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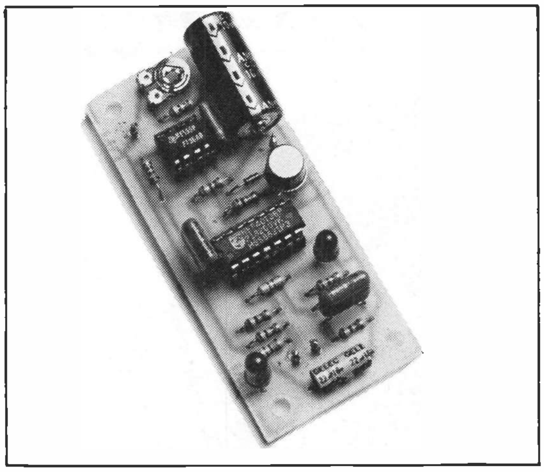
THE SCIENCE MAGAZINE
FOR SERIOUS ELECTRONICS AND COMPUTER ENTHUSIASTS

# PRACTICAL ELECTRONICS

**PE VOL 23 NO 11** **NOVEMBER 1987**

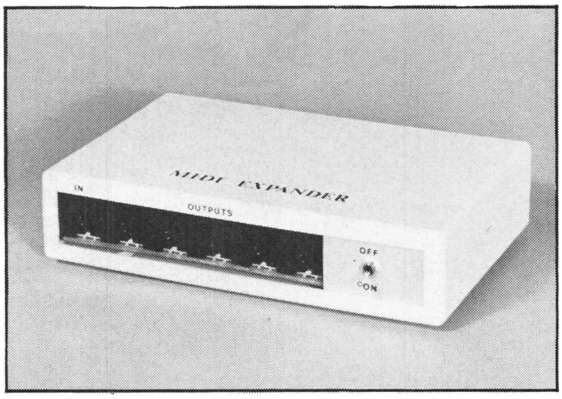



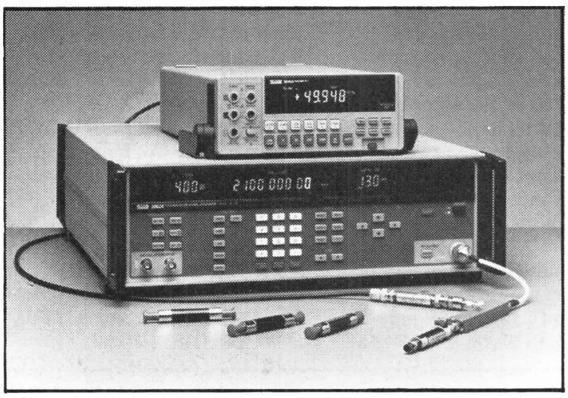
## CONSTRUCTIONAL PROJECTS



## SPECIAL FEATURES





## REGULAR FEATURES



## NEXT MONTH . . .

**RADIO RECEIVER – ANOTHER GCSE PROJECT IDEA • MULTIZONE BURGLAR ALARM • RS232C TO MIDI CONVERTER • SEMICONDUCTOR TECHNOLOGY • CODED LOCK TECHNIQUES • APPLIANCE TIMER • TELEPHONES ANCIENT AND MODERN • SOLAR CELLS •**
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**THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS ENTHUSIASTS**

## CATALOGUE CASEBOOK


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

**Bulgin.** 272 pages of electrical and electromechanical components are featured in the comprehensive new **catalogue for design engineers** and buyers. Marketing Dept, **AF Bulgin & Co PLC,** Bypass Road, Barking, Essex, IG11 0AZ. 01 594 5588.

**Electromail.** Full catalogue of the **entire range available** from the hobbyist relative of RS Components. **Electromail,** PO Box 33, Birchington, Corby, Northants, NN17 9EL. 0536 20455.

**Feedback Instruments'** new 12 page colour catalogue features the product supplied by their recently formed **test and measurement** division. **Feedback Instruments,** Park Road, Crowborough, East Sussex, TN6 2QR. 08926 3322.

**IEEIE.** Compendium of Active Devices — a technical monograph containing concise **definitions of the terminology** and acronyms used in semiconductor technologies. £4.95 each incl p&p from Institution of Electrical and Electronics Incorporated Engineers. **IEEIE,** Savoy Hill House, Savoy Hill, London, WC2R 0BS. 01-836-3357.

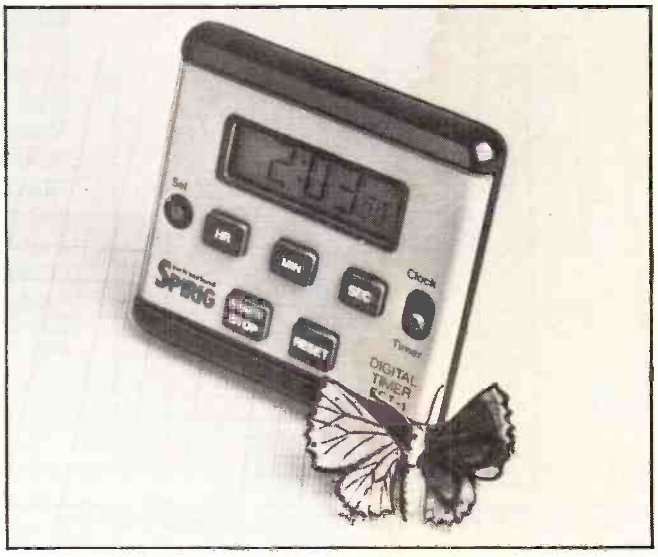
**Heinemann Professional and Technical Publishing.** Complete 1987 catalogue of **new and current books,** including electrical and electronic engineering. **Same address as Made Simple books.**

**Made Simple Books.** Complete 1987–1988 catalogue of **books for many subjects,** including electronics and computing. **William Heinemann Ltd,** Dept MS-87, Freepost 10, London W1E 7YZ.

**Maplin 1987 buyer's guide** to electronic components. Nearly **500 pages of electronic components,** equipment, data and books. £1.50 from booksellers or £1.50 + 40 p&p from **Maplin Electronic Supplies Ltd,** PO Box 3, Rayleigh, Essex, SS6 8LR. 0702 554161.

**STC Mercator.** 335 page colour catalogue of components, soldering equipment and speech systems, with **specifications and technical diagrams** for designers. **STC Mercator,** South Denes, Great Yarmouth, Norwich, NR30 3BR. 0493 844911.

# WHAT'S NEW




### Slim Time

No strenuous exercises to set time into shape with the new ECT-1 timer from Cobonic.

Chronology and technology have been neatly combined into this slim time piece that incorporates a true stop-watch function, a clock, a countdown and countup timer, and an alarm. Measuring just 6.4 × 6 × 1.2 cm, the timer can be slipped into a pocket, set upright on its integral stand, clipped to a pad, or magnetically attached to a suitable surface. The liquid crystal display shows hours, minutes and flashing seconds. Normal clock display is independent of the stopwatch and timer circuits, with a switch to select between the two, so once the timer has been started, it can continue uninterrupted even when the clock display is selected.

The countdown timer can be set for any period between 1 second and 23 hours 59 mins 59 secs, with an alarm sounding at the end of the timed period. Since the alarm duration is limited to 60 seconds, battery power consumption is minimised. The last time interval used remains automatically in the memory so identical time settings can be repeated without resetting the values already used. Another nice touch is the overtime display in the countdown mode, showing how much time has elapsed since the end of the preset period.

In the countup mode, start, stop and reset buttons allow the timer to be used as a stopwatch. The countup can be halted and restarted at any time without resetting to zero.

The normal list price is £17.50 plus VAT, but Cobonic (a Spirig company) are offering a special three months introductory 20% discount, bringing the price down to £14.00.

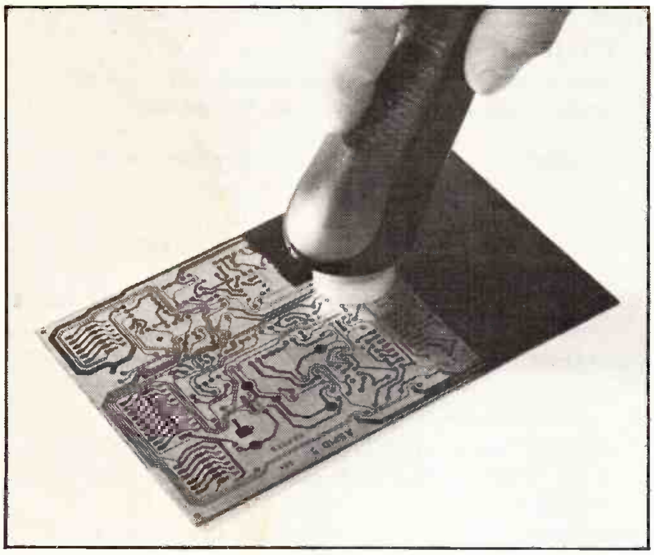
**For further information contact:** Cobonic Ltd, 32 Ludlow Road, Guildford, Surrey, GU2 5NW. Tel: 0483 505260.

### Taping Royalty

A home taping royalty of 10% will be added to the price of blank audio tapes, as part of a new copyright law, the United Kingdom government announced recently. The proceeds of the royalty will be distributed to the performers, composers and producers of sound recordings. The new legislation will be introduced during the 1987-88 session of Parliament.

Commenting on the move, Ian Thomas, IFPI's Director General said: "As the international organisation of the recording industry, IFPI welcomes the British government's firm commitment to copyright reform and in particular its proposal to deal with the home taping problem. Although a royalty does not represent a totally satisfactory solution to the problem of private copying, such a move will bring the United Kingdom into line with the majority of its EEC partners. Three member states (France, Germany, Portugal) already have such a royalty while bills have been introduced in the Parliaments of Spain, Belguim and Italy, and the Dutch government has announced its intention to provide a private copying royalty."

IFPI, The International Federation of Phonogram and Video Producers, are at 54 Regent Street, London W1R 5PJ. Tel: 01-434-3521.



## Low-Cost PCB System

MEGA Electronics have announced the introduction of a comprehensive but low-cost system for the prototyping of printed circuit boards.

This system, the SENO Workstation, is simple to use, yet embodies all of the components required for the design and production of high-quality printed circuit boards. Moreover, it utilises chemicals which are completely safe, and which may be disposed of by conventional means.

Priced at only £45, the SENO Workstation contains every essential element for PCB prototyping. It includes artwork materials for PCB design and circuit layout; PCB laminate materials; cleaning block; spraywash facilities, which obviate the need for mains water; an environmentally-safe board etching system, and chemicals which are contained in unique, simple to use disposable applicators. Moreover, the chemicals are themselves non-hazardous and non-toxic, and do not require special disposal procedures or precautions. The applicators have been especially developed to simplify the use of these chemicals and to remove problems associated with their disposal.

Mega Electronics Ltd. is a principal manufacturer and distributor of equipment and materials used in the design and production of printed circuit boards, signs and labels.

**For further information contact: Mega Electronics Ltd, 9 Radwinter Road, Saffron Walden, Essex, CB11 3HU. Tel: 0799 21918.**

## Maplin Market Heath Kit

NEW HEATHKIT products featured in "The 1987 Maplin Buyer's Guide to Electronic Components" include the Novice CWTransceiver HW-99, VLF Converter HD-1420, Audio Filter HD-1418 and a DTMF DTMF Decoder HD-1530.

Also new to the Maplin range are the Heathkit HI-Fi and Hobby kits. These include an Audio Amp Starter Kit SK-104, a 1-watt Audio Amplifier at only £14.95. A Pseudo-Stereo Starter Kit SK-107 is designed to convert a mono tv input from a video into two different channels for synthesised stereo. £16.95.

The Heathkit range of educational courses and products are well established and are available on a wide range of computing and electronic subjects.

**Contact: Maplin Electronics Supplies Ltd, P.O.Box 3, Rayleigh, Essex, SS6 8LR. Tel: 0702 552911.**

## Broader Crotech Scope

TWO precision ancilliary amplifiers, the Crotech Waugh UA1 and 1A1, extend an oscilloscope's voltage range from as low as 100$\mu$V up to 1.5kV.

Now available from Electronic and Computer Workshop (ECW), the UA1 is a micro pre-amplifier that has a wide bandwidth from d.c. to 2MHz and allows oscilloscope users to extend the switched sensitivity down the the microvolt level. This is a very useful accessory for working with sensor outputs and other low-level analogue signals. Supplied with batteries, the UA1 is offered by ECW at a price of £179.40.

The amplifier can be used with virtually any type of oscilloscope requiring extension of the input voltage range.

**Contact: Electronic and Computer Workshop Ltd, 171 Broomfield Road, Chelmsford, Essex, CM1 1RY. Tel: 0245 262149**

## Amstrad Programmable Interface

THE PC-14 programmable interface card for the Amstrad PC 1512, IBM PC or other compatible personal computers provides up to 48 input or output TTL lines and three independent 16-bit counter/timers on a single card. Applications include use as a plotter, printer or other bcd/binary interface, to provide programmable delays as a real time clock, to count events or to control machine tools.

Each 8 or 4 bit digital port may be configured as input or output under software control and operate bi-directional, uni-directional or to provide interrupt or handshake signals. The three independent counter/timers may be programmed as event counters, single shot pulse counters, rate generators or as hardware or software triggered strobes.

The PC-14, priced at £54, is one of 38 economically-priced industrial boards available on same day despatch from **Amplicon Liveline Limited who may be telephoned free on 0800 525 335.**

## Flat pack racks

Eminence Audio Ltd have recently put onto the market a range of good quality self-assembly 19in rack mounting equipment cases and cabinets, known as Rackz. These are sold as flat pack kits.

The equipment cases have a black anodised 3mm aluminium front panel, with the rest of the case constructed from .7mm and .9mm 'Stelvetite' PCV-coated steel, with front panel handles and rubber feet supplied. Equipment cases are available in 44mm, 88mm, 132mm and 176mm heights, all 438mm wide, 254mm deep and with 482 (19in) front panels. Current prices are £19.41, £22.58, £25.16 and £28.08 respectively.

**For more information contact: Eminence Audio Ltd, Combe House, Stoke St. Michael, Bath, Somerset BA3 5HN. Tel: (0749) 840102.**

## Binatone's White Knight

BINATONE International Limited, the UK's largest privately owned consumer electronics company, is introducing a new white-fronted version of their hugely successful midi system – the Midi 40.

The new Midi 40 has all the features offered on the original design, including: 5 band graphic equaliser, 3 band MW/LW/VHF-FM stereo tuner, 20 watts Total Peak Music Power, stereo headphone and stereo mic sockets, matching full range speakers, compatibility to CD units.

Binatone firmly believe that the new white-fronted Midi 40 will pioneer this new fashion-styling direction. The retail price is around £129.99.

**Contact: Sue Morris, Morris Media, London House, 26-40 Kensington High St, London W8. Tel: 01-938 2222.**

## COUNTDOWN

*If you are organising any electronic, computing, electrical, scientific or radio event, big or small, drop us a line. We shall be glad to include it here.*

*PLEASE NOTE: Some events listed here may be trade only, or restricted to certain categories of visitor. Also, please check dates, times and other relevant details with the organisers before setting out as we cannot guarantee information accuracy.*

**Autumn Course** on The Art of Hi Fi. For 10 weeks from Sept 28th 1987. Charles Keene College of Further Education, Leicester. 0533 516037.

**Oct 6-8.** Internepcon Packaging Show. Metropole Convention Centre, Brighton. 01-891-5051.

**Oct 13-15.** British Laboratory Week '87. Grand Hall, Olympia, London. 0799-26699.

**Oct 20-22.** International Test & Transducer Exhibition. Wembley Conference Centre. 0822-4671.

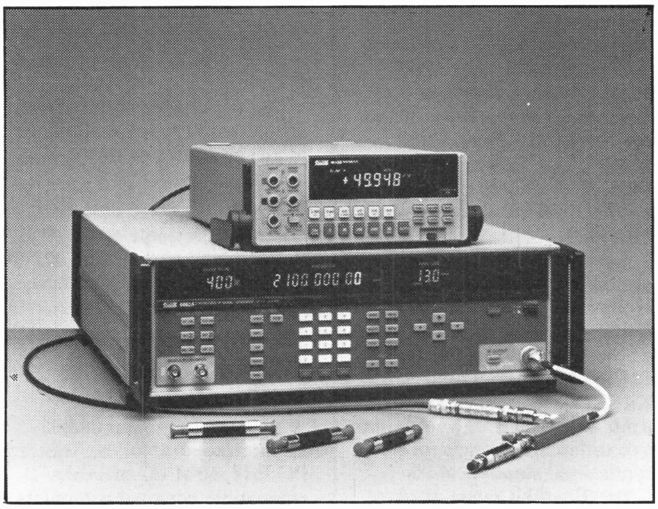
**Oct 20-22.** Testmex. Business Design Centre, Islington, 0799-26699.

**Nov 3-5.** Custom Electronics and Design Techniques Show. Heathrow Penta. 0799-26699.

**Nov 3-Dec 10.** Research and Development Society Silver Jubilee Exhibition. The Design Centre. London. 01-235-6111.

**Nov 5-8.** Reproduced Sound Conference – IOA. Windermere Hydro Hotel. 031-225-2143.

**Nov 19-20.** Desktop Publishing. Cumberland Hotel, London. 01-871 2546.



### Synthesised Fluke Gen

FLUKE announces the introduction of the 6062A Synthesized Signal Generator, with extended frequency generation capabilities from 0.1MHz right up to 2.1GHz. In addition, the 6062A incorporates a high-performance pulse modulator which uses gallium arsenide switch technology to achieve rise/fall times of 15nS and on/off ratios of 80dB. The 6062A is designed for L-band testing applications in avionics, communications and navigation.

Specific applications include secondary surveillance radar, IFF, Microwavelinks, Global positioning systems and satellite communications. The 6062A brings extended frequency to Fluke's family of high performance, low-cost signal generators and complements the performance of their general purpose 6060B and the low noise 6061A models, both of which operate to 1.05GHz. The 6062A's output level is adjustable over the range of +16 to −137dBm to 1050MHz, and +13 to −137dBm to 2100MHz. Absolute accuracy is ±1.5dB. Amplitude can be displayed in volts, dBm, dB, $\mu$V, or relative to any specified reference.

It also increases the modulation capabilities of the 6060 line with FM deviations to 400kHz, and added phase modulation. The pulse modulation on the 6062A has the high on/off ratio (80dB minimum) that is need for radar simulation. Fast rise and fall times permit quality pulses of less than 50nS duration.

The low noise capabilities of the 6061A are incorporated in the new 6062A. Residual FM is guaranteed to be less than 6Hz (0.3 to 3kHz) in the frequency range of 245 to 512MHz (typically less than 4Hz rms). Non-harmonic spurious products are less than −60dBc to 1050MHz, −54dBc to 2100MHz, with −123dBc typical SSB phase noise 20kHz offset from a 500MHz carrier frequency.

Other standard features on the 6062A include: AM, FM and phase modulation, AC/DC-coupled AM, full talk-listen IEEE 488 interface, 400kHz FM deviation on 1050 to 2100MHz range, relative frequency and amplitude modes, "Step" programmings and "Bright-Digit" editing, 50 location non-volatile memory, 25 watt reverse power protection, sub-harmonic external reference, low microphones due to robust construction, self-diagnostics.

**Contact: Fluke (GB) Ltd., Colonial Way, Watford, Herts, WD2 4TT. Tel: 0923 40511.**

## CHIP COUNT!

***This month's list of new component details received — mainly chips, but other items may be included.***

**HA11505.** Two channel, wide frequency band (100MHz) video amplifier-multiplexer simplifying video signal mixing (HT).

**HD6314.** Intelligent peripheral controller that dramatically increases a system's efficiency. Includes a 10-bit A-D converter, 1K of SRAM and a Watchdog timer. (HT).

**LM107L.** Compact LCD display module using a new construction system for greater efficiency (45%) of the total external PCB area (HT).

**MC3361.** Signal processor for improved performance from cordless telephones and mobile radios up to 60MHz (ML).

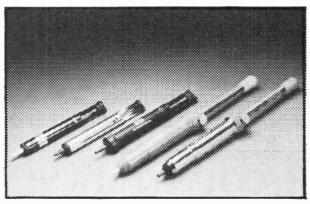
**NE5050.** Power line modem capable of listening to the line to detect broadcasts from remote transmitters and also to verify its own transmissions (ML).

**SAA3009 & SAA3049.** Decoders for infrared remote control systems (ML).

**SCC53484.** Advanced CRT controller for graphics and characters with maximum resolution of 4096 × 4096 pixels in monochrome (ML).

**TC11000 J10.** One megabit DRAM for surface mounting (TS).

**Manufacturers, and contact telephone numbers for further details.** (HT) Hitachi. 0923 246488. (ML) Mullard. 01 580 6633. (TS) Toshiba. 0279 442971.



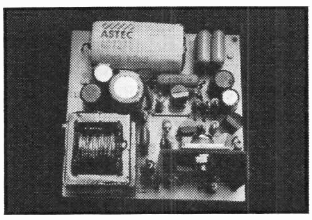
### Desolder Pumps

OK Industries now have a range of desolder pumps which they claim are suited all applications and competitively priced at between £3.75 and £25.32. Model DP-1 offers full industrial performance and self cleans on each stroke. Its anti-static variant, the DP-2, is conductive through the full length of the tool making it suitable for removing sensitive CMOS components.

DP-3 is a low cost static-free unit manufactured in accordance with UK and MIL standards to satisfy MIL/8/881705 2nd barrier electrostatic free material requirements. Designed for high precision work and engineered to provide precise, repeatable operation, DP-4 has corrosion-resistant parts. Its anti-static variant is the DP-5.

The SA6-VDE is a VDE approved electric desoldering iron combining the ease and portability of a hand-held pump with the performance of an industrial desoldering station. It is available for mains or 24V operation.

**Contact:** OK Industries UK Ltd., Barton Farm Industrial Estate, Chickenhall Lane, Eastleigh, Hants, SO5 5RR. Tel: 0703 619841.



### Astec SMPSU

GREENWELD Electronics have produced a very neat switched mode power supply on a pcb just 50mm square. Called the Astec AA7271, it will accept inputs up to 24V dc, and give a stable 5V dc output at up to 2 amps. The six transistor circuit provides current overload protection, thermal cutout, and excellent filtering.

It is offered at the remarkably low price of just £5.00 including VAT and postage.

**Contact:** Greenweld Electronic Components, 443 Millbrook Road, Southampton, SO1 0HX. Tel: 0703 772501.

### Desktop Laser Printer

NCR Limited has announced its first desktop laser printer, the NCR 6416. Users of NCR's Tower, Personal Computer and WorkSaver systems can now obtain up to eight pages per minute of high quality text and graphics reproduction from this quiet, compact and versatile printer.

The NCR 6416, which can provide letter-quality print on ordinary cut-sheet paper, combines electrophotography, electronics and semiconductor laser technologies. It is duty-rated at up to 3,000 pages per month, and its combination of 55dBA noise level and high print quality makes it ideal for applications such as desktop publishing in office environments.

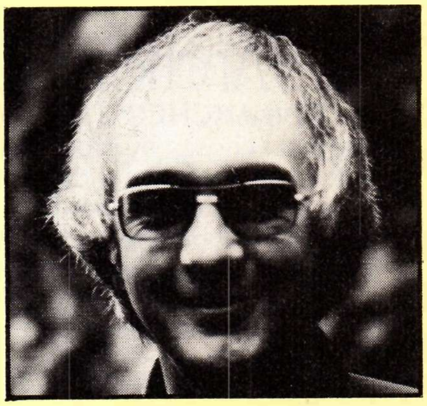
The lightweight and compact NCR 6416 will print on letter, legal, A4 and B5 paper and envelopes. It offers four typefaces as standard – Courier 10 with Italic, Boldface and Super/Script – with a wide selection of font cartridges such as Pica and Elite, landscape and portrait if required.

The NCR 6416 laser printer is available for immediate delivery and will cost approximately £2,700.

**For more information please contact:** Matthew Spencer, NCR Limited Tel: 01-725 8337.

# THE LEADING EDGE

BY BARRY FOX



## Blurred women crack up on TV

*Low standards lead to crummy conversions. Digital methods offer a better way, but will they get the opportunity?*

It seems that the Great British Public does care about the quality of TV pictures, after all. The BBC had to contend with a deluge of complaints about *Dallas*.

Most glossy TV programmes from Hollywood are shot on 35 mm film, and edited on film, like a cinema feature. So until last year, *Dallas* episodes were being flown over to Britain as cans of 35 mm film.

Then things changed, for the worse. Although Hollywood still shoots *Dallas* on 35 mm film, it is now transfered from film to videotape. The tape is of 525 line, 30 picture frames per second NTSC format. The conversion from 24 fps film is tricky because 6 frames a second must be reconstituted from thin air.

To save time and money on *Dallas* the film is never edited. All editing is on the video tape. When finished, each taped episode is shown on American TV at 30 pictures a second. The tapes are also converted to the 625 line, 25Hz PAL format needed for Britain and most of Europe. For every picture 100 lines must be conjured from nothing and every second 5 pictures must be discarded.

That's why the pictures are so poor. Nothing looks crisp and clear. The opening credit title sequence judders. Anything that moves, blurs.

The BBC has its own standards converters which can perform fine tricks on 525 line, 30Hz tapes. But in the case of *Dallas* the BBC gets rolls of tape, already converted and already spoiled.

You see the effect of poor standards conversion on other imported soaps. One of the worst was *Golden Girls* on Channel 4. Lower budget programmes like this are not shot on film. They go straight to video in the 525 line, 30 Hz NTSC format. The tables then have to be converted for showing in 625 line, 24 Hz Britain. Poor conversion makes faces look artificially smooth, like plastic, while the actresses are talking; then when they stop, and the conversion circuitry is working on the stationary detail, the faces briefly show facial lines and hairline detail. It's very, very disturbing once you have noticed the effect.

British company AVS of Chessington in Surrey is selling a new standards converter called ADAC, Advanced Digital Adaptive Converter, which combines video and computer technology. Talking of *Dallas*, AVS says ADAC could "definitely do the job better".

Although the US and Japan uses 525 lines per picture, and 30 pictures a second, and Europe uses 625 line, and 25 pictures, both systems have one thing in common. Each full picture "frame" is made up from 2 interlaced half pictures or "fields".

In all standards converters the incoming picture signal is converted into digital code. The code for at least 2 fields is stored in a solid state memory and averaged, so that 100 lines and 10 fields a second can either be discarded or created.

The AVS Advanced Digital Adaptive Converter spreads the averaging much further and takes account of the fact that stationary objects in the picture do not suffer from smear or judder. A motion detector distinguishes moving parts of the picture from stationary parts, and applies different averaging techniques accordingly. The sensor analyses each individual pixel or picture point in each line of each picture. It then pulls an appropriate averaging algorithm out of pre-programmed memory and processes it in the best possible way.

Each TV picture is made from around 0.5 million pixels so the 16 bit computer processor inside ADAC must analyse and average nearly 15 million items of picture information every second.

The converter costs £80,000 or more, depending on features and facilities. That is the price the broadcast industry must pay if programmes imported from the US are to look good on British TV.

The use of processing equipment like this ties in with a revolution in the TV industry. More and more equipment now works in the digital domain. In fact the Independent Television Companies Association, ITCA, is currently spending £1m on practical research into the best way to convert British TV studios so that they can work with digital TV signals.

Thames now has the first control room in the world which can take live pictures from a TV studio and process them fully digitally. The French CCETT (Centrale Commune d'Etudes de Television et Telecommunication) has a rather similar test facility at Rennes, but it is working with tape-recorded signals.

There is now a world standard for digital video recording set by the European Broadcasting Union, EBU, Society of Motion Picture and Television Engineers, SMPTE, and International Radio Consultative Committee. The CCIR's Recommendation 601 specifies the digital coding format and the type of cassette to be used for recording TV signals digitally. US company Ampex, which invented video recording 30 years ago, has proposed a modified approach which costs less and triples recording time per cassette, but loses a little in picture quality. The EBU has objected to what it sees as de-standardisation by Ampex and the ITCA has decided against using Ampex technology. The Teddington studio has Sony digital video recorders which follow the CCIR 601 standard.

CCIR 601 is a "component" system. The raw red, green and blue signals which make up all TV pictures are combined to produce a black and white or 'luminance' sum signal and two colour or 'chroma' signals. The luminance signal is digitally sampled at 13.5MHz and each of the two chroma signals is sampled at half this rate, 6.75MHz. This gives a sampling ration of 4:2:2. Hence the 601 standard is often identified simply as 4:2:2. Each sample is digitally coded in an 8 bit word, to give a digital stream of 216 Mbits/s.

The standard digital video recording cassette is called D1, uses 19mm tape and comes in three sizes: small to offer up to 13 minutes playing time, medium for up to 41 minutes and large for up to 94 minutes. The recorder mechanism automatically adjusts to the cassette size.

The 216 Mbit/s signal is very difficult, and expensive, to record onto tape. This is why Ampex has suggested an alternative to component coding. The

**CONTINUED ON PAGE 56**

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**Cover Photo:**
Chris Bell

# *SECURITY*

*If there is any area of society where it is not true that security concerns us all, I have still not managed to think of it.*

*To most of us, probably security of property is the matter that first comes to mind. Can someone pinch the car; the video; the expensive trinkets; the souvenirs that span a lifetime? Yes they can, and they will given half a chance.*

*Even those who are not yet adult may have bikes, computers, books, even secrets, that need to be kept out of other's hands. On another level, shops, banks, club treasurers, need to be ever vigilant against theft of one sort or another.*

*Fortunately, electronics is well suited to the design of systems that can help to protect property. For example, Tim Pike in last month's issue described a simple method of using digital coding to produce an intruder resistant lock. Although the main intention of the design was to discuss electronics for GCSE courses, it has practical uses for almost anyone who needs to deter unauthorised entry.*

*Following on from this, much wider ranging aspects of protection are discussed by Bill Kent in the Intruder Alarm Controller project. In part one, an example of a simple burglar alarm is described, and is ideal for anyone with just a room, shed, or garage to protect. This too is a good project idea for anyone doing GCSE electronics.*

*Part two of the article, next month, extends the discussion and illustrates a far more complex security alarm controller that can be used in a multitude of applications, from house protection, to security for the elderly or sick.*

*Robert Penfold is also contributing a related article next month. In this he will take a broad look at how locks can be electronically controlled in ways other than digital, from frequency detection to infrared methods.*

*Between them, the three authors demonstrate the use of electronics for just some aspects of protection. It is an alarming fact though, that electronics is also the cause of the need for security. Insecurity of computerised data is frequently publicised.*

*Huge profits are lost annually through financial fraud aided by illegal entry to computerised data banks. More money is lost through the illegal copying and selling of copyright software and audio recordings. Unethical access to personal data files, though not theft in the same sense, is also misappropriation of electronically stored information.*

*Although legislation like the Data Protection Act, represents one way of strengthening security, electronic methods still seem to be best suited to combatting illegal use of electronic material.*

*However, human nature being what it is, there will always be someone wanting something free. All we can reasonably hope to achieve with any security system is that it is more intelligently designed than the system designed to counter it. We must be cleverer than the thief.*

**THE EDITOR**

**PLEASE NOTE OUR NEW ADDRESS**

**OUR DECEMBER 1987 ISSUE WILL BE ON SALE FRIDAY, NOVEMBER 6th 1987 (see page 2)**

# 01-208 1177 TECHNOMATIC LTD 01-208 1177

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Allows an easy method to reconfigure pin functions without rewiring the cable assay. Jumpers can be used and reused. £22 (d)

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### I.D. CONNECTORS

**(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 |
| Screw Lock | 130 | 150 | 175 | – |

### TEXTOOL ZIF

**SOCKETS**
24-pin £7.50
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40-pin £12:10

### EDGE CONNECTORS

| | 0 1 | 0 156 |
|---|---|---|
| 2 × 6-way (commodore) | – | 300p |
| 2 × 10 way | 150p | – |
| 2 × 12 way (vic 20) | – | 350p |
| 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 |
|---|---|---|
| 2 × 32 way St Pin | 230p | 275p |
| 2 × 32 way Ang Pin | 275p | 320p |
| 3 × 32 way St Pin | 260p | 300p |
| 3 × 32 way Ang Pin | 375p | 400p |
| IDC Skt A + B | 400p | |
| IDC Skt A + C | 400p | |

**For 2 × 32 way please specify spacing (A + B, A + C).**

### MISC CONNS

21 pin Scart Connector 200p
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36 way plug Centronics (solder **500p** (IDC) **475p**
36 way skt Centronics (solder) **550p** (IDC) **500p**
24 way plug IEEE (solder) **475p** (IDC) **475p**
24 way skt IEEE (solder) **500p** (IDC) **500p**
**PCB Mtg Skt Ang Pin**
24 way **700p** 36 way 750p

### GENDER CHANGERS

**25 way D type**

Male to Male £10
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(25 way D)

| | |
|---|---|
| 24" Single end Male | £5.00 |
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| 24" Male Female | £9.50 |

### DIL SWITCHES

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

**All prices in this double page advertisement are subject to change without notice.**
**ALL PRICES EXCLUDE VAT**
**Please add carriage 50p unless indicated as follows: (a) £8 (b) £2.50 (c) £1.50 (d) £1.00**

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*The old-fashioned burglar is a comic figure, but being burgled is far from funny. Here are described two control units, one simple, one sophisticated, which act as the heart of deterrent alarm systems. Arm with an alarm!*

# INTRUDER ALARM CONTROLLERS

**PART ONE BY BILL KENT**

## Detectors deter delinquents

Do you feel like a sitting duck? If your neighbours have intruder alarms, but you do not, it is likely your home will be burgled in preference to theirs.

We are all aware of the increase in the crime figures over the last few years. A high percentage of these crimes are casual burglaries, carried out against domestic premises. Frequently the thefts are by opportunist thieves on the look out for readily accessible properties. To this type of thief, a house, bungalow or flat that has an alarm bell showing is less of a good bet than one that does not. It is even widely believed that just the presence of a bell, even though it may not be connected to anything, represents a deterrent factor to the would-be burglar.

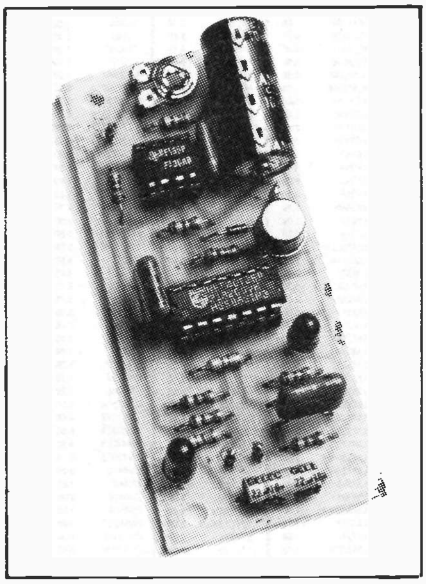
### SELF HELP

The police are notoriously undermanned, and are placing increasing emphasis on the need for the public also to take an active part in crime prevention. Such measures include the simple expedients of adding further locks to doors and windows, and the marking of property with the owner's postcode using non-erasable ultraviolet ink, or etching and engraving tools. The use of window stickers announcing the existence of marked items is recommended, as is photographing all belongings, especially the valuable bits and pieces. While these actions will not prevent theft, they act as a deterrent since it is less easy to dispose of readily indentifiable stolen property. The markings also help the police to return property to the owners if found.

The interest of the public in carrying out these simple and relatively inexpensive precautions is slowly being aroused, though it is still not as widespread as the police would prefer. Despite this, public interest shows itself in other ways, as the success of such TV programs as Crime Watch, and Police Five demonstrates.

### NEIGHBOURHOOD WATCH

The spread of neighbourhood watch schemes also illustrates how the public can be active in both crime detection



*The simple controller unit to be described in part one*

and prevention. Increasing numbers of these groups of concerned residents have been organised around the country. Figures announced at the time of writing (July 1987), state that over thirty thousand groups exist.

Many of them are probably extensions of the activities of existing residents' associations. In my own area, an association for about 200 houses had existed for many years, though few residents would normally attend the meetings. Yet, when the intention of setting up a watch scheme was announced, practically all households sent representatives to the discussion.

This was organised in conjunction with local police crime prevention officers, who lectured on various aspects of home sercurity, and how to operate the watch scheme. Essentially this is only a matter of neighbours looking out for each other's welfare, advising of prolonged absence, and generally watching for unusual activity by strangers, reporting this to the police if suspicions are aroused. Subsequently, around two thirds of the households joined the scheme, and over the last three years an encouraging reduction in crime on the estate has been experienced.

### ALARMING FACTORS

With improved awareness and active participation in preventing crime, the number of burglar alarms installed has also been increasing. It seems probable that the increase will snowball as more people realise that they are more likely to be burgled in preference to a neighbour who has a alarm.

The type of system installed will depend on the degree of risk that is felt. No system will prevent a determined burglar getting in, as recently reported high value thefts show. The more sophisticated the system though, the harder it is for it to be bypassed.

In assessing the quality of the system needed to offer reasonable protection, the two main factors to be considered are the value of the property to be protected, and the level of risk that already exists in the particular area. In assessing value, one significant factor is the degree of distress that a burglar might cause. Although value of the property owned may not be great in money terms, most people have items that have strong sentimental value, the loss of which can never be replaced. A large number of illegal entries also involve sheer vandalism with belongings being destroyed or disfigured for no sane reason. This can cause as much, if not more distress than simple theft.

Many companies supply and install burglar alarm systems of varying degress of sophistication. In my local area, some companies will install simple systems from as little as around three hundred pounds, up to several thousands of pounds. Considerable savings can be made though, by installing your own system from pre-assembled units that just need wiring together. Several companies offer these units, and installation is quite straight forward. The main cost, though, is in the master control unit, and if this can be built by oneself even greater savings can be made.

### PRACTICAL CONTROL

Two such control units will be described here, one very simple, and the other offering several levels of detection and alarm control. Both are intended for use with readily available low cost intruder detectors, bells, buzzers and flashers. The main unit has been designed in the light of my experience with several commercial units, some of which had a few shortcomings. Additionally, I referred to the British Standard recommendations for burglar alarms, and although I do not claim that the main unit conforms to BSI specifications, I am not aware that it contravenes them.

The primary requirements for a burglar alarm are that it should detect when premises have been entered, and sound an alarm in response. In principle, this can simply be achieved by having a switch connected to a bell and a battery (Fig.1a). If the switch S1 is closed, the bell will ring.

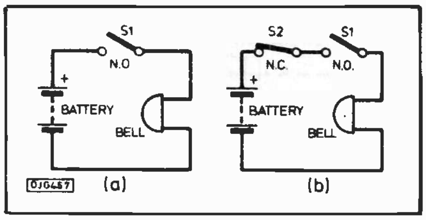



**Fig.1.**

With this system, the switch would be mounted on a relevent entry door in such a way that when the door was opened, the switch would be turned on, so ringing the bell. A simple release to make contact switch would do it.

This method has the obvious drawback that the bell will ring every time the door is open, and the door will need to be closed to stop it. A second switch S2, is thus needed to turn off the bell if the door needs to be opened legally, (Fig.1b), and should be capable of being operated only by an authorised person. This switch therefore would usually be operated by a key, though it could be of the type described by Tim Pike in the October issue of PE in the GCSE coded lock project.

In practice, it is desirable to invert the switching so that if the wire is cut through, this will also trigger the bell. Consequently the circuit should operate through a relay of some sort, with the relay contacts held open while the circuit is closed. Then, if the circuit is opened, the relay coil would cease conducting, causing the contacts to close, and so ring the bell (Fig.2).

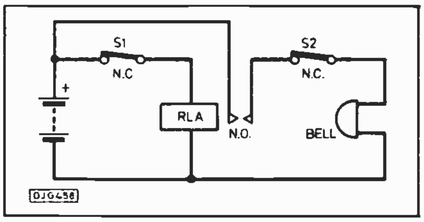



**Fig.2.**

The control switching should also prevent the door from being immediately reclosed to switch off the bell, so stopping a speedy burgular from entering and immediately switching the bell off. This means then, that when the door is undesirably opened, the bell should latch into the triggered condition until intentionally turned off in an authorised fashion. Fig.3 shows a possible arrangement, using S3 as the primer switch.

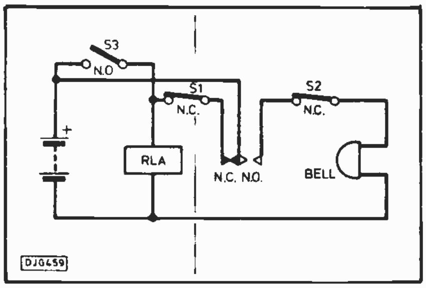



**Fig.3.**

## RING TIME

However, it is conventional to have regard for the sensitivities of neighbours' ears. An alarm bell riging incessantly can be of considerable annoyance not only to a burglar, but to anyone else within earshot. Any sensible burglar will flee if an alarm bell is triggered, but innocent neighbours could suffer until the bell is deliberately switched off. Consequently, it is usual for an alarm system to have an automatic switch that turns off the bell after a predetermined period of time. This duration should be long enough for neighbours to know that the bell has not been inadvertently triggered by the carelessness of an authorised person who, realising the error, hurriedly switches the bell off.

For greater security, it is preferable to know whether or not the system has been triggered during one's absence, even if the bell is not ringing. So there is the need for another latching circuit that will not be reset when the bell stops. This could operate a lamp of some sort, or a low volume audible warning device, like a buzzer.

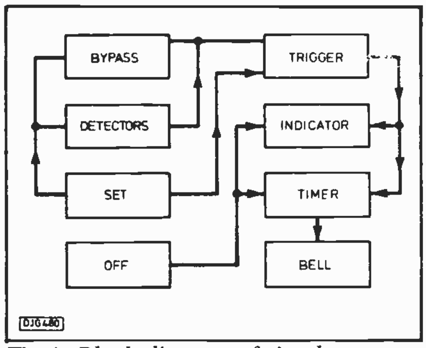



**Fig.4.** *Block diagram of simple controller.*

## SIMPLE SYSTEM

Fig. 4 shows the block diagram of a simple system that will operate according to these requirements. It is an ideal circuit for anyone with only the simplest of security needs, like for example protecting just one or two rooms from casual illegal entry. It is also a very suitable project for anyone who is studying for GCSE electronics. The power supply can be any between +5V

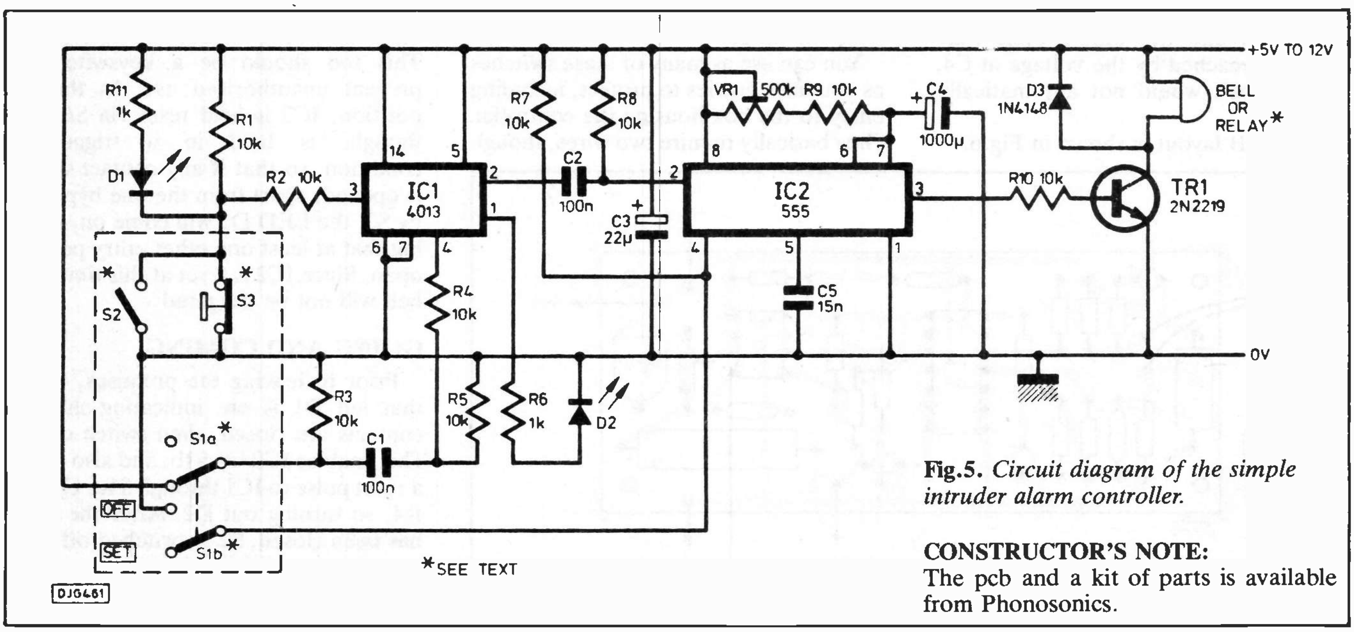



**Fig.5.** *Circuit diagram of the simple intruder alarm controller.*

**CONSTRUCTOR'S NOTE:**
The pcb and a kit of parts is available from Phonosonics.

and +12V, and ideally should be drawn from a mains operated PSU in conjunction with a heavy duty battery back-up supply.

The circuit details are in Fig.5, and consist of the latching chip IC1, and a timing control around IC2. The controlling switches are within the dotted box, of which more presently.

The voltage at the input of IC1, pin 3, is normally held low by either S3 or S2. If both are open, pin 3 rises to the full line voltage via R1 and R2. This rising change of level triggers IC1 so that pin 1 goes high, turning on the LED monitor D2. IC1 will remain in this state until deliberately reset by S1.

Pin 2 of IC1 simultaneously goes from high to low, sending a negative going pulse via C2 to the trigger input of IC2. Between them C2 and R8 determine the length of the pulse. IC2 is a 555 timing chip, wired as a simple one-shot monostable. Its output pin 3 goes high when triggered, and remains high for the time set by VR1, R9 and C4. At the end of this time, the output returns to the low state. While it is high, TR1 is turned on via R10, causing it to conduct via the load in its collector path.

The load can be any suitable warning device, such as a 12V low current (200mA) bell, buzzer or strobe light. The load could alternatively be a relay that switches higher powered units. D3 is included for use across a relay coil, but could be omitted if the load is non-inductive.

VR1 is used to set the required delay time. At minimum this is around 17 seconds, and at maximum around 15 minutes. Electrolytic capacitors have a broad tolerance, and a largish leakage current, so the precise timings may vary to either side of these figures. A longer time could be set by increasing R9, but the total resistance of R9 and VR1 should allow more current to pass than is being drawn by the leakage of C4. If it does not then the threshold level needed to end the timing cycle may never be reached by the voltage at C4, and the bell would not automatically turn off.

The PCB layout is shown in Fig.6.

## SWITCHES

Both IC1 and IC2 can be intentionally reset by switching off S1. This will stop the bell, and turn out the LED D2.

The intrusion detector switches are represented by S3. These can be any type of switch that will be normally open, but will close when the door or window to which they are attached is closed. These could be contact switches, or preferably magnetically operated switches that will close when a magnet is brought close to them.

They are available from many suppliers, including those who stock RS components. There are two basic types, flush mounting, and surface mounting. The former require setting into the door or window frame, and so need holes to be cut into the frame. The others, as the name implies, are screwed to the frame. They are the easiest to mount, but are less sightly. They both come in two halves, the magnetically operated switch, which is normally mounted on the fixed frame since it needs wires connected to it, and the section that holds the permanent magnet. This goes on the moving part of the frame and is positioned so that when the frame is closed, or within about half an inch of closing, the magnet attracts the switch contracts together, so closing the circuit. All should go on the frame side furthest from the hinge.

You can use as many of these switches as you have entries to protect, including entry to the box housing the controller. They basically require two wires, though the use of four wires for anti-tamper protection will be needed for the more complex control unit to be described in part two.

A twin flex is taken from the control board to each location to be protected in series, and is firmly stapled at frequent intervals to hold it in postion. At each location a switch is inserted into one of the leads; it does not matter particularly which one.

At the final switch one wire goes to one side of the switch, and the second wire to the other. You thus end up with a continuous loop of wire with the many switches in series with one another (Fig.7). With all switches closed, R1 will be shorted to ground, but if any switch is opened, the circuit will be broken, allowing the voltage at R1 and R2 to rise, so triggering IC1 as described earlier.

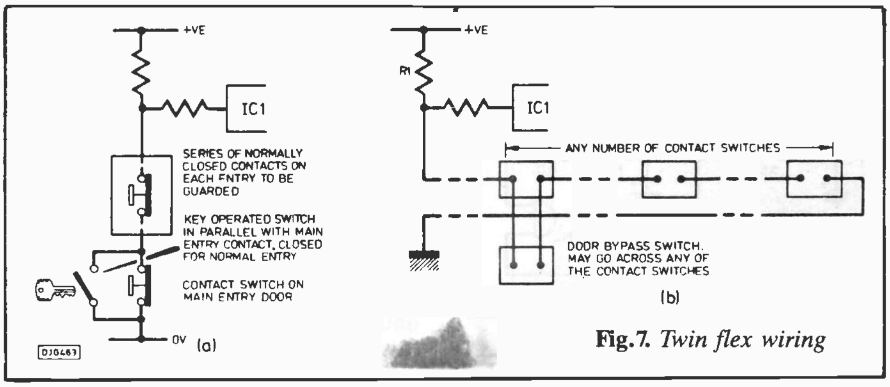



**Fig.7.** *Twin flex wiring*

At the main point of legal entry, two switches are needed, one of the magnetic type, and the other operated by a key. They are wired in parallel. For normal entry the key is turned, closing the contacts of that switch. This bypasses the magnetic switch, so allowing the door to open without triggering the alarm. For the magnetic switch to operate as a detector, the keyswitch is turned the other way, opening it, so that only the magnetic switch is in circuit.

The master set and reset switch S1, is mounted on the control unit front panel. This too should be a keyswitch, to prevent unauthorised use. In the off position, IC2 is held reset via S1. IC2 though, is held in a triggerable condition, so that if any contact switch is opened, apart from the one bypassed by S2, the LED D2 will come on, showing that at least one other entry point is open. Since IC2 is reset at this time, the bell will not be triggered.

## GOING AND COMING

Prior to leaving the premises, check that led D1 is on, indicating that all contacts are closed, then switch on S1. This enables IC2 via S1b, and also sends a reset pulse to IC1 through S1a, C1 and R4, so turning out D2. After the door has been closed, S2 is switched off. The system is now activated and will respond to any of the contact switches being opened.

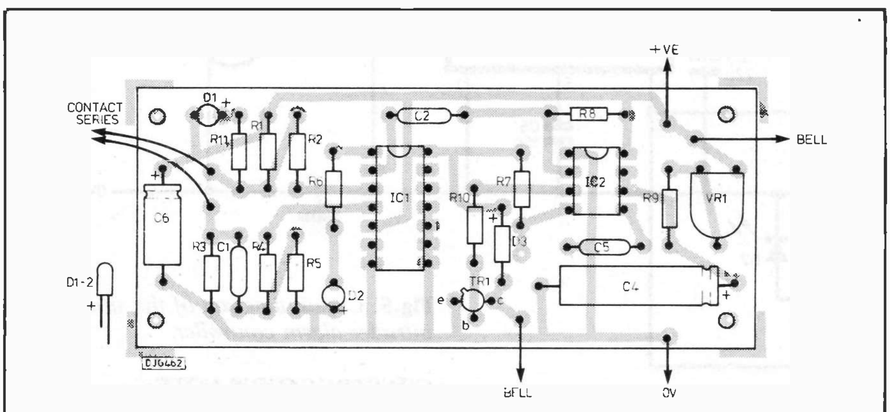



**Fig.6.** *PCB details for simple alarm controller.*

### SIMPLE BURGLAR ALARM

**RESISTORS**

| | |
|---|---|
| R1-R5,R7-R10 | 10k (9 off) |
| R6,R11 | 1k (2 off) |

All resistors ¼w 5% carbon film

**CAPACITORS**

| | |
|---|---|
| C1,C2 | 100n polyester (2 off) |
| C3 | 22µ 16V electrolytic |
| C4 | 1000µ 10V electrolytic |
| C5 | 15n polyester |

**POTENTIOMETERS**

| | |
|---|---|
| VR1 | 500k skeleton |

**SEMICONDUCTORS**

| | |
|---|---|
| D1,D2 | LED (2 off) |
| D3 | 1N4148 |
| TR1 | 2N2219 |
| IC1 | 4013 |
| IC2 | 555 |

**MISCELLANEOUS**

Pcb clips (4 off), PCB279A, 8-pin i.c. socket. 14-pin i.c. socket.

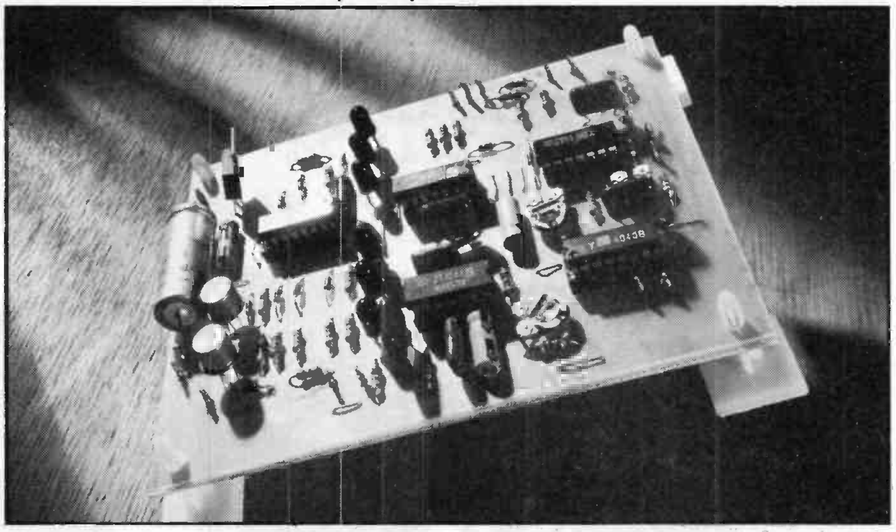
**SECURITY PRODUCTS NEEDED: (SEE TEXT):**

Bell, magnetic contract switches, SP key operated switch, DPCO key operated switch, 2-core cable.

Upon return to the premises, first switch off S2. Open the door, then switch off S1. If none of the contacts have been broken during absence D1 should still be on, and D2 should be off. If D2 is on, then the circuit has been broken, even though the bell may have automatically been turned off. If D1 is off, then the circuit is still broken.

### NEXT MONTH

In part two, the more complex circuit to be described shows how anti-tamper circuitry can be used, and how two or more zones can be monitored seperately. Other facilities include a timed entry and exit delay, control of a strobe light that remains on after the bell has been automatically turned off, and an option that automatically re-arms the bell circuit. There is also a 'granny-bashing!' alarm control that causes the bell to ring until help arrives. This can be triggered at any time whether or not the full system is switched on – an obvious advantage for anyone confronted by an unwelcome intruder, or for use in the event of sudden illness for anyone living on their own. PE



# SEMICONDUCTORS

BY ANDREW ARMSTRONG

## PART 1: PRINCIPLES

How many holes in Blackburn, Lancashire? Not half as many as in the average semiconductor, and they move about, as well. And that's just the start. No-one said semiconductors were simple, but they are fascinating and, more to the point, essential.

In this multi part feature I hope to de-mystify the business of choosing and using semiconductor devices, from the humble diode to complex LSIs. The user of semiconductors does not need to be an expert on fabrication technology, or semiconductor physics, but a little knowledge of device structure can help you to make better use of the data provided by manufacturers.

### PRINCIPLES

The simplest semiconductor device is the diode. Fig. 1 shows a simple diode made from P and N type silicon. The silicon is doped P or N type by the addition of small quantities of impurities which disrupt the crystal lattice in such a way as to leave either a "spare" electron which can move around, or a vacant site or "hole" for an electron. If the vacant site absorbs an electron from a neighbouring atom, then the "hole" has moved, and can carry charge in the same way as movement of a free electron. The mobility of the electron is higher than that of the hole, as one might expect.

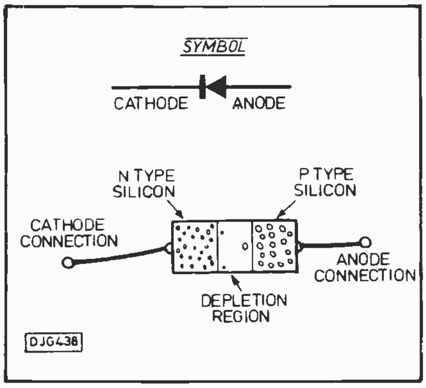



**Fig.1.** *The diode*

Back to the diode junction. Conduction is possible in the P type silicon and in the N type, but not at first sight in the depletion region. In this narrow region, the free electrons have fallen into the holes, leaving no charge carriers. There are a very few thermally generated electron-hole pairs, but the depletion region is almost an insulator if only a few millivolts is applied across it. If an increasing positive voltage is applied to the anode with respect to the cathode, electrons encroach further and further into the depletion region from the N type silicon. On the other side, holes (which may be regarded as a slower and heavier positive version of an electron) also encroach.

The boundaries of the depletion region are not abrupt, but imprecise and statistical. As the forward voltage across the device is increased, increasing numbers of electrons and holes cross the region, and current flow takes place. The current shows an exponential increase with voltage. The voltage at which significant current flow starts is normally around 0.6V to 0.7V.

If a voltage is applied in the reverse direction, positive to the cathode and negative to the anode, then it is attempting to remove electrons from the region where there are holes but no free electrons, and propel them to the N region where there are plenty of free electrons. Needless to say no significant current flows. A very small current, largely independent of voltage, flows due to the existence of thermally generated electron-hole pairs.

The forward and reverse conduction characteristics of a typical diode are shown in Fig. 2

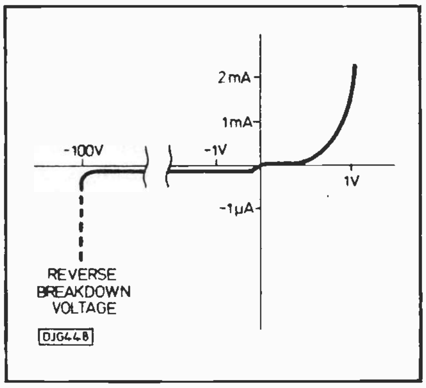



**Fig.2.** *Diode characteristics.*

As the reverse voltage is increased the depletion region widens, until at some point its insulating property is no longer adequate and it breaks down, usually catastrophically. This property is put to good use in the zener diode, which is so doped as to have a low reverse breakdown voltage which is little affected by current.

The charge distribution in a reverse biased diode is very similar to that in a parallel plate capacitor, and sure enough the diode has a capacitance which depends on the width of the junction and the thickness of the depletion region. Thus the capacitance depends on the reverse bias voltage, a property which is used to allow diodes to serve as the adjustable element in a tuned circuit.

The junction capacitance of a diode limits its speed of operation, but there is another effect which limits its switch-off speed when the bias across it is switched from forward to reverse. While the diode is conducting, the depletion region contains many charge carriers. When the polarity of the voltage across the diode reverses these charge carriers do not disappear immediately and current continues to flow until all these are swept out into the P and N regions away from the junction. This effect can often prove more of a limitation on high speed switching than junction capacitance.

The silicon junction diode is not the only variety available. Germanium is still used for some signal and rectifier diodes in applications where low forward voltage drop is required, along with a modest junction capacitance. The functioning of the germanium diode is like the silicon diode, but the forward voltage required for moderate forward current is only about 300mV, as against the 600mV to 700mV of the silicon diode. This forward voltage is a function of the difference in electron energy levels between the P and N type materials, and the difference is less in germanium than silicon.

Another diode technology which exhibits almost no specific forward drop is the Schottky diode. In practice there is forward drop, of course, because the device possesses resistance (higher resistance, in fact, than silicon junction diodes of similar size). The Schottky diode uses a junction of metal to silicon rather than two oppositely doped silicon layers. Electrons in a metal are much freer than in a semiconductor, and the common image of a metal is of an array of atoms in a sea of mobile electrons. For this reason electrons are available at almost any energy level, and in great quantity. There is little in the way of a depletion region to overcome, so that forward conduction can occur very easily. Equally, without a depletion region to store charge, one limitation on switching speed is removed.

There are drawbacks, of course. The lack of a depletion region at zero bias means that the junction capacitance is much higher per unit area than an ordinary junction diode, because the "capacitor plates" are closer together. The relatively high ohmic resistance of the device mandates larger area junctions to obtain the low voltage drop advantage of the device, so the junction capacitance can be very high. It is more difficult to make high reverse voltage Schottky diodes, and a few devices are available with ratings above 30V. They are generally more expensive as well.

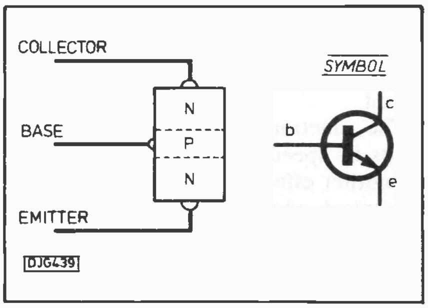



**Fig.3.** *Junction transistor.*

## THE JUNCTION TRANSISTOR

The structure of the junction transistor is represented in Fig. 3. If it is connected as shown in Fig. 4 then the collector-base junction is reverse biased, and no current flows. A test circuit such as that shown in Fig. 5 will yield experimental results along the lines of the graph shown in Fig. 6.

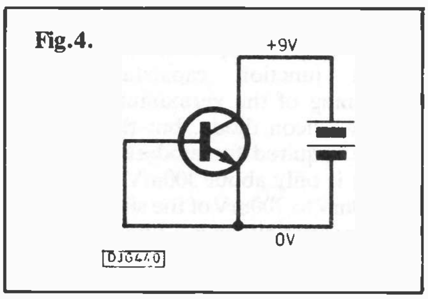



**Fig.4.**

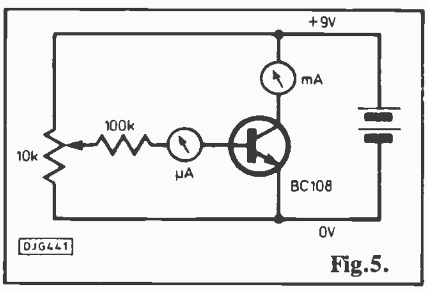



**Fig.5.**

As the potentiometer is turned up, the base-emitter junction becomes forward biased. Electrons are attracted into the thin base region by the electric field, and instead of leaving the base region by the base connection, most of them are further attracted by the positive potential on the collector and cross the reverse biased collector-base junction. This is only possible because the base region is very thin and electrons entering it from the emitter can immediately experience the electric field due to the positive potential on the collector.

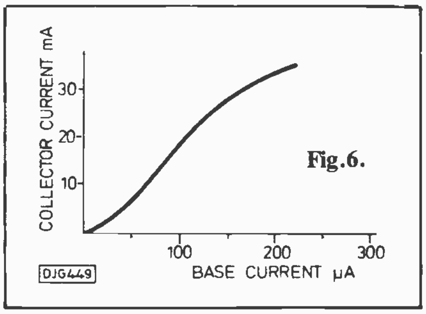



**Fig.6.**

The ratio between the number of electrons crossing to the collector region and those leaving by the base connection is called the current gain, and is represented by the symbol $h_{fe}$. For small signal transistors this value can range from about 50 to 1000, depending on transistor type. Its precise value varies with current, but is much more constant than the gain with respect to base voltage. If a graph of collector current against base voltage were to be plotted, it would look much like Fig. 2.

Few if any transistors are made in the form illustrated nowadays. It is more economical and gives more uniform results to manufacture planar transistors, in which the base, emitter and collector regions are diffused into a flat plate of silicon.

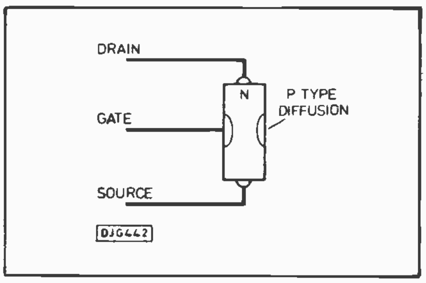



**Fig.7.** *Junction FET*

## THE FIELD EFFECT TRANSISTOR

In the field effect transistor (f.e.t.), the situation is entirely different. The current through the device depends on the voltage applied to the control terminal, the gate. A representative structure for a f.e.t. is shown in Fig.7. In this particular type, the junction f.e.t., the N type material is normally conducting. If a negative potential is applied to the gate relative to the source, as shown in Fig. 8, the depletion region around the junction becomes wider. This narrows the channel in which the current can flow, and the current is reduced. The graph of drain current against gate voltage is of the form shown in Fig. 9.

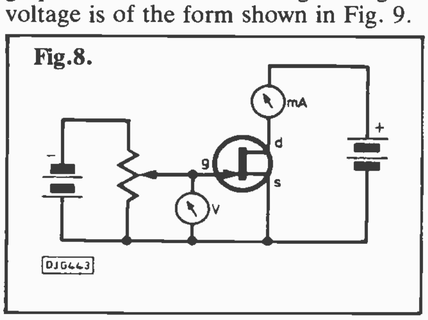



**Fig.8.**

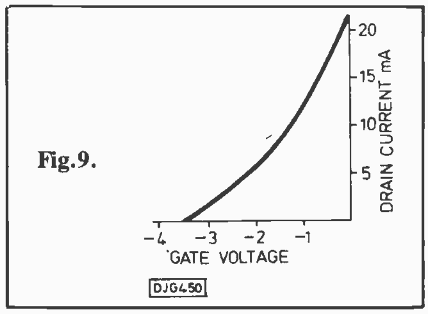



**Fig.9.**

It is also possible to produce a f.e.t. which is normally in the non-conducting state, and which can be made to conduct by application of a gate voltage. In this case, the gate must be insulatated from the channel, or else the gate-channel junction would be forward biased and gate current would flow.

A possible layout of an N channel planar enchancement m.o.s.f.e.t. is shown in Fig. 10. In this device the channel is normally blocked by a depletion region, but the presence of a positive potential on the gate metalisation attracts charge carriers and permits the channel to conduct. This effect is shown in Fig. 11.

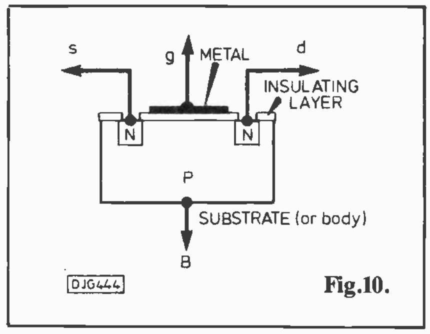



**Fig.10.**

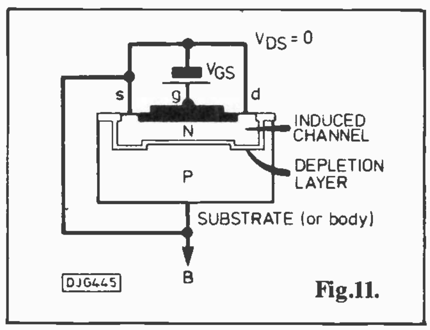



**Fig.11.**

For small values of drain-source voltage this channel behaves largely resistively, but when the drain-source voltage is a significant fraction of the gate-source voltage this is no longer true. The effective gate voltage now varies along the length of the channel, and hence the channel width varies along its length. This is illustrated in Fig. 12. As the drainsource voltage increases and the channel narrows the incremental resistance of the channel increases until changing the drain-source voltage varies the current hardly at all.

Inspection of Fig. 12 shows what looks like an unusually shaped npn transistor, if you ignore the channel and the gate connection. This configuration is not

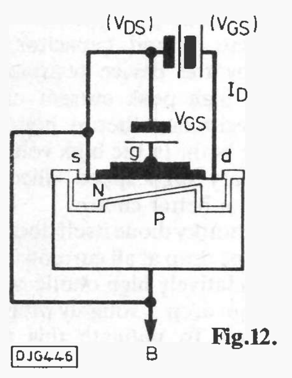



Fig.12.

ideal for transistor action, but under some circumstances this "parasitic transistor" can conduct and cause trouble. For this reason, some f.e.t.s. of this type have a connection to the substrate, which should be connected (in the case of an N channel f.e.t.) to a point in the circuit more negative than the source (0V or the negative power supply). This biases off the parasitic transistor and allows the f.e.t. to work as expected.

## REAL DIODES

Diodes come in a wide range of sizes, from small signal types to rectifiers rated at hundreds of amps. They are designed for many different purposes, including voltage regulation, tuning, and frequency multiplication as well as rectification. However, for most people the most familiar type of diode is the general purpose signal diode such as the 1N4148. The 1N4148 is a fast, low capacitance diode, as shown in table 1. This table includes some less common small silicon diodes for comparison of characteristics. As you can see, many of the characteristics are similar, and different diode types often differ only slightly. For most projects published in PE which use the 1N4148, any of these diodes would be suitable. In fact, the chances are that any small silicon signal diode which may be lying around will work perfectly well.

TABLE 1 DIODES

| Type No. | Vr(max) V | If(av) mA | Vf V | @ If mA | Cd pF | $t_{rr}$ ns | COMMENTS |
|---|---|---|---|---|---|---|---|
| IN4148 | 75 | 75 | 1 | 10 | 4 | 4 | Vrrm = 75V |
| IN916 | 75 | 75 | 1 | 10 | 2 | 4 | Vrrm = 100V |
| OA200 | 50 | 80 | 0.9 | 30 | 25 | 3.5$\mu$(typ) | |
| BAV10 | Vrrm = 60 | 300 | 1 | 200 | 2.5 | 6 | Ifsm = 600,A |
| BAV20 | Vrrm = 200 | 250 | 1.25 | 200 | 5 | 50 | |
| BAV45 | Vrrm = 35 | 50 | Low capacitance, low leakage Ir=5pA @ Vr=5V | | | | |
| BA481 | 4 | 30 | 0.55 | 10 | 1.1 | – | UHF mixer diode |
| 11DQ04 | 40 | 1A | – | – | – | – | Schottky rectifier |
| VSK530 | 30 | 5A | – | – | – | – | Schottky rectifier |
| 1N4001 | 50 | 1A | | | Approx 60 (typ) | | IN4003=200V, '04=400V '06=800V, '07=1kV |
| 1N5401 | 100 | 3A | | | | | 1N5406 = 600V |
| 40HF20 | 200 | 40mA | Stud mounting – 40HFR 20 = reverse polarity | | | | |
| BYV27-100 | 100 | 2A | | | | 25 | Avalanche fast recovery |
| BYV95A | 200 | 1.5A | | | | 250 | Avalanche soft fast recovery, BYV95C=600V |

**KEY:**
Vr(max) = maximum steady state reverse voltage
Vrrm(max) = Maximum repetitive peak reverse voltage
If(av) = Average forward current
Ifsm = Maximum repetitive peak forward current
$t_{rr}$ = Switch off time

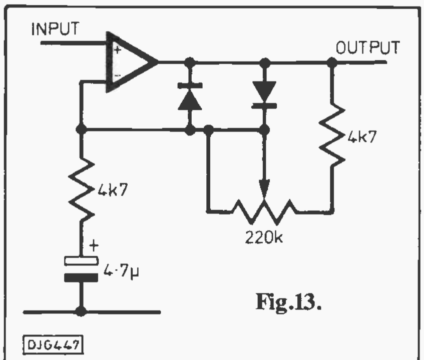


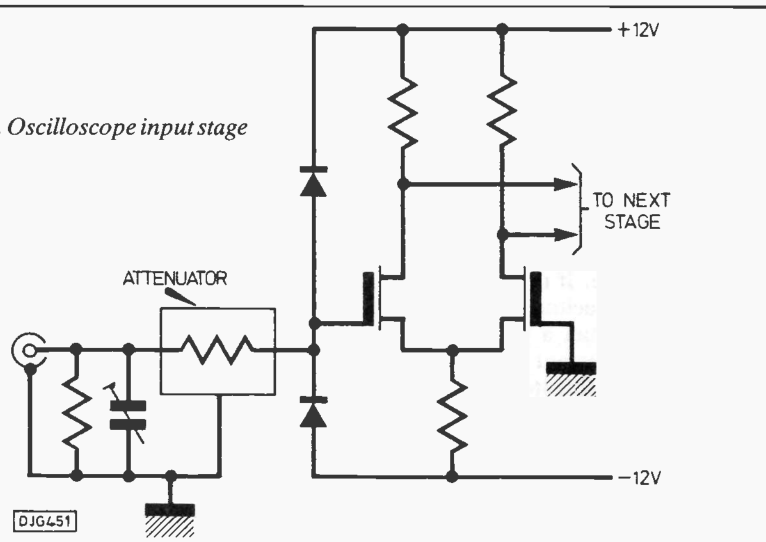

Fig.13.

To illustrate this, consider the circuit shown in Fig. 13. This is a stage from Robert Penfold's "Bright Fuzz" design (PE May 1987). The diodes are used to clip the audio signal and produce the well known fuzz sound. The maximum reverse voltage which the diodes experience is about 0.6V. The peak current is likely to be a few hundred microamps, but even a few microamps' reverse leakage will have little effect on the performance. The switching time ($t_{rr}$) can be as long as 20us without affecting the sound, and even a junction capacitance of a hundred picofarads will have little effect on performance. The diodes specified for the circuit, 1N4148s, exceed the minimum specification by a big margin, and they were chosen as the most economical small diode. In fact it would be difficult to find a diode which would not be suitable for the job.

Some diode applications place emphasis on one or two parameters while being non-critical in other respects. Fig. 14 shows an oscilloscope input stage, with two protection diodes. It is these diodes which permit the input to withstand a high voltage even when the attenuator is set to a sensitive range. The attenuator must always impose a series resistance between input and diodes to permit this scheme to work. To avoid disturbing the DC level of the input, the diodes must be ultra low leakage types, and should preferably have a low junction capacitance, though this can be compensated if not too great. The voltage rating of the protection diodes need not be very high, as they will never experience more than the rail to rail power supply voltage.

The diodes in the voltage multiplier shown in Fig. 15 have a different set of requirements of optimum circuit operation. Leakage current in the range nor-

**Fig.14.** *Oscilloscope input stage*



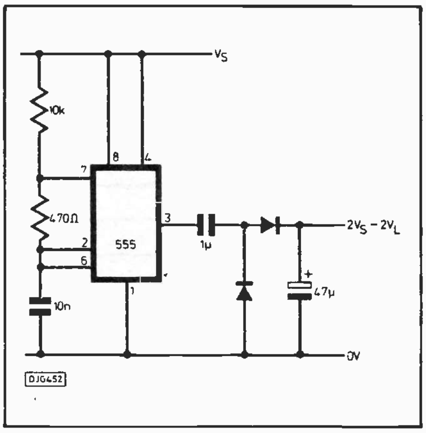



**Fig.15.** *Voltage multiplier*

mally found in diodes is insignificant, but forward voltage drop can reduce the output voltage of the circuit. Inefficiency can also result from too slow a switching of the diodes, so that the use of large diodes to minimise the ohmic part of the forward drop may not be beneficial. For moderate output currents, small Schottky diodes such as the BAT42 or BAT85 would be suitable.

In some uses of the circuit, the precise output voltage is not important and ordinary silicon diodes such as the 1N4148 would work very well. An example of such an application would be to multiply the voltage from a car battery to charge a 12V stack of nickel cadmium cells.

Small signal Schottky diodes are also useful as high frequency mixers or detectors because of their very fast switching characteristics. Such diodes are made with very small area junctions to minimise the capacitance, and are capable, in some cases, of picosecond switching.

## RECTIFIERS

Encapsulated bridge recifiers are often used to construct power supplies, but discrete diodes are also used. 1N4000 series plastic encapsulated diodes are a frequent choice for modest currents, while 1N5400 series are used for higher average or peak currents. Some very high current power supplies use Schottky diodes. The lower voltage drop available from these devices can be critical in reducing the heat generated in, say, a 100A 5V supply.

To choose rectifiers for ordinary transformer operated mains power supplies it is important to look carefully at the current rating. In a bridge rectifier circuit, current flows in any one diode for only half the cycle. If the power supply has a large capacitor following the recitifier rather than a purely resistive load, the peak current flowing in the diode will be much greater than the average current. This is becuase the capacitor is charging only near to the peak of the waveform. Diodes often have very different peak and average current ratings, and in different applications either one or the other may be critical.

In making the choice, if you are in any doubt as to whether a rectifier's ratings may be exceeded, it is probably best to choose a device with higher ratings and guarantee an adequate overload margin. The few extra pence is well worth it for a reliable project. The only time it is worth designing to the limit with such a component is if you are designing an item for very high volume manufacture, where small cost savings can amount to a lot of money.

Schottky rectifiers are often used in switched mode power supplies rather than to rectify the output of a mains transformer. In 5V supplies in particular, the low voltage drop can cut the total loss in the supply by up to perhaps 50%. The high capacitance of a Schottky rectifier renders it most suitable for use in situations where it does not receive a very large reverse voltage. Otherwise, the losses in switching components to charge and discharge the capacitance can nullify some of the saving.

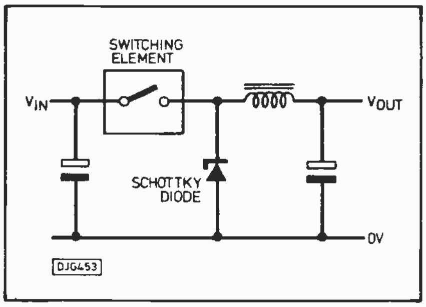



**Fig.16.** *Part of switched mode power supply*

The circuit of Fig. 16 illustrates this. If the input voltage is around 10V, and the output is at 5V, the extra switching losses incurred due to extra capacitance of the Schottky diode are negligible. If on the other hand the input voltage is 30V, much higher switching losses in the switching transistor are to be expected. Effectively, the transistor is being asked to connect two capacitors, one charged, the other discharged, and the current to charge the second capacitor is only limited by the device resistance. This means a high peak current or a high device resistance (hence high voltage drop), or both. In the high voltage case, an ordinary high speed silicon diode would be a better choice.

The Schottky diode itself does not give low voltage drop at all currents. Because it has a relatively high ohmic resistance, the voltage drop is roughly proportional to current. To mitigate this problem, Schottky rectifiers are fabricated to include a silicon junction diode ring around the Schottky junction. It is this ring which carries most of the peak current, while the advantages of lower voltage drop are gained at slightly lower currents than the maximum rating of the device. Therefore, for most power supplies with higher voltage outputs it is simpler and cheaper to use a high speed silicon rectifier.

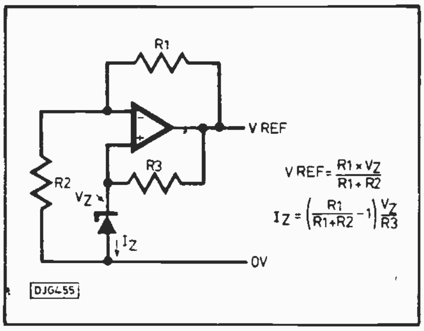



**Fig.17.** *Improved zener reference*

## ZENER DIODES

While on the subject of power supplies, we must not forget the zener diode. This is designed to "break down" non-destructively and at a substantially constant voltage. 400mW zener diodes are available in a wide range of voltages, but it is important to remember that the

TABLE 2 ZENER DIODES

| Type No. | Working voltage Vz at Iz = 20mA | | | Temperature coefficent mV/°C @ Iz = 20mA | | | Differential resistance Ohms at Iz = 20mA | | |
|---|---|---|---|---|---|---|---|---|---|
| BZY88C. | min | nom | max | min | typ | max | min | typ | max |
| 2V7 | 3 | 3.25 | 3.5 | −3.5 | −2.V | −0.6 | 18 | 22 | 26 |
| 4V7 | 4.9 | 5.1 | 5.3 | −1.5 | 0 | 12 | 15 | 17 | |
| 5V1 | 5.1 | 5.35 | 5.7 | −1.5 | −0.8 | 0 | 4 | 7 | 11 |
| 5V6 | 5.45 | 5.75 | 6.1 | −1.0 | +1.0 | +3.0 | 1.5 | 4 | 8 |
| 6V8 | 6.6 | 6.9 | 7.25 | +2.8 | +3.2 | +3.8 | 0.7 | 1.3 | 3 |
| 10V | 9.5 | 10.1 | 10.8 | +7.0 | +7.3 | +7.5 | 1 | 2 | 8 |
| C15V | 14.1 | 15.3 | £5.9 | +12 | +13.5 | +14.5 | 2 | 6 | 25 |
| C20V | 19.3 | 20.5 | 21.9 | +17.5 | +18.5 | +20.5 | 5 | 15 | 35 |
| C30V | 29 | 31.3 | 33.4 | +25 | +28 | +32 | 10 | 35 | 50 |

All BZY88 series 400mW power dissipation

IN5339B 5.6± 5% Power dissipation = 5W

NOTE: IN5339B is included as a component seen in a recent PE advertisement.

diode will only work at its specified voltage (+/– the tolerance) when a specific current is passed through it. The incremental resistance is paradoxically higher for the very low voltage devices, as can be seen from Table 2. It is preferable to operate zener diodes at a constant current, and a circuit to achieve this is shown in Fig. 17.

Zener diodes also have a temperature coefficient, again as shown in Table 2. The lowest typical temperature coefficient for the BZY88 range is that of the 5V6, but the 5V1, a very useful voltage, also has a fairly low tempco. Zener diodes also generate a fairly large amount of noise, so a capacitor is often connected in parallel with a zener diode reference to minimise this.

Another property of diodes which has hitherto only been briefly mentioned is that of changeable junction capitance. If an effect exists, an engineer somewhere will almost certainly find a use for it. In this case, the variable junction capacitance can be used as a variable capacitor in tuned circuits. Special high capacitance diodes are available for the purpose, and they are called varicap diodes.

There are drawbacks in the use of varicap diodes. One such is that the change of capacitance is not proportional to the voltage. As the reverse voltage applied to the device is increased, the change of capacitance per volt becomes less and less. This interacts with a more fundamental limitation: because the capacitance changes with voltage, it also changes in step with any signal on the tuned circuit, of which the varicap forms part. The lower the reverse bias applied to the varicap diode, the bigger proportional change will be made by the signal. Unfortunately, the most useful range of capacitance of a varicap is usually at a fairly low voltage.

This interaction of signal and tuning voltage in a tuned circuit of, for example, a television receiver causes nonlinearity and allows intermodulation to take place. In this way a perfectly legal amateur radio or CB transmission which

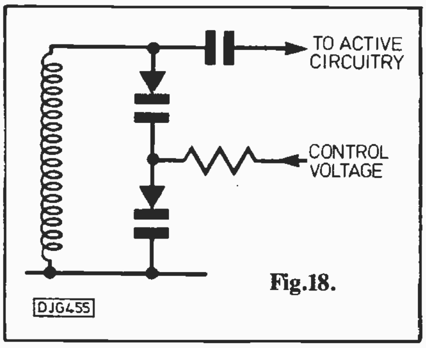



Fig.18.

has no harmonics anywhere near the frequency of BBC 1 can totally obliterate reception of said channel. The interfering harmonics are being produced in the television tuner itself, because it uses varicap diodes to provide electronic tuning. This effect can be minimised by using back to back varicaps as illustrated in Fig. 18.

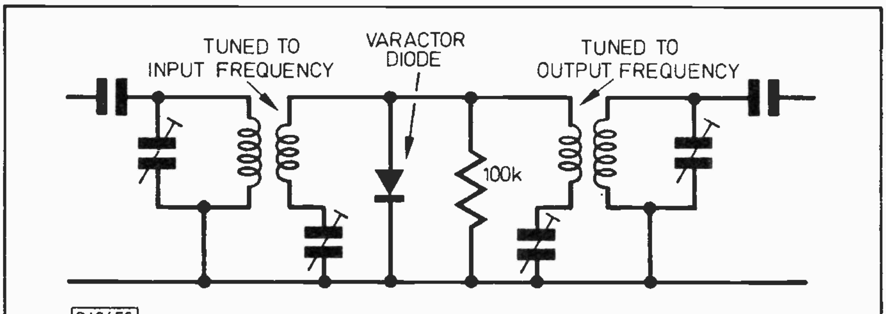



Fig.19.

The non-linearity of the varicap diode is put to good use in the varactor frequency multiplier. When UHF transistors were less available than they are now, the varactor frequency multiplier was widely used as a means of generating frequencies from about 500MHz upwards. An ordinary diode can generate numerous harmonics if a signal is fed into it, due to its non-linear conduction. A varactor multiplies frequency in a different manner, however. Little forward current flows in the device. It works by storing charge when its capacitance is high, and then dumping it out into the surrounding circuit. In this way relatively little power is lost, and efficiencies for a tripler can be around 50% as a result.

Fig. 19 shows an example of a varactor frequency multiplier circuit. Signals fed in at a subharmonic of the resonant frequency of the tuned circuit will be changed to that of the circuit. Apart from the bias level on the varactor, this circuit bears some resemblance to the input stage of a television tuner. This factor has probably caused as much friction between radio enthusiasts and "Dallasty" watchers as all other causes put together.

As I hope I have demonstrated, the humble diode is more important than may be apparent at first. Part two of this series is planned to cover junction transistors, f.e.t.s., thyristors, triacs etc, and it is intended that part three will cover common types of integrated circuit.

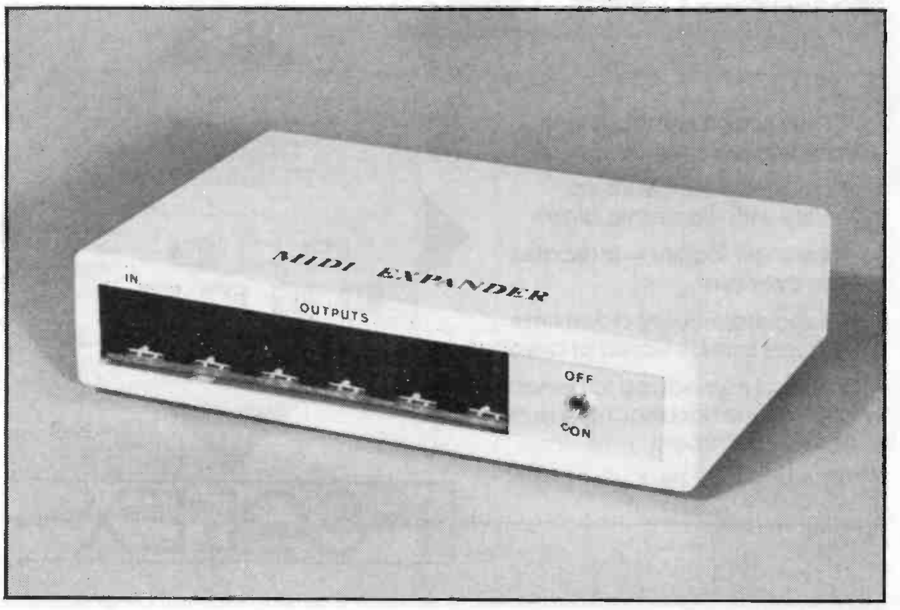
PE

*The MIDI expander converts a single MIDI controller or a computer with MIDI software into a system with five or more outputs, which is more effficient than "chaining" several instruments in sequence.*

# MIDI EXPANDER

BY ROBERT PENFOLD

## WE'RE GONNA MAKE YOU A STAR!




While this project will not go down in the history of Practical Electronics as the most complex project ever published (it is comprised of little more than a dozen components), it is nevertheless a very useful little gadget for anyone who is setting up a MIDI system. A MIDI expander simply takes a single MIDI output signal and splits it into several outputs available at individual sockets. This enables several MIDI instruments to be driven from one MIDI controller using the so called "star" method of connection.

### THE STAR SYSTEM

As discussed in PE September 1987 the MIDI system uses a form of serial data transmission that is similar to the standard RS232C asynchronous type, but which is at a higher baud rate of 31.25 kilobaud. Also, it is a 5 milliamp current loop system, with opto-isolators at all inputs. Most MIDI equipment has "IN", "OUT", and "THRU" sockets, and a typical set up would be a controller and four instruments connected as shown in Fig.1.

Here we are assuming that the controller is a computer plus suitable software, or a purpose made microprocessor based controller. In either case it is unlikely to have a built-in piano type keyboard, and so the first instrument in the system has its "OUT" socket coupled back to the "IN" socket of controller. The keyboard of instrument 1 can then be used to feed information into the system, such as when recording in "real-time". Although any MIDI equipped keyboard instrument could be used as instrument 1, it would be sensible to use whichever instrument has the best keyboard (preferably one with a six or seven octave compass and touch sensitivity). The "OUT" socket of the controller connects to the "IN" socket of the next one in the chain. In theory, any number of instruments can be connected into the system in this way, but note that the "THRU" socket of the final instrument should be left unconnected. Wiring it back to the input of the controller would result in any signal fed into the system circulating indefinitely!

With the "star" method of connection, as outlined in Fig.2, the output of instrument 1 connects back to the input of the controller, as before. However, the output of the controller now connects to a MIDI expander, and then each instrument is fed from a separate output of the expander unit. On the face of it there is no advantage to this system which achieves no more than the chaining method of connection, but there can in fact be advantages to the "star" system. Actually, in some cases it is the only method that can be used, as not all instruments have a "THRU" socket. My SCI "Six Trak" synthesizers lack this feature for example. The absence of a "THRU" socket does not matter if it only afflicts one instrument, as this instrument can be fitted at the end of the chain, but otherwise the chaining method of connection is not usable.

Where the "chain" system is feasible, many MIDI users still prefer the "star" system. One advantage of the latter that is sometimes put forward is its equal delay time, with all instruments receiving information simultaneously. With the "chain" system there is a slight delay between a signal being received at the "IN" socket and transmitted at the "THRU" socket, and this delay builds up as the signal progresses along the chain. I would have to say that from experiments I have made this delay time seems to be totally insignificant, but possibly not all instruments drive the "THRU" socket in the same way, and it might be more significant with some instruments than with others.

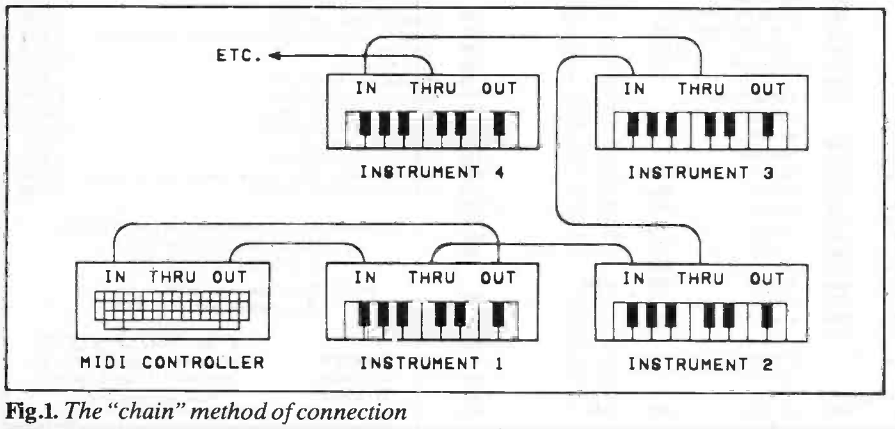



**Fig.1.** *The "chain" method of connection*

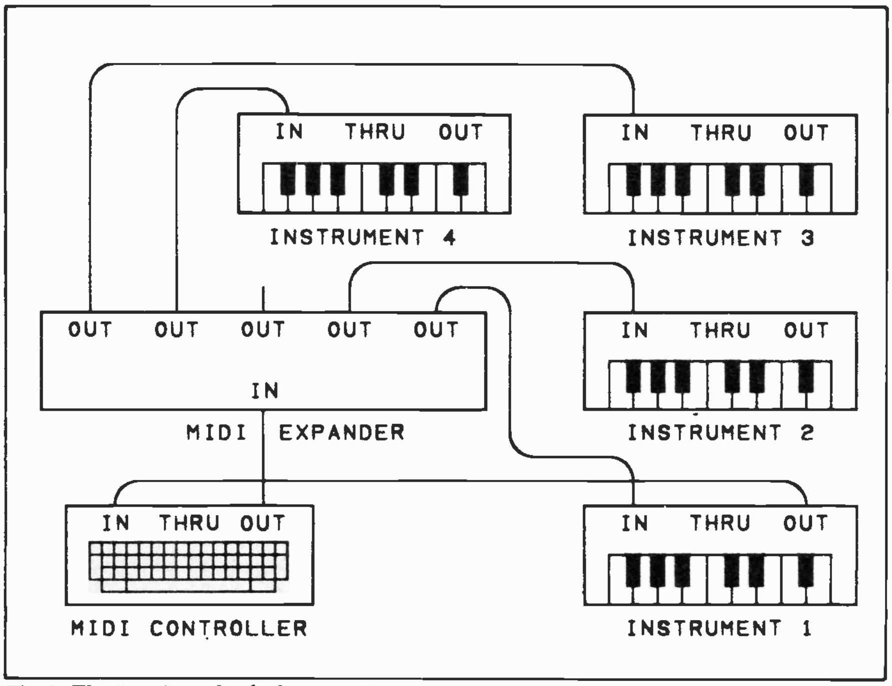



**Fig.2.** *The "star" method of connection.*

What is more worrying about the "chain" method, especially for a large MIDI system, is that the signal is inevitably degraded each time it passes through an instrument. Any smearing of the signal as it passes through the opto-isolator and buffer stage should only be very slight, even bearing in mind the relative slowness of opto-isolators. However, the cumulative effects of this smearing could compromise reliability, and MIDI devices seem to be very unforgiving of any slight distortion of the signal waveform.

## EXPANDER CIRCUIT

MIDI expanders can be quite expensive to buy ready-made, but can be home constructed at quite low cost. As can be seen from the circuit diagram for this unit (Fig.3), only a handful of low cost components are required.

IC1 is the opto-isolator, and it is important to use a type which has suitably fast switching times. Devices such as the popular TIL111 type seem to be inadequate in this respect, even with the aid of an output switch to speed things up slightly. The CNY17-3 seems to offer good reliability but is not excessively expensive. An opto-isolated input is not strictly necessary, since the units fed from the expander will all have isolated inputs that will prevent any direct connection between them via the expander. However, MIDI outputs are designed to drive this type of device, and it was felt that an opto-isolator at the input represented the most reliable method of interfacing to the controller. R1 provides input current limiting, and it really only included to protect IC1 in the event of a fault occurring in the driver circuit.

On the output side of IC1 the phototransistor operates in the emitter follower mode with R2 as its load resistor. TR1 is a common emitter switch which is directly coupled to the output of IC1. Normally TR1 is cut off, but when the LED at the input of the opto-isolator is switched on, its light output produces increased leakage through the output transistor. This in turn switches on TR1 which then drives all five outputs via separate current limiting resistors (R3 to R7). In the original circuit there were individual driver transistors for each output, but with five outputs a single driver seems to be more than adequate to drive all the outputs properly.

The circuit might look rather risky in that there is no current limiting resistor in the base circuit of TR1. In practice there is no problem here in that the efficiency of IC1 (although at least 100%) is not high enough to give an excessive base current. Adding a current limiting resistor does not seem to have any great detrimental effect on the output waveform, but still seems to prevent the unit from functioning properly!

Power is obtained from a 9 volt battery, and a small type such as a PP3 is adequate. The quiescent current consumption is extemely small, and if the unit should be accidentally left switched on this may well fail to deplete the battery significantly. In operation the current consumption can reach around 10 milliamps with large amounts of data being passed and all five outputs in use.

## CONSTRUCTION

Virtually all the components fit onto the printed circuit board, and the battery is, in fact, the only off-board component. Details of the circuit board are provided in Fig.4. There is little here that should give any real problems. A six pin DIL holder for IC1 might prove difficult to obtain (they do exist), but it is quite easy to trim an 8 pin type down to size. I would not recommend the use of alternative types to the CNY17-3, and it is important to use a device having the "−3" suffix.

A case measuring about 180 by 120 by 40 millimetres is used on the prototype. This is largely filled by empty space rather than components, but a smaller case would probably provide inadequate width to accommodate the row of six sockets and the on/off switch along the front panel. Ideally the printed circuit board should be mounted so that the six sockets are immediately behind a cutout

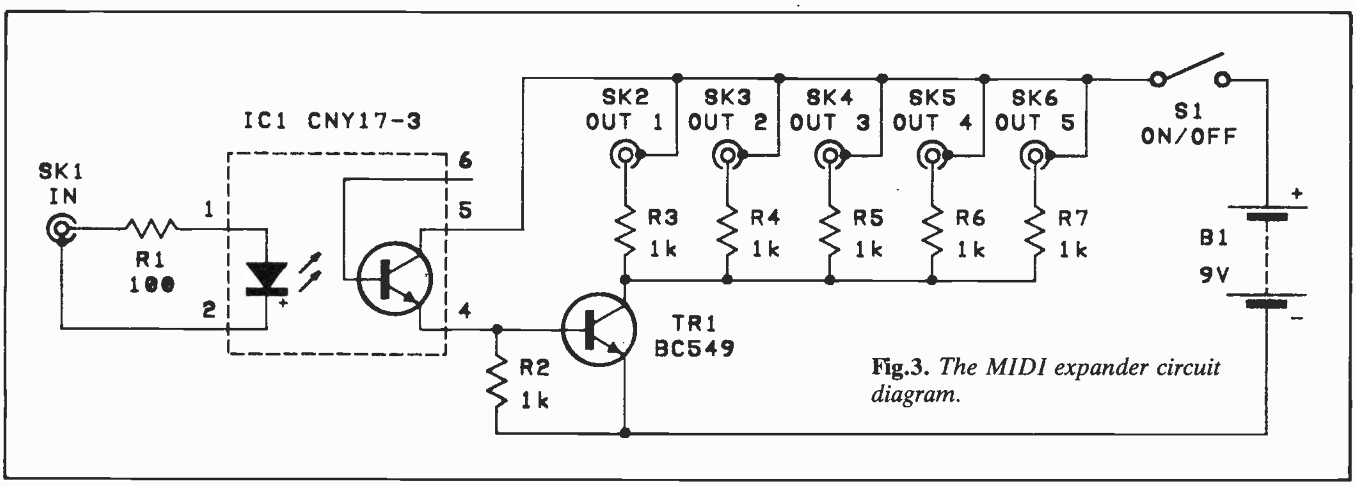



**Fig.3.** *The MIDI expander circuit diagram.*

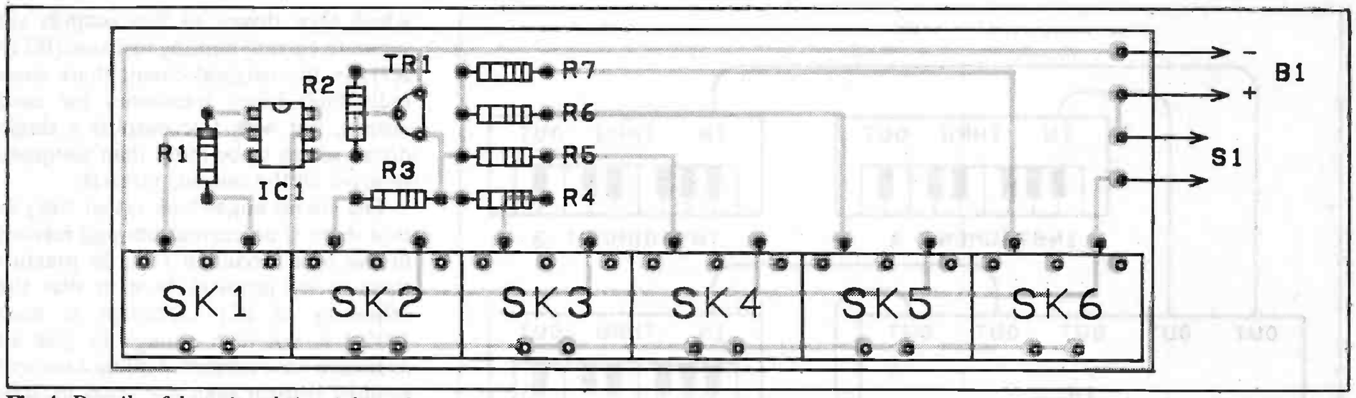


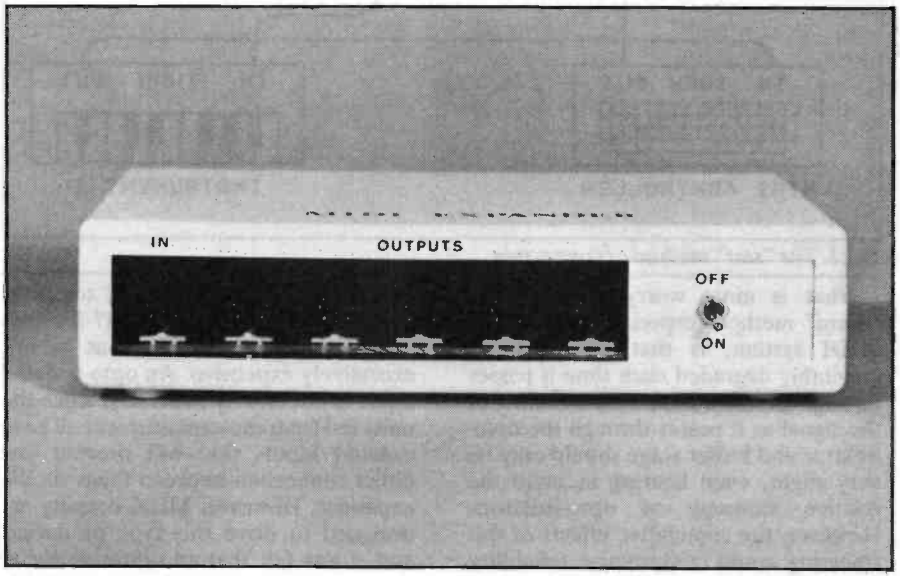

**Fig.4.** *Details of the printed circuit board.*

## COMPONENTS

### RESISTORS
R1 100
R2 to R7 1k (6 off)
All ¼W 5% carbon film or better.

### SEMICONDUCTORS
IC1 CNY17-3 opto-isolator
TR1 BC549

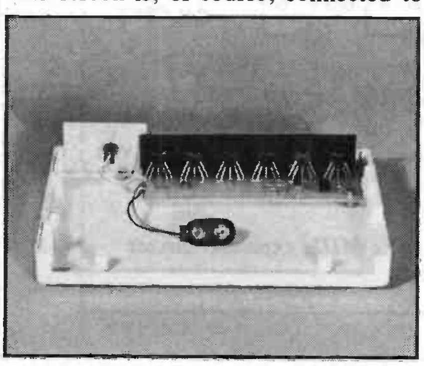
### MISCELLANEOUS
SK1 to SK6 5 way 180 degree p.c.m. DIN socket (6 off)
S1 SPST sub-min toggle
B1 9 volt (PP3 size)
Printed circuit board, case about 180 x 120 x 40mm, battery connector, pins wire, etc.




made in the front panel. With the specified case it would be very difficult to make a suitable cutout in the panel as there would be very little panel left after the cutout had been made. I opted for the simple alternative of simply cutting off the whole of the section of the panel in front of the sockets, but those with the necessary skills and tools could probably produce a much neater job by making a proper panel cutout.

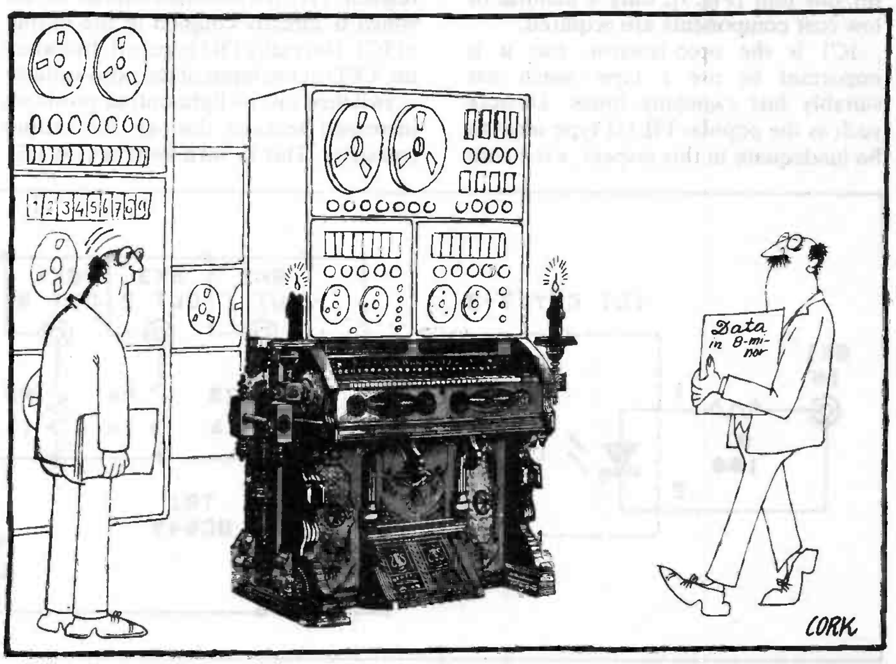
## IN USE

The system is wired up using standard 5 way DIN plug to 5 way DIN plug leads. If you are making up your own leads, twin screened cable is required, with pins 4 and 5 on one plug connecting to the corresponding pins of the other plug. The screen is, of course, connected to the chassis tags of the plugs. With five outputs the unit should be adequate for most systems, but if necessary a few additional sockets and current limiting resistors could be driven from TR1, or two expanders could be wired in series to give nine outputs. Another alternative would be to use a mixture of "star" and "chain" connection. PE



## CONSTRUCTOR'S NOTE

Robert Penfold advises that the CNY17-3 opto-isolator is available from Electrovalue Ltd. The PCB may be bought through the PE PCB Service. A full kit of parts is also available from Magenta.



# OPTICAL FIBRES, LASERS AND COMMUNICATIONS

**BY BARRY FOX**

## There's no need to repeat everything

*Light travels in straight lines – unless it is piped down a filament of glass. But once it has been persuaded to go round corners it needs – you might say – no further coaxing ...*

Every day now brings some new announcement about the use of optical fibre as a wide bandwidth signal carrier, instead of traditional copper coaxial cable. There are continual developmetns, too, in the lasers used to send signals down a fibre link. Recently systems have become available which use an infra-red laser to transmit sound and picture signals by direct line-of-sight link.

All this news builds on basic principles which are perhaps not as widely understood as they could be.

A few years ago, the Department of Trade and Industry – which encourages interest in Information Technology – chanced its arm with an experiment. Normally the DTI only organises press conferences when there is something newsworthy to announce. But the DTI thought that a few journalists might be interested in a briefing on fibre optic technology.

The DTI invited every journalist on its IT list, a total of 250, to come along and hear experts talk generally about fibre optic technology. The DTI reckoned that if a dozen people turned up it would be worthwhile. But a staggering 70 said they would like to come, and of these over 50 actually arrived to be educated. This, the DTI press office ruefully admitted to me, was a better turn out than they would normally get for a major announcement on Government policy by a senior minister. Significantly – but inevitably – most of the journalists who couldn't find time to attend, or even reply to their invites, were Fleet Street hacks with famous names.

Because fibres carry electrical signals as light pulses, they are free from interference and virtually immune from bugging. Optical cables are smaller than coaxial cables, too. And the frequency of light is so high that the modulation bandwidth is in theory almost infinitely wide.

Fibres are cheaper because they are made of relatively common glass-like materials. They are waterproof so underground links don't stop working when it rains.

But new technology brings with it new problems. Primarily, expensive ancillary equipment is needed to convert electrical signals into light pulses and back again at each end of the fibre.

### TRADITIONAL COAX

The importance of optical fibre as a new technology can only be appreciated when the problems of using traditional coaxial cable technology are analysed. Out of sheer necessity, the cable TV and telephone industries have stretched the performance limit of copper coax to breaking point. The more phone calls or TV channels which they can pipe down a wire, the more money they can earn on revenue from subscribers.

A colour tv channel needs a bandwidth of 6MHz, with guard bands to eliminate cross-talk between adjacent channels. So each TV channel carried on a cable link soaks up 8MHz of bandwidth – which is equivalent to around 2,000 telephone speech channels.

Domestic cable distribution systems keep the TV signal in its original analogue form and separate the different channels by stacking them one on top of the other in frequency – Frequency Division Multiplexing. This means that the cable must carry very high frequency signals. But the cable must not leak them or it will act as a transmitting aerial and interfere with broadcast signals. The cable also has to stop unwanted signals, such as ignition spark interference, leaking in.

Hence the use of coaxial cable. This originally had a central copper core surrounded by a solid plastic insulating sheath, itself surrounded by copper braid or foil and extra insulation and protection. The braid acts as a screen to block interference and prevent leakage. Modern coaxial cable is lighter and cheaper, because it uses an air space instead of solid plastic insulation. But early cables of this type, made in the 1970s, broke or kinked. The kinks left gaps in the screen which let stray signals in and out.

To complicate the equation there is a finite limit on the number of amplifiers which can be connected in cascade along a cable run. For conventional amplifiers it is 25; for the more modern expensive low distortion devices it is 40. This puts a finite limit on the total area that the coax cable system can cover.

There must also be an exact match between the electrical impedance and the cable and the amplifier. Nominally cable impedance is 75ohms, but if there is mismatch by even 1 ohm, some of the signal is reflected back down the cable. This causes ghost images. Any impedance mismatch where the cable is split and joined will cause a similar effect.

In practice cable stations do not try and squeeze more than 450MHz out of coaxial cable. To double the capacity it is easier to lay another cable alongside the first. At these frequencies, the signals need regular boosting, ideally every 250 metres. To complicate the issue the channels which are stacked at the higher frequency end of the multiplex spectrum need boosting more than the lower frequency channels, because

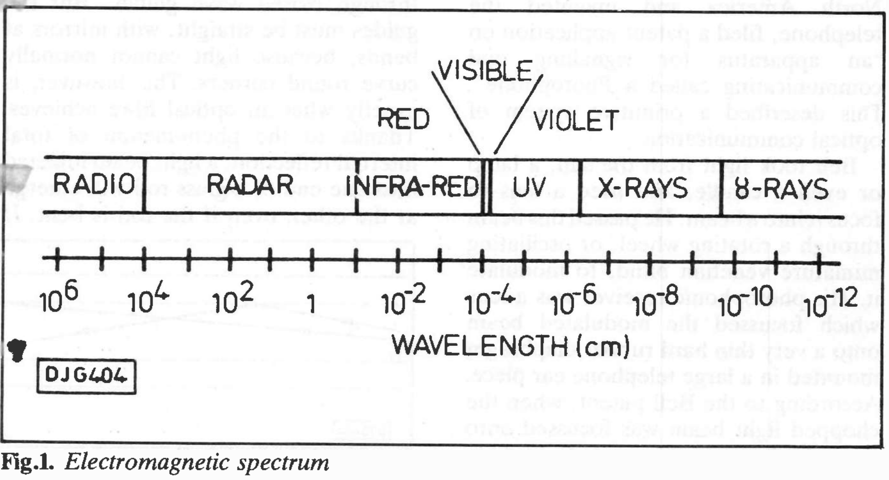



**Fig.1.** *Electromagnetic spectrum*

signal loss is not linear with frequency.

Under the circumstances it is hardly surprising that telecomms engineers have been looking for an alternative to copper coax!

Early types of air-spaced coax used plastic foam, or cartwheel spokes, to space the screen from the core. But if water gets in at one end, the cable fills like a pipe under capillary action. More modern coaxial cable uses foam with closed cells but this has odd electrical characteristics at high frequencies. For this reason some wide bandwidth coaxial cables have bamboo-like rings along their length. These seal the air space into a large number of discrete, waterproof compartments, as in a submarine.

## AMPLIFYING REPEATERS

Electrical resistance is an important factor. With cheap thin cable, more money must be spent on amplifiers to boost the signal along its route. In the early days of cable TV a bandwidth of around 230MHz was thought more than adequate for the relatively few channels distributed. This is why cable performance is often measured in decibels of signal loss per 100 metre run at this frequency.

With 3dB cable an amplifier is necessary every 600 metre or so to ensure strong signals and clear pictures for subscribers. In practice this bandwidth is only enough for around 12 or 18 TV channels. When the number of channels to be carried is raised to 32, the bandwidth must go up to 400MHz. Signal loss increases with frequency, so amplifiers must be used every few hundred metres. If the cable operator cuts cost and uses cheaper coax, with 6dB loss instead of 3dB, then the amplifiers must be spaced at half the distance. If the operator spends more money underground, and lays 1.5dB cable, the distance between amplifiers is doubled.

## ANCIENT LIGHTS

The idea of transmitting signals by light is old. In 1880 Alexander Graham Bell, the Scotsman who emigrated to North America and invented the telephone, filed a patent application on "an apparatus for signalling and communicating called a Photophone". This described a primitive system of optical communication.

Bell took light from the sun, a lamp or even a candle, and used a lens to focus it into a beam. He passed this beam through a rotating wheel, or oscillating miniature venetian blind, to modulate it. His photophonic receiver was a lens which focussed the modulated beam onto a very thin hard rubber diaphragm mounted in a large telephone ear piece. According to the Bell patent, when the chopped light beam was focussed onto the diaphragm it created audible sympathetic movements.

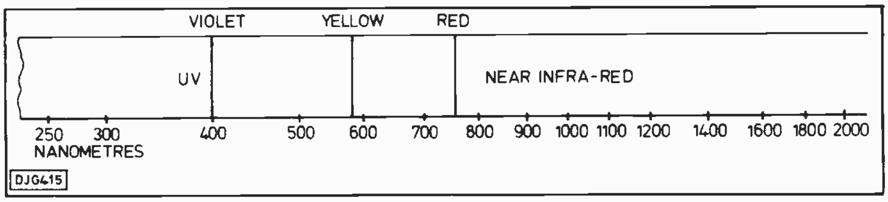



**Fig.2.** *Optical Spectrum*

Bell soon realised that it was impractical to convert light energy direct into acoustic energy at the receiver. So he replaced the diaphragm with a piece of light sensitive selenium, connected in series with a battery and telephone ear piece. This incoming light beam was focussed onto the selenium which changed its resistance in dependence on the strength of the beams. So the fluctuating beam created a fluctuating resistance in the telephone circuit and this produced a fluctuating current in the ear piece, which in turn produced sound. Bell built a prototype system which for nearly a hundred years lay in the Smithsonian Institution in Washington DC, until a curator realised what it was.

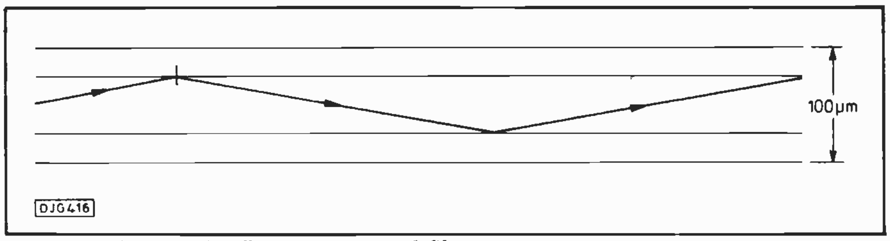



**Fig.3.** *Total internal reflection in optical fibre*

## GUIDING LIGHT

The obvious snag with free space communication by light is that the atmosphere attenuates the beam. Rain, fog, snow, smoke or pollution in the air all interfere with the signal. A laser beam has more chance of cutting through, and there are free space laser communication systems available. They carry sound and picture signals, but only over short distances – especially in urban areas with dirty air.

Twenty years ago Bell Labs in the US, the research department of the American equivalent of the British Post Office, tried sending a light beam through closed wave guides. But the guides must be straight, with mirrors at bends, because light cannot normally curve round corners. This however, is exactly what an optical fibre achieves. Thanks to the phenomenon of total internal reflection, a light beam injected into one end of a glass rod will emerge at the other, even if the rod is bent. If the glass is made thin enough, and woven into a fibre, it will be flexible.

The original work on fibre optics was done at the Standard Telecommunications Laboratories at Harlow, in the 60s, by Hong Kong scientist Charles Kao. His paper, published by the IEE in July 1966, made mathematical predictions of how light could be transmitted by pure glass waveguides, without significant signal loss.

## OPTICAL PURITY

The obstacle to light fibre communication is light loss, due to impurities in the glass material. Advances in light fibre communication over the last twenty years are all the result of dramatic improvements in optical purity. High temperature gas cleaning techniques are used to remove the water and metal ions which are a natural constituent of silica glass, and which attenuate light.

Most fibre is now made by the Modified Chemical Vapour Deposition process, invented by Bell Labs in America. Pure silica glass is deposited in a tube by burning silicon and germanium tetrachlorides and phosphorous oxichloride. The pure glass pre-form is then drawn from a furnace into fibre.

A single silica MCVD pre-form, taking two or three hours to produce, can be drawn into between 20 and 30 kilometres of fibre at the rate of several metres second. Dust is the main enemy of the process. Any foreign particle trapped in the pre-form will end up somewhere in the drawn fibre and either cause a break or block the passage of light. The pre-form cannot be checked for purity until it is drawn into fibre.

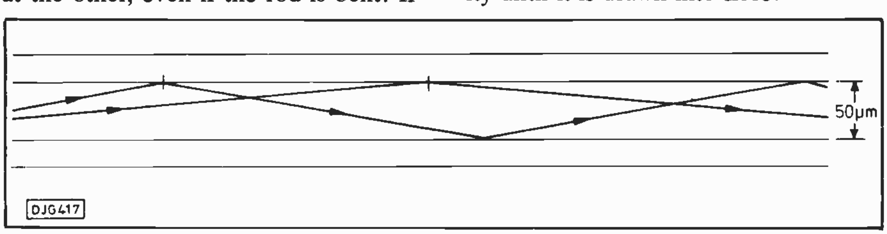



**Fig.4.** *Multiple reflections*

## REFRACTIVE INDEX

In any optical fibre, there is a difference in refractive index between the central core of the glass and the outer region or cladding. This is what causes total internal reflection, in the same way that someone swimming under water cannot see out in all directions to the dry world above. Light reflects from the boundary.

The central core of the fibre has the higher refractive index. If the refractive index sharply changes, between a high centre value and a low outside value, the fibre is said to have a "stepped index". Light transmitted along the fibre reflects many times from the boundaries, in a random fashion. The reflected signals arrive at different times to create a multipath effect. This distorts an analogue signal and introduces errors into a digital pulse train. Fibre of this tape is termed "multimode" because of the many modes of reflections inside the core.

If the refractive index of the glass varies gradually between the centre high value and lower outer value, the result is a "graded index" fibre. There is less risk of multipath distortion.

However, the most elegant approach is to use a stepped index fibre with a very narrow central core, so narrow in fact that a light beam passes down it in a straight line. This is "monomode" fibre. In practice the working core diameter of step index fibre is around 50 microns, for graded index it is over 100 microns and for monomode fibre it is just 5 microns.

It is obviously more difficult to inject light into the end of a fibre whose usable core is 5 microns wide. The light source must be aligned to an accuracy of just 0.5 microns. It is also difficult to join monomode fibre, because the tiny cores must be accurately aligned.

Wide core multimode fibres with a wider optical core are much easier to join and couple with a light source. But spurious reflections limit the working length of multimode fibre. There must be frequent booster stages which receive light, reconstitute and amplify electrical signals, and re-inject light into the next stage of the fibre run. Obviously this puts up the system cost over long distances. So multimode fibre is better for use on short runs and monomode fibre is better for long runs.

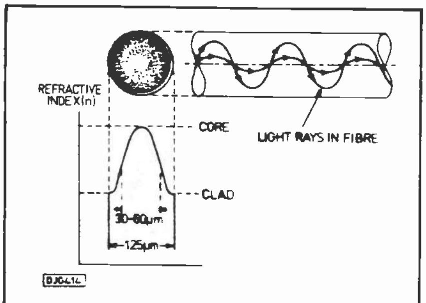



**Fig.5.** *Multimode transmission*

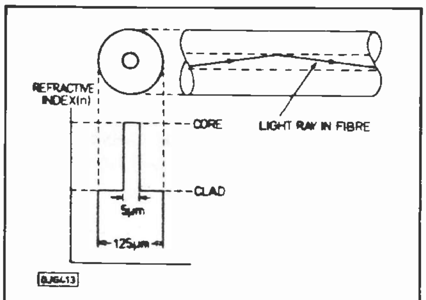



**Fig.6.** *Monomode transmission*

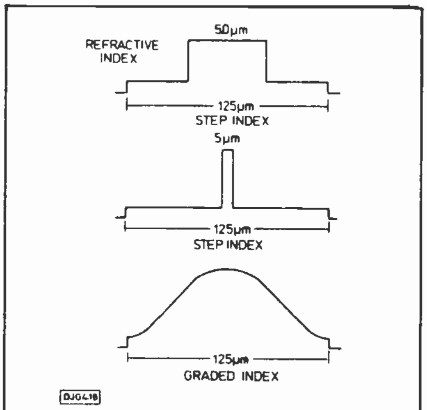



**Fig.7.** *Stepped and graded indices*

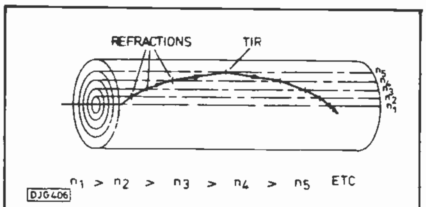



**Fig.8.** *Stepped index model of a graded index fibre*

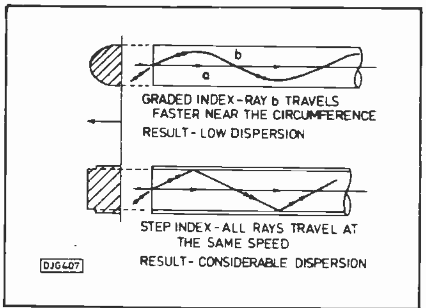



**Fig.9.** *Transmission of graded and stepped index fibres*

## LIGHT TRANSMISSION

There are two way of transmitting a signal by light; the light source can be varied in intensity as an analogue of the signal or it can be switched on and off in digital code.

There are two ways of injecting light into a fibre; either with a solid state laser or a solid state light emitting diode. A laser produces a beam which is easier to focus into a tiny monomode fibre, because its light does not spread in frequency as much as the light from an LED. But for mulitmode fibre, an LED will do as a source.

LEDs are cheaper than lasers but the cost of solid state laser is continually falling, largely as a result of the research and development work done for the consumer electronic boom in optical, video and audio disc players. However, disc player lasers are required only to produce a constant beam of light on the disc surface. The lasers used for optical fibre communication must be modulated at a very high frequency. This explains why professional lasers can cost hundreds of pounds each, compared to the few pounds, or less, now charged for the laser in a disc player.

## FREQUENCY FACTORS

The frequency used for optical fibre transmission is an important factor. At some frequencies even the best optical fibre available will absorb or scatter light, whereas at other frequencies it will pass light with almost no attenuation or scattering.

At high frequencies and short wavelengths, below around 0.7 micrometres or microns, spurious reflections kill the signal. At 1.4 microns residual water molecules cause a drastic attenuation peak. At longer wavelengths, around 1.8 micrometres, there is another water absorption peak. But at 0.8 microns, 1.3 microns and 1.6 microns there are "windows"; an absorption dip and peak in transmission.

Although in theory the bandwidth of a light link approaches infinity, in practice all lasers, photo receptors and conversion circuits have a finite bandwidth of operation. References to bandwidth are also meaningless unless qualified by distance of the run. The longer the run the more the waves spread or the more the digital pulses scatter. So a fibre link which has a bandwidth of 5 GHz over 1 kilometre may have a bandwidth of 1 GHz for a 5 kilometre run and so on. Bandwidth is also limited by the performance of the terminations at the end of the fibre.

British Telecom has for several years been able to transmit four analogue TV channels, of 8MHz bandwidth, down a single otpical fibre using frequency division multiplexing with a laser operating at 0.8 microns wavelength.

## DISTRIBUTION

Seven of London University's colleges are now linked by an interactive TV and video network, called Livenet, which relies on BT's optical fibre cable. Multimode cables are used for short distance links across London (up to 4 kilometres) and monomode for the longer distances (up to 25 kilometres) out to the Royal Holloway and Bedford New College

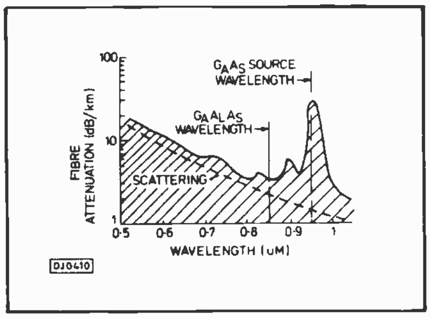



**Fig.10.** *Spectral response of a silica fibre*

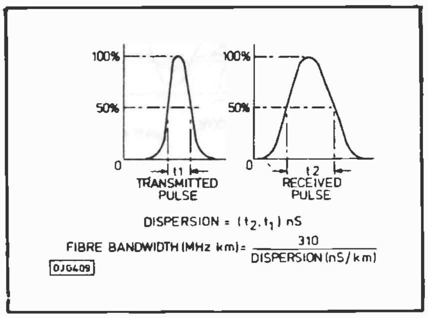



**Fig.11.** *Measurement of dispersion*

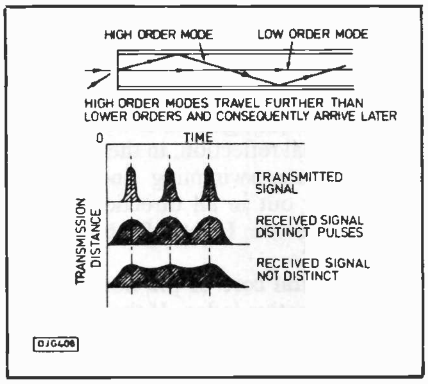



**Fig.12.** *Signal dispersion caused by multiple ray paths.*

near Windsor. There are four FM analogue video channels per fibre, with a fifth digital channel, available for data transmission of up to 2 Mbit/second. The laser transmitters are amplitude modulated by the multiplex of the five channels.

In future, analogue channel capacity with a single light carrier can probably be doubled with a single light carrier. But to increase bandwidth and the number of channels further, the trick is to inject the light from several separate lasers into a single fibre. Each laser operates at a different light wavelength and is separately modulated by several TV channels. This trick is hard to perform, because the lasers must be locked very tightly onto their operating frequencies.

The alternative approach is to convert the signal into digital code before optical transmission. But this is very wasteful of bandwidth. If studio quality pictures are needed, the data stream must run at around 200 megabits per second per channel.

British Telecom has for several years been using optical fibre links as telephone trunk lines. This follows a crucial decision made by BT in 1980. That was when engineers at the research laboratories in Martlesham decided to switch work from graded index to monomode fibre. The switch proved far easier than expected. "The problems just tumbled as people put their minds to them", said Dr John Midwinter, of the research laboratories, soon after.

BT planned its first optic fibre field trials in 1974 and began them in 1977. In October 1983 BT announced the successful test of a 27 kilometre optical link between Luton and Milton Keynes, and gave the go-ahead for a submarine fibre cable to carry phone calls and data under the Atlantic. This will be ready to use next summer (1988).

## INTERCITY LINKS

Currently 51% of BT's inter-city trunk lines are fibre; 15% of calls are carried by microwave link, and 34% by coax. No new coax has been laid since 1983.

Intercity fibre trunks can carry 2000 simultanteous telephone calls in digital code at a data rate of 140 Megabits/second with repeater stations every 30 kilometres. Soon as the fibres improve the spacing will be 50 km, and the data rate will rise to 565 MBits/s for 8000 simultaneous calls. The longest fibre route without a repeater is from Guernsey to Dartmouth, 135 km. The coax cables still in use as intercity phone trunk lines have a 12 MHz bandwidth, are paired to carry 54000 calls and need repeaters every 2 kilometres.

British Telecom's rival, Mercury, is laying optical fibre links around Britain to provide an alternative telephone service. Mercury recently laid a 51 kilometre fibre between Wolverton in Buckinghamshire and Mercury's satellite earth station near Oxford. Originally it was planned to put a repeater halfway along the run, but the fibre was able to support a 565 Mbit/s data stream without the need for any midpoint amplification. The fibre is of monomode type, with a wavelength of 1.3 micrometres.

When BT's submarine fibre cable to America is ready it will handle data at 280 Mbit/s and, by novel multiplexing tricks, carry 38,000 calls simultaneously. Undersea repeaters are being laid every 50 km. The current coax cable under the Atlantic carries 4246 calls and needs a repeater every 5 km.

## TUNING RESEARCH

With sights set on optical multiplexing BT engineers at Martlesham, and the STC laboratories at Harlow, have been researching laser which generate light tune very tightly to a specific frequency. Numerous discrete light channels can then be separated by slight shifts in light carrier frequency. The use of tightly defined frequencies also limits dispersion and makes it possible to use optical boosters instead of converting light into electricity and then back into light again. With tight light frequency tuning the receiver at the far end of the cable can work on the heterodyne principle, just like a radio receiver; the incoming light signal beats with a beam of locally generated laser light to produce an intermediate frequency of much longer wavelength. So tight tuning dramatically increases the number of information channels that can be sent down existing fibres and makes it

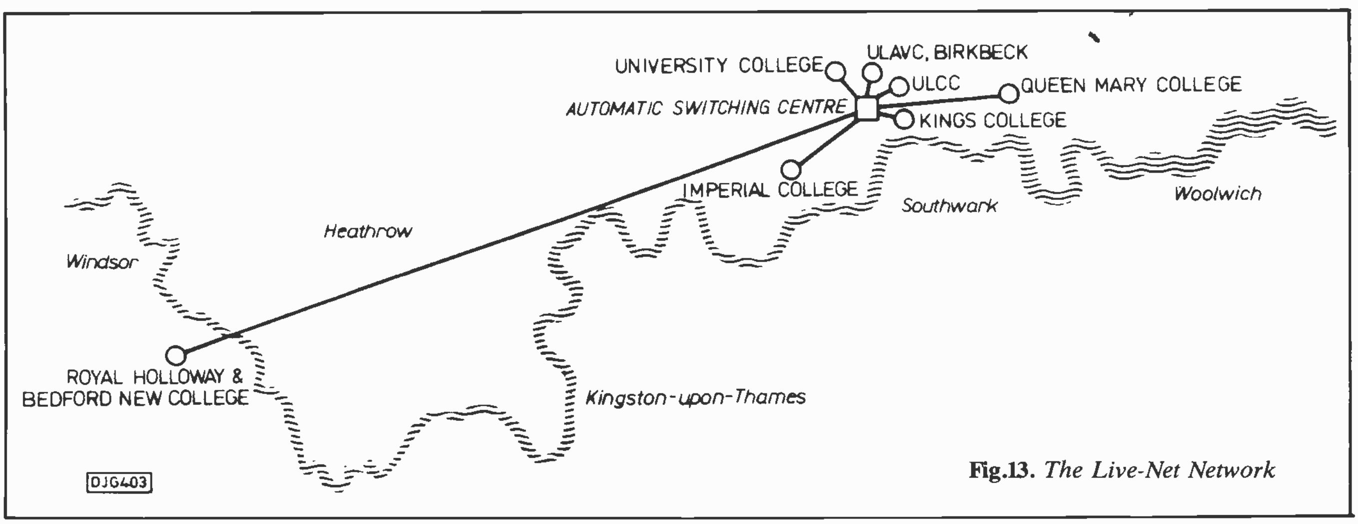



**Fig.13.** *The Live-Net Network*

possible to send signals further down a mono mode link, without any boosting along the route.

Clearly the development of lasers and fibres goes hand in hand. New lasers must exploit the optical windows offered by new fibres; new fibres must work at the wavelengths at which lasers lase.

Laser-fibre development is moving in two directions, towards shorter and longer wavelengths. Fibres working with the 1.3 micron window are reaching theoretical limits of performance, with a loss of 0.1 dB per kilometre.

## LASING DIODES

Although early fibre links used bulky gas lasers, they are now all solid state diodes. A tiny particle of active material is sandwiched between reflectors in an intergrated circuit. The sandwich filling determines the light output: gallium arsenide for wavelengths of around 0.8 microns and gallium indium arsenide phosphide for around 1.3 microns.

When a semiconductor diode emits light it spreads over a bandwidth of around 100 nanometres; when the diode lases, through oscillation of the light between reflectors, the bandwidth tunes down to around 1 nanometre. STL has been working with diffraction gratings which tune the lased light even tighter.

The Philips research lab at Redhill in Surrey has been working on laser diodes with shorter wavelengths. The technique used is MBE, molecular beam epitaxy, a way of growing very thin layers of semiconductor crystal. The semiconductor material is evaporated in a vacuum and beamed onto a heated substrate. It grows in layers at a rate of around one atom per second. By rotating the substrate and switching the beams on and off with a shutter it is possible to build up very thin, very even, layers of gallium and arsenic. When the layers are superthin, the gallium arsenide behaves in an odd way because its atoms are effectively squashed into two dimensions instead of the usual three.

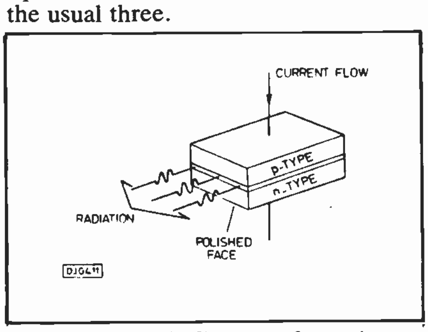



**Fig.14.** *Schematic diagram of a semi-conductor laser.*

The laser sandwich has two layers of aluminium gallium arsenide, with gallium arsenide in the middle. As the thickness of the middle layer goes down, so does the wavelength. Philips has now got down to a layer of around 13 angstrom, which is the equivalent of about five atomic layers. At this thickness, the laser starts emitting light of such short wavelengths and high frequency that it comes into the visible band. The tiny laser chip actually glows red in the dark. The wavelength achieved is around 700 nanometres, which is 0.7 microns. This is very short for a solid state laser. Normally only gas lasers can go that low. Philips believes that with MBE it can go even further, probably down to 0.65 microns.

The new diodes are called "short wavelength quantum well lasers". The "quantum well" describes the filling of the sandwich which is only a few atoms thick.

Meanwhile Toshiba in Japan says it already has a semiconductor laser working at a wavelength of 0.656 micrometres. It uses InGaA1P, a layering of indium-gallium-aluminium-phosphorous. Toshiba claims that this is the world's first solid state laser to work at this wavelength.

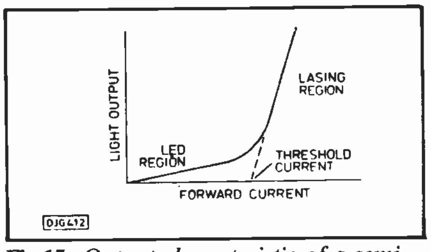



**Fig.15.** *Output characteristic of a semi-conductor laser*

## LONGER WAVELENGTHS

Although all current opto-electronic technology relies on light with a wavelength of below 2 microns, there is mounting interest in light at longer wavelengths. Doctors use 10.6 micron light from an infra red gas laser, for surgery. The same lasers are used in industry, to cut steel. Until now this long wavelength light has been carried by waveguides with mirrors at the corners. Silica glass simply absorbs light of this long wavelength. A new generation of fluoride glass fibres is emerging which can handle light of between 2 and 12 micron wavelength. But flouride glass is difficult to draw and the fibres are fragile when formed.

STL in Britain has been working with glass fibre made from zirconium flouride. This caries infra red light efficiently but is still fragile. It can break when bent round a corner. Matsushita in Japan make long wavelength fibre from thallium bromoiodide which it claims is both flexible and an efficient carrier for infra red. The surgical laser fibre has such low absorption that it can carry a 30 watt beam without overheating. It bends round a curve of 15 centimetre radius without fracturing.

The Japanese success with infra red fibre will greatly interest the armed forces. When thermal imaging cameras are used on the wings of aircraft for surveillance, the infra red data collected by the sensors has until now had to be converted to electricity before transmission along wires to flight recorders inside the body. With the new otpical fibres, the sensor data can be carried as light.

## HYDROGEN ABSORPTION

In the new field of optoelectronics there is always something new to learn. It was during blue sky experimetns on future fibres a few years ago that BT made a discovery which sent shock waves through the entire optical fibre industry. When glass fibre comes into contact with hydrogen, it absorbs the gas and the chemical structure of the glass modifies. The glass then starts to absorb light at just those frequencies which are used for laser transmission. This makes the fibre permanently useless for communication.

Dr John Midwinter of BT described the discovery at the time as "coming like a joker out of the blue". Even a few per cent of hydrogen in the atmosphere surrounding the fibre can cause permanent damage. Fortunately the problem was discovered before trans-Atlantic fibre cables were laid. The galvanic effect of seawater on the steel cladding used to protect a submarine fibre cable could easily have generated hydrogen gas which might then diffuse through the cladding to the glass. Neither steel or iron can be relied on to block hydrogen molecules, which are very mobile. BT is confident that the problem has been solved by a careful choice of caulking and joint seals. The industry can be excused hoping that there are no new jokers like this still waiting to be discovered. PE

## LASER POWER

We have perhaps become so used to the West being the main source of advanced technology, that the achievements of the Russians are sometimes overlooked.

A notable example was reported recently in *The Times* when they revealed that the Russians appear to be working towards constructing giant orbiting satelites that will be capable of beaming solar power to specific locations on earth.

These would take the form of huge reflectors, possibly as much as one kilometre across, in geostationary orbit at around 22 thousand miles high. They would concentrate sunlight by a factor of 1000, and feed it to gallium aluminium arsenide solar cells. With an estimated 27% efficiency, the intense power would then be transmitted to earth by laser generators. Operating in the infra-red region of the spectrum, around 500 megawatts could be produced.

A suitable system of satelites could well be in orbit by 1995-2005. PE

# HOW TO USE THESE TRACKS

### FIRST MAKE TRANSPARENT COPY

(We regret that we cannot supply transparent copies of PCB track layouts.)

### STUDIO COPY METHOD

Ask local photographic studio to produce high contrast 1 to 1 positive transparency.

### HOME PHOTOGRAPHY METHOD

Using even, bright illumination, photograph track onto fine grain black and white negative film. Develop film for high contrast. Photographically enlarge image up to lifesize, and print onto high contrast lithographic cut film, such as Agfa Copyline HDU 3P Type 2. Develop in Agfa Litex G90T litho developer, or similar.

### PHOTOCOPY METHOD

Ask local photocopy shop to make a good contrast copy onto acetate film. (Some copiers are better than others – shop around.) Then touch up tracks with dense black ink, or photographic opaque ink.

### ISODRAFT METHOD

Have a normal photocopy made, ensuring good dense black image. Spray ISOdraft Transparentiser onto copy in accordance with supplied instructions. **ISOdraft** is available from **Cannon & Wrin**, 68 High Street, Chislehurst, Kent. Tel: 01-476 0935.

### PAINSTAKING METHODS

Draw image by hand onto clear film or drafting film using dense black ink. Draw direct onto copper surface of PCB fibreglass, using etch-resist inking pen. Use etch resist PCB tracks and pads, taping direct to copper surface, or onto drafting film.

### NEXT PRINT ONTO PCB

Place positive transparency onto photosensitised copper clad fibre glass, cover with glass to ensure full contact. Expose to Ultraviolet light for several minutes (experiment to find correct time – depends on UV intensity).

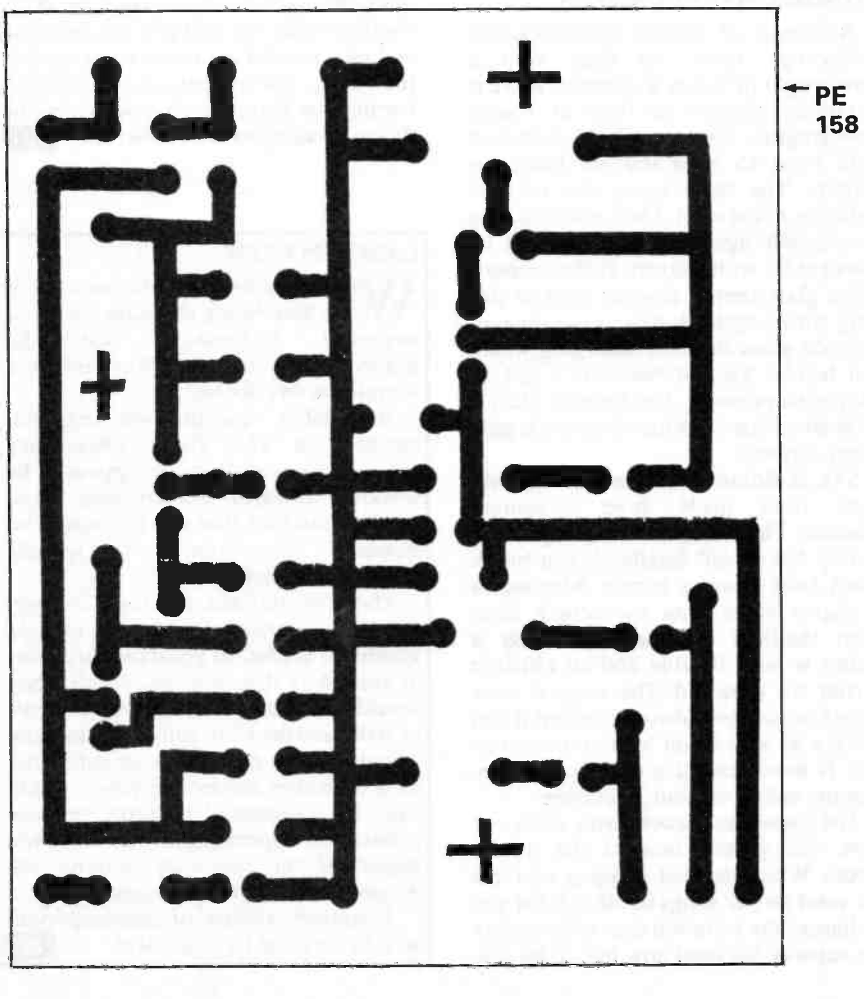
Develop PCB in Sodium Hydroxide (available from chemists) until clean track image is seen, wash in warm running water. Etch in hot Ferric Chloride, frequently withdrawing PCB to allow exposure to air. Wash PCB in running water, dry, and drill holes, normally using a 1mm drill bit.

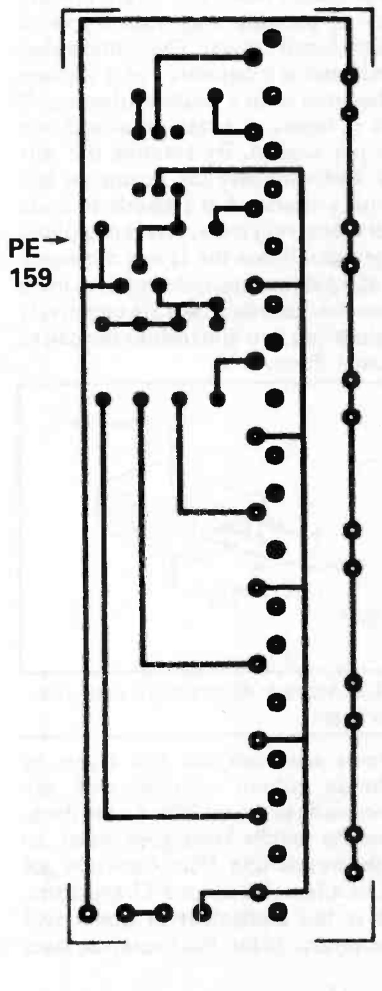
(PCB materials and chemicals are available from several sources – study advertisements.)

*** CAUTION – ENSURE THAT UV LIGHT DOES NOT SHINE INTO YOUR EYES. PROTECT HANDS WITH RUBBER GLOVES WHEN USING CHEMICALS.**

### ALTERNATIVE METHOD

Buy your PCB ready made through the PE PCB SERVICE, most are usually available – see page 60. PE



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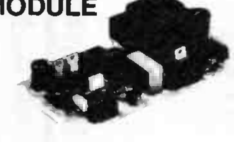
## CA 1250 LOW COST ALARM CONTROL MODULE



This tried and tested control unit represents the finest value for money in control systems, providing the following features:

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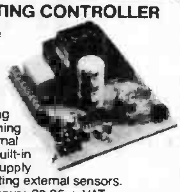
Price **£19.95** + VAT

## DP 3570 LIGHTING CONTROLLER



This versatile module provides timed switching of loads up to 3A for pre-set times between 10 secs and 5 mins. the timed period being triggered by the opening or closing of an external loop or switch. The built-in 12V 250mA power supply is available for operating external sensors. Suitable plastic enclosure £2.85 + VAT.

Only **£13.95** + VAT

## FL 500 QUARTZ HALOGEN FLOOD LIGHT

Whilst intended for security lighting applications, this unit is suitable for lighting patios, pathways and gardens etc. Supplied complete with 500W lamp, Protective grill, £1.95 + VAT.

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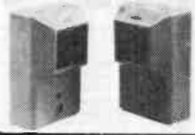
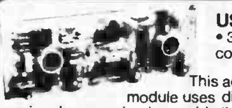


Consists of a separate transmitter & receiver, the system provides an invisible modulated beam which when broken operates the built-in relay. For use with security systems, but also ideal for photographic purposes and industrial applications. Size: 80x50x35mm. Only **£25.61** + VAT

## US 5063 DIGITAL ULTRASONIC DETECTOR



• 3 levels of discrimination against false alarms • Crystal control for greater stability • Adjustable range up to 25ft • Built-in delays • 12V operation.

This advanced module uses digital signal processing to provide the highest level of sensitivity whilst discriminating against potential false alarm conditions.

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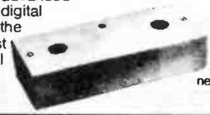
## ULTRASONIC MODULE ENCLOSURE



Suitable steel enclosure for housing the US 5063 supplied with the necessary mounting pillars and fixings.

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| 74LS40 | 0.20 |
| 74LS42 | 0.32 |
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| 74LS48 | 0.56 |
| 74LS49 | 0.64 |
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| 74LS76 | 0.28 |
| 74LS77 | 0.99 |
| 74LS78 | 0.30 |
| 74LS83 | 0.45 |
| 74LS85 | 0.42 |
| 74LS86 | 0.30 |
| 74LS90 | 0.32 |
| 74LS91 | 0.60 |
| 74LS92 | 0.36 |
| 74LS93 | 0.32 |
| 74LS95 | 0.47 |
| 74LS96 | 0.60 |
| 74LS107 | 0.32 |
| 74LS109 | 0.32 |
| 74LS112 | 0.32 |
| 74LS113 | 0.32 |
| 74LS114 | 0.32 |
| 74LS122 | 0.40 |
| 74LS123 | 0.42 |
| 74LS125 | 0.35 |
| 74LS126 | 0.35 |
| 74LS132 | 0.35 |
| 74LS133 | 0.35 |
| 74LS136 | 0.35 |
| 74LS137 | 0.76 |
| 74LS138 | 0.36 |
| 74LS139 | 0.36 |
| 74LS145 | 0.76 |
| 74LS147 | 1.12 |
| 74LS148 | 0.85 |
| 74LS151 | 0.32 |
| 74LS153 | 0.40 |
| 74LS154 | 0.94 |
| 74LS155 | 0.40 |
| 74LS156 | 0.44 |
| 74LS157 | 0.32 |
| 74LS158 | 0.34 |
| 74LS160 | 0.48 |
| 74LS161 | 0.48 |
| 74LS162 | 0.46 |
| 74LS163 | 0.46 |
| 74LS164 | 0.43 |
| 74LS165 | 0.62 |
| 74LS166 | 0.67 |
| 74LS168 | 0.72 |
| 74LS169 | 0.65 |
| 74LS170 | 0.79 |
| 74LS173 | 0.72 |
| 74LS174 | 0.39 |
| 74LS175 | 0.42 |
| 74LS1B1 | 1.50 |
| 74LS183 | 1.53 |
| 74LS189 | 1.70 |
| 74LS190 | 0.55 |
| 74LS191 | 0.52 |
| 74LS192 | 0.50 |
| 74LS193 | 0.51 |
| 74LS194 | 0.53 |
| 74LS195 | 0.52 |
| 74LS196 | 0.60 |
| 74LS197 | 0.52 |
| 74LS221 | 0.56 |
| 74LS240 | 0.55 |
| 74LS241 | 0.48 |
| 74LS242 | 0.55 |
| 74LS243 | 0.60 |
| 74LS244 | 0.48 |
| 74LS245 | 0.52 |
| 74LS247 | 0.50 |
| 74LS248 | 0.52 |
| 74LS249 | 0.82 |
| 74LS251 | 0.34 |
| 74LS253 | 0.34 |
| 74LS256 | 0.62 |
| 74LS257 | 0.42 |
| 74LS258 | 0.42 |
| 74LS259 | 0.56 |
| 74LS260 | 0.48 |
| 74LS266 | 0.28 |
| 74LS273 | 0.54 |
| 74LS279 | 0.40 |
| 74LS280 | 1.20 |
| 74LS283 | 0.58 |
| 74LS290 | 0.41 |
| 74LS293 | 0.41 |
| 74LS295 | 0.99 |
| 74LS298 | 0.72 |
| 74LS299 | 1.45 |
| 74LS321 | 5.64 |
| 74LS322 | 1.80 |
| 74LS323 | 1.80 |
| 74LS324 | 3.25 |
| 74LS347 | 2.47 |
| 74LS348 | 1.54 |
| 74LS352 | 0.90 |
| 74LS353 | 0.90 |
| 74LS365 | 0.28 |
| 74LS366 | 0.37 |
| 74LS367 | 0.37 |
| 74LS368 | 0.37 |
| 74LS373 | 0.55 |
| 74L5374 | 0.55 |
| 74LS375 | 0.55 |
| 74LS377 | 0.90 |
| 74LS378 | 0.72 |
| 74LS385 | 2.46 |
| 74LS386 | 0.48 |
| 74LS390 | 0.50 |
| 74LS393 | 0.45 |
| 74LS395 | 0.78 |
| 74LS396 | 2.90 |
| 74LS398 | 1.60 |
| 74LS399 | 0.80 |
| 74LS490 | 0.99 |
| 74LS540 | 0.99 |
| 74LS541 | 0.99 |
| 74LS624 | 3.39 |
| 74LS625 | 2.88 |
| 74LS626 | 2.47 |
| 74LS627 | 4.45 |
| 74LS628 | 2.47 |
| 74LS629 | 1.65 |
| 74LS640 | 1.20 |
| 74LS641 | 1.10 |
| 74LS642 | 1.40 |
| 74LS644 | 1.40 |
| 74LS645 | 1.40 |
| 74LS668 | 0.99 |
| 74LS670 | 0.72 |
| 74LS673 | 3.40 |
| 74LS674 | 3.40 |
| 74LS682 | 2.45 |
| 74LS683 | 2.70 |
| 74LS684 | 2.70 |
| 74LS685 | 2.70 |
| 74LS686 | 3.30 |
| 74LS687 | 2.70 |
| 74LS783 | 14.60 |
| 74LS785 | 19.40 |

### 74HC SERIES

| | £ p |
|---|---|
| 74HC00 | 0.14 |
| 74HC02 | 0.14 |
| 74HC03 | 0.14 |
| 74HC04 | 0.15 |
| 74HCU04 | 0.24 |
| 74HC08 | 0.24 |
| 74HC10 | 0.24 |
| 74HC11 | 0.14 |
| 74HC14 | 0.33 |
| 74HC20 | 0.24 |
| 74HC21 | 0.24 |
| 74HC27 | 0.24 |
| 74HC30 | 0.24 |
| 74HC32 | 0.24 |
| 74HC42 | 0.24 |
| 74HC51 | 0.24 |
| 74HC58 | 0.24 |
| 74HC73 | 0.31 |
| 74HC74 | 0.31 |
| 74HC75 | 0.35 |
| 74HC76 | 0.35 |
| 74HC77 | 0.45 |
| 74HC85 | 0.33 |
| 74HC86 | 0.36 |
| 74HC107 | 0.36 |
| 74HC109 | 0.36 |
| 74HC112 | 0.36 |
| 74HC113 | 0.36 |
| 74HC123 | 0.49 |
| 74HC125 | 0.39 |
| 74HC126 | 0.39 |
| 74HC132 | 0.42 |
| 74HC133 | 0.42 |
| 74HC137 | 0.68 |
| 74HC138 | 0.42 |
| 74HC139 | 0.27 |
| 74HC147 | 5.23 |
| 74HC151 | 0.42 |
| 74HC153 | 0.42 |
| 74HC154 | 1.22 |
| 74HC157 | 0.42 |
| 74HC158 | 0.42 |
| 74HC160 | 0.49 |
| 74HC161 | 0.49 |
| 74HC162 | 0.49 |
| 74HC163 | 0.49 |
| 74HC164 | 0.49 |
| 74HC165 | 0.65 |
| 74HC166 | 0.93 |
| 74HC173 | 0.65 |
| 74HC174 | 0.44 |
| 74HC175 | 0.44 |
| 74HC190 | 0.52 |
| 74HC192 | 0.76 |
| 74HC193 | 0.50 |
| 74HC194 | 0.54 |
| 74HC195 | 0.54 |
| 74HC237 | 0.58 |
| 74HC240 | 0.49 |
| 74HC241 | 0.56 |
| 74HC242 | 0.63 |
| 74HC243 | 0.68 |
| 74HC244 | 0.49 |
| 74HC245 | 0.53 |
| 74HC251 | 0.27 |
| 74HC253 | 0.42 |
| 74HC257 | 0.48 |
| 74HC258 | 0.59 |
| 74HC259 | 0.89 |
| 74HC273 | 0.49 |
| 74HC280 | 0.81 |
| 74HC299 | 1.23 |
| 74HC354 | 0.42 |
| 74HC356 | 0.51 |
| 74HC365 | 0.44 |
| 74HC366 | 0.44 |
| 74HC367 | 0.44 |
| 74HC368 | 0.44 |
| 74HC373 | 0.53 |
| 74HC374 | 0.69 |
| 74HC375 | 0.82 |
| 74HC390 | 0.60 |
| 74HC393 | 0.60 |
| 74HC423 | 0.92 |
| 74HC533 | 0.81 |
| 74HC540 | 0.84 |
| 74HC541 | 0.84 |
| 74HC573 | 0.84 |
| 74HC574 | 0.84 |
| 74HC589 | 1.12 |
| 74HC595 | 0.99 |
| 74HC597 | 0.99 |
| 74HC640 | 1.05 |
| 74HC643 | 1.05 |
| 74HC645 | 3.56 |
| 74HC646 | 2.08 |
| 74HC648 | 2.08 |
| 74HC658 | 4.42 |
| 74HC688 | 1.85 |
| 74HC4002 | 0.31 |
| 74HC4017 | 0.59 |
| 74HC4020 | 0.59 |
| 74HC4024 | 0.39 |
| 74HC4040 | 0.39 |
| 74HC4049 | 0.62 |
| 74HC4050 | 0.62 |
| 74HC4051 | 1.12 |
| 74HC4052 | 1.12 |
| 74HC4053 | 1.12 |
| 74HC4060 | 0.38 |
| 74HC4075 | 0.32 |
| 74HC4078 | 0.38 |
| 74HC4511 | 0.99 |
| 74HC4514 | 1.70 |
| 74HC4538 | 1.08 |
| 74HC4543 | 1.62 |

### 74HCT SERIES

| | £ p |
|---|---|
| 74HCT00 | 0.32 |
| 74HCT02 | 0.32 |
| 74HCT03 | 0.49 |
| 74HCT04 | 0.32 |
| 74HCT08 | 0.32 |
| 74HCT10 | 0.32 |
| 74HCT11 | 0.32 |
| 74HCT14 | 0.54 |
| 74HCT20 | 0.34 |
| 74HCT21 | 0.32 |
| 74HCT27 | 0.40 |
| 74HCT30 | 0.41 |
| 74HCT32 | 0.32 |
| 74HCT42 | 0.68 |
| 74HCT73 | 0.49 |
| 74HCT74 | 0.45 |
| 74HCT75 | 0.54 |
| 74HCT85 | 0.76 |
| 74HCT86 | 0.54 |
| 74HCT123 | 0.78 |
| 74HCT132 | 0.78 |
| 74HCT138 | 0.59 |
| 74HCT139 | 0.57 |
| 74HCT153 | 0.76 |
| 74HCT154 | 1.70 |
| 74HCT157 | 0.59 |
| 74HCT160 | 0.79 |
| 74HCT161 | 0.86 |
| 74HCT175 | 0.72 |
| 74HCT238 | 0.85 |
| 74HCT238 | 0.85 |
| 74HCT240 | 0.95 |
| 74HCT241 | 0.95 |
| 74HCT244 | 0.95 |
| 74HCT245 | 1.32 |
| 74HCT273 | 1.28 |
| 74HCT373 | 0.99 |
| 74HCT374 | 0.99 |
| 74HCT390 | 0.95 |
| 74HCT393 | 0.95 |
| 74HCT540 | 1.62 |
| 74HCT541 | 1.77 |
| 74HCT573 | 1.24 |
| 74HCT574 | 2.11 |
| 74HCT640 | 1.54 |
| 74HCT643 | 1.54 |
| 74HCT646 | 2.09 |

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|---|---|
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| 14C89AN | 1.06 |
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| 6809P | 6.60 |
| 6821P | 1.94 |
| 68B21P | 4.50 |
| 6840P | 3.90 |
| 6845L | 7.40 |
| 7130L-100P | 23.45 |
| 74ACT874P | 4.20 |
| 75176AP | 2.26 |
| 80C85A-2RS | 13.70 |
| 80C86AL-2 | 24.90 |
| 82C54P 8MHZ | 5.90 |
| 82C59A-2RS | 4.50 |
| 82C88AS | 14.36 |
| AY-5-8136 | 5.95 |
| HCPL-2630 | 5.86 |
| HCPL-4100 | 5.82 |
| HCPL-4200 | 5.82 |
| ICL7673CPA | 2.49 |
| MC145406P | 2.65 |
| UA9638CP | 2.35 |
| UPD7201AC | 5.82 |

### DYNAMIC RAM 5V

| | |
|---|---|
| 4164B-15 | 0.90 |
| 4416-15 | 3.30 |
| 41464-12 | 3.30 |
| 41256C-15 | 3.30 |

### STATIC RAM 5V

| | |
|---|---|
| 2114LP-30 | 1.50 |
| 2114LP-20 | 1.80 |
| 6116LP-12 | 1.70 |
| 6116LP-15 | 1.70 |
| 6264LP-15 | 2.40 |
| CXK58256P-12L | 13.20 |

### EPROMS & EEPROMS

| Device | PGMV | |
|---|---|---|
| 27256-25 | 12.5V | 3.75 |
| 27C256-15 | 12.5V | 5.60 |
| 27C256-25 | 12.5V | 5.20 |
| 27C256-25 | 21V | 5.20 |
| 27C256-30 | 21V | 5.20 |
| 27C512-15 | 12.5V | 13.65 |
| X2864AP-35 | | 16.95 |

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| | |
|---|---|
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| 3MHZ to 18MHZ | 1.50 |

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# TEACHER POWER

**BY TIM PIKE**

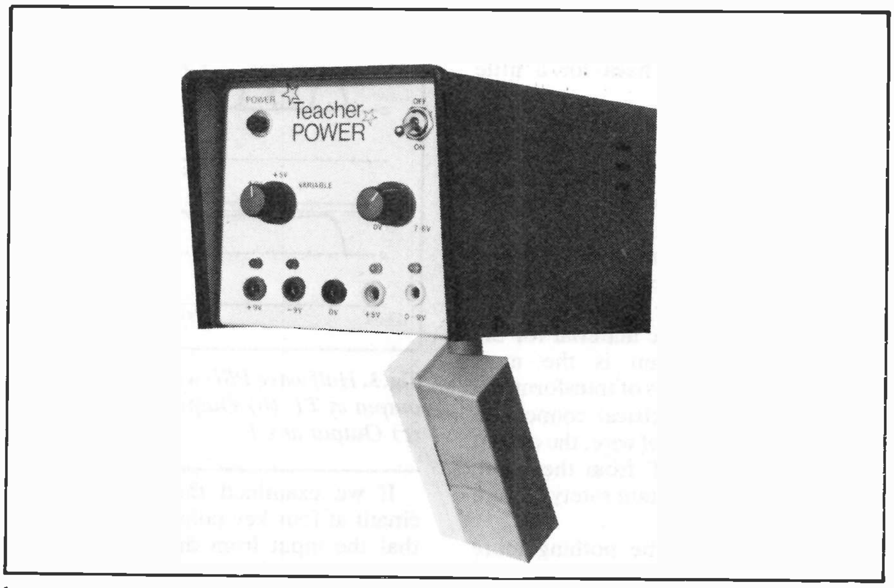
## A series of designs for general purpose low voltage power supplies suitable for use with GCSE projects

*Power is the sine qua non of electronics, so your power supply will be one of the most important projects you construct. Learning to wire up a mains supply safely is also important. Read on and take your choice.*

FOR the third project in this series I have chosen to go back to square one and to consider a number of relatively simple designs for low voltage power supplies which could be used to run any of the other projects in this series. Readers who have followed the series so far will recall that the first project *(Teacher Timer*, PE Sept 87) required a dual ± 9V supply which it was suggested might conveniently be produced by using two PP3 batteries.

The second project *(Teacher Locker*, PE Oct 87) required the use of just one 9V supply. In general, many projects are designed around the use of a single 9V supply because the PP3 battery is so simple to use and takes up relatively little space. TTL devices which work on a +5V supply can be accommodated if a simple 5V regulator circuit is added.

The intention in this article is to develop a number of circuits for low voltage supplies with a range of useful output voltages which between them will be suitable for any GCSE project and indeed for almost all general practical work.




### SAFETY CONSIDERATIONS

It is impossible to lay too much emphasis on the safety requirements of circuits of this type. It is also most important for teachers and students alike to consult the examination syllabus which they are following to find out exactly how much of the theory and practice of power supply circuits they need to cover.

Certainly no examination course at this level (GCSE) will ever require students to work with mains voltages. My research leads me to conclude that for this very reason a number of the GCSE syllabuses do not even mention transformers. I think that this is unfortunate if only because the transformer principle is one so fundamental to electromagnetic work in physics and to many useful devices in practical electronics.

In order to offer a complete picture of the circuits which I shall develop in this article, I am going to start from a mains input and thereby include the transformer stage. Each circuit will clearly show an alternative which requires only a very low voltage a.c. input, effectively working through from beyond the transformer stage. By this means I hope to satisfy both the educational safety requirements of the project and yet offer the enthusiast who is quite at home with mains voltages something complete.

Returning for a moment to the general safety requirements, I would draw the attention of all readers to the excellent article on *Electrical Safety* by Ray Stuart (PE May 87). I will be stressing a number of safety features along the way, all of which were discussed in detail in that article.

### BUILDING BLOCKS

In its very simplest form a mains powered low voltage supply will consist of three basic stages: a transformer to reduce (step down) the mains voltage to some much lower value and to provide isolation from the mains, a rectifier to convert the a.c. output of the transformer to a very crude form of d.c. and a smoothing circuit to improve the quality of the d.c. output (Fig.1).

Already we have used a number of technical terms which may be unfamiliar to some students. A transformer is a device which consists of two quite separate coils of insulated wire wound onto a common core or former. One coil usually has many more turns of wire than the other. If the transformer is being used to step down the voltage from a higher value to a lower one then the input coil (the primary) will have the larger number of turns. The turns ratio defines the ratio of:

$$\frac{\text{No. of turns on secondary winding (Output)}}{\text{No. of turns on primary winding (Input)}}$$

So for the step down transformer which we will need this ratio is much less than 1. For a transformer which is doing no work (i.e. no current being drawn from its secondary winding) the turns ratio also equals the ratio of:

$$\frac{\text{Voltage induced in secondary}}{\text{Voltage applied to primary}}$$

Once the transformer is made to work

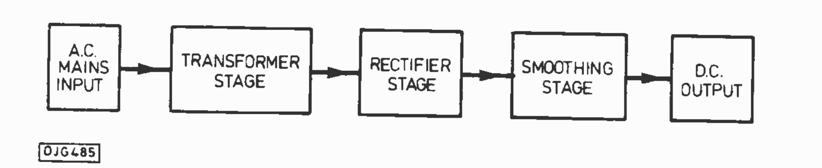



**Fig.1.** *Building blocks of simple low voltage supply.*

by connecting a load to the secondary coil, the energy being drawn must be supplied from the primary coil and therefore from the mains input. The transformer operates by converting the electrical energy from the current in the primary coil into an alternating magnetic field in and around the core of the transformer.

This magnetic energy is reconverted to electrical energy in the secondary coil by electromagnetic induction. Inevitably there are energy losses in this double conversion process. Some energy is lost as magnetism but more can be lost as heat. You will find that the core of a transformer becomes quite warm after it has been working hard for a little while.

Various steps are taken to keep energy losses to the absolute minimum. These include using a very good conducting material for the coils (usually copper wire), 'laminating' the core of the transformer (this means making it of lots of thin strips of material stuck together instead of out of one solid piece) and using a good magnetic material for the core itself. (Soft iron is the most common for these types of transformer).

As there is no electrical connection between the two coils of wire, the output is said to be 'isolated' from the input. This is one very important safety feature of the transformer.

The rectifier may be nothing more than one semiconductor diode arranged so that it passes the positive half cycles of the alternating current but blocks the negative half cycles. This very simple form of rectification is called 'half wave rectification' because the output consists of either the positive or the negative half waves of the a.c. input.

The smoothing circuit may be one fairly large value electrolytic capacitor acting as a temporary reservoir for storing electrical charge. When the half cycle which is being passed by the diode comes along, the capacitor charges up and then releases its charge during the half cycle when the diode is blocking.

Fig.2a. shows the arrangement of these three components to form a half wave power supply circuit. Notice the first of a number of safety features which we will build into these designs right from the start. A neon indicator lamp is connected across the primary winding of the transformer to show the presence of the mains input. A double pole On-Off switch is used so that both the Live and the Neutral connections from the mains are disconnected when the switch is off. A suitable fuse is included in the live input. Fig.2b shows the same principle but working from an existing a.c. low voltage supply.

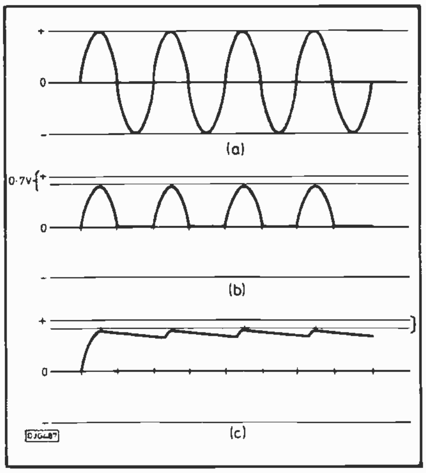



**Fig.3.** *Half wave PSU waveforms (a) a.c. output at T1. (b) Output after D1. (c) Output at C1.*

If we examined the signals in this circuit at four key points we would find that the input from the mains and the output from the transformer are both pure sine waves (Fig.3a). Transformers preserve frequency and so the period of the waves would be about 0.02 seconds corresponding to a 50Hz input waveform. The amplitudes would of course differ considerably and approximately by the turns ratio of the transformer. In comparison to the output of the transformer, the signal measured after the diode, D1, would have a slightly reduced peak voltage in the positive direction (caused by the loss of about 0.7V across the diode) but zero amplitude in the negative direction. This is the familiar half wave rectified a.c. pattern (Fig.3b). Technically we have now produced direct current (i.e. the current flows one way only) but of a very crude and unacceptable type. The pulses of d.c. rise and fall rapidly (fifty times a second) and actually disappear altogether for half the time.

A considerable improvement is made if a fairly large value electrolytic capacitor is connected across the output. Whatever value is chosen for C1, it is impossible to provide a perfectly smooth d.c. output.

## FULL WAVE RECTIFICATION

In practice, the simple half wave circuit is rarely used because it is very inefficient. It is clear from the diagrams of Fig.3 that somewhat less than half the maximum transformer output power can possibly appear at the d.c. output. Ignoring the smoothing effect of the capacitor it can be seen quite clearly that the rectified output consists of only one half of the original waveform and that even this half will have a slightly reduced amplitude. Very large smoothing capacitors are needed to cover the relatively long intervals between pulses of charge from the rectified output. To some extent at least the use of a full wave rectifier circuit improves the situation and reduces the demands on the smoothing capacitor.

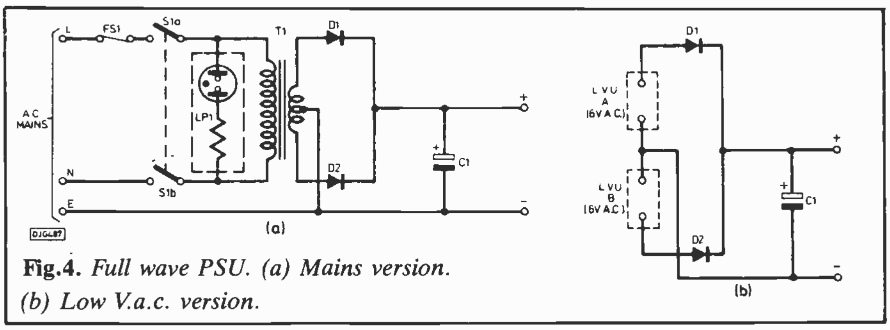



**Fig.4.** *Full wave PSU. (a) Mains version. (b) Low V.a.c. version.*

The simplest full wave circuit requires the use of a centre-tapped mains transformer. (Fig.4a). Two identical secondary windings connected in series will produce the same effect. If you are avoiding the use of mains transformers within your own construction and you wish to simulate this method by using commercial low voltage a.c. supplies then you can connect two of these in series and use the mid-point as the centre tap equivalent. But beware! Some commercial low voltage supplies will work against each other if connected incorrectly. To ensure that this is not happening, start each supply on a very low output value (say 1V). Make sure by using an a.c. voltmeter or an oscilloscope that the combined outputs are what you

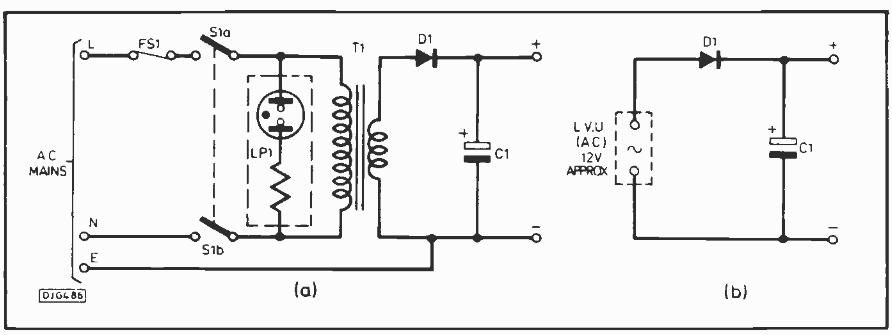



**Fig.2.** *Half wave PSU. (a) Mains version. (b) Low V.a.c. version.*

would expect (i.e. the sum of the two separate outputs). Once you are sure about this it is safe to turn them both up to whatever level you require. Do this before you connect the load across them. It is also quite important to 'balance' the two L.V.U.s if you are using this method. Try to make sure that they are contributing equally to the total a.c. output (Fig.4b).

The two halves of the secondary (or the two L.V.U. outputs) are effectively fed to separate half wave rectifying circuits but operating in a push-pull mode. Diode D1 conducts on one half-cycle; diode D2 conducts on the other half-cycle, but in both cases the pulse of charge received by C1 is in the same direction. As the capacitor now receives two charges per cycle, there is less time for the capacitor to discharge between pulses and therefore a smaller capacitor will give the same level of smoothing.

The diagram of Fig.5 show the output waveforms at the same key points in circuit as for Fig.3.

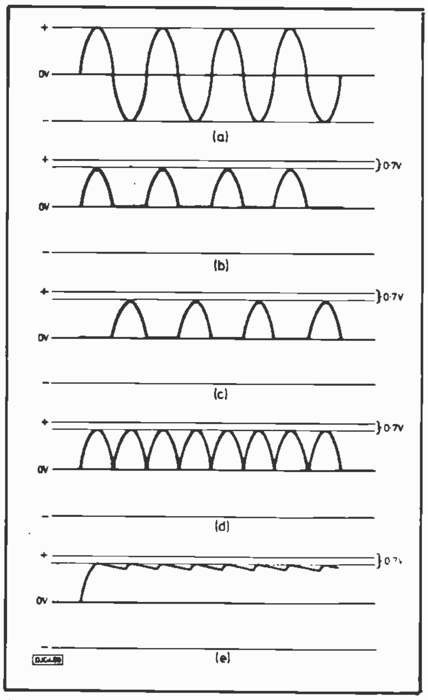



**Fig.5.** *Full wave PSU output waveforms. (a) At T1. (b) At D1. (c) At D2. (d) At D1/D2, without C1. (e) At D1/D2 with C1.*

One other point worthy of mention here is that the frequency of the ripple from the full wave rectifier circuit is twice what it was from the half wave circuit. This means that with the U.K. mains operating at 50Hz, the full wave ripple frequency will be at 100Hz. This might be significant in an audio system where 'hum' from the mains will form part of the unwanted noise signals. A signal at 100Hz is more likely to be audible than one at the same intensity at 50Hz. The human ear is most sensitive to low intensity sounds at a mid-range frequency of about 1kHz. A hum at 100Hz is therefore a little closer to this than one at 50Hz.

This slight disadvantage does not outweigh the considerable advantages of the full wave method over the half wave method in terms of the ease of smoothing.

Some students find it very difficult to memorise or to work out the correct arrangement of diodes. Notice though a number of important features: Firstly that diodes on opposite sides of the 'square' face the same way. Secondly, that at corners where the a.c. supply is connected, one diode must face the corner, the other must face away from it. Lastly it must be true that at the d.c. corners, the eventual '+' terminal will have two diodes facing it whereas the '−' terminal will have diodes facing away from it.

These observations are not just to do with logical patterns, rather they are inherent to the way in which the bridge must operate.

Consider the secondary winding, the bridge and the capacitor drawn schematically as in Fig.7. In the first diagram (Fig.7a) the a.c. path is clockwise through the secondary coil. Diodes D2 and D3 complete the path through the load and back to the coil. When the current in the secondary reverses, diodes D4 and D1 are now forward biased and lead the current through the load (in the same direction as before) and back to the coil. So regardless of the direction of a.c. current, the d.c. current always flows through the load in the same direction. Two diodes are conducting at any one time; the other two are blocking.

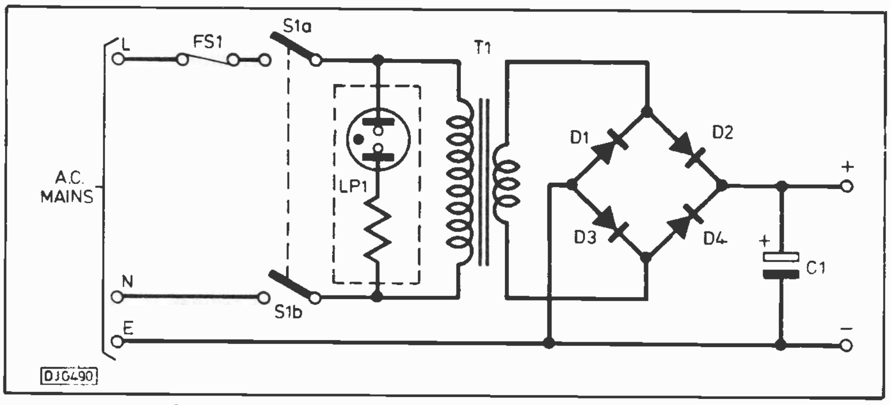



**Fig.6.** *Basic bridge rectifier circuit (mains version)*

## THE BRIDGE RECTIFIER

A bridge rectifier is an arrangement of four rectifier diodes which allows full wave rectification without the need for a centre-tapped transformer. Since just one secondary winding is now able to provide two charging pulses per cycle, this circuit is also much more efficient than either of the others. The only penalty is that there are now two diodes in the conduction path at any one time. This means that there will be a voltage drop of around 1.4V rather than the 0.7V experienced previously. Fig.6 shows the basic arrangement for a full wave bridge rectified circuit. Again, note that the mains connections and transformer could be replaced by a commercial a.c. low voltage supply with the same rectifier and smoothing components attached.

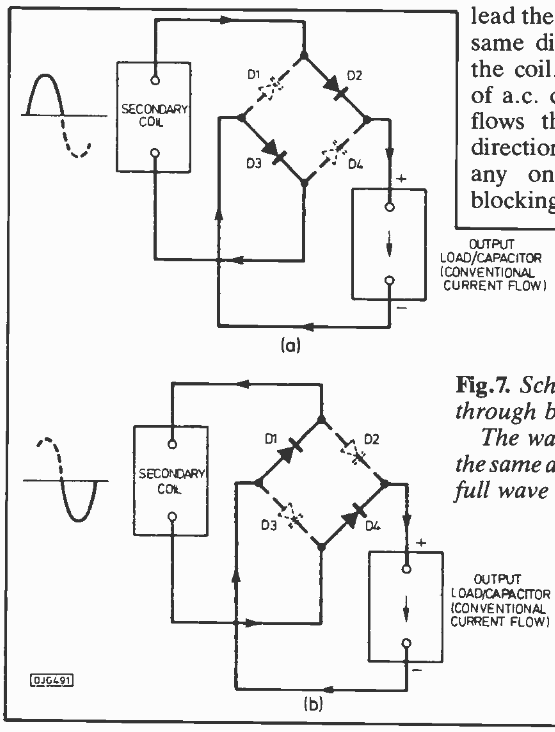



**Fig.7.** *Schematics showing current paths through bridge on each half cycle.*
*The waveforms produced are exactly the same as in Fig.5. for the centre-tapped full wave supply.*

## LOADING EFFECT

All the supplies considered so far are of the unregulated type. This means that the output voltage can vary considerably according to changes elsewhere.

It is tempting to think that the most likely cause of output voltage variation would be fluctuation in the mains supply voltage. In practice this is relatively unimportant. Suppose the mains voltage dropped by 12V from its nominal value of 240V. This represents a 5% reduction. All voltages would therefore be reduced by 5%. If our d.c. supply was intended to give +9V out, then it would fall to 95% x 9V is 8.55V. It is unlikely that this would be too devastating. Such relatively large changes in the mains supply voltage do not normally occur and so we must look elsewhere for the culprit.

In fact most of the variation in output voltage of an unregulated supply is due to the loading effect of the supply. The secondary winding of the transformer and the other components used in the output circuit will all contribute to a global resistance figure. This might otherwise be called the output impedance of the power supply. When current is drawn from the supply, a voltage is developed across this output impedance proportional to the amount of current being drawn. This loss of voltage is subtracted directly from the available output voltage. So the more current is drawn, the lower the output voltage becomes.

## CURRENT ALLOWANCE

To a certain extent this is allowed for in the design of transformers. A transformer which is quoted as being 12-0-12 volts at 2.5 amp is designed to give two separate 12V outputs each delivering a current of 2.5A to its load. Alternatively one 24V output could be obtained, again at 2.5A. Such a transformer would be rated as 60VA. (24V x 2.5A = 60VA). Note that the electrical unit of power (the Watt) is not used here. This is because the transformer is not consuming energy at the rate of 60W – ideally it is consuming nothing itself! If a much lower current (say only 0.5A) was drawn from the transformer then the output voltage of each winding would be much more than 12V, possibly even as high as 18V for an unloaded transformer.

Many items of electronic equipment use varying amounts of current at different times. Certainly the current drawn by analogue amplifier circuits and by digital switching circuits might vary enormously from a fairly low background level to peaks which might be a hundred times bigger. As the current drawn from the supply rises and falls so the output voltage will fall and rise. We have already seen that there can be as much as a fifty percent increase in nominal output voltage if the circuit is practically unloaded.

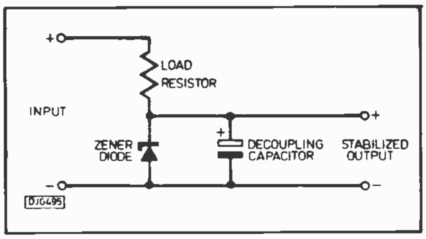



**Fig.8.** *Zener regulator*

## REGULATED SUPPLIES

In order to overcome these difficulties some form of 'regulation' or 'stabilisation' of the output voltage is required.

The simplest form of voltage regulator is the Zener shunt circuit shown in Fig.8. A Zener diode is chosen to give the required output voltage or as near to it as the preferred values will allow. At voltages below the Zener voltage, the diode has a very high resistance and therefore behaves like an open circuit. At or very close to the Zener voltage, the diode suddenly starts to conduct with an effective resistance of only a few ohms. Whatever excess voltage exists between the input voltage and the Zener voltage is dropped across the series resistor. Further increases in input voltage cause the diode to conduct even more current and thereby increase the voltage dropped across the resistor. By this means the output (stabilised) voltage is kept within a very small margin of the chosen Zener voltage.

There is one problem with this simple arrangement and that is that the rapidly changing currents flowing in the semiconductor materials of the Zener diode serve to generate large amounts of elecrical noise. In some applications this would be very annoying. A decoupling capacitor in parallel with the diode works well at attenuating (cutting down) the amount of noise.

Another more serious problem applies to the lower voltage values of Zener diodes. Theoretically the Zener diode should maintain a steady output voltage over a considerable range of output current. The Zener voltage values larger than about 6V do this within about 5% of their stated value. The smaller Zener values (e.g. 3V) may vary from only 2V at zero current output to 5V at the stated maximum current. Fig.9 shows (a) the ideal Zener response at 6V, (b) the response of a typical Zener diode at 10V and (c) the relatively poor response of a typical Zener diode at 2.4V.

One other extremely important feature of the Zener diode is that it is always used in reverse bias. (Fig.8). If the diode is connected in forward bias then it behaves more or less as an ordinary silicon diode with a steady voltage drop of around 0.7V across it, regardless of its Zener value.

## THREE TERMINAL REGULATORS

There are many clever ways of designing regulator circuits around the Zener principle. One or more transistors can be added to give more output current or even to produce current limiting (automatic shut-down if too much current is drawn).

Many of these sophisticated design problems have been overcome by the introduction of whole families of high performance monolithic voltage regulators at very low prices. Of these the 7805 is probably the best known because it has appeared in many voltage regulator circuits for well over a decade.

Nowadays there are regulators available to give stable voltages from +5V to +24V, from −5V to −24V and even adjustable regulators working up to 125V. Essentially the price you pay determines how much current you can draw. The faithful old 7805 will happily give at least 1A if connected to a reasonable heat sink.

All of these devices consist of three terminals. An input (unregulated), an output (regulated) and a common connection. (Fig.10). Most monolithic regulators have current limiting output

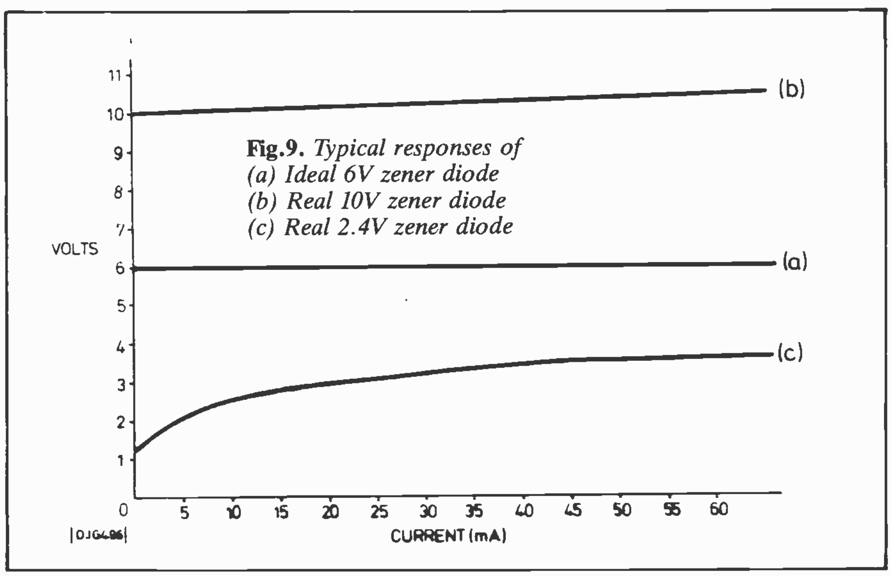



**Fig.9.** *Typical responses of*
*(a) Ideal 6V zener diode*
*(b) Real 10V zener diode*
*(c) Real 2.4V zener diode*

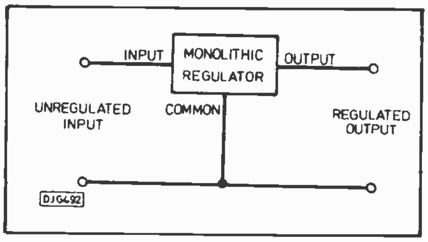



**Fig.10.** *Three terminal regulators*

short circuit protection and very often include 'foldback' current limiting. This means that if the device is overloaded (i.e. an attempt to draw too much current from it) then not only does it limit the maximum current which it will provide but it actually reduces it, until the overload is removed.

David Silvester discussed this principle in last month's issue. Many devices also include 'thermal shutdown' which reduces the output current if the device starts to overheat. In short, these integrated circuits are very hardy and not easily destroyed. Their one weakness is that they can be damaged by an excesssive input voltage. A device intended to give an output of, say, 5V requires a minimum input voltage of 7V and a maximum input voltage of around 25V. There is still considerable scope left to choose the transformer and rectifier to match these requirements.

A practical circuit for a supply capable of delivering up to 1A at a fixed voltage of +12V is shown in Fig. 11. If you are not building the mains transformer into your circuit then you will require two identical low voltage (12V min) a.c. supplies connected in series as in Fig.4b.

It is not difficult to produce a dual rail output if we are using a centre-tapped transformer. The +5V can be derived from the +9V output and does not need a separate source. We will need to protect the supply against misuse.

## VARIABLE VOLTAGE SUPPLY

Although there is no real need to start from a regulated output if the purpose of this section is to allow variable control from 0V to 7.5V it is still an advantage to do so for two reasons.

Firstly we have (or will have) a +9V regulated supply available anyway and secondly by using this as the source, we can benefit from the current limiting features of the regulator.

A power transistor will provide the necessary output providing we can control its base current carefully. GCSE students should be aware of the ways in which two transistors can be coupled to give such accurate control. One method (the Darlington pair) was mentioned in the *Teacher Timer* article, so this time we will use the Super Alpha Pair configuration. An ordinary general purpose transistor (e.g. BC108) has its base run from a simple potential divider circuit. The emitter current from this transistor becomes the base current to the second stage which will then give the required range at whatever current we choose. A suitable diode in reverse bias is connected across the output of the power transistor in case inductive loads are driven which might then generate high reverse voltages on the emitter. A 1k resistor is also included as a dummy load. (Fig.12).

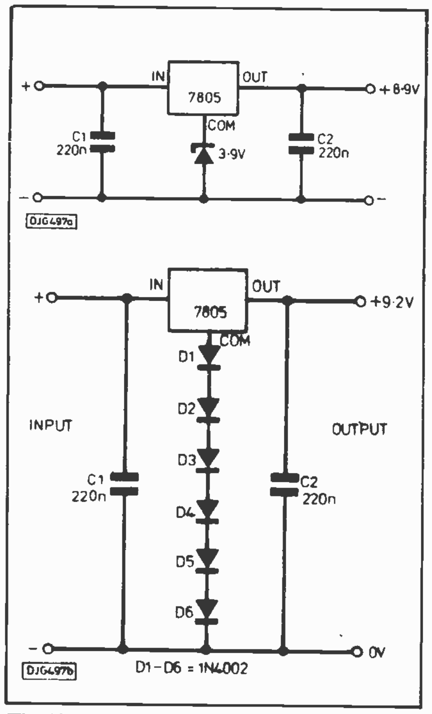



**Fig.13.** *Two methods of increasing +5V output to approximately +9V.*

## DIODE BOOSTER

There is however a little trick which we might employ to 'boost' a 5V regulator to give 9V. If a 3.9V Zener diode is inserted between the common terminal and the common rail (in reverse bias, of course) then the output voltage will be increased by this same amount.

Since we know that the maximum current drawn from the regulator will not exceed 1A, a 1W Zener diode will probably suffice, though a 5W will certainly guarantee that we do not damage this device. Fig.13 gives the method for increasing +5V to +8.9V which is surely good enough. Alternatively a chain of ordinary silicon rectifier diodes in forward bias could also be used. Six diodes would give about 4.2V needed to increase from +5V to about +9V. The same technique can be used to obtain −9V from −5V but care needs to be taken with the polarity of the diode(s).

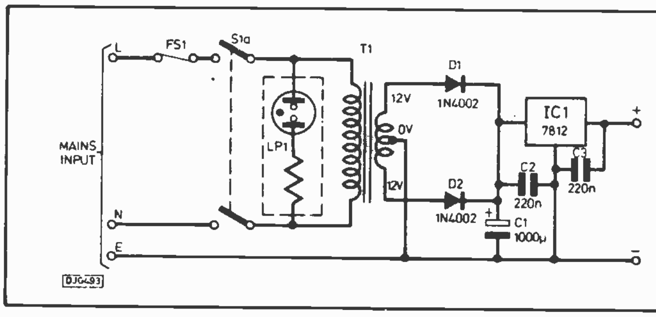



**Fig.11.** *A regulated supply capable of delivering 1 amp at 12V.*

## PEAK VALUES

It should be noted that a.c. voltages are normally expressed as r.m.s. values (root of the mean square) and that the actual peak value is approximately 1.41 times greater.

## MULTIPLE OUTPUT VOLTAGES

To be of general use our final supply needs to provide the following minimum specification:

(a) ±9V outputs to act as battery eliminators for projects where PP3 batteries are suggested.
(b) +5V output for TTL use.
(c) A variable 0–7.5V output for general practical use.

An output current of up to 1A should be sufficient for each of these voltage sources.

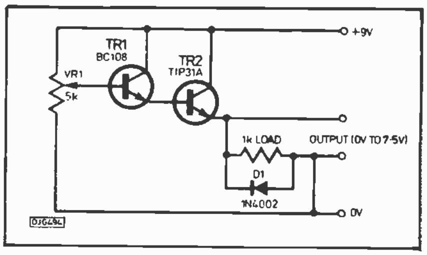



**Fig.12.** *A method of obtaining a variable output voltage*

Although an extensive range of monolithic regulators now exists, you will be hard put to find one that gives 9V. (*I don't know of any 9V ones. Ed.*) 5V, 12V, 15V, 18V and 24V are the most common types. One or two manufacturers also produce 6V and 8V types but these can be more expensive.

## THE FINAL DESIGN

Since we require a +5V output for TTL use, the method used above to obtain +9V from +5V simply needs to be cut out to give the +5V output. The switch will therefore need to short out the Zener diode when +5V is required. The final design incorporating all these ideas is given in Fig.14. Coloured LEDs are used to monitor the 'active' outputs for each position of the rotary switch, S2. This switch, you will note, prevents more than one type of output being used at once. The user has the choice of ±9V or +5V or the variable output. Fig.15 gives the required connections for switch S2 which must have 3 poles and 3 ways (or more).

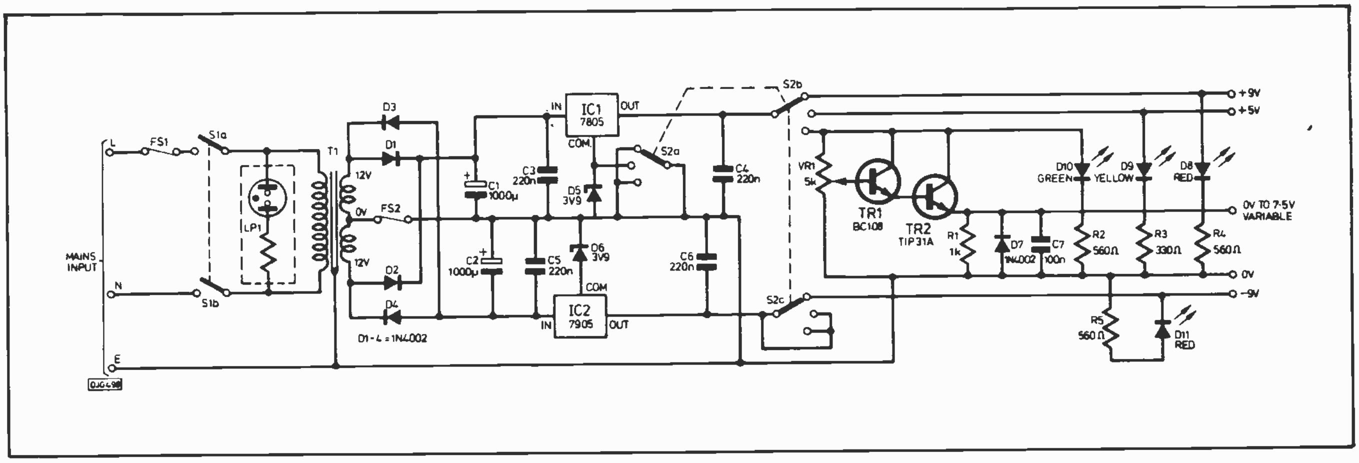



**Fig.14.** *Final design with ±9V, +5V, and variable 0V to +7.5V outputs.*

## CONSTRUCTION AND TESTING

One possible printed circuit layout for the final design is given in Fig.15. As with previous projects, students should be encouraged to develop their own ideas. One particular requirement of this project though is that as a power supply it will develop fairly high currents and may involve the use of mains voltages. Both of these factors make it essential that the PCB design is well organised with strong, wide tracks to carry the current.

As with previous designs, mains voltages can be avoided. The transformer is substituted by a pair of commercial a.c. supplies each producing 12V to 15V. The rest of the circuitry can remain the same.

If the full project is attempted then the choice of transformer and rectifiers is important.

The transformer must have two secondary windings, each giving an a.c. output of around highest d.c. output required. The 9V regulators will require at least 11V input to operate properly. A 12-0-12V transformer will do but a 15-0-15V device could be used. As we have limited the output current to 1A, a 30VA transformer will suffice. Depending on your supplier, you may need to buy a 50VA device.

The rectifier diodes must have a current rating at least equal to the maximum output current. Their peak inverse voltage (p.i.v.) must be at least three times the secondary r.m.s. voltage. So in this case the diodes must be 1A minimum and p.i.v. at least 90V. My choice is therefore the IN4002 diodes.

## FUSING AND EARTHING

Great care needs to be taken with the construction of this device. A metal box, rather than a plastic one, enables easy and safe earthing to the mains earth pin. An internal mains fuse rated at 250mA will protect the primary winding of the transformer. In case the smoothing capacitors or rectifiers go short circuit a fuse in the secondary is also a good idea. This must be placed in the centre tap connection and should be rated at 2A.

An anti-surge fuse is advisable in case the initial charging current of the capacitors is sufficient to destroy the 'quick blow' type. A proper rubber grommet and cable clamp or alternatively a cable gland must be used for cable entry and fixing.

Ventilation holes must be drilled in the case, if these are not already present, but not so as to allow access to mains voltages even with a small screwdriver. You will need to work this out for yourself once you have selected your container.

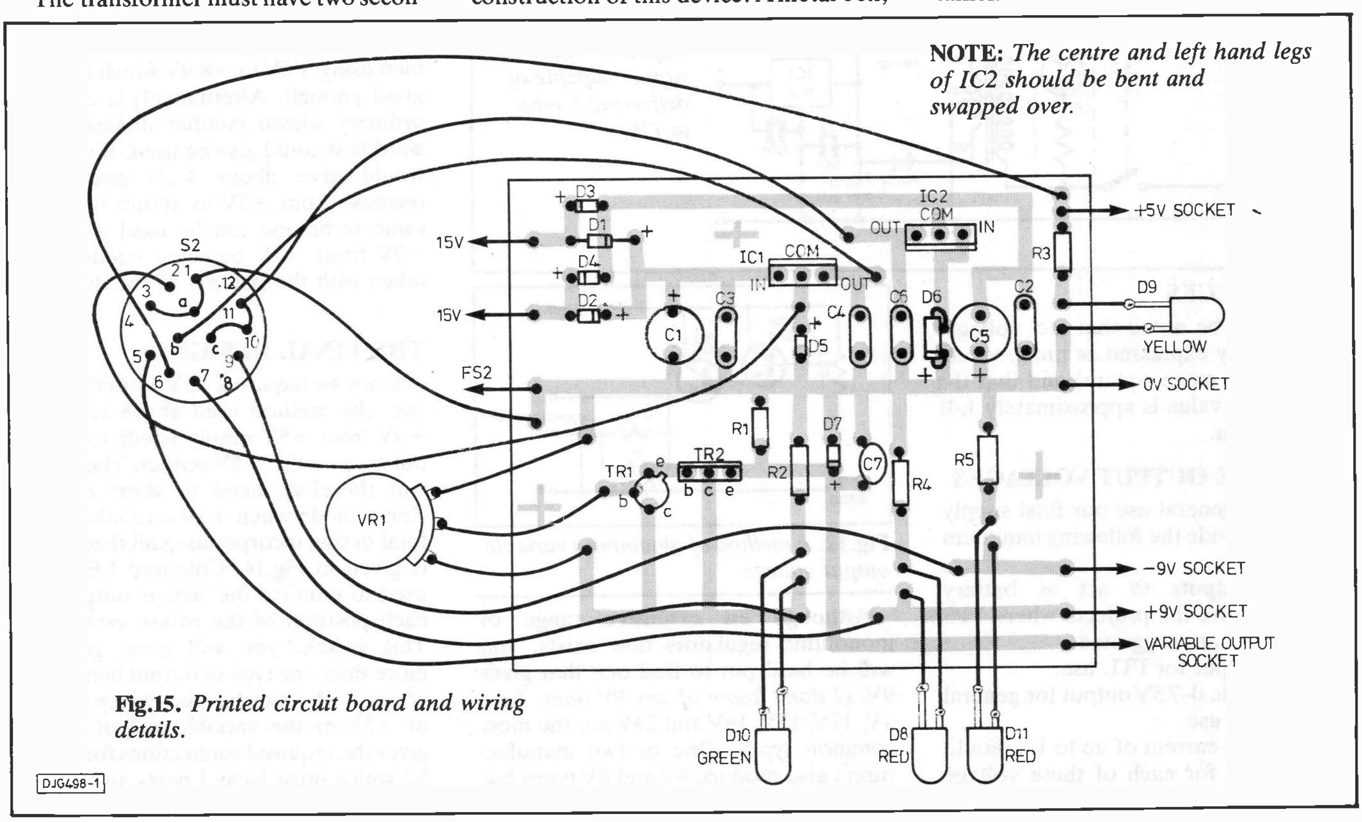



**Fig.15.** *Printed circuit board and wiring details.*

## COMPONENTS

**RESISTORS**

| | |
|---|---|
| R1 | 1k |
| R2,R4,R5 | 560R (3 off) |
| R3 | 330R |
| All 0.25W carbon 5% | |

**POTENTIOMETER**

| | |
|---|---|
| VR1 | 5k Lin Rotary |

**CAPACITORS**

| | |
|---|---|
| C1,C2 | 1000$\mu$F 25V electrolytic (2 off) |
| C3,C4,C5,C6 | 220nF (4 off) |
| C7 | 100nF |

**SEMICONDUCTORS**

| | |
|---|---|
| D1-D4,D7 | 1N4002 (5 off) |
| D8,D11 | LED, Red (2 off) |
| D9 | LED, Yellow |
| D10 | LED, Green |
| D5,D6 | 3V9 Zener (2 off) |
| TR1 | BC108 |
| TR2 | TIP31A |
| IC1 | 7805 |
| IC2 | 7905 |

**MISCELLANEOUS**

| | |
|---|---|
| FS1 | 20mm 250mA fuse (quick blow) |
| FS2 | 20mm 2A fuse (anti-surge) |
| S1 | DPDT mains toggle switch |
| S2 | 3-pole 3-way rotary switch (see text) |
| T1 | 12-0-12V, 30VA mains transformer (see text) |
| LP1 | Mains neon with integral resistor |

Box to suit, 13A mains plug, mains cable, panel mounting fuseholders (2 off), knobs, 4mm sockets (5 off), cable clamp/grommet, wire, solder, printed circuit board.

The PE PCB Service can supply the PCB. Magenta can supply a full kit of parts, including the PCB.

### SAFETY FIRST

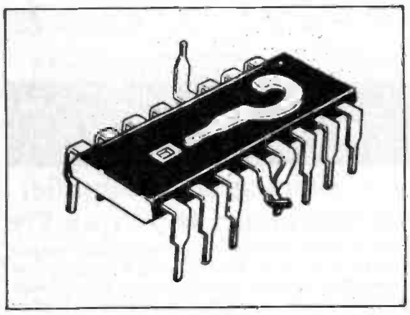
Potentially this is the most useful project of any that you might attempt. It is also the most dangerous. Do not work with mains voltages unless you are confident that you know what you are doing. Even if you are confident, take care. If in doubt, seek advice. I hope the finished product lives up to your expectations and saves you money in batteries!

PE

**TABLE 1: TESTS TO CHECK FOR CORRECT OPERATION**

| | |
|---|---|
| T1 (centre tap) | 0V a.c. |
| T1 (outputs) | 12V a.c. min. (each side) |
| 7805 input | +15V d.c. min. |
| 7905 input | −15V d.c. min. |
| 7805 common | |
| S2 to ±9V | +3.9V d.c. |
| S2 to +5V | 0V d.c. |
| 7805 output | |
| S2 to ±9V | +8.9V d.c. |
| S2 to +5V | +5V d.c. |
| S2 to variable O/P | +8.9V d.c. |
| 7905 output | −8.9V d.c. |
| Collector TR1/TR2 | |
| S2 to variable O/P | +8.9V d.c. |
| S2 other positions | 0V d.c. |
| Base TR1 | 0 to 7.5V d.c. variable |
| +5V socket | |
| S2 to +5V | +5V d.c. (yellow LED ON) |
| +9V socket | |
| S2 to ±9V | +8.9V d.c. (red LEDs ON) |
| −9V socket | |
| S2 to ±9V | −8.9V d.c. (red LEDs ON) |
| 0–7.5V socket | |
| S2 to variable O/P | 0 to 7.5V d.c. depending on VR1 (green LED ON) |

# CHIPCHOP – PUZZLE NO 2 TEST YOUR LOGICAL RESEARCH ABILITY AND WIN 12 MONTH'S SUBSCRIPTION TO PE



Some of the chips from this month's and last month's circuits have been chopped and their pins jumbled. Can you name the chips chosen?

Also tell me which features or projects in this month's issue you found most interesting, and which you found least interesting – state as many as you like.

Answers to the editorial office to arrive before the publication date of the next issue. The first three senders of the correct chip identity answers will receive 12 month's free subscription to PE. Where there is ambiguity through chips having identical pin-outs, either answer is acceptable.

First 50 entrants wil receive a valuable set of CMOS pin data references.

Answer and another CHIPCHOP puzzle next month. The Editor's decision is final.

Follow the series and collect the data!

```
CHIPCHOP PUZZLE 2

ALLOCATE THESE PIN FUNCTIONS AND NAME THE CHIPS

+IN,+INA,+INB,+VE,+VE,-IN,-INA,-INB,-QA,-QB,-VE,-VE,ANODE,B,C,C,C,CA,CATHODE,
CB,COM,COMPA,COMPB,CP1,CP2,CTRL,DA,DB,DISCHARGE,DS,E,GND,GND,IN,IN,IN1A,IN1B,
IN1C,IN1D,IN2A,IN2B,IN2C,IN2D,NC,NC,NC,NC,NC,NC,NC,OFFSET,OUT,OUT,OUT,OUT1,
OUT2,OUTA,OUTA,OUTB,OUTB,OUTC,OUTD,P1,P2,P3,P4,P5,P6,P7,P8,PS,Q1,Q10,Q11,Q12,
Q2,Q3,Q4,Q5,Q6,Q6,Q7,Q7,Q8,Q8,Q9,QA,QB,R,RA,RB,RESET,SA,SB,THRESHOLD,TRIG,VCC,
VDD,VDD,VDD,VDD,VDD,VGG,VSS,VSS,VSS,VSS,
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ANSWER TO BINARY CHOP PUZZLE 6

CRACK THE WITCHES CODE.
030F0D02090E090E07 130309050E03052C 050415030114090F0E2C 140503080E0F
0C0F0719 010E04030F0D101514090E072C 1012010314090301 0C 050C050314120F
0E090313 0913 140805 0C050104090E070D0107011A090E05 060F12 010C0C 1305
12090F1513 050C050314120F0E090313 010E04 030F0D1015140512050E14081513
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(SUBSTITUTING ZERO FOR LETTER O THE ABOVE CODE IS IN HEX AND
TRANSLATES AS FOLLOWS. COMBINING SCIENCE, EDUCATION, TECHNOLOGY AND
COMPUTING, PRACTICAL ELECTRONICS IS THE LEADING MAGAZINE FOR ALL
SERIOUS ELECTRONICS AND COMPUTER ENTHUSIASTS.)
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*I asked our artist to draw a picture representing a brain twister, but he must have misheard me! Ed*

*This basic interface controls a d.c. motor from six output port lines with 16 speed control stops. Designed to control motors up to 6V/1A, from a BBC-B, it can be adapted for larger motors and other computers.*

# COMPUTER D.C. MOTOR CONTROLLER

**BY MARK STUART**

## With connections and programs for the BBC-B

The widespread use of computers has led to many applications beyond word processing, games, and business uses.

In many fields there is a need for interfacing with mechanical input and output devices. Inputs from sensors such as switches, potentiometers, and photocells provide the computer with a 'feel' for its environment. In response to these signals the computer will frequently be required to produce outputs via such devices as solenoids, stepping motors, and d.c. motors.

The circuit presented here enables the speed and direction of a d.c. motor to be controlled by six computer output port lines. The controller contains a 4 bit D to A converter and so gives speed control in 16 steps from zero to maximum. Two other control bits are used to select the direction of rotation and to switch power on and off (enable/disable). The motor drive circuitry uses current sensing 'negative resistance' feedback to stabilise motor speed regardless of the load applied.

In its standard form the circuit will power motors requiring up to 6 volts and 1 amp. Alternative power supply arrangements and amplifier scaling factors can easily be used to extend the controller to much larger drives.

### CIRCUIT

Fig.1 shows the circuit diagram which can be divided into three parts: Power Supply, D to A Converter, and Motor Driver.

The power supply is a standard arrangement with unregulated ± 9 volt outputs and a regulated 5 volt output.

### A-D CONVERTER

The A-D converter consists of IC1a-d and IC2a. Four output lines PB0 – PB3 from the computer drive a binary weighted set of resistors R1 to R4/R5 gates IC1a-d. The other inputs of the gates are parallelled and driven by inverter transistor TR1. This provides a select/deselect function. When selected the output of each gate goes from 0V to +5V and injects a current into the inverting op-amp IC2a. The input of IC2a is a 'virtual earth' point the voltage of which is maintained at 0V by current feedback via R11, which is exactly equal and opposite to the current injected. This means that the voltage at the output of IC2 is directly proportional to the injected input current.

Resistors R1, R2, R3, R4/5 inject 1mA, 0.5mA, 0.25mA and 0.125mA respectively so that when full speed is selected the maximum current into IC2a is 1.875mA. Applying Ohm's law to R11 gives a full speed output voltage of 1.875 x 2.4 = 4.5V. The lowest speed is selected when just PB0 is set to logic 1 level and the output voltage from IC2a is then 0.3V. Intermediate binary inputs produce output voltages in steps of 0.3V. As the gates are CMOS types, provision has been made on the board to fit pull-down resistors if required.

### DIRECTION CONTROL

The output from IC2a is a negative going voltage which would drive the motor in only one direction. To provide the necessary bi-directional control a switchable inverting/non-inverting amplifier stage is used. This stage consists of IC2b in conjunction with Tr2, Tr3 and Tr4. Direction control is by means of computer output line PB5. When this line is held high Tr2 is turned

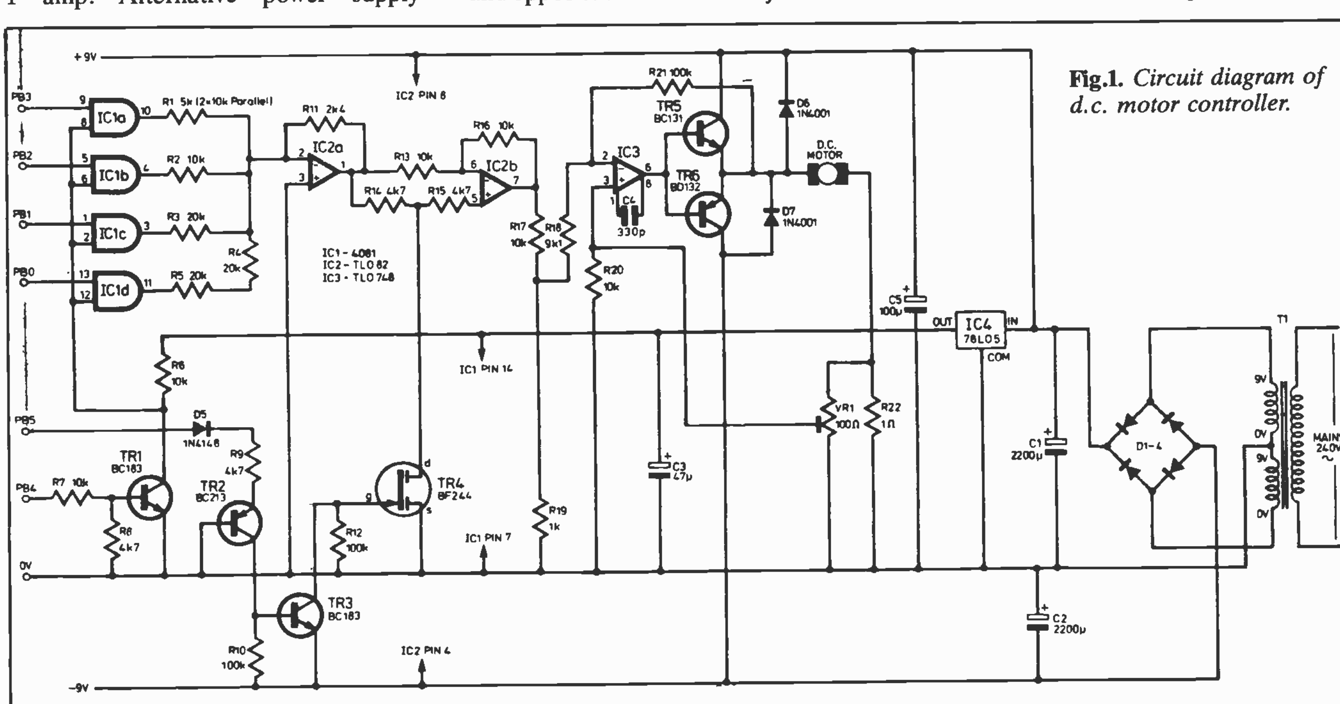



**Fig.1.** *Circuit diagram of d.c. motor controller.*

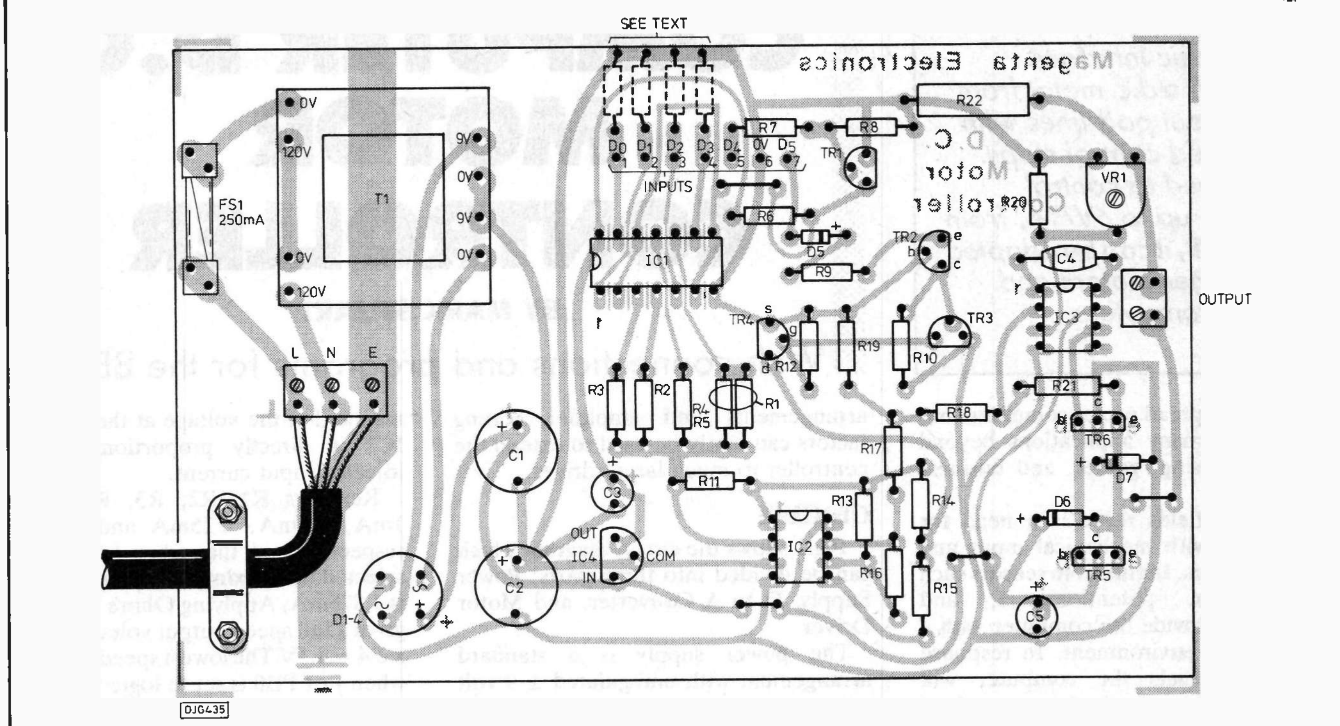



**Fig.2.** *Printed circuit board details.*

on and turns on Tr3. This arrangement of Tr2 and Tr3 is necessary for level shifting purposes so that the negative 9V rail can be used for bias on the f.e.t. Tr4.

With Tr3 turned on Tr4 is turned off because its gate voltage is −9 Volts. In this condition IC2b works as a simple non-inverting amplifier with a gain of one. This circuit is easy to understand if the amplifier is considered as a simple inverting amplifier stage the input to which (applied to R13) is always equal to the bias voltage (applied via R14 and R15) to the non-inverting input. In this conditions there is, in effect, no input signal and the output voltage is equal to the bias voltage. As the bias voltage varies, the output voltage follows it exactly so that the circuit acts as a unity gain non-inverting buffer stage. When PB5 is held low (logic 0) then Tr2 and Tr3 are turned off and Tr4 is turned on as its gate voltage rises to 0V.

In this condition the input of IC2b via R14 and R15 is short-circuited by Tr4. The non-inverting amplifier stage with a gain of one set by R16 and R13.

The output from IC2b passes via the voltage divider R17/R19 and on to IC3 via R18.

## POWER OUTPUT STAGE

IC3 is configured as a standard inverting amplifier with its output capability boosted by emitter followers Tr5 and Tr6. The gain of this stage is set at slightly over ten by R18 and feedback resistor R21.

Diodes D6 and D7 guard against inductive 'kick-back' from the motor by providing continuous paths for positive and negative currents to the two power supply rails.

If the action of R20, VR1 and R22 are disregarded the motor can be seen to be fed with a voltage which is directly proportional to the output from the A–D converter stage. The motor would thus be driven in 'constant voltage' mode. In this mode the performance of the motor is limited by its winding series resistance, which causes the speed to drop under load as the motor demands more current.

## CURRENT SENSING FEEDBACK

Where precise control of motor speed is required, constant voltage mode is inadequate. The ideal way to obtain precise speed control is by attaching a tachometer to the motor spindle, sensing speed directly and using this as feedback to control the motor drive voltage. This technique is excellent but is rather expensive and elaborate for some applications.

An alternative approach is to sense the motor current and modify the drive voltage so that the effect of winding series resistance is cancelled out. This is achieved in the present circuit by means of R20, R22 nd VR1, which apply feedback to the non-inverting input of IC3. The source of the feedback signal is the voltage generated across R22 by the motor current passing through it.

A proportion of this voltage is tapped off from the slider of VR1 and fed to IC3. The actual value of R22 is not important, but it should be selected so that it does not drop too much of the available voltage at the maximum motor operating current. It should also be high enough to provide sufficient feedback voltage. The power rating of the resistor should also be taken into account, bearing in mind that the motor could be stalled by a heavy load while the circuit is applying full voltage to it.

With the value given in the parts list a current of one amp through the motor gives rise to a drop of one volt across R22. As the feedback is applied to the non-inverting input of IC3, its effect is to increase the output voltage as the output current increases. This is exactly what is required. As the motor is loaded, the speed falls and the current drawn increases. The feedback network senses this increase in current so that more voltage is applied to the motor and its speed is brought back up.

VR1 is provided so that the amount of feedback can be adjusted to suit a range of motors. Too much feedback results in the motor 'hunting', that is, the speed jittering up and down as the circuit over-compensates. Too little feedback results in inadequate speed compensation and generally poor performance.

At the correct setting it is possible to obtain excellent performance, especially at low speeds where non-linear friction effects can cause problems. Even cheap model motors will run very smoothly, while higher quality motors such as those found in cassette recorders run beautifully.

## CONSTRUCTION

The circuit is constructed on a single printed circuit board which is completely self-contained as it includes the mains transformer and fuse. Fig.2 shows the component layout. Seven connections are to be made to the host computer (which can be anything with six available

## COMPONENTS

### COMPUTER D.C. MOTOR CONTROLLER

**RESISTORS**

| | |
|---|---|
| R1 | 5k 1% (2 x 10k in parallel) |
| R2 | 10k 1% |
| R3 | 20k 1% |
| R4,R5 | 20k 1% (2 off) |
| R6,R7,R13 R16,R17,R20 | 10k 5% (6 off) |
| R8,R9,R14 R15 | 4k7 5% (4 off) |
| R10,R12,R21 | 100k 5% (3 off) |
| R11 | 2k4 1% |
| R18 | 9k1 1% |
| R19 | 1k 5% |
| R22 | 1R 2.5 watt 10% |

All ¼W except R22

**POTENTIOMETER**

| | |
|---|---|
| VR1 | 100R horizontal preset |

**CAPCITORS**

| | |
|---|---|
| C1,C2 | 2 200$\mu$F 16V radial electrolytic |
| C3 | 47$\mu$F 10V radial |
| C4 | 330Pf ceramic or polystyrene |
| C5 | 100$\mu$F 25V radial |

**SEMICONDUCTORS**

| | |
|---|---|
| IC1 | 4081 CMOS |
| IC2 | TL082 |
| IC3 | 748 |
| IC4 | 78L05 |
| TR1,TR3 | BC183 |
| TR2 | BC213 |
| TR4 | BF244 |
| TR5 | BD131 |
| TR6 | BD132 |
| D1,D4 | W005 BRIDGE |
| D5 | 1N4148 |
| D6,D7 | 1N4001 |

**MISCELLANEOUS**

T1 – 6VA PCB mounting transformer with 9V output.
Ic sockets, printed circuit board, fuse clips, fuse, mains cable, saddle clamp (for mains cable), output terminals, wire, screws and nuts, grommet, case.

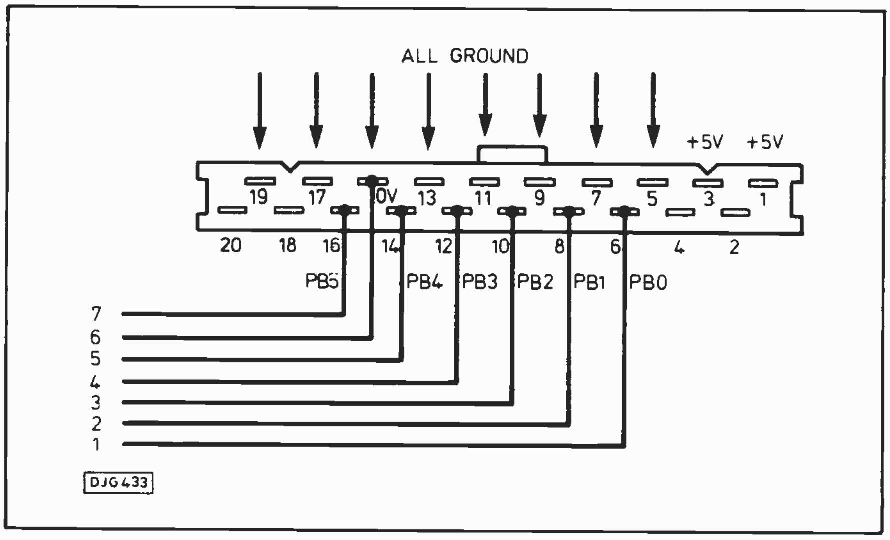



**Fig.3.** *Connections for BBC computer user port.*

user port lines). These connections are made directly to the board using suitable ribbon cable. Connections for a BBC computer user port are shown in Fig.3.

With the power supply and components shown the circuit can deliver up to one amp at five volts to the motor. For larger drives the addition of darlington output transistors and uprated power supplies (up to ± 15 volts) will extend equally flexible control.

For higher current applications it will of course be necessary to mount the output devices off the board to ensure good quality current paths. Heatsinks are not strictly necessary for the standard version, but small push-on types will give extra protection in the event of output short circuits.

The prototype was built in a plastic case with an earthed metal lid and fitted with two 4mm screw terminals for the output connections.

## TESTING

The circuit is simply tested by connecting a small motor and setting the appropriate logic levels on the input lines. This can be done with or without a computer. The setting of VR1 is best arrived at by trial and error and should be checked at all motor speeds as motor behaviour is not strictly linear. The best setting is that which gives good speed control without instability at any speed.

To check the effect of feedback it is simply a matter of applying a load to the motor (finger pressure) and observing the effect on the speed. Adjusting VR1 to minimum allows the uncompensated operation to be compared with compensated operation. The effect is quite dramatic, especially at low speeds where some small motors have great difficulty running at all without feedback, but run smoothly as soon as it is applied.

## SOFTWARE

For BBC computer users a set of programs is available on cassette (see constructor's note). One program allows small positional servo systems to be built using two potentiometers connected to the analogue port as position sensors, and a motor connected to the driver circuit as an actuator. Different loop gain settings, and 'dead-band' widths can be programmed so that the effect on positional accuracy and loop stability can be assessed.

Another program allows each user port bit to be set independently so that the effect on motor speed and direction of each bit can be observed.

Other computer users must write their own programs, but it is a relatively simple task to get the motor moving by setting up the necessary output port values. Further programming, leading to full control of motorised systems, can soon be learned by experiment. PE

**CONSTRUCTOR'S NOTE:**
Magenta Electronics are offering a full kit of parts including case and PCB for £24.49. They will also supply the PCB only at £5.37, and a software cassette (BBC only) for £4.95. Prices include VAT, but add £1.00 per order for postage.

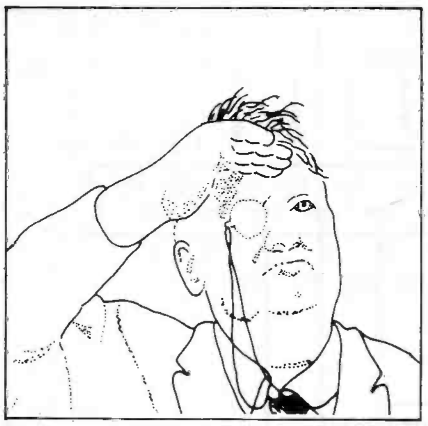
## MOTORING-BACK

Reading though Mark Stuart's article I wondered how much the motor control has changed over the years. Turning to a book first published in 1943, I found that motors were at one time used in radio receivers.

No, they were not used for mobile radio stations, but instead were used for tuning purposes. As an elaboration of the manual mechanical system, motor driven arrangements turned the gang-tuning condenser to preset positions for selected stations.

The general principle was that when any station button was pressed, the motor started, an automatic clutch came into operation, and the motor turned the condenser through suitable gearing until the point was reached where the selected station was tuned in, whereupon the motor stopped. The sensing of this position was done by using a protruding terminal brush to find an insulated section of an otherwise conducting rotary wafer. The rotor simply turned until the insulation cut off the current.

**Ed**



OUR REGULAR LOOK AT ASTRONOMY

# SPACEWATCH

**BY DR PATRICK MOORE OBE**

Supernova SN 1987A continues to behave in unpredictable ways, while quasar PKS 1145-071, believed to be a single object, may be a true double after all.

THE supernova SN 1987A, in the Large Cloud of Magellan, continues to puzzle astronomers. It simply does not follow the rules. It is, moreover, under luminous by supernova standards, and there may possibly be some affinity with the supernova S Andromeda, which blazed out in the Andromeda Spiral in 1885. At that time its nature was not appreciated (it was generally believed to be in the foreground; remember, it was not even known that the Spiral is an external system). But the 1987 supernova has a strange companion, which is being called Mystery Spot, at least two light-weeks from the main outburst (that is to say, 0.057 arc seconds as seen from Earth). Just what Mystery Spot may be remains, for the moment, unknown. SN 1987A itself has faded below naked-eye visibility, but retains its strong red colour. Whether or not it will produce a pulsar remains to be seen.

Another supernova has been in the news — Cassiopeia A, which is thought to be about 9,000 light-years away. It was not definitely seen, though the first Astronomer Royal, John Flamsteed, may have noted it in 1680 as a star of the sixth magnitude (in that area of the sky, obscuration by dust in the Milky Way region dims all remote objects). Today, the site is associated with faint nebulosity. New studies of this material by R.A. Fesen and W. Blair, in America, indicate that fast-moving, nitrogen-rich knots of material may be actual fragments of the outer layers of the destroyed star, which could have been a very hot and massive body of the type known as a Wolf-Rayet star.

## A TRUE DOUBLE QUASAR?

Quasars are among the most fascinating objects known to us. They were identified in 1963, and are now known to be very remote and super-luminous; it seems that they are the nuclei of very active galaxies. They are thousands of millions of light-years away, and are much more luminous than normal galaxies.

Sometimes it is found that a quasar has a twin, close beside it — absolutely

## The Sky This Month

*THE two giant planets, Jupiter and Saturn, are on view this month. Saturn, magnitude +0.6, is in Ophiuchus, and can be seen in the south-west after dark. It is now past its best for this year, and will be lost to view after early November; but the rings are wide open, so that in even a small telescope Saturn is a glorious sight.*

*Jupiter comes to oppostion on 18 October, in Pisces — to the north of the celestial equator, so that it is excellently placed for British observers. Its magnitude is −2.9, much brighter than any other planet or star apart from Venus — which is just starting to emerge in the evening sky, low in the west after sunset, but is not yet prominent.*

*Jupiter is an interesting sight telescopically, with its yellowish, flattened disc, its cloud belts, and its four bright satellites Io, Europa, Ganymede and Callisto. Good binoculars will show Ganymede at least; there are some exceptionally keen-sighted people who can see the satellites with the naked eye. On Jupiter's disc, the famous Great Red Spot has not been in evidence lately, but it is never absent for long. It is now known to be a whirling storm — a phenomenon of Jovian meteorology — and the colour seems to be due to phosphorus.*

*Of the other planets, Mercury is technically an evening object, but as it is well south of the celestial equator it is not likely to be a naked eye object from Britain. Mars is just detectable in the eastern sky before dawn, during the latter part of October, but is still a long way away, and not even large telescopes can show much on its disc.*

*Summer Time ends on October 25, which at least makes the evenings darker! The Moon is full on October 7, and new on the 22nd.*

*During October evenings the Great Bear or Plough (Ursa Major) is at its lowest in the north, though of course it always remains above the horizon. The W of Cassiopeia is almost overhead, and the Milky Way is very much in evidence, stretching across the sky from one horizon to the other. The "Summer Triangle" (Vega in Lyra, Altair in Aquila, and Deneb in Cygnus) is still prominent, though Altair is becoming low in the west; it is not circumpolar, whereas from Britain both Vega and Deneb skirt the horizon without dipping below it. Capella is rising in the east. It is worth noting that Vega and Capella are on opposite sides of the Pole Star, and at about the same distance from it.*

*The main autumn constellation is Pegasus, whose four main stars make up a square and which is now high in the south. Maps tend to make it appear smaller and brighter than it really is, but it is so distinctive that it can hardly be mistaken. Leading off from it is the line of stars making Andromeda; look for the Great Spiral, Messier 31 — a system larger than our Galaxy, and more than 2,000,000 light-years away. It is just visible with the naked eye; binoculars show it easily, but photographs with large telescopes are needed to bring out its details. Like our Galaxy, it is spiral in shape, but unfortunately it lies almost edge-on to us, so that its full beauty is lost.*

*Below the Square of Pegasus, look for Fomalhaut in the Southern Fish, the most southerly of the first-magnitude stars ever visible from Britain. From South England it is easy to see, but from North Scotland it is always so low down that even the slightest mist will hide it.*

identical in every way. For some time this was a puzzle, but then an explanation came forward. It seems that there is only one quasar, but that between it and ourselves there is a large galaxy which cannot be seen directly. According to relativity theory, light is bent by a gravitational field — so that the light-rays from the background quasar are bent by the unseen galaxy, and pass either side of it, making a false double image. This is what has become known as the gravitational lens effect.

This is all very well, but there has been a recent new development. Using the 2.2-metre telescope at La Silla in Chile, astronomers have studied the quasar pair known as PKS 1145-071 in the little constellation of Crater, the Cup. It is double — but apparently not a gravitational lens pair. Obviously, the two images of a lens effect must be exactly alike (because they are in fact the same thing), but with the Crater pair there were spectral differences, and the optical astronomers called in their radio astronomy colleagues. At Socorro, in New Mexico, there is a vast establishment known as the VLA or Very Large Array. Here, Richard Perley and his colleagues found that at radio wavelengths, one of the 'twins' disappeared — it did not transmit in that region of the electromagnetic spectrum, whereas the other member did. So they could not be identical; we must be dealing with two quasars, side by side.

This is very important. It now looks as though the total mass of the pair is around 100,000 million times that of the Sun, which is about the same as that of our own Galaxy, and the distance is of the order of 10,000 million light-years. But we are still only at the very beginning of the investigation, and it is hoped that we will learn a great deal from the first genuine double quasar. **PE**

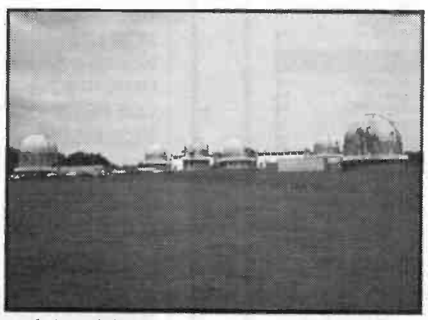


## HERSTMONCEUX

The likely move of the R.G.O. from Herstmonceux has frequently been mentioned in Spacewatch. Last month's column prompted me to take a trip there before it moves.

It's an interesting place to visit, and I was pleased to learn that at least part will remain. Basically, it is the research facilities that will move to Cambridge. Since these are largely contained within the main building complex the outward appearance will probably remain unchanged.

I was relieved to learn that the group of telescope domes will remain on site. They are well worth a visit for their own sake. The external view is quite dramatic



and inspiring to the imagination. Two domes were open to public view, complete with a telescope in each. A video theatre displayed additional information and gave a short run down on the history. The other exhibitions and the souvenir shop are well worth visiting, but the main research centre is not open to the public. There is a teashop.

Selected areas of Herstmonceux Castle itself, together with a display of historical books and archives, are also open a few days each year.

The R.G.O. site is now closed for this year, but will re-open at Easter, and then be open daily until September 30th, from 10.30am to 5.30pm, with last admission at 4.30pm. It's best to use your own transport – access by bus or train appears difficult. For further information ring 0323 833171. **Ed.**

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| 7915 | 40p |
| 7918 | 40p |
| 7924 | 40p |
| 78L05 | 28p |
| 78L12 | 28p |
| 78L15 | 28p |
| 78L18 | 28p |
| 78L24 | 28p |
| 79L05 | 40p |
| 79L12 | 45p |
| 79L15 | 48p |
| 7918KC | 100p |
| 7824KC | 100p |
| LM309K | 100p |
| LM317K | 220p |
| LM317T | 180p |
| LM323K | 420p |
| LM723 | 40p |
| 78HGKC | 570p |
| 78HO5KC | 800p |
| 78H12KC | 700p |
| 78GUIC | 190p |
| 79GUIC | 215p |
| 79HGKC | 800p |

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|---|---|
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| BZY88 RANGE 2v7 to 39V | 6p |
| 1.3W | |
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| | |
|---|---|
| LED 3mm RED | 5p |
| LED 3mm YEL | 10p |
| LED 3mm GRN | 10p |
| LED 5mm RED | 5p |
| LED 5mm YEL | 10p |
| LED 5mm GRN | 10p |

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*Soloman was the wisest and, surely, the most logical of men, but even in all his glory he was never array'd like one of these. Imagine the problems he might have solved with the help of a few advanced FPLAs ...*

# PROGRAMMABLE LOGIC DEVICES

**PART TWO BY CHRIS KELLY**

## Arrays in all their glory

Part One of this series introduced programmable logic devices (PLDs), discussed their advantages over standard logic chips, and briefly outlined the different types currently available. The simplest types of PLDs, being field programmable gate arrays (FPGAs) and PROMs, were described with practical examples.

Now in Part Two we turn our attention to the more versatile devices or logic arrays known as PALs and FPLAs, and logic sequencers known as FPLSs.

### PROGRAMMABLE ARRAY LOGIC

Programmable array logic (PAL) was developed by a U.S. company called Monolithic Memories many years ago and has been steadily gaining acceptance. Now it is one of the most popular types of PLDs.

The PAL structure comprises a programmable AND array followed by a fixed OR array (unlike the PROM which is a fixed AND followed by a programmable OR array). A typical but simplified PAL arrangement is shown in Fig.10.

PALs can be programmed to represent 'sum of product terms', which are Boolean logic expressions where the input variables are shown as a number of AND functions with the outputs of all ANDs ORed (eg F = X.Y.Z + X.Y.Z + X.Y.Z + X.Y.Z). All combinational logic can be expressed this way. The size of the sum of product terms which can be programmed using PALs is limited only by the number of connections in the AND/OR arrays.

As an example, take the simple exclusive-OR expression where output = A.B + A.B. This can be implemented by leaving certain fuses intact as shown in Fig.11, and arranging for all other fuses to be blown.

PALs come in many configurations. Fig.12 shows a 4 in, 4 out, 16 product term PAL. Some PALs have programmable input-output lines with a three-state buffer which when enabled by a product term drives the output. The output can also be fed back into the AND array for operations such as shifting or rotating data. When the three-state buffer is disabled, the line can be used solely as an input. This gives greater flexibility of applications as the number of inputs and outputs are not rigidly fixed. Also, these lines can be programmed as bi-directional buffers.

Many PALs have registered outputs (Fig.13) using D-type bistables to latch the data. These can be used for straightforward data buffers such as for input and output ports of microcomputers. The inverted output Q is fed back into the AND array which allows sequential circuits such as counters and sequential state machines to be made.

Table 2 shows a selection of PAL types with relevant details of inputs and outputs and the number of registered outputs included.

Programming PALs is not so straightforward as PROMs as many of the pins are multiplexed to obtain access to the relevant fuse links. Special programmers with PAL adapters are used with a 'fuse-map' technique. This is a line list showing which fuses are left intact and which are to be blown.

The alternative method of programming a PAL is to use a high-level computer program running on computers such as the IBM PC which permits the user to define inputs and outputs for a particular PAL type and then link the outputs to the inputs using a Boolean Expression. This information is then assembled into fuse-map information which can be downloaded directly to a PAL programmer. For this purpose, Monolithic Memories provides a program called PALASM.

PALs are claimed to be faster than the rival families of FPLAs because the fixed OR inputs of PALs have lower capacitance, but balanced against this is their limited flexibility.

### FIELD PROGRAMMABLE LOGIC ARRAYS (FPLAs)

A typical FPLA comprises a programmable-AND array followed by a programmable-OR array, possibly with bistable registers at the outputs. Sometimes these devices are simply called PLAs or, as with Mullard/Signetics devices, the family is referred to as IFL (Integrated Fuse Logic).

FPLAs have a greater flexibility of applications than PALs in that more complex logic circuits can be implemented on a single device. But they are gen-

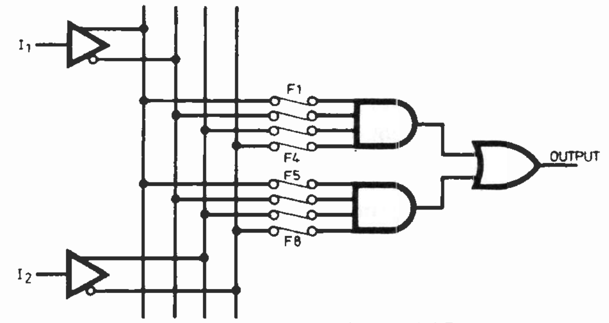



**Fig.10.** *PAL arrangement*

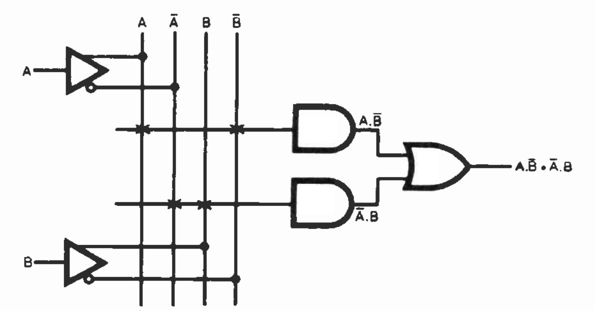
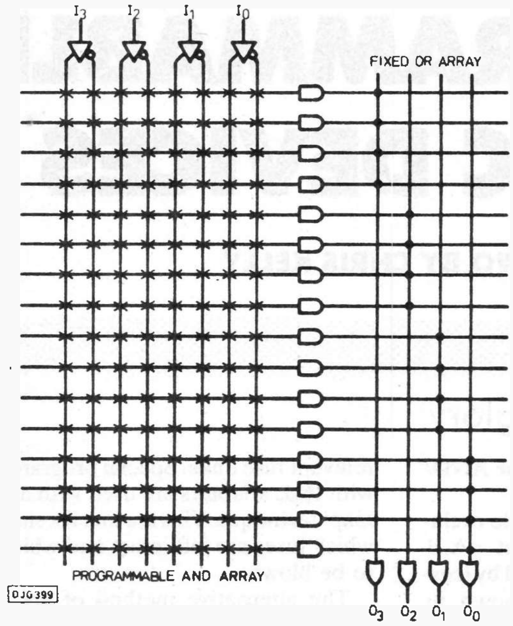



**Fig.11.** *PAL notation*



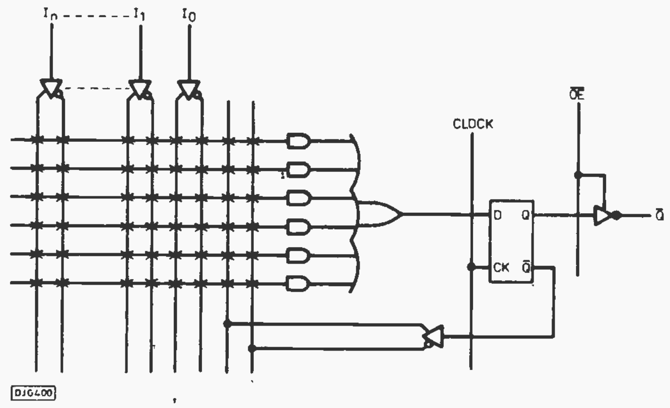




**Fig.12.** *(left) PAL 4in – 4out – 16 products.*
**Fig.13.** *(above) PAL with registered output.*

erally more expensive with more complex programming procedures.

An example application is shown in Fig.14, using the Mullard/Signetics PLS 153 as an 8-to-1 bi-directional multiplexer/demultiplexer. Table 3 describes the operation as follows. Three address lines $A_0$, $A_1$ and $A_2$ select one of eight parallel data lines $X_0$ to $X_7$ to be linked to the serial data line Y. The direction of data flow is determined by DIR. When DIR=1 (high or H) the data flow is from the selected X input to Y output. When DIR=0 (low or L) the data flow is from Y as input to the selected X output. Therefore, bi-directional input-output pins are designated for the X and Y lines.

The PLS 153 has 8 inputs $I_0$ to $I_7$ and 10 bi-directional lines $B_0$ to $B_9$ as shown in Fig.15. The top left shaded block is the AND fuse array and the lower left hand block is the OR fuse array. Outputs from the OR gates are fed into exclusive-OR gates which can be programmed as true or complement outputs by the fuses labelled $S_0$ to $S_9$.

The top right hand shaded block labelled Control Terms serves a number of purposes. Any combination of inputs can be programmed to the D AND gates to enable any of the three-state buffers so that the corresponding B lines are outputs. Also, B lines can be programmed as inputs by the control terms disabling the appropriate three-state buffer.

**TABLE 2.** *PAL Input/Output/Function/Performance Chart*

| Part No. | Input | Output | Programmable I/O's | Feedback Register | Output Polarity | Functions |
|---|---|---|---|---|---|---|
| 0HB | 10 | 8 | | | AND-OR | AND-OR Gate Array |
| 12H6 | 12 | 6 | | | AND-OR | AND-OR Gate Array |
| 14H4 | 14 | 4 | | | AND-OR | AND-OR Gate Array |
| 16H2 | 16 | 2 | | | AND-OR | AND-OR Gate Array |
| 16C1 | 16 | 2 | | | BOTH | AND-OR Gate Array |
| 20C1 | 20 | 2 | | | BOTH | AND-OR Gate Array |
| 10LB | 10 | 8 | | | AND-NOR | AND-OR Invert Gate Array |
| 12L6 | 12 | 6 | | | AND-NOR | AND-OR Invert Gate Array |
| 14L4 | 14 | 4 | | | AND-NOR | AND-OR Invert Gate Array |
| 16L2 | 16 | 2 | | | AND-NOR | AND-OR Invert Gate Array |
| 12L10 | 12 | 10 | | | AND-NOR | AND-OR Invert Gate Array |
| 14L8 | 14 | 8 | | | AND-NOR | AND-OR Invert Gate Array |
| 16L6 | 16 | 6 | | | AND-NOR | AND-OR Invert Gate Array |
| 18L4 | 18 | 4 | | | AND-NOR | AND-OR Invert Gate Array |
| 20L2 | 20 | 2 | | | AND-NOR | AND-OR Invert Gate Array |
| 16L8 | 10 | 2 | 6 | | AND-NOR | AND-OR Invert Gate Array |
| 20L8 | 14 | 2 | 6 | | AND-NOR | AND-OR Invert Gate Array |
| 20L10 | 12 | 2 | 8 | | AND-NOR | AND-OR Invert Gate Array |
| 16R8 | 8 | 8 | | 8 | AND-NOR | AND-OR Invert Gate Array w/Reg's |
| 16R6 | 8 | 6 | 2 | 6 | AND-NOR | AND-OR Invert Array w/Reg's |
| 16R4 | 8 | 4 | 4 | 4 | AND-NOR | AND-OR Invert Array w/Reg's |
| 20R8 | 12 | 8 | | 8 | AND-NOR | AND-OR Invert w/Reg's |
| 20R6 | 12 | 6 | 2 | 6 | AND-NOR | AND-OR Invert w/Reg's |
| 20R4 | 12 | 4 | 4 | 4 | AND-NOR | AND-OR Invert w/Reg's |
| 20X10 | 10 | 10 | | 10 | AND-NOR | AND-OR-XOR Invert w/Reg's |
| 20X8 | 10 | 8 | 2 | 8 | AND-NOR | AND-OR-XOR Invert w/Reg's |
| 20X4 | 10 | 4 | 6 | 4 | AND-NOR | AND-OR-XOR Invert w/Reg's |
| 16X4 | 8 | 4 | 4 | 4 | AND-NOR | AND-OR-XOR Invert w/Reg's |
| 16A4 | 8 | 4 | 4 | 4 | AND-NOR | AND-CARRY-OR-XOR Invert w/Reg's |

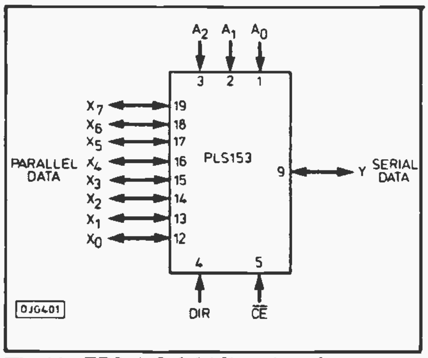



**Fig.14.** *FPLA 8:1 bidirectional multiplexer/demultiplexer*

## PROGRAMMABLE LOGIC SEQUENCERS

Field programmable logic sequencers (FPLSs) are single chip devices which can be programmed to step through a sequence of fixed states under control of clock pulses. An example is a bi-directional decade counter as shown in Fig.16. The U/D input determines the direction of the count where U/D=1 for up counting at outputs A,B,C and D, and U/D=0 for down counting. The sequence of output changes is shown by the state diagram of Fig.17.

The conventional method of designing such a circuit can be very complex, involving tables of present/next states and simplifying Boolean equations using Karnaugh Maps and De Morgan's Theorems for every output. The follow-

**TABLE 3.** *Truth table for 8-to-1 multiplexer/demultiplexer*

| CE | DIR | $A_2$ | $A_1$ | $A_0$ | $X_7$ | $X_6$ | $X_5$ | $X_4$ | $X_3$ | $X_2$ | $X_1$ | $X_0$ | Y | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | X | X | X | X | Z | Z | Z | Z | Z | Z | Z | Z | Z | |
| L | H | L | L | L | | | | INPUTS | | | | | $X_0$ | |
| L | H | L | L | H | | | | INPUTS | | | | | $X_1$ | |
| L | H | L | H | L | | | | INPUTS | | | | | $X_2$ | |
| L | H | L | H | H | | | | INPUTS | | | | | $X_3$ | outputY |
| L | H | H | L | L | | | | INPUTS | | | | | $X_4$ | |
| L | H | H | L | H | | | | INPUTS | | | | | $X_5$ | |
| L | H | H | H | L | | | | INPUTS | | | | | $X_6$ | |
| L | H | H | H | H | | | | INPUTS | | | | | $X_7$ | |
| L | L | L | L | L | Z | Z | Z | Z | Z | Z | Z | Y | I | |
| L | L | L | L | H | Z | Z | Z | Z | Z | Z | Y | Z | I | |
| L | L | L | H | L | Z | Z | Z | Z | Z | Y | Z | Z | I | |
| L | L | L | H | H | Z | Z | Z | Z | Y | Z | Z | Z | I | inputY |
| L | L | H | L | L | Z | Z | Z | Y | Z | Z | Z | Z | I | |
| L | L | H | L | H | Z | Z | Y | Z | Z | Z | Z | Z | I | |
| L | L | H | H | L | Z | Y | Z | Z | Z | Z | Z | Z | I | |
| L | L | H | H | H | Y | Z | Z | Z | Z | Z | Z | Z | I | |

Z = High impedance
X = Don't care (1 or 0)
I = Input state

ing describes how easier and quicker the design becomes when using an FPLA.

A typical FPLS is the PLS105. This device includes programmable AND/OR arrays which are used for the combinational logic to control the transitions between 8 output registers and 6 internal state registers.

The programming of the PLS105 for the counter example is shown using the program table, Table 4. The table shows that at power up, the outputs ABCD are all low. If the clear (CLR) pin is high (inactive) and U/D is high, each clock pulse causes the internal state register to change from the present states (columns labelled P) to the next stages (labelled N). The device outputs labelled F, reflect the present states P. The down count state changes are defined from rows 10 to 19.

The contents of the program table are simply keyed into a PLD programmer which programs the PLS105 accordingly, cutting design time, from first putting pencil on paper to the finished circuit, down to a matter of minutes.

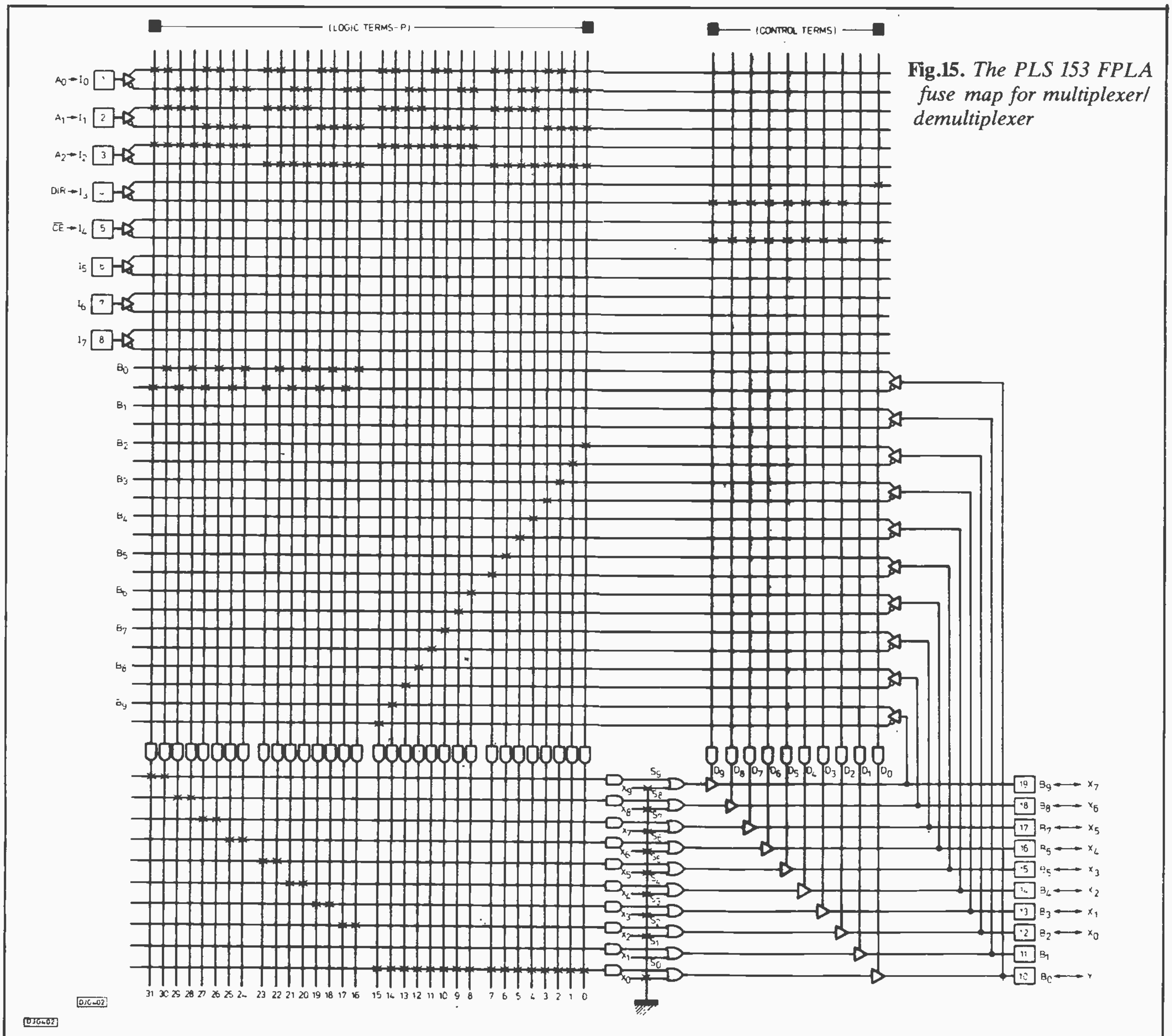
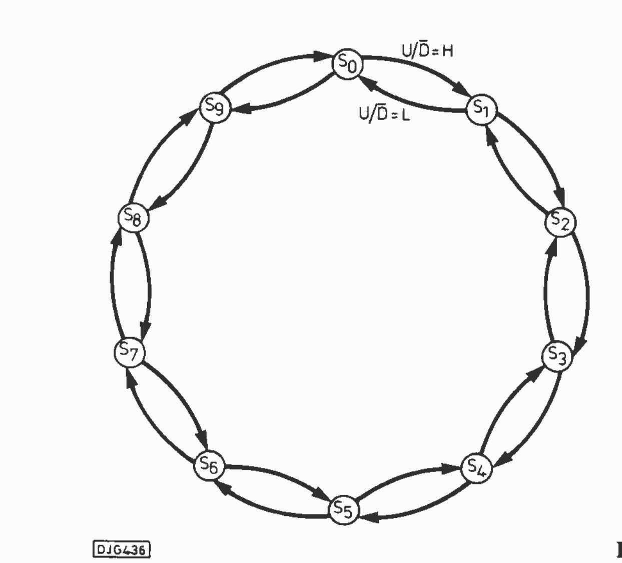



**Fig.15.** *The PLS 153 FPLA fuse map for multiplexer/demultiplexer*

**TABLE 4.** *A computer high-level listing for PLD design*

```
State S0: case (Mode == Up)    : S1;
               (Mode == Down)  : S9;
               (Mode == Clear) : S0;
          endcase;
State S1: case (Mode == Up)    : S2;
               (Mode == Down)  : S0;
               (Mode == Clear) : S0;
          endcase;
State S2: case (Mode == Up)    : S3;
               (Mode == Down)  : S1;
               (Mode == Clear) : S0;
          endcase;
State S3: case (Mode == Up)    : S4;
               (Mode == Down)  : S2;
               (Mode == Clear) : S0;
          endcase;
State S4: case (Mode == Up)    : S5;
               (Mode == Down)  : S3;
               (Mode == Clear) : S0;
          endcase;
State S5: case (Mode == Up)    : S6;
               (Mode == Down)  : S4;
               (Mode == Clear) : S0;
          endcase;
State S6: case (Mode == Up)    : S7;
               (Mode == Down)  : S5;
               (Mode == Clear) : S0;
          endcase;
State S7: case (Mode == Up)    : S8;
               (Mode == Down)  : S6;
               (Mode == Clear) : S0;
          endcase;
State S8: case (Mode == Up)    : S9;
               (Mode == Down)  : S7;
               (Mode == Clear) : S0;
          endcase;
State S9: case (Mode == Up)    : S0;
               (Mode == Down)  : S8;
               (Mode == Clear) : S0;
          endcase;
```




| STATE | D | C | B | A |
|---|---|---|---|---|
| $S_0$ | L | L | L | L |
| $S_1$ | L | L | L | H |
| $S_2$ | L | L | H | L |
| $S_3$ | L | L | H | H |
| $S_4$ | L | H | L | L |
| $S_5$ | L | H | L | H |
| $S_6$ | L | H | H | L |
| $S_7$ | L | H | H | H |
| $S_8$ | H | L | L | L |
| $S_9$ | H | L | L | H |

**Fig.17.** *State diagram for Up/Down Counter*

## HIGH-LEVEL PLD LANGUAGES

There are a number of high-level PLD computer aided design programs available, primarily for PCs such as the IBM PC or similar. These generally enable very complex designs to be developed, simulated for a particular PLD and then the fuse-map information downloaded to a programming device using a standard known as JEDEC.

Monolithic Memories provide a program called PALASM which, as its name suggests, can only be used with PALs. Mullard/Signetics provide a program called AMAZE (Automatic Map And Zap Equation Entry!) which, as you may have guessed, can only be used with their own PLDs.

Both PALASM and AMAZE are extremely powerful development tools but limit you to one manufacturer's range of devices. There are now available programs such as CUPL and ABEL which accommodate any type of device, but these programs are very expensive.

Table 4 shows a typical high-level language entry for the decade counter example described under FPLSs. All the states are defined, followed by the selection of a device, and then each transition is entered line by line. Once mastered, these high-level languages make complex design even faster. PE

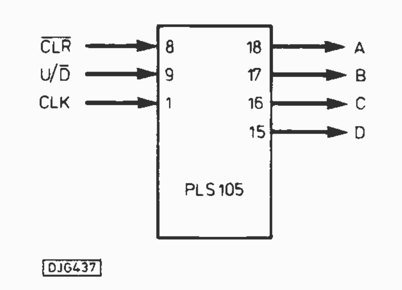



**Fig.16.** *PLS105 FPLS as an up/down counter with clear.*

*COMING SOON:* Early in 1988 Chris Kelly will describe a PLD Programmer Constructional Project.

# CLASSROOM ROBOTICS

**BY LAWRENCE HAMBURG**

## Young hopefuls takes control

*A look at an approach involving computer-controlled robots and their role within one particular area of education*

The local education authority in Bradford, West Yorkshire, is currently looking into the expansion and development of its Enterprise Education Centres/Work Practice Units. They are intended to provide the opportunity for all fourth formers, from local schools, to attend for a two week experience course. Through a practical approach part of the aims of such a centre are to provide a contact for previously gained knowledge within school, and to help relate this to the adult world of industry and commerce etc. Experience of working relationships and disciplines of the world outside school, with the emphasis on education, are incorporated into various aspects of the centres, such as the requirement for all students to clock or sign in and out.

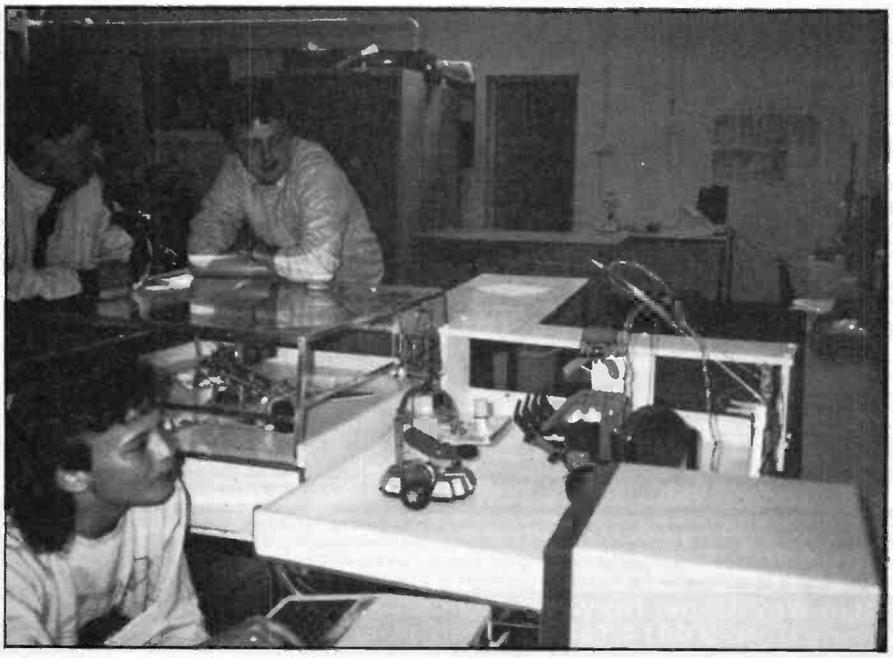
### TECHNOLOGY AND EDUCATION

As coordinator for the North Bradford Centre I believe that this presents an exciting opportunity to develop areas in which young people can work using modern technology. When fully established the centre will open its doors to over 1200 young people a year. Its functions will include the integration of technology, such as for example computer applications, into all areas – office, catering, stores, design etc. – the emphasis being on its use to assist in the completion of a task, rather than specifically focusing attention of the equipment itself.

The Centre is also to be regarded as a resource, providing certain activities which can be integrated into the requirements of a school situation. Amongst these I intend to establish a robotics and electronics area, subjects in which I am particularly interested – some would say obsessed! It is firmly believed that an appreciation of new technology, in this case through robotics and electronics providing a simple introductory hands-on approach, is a useful asset for all young people. I am fortunate enough to be in a position to put this belief into practice.

### EDUCATIONAL ROBOTS

In the situation where the robots described here are to be used the emphasis is on the student experimenting, with little input from tutors or staff – "there is the robot, switch it on and control it". The students will normally be in the robotics area for only one day.

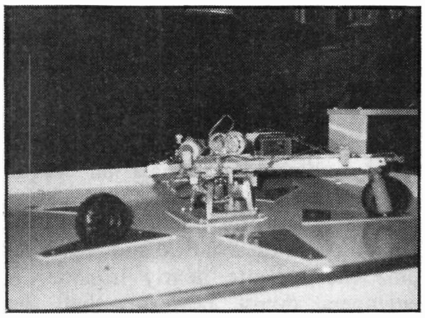


Given this situation and that many of the students will be new to robotics, the emphasis must be towards providing an introduction to this exciting area. One problem with commercially available educational robots of the low cost introductory type is that, while they may possibly offer a progressive hands-on approach to robotics, they tend to be delicate and 'unrealistic' in appearance. It is important that the robots available are 'appealing' to the students. A mass of tangled wires, coupled to a flimsy robot on the edge of a desk, will only serve to dampen any previous interest shown towards this area – students are better motivated into becoming involved if the presentation is attractive.

### DEVELOPMENT

To provide computer-controlled robots suitable for this application, I have developed and constructed my own robots, interfaces and other equipment, and adapted suitable software. The emphasis is on readily available low cost components and ease of replacement. They are intended for use with the BBC range of computers (although their use is to be extended to include the RM Nimbus). The robots are of the arm and floor type, and have cost under £100 each to construct. They are solidly constructed and only the minimum number of components, including robust metal gearboxes, is attached to them. The students can therefore move the robots around without fear of altering any settings or controls – there is no need to provide a list of don'ts or for staff to check and interfere.

Apart from hands-on experience the aims of this area include the encouragment of problem solving and decision making techniques, and to present the opportunity for a team student centred approach. All students will have the opportunity to control a robot using a computer – new technology is for all. The programs used are progressive, to allow students of differing abilities to participate. One encouraging point is the way girls have taken to this area, after only a little push – technology is not just for boys.



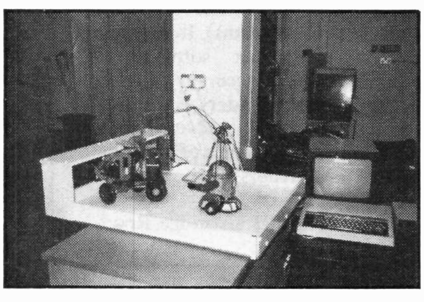
## ROBOT ARM

This is constructed from a variety of materials consisting mainly of aluminium section. The intention is to provide an arm which is realistic in appearance, in relation to illustrating possible links towards applications in an industrial setting. In addition to the arm being of robust construction it is housed in a perspex case, to prevent accidental damage (access being provided for placing and moving objects around).

There are three DC motors to control turntable rotation, arm extension and gripper opening/closing. The first two have positional feed back facilities in the form of potentiometers which inform the computer about the position of the arm. The screen then displays turntable rotation in degrees and arm extension in millimetres. The gripper performs two actions in one operation: as it moves downwards the jaws open; as it moves upwards the jaws close. It is, therefore, possible to move objects to and from various positions on the board. The students can experiment and develop a correct sequence of operations for this to be achieved.

## ROBOT – FLOOR TYPE

Two types have been constructed, each utilising two stepper motors and gearboxes, one for each wheel and mounted on 'toy' robots, offering a 'robot look' to the construction. One model consists of a tractor and trailer, giving the added bonus and problem of reversing – one skill in which I need more practice! Despite their large size, weight and low dynamic torque (turning force), for this application the accuracy provided by stepper motors justifies their use. There is no need to burden the robot with further components to provide positional feedback facilities, as would be required if DC motors were to be used. These particular robots, unlike the arm, can be picked up and moved around the board; only the stepper motors and gearboxes need to be attached to the robot. This allows for a more robust construction that is less prone to damage.

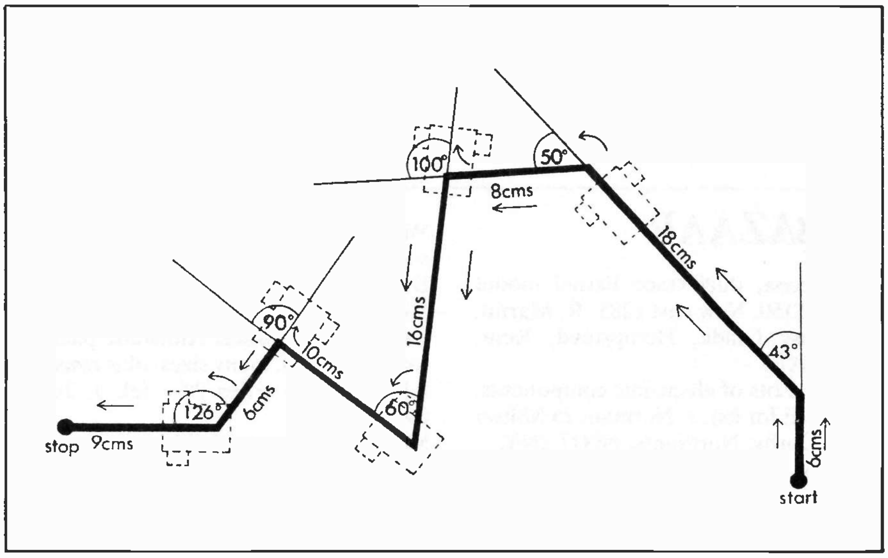


The interface between the computer and robot permits the control of various relays. The computer simply activates the required relay for a specified time, with each relay determining in which direction the robot is to move. The two stepper motors are operated through a control board and power interface constructed on stripboard. This hardware approach, in the control of stepper motors, allows the opportunity to demonstrate to the student how the robot can be operated without the use of a computer. This is achieved through the use of push button switches, mounted on the robot board, which simply operate the required relay. A progressive approach can then be adopted, from using the computer keyboard for manual control, to programs enabling a sequence of instructions to be stored and repeated as required.

## EXCITING OPPORTUNITY

Upon completion, the students can then simply load the word processor program, record their achievement, switch over to the printer and provide themselves with a print-out. One rewarding aspect is when students ask where they can obtain the circuits and electronic components for building their own robots and linking them to their home computer.

This is only one particular approach towards introducing robotics into an educational setting. It presents an exciting opportunity in which hands-on experience and sound educational principles, can be put into practice – by using it as a tool to encourage problem solving, decision making skills etc. Young people are going to experience many different situations, mainly as a result of advancements in technology, and they therefore need to have the desire and ability to adapt and become part of a changing society. The education system must play its part.




*Typical control course*

## COURSE CONTROL

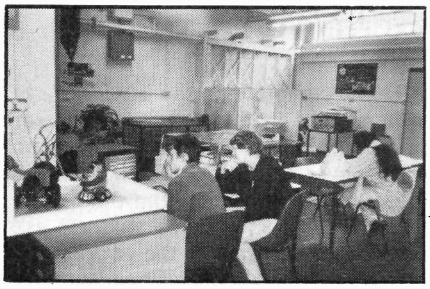
To encourage the use of a range of skills and knowledge, this area also requires various courses to be constructed for the robot to follow. As regards the floor type robot, this includes the requirement to convert specific 'robot units of movement' into centimetres and degrees of rotation, ie. The use of applied maths.

The students, using calculators, protractors, rulers and pencils, draw the course details on the board. They can then try out the different programs available and instruct the robot to follow the course, collect the object from the gripper, and return to the starting point. The courses have been designed to be progressive, starting with simple routes and advancing to those requiring a greater degree of planning.

## BIOGRAPHICAL NOTE

*Lawrence Hamburg is studying part-time for an M.A. in applied educational research. He is part of a five member team sponsored by the Bradford Authority to look at the various aspects of the new educational initiatives – particularly in relation to courses funded by the Manpower Services Commission, an organisation which with the Government's backing is radically changing some aspects of education towards a vocational emphasis. His particular area is new technology and its role within education, especially stressing the link between school and industry.*

*Bradford has recently put in a bid for and will obtain millions of pounds under the Technical & Vocational Education Initiative – there are various local authorities involved in this scheme.*

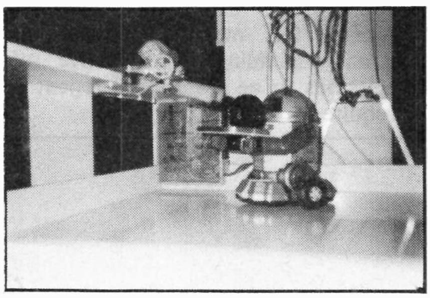


*One of the conditions attached to the funding is that a major part of it must be spent on 'technology across the curriculum'. The Bradford team have all entered education from industry and commerce. One (female) member is particularly interested in the participation of girls in technological subjects.*

*As a point of interest and encouragement, with more emphasis being placed on new technology in education, a number of people in education have asked Lawrence Hamburg's advice on how to learn about electronics – "its about time I learnt about electronics" or "my children are growing up and I want to help them learn about electronics". He is currently working on a practical approach to electronics – no soldering and using a 'paint by numbers' method.*

*He remembers that his first introduction to electronics was through one of the early Phillips electronic engineer kits, which he received as a birthday present in the mid 1960s – and for which no previous knowledge required. This provided the motivation to go on and build more complicated projects. As he progressed he realised the need for theory and read the required books and magazines, including PE. He believes that this is how education should approach electronics. "It's extremely rewarding", he says, "when a youngster after only a day in the electronics circuit assembly area, asks where to obtain the various instructions and components to build his or her own circuits at home".*

*In view of the increasing importance of modern technology in the education system, and the necessity for teachers and parents to respond to this change, he believes that there is a case for devoting a regular spot in PE to cover this area. We agree with him.* PE



**Leading Edge** *Continued from page 8*

Ampex idea is to sample and code the TV signal in the "composite" form in which it is transmitted to the public. This is a single TV signal with the black-and-white and colour signals all mixed together as PAL, SECAM or NTSC – depending on the country or origin. Digital data rate is halved and recording time per cassette nearly tripled. TV engineers doubt however that the composite coding system will give them the picture quality which they can get from component coding.

First tests by the ITCA and Thames at Teddington have shown that a digital recording made according to the CCIR standard can be copied over 50 times without any noticeable loss of quality. This is important for video editing where the only way to add special effects is to keep copying the programme material over and over again. Even the best analogue recorder gives blurred pictures after 10 copy generations. If Hollywood shot *Dallas* on digital video the conversion problems would be eased.

By the way, I only picked *Dallas* as an example for technical reasons. Personally I think that as a programme it is unwatchable, whatever the picture quality. *(PE does not necessarily endorse all the views of its authors! Ed.)* PE

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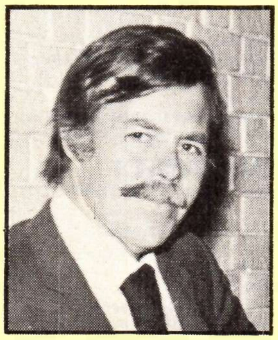

# INDUSTRY NOTEBOOK

## FIVE BILLION CUSTOMERS

**REPORT BY TOM IVALL**

*More heads is not quite the same as more consumers. Changing patters in the world's population will eventually give birth to new priorities in electronics.*

EARLIER this year the United Nations announced that the population of the world had reached 5 billion some time during the summer. The official day to mark the event was 11 July, though of course nobody could know for sure the exact time when the five-billionth baby was born. Enormous as the actual number is, a much more significant fact is that it lies on a part of the population curve which is rising exponentially at a rate faster than ever before. According to an old book of statistics I have, the world population in 1911, after several million years of multiplication of the species, had reached 1.602 billion. Now, only 76 years later – or just one orbit of Halley's Comet – it has increased by some 3.4 billion. Currently the growth is about 78 million new inhabitants of the planet per annum.

What significance does this population growth have to our present discussion on the interaction of the electronics industry with society? In so far as everyone is to some extent a consumer of goods and services it means, simplistically, that the world electronics industry now has a potential 5 billion customers. In reality, of course, this is not so. First of all not every individual can be regarded as a direct consumer of the products of this industry. Secondly, most of the population growth is taking place in the poorest countries of the world. You will find the odd radio set or digital watch here and there among the villages of Africa, India and Latin America but these people are, and will be for a long time, predominantly consumers of the basic necessities of life – food, clothing and shelter.

Yet the sales of electronics products are undoubtedly increasing at a fast rate. According to Jürgen Knorr, a senior manager of Siemens in Munich, the world electronics market is now expanding somewhat faster than that for conventional electrical goods. Over the past 15 years, whereas the conventional electrical market has grown at an average annual rate of about 6%, the electronics market has expanded at about 9.5% per annum. And in the coming five years, while the electrical market is expected to increase by only 2.5% p.a., the electronics market will probably grow at approximately 8.5% p.a.

It's tempting to superficially correlate these sales figures with the population growth statistics, especially when one remembers that modern electronics is very much centred on the technology of integrated circuits. The sales of ICs are currently increasing somewhat faster than those of passive components and discrete semiconductors put together. With their small size, low power consumption and decreasing price per function on a chip, they are obviously attractive products if you can use them. Theoretically, a Third World villager with a simple diet and few home comforts could still afford to buy a sizable number of binary storage cells or logic functions. He or she might even be able to afford a whole microprocessor. But what would be the point?

I raise this rather absurd idea simply to underline the realities of the present situation. Integrated circuits are being bought to make electronic equipment not by the developing countries with their rapidly growing populations but overwhelmingly by the already highly developed, industrialized countries where the populations are either virtually static or growing very slowly. Jürgen Knorr says that by the year 1990 Japan will constitute 40% of this market, the United States 36% and Western Europe 18%, the rest of the world's countries accounting for the remaining tiny 6%.

The reason for this imbalance is not far to seek. Predominantly the world's output of ICs is being used to make communications equipment and computers – the heart of information technology. And this equipment has its most intensive application and offers its greatest benefits in those countries where, regardless of population size, society is highly organized in the economic and industrial sense, where the socio-economic functions of individuals and groups are highly interdependent. The information technology equipment and systems have become almost essential to keep everything running smoothly. In its personal relationships, families and other cultural groups the society may be falling apart, its human values disintegrating, but the system keeps working.

There are, however, certain ways in which electronics technology, its products and services, do reach out to the poorest people in the remotest areas of Third World countries. First, the administrations and industries of these developing countries are beginning to make use of computers – though in a limited way compared with the intensive application of the industrialized world. Secondly, communication satellites are being used by governments to beam educational and entertainment services down to remote and isolated communities which so far have not had access to the terrestrial broadcasting centred on the large cities.

A third factor is the rise of nationalism and the rivalries it produces. My old book of statistics shows that there were fewer than 50 countries in the world in 1911. Now, after widespread decolonisation, there are over 150 independent nations. Each of these has its own sovereignty as a territorial/political/economic entity, and we see various forms of competition and sometimes wars to assert these national rights. Many of these developing countries turn their eyes to the industrialized world as a model to be emulated, with its technology to be bought, copied or adapted.

Instead of relying on cheap labour, minerals or cash crops to pay their way in the world, some of the developing countries have understood the need to harness high technologies such as elcetronics to increase the productivity of their industries as a means of speeding up the accumulation of capital. Such capital is required for rural and urban development, for providing manufactured products to help agriculture and for meeting the urgent material need of the people.

Thus, overall, there are several trends which are likely to produce in the futrure a far more widely distributed usage of electronics than we have today in the world's population.

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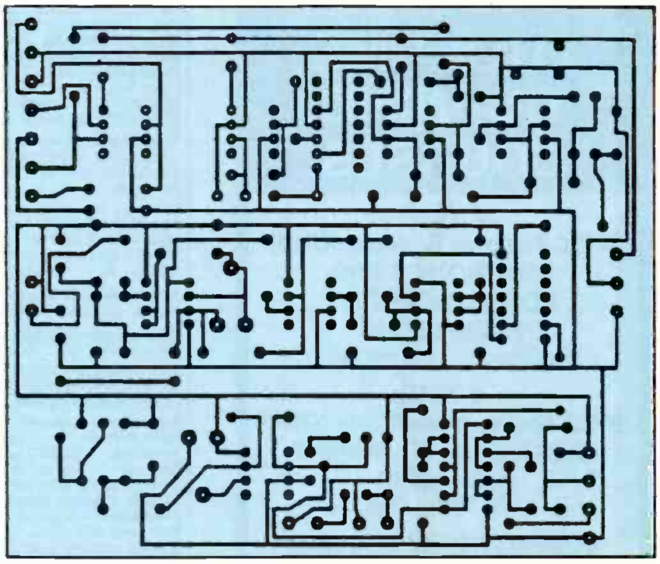

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| **JUL 87** | | |
| **WORD GENERATOR** – produces binary words of up to 16 bits | 147 | £13.42 |
| **SCOPE STORE** oscilloscope add-on data storage | 148 | £11.94 |
| **AUG 87** | | |
| **PSEUDO STEREO** – mono to simulated stereo | 149 | £7.37 |
| **SEP 87** | | |
| **SPEECH PROCESSOR** – clarifies transmitted speech quality | 150 | £5.86 |
| **GCSE TIMER UNIT** – versatile variable delay AWD and switching | 151 | £5.18 |
| **FUNGEN** – triple waveform signal generator | 152/153 | £9.69 |
| **LIGHT CONTROLLER** – delayed switching | 154 | £4.64 |
| **OCT 87** | | |
| **TEACHER LOCKER** – digital lock control | 155 | £7.50 |
| **POWER SUPPLY** – stabilised ±15V | 156 | £7.50 |
| **GUITAR TO SYNTH** – music interface | 157A/B | £9.95 |

## THIS MONTH'S BOARDS

| | | |
|---|---|---|
| **NOV 87** | | |
| **DUAL POWER SUPPLY** – GCSE | 158 | £6.20 |
| **MIDI EXPANDER** – Music Interface | 159 | £5.04 |

## INDEX TO ADVERTISERS

# £1 BAKERS DOZEN PARCELS

Price per parcel is £1.00, but if you order 12 you get one extra free.
All the parcels listed below are brand new components. Unless marked s.h.

1 – 5 13 amp ring main junction boxes
2 – 5 13 amp ring main spur boxes
5 – 3 flush electrical switches
7 – 4 in flex line switches with neons
8 – 2 80 watt brass cased elements
9 – 2 mains transformers with 6V 1A secondaries
10 – 2 mains transformers with 12V ½A secondaries
11 – 1 extension speaker cabinet for 6½" speaker
12 – 5 octal bases for relays or valves
13 – 12 glass reed switches
14 – 4 OCP 70 photo transistors
16 – 4 tape heads, 2 record, 2 erase
17 – 1 ultra sonic transmitters and 1 ditto receiver
18 – 2 15000 mfd computer grade electrollics
19 – 2 light dependent resistors
20 – 5 different micro switches
21 – 2 mains interference suppressors
22 – 2 25 watt crossover units 2 way
23 – 1 40 watt 3 way crossover unit
28 – 1 6 digit counter mains voltage
30 – 2 Nicad battery chargers
31 – 1 key switch with key
32 – 2 humidity switches
33 – 2 aerosol cans of ICI Dry Lubricant
34 – 96 x 1 metre lengths colour-coded connecting wires
36 – 2 air spaced 2 gang tuning condensors
37 – 2 solid diaelectric 2 gang tuning condensors
38 – 10 compression trimmers
41 – 6 Rocker Switches 10 amp mains SPST
43 – 5 Rocker Switches 10 amp SPDT Centre Off
44 – 4 Rocker Switches 10 amp DPDT
45 – 1 24 hour time switch mains operated (s.h.)
46 – 1 6 hour clock timeswitch
48 – 2 6V operated reed switch relays
49 – 10 neon valves – make good night lights
50 – 2 x 12V DC or 24V AC, 4 CO relays
51 – 1 x 12V 2C O very sensitive relay
52 – 1 12V 4C relay
53 – 2 mains operated relays 3 x 8 amp changeovers
55 – 1 locking mechanism with 2 keys
56 – Miniature Uniselector with circuit for electric jigsaw
57 – 5 Dolls' House switches
60 – 5 ferrite rods 4" x 5/16" diameter aerials
61 – 4 ferrite slab aerials with L & M wave coils
62 – 4 200 ohm earpieces
63 – 1 Mullard thyristor trigger module
64 – 10 assorted knobs ¼ spindles
65 – 5 different thermostats, mainly bi metal
66 – Magnetic brake – stops rotation instantly
67 – Low pressure 3 level switch
69 – 2 25 watt pots 8 ohm
70 – 2 25 watt pots 1000 ohm
71 – 4 wire wound pots – 18, 33, 50 and 100 ohm
73 – 4 3 watt wire wound pots 50 ohm
77 – 1 time reminder adjustable 1-60 mins
78 – 5.5 amp stud rectifiers 400V
85 – 1 mains shaded pole motor ⅝" stack – ¼ shaft
86 – 2 5" all fan blades fit ¼" shaft
87 – 2 3" plastic fan blades fit ⅛" shaft
88 – Mains motor suitable for above blades
89 – 1 mains motor with gear box 1 rev per 24 hours
91 – 2 mains motors with gear box 16 rpm
93 – 4 11 pin moulded bases for relays
94 – 5 B7G valve bases
95 – 4 skirted B9A valve bases
96 – 1 thermostat for fridge
98 – 1 motorised stud switch (s.h.)
101 – 1 2½ hours delay switch
103 – 1 6V mains power supply unit
104 – 1 4½V mains power supply unit
105 – 1 5 pin flex plug and panel socket
107 – 1 5" speaker size radio cabinet with handle
109 – 10¼" spindle type volume controls
110 – 10 slider type volume controls
112 – 1 heating pad 200 watts mains
114 – 1 1W amplifier Mullard 1172
115 – Wall mounting thermostat 24V
118 – Teak effect extension 5" speaker cabinet
120 – p.c.b. with 2 amp full wave and 17 other recs
122 – 10 mtrs twin screened flex white p.v.c. outer
132 – 2 plastic boxes with windows, ideal for interrupted beam switch etc
155 – 3 varicap push button tuners with knobs
188 – 1 plastic box, sloping metal front, 16 x 95mm, average depth 45mm
241 – 1 car door speaker (very flat) 6½" 15 ohm made for Radiomobile
243 – 2 speakers' 6" x 4" 15 ohm 5 watt made for Radiomobile
266 – 2 mains transformer 9V ½A secondary split primary so OK also for 115V
267 – 1 mains transformers 15V 1A secondary p.c.b. mounting
330 – 2 6V 0.6V mains transformer .3A p.c.b. mounting
350 – 40 double pole leaf switches
365 – 1 7uf 660V 50hz metal cased condenser
453 – 2 2¼in. 80ohm loudspeakers
454 – 2 2¼in. 8ohm loudspeakers
463 – 1 mains operated relay with 2 sets c/o contacts
464 – 2 packets resin filler/sealer with cures
465 – 3 5A round 3 pin plugs will fit item 193
466 – 4 7 segment l.e.d. displays
470 – 4 pc boards for stripping, lots of valuable parts
473 – 1 5" 4ohm speaker with built in tweeter Radiomobile
480 – 1 3A double pole magnetic trip, saves repairing fuses
498 – 4 1000uf 25V axial electrolytic capacitors

## TELEPHONE BITS

Master socket (has surge arrestor – ringing condenser etc) and takes B.T. plug .......... £3.95
Extension socket .......... £2.95
Dual adaptors (2 from one socket) .......... £3.95
Cord terminating with 8 T. plug 3 metres .......... £1
Kit for converting old entry terminal box to new B.T. master socket, complete with 4 core cable, cable clips and 2 BT extension sockets .......... £11.50
100 mtrs 4 core telephone cable .......... £8.50

## COMPACT FLOPPY DISC DRIVE EME-101

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

## EVERLASTING BATTERIES!

Well not quite, but if you don't switch it on, the lithium battery has an almost indefinite shelf life, which makes it suitable for emergency, standby & similar applications, also for quartz clocks and instruments that draw only microscopic currents. The lithium battery we have is 3V and about as big and thick as 2p coin. Price 2 for £1 ref BD 558. Note these plug into Dil socket our ref BD553.

## 3 POLE MODEL MOTOR

Will operate from as low as 1.5V and speed will increase steadily as the voltage is increased, at 9V however a governor takes over and the speed remains constant – and ideal motor for models. Size approx 28mm × 40mm easily reversible and with good length spindle 60p each our ref BM30.

## CASSETTE STEREO TAPE HEADS

With mounting brackets and with tape guides pairs, one record/playback and the other erase £1 pair ref BD541.

## OPTO INTERRUPTER

Consists of a IR emitter mounted close to light dependent resistor when light or IR is interrupted the change of resistance can be made to switch or operate a relay – useful for counting, motor stopping etc. Price 2 for £1 ref BD545

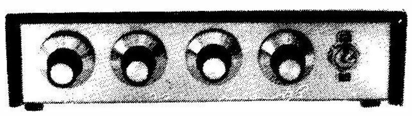
**Ex-Electricity Board. Guaranteed 12 months.**

## VENNER TIME SWITCH

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

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

## SOUND TO LIGHT UNIT



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

## This Month's Snip

**9" VDU OR MONITOR** ideal to work with computer or video camera uses Philips black and white tube ref M24/306W. Which tube is implosion and X-Ray radiation protected VDU is brand new and has a time base and EHT circuity Requires only a 16V dc supply to set it going. It's made up in a lacquered metal framework but has open sides so should be cased (if you are handy with a drill and file you could make a case out of two of our 6½" speaker cabinets) The VDU comes complete with circuit diagram and has been line tested and has our six months guarantee Offered at a lot less than some firms are asking for the tube alone, only £16 plus £3 post We also have some that failed the line test, again brand new but offered without guarantee at £8 plus £3 post. We do a kit for the 16V 2A psu to operate this monitor price is £3 our ref 3P26

## SLIDE SWITCHES

Sub miniature size only 10mm × 4mm single pole change over or on/off Price 5 for £1 ref BD553

## LOW VOLTAGE RELAY

OMRON 3.5V coil, plug in dil sockets, 5a c/o contacts. Brand new offered at a silly price 2 for £1 ref BD548.

## POLARISED RELAY

Depending upon its direction dc current as low 14 Ma makes this open circuit, so it could be used to protect delicate instruments or as on earth leakage, or reverse voltage trip etc 2 for £1 ref BD549.

## SLOTTED OPTO SWITCH

Infra red emitter and sensor mounted in slotted moulding, so that the emitter beam when broken makes a contactless switch, can be used in electronic ignition, speed sensing etc. etc. Price 2 for £1 ref BD545.

## 24hr TIME SWITCH

Beautifully made with West German precision. Just under 4" square with 15amp c/o contacts can be set anywhere around 24hr dial to the nearest 15 mins also with a overide switch. Ref 8P6 but hurry we hav eonly 300. Price £8.

## COMPUTERS

The Acorn "Electron" as used in many schools for games and serious jobs. Works into colour or Black and White TV. Proper price was £199, our Price, tested and working £45 + £3 post, tested but slightly faulty £36 + £3 post and lastly tested but not working £20 + £3 post, all are new and complete with: mains P.S.U., 300 page handbook, TV lead, and starter cassette. Full range of Software also in stock at very low prices.

## TELEPHONE LEAD

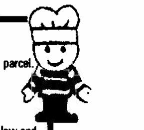
3 mtrs long terminating one end with new BT, flat plug and the other end with 4 correctly coloured coded wires to fit to phone or appliance. Replaces the lead on old phone making it suitable for new BT socket. Price £1 ref BD552 or 3 for £2 ref 2P164.

## POWERFUL IONISER

Generates approx. 10 times more IONS than the ETI and similar circuits. Will refresh your home, office, shop, work room etc. Makes you feel better and work harder – a complete mains operated kit, case included. **£9.50 + £2 P&P.**

# J & N BULL ELECTRICAL
## Dept. E.E., 250 PORTLAND ROAD, HOVE, BRIGHTON, SUSSEX BN3 5QT

MAIL ORDER TERMS: Cash, P.O. or cheque with order. Orders under £20 add £1 service charge. Monthly account orders accepted from schools and public companies. Access & B/card orders accepted. Brighton 0273 734648 or 203500.



# NEW ITEMS

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

## £2 POUNDERS*

2P120 – 1 combined clockwork switch and thermostat for boiler control
2P122 – 1 30a rotary switch, surface mounting with pointer knob
2P123 – 1 25a rotary switch, surface mounting, cover engraved, high, medium low and off
2P124 – 1 28kv .001mfd block condensor
2P127 – 1 30a bridge rectifier assembly on heat sinks
2P129 – 1 10rpm motor 115V so supplied with adaptor for 230V
2P131 – 1 Crouzet motor 230V fits the Crouzet gearbox
2P132 – 1 ceiling heat-stat for fire warning or protection
2P133 – 1 Circuit breaker 20a, Crabtree ref C50
2P134 – 1 9V 500mA psu, plugs into 13a socket
2P135 – 10m 10 conductor intercom cable
2P136 – 1 2½kw element made for tangential blowers
2P137 – 1 Thermo couple, stainless steel tipped for measuring internal heat
2P138 – 1 Mains transformer 20V–0–20V 1a upright mounting
2P141 – 1 rechargeable battery D size (4 AH) solder tag ended
2P142 – 10m 4 pair intercom cable White PVC outer
2P144 – 1 mains operated relay with 4 × 8a c/o contacts
2P145 – 1 10,000 uf 7DV d.c. smoothing capacitor
2P146 – 1 7,800 uf 150C d.c. smoothing capacitor
2P147 – 1 10w 100ohm line matching transformer
2P148 – 1 Technical information on 3" FDD refundable if you buy fdd
2P149 – 5 diff battery operated model motors
2P150 – 1 PSU chassis with all components for 24V 2A d.c. unwired
2P151 – 1 Metal box 14½ × 14 × 4 with lid add £2.00 post
2P152 – 1 Motor start capacitor 80uf 250V
2P153 – 1 Two station intercom unused but line reject
2P154a – 1 Nicad charger — plug into 13a socket 5.2V .7UA output
2P154b – 1 Nicad charger — plug into 13a socket 6V .9VA output
2P155 – 1 Mains translormer giving 16, 17, 18 & 20V 60W
2P158 – 1 Oven thermostat with temp calibrated knob
2P159 – 1 9V 500ma cased with mains lead and output lead
2P160 – 1 13a plug adaptor fused takes 3 × 13a plugs
2P161 – 1 6" diagonal side cutters
2P162 – 1 Stereo Matrix PCB mounting deemphasis K35
2P163 – 1 AC Working capacitor 12uf 660V AC or 1500V dc
2P163a – 1 AC Working capacitor 14uf 350V AC or 800V dc
2P164 – 3 Phone leads 3 mtrs long tags one end B.T. plug other end

## £3 POUNDERS*

3P7 – 1 DC voltage, doubler or halver for 12V to 24V 12 to 6V 24 to 12V
3P8 – 1 24hr time switch Sangamo, new condition Guaranteed 1 year
3P9 – 12V 500mA psu plugs in 13a socket
3P10 – 1 Mains transformer 50V 2A with 6.3 pilot light winding, upright mounting, fully shrouded
3p13 – 1 Noise filter to fit in mains lead of appliance up to 25a
3P15 – 1 waterproof case will take 200 watt transformer
3P16 – 1 signal box, 3 lamps on face plate of metal box size 5½ × 3½
3P17 – 1 choke and starter to work 8" fluorescent tube at 125W
3P18 – 1 22V 3a mains transformer with bridge rect fitted on top panel
3P20 – 1 0–5a ammeter 3½ ac/dc ex equipment
3P21 – 1 power factor correction condenser 35uf 350ac
3P22 – 1 200va – auto transformer 230 to 115V torroidal encapsulated £1.50 post
3P23 – 1 36V–0–36V tapped 20V–0–20V 100va
3P24 – 1 3" floppy disc for Amstrad etc.
3P25 – 1 7" Electricians pliers

## £4 POUNDERS*

4P11 – 1 Car Radio aerial
4P12 – 50m low loss co-ax 75ohm + £1 post
4P13 – 3 Hortsman time and set switches 15amp
4P14 – 1 150w mains transformer "c" core 43V 3.5A secondary
4P15 – 1 powerful motor 2" stack fitted with gearbox final speed 60rpm mains operated, could operate door opener etc.
4P17 – 1 Uniselector 3 pole 25W, 50V coil standard size
4P18 – 1 Volt meter with digital display (DIGIVISOR)
4P19 – 1 12V dc motor will fit to gearbox 4P20
4P20 – 1 Gear train giving speed reduction

## £5 POUNDERS*

5P86 – 1 Transformer upright mounting 230/240V primary 2 × 100 1a secondary
5P88 – 1 Transformer in waterproof metal box 24V 5A add £2 post
5P89 – 1 4 bank heating element each 2kw ideal convector heater
5P90 – 1 18" long tangential blower with motor at one end
5P91 – 1 14" blower, motor in middle
5P92 – 10m Audio co-ax double screened 75ohm super low loss for TV
5P93 – 1 6" Alarm bell 24V dc or ac
5P94 – 1 Current transformer 14V out with 1a dc input
5P95 – 1 Vintage photo cell
5P97 – 1 Impedance matching transformer 0–4–5–8–160 ohm 100 add £150 post
5P98a – 1 0–90a ammeter for mounting outside control panel
5P98b – 1 0–180a ammeter for mounting outside control panel
5P99 – 1 Mains operated blower centrifugal output size app. 5" × 1½"
5P100 – 1 Mains splitter 45a switch 3 × 15a fused circuits
5P101 – 1 Model motor 1 rpm from 6V reversible

## £7 POUNDERS*

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

## £8 POUNDERS*

8P1 – 1 Charger transformer 10a upright mounting 230/240 primary 16v 10a secondary
8P2 – 1 6" underdome alarmbell suitable for a fire alarm or burglar alarm mains operated.
8P3 – 1 heat sink big powerful so ideal for power transmitter
8P5 – 1 1/3 hp motor 900 rpm capacitor run
8P6 – 1 24hr time switch – 2 on offs 16a c/o contacs 3" × 3" × 1½"
8P7 – 1 Silent sentinel invisible ray kit
8P8 – 1 Papst fan 3½ × 3½ × 1½ 230V metal bodied

## £10 POUNDERS*

10P13 – 1 reversible motor with gearbox 104rpm Parvalux
10P14 – 1 100a time switch 1 on/off per 24hr extra triggers £1 pair
10P15 – 1 Max demand meter 230 ac mains
10P16 – 1 powerful air mover 2 small type blowers with motor in middle
10P18 – 1 mains operated klaxon
10P19 – 1 12V alarm bell really loud, mains operated, in iron case + £5 post
10P21 – 1 super metal box size 19" × 20" × 7" deep lockable + £3 post
10P22 – 1 sensitive volt meter relay
10P23 – 1 fruit machine heart 3 fruit wheels each stepper motor operated
10P24 – 1 big panel meter face size 4¾ × 2½ 200uA movement scaled 1–10
10P25 – 1 100W audio transformer 50–0–50W primary 8 ohm secondary
10P26 – 1 "Secretary" phone auto-dialler complete untested sold as such
10P29 – 1 12V engine cooling fan
10P30 – 1 instrument psu on pcb has 4 outputs .12V/.5V 6A/12V 5A/5V .5A
10P31 – 1 7 day time switch 16a c/o contacts sep switches for each day
10P32 – 1 68 rpm 1/8th hp motor reversible

## £15 POUNDERS*

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

## £25 POUNDERS*

25P1 – 1 1500 PSI hydraulic pump 24V dc motor, made for operating aircraft undercarriage etc.

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


1988 BUYER'S GUIDE TO ELECTRONIC COMPONENTS
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