PRACTICAL

# ELECTRONICS

APRIL 1989 • £1.25

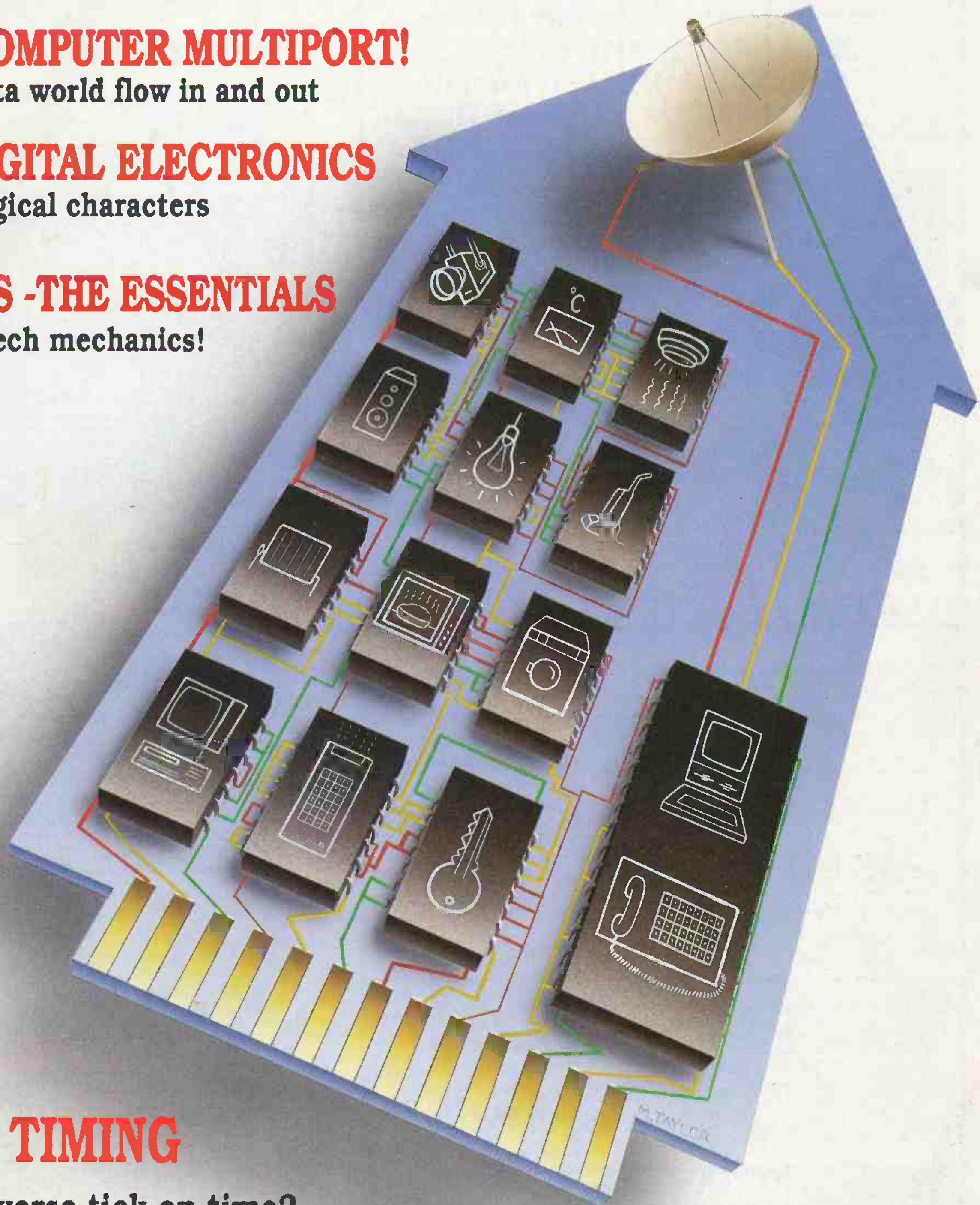
SCIENCE & TECHNOLOGY

## HOME AUTOMATION
User-friendly technology revolution

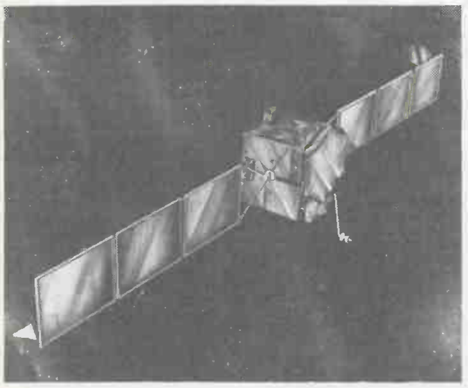
## BUILD A COMPUTER MULTIPORT!
and let the data world flow in and out

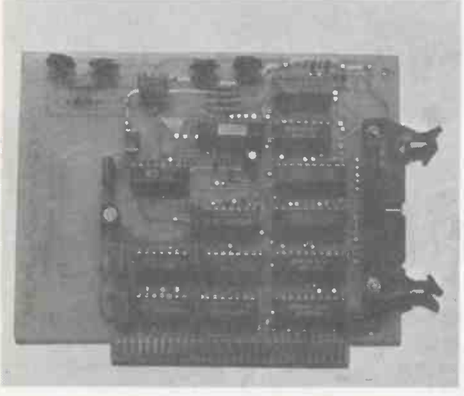
## DIY-ING DIGITAL ELECTRONICS
Registering logical characters

## SATELLITES -THE ESSENTIALS
Grasp the hi-tech mechanics!



## HI-TECH TIMING
Does the universe tick on time?





## NEXT MONTH

Have we got news for you? Yes indeed - next month PE will look even better and brighter. We're nearing our 25th birthday and to prepare for it we've got the decorators in! And we shall be asking for your help in deciding how your favourite magazine should look as we approach the 1990s. There's the customary great mix of projects and features too, plus another fabulous competition to enter!

**★ DON'T MISS OUR MAY 1989 ISSUE**

**★ ON SALE FROM FRIDAY APRIL 7TH**

**★ AND STILL AT ONLY £1.25**

**★ YOU CAN'T BEAT OUR VALUE**

# PRACTICAL ELECTRONICS

VOL 25 NO 4 APRIL 1989

## CONTENTS



**PE TAKES TECHNOLOGY FURTHER - BE PART OF IT!**


***We have recently received the following catalogues and literature:***

**Five Star Connectors** (a division of STC) have produced a new 446 page A5 catalogue covering a **comprehensive range of connectors** from 16 of the world's leading manufacturers. It's easy to use format makes it essential reading for anybody buying connectors. **Five Star Connectors,** Edinburgh Way, Harlow, Essex, CM20 2DF. 0279 442851.

**Fane** are well known for the quality of their loudspeakers and their new 52 page brochure well illustrates **speaker enclosure design and construction.** Its schematic drawings will also be of interest to anyone withing to build their own enclosures. **Fane Acoustics Ltd.,** 286 Bradford Road, Batley, W.Yorks, WF17 5PW. Batley 476431.

**D and M Components'** computer listing of their product range has been received – 14 pages of **parts of interest to any constructor.** D & M will also do their best to obtain **specialist components to order,** they have a bulk purchase offer, and a discount scheme for electronics club members. **D and M Component Supp.y Service,** 2 Glentworth Avenue, Whitmore Park, Coventry, W.Mids, CV6 2HW. 0203 333195.

**Unitel** have extended their range of **ferrite products** and issued a new 8 page catalogue which additionally features a useful applications guide. **Unitel Ltd,** Unitel House, Fishers Green Road, Stevenage, Herts, SG1 2PT. 0438 312393.


## 'Allo 'Allo

Listen very closely, I shall say this only once:

You might think that in calling its latest product a universal calibrator, the French company Aoip is pitching its claims too high.

Yet in fact there is very little the PJN 5208 cannot do in the way of monitoring, testing and calibrating other measuring instruments. For a start, you can use it to measure resistance, or voltage from 50mV up to 50V, and current with a 50mA range setting. It is also capable of simulating a resistor or generating dc voltage and current signals.

Then it has an equally wide range of functions for measuring temperature using thermocouples and resistance sensors. And there is a corresponding facility for simulating the behaviour of temperature sensors.

Standard features include a 24-key keypad, an alphanumeric lcd display, and power from rechargeable batteries. As an option, you can add a memory capacity for storing up to 1,000 readings and an RS232 link which allows you to download stored values to a microcomputer. The memory can be used for holding 100 preset simulation values or calibration points.

Aoip has designed the unit for maximum portability, making it particularly suitable for use in the field with remote measuring instruments.

It's probably even suitable for testing Knockwurst sausages!

**CONTACT:** Julian Wainwright, Hawco Ltd., Hawco House, Cathedral Hill Industrial Estate, Guildford, Surrey, GU2 5YD. Tel: 0483 60606

# WHAT'S NEW

## Canon Stills Video

A new compact High-band still video system has been launched by Canon with many applications, particularly in the areas of audio visual presentations. The NTSC-compatible system comprises the RC-470 fully automatic compact still video camera, the RV-301 video player, and a new colour video printer is also available, the RP-420.

The RC-470 is a light weight autofocus camera capable of a fast 20 images-per-second operation using a half-inch ccd with 360,000 pixels and a video resolution of 400 lines both horizontally and vertically for high quality pictures. In frame mode, the camera can record up to 25 images on video floppy disk in optimum quality, with each image using two tracks, while 50 images can be recorded in field mode in situations where use of the maximum number of images is more important. The disks can either be stored or erased for re-use.

A bright bifocal lens offers a choice of 9mm wide or 16mm tele (equivalent to 48mm and 86mm camera), and automatic functions include exposure control, backlight compensation, and variable built-in flash.

Images on the floppy disk can be viewed on an NTSC tv screen or monitor by inserting it in the RV-301 video player, and output can also be recorded on any compatible video deck. For fast colour printing of images from any NTSC video source, including still video, the RP-420 colour video printer offers a variety of formats by a colour ink/film thermotransfer method.

**CONTACT:** Canon (UK) Ltd., Canon House, Manor Road, Wallington, Surrey, SM6 0AJ. Tel: 01-773 3173

## How Green Is Your Battery?

If you're switched on to environmental issues you may want to switch to the powerful new Philips Greenline range of mercury-free batteries.

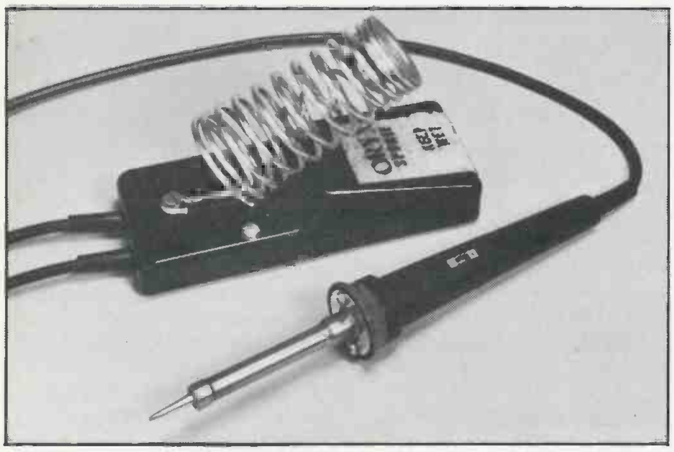
As well as being friendlier to the environment these batteries have a 10% longer life than their "Super" batteries. They are produced in three sizes – R20G, R14G and R6G and available immediately from battery retailers.

"Mercury is a strong environmental issue in Europe and although the mercury content in our zinc-carbon batteries was always low, it has now been reduced to zero," explained Peter Croker, marketing manager, Philips Consumer Lighting.

Greenline are interchangeable with normal batteries so have a wide variety of uses from alarm clocks to toys and are particularly useful for "high drain" equipment such as personal stereos and radios. Philips claim that under normal use they are 100% leakproof.

The introduction of these batteries to the UK follows closely upon the immediate success of the new range in Germany where 'green' issues are also widely supported and Greenline batteries are the leading mercury-free brand.

**CONTACT:** Publicis Ltd., 67 Brompton Road, London, SW3 1EF. Tel: 01-823 9000



## Ironing Out Hot-spots

Greenwood Electronics have introduced a new version of their highly-successful electronically-controlled Oryx Platinum 45 mains iron.

While still offering such advanced features as spike-free switching and proportional control electronics, a radical redesign now relocates the warmer parts of the control circuit to the base of the safety stand. Not only does this eliminate heat from the handle, it also reduces the weight of the iron and enables the platinum sensor to concentrate on measuring the heating element without having to compensate for other hot spots. This leads to far greater accuracy of temperature control – now to within just 2%.

The solid-state electronic control system has been designed for conditions where stability, reliability and mechanical strength are prime requirements. The 45W iron is available in 24V, 115V and 220-240V versions and is now supplied with a safety stand at no extra cost.

**CONTACT:** Greenwood Electronics, Portman Road, Reading, Berkshire, RG3 1NE, England. Tel: 0734 595843

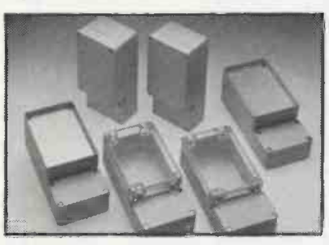
## Double Hyding

The new Boplast Plus housing from enclosure specialists West Hyde has two separate compartments, one for the electronics and a smaller one with its own lid for the terminations.

This compact housing has been developed from the best-selling Boplast range of sealed plastic enclosures. The case is moulded in light grey ABS and has a neoprene rubber gasket in each lid, providing a dustproof and hoseproof seal. The lid of the main compartment may be either light grey or clear material; alternatively a recessed type provides a degree of mechanical protection for displays and controls.

Both lids are secured by means of captive, stainless steel screws. Mounting bosses with M3 brass inserts and provided in the base, and a pcb may extend through into the smaller compartment. A set of four wall mounting brackets is available separately.

**CONTACT:** West Hyde Developments Limited, Unit 9, Park Street Industrial Estate, Aylesbury, Bucks, HP20 1ET. Tel: 0296 20441.



## Telecom-puters

British Telecom have launched a new family of powerful business computers of its own design and manufacture, with sales prospects of £200 million during the next few years.

The new machines, known as the M6000 series, use a Unix operating system. They are able to interwork with many existing machines from other suppliers. This will give users rapid access to up-to-date information stored on computers sited elsewhere – whether in the same building or on the other side of the globe.

In addition, they will have the power of the M6000 processors at their fingertips for the full range of administrative and business activities such as integrated office automation, word processing, spreadsheets, database access, electronic mail, graphics, telex management, personal organiser, and desk calculator.

The M6000 machines have been designed by British Telecom and are made in its Fulcrum factories in Birmingham.

Commenting on the new machines, Mr. John McMonigall, Managing Director Operations, of British Telecom's Communications Systems Division, said: "Our M6000 computers are yet another indication that British Telecom is steadily implementing its strategic intention of becoming a major player in the information services market place.

**CONTACT:** British Telecom Centre, Floor A3, 81 Newgate Street, London, EC1A 7AJ. Tel: 01-726 4444


## COUNTDOWN

***If you are organising any event to do with electronics, big or small, drop us a line – we shall be glad to include it here.***

**Please note:** Some events listed here may be trade or restricted category only. Also, we cannot guarantee information accuracy, so check details with the organisers before setting out.

**Mar. 14-16.** EPOS North 89. Seminar and exhibition of retail information systems. Armitage Centre, Manchester. RMDP. 0273 722687.

**Mar. 21-22.** Instrumentation Bristol. Crest Hotel, Filton, Bristol. 0822 614671.

**Mar. 21-23.** Corporate Electronic Publishing Systems. Exhibition and conference. Olympia 2, London. 01-891 5051.

**Apr. 4-6.** Scottish Computer Show. Scottish Exhibition Centre, Glasgow. 061 832 4242.

**Apr. 5-6.** Laboratory Science and Technology Show, Kelsey Kerridge, Cambridge. 0799 26699.

**Apr. 11-13** Portable Computing and Data Capture 89. Conference and exhibition. Rivermead, Reading. RMDP. 0273 722687.

**Apr. 25-27.** British Electronics Week. Olympia. 0799 26699.

**May 8-10.** Eurobus 89 – German Conference. Munich Sheraton Hotel, Munich. 01-940 4625.

**May 9-12.** Automan. Robotics and automation exhibition. NEC, Birmingham. 01-891 5051.

**May 31-Jun 2.** Computer Training Show. Olympia 2, London. 01-486 1951.

**Jun. 5-9.** Lasers, Optoelectronics, Microwaves. 9th International Trade Fair and Congress. Munich Fair Centre. 01-948 5166.

**Jun. 6-8.** Computer North. G-Mex, Manchester. 061 832 4242.

**Jun. 13-15.** Software Tools 89. Wembley Conference Centre. 01-868 4466.

**Jun. 14-15.** Instrumentation Scotland. The Forum, Livingstone. 0822 614671.

**Jul. 10-13.** EWEC '89. European wind energy conference and exhibition. Scottish Conference and Exhibition Centre, Glasgow. No reference tel. known.

**Aug. 25-Sep 3.** International Audio and Video Fair. Berlin.

**Sep. 4-6.** Eurobus 89 – UK Conference. Novotel Hotel, London. 01-940 4625.

**Sep. 12-15.** EPOS 89. The World's largest exhibition of retail information systems. Alexandra Palace, London. RMDP. 0273 722687.

**Oct. 16-20.** Systems, Computers and Communications. 11th International Trade Fair and Congress. Munich Trade Fair Centre. 01-948 5166.

**Oct. 24-26.** Sensors and Systems – International Transducer Exhibition and Conference. Wembley Conference Centre. 0822 614671.

**Nov. 7-11.** Productronica. 8th International Trade Fair for Electronics Production. Munich Trade Fair Centre. 01-948 5166.

## Reaching Asic Giraffe

Cobin Crane of Quantel won this state-of-the-art autodiagnostic giraffe at the recent Custom Electronics Show in London. Housed in a four-legged package for easy mounting, the giraffe was raffled by Hitachi, which has recently run a highly successful advertising campaign featuring a giraffe and the slogan 'Hitachi puts ASIC technology within reach'.

Autodiagnosis, a unique feature of Hitachi's cmos and bcmos gate arrays, is a development tool that greatly reduces the time required to achieve reliable designs with fault coverages in excess of 95%. The technique involves adding automatically designed test circuitry to the array, followed by automatic test pattern generation.

Shown in the picture, from left to right, are Steve Dubber (Account Manager, Hitachi). Robin Crane (Project Manager, Quantel) and Simon Gray (Product Marketing Engineer, Hitachi).

For further information **CONTACT:** Sue Jenner, Hitachi Europe Ltd., Electronic Components Division, 21 Upton Road, Watford, Herts, WD1 7TB. Tel: 0923 246488

## Commanding Full House

The Winter Consumer Electronic Show, major US showcase for electronic products, was this year held in Las Vegas from 7th until 11th January. The show embraced personal computers, TVs, videos, stereos, robotics and other consumer electronic products.

It was held at four different locations in this gambling capital of the world and according to the show spokesman, nearly 1,500 exhibitors from the US and abroad and spread their products covering an area of 17 football (American!) pitches. All major companies were represented. The total attendance over four days was 100,000 visitors.

The main theme at this year's CES was the automation of the home. Several US exhibitors at the show proposed that all electrical appliances in the near future should have a special connector called CeBus, which would act like an RS232 serial port interface on computers. CeBus socket would enable domestic appliances to be connected to each other and also, by using a command language similar to BASIC, to be controlled by computers.

It's clear from shows like this, as well as the London conference on which we report on page 12, that internationally, manufacturers believe domestic automation is no gamble.

## Young Women Engineer Award

Susan Holbrook, age 27, a Telecommunications Engineer from Gomersal, West Yorkshire, has won the 1988 Young Woman Engineer of the Year Award. At a recent ceremony in London, The Rt Hon Kenneth Baker MP, Secretary of State for Education and Science, presented her with the prize of £250 and an inscribed rose bowl. Two special awards of £100 each were presented to Kathryn Maund, age 27, a Research and Development Engineer from Northolt, Middlesex, and Carol Smith, 24, an Electrical Designer from Warrington, Cheshire, the joint runners-up in this nationwide competition.

Sponsored by The Caroline Haslett Memorial Trust (CHMT) and The Institution of Electrical and Electronics Incorporated Engineers (IEEIE), this Award – fomerly The Girl Technician Engineer of the Year Award and now in its eleventh year – focuses attention on electrical and electronic engineering as a worthwhile professional career for women, and highlights the role of the Incorporated Engineer.

**CONTACT:** John Channell, IEEIE, Savoy Hill House, Savoy Hill, London, WC2R 0BS. Tel: 01-836 3357

## Biotech

Zola McMalcolm's Biochromatic Electronics parable of PE April 88 would appear to be taking on greater reality -Macmillan have published three new reference works on biotechnology. They are the International Biotechnology Directory 1989, the Biotechnology Guide USA, and Biotechnology in Singapore, South Korea and Taiwan. They cost £85, £80 and £45 respectively, plus £2 post per book, and are available from Globe Book Services Ltd, Stockton House, 1 Melbourne Place, London WC2B 4LF. Tel 01-379 4687.

*P.S. If anyone is hoping to find an update on Zola McMalcolm's work to commemorate the April Anniversary, so sorry but space has precluded it!*

**Ed.**

## Yeda Awards 1989

Now officially launched, the 1989 Young Electronic Designer Awards scheme has won the enthusiastic backing of the Confederation of British Industry and renewed sponsorship from leading semiconductor and computer manufacturers Texas Instruments Ltd, and electronics distributors Cirkit Holdings plc.

Commenting on the YEDA Scheme, CBI director general John Banham said, "As we move into the 21st century British business faces ever growing international competition. If we are to succeed it is vital that we ensure today's young people – tomorrow's workforce – not only have the necessary technical and commercial skills, but also a sense of the excitement and challenge of developing a product or service which will meet a market need. Over the last five years the YEDA scheme has made a most impressive contribution to doing just this, by encouraging young people to combine their technical skills creatively with an appreciation of the commercial demands of the marketplace. I have no hesitation in commending this initiative and wishing it continued success."

The basic challenge of the scheme is for students to produce an electronic device of their own which is original, effective and has a useful application in everyday life. YEDA seeks to encourage young people to recognise areas in which innovative electronics could be of benefit and to carry the matter through from initial concept to marketable commodity. Thus, preparation requires not only theoretical knowledge but the development of commercial awareness.

A prestigious trophy and valuable cash prizes are presented to the winners in each category and in the senior age group there are the prospects of a job in electronics and course sponsorship.

Each school or college with one or more entrants reaching the regional judging stages in May qualifies for a special award of useful electronic equipment from Cirkit, whilst a desk-top publishing system valued at around £10,000 will be given by Texas Instruments to the educational establishment producing the project with most commercial potential. Every finalist wins a personal prize, as do their teachers.

The 1989 finals will be held next June/July in London followed by an awards luncheon attended by finalists, their tutors and parents, representatives from the world of commerce, industry, education and the press.

For further information **CONTACT:** The YEDA Trust, 24 London Road, Horsham, West Sussex, RH12 1AY. Tel: 0403 211048

## ELMASET INSTRUMENT CASE
300 x 133 x 217mm deep .... **£10 ea (£2.20)**

## REGULATORS
LM317T PLASTIC T0220 variable .... £1
LM317 METAL .... £2.20
7812 METAL 12V 1A .... £1
7805/12/15/24V plastic .... 45p 100+20p 1000+ 15p
7905/12/15/24 plastic .... 45p 100+20p 1000+ 15p
CA3085 T099 variable reg .... 2/£1
LM338 5A VARIABLE .... £5

## COMPUTER ICS
IM6402 UART .... £3
8086 processor equipment .... £2
USED 41256-15 .... £4.20
4164-15 ex equipment .... £1
9 x 41256-15 SIMM MODULE NEW .... £36
41256-10 SURFACE MOUNT EX NEW BOARDS .... £4
HD146818 CLOCK IC .... £2
2864 EEPROM .... £6
27128A 250nS EPROM NEW .... £3.20
1770 FLOPPY DISC CONTROLLER CHIP .... £10
68008 PROCESSOR EX-EQPT .... £5
ALL USED EPROMS ERASED AND BLANK CHECKED CAN BE PROGRAMMED IF DESIRED.
2764-30 USED .... £2
2716-45 USED .... £2 100/£1
2732-45 USED .... £2 100/£1
2764-30 USED .... £2 100/£1.60
27128-25/30 USED .... £2.50
27C256-30 USED .... £3
1702 EPROM EX EQPT .... £5
2114 EX EQPT 60p 4116 EX EQPT .... 70p
6264-15 8k static ram .... £6
4416 RAM .... £3.50
ZN427E-8 .... £3.50
ZN428E-8 .... £3.50

## CRYSTAL OSCILLATOR
1.8342 MHz .... 2/£1

## CRYSTALS
2.77 MHz/4.9152 MHz/49.504MHz .... £1 each

## TRANSISTORS
BC107, BCY70 PREFORMED LEADS
full spec .... £1 £4/100 £30/1000
BC557, BC548B .... 30/£1 £3.50100

## SIL RESISTOR NETWORKS
8 PIN 10k 22k .... 5/£1
9 PIN 22k .... 5/£1
10 PIN 68R 180R 22k .... 5/£1

## POWER TRANSISTORS
OC35 (Marked CV7084) .... £1
POWER FET IRF9531 8A 60V .... 2/£1
2SC1520 sim BF259 .... 3/£1 100/£22
TIP141/2 £1 ea TIP112/125/42B .... 2/£1
TIP35B TIP35C .... £1.50
SE9301 100V 10A DARL. SIM TIP121 .... 2/£1
2N3055 EX EQPT TESTED .... 4/£1
PLASTIC 3055 OR 2955 equlv 50p .... 100/£35
2N3773 NPN 25A 160V £1.80 .... 10/£16
BD132 .... 5/£1

## QUARTZ HALOGEN LAMPS
A1/216 24V 150 WATTS .... £2.25
H1 12V 50W (CAR SPOT) .... £1.50

## NICKEL CADMIUM BATTERIES
7.2 volts 1.8 A/hr.C CELLS IN PACKS OF 6 .... £5 p&p £1
ZIF SOCKETS .... 2/£1.50
TEXTOOL single in line 32 way. Can be ganged (coupling supplied) for use with any dual in line devices.

## LARGE ELECTROLYTIC CAPACITORS COMPUTER GRADE
300uF 350V SIC SAFCO FELSIC 037 .... £6(£1.50)
2200uF 160V SIC SAFCO FELSIC CO38 .... £4(£1.20)

## TURNS COUNTING DIALS FOR MULTI TURN POTENTIOMETERS
15 turn dial 21mm dia. fits 0.25" spindle .... £2.50
10 turn dial 21 mm dia. fits 3mm spindle .... £2
10 turn digital dial (3 digits) for 3mm or 6mm shaft .... £3.50
10 turn clock face dial for 6mm spindle .... £4
6mm bushes can be drilled to fit 0.25" spindles

## MISCELLANEOUS
HUMIDITY SWITCH ADJUSTABLE .... £2
WIRE ENDED FUSES 0.25A .... 30/£1
NEW ULTRASONIC TRANSDUCERS 40kHz .... £1.50 pair
12 CORE CABLE OVERALL SCREEN .... £1/3 metres
POWERFUL SMALL CYLINDRICAL MAGNETS .... 3/£1
OP AMP LM10CLN .... £2.90
BNC 50 OHM SCREENED CHASSIS SOCKET .... 3/£1
BNC TO CROC CLIPS LEAD 1 metre .... £1
MOULDED INDUCTOR 470μH
size of a 1 watt film resistor .... 5/£1
TO-220 HEAT SINK sim RS 403-162 .... 10/£2.50
SMALL MICROWAVE DIODES AEI DC1028A .... 2/£1
D.I.L. SWITCHES 10 WAY £1 8 WAY 80p 4/5/6 WAY .... 50p
180 volt 1 watt ZENERS also 12v & 75v .... 20/£1
OLIVETTI LOGOS CALCULATOR KEYBOARD (27 KEY) PLUS 12 DIGIT FLUORESCENT DISPLAY ON DRIVER BOARD (i.e. CALCULATOR LESS CASE, TRANSFORMER AND PRINTER) .... £1.30
PLASTIC EQUIPMENT CASE 9 x 6 x 1.25 in. WITH FRONT AND REAR PANELS CONTAINING PCB WITH EPROM 2764-30 AND ICS 7417 LS30 LS32 LS74 LS367 LM311 7805 REG, 9 WAY D PLUG, PUSH BUTTON SWITCH, DIN SOCKET .... £1.90
VN10LM 60v ½A 5ohm TO-92 mosfet .... 4/£1 100/£20
MIN GLASS NEONS .... 10/£1
RELAY 5v 2 pole changeover looks like RS 355-741 marked STC 47WB05T .... 2/£1
MINIATURE CO-AX FREE PLUG RS 456-071 .... 2/£1
MINIATURE CO-AX FREE SKT. RS 456-273 .... 2/£1.50
DIL REED RELAY 2 POLE n/o CONTACTS .... £1
PCB WITH 2N2646 UNIJUNCTION with 12v 4 POLE RELAY .... £1
400m 0.5w thick film resistors (yes four hundred megohms) .... 4/£1
MINIATURE CO-AX FREE PLUG RS 456-071 .... 2/£1
MINIATURE CO-AX FREE SKT. RS 456-273 .... 2/£1.50
STRAIN GAUGES 40 ohm Foil type polyester backed balco grid alloy .... £1.50 ea 10+ £1
ELECTRET MICROPHONE INSERT .... £0.90
Linear Hall effect IC Micro Switch no 613 SS4 sim RS 304-267 .... £2.50 100+ £1.50
HALL EFFECT IC UGS3040 + MAGNET .... £1
OSCILLOSCOPE PROBE SWITCHED X1 X10 .... £10
CHEAP PHONO PLUGS .... 100/£2 1000/£18
1 pole 12 way rotary switch .... 4/£1
AUDIO ICS LM380 LM386 .... £1 ea
555 TIMER 5/£1 741 OP AMP .... 5/£1
ZN414 AM RADIO CHIP .... 80p
COAX PLUGS nice ones .... 4/£1
COAXX BACK TO BACK JOINERS .... 3/£1
4 x 4 MEMBRANE KEYBOARD .... £1.50
15,000uF 40V .... £2.50 (£1.25)
INDUCTOR 20uH 1.5A .... 5/£1
NEW BT PLUG + LEAD .... £1.50
1.25" PANEL FUSEHOLDERS .... 5/£1
CHROMED STEEL HINGES 14.5 x 1" OPEN .... £1 each
12v 1.2w small wire ended lamps fit AUDI VW TR7 SAAB VOLVO .... 10/£1
12V MES LAMPS .... 10/£1
STEREO CASSETTE HEAD .... £2
MONO CASS.HEAD £1 ERASE HEAD .... 50p
THERMAL CUT OUTS 50 77 85 120°C .... £1 ea
THERMAL FUSE 121°C 240V 15A .... 5/£1
TRANSISTOR MOUNTING PADS TO-5/TO-18 .... £3/1000
TO-3 TRANSISTOR COVERS .... 10/£1
STICK ON CABINET FEET .... 30/£1
PCB PINS FIT 0.1" VERO .... 200/£1
TO-220 micas + bushes .... 10/50p 100/£2
TO-3 mica + bushes .... 20/£1
PTFE min screened cable .... 10m/£1
Large heat shrink sleeving pack .... £2
CERAMIC FILTERS 6M/9M/10.7M .... 50p 100/£20
TOKIN MAINS RFI FILTER 250v 15A .... £3
IEC chassis plug rfi filter 10A .... £3
Potentiometers short spindles values 2k5 10k 25k 1m
2M5 lin .... 5/£1
500k lin 500k log .... 4/£1
40Khz ULTRASONIC TRANSDUCERS EX-EQPT NO DATA .... £1/pr
PLESSEY INVERTER TRANSFORMER .... 50 CYCLES
11.5-0-11.5V to 240v 200VA .... £6 (£3)

## ZENERS
5.6V 1W3 SEMIKRON 50K AVAILABLE @£25/1000
SUPRESSOR OF606 120V BI DIRECTIONAL ZENER IN 3 AMP W/E PACKAGE .... 5/£1

## DIODES AND RECTIFIERS
1N4148 .... 100/£1.50
1N4004/SD4 1A 300V .... 100/£3
1N5401 3A 100V .... 10/£1
BA158 1A 400V fast recovery .... 100/£3
BA159 1A 1000V fast recovery .... 100/£4
120V 35A STUD .... 65p
BY127 1200V 1.2A .... 10/£1
BY254 800V 3A .... 8/£1
BY255 1300V 3A .... 6/£1
6A 100V SIMILAR MR751 .... 4/£1
1A 800V BRIDGE RECTIFIER .... 4/£1
4A 100V BRIDGE .... 3/£1
6A 100V BRIDGE .... 2/£1
8A 200V BRIDGE .... 2/£1.35
10A 200V BRIDGE .... £1.50
25A 200V BRIDGE £2 .... 10/£18
25A 400V BRIDGE £2.50 .... 10/£22

## SCRS
2P4M EQUIV CI06D .... 3/£1 100/£20
MCR72-6 10A 600V SCR .... £1
35A 600V STUD SCR .... £2
TICV106D 800mA 400V SCR .... 3/£1 100/£15
MEU21 PROG. UNIJUNCTION .... 3/£1

## TRIACS .... DIACS 4/£1
BT137-600 8A TO-220 .... 2/£1
BT138-600 12A TO-220 .... 70p
NEC TRIAC AC08F 8A 600V TO220 .... 5/£2 100/£30
TXAL225 8A 400V 5mA GATE .... 2/£1 100/£35
TRAL2230D 30A 400V ISOLATED STUD .... £4 each

## CONNECTORS
34 way card edge IDC CONNECTOR (disk drive type) .... £1.25
CENTRONICS 36 WAY IDC PLUG .... £2.50
CENTRONICS 36 WAY IDC SKT .... £4.00
BBC TO CENTRONICS PRINTER LEAD 1.5M .... £3.50
CENTRONICS 36 WAY PLUG SOLDER TYPE .... £4
USED CENTRONICS 36W PLUG+SKT .... £3

## USED D CONNECTORS price per pair
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Access

# GIGA-SAT TOUCHE

**BY BARRY FOX**
**Winner of the UK Technology Press Award**

## AND THE BUMBLE OF FLIGHT BYTES

*The first technology to get a toehold keeps its feet under the table – sometimes with disconcerting results.*

The Government White Paper on the future of Broadcasting in Britain promises several extra terrestrial tv channels in the 90s, in addition to the new satellite channels. Two quite different technologies will enable this; the more efficient use of existing frequencies in the uhf band, and extension of broadcasting into new, much higher, frequency bands.

Before publishing the White Paper – as a trigger for discussion and debate – the government had been waiting for a series of technical reports on high frequency (microwave) broadcasting commissioned by the Home Office and DTI. These tell us what is technically feasible.

The DTI had hired management consultants Touche Ross to advise on the feasibility of using microwave video distributing systems to give British tv viewers a wider choice of channels (*Report on the potential for microwave video distributions systems in the UK*, HMSO £8.75). The report looks at mvds as a way of providing 70% of British households with at least six, and ideally twelve extra tv channels; alternatively letting cable companies use microwave links instead laying cable under the ground.

Some countries, eg the US, already use mvds at relatively low frequency (between 1 and 6GHz). But the equipment comes mainly from Japan and this frequency band is already congested. At higher frequency (between 6GHz and 20GHz) more bandwidth is available but the receivers need gallium arsenide microchips which are not ready for mass production.

There is no margin for error when aligning the receiver dish at these frequencies, so do-it-yourself installation is impractical. Touche Ross believes that the development of circuitry to receive direct satellite broadcasts, at 12GHz, may make mvds equipment which operates at around this frequency available within eighteen months.

Frequencies above 20GHz are free, but transmitters which work with millimetre wavelengths are more expensive and receiver technology is still at the research stage. The DTI's researchers think low cost integrated circuitry may be 10 years off. Touche Ross talks of 5-7 years. Only British Telecom, which is experimenting with high frequency mvds links at Saxmundham in Suffolk, talks optimistically about the technology being ready for exploitation now.

All microwave frequencies travel along line of sight, so the taller the transmitter the further they reach, provided there are no obstructions such as buildings or trees. Extra transmitters are needed to cover areas shaded from the main mast by obstructions. When atmospheric conditions make conventional uhf tv transmissions fade, the effect is slight and brief. With microwave transmissions, fades are deep and last for minutes.

At frequencies below 14GHz, reflections from buildings are most likely to spoil the signal. Above that, bad weather and atmospheric pollution cut transmission range. At specific frequencies, chemicals block the signal path: water vapour at 22.5GHz and oxygen at 60GHz. This can be an advantage, for instance to keep transmissions private, or in a cellular radio system where separate transmitters serve individual zones.

Touche Ross believes that a 12 channel mvds service with 70% coverage of the UK is possible from around 40 transmitters – but only if space is found in the lower frequency band for which imported equipment is already available. Higher frequencies would need 50% more transmitters.

Touche Ross says that mvds is a cheaper way of offering extra tv channels than either cable or satellite. So if introduced early, it could stifle the growth of cable and satellite. But if introduced late, cable and satellite will have gained such a foothold that mvds could not compete, even though cheaper.

So the DTI and Home Office now have some tricky decisions to make.

### TERMINAL ENCORE

Recently I got a shock. Computer firm Unisys announced that it had sold some new computer equipment to the Federal Aviation Administration in the US. The equipment will help air traffic controllers guide aircraft in and out of Kennedy, La Guardia, Network and Islip airports. I asked for more details. When I finally got them I was left wondering how many people realise that New York's terminal radar approach system, known as NY Tracon, has until a few months ago been handling 1.7 million air operations a year with computer equipment that was installed in 1970.

As a result the NY Tracon computer has, until the Unisys upgrade, been relying on a 256 kilobyte memory, made from magnetic cores. This technology was invented in the 1950s, by the Massachusetts Institute of Technology and was the first solid state memory. Each memory element is a doughnut-shaped ferrite core, wound with wires which carry an electric signal to switch the core magnetism between north and south, to store a binary one or zero. Groups of cores are wired together, in a flat cat's cradle, and sheets of wound cores are then stacked in a three dimensional memory module.

The advantage of core memory is that it is non-volatile. The digital code remains if the power fails. But core memory is very slow. Accessing each bit takes 850 nanoseconds. And modern computers have backup power supplies to keep the RAM working even when there is a power cut.

The new Unisys system uses conventional random access memory, of the type now standard for all personal computers. Memory capacity in the Tracon facility remains at 256k bytes, but access time reduces to 350ns. ram is far smaller too. The 256k bytes of core memory spread over six cabinets each a metre high, whereas only eight microchips are needed to provide 256K bytes of ram. The bulk storage system remains the same, a 100 Mbyte magnetic disk.

The NY Tracon facility has until now also used a primitive display system, with each controller working on a "dumb" terminal which simply displays images provided by the central computer. Tracon now gets 37 "smart" terminals of the type found in most modern offices, each incorporating its own microprocessor. The main computer software takes advantage of this intelligence to save more time.

The old system could handle 1200 aircraft at any one time. The new system manages 1500. By 1990 it will be able to track 2800. According to Unisys, many of the major air traffic control centres in the US are still using magnetic core memory.

I wonder how many people know that.....

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SILVER JUBILEE YEAR PE 25 1964-1989

# DOMOTIC TECHNOLOGY

Recently, I came across a word I hadn't heard before, an apparently concocted word, and one which I dislike intensely. But like it or not, it's a word that could become increasingly part of our vocabulary. The word is *domotic*.

Its definition, judging by its usage, is "that which pertains to automation of the home". The word's origin is not known, but I have also seen it used in French technical literature, with the spelling of "domotique", so perhaps they're to blame! Certainly, with that pronunciation, it has a better ring to it than the Anglicised version. Whether French or English, the word probably comes from the integration of *domestic* and *robotic*.

Granted that, and my dislike of the word, I tried to think of another word which would express the same concept, but with a more appealing sound. Going back to origins, the words *domestic* and *robotic* stem from Latin and, you may be surprised to know, from Czech. The Latin source probably will not come as a cultural shock to those who know how the Romans revised our language as much as they did our transport system. (And some of today's roads are still pretty historic!) *Domus* is the Latin root, meaning *home* or *house*.

But, "*Robot* is Czech?", do you cry in automatic disbelief? So it seems. The root is supposedly *robota*, meaning *statute labour*. History has it that a certain Czech by the name of Karel Capek coined the word to describe a person of machine-like efficiency for the 1920 play "R.U.R." ("*Rossum's Universal Robots*"). Curiously, I recall once being told the root was the Polish word *robare* meaning *to work*. Still, perhaps one should be beware of memory and history ("History is bunk", said Henry Ford in 1919, and someone I can't remember said, "Memory is the thing you forget with"; note that, all computer users!) It could just be, of course, that both have their origins in the Latin *roboro – to strengthen*.

So what about another root meaning *home* or *house*? Problem, *dom* seems to be a common syllabic root for many languages, even Serbo-Croat appears to use it. How about Ancient Greek? The only thing AG ever did for me was to teach me the letters of the electronic alphabet, micros, omegas, things like that. However, my AG dictionary (equally ancient) gives *oikus* - no, no-one would ever know what *oikotics* is/are. Couldn't possibly use Modern Greek - *spiti*! The current home of automation, Japan, holds no answers either - uchi. *Uchiotics*? Yuk!

I'm not often defeated, but I am this time, I can't think of better word to use in place of *domotic*. This is a pity, because home automation technology is a subject currently receiving multi-billion pound international attention. Its implementation is no science fiction or amateur-boffin dream and it ought to have an acceptable short descriptive title. Heath-Robinson concepts are now relegated to the realms of fantasy (or the new museum soon to be opened!), big business is actively determined to make home automation a practical and desirable part of all our lives. Find out how real the technology is becoming by reading our Home Automation report.

**THE EDITOR**

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(Speedblock Type)

| No of ways | Header Plug | Receptacle | Edge Conn |
|---|---|---|---|
| 10 | 90p | 85p | 120p |
| 20 | 145p | 125p | 195p |
| 26 | 175p | 150p | 240p |
| 34 | 200p | 160p | 320p |
| 40 | 220p | 190p | 340p |
| 50 | 235p | 200p | 390p |

### D CONNECTORS

| No of Ways | 9 | 15 | 25 | 37 |
|---|---|---|---|---|
| **MALE:** | | | | |
| Ang Pins | 120 | 180 | 230 | 350 |
| Solder | 60 | 85 | 125 | 170 |
| IDC | 175 | 275 | 325 | — |
| **FEMALE:** | | | | |
| St Pin | 100 | 140 | 210 | 380 |
| Ang Pins | 160 | 210 | 275 | 440 |
| Solder | 90 | 130 | 195 | 290 |
| IDC | 195 | 325 | 375 | — |
| St Hood | 90 | 95 | 100 | 120 |
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| | 0 1 | 0 156 |
|---|---|---|
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| 2 × 18 way | — | 140p |
| 2 × 23 way (ZX81) | 175p | 220p |
| 2 × 25 way | 225p | 220p |
| 2 × 28 way (Spectrum) | 200p | — |
| 2 × 36 way | 250p | — |
| 1 × 43 way | 260p | — |
| 2 × 22 way | 190p | — |
| 2 × 43-way | 395p | — |
| 1 × 77 way | 400p | 500p |
| 2 × 50 way (S100conn) | 600p | — |

### EURO CONNECTORS

| DIN 41612 | Plug | Skt |
|---|---|---|
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| 3 × 32 way Ang Pin | 375p | 400p |
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For 2 × 32 way please specify spacing (A + B, A + C).

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(25 way D)

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| | | | |
|---|---|---|---|
| 4-way | 90p | 6-way | 105p |
| 8-way | 120p | 10-way | 150p |

### RIBBON CABLE

(grey/metre)

| | | | |
|---|---|---|---|
| 10-way | 40p | 34-way | 160p |
| 16-way | 60p | 40-way | 180p |
| 20-way | 85p | 50-way | 200p |
| 26-way | 120p | 64-way | 280p |

### DIL HEADERS

| | Solder | IDC |
|---|---|---|
| 14 pin | 40p | 100p |
| 16 pin | 50p | 110p |
| 18 pin | 60p | — |
| 20 pin | 75p | — |
| 24 pin | 100p | 150p |
| 28 pin | 160p | 200p |
| 40 pin | 200p | 225p |

### ATTENTION

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# PC MULTIPORT

BY PHILIP SMALL

## PLAN FOR A PC-FUL WORLD

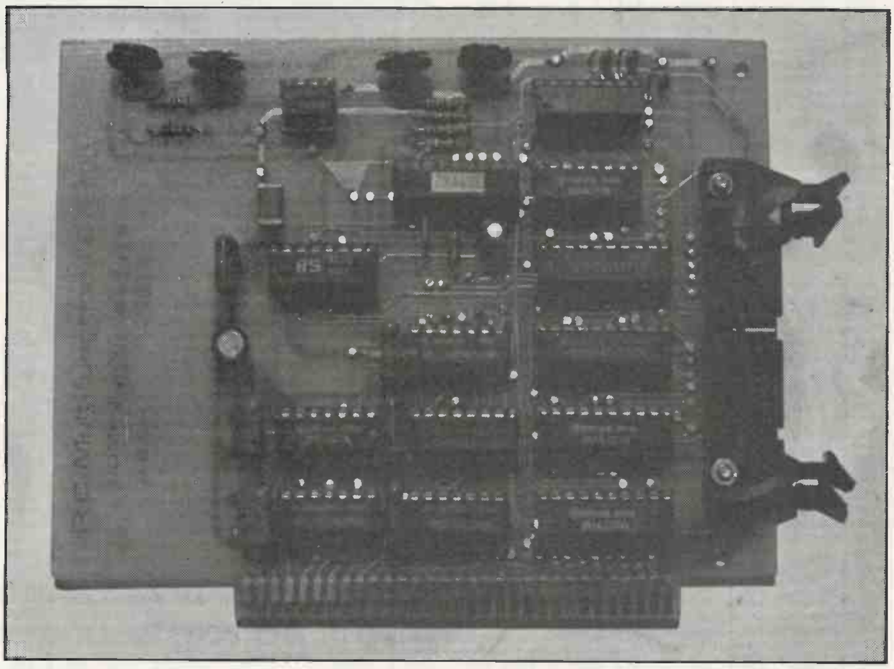
*A straight forward eight-line dual analogue and digital interface board for PC-compatibles.*

The objective of this article is to describe a circuit that can be easily driven from the Amstrad PC1512, or other PC-Compatible, and will enable interfacing with both analogue and digital devices. The outline specification is as follows.

### SPECIFICATION:

Eight lines of digital output, ttl compatible.
Eight lines of digital input, ttl compatible.
Eight lines of multiplexed analogue input.
One line of analogue output.

In the i/o address map of the PC1512 addresses 300H to 31FH have been designated for prototype cards, so that the use of these addresses is user definable. Thus for this circuit card the ports that are to be used will be contained within this range.



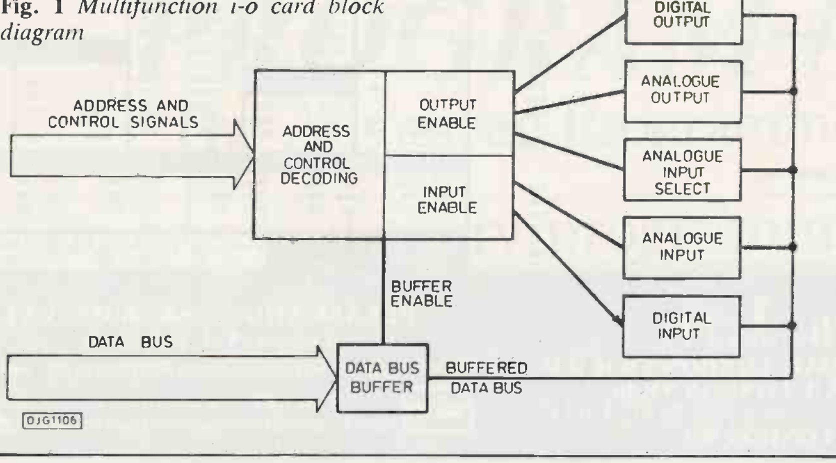
*Multifunction in-out printed circuit board.*

### EXPANSION SLOT

The expansion slot is essentially an extension of the microprocessor bus that has been repowered and demultiplexed, so greatly simplifying the task of interfacing to the computer.

With the expansion bus there are certain constraints for effective interfacing to the microprocessor. For this particular system there is obviously a constraint on the current that a card can draw, though for this application the current drawn by the card is minimal. Another constraint is that the maximum number of loads per signal line should be no greater than two low-power Schottky, ls, devices. This presents a problem with the board as there are more than two devices to be connected to the data bus. It is thus necessary to buffer the data bus to ensure that the correct logic levels are maintained on all expansion slots. The type of device that will be used for this is a bi-directional non-inverting tristate buffer, type 74LS245.

**Fig. 1** *Multifunction i-o card block diagram*




### BASIC CIRCUIT DESIGN

In the outline specification there are eight lines of analogue input, and there are basically two ways in which this could be provided; to use an eight channel analogue to digital converter, or to use a single channel adc and to multiplex the analogue inputs, the selection being performed in sofware.

Although the first method seems to be the easiest it is unfortunately the most expensive by a considerable margin, so the second method is adopted for this particular design.

For this implementation it is necessary to use an analogue multiplexer. These devices are only available in the cmos range of ics, and the particular type of device chosen is the 4051 8-to-1 device.

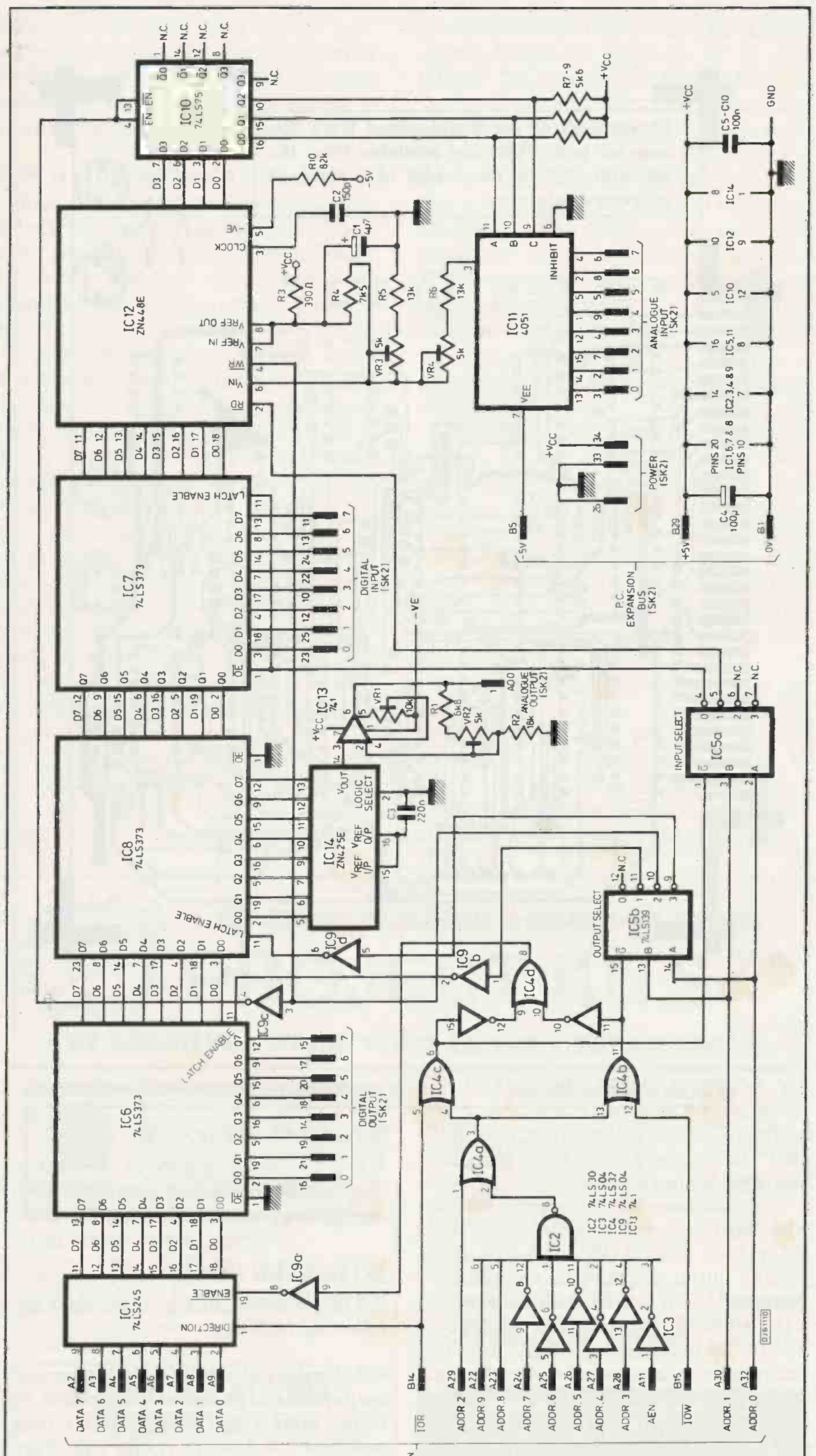


**Fig. 2** *Circuit diagram for the multifunction i-o card*

The input that is effectively connected to the adc is selected by software. The three select inputs on the 4051 are held in their required states by a 74LS75 4 bit D type latch. The adc used is the ZN448E, an 8 bit device with a linearity error of ±½ lsb. If a lower linearity error of ±¼ lsb is acceptable the ZN447E could be used; another alternative is the ZN449E which has a linearity error of ±1 lsb.

The analogue output is provided by the type ZN425E 8-bit digital to analogue converter and a 741 opamp.

The digital input and output lines are provided by an octal transparent latch with tri-state outputs, type 74LS373. The high impedance tri-state output options are not required for this project and accordingly the outputs are held permanently active.

The distribution of control and data lines is shown in the block diagram or Fig.1.

## CIRCUIT DESCRIPTION

Since I am using the port addresses from 300H to 303H for both input and output, the following signals have to be asserted to gain access to the board:

| SIGNAL | ACTIVE STATE |
|---|---|
| AEN | LOW |
| ADDR3 | LOW |
| ADDR4 | LOW |
| ADDR5 | LOW |
| ADDR6 | LOW |
| ADDR7 | LOW |
| ADDR8 | HIGH |
| ADDR9 | HIGH |
| ADDR10 | HIGH |

When these lines are in their respective active states the output of ic4a (Fig.2.) will be low, indicating that the correct address is present to access the board. Although the address may be valid it does not necessarily mean that the cpu is trying to address i/o; it could for example be trying to access memory. It is therefore necessary to see if the cpu is trying to address i/o, and this is achieved by using ic4b and ic4c. If the cpu is trying to perform a read operation then the output of ic4c will go low due t it being low. However, if a write oper tion is to be effected then the output ic4b will go low due to iow being take low. If either of the outputs of ic4b or ic4 are low this indicates that a valid i/o operation is in progress, in which case the data bus buffer, ic1, has to be enabled by ic4d. The direction of the data flow is determined by the state of ior.

Assuming that a valid i/o operation is in progress the next function is to decode address lines 1 and 0. For this purpose a dual 2-to-4 decoder, type 74LS139, is used. If an output operation is required then ic5b is enabled, otherwise, for an input operation ic5a is enabled. The port address map is given below:

| | Address | Allocation |
|---|---|---|
| **INPUT:** | 300H | digital input |
| | 301H | analogue input |
| | 302H | n/a |
| | 303H | n/a |
| **OUTPUT:** | 300H | n/a |
| | 301H | digital output |
| | 302H | analogue input select |
| | 303H | analogue output |

## INPUT CIRCUITRY

When address 300H is selected for a read operation the output ic7 is enabled and its latch disabled, ensuring that the data being read from the device is stable.

When address 301H is selected the data on the output of the adc is read in. The signal source input, ie AI0 to AI7, must have previously been selected to provide a start conversion signal. The reading of data from this device is conditional neither on the adc having finished its conversion, nor on the analogue switch ic11 having finished switching. In this mode of operation it is thus necessary to allow the adc and associated components a fixed amount of time to finish their respective operations. In practice, this means a delay between triggering and reading of around 20 microseconds.

It should be noted that any of the voltages fed into the analogue multiplexer must be within the range of –5V to +5V, otherwise the board and maybe even the PC could be damaged.

If addresses 302H or 303H are selected for a read operation the data read would be equivalent to looking at the data bus in its tri-state condition.

## OUTPUT CIRCUITRY

Selection of address 300H for a write operation is invalid.

When address 301H is selected for a write operation the data on the locally buffered data bus is latched into ic6 and, after the normal propagation delay, is available on the output.

When address 302H is selected for a write operation ic10 is enabled and the lower four bits of the data bus are clocked into it. Three of its outputs are then used to drive the switch selector of ic11, allowing the required analogue input to be fed to ic12. R7 to R9 are the tie up resistors required when interfacing ttl outputs to cmos inputs. Another event occurring upon writing data to this port is that the adc is supplied with a start conversion signal.

The analogue signals fed into the analogue multiplexer are taken off the main circuit board in such a way that they are interleaved with ground signals to avoid channel cross coupling.

When address 303H is selected the contents of the data bus are latched into ic8. The output of which is used to drive the dac, formed by ic13, ic14, and associated components. The analogue output from ic8 is always available.

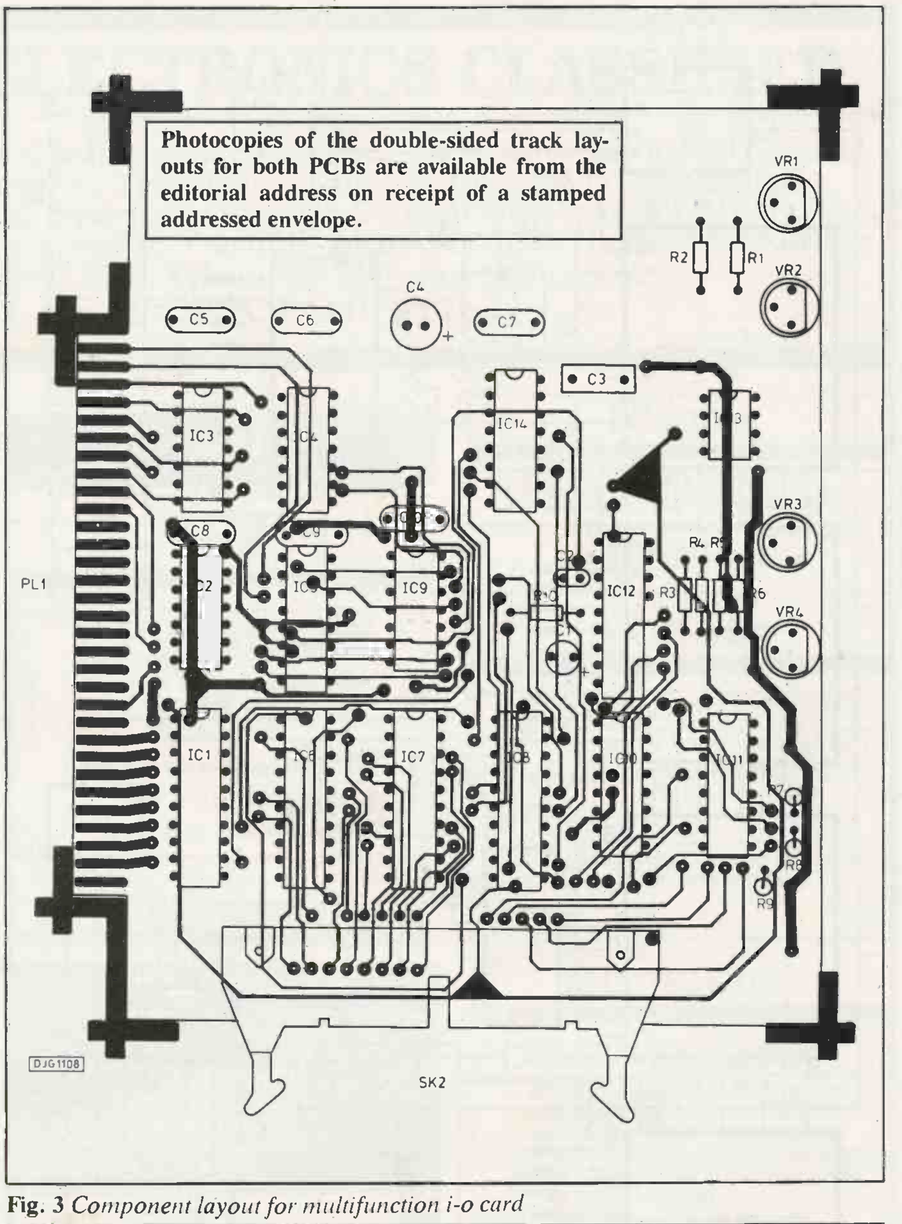



**Fig. 3** *Component layout for multifunction i-o card*

## MAIN BOARD COMPONENTS

### SEMICONDUCTORS

| | |
|---|---|
| IC1 | 74LS245 |
| IC2 | 74LS30 |
| IC3, IC9 | 74LS04 |
| IC4 | 74LS32 |
| IC5 | 74LS139 |
| IC6-IC8 | 74LS373 |
| IC10 | 74LS75 |
| IC11 | 4051 |
| IC12 | ZN447/8/9E (see text) |
| IC13 | uA741 |
| IC14 | ZN425E |

### RESISTORS

| | |
|---|---|
| R1 | 6k8 |
| R2 | 18k |
| R3 | 390Ω |
| R4 | 7k5 |
| R5,R6 | 13k |
| R7,R8,R9 | 5k6 |
| R10 | 82k |

### POTENTIOMETERS

| | |
|---|---|
| VR1 | 10k preset |
| VR2-VR4 | 5k preset |

### CAPACITORS

| | |
|---|---|
| C1 | 4.7µ pcb mounting electrolytic |
| C2 | 150pF ceramic |
| C3 | 220nF polyester |
| C4 | 100µF pcb mounting electrolytic |
| C5-C10 | 100nF polyester |

### CONNECTOR

| | |
|---|---|
| PL2 34-way | right-angled idc header |

## POWER SUPPLIES

The 5V power supply to the unit is obtained from the host computer, with decoupling provided by c4 to c10.

## I/O BUFFER BOARD

The i/o buffer of Fig.3. provides the following facilities:

1. Enables all of the digital input and output lines to be tested. This is done by fitting links 1 to 16 only and setting switched 1 to 8 to off. (Links 9 to 16 are only to be fitted for test purposes.) The test software is then run to write data to the output port read it back to check the transfer accurately.
2. Enables all digital outputs to be monitored by fitting links 1 to 8.
3. Allows the logic level of any digital input line to be set by ftting links 17 to 24 and setting the appropriate switch, on for low, and off for high.
4. Allows any of the analogue inputs to be set within the ±5V limits.

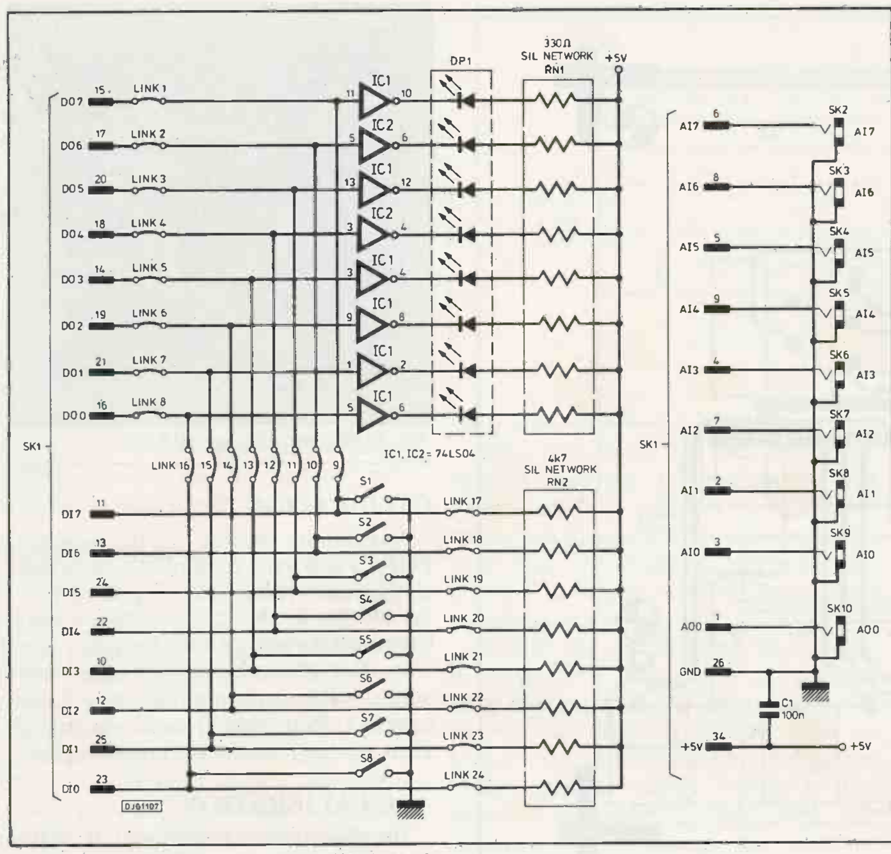


Fig. 4 *Circuit diagram of i-o buffer board*

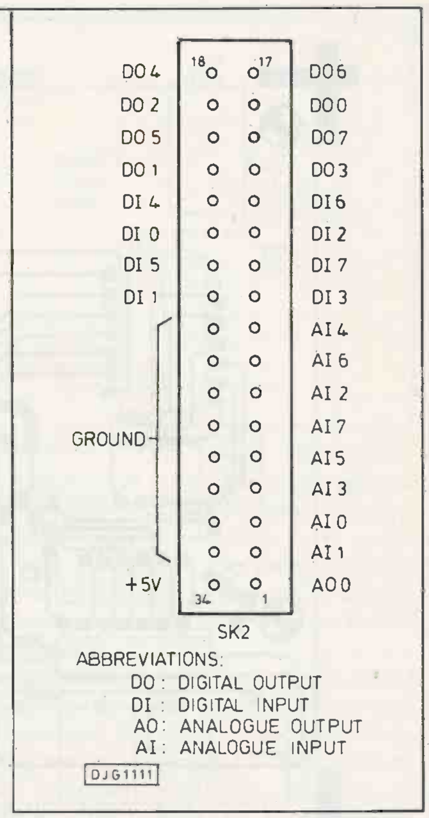



**Fig. 5** *Board connector SK2 (viewed from front)*

5. Allows the analogue output to be monitored.

In addition to these features a small prototype area has been included.

## BOARD CONNECTION

This can be easily achieved by a reasonable length of 34-way ribbon cable, eg less than about 1.5 metres, and two 34-way idc sockets.

### BUFFER BOARD

**SEMICONDUCTORS**

| | |
|---|---|
| IC1, IC2 | 74LS04 |

**RESISTORS**

| | |
|---|---|
| RN1 | 330Ω sil network |
| RN2 | 4k7 network |

**CAPACITORS**

| | |
|---|---|
| C1 | 100nF polyester |

**CONNECTORS**

| | |
|---|---|
| PL1 | 34-way vertical mounting idc header |
| PL2 to PL9 | 2.5mm pcb mounting jack sockets |
| PL10 | 3.5mm pcb mounting jack socket |

**SWITCHES**

| | |
|---|---|
| S1 to S8 | dil switch to spst 8-way |

```
10  REM *
20  REM * PORTS
30  REM *
40  REM * 2nd September 1988
50  REM *
60  REM * Allows any port to be accessed by the user
70  REM *

80  CLS
90  PRINT "PORT EXAMINATION PROGRAM :"
100 PRINT "------------------------- "
110 PRINT
120 PRINT "Please specify option required : "
130 PRINT "W : write    R : read     X : exit "

140 a$ = INKEY$
150 IF a$ = "W" OR a$ = "w" THEN GOSUB 200
160 IF a$ = "R" OR a$ = "r" THEN GOSUB 300
170 IF a$ = "X" OR a$ = "x" THEN 400
175 IF a$ = "" THEN 140
180 PRINT
190 GOTO 90

199 REM * Write data to port option
200 PRINT
205 PRINT
210 PRINT "Enter the address of the port to be written too ( in decimal ) : ";
215 INPUT port
220 PRINT
225 PRINT "Enter the value to be written to port " , port " ( in decimal ) : ";
230 INPUT value
235 PRINT

240 REM * Value to output valid ?
245 IF value < 0 OR value > 255 THEN 225
250 OUT port , value
255 RETURN

290 REM * Read data from port
300 PRINT
305 PRINT
310 PRINT "Enter the address of the port to be read from ( in decimal ) : ";
315 INPUT port
320 PRINT
325 PRINT "Value read from port " , port , " was " , INP ( port ) "."
330 RETURN

390 REM * Exit option
400 END
```

*BASIC program PORTS*

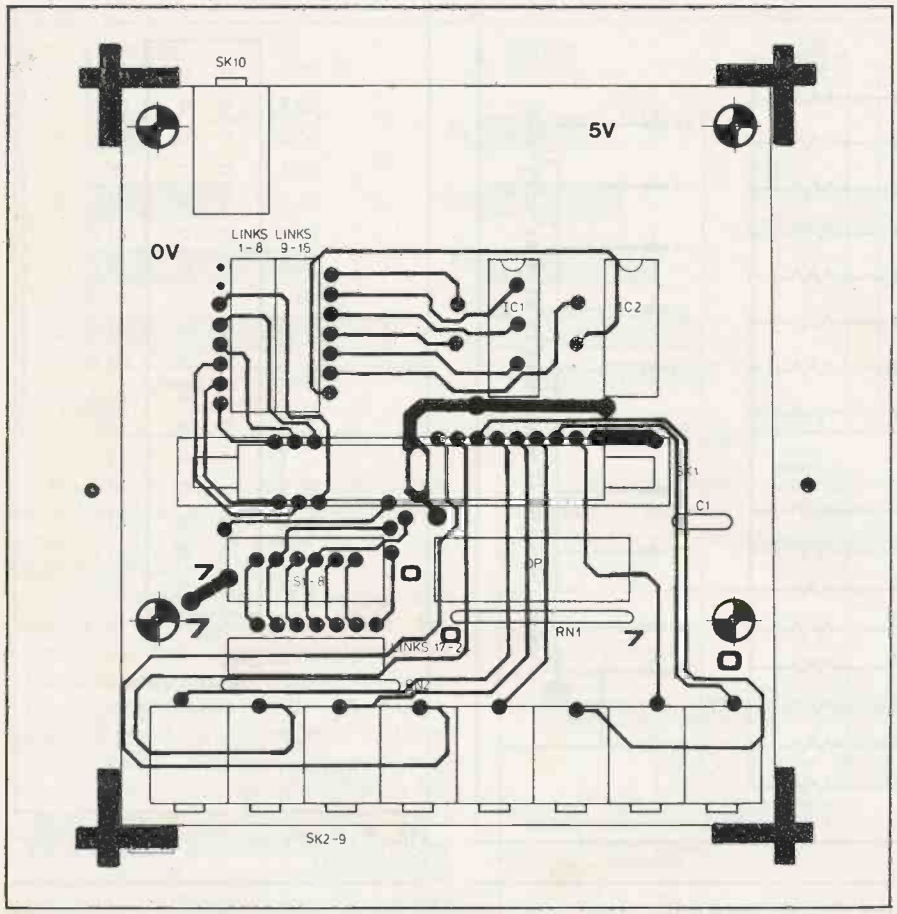


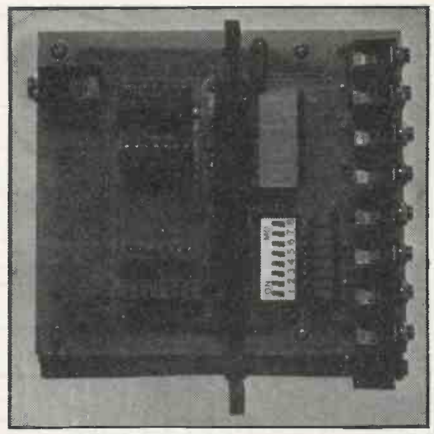

**Fig. 6** *Component layout for the buffer board*

```
10  REM *
20  REM * ADCCAL
30  REM *
40  REM * 2nd September 1988
50  REM *
60  REM * This program will continuously read data from Analogue Input
70  REM * 0 ( AI0 ) and will display the result in decimal
80  REM *

100  REM * Select AI0 and trigger ADC
110  OUT 770,0

120  REM * Wait for ADC to do conversion
130  FOR i = 0 TO 50
140  NEXT i

150  PRINT "  Data read from Analogue Input 0 was : " INP (769) ;

160  GOTO 20 110
```

*ADCAL program*

```
10  REM *
20  REM * VOLTS
30  REM *
40  REM * 2nd September 1988
50  REM *
60  REM * This program sequentially scans the eight channels of analogue
70  REM * input and displays the value read , and the value in volts.
80  REM *

100 FOR i = 0 TO 7

110 OUT 770 , i        : REM * Select channel to read
120 OUT 769 , i        : REM * Echo channel to digital output port

125 REM * Delay to allow conversion to take place
130 FOR j = 0 TO 100
140 NEXT j

150 value = INP ( 769 )
160 volts = (( value - 128 ) / 127 ) * 5
170 PRINT "Channel selected " i " value read " value " Voltage = " volts "V"

180 NEXT i
190 GOTO 100
```

*VOLTS program*



*The buffer printed circuit board*

## CALIBRATION

To calibrate the dac run the program PORTS and write to port 303. Note that all the values referred to are given in hex. Set all bits to the dac low, then adjust VR1 until the output voltage equals zero volts. Set all bits to the dac high, then adjust VR2 until the output voltage equals 3.825v, (this gives an output of 15mv per lsb). Repeat the process again.

## ADC CALIBRATION

To calibrate the adc the program ADCCAL should be run. This continually reads data from analogue input zero. Then observe the following sequence to set up the device:

1. Apply a voltage of –4.9805V to analogue input zero and adjust VR4 until the data read back flickers between 01 and 00.
2. Apply a voltage of 4.9414V to analogue input zero and adjust VR3 until the data read back flickers between fe and ff.
3. Repeat step 1.
4. To halt the program press BREAK.

*Obviously, this degree of accuracy is only available those with a sophisticated digital multimeter and a precision power supply. In most instances less precise setting up should provide satisfactory.* **ED.**

**PE**

## AIR FLOW

In my report (PE Feb 89) on the Munich exhibition I commented that a breakdown in the Heathrow computer had resulted in our plane being held at take off point with engines switched off for more than half an hour. I've since discovered that when flying from Heathrow to Munich an aircraft has to pass through 13 separate air traffic control systems. It is thus welcome news that a European air traffic control centre is to be developed to coordinate the flow of aircraft and help prevent delays, particularly those like last summer's.

The control centre is to be based either at Frankfurt or Brussels and should be operational by the early 1990s.

**Ed.**

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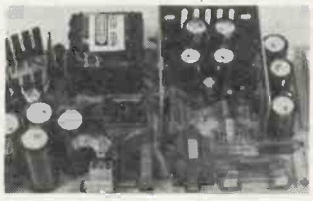

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# HOME AUTOMATION

PART ONE BY JOHN BECKER

*"ACROSS THE RAINBOW BRIDGE ... AND FROM WITHIN THE CASTLE'S CONFINES I YET MAY WIN THE WORLD"*
*(Wotan, expressing hopes for Valhalla)*

***Automation of the home is expected to provide the next mass market for goods and services based on microelectronics and modern communications. The market will be worth many millions of pounds in the UK, billions worldwide. At a two-day conference in London, leading experts discussed the current state of affairs and the outlook for the future.***

*The Automating the Home 88 conference and exhibition held during December was organised by the combined forces of the National Economic Development Office and RMDP to create a forum in which to explore the opportunities offered by the new market in home automation. The objective of the conference was to inform delegates about the concept of home automation and its importance as a market, and to provide information on some of the most important technological developments.*

*It was overwhelmingly clear that the speakers had great confidence in the abilities of home automation to provide society with products and services that will allow greater personal freedom, broader access to information,better conservation of energy and wider protection of the environment. Stress was placed on the importance of ensuring standardisation, on the need for reliability and simplicity of operation, and on the need for European manufacturers to win acceptance in a market threatened by US and Japanese domination.*

*Whereas Wotan's Valhalla was destined to collapse through greed and conflict, Europe's dawning Utopia has every potential for success if manufacturers can get their acts together and ensure that consumers can have confidence in the new products and services. For Britain's manufacturers in particular, there are golden opportunities if they can meet the challenge and capitalise on their expertise. And for consumers around the world there are countless benefits to be gained from the new technologies emerging for the automated home.*

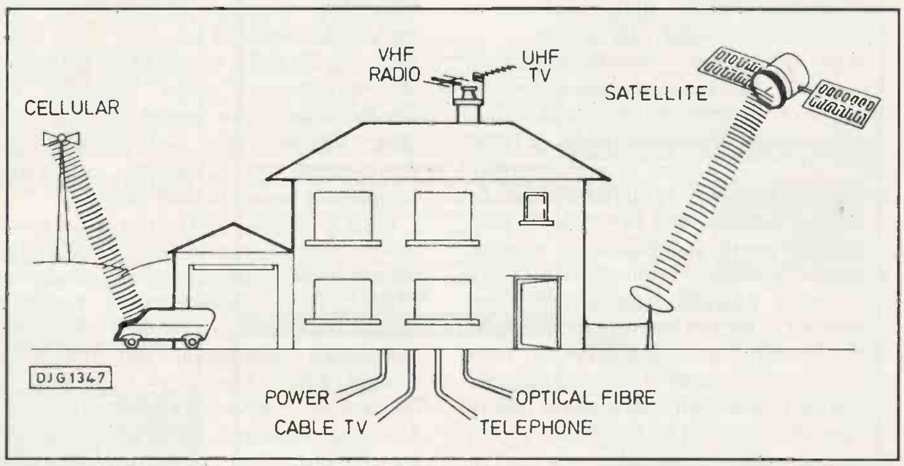



**Fig.1.** *Principle domestic communications access*

***I am grateful to RMDP for their kind permission to publish summaries of the information presented at the conference.***

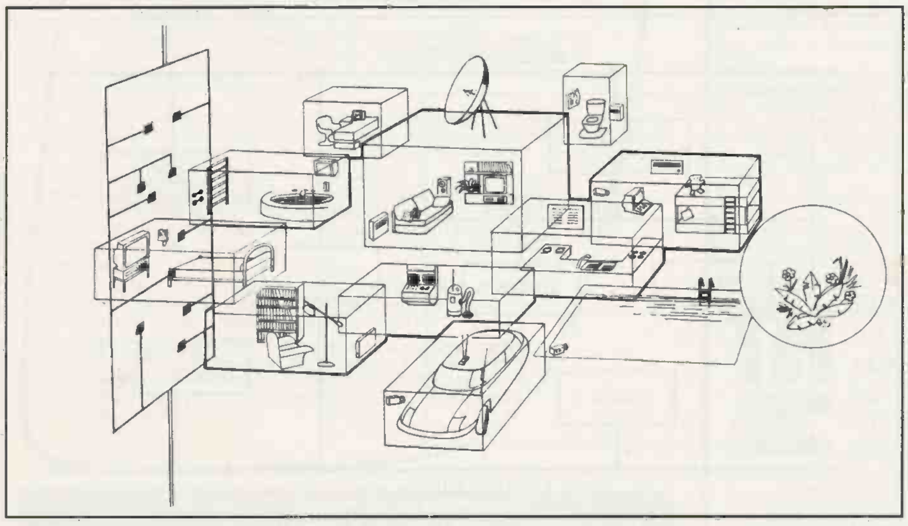


**Fig.2.** *Stylised European concept of home automation as seen by APMF*

## THE SCOPE OF HOME AUTOMATION

*Dr Gil Jones, the chief executive and founder of RMDP, is a leading expert in retail management information systems and IT applications. He believes that home automation is a very simple concept, and that it has two elements...*

The first is *integration* – the interconnection of systems and appliances that currently operate independently, so allowing easier and more sensitive control. We already have familiar examples of integration, such as videos programmed to record directly from the tv, Prestel which makes use of the tv and the phone, and alarm systems that respond to smoke detection. A fully integrated home would allow control of many other functions, and could, for example, maximise efficiency by bringing all energy-using appliances under a single control.

*Interactivity* is the second element, a current example of which is the telephone, allowing a two-way link with the outside world. In an automated home the phone could be used for remote programming of appliances by a householder who is many miles from home. Many other benefits will also follow by taking advantage of existing technologies. The implementation does not require a massive new programme of

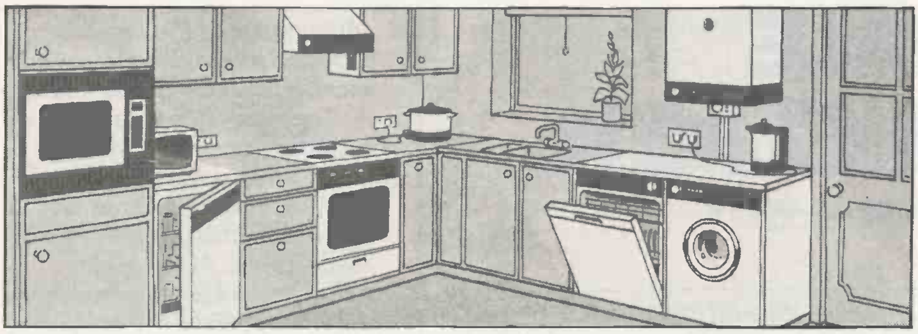


**Fig.3.** *The scope for electronic home management in the kitchen as envisaged by Philips Components*

technological development but it does require that domestic appliances, controls and communications must conform to consistent interconnective techniques.

With so much intercommunication between the home and the outside world, the issue of standards assumes even greater importance. The European model of home automation is of a home network to which appliances from any manufacturer can be connected and be able to speak to each other. For home automation to succeed, consumers must have a wide product choice from many different manufacturers, and confidence in the full compatibility between them. If consumers are forced to buy from only one manufacturer in order to maintain appliance compatibility, they could readily become disenchanted with the idea of full home automation. Standards are a kind of universal language, ensuring that intercommunication between products of the various conforming manufacturers are carried out accurately and easily, both within and outside the home.

As yet agreement on acceptable standards has not been reached. If Europe is to remain ahead of the competition in home automation threatened by Japan and the USA, European standards must be determined and published as quickly and widely as possible, and that they should be adhered to. If consumers are offered a hotch potch of incompatible European products that cause them a lot of hassle and pain, they won't buy. South-east Asian companies have already largely mopped up the market in home electronics, motor bikes, cars etc. This time, let's ensure that Britain is able to capitalise on its early expertise.

## IHS EUREKA PROJECT

*John Ryan, of Thorn EMI Central Research Laboratories, discussed the progress and objectives of the Eureka Integrated Homes Systems Project (IHS Eureka), of which he is the project manager. This involves coordinating industry-led groups in France, Italy, Netherlands, UK, West Germany and Sweden. The companies participating are Electrolux/Zanussi, GEC, Philips, Siemens, Thomson and Thorn EMI...*

The main objective of the project is to define an industry specification or standard for home systems. The standard will cover all layers of communications protocols from the physical interface to the application command language. Apart from achieving the direct benefit to the consumer of choice, a major reason for standardisation is to inspire the necessary sales volume that will justify the development of low-cost electronic components for world-wide markets.

Eureka's scope covers three main areas: *Control and monitoring* – covering security/safety, heating and environmental control, energy management, appliance control. *Entertainment/learning* – covering audio/video distribution and interactive learning. *External services* – in the form of information services, home banking /shopping, work from home, telecontrol and telemetering.

The studies indicate that a very flexible communications network is required, and that for maximum flexibility each application should have a separate control box, containing its own control program, situated at a convenient point in the house. This must be able to communicate with other devices and appliances elsewhere in the house. There should be several levels of communications control media available to the systems designer, who would select those best suited to the application, either individually or as a combination. The choice of media should include wire-pairs, coax cable, mainsborne signalling, infrared and low power radio.

Many sub-networks can be created geographically (room-based) or by medium, enabling complex structures to be chosen. Fig.4 shows an example of a small section of such a network comprising three sub-networks.

One of the main tasks on the project has been to ensure that installation, maintenance and extension of networks can be carried out with a minimum of skill and knowledge. Although the system will use uniquely coded address signals for each application, these should be transparent to the user. Even when installing a new appliance for the first time, or simply moving it from one room to another, all the user needs to know is that he or she plugs in the device, and at most presses a button in order to register it with the system.

Currently, the main task of the project is to complete the demonstration models in order to test and finalise the specifications for the protocols and media. The remaining technical work on Eureka IHS should be complete in Spring 1989.

In parallel with the Eureka IHS project, other international standards bodies are preparing standards on home electronic systems. World-wide there is a joint committee of the International Standards Organisation (ISO) and the International Electrotechnical Commission (IEC). In Europe CENELEC is working on an official European standard, the planned single European market of 1992 being one of the driving forces. The Eureka group has been contributing to the international standards bodies and is studying the standards emerging from the USA and Japan.

The Eureka work ends during 1989, but the participants are planning an Esprit II Home Systems project to continue the work for the future. Additional major European companies have joined this consortium; ABB, AEG, British Telecom and Legrand. Philips will be the prime contractor and a further eleven smaller organisations have become associate contractors. Esprit II will further develop the work of Eureka, taking into account new technology and a wider range of applications.

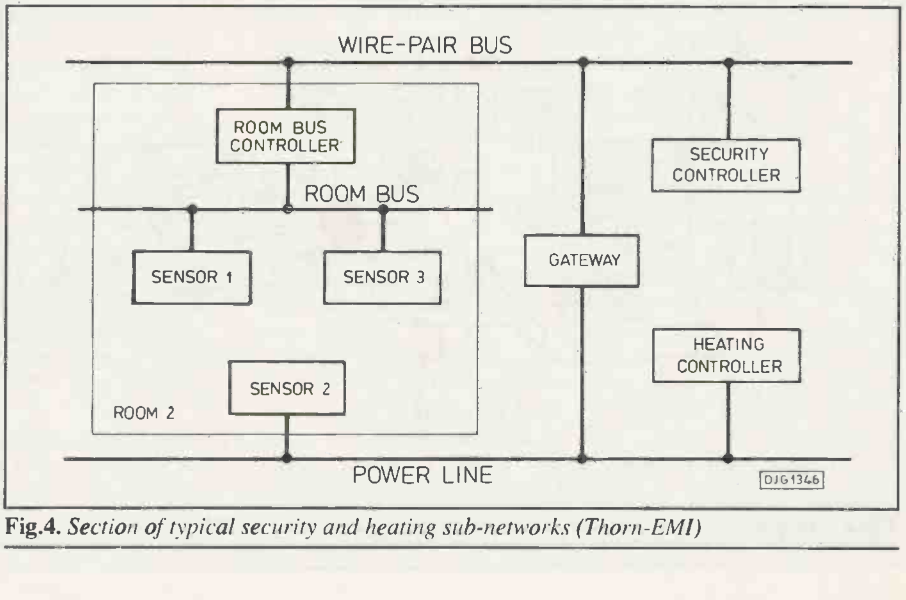



**Fig.4.** *Section of typical security and heating sub-networks (Thorn-EMI)*

## REAL WORLD INTERFACING

*Keith Clarke, of British Telecom Research Laboratories, where he is General Manager – Information Technology Products, enlightened the conference on the "Telco Role" in connecting the automated home to the outside world...*

Telephone companies will play a major role in home automation, but difficulties arise if we attempt to segregate developments in the telephone network from those in radio communications, satellite broadcasting and cable tv, since these technologies are still emerging. All the major technical developments foreseen weaken the existing distinctions between the technical media that are used to carry tv, music, business data, computer software and voice telephony. Consequently, the data routing to the home of the future will probably be typified by Fig.1.

Electric power cables are likely to be used for carrying low speed data for applications such as meter reading and domestic appliance control. Further data can be carried via the copper cables of the existing telephone network, and these will in due course be replaced by optical fibres. Coax cables are used by cable tv companies, and these can be configured in a variety of modes. Radio waves at many frequencies can beam data into the home from a variety of locations, ranging from the top of a local telephone pole or city tower block, to orbiting satellites. And of course, data can be physically carried into the home via a wide variety of devices, such as audio and video cassettes, optical, compact and computer discs, and smart cards.

*In addition to the applications previously identified, Keith Clarke pointed out the importance of communications via the automated home in terms of help for the disabled and sick, and recognised that many more applications will emerge, becoming more demanding as the years go by...*

Many applications will require two-way communication, though some only work effectively in one direction, such as discs, cassettes and most of the radio technologies, with the important exception of cellular. Cellular radio is important because it will link into a European-wide, and possibly world-wide, personal mobility network operated by Telco and others. Some sophisticated cable tv networks can also provide two-way communication.

Security is vital to communications systems serving the automated home. Programme providers will not wish to lose revenue through unauthorised access, and IT systems within the home will contain confidential information, not only of a personal nature, but possibly relating to companies for whom the occupant may be teleworking from home. Providing complete security for IT systems poses a formidable challenge to operators granted the record of computer hackers, telephone and cable tv freaks, video and software pirates.

The problem is most severe for those media which rely on local decoding devices for their security. Secure devices can be created, but only at a price. Systems which take into the home only the information which is required there, such as the telephone network and optical fibre network of the future will be better placed to offer lasting security at an affordable cost.

The technically most attractive facilities must be affordable to the customer. There are no easy solutions, but for technically advanced products, low costs to the customer are achieved through volume manufacture. Two mechanisms can help to achieve this – by applying techniques previously proven in the business sector, and implementing satisfactory international standards.

Currently, POTS (the Plain Old Telephone Service!) provides many services, such as Prestel Videotex, for example. This was invented in the UK nine years ago, and has provided a valuable insight into the types of services that customers, when purchasing in an unsubsidised free market, require. They include teleshopping, home banking, agricultural information, and the purchase via the phone of software for home computers. Operating in a completely different and commercial regulatory environment, the French Minitel operation has put four million terminals into domestic homes and has stimulated a whole range of electronic services.

Services based on voice recognition also have major potential and the Royal Bank of Scotland experiment, using equipment developed by BT has had most encouraging results. Additionally, BT has of course been offering burglar alarm monitoring via the telephone for many years.

BT has introduced Integrated Digital Access (IDA). This has upgraded its copper network to carry digital data at rates up to 128 Kbits/sec for the benefit of business customers. Enhanced signalling facilities such as calling line identification currently enhance business security by identifying which customer is calling. This ability will enhance the security of several home

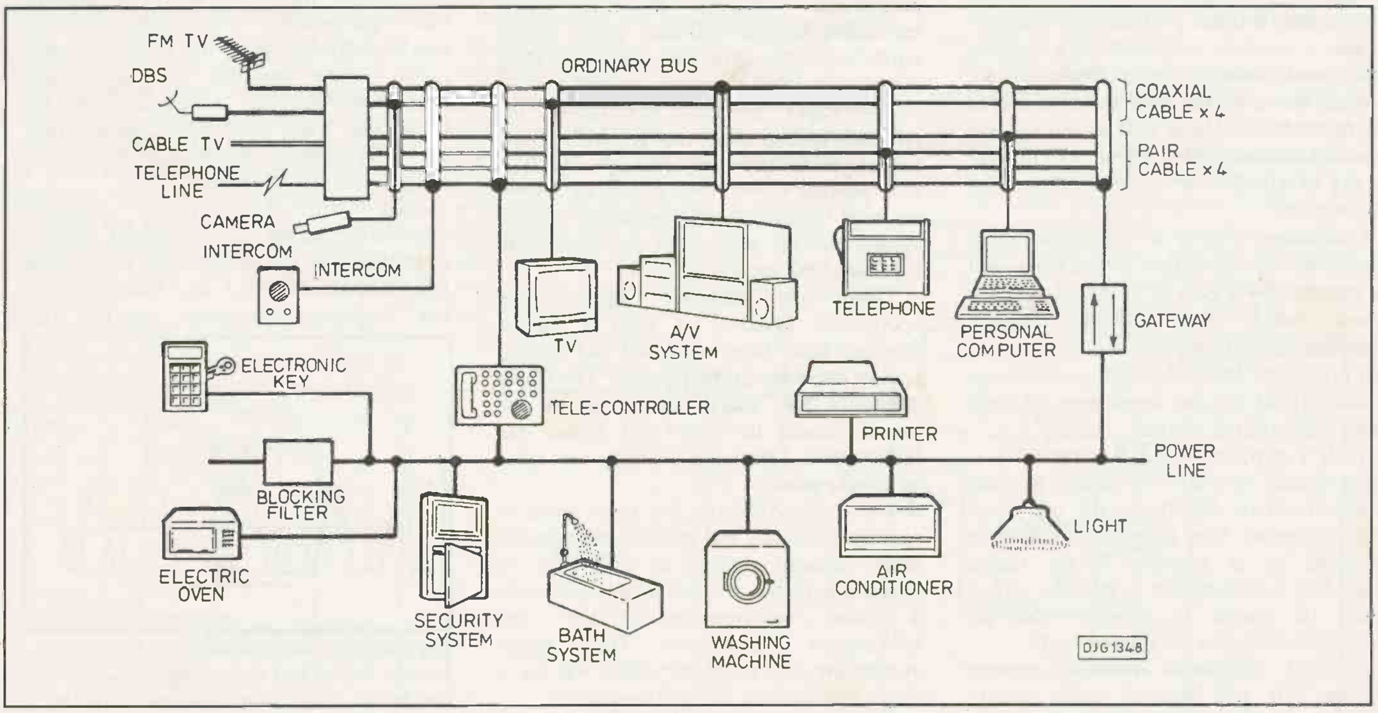



**Fig.5.** *Section of a typical total home bus system (NEC Home ElectronicsLtd)*

automation applications. It will have further impact in visual telecommunications, permitting still and, with some limitations, moving coloured pictures to be transmitted. This opens the way for the "viewphone" – of particular benefit in teleshopping applications where good quality photographs can be provided via Photovideotex, allowing closer examination of goods before purchase. Upgrading the bandwidth of the telephone network will increase the role for voice recognition services, allowing system vocabularies to be increased. The greatest contribution IDA could make towards automation in the home is through teleworking. IDA would permit computer programming, and other areas such as graphical design, to be equally well performed from home.

The future of the telephone network lies with optical fibres extending to every home. This will facilitate the two-way transfer of high grade visual images for advanced viewphones and teleworking. The speed of implementation is likely to be influenced as much by regulatory restraints as by technical progress, though development is well under way. It is possible that the networks of the future may well be passive optical networks in which channels are switched without converting light to and from electronics, ie, they will be photonic. This is probably the only communications system capable of offering the two-directional bandwidth and the security that will be required for the more ambitious applications in home automation.

Future optical fibre telephone networks will be surrounded by radio transmitters operating in a variety of modes and frequencies, giving customers full personal mobility. Cellular radio, cordless telephones and radio pagers are already well accepted, though their systems are currently fragmented. It is not possible, for example, to use a cordless telephone as a cellular radio even though the technologies are similar. However, the expectation is that in the future the customer will have a stylised personal communicator, which will operate to any of a large number of receivers and transmitters.

Continuing growth in the transmission capabilities of connections to the home will be matched by a growth in the intelligence stored within the network. Modern exchanges already provide services such as call diversion, three-way calling and charge advice. These are the forerunners of even more sophisticated services.

With a periphery of radio transmitters, the telephone network will be able to route communications directly to the individual required, rather than to specific telephone locations as at present. If the called individual is unavailable to take the call, it could be routed to another specified individual, or stored for later retrieval.

Itemised telephone bills is another service that will become more widely available – providing the customer actually wants it. Some subscribers may not wish that records are made of the numbers being called, and such facilities may need to be restricted by customer preference, or by regulation.

The telephone, or more correctly, the communication networks of the future will have a key role in bringing about the automated home. The networks will be progressively enhanced so that they can carry as much bandwidth as any of the applications now conceived will demand. The question remaining is – has society and the market decided want it wants?

## CABLE SYSTEMS

*Keith Miles is the Director of Finance and Administration at the Institute of Economic Affairs, the well known free-market "Think Tank". Formerly the Director of Finance and Operations at the Cable Authority, he has a past, present and continuing interest in the development of new marketplace services on telecommunication systems. At the time of the conference he had just received the recent White Paper on Broadcasting, and though he'd had little time to digest its implications, he felt obliged to comment on it. He considered that its proposals could have an important effect on the pace of development for cable systems...*

Development will also be affected by the infrastructure study being carried out by the DTI into telecommunications. One paragraph in the White Paper succinctly puts the present policy – "The Government has been keen to facilitate the development of broadband cable, at a pace determined by the market, as a way of providing additional programme services, developing new interactive services and also, in the longer term, as a possible route to increasing competition in telecommunications".

The Paper correctly summarises the present position that "the growth of new cable systems has been slow, though it is now picking up. ....(One reason has been) the high capital costs of installing a cable system and the absence of any significant revenue in the early years."

There are currently eleven new operational systems, at least a further fourteen have been awarded, and around sixteen more are in the pipeline. The Cable Authority has stated that most of the country could be franchised before the Independent Television Commission takes on its new powers.

The Cable Authority has done much to encourage interest and specific experiments have included access to a library of interactive videos, a video juke box service, a video conferencing service, and information databases. The recent availability of Prestel on cable will be a major step forward for both operations.

The new interactive services will be very cost effective on cable systems in the home situation since the major costs of construction are paid for by the entertainment services. The non-entertainment services on cable are likely to be teleshopping, home banking, booking services, telesoftware, energy management, home security systems, remote meter reading, market research, electronic mail, closed user groups, data transmission, interactive education, database access, and traffic management.

It is clear that interactive services which need a national and very comprehensive service will continue to develop on the public telephone network, whereas those which need bandwidth, such as energy management systems or real time security and local services, will develop on cable. However, in the long term, as the services increase so greater broadband capacity will be required and cable systems will increasing provide the delivery method.

As the findings of the DTI infrastructure study are not yet known caution is advised, but if the study is forward looking, we are in for exciting times.

## BBC'S RADIO DATA SYSTEM

*David Lees works for the BBC, advising on radio and television reception and promoting the world-leading achievements of the BBC's Engineering Division...*

Since almost every home has one or more radios, radio broadcasting is probably the most cost efficient means of getting a multiplicity of programme and data channels into the home for education, information and entertainment. Consequently the BBC has for some time been encouraging more use of fm broadcasts, better performance from radio receivers, and the introduction of the fully automated radio – radio provided with intelligence from data channels associated with the broadcasts. Such radio data channels may also carry services, independent of the radio programme, into the home.

Data will be digitally encoded information added to a broadcast without disturbance to the programme sound. The BBC has developed a data system for its low frequency broadcasts and has also

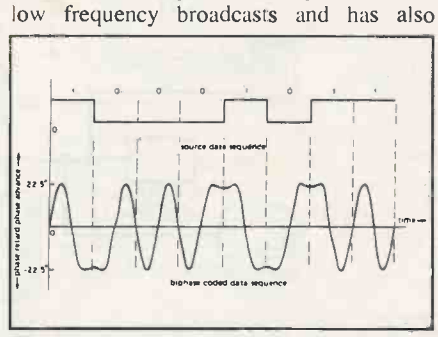



**Fig.6.** *Radio-data modulation of an LF carrier. Above is a source data sequence and below it, the same sequence bi-phase coded. (BBC)*

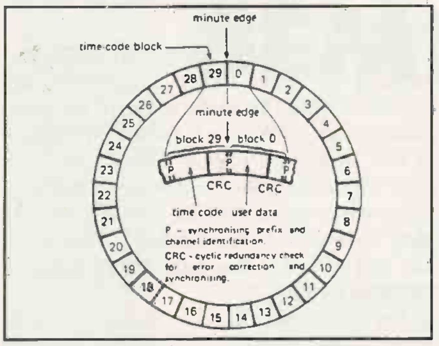



**Fig.7.** *Arrangement of LF radio-data blocks. Block 0 begins exactly on the clock-time minute. (BBC)*

pioneered, together with European Broadcasting Union partners, the radio data system (RDS) which is used with fm broadcasts.

Three lf transmitters are used by the BBC and operate as a synchronised group on 198kHz, based at Burghead, Droitwich and Westerglen. They have a range of several hundred kilometres and offer national coverage for sixteen low-bit rate data channels. One transmits an accurate clock-time and the others are available for user data.

The UK electricity supply industry has financed BBC's development of the Teleswitching system which uses some of the lf data channels. Teleswitching is used for remote control of electricity use via special electronic time switches (radio teleswitch receivers) installed in the home, so evening out the demand for electricity. This is a prime example of a cost-efficient aspect of home automation.

The long range of lf transmissions also suits them for transmission of digital weather information for land and sea areas without the need to listen to spoken reports.

Spring 1987 saw completion of the initial RDS service ahead of schedule, allowing manufacturers of RDS receivers to "road test" their products. The service went live on 20 Sept 1988 and the installation of the 98 BBC-designed encoders at 48 sites ultimately will bring an RDS service to 75 per cent of the population.

There are five primary RDS features provided by the BBC – PS, PI, AF, ON and CT. The program service name (PS) is eight text characters used to indicate, on an lcd or similar, the service being received. The programme identification code (PI) is used by the radio to confirm the correct reception of the chosen service. The alternative frequency list (AF) is a sequence of codes representing other radio frequencies used by the chosen service in adjacent areas. This feature is of great value for mobile reception where the RDS radio will retune to the best frequency without having to scan through the whole radio band.

Other networks information (ON) gives tuning information about other services to allow rapid retuning to another programme or to travel announcements. Clock time and date (CT) is derived from the National Physical Laboratory and is automatically updated at changes between GMT and BST.

Motorists will especially benefit from the RDS travel service. The radio can scan for and select a broadcast which carries regular travel messages. When a travel announcement is made the radio is automatically alerted and retunes to the local service providing the travel information. The BBC will start a trial RDS travel service in spring 1989 via five local radio stations – Radio WM, GLR, BBC Essex, Radio Bedfordshire and Radio Kent. A full travel service for the entire UK will follow in due course.

RDS will eventually offer many other features, such as additional motorist's information, radio paging and programme type selection. The latter is used to command the radio to search for a particular type of programme, for example, news, sport, jazz etc. The receivers can also be preprogrammed to automatically recognise and switch on to a particular programme. A radio text service will become available to provide programme related information to home receivers fitted with a display screen. Text messages of up to 64 characters will show programme titles, names, details of music etc. A "transparent" data channel has been designed to permit the delivery of data to specialised external devices – the applications for this channel are numerous and include home automation control. Additional features will also become available.

The BBC considered it essential that an RDS interface should be provided to external devices such as a speech synthesiser, graphics display, printer and personal computer system. As yet the interface has not been fully specified but will have a minimum of seven lines and each external device should provide an interface connector to daisy-chain to other devices.

Looking further to the future the BBC will base developments on a digital broadcasting system. Sixteen radio channels delivered primarily from satellite and supplemented from terrestrial transmitters will be available to a future generation of fully digital, autotuning receivers.

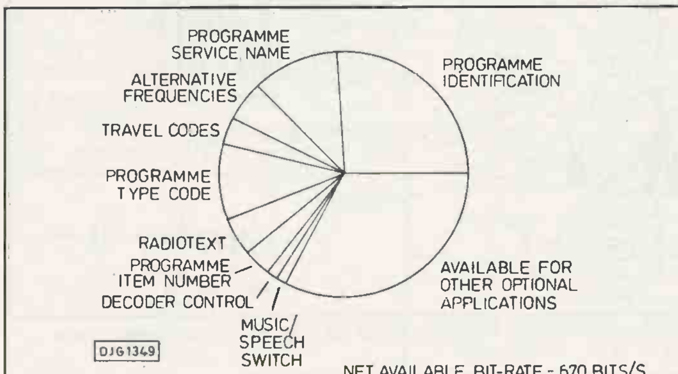



**Fig.8.** *Recommended RDS channel usage. (BBC)*

## DIRECT BROADCAST SATELLITES

*Walter Anderson, on behalf of the IBA, discussed the new satellite tv services which should become available in the UK over the next few years. By the time this report is published the Astra satellite should already be operational. His expressed opinion is that the BSB satellite will be the most important...*

*The IBA's two eight metre diameter satellite up-link dishes in preparation.*

In the UK, the four earth-bound tv programmes are transmitted from around 900 separate sites and can be received by about 98 per cent of households. Cable distribution networks reach roughly 250,000 households and provide further tv channels, though only where conditions are favourable. The successful launching of the Astra and BSB satellites will permit many more households throughout the UK to receive several additional programmes.

BSB is due to be launched in the autumn and will be a high power direct broadcasting satellite giving three channels. This could be the first operational European satellite service complying with the CCIR standards agreed at the World Administrative Radio Conference in 1977. Although the WARC standards were designed to allow easy reception of high power dbs signals using a one metre antenna, improvements in receiver technology now allow domestic equipment to receive lower power transmissions in the fixed satellite service band. The Astra project is based on a medium power concept and is capable of transmitting 16 channels.

Viewers connected to a modern broadband cable network can probably expect the satellite services to be available for an extra fee, and possibly without modification to the existing tv set. Other viewers wishing to receive satellite broadcasts will need additional equipment. Since the signal modulations of the two satellites are different, separate aerials and decoders specifically designed for either Astra or BSB will be required. Combined equipment capable of handling signals from both satellites will eventually be produced, but is not yet available. The installation of two separate satellite tv antennas will probably need local planning permission since a Home Office circular on this subject specifies only ONE antenna.

*Walter Anderson went on to discuss the technicalities and merits of the PAL and MAC systems employed by Astra and BSB respectively. He also looked at the medium-term future for satellite tv, including the introduction of high definition sets. Since these subjects have recently been well aired in the media, including PE, and have no immediate significance for home automation control, we have omitted his summary.*

## SMART HOMES

*David Gann of the Science Policy Research Unit (SPRU) at the University of Sussex considered the lessons that can be learnt in the residential market for automated homes from the experience gained with "Intelligent Buildings" in the business sector. He stressed two points, the need for long-term collaboration in strategic research and development, and the need for appropriate skills in design, development, installation, operation and maintenance – in other words, the need for "smart people". He pointed out how IT is having an impact on financial services, office automation, the automobile industry, and how American and Japanese firms are gearing up for the Single European Market. With regard to the building industry, he quoted from Kipling –*

How very little,
Since things were made
Things have altered
In the building trade.

Should we be surprised at predictions of radical change spurred by IT in the building industry which everyone thinks to be so traditional and slow moving? Can British firms respond to the challenge?

The diffusion of microelectronics into buildings provides a massive potential for new market opportunities. The smart home is a scaled down version of the intelligent office – the principles are the same and they both use similar technologies. There are few examples of intelligent buildings, though there are those which incorporate integrated building management in which the energy management system is a central feature.

An intelligent office building would include – *Building Automation* comprising energy management, temperature and humidity control, fire and security protection, lighting and maintenance management, and access control. *Office Automation* would consist of LANs, EM, data and word processing, management reporting, and other internal communications such as audio/visual. *Enhanced Telecoms* would include digital PABX, routing cost analysis, and teleconferencing. *Responsiveness to Change* would reflect the ability of buildings to accommodate changes in individual requirements and organisational demands. Many of these facilities would be expected in scaled down form in smart homes, substituting entertainment in place of the audio/visual and teleconferencing facilities.

The demand for intelligent buildings has been fueled by the need for greater energy efficiency, better control over the internal environment, and new ways of doing business via IT. Response to this demand has led to a number of new small innovative firms entering the market and competing successfully with large established firms. However, short product life cycles and long lead times in development may force many smaller firms to enter into collaborative agreements. Investment in long term strategic R&D is of paramount importance – as the Japanese have already recognised. The Eureka project discussed earlier is a European example of collaborative R&D. The Japanese involvement in intelligent buildings has prompted large construction firms to invest more on R&D in collaborative ventures. Where possible British manufacturers and construction firms (ie, house builders) should participate in greater collaboration.

Furthermore, there is the need to tie down standards in the industry to provide better systems integration. Firms may resist systems compatibility to preserve a market niche, but this could slow the overall growth of the market.

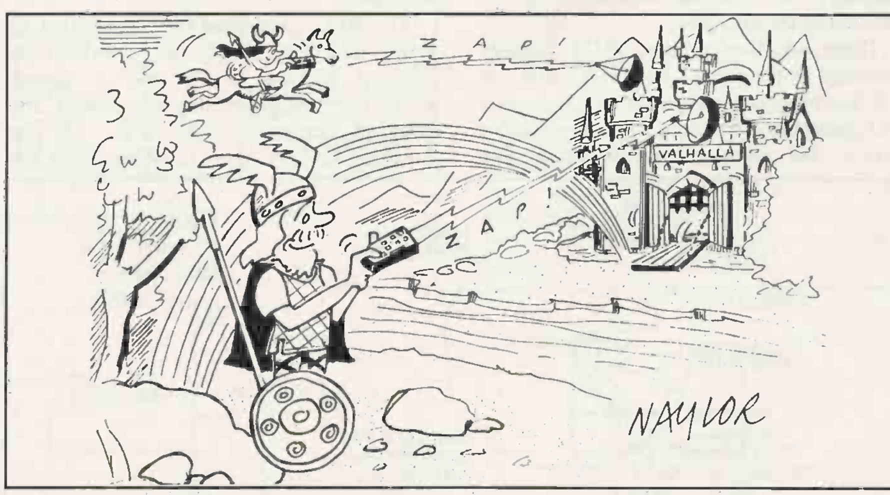
Firms also need to address education and training on two fronts. Customers and consumers must be made aware of the smart house concept: Why is it useful? What does it do? How does it work? How easy is to use? There are several cases where building users have turned off their systems because they have not understood them. This is not the sort of image that an industry needs to promote its sales.

On the second front, the industry is in its infancy and needs to consider where the skills will come from to design, develop, manufacture, install and maintain the systems. Inadequate training is threatening to curtail the rate of growth in the business sector. Skill shortages and poaching at all levels are making it difficult for firms to plan their work loads. Cowboys have discredited certain quarters of the building industry, particularly domestic repair and maintenance – will we see the rise of the smart homes cowboy? And will the declining number of school leavers pose a constraint to expansion in the future?

Collaboration in strategic R&D and training a skilled workforce are matters vital to the implementation of the smart homes concept.

*Having seen how information can be brought into and out of the home, next month we shall look areas in which home automation can be applied.* **PE**

*Just for interest – Thorn EMI's purpose-built experimental automated house.*




*If Wotan had installed Home Automation, Valhalla might have been a dream home come true as well.*

# SATELLITE FUNDAMENTALS

PART ONE – BY TOM IVALL

## SPACECRAFT LAUNCHING AND ORBITING

*Once launched, its height above the Earth's surface, direction with regard to Earth's axis, and speed of travel all have a bearing on the function of a communications satellite.*

This year the British public should be in a position to receive television programmes from a completely new source – direct broadcasting satellites. In October 1988 the French launched their high-power TDF-1 and in December Luxembourg-based company Société Européenne des Satellites put its medium-power Astra into orbit. And if all goes according to plan, British Satellite Broadcasting will be transmitting programmes on high power from a UK-owned spacecraft due to be launched in August this year.

Before the advent of these direct broadcasting types all the satellite tv programmes we have been receiving so far have come from relatively low power communications satellites. Originally the idea was to use these comsats simply to send tv signals from point to point, as if along a cable. This point-to-point communication has two main purposes: to exchange tv programmes between broadcasting organizations in different parts of the world; and to send tv signals to cable television stations for subsequent local distribution.

But because the beams from these communications satellites cover very large areas of the Earth the signals also became available, willy-nilly, to everyone living in these areas. It was broadcasting by accident, you might say. Hence the rise of a small, specialised industry for supplying what is called television receive-only (TVRO) equipment to the general public.

A later article will deal with what you need to know and do if you are thinking of setting up your own station to receive either the low power or the direct broadcast (higher power) tv programmes. But these, of course, are not the only satellite signals which PE readers might be interested in picking up with their own equipment. There are other transmission, for example from the Oscar amateur radio satellites and from weather satellites.

Although the orbits, frequencies, powers, modulation and coding systems and so on widely over the whole range of transmissions from spacecraft, the fundamental principles are the same. They are based on the laws of physics, of course. If you have a good grasp of these principles you can apply them to any particular kind of satellite in which you are interested.

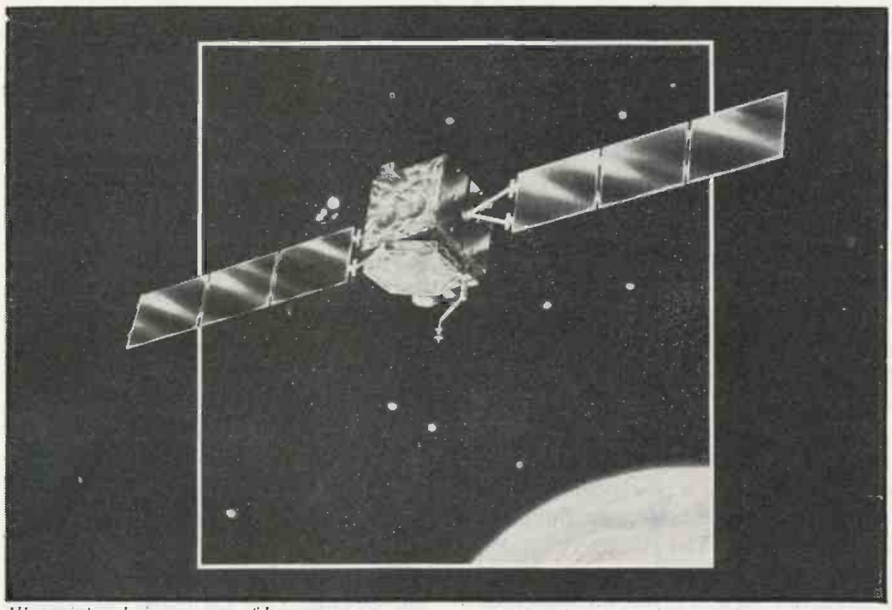


*Illustration by courtesy of Inmarsat*

### SATELLITE TYPES

There are two major groups of spacecraft orbiting the Earth. The ones nearest to us are mainly used for observing the Earth through various instruments, for scientific, meteorological, geophysical, military and other such purposes. They are at altitudes in the region of 200 to 300 kilometres and travel right round the Earth in about 1½ hours in what are called low Earth orbits (LEO). This works out to a speed of about 8 km per second.

Because these LEO spacecraft appear and disappear quite rapidly – travelling from one part of the horizon to another in about 30 minutes – they are not suitable for communications or broadcasting work. But of course the optical or other physical information they provide has to be transmitted to Earth by radio signals. So ground receiving stations have to track them as they pass overhead, or special high-altitude relay satellites have to pick up the signals as they pass below.

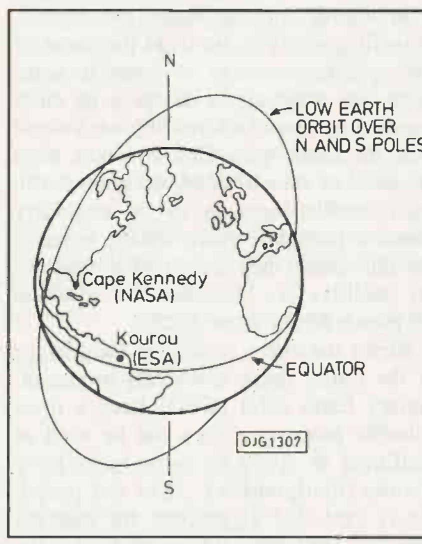



**Fig.1.** *Example of orbit of low-altitude satellite, passing over the poles. Many other orbital planes at various angles to the equator are in use. The two launching sites shown on the globe were chosen to be as near to the equator as possible. Other sites are in southern regions of China, Japan and the Soviet Union.*

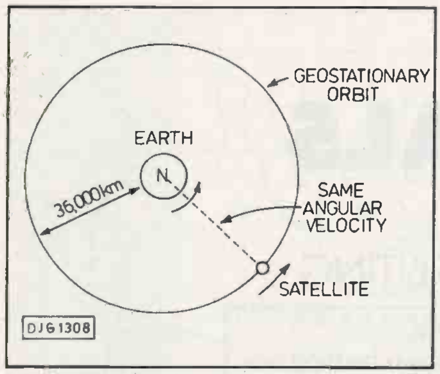



**Fig.2.** *Satellite in geostationary orbit, pictured from a point 'above' the North pole. It travels round at exactly the same speed (angular velocity) as the rotation of the Earth and so appears to be stationary over a fixed point on the equator.*

Fig. 1 shows an example of a low Earth orbit going more or less over the north and south poles – a polar orbit. It has the advantage that as the Earth revolves on its own (spin) axis under this orbital path the observational satellite scans a fresh north-south strip of the Earth's surface every 90 minutes or so – thus covering the entire surface in 16 orbits.

America's space shuttle operates at LEO altitude – for a while becoming an orbiting rather than a power-driven vehicle – when it is launching satellites and doing other jobs. The Discovery orbiter, for example, travelled round at an altitude of 257 km in its successful four-day mission last September. Presumably the Soviet Union's space shuttle will be doing much the same.

The second major group of satellites is at an altitude of about 36,000 km (Fig. 2). Travelling at about 3km/s in the plane of the equator, they take 24 hours to complete one orbit of the Earth – in other words they have the same angular velocity as the Earth spin. Consequently, from the point of view of an observer on Earth, each satellite appears to be stationary above a particular point on the equator. For this reason they are called geostationary satellites (see Mike Sanders' article in PE March 88 for more details).

Being stationary relative to the surface of the Earth, these spacecraft in geostationary Earth orbit (GEO) have a most valuable property. They can be used as platforms in space to carry radio relay stations (transponders). How this principle is exploited in practice for relaying signals over great distances round the Earth is explained in detail in Mike Sanders' three articles mainly devoted to communications satellites (Mar, Apr, May 88). In addition these geostationary satellites are used for broadcasting to particular areas – the transmitter of the relay station being more powerful than in comstats – and for observing the Earth's cloud cover for meteorological and weather forecasting purposes.

Between these LEO and GEO groups of spacecraft there are various other satellites at intermediate altitudes. For example, at about half way between the LEO and GEO groups there are some navigational satellites (both American and Russian) by which ships, aircraft and land vehicles can find their positions electronically.

One of the latest amateur radio satellites to be launched, Oscar 13 (also known as Amsat IIIC), orbits at an altitude which is varying all the time. The lowest point of the orbit, called the perigee, is 1500 km, while the highest point, or apogee, is at 36,000 km. When traced out in space this path forms an ellipse. All such tracks in which the satellite altitude is continuously varying are called elliptical orbits (see example in Fig. 3).

In contrast, all of the GEO spacecraft and some of the others mentioned above travel at constant altitudes and therefore have circular orbits.

## EARTH ORBITS

Let us now look at orbits in a bit more detail. In general terms an orbit is the path followed by an object round a centre of mass. The orbiting object can be a natural satellite like the moon or an artificial satellite as discussed in this article.

The centre of mass is at a point somewhere between the Earth and the satellite. It is where the total mass of the system – Earth plus satellite – can be considered to be concentrated at a single point in space. But as the mass of the Earth is so very much greater than that of the satellite it has a swamping effect, so that the centre of mass is in fact very close to the centre of the Earth.

Strictly speaking, both the Earth and satellite are orbiting this common centre of mass. But because this common centre is so close to the Earth's geophysical centre we can ignore the theory and for all practical purposes simple consider the Earth as 'fixed' and the satellite as orbiting its normal centre.

Once an artificial satellite has been put into orbit by a launching vehicle it is no longer being driven directly by a motor or engine. How, then, does it manage to stay up there, almost indefinitely?

The short answer is that it stays up there for the same reason that the moon remains in orbit and doesn't crash into the Earth. The spacecraft is being moved by the combined effect of two main forces acting on its mass. One is the original force imparted to it by the launching rocket or space shuttle – just as a cricket ball has a force imparted to it by the arm of the bowler and continues on towards the batsman. In physics language this is the inertia of the body.

The second force is gravitational pull, or more precisely the force resulting from the gravitational attraction between the mass of the Earth and the mass of the satellite. As Isaac Newton discovered, this is proportional to the product of the two masses and inversely proportional to the square of the distance between them (the inverse square law).

Leaving aside other influences, the launcher on its own would cause the satellite to travel in a straight line right away from the Earth. But the force of gravity prevents this by pulling the satellite towards the Earth. In a sense the orbiting satellite is always falling towards Earth, but it never actually hits the planet because the original launching force and the inertia of the satellite are acting against this. The result of this interaction of forces on the mass of the satellite is the orbital path round the centre of the Earth.

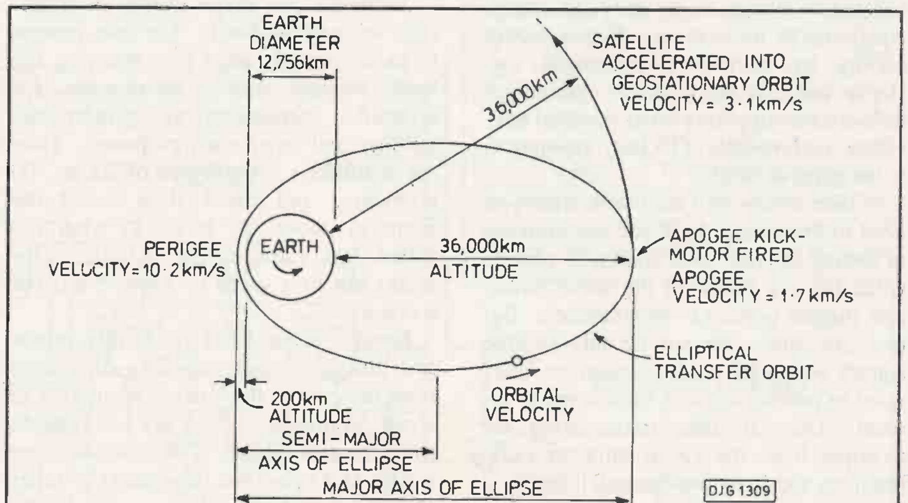



**Fig.3.** *Launching a geostationary satellite by means of an elliptical transfer orbit. The diagram also carries particular examples of characteristics and measurements used to define all satellite orbits.*

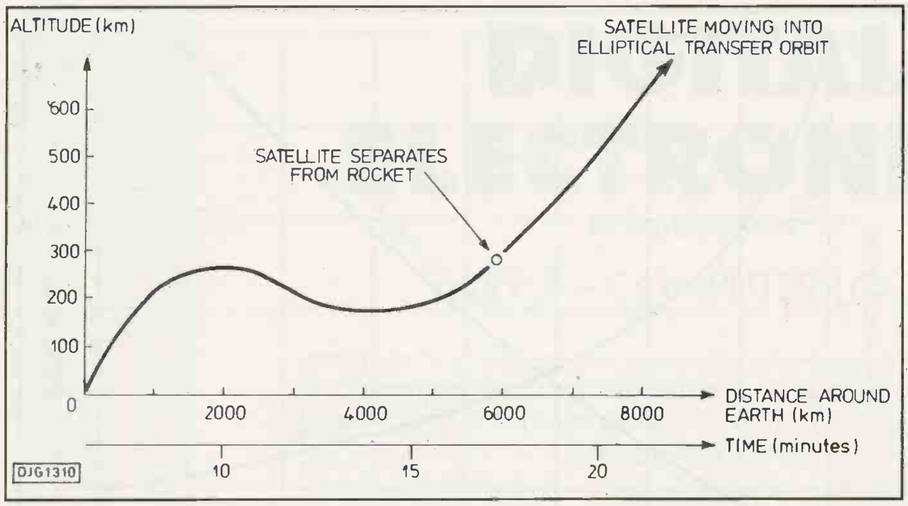



**Fig.4.** *Launching trajectory of an Ariane-3 rocket, lifting-off from the Kourou site shown in Fig. 1. After separating from the rocket, the satellite continues on in the same trajectory into an elliptical transfer orbit.*

## ORBIT CHARACTERISTICS

The orbital path thus traced out by the satellite has a size, a shape and a position in space relative to the Earth. First, as we have seen, the spacecraft has an altitude – constant in circular orbits, varying in elliptical orbits. There is a lowest point (perigee) and a highest point (apogee).

If you imagine the orbital path as being drawn on a huge flat surface, this surface forms what is called the orbital plane. And the orbital plane lies at a particular angle relative to the Earth – see Fig. 1 for example. This angle is in fact measured between the orbital plane and the plane of the Earth's equator, and is called the inclination. Oscar 13, for example, travels in an orbital plane with an inclination of 57°.

An elliptical orbit, as the name implies, has the properties of a mathematical ellipse (one of the conic sections). Its size and shape are defined by measuring its semi-major axis and calculating its eccentricity (distance between ellipse foci divided by length of major axis).

But apart from size and shape the orbit also has a position in space relative to the Earth's lines of latitude and longitude. In Fig. 1, for example, the plane of the polar orbit cuts across the equator just south of Mexico at a longitude of about 95° East. The position of the orbit is actually measured as an angle relative to zero degrees longitude (the Greenwich meridian). Furthermore, to define an orbit properly we have to know where its apogee and perigee lie relative to the Earth. This is measured as the angle between the perigee and a point, called the ascending node, where the satellite crosses the Earth's equator from south to north.

Only one thing remains to give a full specification of a satellite's orbit. This is the time taken to complete one orbit, called the orbital period. As we've seen, this is in the region of 1½ hours for LEO satellites and 24 hours for GEO satellites (to be precise, 23 hours, 56 minutes, 4.1 seconds). Oscar 13 has an orbital period of about 11 hours. To get the exact position of the spacecraft at any given moment we also need to know the time at which it passes through the perigee.

## LAUNCHING SATELLITES

As the next article will be mainly about picking up signals from geostationary satellites, let us illustrate the principles outlined above with an example of one of these – the launching and injection into orbit of the Eutelsat I-F5 communications satellite. Like earlier ones in the same series, this spacecraft was specified, purchased from the manufacturers and then launched, under the name ECS-5, by the European Space Agency. After putting the comsat into orbit ESA handed it over to the European Telecommunications Satellite Organization (Eutelsat), which now manages and operates it.

Eutelsat I-F5 was put into a geostationary orbit by using what is called a geostationary transfer orbit (GTO). This is elliptical in shape, as shown in Fig. 3. The procedure is the most economical one possible in the use of rocket and spacecraft fuel and therefore minimises the cost of launching and the cost of the satellite system overall. So it is widely used for launching, having now proved itself for 25 years or more.

An Ariane-3 rocket launched the satellite (together with an Indian comsat, Insat 1C) from the launching site of the Arianespace company at Kourou, French Guiana. This is on the Atlantic coast of South America, just north of the mouth of the Amazon river (Fig. 1). Being only about 5° north of the equator, it is in a good position to take advantage of the 'sling-shot' effect given by the rotation of the Earth, which has maximum velocity at the equator. The satellites in their rockets are launched in an easterly direction over the Atlantic and they get an extra velocity boost of about 4.5 metres per second from this natural sling-shot effect, again saving some rocket fuel.

Fig. 4 shows the rocket/satellite launching trajectory. The Ariane-3 rocket initially goes up vertically from the lift-off pad but is soon tilted by its controls in an easterly direction. By the time it has travelled about 2000 km down range it is more or less horizontal and parallel with the Earth's surface.

At this stage the rocket trajectory is virtually part of a low Earth orbit, at an altitude of about 200 km. This trajectory continues for approximately 15 minutes after lift-off, until the rocket is approaching the west coast of Africa, some 5000 km down range.

If the rocket were indeed in a low Earth orbit it would of course continue to travel around indefinitely at a constant altitude of about 200 km. But in fact, with all three of its propulsion stages now fired, the rocket has already increased its speed beyond the 8 km/s necessary to keep it in the circular low Earth orbit. The effect of this acceleration is to throw the rocket outwards, away from the Earth, so that it moves from part of a circular orbit into an elliptical orbit, as shown in Fig. 3.

At about 18 minutes after lift-off and some 6000 km along this new track the satellite separated from the rocket and continued to travel onward in the same elliptical path. Initially it had a velocity in the region of 10 km/s but gradually slowed down over several hours as it approached the apogee – rather as a cricket ball thrown upwards slows down as it nears the top of its trajectory.

At the apogee in Fig. 3 the orbital velocity was only about 1.7 km/s. In this region 36,000 km away from the Earth the spacecraft doesn't need as much orbital velocity to satisfy the equation of motion for an elliptical orbit. This is because, at such a great distance, the gravitational attractive force between Earth and satellite is so much less, in accordance with the inverse square law in Newton's equation.

As the spacecraft returned towards Earth it speeded up again under the increasing gravitational attractive force. Returning to the perigee some 10½ hours after lift-off, it reached an orbital velocity of about 10.2 km/s. Here again this high velocity is needed to counteract the very large gravitational attractive force at the low altitude of 200 km.

The satellite is allowed to remain in this elliptical transfer orbit as long as required by the pre-arranged launching procedure. In the case of Eutelsat I-F5 this period was just over 36 hours, or more than three complete elliptical orbits. Because Kourou is slightly north of the equator (Fig. 1) the plane of the transfer orbit was not exactly in the equatorial plane as implied in Fig. 3 but at a small inclination of 7°. Subsequently this had to be corrected to bring it to 0°.

To propel a satellite from the elliptical transfer orbit into its final circular geostationary orbit, a small reaction-propulsion motor, called an apogee kick motor, is fired by telecommand from the ground. This is done at one of the times when the satellite is at the 36,000-km apogee. With Eutelsat I-F5 the kick motor was fired after three complete elliptical orbits, as the spacecraft reached the apogee for the fourth time.

The resulting acceleration to a higher speed again throws the spacecraft outwards, and it now gradually moves into a circular geostationary orbit (inclination = 0°) at an orbital velocity of 3.1 km/s. In this way the manoeuvre was completed with the least possible expenditure of energy and hence propellant fuel in both the Ariane-3 launching rocket and the satellite's apogee kick motor.

Eutelsat I-F5 was actually launched at 23.13 hours GMT on 21 July 1988. Its apogee kick motor was fired at 12.23 hours GMT on 23 July, using up 3.5 kg of the total 122 kg of hydrazine propellant fuel carried in the spacecraft. This satellite reached its initial position of 16°E in the geostationary orbit in mid August, later being moved to 10°E.

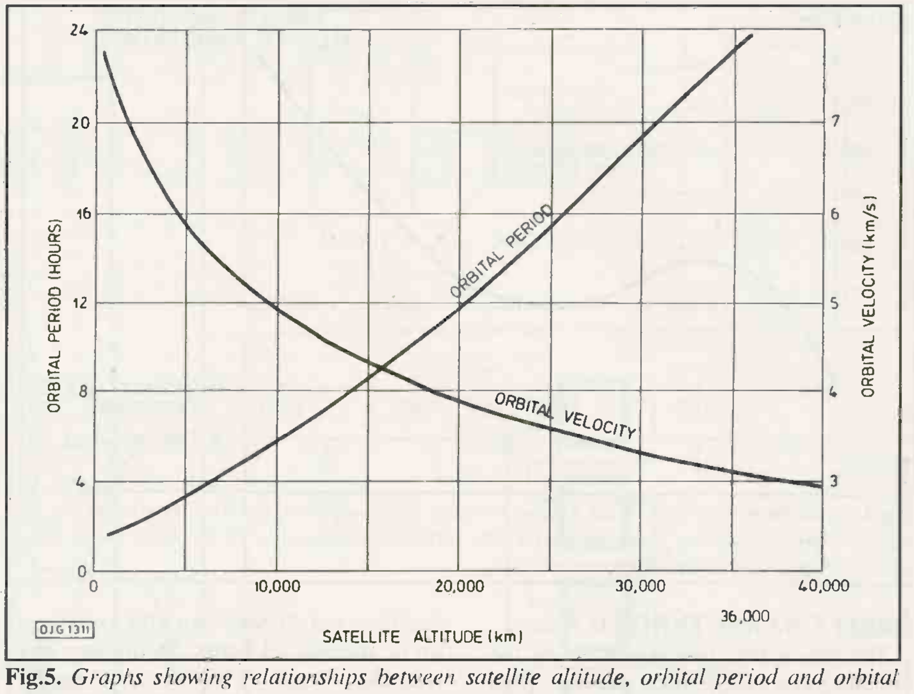


**Fig.5.** *Graphs showing relationships between satellite altitude, orbital period and orbital velocity. They are plotted from equations of motion derived from Newton's law of mechanics.*

## CELESTIAL MECHANICS

The altitude of a satellite, its orbital velocity and orbital period are all related to each other by the mathematical laws of mechanics. These are derived from Newton's famous three laws of motion and his laws of universal gravitation mentioned above. Although the equations relating altitude, velocity and period are really quite simple algebraic expressions they are very general and apply to the whole of the universe. But by putting specific values from the Earth-satellites system into these equations we can plot the relationships as useful graphs. Fig. 5 shows the result.

These graphs bring out two things. First, the higher the altitude of an orbiting body the longer is the orbital period. If, for example, we extended the 'altitude' scale to the mean distance of the moon from the Earth, some 384,000 km, the 'period' graph would indicate an increase to just over 27 days – the moon's natural period of rotation around the Earth.

Secondly the graphs show that the higher the altitude the lower is the orbital velocity. This is because the gravitational pull on the satellite decreases the farther it is away from the Earth. Consequently, in the natural 'balancing act' of the orbit mechanics, the satellite does not need as much forward-directed force to counteract gravity. And this counteracting force (see above) depends on the orbital velocity, being proportional to the square of this velocity.

When the orbit is circular all these conditions remain constant. But with an elliptical orbit the altitude is changing all the time. Consequently as the satellite travels nearer to the Earth it needs more and more orbital velocity to counteract the increasing gravitational pull. Thus with an elliptical orbit the orbital velocity is highest at the perigee and lowest at the apogee.

In the theory of the subject a circular orbit is considered as a special case of an elliptical orbit in which the eccentricity of the ellipse happens to be zero. For example, the orbit of the moon round the Earth may seem circular but in fact is slightly elliptical. The departure from a circle is so small that the eccentricity of this ellipse (defined above) is only 0.0549.

To sum up, the orbit of any satellite can be defined by six values, which are called orbital elements. The first is the length of the semi-major axis of the ellipse. The second is the eccentricity of the ellipse. Inclination of the orbital plane is the third element, while the position of the whole orbital plane relative to the Greenwich meridian (zero degrees longitude) is the fourth.

Orbital element number five is an angle showing where the perigee lies within the orbital plane. It's actually an angle between the perigee and the point on the orbital plane where the satellite crosses the equator from south to north. Finally, the sixth orbital element is the instant of time at which the satellite passes through the perigee of its orbit. The interval of time between two such instants is the orbital period.

In the next article we'll look at the fundamentals of receiving signals from satellites – with some practical information on what you need to set up your own receiving station. **PE**

### Profit and Loss

InterTAN Incorporated, better known to many as Tandy, have announced that consolidated sales for the first quarter of its 1989 fiscal year were $132,847,000, an increase of 22% over the year earlier sales of $109,305,000. Net income increased 35% from $2,477,000 for the three months ended September 30, 1987 to $3,339,000 for the three months ended September 30, 1988.

In contrast, National Semiconductor Corporation has announced that it expects to report a significant operating loss for the second quarter of fiscal year 1989. The company has been affected by weakened performance in its semiconductor operations, and also cite a sharp decline in bookings and sales in its distribution channel, along with the overall softness in the semiconductor market, as the principal factors affecting its performance.

In view of the optimism apparent at the Munich Exhibition in November, National's loss announcement comes as a surprise.

However, the company also said that it expected second quarter operating performance for its Information Systems Group to show significant improvement over that of the first quarter.

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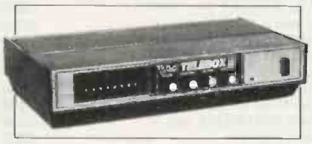

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# DIGITAL ELECTRONICS

BY OWEN BISHOP

## PART 7 – COMPUTER LOGIC

*Computers can't move and can't think, but they can shift and register. If they see the light (UV, that is), they can even change their minds.*

This month we are going to look at some circuits that perform the kind of logic used in computers. We shall not get as far as studying a complete computer circuit – that comes in another part – but the simple circuits that we study this month will help you understand the workings of the rather more complicated ones in a computer.

One logic circuit that forms the basis of a number of other useful computing circuits is the D-type flip-flop (Fig. 1). We tried this out in Part 4 (PE Dec. 88) but, for readers who are new to the series (and for those who can't *quite* remember what it was all about!), we recap its main features:

*data (low or high logic levels) is fed to the D input

*nothing happens until the clock input is changed from low to high

*at that instant the data on the D input appears at the Q output

*the $\overline{Q}$ output is the inverse of the Q output.

Data is transferred as the clock input *changes;* we say the flip-flop is *edge-triggered.* The change occurs only when the clock changes from low to high – it is triggered on a *positive-going edge.* In addition to the above, most D-type flip-flops have a *set* (or preset) input and a *reset* (or clear) input. These inputs are normally held high. When *one* of these inputs is made low, the Q output goes high (set) or low (reset) immediately, *whatever the state of the clock.*

In Part 4 we showed how a chain of D-type flip-flops is connected together to make a counter or frequency-divider circuit. Now we will look at some further applications of this flip-flop.

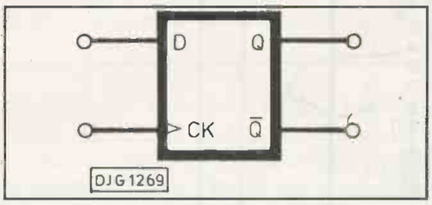



**Fig.1.** *D-typ' flip-flop*

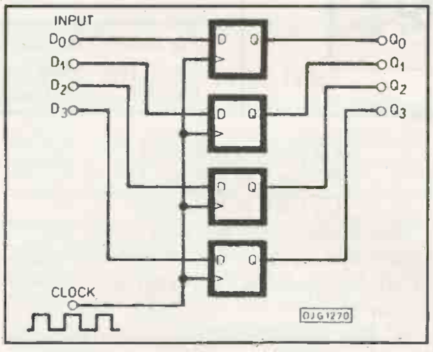



**Fig.2.** *A storage register*

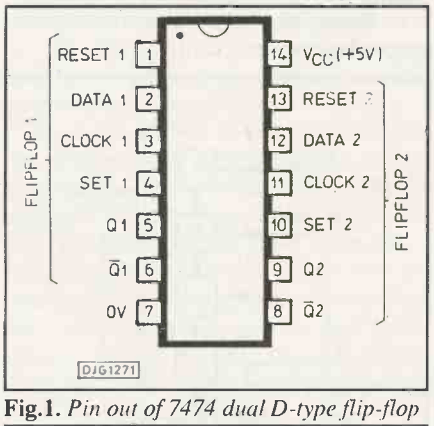



**Fig.1.** *Pin out of 7474 dual D-type flip-flop*

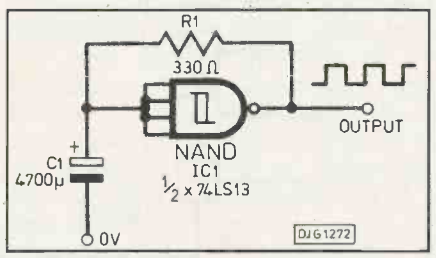



**Fig.4.** *Clock made from Schmitt trigger nand gate.*

## STORAGE REGISTER

Fig. 2 shows a storage register made from four D-type flip-flops. It is used to store four bits of data. The four bits $D_0$ to $D_3$ are fed to the D inputs of the flip-flops. The clock inputs are all connected to a single clock input. When the clock input rises from low to high, the data at $D_0$ to $D_3$ appears to $Q_0$ to $Q_3$. In a computer, the register could be used to hold data temporarily. Data could be a binary number or a coded instruction. Something of this kind is found inside a microprocessor, though it is usually an 8-bit or 16-bit register. The storage register is a kind of memory device though, as we shall see later, computer memories have additional features that this register does not have. Let us see the register in action.

### Investigation 1

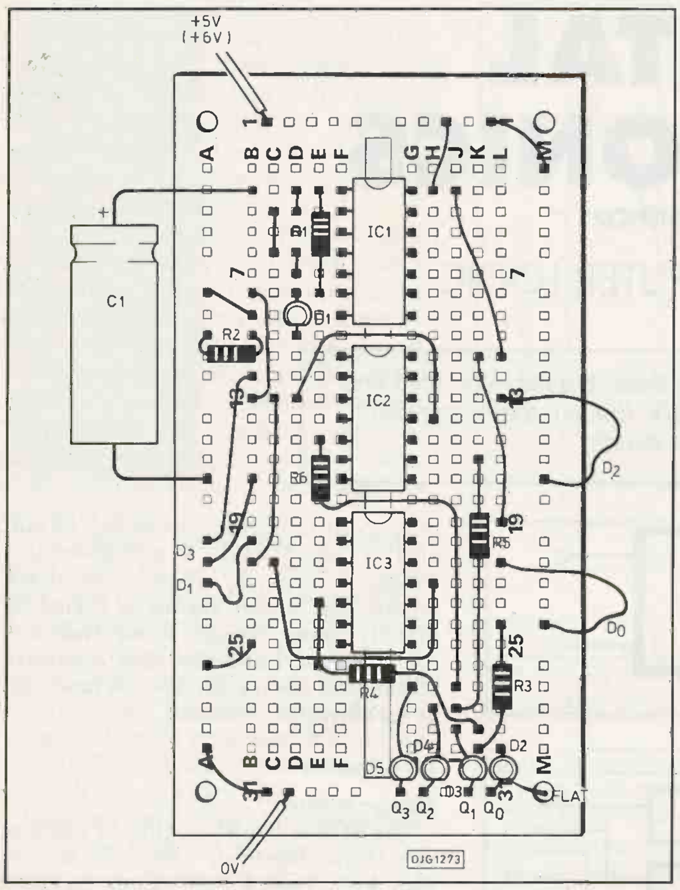
***Storage register***

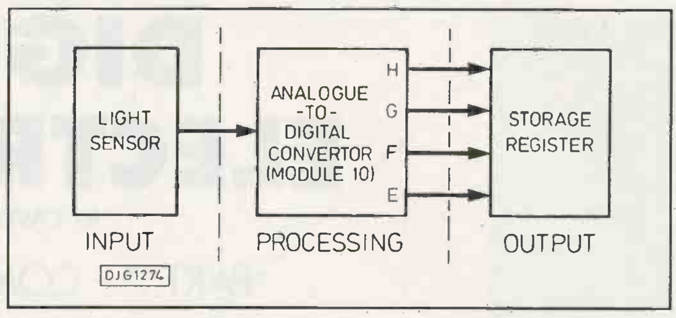
The 7474 or 74LS74 ic (Fig. 3) contains two D-type flip-flops. We need two of these ics to build a 4-bit register. To make the clock to drive the register we use a Schmitt trigger gate, as in Fig. 4. Timing is decided by the value of C1. We have chosen a fairly high value for this so that the clock runs slowly and gives you time to see what is happening. As an alternative you could use a 555 timer, or Module 5 (PE Nov. 88), in astable mode running at about 0.25Hz (one oscillation every four seconds). The reason we prefer to use this type of clock in this circuit, rather than the 555, is that the 555 tends to produce spikes on the supply lines. These can affect the operation of flip-flops and registers, causing them to change state unpredictably.

Fig. 5 shows how to lay out the storage resister on the breadboard. If you have only one 7474 ic a 2-bit register is sufficient for this demonstration. IC1 is the clock (74LS13) connected as in Fig. 4. The led D1 shows the state of the clock output. The leds D2 to D5 show the states of the flip-flop outputs $Q_0$ to $Q_3$. There are four flying leads, $D_0$ to $D_3$. The figure shows $D_0$ and $D_2$ connected to the 5V rail (on the right), while $D_1$ and $D_2$ are connected to the 0V rail (on the left).

While the clock is running, try plugging the leads into the 0V rail (low input = 0), or 5V rail (high input = 1). Watch how *and when* the outputs change. (Answer at the end.)

If you have made last month's analogue-to-digital converter module (Module 10), you could use its four most significant output lines to provide the input for the storage register. The input of the a/d circuit could come from a light-sensitive interface.



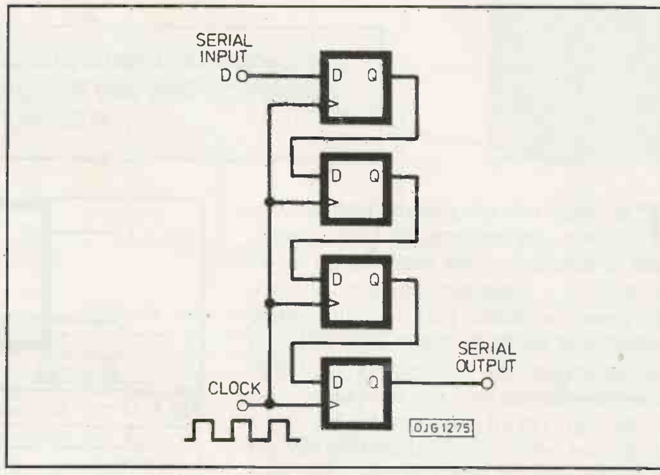




**Fig.5.** *(left) Breadboard storage register.*
**Fig.6.** *(top right) Light-level register system.*
**Fig.7.** *(above) A shift register.*

The complete system is shown in Fig. 6. As light levels change, the output of the d/a is transferred to the storage register once every four seconds (approx.). This gives you time to read the binary value before it changes again. In this system, the storage register is acting as a *sample and hold* register. It registers (or samples) the data as the clock goes high and then holds it for a while, until you have had a chance to read it.

Keep the storage register circuit on the breadboard when you have finished, for we shall use most of it again.

## SHIFT REGISTER

Fig. 7 shows a 4-bit shift register made from four D-type flip-flops. The flip-flops are joined in a chain, the Q output of one flip-flop is connected to the D input of the next. The clock inputs are joined together, so that all flip-flops are clocked at the same instant. The best way to work out what this circuit does is to build it and try it.

### Investigation 2

***Shift register***

The layout of the storage register (Fig. 5) is quickly adapted to turn it into a shift register.

1. Remove the three flying leads that go to pins 2 and 12 of IC2 and pin 2 of IC3. This leaves the single lead $D_0$, the input to the first flip-flop of the chain. This is known as the *serial input*.
2. Connect the outputs to the inputs of the next flip-flop by joining:

IC2 pin 9 to IC2 pin 2
IC2 pin 5 to IC1 pin 12
IC1 pin 9 to IC1 pin 2

The connections are now as in Fig. 7, except that we have leds to show the states of all the flip-flops. D5 ($Q_3$) is the *serial output*.

3. Run the circuit, plugging the flying lead into the 0V rail or the +5V rail. Change it from one to the other frequently.
4. Watch the leds. Describe what is happening (answer at end).

## USING SHIFT REGISTERS

The shift register of Fig. 7 is the simplest kind. Data goes in at one end, the serial input. It is shifted along the chain of flip-flops and appears at the serial output four clock pulses later. It has applications as a *delay* circuit. This type of shift register is known as a *serial-in-serial-out* register, often shortened to siso.

The register we built on the breadboard has outputs from all four flip-flops. We feed the data in a bit at a time, but can read

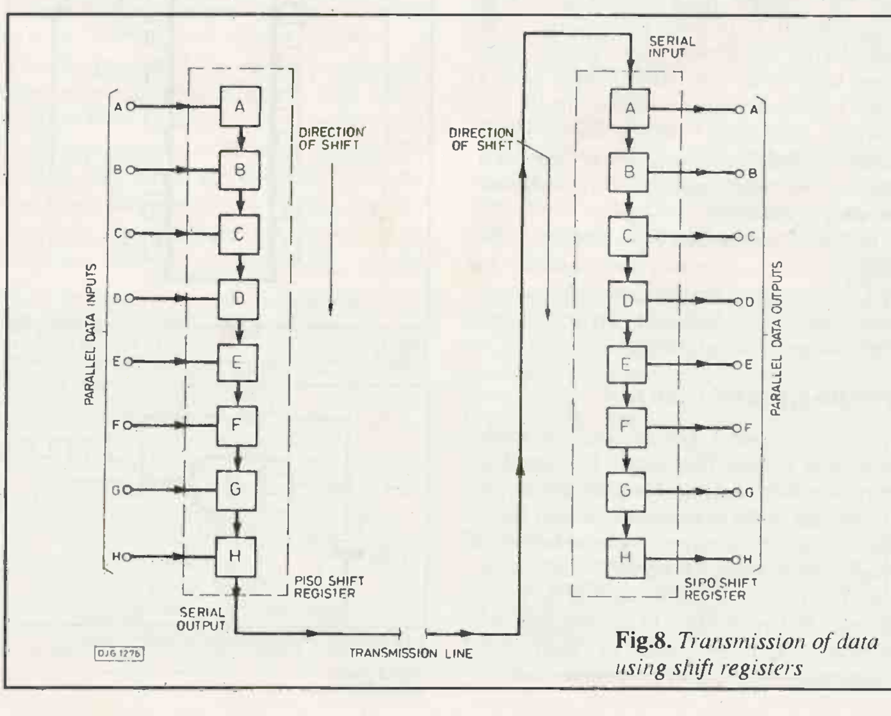



**Fig.8.** *Transmission of data using shift registers*

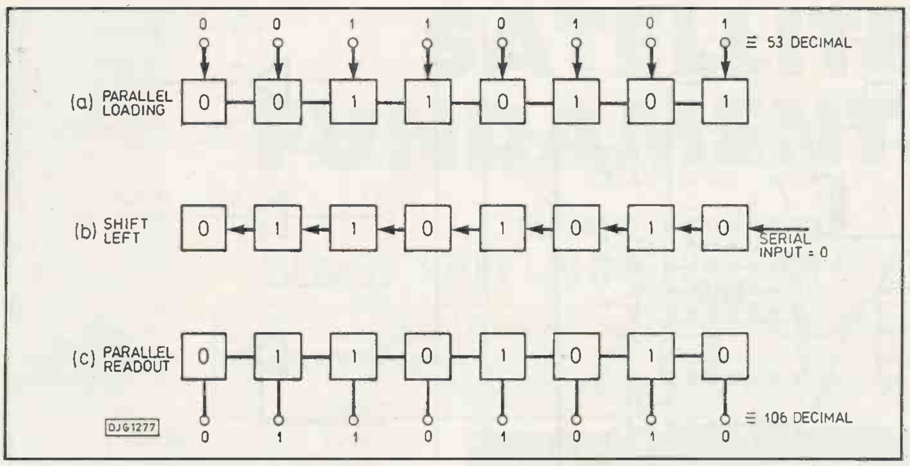



**Fig.9.** *Using a shift register to multiply*

the state of all four flip-flops at once. In other words, we have parallel output. This is a *serial-in-parellel-out* (sipo) shift register. Several sipo register ics are available. Other shift registers have parallel inputs too. Four (or more) bits can be loaded at once, shifted along a few steps and then unloaded in a parallel (pipo) or serially (piso).

The piso registers are useful for data transmission. Suppose you want to send data from a sensing device to a central computer. Suppose too that your data consists of 8-bit bytes. You try to send all eight bits at once, in parallel. This would be the fastest method, but you need eight lines (plus a 0V line) running from the sensor to the computer. If the distance is great, the cost of the cable is unduly high. Instead, the eight bits are fed in parallel to a shift register (Fig. 8). Then the bits are shifted out one at a time through the serial output. Only two connecting wires (the data wire and the 0V wire) are needed.

At the computer, the process works in reverse. The data arrives a bit at a time, enters the serial input and is shifted along the chain of registers. When all eight bits have arrived, they are unloaded in parallel into the computer circuit (eg into memory). Shift registers are used a lot in devices such as modems which are used for transmitting data from one computer to another by way of the public telephone system, or by radio. They may also be used for feeding data from a computer to a disk drive or a printer with serial input.

Fig. 9 illustrates an entirely different use for a shift register. A binary number (00110101) is loaded in parallel into a shift register. A clock pulse is applied to shift the data one place to the left. It is then unloaded, in parallel. The shifted data is (01101010), for a zero has been shifted in as the least significant digit.

Before shifting, the value was 00110101, equivalent to 53 decimal. After shifting, the value is 01101010, equivalent to 106 decimal.

Shifting the binary number one place to the left has the effect of multiplying it by two. Another shift, giving 11010100, multiplies it by two again. This is one way multiplication is performed in a microprocessor. 'Shift left' is one of the instructions available in microprocessors. It can be repeated as many times as necessary for multiplying by 2, 4, 8, 16 or higher powers of 2.

You may wonder how we can multiply by other numbers, such as 13. Easy! Store the original number (Fig. 10), multiply the original number by four (shift it twice) and store the result. Multiply the original number by eight (one more shift) and store the result. Sum the original number and the two stored numbers – the result is the original number multiplied by 13, since 1+4+8=13. This sounds a slow way of going about multiplication – but microprocessors more than compensate for this by working *extremely* fast. This digression into computer mathematics is intended to illustrate the fact that the humble shift register can do all kinds of wonderful things when used in the right way.

The reverse instruction, 'shift right' is used for the reverse mathematical operation – division. A single shift right divides a number by two. We return to the subject of computer calculations later on.

## LATCHES

The terms 'register' and 'latch' are often used as if they mean the same thing. But there is a difference. A register registers the data that is being fed to it at the instant when the clock changes from low to high. At other times it ignores the data. The output remains fixed, showing what the data was at the last low-high change of the clock. To see what a latch does, we will examine one in operation.

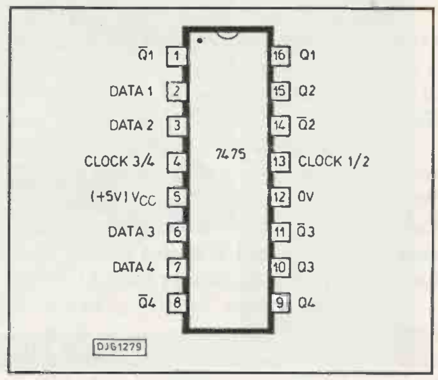



**Fig.11.** *Pinout of 7475 quadruple latch.*

### Investigation 3

***A data latch***

The 7475 ic contains four latches. Each has its own data input, Q output and $\overline{Q}$ output (Fig. 11). Latches 1 and 2 share a clock input and so do latches 3 and 4. In Fig. 12 the 7475 is breadboarded with the same clock as we used before. Its data inputs are connected to the 0V rail. The Q outputs of its latches are indicated by the four leds. Run the circuit, experiment with the data inputs, and find out how the latch differs from a register.

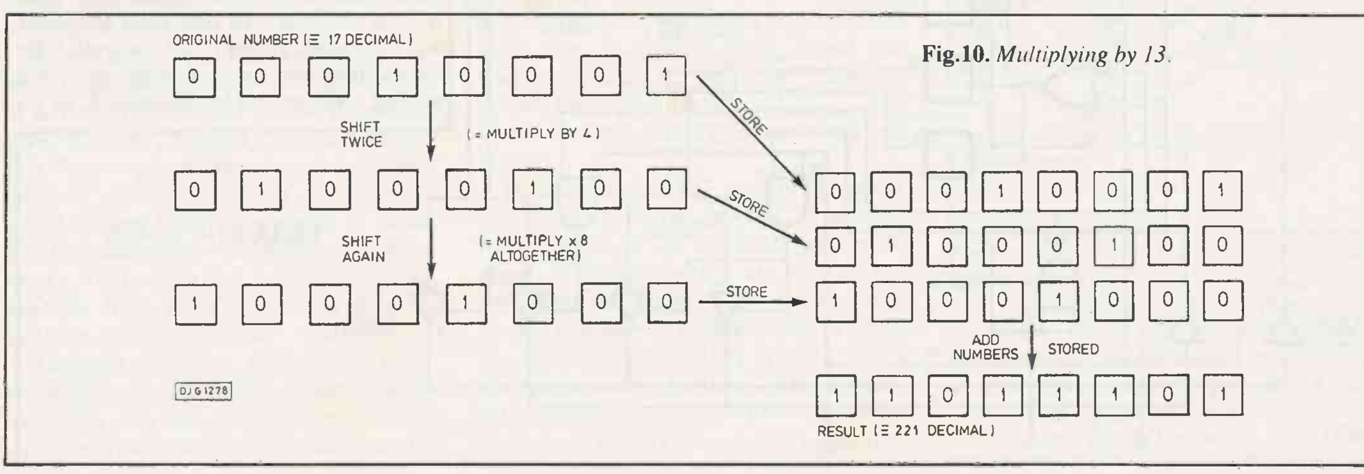



**Fig.10.** *Multiplying by 13.*

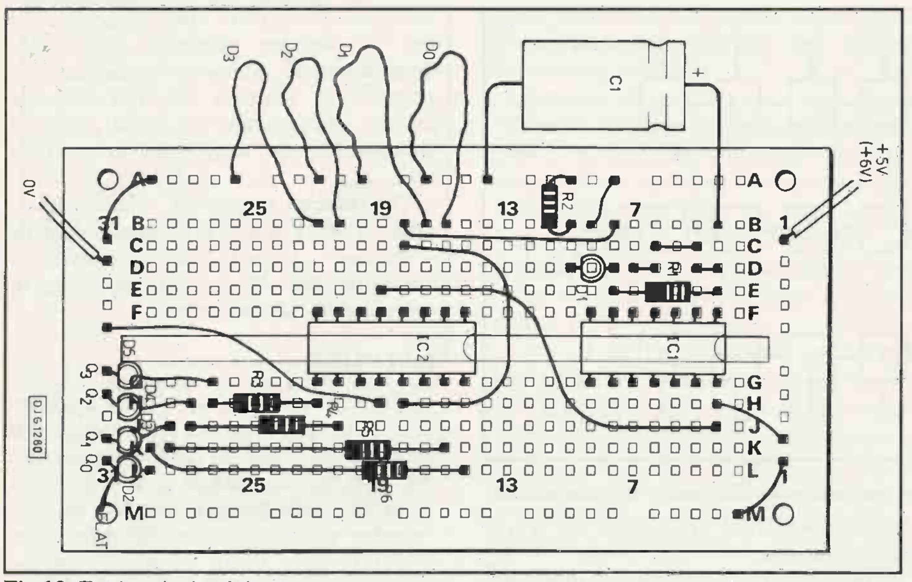



**Fig.12.** *Testing the latch ic.*

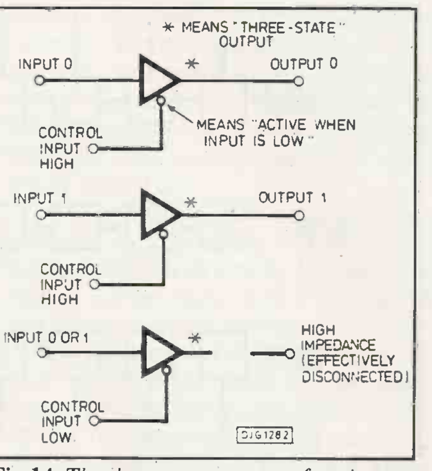



**Fig.14.** *The three output states of a tri-state buffer*

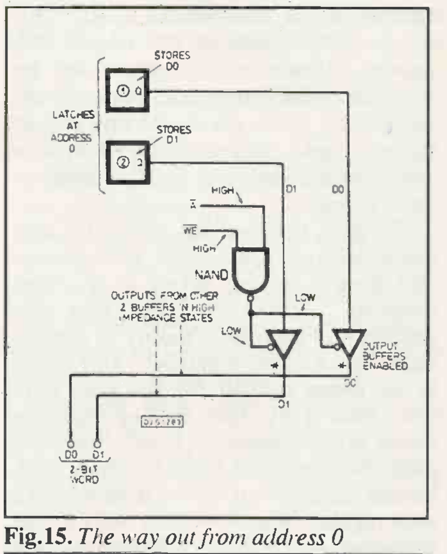



**Fig.15.** *The way out from address 0*

## DIY MEMORY

A latch lacks some of the features that we expect a memory to have. But, by 'dressing it up a bit', we can add a few logic circuits to the 7475 latch and turn it into a memory (Fig. 13).

The centre of the circuit is the set of four latches. These are where the data is stored. We have arranged this circuit so that the four latches are in two pairs of two latches each. Latches 1 and 2 store a pair of bits. Latches 3 and 4 store another pair of bits.

In the diagram, the 74LS75 is lost in a forest of connections. But, if we keep a clear head, we can find our way through from the latches to the data bus. The data from the Q outputs of the latches goes to four *output buffers* (IC4). These are non-inverting or *true* gates; a 0 input gives a 0 output and a 1 input give a 1 output. The point about these buffers is that they have *3-state outputs*. In the high-impedance state the output of the gate is, in effect, disconnected from the circuit (Fig. 14).

When we store (write) data in the latches or read data from them, we use the latches in pairs. Either we use latches 1 and 2 *or* we use 3 and 4. We can say that the two pairs of latches have two *addresses* in the memory. Latches 1 and 2 have address 0; latches 3 and 4 have address 1. Fig. 15 shows the connections when we are reading data from address 0.

The buffers connected to latches 1 and 2 are both controlled by the output from a NAND gate. The truth table of this gate is:

| NAND input | | NAND output | Effect |
|---|---|---|---|
| $\overline{WE}$ | $\overline{A}$ | (= buffer control) | |
| 0 | 0 | 1 | 3-state |
| 0 | 1 | 1 | 3-state |
| 1 | 0 | 1 | 3-state |
| 1 | 1 | 0 | read data |

Data passes through the buffers only when $\overline{WE}$ is high and $\overline{A}$ is high, as in Fig. 15. So what are $\overline{WE}$ and $\overline{A}$, and why do they have these 'bars' over their names?

$\overline{WE}$ is the *write enable* line. It controls whether data is to be written into (stored in) the memory. $\overline{WE}$ is high or low – not both at the same time. So we can not write and read at the same time. This is important, because the data terminals $D_0$ and $D_1$ are used both as inputs and as outputs (but not both at the same time). The bar over $\overline{WE}$ has the same meaning as the little circle on the buffer control – 'has its effect when low'. Low means 'write'. To *read* data, $\overline{WE}$ must be high, as in the truth table above.

The control line that is used to select which address is to be written to or read from is called A. To read from address 0, we must make A low. But the truth table shows that we need a high input for reading. We get this by inverting A, to get

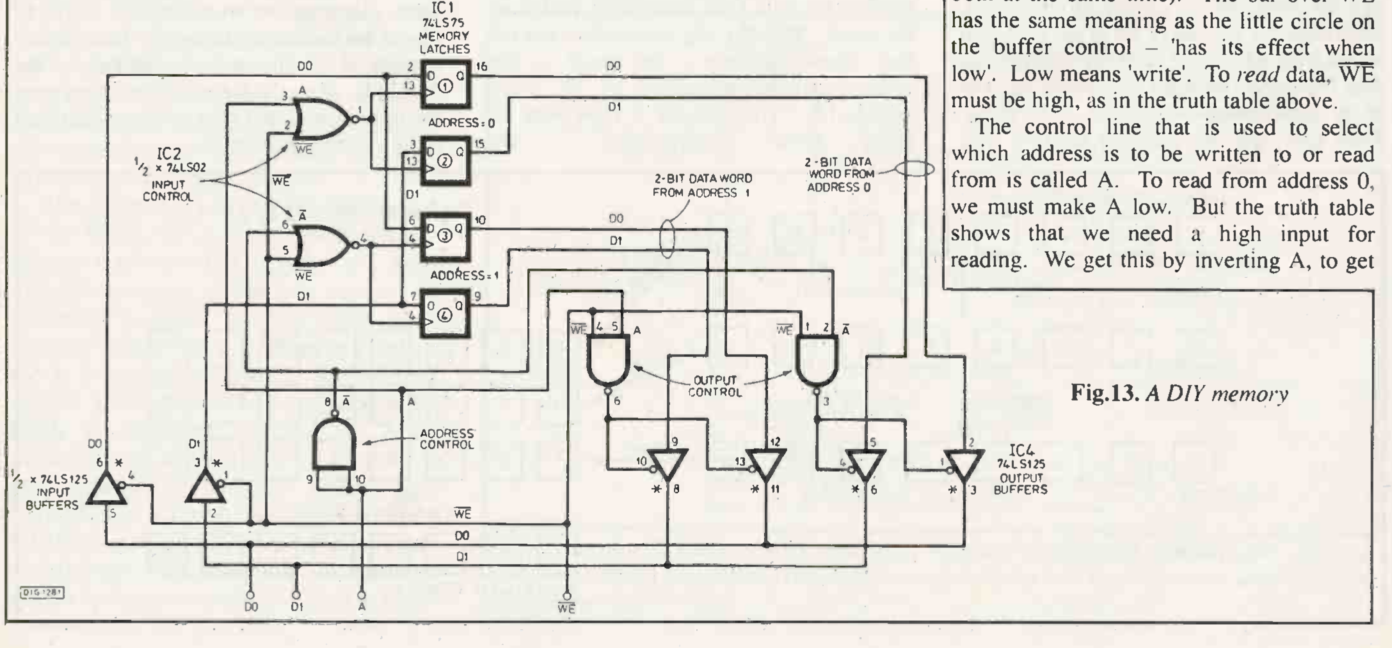



**Fig.13.** *A DIY memory*

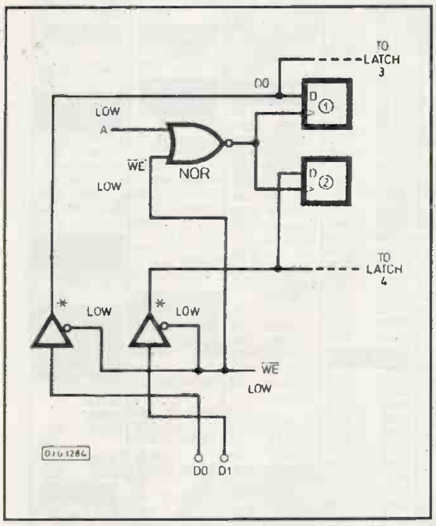



**Fig.16.** *The way in to address 0.*

***Answers to questions***

***Investigation 1:***

The output changes to become the same as the D input. The output changes at the instant the clock input rises from low to high.

***Investigation 2:***

As the clock goes high, the data on each register is shifted along the chain to the next register. One new bit of data enters the first register. The data in the last register is lost.

$\overline{A}$. When A is low, $\overline{A}$ is high (see truth table) and the buffers send the data to the data lines $D_0$ and $D_1$.

Reading from address 1 (latches 3/4) is similar, except that A is high. We use A, not $\overline{A}$, as the input to the NAND gate. In this way, when $\overline{WE}$ is high, the data from address 0 *or* from address 1 appears at the data outputs.

Summing up – to read data we have to:
*make $\overline{WE}$ high
*set A to the address we want to read (0 or 1).

**RETURN JOURNEY**

Now we find our way back in. How do we store or *write* data into the latches? Obviously we must make $\overline{WE}$ low. This puts all four output buffers in IC4 into high-impedance state. The data already stored there cannot get to $D_0$ and $D_1$. The low on $\overline{WE}$ enables the two input buffers, in IC3 (left of Fig. 13). Data passing in through these buffers goes to latches 1 and 3 ($D_0$) and to latches 2 and 4 ($D_1$).

Fig. 16 shows the parts of the circuit involved in writing to address 0. Data is stored in a latch only when the clock input goes from low to high. The clock inputs are controlled by two NOR gates of IC2. The truth table of the NOR gate of Fig. 16 is:

| Inputs $\overline{WE}$ | A | Output | Effect |
|---|---|---|---|
| 0 | 0 | 1 | follow |
| 0 | 1 | 0 | latched |
| 1 | 0 | 0 | latched (reading) |
| 1 | 1 | 0 | latched (reading) |

When we are writing to address 0, A is low and $\overline{WE}$ is low. Since both inputs are low (00), the clock input of both latches is high. The data in the latches follows the input data. This allows the data to change, if necessary. But when we make $\overline{WE}$ high again (read), the clock input becomes low. Data present on the inputs at that time becomes latched.

The other NOR gate, controlling input to address 1, has $\overline{A}$ as its input. When we are writing to address 0, A is low, $\overline{A}$ is high. Thus inputs to that gate are 01 or 11 and the clock input of latches 3 and 4 remains high. It never goes low to enable the data to change. Writing to address 0 has no effect on the data stored at address 1. Writing to address 1 had no effect on data stored at address 0.

Summing up, to write data we have to:
*set A to the address we want to write to
*make $\overline{WE}$ low
*set the new data input
*make $\overline{WE}$ high

**Next month we continue this discussion on computer logic and begin by looking at Investigation 4.** PE

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**POLYESTER CAPACITORS 5mm PCM 63v 10%**
4.7nF 0.06
6.8nF 0.06
10nF 0.06
15nF 0.07
22nF 0.07
33nF 0.07
47nF 0.07
68nF 0.08
100nF 0.08
150nF 0.12
220nF 0.10
330nF 0.17
470nF 0.22
680nF 0.22
1µF 0.32
1.5µF 0.40

**100V 10%**
100nF 0.08
150nF 0.09
220nF 0.10
330nF 0.13
470nF 0.17

**7.5mm PCM 400V 10%**
1nF 0.06
1.5nF 0.06
2.2nF 0.06
3.3nF 0.06
4.7nF 0.06
6.8nF 0.06
10nF 0.06

**250V 10%**
15nF 0.06
22nF 0.06
33nF 0.06
47nF 0.07

**100V 10%**
68nF 0.07
100nF 0.07
150nF 0.08
220nF 0.09
330nF 0.11

**CERAMIC PLATE**
Short leads
**100V 2%**
1.8pF to 330pF 0.06
470pF to 1000pF 0.08

**CERAMIC MULTILAYER COG 100v 5%**
10pF 0.05
22pF 0.05
47pF 0.05
68pF 0.05
100pF 0.05
220pF 0.06
470pF 0.06
1nF 0.07

**COG 63v 5%**
2.2nF 0.08
4.7nF 0.12

**X7R 63V 10%**
4700pF 0.05
6800pF 0.05
10nF 0.05
22nF 0.06
47nF 0.06
100nF 0.07
220nF 0.13
470nF 0.23

**Z5U 63V 20%**
100nF 0.05
220nF 0.11
470nF 0.13
1µF 0.21
2.2µF 0.48

**Hi-K CERAMIC**
µF 63v +50-20%
0.01 0.06
0.022 0.06
0.033 0.06
0.047 0.06
0.068 0.07
0.1 0.08

**CERAMIC DISC 300V ac**
1nF 0.10
10nF 0.16

**ELECTROLYTIC RADIAL**
µF V
1 100 0.05
2.2 63 0.05
4.7 63 0.06
10 63 0.07
22 63 0.08
47 16 0.06
47 40 0.08
100 16 0.07
100 25 0.08
100 63 0.12
220 16 0.08
220 25 0.12
220 63 0.16
470 6 0.08
470 16 0.12
470 25 0.16
470 40 0.30
1000 16 0.16
1000 25 0.33

**TANT BEADS**
µF V
0.1 35 0.10
0.22 35 0.10
0.47 35 0.10
1.0 35 0.10
2.2 16 0.10
2.2 35 0.13
3.3 35 0.15
4.7 16 0.13
4.7 35 0.16
6.8 16 0.15
6.8 25 0.16
10 6 0.13
10 16 0.15
10 25 0.20
22 6 0.16
22 16 0.26
22 25 0.42
33 6 0.14
33 10 0.26
33 16 0.38
47 6 0.26
100 3 0.15
100 10 0.84

**ELECTROLYTIC AXIAL**
µF V
1.0 63 0.12
2.2 63 0.13
4.7 63 0.12
4.7 100 0.17
6.8 40 0.11
10 25 0.11
10 40 0.12
10 63 0.17
10 100 0.19
10 350 0.45
22 10 0.09
22 25 0.13
22 40 0.17
22 63 0.19
22 100 0.21
22 350 0.57
47 10 0.13
47 25 0.17
47 40 0.19
47 63 0.21
47 100 0.24
47 350 1.03
100 10 0.17
100 16 0.19
100 25 0.19
100 40 0.22
100 63 0.23
100 100 0.34
100 160 0.93
220 10 0.19
220 16 0.20
220 25 0.22
220 40 0.23
220 63 0.32
220 100 0.54
470 10 0.22
470 16 0.23
470 25 0.31
470 40 0.32
470 63 0.50
470 100 1.06
1000 10 0.29
1000 16 0.31
1000 25 0.38
1000 40 0.50
1000 63 1.00
2200 16 0.49
2200 25 0.67
2200 40 1.01
2200 63 1.25
4700 16 0.94
4700 25 1.18
10000 10 1.31

**REVERSIBLE ELECTROLYTIC 50V peak, 20v**
2µF 0.29
4µF 0.32
6µF 0.35
8µF 0.37
10µF 0.40
16µF 0.44
25µF 0.51
40µF 0.63
50µF 0.69
60µF 0.72
100µF 0.94
150µF 1.30
300µF 2.39

**ELECTROLYTIC CANS**
µF V
100 350 1.65
220 350 2.21
220 385 2.47
470 100 2.01
1000 63 1.98
2200 40 1.70
2200 63 2.05
2200 100 4.01
4700 40 2.11
4700 63 4.05
4700 100 6.78
10000 16 2.02
10000 25 2.61
10000 40 3.69
10000 63 6.57
22000 16 3.36
22000 25 5.48

**COMPUTER GRADE**
µF V
3300 350 35.58
4700 40 3.90
10000 16 3.65
10000 40 6.25
22000 16 6.18
22000 40 10.93
22000 63 15.76
47000 16 8.38
47000 40 16.55
100K 16 15.34

**VARIABLE AIR SPACED Jackson C804**
5pF 3.25
10pF 3.25
15pF 3.25
20pF 3.25
25pF 3.42
30pF 3.95
50pF 3.42
60pF 3.95
75pF 3.95
100pF 3.95
150pF 4.90

**SOLID DIELECTRIC**
100pF 2.36
200pF 3.45
300pF 4.40
500pF 4.85

**STANDARD single**
365pF 5.19

**Twin**
365+ 365pF 7.45

**MINIATURE TWIN-GANG**
350+ 350pF 1.50

**TRIMMER Polyester**
2-10pF 0.24
2-22pF 0.30
5.5-65pF 0.43

**CHOKES miniature RF**
0.1µH 0.11
0.15µH 0.11
0.22µH 0.11
0.33µH 0.11
0.47µH 0.11
0.68µH 0.11
1.0µH 0.12
1.5µH 0.12
2.2µH 0.12
3.3µH 0.12
4.7µH 0.12
6.8µH 0.12
10µH 0.12
15µH 0.12
22µH 0.12
33µH 0.12
47µH 0.12
68µH 0.12
100µH 0.12
150µH 0.13
180µH 0.13
220µH 0.13
330µH 0.13
470µH 0.13
680µH 0.13
1000µH 0.14
1500µH 0.14
2200µH 0.14
3300µH 0.14
4700µH 0.14

**CONNECTORS DIN. AUDIO SOCKETS**
2-way 0.08
3-way 0.18
4-way 0.20
5-way 180° 0.20
5-way 240° 0.20
5-way 360° 0.20
6-way 0.20
7-way 0.22
8-way 0.28

**Plugs**
2-way 0.09
3-way 0.14
4-way 0.18
5-way 180° 0.20
5-way 240° 0.16
5-way 360° 0.20
6-way 0.22
7-way 0.22
8-way 0.26

**JACKS AUDIO 2.5mm**
Socket 0.12
Plug 0.10
Line skt. 0.24

**3.5mm**
Socket 0.19
Plug 0.25
Line skt. 0.28

**6.3mm 0.25"**
Socket 0.19
Plug 0.44
Line skt. 0.24

**D-SERIES Plugs**
9-way 0.38
15-way 0.51
25-way 0.73
37-way 1.05
50-way 1.32

**Sockets**
9-way 0.50
15-way 0.77
25-way 1.06
37-way 1.66
50-way 2.02

**Hoods**
9-way 0.45
15-way 0.45
25-way 0.50
37-way 1.15
50-way 1.28

**DIN 41612 Straight**
Plug 64p 3.05
Skt 64p 1.96
Plug 96p 3.93
Skt 96p 2.73

**Rt.angled**
Plug 84p 1.43
Skt 64p 4.86
Plug 96p 1.93
Skt 96p 3.93

**DIODES**
1N914 0.03
1N914B 0.10
1N916 0.11
1N4007 0.05
1N4148 0.03
1N5408 0.15
AA113 0.17
AA118 0.18
BA127D 0.11
BA138 0.15
BA174 0.11
BAR12-1 2.78
BAR16-1 1.53
BAR74 0.11
BAS40-04 1.36
BAS70-04 1.43
BAV20 0.20
BAV70 0.09
BAV99 0.09
BAW56 0.09
BB105G 0.36
BB112 2.38
BB204B 0.73
BB204G 0.73
BB304 0.84
BB409 0.62
BB505B 0.64
BB609A 0.64
BB801 1.05
BY350 1.62
BY360 0.65
BYS21-45 0.83
BYS21-90 0.92
BYS26-45 1.77
BYS28-90 2.49
OA47 0.25
OA91 0.14
OA202 0.16

**BRIDGES 250V ac**
1A W04 0.20
3A BR34 0.60
6A BR64 0.75
25A FB2506 1.65
35A FB3506 2.50

**THYRISTORS 400V**
0.8A MCR100 0.38
3A B0226 0.33
4A C106D1 0.72
5A TIC106D 0.58
12A TIC126D 0.66

**TRIACS**
4A TIC206D 0.67
8A TIC226D 0.80
16A TIC246 1.20
25A T2513NK 6.20

**DIACS 32V**
A9903 0.36
D0201YR 0.22

**TRANSISTORS**
2N697 0.37
2N706 0.25
2N930 0.40
2N1613 0.34
2N1711 0.34
2N1893 0.45
2N2218A 0.36
2N2219A 0.40
2N2222A 0.30
2N2369A 0.30
2N2484 0.30
2N2646 0.60
2N2905A 0.36
2N3053 0.40
2N3054 0.55
2N3055 (RCA) 0.66
2N3702 0.18
2N3703 0.18
2N3704 0.18
2N3705 0.18
2N3706 0.18
2N3707 0.18
2N3708 0.18
2N3710 0.18
2N3711 0.18
2N3771 1.85
2N3772 1.85
2N3773 1.85
2N3819 0.55
2N3820 0.90
2N3823 1.00
2N3904 0.18
2N3906 0.18
2N4036 0.70
2N4058 0.18
2N4062 0.18
2N4124 0.25
2N4126 0.25
2N4303 0.48
2N4991 0.64
2N5163 0.42
2N5192 1.59
2N5195 1.40
2N5457 0.60
2N5459 0.60
2N6050 3.38
2N6057 3.38
AC126 0.30
AC128 0.33
AC153K 0.18
AC176 0.35
AD133 3.90
AD136 1.30
AD149 1.40
AD161 0.30
AD162 0.80
AF124 0.56
AF126 0.56
AF127 0.56
AF200 0.09
AF279 0.25
BC107A 0.24
BC107B 0.24
BC108B 0.21
BC108C 0.19
BC109B 0.25
BC109C 0.25
BC121 0.20
BC125 0.40
BC126 0.40

BC141 0.40
BC147 0.18
BC149C 0.18
BC159 0.15
BC160 0.35
BC161 0.40
BC167A 0.21
BC167B 0.17
BC168C 0.21
BC169C 0.27
BC177B 0.21
BC179B 0.21
BC182 0.17
BC182L 0.17
BC183 0.17
BC183L 0.17
BC184 0.17
BC184L 0.17
BC212 0.17
BC212L 0.17
BC213 0.17
BC213L 0.17
BC214 0.17
BC214L 0.17
BC237A 0.13
BC237B 0.14
BC238C 0.13
BC239C 0.15
BC257A 0.20
BC258B 0.17
BC267 0.25
BC300 0.40
BC301 0.35
BC303 0.40
BC307B 0.16
BC327 0.20
BC328 0.20
BC337 0.20
BC338 0.20
BC413 0.17
BC414 0.27

BF244B 0.40
BF254 0.17
BF255 0.17
BF420 0.30

BU407 1.05
BUX26 3.76
BUX82 2.00
BUX85 1.30

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BC559C 0.15
BC560C 0.20
BC639 0.25
BC640 0.26
BC807 0.16
BC817 0.16
BC847B 0.13
BC857B 0.13
BC877 0.56
BC879 0.59
BC880 0.61
BCV46 0.28
BCV47 0.28
BCW66G 0.21
BCW68G 0.21
BCX41 0.42
BCX42 0.42
BCX70K 0.13
BCX71K 0.13
BCX79 0.30
BCY58 0.30
BCY59 0.39
BCY70 0.25
BCY71 0.25
BCY72 0.25
BD131 0.60
BD132 0.60
BD135 0.31
BD136 0.33
BD139 0.36
BD140 0.36
BDX33C 0.65
BF115 0.48
BF167 0.48
BF178 0.35

BF421 0.32
BF457 0.21
BF459 0.25
BF597 0.18
BF989 1.78
BFQ69 2.61
BFQ71 8.91
BFR15A 5.48
BFR34A 1.73
BFR35AP 1.64
BFR92P 1.31
BFT65 1.64
BFT66 4.97
BFT92 3.32
BFT93 3.60
BFX29 0.40
BFX84 0.40
BFX85 0.40
BFX87 0.36
BFX88 0.35
BFY50 0.40
BFY51 0.40
BFY52 0.40
BFY90 2.28
BRY39 0.95
BS884 0.90
BSS87 1.45
BSS89 0.81
BSS91 0.77
BSS92 0.91
BSS95 0.88
BSS97 0.96
BSS100 0.51
BSS101 0.54
BSS110 0.56
BSS123 0.82
BSS125E 1.38
BSS129 0.97
BSX20 0.30
BU205 1.50
BU208A 1.05

BUZ10 1.35
BUZ10A 1.40
BUZ11 2.16
BUZ11A 1.84
BUZ15 6.40
BUZ20 1.22
BUZ21 2.02
BUZ23 3.69
BUZ24 6.47
BUZ30 1.60
BUZ31 2.00
BUZ32 1.25
BUZ35 4.11
BUZ36 6.56
BUZ41A 1.47
BUZ44A 2.58
BUZ45 7.00
BUZ46 4.80
BUZ50A 3.69
BUZ54 12.29
BUZ54A 11.47
BUZ63 6.79
BUZ64 6.58
BUZ71 0.72
BUZ71A 0.71
BUZ71L 1.04
BUZ73 0.82
BUZ73A 0.79
BUZ74 0.97
BUZ74A 0.95
BUZ76 0.97
BUZ76A 0.95
BUZ80 3.12
BUZ80A 3.40
BUZ83 5.51
BUZ83A 5.89
BUZ171 1.05
BUZ353 6.81
CFY17 22.85
CFY18-23 35.79

CFY19-18 17.61
CFY19-27 8.27
MJ2955 0.90
MJE340 0.48
MJE2955 0.95
MJE3055 0.70
MPS6531 0.40
MPS6534 0.42
MPSA12 0.23
MPSA63 0.47
TIP31A 0.36
TIP32A 0.36
TIP41A 0.45
TIP41C 0.60
TIP42A 0.45
TIP42C 0.60
TIP122 0.45
TIP127 0.68
TIP150 1.41
TIP2955 0.66
TIP3055 0.66
VN10KM 0.78
VN46AF 1.50
VN66AF 1.95
VN88AF 2.20
ZTX107 0.18
ZTX108 0.18
ZTX109 0.19
ZTX300 0.18
ZTX301 0.18
ZTX302 0.18
ZTX304 0.18
ZTX331 0.19
ZTX500 0.18
ZTX501 0.18
ZTX502 0.19
ZTX503 0.19
ZTX504 0.19
ZTX531 0.20

**IC'S 7400 SERIES**
7400 0.30
7401 0.30
7402 0.30
7403 0.30
7404 0.30
7405 0.30
7406 0.40
7407 0.40
7408 0.25
7409 0.30
7410 0.30
7413 0.35
7414 0.70
7420 0.30
7430 0.30
7440 0.30
7442 0.65
7443 0.70
7444 0.80
7447 1.85
7448 1.00
7450 0.30
7451 0.25
7453 0.25
7454 0.30
7460 0.45
7470 0.40
7472 0.35
7473 0.55
7474 0.45
7475 0.60
7476 0.55
7480 0.80
7483 0.85
7485 0.85
7486 0.40
7489 1.90
7490 0.55

7491 0.65
7492 0.55
7493 0.55
7494 0.70
7495 0.85
7496 0.75
74100 2.00
74104 0.65
74107 0.40
74121 0.45
74123 0.75
74125 0.65
74126 0.75
74141 0.75
74151 0.55
74154 0.85
75155 0.55
74156 0.55
74157 0.60
74190 1.00
74191 1.00
74192 1.00
74193 1.00
74393 1.20

**74LS SERIES**
LS00 0.24
LS02 0.24
LS03 0.24
LS04 0.24
LS05 0.24
LS08 0.24
LS10 0.24
LS11 0.24
LS13 0.24
LS14 0.40
LS20 0.22
LS21 0.22
LS22 0.22
LS27 0.24
LS30 0.24
LS32 0.24
LS37 0.24
LS38 0.24
LS40 0.24
LS42 0.40
LS47 0.75
LS51 0.22
LS54 0.24
LS73 0.24
LS74 0.30
LS75 0.40
LS76 0.29
LS83 0.40
LS85 0.40
LS86 0.29
LS90 0.40
LS92 0.35
LS93 0.54
LS96 0.95
LS107 0.35
LS109 0.40
LS112 0.35
LS122 0.55
LS123 0.75
LS125 0.35
LS126 0.50
LS132 0.60
LS136 0.35
LS138 0.55
LS139 0.50
LS145 0.80
LS148 1.05
LS151 0.35
LS153 0.35
LS154 0.95
LS155 0.45
LS156 0.45
LS157 0.45
LS158 0.45
LS160 0.55
LS161 0.55
LS163 0.55
LS164 0.55
LS165 0.55
LS166 0.55
LS169 0.95
LS173 0.75
LS174 0.55
LS175 0.65
LS181 1.30
LS191 0.55
LS192 0.55
LS193 0.55
LS194 0.55
LS195 0.55
LS196 0.80
LS197 0.80
LS221 0.80
LS240 0.80
LS241 0.80
LS242 0.80
LS243 0.80
LS244 0.80
LS245 0.80
LS247 0.80
LS251 0.65
LS253 0.60
LS256 0.80
LS257 0.45

LS259 0.80
LS266 0.50
LS273 0.80
LS279 0.55
LS280 1.10
LS283 0.70
LS290 0.60
LS293 0.70
LS295 0.80
LS298 0.80
LS299 1.60
LS366 0.60
LS367 0.45
LS368 0.50
LS373 0.60
LS374 0.60
LS375 0.60
LS378 0.60
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4012 0.22
4013 0.24
4014 0.36
4015 0.36
4016 0.28
4017 0.40
4018 0.36
4019 0.24
4020 0.35
4021 0.36
4022 0.36
4023 0.15
4024 0.30
4025 0.18
4026 0.70
4027 0.30
4028 0.36
4029 0.40
4030 0.25
4035 0.45
4040 0.40
4041 0.50
4042 0.40
4043 0.40
4044 0.36
4046 0.50
4047 0.50
4049 0.30
4050 0.25
4052 0.45
4053 0.45
4060 0.45
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SAS590 4.21
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LM3915 2.90
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TDA4292 7.08
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# SEMICONDUCTORS

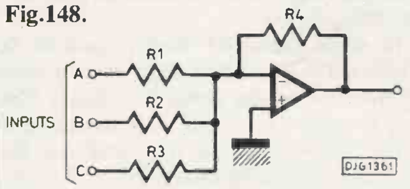
BY ANDREW ARMSTRONG

## PART 15 – Signal Conditioning

*Signal processing, measurement, and generation. Opamps do it all.*

As well as being widely used in audio circuits, opamps are used in general signal conditioning circuits. Rather than being used in totally analogue instrumentation systems, many opamps are used to process signals for analogue to digital conversion for use in microprocessor control systems.

**Fig.148.**




One signal conditioning circuit which is more used in audio than instrumentation is the adder shown in Fig. 148. This circuit adds signals A, B, and C and inverts the result. The output is given by the equation $Vout = -R4 \times (A/R1 + B/R2 + C/R3)$. The circuit is obviously not limited to three inputs, but three inputs can be convenient as shown in Fig. 149.

In this circuit the adder circuit is used to add three audio signals. Each audio signal is buffered by one opamp, and the addition is performed by a further opamp. This circuit can conveniently be made using a quad opamp such as the LM324. This circuit arrangement has interesting implications for gain bandwidth product. As far as the opamp is concerned, it is operating at a gain given by $(R4+Rp)/Rp$ where Rp is the parallel combination of R1, R2, and R3. The opamp may not be unity gain stable, but in the circuit shown in Fig. 148 the gain at which the opamp is working is much greater than the gain from each input. If all resistors are equal, the gain from the point of view of the opamp is 4. That is to say that the feedback voltage is 1/4 of the output voltage minus the sum of the input voltages. In reality, the feedback voltage relative to 0V is only the error signal, because the non-inverting input is connected to 0V. Therefore the output error is greater than would be the case if only a single input were connected.

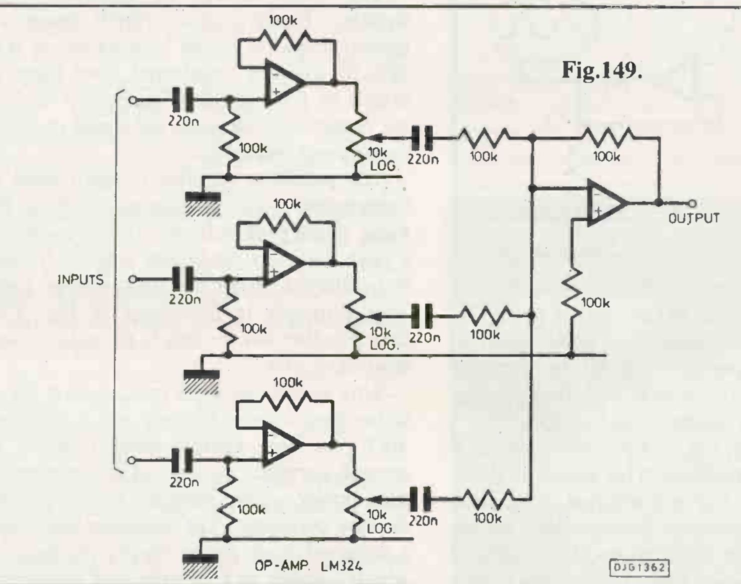


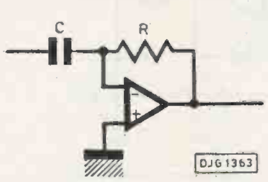

**Fig.149.**

## DIFFERENTIATION

It is sometimes necessary to detect a changing condition rather than measure an absolute value. For example, time to recharge a nickel cadmium battery may be indicated by a sharp fall in voltage. Simply detecting the absolute voltage would not be effective because this can be influenced by the temperature, the current drain, and the age of the cells.

The output signal depends on the rate of change of input voltage and the RC time constant. The currents charging the capacitor and flowing in the resistor are the same, and capacitive charging current is given by the formula $C \times dV/dt$. Therefore output voltage + $-R \times C \times dV/dt$.

**Fig.150.**




Since the mathematical function of differentiation has an electronic analogue, it is no surprise that the same holds true for integration. The circuit of Fig. 151 illustrates the principle. The output is RC V dt. The integral period is from the last reset pulse, which discharges the capacitor. This circuit will, of course, integrate everything impartially, including the opamp's bias current, so it is best used to integrate over fairly short periods.

A practical application for an integrator is shown in Fig. 152. In this circuit the unsmoothed rectified waveform from the transformer synchronises the reset of the integrator. The integrator integrates this same waveform, producing the S shaped waveform shown on the output. One application of this is to provide a smooth brightness control law for lamp dimmers.

If a more carefully controlled reset pulse were used, the output waveform from the integrator could be sampled just before reset to give a half-cycle by half-cycle measurement of the mean voltage.

## RECTIFICATION

Beloved of academics is the concept of the perfect diode. This fictional beast conducts perfectly in one direction and not

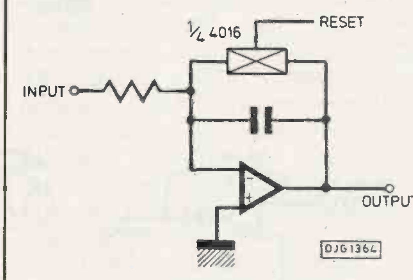



**Fig.151.**

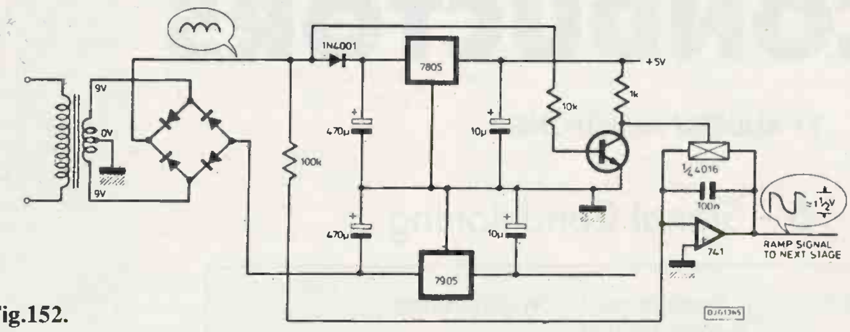



Fig.152.

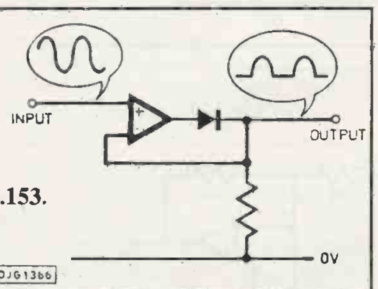



Fig.153.

at all in the other. It has no resistance or voltage drop. The addition of an opamp to a real diode can produce a good approximation to this perfect diode for the purposes of signal rectification at low frequencies. The concept is illustrated in Fig. 153.

The circuit of Fig. 154 provides full wave "perfect" rectification. This circuit is good in many ways, but it is affected by resistor tolerance and contains four resistors whose tolerance affects the accuracy of the circuit.

The circuit of Fig. 155 reduces this problem, but in order to work properly it must be driven from a very low impedance, and its output must feed into a very high impedance. Another advantage of this circuit is that it can rectify a signal which goes negative of the opamp's negative power supply (if a "single railable" opamp such as the LM358 is used).

It must be driven from a very low impedance because any extra impedance in series with R1 will change the gain of the circuit with respect to negative input signals. Positive input signals cause the opamp output to swing as negative as it is able to, and are transferred from input to output by R1 and R2. Clearly any load on the output will attenuate the signal received under these conditions.

The precision rectifier is often used in conjunction with a capacitor to hold the value of the peak voltage. This is known as a peak detector. Generally a bleed resistor is included to limit the peak storage time. This principle is illustrated in Fig. 156. One possible use for this is to make a peak reading ac meter.

Why would one use a peak reading meter rather than a mean reading one, I hear you ask? As one example from a choice of several, consider the case of an uninterruptible power supply intended to run a small desktop computer. The computer itself uses a switched mode power supply, the input of which consists of a rectifier and smoothing capacitor connected to the mains. The capacitor will charge to the peak of the incoming voltage, and it is the peak rather than the mean or the rms value which controls whether the power supply will work properly. A peak detector to measure the voltage in this type of application would probably include a resistor in series with the diode to prevent the circuit from responding to very brief spikes.

The speed of response can be a problem with peak detectors anyway. If a large capacitor value is used, the speed may be limited by the maximum current which the opamp can deliver to charge the capacitor. This will limit the circuit's ability to measure glitches and interference. If, on the other hand, a very small value of capacitor is used, the circuit may detect fast glitches but they may not be held on the capacitor long enough to be displayed.

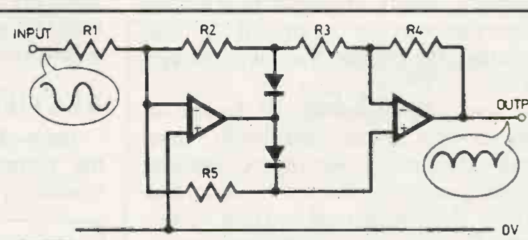
Even then, the speed response is limited by the slew rate of the opamp. This is more of a problem than it appears, because during all the time that the voltage on the non-inverting input is below that on the inverting input, the output of the opamp will be as negative as the power supply allows it to be. If the opamp is supplied from ±12V, and it has to detect a +3V spike, its output will have to slew 15V rather than the 3V of the signal to be measured. The circuit shown in Fig. 157 can get around this problem in some cases, but it is not always suitable because the voltage on the inverting input follows that on the non-inverting input.

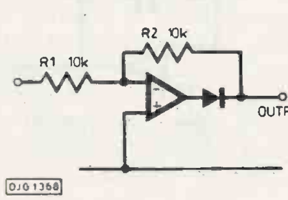
In some cases R1 would need to be connected to 0V, and in these cases a more complicated system would be needed. One way to make the circuit work would be to buffer the voltage on C1, and use the buffered signal as feedback.

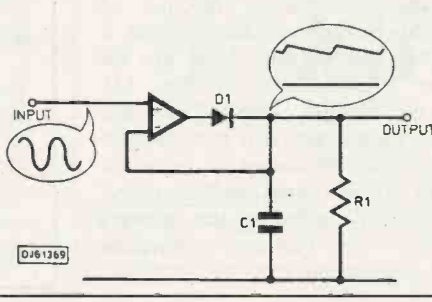
There are several ways to detect short spikes and store them for long enough to be displayed. One way would be to use a differentiator following the peak detector to detect a rapid increase in voltage, and to use this to trigger an analogue to digital conversion. Another technique would be to follow the short time constant peak detector with a slower long time constant one. Yet another technique is to use a transistor to increase the available charging current, as illustrated in Fig. 158. This circuit can provide a very high charge current, so the peak current is limited by R1, which forms a time constant in conjunction with C1 rather than a current limit.

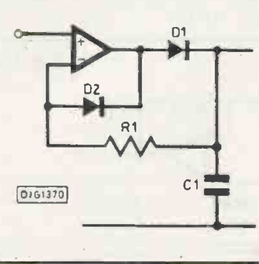
The substantial peak currents drawn by this circuit could interfere with other circuitry on the same pcb, either because the power supply voltage dips momentarily or, more likely, because of noise induced on the 0V track by the heavy peak currents. Consequently a local decoupling capacitor, C2, must be inserted, and its value must be considerably greater than that of C1. The heavy currents then circulate in C2, C1 and Q1, and the pulse of current drawn from the supply on the reset of the pcb is longer and lower.

**Fig.154.** *(right)*
**Fig.155.** *(below)*
**Fig.156.** *(centre)*
**Fig.157.** *(far right)*



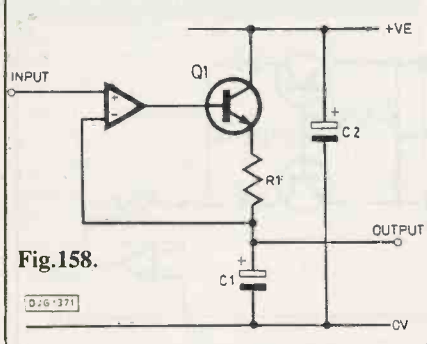


Fig.158.

## DOING SUMS

It is easy to add and subtract using analogue circuits, but it is a lot harder to multiply or divide two voltages. One way to multiply and divide voltages is to take the log, then add or subtract, then take the antilog of the result. To a first approximation the current in a diode is the log of the voltage across it (ignoring temperature effects) but this is a poor approximation. For obscure reasons to do with the diffusion process, a transistor base-emitter junction provides a much better approximation. Consequently the log circuit shown in Fig. 159 uses a transistor in the configuration known as transdiode.

Disregarding R2 and C1, which are present purely for stability, the emitter current of Q1 is equal to the minus the log of the output voltage. The collector current is approximately the same. The accuracy of the approximation depends on the gain of the transistor, so as high a gain type as possible should be used. The values of the stability components should be determined by experiment, but a reasonable place to start would be 10R and 100pF.

The form of the graph of output against input is logarithmic, but the scale depends on the transistor characteristics and the temperature. For this reason the output is shown multiplied by a constant, which will be the same for all similar transistors at the same temperature. This circuit as it stands is of little use because it is affected by temperature. It is possible to temperature compensate log amplifiers if necessary, but this is not an easy task, and not a necessary one if the end result is to be multiplication or division.

The circuit shown in Fig. 160 uses three log amplifiers, an adder/subtractor, and an antilog amplifier to multiply and divide

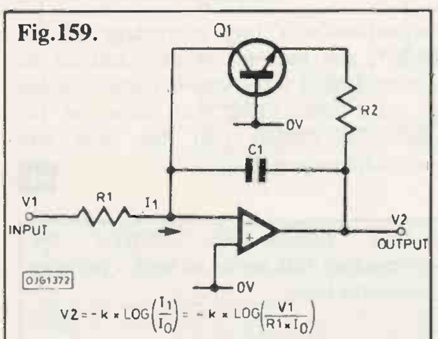


Fig.159.

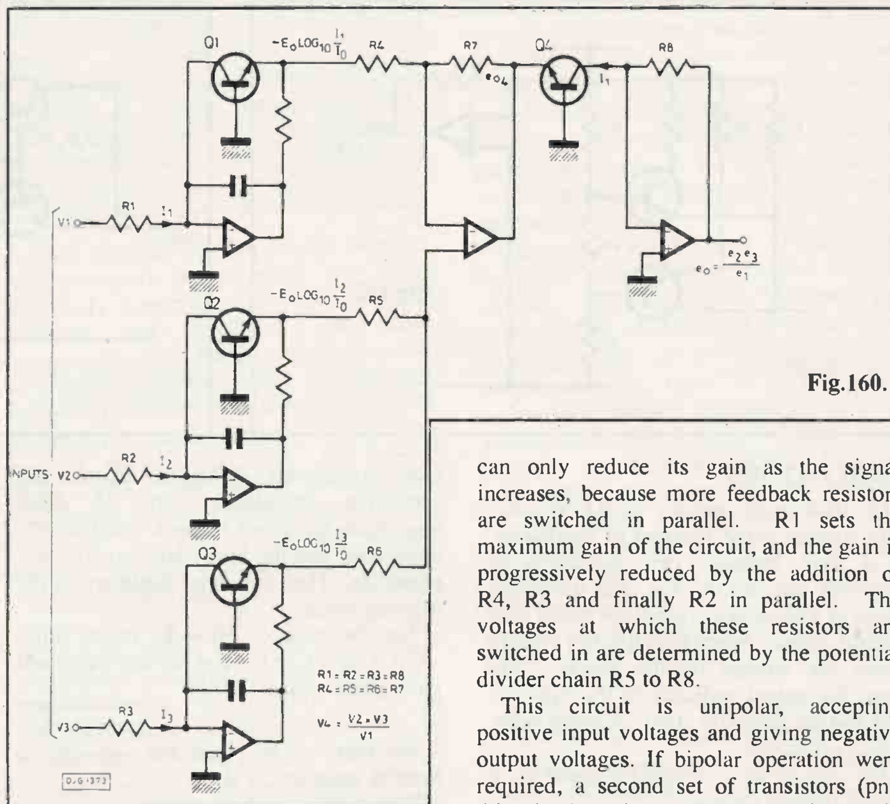


Fig.160.

voltages. If all the transistors are similar – perhaps all part of the same transistor array, and all at the same temperature – then the constant terms cancel to give reasonably accurate multiplication and division.

This circuit can, of course, only multiply and divide positive voltages. There is no proper answer to the log of 0 or of a negative quantity, so the circuit can only function properly with positive voltages large enough to bring the outputs within the range available to the opamp.

What do you do if you want an approximately logarithmic response, but do not want the output to go unbounded at zero volts input? It is possible, but not by using this type of circuit. Instead, nonlinear feedback is applied to an opamp by changing the effective feedback resistance at specific levels of output voltage. Using this system, known as an arbitrary function generator, one can generate almost any input/output curve as a series of straight line approximations.

The circuit of Fig. 161 is an example of an arbitrary function generator. This circuit can only reduce its gain as the signal increases, because more feedback resistors are switched in parallel. R1 sets the maximum gain of the circuit, and the gain is progressively reduced by the addition of R4, R3 and finally R2 in parallel. The voltages at which these resistors are switched in are determined by the potential divider chain R5 to R8.

This circuit is unipolar, accepting positive input voltages and giving negative output voltages. If bipolar operation were required, a second set of transistors (pnp this time) and a separate divider chain connected to a negative reference voltage could be used.

If a circuit which increases its gain with increasing input voltage is needed, then the circuit of Fig. 162 would do the job. In this circuit, extra resistors are switched in parallel with the input resistor as the input voltage increases, thus increasing the gain. The two types of circuit could be combined, to provide, for example, an S shaped amplitude response. The calculations for this, especially based on using preferred value resistors, would be complicated and best done by computer.

The Vbe of transistors can be used to set the response of a circuit, as shown in Fig. 163. This is the circuit of a triangle to sinewave converter, which operates symmetrically by virtue of using the same resistors for each half of the response. Fig. 164 shows the corresponding circuit to increase gain with signal level. Perhaps this could be used for a sinewave to triangle wave converter, whatever use that would be.

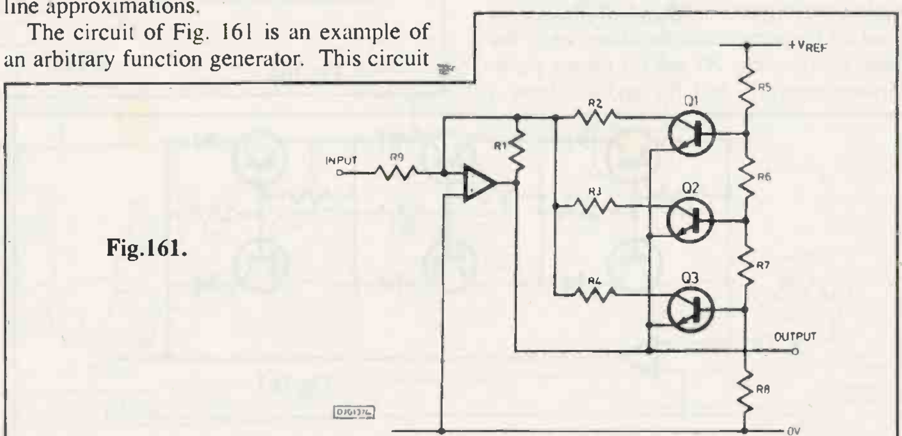


Fig.161.

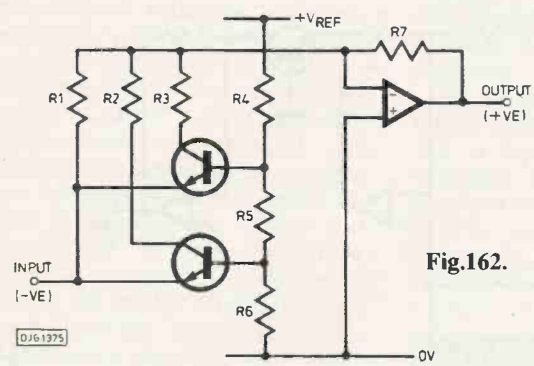



Fig.162.

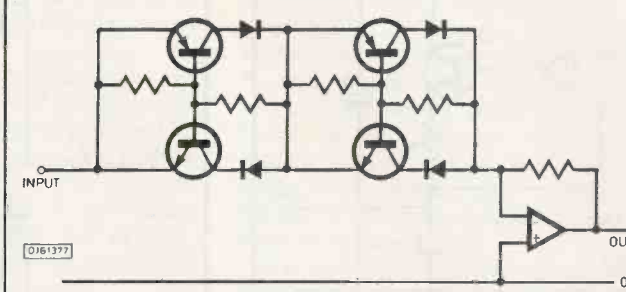



Fig.164.

## OSCILLATORS

No treatise on opamps would be complete without some mention of oscillators. So I have included two specimens to exemplify the subject. Fig. 165 shows the circuit of a squarewave oscillator based on a Schmitt trigger. When the capacitor voltage passes the voltage on the non-inverting input, the output switches to the opposite state and the capacitor starts charging in the opposite direction.

The voltage on a capacitor charged via a resistor follows the law:

$V = Va \times (1 - e^{(-t/(R \times C))})$ where Va is the applied voltage.

Each half cycle of oscillation starts with the capacitor starts with the capacitor charged to (say) -V and finishes with it charged to +V or vice-versa. From all this plus the assumption that the output of the opamp gives equal positive and negative output swings one can eventually deduce that the time for one half cycle of oscillation is given by the formula:

$$T = -R \times C \times \ln\ 1 - \frac{2 \times R3}{R2 + 2 \times R3}$$

Ln means log to base e

To find the frequency, of course, just multiply the period of a half cycle by two and take the reciprocal.

For many applications a sinewave oscillator is needed. The circuit of Fig. 166 is one such. This is a Wien bridge oscillator, a standard circuit configuration. It relies on frequency dependent phase shift to set its frequency, and oscillates when the phase shift is zero. R1 and C1 form a phase advance network, and R2 and C2 form a phase lag network. When the resistive and capacitive impedances are of equal magnitude the upper network provides 45° phase lead and the lower one provides 45° phase leg. Here is a brief summary of the relevant maths:

For the parallel network, phase shift= -ATAN (ω x C x R), and for the series network phase shift = -ATAN $\frac{1}{\omega \times C \times R}$

For these to be equal and opposite, ω must be equal to C x R.

The magnitude equations are:

$$\frac{R \times \sqrt{1 + \omega^2 \times C^2 \times R^2}}{1 + \omega^2 \times C^2 \times R^2}$$

Parallel network $\sqrt{R^2 + \frac{1}{\omega^2 \times C^2}}$

And, substituting ω = C x R we have:

Parallel magnitude = $R \times \frac{\sqrt{2}}{2}$

Series magnitude = $R \times \sqrt{2}$

Network gain = Parallel magnitude/ (series magnitude + parallel magnitude) = 1/3

Therefore, the oscillation frequency is given by f = 1/(2 x π x R x C), and oscillation occurs when the amplifier gain is 3.

Clearly oscillation cannot start unless the amplifier gain is a little above 3, but if the gain remains above 3 the amplitude rises until the opamp clips and the output is no longer a sinewave. To combat this problem, the negative feedback is adjustable to set the nominal gain to just greater than 3, and an extra resistor (R4) is added in parallel with R3 and VR1 when the amplitude of the signal is great enough to switch on the diodes. This reduces the gain just slightly and stabilises the amplitude with minimal distortion. In practice this circuit can, if carefully adjusted, provide a very clean sinewave.

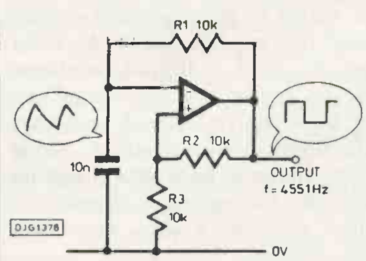



Fig.165.

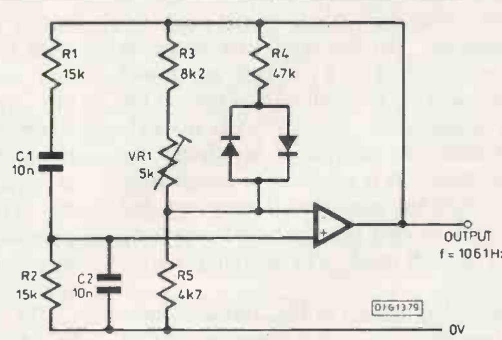



Fig.166.

## SALUTATIONS

Well, that about wraps it up for semiconductors. This monster series has covered only a tiny percentage of the subject, and has just about exhausted its author. I hope it has whetted your appetite to learn more, and that some of the application circuits find their way into successful project designs.

PE

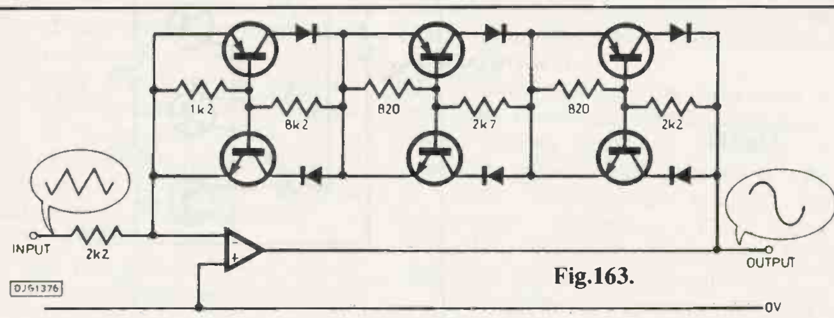



Fig.163.

**Our thanks to Andrew for conducting this series so well – no semi measures here!**

**Ed.**

OUR REGULAR LOOK AT ASTRONOMY

# SPACEWATCH

**BY DR PATRICK MOORE CBE**

## STAR DRECK

*Space rubbish orbiting the earth may hamper future space shots. On the other hand, our flotsam could be our ambassador.*

Two recent comments concerning space research programmes are worth noting. First, there is increasing anxiety about the effects of man's activity upon the space environment. Many thousands of artificial satellites have been sent up since the launch of Sputnik 1 on 4 October 1957, and there have been some mishaps; a considerable quantity of débris is now in orbit, and cannot be tracked. There is therefore an increasing threat to future vehicles and even space-stations. A scientific satellite could be badly damaged by a head-on collision with a fragment much less than an inch in diameter, and it has been claimed that unless something is done, the problem may reach an unacceptable level in no more than a decade. Even worse is the danger from nuclear reactors in space – remember Cosmos 944, which crashed in Canada and spread radioactive débris over a wide area. Military preparations in space are an obvious hazard, as well as shifting the emphasis away from scientific research, and there is an urgent need for better monitoring of the whole environment.

On a different tack, a Russian commentator, S. Leskov, has criticized the Soviet 'space-lifts' of cosmonauts from other countries, and maintains that the countries concerned should bear the cost. At least this shows that the Russians are at last becoming commercially-minded!

Brown dwarfs are back in the news. By definition, a brown dwarf is an object with a mass less than 0.08 that of the Sun, so that its core will never become hot enough to trigger off nuclear reactions and make the object shine; it is in fact a star which has failed its entrance examination, and there seems to be a rather blurred boundary between a brown dwarf and a planet. Two American astronomers, Eric Becklin and B. Zuckerman, have now identified a low-mass object in orbit round a white dwarf star, GD 15, which is about 84 light-years from the Sun. The companion of the white dwarf has a surface temperature of no more than about 2000 degrees C, and has only 1/800,000 of the Sun's luminosity. If it is a true brown dwarf, it adds force to the contention that these very low-mass objects may be important constituents of our Galaxy.

### VOYAGER PROBES: SOLAR SYSTEM OVERVIEW?

Both the Voyager probes to the outer Solar System are still in full working order. Voyager 2 will by-pass Neptune next August; Voyager 1 will encounter no more planets, but will go on receding until we lose track of it. Will these probes, then, be able to send back pictures of the complete Solar System from far distance?

Sadly, the answer seems to be 'no'. With regard to Voyager 1, it seems that after the early 1990s the transmitter would be too weak to send back images, and in mid-1990 it is planned to shut down the cameras permanently, thereby saving power and allowing other less demanding instruments to

## The Sky This Month

*Not many of the planets are well placed this month. Venus is too near the sun to be seen at all; Mercury is in theory a morning object, but from Britain will not be a naked-eye object; Saturn, at magnitude 0.6, can be seen in the early morning, but is very low, in Sagittarius, and not too easy to observe. This leaves us with Jupiter and Mars, both of which are in the evening sky, lying in Taurus.*

*Jupiter passed opposition in late November last, and will not be in conjunction with the Sun until next June; its magnitude this month is -2.2. Mars, which actually surpassed Jupiter last summer, has now decreased to magnitude 1.2, inferior to Aldebaran and a full three magnitudes below Jupiter; the apparent diameter is now less than 6 seconds of arc, so that not even large telescopes will show much upon its disc. It lies between the Hyades and the Pleiades, and on 12 March it and Jupiter are only two degrees apart. This conjunction is not in the least important, but at least it will be worth photographing.*

*No major meteor showers are due this month, and no bright comets have been predicted. The Moon is new on 7 March, and full on the 22nd; remember, too, that British Summer Time begins on 26 March.*

*Ursa Major, the Great Bear or Plough, is now almost overhead after dark. Note the second star in the Bear's 'tail', Mizar, which has a fainter companion, Alcor; strangely the Arabs of a thousand years ago regarded Alcor as a test of keen eyesight, whereas today it is quite/obvious on any reasonably clear night. Telescopically, it is seen that Mizar is itself double, with one component rather brighter than the other.*

*High in the south you will find Leo, the Lion, with its curved arrangement of stars making up the famous 'Sickle'; the brightest of them, Regulus,is of the first magnitude. Two other first-magazine stars are also easy to find. Follow round the 'curve' of the Great Bear's tail, and you will come first to the brilliant orange Arcturus, in the constellation of Boötes (the Herdsman) and then to Spica, in Virgo (the Virgin). Virgo is a large constellation containing many faint galaxies; in this direction we come to the so-called Virgo Cluster of galaxies, around 60,000,000 light-years away, containing many hundreds of separate star-systems. Lower down in the south lies the large but dim constellation of Hydra (the Watersnake), which contains only one fairly bright star, the reddish second-magnitude Alphard.*

*Orion sets in the west not long after dark, but some members of its retinue, notably the Twins (Castor and Pollux) and Capella in Auriga (the Charioteer) remain on view. Capella never actually sets over Britain, though during summer evenings it almost touches the northern horizon and will probably not be seen.*

continue operating. In any case, obtaining views of objects very near the Sun in the sky is a difficult matter, because even from the distance of the orbit of Neptune the sunlight is still bright enough to illuminate the front lenses of the cameras and ruin pictures by scattering.

Efforts have been made to manoeuvre Voyager 1 so that the cameras remain in the shadow of the large dish antenna while photography is being attempted. Unfortunately, success has been only partial, and it has not been possible to record any objects closer to the Sun than Mars.

With luck, we should be able to maintain contact with the probe until it reaches the heliopause – that is to say, the region where the solar wind becomes undetectable – but Voyager 1 will not penetrate as far as this until about the year 2020, so that imaging would be quite out of the question in any case. As has been pointed out by scientists at the Jet Propulsion Laboratory an 'overall view' of the Solar System must be left to a future probe much better adapted to the task than the present Voyagers.

Presumably both Voyager 1 and Voyager 2 will continue travelling between the stars, unseen, unheard and untrackable, until they are destroyed by collision with some solid body, and this may not occur for many millions of years. There is always a chance that they will be picked up by some alien civilization, and they even carry plaques and recordings which would – it is hoped – give a clue to their system of origin, but one has to admit that the chances of anything of the kind are extremely slight. All the same, it is a measure of our changed attitude that it was thought worth while to include the information at all.

PE

# HI-TECH TIMING

BY ANTHONY H. SMITH BSC

## ATOMIC FREQUENCY STANDARDS

*Few things are more certain than f, where it equals E/h. Yet to create a chronometer around this equation requires the sub-atomic equivalent of a lot of cogwheels.*

At the International Bureau of Weights and Measures at Sèvres near Paris, there is a platinum-iridium cylinder whose mass has been assigned by international agreement to be exactly one kilogram. This cylinder is the primary standard of mass: occasionally, it is taken out of its protective enclosure so that other mass standards can be checked against it.

Unfortunately, the unit of time is intangible: it is not possible to keep a second locked away inside a vault. Instead, it must be generated by a suitable piece of equipment which itself constitutes the standard of time.

For example, we could use a monostable device to generate a pulse whose width is precisely one second; however, because a time standard has the dual role of providing an accurate reference of time *and* frequency, the aperiodic output of the monostable is useless, and invariably the standard has always taken the form of some kind of *oscillator*.

This oscillator is not only responsible for generating an accurate time *interval* equal to one second, but should also be ideally suited to the task of *timekeeping*.

Timekeeping involves keeping track of events which occur in relation to an established time scale; navigation, astronomical observations, satellite tracking, and, indeed, our own comings and goings, all depend to a greater or lesser extent on an accurate timekeeping system.

Correcting the output of a frequency standard consists only of resetting it to agree with a primary reference; however, if this standard is being used to drive a time clock, correcting the frequency does not correct the time.

Consequently, our time and frequency standard must not only be accurate, but must also be stable (it must not drift with time), and be reliable.

Various time scales such as 'apparent solar time', 'mean solar time', 'universal time', and 'ephemeris time' have been used at one time or another, and all depend upon the relative periodic movements of bodies in space. Indeed, up until recently, the unit of time itself was based upon the rotation of the earth about its axis, and the second was defined as the fraction 1/86,400 of the average daily rotation of the earth.

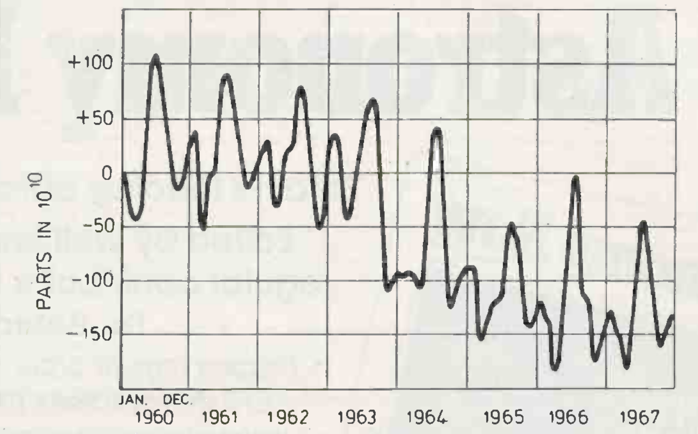



**Fig.1.** *Variation in rate of earth's axial rotation by comparison with Caesium clock.*

However, it had been known for some time that the earth's axial rotation was subject to unpredictable irregularities and long term drifts, and so in 1956 the International Committee on Weights and Measures chose to define the second as "... the fraction 1/31,556,925.9747 of the tropical year for January 0, 1900 at 12 hours Ephemeris Time."

The ephemeris second was an improvement over the previous definition since it depended on the more stable rotation of the earth about the sun. However, astronomers could not implement the definition with enough accuracy to justify its use as a universal standard. Consequently, there was a need to establish an invariable time interval which could be generated, observed and measured electronically with great accuracy.

For some time, quartz crystal clocks had provided satisfactory operation as secondary time standards, but even precision examples could not guarantee accuracies and stabilities better than a few parts in $10^9$ Even though this meant that the best quartz clocks could keep time for a year with an error no greater than 0.03 seconds, it was still not accurate enough to meet the increasing demands of scientific research and communication and navigation systems.

Thus, having exploited the resonant qualities of the solar system, of pendulums, tuned-circuits and quartz crystals, it became necessary to find some other phenomenon which could be used to realise a far superior time standard.

Fortunately, Essen and Parry working at the National Physical Laboratory (NPL) in Teddington, England, had developed a new kind of time and frequency reference whose accuracy exceeded that of previous standards. Their device, the caesium resonator, became known as the 'atomic clock' since it depended for its operation on precise energy changes in the atoms of the caesium 133 isotope.

Eventually, after refinements and improvements had been made to the atomic clocks at NPL and other international laboratories, the caesium resonator was adopted as the new standard of frequency and time, and in 1967 the 13th General Conference on Weights and Measures redefined the second in the following terms:

"The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom."

The atomic standard realised levels of accuracy, stability and convenience far in excess of earlier techniques, and it became possible to make precise measurements which had previously been impossible.

For example, the perturbations in the earth's axial rotation mentioned previously could now be measured with considerable accuracy: Fig.1 shows the variation in rotation over an eight year period.

Notice how the rotation rate is higher in summer than in winter; this is due to seasonal motion of the earth's winds. Note, also, how the rate is gradually decreasing, due largely to tidal friction between the water and land. Other variations are caused by melting and refreezing of polar icecaps.

## QUANTUM PHYSICS

The atomic phenomena exploited in the caesium resonator are by no means unique to caesium - many other elements have been used as the source material in a variety of successful atomic clocks, such as the ammonia maser, the methane laser, the thallium beam tube, and so on.

Three of the most highly-developed devices are the rubidium gas-cell resonator, the hydrogen maser, and, of course, the caesium beam resonator. However, in order to understand the operation of these devices, we must first review some of the fundamental principles of quantum physics (but before you reach for the Valium, don't worry - we'll only be considering the basic ideas.)

Our starting point is the familiar 'planetary' atomic model developed by Niels Bohr in 1913 - Fig.2 shows examples for the hydrogen and sodium atoms.

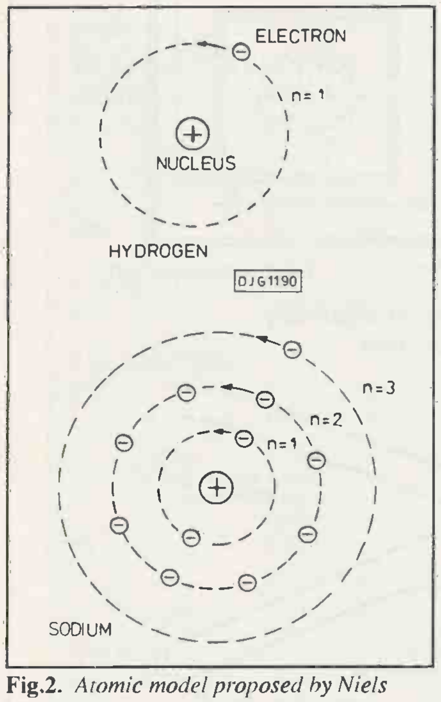



**Fig.2.** *Atomic model proposed by Niels Bohr*

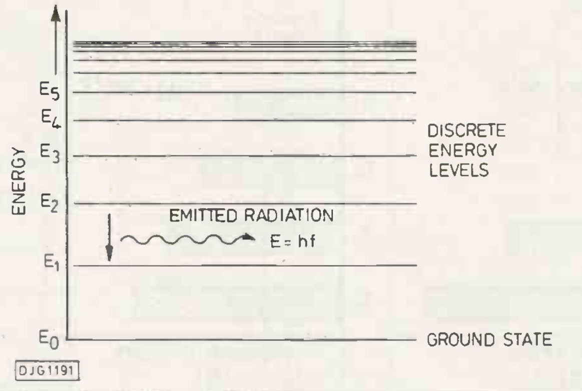



**Fig.3.** *Atomic energy levels*

Bohr postulated that the negatively charged electrons revolve around the positive nucleus only in certain discrete orbits, and that each orbit can contain no more than $2n^2$ electrons, where no, the principal quantum number, defines the particular orbit.

Because the electron and the nucleus are oppositely charged, an electrostatic force of attraction exists between them: if we were to move an electron from its present orbit to one of greater radius, we would need to supply energy to the electron in order to overcome the attractive force pulling the electron toward the nucleus. For this reason, electrons in outer orbits have greater potential energy than those close to the nucleus.

Furthermore, since the electrons can occupy only particular allowed orbits, the electron energies can only take certain discrete values. Consequently, the overall energy of the atom itself is quantised into discrete levels. Fig.3 is a graphical representation of atomic energy levels; when all the electrons are in their lowest orbits, the energy is a minimum and the atom is said to be in its 'ground state'.

If we now energise the atom - for example, by heating it - one or more electrons may acquire sufficient energy to move into outer orbits, and the atom is no longer in its ground state but is said to be 'excited'.

However, the electrons do not remain in their excited states, but gradually return to orbits of lower energy, and in the process of falling from a high energy level to a lower one, the electron emits radiation of frequency f, according to the formula:

$$E = hf, \text{ or } f = E/h,$$

where h is a constant known as Planck's constant (equal to 6.62 x $10^{-34}$ Joules-sec), and E is the difference in energy states (for example, in Fig.3, the energy difference is shown as being $E = E_2 - E_1$.) The relationship E=hf represents perhaps the most significant principle in quantum physics, namely that the radiation resulting from a particular energy change has one - *and one only* - characteristic frequency. This fact immediately suggests that we have an atomic mechanism capable of realising a precise, invariant frequency source.

Each atom has its own particular set of emitted frequencies which can be used to identify the atom rather like an 'atomic fingerprint'.

Unfortunately, quantum physics is not quite so straightforward. Experimenters discovered that where there should be only one energy level for each value of the quantum number n, energies of slightly different values showed up as well. It became apparent that other atomic mechanisms were responsible for these energy differences, and it was necessary to introduce additional quantum numbers to take account of their effects.

For example, the quantum number l specifies the angular momentum of the electron, while the 'spin' quantum number s takes account of the fact that each electron is spinning about its own axis, as well as around the nucleus.

Extra complications arise due to the magnetic interaction of the electrons and the nucleus, causing a splitting of the basic energy levels into additional, 'hyperfine' levels denoted by the quantum number F. Furthermore, if we expose the atom to an external magnetic field, the hyperfine energy levels themselves split into further quantum levels, known as Zeeman levels, represented by the number $m_F$.

Nevertheless, in spite of all these additional effects, the atomic energy levels still remain quantised, as do the frequencies of emitted radiation. The problem is, how do we utilise these quantum effects to create a high-accuracy, ultra-stable oscillator?

## MASERS AND LASERS

The maser (microwave amplification by stimulated emission of radiation) is essentially the same device as the laser, the main difference being that the maser handles microwave frequencies, whereas the laser works with the much greater lightwave frequencies.

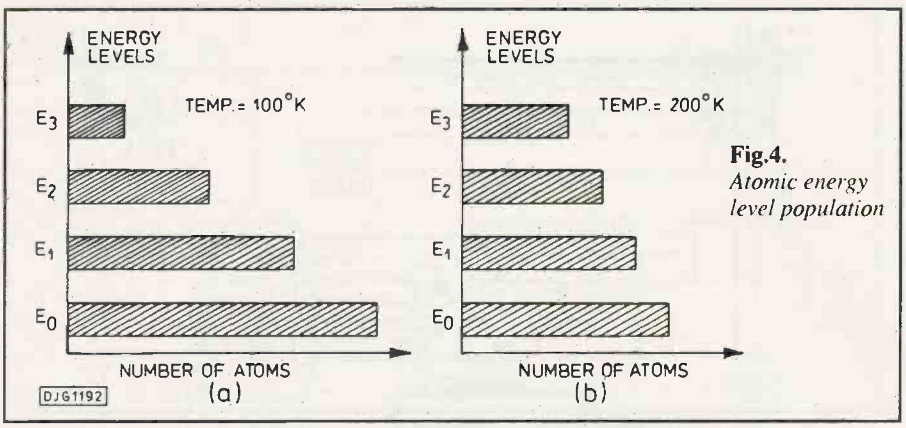



**Fig.4.** *Atomic energy level population*

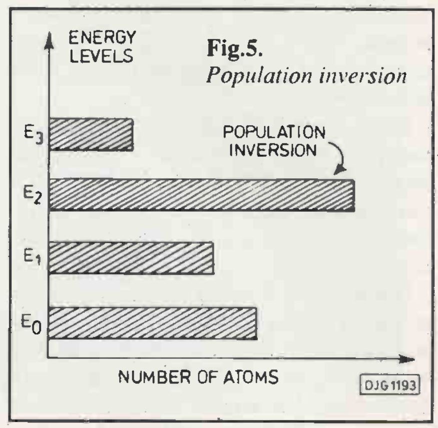



**Fig.5.** *Population inversion*

In addition to its important application as a low-noise microwave amplifier, the maser is also ideally suited for use as a high-precision oscillator.

If we were to look, for example, at a hydrogen molecule, we would see various electrons excited to higher energy levels as they absorbed thermal energy from their surroundings. Eventually, these electrons would fall back to lower energy levels, emitting radiation as they do so. Because this thermal agitation is a random process, the atomic energy levels are continually increasing and decreasing in a haphazard manner, and the emitted radiation - although quantised - varies randomly, and is said to be *incoherent*.

If we now extend our analysis to a gas of many hydrogen atoms, we find that most of them exist in lower energy states, whereas the higher energy levels contain fewer and fewer atoms; as an example, Fig.4a shows the average population of energy levels for a temperature of 100° Kelvin.

At higher temperatures - Fig.4b - more atoms have gained sufficient thermal energy to move into higher energy levels; nevertheless, the greater population of atoms still exists in the lower energy states.

If by some means a higher energy level were to contain more atoms than the lower levels, we would have a condition known as 'population inversion'; Fig.5 shows such an inversion in energy level $E_2$.

However, the population inversion, being a condition of thermal nonequilibrium, would not last indefinitely, and the atoms would gradually relax to lower energy levels, at the same time emitting incoherent radiation. This is known as *spontaneous* emission.

Suppose, however, that before the excited atoms have had a chance to fall randomly to the lower energy levels, incoming radiation impinges on them. If the energy (and, thus, the frequency) of the incoming radiation is of the right value, then many of the excited atoms in the population inversion will be stimulated into falling down to a lower level, emitting radiation as they go.

This process, known as 'stimulated emission of radiation', is essential to maser and laser action; the basic steps are shown in Fig.6.

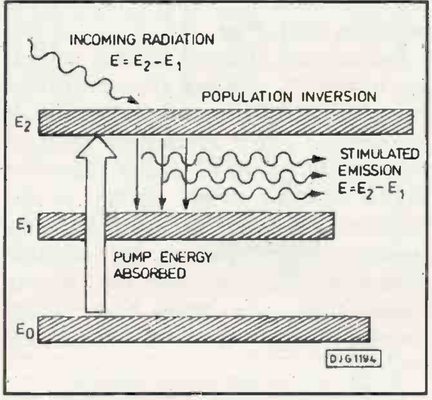



**Fig.6.** *Maser (and laser) action*

Initially, the atoms are bombarded by radiation having the right energy to 'pump' atoms from lower levels up into the higher $E_2$ state, thus creating a population inversion.

Next, incoming radiation of energy E ($\doteq E_2 - E_1$) impinges on the excited atoms, triggering some of them to fall to level E1, thus emitting radiation also, of course, of energy E. The incoming radiation continues on its way, augmented by the stimulated radiation, and goes on to trigger the emission of more radiation of energy E, thus producing an 'avalanche' effect.

The result is that the small incoming radiation is considerably amplified, and the output radiation - which is all in phase and of the same frequency – is coherent microwave energy (or coherent

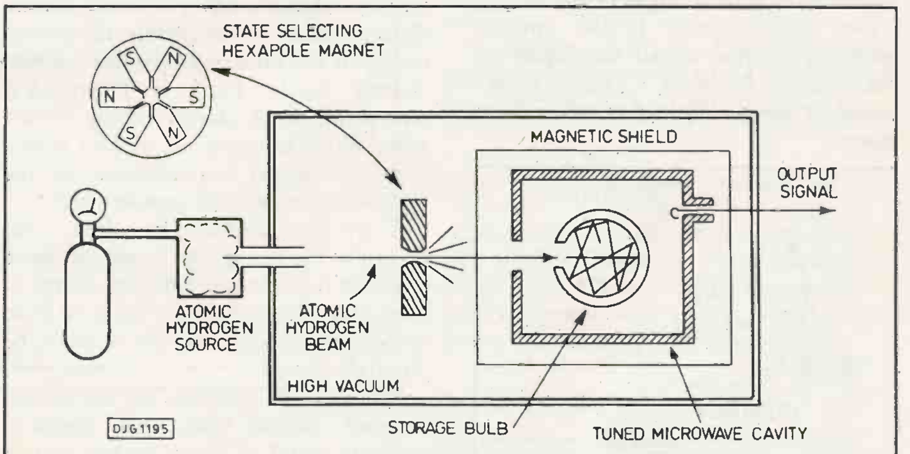
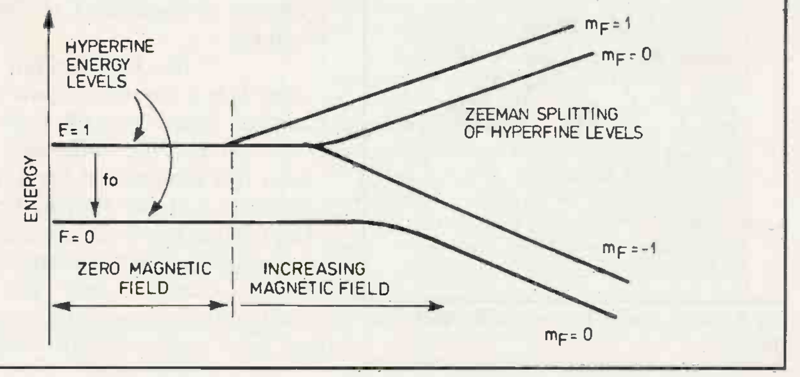



**Fig.7a.** *(above) Simplified arrangement of hydrogen maser.*
**Fig.7b.** *(below) Energy levels of hydrogen atom.*



light in the case of the laser).

We are not, of course, getting 'something for nothing', since we must continually provide 'pumping' energy to maintain the population inversion.

**THE HYDROGEN MASER**

Such, then, are the amplifying qualities of the maser, but how can we make use of maser principles to create a high accuracy oscillator? This can be explained by referring to the hydrogen maser shown in Fig.7a.

Fig.7b shows the ground state hyperfine energy levels for hydrogen; we see that the energy of the two upper states, denoted [F=1, $m_F$=0] and [F=1, $m_F$=1], *increases* in the presence of an external magnetic field, whereas the energy of the lower states, namely [F=1, $m_F$=-1] and [F=0, $m_F$=0], *decreases*.

Consequently, the hexapole field of the state selection magnet focuses the upper state atoms into the storage bulb, while the lower states are deflected away. This results in a population inversion within the storage bulb, since it becomes populated only with atoms in states [F = 1, $m_F$ = 0] and [F = 1, $m_F$ = 1]

Now, when atoms in the [F = 1, $m_F$ = 0] level relax down to the [F = 0, $m_F$ = 0] state, the hyperfine transition radiates energy at the frequency of $f_o$=1,420,405,751.778Hz: this is the desired output frequency. However, it is also possible for atoms in the [F = 1, $m_F$ = 1] level to relax and emit unwanted radiation; consequently, the storage bulb is placed inside a microwave cavity whose dimensions are precisely set such that it is 'tuned' to the required transition frequency, thus discouraging unwanted emissions. The storage bulb is necessary to hold the atoms long enough to ensure maser operation begins. The walls of the bulb are coated with Teflon to minimise the disturbances caused by the many thousands of collisions each atom makes with the bulb walls.

The atoms are held for around a second, or so; during this time, they relax, giving up their energy to the microwave field in the cavity. This field stimulates more atoms to relax, increasing the radiation until steady state maser operation is established. The output signal is coupled from the cavity by a small wire loop immersed in the microwave field.

So much for the impressive theory of the hydrogen maser, but just how sophisticated is the practical device? Well, the maser is accurate to at least 1 part in $10^{12}$, and has an incredibly high Q-factor of around two thousand million - a thousand times greater than the best quartz crystals! This leads to a stability of better than 1 part in $10^{12}$ per year – thus, a hydrogen maser atomic clock will have drifted by less than one pico-second after running for a year.

However, the operation and environment of the maser must be carefully controlled if this degree of excellence is to be maintained.

For example, the system must be enclosed in a vacuum to prevent contamination of the storage bulb, and the microwave cavity must also be evacuated to prevent atmospheric disturbance of the tuning.

External magnetic fields can also cause problems, since the transition frequency has a quadratic field dependence, and the exact frequency is given by:

$$f = (f_o + 2750 \times 10^8 \times B^2) = (1{,}420{,}405{,}751.778 + 2750 \times 10^8 \times B^2)\ \text{Hz.},$$

where B is the external flux density in Tesla. Since the earth's magnetic field is around 50µT, this is enough to cause a frequency deviation as large as 690Hz. Fortunately, the effects of external fields can be minimised by the use of concentric shields surrounding the microwave cavity. PE

**Next month we take a look at Rubidium resonators.**

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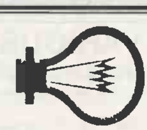

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# PATCHING THE BODY

BY TOM IVALL

## AUTO RESPONSE IS NO KNEE-JERK

*Medicine is leaving behind wooden legs and iron lungs, and learning to connect the body's own electrical system in to its artificial parts – like a telephone exchange.*

When I went into hospital for an operation recently, one of the questions fired at me by the reception nurse from a long list was: "Have you any spare parts?"

I was tempted to reply "No, sorry, I need them all" but decided that any deliberate misunderstanding for the sake of humour was probably not very wise on the run-up to major surgery. Of course I realized that she was actually referring to things like artificial limbs and heart valves. But the routine nature of the enquiry made me fully aware that repairs to the human body using man-made devices – prostheses as they're known in the trade – are now a well-established service available to Homo sapiens.

It goes without saying that electronics is playing an increasingly important role here. Probably as may PE readers know about heart pacemakers as are aware of artificial hip joints. Perhaps less familiar among the mechanical prostheses are artificial ligaments, tendons, knee joints, sphincter muscles, blood vessels and larynxes. For cosmetic purposes, silicone rubber is used to replace tissue which has been lost through injury or surgery. The man-made implantable heart will probably follow the biological transplant but is still at the research stage.

Some of these mechanical devices are already being controlled through electronic systems, when control of movement is needed. For example, artificial hands and forearms can be actuated at will by byoelectric potentials picked up by electrodes from muscles which remain. The user learns to generate these biological control signals from the muscle fibres by making suitable movements.

Feedback or closed-loop control systems – which already exist in natural form in the physiology of animals and humans – are most valuable for prosthetic devices. Their essence, of course, is to monitor what is actually happening and compare it with what is wanted, in order to produce a difference or error signal that shows what has still to be done. Thus, in some devices developed at Bath University to enable leg-paralysed patients (paraplegics) to stand up or perhaps even walk a little, the bending angles of the two knees are continuously measured by potentiometers mounted on callipers to provide the 'actual-position' electrical feedback signals.

Where electronics really shows to advantage in prosthetic devices is, of course, in relation to the electrical activity of the human body. This is centred in the nerve cells – in both the central nervous system of the brain and spinal cord and the peripheral nervous system with its sensory and motor nerves.

The complex electrochemical processes of nerve fibres convey physiological signals as 'travelling reversals' of the polarisation that exists between the inside and outside of the fibres. Each temporary depolarisation, which is automatically repaired a millisecond or so afterwards, can be detected as an electrical impulse or 'action potential'. Whole sequences of these events travel along the nerve fibres and can be picked up as pulse trains by electrodes.

So electronic devices can detect, amplify, process and transmit these nerve signals. But they can also generate them artificially to feed into nerve fibres which are not receiving their normal input of natural impulses because of some injury or disease. This is called functional electrical stimulation and is mostly applied to the motor nerve fibres, which cause muscles to contract and so produce movement. The surgically implanted heart pacemaker, which helps the heart muscle to function properly, is a good example of this.

Implanted stimulators, of course, owe a great deal to the miniaturisation and low power consumption made possible by microelectronics technology. But the designers and manufacturers of these implants have to take an immense amount of trouble to ensure that they will work reliably in the most hostile environment imaginable for electrical devices. Inside the human body is, of course, wet, warm, salty and continually shifting about.

I've been able to learn a good deal about one particular implanted stimulator from its designer and a user. This implant, developed by the Medical Research Council's Neurological Prosthesis Unit and made by Finetech (Engineering) Ltd, allows the patient to stimulate at will certain motor nerve fibres. These have lost their normal input of actin potentials from the central nervous system as a result of injury or disease.

One application is to help the patient to breathe. Because of the loss of motor nerve function – which normally makes the respiratory muscles contract and expand automatically in a regular cycle – the patient often has to live inside a respirator or 'iron lung' in order to breathe properly. An implanted stimulator sending appropriate impulses into the respiratory muscles makes this unnecessary.

A more widespread use for the same implant is to allow paraplegic patients to urinate when they wish to. Usually a serious injury to the spinal cord causes all muscles in the lower part of the body to go out of action, including those of the bladder. Before the implant technique became available, dealing with urinary problems was uncomfortable and unpleasant for the patient. What the implanted stimulator does is to send impulses to the muscle which compresses the bladder to empty it and also to the sphincter muscle which opens to allow an outflow of urine – all under control of the patient.

To activate the stimulator, which is surgically implanted under the skin in the lower front chest wall, the patient switches on a small, external, hand-held unit and places it over the implant. This unit generates the necessary pulses, which modulate an rf oscillator. The rf power is transmitted by inductive coupling through the patient's clothing and skin to a miniature receiver in the implant. As this receiver is a simple passive circuit (basically a tuned coil and diode detector) – it needs no other power to operate it.

In the implant, the received rf pulses are demodulated into dc pulses and then carried by an implanted flexible cable to the stimulating electrodes. These electrodes are attached to the roots of the motor nerves concerned, which are actually inside the spinal cord – an extremely delicate operation for the surgeon to perform.

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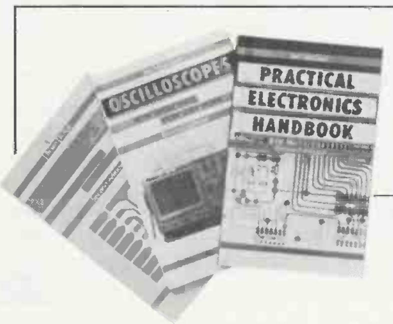


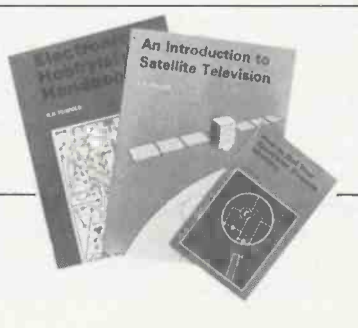


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**R.A.Penfold. 160 pages. £5.95.**
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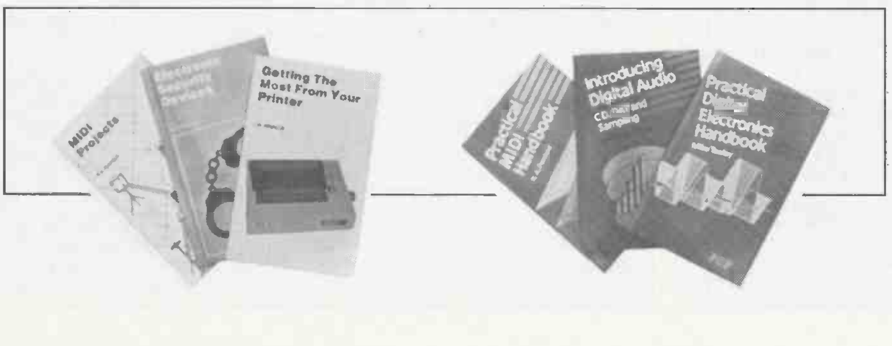


## DATA AND INFORMATION BOOKS

**Digital IC Equivalents and Pin Connections**
**A.Michaels. 320 pages. £5.95.**
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**Linear IC Equivalents and Pin Connections**
**A.Michaels. 256 pages. £5.95.**
**Order Code BP141**
Between them these two books show equivalents and pin connections of a popular user-orientated selection of European, American and Japanese ics. They also include details of functions, manufacturer and country of origin. The Digital ICs book also quotes details of packaging and families.

**Opamps**
**B.Dance. £6.50.**
**Order CodeNT2**
Subtitled 'Their Principles and Applications' this interesting book is written in a simple non-mathematical style and provides a source of practical circuits that use both commonplace and more sophisticated opamps.

**Electronic Hobbyists Handbook**
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Provides a source of useful information that the amateur enthusiast is likely to need for day-to-day pursuance of hobby electronics.

**Practical Electronics Handbook**
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**Newnes Electronics Pocket Book**
**I.E.Parr. £6.95.**
**Order Code NT10**
Presents all aspects of modern electronics in a readable and largely non-mathematical style, and is a good source of valuable information for enthusiasts and professional engineers alike.

**NEW Key Techniques for Circuit Design**
**G.C. Loveday. £6.95.**
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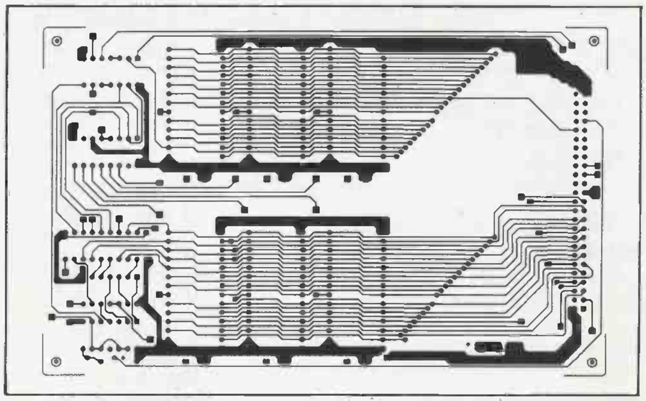

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# ED'S CRYSTAL TV WINNERS!

*At last it can be revealed - the hat-drawn triumphant three who have each won a superb Ferguson PTV01 pocket-sized LCD TV!*

STEPHEN HORAN of HELENSBURGH
KAMELESH PATEL of WEMBLEY
JAMES DAVIDof UPMINSTER

## Congratulations folks!

And best wishes plus twelve month's free subscription to PE go to the three runners-up: Alex Shepherd of BFPO 49, Keith Robins of Lanarkshire, and V.H.Thomas of Ipswich.

The correct answers I was looking for to the first eight questions were in order of: Capacitance, Battery, Microprocessor, Farad, Henry, Chip, Resistance, Impedance. The next two answers I wanted were: Practical Electronics (or PE) and Ferguson.

### FACTS AND FIGURES

85% of you had all ten correct answers. 4.6% swapped Impedance and Resistance. Three people swapped Watts and Henry. One person swapped Henry and Ferguson. Two people can't spell Chip and wrote Substrate, and one wrote Load instead of Resistor. (How on Earth could these last three do that? I gave the words I wanted in the instructions!) One person was almost totally all at sea giving the answers in order of F, B, M, H, I, Chip, Cap, Res. No-one got battery wrong!

All except three people knew that PE was the answer to Q9. One of these said "Your Computer", two gave no answer at all, how odd. Q10 got a wide variety of answers - 29 other companies were stated instead of Ferguson, the most common being Thorn/EMI, IEEE and Amstrad. Some people gave PE or Intra Press as the answer. However meritorious these other answers to Q10, it was Ferguson I wanted quoted - after all it was with their kind help that we were offering the lcd tvs!

### COMPUTER FACTS

86% of PE readers own or have access to computers. In order of manufacturer, readers' preferences are: BBC 23%, Sinclair 20%, Amstrad 17%, Commodore and IBM tie at 13% each, Atari 4%, Apple 2%. A wide range other names make up the balance. Nearly 200 varieties of computer were quoted. 1% were home-made. 14% of you use two computers, 4.5% use 3, 2.5% use 4, 0.8% use 5, 0.2% use 6, the balance use only one.


86% of readers know how to write programs to lesser and greater degrees of expertise. (It's coincidence that 86% use computers - some know a language without having access to a computer, others use them without programming knowledge.) 81% know Basic, 24% are familiar with several varieties of machine code, 17% know Pascal, 10% Fortran, 6.5% "C", 4% Forth, 2.5% Cobol, 2.5% Logo. A large array of other dialects was quoted, though none of these showed significant statistical merit. Interestingly, a fair number of you consider that knowledge of system protocols and custom software qualifies as programming language knowledge.

### LINGUISTICS

Although 44% of you know only one language, some of you are really multilingual. 22% know 2, 11% know 3, 5% know 4, 1% know 6, 0.6% know 7. One person says he knows 10. Another claims knowledge of all programming languages; if he's including all 60 variations the rest of you quoted, he's amazing!

Also interesting is that a few of you sent in more than one entry form, usually on different dates. Nothing wrong with that, I didn't say you couldn't - it certainly shows enthusiasm and there were not enough to upset the statistics. I noted many regular entrants, and previous winners - hi folks!

Thanks for telling me some fascinating and useful facts. We'll be having another competition in our May 89 issue, and shall also be asking for more opinions and statistics.

## WATCH OUT!

For another fabulous competition in our May issue with Shaye portable phones as the main prize!

## INDEX TO ADVERTISERS



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Evening on the planet Oldana, as the Maplin Juggertrain thunders along the highway; captured on canvas by galaxy famous artist Lionel Jeans and featured on the cover of the new Maplin Catalogue.