OM POWER AMPLIFIER MODULES

Newly developed for use in 3" voice coil loudspeakers. Powerful, compact, lightweight and efficient. Ideal for professional and hobby market. 100% FULLY RATED.

**Supplied ready built and tested**

**OM Power Amplifier Module 100**
- 110 watts RMS into 4 ohms.
- Frequency Response 1Hz - 100KHz.
- Damping Factor 30.5.
- Slew Rate 45V/μs.
- THD Typical 0.0015%
- Input Sensitivity 500mV.
- S/N Ratio 106dB.
- Size 300 x 115 x 65mm.
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**OM Power Amplifier Module 200**
- 220 watts RMS into 4 ohms.
- Frequency Response 1Hz - 100KHz.
- Damping Factor 29.
- Slew Rate 60V/μs.
- THD Typical 0.002%
- Input Sensitivity 500mV.
- S/N Ratio 105dB.
- Size 300 x 123 x 160mm.
- Price £57.87 + £4.00 P&P.

**OM Power Amplifier Module 300**
- 300 watts RMS into 4 ohms.
- Frequency Response 1Hz - 100KHz.
- Damping Factor 29.
- Slew Rate 85V/μs.
- THD Typical 0.002%
- Input Sensitivity 500mV.
- S/N Ratio 101dB.
- Size 300 x 123 x 160mm.
- Price £89.52 + £4.00 P&P.

**MCKENZIE**
- 1" voice coil.
- Frequency Response 45Hz - 6.5KHz.
- Sensitivity 98dB.
- Price £29.99 + £2.50 P&P ea.

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- 1" voice coil.
- Frequency Response 56Hz - 20KHz.
- Sensitivity 92dB.
- Price £110.99 + £1.50 P&P ea.

**WEM**
- 1" voice coil.
- Frequency Response 63Hz - 20KHz.
- Sensitivity 86dB.
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**PSI**
- 30 Inputs with individual faders providing a 3 way crossover.
- Price £45.90 each - 40p P&P.

**Freight charges**
- Minimum order £1.50. S.A.E. for complete list. Costs: 1st order (75p each)

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- Price £1.50 each. Suitable for both resistance and inductive loads including mains failure. Price £6.99 each (100p)

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**D B's PRICE £4.99 ea. P&P 50p**

**PIEZO ELECTRIC TWEETERS**
- VUVAC STEREO RACK AMPS
- 1K-WATT SLIDE DIMMER
- 15" 150 WATT R.M.S. C15 Bass Guitar/Disco.
- 12" 100 WATT R.M.S. HI-FI/Disco
- 8" 60 WATT R.M.S. Hi-Fi/Multiple Array Disco etc.
- 6" STEREO RACK AMPS

**FREE DELIVERIES**

**Burglar Alarm**
- Better to be Alarmed than到时候.
- Thrandr's famous burglar alarm system.
- Superior microphone performance.
- Supplied with interconnection, fully guaranteed.

**Ideal for Work" Homes, Offices, etc.**

**Prices include VAT + Prompt Deliveries + Friendly Service.**

**Large S.A.E. 26p Stamp for Current List.**

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- To 15" up to 400 WATTS R.M.S.
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- Sensitivity 89dB.
- Price £16.49 per pair.

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**Price List**
- 15" 150 WATT R.M.S. C15 Bass Guitar/Disco.
- 12" 100 WATT R.M.S. HI-FI/Disco
- 8" 60 WATT R.M.S. Hi-Fi/Multiple Array Disco etc.
- 6" STEREO RACK AMPS

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**Postage and packing**
- Minimum order £1.50. S.A.E. for complete list. Costs: 1st order (75p each)

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- 15" 150 WATT R.M.S. C15 Bass Guitar/Disco.
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- 6" STEREO RACK AMPS

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**Order Form**
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- 8" 60 WATT R.M.S. Hi-Fi/Multiple Array Disco etc.
- 6" STEREO RACK AMPS

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**Payment Options**
- VISA/ACCESS/C.O.D. ACCEPTED
- B.O.D. C.T.C. PRICES INCLUSIVE OF V.A.T. SALES COUNTER
- POSTAL CHARGES PER ORDER £1.00 minimum. OFFICIAL ORDER FORM AVAILABLE.

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**Prices**
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**For all orders please contact**
- UNIT 5, COMET WAY, SOUTHEND-ON-SEA, ESSEX. SS2 6TR TEL: 0702-527572

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**For further details please contact**
- UNIT 5, COMET WAY, SOUTHEND-ON-SEA, ESSEX. SS2 6TR TEL: 0702-527572

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British customers can now buy components from Conrad Electronic, a West German company which claims to be the largest specialist mail-order component supplier in Europe. The complete range is described in six catalogues, one of which describes the more popular product lines and is written in English. The others are in German but the samples we have seen are well illustrated and fairly easy to understand. Prices are quoted in Deutsch Marks but the order forms explain how to convert to Sterling. For details contact Conrad's distributors, Smith Electronics, 157 Chapel Street, Leigh, Lancashire WN7 2AL. Tel: (0942) 606 674.

In 1990 a new EEC directive will come into effect requiring employers to check noise levels and reduce them where appropriate. Workers in noisy environments will also have the right to demand ear protectors and to have regular hearing checks. To help us understand the new regulations (and presumably to advertise its own services), a company called Noise Reduction Ltd has prepared a series of factsheets looking at various aspects of noise pollution and the new regulations. Copies can be obtained by writing to Noise Reduction Ltd, Factory 1, Phoenix Park, Chichester, Sussex PO19 1PA. Tel: (0903) 656 674.

The British Standards Institution has published two catalogues relating to broadcast video tape recorders. BS 6758 covers type C helical VTRs and is designed to ensure compatibility between machines from different manufacturers. BS 6865 specifies time and control codes for VTRs, providing a standard digital code format in accordance with IEC 461 which allows VTRs to be linked to one another and to separate audio recorders. Copies of both documents can be obtained from BSI Sales, Linford Wood, Milton Keynes MK14 6LE. Tel: 01-629 9000.

IOtech is based in Cleveland, Ohio, and manufactures controllers, converters, buffers, extenders and software for use with equipment employing the IEEE488 bus standard. The range includes interfaces which allow any computer with an RS232 port to communicate with IEEE488 equipment using simple commands in BASIC or other high-level languages. A catalogue describing the IOtech range is available from the company's distributors, Keithley Instruments Ltd, 1 Boulton Road, Reading, Berkshire. Tel: (0734) 861 287.

ERT NOVEMBER 1987

Colour Portables On The Way

The race to put a pocket LCD colour television on the market is heating up with both Sharp and Ferguson due to launch products in the next few months. The Sharp model was previewed at the recent Brown Goods Show and is due to go on sale before the end of the year.

Now Ferguson has announced its PTV01 pocket television which has a 2.6in LCD screen. It receives all four UK television channels and features a built-in loudspeaker which can be disconnected for earphone listening, a telescopic aerial and a socket for use with an external aerial. It offers up to 2½ hours continuous operation on alkaline batteries and can also be powered by a rechargeable battery pack or from the mains or a car battery using optional adaptors.

The screen uses an efficient backlighting system to ensure bright pictures even in the dark and Ferguson says the viewing angle is large enough to allow more than one person to watch the picture simultaneously. The LCD has a resolution of 56,000 pixels and uses an MIM (metal-insulator-metal) active matrix system.

The PTV01 measures 85 x 145 x 35mm, weighs 330g (11.8oz) and should be on sale in November at a retail price of around £250.

Ferguson, Cambridge House, Great Cambridge Road, Enfield, Middlesex EN1 1UL. Tel: 01-363 5353.

Fast Soldering Takes To The Road

Cirkit has introduced a rechargeable soldering iron which it says is ideal for use on static sensitive circuitry and in situations where mains supply is available.

The Turbo Solveror is rated at 12W and can be recharged either from the mains or a car battery. Features include a 2mm diameter illuminated tip, fast warm-up time and a capacity of around 200 standard joints on each 12-hour charge.

It comes complete with a wall-mounting socket, a mains charger unit and a 12V charging lead which plugs into a standard car cigarette lighter socket. A safety hood is provided for protection during operation and Cirkit says it will also be supplying spare illuminated tip assemblies.

The Turbo Solveror costs £15.00 plus VAT and postage from Cirkit Holdings PLC, Park Lane, Bracknbourne, Hertfordshire EN10 7QN. Tel: (0992) 444 111.

DAT Arrives For The Few

The first digital audio tape (DAT) recorders are due to go on sale in this country in the next week or two.

Manufactured by Sony, the machines will sell for around £1300 and will include a 'spoiler' to prevent direct digital copies being made from compact discs.

The DTC1000ES is described as a full-function DAT player. It can record from analogue signals in the normal way and will also accept digital signals sampled at 48kHz. It will not accept digital signals sampled at the 44.1kHz rate used on compact discs, although CDs can be copied by going through an intermediate analogue stage.

Sony expects the DTC1000ES to be bought by professional and semi-professional recording engineers and musicians. The company accepts that the high price will deter all but the most affluent of hi-fi enthusiasts.

The launch of DAT outside Japan follows a long period of heated debate between the record companies and recorder manufacturers and the average hi-fi enthusiast would be unable to afford one.

It points out that digital tapes will wear out just as analogue cassettes do and also that the access time for digital tapes is far higher than on CDs. Because of this, DAT is seen as complementary to compact disc with particular advantages in the car or, eventually, in Wall-street style tape players. However, Sony says it will be some time before DAT players become as small as present day compact cassette players.

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IC Industry
Short Of Staff

Senior figures in the UK semiconductor industry believe the current recession may be nearing an end but fear that a shortage of skilled staff will hinder future progress.

These are the findings of a survey carried out by Plus Four Market Research on behalf of Cahners Exhibitions, organisers of the Semiconductor International Exhibition held in Birmingham at the end of September. The survey found that 7% of senior engineers and managers in UK semiconductor manufacturing companies expect to invest more in plant over the next three years and 52% expect to take on more staff.

Sixty percent felt that the levels of trained staff in the industry have risen over the last three years but over 80% confirmed that electronics designers and engineers are still in short supply. A significant number believe the situation is actually getting worse.

The survey also noted that 20% of respondents are looking at the use of galium arsenide.

Cahners Exhibitions Ltd, Chatsworth House, 29 London Road, Twickenham, Middlesex TW1 3SZ. Tel: 01-891 5051.

UK Out Of Step
On Robots

The UK is a 'notable exception' in the general trend towards increased use of robots in industry.

A recent report by international market analysts Frost & Sullivan shows that the total number of robots in this country in 1986 was only around 3200 - less than the increase alone in the European countries.

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THE HEAT IS ON
The December ETI is the fitting place to find the electronic answer to your fuel bill problems. Next month sees the project to computerise your central heating system. Save money and keep warm this winter with ETI!

SWR METER
No, it's nothing to do with small white radiators despite the central heating controller. If you know a little about radio you’ll know this stands for standing wave ratio and you’ll know why you want one. If you don’t, read ETI next month and find out.

TESTING TIMES
We all know that some kind of test equipment is a good idea but with such a bewildering variety around, mostly at mind boggling prices, it pays to know exactly what you need and how to use it. ETI reveals all next month. If you spend your last few pennies on the mag you’ll also be pleased to read the article on making your money go further — what to look for and what to avoid when buying second hand test gear.

AND FREE WITH EVERY COPY...
Of course, next month sees the free components to build the Dream Machine on this month’s free PCB. There’s also all your favourites packing out next month’s issue — Hardware Design Concepts, Circuit Theory, News, Diary, Open Channel, Playback, Keynotes, Readers’ Ads and so on. Don’t miss your copy of ETI — the mag to be seen reading this winter.

The articles listed are all under way but unforeseen circumstances may prevent publication.

DECEMBER ETI — OUT NOVEMBER 6th

THE TIME—PRECISELY
THE SOLEX MICROCIRCUIT LABORATORY TIMER

ONLY £14.95 inc. P & P

Special Offer!
Free five function stopwatch worth £10 (inc. VAT) with every timer ordered before 31st December 1987
Send no money — we will send your Solex timer and your free stopwatch on 14 day approval. If not completely satisfied you can return them.

SOLEX INTERNATIONAL
44 Main Street,
Broughton Astley,
Leicestershire
LE9 6RD

Send full name and address to the above address. Orders must be received by 1st December 1987. P & P is included. Orders close 31st December 1987.

44 DAYS FREE APPROVAL
Stackable Display IC

Large, flat-panel graphics displays can be constructed with ease using a new 8 x 8 dot-matrix LED array from Siemens. Available in orange or green, the displays incorporate a CMOS IC which handles multiplexing, memory, lamp drive and internal logic. Each dot is separately addressable via an 8-bit TTL-compatible data bus.

Siemens Ltd, Siemens House, Windmill Road, Sunbury-on-Thames, Middlesex TW16 7HS. Tel: (09327) 85691.

City Of London Gets High-Tech 'Craft Guild'

Tradition and innovation are to meet head on with the formation of a new Company of Information Technologists.

Alongside such ancient Companies as the Weavers, the Cutters and the Grocers, many of which began their lives as craft guilds in the middle ages, the new Company will concern itself with the setting and maintenance of standards in business conduct and with charitable works.

The City Companies are generally known as Livery Companies because many of the craft guilds adopted distinctive dress for use on ceremonial and other occasions. As with other Companies formed in modern times, the Information Technologists will not be adopting a livery but they have applied for permission to use armorial bearings.

In keeping with City traditions the new Company has 100 founder members and its management committee follows the historic structure with a Master, Senior and Junior Wardens, Assistants and a Clerk. All the founder members have strong connections both with the City and with information technology, many holding senior positions in UK computer and electronics companies.

The Company of Information Technologists, 25 Enford Street, London W1H 2BH. Tel: 01-223 5882.


Capacitor And Resistor Technology Symposium — October 6-8th
Ramada Renaissance Hotel, Brighton. Organised in conjunction with the American IEEE and staged outside of the USA for the first time. Contact CARRS-Europe on (0422) 73578.

Internecon — October 6-8th
Metropole Convention Centre, Brighton. See July '87 ETI or contact Cahners at the address below.

Digital Audio Post Production — October 11th
BAFTA, London. Training seminar organised by BAFTA, London. See July '87 ETI or contact the BKSTS. Contact them at the address below.

Automotive Electronics — October 12-15th
The IEE, London. See July '87 ETI or contact the IEE at the address below.

Computer Graphics Exhibition and Conference — October 13-15th
Wembley Conference Centre, London. For details contact Online on 01-961 446.

Starting Your Own Business — October 16th
The IEE, London. Discussion meeting featuring speakers from the small firms centre. Contact the IEE at the address below.

Conference for Young Engineers — October 18-20th
Strand Palace Hotel, London. See July '87 ETI or contact the IEE at the address below.

International Video & Communications Exhibitions — October 18-21st
Metropole Exhibition Centre, Brighton. See July '87 ETI or contact Peter Peregrinus Ltd at the IEE address below.

Room Temperature Superconductivity — October 19th
The IEE, London. For details contact the IEE at the address below.

Radar '87 — October 19-21st
Kensington & Chelsea Town Hall, London. See July '87 ETI or contact the IEE at the address below.

Testex '87 — October 20-22nd
Business Design Centre, London. See July '87 ETI or contact Network Events at the address below.

Amstrad Computer Show — October 23-25th
G-Mex, Manchester. For details contact Cahners at the address below.

Reproduced Sound Conference — November 5-8th
Hydro Hotel, Windermere. Topics covered include acoustics, digital techniques, measurements and electro-acoustic music. Contact the Institute of Acoustics on 031-225 2143.

The Future Of The Personal/Home Computer — November 10th
The IEE, London. Lecture by Sir Clive Sinclair. Contact the IEE at the address below.

Electronic Displays — November 17-19th
Kensington Exhibition Centre, London. Contact Network Events at the address below.

Interact '87 — November 17-19th
Kensington Exhibition Centre, London. See June '87 ETI or contact Network Events at the address below.


Satellite Communications And Broadcasting December 13-15th
London. For venue and other details contact Online on 01-868 446.

The UK Space Programme — December 7th
The IEE, London. Lecture by R. Gibson of the British National Space Centre. Contact the IEE at the address below.

The Which Computer Show — January 19-22nd
NEC, Birmingham. Contact Cahners at the address below.

Electro-Optics And Laser UK — March 22-24th
NEC, Birmingham. Exhibition which runs alongside the Optics-Ecossa '88 conference at the Birmingham Metropole Hotel. Contact Cahners at the address below.

HF Radio Systems And Techniques — April 11-13th
The IEE, London. Conference organised by the IEE and the Institute of Mathematics and its Applications. Contact the IEE at the address below.

Addresses:
British Kinematograph Sound and Television Society, S47-549 Victoria House, Vernon Place, London WC1B 4DJ. Tel: 01-242 8400.

Cahners Exhibitions Ltd, Chatworth House, 59 London Road, Twickenham TW1 3SZ. Tel: 01-891 5051.

Institution of Electrical Engineers, Savoy Place, London WC2 0BL. Tel: 01-240 1071.

Network Events Ltd, Printers Mews, Market Hill, Buckingham MK18 1X. Tel: (0280) 815 226.

© Those of you who read about the FLT-101 analogue workstation in the August issue may be interested to learn that Flight Electronics has introduced a digital version. The FLT-100 has thirty logic gates with mimic diagrams and a large solderless breadboard which allows gates and other components to be connected up as required. Also included are a pulse generator and dual-rail stabilised power supplies with short circuit protection. For further details contact Flight Electronics Ltd, Ascupert Street, Southampton SO1 1LU. Tel: (0703) 227 721.

© STC has produced a 4-page full colour brochure on its range of Union Carbide Kemel capacitors. Among the product lines featured are two different types of dipped tantalum capacitors, several multilayer ceramic types and a number of axial and radial moulded capacitors. Full product specifications are included and there are also some notes on applications for some of the BF-approved capacitors in the range. Contact The Capacitor Group, STC Electronic Services, Edinburgh Way, Harlow, Essex CM20 2DF. Tel: (0279) 26777.
ANY future enhancements to the Teletext system e.g.: full field Bit data transfer, 2k pages etc.
- Simply plug into any existing television set.
- Low power consumption, less than 200ma. Optional power supply available.
- User friendly menu driven software including extended OSCU and OSWord commands for access from BASIC programs.
- Supplied with 16k ATS (Advanced Teletext Software) and 16k TALB RAM disc software inc. printer dumps, page spoolers etc.
- FREE Teletextware, no access charges (updated weekly).
- Saved searches are automatically transferred to a printer.
- Full access to all Teletext services and channels e.g.: CEFAX, ORACLE, 4-TEL.
- Gives you a real-time clock at your disposal (TIME).
- Software upgradage to allow for any enhancements to the Teletext service, e.g.: extra channels, full field data on cable & satellite systems etc. (only the media charge).
- Easy to follow comprehensive user guide.
- No hardware limitations, it can for example receive virtually unlimited numbers of channels.
- User disk available including printer drivers allows pages to be selected and dumped direct to a printer (no more TV or Radio Times to buy).

WHAT THE REVIEWERS SAID:
...In terms of price, performance, future expansion possibilities and those little touches that show thought for the end user (would recommend the Morley unit.) - (Acorn User, January, 1986).
...The Morley unit has been designed to ensure that its operation is simple and smooth. It is the ideal Teletext adapter for school use."- (AAB Computing, June, 1986).
...Using it over a number of months in different schools, it has proved utterly reliable, and may confidently be recommended." - (The Times Educational Supplement, September, 1986).

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Please allow 28 days for delivery.
READ/WRITE

Portable Problems

Alan Watling appears to have things in a slight muddle when he wired up the speakers for his portable PA system (ETI September).

He says the ideal loudspeaker system would be a line source. He could have achieved that in effect if he had wired up the five loudspeakers as shown.

John Tyzzer
Guildford, Surrey.

Mr. Tyzzer's arrangement will give maximum output in the centre of the line (C), a lower level of output from the loudspeakers on either side of the centre (B and D) and a lower level still from either end of the line (A and E). This gives a reasonably close approximation to ideal line-source characteristics and works well when the loudspeakers can be pointed directly at an audience. In the Portable PA, the loudspeaker column has been deliberately tilted backwards by a few degrees to provide mechanical stability. To counteract this, the loudspeakers are arranged so that there is more output in the lower part of the sound distribution pattern. This involves a further departure from true line-source characteristics but works well in practice.

RIAA (Again)

In Read/Write of the August ETI Mr. Leach wonders whether the equalisation used by record companies is sufficiently accurate to justify the use of precise RIAA replay networks in hi-fi amplifiers.

The listening chain contains a number of elements (microphone — record cutter — cartridge — amplifier — loudspeaker, to mention just the major ones) and it is possible to take the view that highly-accurate equalisation at one point in the chain will almost certainly be compromised by greater variations elsewhere. I remember a graph prepared in the 1960s (I forget the source) which showed wide variations in recording equalisation from one company to another, some being as much as 6dB out from the RIAA standard over certain parts of the audio spectrum.

Fortunately things have changed since then. Recording equalisation is necessarily more complex than replay equalisation because it has to take into account the characteristics of the cutting head but even so the better record companies aim for an accuracy of 0.2dB.

Surely Mr. Leach cannot be satisfied with errors of the order of 1dB in his replay network, especially when greater accuracy can be achieved at trifling cost?

Wilfred Harms
Bexhill, East Sussex.

Circuit Theory

I have read many electronics magazines and books but have always found them empty. It has taken me seven years to see this emptiness.

People read electronics magazines with a goal of understanding what electronics is about. How It Works sections of projects are the simplest attempts. We run two regular series teaching the principles behind electronics design. Circuit Theory is intended to cover the more fundamental aspects of the spectrum and to introduce basic mathematical tools.

Hardware Design Concepts is for more advanced readers and looks at the latest ICs available and advises on design techniques when using them. Other features go into specific topics in more depth.

A good many ETI projects do include some history of their design. Many are arrived at by a good deal of trial and error which cannot be 'taught'. If we were to include a full mathematical explanation of every project we would not only repeat ourselves continually but only publish around three projects a year!

This would enable many readers to do a lot of thinking for you and contribute projects rather than just building them parrot fashion.

N. Charebeigui
Chiswick, London.

It is indeed one of the aims of ETI to teach an understanding of electronics and we try to do this in several ways. The How It Works sections of projects are the simplest attempts. We run two regular sections teaching the principles behind electronics design. Circuit Theory is intended to cover the more fundamental aspects of the spectrum and to introduce basic mathematical tools.

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Winter's drawing in. The days are shortening and soon leaves will bespeckle the otherwise immaculate tarmac of Golden Square. Now is the time for settling down of an evening with a good book, a good electronics project or even with pen and paper to compose a letter to bolster those ever-labouring boys in the ETI office.

Write now and you may catch the December issue.

Electronics Today International
1 Golden Square
London WIR 3AB.
Barry Thurlow, a Systems Designer at Logica, explains the workings behind the teletext system and delves a little into future developments.

In its common form, as the Ceefax and Oracle services, teletext can be seen on display in TV stores and many homes all over the country but few people really know its capabilities nor how it arrives at the set. This article aims to introduce some of the services available now and some of the exciting services proposed for the future and to explain the details of how the system works.

Teletext is a digital data signal carried as part of the broadcast TV signal and arrives in the home via the TV aerial. The explanation of the teletext signal, then, depends on the nature of the TV broadcast itself.

In a TV camera the picture is scanned from top to bottom in 312.5 evenly-spaced lines. Then it is scanned again making another 312.5 lines positioned in the gaps between the first set. This two-pass scanning is called interlacing (Fig. 1).

The total number of lines for a full resolution picture is 625 which is why the system is often referred to as the '625-line system'. The scanning is interlaced to reduce flicker in the scanning process. The analogue waveform which represents the luminous intensity along the lines is transmitted along with added pulses which mark the start of each line.

It takes 52\(\mu\)s to transmit the picture information for one line of the picture. A further 12\(\mu\)s is allowed for the receiving monitor to reposition for the start of the next line. During this time a negative going pulse (the 'line sync') is transmitted (Fig. 2a). So a total of 64\(\mu\)s per line is required, giving a line rate of 15.625kHz.

The full 3125 lines displayed in one sweep from top to bottom is called a 'field'. The two separate fields in the interlace system are called 'odd' and 'even'. When the bottom of the picture is reached, extra time must be allowed for the receiving set to return to the top for the next field. This period before the start of each field is called the vertical blanking interval (VBI). The VBI is 25 lines long leaving 2475 lines per field for the picture.

To indicate to the receiving monitor when to return to the top of the picture the regular chain of line sync pulses is changed. The normal 4.74\(\mu\)s line sync pulse is extended to 22.31\(\mu\)s with a second pulse occurring in the middle of the line (Fig. 2b).

Since many old TV sets take a long time to recover from the return to the top of the screen, the picture information is held off until line 23, leaving lines 7 to 22 unused.
However, the broadcasters are not ones to let these lines go to waste. Lines 19 to 21 are usually used for test signals which allow for constant monitoring of signal path quality. Line 22 is usually quiet and is used for noise measurements. Lines 13 to 18 carry a digital signal — teletext.

**The Teletext Waveform**

Figure 3 shows the line sync pulse for line 13 and the digital signal which follows it. The first eight cycles follow a fixed regular pattern. These 16 alternate 0's and 1's are known as the clock run-in. This enables the receiver to lock-in to the centres of the data bits.

Following the clock run-in is another fixed pattern of eight bits known as the framing code. These bits read 11100100 (from left to right) and as the data arrives eight consecutive bits are compared with the expected framing code. This is done at each bit boundary by shifting the data through an 8-bit register and testing the parallel output.

When the 11100100 pattern is seen in the 8-bit window the receiver knows it is looking at a whole byte rather than eight bits from two adjacent bytes. During the rest of the line, allocation of groups of eight bits into bytes is done by counting bits from this known reference.

**The SAA5230**

There are a number of ICs on the market which perform the task of recovering the teletext data stream from the video signal. One of the most common is Mullard's SAA5230 (Fig. 4). The Mullard chip performs all the video processing functions required to turn the 1V composite video waveform into serial data and clock.

The main functions of the SAA5230 are sync separation, 6MHz voltage controlled oscillator (VCO), adaptive data slicing and data clock regeneration.

Sync separation is the process of recovering the start of line and start of field pulses from the video signal. One chip first slices the video signal at about 0.15V to produce a TTL waveform corresponding to the negative or sync part of the video. This signal (VCS on pin 25) contains line sync pulses of about 4.7ps width at 64 lines separation and the field pulse encoded as broad pulses for 2.5 lines every 20ms.

The 6MHz VCO is used in conjunction with an external divide-by-384 counter in a phase locked loop to make a locked dot-clock for a character generator. The SAA5240 chip (Fig. 5) contains both a suitable divider and a character generator.

The adaptive data slicer is used to convert the video data bits to TTL. It comprises maximum and minimum
detectors and an analogue comparator whose threshold is the half-way point. The capacitors on pins 5 and 6 store the signal peak and zero levels respectively. The sliced data at TTL level is available at pin 15. The use of adaptive slicing makes the circuit insensitive to changes in amplitude and DC offset on the input.

A clock signal (TTC on pin 14) is generated using an accurate crystal oscillator. The oscillator runs at twice the teletext bit rate and is divided down and re-phased from transitions in the data. TTC is timed to have a rising edge in the centre of each valid data bit.

**Specification**

After successful trials with teletext at the BBC in the mid 1970's it was realised that commercial teletext would only take off if the cost of including the decoder in the TV set was low. The target figure was for the teletext-equipped set to cost no more than £50 more than a TV set was low. The target figure was for the teletext only to take off if the cost of including the decoder in the set to do the complex decoding task instead of the 30 chips used in the experimental decoders. Such chips are easily connected to form a complete teletext decoder (Fig. 6). However, the chip manufacturers needed a fixed specification to work to before they could commit to the large development cost required to design and produce such a chip. Jointly the BBC, the IBA and BREMA published the 'Broadcast Teletext Specification' in September 1976.

This document defines the signals and data which are transmitted and the characters, colours and other responses which are expected of the receiver. Both the BBC's Ceefax service and the IBA's Oracle service work to this specification.

The specification ensured the chip manufacturers knew what was being transmitted and the broadcasters knew how their pages would look to the viewer. It is still the reference document for Level 1 Teletext.

**The Teletext Page**

The photographs show several typical teletext pages. There are 40 characters per row, with 24 rows including a page header at the top. Each row (including the header) is transmitted as a single packet of data filling one TV line in the VBI.

Each packet contains 45 bytes including the first three (the clock run-in and the framing code). The next two bytes contain the magazine number and row address used to position the row on the screen.

For example, the header has an address of 0 as it is the top row. Addresses 1 to 23 give the row position down the page. As there are no rows 24 to 31 packets with these codes are treated differently and we'll come to these in a while.

The header (packet 0) is required not only as the top

row containing the familiar service name and date but also as a key to decoding the rest of the page. It contains (in binary) the page number and various flags indicating the type of page display required. It is always transmitted one field before the rest of the page to allow the decoder time to act on the information. The format of the header is shown in Fig. 7.

The decoder compares the transmitted page number with the one selected by the viewer and updates the page display only if a match is found. Having the page number only in the header packet is a great saving in bytes over each row being explicitly addressed.

The price for this is that an error in receiving the header would render the whole page unreadable. To alleviate this difficulty the eight control bytes are Hamming coded for error recovery.

<table>
<thead>
<tr>
<th>MESSAGE BITS</th>
<th>RESULTS OF PARITY</th>
<th>INFERENCE</th>
<th>ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>Protection bits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td>Inferred bits</td>
<td>Accept</td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td>Reject message bits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Hamming codes and error checking.

Figure 7 shows a number of single-bit flags in the control bytes of the header. These are denoted C4 to C14.

C4 is the Erase Page bit and is set when the broadcaster requires the decoder specifically to clear the old page before showing the new one. This is usually done between rolling pages or when the contents of a page have been updated. It gives the editor the flexibility to have an obvious change of content or (by not setting the bit) to have a page change only in part. This is also done sometimes to give an impression of animation.

C5 is the Newsflash bit, set if a page contains information which the viewer may wish to see superimposed on the TV picture. Most decoders will allow the viewer to select the newsflash option in such a way as to allow continued viewing of the program until the newsflash occurs.

Pages intended to be seen as subtitles to a program will have bit C6 set. This allows the decoder to display them with the text set in a dark background cut into the picture.

C7 is the Suppress Header bit. Setting this bit causes the decoder to blank the header row. This feature is used at the editor's discretion to enhance the appearance of the page.

Pages in teletext are transmitted repeatedly so someone who has just switched on will not have long to wait to see their chosen page. However, once the page has been read the viewer may wish to go back to watching the TV program until the page changes. This is particularly true of a rolling page. The transmission computer will automatically set C8 (the Update bit) for the first transmission of a page after it has been updated. The decoder may then signal to the viewer that a new page is ready (usually by showing the page number in the corner of the screen).

Some pages in teletext are transmitted more frequently than can be allowed by sequential transmission of all pages — for example, the index page which the viewer may refer to more often than any other page. Transmissions other than the first in a cycle will be out of sequence and this would have the effect of making the page number shown in the header roll in an erratic way if it was not for the use of Out of Sequence bit, C9.

The decoder, detecting that a header is not in sequence will leave the previous header at the top of the screen. The rolling page numbers may pause briefly as the out of sequence page goes past but will remain in order.

C10 is the Inhibit Display bit. Setting this bit prevents the page from being seen by a TV set not specially modified. This is used to avoid showing meaningless
displays such as would result from a page whose contents were encrypted.

The Magazine Serial bit, C11 is used by the broadcasters to allow flexibility in transmission methods without adversely affecting the quality of the viewer's teletext display.

Bits C12 to C14 contain a 3-bit code for the language of the page. More advanced decoders such as the Mullard SAA5240 will use these bits to enable foreign character sets to be used automatically.

**Editing**

Now we have seen how pages are addressed, we should consider how these mechanisms are put to work by the teletext editor when preparing pages for transmission.

Teletext pages are accessed by the viewer using a three digit code (000 to 799) and optionally by a sub code. The editor may use the page number to group together pages of a particular type. The hundreds digit of the page number is termed the magazine number and has the special property of being present in all packets. The editor may choose to transmit the magazines in serial:

```
100 101 102 ...
200 201 202 ...
300 301 302 ...
```

or in parallel:

```
100 200 300 400 ...
101 201 301 401 ...
102 202 302 402 ...
```

If parallel transmission is chosen the viewer will see only page numbers from the selected magazine rolling round.

On the transmission computer the editor will have a library of 26 magazines (A to Z) from which he may assign any eight to the transmitted magazines (0XX to 7XX). (As the magazine number is three bits long, 0X0 and 8X0 may be used interchangeably according to taste).

The editor can further control the transmission of magazines by setting a transmission order in which a magazine may appear more than once. During Saturday afternoon, for example, the magazine used for sports (say 300) may be considered to require faster access than the total number of pages in all magazines would allow. The editor could therefore choose to transmit the magazines in the order:

```
100 300 200 300 700 300 ...
```

thus cutting the waiting time for a 300 page to one third that of the other magazines.

**Subtitling**

One of the most important uses of teletext is to provide subtitles on broadcast programmes for the hard of hearing. The subtitles which we see on foreign films are inserted into the video signal at the time the film is edited so there is no choice about seeing them. Not everyone, however, would want to watch English subtitles all the time so a choice is provided.

Teletext subtitles are inserted in the picture by the receiving set and, like other teletext pages, they are only shown when selected. Insertion is done with boxing where the text from a specified part of a teletext page is made to appear on its own background superimposed on the picture.

The teletext characters 10 and 11 (hex) are placed at the points on each row where the changes from picture to text and back are to be made. The subtitle creation computer will allow the editor to choose whether the box is rectangular (fitting the widest line of text) or variable (following the shape of the text). The editor may also position the boxed text anywhere on the screen so as not to obscure the action.

In preparation, teletext subtitles are viewed against a tape of the program and the tape positioned to the exact instant the text should appear. The time-code of the tape position is stored with the text on the computer. This way the text can be synchronised to a change of scene or a movement of the lips. It can take several hours to prepare the subtitles for a half hour show.

In transmission, the subtitles are read on the transmission computer and their times for appearance and disappearance compared to the time-code from the video tape or film. When the times match, the transmission computer schedules the subtitle page for immediate transmission, out of the page sequence to preserve the timing accuracy.

A recent development in teletext subtitles is live subtitling. A news interview or sports event may be subtitled. Obviously, the difficulty is how to enter the subtitle into the computer when it is not known what will be said. The subtitling computer helps greatly by allowing for the use of 'short forms'.

In a political interview it may be a reasonable assumption that the phrase 'the Conservative government' may crop up. Before the interview the computer is given a large number of such phrases and shortforms such as 'CVT: If the operator uses the shortform during live subtitling the computer will automatically expand it up to the long form and fit the other text after it.

The SAA5240 provides a switching signal (BLAN) which is used in the colour decoder chip to switch between text and picture. This signal is used for boxed subtitles and for superimpose mode where the text is cut-into the picture.

**Full Level One Facilities**

So far we have been talking about what is called Level 1 teletext. That is to say, Level 1 as was cost effective to implement in 1976. It has basic textual features and simple graphics. Pages are all accessed by three digit numbers which can take time to get used to.

Full Level One Facilities (FLF) is the implementation of several advanced features not very different to level 1 but which could not be economically processed by the chips of the first generation.

Technology has moved on a great deal since 1976 and now it is possible to put a lot more intelligence inside a TV set. Appearing in the shops now are TV sets with CCT (computer controlled teletext). The Mullard SAA5240 is a CCT device. Much higher integration density than was previously possible has enabled more functions and
FEATURE: Teletext

a serial computer interface to be provided by only two chips.

Remember the row address number — a 5-bit number which only requires values 0 to 23? Some of the missing codes are used in FLOF. Packet 24 is used to provide an extra row of text which will contain operational prompts as defined by the editor. Packet 27 contains link control information for linked pages. Packet 8/30 (packet 30 of magazine 8 only) contains various flags and digital information.

Linked Pages

One of the infuriating facts about teletext is that there is a wait for the selected page to appear. This problem could be overcome if there was sufficient memory in the TV set to hold all the pages, using the live signal only to update this database. However, as there are typically about 400 pages on the cycle, this would require a very large memory. Page linking gets around the access time problem while requiring only a modest amount of memory.

For any given page there are a small number of likely next pages. For a sports page, say, the viewer would typically want to step on to the next sequential page, go back to the sports index, go back to the main index or go to a profile of the goal scorer mentioned in the page he is reading.

The four associated pages are made the ‘linked pages’ for the current page. The editor decides which pages are to be linked to which and will enter the information on the computer when the page is compiled. The computer will also fill in any unused links if possible and inform the editor of any inconsistencies before allowing transmission.

Packet 27 contains a list of linked page numbers readable by the CCT computer. These are used by the decoder to acquire the linked pages in advance of the viewer selecting any of them. This requires a memory of only 4K.

Packet 24 of the current page will be displayed (normally at the bottom of the screen) to indicate the contents of the local memory. This might read: NEXT SPORT INDEX, MAIN PROFILE

Each choice is in a different colour corresponding to four coloured buttons on the remote control. The viewer may choose one of the linked pages by pressing the appropriate coloured button and as it is already stored in the local memory there is no need to wait for the page to come around.

Of course, if the page the viewer wants is not one of the four then the page number may be keyed-in explicitly and the page will be picked up as it is transmitted.

Television Service Data Packet

Packet 8/30 contains information about the broadcaster whose signal is being received and about the time and date. It is intended to be processed by the CCT computer and so the use made of the data will differ from one set to another depending on the software supplied by the set maker.

Home Computer Teletext

It is possible to receive teletext data, including the extra FLOF packets, on a home computer. A special teletext adaptor is needed and several manufacturers produce these.

Acorn and Morley produce models for the BBC micro and a unit from Volex is available for the Spectrum and Amstrad CPC micros as well as the Beeb.

Morley’s decoder for the BBC micro contains the Mullard CCT chip-set and a tuner making it straightforward to connect, requiring only an aerial. The unit comes complete with software for the BBC micro to load and display pages.

The use of teletext with a home computer allows more than just paper printout. Pages can be stored in RAM or on disk for really fast access. It is possible to have your morning paper printed for you by your computer accessing the news pages. Your paper will be hours ahead of those in the local newsagent.

In the future you could have your computer controlling the video recording from the information in packet 8/30 and record your favourite programme when it actually comes on — without the 15mins of overrunning cricket causing you to miss the end of your film.

Telesoftware

Telesoftware is the name given to the service by which free software may be broadcast via teletext. The software appears as tokenised Basic or machine code bytes compressed so the lines of the program wrap around the teletext rows. Telesoftware is intended only for machine reading and makes use of packets 27 to link pages and hence allow programs to be longer than 24 lines.

Teletext decoders for home computers are usually supplied with software to make use of the broadcast telesoftware.

Datacast

The latest use of Teletext is Datacast — the BBC's data broadcasting system. This uses teletext packet 31 in a special format to carry information on behalf of private data providers.

Packet 31 is not received at all by the SAA5240 so a purpose-built decoder is needed in order to receive it. Such a receiver is available from Volex to work with the BBC micro, Spectrum and Amstrad.

Datacast is intended for retail chains, financial institutions and the like wishing to send data simultaneously to many branches. One newspaper is currently considering installing a Datacast receiver in each of it’s newsagent shops to be connected to a suitable moving message display.

The headlines would then be received simultaneously in all the shops each morning and displayed in large letters in the window to attract the attention of passers by.

To make use of the Datacast system the data provider sends data to the BBC in London by landline where the Datacast computer will format it for transmission. The BBC is constantly improving the service and will be able to help with the latest information on how to access Datacast as a data provider.

For the data user, only a suitable receiver and a computer is required to decode the special format. The BBC produce a receiver for professional use which
contains a Z80 microprocessor to recover the data from the packet structure and to output it as an RS232 signal suitable for a printer, computer or display.

This is a sophisticated receiver to allow it to process the data it receives in an intelligent manner, programmable to check errors and only send out error free packets or try for an error free packet and then pass on the last copy of that packet error-free or not.

At present the system is using one line on BBC1 and BBC2 for a combination of real and test data. With a single line an end-to-end throughput of 19,200 baud is possible. By contrast, a modem directly coupled to the phone line can only usually achieve a throughput of 1200 baud.

The contrast is further emphasised when comparing the time taken to phone individual destinations with the time taken on Datacast to broadcast to all at once. Take a typical news headline of 100 characters which is to be sent to each of 1000 shops. A modem would take about a second to transmit the data and around 10 seconds to dial. For all the shops this would take around three hours. Datacast would take about 55ms to send the data plus the time taken to send the data to the BBC by phone, say, around 15 seconds. A ratio of over 700:1!

**Datacast Packets**

Figure 8 shows the contents of the Datacast packet (packet 31). Individual receivers may be addressed using an address field which is up to six bytes long giving a 24-bit address. The packet is further identified within the users data stream by the continuity indicator (CI) and repeat indicator (RI). The RI gives the number of a packet, which has been repeated, within the set of repeats. The RI is modulo 16 and uses the lowest four bits of the byte. The CI is used to check that no packets have been missed out in case of poor signal quality. It is a modulo 256 number incremented for each new packet.

Following the CI and RI is a data length byte, the data and finally a two byte cyclic redundancy check (CRC). The CRC is calculated using feedback on bits 0, 4, 7, 9 and 16. These provisions make Datacast suitable for financial and other numerical data where integrity is of utmost importance.

Full details of the Datacast service are available from the BBC. For professional consultancy on the use of Datacast in business readers are recommended to contact Logica.

**Private Teletext**

So far we have only considered the source of teletext to be the two broadcasting companies. It is also possible to gain the advantages of teletext in a private video network.

Hotels, chalet parks, large stores and even factories may have their own network broadcasting video to their guests, customers or workers. Such institutions can include teletext in their signal and add to their services the ability to distribute textual data. The advantage of teletext over simply using computer terminals is twofold.

- The network of cables already exists.
- The receiver (teletext TV set) is inexpensive.

It is possible to combine the signal from, say, the BBC with locally-added teletext so that a hotel guest, for example, can view the normal programs and also dial up the latest menu, lists of hotel facilities or local tour information. Using the newsflash facility a guest could keep informed about the opening of the restaurant. The hotel could incorporate a paging service too.

**Building Teletext Generators**

Level 1 teletext in its simplest form consists of largely ASCII text with the magazine and row number and the header added around it. At the hardware level it is merely a series of black and white dots at a particular frequency and in a particular position in the video field. A programmable graphics chip such as Motorola 6845 can be programmed to produce such a dot pattern (Fig. 9).

To use the 6845 as a teletext generator the crystal frequency must be changed to 6.97MHz and the device programmed to output on, say, line 18 only. The data on the line will be from an area of RAM and at these addresses bytes corresponding to clock run-in, framing code, magazine and row address and row or header bytes must be placed. Some care is required to ensure the timing is correct. The penultimate cycle of the clock run-in must be at 12µs from the falling edge of line sync (as in Fig. 4).

The software must generate complete pages of text in memory including the header and initial bytes making 45 bytes per row. By incrementing the starting address pointer of the 6845 it may be made to generate teletext from one row after another. It would be best to use interrupts to increment this pointer after each field sync but if this is not possible on your computer it does not matter as teletext rows may be transmitted more than once without harm.

**Full Field Teletext**

Normal teletext, more properly known as V81 teletext,
uses no more than 16 lines of the video field. This limits the effective data rate to a maximum of 32K per second. If there is no requirement to have a TV picture at all then all 263 lines may be used giving a massive data rate of 526K per second.

With 300 pages in the cycle this would cut the access time from around nine seconds to 0.6s.

This method has been successfully applied in the Hong Kong Stock Exchange to provide very rapid access to stock information for some 600 terminals. With teletext the number of terminals is not important. If they had been standard computer terminals the computer servicing the requests would have had only 1ms to process the request for each terminal in order to guarantee the same performance.

The Future

To control the cost of teletext while allowing manufacturers to move with technology, a number of levels of teletext service have been defined by the DTI in their document 'The World System Teletext Technical Specification and an Introduction to Videotext'. Each level is intended to be brought into service as and when technology permits.

Level 1 and FLOF teletext pages look similar with their seven bright colours, limited character sets and crude mosaic type graphics. However, in the future we should be seeing lots of good things.

Levels 2 and 3 propose more colours for more subtle effects, lots more characters allowing foreign language and mathematical symbols to be mixed on a page. There are also double height and double width characters to make text displays more interesting (see Fig. 10). One of the outstanding new features is the possibility of redefinable characters. This means the bit-pattern for a character square may be sent to the decoder in advance of using the character so it can take any shape desired.

This can be used to produce high resolution graphic images by grouping a number of redefined characters together as a large bit-mapped area. Images such as the space shuttle in Fig.10 open the door to better presentation of title pages and advertisers' products.

The Mullard EUROM chip is a level 3 display controller. It provides for 32 different colours at a time chosen from a palette of 4096. It has redefinable chareters on a 10-by-12 matrix which may be used to provide graphics with an effective resolution of 400 by 300 pixels or to give a very high quality text display. It has four built-in character tables which provide a wide variety of characters, foreign and English, symbols, and shapes for line drawing. The EUROM can be used to make a genuinely attractive display.

Further in the future are levels 4 and 5. Level 4 the so-called 'Alpha-Geometric' presentation level will expect the receiver to be able to produce many basic graphic elements from transmitted instructions. A number of drawing primitives such as ARC, VECTOR, AREA FILL will be used to produce ever better and more attractive images.

Level 5 is termed 'Alpha-Photographic' presentation. This level will require large amounts of memory and will produce full resolution still pictures. The enormous amounts of data required may limit this service to the cable networks where a full channel teletext service could use level 5 for home shopping for goods which need to be seen and which previously would have required a visit to the shop.

The high quality display system which will be in the TV set of the year 2000 will I'm sure also be used as the display for other parts of the home entertainment and communication system. All the settings of the TV brightness, volume, tuning, and so on, as well as those of the radio, amplifier and CD will be shown and altered using on-screen displays.

The video recorder will be programmed not by programme times but, through teletext, by names of the programmes and even actors and actresses. The home communication system will search the listings on teletext and automatically record all films starring, say, Peter Sellers or any program with the word ‘gardening' in the title.

As storage devices become ever lower in cost we may have our entire library on-line. Teletext could be used to send us new editions and updates as they are ready. One could subscribe to the complete Oxford English Dictionary or Encyclopedia Britannica and have it constantly updated and available for instant computer access from your optical disk.

Teletext is really only just beginning.

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HARDWARE DESIGN CONCEPTS

Mike Barwise takes an introductory look at emitter coupled logic (ECL) chips — superfast but tricky with it.

The superfast logic family, ECL, of which super computers like Crays are made, has actually been around since the mid 1960's but has never caught on among amateurs. There are many myths about the difficulties of working with it but I don't think it poses any insuperable problems for the enthusiast except perhaps the cost of the requisite fast test gear. The advantages of working with ECL are phenomenal speed, noise immunity and the ability to use a wide range of specialist components only made in this technology, such as flash analogue to digital converters and content addressable memory.

The main disadvantages compared with more familiar technologies (TTL and CMOS) are considerable power dissipation and heat generation. Circuits of more than about half a dozen packages should really be fan cooled. There is also a need for much more rigorous adherence to design rules and to some extent a lack of VLSI components, although this is rapidly being corrected as new devices appear at an amazing rate.

ECL was first introduced by Motorola in 1962 as MECL I, which, at a working speed of 30MHz, was far the fastest logic family of its day. It has passed through several alterations up to the present set of three types or 'families'.

ECL is currently available in various types which differ in speed and use. Briefly, these are:
- MECL10K (125-200MHz, introduced 1971-76)
- MECL10KH (250MHz, 1981)
- MECL III (500MHz, 1968)
(Motorola designations).

All of them work on the same basic principle but differ in internal layout and silicon technology. The faster types do get increasingly tricky to work with, so the one I recommend for experimentation is MECL10K. This is the slowest (a mere 150MHz!) and poses the least problem to the rule of thumb worker.

Saturated And Unsaturated

The now familiar CMOS and TTL logic families work by switching internal transistors fully on and fully off (driving them into saturation and cut-off). The collector-emitter current of a transistor varies according to the current applied to its base. However, there is a point beyond which additional base current cannot increase collector-emitter current and this is termed 'saturation'.

Similarly, with reducing base current, the transistor will always stop conducting before the base current reaches zero. The base current at which this happens is called 'cut-off'.

The ECL Circuit

TTL gate inputs use multiple-emitter transistors which are in effect a refinement of the simple diode gate. ECL works on an entirely different principle. Each input is the base of a separate transistor in a parallel connected bank which forms one half of an emitter coupled differential amplifier (Fig.1).

The other half of this differential amplifier is driven by a reference voltage, creating what amounts to a comparator. In passing, it is worth mentioning that the ECL input stage is reminiscent of the 'long tailed pair' of valve days (dates me doesn't it!).

Fig.1 The Basic gate circuit for the MECL10K family.

The problem with switching between saturation and cut-off is that it slows you down. Crudely speaking, the capacitance of the transistor holds a charge when the transistor is in saturation and this dissipates relatively slowly, delaying the passing of the cut-off threshold.

ECL, unlike TTL, uses 'unsaturated logic'. This means that the internal transistors are switched within their linear region, never cutting off or saturating. This is the main reason why ECL is inherently faster than TTL — 150MHz to 500MHz as opposed to the maximum of 90MHz available from F series TTL.
Working With ECL

At first sight ECL looks rather odd to anyone familiar with solely TTL and CMOS saturated logic families. There are no AND gates in any ECL family, most gates have true and inverting outputs and the supply and logic levels are funny, being nominally -5.2V (yes, minus!) supply and -0.9/-1.8V logic high/low.

However, none of these points constitute any real problem to the user. They simply amount to a different convention. Such problems as ECL does pose are not unique to it. They are the general problems encountered when working at the high speeds of which ECL is capable.

At switching speeds in excess of about 100MHz, interconnections exhibit inductive and capacitative characteristics which must be carefully controlled to avoid serious degradation of the signals passing along them. The parasitic RC component of an interconnection creates a 'characteristic impedance' which must be matched to the input and output impedances of the devices connected to either end of the interconnection. Interconnections with defined characteristic impedance are known as 'transmission lines' and their precise performance can be defined and predicted by mathematical means.

I do not intend to go into the calculations here, as they would put you off (and me too!). It is sufficient to say that without a lot of careful measurement and maths you cannot reliably use MECL III (500MHz). However, you can use the slower families (allowing 250MHz operation) as Motorola have been very crafty in the design of MECL10K and 10KH.

The two factors which affect overall logic system speed are risetime (the time the logic takes to make a nominal transition between high and low) and propagation delay (the time between a threshold transition at the input of a device and a resultant threshold transition at its output).

Of these two parameters, propagation delay is the worst offender in slowing down systems. The propagation delays of all cascaded logic stages add together, whereas the risetime of an overall system can be roughly considered as the slowest component risetime.

However, risetime is the factor which most significantly affects the requirements for transmission line impedance matching as the 'squarer' the waveform, the greater the range of high order harmonics present and so the greater the bandwidth of the system needs to be.

MECL III has equal risetime and propagation delays of 1ns. This means the bandwidth of the device interconnections must be greater than 1GHz (1000MHz) by a factor of at least two. The craftiness in the case of MECL10K and 10KH is to make the risetime slower than the propagation delay.

So MECL10K has a risetime of 2½-3½ns and a propagation delay of 1½-2ns and 10KH a risetime of 1½ns and propagation delay of 1ns. This means the interconnection bandwidth requirement is substantially relaxed even to the extent that wire wrapping techniques may be used (with care).

Design Rules For 10K And 10KH

The following rules are probably adequate for prototypes and experimentation.

• Use a proto board with a ground plane and copper power distribution. The board layout for my articles on the construction of the TTL pulse generator (Fig3) would be a good starting point.

• All wiring should follow the shortest possible route. This is called 'point to point' wiring. It may look
FEATURE: Hardware Design

less tidy but it will dramatically improve performance.

- All wiring should be laid as close as possible to the ground plane. With wire wrap this means in contact with the underside of the PCB. If soldered wiring is used, it should be on the topside in contact with the ground plane.

- Great care must be taken to ensure the power supply rails meet optimum voltage specifications. Performance degradation in ECL is much worse than in other logic families with bad power supplies and will manifest itself as reduced noise immunity.

- ECL must be adequately cooled. It will blow up if it is not! Even proto boards should be mounted in some kind of case and have air blown over them by a fan if there are more than 5-10 packages in the circuit.

Where To From Here?
For further reading I strongly suggest the MECL Device Data manual and the MECL System Design Handbook, both available at about £5 each from Motorola distributors. The latter book goes into the maths required for MECL III (if you feel strong!). There is no substitute for the information in these books — they will be your ECL bible.

Two of the most interesting components, however, are the MC101H24 and MC101H25, which are quad TTL-ECL and ECL-TTL translators. Using these devices, the fastest flash ADC chips (working at about 50 million samples per second which TTL can handle) may be used. I will go into these in more detail very soon, as they open the doors to a host of really neat designs.

Next month I will take a look at new departures in analogue signal filtering, including both analogue and digital solutions.

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>MECL 10K</th>
<th>MECL 10L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year Introduced</td>
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<td>1976</td>
</tr>
<tr>
<td>Bias Driver</td>
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<tr>
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</tr>
<tr>
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<tr>
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<td>Open Wire Length (less than 100mV undershoot)</td>
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<td>Use of Series Damping Resistors</td>
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<td>*Voltage Compensated</td>
<td>Yes</td>
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</table>

Table 1 MECL family comparison

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- 8-bit input port
- 8-bit output port
- four switch sensor inputs
- four relay-switched 12V 1A outputs
- eight channel multiplexed analogue to digital converter
- precision 2.5V reference
- external power supply
- 15-way expansion bus

All sections of the interface are memory mapped in the 1MHz expansion map for maximum ease of use and compatibility with existing peripherals.

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Paul Chappell delves further into phasors and finds that capacitors can't predict the future after all.

Last month we saw how sine waves could be represented by rotating rods on a phasor diagram. In any linear network driven by a sine wave, every one of the resulting voltages and currents will also be a sine wave of the same frequency, so phasor diagrams come in handy for displaying the phase relationships between them. Better than that, they also give a lot of help in working out the voltages and currents in the first place, as we'll see in a moment.

First of all, let's take a look at individual components and see what happens when a sine wave voltage is applied. For a resistor the current at any instant is proportional to the voltage, so it comes as no surprise to find that the voltage sine wave gives rise to a current sine wave in phase with it (Fig. 1a).

How about a capacitor? The relationship between voltage and current is:

\[ i = C \frac{dv}{dt} \]

For a general sine wave voltage of peak voltage \( V \), \( v = \sin(Vo t + \theta) \) so the current will be:

\[ i = \sin \omega t \sin(\omega t + \theta) \]

\[ = \omega V C \cos(\omega t + \theta) \]

\[ = \omega V C (\sin \omega t + \theta + 90°) \]

So the magnitude of the current will be \( \omega C \) times the voltage and its phase will lead the voltage by 90° (Fig.1b).

The idea of the current leading the voltage that is producing it often causes confusion. It seems to suggest that capacitors have supernatural powers and can predict the future!

Let's put it to the test. We'll give the capacitor a sine wave voltage input until point A of Fig. 1c, at which point we'll let it level out. If the capacitor really does have precognition, it should level out the current at point B. Does it? Of course not! So much for psychic capacitors. Figure 1d shows what really happens.

The reason for the apparent supernatural power is that the voltage at any instant gives rise to a current proportional to its rate of change at any instant.

If the voltage is sinusoidal, it just happens that the current will also be a sine displaced by 90°. Leading and lagging is just a convenient way to talk about the phase relationship between the two.

With other waveforms, the current waveform will not even be the same shape as the voltage waveform (see Fig. 1e, for example) so any talk of leading and lagging is meaningless. Can you think of a voltage other than a sine wave that produces a current of the same shape? Don't spend more than five hours looking for one! (I'm not allowing exponentials — they don't repeat!)

After that digression, let's return to the business in hand. Since a sine wave voltage applied to a capacitor produces a sine wave current, if we only consider the magnitude of the two sine waves the capacitor seems to behave in a similar way to the resistor. The voltage produces a current at times as big, so the capacitor has a kind of 'resistance' to sine waves \( 1/\omega C \). This 'resistance' is not fixed — it varies with frequency. It's also different from ordinary resistance because it only works for sine waves and gives a shift in phase.

An inductor has a similar sine wave voltage to current relationship, but this time the current lags the voltage by 90°. The 'resistance' of an inductor is \( \omega L \).

Do these 'resistances' behave in the same way as ordinary resistances? For instance, if a resistor \( R \) is wired in series with a capacitor \( C \) (Fig. 2a) can we just add the apparent resistances? Is the 'resistance' of the two components together \( R + 1/\omega C \)? Let's use a phasor diagram to find out.

If you remember from last month, the process for making a phasor diagram is to arrange all the rods in the correct phase relationship to each other. To make the sine

---

**Fig. 1** (a) The current through a resistor with a sine wave voltage applied. (b) The current through a capacitor with a sine voltage. (c) Future prediction by a capacitor. (d) What really happens. (e) The current through a capacitor with a complex voltage wave.
waves, the machine is started up to spin all the rods around, still locked in the same angular relationship.

Since all the rods move in a complete circle for each cycle of the sine waves, we can put the first one in at any old angle. As long as the others are arranged at the correct angle to the first reference rod, the sine waves will all have the proper phase relationship.

Let's begin with the current phasor for Fig. 2a. Just to make the calculations easy, we'll give it a length of 1, making the current waveform peak at 1A. Quite a lot really but imaginary components don't burn so it should be OK. The current phasor is shown in Fig. 2b.

The voltage across the resistor is an easy phasor to add. It will be in phase with the current and R times its length (Fig. 2c).

The voltage across the capacitor will have an amplitude of 1/jωC and will lag the current by 90° so let's put that one in next (Fig. 2d).

Finally, we can work out the voltage across the whole circuit. It will be the sum of the capacitor and resistor voltage phasors (Fig. 2e).

The amplitude of the voltage is \( V = \sqrt{R^2 + \frac{1}{\omega C}} \) and since the current has an amplitude of 1A, this is also the effective resistance of the circuit to sine waves. It's not quite the same as the \( R + \frac{1}{\omega C} \) we were hoping for!

The current in the circuit as a whole leads the voltage by somewhere between the 90° lead for a capacitor and the zero phase shift for a resistor. The contribution the capacitor makes to the phase shift varies with frequency. If the frequency increases, \( \frac{1}{\omega C} \) becomes smaller and the circuit looks more and more like a resistor to the driving circuit (Fig. 2f). For low frequencies the opposite is true and the circuit looks more like a capacitor (Fig. 2g).

There's another trick we can do with this diagram. If someone gave us the voltage and current phasors of the circuit for a particular frequency, we could deduce the values of R and C.

If the current phasor was of unit length and assumed to be along the positive x axis, all we need would be the voltage phasor. The resistor's 'shadow' on the horizontal axis and the capacitor's 'resistance' (from which we could work out its value) would be the shadow on the vertical axis (Fig. 2h).

What would we make of the voltage phasor shown in Fig.2i? Obviously the circuit can't be a resistor and capacitor because the voltage is leading the current. A resistor and inductor would do the trick.

It's usual to split the apparent sine wave 'resistance' of a circuit into two parts. The part that gives a voltage in phase with the current (the shadow on the horizontal axis) is the resistance, the part that gives a 90° phase shift (the shadow on the vertical axis) is the reactance. The sum of the two is called the impedance. Resistance and reactance are both measured in ohms.

To distinguish between phase lead and phase lag, the capacitive type of reactance, where the voltage lags the current, is given a negative sign. The reactance of a capacitor is \( X_C = -\frac{1}{\omega C} \). The inductive type of reactance (voltage leading current) is given a positive sign. The reactance of an inductor is \( X_L \).

The impedance of any combination of resistors, capacitors and inductors can be split into reactive and resistive components and so they will appear to the driving circuit to be a resistor and an inductor or capacitor. In general the driving point impedance will change with frequency in a way that can't be matched by a pair of components, so the idea is not quite so useful as reducing a resistor network to a single resistor. Having said that, it is often useful to know how the driving point impedance changes with frequency, so we'll have a look at that next month.
THE UNUSED OSCILLATOR

Neville Croucher finds innumerable uses for the humble CMOS Schmitt trigger gate.

An oscillator is one of the most common building blocks in electronics. There are hundreds of different designs ranging from atomic references to simple RC circuits. Ever since the introduction of the 555 timer many years ago millions have been used, along with the newer generation of low power equivalent devices. However, there are another couple of ICs which offer a choice of either four gated or six free running oscillators. Combined with the extremely low power consumption and near perfect output characteristics these must be among the most underused devices available.

The devices in question are the CMOS 4093 quad NAND gate and the 40106 hex inverter. What makes these special is that the inputs use Schmitt trigger switching and while most designers are aware of the application of these as a waveform shaper it is not always known how easy it is to produce an oscillator out of just one of these gates as shown in Fig. 1.

To understand why the circuit works it is necessary to understand what happens in a Schmitt trigger circuit. Figure 2 illustrates the schmitt action.

When the input voltage rises above the upper threshold point, the output changes from a high to a low level. However, as the voltage falls below the upper threshold the output does not change until the lower threshold point is reached. This affect is called hysteresis and the symbol used to represent a Schmitt trigger is a representation of a hysteresis loop.

Once the action of the Schmitt is understood, it is easy to appreciate the operation of the oscillator. When the supply is first connected the capacitor will be discharged and so the input voltage will be zero (Fig. 3). This will cause the output to go high and so the capacitor will start to charge through the resistor. When the voltage on the capacitor reaches the upper threshold voltage at point 1, the output will then go low and the capacitor voltage will fall. When the capacitor voltage reaches the lower threshold voltage point 2, the output will go high and the action continues indefinitely.

It will be noticed that the time from start to point 1 is longer than that from 2 to 3 but this only occurs on the first cycle.

The frequency of the oscillator is dependent on the threshold voltages and the values of the timing components. Because the output voltage and the threshold voltages are both dependent on the supply, the actual frequency is difficult to predict as the threshold levels vary from one device to another although as a rough guide the complete time period is approximately equal to the time constant RC.

For a frequency of 1kHz a good starting value would be 100n and 10k. When choosing these values it is sensible to keep the resistor between 3k3 and 10M. The capacitor should ideally be chosen so that a resistor value between 10k and 100k can be used. If this is done there is plenty of tolerance in the resistor value to allow for fine adjustment if necessary.

If the oscillator is to be battery powered it is worth bearing in mind that the low power consumption available using CMOS is only an advantage if the rest of the circuitry is not going to take a lot of power. This will only be the case if quite high value resistors are used.

The pinout of the 40106 is shown in Fig. 4. This chip
Fig. 4 Pinouts of the Schmitt trigger chips used.

Fig. 5 A gated Schmitt oscillator.

Fig. 6 Variable duty cycle Schmitt oscillators.

Fig. 7 An efficient method of driving a loudspeaker or other load.

Fig. 8 A digitally selected two frequency oscillator.

Fig. 9 A simple pulse generator built around a single chip.

contains six separate inverters and so six different oscillators can be made from one single chip. The 4093 is a quad NAND with Schmitt inputs which allows us to gate the oscillator very simply as shown in Fig. 5. When the gate input is connected to 0V the output of the gate is forced high and does not oscillate. When the gate input is taken high the oscillator is enabled. If the output is required to be low when the oscillator is off then the output should be inverted using one of the other gates in the package. As always with CMOS, unused inputs must be connected to either 0V or the supply.

With the oscillators shown so far the duty cycle is always 50%, allowing for tolerances within the device itself. If a different duty cycle is required this can be achieved in two ways as shown in Fig. 6.

In the first circuit, the capacitor is discharged only through R1. When the capacitor is charging the diode conducts and the resulting pulse width is dependent on R1 and R2 in parallel. If a short off period is required it is simply a case of turning the diode the other way.

In the second circuit the two time periods are each controlled by a separate resistor by use of the two diodes. R1 affects the high output and R2 affects the low output.

If the output is required to drive a loudspeaker or an LED it is possible to drive the output directly. If however a power efficient circuit is required, a useful technique is to use the stored energy in the capacitor to power the load. In Fig. 7 the capacitor charges from the supply through the resistor. When the upper threshold point is reached the transistor is turned on and the capacitor discharges through the speaker (or LED or whatever). In this way it is possible to build circuits for battery operation that consume a minimal amount of power.

Figure 8 shows a circuit which selects between two different output frequencies depending on whether the input is high or low. This is useful for applications requiring tone encoding for transmitting digital signals.

Finally, Fig. 9 shows a simple but versatile pulse generator circuit. The output may be continuous or gated by the built-in modulator. The output frequency is in three ranges covering approx 1-33Hz, 33-1000Hz, and 1-33kHz. The modulation has separate on and off times, each variable between 10ms and 1s. The whole pulse generator uses just one chip.

With all of these circuits the aim is to show how simple to use and how versatile these devices are. They are intended as examples only but should give plenty of ideas for experimentation.
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DESIGNING FOR EFFICIENCY

Switching on a switch mode power supply isn't as easy as it sounds. Les Sage explains why.

The operating principles and the various waveforms found in modern switch mode power supplies (SMPS) were described in last month's article. A number of design problems were highlighted, and we will now see how modern thinking has managed to overcome these problems to produce SMPS offering very high efficiencies and high reliability.

Switch On

Now that the normal running operation is understood it is necessary to look at what happens at switch on. As we know, very little dissipation occurs in the transistor when it switches on provided there is zero energy (a small step in the collector waveform) in the transformer. The collector current begins to ramp upwards linearly at the rate of \( I = \frac{tV}{L} \) (where \( I \) is in amps, \( t \) in seconds, \( V \) in volts and \( L \) in Henrys). As this forward phase is storing energy in the core no output voltage will occur. The feedback loop detects this and treats it as a heavy output load requiring more input energy, so the control signal to the drive circuit continues to increase the on-time still further.

The point is that there will never be any output whilst the chopper transistor is conducting because energy is only transferred to the output when the transistor switches off. The feedback loop is in fact holding off the output energy so long as it senses low or zero output volts. The net result is that the collector current continues to rise until the core saturates. With a saturated core the inductance disappears, the transistor comes out of saturation and exceeds its safe operating area (SOAR) turning into a now useless piece of scrap metal. The feedback loop essential for normal correct operation has in fact destroyed the transistor at switch on. This also happens should the output be short-circuited or if the mains input level falls dramatically (brownout), all resulting in long on-times destroying the chopper transistor.

There are two important points to get right regarding these problems. The first is that the drive circuit must be free-running (ie. self oscillating) with a frequency sufficiently low to ensure that the free running period is greater than the maximum on-time plus the off-time required under worst case conditions, this occurring at maximum output power and minimum mains voltage.

The second point is that at first switch on, only short, low repetition rate pulses should be available. These are not under loop control and serve to establish a small output potential. If this potential does not appear the logic circuitry detects this and provides the PSU with a very short, safe, pulse width which can be maintained indefinitely. This is the short circuit protection mode.

If the small output potential does appear, then the pulse width is gradually increased until at a threshold point a flipflop switches control over to the normal feedback loop. Normal regulatory operation is now resumed, although circuitry is normally included to continuously monitor the input mains and the output DC. If the mains falls below a predetermined level (undervoltage lockout) then the protection cycle is re-entered.

This type of circuitry is not normally built in discrete component form although some manufacturers have tried. There are several modern integrated circuits which perform all the functions required, although a lot of ICs are only basic types which lack some or all of the features discussed. Throughout this article I will at times refer to discrete circuitry in an attempt to give a fuller and more easily understandable explanation.

A Supply For A Supply

Drive circuitry can be quite complex, including linear and logic circuits, and all this circuitry will need its own power supply at, say, 12V.

It would be silly to include a separate 50Hz mains transformer to supply 12V for the drive circuitry. It would be nice if the drive and control circuit could be driven off the mains direct via a dropper resistor and zener.

The problem is that although modern technology allows us to build all sorts of logic and linear circuitry with a total consumption of only several milliamps, the switching transistor itself requires much higher base currents. As an example, a typical 150W switcher operating at 30kHz would have a transistor collector peak current of \( Ic = 2.\frac{Po}{Vs}.Ton.f = 3.6 \text{ amps max} \).

High voltage, high frequency chopper transistors with low \( V_{Sat} \) characteristics are notoriously very low gain. A BU208A for instance has a current gain of just 3 at 36 amps, requiring over 1A base current to remain in...
saturation. To supply 1A base current direct from the mains is clearly impractical.

Earlier it was stated that the initial turn on phase uses very short pulses to establish correct operation. Figure 1 shows that power for this can be obtained initially from the mains via a dropper resistor storing charge on a decoupling capacitor. This capacitor then supplies the required short high current output drive pulses required by the transistor's base. As soon as the PSU has established an output voltage, this output voltage itself can supply the power required to fully drive the chopper transistor under normal conditions. This scheme is almost universally adopted.

**Collector Current Proportionality**

It has been stated a few times that the key to modern SMPS design lies in the base drive. We haven't quite finished with drive yet as there is one more very neat trick used to give quite a substantial increase in overall efficiency. This is called collector current proportionality and is achieved in a surprisingly simple way.

The normal DC power supply for most ICs is 12V. Much less than this and the control loop comparator will have insufficient headroom for complete control. However we have already seen that the chopper transistor requires around 1A base current to fully saturate in a typical application. Even though this current is supplied by the SMPS transformer itself, 1A at 12V is 12W wasted as heat, and this is almost 10% of the maximum output.

Worse still, if the IC is to drive the chopper transistor direct (for low parts count) all this 12W drive power is dissipated within the IC, requiring an expensive 'power package' device. Figure 2 shows that the collector current rises linearly with time, starting from zero and reaching a maximum of 3.6A at the turn off point. It follows that it's not necessary to supply the full 1A base current all the time. 1A is required only at the end of the conduction on-time phase. If the base current is therefore made to rise linearly as well as the collector current, with just enough current to maintain the transistor in saturation, a considerable saving in drive power and IC dissipation will result.

A typical value would be around 1.5W compared to 12W, allowing a low-cost copper leadframe-type DIL IC to be used.

**Collector Current Simulation**

The base current must ramp upwards exactly in line with the collector current, otherwise the transistor may never saturate resulting in very high chopper dissipation. The problem is that the collector current varies from condition to condition. Figures 2a-c show the collector current for various loads and mains input voltages.

It is therefore necessary to vary the base current ramp in proportion to the collector current. The collector current cannot itself be monitored very easily since the collector is busy swinging up and down from 0 to +800V. The emitter current is not a reliable means of collector current monitoring since it includes the base current and this is not constant since hFE varies with current and saturation level.

A simple piece of circuitry designed to simulate the collector current is used. Since the collector load is almost a pure inductor the collector current is proportional to the supply voltage Vs with respect to time. It is only necessary to monitor the supply voltage and to integrate this over a time period to determine the actual collector current at any given moment. This can then be impressed upon the base current drive, giving a base current proportional to the actual collector current which will increase or decrease with supply variations, and load on-time variations exactly following the collector current variations.

A discrete circuit block achieving this for those intrigued is shown in Fig. 3 while Fig. 4 indicates the collector/base current waveforms. The base current ramp is stood on a small pedestal thus ensuring collector saturation at all times. The short spike at the beginning of the collector current just as the transistor turns on is due to the snubber capacitor energy discharge and represents a small waste of energy.

The output driver stage consists of a high current Totempole/Style stage (Q2) acting as an emitter follower for the forward phase whilst Q3 is the drive transistor for the off phase. Remember we said that the most important time is the off phase: that's why Q3 is configured as a common emitter amplifier which turns on very quickly since it provides current and voltage gain over the control drive current. The base drive is capacitively coupled to the base so as to give the required off drive potential.

The on phase, controlled by Q2, is actually very slow compared to collector current, so Q2 acting as an emitter follower will follow the signal at its base without adding voltage gain. The output stage then satisfies the earlier
familiar step in the collector waveform. It soon occurred to designers that this step time was actually wasted time, time in which nothing at all is happening. Unfortunately it is required for regulation in a fixed frequency SMPS and varies inversely with load/line variations. Figures 5 b,c show the variation of this time, and the effect on magnetizing current for changes in load. Note particularly Fig. 5c which shows a squarewave collector voltage without step time and indicates the result. The effect is that the magnetizing current has not returned to zero, and you will recall that this straightforward squarewave drive leads to unreliability. However, if the maximum load occurs where the step time and the flux just tend to zero, maximum switching efficiency occurs. The reason for this is twofold. First, at all times action is occurring, so time is not wasted by concentrating the switching into a shorter time period than necessary. Secondly, at the step corner there is zero energy, so switching on at this moment could in theory result in zero switching dissipation.

If the circuit is still to be capable of regulation it is necessary to have circuitry which detects this zero energy point (termed zero crossing on the voltage waveform). A signal must be sent to the control circuit telling it, regardless of what it thinks, that it's now time to switch off the chopper transistor. The result will be a shorter overall time period (ie, higher frequency operation) but successive cycles will shorten the on-time to maintain the correct output energy. As the load varies the overall period/frequency varies to maintain regulation and, ensure that switch on always occurs at the zero energy point.

Since the on and off times are now no longer fixed, the frequency varies with load and line variations. The SMPS cannot, as in fixed frequency units, be synchronised to an external clock, so it is termed non-synchronous. In practice we find that for varying output loads the mark-to-space ratio remains virtually constant whilst the frequency varies inversely with load level (ie., high loads = low frequency). For mains line input variations we find that the frequency remains fairly constant but the mark-to-space ratio varies in proportion to the input volts. This continuous, complex variation of both mark-to-space and frequency ratio whilst maintaining continuous core magnetization is termed 'Mesh' operation.

These ideal waveforms do not occur in practice so we have to turn our attention back to the real switching waveform. At switch off it was stated that the snubber capacitor slows down the Vce dv/dt, improving transistor power dissipation in the all important off phase. This dissipation is traded for dissipation during the on phase since all the energy stored in the snubber has to be removed by the transistor prior to the following off phase.

Figure 6 shows the mesh waveform in more detail with the now familiar ringing due to transformer inductance and snubber/stray capacitance. The capacitor's stored charge is dissipated at the point of transistor turn on, but looking at the entire ringing waveform shows that it is a resonant circuit with the Tx inductance. In a resonant circuit energy is repeatedly cycled back and forth from the inductor to the capacitor. Looking at the first quarter cycle, point x is where all the capacitor's charge has been transferred to the transformer. If the transistor is driven on at this point there will be no energy in the capacitor to dissipate since it's stored in the transformer. Therefore it will be added to the following on-time energy storage phase. The resulting efficiency is extremely high due to the transistor switching on and off at the moment of zero energy.
The delay required between zero magnetic energy and zero snubber energy is normally quite small and fairly constant regardless of the load/line conditions. Therefore a simple short delay in the zero-crossing detector will allow for this.

To prove the validity of this technique it is quite simple to wire up a standard power supply with a fixed load and to vary the frequency via the sync input terminal whilst monitoring the collector waveform on a scope and also monitoring the mains input power. As the frequency is varied so that the switch on cycle occurs anywhere either side of point x (Fig. 6) for a given output load the input power will increase. Switching on early before zero core flux is reached causes large increases in input power and increased transistor temperature.

As no circuit is ideal, most SMPS will not be capable of transferring all the snubber energy into the transformer so the transistor will still have to discharge the remaining snubber energy indicated by x,y in Fig. 13. To further improve transistor reliability the snubber usually incorporates a paralleled resistor and diode in series with the snubber. The resistor limiting the peak discharge current allows lower base drive power requirements whilst the diode ensures the capacitor conducts the full transformer current at turn off, so maintaining correct snubber action.

It is obviously necessary to design the inductance and total collector capacitance with care so as to maximise this energy transfer/switching cycle. Otherwise its benefits will easily be lost.

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ETI NOVEMBER 1987
THE DREAM MACHINE

Paul Chappell looks into the complexities of sleep and finds it can do with an electronic helping hand. This is such stuff as dreams are made of.

Free gift time has come around again and this year we've got something rather special for you — a dream machine! You will already have found the printed circuit board on this month's cover and next month there will be the components too.

Imagine this: you are in the middle of a particularly exciting adventure when you suddenly recognise it for what it is — a dream. Since it's a dream, you have the power to do anything you choose. You can go anywhere, do anything, break the laws of physics, defy social conventions — you have supreme authority! What will you do?

If you've ever had this experience, you may be interested to know it's not uncommon. In the psychology trade these are known as 'lucid dreams'. They often occur spontaneously during nightmares — suddenly you realise that nothing in real life could be quite so bad, so you must be dreaming. Having turned your enemies to toads, you can get on with conjuring up more pleasant scenes for yourself! You may have had a recurring dream that becomes so familiar that you recognise it.

Often, lucid dreams are brought about just by reading about them — knowing that it's possible — so who can tell what might happen to you tonight?

When lucid dreams happen spontaneously you usually lose control after a while and slip back into a normal dream. With a little practice they can be sustained and become ever more frequent and powerful. With the Dream Machine by your bedside, some very strange experiences are waiting for you. This is not a project for the faint hearted!

Dreams are such personal things that they are not really
amenable to the methods of scientific investigations. Most people have trouble recalling their own dreams with any accuracy, so the difficulties in trying to make sense of second hand accounts are almost insurmountable.

Much has been written about dreams with apparent authority, which on closer investigation turns out to be little more than opinion and prejudice. Some claim that dreams can be prophetic or didactic, others that they are composed of fragments from the day's activities put together in a bizarre way. Others still would claim that they are merely rubbish churned up as the brain sorts out its internal filing system during the night.

Coleridge claimed to have heard the poem 'Kublai Khan' word for word in a dream. Jung saw dreams as a 'hidden door' to the secret recesses of the mind. Joseph saved Egypt from famine after interpreting Pharaoh's dream. Was Coleridge a liar? Was Jung and all the present psychiatrists who borrow from his techniques merely misguided? Was Joseph's shrewd intervention in the Egyptian economy a lucky accident?

Any theory put forward to explain the purpose of dreaming has a great variety of factors to take into account!

Sleep (Perchance To Dream)

The reason for sleep is still something of a mystery. The problem is that the obvious explanation (that the body and mind need rest to recover from the day's activities) just doesn't hold up under close scrutiny.

Any period of inactivity (sitting in an armchair in front of the TV will do) is quite enough to give the skeletal muscles all the relaxation they need. As far as the mind is concerned, the electrical activity certainly changes during sleep, but far from decreasing it becomes considerably greater!

In the search for an alternative explanation, scientists spent a great deal of time and energy searching for substances known as 'hypnotoxins'. The idea was that these toxins (poisons) would build up during the day until they reached a certain preset level which would trigger the sleep mechanism. During sleep, no more poisons would build up and those accumulated during the day would be gradually eliminated until they reached a lower threshold which would signal 'time to get up'.

This attractively simple idea was spoiled by the complete failure to find any sign of substances that would fit the description of hypnotoxins and so now it's been largely abandoned. Perhaps sleep is not necessary at all? Maybe an occasional period of physical inactivity would be just as good? This doesn't work either (Fig.2). The evidence that sleep is
absolutely vital to survival comes mainly from circumstances where sleep deprivation is used as a form of torture.

Destructive testing of human beings under these conditions show they can rarely last more than ten days without sleep. Death is preceded by intense hallucinations and often by insanity. Those who have survived long periods of sleep deprivation are not keen to recommend it and often suffer periods of depression and mental disturbance for months or even years afterwards.

So what is known about sleep? The hard facts are interesting but not particularly enlightening. Sleep is arbitrarily divided into levels, mainly on the basis of EEG recordings. The normal sleeping pattern is to sink through the various levels of sleep to reach the deepest level within about 45 minutes. This deep sleep is broken roughly every hour and a half by paradoxical sleep, so called because the brain waves take on a pattern that would normally be associated with alert wakefulness (Fig.3).

As the night progresses, the trend is for sleep to become lighter and the periods of paradoxical sleep to become longer, from about ten minutes early in the night to half an hour or so later on.

Paradoxical sleep is also known as rapid eye movement (REM) sleep. In the early 1950's it was discovered that this phase is accompanied by bursts of eye movement behind the closed lids. As this is clearly visible, particularly in babies (where it was first noticed) it's astonishing that it took so long for anyone to discover it!

Dreams seem to occur with far greater frequency during REM sleep than at any other time. This was discovered by the simple expedient of waking people up during REM and non-REM phases and asking if they'd just been dreaming. Those woken from REM sleep almost invariably reported having a dream, whereas those in the non-REM stage rarely did.

In several experiments sleepers have been denied the opportunity for dreaming by being woken at the onset of each REM phase. They were allowed to sleep again immediately but would be woken at the first sign of any eye movement. The total sleep period allowed was the same as usual but it was a broken and dreamless sleep.

One result was that sleepers were so keen to enter the REM phase that it would begin almost as soon as their heads touched the pillow. The second was that the sleep period just didn't seem to refresh the subjects. After a few days they would show similar disturbances to those who were deprived of sleep altogether.

Other groups of sleepers woken just as often (but always during the non-REM phase) showed hardly any effect at all.

It is tempting to draw the conclusion that sleep deprivation is really dream deprivation — that the whole purpose of sleep is to allow dreaming. Some have said just this. Others would claim that dreams are an incidental product of some essential activity which takes place during REM sleep.

Whatever the truth of the matter — whether dreams are the essential ingredient or a manifestation of some other vital process — it seems likely that the study of dreams can make a valuable contribution to the understanding of sleep. Very little seems to be forthcoming from other sources!

### Improving Your Dream Life

Did you dream last night? You almost certainly did but there's a good chance that you don't remember a thing about it. If you're keen to know whether your dreams have a message for you, whether they can help with your day to day problems or if they're simply the result of last night's supper or TV viewing, the first step is to recall them in the morning.

Your dream memories will be at their sharpest when you are just in the process of waking up. Let the dream run through your mind in this state and it will remain fixed in your memory for some time. When you are fully awake, you can jot down the details if you like.

After that comes the fun of trying to analyse the results. A single dream is not much to go on but if you keep a 'dream diary' you may see all kinds of patterns emerging.

Many people have claimed to be able to decide on the subject of their dreams by thinking about it just as they drift off to sleep. Some claim to be able to return night after night to a favourite dream to watch the next episode unfold.

A strange effect is the ability of dreams to weave external events into their own fabric. An interesting experiment (it can hardly be dignified by calling it 'research') was carried out by a certain Major Wellesley Tudor Pole who hit upon the charming idea of waking people from sleep by firing a pistol close to their ears. In every case where a dream was reported, the pistol shot was somehow built into the story as the natural culmination of the dream. Whether the good Major's friends
ever spoke to him again afterwards is not recorded.

The Dream Machine

The Dream Machine was conceived as a project that everybody can have fun building and experimenting with and one which can also serve a useful purpose. One of its functions is to bring about a state of relaxed drowsiness conducive to having a good night’s sleep. Being something of an insomniac myself, I had a definite personal interest in its success!

We tend to think of sleep as a time of relaxation but most people spend the night in such a state of tension that the experience is nowhere near as refreshing as it ought to be. I want to bounce out of bed in the morning feeling totally renewed and full of energy, not groggy and bleary eyed. So, you see, the project was really made for me, but I’ll share it with you!

The principle of the Dream Machine is this: it produces pink noise. The sound of pink noise is similar to the sound of surf on the beach, wind in the trees or similar to the sound of light rain. Quite poetic, really. Some extravagant claims have been made for the effects of pink noise. I remember reading some years ago that people became so hypnotised by prolonged exposure to it that they could have their teeth pulled out without anaesthetics! Just the thing to amuse you on a rainy afternoon.

Noise

In most circuits the aim is to keep noise to a minimum but for this project we want to increase it! Luckily, we don’t have far to look for sources of electrical noise. All kinds of things produce it — resistors, transistors, wastepaper baskets, ashtrays...everything on earth produces thermal noise voltages (Fig.6).

Thermal, or Johnson, noise is for most ashtrays. Ask a resistor to do some work like passing a bit of current and up goes the noise (for most types, anyway). The Johnson noise is the lowest possible noise, sometimes called the noise floor. On top of that comes 1/f noise (the noise carpet?). In semiconductors there are other odds and ends too: mostly shot noise with a touch of partition noise (a bad habit picked up from valves).

How these noise mechanisms work (and how to put them out of action) is something I have in mind for a future Circuit Theory article. For the moment we’ll just give thanks that they exist.

Other components can be even noisier. A zener diode on the point of conduction will produce enough noise to wake the neighbours and it is this I have chosen as the generator for the project. Thermal noise has a spectrum with the same power in a given bandwidth no matter what the centre frequency may be. Between 50Hz and 100Hz there’s just the same amount as between 1,000,000Hz and 1,000,050Hz, all things being equal (which they never are). It is called white noise by analogy with white light (which has an entirely different distribution — it’s not really a very good name).

If the power varies inversely with frequency, the noise contains more of the low (red) frequencies and is called pink noise (Fig.7). In semiconductor devices, 1/f (pink) noise tends to predominate up to about 1kHz. Above that, the spectrum is fairly flat (on a linear frequency scale).

The noise from a zener diode is already tinged with pink, so judicious use of a capacitor and pot can vary it from pale pink to almost red (close enough for our purposes, anyway).

Next month you’ll be getting the components and I’ll start on the construction details. In the meantime, sweet dreams!

This works out to near as damn 18µV. This is usable (and quite enough to cause problems in hi-fi amplifiers and brainwave monitors) but not much of a start for the Dream Machine. The noise from a 10,000M ceramic ashtray would be better. 100 times as good, in fact. But the currents would be much too small.

Luckily for us, thermal noise is not the only source of noise in electronic components (though it is for most ashtrays). Ask a resistor to do some work like passing a bit of current and up goes the noise (for most types, anyway). The Johnson noise is the lowest possible noise, sometimes called the noise floor. On top of that comes 1/f noise (the noise carpet?). In semiconductors there are other odds and ends too: mostly shot noise with a touch of partition noise (a bad habit picked up from valves).

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Next month you’ll be getting the components and I’ll start on the construction details. In the meantime, sweet dreams!
Are we about to create a race of Superman?

Brainwave Monitor

The ETI Brainwave Monitor must be the most astonishing project ever to appear in the pages of an electronics magazine. It will allow you to hear your brainwaves and judge the relative levels of various states. It will also help you to control your mind more effectively, to be at peak performance in all situations.

Doees my mind work perfectly well when left to its own devices? If you've ever been confused, unsure of yourself, shy, unable to pass exams or to impress people at interviews, you know perfectly well that it doesn't. Your mind (and everybody else's) is full of bad habits, inappropriate responses, feelings of inadequacy... all pulling you down. Why should you put up with it?

Mind training sounds like hard work!

It can be. If you want to do it the hard way, go and study under a Zen master for fifty years. Or it can be done easier. The ETI's Alpha Plan was reliable, good in ETI. It's a last, an ioniser that was comparable with 'dead air cleaner and purer, and seems much more invigorating than 'ordinary air'.

A friend told me I could use brain power to control lights and things. I can't believe it! As a matter of fact, you can do more than that! The interface sockets on the monitor allow you to turn lights on and off, control toys and electrical gadgets, play computer games... all with your mind! Are we about to create a race of Supermen? Only time will tell.

The Brainwave Monitor is featured in the September, October and November 1987 issues of ETI. The approved parts set contains: two PCBs, all components including three PM1 precision amplifiers, shielded box for screening the bio-amplifier, attractive instrument case with titling text, controls, switches, knobs, plugs and sockets, leads and materials for electrodes, full instructions for assembly and use.

Parts are available separately. We also have a range of accessories, professional electronics, books, etc. Please send a stamped, self-addressed envelope if you want the lists. Otherwise, an SAE (£2) will bring you lists, construction details and further information.

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FULL INSTRUCTIONS

(You will need the free components and PCB from the November and December issues of ETI to complete the project.)

Prices shown are exclusive of VAT, so please add 15% to the order totals. UK postage is 50p on any order. Carriage and insurance for overseas orders £1.50. Please allow up to 14 days for delivery.
Robert Stevenson continues his description of the ultimate mains controller.

The construction of the Concept controller was covered last month. In this issue the calibration and operation of the controller will be described.

The Concept's operating system software is held in EPROM on the CPU board (IC3). The EPROM used can be either a 2764 (8K) chip or a 27128 (16K) chip depending on availability. Only just over 7K of the EPROM is used and the hex dump of the used portions is given in Listing 1. Alternatively, pre-programmed EPROMs and the source and object code on a BBC micro disk are available from the author. See last month's Buylines for details.

**Calibration**

When the Concept is fully assembled and all the wiring checked carefully, plug in and switch on.

All the display LEDs should light for a second and then the Concept should go into time display mode. As this is the first power-up this should show 00.00. The centre decimal point should flash at 1Hz and the top left LED should light to indicate time mode.

Press the mode (MDE) key and the Concept should go into cost mode and display 000.0. Another press puts it into power mode. The display may show a figure now. This is meaningless until the unit is calibrated.

Switch off and connect the 'normal' link on the power board. Switch again and allow at least a half hour for the unit to warm up. Press the MDE key twice to enter power mode.

With an insulated trimmer tool and some care adjust RV1 to give a reading of 0005 on the display. Now press SET and MDE to initiate the auto-zero routine which takes about ten seconds. The offset value calculated is stored in the battery backed RAM and so this procedure should not need repeating.

Switch off again and change the link to 'calibrate'. After switching on and warm up, the multi-turn preset RV2 should be adjusted to give a reading of 2450. The last digit may fluctuate but this is quite normal.

Switch off and return the link connection to the 'normal' position. The Concept is now calibrated and ready for use.

In use, slight drift of the power measurement circuitry can cause a reading of 1W when nothing is connected to the Concept. This is quite normal and although it can create a cumulative cost error, this is unlikely to exceed ½p a day. If a permanent drift is experienced, the calibration procedure should be repeated.

Certain types of appliance may give unexpectedly low power readings. This is particularly true of TVs and computers which use switch mode power supplies. The Concept measures the in-phase power that the domestic electricity meter counts on. The cost displayed is therefore the cost you pay.

**Problems?**

If the Concept fails to work first time, try switching it off and then on. If that doesn't solve the problem make another check on the orientation of all the ICS and for broken and shorted tracks on the PCBs.

Using an oscilloscope or logic probe check for address and data bus activity. If this is okay, monitor the 6502 IRQ line (ICI, pin4) for a low pulse every 5ms with a longer pulse every second.

If the CPU appears to be working, check that the relays can be switched on manually. If they cannot, examine the driving circuitry.

If the battery is not fully charged, the RAM can become corrupted causing occasional strange functioning of the Concept. The best cure for this is to switch off and short out the RAM, erasing it totally. Short across pins 12 and 24 of IC10.

**Operation**

In general, the Concept is programmed with the sequence SET-function-data-SET. Pressing CE/C will cancel data entry or a selected function. The status LEDs light when a function is operating and flash when data entry is expected.

The time is set by pressing SET and then key 5 (HR). This blanks the hours digits and flashes the hour LED. Type in two digits for the hours in 24 hour format. A further press of SET stores the setting.

The minutes and day are set in the same way using keys 6 (MIN) and 4 (DAY). The day required is entered using the numbers 1 to 7 (Sunday to Saturday).

The mains outputs are turned on manually using the MAN key followed by keys 1 to 4. This toggles the output from its...
Listing 1 The used sections of the 2764 EPROM (IC3 on the CPU board).
The countdown may be cancelled with SET-1 (CDN) followed by one of the keys 1 to 4 or 7 to select the output channel. Then enter the delay required (up to 99) followed by SET again to start the countdown.

At the end of the timed period the selected output is toggled. The countdown may be cancelled at anytime by pressing SET—CDN again.

The timer is programmed using the PRG key. Each channel can be programmed with seven separate on/off time program pairs. Select channel one (key 1) and the display will show either P1 1 or u1. 1. The letter indicates if that on/off time has been programmed. The first number indicates the channel and the second the on/off time program number (1 to 7). The seven time programs can be selected by further presses of the PRG key. A seventh press exits the programming routine.

When the required program is selected, SET allows the on/off time to be programmed. The display shows the previously set on time (00.00 if unprogrammed). A four digit number (hours then minutes) should be entered SET pressed and then the day number followed by SET to store this time. The off time day is then entered in the same way. The display will now show Pr 7. If you are not programming another on/off time you must exit the routine by successive pressing of the SET key and not by using CE/C.

Needless to say, the other channels can be programmed by selecting the relevant channel number at the start of the procedure.

To set the same on/off time for each day of the week, program the first time program with the required times (the day is unimportant), exit the routine in the normal way and enter SET—0 (ED) followed by the channel number. This copies the set times into each time program for each day of the week.

Entering SET—9 (CAP) and then a channel number clears all the time programs assigned to that channel.

The output channels can also be turned off by external trigger signals applied to the DIN socket. The signal should be from a TTL type circuit with open collector outputs. A logic low on the inputs will turn off an output and prevent it from coming on if a programmed on-time occurs.

The external controls are ignored by default and should be enabled first by entering SET—MAN (C-SW). The C.SW LED lights when the conditional switching is enabled.

The Concept's real time clock will run slightly slow. This can be compensated for by the software. The trim factor is entered after pressing SET—3 (TRM). The number entered should be between 0 and 999 and represents the number of s to add every hour.

By carefully monitoring the Concept's timekeeping and adjusting the trim factor accordingly, an accuracy of better than five seconds a week can be achieved.

Cost Power

The Concept can display both the instantaneous power drawn by the outputs and the cumulative cost. Pressing the MDE key switches the display between the three modes of time, power and cost.

The cumulative cost is zeroed by entering SET—MDE (RST) when the display is showing the cost.

The rate at which the power is 'charged' is set by entering SET—8 (RTE). The cost in pence per kWhr is then entered as three digits up to a maximum of 999p.

The projected cost per day or per week can also be displayed. Entering PROJ.COST—4 and PROJ.COST—2 displays the cost per day and week, respectively, based on the instantaneous power consumption. PROJ.COST—3 and PROJ.COST—1 display the daily and weekly cost based on the power consumed during the past hour. PROJ.COST—7 displays the average power over the past hour.

The last function of the Concept is the software lock. The keypad of the Concept can be disabled to prevent unauthorised use. When locked, the MAN, PRG, MDE and PROJ.COST keys cannot then be used. Press SET—2 (LCK), enter a four digit number and remember it! The SET key should then be pressed and held for four seconds until the display shows Loc. The lock can be used in any of the three modes — time, power or cost.

To unlock the Concept simply enter the four digits and press SET. After three failed attempts at entering the code, the Concept displays STOP and totally locks up for five minutes. If the power is removed during this period, the lock-up period restarts again on power-up.

The Concept software also includes extensive error coding. If an invalid input is entered the display shows Err. followed by a number identifying the error. The error display can be cleared by pressing C/CE. The error codes are as follows:

0 time minutes > 59
1 time hours > 23
2 timer hours > 23
3 timer minutes > 59
4 countdown = 0
5 CAP with all channels selected
6 PRG with all channels selected
7 ED with all channels selected
8 overflow on projected cost
9 overflow on compensation (requires re-adjustment)

ETI NOVEMBER 1987
QUIZ CONTROLLER
Andrew Armstrong and Ron Keeley strive for peace in our time at the Trivial Pursuits board.

A quiz has an endless fascination. Is this because we enjoy displaying our knowledge? For the challenge? Is it some kind of masochistic holdover from our schooldays when quizzes were more of a torture than a pleasure? Or is it the sheer satisfaction of getting it right?

Whatever the reason, in recent years the quiz has become almost a way of life. In the week this article is being written, there are no less than ten quiz games of one kind or another appearing on our TV screens, two of them running every night of the week.

All over the country this weekend, people will be sitting down to play Trivial Pursuit, Quizwrangle or one of the look-alike quiz board games.

Even our most treasured leisure hours down at the Three Ferrets are now threatened by an invasion of electronic quiz machines (they are best played in teams, if you want to win!).

Many of the most popular games on TV pit teams or individuals against each other, with the first person to indicate that they know the answer being given the opportunity to reply to the $64m question.

Figure 1 show the circuit diagram. A pair of NAND gates (IC3c,d) are configured as a simple clock producing a square wave output at around 2kHz. The clock signal drives IC4, a 4029 4-bit binary/BCD up/down counter. This has both pin 10 (U/D) and pin 9 (BIN/DEC) tied to the +9V rail, which sets up the IC to count up in binary. It is permanently enabled by the C/E terminal, pin 5, tied to 0V. The lower three bits of the counter output are used to sequence the channels of a 4051 eight-channel analogue switch.

This has eight independent analogue switches with eight independent input/outputs, Y0 - Y7, and a common input/output, Z, on pin 3. The outputs are connected via individual jack plugs and two wires to an LED and a push-button switch wired in parallel. Each switch is selected in turn as the binary counter clocks the address pins 9, 10, 11 and in turn each LED is connected to the 9V rail via pin 3 and resistor, R1. At this stage the LEDs will be dimly illuminated as each is on for just 1/8 of the time.

However if one of the push-buttons is selected, the Z input on pin 3 immediately goes to 0V, triggering IC2, a BIFET op-amp wired as a comparator. With the inverting input biased at just under 2V, the output on pin 6 will go low, tripping the latch configured from IC3a,b which in turn locks up the clock.

The 4051 remains switched to the channel on which the button was pressed and when the button is released, the corresponding LED comes on at full brightness. Until a switch is pressed, the forward drop of the LEDs is greater than the voltage on the inverting input of the comparator, so its output is normally high.

The latch is reset by a master switch, SW9, in the hands of the quiz master. This releases the clock and re-starts the sequencing of the quiz stations by IC1. Although the voltage on the comparator input is momentarily dropping below the comparator threshold due to charging up the capacitance of the wiring, it does not stay low long enough to trigger the comparator.

HOW IT WORKS

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Construction
The PCB measures just 75x35mm and can be built into any convenient sized case, but be sure it has a surface wide enough to take the eight 2.5mm sockets leading to the quiz stations.

Begin construction with the resistors (all six of them), the single capacitor and the two wire links (see Fig. 2). The master reset switch SW9 should be soldered in too, along with the leads for the PP3 battery connector.

You could, at this stage, also solder in short lengths of wire from the IC1 switch outputs and one short lead from the 0V rail, ready to hook up to the eight 2.5mm jack sockets.

The ICs can be soldered in (there are only four of them) observing the usual precautions when handling the CMOS types. Wire a switch and LED across one of the quiz station outputs, fit a PP3 battery to its connector and the board should be operational.

The LED should be glowing dimly until the reset button is pressed at which point it should come on at full brightness. Press SW9 on the PCB and the LED should revert to the dimly lit state. If you fail to achieve these results check the board for the usual misconnections, solder bridges across tracks, dry joints and so on. The circuit and construction are so simple that very little can go wrong!

The enclosure will need a cutout on the top through which SW9 can protrude and eight holes drilled for the 2.5mm sockets. The prototype did not include a power switch, but a miniature toggle can easily be installed and wired in series with the +9V battery lead as shown in Fig. 1. Alternatively another 2.5mm socket could be fitted and a shorted jack plug used to switch the +9V lead.

Finish off the construction by wiring up the jack sockets. The board can be mounted on top of the PP3 battery with a small square of double-sided tape, using sufficient to lift SW9 through the top cut-out. Another piece of tape will keep the battery firmly fixed to the bottom of the box.

The individual quiz stations are connected to the controller via 2.5mm jacks and twisted pair cable of required length. Another option is to use one pair of a length of two-pair telephone cable.

All that remains is to set up your quiz game. Fingers on your buttons please; you have two minutes starting from ... NOW.

Football has been banned in England on at least four separate occasions. When was the first such occasion?

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AUDIOKITS

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Tel: 0332-674929
MULTI-STANDARD PRINTER BUFFER

Leycester Whewell’s micro is quick off the mark thanks to this 256K printer buffer with Centronics and RS232 interfaces.

A most irritating feature of many printers is their data acceptance rate. Many have sufficient capacity to hold only a single line of text, although some can store 2K, 4K or 8K of data. So, when listing a program or document of any reasonable size, the computer is effectively slowed down to the speed of the printer.

A printer buffer appears as a very fast printer to the computer, storing its output so that the operator can get on with the next task without an enforced coffee break. Meanwhile, the buffer outputs data to the printer at its normal speed.

Features

Although the idea of a printer buffer is not a new one (and designs have appeared in ETI before) this device has an ample memory capacity of either 64K or 256K — approximately 20 or 80 pages of A4 text respectively.

The buffer also allows parallel-parallel, serial-parallel, parallel-serial and serial-serial data transfers with a serial data rate of either 1200 or 9600 baud. This should accommodate just about any combination of printer and micro.

The unit is driven by an 8-bit microprocessor, the 6803 (see Fig. 1). This is a 6800 with the added features of 128 bytes of zero page RAM, a timer, a serial communications interface, parallel I/O and some additional instructions.

The software checks the state of the interfaces in turn in a continuous loop. Whenever a data transfer has been acknowledged then the next character is processed. This allows the asynchronous supply of data and retrieval of data from the buffer.

At the end of each loop the status LEDs are updated. A regular timed interrupt is used to initiate a software refresh of the DRAM and test whether the PAUSE switch is pressed or not.

Construction

A soldering iron with a fine tip is needed to prevent solder bridges between the fine tracks of the PCB. Solder all the through pins first.

Unless you are an experienced constructor and have a temperature controlled iron, it is recommended that sockets are...
The non-multiplexed upper address lines and signals such as Read/Write are also stable by this time. The data to be read or written is transferred during the second part of the cycle, when E is high. It is important that the data buffers in peripheral devices are not activated until E is asserted otherwise bus contention will occur.

To keep the DRAM chips as small and cheap as possible, their address lines are multiplexed. Two strobes, Row Address Strobe (RAS) and Column Address Strobe (CAS) are used to latch each half of the address.

The strobes are so named because each DRAM chip has its memory cells arranged as a square matrix of n rows and n columns, where n is 256 for 64K chips and 256 x 128 for 256K chips. Strict timings between these signals and the periods of valid data must be adhered to in order to achieve correct operation. See Fig. 3.

The time delay from E rising to RAS falling is different for read and write cycles. During a read cycle, data from the DRAM must be set up in time for it to be accepted by the 6803 and during a write cycle, the DRAM must wait until data from the 6803 is valid before accepting it. The input clock to the 6803, which is divided by four to produce E, is used with a dual D type latch K16 to generate the different RAS/CAS timings. No data has been published by the manufacturers as to the relationship between the clock input and the data strobe E. However, tests on several devices show that there is typically a 50ns delay from the falling edge of the clock to a transition of E.

The Read/Write signal is used to modify the time when the IC6 latches are clocked. This is done with an exclusive-OR gate. When reading, the RAS signal is sent low on the first clock transition after E is high — this is the low to high edge. The low half of the address is latched into the DRAM at this point. Two logic gate delays provide the interval between RAS going low and the select signal of the 74LS257 multiplexers changing, so that the other half of the address is ready for when CAS goes low.

On the next clock transition of the same phase, if the correct address is decoded then CAS is sent low. Sufficient time is allowed for the data to be read by the CPU — which latches it on the falling edge of E. RAS and CAS are sent high again when E goes low and thus completes the read cycle.

During the write cycle, the same process as above occurs, but the Read/Write line now makes IC16 clock on the high to low edge of the input clock. This delays the production of RAS and CAS by half a clock period (about 100ns), ensuring the data from the CPU is valid by the time that it is latched into the DRAM by the falling edge of CAS.

Since the period of E is fixed, the active part of a DRAM write cycle is 100ns shorter than for a read cycle. Each time that the DRAM is accessed, all the locations in the column row that is addressed are refreshed. To refresh the whole chip, every row must be accessed at intervals of not more than 4ms.

A background program accesses every row once in 4ms. Timed interrupts trigger a program that runs through 256 consecutive bytes of EPROM. By arranging the low order address to be latched by RAS and strobing RAS on every memory access cycle even if the DRAM is not being accessed, the program in EPROM will keep the memory refreshed. A loss of just 5% processing speed results.

Interfaces

The centronics interfaces are connected to a 6522 Versatile Interface Adaptor IC20. Port B is used for parallel data output and Port A for parallel data input. Each centronics interface has three handshake lines. When the data has been set up and is stable, the sending unit puts the STROBE line low for a minimum of 0.5us. The BUSY line is then sent high by the receiving device until it is ready to accept more.

At this point the ACKNOWLEGDE line is given a low pulse by the receiving unit to indicate that the current transfer is complete. The 6522's handshake lines are set to act as STROBE and ACKNOWLEGDE signals for each port although an additional RS flip-flop is required to generate the BUSY signal.

Parallel output data is buffered by a K21 and the handshake lines are buffered using spare gates from ICI. This enables long cables (over 3m) to be used.

The 6803's Serial Communications Interface is programmed to operate in the standard mark/space format with one start bit, one stop bit and no parity. The clock source is derived from the processor clock. A 4.9152MHz crystal must be used to generate the common baud rates of 1200 and 9600.

Consequently, the processor clock is 1.23MHz which requires a 1.25MHz version of the 6803, or better, and a 1.5MHz version of the 6522. It is unlikely a 1MHz 6803 and 6522 will fail to operate under these conditions.

The RTS and CTS handshaking lines are used with no facility for XON/XOFF handshaking. So, a full duplex interface can be split in two, one to receive data only from the computer and the other to send data only to the printer. This enables serial-serial data transfers to take place concurrently without plug changing. If serial-serial transfers will never be used in a particular application, there is little point in using two D-type connectors.

In order to fit I/O lines onto the 6803 CPU without departing from a 40 pin package, the I/O address bus and data bus have been multiplexed. As a consequence each memory access cycle is split in two. During the first half, when the Data Strobe (E) is low, the low order address is placed on the multiplexed bus. The falling edge of the Address Strobe (AS) is provided to latch the data into a transparent latch (IC18).
Fig. 2 The circuit diagram of the printer buffer.
The freshly soldered PCB should be carefully cleaned of flux on the underside of the board using a small brush and paraffin, with a finer solvent used afterwards to wash away the paraffin.

Finally, insert the ICs. Avoid wearing man-made clothes so as to keep static to a minimum and always rest ICs on a conducting surface such as the non-painted side of a biscuit tin lid.

Either 4164 or 41256 ICs may be used for IC3-10 to give a buffer size of 64K or 256K. The correct first byte of the EPROM software for the buffer size must be used. The printer buffer has been designed to fit into a pressed sheet metal box approximately 160mm wide, 80mm tall and 200mm long. The voltage regulator (IC26) bolts to the side of the case.

In the prototype the Centronics connectors are mounted on each side of the box, the RS232 connectors on the back with the switches and LEDs on the front. All connections to off-board components are made via a 64-way DIN 41612 connector located at one end (Fig. 6). Three support locations have been provided on the PCB so that it can be fixed to the base of the box, straddling the mains transformer.

Before drilling any holes, satisfy yourself that the components will all fit together in their intended positions. Remember to allow enough space for the DIN connector to be removed from the PCB with all the wires attached to it. For greatest safety, the earth of the mains cable should be bolted directly to the base of the case using a spade terminal. If the signal ground potential of any of the units likely to be connected to the buffer is not floating or Earth, then the 7805 regulator must be insulated from the case using standard TO220 insulating washers.

Software
Finally, a programmed EPROM should be plugged into position as IC13. The EPROM can be either a 2764 or 27128 type and it should be programmed according to Listing 1. For use with a 64K buffer the first byte should contain the number 06. For a 256K buffer the first byte should be 00. This arrangement also allows a 64K buffer to be upgraded to 256K by replacing the RAM chips and over-programming the first byte with 00.

Testing
Before using the unit a series of checks must be made. Run through the connections to the DIN plug and make sure that all are correct. Take particular care with the supply wires from the transformer. Turn the unit on.

---

**Parts List**

<table>
<thead>
<tr>
<th>RESISTORS (all ½W 5%)</th>
<th>R1,13</th>
<th>4k7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R2,12</td>
<td>470R</td>
</tr>
<tr>
<td></td>
<td>R3,9</td>
<td>3k3</td>
</tr>
<tr>
<td></td>
<td>R4</td>
<td>10k</td>
</tr>
<tr>
<td></td>
<td>R5-8</td>
<td>240R</td>
</tr>
<tr>
<td></td>
<td>R10,11</td>
<td>1M0</td>
</tr>
<tr>
<td></td>
<td>R14,15</td>
<td>1k0</td>
</tr>
<tr>
<td></td>
<td>R16</td>
<td>6k8</td>
</tr>
</tbody>
</table>

**Capacitors**

| C1,2 | 4700p 6V tantalum  |
| C28   | 100n ceramic     |
| C11   | 10n ceramic      |
| C30   | 4700p 16V radial electrolytic |
| C31   | 4700p 16V radial electrolytic |
| C32   | 100p ceramic     |

**Semiconductors**

| IC1   | 7407   |
| IC2   | 75LS138 |
| IC3-10 | 4164 or 41256 |
| IC11,12 | 74LS257 |
| IC13  | 7264   |
| IC14,22 | 74LS00 |
| IC15  | 74LS86 |
| IC16  | 74LS74 |
| IC17  | 74LS04 |
| IC18  | 74LS373 |
| IC19  | 6803   |
| IC20  | 6522   |
| IC21  | 74LS245 |
| IC23  | MC1489 |
| IC24  | MC1488 |
| IC25  | 55S   |
| IC26  | 7805   |
| LED1,4 | Green LED |
| LED2  | Red LED |
| LED3  | Yellow LED |
| DS-4  | 1N4001 |
| DS-8  | 1N4148 |

**Miscellaneous**

| CON1 | 64 way DIN 41612 plug & socket |
| SK1,2 | 36 way Amphenol Centronics socket |
| SK3,4 | 25 way RS232 D socket |
| SW1   | 1 pole 8 way rotary |
| SW2,3 | 1 pole push button |
| T1    | 9-0-9V 30V toroidal mains transformer |
| T0220 | 4.9152MHz crystal |
| PCB; IC sockets; case; PCB standoffs; TO220 mounting kit; nuts and bolts. |
**PROJECT: Printer Buffer**

Fig. 4 The component overlay for the printer buffer board.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Row a</th>
<th>Row b</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ground</td>
<td>ground</td>
</tr>
<tr>
<td>2</td>
<td>+5V</td>
<td>+5V</td>
</tr>
<tr>
<td>3</td>
<td>mode 7 select</td>
<td>LED anodes</td>
</tr>
<tr>
<td>4</td>
<td>mode 6 select</td>
<td>EMPTY LED cathode</td>
</tr>
<tr>
<td>5</td>
<td>mode 5 select</td>
<td>FULLNESS LED cathode</td>
</tr>
<tr>
<td>6</td>
<td>mode 4 select</td>
<td>FULL LED cathode</td>
</tr>
<tr>
<td>7</td>
<td>mode 3 select</td>
<td>PAUSE LED cathode</td>
</tr>
<tr>
<td>8</td>
<td>mode 2 select</td>
<td>PAUSE switch</td>
</tr>
<tr>
<td>9</td>
<td>mode 1 select</td>
<td>PAUSE/RESET common</td>
</tr>
<tr>
<td>10</td>
<td>mode 0 select</td>
<td>mode select return</td>
</tr>
<tr>
<td>11</td>
<td>TxD</td>
<td>RxD</td>
</tr>
<tr>
<td>12</td>
<td>CTS</td>
<td>RTS</td>
</tr>
<tr>
<td>13</td>
<td>IC24 +V</td>
<td>IC24 -V</td>
</tr>
<tr>
<td>14</td>
<td>RS232 ground</td>
<td>RESET switch</td>
</tr>
<tr>
<td>15</td>
<td>+V rectified output</td>
<td>+V rectified output</td>
</tr>
<tr>
<td>16</td>
<td>7805 regulator ground</td>
<td>7805 regulator ground</td>
</tr>
<tr>
<td>17</td>
<td>-V rectified output</td>
<td>-V rectified output</td>
</tr>
<tr>
<td>18</td>
<td>T1 secondary I</td>
<td>T1 secondary I</td>
</tr>
<tr>
<td>19</td>
<td>T1 secondary II</td>
<td>T1 secondary II</td>
</tr>
<tr>
<td>20</td>
<td>Centronics data ground</td>
<td>BUSY (IN)</td>
</tr>
</tbody>
</table>

Table 1 DIN 41612 connector pin-out.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strobe</td>
</tr>
<tr>
<td>2</td>
<td>D0</td>
</tr>
<tr>
<td>3</td>
<td>D1</td>
</tr>
<tr>
<td>4</td>
<td>D2</td>
</tr>
<tr>
<td>5</td>
<td>D3</td>
</tr>
<tr>
<td>6</td>
<td>D4</td>
</tr>
<tr>
<td>7</td>
<td>D5</td>
</tr>
<tr>
<td>8</td>
<td>D6</td>
</tr>
<tr>
<td>9</td>
<td>D7</td>
</tr>
<tr>
<td>10</td>
<td>Acknowledge</td>
</tr>
<tr>
<td>11</td>
<td>Busy</td>
</tr>
<tr>
<td>12-18</td>
<td>Not connected</td>
</tr>
<tr>
<td>19-28</td>
<td>Ground</td>
</tr>
<tr>
<td>29-36</td>
<td>Not connected</td>
</tr>
</tbody>
</table>

Table 2 Centronics interface connections.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>TxD</td>
</tr>
<tr>
<td>3</td>
<td>RxD</td>
</tr>
<tr>
<td>4</td>
<td>RTS</td>
</tr>
<tr>
<td>5</td>
<td>CTS</td>
</tr>
<tr>
<td>7</td>
<td>Ground</td>
</tr>
</tbody>
</table>

Table 3 RS232 interface connections.
Software
The 128 bytes of zero page RAM are used both for the stack and program variables. The main requirement of the stack is to store registers during a refresh interrupt — using seven bytes at a time. This leaves the entire DRAM free to hold data.

After the buffer has been reset it must decide which operating mode it is in. In order to save components, the CPU I/O lines connected to the LED outputs also drive the mode select decoder (IC2). The decoder is enabled and each output is selected in turn until the return connection causes an NMI interrupt.

The selected output at that time determines the mode. The I/O lines then revert to their normal operation.

The main buffer program selected by the mode switch consists of a never-ending loop. If the buffer has spare capacity, the input source is checked and if more data is ready it is read and put into the buffer. In the case of serial input, if there are less than 64 bytes free then the CTS handshake line is negated. The loop then checks the status of the output port. If there is data in the buffer and the printer is ready to accept it (either by acknowledging the previous byte sent to the Centronics output or asserting the RTS serial handshake line) the next byte is sent.

Again, for serial inputs, the CTS output is asserted if there are over 128 bytes free in the buffer. A branch back to the start of the loop is then made. This alternate sampling ensures the printer is kept supplied with data even if the computer is sending data very rapidly. When receiving serial input, any characters that result from a framing error are ignored. It is less annoying to find a character missing in a piece of text than to have a corrupted character ruin a printout by changing one of the printer's internal settings.

Listing 1

Hex dump of the used sections of the EPROM (see text for first byte).

BUYLINES

The printer buffer uses components which are for the most part easily obtainable from usual suppliers. The case used for the prototype is available from Maplin (part no. XB71N). The 6803 can be bought from Midwich (Tel: (0379) 4131).

The PC board is available from the ETI PC Serviceware and see the back of this issue for details.
The author can supply the source code (£3.00) or the source code and a 6803 assembler (£15) copied onto formatted BBC micro disks supplied by readers.

Programmed EPROMs are available for £6 (reader's 2764 or 2728 EPROM) or £9 (EPROM supplied). Please specify whether the 64K or 256K version is required.
The author will also build and test boards purchased from the PC board service for £70. This includes all on-board components but not the case, switches, connectors and so forth. Please address all inquiries and orders to Leicester Whewell, St. Just, Berrington Road, Tenbury Wells, WR15 8EJ.

without the PCB plugged in and check that each of the supply inputs read 9V relative to ground and that they are at 18V relative to each other.

Plug in the PCB and run the unit in the self test mode. The memory test involves writing to every byte of RAM, waiting 10ms to check the refresh system and then verifying that data. If successful, the EMPTY LED is toggled and next time the process is repeated with a different arrangement of data. A full check on 256K of RAM takes a couple of seconds.

To check the parallel ports, a lead with a Centronics connector at each end is required. By connecting the output to the input, a check is made on the transfer of 256 bytes of data. When the data is verified and separate tests on the handshake lines are satisfactory then the FULL LED is toggled.

If the serial interface is checked in a similar way — by connecting the data lines and the handshake lines together. Tests are performed at 1200 and 9600 baud and if the FULLNESS LED is toggled. If all is well, the buffer is now ready to earn its keep.

ETI

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THE LOGICAL CHOICE

ETI NOVEMBER 1987
Paul Chappell describes how to connect up your computer and your train set to the brainwave monitor.

I got so carried away on the subject of electrodes and biofeedback last month, I had no space to tell you about the output sockets. I'll put that right in this final article.

The circuits I have suggested later on are in the nature of Tech Tips — ideas for you to experiment with and adapt for your own use. Half the fun of electronics is in getting your own circuit designs up and running and since the interface requirements of the monitor are quite straightforward (and the outputs pretty indestructible unless you try really hard) it's the ideal place to start.

Before starting on the circuits I should say a few words about safety. In the earlier articles the monitor has been used as a stand alone, battery powered instrument and as such can't do you any harm. The outputs have been designed to allow the connection of mains powered equipment without undue risk but there are a few precautions to be aware of.

**Safety**

Electronic equipment can and does go wrong. If this happens with a bio-medical device where your body forms part of the circuit, the consequences could be unpleasant and possibly fatal.

The current necessary to harm you depends very much on where the electrodes are placed. From two electrodes on the same hand, for instance, you could take a considerable current without lasting effect. With electrodes on opposite hands, allowing a current path through the heart, a few tens of milliamps may be enough to put you out of action for good.

A rough guide is that 1mA will produce a tingling sensation (like a 9V battery touched to your tongue), 20mA will cause muscle contractions which may mean that you are unable to let go of the conductor, 50mA and above may interrupt the heart rhythm or stop it altogether, cause tissue damage and stop you from breathing.

For safety, the EEG monitor is powered from batteries and all connections to external circuitry are optically isolated. A few simple rules must be observed for your own protection:

- The monitor must not be operated from a mains power supply or 'battery eliminator'.
- The case of the monitor or any part of the circuit or electrodes must not be connected directly or indirectly to earth.
- An indirect connection to mains earth might happen if external equipment is plugged into the monitor's outputs and connection is made to the shell of the plug. Only the pins of the plug should be connected. If you use screened wire, the screen should be connected to the ground pin and not to the plug shell.
- The monitor should not be probed with mains powered equipment (an oscilloscope, for instance) while you are wearing the electrodes.

Household earthing systems are not always as good as they might be, particularly in older properties. Connecting the monitor to mains earth could put you at risk if a fault develops in an appliance anywhere in the house. There is also the possibility that the earth wire may become disconnected and allow leakage currents from (say) a capacitive mains filter to flow through you if you happen to touch a grounded metal object (a central heating radiator, perhaps).

Household safety regulations are made on the assumption that any contact with faulty equipment will be casual and through dry skin. Strapping electrodes to your head and reducing your skin resistance to a low value with saline solution is a different matter altogether!

Please take care. We don't want to lose any readers!

**The Switching Output**

The output from SK3 switches at a level set by R45 and R46. If you set the monitor to *alpha*, this output will be high when you are producing a small amount of *alpha* and low when you produce a lot. It can be connected directly
to a home computer in place of the usual fire button on the joystick. Figure 1a shows how. The other joystick controls can be left connected in the usual way.

You'll have to be a pretty agile alpha producer to play ordinary computer games like this but don't let me discourage you from having a go. Otherwise, you can write programs for yourself which run at a slower pace.

If you saw the BBC's QED program on alpha a few months ago, you may remember Dr. Lewis had his trainees connected to an electric train set. When they produced alpha the train would go, when they didn't it would stop. The easiest way to do this is shown in Fig. 1b.

To select the 'on' speed of the train, short across pins 2 and 3 of the monitor's output socket and set the transformer control to give the speed you want. A small heatsink will be needed for the power FET.

Switching of other low voltage circuits can be achieved in a similar way (Fig. 1c). The capacitor C1 of Fig. 1b will not usually be necessary. It is included in the train controller because train set transformers usually have little or no smoothing.

The 1N4001 rectifier can also be left out. It is included to prevent damage to the circuit if the train set control is reversed. The only components necessary are the FET and a resistor!

The supply voltage for Fig. 1c can be anywhere between 9V and 40V — whatever the load requires. The specified FET will switch currents up to 4A, which should be enough for most purposes! A heat sink will be needed for currents above about 1A. You can use the circuit to give a practical demonstration of mind power by turning a light bulb or radio set on and off.

The switching threshold can be roughly set by varying the monitor's gain control but if you intend to make frequent use of this output, you may like to consider wiring a 47K log pot in place of R46. This will give more direct control over the switching point. The track of the pot is connected across the R46 position and the slider goes to IC6 pin 2. You may have trouble finding room for the extra control on the front panel!

The Analogue Output

The analogue output from SK2 gives a much finer control over computer games than the switching output. A general purpose monitor-to-computer interface circuit is shown in Fig. 3a. The circuit will work with almost any computer with an analogue input port (either built in or as an add-on).

The interface circuit adjusts the output voltage range of the monitor to one which suits the computer. The LM358 was chosen for this circuit because it will operate from the low voltage supply, it takes very little current (less than 2mA) and has an output which will go all the way down to 0V (with the help of R7)!

RV3 sets the gain of the circuit so that a given increase in alpha can make a small or a large difference to the output voltage. RV1 and RV2 set the lower limit of the output voltage. It's useful to have RV2 as a pot rather than a preset — it can then be used as a kind of Y-shift control for the computer screen.

Setting the pots is best explained with reference to an actual game, and by a strange coincidence we've got one for you in Listing 1. The game runs on the BBC micro and will stretch your mental powers to the limit!

Your player starts at the left of the screen with the same aim as the chicken when it crossed the
Listing 1. The BBC Basic alpha wave controlled computer game.

```
10 MODE1
20 ON ERROR RUN
30 DATA 1,15, 1,10, 1,5, 2,4, 15, 3,4, 11,17, 4,3,8,13,17
40 VDU19,0,4.0.23,1,0.0.0.0.
50 VDU23,240,254,254,254,254,254,254,0,0,23,241,239,239,239,239,239,239,0,0,23,255,0,-1,-1,-1,-1,0,23,254,0,127,127,127,127,127,127,0
60 VDU23,242,60,126,219,255,189,219,102,60
70 8$=STRING$(9,CHR$240+CHRS240+CHR$240+CHR$240+CHR$8+CHR$8+CHRS8+CHR$8+CHR$8+CHR$8+CHR$241+CHR$241+CHR$241+CHR$241+CHR$8+CHR$8+CHR$118+CHR$8+CHR$101
80 inc%=2
90 SC=0:FOR screen%=0 TO 5
100 COLOUR130:CLSRCOLOU.RGCOL0,2
110 V01124,8;104;1271;1016;16
120 READN7..FORI%=ITON7.
130 READAX.PRINTTAB(A%.2,11.((screen%+1%)MOD2))13$.
140 MOVEA%.64-4,448-352.((screen%+1%)MOD2):DRAWA70.64-4,1020-352.((screen%+1%)MOD2):DRAWA%.64+124,1020-352.((screen%+1%)MOD2)
150 NEXT I%
160 COLOUR128:PRINTTAB(1,30)SPC(21)
170 COLDUR130.COLOU.RGCOLO:PRINTTAB(25,30).
180 PRINTTAB(37-LEN(STRS(INT(SC))),30)
190 GCOL3,3.FX=FALSE
200 X%= -32,Y%=500
210 I%=INKEY(50)
220 REPEAT
230 SOUND2,-5,100+screen%e10,1
240 I%=INKEY(5)
250 OX%=X%:X%=X%+inc7.:0Y%=Y%
260 Y%=ADVAL(1)/73+128
270 VDU4,23,1,0.0.0.0;
280 COLOU.RGCOLO
290 PRINTTAB(1,30)CHR$240.STRINGS(V7/51-1,CHR$240);SPC(21-Y7./51)
300 COLOUR130:COLOU.RGCOLO
310 SC=SC+0.125
320 PRINTTAB(37-LEN(STRS(INT(SC))),30)
330 VDUS
340 VIK125,4,0X7..0Y74242,25,4,X7.;YX.242
350 IF POINT(XY.+32,YX)>0 OR POINT(X%+32,Y%-32)>0 PROCBOOM
360 UNTIL F% OR X%>1279
370 VDU4,23,1,0;0;0;0;
380 IF F% G0T0430
390 FORN%=0T050.I%=INKEY(4)
400 SOUND1,-10,200+N%O.SC=SC+1
410 PRINTTAB(37-LEN(STR*(INT(SC))),30)
420 NEXT NY.
430 I%=INKEY(80)
440 NEXT screen%
450 COLOUR130:CLS
460 VDU24,80;1271;1016;16
470 COLOUR128.COLOUR3
480 PRINTTAB(14,10).SCORE..INT(SC)
490 TX=TIME:REPEAT UNTIL TIME>T%+1000
500 R INKEY(0)=32
510 inc%=Inc7s2:RESTORE.GOTO 90
520 END
530 DEF PROCBOOM
540 FX=TRUE
550 SOUND1,-10,200.SOUND0,-15,6,20
560 INPROC
```

Fig. 3 Interfacing with the analogue output. (a) The circuit for connection to a micro's analogue joystick input. (b) A more sophisticated train set controller.

road. (To get to the other side — right?) Sad to say, somebody has built a wall in the way, so your player must jump over it. You help him by giving a burst of alpha which makes him light as a feather. Stopping the alpha lets him sink back to earth again.

The first screen has only one wall and moves slowly, so use it to set up the interface. Connect up the electrodes, set the monitor's mode switch to alpha, the output switch to integrate and the gain control to mid position. The sound output may be a distraction, so set it to mute or turn down the volume.

Set all the interface pots to mid position. Adjust RV1 to put the player fairly close to the bottom of the screen. If you've learned to produce alpha, try a burst now and see how far the player moves up the screen. Adjust RV3 to increase or decrease the responsiveness as necessary. If you haven't learned to produce alpha and you're using the game to train yourself, leave RV3 at mid position and adjust RV2 until the player is just a little below the top of the wall. See if you can get your player to float just that bit higher to get over it. The first screen moves very slowly and will give you plenty of time to compose yourself. When you manage to get over the wall, don't go on to the next screen yet. Press Escape to re-start and try again with RV2 adjusted to start your player a bit lower down. Carry on until you can float him from somewhere near the bottom of the screen. You'll need to do this before tackling any of the downward pointing walls or you'll never get underneath!

A simple circuit for speed control of an electric train set is shown in Fig. 3b. The more alpha you produce, the faster goes the train! Q2 will need a substantial heatsink. Set the monitor to alpha, integrate, and about half
PROJECT: EEG Monitor

gain to begin with, and away you go. Choo choo!
That completes the tips on using the monitor but if you invent an interesting circuit or application, don't forget our Tech Tips page — we'd all like to have a go! If you develop exceptional alpha-control abilities we'd like to hear about that too.

Commercial EEG Equipment

Just to put things in perspective, you may be interested to know what you'd get for your money (£5,000 for a cheap 'n' cheerful one) if you bought a commercial EEG machine. Photo 1 shows an elderly EEG recorder of about mid-sixties vintage (kindly lent by Mr. J. Fleming, research physicist at the Queen Mother's Hospital, Glasgow) and Photo 2 shows a currently available model.

The differences between these models are much less than you might think. The essential ingredients are that EEG recorders produce output in the form of a trace on paper and they usually have several channels to make simultaneous recordings from different areas of the scalp.

The essential ingredients of an EEG machine are the electrodes, head box, montage selector, amplifiers and chart recorder.

When an EEG recording is made, the subject or patient will usually be sitting or lying down. The head box is fixed to the chair or couch or to a support close to the subject's head. The box is marked (usually in relation to the 10-20 electrode system) to label each signal that is fed into it.

In the older machine the head box is nothing more than a group of 4mm sockets connected to a cable — there's no electronics inside. The modern trend is to at least buffer the signals at the head box and often to incorporate an electrode tester (an AC resistance meter) and calibration signal source.

Once the signals arrive at the recorder, there's a slight problem. There may be twenty or so inputs and, on a small machine, only eight recording channels! Traces are made from eight electrodes at a time, the selection being changed (say) every five minutes. This requires some kind of switching for different electrode combinations, or 'montages' in the jargon.

It's a little more complicated than just selecting electrodes — there are a number of ways that signals can be combined to produce a recording. The most common is the 'bipolar' recording where the traces show the difference in signals from selected pairs of electrodes. The ETI monitor has a bipolar input — it responds to differences between the signals at the two active electrodes.

The other possibility is to make a unipolar recording, where the signal from each electrode is taken relative to some arbitrary zero reference. The UV signal may be taken from an electrode connected to, say, an earlobe (often both earlobes connected together), or may be an average signal from all the active electrodes.

In the older EEG machine, the left hand half of the box is entirely taken up by a huge multi-way switch which allows various montages to be set up and selected in sequence. At the switch the EEG signals have still not been buffered or amplified!

In modern EEG machines, the Montage selector would very likely consist of a microprocessor, memory and analogue switch ICs.

After the montage switching comes the amplifiers and filters. The amplifiers will usually have switched gain to give a calibrated trace of the selected number of microvolts per centimeter. There will be a high pass filter, usually calibrated in terms of the time constant, and a low pass filter giving a gentle roll off above the frequency range of interest. There will also be a 50Hz notch filter for each channel which can be switched in or out as required.

After the amplifier section comes the chart recorder. This will have various switched paper speeds from 15mm/s to 60mm/s and possibly even faster. EEG machines are not economical on paper! The recorder may have facilities for adding a time marker and possibly an extra channel for a heart signal so that any interference with the EEG can be detected.

Where next?

Our description of the project has now come to an end, so any further experiment is up to you. You may like to develop a fine degree of alpha or theta control or to devise better ways of putting them to use. Whatever you do, we'd like to hear about it — either for our Tech Tips or letters page or for inclusion in a future article.

Just for fun we are offering a prize for the most spectacular or original brainwave feat reported before the end of December 1987. Be prepared to prove it! The prize will be £50 of ETI project kits from Specialist Semiconductors (See the ad in this issue) with extra prizes of £10 each for the two runners up. Prizes will consist of vouchers to be used in full or part payment for the kits and will be awarded at the discretion and whim of the ETI editorial staff.

Winners will be notified early in the new year and reports of any exceptional feats may be featured in future issues of ETI.
difficult. Even if you succeed, the resistance is higher. So that the resistance is higher.

Some crossovers are simple. Especially those involving just a pair of simple capacitors and inductors. These units exhibit slightly non-linear crossover unit to match the drive units, each optimised for a certain range. The signal from the amplifier is split into suitable frequency bands by the use of capacitors and inductors.

However, the crossover units will split the sound into bands introduce their own frequency response. Some designs I have seen have used non-polarised electrolytic capacitors to split off the treble signal. These capacitors can change their value with voltage, which split the sound into bands. These components. This really can kill mechanical resonances.

A small further improvement could be gained by designing the bass and middle amplifiers to have a small negative incremental output resistance, almost enough to cancel the resistance of the coil. The coil would then be virtually incapable of moving in any way not specified by the amplifier. Try it. It really can make a small, great pair of speakers sound like a quite reasonable pair!

Laser Sound

For the 'ultimate' hi-fi loudspeaker, take a good wide range loudspeaker design and add a positional feedback system, perhaps using laser optics, to measure the cone displacement very accurately. Now design a servo system that will allow the cone to follow an input signal over the entire audio frequency range. The electrical output of the servo amplifier may not be much like the input but if the cone reproduces the input signal under all circumstances it doesn't matter a fig, what the servo amplifier is doing internally.

Of course, even with the ultimate loudspeaker system you are still left with the room acoustics which become the dominant extraneous effect.

Andrew Armstrong

A recent decision by British Satellite Broadcasting (BSB), the British franchise holder for DBS television services, puts into doubt the hope that cheap receivers will be available for the promised DBS launch date of 1989. There is now every reason to doubt that a version of the MAC (multi-dual analogue component) transmission format would be used in DBS but as many versions of MAC exist the final choice was largely a matter of national concern. The French and German DBS television systems are to use the version known as D2-MAC and many continental manufacturers agree that the development of the necessary chip sets to allow reception is sufficiently far down the road that D2-MAC receivers are just months away.

To use a D2-MAC DBS system for the British service would have meant two important and useful things: receivers would have been available in Britain quickly and programmes broadcast from one country's satellite would have been receivable (albeit with larger aerial requirements) in another.

But DBS has, however, opted for another version of MAC known as D-MAC. Technically, D-MAC differs from D2-MAC in that it has advantages in the amount of extra facilities which can be incorporated in the transmission. BSB's choice means, though, that the present continental receivers cannot be used to receive British transmissions and vice versa.

British manufacturers now have to design and develop D-MAC chip sets for the British receivers; in 18 months, if the proposed launch date is to be maintained.

It may seem a bit crazy to use an undevolved system when other alternatives are almost in existence and probably cheaper. However, things are a bit more subtle than that.

If we were to use D2-MAC, continental manufacturers could quickly flood our market with little potential profit for British manufacturers. Few continental manufacturers, on the other hand, are likely to develop D-MAC chip sets just to get at the British market (they've already spent a lot of money developing continental chip sets and need to recoup some of that first). There's the rub. To make sure British manufacturers get a fair share of their own market we have to use a different system technique to everyone else. This, of course, is not precedent. The British PAL television system differs sufficiently from continental PAL systems to give the same result.

The BSB decision is a text book delaying tactic to give our own manufacturers time to develop British chip sets and British receivers to suit the British public. I only hope the Japanese haven't got a copy of the same text book!

Keith Brindley
This year’s British Music Fair (held at Olympia between 28th July and 2nd August) was as dull as ever, despite being larger than last year’s event.

London is often heralded as being the hub of the musical world and so it is incongruous, to say the least, that the BMF should have so little to offer with regard to international presence or new product releases.

ADT, AMS, Fairlight, Hybrid Technology, Ibanez, Kurzweil, Lesasonic, Oberheim, OSC, Sequential, Stepp, Synclavier and even Technology, Ibanez, Kurzweil, have so little to offer with regard to being the hub of the musical world and so it is incongruous, to say the least, that the BMF should have so little to offer with regard to international presence or new product releases.

Perhaps the most exciting new products on display at this year’s BMF were the attractively-styled musical socks on the William Elkin Music Services stand.

There must be a good reason for this sad state of affairs and indeed there is one. The show organiser, Philbeach Events, delegates the responsibility of selecting applications from would-be electronic equipment exhibitors to the Music Industries Association.

Membership of the MIA is a prerequisite for exhibiting (reasonably enough) but the catch is that in order to qualify for membership, a manufacturer must be ‘established’, ‘reputable’ and able to provide documentary evidence that it sells goods exclusively via approved distributors and has been doing so for more than one year.

Either that, or you have to be on very amicable terms with the committee which comprises representatives from all the obvious and familiar names except those listed above.

The charter of the MIA is, in their own words, to promote the interests of manufacturers and wholesale distributors. In practice this means keeping competitors and dangerously-innovative smaller firms safely outside the front door.

Sample Software

Steinberg’s ‘Soundworks’ sample editing software is one of a number of good examples of packages that can turn the combination of a MIDI sampler and personal computer into something greater than the sum of its parts.

In this particular instance the sampler is Akai’s 12-bit S900 and the computer is the Atari ST. Capability extends far beyond the usual sample looping, crossfading, enveloping and transposition functions to offer filtering, Fourier analysis/resynthesis, waveform drawing and FM synthesis.

Samples are passed between the ST and S900 via MIDI, using the MIDI Sample Dump Standard (SDS) protocol. This data transfer is twenty-six times slower than the 31.125Kb pace of MIDI but at least samples can be stored on the S900’s floppy disc or replayed instantly, once they have arrived.

We should be aware of the Akai stand as the BMF authorities have made it clear that the sound option will not be available for several months to come.

Apparentely the circuitry was designed in this country and adds not only a 40Mb drive but also a Small Computer System Interface (SCSI) - a popular communication standard. SCSI is fast enough to implement the real-time transfer of two channels of 16-bit, full audio bandwidth and it’s also flexible enough to allow the simultaneous exchange of system and control information.

The increased use of computers in MIDI set-ups has in general highlighted the built-in deficiencies of the MIDI standard (which is now past its fifth birthday) and it might be true to say that many equipment manufacturers, software writers and users are becoming impatient with its limitations. After all, MIDI was never designed to handle the many and varied uses to which it is now being put.

Akai is making a brave move with an interesting piece of equipment which is very amicable to see one piece of equipment that combines the two.

The Amba ‘Multi-function Electronic Tester’ from Goport is a very simple but ingenious piece of equipment that does just that.

The Multi-tester is a bit larger and clumsier to use than a mains testing screwdriver but considerably smaller than most comparable continuity testers.

It’s housed in a plastic case with a sharp insulation-proving piercing tip at the tip. It looks rather like a pulse injector or logic probe.

On the upper face of the case is an LED and a small aluminium panel with the Amba logo screenprinted on it.

When using the Multi-function Tester as a mains tester the probe is placed on the terminal to be tested and the other point touched with a finger or thumb (or any other part of the anatomy, for that matter). Should the terminal be live, the LED lights.

For continuity testing the probe is touched to one point in the circuit, the metal plate touched and the other point touched with your other hand (foot, nose, etc). If there is, and the metal plate is connected, again, the LED lights.

To say this device is simple is overcomplicating matters. Inside the red plastic case there is a circuit comprising all of one transistor, one diode, a capacitor, three resistors and a PP3 battery (plus the LED, of course). I’ll leave it to readers to work out what the circuit is!

This makes it a bit expensive at £12.60. However, this is an extremely useful little companion and well worth a place in your car, briefcase, glove compartment or whatever, for those unexpected emergencies.

As the continuity testing aspect of this device is active rather than just a battery and a bulb (OK, so it’s only one transistor but it’s still active) quite large resistances (with correspondingly small currents flowing through them) can be detected.

This means the tester can be used to check diodes and transistors and when you’re working on the car and want to test the continuity between the tail light and the battery you can either use a length or wire as the return loop or someone’s body! Just hold hands with a helper (or two) to complete the circuit.

The only real criticism of this device is that it makes rather a hole in your pocket, in two ways — it is far too costly and the probe is very sharp and can get most uncomfortable! A better probe cover than the 9/16in piece of plastic sleeving would be a good idea.

However, there is no denying that this is a clever and genuinely useful piece of equipment which will pay for itself after a few instant diagnoses.

The Goport Company
York House
Empire Way
Wembley
HA9 0QH
Tel: 01-903 2065

Bruno Hewitt

There can be no more essential piece of test gear for an electrician than a mains testing screwdriver. There can be no more fundamental piece of equipment for the electronics enthusiast than a continuity tester.

How nice it would be then, to see one piece of equipment that combines the two.

The Amba ‘Multi-function Electronic Tester’ from Goport is a very simple but ingenious piece of equipment that does just that.

Perhaps the most exciting new packages that can turn the combination of a MIDI sampler and personal computer into something greater than the sum of its parts.

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To say this device is simple is overcomplicating matters. Inside the red plastic case there is a circuit comprising all of one transistor, one diode, a capacitor, three resistors and a PP3 battery (plus the LED, of course). I’ll leave it to readers to work out what the circuit is!

This makes it a bit expensive at £12.60. However, this is an extremely useful little companion and well worth a place in your car, briefcase, glove compartment or whatever, for those unexpected emergencies.

As the continuity testing aspect of this device is active rather than just a battery and a bulb (OK, so it’s only one transistor but it’s still active) quite large resistances (with correspondingly small currents flowing through them) can be detected.

This means the tester can be used to check diodes and transistors and when you’re working on the car and want to test the continuity between the tail light and the battery you can either use a length or wire as the return loop or someone’s body! Just hold hands with a helper (or two) to complete the circuit.

The only real criticism of this device is that it makes rather a hole in your pocket, in two ways — it is far too costly and the probe is very sharp and can get most uncomfortable! A better probe cover than the 9/16in piece of plastic sleeving would be a good idea.

However, there is no denying that this is a clever and genuinely useful piece of equipment which will pay for itself after a few instant diagnoses.
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  - Phone for our catalogue
  - 01 452 0161/450 0995 Telex: 914 977
- For Components Ltd, 49 Cricklewood Broadway
- London NW2 3ET

TYNE AND WEAR

ELECTRONIC COMPONENTS AND KITS
- 37 Station Road, Cullercoats,
- North Shields, Tyne & Wear NE30 4PQ
- Tel: 0151 492 1734
- MON-SAT 9.30 to 5.30
- CLOSED THURS.

WE ARE THE BUSINESS FOR QUALITY COMPONENTS
- Turntable belts Head Rams Plugs Leads Snodding iron Akiles Crosswise print copy. Kits etc. Call us the specialists...
- MICROCHIP: MC6800, Laser Printer 913X
- SEND OR PHONE FOR FREE LISTS
- STRACHAN ELECTRONICS, 9 Croall Place, Edinburgh EH7 4LT.
- Tel: 031-251 3349

PAYNE ELECTROPRINT LTD
- Marcus Road, Denkeswell,
- Hornton, Devon EX14 0RA.
- Metal cases manufactured to your design. Your ETI projects professionally silk screen printed. Manufacturers of Printed Circuit Boards.

CLASSIFIED ADVERTISING
- Terms & Conditions
  - Our terms for new advertisers (semi-display and labelled ads are strictly by terms payments until satisfactory reference can be taken up (excluding recognised advertising agencies). Cheques and P.O.'s should be crossed and made payable to ARS SPECIALIST PUBLISHING LTD. and sent together with the advertisements, to:
  - The Classified Dept.,
  - No. 1 Golden Square,
  - London W1R 3AB.
  - There are no requirements for cancellations. All advertisements arriving too late for a particular issue will be inserted in the following issue unless accompanied by payment of the full charge. The publishers will not accept any liability or offer any reduction in charges.
  - All advertising sales subject to Govern- ment Regulations concerning VAT. Advertisers are responsible for in- crumptions to the Trade Description Act, sex discrimination Act and the Serious Legal Requirements in force. The publishers will not accept any liability or offer any cler reduction in charges.

TERMS & CONDITIONS
- We are unable to accept any offers for collateral supplies or services. All offers must be accompanied by a remittance cheque or postal order. Cheques and P.O.'s are strictly by terms payments until satisfactory reference can be taken up.
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JOIN OUR EXPANDING "COMPONENTS" SECTION. RING
- 01 437 0626

MAKE CONTACT WITH MEL
- If you require a TOP
  - QUALITY DESIGN and
  - PRODUCTION SERVICE
  - CIRCUIT DESIGN
  - PROTOTYPE
  - MANUFACTURE
  - PCB ARTWORK LAYOUT
  - ASSEMBLY
  - Quality work by professionals at
  - very competitive prices is the
  - MEL motto.

MEL DESIGN
- PRODUCTION LTD
- Unit 8, Newgate Court
- Paradise Street, Coventry,
- West Midlands CV1 2RU
- Tel: 0203 262 882.
Recognize This?

Now test it.

Whether you are already working in electronics or recognise the above chip because of your favourite hobby, we at Texas Instruments Limited in Bedford are looking for someone like you.

As one of the world's top manufacturers of semiconductors, we can offer you a career in our ASIC Engineering Department. Using our state-of-the-art VLSI computerised equipment in a modern hi-tech environment, your main task will be testing advanced CMOS semicustom integrated circuits as part of our overall quality service to customers.

You are a practical person – both logical and creative – and enjoy solving complex problems. You are good at piecing together complicated "technical jigsaws". Even if you haven't got the usual educational qualifications we will undertake to give you extensive in-house training both at the outset and throughout your career with us.

We will offer you an attractive salary with relocation assistance where necessary and a full range of company benefits including life assurance, a private health-care plan, pension plan, profit sharing and discount sports and social facilities.

Please send a full CV quoting reference VPT 12 to Mrs V. Tilbury, Recruitment Administrator, Texas Instruments Limited, Manton Lane, Bedford MK41 7PA (No agencies).
ETI NOVEMBER 1987

KITS AND READY BUILT

QUALITY KITS

Sensitivc F.M. Wireless microphone £4
VHF/F.M Transmitter in plastic cigarette case £5
Electronic kick with tamper alarm and keyboard £8
Mini Electing Organ with speaker & keyboard £8

ARTKOS ELECTRONICS LTD
46 Warerdes Lane, Salty Park, Birmingham B20 7RE.
Tel: 0522 4352

ETI KITS assembled and tested by electronic trainees under supervision within a purpose built electronic workshop for as little as £10* (*depending on type of kit and complexity) Contact: AJ Smith, Dept. K.A. Electronics Workshop, Lincoln I.T.E.C. Dean Road, Lincoln LN2 4JZ. Tel: 0522 4352.

ELECTRONIC KITS—For those interested in electronics, solar and wind generators, high voltage teslas, surveillance devices, pyrotechnics (including high voltage teslas, surveillance devices, pyrotechnics) all projects included. By A.J. Capstick, Electronic Workshop, Lincoln I.T.E.C. Dean Road, Lincoln LN2 4JZ. Tel: 0522 4352.

PLANS & DESIGNS

ELECTRONIC PLANS, laser designs, solar and wind generators, high voltage teslas, surveillance devices, pyrotechnics and computer graphics tablet 150 projects. For catalogue, SAE to Plancentre Computer Graphics, Unit 42, Bournemouth, Dorset BH6 3JR. Tel: 0202 458375.

RACKZ MOUNTING PRODUCTS

VHF/F.M Transmitter in plastic cigarette case £5
electronic kick with tamper alarm and keyboard £8
mini electing Organ with speaker & keyboard £8
ARTKOS ELECTRONICS LTD
46 Warerdes Lane, Salty Park, Birmingham B20 7RE. Tel: 0522 4352.

RING JULIE CAPSTICK ON 01 437 0626 FOR DETAILS ON SERIES DISCOUNTS

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CLASSIFIED ADVERTISING COUPON
Post to: ETI, 1 Golden Square, London W1A 3RB
Rates:- 44p per word (min. charge £6.60 (VAT incl)). Semi display (min. 2cms) £12.20 (+ VAT) per single column centimetre.
Please debit my Access/Barclaycard No. ____________________________ Expiry date ____________________________
Or enclose my cheque/PO for £ ____________________________ for insertions.

Please use BLOCK CAPITALS and include post codes.
Classification ____________________________
Name (Mr/Mrs/Miss/Ms) ____________________________
Address ____________________________
Signature ____________________________ Date ____________________________
Daytime Tel. No. ____________________________

GCHQ

TRAINEE RADIO OFFICERS

Are you looking for a secure shore-based job which offers rewarding career in the forefront of modern telecommunications technology? Then consider joining GCHQ as a Trainee Radio Officer. Training involves a 52 week residential course, plus 6 weeks extra if you cannot touch type (after which you will be appointed RADIO OFFICER and undertake a variety of specialist duties covering the whole of the spectrum from DC to Light) We offer: Job Security Good Career Prospects Opportunities for Overseas Service Attractive Salaries... and much more.

To be eligible you must hold or hope to obtain an MRGC or HNC in a telecommunications subject with an ability to read morse of 20wpm.

Write or telephone for on application form to:

THE RECRUITMENT OFFICE, GCHQ, ROOM A 1108 OAKLEY Priors Road, CIOLETTI TUNNTAL G5S 6G2 5AL OR TELEPHONE: 05212 23341/2

TRAINEE RADIO OFFICERS

Are you looking for a secure shore-based job which offers rewarding career in the forefront of modern telecommunications technology, then consider joining GCHQ as a Trainee Radio Officer. Training involves a 52 week residential course, plus 6 weeks extra if you cannot touch type (after which you will be appointed RADIO OFFICER and undertake a variety of specialist duties covering the whole of the spectrum from DC to Light).

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THE RECRUITMENT OFFICE, GCHQ, ROOM A 1108 OAKLEY PRIORS ROAD, CIOLETTI TUNNTAL G5S 6G2 5AL OR TELEPHONE: 05212 23341/2

THE RECRUITMENT OFFICE, GCHQ, ROOM A 1108 OAKLEY PRIORS ROAD, CIOLETTI TUNNTAL G5S 6G2 5AL OR TELEPHONE: 05212 23341/2
1988 BUYER'S GUIDE TO ELECTRONIC COMPONENTS

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