines).

The Z80 has relatively complex internal architecture which comprises no less than eighteen 8-bit and four 16-bit registers. For convenience, the Z80's internal registers can be divided into three groups; a main general purpose register set, an alternate general purpose register set, and a group of special purpose registers. The main and alternate general purpose register sets are identical and can be interchanged at will. Six of the 8-bit general purpose registers within each group can be used "end-on" to form 16-bit registers. This permits implied addressing (using, for example, the HL register pair) as well as 16-bit counting (using the BC register pair).

The special purpose register group contains a program counter (PC) and stack pointer (SP) both of which are 16-bits in length. Two independent 16-bit index registers (IX and IY) are provided as are 8-bit interrupt (I) and memory refresh (R) registers. This latter register is of little practical value to the programmer (other than as a simple random number generator) and is used in conjunction with the Z80's memory refresh facility (a means of automatically refreshing the contents of dynamic RAM during normal program execution).

The Z80 has three interrupt modes (Mode 0, 1 and 2). During reset, the Z80 is initialised in Mode 0 but, thereafter, the programmer can alter the interrupt mode using appropriate software instructions. Interrupt Mode 0 is the same as the 8080 interrupt response and it allows for up to eight different interrupt service routines with execution restarting at addresses



spaced every eight bytes between 0000H and 0038H. Interrupt Mode is designed for systems with minimal I/O and allows for only one service routine with execution restarting at address 0038H. Interrupt Mode 2 (the most complex of the three) allows for a total of 128 different service routines with addresses placed in a 256-byte table of vectors located on a page boundary defined by the programmer at any convenient location within the Z80's 64K memory space.

The Z80 has a very large instruction set (over 170 basic instructions). Some of these instructions have exact equivalents within the 8080 instruction set but use different mnemonics. Advanced instructions are used for bit manipulation (testing and setting) and also for moving blocks of data in memory.

The Z80 is well supported with a family of peripheral devices suitable for a wide variety of applications. These devices include:

Z80-CTC (Z8430) Counter timer circuit with four programmable counter/timer channels

Z80-PIO (Z8420) Programmable parallel I/O device with two independent 8-bit I/O ports

Z80-DMA (Z8410) Direct memory access controller

Z80-SIO (Z8440) Serial input/output controller

Z80-DART (Z8470) Dual asynchronous receiver/transmitter

8080 and 8085 peripheral devices may also be readily used with the Z80 device. MSX machines, for example, make use of the 8255 programmable parallel interface (PPI).

The Z80 and its associated peripheral devices is available in an A-series (i.e. Z80A, Z8430A etc) which will operate with clock frequencies up to 4MHz and a B-series (i.e. Z80B, Z8430B) which will operate with clock frequencies of up to 6MHz. CMOS versions are also available (e.g. 84C00A is a CMOS version of the Z80 which will operate with a clock frequency of up to 4MHz).

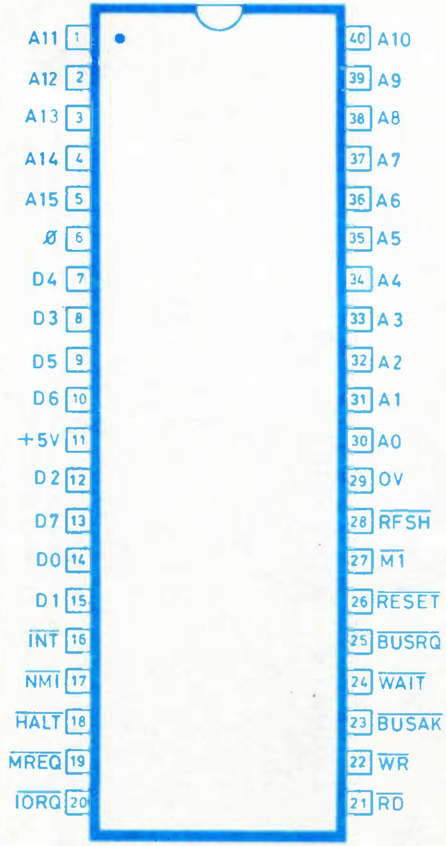
Z80 Signal Lines

Signal	Function	Direction
A0 – A15	Address bus	Output (tri-state)
D0 – D7	Data bus	Bi-directional (tri-state)
$\overline{\text{RD}}$	Read	Output
$\overline{\text{WR}}$	Write	Output
$\overline{\text{MREQ}}$	Memory request	Output
$\overline{\text{IORQ}}$	Input/output request	Output
$\overline{\text{NMI}}$	Non-maskable interrupt request	Input
$\overline{\text{INT}}$	Interrupt request	Input
$\overline{\text{RESET}}$	Reset	Input
Ø	Clock	Input
$\overline{\text{RFSH}}$	Refresh	Output
$\overline{\text{HALT}}$	Wait	Input
$\overline{\text{WAIT}}$	Wait	Input
$\overline{\text{BUSRQ}}$	Bus request	Input
$\overline{\text{BUSAK}}$	Bus acknowledge	Output
$\overline{\text{M1}}$	Instruction fetch	Output

Popular semiconductor RAM devices

Type	Technology	Size (bits)	Organization	Package
2012A	NMOS static	1024	1K words × 1 bit	16-pin d.i.l.
2110	ECL static	1024	1K words × 1 bit	16-pin d.i.l.
2112	ECL static	1024	256 words × 4 bits	16-pin d.i.l.
2112A	NMOS static	1024	256 words × 4 bits	16-pin d.i.l.
2114	NMOS static	4096	1K words × 4 bits	18-pin d.i.l.
2118	NMOS dynamic	16384	16K words × 1 bit	16-pin d.i.l.
2128	NMOS static	16384	2K words × 8 bits	24-pin d.i.l.
2142	ECL static	4096	4K words × 1 bit	20-pin d.i.l.
2147	NMOS static	4096	4K words × 1 bit	18-pin d.i.l.
2148	CMOS static	4096	1K words × 4 bits	18-pin d.i.l.
2167	CMOS static	16384	16K words × 1 bit	20-pin d.i.l.
2168	CMOS static	16384	4K words × 4 bits	20-pin d.i.l.
2504	TTL static	256	256 words × 1 bit	16-pin d.i.l.
2510	TTL static	1024	1K words × 1 bit	16-pin d.i.l.
2511	TTL static	1024	1K words × 1 bit	16-pin d.i.l.
4116	NMOS dynamic	16384	16K words × 1 bit	16-pin d.i.l.
4118	NMOS static	8192	1K words × 8 bits	24-pin d.i.l.
4164	NMOS dynamic	65536	64K words × 1 bit	16-pin d.i.l.
4256	NMOS dynamic	262144	256K words × 1 bit	16-pin d.i.l.
4334	CMOS static	4096	1K words × 4 bits	18-pin d.i.l.
4416	NMOS dynamic	65536	16K words × 4 bits	18-pin d.i.l.
4464	CMOS static	65536	8K words × 8 bits	28-pin d.i.l.
4716	NMOS dynamic	16384	16K words × 1 bit	16-pin d.i.l.
4801	NMOS static	8192	1K words × 8 bits	24-pin d.i.l.
4802	NMOS static	16384	2K words × 8 bits	24-pin d.i.l.
4816	NMOS dyamic	16384	16K words × 1 bit	16-pin d.i.l.
4864	NMOS dynamic	65536	64K words × 1 bit	16-pin d.i.l.
4865	NMOS dynamic	65536	64K words × 1 bit	16-pin d.i.l.
5101	CMOS static	1024	256 words × 4 bits	22-pin d.i.l.
5257	CMOS static	4096	4K words × 1 bit	18-pin d.i.l.
5516	CMOS static	16384	2K words × 8 bits	24-pin d.i.l.
6116	CMOS static	16384	2K words × 8 bits	24-pin d.i.l.
6117	CMOS static	16384	2K words × 8 bits	24-pin d.i.l.
6147	CMOS static	4096	4K words × 1 bit	18-pin d.i.l.
6148	CMOS static	4096	1K words × 4 bits	18-pin d.i.l.
6167	CMOS static	16384	16K words × 1 bit	20-pin d.i.l.
6168	CMOS static	16384	4K words × 4 bits	20-pin d.i.l.
6264	CMOS static	65536	8K words × 8 bits	28-pin d.i.l.
10422	ECL static	1024	256 words × 4 bits	24-pin d.i.l.
10470	ECL static	4096	4K words × 1 bit	18-pin d.i.l.
10474	ECL static	4096	1K words × 4 bits	24-pin d.i.l.
10480	ECL static	16384	16K words × 1 bit	20-pin d.i.l.
41256	NMOS dynamic	262144	256K words × 1 bit	16-pin d.i.l.
43256	CMOS static	262144	32K words × 8 bits	28-pin d.i.l.
50256	NMOS dynamic	262144	256K words × 1 bit	16-pin d.i.l.
50257	NMOS dynamic	262144	256K words × 1 bit	16-pin d.i.l.
50464	NMOS dynamic	262144	64K words × 4 bits	18-pin d.i.l.

The Z80 Microprocessor



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