NUCLEAR STRATEGY
Electronic simulator to build

PLUS:
SURFACE MOUNTING
PROGRAMMABLE LOGIC DEVICES
TRANSMISSION LINE SPEAKERS
TELEPHONE ALARM

.. AUDIO .... COMPUTING .... MUSIC .... RADIO .... ROBOTICS ...
SOUNDLAB (Full Range Twin Cone)

10" 300 WATT R.M.S. Disco/Sound re-enforcement etc.

10" voice coil. Response 1Hz - 100KHz -3dB, Damping Factor 0.002%, Input Sensitivity 500mV, S.N.R. -125dB Suse 300 x 123 x 60mm. PRICE £33.99 + £3.50 P&P.

Professional 19" cased Mos-Fet stereo amps: Used the World over in clubs, pubs, discos, etc. With the same popular range of toroidal power supplies, XLR connections. MF80 Fan cooled. Three models (Ratings R.M.S. into 4 ohms). Input Sensitivity 75mV. MF200 (100 + 100)W. £169.00 Securicor R.M.S. into 4 ohms). Input Sensitivity 775mV. Size 360 X 280 X 90mm. PRICE £9.99 each + £4.50 P&P.

85R P295 ELECTRONIC TURNTABLE

- Electronic speed control (Philips Accuride) 19"
- Variable pitch control + Belt driven + Aluminium turntable with carbon fibre belt
- Adjustable counter balance + Manual arm + 19" cartridge
- Supplied complete with cut-out template + D.C. Operation
- 14V D.C. 65mA

Price £38.99 + £3.00 P&P.

ACD 04 cartridge for above Price £4.99 ea. P&P £0.50 each.

PIEZO ELECTRO TWEETERS MOTOLORA

Join the Piezo revolution! The low dynamic mass of a piezo crystal produces an improved transient response with a lower distortion level than typical dynamic tweeters. As a result Piezo tweeters are often essential in hi-fi, stereo, home theatre, and inductive loads. In-Phase and cross over filters are not required using Piezo tweeters.

* Suitable for both resistive and inductive loads in numberous applications in industry, the home, and professional performance. R.M.S. into 4 ohms, Frequency Response 1Hz - 20KHz, Frequency Response 0.002%, Input Sensitivity 500mV. S.N.R. -125dB.

Price £9.99 each + £4.99 P&P.

LEVEL CONTROL. Combines on a recessed mounting plate, level control and cabinet input tack socket. 80 - 85 mm Price £3.99 + £0.50 P&P.

STEREO DISCO MIXER

STEREO DISCO MIXER with 1 & 1/2 channel. A.

R. graphic equalizers and twin 10 segment LED VU meters. Many optional features: 5 Inputs with individual faders providing useful combination of the features.

Price £49.99 each + £4.99 P&P.

3 Turntables (Mag). 3 Mic. 4 line plus Mic with talk over switch. Headphone Monitor. Pedal foot L & R Master Output. 1000Watt Output. 775mV Size 360 x 280 x 90mm. PRICE £134.99 - £3.00 P&P.

Prices include V.A.T. * Prompt deliveries * Friendly service * Large S.A.E. 28p stamp for current list.

Ideal for workshops, factories, schools, systems etc. Prices offices, home etc. Supplied ready built.

OVP POWER AMPLIFIER MODULES

Now enjoy a world wide guarantee, reliability and performance at a realistic price. Four models, each with their own special features designed to complement any stereo system. Glass Printed Circuit Boards and0/05% Tolerance to power compatible Vu meter. Open and short circuit proof. Sold in stock for fast delivery. Large selection of McKenzie parts available to suit the needs of the professional and hobby market.

* Easy snap in fixing and medium sized Hi-fi speakers. Price £40 each - 40p P&P.

BUY 1 GET 2 FREE. CANADIAN LEAFLETS SUPPLIED WITH EACH TWEETER

TYPE 'A' (KSN2036A) 2". 1/2" wide dispersion horn. For quality Hi-Fi and professional speakers, disco and PA systems etc Price £10.99 each - 40p P&P.

Type 'C' (KSN1016A) 1/2". 1/2" wide dispersion horn. For quality Hi-Fi and professional speakers, disco and PA systems etc Price £6.99 each - 40p P&P.

Type 'E' (KSN2038A) 3/4". 1/2" wide. high frequency horn with attractive silver finish. Suitable for Hi-Fi monitor speakers. Price £9.99 each - 40p P&P.

LEVEL CONTROL. Combines on a recessed mounting plate, level control and cabinet input tack socket. 80 - 85 mm Price £3.99 + £0.50 P&P.

LUOUDSPEAKERS 6" to 15" up to 400 watts R.M.S.

Supplied ready built and tested.

OMP100 Mk II Bi-Polar Output power: 110 watts R.M.S. into 4 ohms. Frequency Response 15Hz - 30KHz -3dB. Damping Factor 80. Strobe Rate 45v u/s. T.H.D. Typical 0.002%. Input Sensitivity 500mV, S.N.R. -125dB Suse 500 x 230 x 60mm. PRICE £33.99 - £3.00 P&P.

OMF190 Mos-Fet Output power: 110 watts R.M.S. into 4 ohms. Frequency Response 1Hz -100KHz -3dB. Damping Factor 80. Strobe Rate 45v u/s. T.H.D. Typical 0.002%. Input Sensitivity 500mV, S.N.R. -125dB Suse 300 x 123 x 60mm. PRICE £62.99 - £5.00 P&P.

OMF200 Mos-Fet Output power: 200 watts R.M.S. into 4 ohms. Frequency Response 1Hz -100KHz -3dB. Damping Factor 80. Strobe Rate 45v u/s. T.H.D. Typical 0.002%. Input Sensitivity 500mV, S.N.R. -125dB Suse 330 x 147 x 102mm. PRICE £79.99 - £4.50 P&P.

Note: Voc Freq. supplied standard 11000X/kHz. with a S/N ratio of 97db. frees P.A. version (300W) bandwidth & Input Sensitivity 775mV. Order - Standard or P.A.

VOICE coil. Ground ally fixing escutcheon. Response 40Hz - 20KHz Size 24 - 47mm. PRICE £6.50 - 50p ea.

POWER RANGE

6.5" 50 WATT R.M.S. Hi-Fi/Disco

10" 100 WATT R.M.S. Hi-Fi/Disco

3" 3 watt FM transmitter. Price £4.99 ea. P&P £0.50 each.

15" 400 WATT R.M.S. C15400 High Power Bass.


12" Waits R.M.S. per cabinet. Sensitivity 1W 1mtr. dB. Price £134.99 each + £3.00 P&P.

Delivered Securicor £8.00 per pair.

IDEA FOR WORKSHOPS. FACTORIES, SCHOOLS, SYSTEMS ETC. PRICES OFFICES. HOME ETC. SUPPLIED READY BUILT.

BURGLAR ALARM

twin bi-alarms with 3Hz to 3KHz tone.

Superior microphone principle Supplied as three units complete with interconnect cable. FULLY GUARANTEED.

Protective Cover. House wired microphone, receiver, output box and fuses etc. Monitored 24 hour service. £150 - 12". Waits R.M.S. per cabinet. Sensitive 1W 1mtr dB.

Both the control unit and outdoor alarm contain rechargeable batteries which provide full protection over the winter months. AC: 50/60Hz. Expendable with door sensors, panic buttons etc. Complete with replacement batteries. Sold in pairs. £138.00 each.

Save £138.00 each. Usually Price £228.65.

BKE'S PRICE £89.99 + £4.00 P&P.

* Why use a circuit of self assembly能力?

FREE Switcheable filter supplied with each Tone. Price £6.99 ea. P&P £0.50 each.

PRICES INCLUDE V.A.T. * PROMPT DELIVERIES * FRIENDLY SERVICE. LARGE S.A.E. 28P STAMP FOR CURRENT LIST.

UNIT 5, COMET WAY, SOUTHEND-ON-SEA, ESSEX, SS2 6TR TEL: 0702-527572
ALL ABOVE BOARD ..........13
Is small really beautiful? Mike Bedford certainly thinks so and he's been looking into the increasingly popular use of tiny surface mounting components.

CIRCUIT THEORY ..........18
Paul Chappell continues to fathom Fourier and finds it's all not as tricky as it first appears.

HARDWARE DESIGN CONCEPTS ..........21
Top breeders recommend PAL. Who is Mike Barwise to argue with that?

NUCLEAR STRATEGY SIMULATOR ..........28
David Guinness has found détente is not all it's cracked up to be. His simulator lets you prove the point for yourself.

THE ETI KAPPELMIESTER ..........33
Vivian Capell's novel transmission line loudspeakers are cheap to build, small and sound wonderful. What more could you ask for?

RED CURRY ..........26
Helen Armstrong talks to Sinclair's main rival in the 'Founding father of British home computing' stakes.

PROJECT INDEX 1872-1987 ..........Centre Pages
The final pull-out part of the indispensable guide to all of ETI's long history of projects.

MIDI MASTER KEYBOARD ..........40
John Yau's keyboard is really shaping up now with the final circuit board and details of the cabinet construction.

TELEPHONE ALARM ..........44
Barry Taylor has come up with an ingenious way of keeping tabs on his house. Intruders beware!

TECH TIPS ..........52
Some more circuit ideas hot off the backs of readers' envelopes.

REGULARS

NEWS ..........6
NEXT MONTH ..........8
DIARY ..........9
READ/WRITE ..........11
SPECIAL OFFER ..........38
PHOTOCOPIES ..........54
BACKNUMBERS ..........54
PLAYBACK ..........48
BOOK LOOK ..........48

KEYNOTES ..........49
OPEN CHANNEL ..........49
PCB SERVICE ..........50
READERS' FREE ADS ..........53
PCB FOILS ..........56
VELLEMAN KITS OFFER ..........58
CLASSIFIED ADS ..........60
AD INDEX ..........62
DISC DRIVES

These are fully cased and wired drives with slim line high quality mechanisms. Drives supplied with cables manuals and formatting disc suitable for the BBC computer. All 80 track drives are supplied with 40/80 track switching as standard. All drives can be operated in single or dual density format. All floppy discs carry a two year warranty.

<table>
<thead>
<tr>
<th>Type</th>
<th>Details</th>
<th>Price</th>
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<tbody>
<tr>
<td>PS4000 (2 x 400K/2 x 640K 40/80 DT)</td>
<td>New in stock</td>
<td>£129 (a)</td>
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<tr>
<td>PS5000 (640K or 1M)(with PSU)</td>
<td>New in stock</td>
<td>£249 (a)</td>
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<tr>
<td>PS9000 (2 x 400K/2 x 640K)</td>
<td>New in stock</td>
<td>£229 (a)</td>
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<tr>
<td>TD6000 (as PS9800 but with 5 1/4 inch drive)</td>
<td>New in stock</td>
<td>£119 (b)</td>
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<tr>
<td>TD4000 (2 x 400K/2 x 640K 40/80 DT)</td>
<td>New in stock</td>
<td>£135 (b)</td>
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**3M FLOPPY DISCS**

High quality discs that offer a reliable error free performance for life. Each disc is individually tested and guaranteed for life. Ten discs are supplied in a sturdy cardboard box.

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<thead>
<tr>
<th>Type</th>
<th>Price</th>
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<tr>
<td>3M DISCS</td>
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<td>5M DISCS</td>
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<tr>
<td>10M DISCS</td>
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**MICROVITEC: 14" RGB**

14" RGB with PAL & Audio

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<tr>
<th>Type</th>
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<tr>
<td>TAXAN SUPERVISION 620 12&quot; High Resolution</td>
<td>£239 (a)</td>
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<tr>
<td>TS400 1 x 400K/1 x 640K 40/80 TD</td>
<td>£25.00 (d)</td>
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**MONITORS**

All 14" monitors now available in plastic or metal cases, please specify.

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<tr>
<th>Type</th>
<th>Price</th>
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<tr>
<td>TAXAN KX 1201G Hi Res 12&quot; Etched Green Screen</td>
<td>£56 (a)</td>
</tr>
<tr>
<td>TAXAN HX 1202G Hi Res 12&quot; High Resolution</td>
<td>£299 (a)</td>
</tr>
<tr>
<td>TAXAN KX 1201G Hi Res 12&quot; Hi Res Green Screen</td>
<td>£105 (a)</td>
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**SPECIAL OFFER**

2764-25 - 27128-25 - 6264L-15

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<tr>
<th>Type</th>
<th>Price</th>
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<tr>
<td>Serial Mini Patch Box</td>
<td>£21 (d)</td>
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**GANG OF EIGHT INTELLIGENT FAST EPROM COPIER**

Copies up to 6 eproms at a time, £147 (a) £109 (d) £95 (c)

**SOFTLY II**

This low cost intelligent epoxy copier can cope with 27128, 27352, 2764, 2764D and with an adapter, 2649 and 2764. Displays 312 byte page on 2 lines. A parallel or serial output can be used and a serial input can be used by all 2764s.

<table>
<thead>
<tr>
<th>Type</th>
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<tr>
<td>16 pin 2764A connector</td>
<td>£8.50</td>
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**UV ERASERS**

All erasers with built in safety switch and main indicator.

UV1B up to 6 eproms at a time, £47 (c) £28 (b) £15 (d)

UV1 as above but with a timer, £59 (c) £30 (b) £25 (d)

UV1A as above but with a timer, £59 (c) £30 (b) £25 (d)

**CONNECTOR SYSTEMS**

<table>
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<th>Type</th>
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<tr>
<td>D9 CONNECTORS</td>
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<td>D9 CONNECTORS</td>
<td>£8.00</td>
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**TEXTOL ZIF**

Sockets 2 pin £7.00 3 pin £8.00 4 pin £10.00

**MISC CONNS**

21 pin SBC Connector £2.00

8 pin Video Connector £2.00

**ATTENTION**

All prices in this double page advertisement are subject to change without notice.

**ALL PRODUCTS EXCLUDE VAT**

Please add carriage unless specified. All details are subject to change without notice.
IC Firms Fight Health Scare

Electronics companies in America's Silicon Valley are fighting to retain their non-union working policies following the publication of a report which highlights increasing health problems among female workers at a semiconductor plant. Labour and women's rights groups have seized on the findings and used them to challenge the safety of semiconductor manufacturing plants around the world.

Worried by the bad publicity, some companies have refused to employ women on production tasks. Women's rights groups insist this is discrimination and say the companies should concentrate on finding the cause of the problems.

A coalition of concerned groups wrote to the heads of 15 major semiconductor manufacturers and invited them to meet and discuss the report. Many refused, believing that to respond to the letter would compromise recognition on the groups' issues with their representatives and so open up the way to unionisation. This would remove the manufacturers' ability to cut costs rapidly when necessary simply by sacking thousands of workers.

Instead, the industry has responded with an attempt to discredit the report, describing it as 'too small to make it applicable to the industry as a whole'. An internal report is being planned by the Semiconductor Industry Association (SIA) to determine how best to mount a health study. However, many people are critical of the SIA's decision not to accept an offer of help from the University of California, widely recognised as a centre of excellence in occupational health matters.

TV Sound In The Balance

The BBC and the IBA are planning to conduct a series of tests to investigate the intelligibility of dialogue in television programmes.

The initiative follows complaints from people with hearing difficulties who say they cannot follow dialogue easily when it is accompanied by background music, sound effects or audience noises. A working party set up by the two organisations is assessing the intelligibility of dialogue both for people with hearing difficulties and those with normal hearing.
**Z80 Features, Sixteen Bits**

Following the success of the 8-bit Z80 microprocessor, Zilog has introduced a CMOS 16-bit version which offers full compatibility and improved performance. The Z280 can operate in 8- or 16-bit mode, allowing it to use all existing Z80 applications software and to be interfaced easily with Z80 peripherals. In 16-bit mode it can be used with Zilog's family of Z-BUS peripherals.

Improved features include clock speeds from 10 to 25MHz, a 16M byte on-chip memory management unit and a 256 byte instruction and data cache which can be used in conjunction with the burst mode access facility on modern DRAMs. A number of functions which would previously have been carried out by peripheral devices have been built-in to the Z280 including three binary counters/timers, a full duplex UART and four channels of DMA.

Zilog claims to have captured over 80% of the 16-bit market with the Z80 and says the library of software available for the device is the most extensive in the world. The Z280 will allow companies to preserve the value of their investment in Z80 hardware and software while gaining the benefits of improved performance, higher levels of integration and low power consumption.

The Z280 is available now and costs about $27 in quantities of a thousand.

Zilog, 335 Dell Avenue, Campbell, California 95008, United States of America.

**A Job — If You’re Quick Enough**

Students who don’t start job hunting until they have finished their studies are taking an unnecessary risk according to a new report from PA Personnel Services.

Completion for graduates has been building up for several years, and employers now start recruiting as early as October in the final year in order to secure the best students.

Those studying shortage subjects such as electronic engineering or computer sciences may still be able to find jobs once the exams are over, but in general employers are only taking the best and those who show real initiative. Late entry into the employment market is inadvisable in today’s climate of high unemployment, the report says.

**Small PSU For Small Budgets**

The Minipower PSU is a single-rail bench power supply which has been designed to offer good performance at a low price.

At just over £30 inclusive, the Minipower is expected to prove popular with schools and colleges, hobbyists, model-makers and any individual or organisation operating on a tight budget.

The Minipower provides a regulated DC voltage which is continuously variable between 0 and 30V (35V absolute maximum) at currents up to 1.5A. An automatic current limiting circuit protects the supply from overload. The output voltage remains constant to within 0.01% from zero to full load, line regulation is to within 0.3% and the total output noise level is 150uV.

The Minipower PSU costs £31.70 including VAT and postage and is available from Wednesday Electronics, 4 Church Street, Offenham, Worcestershire WR11 5RW. Tel: (0386) 40314.

**Optical Communications The Easy Way**

New data communication link from Hitachi offers all the advantages of fibre optic cable but is as easy to use as an ordinary digital serial interface.

The HAC105 cable has two fibre optic cores to allow full duplex operation and has all the necessary transmit and receive circuitry built into the moulded plugs at each end. A simple PCB-mounting socket allows the cable to be connected directly to logic circuit boards while an active adaptor is available to enable the cable to be used with RS232 links.

The cable is available in standard lengths of 5, 15 and 20 metres with other lengths available to order in suitable quantities. Power for the cable circuitry is derived from the board circuitry where a PCB socket is used or from a mains power unit when the RS232 adaptor is being used.

The cable and adaptors are only available in large quantities at present but Hitachi hope to arrange dealings which will make them available in smaller quantities. A one-off price of around £30 is anticipated for the cable with the ADP51 RS232 adaptors costing around £65.

A brochure giving full technical details of the system is available from Hitachi Optical Components (UK) Ltd, 21 Upton Road, Watford, Hertfordshire WD1 7TP. Tel: (0923) 46488.

**The latest edition of ferranti’s MOSFET handbook contains over 340 pages of data on the company’s range of enhancement mode N and P channel devices. Surface mounting types are now included along with the more traditional TO-92, TO-39 and TO-220 packages and the handbook also features a comprehensive cross reference list of industry part numbers available free-of-charge from Ferranti Electronics Ltd, Fields New Road, Chadderton, Oldham, Lancashire OL2 8NP. Tel: 061-624 0515.**

**A new 44-page colour brochure from PKS-Digiplan Ltd contains a wealth of information on motion control techniques as well as describing the company's range of motor drive and control modules. The topics covered include open and closed loop control of DC and stepper motors, motor and drive selection criteria, torque calculation and inertia matching. There are also demonstrations for a variety of different applications. PKS-Digiplan Ltd, 21-22 Balena Close, Creekmoor, Poole, Dorset BH17 7DX. Tel: (0202) 690 911.**

**Omni Electronics is a recently-established, family-run company which supplies electronic components, kits, tools and accessories. Everything listed in their catalogue is normally available by return of post and the company will also try to obtain 'difficult' components to order. The catalogue costs £38p inclusive from Omni Electronics, 174 Dalkeith Road, Edinburgh EH16 5DX. Tel: (031) 660 2611.**

**A potentially serious bug has been found in the 32-bit multiplier logic of Intel's 80386 microprocessor. About 100,000 of the devices have already been sold but most have been used in 16-bit DOS applications where the bug is not apparent. However, Intel believes that many companies are now planning to use the 80386 in more critical applications and reckons it has about nine months to correct the fault. The cost of field-replacement for faulty devices could run as high as £30 million, a heavy blow for the company which has just returned to profitability after a period of heavy losses.**

**Yes, we know, the supposed safety problem with Amstrad's PC1512 IBM clone was the absence of a mains lead, not the absence of a mains lead as we reported last month. A suitable revenge awaits our news writer should we ever find him again, but just at the moment he seems to have gone to ground.**
CARS CARS CARS
The August issue of ETI contains a whole bundle of stuff for the motorist and the DVLC has graciously decided to bring out a new registration number prefix (E for ETI) in August in our honour.

Keith Brindley has been taking a look at the world of auto electronics. Although high technology has been comparatively slow to filter through to the conservative car industry it looks like things are changing at last.

There's several short and easy projects for the DIY motorist in the August issue too — everything from a car alarm to a very novel rev counter.

PLUS
For readers reliant on public transport, next month's ETI has all the old favourites which go to make up Britain's best loved magazine for the electronics enthusiast. There's projects, features, news, diary, Tech Tips, ads, special offers, letters and so much more.

THE AUGUST ISSUE OF ETI — OUT 3rd JULY
MISS IT AT YOUR PERIL!

All the articles listed are in an advanced state of preparation but circumstances beyond our control may prevent publication.

From Woodworker, Britain's leading woodworking magazine . . .

make your home more secure: doors, windows, alarms, fire precautions and child proofing — it's all in this invaluable do-it-yourself manual.

At your newsagent NOW! or order direct for £1.50 + 50p p&p from Infonet, 10-13 Times House, 179 The Marlowes, Hemel Hempstead, Herts. HP1 1BB.
The Italian Collection

West Hyde has extended its range of instrument cases with the introduction of several new low-cost designs from Teko of Italy. They come in free-standing and wall-mounting varieties, in a range of colours and can be specified with lacquered aluminium front panels, internal PCB mounting slots and many other features. Contact West Hyde Developments Ltd, 9-10 Park Street, Aylesbury, Buckinghamshire HP20 1EF. Tel: (0296) 20441.

Changing Attitudes To Information Technology

Britain is in a good position to take advantage of information technology and meet the challenges of the 21st century, according to a new report from the National Economical Development Office. However, if we are to take up the challenge we need to pay far more attention to education and training, in order to change many of our attitudes.

The report considers the changes likely to result from the application of information technology in Britain in the period up to the year 2010. As well as taking such a long-term view it takes account of values. To bring about positive changes we need to overhaul our educational system. The report describes education as 'massively under-resourced' and calls for expansion coupled with a shift of emphasis from theory to practical application. The present policy of providing science and engineering places at the expense of arts places is rejected by the authors who feel our society will need more of both types of student in the future.

The report is entitled IT Futures . . . IT Can Work and costs £20 inclusive from NEDO Books, Millbank Tower, Millbank, London SW1P 4QX. Tel: 01-271 5989.

UK Telecommunications Networks: Present & Future — June 2-3rd

IEE, London. Conference. Contact the IEE at the address below.

CableSat '87 — June 2-4th

Metropole Hotel, Brighton. Exhibition and conference. Contact Online at the address below.

International ISDN Conference — June 15-18th


Networks '87 — June 16-18th

London. For details contact Online at the address below.

Scottish Technology Week — June 16-18th

Scottish Exhibition Centre, Glasgow. Single event combining the Scottish Electronic Technology Show & Conference, the Scottish Factory Efficiency Show & Conference and OEM Scotland. Contact Cahners at the address below.

Radio Frequency Techniques — July 19-24th

University of Bradford. Vacation school organised by the IEE. Contact them at the address below.

Condition Monitoring For Safety — June 23rd

Regent Crest Hotel, London. Seminar and Exhibition. Contact ERA Technology on (0372) 374 151.

Satellite Communication Systems — July 26-31st

University of Surrey. Vacation school organised by the IEE. Contact them at the address below.

Describing For Electromagnetic Compatibility — September 13-18th

University of Sussex. Vacation school organised by the IEE. See address below.

7th International Display Research Conference — September 15-17th

The IEE, London. Conference covering all aspects of electronic display research. Jointly organised by a number of professional bodies. Contact the Institute of Physics on 01-235 6111.

Design Engineering Show — September 15-18th

NEC, Birmingham. Exhibition and conference covering all areas of engineering including electronics and CAD/CAM. Contact Cahners on 01-891 5051.

IDEX '87 — September 21-23rd

Metropole Exhibition Halls, Brighton. See April '87 ETI or contact Nutwood Exhibitions on (04848) 25891.

Semiconductor International — September

NEC, Birmingham. Covers materials, design assembly and testing of semiconductors. Contact Cahners at the address below.

Internepec — October 6-8th

Metropole Convention Centre, Brighton. Exhibition and conference covering wire, cables, supplies, components and racks/cases. Contact Cahners at the address below.

Automotive Electronics — October 12-15th

The IEE, London. International conference organised by the IEE in conjunction with many other professional bodies. Contact them at the address below.

Conference For Young Engineers — October 16-18th

Strand Palace Hotel, London. Weekend conference on commercial awareness and business skills for young engineers (under 30) of all disciplines. Events include an engineering company simulation game which tests the ideas under discussion. Contact the IEE at the address below.

Radar '87 — October 19-21st

Kensington & Chelsea Town Hall, London. International conference on civil and military systems organised by the IEE and the American IEEE. Contact the IEE at the address below.

International Video & Communications Exhibitions — October 18-21st

Metropole Exhibition Centre, Brighton. Exhibition with seminar programme covering video equipment, services, programme production, etc. Contact Peter Peregrinus Ltd at the IEE address below.

Testmex '87 — October 28-29th

Business Design Centre, London. Exhibition covering all areas of electronic test and measurement. Contact Network Events on (0280) 815 226.

Addresses:

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

Institute of Electrical Engineers, Savoy Place, London WC2R 0BL. Tel: 01-240 1871.

Online Conferences Ltd, Pinner Green House, Ash Hill Drive, Pinner, Middlesex HA5 2AE. Tel: 01-868 4466.
**LEDSCOPE**

**FEATURED IN ETI, JANUARY 1987**

Tony Ellis's famous LED oscilloscope. The complete parts set includes a moulded plastic enclosure, power supply, and all components, with full instructions.

**COMPATIBLE WITH JG66**


d) Tune your engine.
b) Buy a set of fluffy dice and sticker saying "My other car is a..."

**POWERFUL AIR IONISER**

**FEATURED IN ETI, JULY 1986**

Thirdly, I've been introduced to the Plethysmograph, a device that measures the blood volume of a finger or toe. It looks like a little device you plug into a computer and it shows you a graph of the blood flow. It's quite fascinating and I've been using it to help ease my stress levels. The magnification effect is quite remarkable, and it's opening up new possibilities in the field of bioengineering.

**MATCHBOX AMPLIFIER**

**FEATURED IN ETI, APRIL 1986**

No ordinary amplifiers, these. When you put in the music, the audiosignificant parts can be heard, but it's the same thing with all other devices. A complete parts set includes a moulded plastic enclosure, power supply, and all components, with full instructions.

**MAINS CONDITIONER**

**FEATURED IN ETI, SEPTEMBER 1986**

It is astonishing how many people say they are "in power" and don't even realize it. One reason is that the TV or radio is a noisy, dirty, old-fashioned machine. The new Mains Conditioner is designed to do something about this. It is a simple device that connects to the wall outlet and filters out the noise and interference. It includes components to filter the power, including a low-pass filter and a high-pass filter, and a power supply to provide the necessary voltage. The device is designed to be compatible with most modern power systems and can be used with any equipment that requires a clean power source.

**MATCH BOX AMPLIFIERS**

**20W Single IC parts set £5.50**

**50W Bridge Amplifier parts set £8.90**

**L165V Power Amplifier IC, with data £3.10**

**LM2917 EXPERIMENTER SET**

**COMPLTE PARTS SET £9.80**

The LM2917 is a dual运算放大器 that can be used in a variety of applications, including audio amplification, signal conditioning, and power supply regulation. The parts set includes all the necessary components, including the IC, transistors, capacitors, resistors, and diodes, as well as detailed instructions and schematics. The set is suitable for experimenters, hobbyists, and educators, and can be used to build a variety of projects, including audio amplifiers, signal conditioning circuits, and power supply regulators. The set is designed to be easy to assemble and includes full instructions.
Missing MIDI

I am considering building the MIDI Master Keyboard from the May issue and I have had difficulty in contacting Clef Products for the keyboard mechanism.

It seems that this company is no longer trading. Is there another suitable source for the key switches? Jonathan Templar Richmond, Surrey.

Clef Products do seem to have ceased trading but suitable keyboard mechanisms are available elsewhere. Maplin can supply the keyboard mechanics and the individual contact springs and bus bars. Unfortunately the mechanics are only available in 49 and 61 note versions but a 72 note keyboard could easily be constructed from two of these cut down (wasteful but a good source of spares!).

WEM (Tel: 01-761 6568) can provide two octave keyboard mechanisms (which can be joined end to end), complete with bus bars. These may require a little modification but cost only £8 a time.

Radio Activity

My hobby has always been constructing and experimenting with VHF broadcast transmitters (88-108MHz). I have built and quite often use a stereo FM transmitter with 120W output from solid state electronics. The response from listeners over 40 miles away is fascinating.

However, the limits for space travel and defence it is still against the law to transmit in this way without a licence (which will not be granted for this kind of use).

If you get caught (which should not be difficult for the DTI as you must stick out like the radio equivalent of a sore thumb) the DTI will come down on you like the proverbial ton (or even tonne) of bricks with a hefty fine or a spell at Her Majesty's pleasure and confiscate all your gear.

If any other readers still want to get in touch with Mr. Smith they can write to him care of ETI (enclose a stamped envelope) but don't say we didn't warn you!

Decline And Fall

With less children today interested in an electronics career and talent scouts with cheque books from the States awaiting our graduates, I had hoped the recent budget would have done more for our home based science and technology.

Are we going to see a repeat of the hospitals where a nurse finds a more lucrative career serving in a shop nine to five?

The new Silicon Glen in Scotland is very impressive but when you tour this country and see the wilderness of the forgotten heroes, listen to their despair in Durham, Sheffield and Lincoln, you realise every city needs a Silicon Valley of new industries.

Incidentally, I very much enjoyed Anna Paczuska's contribution on 'Bad Health in Electronics' back in the November and December 1986 ETI. More please! With man pushing the frontiers of Electronics Technology to unknown limits for space travel and defence it is extremely interesting to read the problems behind the science of man's capabilities.

Although low power transmitters are legal in some other European countries and plans for similar legislation here have been made (and shelved) it is still against the law to transmit in this way without a licence (which will not be granted for this kind of use).

We couldn't agree more. Interest in electronics as a hobby has certainly declined over the last few years and government funding for research and development and for investment in industry seems set to do its best to kill off what is left of the British electronics manufacturing base.

Any millionaire ETI readers should find a local electronics firm to invest in immediately.

Shock, Horror, Probes

What a surprise you would get if you held the ends of the probes from a resistance meter and got the reading I did. Please explain this one.

C. Ford

Easy one this, for any regular reader of ETI. If you're not a regular reader go and stand in the corner immediately. If you are a regular reader but didn't read the pieces on biofeedback and galvanic skin response back in the November and December 1986 issues, go and stand in two corners (at once).

Skin has a fairly low resistance — anything from about 5kΩ to 1MΩ. The variations in resistance tell you all sorts of interesting things about your body and state of mind. In the ETI office we go around the whole time with probes sticking into bits of our anatomy just to see if we're still awake!
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EEI JULY 1987
ALL ABOVE BOARD

Mike Bedford takes a look at surface mounting components and techniques — the miniature future of electronics.

Throughout the realm of electronics and especially in digital applications, one type of component has become increasingly predominant over the past 15 years or so — the ‘chip’ or integrated circuit housed in one of the various DIL packages.

Of course it is a misnomer to refer to a DIL package as a chip. The actual chip is a small square of silicon embedded inside. The plastic or ceramic housing is provided for purely mechanical reasons. An unpackaged chip could be difficult to handle, prone to damage by environmental factors and impossible to make connections to by conventional manufacturing methods.

Although in the early days the space overhead of DIL packaging was not very significant (most devices requiring only 14 or 16 external connections) this can no longer be said for today’s VLSI devices requiring 40 or 64 pins. Figure 1 shows how in a typical 64 pin DIL package, there is a very high area ratio of packaging to silicon.

Clearly this is inefficient in PCB space and recent moves in IC packaging are providing much greater economy of space. The new ICs also require a departure from conventional PCB assembly methods.

Traditionally, components are mounted through holes in the board making solder connections to the copper tracks on the opposite side to the components. Newer packaging methods are intended for surface mounting which, as the name suggests, means the components are mounted on the surface of the PCB and the solder contact is made on the same side of the board as the components. Figure 2 illustrates the two mounting methods.

Advantages

The most notable advantage of surface mounting is the space saving achieved. This is a result of two factors. Surface mounting packages take up less room than their DIL counterparts. This is not an inherent advantage of surface mounting but results from the fact that a need for efficient board utilisation was a major consideration when the new packages were designed.

Surface mounting devices can also be fitted to both sides of a board.

SIL and DIL Modules

When is a surface mounting package not a surface mounting package? When it is a SIL or DIL module. These forms of packaging provide a means of taking some advantage of the space saving achieved by using surface mounting without the initial capital outlay required to convert to true surface mounting assembly. A SIL module is a small PCB with PLCC packages already mounted on it by the semiconductor manufacturer and pins spaced at 0.1in along its edge. This board can be through mounted on a conventional PCB as a single component. Dynamic RAMs are currently available in this format, a typical SIL pack containing, say, eight 64K x 1 devices giving a capacity of 64K x 8. A DIL module on the other hand is a ceramic substrate with pins along two edges allowing it to match the standard DIL footprint. LCCC packages are mounted on the ceramic substrate and this format is often used for static RAMs.
Although the actual copper pads on the PCB are smaller, significant gains of speed and cost are achieved. But when automated PCB assembly is considered, smaller soldering iron bits and steady hands are required. When surface mounting components by hand, a much greater number of components have to be fitted into holes. Surface mounting also results in PCBs which are less expensive, and space saving becomes even more significant.

The assembly of boards may be slightly more difficult when surface mounting components by hand (a much smaller soldering iron bit and a steady hand are required) but when automated PCB assembly is considered, there are significant gains of speed and costs to be achieved. Although the actual copper pads on the PCB are smaller for surface mounted components, the need for accurately placing leads through small holes is obviated. A moderate degree of inaccuracy in terms of position and rotation of components can be tolerated. A further consideration is that pre-forming passive component leads prior to fitting into holes is no longer required.

Conventional assembly equipment is no longer applicable and so there is a capital outlay requirement on first adopting the technology. However, a long term saving is still achieved.

Surface mounting also claims the advantages of increased reliability (especially where the circuit board is subject to vibration), improved frequency response and decreased immunity to electromagnetic radiation. Of course, there are two points directly attributable to the smaller package size which allows shorter track lengths both within the IC package and on the PCB.

Surface mounting has necessitated improved methods of PCB printing and etching to be developed to cope with the narrower tracks and decreased gaps. Current technology has reduced track widths and spacings to 0.15mm and the through holes to 0.3mm which is sufficient for current surface mounting packages but a further reduction to 0.075mm and 0.1mm respectively will be required for some proposed new packages. Heat dissipation is also a potential problem and is exaggerated by the reduced surface area of the new packages. Some manufacturers have attempted to reduce this problem by incorporating fins onto the packages but the general consensus is that overheating is better avoided than cured. Accordingly, many manufacturers are converting to CMOS for the new devices.

**Packaging**

For well over a decade there has been a high degree of standardisation as far as IC packaging is concerned. ICs for through hole mounting will usually be standard DIL packages.

Surface mounting components are available in a bewildering array of different packages. Clearly there is a need for standardisation in this area and for one or two package types to be accepted as the standard in the same way as the DIL package has been for many years.

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**DIL Package**

The DIL package is currently the standard IC package for through hole PCB assembly. All packages have straight pins spaced at 0.1in in two rows. The row spacing is dependent on the total number of pins in the package. Devices with up to 20 pins use a 0.3in row spacing. For 22 pins the spacing is 0.4in, for 24–40 pins it's 0.6in and for larger devices the row spacing is 0.8in.

New packages (such as the 'skinny DIP' with a row spacing of 0.3in for all ICs) use 0.07in and the pin grid array used for high pin count ICs with a grid of pins on 0.1in centres. All represent attempts to reduce PCB space but are less effective than surface mounting techniques.

**SOP or SOIC**

The Small Outline Package (SOP) or Small Outline Integrated Circuit (SOIC) is a greater departure from DIL packaging having leads on all four sides of a square or rectangle. Like SOICs, the leads are spaced at 0.05in, half the distance of DIPS, but unlike SOICs, the leads are bent under the plastic package in what is referred to as a J-bend. Pin counts available in PLCC are 18, 26, 28, 44, 68 and 84. Currently, logic families, memories, microprocessors, signal peripherals, gate arrays and analogue devices are available in PLCC format.

**PLCC**

Fig. 2 (a) Through hole construction. (b) Surface mounting.
Size Considerations

Surface mounting components are significantly smaller than their DIL counterparts. Figure 3 illustrates this more quantitatively, comparing the surface area of DIL, SOIC, FPP and chip carrier (PLCC or LCCC) packages. Although this graph shows how a very significant saving in board area is achieved, it should be borne in mind that whereas the surface area increases with the square of the linear dimensions, the volume and hence the weight increase with the cube. In other words, the saving in weight will be even more significant so long as we compare similar packaging materials (both plastic or both ceramic).

Discrete Components

As the advantages to be gained by surface mounting integrated circuits would be considerably reduced if discrete components still had to be through mounted, most discrete components are either already available in surface mounting packages or under development. Resistors, capacitors, inductors, diodes and transistors may now be obtained in the surface mounting format from a number of suppliers. Connectors and variable components, on the other hand, are yet to make their

LCCC

The Leadless Ceramic Chip Carrier (LCCC) is similar to the PLCC but has no leads at all, the J-bend leads of the PLCC being replaced by metal contacts moulded into the ceramic body. As LCCCs are thinner than corresponding PLCCs and they lack leads protruding from the package, they are more robust and easily handled by automatic placement equipment. However, they are the most expensive surface mounting package and tend to be used primarily for military applications. Non military uses are mostly microprocessors and EPROMs where a quartz window is required. There are a number of different variants of the LCCC package to accommodate chips of different shapes. For example, there is both a square and a rectangular version of the 28 pin LCCC.

FPP

The Flat Plastic Package (FPP) has probably achieved less overall acceptance than the other three packages but nevertheless is used quite extensively by some manufacturers. Having gull wing leads on all four sides, spaced at even smaller gaps than SOIC, PLCC and LCCC packages, the FPP is well suited for large pin counts.

Currently, FPPs are available with up to 100 pins and the 200 pin package is under development. FPPs have various different pin spacings: 1.0mm, 0.8mm and 0.65mm versions being available and a move to a 0.35mm (0.02in) spacing looking likely.

As the pin spacing decreases as the pin count increases, packages up to 100 pins are all the same size. Clearly a major application of FPPs will be in semi-custom chips, gate arrays, etc - an area in which pin out has traditionally been a major limitation.
appearance in large numbers.

My information on discrete components is based mainly on the Mullard range of surface mounting devices. Although different internal constructions may be adopted by other manufacturers, the case sizes conform to an internationally accepted standard. Discrete components are small but the percentage improvement over through hole mounting components is not as great as with integrated circuits. Since most modern circuit boards are predominantly populated with ICs, however, size is not as critical with discrete components.

One important characteristic of surface mounting discrete components is their ability to withstand high temperatures. The need for this will become clear when we consider assembly.

From a user point of view, there isn’t much to be said about a surface mounting resistor except that they follow the accepted E24 range of values and are very small. The length is only 3.2mm and the width 1.6mm, which compares to a body length of 5mm for a comparable 1/4W conventional resistor. The internal construction consists of a ceramic block on which is deposited a resistive coating which is then trimmed by laser. Metal contacts are fitted at each end in place of leads.

Three technologies are available in surface mounting capacitors — ceramic multilayer, aluminium electrolytic and solid tantalum. The multilayer and tantalum types are similar in appearance to the resistors described above. The electrolytics on the other hand are closer in construction to their through hole counterparts with the aluminium cylinder then encased in a plastic block. Once again small dimensions are a notable feature of these components. Figure 4 shows a surface mounting resistor and two types of capacitor.

**Discrete Semiconductors**

Transistors, MOSFETS and Darlings are available for surface mounting in packages called SOT-23, SOT-89 and SOT-43 (SOT stands for small outline transistor). These SOT packages are very similar in appearance to a diminutive SOIC package with 3 or 4 pins. The SOT-23 and SOT-43 packages are only 3.5mm x 2.7mm and the SOT-89 is a little larger as it tends to be used for Darlington transistors which require a greater heat dissipation. The package used for diodes is the SOD-80. Some typical discrete semiconductors are shown in Fig. 5.

**Assembly Methods**

Conventional assembly involves first inserting the components through holes in the board either by hand.
or by automatic insertion equipment and then passing the PCB through a wave soldering machine.

As the component leads pass through holes in the board the components are held in place while soldering is taking place. This would clearly not be the case with surface mounting components. In this case, some form of adhesive has to be used to secure the components until they are finally soldered. The adhesives used for this purpose fall into two categories — inert adhesive and solder paste.

Ordinary adhesive is used simply to fix the package to the board and is obviously applied to an area of the component well away from its electrodes (for example in the centre of a LCCC package). This type of adhesive is used with wave soldering, but an obvious difference between this and the wave soldering used with through-mounting components is that the solder wave is applied to the component side of the board. This explains why surface mounting packages are designed to withstand high temperatures. Figure 6 illustrates the solder wave method of PCB assembly.

The other type of adhesive (solder paste) is used with a family of assembly methods known as reflow methods. Solder paste is a form of adhesive which actually contains a high proportion of solder powder. This paste is applied to the copper pads of the PCB and the component is fixed to the board by its electrical contacts. The board is then heated to about 260°C at which temperature the solder in the paste melts and forms a solder joint between PCB and component.

Various methods are used for this reflowing. The most widely accepted is vapour phase. In this, the board is placed in the vapour of a boiling inert liquid, usually a fluorinated hydrocarbon. The advantage of vapour phase over other reflow methods is that it enables the reflowing to be carried out at a comparatively low temperature. A constant temperature is achieved without the need for complex control circuitry and the use of an inert atmosphere eliminates the possibility of oxidation. Figure 7 shows a typical arrangement for vapour phase reflow soldering.

Other methods used for reflow heating are infrared, convection, hot air jets, laser and pulse heated solder tools. Of these only infrared and possibly convection offer a viable large scale alternative to vapour phase, the other methods being used for small volume production or repair.

It will be obvious that both board and components are raised to a high temperature during soldering and subsequently both return to room temperature. If the materials used for the PCB and the components have different co-efficients of expansion, there is a very real possibility of stress being placed on the assembly.

In the case of the LCCC and most passive components, this is exaggerated due to the lack of leads which would allow some degree of flexibility. For this reason, a great deal of research has been carried out to find new and more suitable materials for the PCB. New materials used for PCBs for the surface mounting of ceramic chip carriers and which have similar co-efficients of expansion include ceramics and insulated aluminium or copper.

The Future

There is no doubt that surface mounting is the way ahead in the electronics industry, the only questions are How much? and How soon? Today a relatively small percentage of applications have gone to surface mounting due mostly to a resistance to change, the capital outlay required and the higher cost of surface mounting components.

It is generally considered that this price premium is only a short term situation and that by the end of the decade it will be the DIL components which are the more expensive. It is also significant that even now some of the new microprocessor peripherals coming onto the market are only available in PCC or LCCC packages. Despite these factors, however, the move to surface mounting is perhaps not taking place quite as rapidly as predicted only a couple of years ago.

Japan is the current world leader in this technology, being the first country to use it on a large scale in cameras and other consumer goods where space saving is important. About 30% of electronics manufacturing used surface mounting during 1985 in Japan and it is suggested that this will rise to about 50% by 1990.

On the other hand, it looks as if Europe will be using only 35% by the end of the decade. Indications are that it is in the area of active components that the changeover will be most apparent.

Already the world usage of passive components is about 25% surface mounting but the vast majority of transistors used are still leaded. By 1990 it is predicted that the figure for transistors will be approaching 75%.

Certainly time will tell but in the meantime it could be worthwhile getting in some practice with a very small soldering iron and a very steady hand!
Paul Chappell continues to explore the labyrinth of the Fourier series.

Last month I promised you an easy example of a Fourier Series. In all good textbooks (and bad ones for that matter) it is de rigueur to begin with a square wave. Since the calculations are easy, I'll do the same!

In the calculations of the Fourier coefficients, the integrations are carried out over the interval 0 to 2\pi, so to make things really easy let's have a square wave which completes one complete cycle within this period (Fig. 1a).

Our starting point is the series:

\[ f(t) = a_0 + a_1 \cos(t) + b_1 \sin(t) + a_2 \cos(2t) + b_2 \sin(2t) + \ldots \]

If \( f(t) \) is the square wave, this simply says that it is composed of an unknown amount of 'DC', an unknown quantity of 'fundamental' (which is split into a sine and cosine component to avoid the complications of trying to find a phase angle), an unknown amount of 'second harmonic' and so on. Our aim is to find the quantities of each ingredient.

By looking at Fig. 1 it is obvious that the DC component \( a_0 \) is going to be \( 1/2 \)V, but we'll do the calculation anyway. If we integrate the series from 0 to 2\pi all the sine and cosine terms do the vanishing act we saw last month and we are left with:

\[ \int_0^{2\pi} f(t) dt = \int_0^{2\pi} a_0 dt \]

This may bring back terrifying memories of school maths but it's really quite harmless. The left hand side says 'find the area under the square wave over the interval 0 to 2\pi'. Looking at Fig. 1, this is going to be 1 x \( \pi \).

The right hand side says 'find the area under a straight line of 'height' \( a_0 \) over the interval 0 to 2\pi'. From Fig. 1b, it's going to be \( a_0 \times 2\pi \). The 'equals' sign in the middle says 'make the two areas the same'. Once again, it's obvious that the value of \( a_0 \), which will make the two areas the same is \( 1/2 \).

Although it's obvious what the result will be, we'll press on regardless. Replacing \( f(t) \) with the square wave it represents, the result is:

\[ \int_0^{\pi} (1) dt + \int_{\pi}^{2\pi} (0) dt = \int_0^{\pi} a_0 dt \]

What has happened now is that the area under the square wave has been replaced by the area under it when it's equal to 1 (over the first half of the interval from 0 to \( \pi \)) plus the area under it when it's equal to zero (over the second half of the interval from \( \pi \) to 2\pi), which I'm sure you'll agree is the same thing.

Now we do the integrations and end up with:

\[ \pi + 0 = a_0 \times 2\pi \Rightarrow a_0 = \frac{\pi}{2\pi} = \frac{1}{2} \]

We knew it all along, but doesn't it boost your confidence to see the maths trot out the same answer? No! Well, can't please everyone I suppose!

Finding the other coefficient is just as easy. Take \( b_1 \) as an example. Again, start with the series:

\[ f(t) = a_0 + a_1 \cos(t) + b_1 \sin(t) + a_2 \cos(2t) + b_2 \sin(2t) + \ldots \]

Although it's obvious what the result will be, we'll do the calculation anyway. If we integrate the series from 0 to 2\pi all the sine and cosine terms do the vanishing act we saw last month and we are left with:

\[ \int_0^{2\pi} f(t) \sin(t) dt = \int_0^{2\pi} a_0 \sin(t) dt + \int_0^{2\pi} a_1 \cos(t) \sin(t) dt + \int_0^{2\pi} b_1 \sin^2(t) dt + \ldots \]

Now we integrate from 0 to 2\pi (Fig. 2c):

\[ \int_0^{2\pi} f(t) \sin(t) dt = \int_0^{2\pi} a_0 \sin(t) dt + \int_0^{2\pi} a_1 \cos(t) \sin(t) dt + \int_0^{2\pi} b_1 \sin^2(t) dt + \ldots \]

Since all the terms except the one involving \( b_1 \) are zero (Fig. 2d) this leaves:

\[ \int_0^{2\pi} f(t) \sin(t) dt = \int_0^{2\pi} b_1 \sin^2(t) dt \]

Finally, replacing \( f(t) \) by the square wave it represents, the left hand side follows \( \sin(t) \) for half a cycle, then becomes zero for the rest:

\[ \int_0^{\pi} \sin(t) dt = \int_0^{\pi} b_1 \sin(t) dt \]

Now, somehow we have to get rid of all the terms in the series (Fig. 2a) except for the one involving \( b_1 \), (the coefficient we're concentrating on for the moment). If the series is multiplied throughout by \( \sin(t) \), the result is shown graphically in Fig. 2b. It results in all the components having equal areas above and below the axis except for the \( \sin(t) \) part. If we now integrate over one period, the areas above and below the axis cancel out, so all the terms disappear except for the one we're interested in. So, first we multiply through by \( \sin(t) \):

\[ f(t) \sin(t) = a_0 \sin(t) + a_1 \cos(t) \sin(t) + b_1 \sin^2(t) + \ldots \]

Now, the left hand side of this equation says 'find the area under one cycle of a half-wave rectified sine', the right hand side says 'find the area under \( b_1 \sin(t) \) (the two mountain peaks, or whatever else your imagination may make of them, in Fig. 2d). The 'equals' sign says 'make the two areas equal'. This time it's not obvious what value of \( b_1 \) is needed to make the two areas equal, so we'll have to continue with the maths.

There's no need to 'do' the integration on the right hand side — from the orthogonality properties of sines we already know that \[ \int_0^{\pi} \sin^2(t) dt = \frac{\pi}{2} \]

The result is:

\[ \int_0^{\pi} \sin(t) dt = \frac{\pi}{2} \]

The other coefficients are calculated in exactly the same way, so there's nothing to be gained by going through another in detail (but do try one for yourself!). To save time, I'll do all the rest at once:

\[ \int_0^{\pi} \sin(nt) dt = b_n \int_0^{\pi} \sin(nt) \]

Now, somehow we have to get rid of all the terms in the series (Fig. 2a) except for the one involving \( b_1 \), (the coefficient we're concentrating on for the moment). If the series is multiplied throughout by \( \sin(t) \), the result is shown graphically in Fig. 2b. It results in all the components having equal areas above and below the axis except for the \( \sin(t) \) part. If we now integrate over one period, the areas above and below the axis cancel out, so all the terms disappear except for the one we're interested in. So, first we multiply through by \( \sin(t) \):

\[ f(t) \sin(t) = a_0 \sin(t) + a_1 \cos(t) \sin(t) + b_1 \sin^2(t) + \ldots \]

Now we integrate from 0 to 2\pi (Fig. 2c):

\[ \int_0^{2\pi} f(t) \sin(t) dt = \int_0^{2\pi} a_0 \sin(t) dt + \int_0^{2\pi} a_1 \cos(t) \sin(t) dt + \int_0^{2\pi} b_1 \sin^2(t) dt + \ldots \]

Since all the terms except the one involving \( b_1 \) are zero (Fig. 2d) this leaves:

\[ \int_0^{2\pi} f(t) \sin(t) dt = \int_0^{2\pi} b_1 \sin^2(t) dt \]

Finally, replacing \( f(t) \) by the square wave it represents, the left hand side follows \( \sin(t) \) for half a cycle, then becomes zero for the rest:

\[ \int_0^{\pi} \sin(t) dt = \int_0^{\pi} b_1 \sin(t) dt \]

Now, the left hand side of this equation says 'find the area under one cycle of a half-wave rectified sine', the right hand side says 'find the area under \( b_1 \sin(t) \) (the two mountain peaks, or whatever else your imagination may make of them, in Fig. 2d). The 'equals' sign says 'make the two areas equal'. This time it's not obvious what value of \( b_1 \) is needed to make the two areas equal, so we'll have to continue with the maths.

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The result is:

\[ \int_0^{\pi} \sin(t) dt = \frac{\pi}{2} \]

The other coefficients are calculated in exactly the same way, so there's nothing to be gained by going through another in detail (but do try one for yourself!). To save time, I'll do all the rest at once:

\[ \int_0^{\pi} \sin(nt) dt = b_n \int_0^{\pi} \sin(nt) \]
The left hand side is the result of multiplying the square wave by $\sin(\pi t)$. It's equal to $\sin(\pi t)$ over the first half of the interval (0 to $\pi$) and zero thereafter. The right hand side is the remaining term after all except the one involving $b_n$ have vanished.

$$[-1/n \cos \pi t]_n = b_n \Rightarrow b_n = \left\{ \begin{array}{ll} 0 & \text{for } n \text{ even} \\ \pm \frac{1}{n} & \text{for } n \text{ odd} \end{array} \right.$$  

A similar calculation for the cosine coefficients shows that the interval (0 to $\pi$) and zero thereafter. The right hand wave by $\sin(n \pi t)$. It's equal to $\sin(n \pi t)$ over the first half of the values can't be scaled! This doesn't work with non-linear maths or circuits because values which can be scaled afterwards to suit your amplitude of a wave and you double the area under it, because integration is a linear operation (double the spectrum for one square wave, we've found them all. What happens if we want to find the spectrum of a higher frequency square wave? Or higher amplitude one? Or one centred on 0V instead of above it? Do we need to do the calculations all over again? You'll be relieved to hear that having found the time axis can also be scaled for different frequencies. I said earlier that the 0 to $2\pi$ interval represents $2\pi$ seconds, but I could equally well have said $2\pi$ milliseconds, or any other scale I happened to choose.

When calculating a Fourier series it is usual to choose the easiest possible values to work with, which generally means an angular frequency of 1 radian per second and a peak value of 1V. The use of normalised values (easy values which can be scaled afterwards to suit your purposes) is very common in linear circuit theory. (It doesn't work with non-linear maths or circuits because the values can't be scaled!)

As an example, to find the Fourier expansion of an 8V peak-to-peak square wave at 1kHz, varying between $-2V$ and $+6V$, first multiply the coefficients by $8$: 

$$f(t) = 8 \cdot \left( \frac{1}{n} \sin(1000 \pi t) + \frac{1}{3} \sin(3000 \pi t) + \ldots \right)$$

(this wave is of frequency 0.5 Hz, 0 to 8V). Finally, adjust the DC level — the whole wave is shifted ‘downwards’ by 2V, so the mean level will also be 2V lower:

$$f(t) = 2 + 8 \cdot \left( \frac{1}{n} \sin(1000 \pi t) + \frac{1}{3} \sin(3000 \pi t) + \ldots \right)$$

This is 1kHz wave, $-2V$ to $+6V$.

A question I raised last month, but left unanswered, was the range of functions which can be expanded as a Fourier series. In the broadest sense of the question it seems clear that since all the harmonic components repeat after each interval of $2\pi$ the series is only appropriate to continuous, repetitive waveforms. Euler (who derived the ‘Fourier series’ before Fourier did) would have agreed. Fourier himself, with his cavalier attitude to the niceties of maths had no difficulty in accepting that if he could make the series fit over the length of his iron bar, what it did elsewhere was irrelevant.

It’s a notion we feel comfortable with today, but to the mathematicians of Fourier’s time it was a huge conceptual stumbling block. If we do care what the series does beyond the interval of interest, it’s a job for the Fourier integral, which is a story for another day.

On another level, what guarantee do we have that the Fourier series actually matches the initial waveform? Last month I showed graphically how adding extra sines in the correct proportions brought the partial sum (the sum of the harmonic components ‘so far’) closer and closer to a square wave — for the first three at least. Could there be a series in which adding extra sines takes the waveform further and further from the original?

The process of getting a better approximation as more terms are added is called convergence. If the approximation gets worse as more terms are added, the series is said to diverge. The notions of ‘better’ and ‘worse’ are too loose to work with but think about this for a moment.

Suppose I choose some point along the time axis ($\pi/2$, say) for the square wave of Fig. 1, and note the value at that point (it will be 1). Now I'll take the Fourier series for the square wave and calculate the first few partial sums at that point. Taking only the first term, the DC component, it's 1/2. 50% out! Not too good so far. Add in the next term, which is $2/\pi \sin(t)$. At $\pi/2$ this will have a value of roughly $2/3$. Adding to this the first term gives $1/2 + 2/3 = 7/6$, 1/6 too high. The next term has a value of roughly $-2/9$ at $\pi/2$, adding this in gives $77/18$. The value is low again, but only 1/18 out.

With each successive term, the partial sum oscillates about the required value, but the general trend is to get closer to it quite rapidly. From a 50% error to a little over 5% in three terms is not too bad! If this happens for every single point on the square wave and the partial sums remain within any arbitrarily small distance from the true value if enough terms are taken, the series can certainly be said to converge.

The notion of a series converging at every single point is called (naturally enough) pointwise convergence. This aspect of the Fourier series was investigated in detail by Dirichlet (1805-1859). He concluded that a Fourier series will match any continuous waveform with a finite number of turning points. (It can have a million billion of them, a googolplex of them, a moser of them, as many as you like as long as it's finite). If the waveform also has a finite number of discontinuities, it will have a Fourier series which matches it everywhere except at the discon-
continuities, where it will have a value halfway between the points on either side.

An example of a waveform with discontinuities is the square wave. We are used to seeing square wave approximations displayed on ‘scopes, where they have ‘vertical sides’ from a finite rise and fall time, but really a square wave should be drawn as in Fig. 3a. A true square wave leaps instantaneously from one value to another — this is known mathematically as a discontinuity. Dirichlet’s claim is that the Fourier series for the square wave actually adds in spurious points as in Fig. 3b!

It’s easy to see that the series will indeed add in these points. Think about the point \( t = \pi \) where Fig. 1 drops from 1 to 0. Here, every single sine term will have a value 0, so all that remains is the constant term of \( \frac{1}{2} \), which puts in a point smack in the middle of the two square wave values!

What’s going on here? For practical purposes the appearance of a single extra point at each transition makes no difference. After all, a single point lasts for exactly no time at all, so no circuit will ever notice it. But it’s still rather disconcerting to find that the maths is wrong. Thanks to Dirichlet it’s predictably wrong, but wrong all the same.

This is by no means the end of the story. Take the wave in Fig. 3c, for example. It is a square wave except for a few odd points which have gone astray. The Fourier series for this is exactly the same as for a perfect square wave! The common sense reason is that since the Fourier coefficients are calculated by integration, the points have no area beneath them and are therefore ‘invisible’ to the process.

It’s interesting to see how far this notion can be pushed. Clearly, any finite number of points (a million billion, a googolplex, a moser — you name it) will be invisible to the integration. If one point has no area beneath it, a million points will have no area beneath them. There are even some infinite sets of points which will do the trick. If the square wave goes astray on every point in the interval which can be expressed as a rational number (a ‘fraction’) the Fourier coefficients will still turn out with the same values. To see how outrageous this is,

consider that any interval, however small, has a rational number in it. There is not the tiniest portion of the modified square wave where its Fourier series matched it at every point!

At this stage there are two options. You can say ‘Enough of this nonsense!’ and refuse to admit that square waves with points scattered here and there have a Fourier series at all. Alternatively, you can shift the goal posts — devise a new definition of convergence which allows for the fact that it seems to be possible to derive a Fourier series for some very bizarre functions.

Mathematicians, needless to say, have taken the latter course. Research into Fourier series is still a fertile area to this day and a definitive answer to the question of which functions do and do not have a Fourier expansion is still not in sight.

Joseph Fourier
1786-1830

Fourier would probably have thought of himself as a politician rather than a physicist (although he should not be confused with Charles Fourier, the utopian socialist, who was born and died within a few years of J. Fourier). Today he is remembered almost exclusively for his 'Theorie Analytique de la Chaleur' (Analytic Theory of Heat) published in 1822.

Fourier's study of heat conduction led him to believe, by physical rather than mathematical reasoning, that the temperature distribution in a rectangular bar could be expressed as a series of sines and cosines.

He then set off on a most bizarre calculation which involved a Taylor series expansion of functions which didn't actually have one and division by (in effect) infinity. He ignored everything that didn't correspond to his preconceived idea of what the answer ought to be!

Fourier was not the first person to propose sine wave expansions or even to calculate what we now call the Fourier coefficients (Euler had done it some 45 years previously). His outstanding contribution was to recognise the full extent of the validity of the expansion. It had previously been supposed to apply to only a very limited range of functions.

For this insight, Fourier was awarded the Grand Prize of the Academy without having proved a single correct result about the series that bears his name!
Programmable logic devices (PLDs) are frequently considered a great mystery. There is a myth that they are very difficult to use, possibly due to their requirement for programming equipment beyond the pocket of most amateurs.

Designing with PLDs is in fact extremely easy and several suppliers of these devices now run programming services at quite moderate cost (a £25 setup charge is typical) and so the use of PLDs in logic design no longer has to be solely the domain of manufacturing industry.

PLDs come in three basic official categories, PAL, PLE and PLA. It is, however, seldom pointed out that the now familiar EPROM is also a programmable logic device. The assumption that EPROMs only store PROGRAMS is a very limited view of their potential.

I have been asked to mention at this point that PAL and PLE are trademarks of Monolithic Memories, who arguably invented the PAL concept.

Conventional Logic

I do not intend to go into the theory of Boolean algebra here, as there are many good textbooks available. The fundamental concept behind PLDs is worth stating though. The concept is: Any logic function can be reduced to a sum-of-products expression. A sum-of-products expression is a formula equating an output with a set of inputs via the operators AND, OR and NOT. For example the EXCLUSIVE-OR function can be expressed as:

\[ Y = A \cdot B + \overline{A} \cdot \overline{B} \]

where A and B are two inputs, Y is the output, \( \cdot \) means AND, + means OR, the bar means NOT (invert) and = means equals! This relationship is shown as logic gates in Fig. 1.

This axiom holds true for both combinatorial (gates only) and sequential (clocked logic), the only difference being that race conditions establish the timing of combinatorial networks, whereas the outputs of sequential circuits are synchronised by the clock. The conventional symbol for equals in sequential logic equations is := (colon-equals) which is interpreted as results in after clock.

PAL, PLE, PLA: The Differences

Assuming that a finished logic network is constructed according to the axiom given above, there will be considerable variation in the interconnection density at the different levels according to the nature of the logic function implemented. Some functions may need lots of inputs to each AND gate while others need few inputs per AND term but lots of OR inputs from a large AND array. To accommodate these differing requirements, the three types of device have been produced — PAL, PLE and PLA. See Fig. 2.

PAL consists of a programmable AND array with true and inverting inputs to each AND gate, coupled to one fixed OR array per output (Fig. 3). PAL is the most useful when you are designing AND intensive circuits like counters and shift registers. The range of alternative matrix configurations is greater than that of PLE (this is necessary as there is a limited number of AND terms allocated to each OR/output term due to pinout and programming constraints), and many parts have additional ‘higher level’ functions built in, such as registers with feedback into the AND array, or exclusive-OR networks at the inputs to provide additional terms to the array.

PLE is the logic designers’ definition of the familiar PROM. It has a fixed, exhaustively decoded AND array (all possible combinations of all inputs available and no ‘don’t care’ inputs) and a programmable OR array. This is beneficial when you want a complex random logic sequence, or for random block decoders, in fact anywhere your number of alternative output states is the measure of complexity.

Some PLE devices are available with output registers, allowing safe feedback into the PLE or its own outputs. If you can handle the brain strain, this is a method of generating surprisingly complex logic sequences and is the basis of microcontroller design. It is quite possible to cause fed back inputs to conditionally modify the output sequence by gating them externally with real world stimuli.

The PLA is the most complex of the three to work with, but arguably the ultimate in versatility. It has both programmable AND and programmable OR arrays, and
is the next best thing to a fully custom chip layout (Fig. 3). However, design tools for PLA tend to be expensive and flashy (in the £1000-plus bracket) so we won't give these devices much further attention at the moment.

Designing Your Logic

Let us take a very simple problem to start with. Suppose we want to create our own 1-of-8 decoder equivalent to the TTL 74LS138. It can be implemented in a PROM (PLE, EPROM) very easily. There are two common routes to the solution. One is to write out an exhaustive truth table (the whole size of your PROM!) of the data for all addresses (including those not actually required) and then key the PROM output data into a programming file.

The other method is to express the problem as a set of Boolean equations (one for each of the eight PROM outputs) and let a PLE assembler generate the actual programming data. In fact, the limited number of states required (nine) suggests that the latter is the only sensible approach.

The first task is to define the input and output requirements. We must:

- Recognise eight unique input patterns of three bits but only if all enable signals are active.
- Provide a standard null output for all other input patterns.
- Provide eight unique outputs which correspond to the literal binary values of 0-7 in accordance with the relevant inputs.

Supposing we want a direct replication of the 74LS138, we have two low enables and one high enable. However, let us make a small improvement and add another high enable. This gives us three address inputs and four enable inputs (a total of seven) which dictates a PROM size of 128 bytes. We also need eight outputs, so the minimum device is a 128x8 PROM. The sensible EPROM solution is a 2716 (2Kx8) with the three high address lines grounded.

If we design our decoder in EPROM by the truth table method, it is necessary to consider the best choice of address pin for each input. If, for example, the enables were allocated to low address lines (A0, A1, A2, A3) the active data in the EPROM would be widely distributed throughout its memory map (consecutive control bytes 16 addresses apart) which would make data entry very tricky.

The alternative (selection of inputs to simplify the generation of the PROM table) could make the resultant device less easy to connect up in use. A PLE assembly tool such as MMI's Pleasm would automatically handle this problem. As there are no design tools for EPROM, however, we must be our own PLE assembler and we must find a short cut if we want to minimise the possibility of errors and optimise the resultant device. Any short cut will become obvious as soon as the equations for our decoder have been generated, so let's do that next.

The Boolean Solution

The description of the 1-of-8 decoder in sum-of-products form is really very simple. We consider each output in isolation. First we must declare our input and output signals (the constants and variables in our equations).

Let us call our inputs HE1, HE2 (the active high enables), LE1, LE2 (the active low enables), A0, A1, A2 (the three address inputs), and our outputs M0-M7 (memory chip selects).

The universal condition for operation is that all enables are active. So there is a common term to all eight output equations, which is:

\[ ACT = HE1 \cdot HE2 \cdot LE1 \cdot LE2 \]

where ACT is a macro name (a shorthand reference) for the right hand expression. This can be used to reduce the typing burden and improve readability in the remaining equations. The active low enables have been negated to demonstrate their active low status.

Whenever ACT is TRUE (HE1 and HE2 are high and LE1 and LE2 are low) the decoder will generate one of the selectable outputs. ACT is only a theoretical term (the full right hand expression will always by substituted for it eventually) so it can be considered as active high (the default) for convenience.

The equation for M0 (the lowest addressed output) is thus:

\[ M0 = ACT \cdot A2 \cdot A1 \cdot A0 \]

so M0 will go LOW when all enables are active and all three addresses are LOW.

The remaining equations are:

\[ M1 = ACT \cdot A2 \cdot A1 \cdot A0 \]
\[ M2 = ACT \cdot A2 \cdot A1 \cdot A0 \]
\[ M3 = ACT \cdot A2 \cdot A1 \cdot A0 \]
\[ M4 = ACT \cdot A2 \cdot A1 \cdot A0 \]
\[ M5 = ACT \cdot A2 \cdot A1 \cdot A0 \]
\[ M6 = ACT \cdot A2 \cdot A1 \cdot A0 \]
\[ M7 = ACT \cdot A2 \cdot A1 \cdot A0 \]

Note that the outputs are labelled with the NOT symbol to indicate that they are active LOW. All the equations are interpreted in a similar manner to the first.

When this set of equations (which exhaustively describes the 1-of-8 decoder) is fed into a PLE (PROM) assembler, all the internal mapping and address correlation is automatically taken care of and the user only has to specify which device pins he has chosen to perform each function. Similarly, the EPROM user has to decide which pins are which but instead of working out and then keying the whole table into an EPROM programmer, we use our short cut. This consists of
FEATURE: Hardware Design

Fig. 5 A portion of a theoretical PLA.

referencing the chosen inputs and outputs to their theoretical binary weight.

Mapping Into The EPROM

First you choose a convenient input pin for each device input in terms of the physical layout of the final device. You might, for example, want all your enables together at the top left of the chip, and your address inputs below them. At this point you must also decide which inputs are to be used. Note that any EPROM enables must be considered as unused, as these tri-state the device, which we don't want. We are concerned here with address inputs and data outputs only.

Having defined the function of all inputs, you proceed similarly with the outputs. A table of the result of this process demonstrates that each active pin has been assigned a 'binary weight' resulting from its conventional EPROM AD or D values (Table 1). By substitution of these binary weights into both sides of each equation in turn, you arrive at a data byte expected at each of eight unique input addresses (Fig. 6).

Poking these bytes into a table the full size of your EPROM (2K) will produce the desired result (Fig. 6). The large number of 'non-active' states (when the enable term ACT is not true) can be handled by pre-writing the whole EPROM table with FFh. This equates in logic terms to 'all outputs high'.

Any truly 'don't care' inputs (spare address lines) can be hard wired to ground to minimise the size of the required table, otherwise the equations you create must include them as phantom terms. If, for example, eight address lines were present and you have chosen to use the low seven (A0-A6) the table you generate must be duplicated in both the upper and lower halves of the EPROM (selected by A7) unless A7 is assumed hard wired to ground, when only the lower table is needed.

Do not expect much performance from the EPROM decoder. It is really a demonstration rather than a viable option. However the same process applied to a 128x8 or 256x8 bipolar PROM yields a perfectly useable device.

PLE or PAL?

While the 128x8 PROM (PLE) version of the decoder is quite adequate, the number of used terms (in particular the lack of OR terms) makes this decoder a prime candidate for implementation in a PAL.

A PAL is chosen for a given implementation, after the Boolean equations have been written, according to the following criteria:

- How many input pins do you need?
- How many outputs pins do you need?
- How many OR terms per output? If this varies from output to output, is the distribution of OR terms in a given PAL adequate?

This looks surprisingly like the decision set for choice of PLE (PROM), doesn't it? The major difference is the third item. The number of OR terms per output in PAL is fixed so the OR terms matter. Next month we will look in more depth at PAL implementation and consider some more complex examples where PAL scores heavily in terms of neatness and ease of use.

Function | EPROM pin | Binary Weight (hex) |
---|---|---|
HE1 | 1 AD7 | 80 |
HE2 | 2 AD6 | 40 |
LE1 | 3 AD5 | 20 |
LE2 | 4 AD4 | 10 |
A2 | 5 AD3 | 8 |
A1 | 6 AD2 | 4 |
A0 | 7 AD1 | 2 |
GND | 8 A0 | 1 |
M0 | 9 DO | Q1 |
M1 | 10 D1 | Q2 |
M2 | 11 D2 | Q4 |
GND | 12 GND | GND |

Table 1 Binary Weight Table for 1-of-8 decoder in 2716 EPROM. I = input, Q = output, GND = NOT for weighted terms.

**Table 1**

**Function | EPROM pin | Binary Weight (hex) **
---|---|---|
HE1 | 1 AD7 | 80 |
HE2 | 2 AD6 | 40 |
LE1 | 3 AD5 | 20 |
LE2 | 4 AD4 | 10 |
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A1 | 6 AD2 | 4 |
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A0 | 7 AD1 | 2 |
GND | 8 A0 | 1 |
M0 | 9 DO | Q1 |
M1 | 10 D1 | Q2 |
M2 | 11 D2 | Q4 |
GND | 12 GND | GND |

Boolean equation:

\[ M0 = HE1*HE2*LE1*LE2*A2*A1*A0 \]

Assume all inputs/outputs default high:

Input pins A0-A7

Output pins D7-D0

Any included GND = NOT

Expand the equation:

\[ M7*6*5*4*3*2*1*0 = HE1*HE2*LE1*LE2*A2*A1*A0 \]

Substitute EPROM pin names:

\[ D7*D6*D5*D4*D3*D2*D1*D0 = AD7*AD6*AD5*AD4*AD3*AD2*AD1*AD0 \]

Sum the binary weights:

\[ FE (hex) = CO (hex) \]

In other words, program EPROM byte CO (hex) with data FE (hex)

**Fig. 6** Manual function mapping. An example substitution for M0.
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5. Pets
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7. Jazz
8. Travelling
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10. Good food

11. Politics
12. Classical music
13. Art/Literature
14. ‘Live’ theatre
15. Science or technology
16. Creative writing/painting
17. Poetry
18. Philosophy/psychology/sociology
19. History/Archeology
20. Conversation

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RED CURRY

Helen Armstrong finds Chris Curry striving to get back in control.

Chris Curry was in the boardroom of General Information Systems wielding what looked like a twig covered in withered leaves. I remarked the plant did not look well. “On the contrary,” Curry announced. “It’s getting a chance to procreate”. He shook a peppering of seeds from the dried pods into a used envelope, and handed the packet to an assistant with instructions to file it. Chris Curry, former Sinclair collaborator and leading light of Acorn, is still planting for the future.

When Acorn was losing money like a leaky sieve in the race for the cut price micro market and was bought out by Olivetti, co-founder Curry was free to try out a different line of enquiry which had attracted him even before the development of Acorn. He formed General Information Systems (GIS) and with a team of about a dozen people, many former Acorn colleagues, set out to develop and market microprocessor-controlled devices whose application was specific and practical.

Early Days

“When I was first selling microcomputer systems,” says Curry, “it was before the micro boom and we were selling to people like ETI readers who already had an interest in technology. I was always asked ‘what can I do with it?’ This is the most difficult question in the world to answer. If I’d relied on market research, for instance, it would have shown there was no point trying to sell computers because there was no market! Fortunately, we don’t all work by market research.

‘Today the answer to that question is ‘control, timing, energy management, word processing and desk diary’. Interactive control in the home was always talked about but never really achieved except by a few enthusiastic amateurs’.”

Curry’s latest offspring are Red Boxes. Apart from their fire engine colour, Red Boxes could be a cryptic breed of distribution board. They plug into and operate down standard mains wiring and some of them double as mains outlets, but their real task is control.

The first generation of Red Boxes are marketed as add-ons for already popular home micros (BBC micro, Spectrum and Commodore 64) in the form of a £133 starter pack with a control module, a 13A switched outlet and a heat-sensitive movement detector. These are known respectively as Red Leader, Red One and Red Two. “Second World War RAF flying jargon,” explains Curry.

Red Leader contains its own 6502 processor, ROM, RAM and modem. ‘The unit itself detects which computer it is connected to and downloads an appropriate terminal program to the micro. Once programmed, it is no longer dependent on the outside computer, which can be disconnected.

“Anybody with a home computer already has an advantage,” says Curry. They are familiar with keyboard interfaces. There are three million micros out there — mostly Sinclairs, some BBCs and Commodores — which are mostly not being used. A machine which makes them useful again is good in a number of ways. Seeing a computer doing something practical, like switching, has great appeal and putting a discarded machine back into use is highly satisfying.”

In The Future

That assumes centralised microprocessor control will be commonplace in the future. Few people have a clear idea of what they want from it in the home. The old question is still being asked: what do we do with it?

“At the moment,” maintains Curry, “the answers are energy management, security alarms, or simply alarming — like an intelligent timer, but without fiddling with the mains wiring. It’s interesting to notice home security systems are being installed at a rate of knots but they are inflexible. A floodlight is a good deterrent, but only at night. During the day something different (such as a siren) could automatically replace it on the same sensing and timing information. A system which expects different things at different times of the day or year would be even more useful.” A siren (inevitably christened Red Alert) is on the way.

“The next really important step will be a modem which allows you to phone in and bleep the system to alter settings down the line. It will work both ways. It’ll also phone you and indicate if it has received certain readings. No, it won’t speak — we aren’t using voice synthesisers yet! This is particularly important, because people like to be able to change the system remotely.”

With the general extension of remote control into all areas of domestic and business life, the inviolability of these personalised systems has been an important consideration.

Interference

Potential problems of interference between two systems working on the same ring main, and the more sinister threat of accidental or deliberate data tresspass by outside mischief-makers has been forestalled by allocating an incredibly complex address code to each box.

“Anyone trying to break in would have a devil of a time. The data is encrypted in a number of ways. First, there is the large address. Secondly, when the data is sent out it is jumbled with an encryption with a key which is unique to that package of data. Even if they recorded the signal and tried to read it with an oscilloscope, it would remain jumbled. This is unique among mains borne comms systems.”

As they stand, Red Boxes are aimed at micro owners. Programming experience is not required, but it helps. “The system has high programmability at the moment. Red Basic is a bit like BBC Basic with extensions and there is a complete guide to Red Basic in the Basic manual for those who want to get to know the system inside out.”

Eventually there will be a Red Box which is not connected to a computer, with a simple single-line
display, a few buttons, and limited programming possibilities. Even so, will homes be a flourishing market for computer-based hardware in the immediate future? Curry’s attitude is that although it is early days, his boxes have other outlets.

“You could divide Red Boxes into two concepts. On the one hand it is a mains modem, which actually allows you to send digital information along the mains wiring. On the other hand, it is quite a sophisticated communications protocol for point to point serial transmission of data, with a quite powerful control language to go with it. If you put the two things together there are some interesting industrial applications. I don’t have any concrete examples to offer you because the product is too new but at exhibitions a lot of energy management engineers have been showing interest. Security people too. Even in a house, it costs from £500 to £1,000 to have a fairly simple system wired in.”

“These are devices which people can build applications around, enabling devices for all kinds of purposes. People have the opportunity to use their imaginations.

**Communication**

General Information Services, says Curry, was set up to develop the processing of information and the use of computers in information technology. “Computers will be used more frequently for communications than anything else but the information to be carried is not yet available in the quality and quantity needed for the market.”

With their other main project, the Communicator, GIS is looking at ways of introducing a desktop computer which is essentially a remote database terminal with local data manipulation facilities, built in modem and automatic telephony. It can receive Teletext and, with a small modification, Datacast, and can be built into a local area network. “This Communicator was developed by Acorn and they are still marketing it. It’s only available to OEMs at the moment. GIS has the rights to it and we are still working on creating the necessary information base to launch our version. It is a long process, providing a systems house role if you like. We are presenting the hardware with the software, not just the systems house role. People are actually in need of the raw information.

“We are hoping to appeal to the top end of the consumer market, in which case the software must be available as part of the machine. When the Communicator is ready, it must be absolutely straightforward to extract information. You should be able to feed a demand into the computer, and it will search for the database and do the rest. It must be capable of reprocessing the data, of extracting the exact details or figures you want and giving a printout that you don’t have to analyse further. It has half a megabyte of storage — it’s not just a dumb terminal.”

So what is it that appeals to him personally? Developing new ideas, or developing the company as a whole?

“Success. Whether it’s a successful product or a successful company. Both, preferably. The pleasure of seeing something well received, and the added pleasure of seeing it make a profit for the company. I think the two go together. In a small company, which GIS is, if you’re not very close to the conceptual development of a product then you are not close to the company. I’m also very close to the corporate development and strategy of the company. I make no claims to be close to the technical development of the products — there are people much better than me to look after that. But no matter how clever the technology is, if the concept is wrong, the product fails, and vice versa, of course.”

“There are lots of really clever products that have failed because they weren’t marketed properly. The development of a company is an expensive gamble. If you don’t get the market and the product right, you will lose a lot of money.

“Having said that, there are a lot of independent commercial organisations these days where people with an idea can go to get support, without laying out a lot of money. They can get a bit of market research done, or management advice on how best to produce and market the product. That type of support didn’t exist a few years ago. People ought to take full advantage of it, while being careful not to be taken advantage of. Some provide venture capital as well, but I think one should try to separate venture capital from management services. Some sources of capital are offshoots of banks, who probably know less about the management problems of a small company than the inventor of the idea.

“But if you are looking for ongoing management support, it is very important to remember that you must have a good, personal working relationship with any partners. People with ideas don’t like being interfered with. Unfortunately, there are no set rules. You can’t separate being the boffin from running the business in a small company.

“I’m a great believer in working back from the market’s needs. You have to try and imagine what the customer will want and work back to the product without detracting from the craft. As the developer of a product, you are leading the customers. If you ask them what they want, they won’t know. It’s only when they see it they can make a decision. We have to use our imaginations to show people the possibilities open to them. But if the product isn’t right, they won’t have it however clever it is.”
NUCLEAR STRATEGY SIMULATOR

Deterrence is dead, the victim of precisely-targetted Cruise and Trident missiles. So says David Guinness and he sets out to prove it with the aid of a map and a little logic.

Most of us have got used to thinking of nuclear weapons as a simple deterrent: if they launch theirs against us, we'll launch ours back at them. That way, everyone loses so it is in both our interests not to fire first.

This concept of Mutually Assured Destruction (MAD) is out of date in the view of many people. It relied on the fact that missiles were not terribly accurate and a large number would have to be launched against an enemy to ensure complete destruction of important targets. Such an attack could be detected with relative ease long before any missiles arrived, giving the enemy plenty of time to launch their own missiles in response.

Now we have highly accurate weapons such as Cruise and Trident, many of which can fly at low altitude so that they are very difficult to detect until shortly before they hit their target. With this sort of accuracy, missiles can be directed at enemy missile silos and have a good chance of destroying them before the missiles can be launched in return.

The result is a complete reversal of deterrence theory. When it is possible to destroy enemy missiles with little risk to oneself, the best means of defence is to fire first. You may not get enough warning to fire second.

This view is inevitably controversial. Governments don't way to give away a possible advantage so they certainly won't announce that they have a first strike capability in these terms. Indeed, most refuse to concede

Fig. 1 Circuit diagram of the Nuclear Strategy Simulator.
**HOW IT WORKS**

With SW2 closed and SW4 open, the Nuclear Strategy Simulator is set to the DEMO and DETERRENCE modes. One input of ICa and IC1d will be held high and a logic high will appear on the inputs to the two latches (ICa2a and b). These inputs are active low so outputs Q, and Q, will not latch.

When SW1 is pressed the previously high input to ICa is pulled low and a low output level is passed to pin 7 of IC2. The output from pin 9 will go high and remain latched in this state when SW1 is released.

The high output level from the latch is combined in AND gate IC4a with the signal from IC7 and its associated circuitry. IC7 is a 555 timer which generates a low-frequency (roughly 1Hz) square wave. This output is passed via IC3c and IC5e to IC4a and produces a square wave output from which drives Q1/Q2 and causes LP1-5 to flash steadily on and off. These lamps represent USSR cities.

The high level on IC2 pin 9 is also passed to ICb whose output in turn feeds IC4c. The other input of IC4c receives the square wave output from the oscillator circuitry so the output and this gate will also be a square wave. This is inverted by IC5d to Q5/Q6 and causes LEDs 11-20 to flash. These LEDs represent USA missiles.

When SW4 is set to the REAL position, IC3c receives a low on one of its inputs. This stops the oscillator output being passed to the rest of the circuitry. Instead, the output of IC3c goes high and is inverted by IC5e so as to provide a high level on the inputs of the four AND gates, ICa4-d. Pressing SW1 or SW3 now causes one output of IC2 to latch as before and produces a high level on the other input of two AND gates. The resulting high output level is inverted by the buffers IC5a and c or IC5b and d to provide a low level into the transistor pairs. Pressing one of the buttons in the REAL mode therefore causes one set of missile lights and the opposite set of city lights to go out completely.

Moving SW4 from DEMO to REAL also puts a low level on the input of IC6b and a short high level pulse emerges from the differentiating network, C2/R34. This is inverted by IC6a to form a short, low-level pulse input to the two AND gates, IC4a-d. Moving SW4 back to DEMO sends a high level to the other differentiating network, C1/R33, producing a short high level pulse which again inverts IC6a. In this way the two latches are reset every time SW4 is operated.

Opening SW2 transfers the simulator from DETERRENCE to FIRST STRIKE form. R2 pulls up one input on each of the two AND gates, IC3a and b. If SW1 is pressed now, the resulting high on the output of latch ICa2 will take the other input of ICa3 high and place a high level on one input of the OR gate, IC6c, causing its output to go high as well.

The output of IC6c feeds one input of OR gate IC1d which drives the input of latch IC2b. This is designed to prevent the active-low input of IC2b being triggered. In this way, pressing SW1 first prevents SW3 being used and vice versa.

The output of IC1c also feeds the AND gate IC4b, the input of which receives the square wave output from the oscillator circuitry. This signal will be passed to IC5b and the transistor pair Q2/Q3, causing LEDs 1-10 to flash. These LEDs represent USSR missiles.

LEDs 11-20 (representing USA missiles) are passed via IC5d to Q5/Q6 and causes LEDs 11-20 to flash rather than go out. This is helpful while the rules are being explained to players.

**Construction**

All the main circuitry is carried on one printed circuit board which mounts on the back of the map board. The lamps, LEDs and switches are mounted directly through the map board and wired with ribbon cable to three sockets on the PCB.

The only item not mounted on the back of the board is the transformer which will be required for mains operation. This is housed in a separate earthed metal box and only the low-voltage output taken to the Simulator.

The board as it stands is designed to operate from a 6-8V supply, AC or DC. If preferred, the values of the LED series resistors (R12-31) can be altered to allow the Simulator to run from a 12V AC or DC supply such as a car battery. The filament lamps would also need to be changed from 6V to 12V for this. Decide before proceeding which voltage you want the Simulator to run from and select the appropriate resistor values (330R for 6-8V operation, 10R for 12V operation).

The PCB component layout is shown in Fig. 2. Begin assembly by installing the connectors, the fuseholder and the IC sockets (if you plan to use them). The fuseholder has a screw-cap on one end and should be positioned so that this overhangs the side of the board. Insert the resistors and capacitors next and then the transistors. Last of all, solder the ICs into place or install them in their sockets.

The board can be tested by connecting it to a 6V battery or a suitable power supply (you won't need a large battery at this stage because the board draws very little current without the lamps and LEDs). Connect the supply to
SK2 and leave plugs PL1, 3 and 4 empty. Assuming nothing nasty happens at switch on, connect one of the 6V bulbs between V, and the collectors of Q2, Q4, Q6 and Q8 in turn. The bulb should light in each case.

If all seems well, take a piece of wire and briefly short it between OV and the 'TO SW1' connection of PL1. Go back and check the collectors of the four output transistors again. You should find that the bulb lights up when connected to Q8 put flashes when connected to Q2, 4 or 6.

The next stage is to stick the map firmly to its backing board. When complete, it is a good idea to protect the edges of the map and board with tape or edging strip.

Refer to Fig. 3 and drill the holes for the LEDs and filament lamps. Drill the holes from the front of the board and take care not to rip the map.

Drill a further set of holes for the switches, one directly above the other in the lower middle part of the board and one at each side directly below America and the USSR.

The PCB is attached to the back of the board using woodscrews and spacers and the LEDs, lamps and switches are wired using ribbon cable. The LEDs and lamps representing American missiles and cities are wired to one piece of 12-way cable, the LEDs and lamps on the USSR side are wired to another 12-way cable and the four switches are wired to a 6-way ribbon cable.

The wiring of the lights and switches should be obvious from the circuit diagram and component overlay. Each LED has its own resistor on the PCB so ten of the twelve ways on each of the larger connectors are for the LEDs. The remaining connections are a common OV lead for the five lamps and a common V, connection for both the lamps and the LEDs. The only point to watch is that the LEDs must, of course, be wired the right way round.

If you intend using the Simulator from a mains supply, a transformer unit will be needed. This should consist of a metal box with a suitable transformer firmly fixed inside it. The box should be earthed and all the usual care must be taken with the mains input lead and wiring. Use a strain relief bush and include a fuse in the mains circuit.

**In Use**

The Simulator can be used by any number of people from two upwards. Provided clear instructions are printed in a prominent position, it can be left unattended.

### PARTS LIST

<table>
<thead>
<tr>
<th><strong>RESISTORS (all 1/4W)</strong></th>
<th><strong>CAPACITORS</strong></th>
<th><strong>SEMICONDUCTORS</strong></th>
<th><strong>MISCELLANEOUS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>R1, 2, 3, 32 3k3</td>
<td>C1, 2, 6 10n</td>
<td>IC1 4071</td>
<td>FS1 2A 20mm fuse and PCB-mounting holder (fully enclosed type with screw-on end cap — see Buylines)</td>
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<tr>
<td>R4, 6, 8, 10 2k2</td>
<td>C3 1uF 35V tantalum</td>
<td>IC2 4044</td>
<td></td>
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<tr>
<td>R5, 7, 9, 11 802R</td>
<td>C4 470u 16V axial electrolytic</td>
<td>IC3 4081</td>
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<tr>
<td>R12-31 33R or 510R — see text</td>
<td>C5 470u 10V axial electrolytic</td>
<td>IC5 4001</td>
<td></td>
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<tr>
<td>R33, 34, 36 100k</td>
<td></td>
<td>IC6 4049</td>
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<td>R35 1M0</td>
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<td>IC7 355</td>
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<td>IC8 78L05</td>
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<td>Q1, 3, 5, 7 BC109</td>
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<td></td>
<td></td>
<td>Q2, 4, 6, 8 BFY51</td>
<td></td>
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<tr>
<td>LED1-20 0.2&quot; red LEDs, preferably high intensity types</td>
<td></td>
<td>SW1, 3 non-latching push-to-make switch</td>
<td></td>
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<tr>
<td>BR1 5005 bridge rectifier</td>
<td></td>
<td>SW2,4 SPST toggle switch with long shank</td>
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<tr>
<td>LP1-10 6V 60mA wire-ended filament lamps (or 12V 60mA — see text)</td>
<td>PL1 6-way 0.1&quot; PCB plug</td>
<td>PL2 2.1mm DC power plug</td>
<td></td>
</tr>
<tr>
<td>PL3, 4 12-way 0.1&quot; PCB plug</td>
<td>SK1 6-way 0.1&quot; insulation displacement connector</td>
<td>SK2 2.1mm DC power socket, PCB-mounting</td>
<td></td>
</tr>
<tr>
<td>SK3, 4 12-way 0.1&quot; insulation displacement connector</td>
<td>SW1, 3 non-latching push-to-make switch</td>
<td>SW2,4 SPST toggle switch with long shank</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCB; world map; backing board; woodscrews and spacers to mount PCB; ribbon cable, 3-way and 12-way; IC sockets (optional), 1 x 8 pin, 4 x 14 pin, 2 x 16 pin; connecting wire; tape, glue, etc.</td>
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<td></td>
<td>Optional mains transformer unit: chassis-mounting mains transformer with 6-8V output rated at 2A or more (eg., RS/Electromail 207-504 giving 6V at 3.3A); metal case; fuseholder and 1A fuse; cable strain-relief bushes; 3-core mains cable and 2-core low voltage cable; nuts, bolts, etc for transformer mounting.</td>
</tr>
</tbody>
</table>
and people approaching it will work out for themselves what to do. This makes it ideal for use in libraries, in the foyer at conference centres or in any other position where people are passing by.

Where larger groups are expected it is helpful if someone is around to demonstrate the Simulator and explain its significance. In this case, the people present should be divided into two groups ('Russians' and 'Americans'), each of which selects a 'President' to operate the button.

Start with the Simulator set to DEMO and DETERRENCE so that all the lights are on. Explain to the players that the red lights represent missiles and the white lights represent cities. Get one of them to press their button so that one set of missiles and the opposite set of cities start flashing. This represents one superpower using its missiles to threaten the cities on the other side.

Now tell the other side to press their button and show that they can return the threat, causing their missiles and their opponents' cities to flash. Thus either side can launch an attack.

---

Fig. 2 Component overlay for the Simulator PCB.

Fig. 3 Suggested positions for the missile and city lights. The cities have been chosen to give a reasonable geographical spread and do not necessarily represent the five most important strategic targets on each side. The missile sites are largely guesswork since missile silo locations are rarely made public. Note that one missile light on each side has been placed in the sea to represent submarine-launched missiles.
**PROJECT: Simulator**

on the other, but the result will be a return attack on their own cities.

Now set SW4 to REAL (which will reset the flashing lights to full on) and ask both sides how best they can defend themselves. If they have understood the rules correctly they should realise that it would be suicidal to launch an attack.

Switch SW2 from DETERRENCE to FIRST STRIKE and set SW4 back to DEMO. If anyone has been foolish enough to press their button, this will reset all the lights back to full on.

Ask one side to press their launch button now and point out how different the result is. The red missile lights on the attacking side will flash to indicate that the missiles have been fired, but both the city lights and the missile lights on the other side will flash rather than just the city lights as before.

Tell the other side to press their launch button and observe that nothing happens. Because their missiles have been destroyed, they have nothing to fire back.

Now switch SW4 to REAL (which will again reset the flashing lights to full on) and ask both sides once more how best they can defend themselves. If they are anything like the groups which the Simulator has already been tried, they will rapidly realise that the safest thing to do is attack first. With large groups, this can become quite heated with both sides screaming at their ‘President’ to press the button quickly.

**A Final Word**

This simulator shows two very simple scenarios and makes no attempt to represent all the complexities of the international arms race. The aim is to get people thinking about the implications of greater missile accuracy, and once this point has been absorbed there is much that can be discussed and presented by others.

The simulator itself could also be modified to show more complex scenarios. For example, what if only one side has a first strike capability, or if one or both sides have a first strike capability which does not destroy all of their opponents’ missiles? What if Star-Wars technology is added to the equation on one or both sides, allowing any missiles not destroyed by a first strike to be wiped out before reaching their targets? This makes a first strike even more tempting.

**ETI BUYLINES**

Most of the components for this project are readily available from the usual mail-order suppliers. The 6V wire ended-lamps and the fuseholder came from RS/Elmornal (order codes 587-406 and 413-147) and the six and twelve-way PCB connectors came from Maplin. The 500V rectifier was also obtained from Maplin but other 2A, 50V bridge rectifiers should do just as well. Push-button switches with long shanks for SW4 are easy enough to obtain but you may have more difficulty with long-shank toggle switches. The ones used on the prototype came from a surplus store.

World maps can be bought from local bookstores or stationery stores. The one used on the prototype was a 48 x 26in ‘Pioneer’ map from the London Map Centre, Caxton Street, London SW1.
ROBOTICS

Robot arm
- part 1 Sep 1981 50
- part 2 Oct 1981 43
- part 3 May 1982 34
- part 4 Dec 1982 77

Robot motor controller
- part 1 Mar 1982 61
- part 2 Apr 1982 94
- part 3 Mar 1983 59
- part 4 Apr 1985 48

Servo arm interface
- part 1 Sep 1986 36
- part 2 Oct 1986 48

SECURITY

Alarm alarm
- Jul 1977 29
- Jul 1978 16
- Oct 1978 9

Alarm module
- Nov 1982 16

Alarm, ZX-based
- Dec 1983 31

Anti-theft auto alarm
- Jan 1974 16

Automatic car-theft alarm
- Aug 1972 50

Automatic light switch
- May 1984 19

Automatic porch light
- Jul 1980 77

Banshee siren unit
- Sep 1984 35

Burglar alarm system
- Apr 1977 27

Burglar proof your home
- Jun 1977 24
- Jul 1974 30
- Jul 1975 24

Car alarm
- Mar 1975 24
- Dec 1978 16
- Oct 1983 66

Car security device
- Apr 1980 50

CMOS burglar alarm
- Apr 1975 51
- Jan 1978 16

Combination lock
- Mar 1981 74

Ecolight
- Jul 1984 55

Electronic combination lock
- Mar 1975 46

Home security system
- Aug 1981 18
- Jan 1982 16

Infant guard
- Jul 1972 54

Infra-red intruder alarm
- Feb 1981 62

Infra-red Intruder Alarm
- Jul 1984 61
- Aug 1984 59
- Jul 1986 56

Logic lock
- Jun 1982 79
- Jul 1982 39

Porch light

Proximity switch
- Oct 1978 75

Radar intruder alarm
- Aug 1975 21

Second line of defence, the —
- simple house alarm
- Nov 1985 60

Ultrasound burglar alarm
- Aug 1980 86

Warlock alarm system
- Jul 1984 35

Watchdog home security system
- Aug 1981 18

ZX-based alarm
- Dec 1983 31

TELEVISION AND VIDEO

CCTV camera
- Dec 1977 46

Colour board for the Ace microcomputer
- Apr 1984 41

Digital framestore
- May 1984 69
- Dec 1984 61
- Jan 1985 44
- Feb 1985 55
- Mar 1985 59
- Apr 1985 48

Low-cost framestore
- Sep 1986 36
- Oct 1986 48

Low-cost VDU interface
- Nov 1986 43

RGB-composite converter
- Jul 1979 20

Teletext decoder
- Aug 1979 41

TV chess game
- Oct 1976 48

TV games unit
- Sep 1980 73

TV sound tuner
- Dec 1981 37

UHF aerial preamplifier
- Aug 1973 34

VDU Interface (System 68)
- Jun 1977 33

Vector graphic display
- Jul 1977 54

Videograph — TV audio display
- Apr 1979 27

Video Vandal
- Nov 1984 50

TEMPERATURE MEASUREMENT AND CONTROL

Differential temperature switch
- Module
- Mar 1981 49

Digital thermometer
- Oct 1977 20

Economical heater controller
- May 1982 22

Freezer alarm
- Jul 1982 35

Heater controller
- Dec 1977 30

Heat/light controller
- Oct 1982 25

Heat pen — temperature probe for DVMs
- Jun 1985 48

Immersible heater
- Jun 1983 65

Micropower thermal alarm
- Oct 1981 68

Temperature meter
- Dec 1973 23

Temperature meter
- Nov 1974 25

Temperature meter
- Mar 1977 53

Temperature meter
- Apr 1986 44

Temperature meter
- Nov 1984 63

Temperature controllers, three
- Mar 1975 18

Temperature meter
- Aug 1974 30

Temperature meter
- Jul 1978 21

Temperature meter add-on for voltmeters
- May 1976 49

Thermometer — max/min memory thermometer
- Apr 1983 70

Under temperature switch module
- Jul 1983 20

Wine temperature meter
- Dec 1978 31

TEST EQUIPMENT

1kHz function generator
- Mar 1977 55

All purpose power supply, 30V, 1A
- Aug 1978 75

Amplifier, bench (Short Circuit)
- Feb 1977 52

Amplifier, bench
- Aug 1979 67

Amplifier, bench
- Dec 1980 74

Analogue/digital probe
- Apr 1986 36

ETI Modular Test Equipment
- May 1973 53

Attenuator, audio
- Sep 1976 62

Attenuator, RF
- Oct 1986 43
<table>
<thead>
<tr>
<th>Project</th>
<th>Mth</th>
<th>Yr</th>
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<td>Audio frequency meter</td>
<td>Jul</td>
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<td>Audio millivoltmeter, 'A' weighted</td>
<td>Apr</td>
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<td>26</td>
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<td>Audio noise generator</td>
<td>Apr</td>
<td>1976</td>
<td>22</td>
</tr>
<tr>
<td>Audio oscillator</td>
<td>Nov</td>
<td>1980</td>
<td>27</td>
</tr>
<tr>
<td>Audio oscillator with LCD DFM</td>
<td>Nov</td>
<td>1978</td>
<td>71</td>
</tr>
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<td>Audio power meter</td>
<td>Jun</td>
<td>1976</td>
<td>29</td>
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<td>Audio power meter</td>
<td>Mar</td>
<td>1979</td>
<td>67</td>
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<td>Audio spectrum analyser</td>
<td>Mar</td>
<td>1978</td>
<td>27</td>
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<td>Audio wattmeter</td>
<td>Oct</td>
<td>1973</td>
<td>46</td>
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<td>Autoranging capacitance meter</td>
<td>part 1</td>
<td>1982</td>
<td>108</td>
</tr>
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<td>Basic power supply, 4.5A-12V, 0.4A</td>
<td>Oct</td>
<td>1974</td>
<td>53</td>
</tr>
<tr>
<td>Bench amplifier (Short Circuit)</td>
<td>Nov</td>
<td>1974</td>
<td>71</td>
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<td>Bench amplifier</td>
<td>Dec</td>
<td>1980</td>
<td>74</td>
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<td>Bench amplifier, 10pF-10uF</td>
<td>Feb</td>
<td>1977</td>
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<td>Jul</td>
<td>1976</td>
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<td>1982</td>
<td>108</td>
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<td>Capacitance meter</td>
<td>Apr</td>
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<td>Capacitance meter, direct-reading</td>
<td>Nov</td>
<td>1984</td>
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<td>Capacitance meter (ETI Capacitometer)</td>
<td>Mar</td>
<td>1987</td>
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<td>Nov</td>
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<td>1986</td>
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<td>1986</td>
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<td>CMOS IC tester</td>
<td>Aug</td>
<td>1984</td>
<td>64</td>
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<td>Sep</td>
<td>1984</td>
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<td>Component bridge (RCL bridge)</td>
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<td>1985</td>
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<td>Counter/timer module (ETI Modular Test Equipment)</td>
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<td>Cross hatch generator</td>
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<td>1981</td>
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<td>Jun</td>
<td>1977</td>
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<td>Digital frequency meter, 0-150MHz</td>
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<td>1977</td>
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<td>Nov</td>
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<td>Aug</td>
<td>1978</td>
<td>23</td>
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<td>Digital test meter (DMM/DFM)</td>
<td>Sep</td>
<td>1983</td>
<td>51</td>
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<td>Digital voltmeter</td>
<td>Sep</td>
<td>1980</td>
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<td>Mar</td>
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<td>Oct</td>
<td>1975</td>
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<td>1984</td>
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<td>Distortion Meter</td>
<td>Jan</td>
<td>1985</td>
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<td>Feb</td>
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<td>Mar</td>
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<td>Apr</td>
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<td>Oct</td>
<td>1974</td>
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<td>Dummy load for audio testing</td>
<td>Jul</td>
<td>1981</td>
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<td>Frequency counter module, 1 MHz</td>
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<td>Frequency counter, PLL</td>
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<td>Frequency meter, digital, 0-150 MHz</td>
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<td>Frequency meter, digital (Short Circuit)</td>
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<td>1977</td>
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<td>Frequency meter, linear</td>
<td>Jul</td>
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<td>99</td>
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<td>Frequency meter module for DVMs (free PCB Project)</td>
<td>Apr</td>
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<td>Function generator, 1kHz (Short Circuit)</td>
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<td>1979</td>
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<td>1982</td>
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<td>IC power supply</td>
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<td>IF strip tester (Free PCB project)</td>
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<td>Impedance meter, direct reading</td>
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<td>Instrument probe, high-impedance</td>
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<td>Sep</td>
<td>1981</td>
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<td>LEDscope AF flat-screen oscilloscope</td>
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<td>1987</td>
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<td>Linear frequency meter, 100Hz-100kHz</td>
<td>Jul</td>
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<td>Nov</td>
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<td>Logic/analogue probe (ETI Modular Test Equipment)</td>
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<td>Logic analyser (ETI LEDline)</td>
<td>Feb</td>
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<td>1976</td>
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<td>Logic probe, dual</td>
<td>Sep</td>
<td>1982</td>
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<td>Logic probe, TTL/CMOS</td>
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<td>Logic tester, CMOS</td>
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<td>Logic-trigger for oscilloscopes</td>
<td>Mar</td>
<td>1979</td>
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<td>Loudspeaker squeaker</td>
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<td>1984</td>
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<td>Low-ohm meter, 0.1-100R FSD</td>
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<td>1981</td>
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<td>Marker generator</td>
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<td>Memory 'scope display</td>
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<td>Meter mount (multimeter stand)</td>
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<td>Millifaradometer — large-value capacitance meter</td>
<td>Nov</td>
<td>1983</td>
<td>44</td>
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<td>Millivoltmeter, audio, 'A' weighted</td>
<td>Apr</td>
<td>1976</td>
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<td>Modular test equipment</td>
<td>Oct</td>
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<td>Multimeter &amp; digital</td>
<td>Apr</td>
<td>1985</td>
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<td>Multimeter, LCD digital</td>
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<td>Oscillator, audio, with LCD DFM</td>
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<td>Oscillator, sweep</td>
<td>Aug</td>
<td>1977</td>
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<td>May</td>
<td>1982</td>
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<td>Oscilloscope, flat-screen AF (ETI LEDscope)</td>
<td>Jan</td>
<td>1987</td>
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<td>Oscilloscope logic trigger</td>
<td>Mar</td>
<td>1979</td>
<td>39</td>
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<td>Oscilloscope memory display</td>
<td>Nov</td>
<td>1985</td>
<td>28</td>
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<td>Oscilloscope probe, high-impedance</td>
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<td>1982</td>
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<td>Mth Yr</td>
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<td>Oscilloscope, television</td>
<td>part 1</td>
<td>Jul 1983</td>
<td>21</td>
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<td>part 2</td>
<td>Aug 1983</td>
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<td>27</td>
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<td>PLL frequency counter</td>
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<td>part 2</td>
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<td>39</td>
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<td></td>
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<td>Feb 1976</td>
<td>25</td>
<td></td>
</tr>
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<td></td>
<td>Mar 1976</td>
<td>57</td>
<td></td>
</tr>
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<td>Transistor tester</td>
<td>Jul 1974</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>True RMS voltmeter</td>
<td>Mar 1978</td>
<td>13</td>
<td></td>
</tr>
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<td>TTL supermeter</td>
<td>May 1975</td>
<td>30</td>
<td></td>
</tr>
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<td>Jul 1982</td>
<td>50</td>
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<td>TV pattern generator</td>
<td>Nov 1976</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>TV storage 'scope</td>
<td>Jul 1983</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aug 1983</td>
<td>30</td>
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<tr>
<td></td>
<td>Sep 1983</td>
<td>46</td>
<td></td>
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<td>Videograph TV oscilloscope</td>
<td>Apr 1979</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Versatile grid dip oscillator</td>
<td>Aug 1975</td>
<td>34</td>
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</tr>
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<td>Voltmeter, digital</td>
<td>Mar 1977</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jun 1977</td>
<td>9</td>
<td></td>
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<td>Dec 1972</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Voltmeter module, digital</td>
<td>Oct 1975</td>
<td>18</td>
<td></td>
</tr>
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<td>Voltmeter, true RMS</td>
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<td>13</td>
<td></td>
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<td>36</td>
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</tr>
<tr>
<td></td>
<td>Feb 1973</td>
<td>58</td>
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<td>46</td>
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<td>Jun 1978</td>
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<td>Apr 1972</td>
<td>36</td>
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</tr>
</tbody>
</table>

A number of errors have come to light since the publication of the first part of this index in the April 1987 issue. The correct entries are given below in the sequence in which they appear.

**Under the heading AUDIO (page 1 of the index):**

- 2040 II active loudspeaker. September 1982 page 46: a correction concerning this article was published on page 75 of the November 1982 issue;
- Balanced line preamplifier: this article appears on page 38 of the May 1983 issue, not page 63 as stated;
- FM tuner with digital frequency display: this article appears on page 21 of the September 1978 issue, not page 71 as stated;
- Headphone adapter: this article appears on page 53 of the March 1976 issue, not page 52 as stated;
- Preamplifier, RIAA: this article appears on page 98 of the September 1980 issue, not page 73;

**Under the heading CLOCKS and Timers (page III of the index):**

- STAC timer: this article appears in the September 1978 issue, not the September 1981 issue.

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**Errata**

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FIFTEEN YEAR INDEX

XV
**CAPACITORS**

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
<th>Marking</th>
</tr>
</thead>
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<td>500V</td>
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</tr>
<tr>
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<td>500V</td>
</tr>
</tbody>
</table>

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- 5K, 6K8, 10K, 12K, 15K, 22K, 27K
- 33K, 39K, 47K, 56K, 68K, 82K
- 100K, 120K, 150K, 180K, 220K
- 270K, 330K, 390K, 470K, 560K

**SKELETON PRESETS**

- Horizontal 19
- Vertical 19

**OPTO ISOLATORS**

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
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<td>120</td>
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<tr>
<td>Triac driver</td>
<td>150</td>
</tr>
</tbody>
</table>

**ZENER DIODES**

- BZY85C 500mW
- 4V7
- 10V
- 12V
- 24V
- 24V

**LINEAR ICs**

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
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<td>ZN416</td>
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</tr>
</tbody>
</table>

**TRIACS**

- 3 Amp 400V
- 8 Amp 400V
- 90

**B.T. APPROVED TELEPHONES**

- B.T. Statesman with Stone 31.26
- B.T. Viscount with Beige 26.04
- last number redial
- Ice Grey 26.04
- Brown 31.26
- Maroon 31.26
- Red 26.04
- Grey 31.26
- White 24.04

**BRIDGE RECTIFIERS**

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**VOLTAGE REGULATORS**

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<tr>
<td>-5V</td>
<td>70</td>
</tr>
</tbody>
</table>

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Vivian Capel has been hard at work in the garden shed and now emerges to show off his high quality but novel loudspeaker design.

The perfect loudspeaker which exactly reproduces the sound field obtaining at the original performance does not, of course, exist. So many of the requirements are incompatible when applied to practical loudspeaker design. If we want one feature we must sacrifice another.

The designer usually tries to effect a compromise, giving us some of both as far as that is possible. One designer may favour one characteristic and so slant his design in that direction, while another may consider the other to be of greater importance.

The Kapellmeister speaker was designed to fulfil a particular pattern of priorities. Some unorthodox methods were used to achieve them and constructing the prototypes though not difficult, was time-consuming. However, the results obtained more than justified the time and effort expended.

Requirements

The overriding consideration was that of size. In many homes, so much has to be accommodated in a modest living space there just isn't room for two large speaker boxes. However, most of the furniture stands around the walls so it is cabinet width that is the most critical dimension. Depth is of less importance and (within reason) height is no problem at all.

I found that eight inches was the maximum width I could allow for each speaker. This didn't seem very hopeful for a hi-fi unit!

For small size, the infinite baffle seemed the obvious choice, yet I wasn't too happy with the prospect. Pressure acting on the back of the cone is non-linear because it increases as the cone moves back. As the cone can only move in accord with all forces acting on it, its movement is thus not in exact proportion to the applied electrical signal.

The effect is more pronounced at lower frequencies. Indeed, the measured distortion of infinite baffle enclosures is high in the bass region. Internal reflections lead to standing waves and hangover, while high internal pressures produce panel resonances in the cabinet which require rigid construction, careful selection of materials and various forms of damping.

Bass resonance can be tamed only by critical adjustment of cabinet volume in conjunction with the driver parameters. Many designers adjust the cabinet Q to give moderate bass resonance to enhance the bass response. However, in my priorities, low distortion and lack of coloration came higher than a pronounced bass response.

Infinite baffles, especially small ones, need a lot of amplifier power which I did not have, so the infinite baffle enclosure was out.

Reflex enclosures suffer from similar drawbacks although there are some very good ones. These also were rejected.

The rear-loaded folded horn is
an attractive speaker with many advantages — low power requirement being one of them. However, the lowest bass frequency it will produce is proportional to the width of the horn flare. My eight inches wouldn’t even get into the upper bass register, so this prospect too had to be abandoned.

I have always had a hankering after the transmission line principle. It provides a long folded path behind the driver which eventually emerges into the free air. Thus there are no high internal pressures, no non-linear cone excursions, no reflections and no panel resonances. Wadding stuffed into the path absorbs much of the rear wave but its effect is gradual. There are no hard boundaries to cause reflections. The snags are purely practical ones. The area of the rear passage should ideally equal that of the driver cones throughout its run. There should be no sharp turns otherwise the woodwork at the bends could absorb and release energy thus adding coloration, as well as producing back reflections. To get a reasonable bass response, this rear path should be at least eight feet long.

To achieve all this, designs tend to be large, and then there are usually some compromises. So this type of enclosure too seemed a non-starter. However, before rejecting it finally, I decided to resolve some of the other factors.

**Frequency Response**

A wide frequency response is usually considered a top priority and most commercial models vie with each other in getting the widest range possible in their specifications. Often this is just a case of one-up-manship. A wide range is indeed desirable and within certain limits essential for hi-fi but there can be overkill, especially if it is at the expense of other features.

The upper limit of human hearing extends to about 16kHz in the young but falls increasingly over the age of 30. BBC FM music radio broadcasts have 15kHz as their upper limit. A response above 15kHz was therefore deemed superfluous, especially if it is at the expense of other features.

As for the bass, the lowest note produced by any orchestral instrument is 29Hz from the contra-bassoon, while piano goes down to 27.5Hz. In practice it is rare that even these instruments get down that far. When they do, spectrum analysis reveals that the fundamental is very weak anyway and most of the character is imparted to the tone by the harmonics.

The lowest harmonic which is the second in the above cases, is 55Hz and 58Hz respectively. So while it may be desirable to reproduce down to the lowest frequencies, it is by no means essential. In fact sub-bass response can reveal rumble, record warp and even subway trains passing near the studio! A bass response below 45Hz was thus deemed not really essential and given a low priority rating.

**Multi-speaker Systems**

Crossover networks are generally held to be a necessary evil. Tone burst testing around the crossover frequencies shows that ringing (continued oscillation after the signal has stopped) takes place due to the reactive components in the networks. They introduce losses thus reducing the sensitivity of the speaker, and phase shift also occurs. A multiplicity of drivers means more crossover networks hence more spurious signals and phasing problems, with lower sensitivity. Not only this but trying to make the drivers work together can create difficulties. Sensitivities must be carefully matched to ensure an even response, and even when this is done there can be response vagarities around the crossover points due to overlap.
A particular problem is phasing. As the cones of tweeters, mid-range units and bass drivers are of different depths, they are at different distances from the listener when mounted normally.

The resulting phase differences vary with frequency and the total wavefront pattern from all units is quite different from that of the original sounds. These phase anomalies are compounded by those arising from the crossover networks.

Phasing is particularly important in the reproduction of the stereo signal because stereo information is largely conveyed by subtle phase differences between the channels, as well as by amplitude variations. Some commercial speakers have stepped front baffles so that all the cones are in line (and in phase). This is an improvement on the conventional arrangement but only one listener will gain any benefit. Those off axis still have to suffer phase differences. Others have the tweeter reverse-connected to minimise phase shifts in their crossover networks, but all these are really palliatives.

All this casts grave doubts on the desirability of multi-speaker units. The problems can so easily be resolved by using a single full-range speaker if some limitation of the frequency range is accepted. The question is, how much?

Investigation into available drive units revealed a full-range elliptical 8-inch by 5-inch with centre HF cone that had a frequency response of 45Hz to 16,000Hz — just the frequency range I had decided on!

Power rating seemed rather low at eight watts RMS, but without the inherent loss of the infinite baffle enclosure and those of the crossover networks a high efficiency could be anticipated, giving ample sound output.

Freedom from the clutter of extra drivers could well make a transmission line possible too.

A single driver also approaches the ideal point source, something achieved with considerable complication and expense in the prestigious Quad ELS-63 electro-static. Coupled with the narrow eight inch cabinet width, this should produce outstanding stereo imaging.

Is there any disadvantage with using a single driver apart from restricting the frequency response? Doppler effect is one sometimes mentioned. High frequencies are modulated by the forward and backward cone movement made when reproducing bass at the same time. However, with an acoustically efficient system, cone movement due to bass is limited so the effect is small.

Even so, a point sometimes overlooked, is that the microphone diaphragm itself originally experienced doppler effect by responding to some high and low frequencies at the same time, although its bass movements are much smaller than those of a speaker cone. The motion of a single-speaker cone is therefore closer to that of the microphone diaphragm than those of the cones of a multiple-speaker system.

**Design Considerations**

The transmission line type of enclosure is one of the league for pure uncoloured reproduction — providing good design principles are observed. These are not easy to achieve in practice, and usually mean considerable bulk.

The Kapellmeister speakers use some novel and highly successful methods of overcoming the problems, while occupying only 8x11in of floorspace.

One of the requirements is for the area of the transmission line to equal that of the driver cone throughout its length. Any variations result in sound pressure differences, back pressure and other complex effects which upset the smooth passage of sound along the line.

This ideal is frequently compromised in practical designs because of another rule that there should be no sharp bends. These can cause reflections, absorption and release of energy from wooden baffles angled to deflect the sound around the corners. All of this results in coloration.

Conventional designs usually house all the drivers in a cubicle which extends to the back of the cabinet. From this the path, considerably reduced in area, descends to follow its course through horizontal and vertical sections. At the back of the cubicle there is usually a deflection back to the drivers.

For reasons already mentioned, we use only one driver and this simplifies matters because we can dispense with the cubicle. The driver is thereby mounted at one end of the line which does not vary in area throughout its length, so totally fulfilling one of the main requirements.

The path followed is shown in Fig. 1. It is in three sections; the sound travels downwards, then up through the centre section, and finally down again through the rear one to exit at the bottom. This arrangement appears to violate the other main rule regarding bends and deflectors. However, that rule does apply if deflectors could reflect the sound perfectly along the required path without back reflection and without adding coloration.

Wood does not fulfill that requirement but other materials can do. One excellent one is ceramic tile with concrete backing. (Note how sound bounces around in a tiled swimming bath). So, the deflectors are glazed ceramic tiles set on concrete corner blocks. These might seem to be a nuisance when considering construction, but they are easily formed in situ, and are the real secret of the quality obtainable from these speakers.

The tiles are set at an angle of 45° to reflect the sound accurately around the bends. It will be noticed that there is also a tile at the top just above the driver. The purpose of this is to reflect sound generated by the top part of the cone downward.

The wave-front radiated by the back of a loudspeaker cone travels outward along an axis that is perpendicular to the surface of the cone. If the cone is at an angle of 22° the tile should be set at an angle of 56°. If the speaker has a different angle from this, the difference for the angle of the tile should be halved, so a 20° cone should have a tile angle of 55°. Most loudspeakers of this size have cone angles in this region, but the angle varies slightly with cone curvature anyway, so the above figure can be used in most cases and is not too critical.

As the sound pressure on either side of the baffles is almost the same they are not excited into vibration to produce coloration, and this is true also of the back. The top and bottom pieces are of stout timber lined on their insides with the concrete and tiles, so they too are prevented from vibrating.

Only the front panel has a sound pressure differential between its faces but this is much lower than with an enclosed cabinet. Also its narrow width makes for high rigidity which inhibits vibration. The material of
Fig. 3 (a) First stage in construction. The front is glued to top and bottom cheeks using ¼ in supports to lift front into correct position. First pair of side pieces fitted and triangular blocks (small ones at the top) in position. Apply concrete, fit tiles and lay wadding. (b) Fix first baffle, glueing and pinning down to ensure close fit. (c) Fit second pair of side pieces and four triangular blocks (all blocks from now on are regular size). Apply tiles, concrete, and wadding. Tuck two extra lengths of wadding through aperture into first channel. (d) Fit second baffle glueing and pinning. Aperture goes at the top. (e) Glue in third pair of sides and last pair of blocks. Fit tile and concrete, lay wadding and fit back. Double an extra length of wadding around the ends of the full lengths. Sand down, fill crevices, finish top and bottom cheeks, fit fabric and fix legs.

the enclosure thereby adds very little to the sound.

Closed Pipe

The transmission line is in effect a pipe that is closed at one end but open at the other. As such it inhibits a fundamental resonance plus odd harmonics. There are no even harmonics. The fundamental resonance occurs where the total length equals a quarter wavelength of the frequency. Here, the length is just over eight feet, so the resonance is at 35Hz, which is below the lower limit of the driver at 45Hz. However, being broadened by the dampening material in the pipe, it can influence the range of the speaker, usefully extending it by a few Hertz.

The antinodes (points of maximum air motion) at the third harmonic occur at the third and two-thirds positions, that is at the bends. Extra wadding at these points serve to suppress this harmonic. Extending the extra wadding up the first channel and also at the exit dampens out two of the three antinodes of the fifth harmonic. Above the fifth, the harmonics are smaller and the normal wadding fitted throughout the length of the pipe tames them.

The speaker unit is an 8in x 5in elliptical unit which, allowing for the frame and surround, has 7in x 4in cone. Thus the approximate area is 21in². Area of the channels is a 7in x 3in rectangular, which is the same as the cone.

Parameters of the driver are not too critical, so if the specified one is not available any similar unit will do. The size is important and this includes the front to back measurement which should be about 2½ inches. It should be a full-range speaker with a response from 45Hz to 15kHz or better. Generally you will find that an extension at one end is at the expense of the other.

High power is not essential because of the good acoustic and electrical efficiency, but eight watts RMS minimum is recommended. General good quality construction with a magnet of not less than 9,000 gauss should be looked for.

Construction

Although quite a lot of woodworking is needed, none of it is difficult and it consists mostly of cutting straight edges. These must
be straight though, so if your saw cuts tend to wander, get the timber yard to cut them for you. The measurements are uniform with many pieces being the same, which helps.

Use standard 8in x 4in ceramic tiles, cut down to 7in x 4in. That is just one straight cut per tile. The exception is the top tile over the speaker which because of its different angle must be 7in x 3⅜in.

Triangular blocks are used to support the tiles as shown in Fig. 1. These are made by first cutting four 3in squares, then sawing diagonally to give eight triangles. The two blocks for the over-speaker are made by halving a 3in x 2in rectangle. A standard 3:1 mix of sand and cement is used to fill the space behind the tiles. In some cases the cement is applied first between the blocks and the cement applied at the back afterwards.

In all cases screw two or three stout screws at random angles into the wood where the cement is to be laid leaving about an inch out of the wood, so that they will be buried in the cement. These will then secure the concrete block in place when it is dry. Thoroughly wet the back of the tile before applying it to the cement. In some cases the front of the tile may need to be held in place while the cement sets, with panel pins knocked into the wooden sides. It does little harm to leave them in place afterward.

All jointing is done by a strong wood glue. Eovistok wood glue was used for the prototypes which is very strong and convenient to apply. If not available, a substitute can be used but make sure it is a wood glue and not a general purpose adhesive.

Construction must proceed in numerous stages (Fig. 3) to allow the glue and concrete to set before continuing with the next, so some patience must be exercised. Make both speakers at the same time so that each stage can be completed on both and some time saved.

Stages

Having cut all the pieces, we start with the front panel. Lay it face downward supported on some scrap ⅛in ply or hardboard. Glue the top and bottom edges and fit the top and bottom boards. The front edges of these should not rest on the ply supports but directly on the work surface. They will then protrude a quarter of an inch beyond the panel. They should also be positioned to give an equal overlap at either side. The idea is for the top and bottom cheeks to overhang the front, sides and back. Weights should be applied to the free sides of the cheeks to hold them against the panel while drying.

Measure the distance between the rear edges of the top and bottom cheeks to ensure that it is exactly 33in and therefore the top and bottom are parallel. Wait for the glue to set and harden.

Next, fit the first pair of side pieces, gluing the ends and the edge contacting the back of the front panel. Ensure the pieces are flush with the edge of the front panel. Measure across the upper edges to make sure they are ¾in and so are true. Now glue the triangular blocks in place at the bottom and top as shown in Fig. 3. The top ones are the special sized ones. Glue the edges as well as the face that contacts the sides, but be careful in pressing them into place that you do not move the sides. Leave it to set.

Now fit the speaker, screwing it in place over the aperture, and solder a pair of wires which are run down the panel to a hole drilled in the bottom. Leave a few inches free, and make sure both speakers are connected the same way to colour-coded wire. It is prudent to cover the front of the speaker with a piece of card secured by drawing pins to protect the cone during subsequent operations.

Fit supporting screws to the base and top, then fill the space between the bottom blocks with cement (not too wet) and bed the tile. Fit the top narrow tile on the blocks and in behind it with cement. Allow time to harden. If desired, a quick-drying additive can be used to speed matters up.

Saw suitable lengths of quadrant and glue into the corners between the front panel and the sides. If they are warped they should be held in place with panel pins. Glue two further strips of quadrant at the top inside edge of the sides and pins to secure.

Cut three lengths of BAF wadding to size and lay them in the cabinet so that two start at the bottom of the speaker and the third lies over it to the top of the case. Fill the space above the speaker with a rolled up piece of wadding. Make the lengths a few inches longer than the channel so they bend up at the bottom over the tile. The three layers will fill the channel without compression.

Now fit the first baffle with the cut-out at the bottom, glueing to the top edge of both sides and the upper quadrant surface. Also glue to the top and bottom cheeks. Secure with panel pins to ensure a close fit. Next, fit the second pair of side pieces and two pairs of blocks top and bottom. Fit quadrant to the corners, as with the first channel, and to the top edges of the sides. Wait for all the glue to dry.

Fit the tiles and cement as with the first pair, but this time the top one will be bedded and the bottom one re-filled. Wait for the concrete to set.

Cut two pieces of wadding about 18in long and push half the length of each up the lower channel through the cut-out, and lay the other half length back along the top channel. Now lay three full length strips over these along the complete upper channel. This gives the extra density at the first bend needed to dampen the third harmonic antinode.

Next comes the second baffle which is glued and pinned as the first but with the cut-out at the top. Fit the third and final pair of sides, also the last pair of blocks plus the quadrant in the corners and top edges. Allow the glue to harden.

Now for the last tile. Don't forget the screws in the top to secure the concrete block inside. Mount the tile on the blocks using panel pins, and fit in place; this will be easier if the enclosure is stood vertically upside down. Return to the horizontal, and fill in rear with cement. Wait until set.

Lay three strips of wadding in the channel making sure the bend is filled. Put some extra here if necessary to fill completely. Cut another strip about 24in long and tuck half the length under the other three at the outlet, and bring it over the top so that it covers the rough ends.

Lastly glue and pin the back in place. Now for the finishing. Sand down any ridges in the sides, but do not be too fussy, for they will be completely covered with fabric. Check carefully for any cracks or crevices in the jointing and fill.
with wood glue. Sand, then stain or varnish the top cheek and the edges of the bottom one. There is no need to do the underneath. Paint the body with matt black. This is not strictly necessary, but if it isn't done, bare wood can show through the fabric. Take care not to get any paint on the loudspeaker cone as this would affect its flexibility.

Cut the fabric to the exact size to cover the body between the cheek overhangs, but leave a 4in flap 8in wide, at the start. Secure the vertical starting edge at one edge of the back of the enclosure with tacks so that the flap overhangs the bottom. Then pull it around, keeping it taut overlapping the start and securing it with a wooden strip (previously painted) down the middle of the back. Trim the flap to fit between the prongs of the bottom and fix it across the exit port with gimp pins.

Fit some 2in high legs. The rear ones should be inclined backward to give greater stability as in Fig. 1. Pack filler around the hole in the bottom through which the speaker wire passes to make it airtight, and fit a connecting block underneath.

**Performance**

Well, was it all worth it? That's what I wondered when the prototypes were complete. It took very few listening sessions to provide the answer. Ambience and sense of presence was perhaps the first noticeable effect. Woodwind was clear, easily identifiable and rounded in tone. Brass was brilliant yet mellow, staccato passages really were staccato, not slurred as they sometimes sound.

A recording of harpsichord was remarkable, revealing tones and subtleties never heard before. A solo violin sounded natural with no moments of discomfort in the higher passages. One passage in an orchestral work which I always thought was played by the cellos playing pizzicato, could be clearly identified as played on the lower registers of a harp. I am now really hearing many of my recordings for the first time. Stereo broadcast drama is quite dramatic, with positive locational identification even in crowd scenes. Sensitivity of the speakers enabled a 4+4 watt amplifier used for initial tests to provide ample undistorted volume. This opens up the possibility of using low-powered class A amps for even higher fidelity. Just one drawback though, I now find I cannot listen to other speakers with enjoyment (especially infinite baffle systems) so be warned!

---

**BUYLINES**

The speaker used is the ALTAI 8553DU, a full range 8in x 5in elliptical with centre HF cone. Frequency response: 45-16,000Hz, 8W RMS power. Any similar unit can be used, but it must be no more than 2%in deep.

Maplin can supply the Altai model (part number VVY13P) or Wilmslow Audio (Tel: (0625) 526599) can supply an equivalent (part number EM199140EB).

---

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<tr>
<td>ROSL 2</td>
<td>Oryx 15 — Electronic assembly iron</td>
<td>£16.95</td>
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<td>ROSL 3</td>
<td>Oryx 10 — General-purpose iron</td>
<td>£13.50</td>
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<td>Oryx 8 — 63 watt iron</td>
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<tr>
<td>ROSL 7</td>
<td>Soldering iron stand</td>
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John Yau continues his musical masterpiece with a description of building the power supply and wiring the whole system together.

There is just one more PCB to make to complete the electronics of the MIDI Master Keyboard. This is the power supply board.

This month we shall also look at the construction of the keyboard cabinet and show how to wire up all the boards already constructed (the three keyswitch boards, the front panel and the CPU board) to make up the complete keyboard hardware.

The power supply is of a very ordinary design using three 78 series regulator ICs to provide the +5V supply required by all the other boards and ±5V for the analogue to digital converter section of the CPU board.

Construction
Building the power supply PCB is straightforward. Ensure correct orientation of the bridge rectifier BR1 and all the electrolytic.

HOW IT WORKS
The power supply is constructed on a single PCB and supplies all the necessary power rails for the other boards. The main +5V power rail derived from IC37 is used by the front panel PCB, keyswitch PCBs and most of the main CPU board. A separate, lower power, +5V supply rail derived from IC36, along with the -5V rail from IC38 is used to power the joystick section of the CPU board.

The three regulator circuits are extremely standard and require little in the way of explanation.

Independent supply lines for the analogue joystick circuitry ensure maximum stability and noise immunity from the digital circuitry elsewhere.

External components in the power supply circuitry are the mains transformer, fuse and the 7805 +5V voltage regulator (IC37). IC37 is bolted to the aluminium cabinet lid, which acts as an effective heatsink. Current consumption from the main +5V power rail is around 600mA, whilst the other rails draw substantially less power.

Fig. 1 The circuit diagram of the power supply board.
capacitors (especially the big ones) as shown in Fig. 2. Mount C20 and C21 using the hole spacings on the PCB which are most suitable for the capacitors' sizes.

Solder regulators IC36 and IC38 directly onto the PCB and add a clip-on heatsink to IC36. IC37, the main 5V regulator, is to be mounted remotely to a large heatsink. In the prototype the aluminium lid of the keyboard cabinet was used for this. Finish off the power supply PCB by adding veropins for the wire terminal points.

Cabinet Construction

Figure 3 shows the details of the cabinet used by the author in the prototype. The base is made of 1cm plywood whilst the end blocks and struts are of hardwood.

Start construction by joining the front trim to the plywood base, using a combination of wood screws and glue. Next prepare the keyboard chassis strut by cutting a recess large enough for the wiring harness to thread through on its way to the CPU board.

Position the strut on the plywood base so that the plastic notes lie just flush along the wooden front trim. Mark and join it to the base using glue and wood screws from the underside. Glue additional strutting along the join for extra strength.

After the glue has dried, fix the keyboard to the cabinet by attaching the long brass hinge along the length of the keyboard to the mounting strut. The keyboard chassis should then be able to pivot freely about the hinge.

The lid for the prototype cabinet was made out of sheet aluminium, folded and machined to provide all the necessary holes and recesses. Both the front panel and CPU boards are mounted on the underside of the lid. The whole lid is hinged along the

---

**PARTS LIST**

<table>
<thead>
<tr>
<th>CAPACITORS</th>
<th>SEMICONDUCTORS</th>
<th>MISCELLANEOUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>C20</td>
<td>IC36, IC37</td>
<td>F51</td>
</tr>
<tr>
<td></td>
<td>IC38, BR1</td>
<td>200mA fuse and fuseholder</td>
</tr>
<tr>
<td></td>
<td>78M05</td>
<td>9-0-9V mains transformer</td>
</tr>
<tr>
<td></td>
<td>7805</td>
<td>PCB; mains rocker switch; clip-on heatsink for IC36; wire and cable.</td>
</tr>
<tr>
<td></td>
<td>79M05</td>
<td>0V, +5V, -5V</td>
</tr>
<tr>
<td></td>
<td>100n polyester</td>
<td></td>
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</tbody>
</table>

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**BUYLINES**

None of the components used for the power supply board should provide any problems. The PCB will be available from the ETI PCB Service in due course. Details at the back of this issue.
edge of the plywood base using small brass hinges.
This method of mounting allows easy access to the circuit boards.
After the lid of the cabinet has been fabricated, hardwood endblocks should be cut out.
These follow the end profile of the cabinet with about 0.5 cm margin all around. The endblocks are joined to the ends of the cabinet base and wooden struts added to form attachment points for the aluminium lid.
The power supply PCB and mains transformer are mounted on the plywood base, positioned close together.

**Board Inter-wiring**
The inter-board wiring diagram is shown in Fig. 4. The diagram is by and large a topological one. Matters such as cable length and positioning will depend on the final board layout within the keyboard cabinet you have chosen or made.
The first task is to mount the power supply board and components within the cabinet. The power rails to all the other boards should be left to last. Do not connect the power rails until the power supply is checked and functioning correctly.
Great care should be taken to ensure there are no unnecessary mains voltage hazards when assembling the power supply components. All mains wiring should be kept as short as possible and should be sleeved for extra insulation.
Use more sleeving or a silicon rubber compound to insulate the mains transformer and mains power switch wire terminals. It is a good idea at this stage to earth the aluminium cabinet lid and the steel chassis of the keyboard.
Wire up the MIDI OUT DIN sockets to the CPU board and the footswitch sockets to the front panel PCB as shown in Fig. 4, before bolting them onto the aluminium lid. The board clearance of the Front Panel PCB should be such that the push button bank protrudes with the key caps flush with the lid.
Before finally bolting the front panel board into place, make sure the LEDs are all properly slotted into position.
Bolt the two joysticks onto the front panel and make up the wiring harness as shown in Fig. 5. Earth the two potentiometer cases as shown and use screened cable.
for the connections to the potentiometer wiper terminals.

Adjust the modulation joystick potentiometer so as to make the wiper voltage register 0V when the joystick lever is at its lowest point of travel. The potentiometer setting for the pitch bend joystick needs to be set so that the wiper is near the centre of the track when the joystick lever is in its neutral position. The precise position is attained later when adjusting in conjunction with the CPU board powered and operating.

All that remains is to plug all the wiring harness multi-way plugs into their respective destinations — the connectors which jump between the front panel board and CPU board and the one which links the keyswitch PCBs to the CPU board. Prepare the wiring for the power supply rails, but do not finally connect the PSU board until it has been verified that the power supply rails are functioning correctly.

Give the whole assembly a double check for correct inter-board wiring, paying particular attention to the power rail connections. Incorrectly connected power rails are catastrophic as far as the integrated circuits are concerned! Getting the power supply working should be fairly straightforward as very little can go wrong provided all the components are correctly orientated on the PCB. Power on the mains and check the output voltages. If they are incorrect, switch off immediately and check everything over again. If the power supply regulators are operating properly, switch off and disconnect the mains supply before wiring the power rails to all the other boards.

Next month we shall look at the software to drive the MIDI Master Keyboard and the final setting up and testing.
TELEPHONE ALARM

Anyone breaking into Barry Taylor's house had better watch out. This unit will phone him up and tell him just what's going on.

WARNING

The Telephone Alarm was originally designed by the author for commercial manufacture and sale. However, this circuit does not have approval from the British Approvals Board for Telecommunications (BABT) and as such should not be connected to a BT line.

Nevertheless, the Telephone Alarm can legally be used with any private exchange equipment and can form the basis of a submission to BABT for approval.

Even the most sophisticated alarm has a major drawback — it is dependent on the response of passers-by to an alarm bell or siren. Many commercial premises are in self-contained industrial estates with few or no (authorised) visitors walking around after dark. Rural homes and farms can be well isolated and far from any potential help when a break-in occurs.

Moreover, given the frequency of false alarms from all systems and in all premises it is not surprising that few passers-by who do hear an alarm bell starting up in their street do more than curse.

There is clearly a need for an alternative form of alarm. Several companies offer central station monitoring systems to enable alarms to be relayed over the telephone network to a computerised control centre. However, this and the option of systems offering a direct line to the police are well beyond the scope of most pockets.

It's For You-hoo

A cheaper alternative is a unit which would dial up a pre-programmed number and give an audible warning over the telephone that it had been triggered. That is exactly what this project offers.

The Telephone Alarm will automatically dial a pre-programmed number of up to 16 digits on activation of a set of external contacts. It will then transmit an alarm tone for about three minutes before hanging up. The unit is then automatically reset to dial again should another alarm occur.

Naturally, you may be so far away as to not be able to take useful direct action yourself. However, you can call the police (or a neighbour) and rest assured that the alarm has been well and truly raised.

The Telephone Alarm is not only suitable for telling you if your home or business is being burgled. Other uses, less criminal but just as vital to your piece of mind are also possible:

- fire alarm (combined with smoke and heat detectors)
The full circuit of the Telephone Alarm is shown in Fig. 1. The line interface uses VMOS FETs (Q7,8) to make and break the telephone line loop to dial the number and to produce the alarm tone.

The diode bridge (D1-4) ensures that the correct polarity is observed across the FETs. When RLA1 operates the unit is connected to the telephone line and 50V from the line appears across the bridge. This turns on both FETs and to produce the alarm tone.

When a valid key is pressed, the keypad encoder (IC2) outputs a strobe pulse rate of ten per second. The on-board oscillator is set for 16kHz by L1, C1 and C3 to enable a standard of 800ms. The dialling pulses and an interdigit time of 33% mark-to-space ratio for the dialling pulses through to the opto-isolator IC7 to dial the number. Q8 is connected to the telephone line and VMOS FETs (Q7,8) to make and break the telephone line loop to dial the number.

The two schmitt trigger oscillators formed around IC9 and IC10 make up the alarm tone generation circuitry. This is inhibited by IC5b and IC5c from the ringing tone and dialling signals to the exchange.

The exchange is informed that no voltage should be presented to the trigger input.

**The Phone**

Two wires are provided from the telephone exchange to each house or subscriber. These are used for carrying the audio tones, the ringing tone and dialling signals to the exchange.

The exchange is informed that the subscriber wishes to dial by completing the circuit between the two wires. The loop circuit is then broken in a series of short pulses...
pulses to signal the number being dialled.

When the exchange has then connected the call to the intended destination, the line appears as a 600 ohm balanced line for the audio signals.

The Telephone Alarm circuit is in two sections — the line interface and the main body of the circuit. These are electrically isolated from one another by opto-isolators. The main body of the circuit is powered by a battery supply although a simple mains power supply could be added to the circuit. The line interface derives its power from the telephone line.

When triggered, the main body of the Telephone Alarm circuitry produces the correct sequence of making and breaking the telephone line loop to dial the number and then produces an audio tone to signal down the line that the unit has been triggered.

### PARTS LIST

<table>
<thead>
<tr>
<th>RESISTORS (all 1/4W, 5% unless specified)</th>
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<tbody>
<tr>
<td>R1 39R 1/2W</td>
</tr>
<tr>
<td>R2 390k</td>
</tr>
<tr>
<td>R3,4,7 680k</td>
</tr>
<tr>
<td>R5 10k</td>
</tr>
<tr>
<td>R6,15-17 150k</td>
</tr>
<tr>
<td>R7 220k</td>
</tr>
<tr>
<td>R9 470k</td>
</tr>
<tr>
<td>R10 47k</td>
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<tr>
<td>R11-14 27R</td>
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<td>R18,19 470R</td>
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<tr>
<td>R20 10R</td>
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<th>CAPACITORS</th>
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<tr>
<td>C1,2 40n polyester</td>
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<td>C3 220n 100V polyester</td>
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<tr>
<td>C4-7 100n polyester</td>
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<tr>
<td>C8-10 1µF 63V axial electrolytic</td>
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<td>C11 10n ceramic</td>
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<td>C13 10µF 63V axial electrolytic</td>
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<table>
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<th>SEMICONDUCTORS</th>
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<tr>
<td>IC1 4408 or MC14408</td>
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<tr>
<td>IC5 4011</td>
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<td>IC6 40106</td>
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<td>IC7,8 CNY17-3 opto-isolator</td>
</tr>
<tr>
<td>Q1-5 BC237 or BC337</td>
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<td>Q6 TPSA13 or MPSA13</td>
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<tr>
<td>Q7,8 VN10KM or VN10LM</td>
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<td>D7 1N4148</td>
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<tr>
<td>B1 6V (4 x 1.5V) battery</td>
</tr>
<tr>
<td>L1 5mH coil</td>
</tr>
<tr>
<td>PL1 7 way 0.1 in PCB connector (male)</td>
</tr>
<tr>
<td>RLA1 DPDT, 5V coil DI1 relay</td>
</tr>
<tr>
<td>SK1 7 way 0.1 in ribbon cable connector (female)</td>
</tr>
<tr>
<td>SW1,2 SPST push button switch</td>
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<tr>
<td>SW9-14 12 switch keypad 4x3 matrix type</td>
</tr>
<tr>
<td>PCB; 2-way and 4-way terminal blocks;</td>
</tr>
<tr>
<td>telephone lead type 431A; case.</td>
</tr>
</tbody>
</table>

### BUYLINES

The keypad matrix of 4x3 keys used in the prototype is available from MS Components as part number 7331. MS can also supply the relay as part number 8041. MS Components is at Zephyr House, Waring Street, West Norwood, SE27 9LH. Tel: 01-670 4466.

The opto-isolators (IC7,8) used were CNY17-3 types but any six pin opto-isolator which can withstand a Vce of 50V or more should be adequate.

IC1 and IC2 are available from Watford Electronics (Tel: (0923) 377774).

The case used for the prototype was from Legrand although any suitably sized metal or plastic case will do. None of the other components should be difficult to find.

The PCB will be available from the ETI PCB service in due course.

---

Fig. 2 The component overlay for the Telephone Alarm.
Construction

Figure 2 shows the component overlay for the Telephone Alarm PCB. All the ICs used are CMOS types and should be treated with the normal respect reserved for these static-sensitive devices. The usual care should also be taken to ensure the diodes and electrolytic capacitors are inserted the correct way around.

It is recommended that terminal blocks are used to connect the trigger input, the battery and the phone line itself (see Fig. 3).

The keypad should be connected last of all the components. The keypad used for the prototype (see the parts list) is mounted above the PCB on spacers secured to the PCB through the holes, A, B, C and D. The ribbon cable from the keypad is terminated with a seven way connector which is plugged onto the connector on the main PCB.

The keypad can also be mounted in the lid of the case for easy alteration of the programmed number.

You can make up your own keypad as shown in Fig. 4 on a piece of stripboard. The switches used can be any single pole, push to make buttons such as keyboard switches.

Only the switches for the numbers 0 to 9 are actually required for the Telephone Alarm. Many commercial keypads also have the * and # keys found on most push button telephone keypads. The Reset and Test buttons could occupy these positions on a keypad of your own making.

Operation

The Telephone Alarm is very simple to use. The number to be dialled when the unit is triggered is programmed using the keypad and the Reset button. After the Reset button is pressed the number to be dialled (up to 16 digits) is then keyed on the keypad.

If either the Test button is now pressed or the trigger input circuit is closed the unit will dial the programmed number and sound a tone down the telephone line for approximately three minutes before hanging up and resetting the whole system.
After loudspeakers, I reckon that room acoustics have the greatest effect on the sound of good quality systems. Graphic equalisers can help to solve some room acoustic problems but I suspect most people use them to provide their own particular idea of what the sound colour should be.

It can be difficult to detect and null out room resonances but when you do remove a serious resonance there is less 'listener fatigue' even though the difference may not be easy to pin down at first.

All this leads me to speculate on some possible future developments. Some CD recorders nowadays have digital outputs, for connection to an external DAC (digital to analogue converter) to reduce the already minuscule noise and distortion on the original.

As microprocessing speed increases, this opens the door to the possibility of having a programmable digital equaliser, running a high order digital filtering algorithm in up to 32 bits.

Such a microprocessor equaliser could automatically run white noise tests on the system and compute an accurate correction function. By sending many and varied test signals to each channel in turn, it could even provide a digital correction for system non-linearities, effectively determining what distorted signal has to be fed to the loudspeakers to produce a sound equivalent to the original signal source. The amplifier may occasionally be called on to perform crazy contortions but that is no problem.

If the microprocessor equaliser was actually a computer with a colour monitor, the user could superimpose his own chosen tone correction on to the equaliser characteristic by sketching it on the screen using a mouse or lightpen. A menu of different corrections could be stored and accessed at the touch of a key.

Sound And Vision

You may wonder why I specified a colour monitor. Well, those clever chaps at Phillips are extending the CD medium to include a development of their old Laservision system. This was always technologically excellent but it was not what the market had in mind at the time. Their new development will enable five minutes of sound and video plus twenty minutes of sound alone to be encoded on a CDV (CD Video) the same size as a conventional CD. In addition there will be 8in extended play and 12in long play discs, and combination players will be available to play all sizes. Surely a colour computer monitor could also display the CDV pictures and form an integral part of a future audio/video system.

On the 5in CDs (which look like ordinary CDs except for the gold dye in the plastic) the video information is coded on the outer area where the scanning speed is greatest. A linear speed of between 9.2 and 10.2 m/s is used for PAL video, with NTSC requiring slightly higher rates. To keep the scanning rate correct as the scanned diameter varies, the rotational speed varies from 1512 to 2250 RPM.

Audio compact discs have worldwide compatibility but not so the video ones. There is no worldwide video compatibility, you see. They have, however, retained compatibility with the old Laserdiscs, so that they will play on the new players. Laserdiscs used an analogue FM sound system, but the new CDVs use (of course) digital sound.

Whether CDV will catch on remains to be seen. I think it is more likely to suit the market than Laservision ever was and maybe more people will spend money on this than on DAT. The popularity of pop videos cannot be denied, but the new CDVs use (of course) digital sound.

CDV may also stimulate enough interest in CD in general to persuade record companies to manufacture larger quantities of CDs at lower cost. As a byproduct, this may calm the hysteria about DAT making it less economically attractive in comparison with CD.

Andrew Armstrong

At last Newnes (now part of William Heinmann publishers) has produced a version of the run-for-ever Electronic Engineer's Pocket Book exclusively for the computer enthusiast or professional. This is the first edition of this computer version but it looks like there will be many more. This one will (as they say) run and run.

The pocket book is basically a reference work. No enquiring bedtime reading here. What there is, is just about everything you could want to know about computer hardware. Within these pages is condensed data on most of the common processors and support chips, interface standards, operating systems, typicil video waveforms, and so on (and on and on).

The pocket book is in the usual Newnes format of a long thin hardback about 8in by 3 1/2in and around 200 pages long. Into these pages is crammed masses of information. The contents page has over 80 headings!

The information ranges over a wide area. The most basic electronics is covered (items such as TTL pin-outs and Karnaugh maps) as well as the more esoteric micro standards (did you know the format of an IBM 3740 disk?).

This is not a book to leave on the shelf for occasional reference, either. This book should be firmly placed within easy reach of your computer desk or even inside your toolkit if you're into these machines for professional reasons. It will soon prove to be worth the (only slightly inflated) cover price.

It's not just the 'things you always wanted to know but had no idea who to ask' that this book is filled with. There is vast quantities of seemingly trivial data (a table of 'devisors of 256 with remainders...'). Much of this seems just useless padding until you're sitting at the keyboard desperately strainning to work out just what is 256 MOD 21.

It is not the depth and importance of the data that makes this book a must but the sheer quantity, range and compact handiness.

Anyone can get by without the Computer Engineer's Pocket Book but why take the hard way out?

Malcolm Brown

Newnes Computer Engineer's Pocket Book by Michael Tooley (Heinemann) £8.95

Computer Peripherals That You Can Build by Gordon W Wolfe (John Wiley & Son) £15.30

Not a cheap one this, mainly because it comes all the way from the USA. This one's a big book, too — around 280 pages.

The biggest problem facing the computer after they have finished playing the games and 'learning about computers' is what the hell to do with it. It's depressing but true that most people just don't spend time doing anything useful at all.

The raison d'etre often quoted is control, automation, and the like. Now it is probable that few if any computer users will ever really need these claims actually do anything about them themselves. Nevertheless, they leave lots of folk out there wanting to connect up their machines to anything and everything available.

Having got that off my chest, I must say that even if the idea is a little dubious, this book approaches the whole matter in a logical and instructive way. Not a lot of knowledge is assumed at the start but the book covers an amazing amount of ground.

It starts by describing exactly what a computer is and 200 pages later it's showing how to make a flatbed plotter. In between there's paper tape readers, servo controllers, household remote control, and many others.

Each idea is described with a circuit, a brief explanation, and often a short program in Basic or a flow diagram to show how the whole thing can be run. There are next to no constructional details but this is more an ideas book than a list of projects computer engineers can build.

The problem is that it is an American book. This raises the usual problem of the odd difficult component and circuits designed for American electronics. Of course, more importantly all the circuits described are aimed at distinctly American machines. There's not a mention of a BBC micro or a Spectrum here. It's all Apple II, Tandy 1000, TRS-80 and the like.

The good news is that the Commodore 64 is, of course, to the fore.

That aside, you could do a lot worse than this book. Expensive it is. American it is. However, if you've set up wiring up your house to your Spectrum you could learn a lot from this one.
So far, '87 has proved to be a dull year with regard to innovations in music technology. In fact it is difficult to pinpoint any real innovations and, although the year is only half gone, we shall probably be forced to wait until the next NAMM and Frankfurt trade shows (in February respectively) to see anything original emerge.

The question is will the story be the same in 1988 too? Some people are already speculating that the electromusical instrument market may be flattening out from its previously high rate of growth or, in plainer terms, plunging into a recession in the near future. This began hitting the semiconductor industry several years ago. The symptoms are exactly the same — prices stay fixed and new developments all too often outweighed by the high cost of R&D.

The cause might be put down to an increasing saturation of a finite market with cheap key-boards designed to make MIDI, not music. The result may ultimately be for such machines to paint themselves into the dark and suffer the same fate as their suicidal paintbrush.

Signs of middle-aged flatulence are already in evidence and it is intriguing to compare the so-called new developments of '87 with the music trends of our time. Old machines are being reincarnated in new bodies at the same rate with which club remixes are remixed and cover versions are recovered. Furthermore, manufacturers are currently stealing ideas off each other to a degree that puts the 'sample before you get sampled' ethic of Hip-Hop to shame.

'Sequential Circuits' Vector Synthesizer technique, in which four sounds derived from digital wave-forms are mixed under the control of a joystick with X-axis position controlling balance between two sounds and Y-axis position controlling balance between the other two. To be fair, this is a very useful and ergonomic feature, beautiful in its simplicity, but by the same token scarcely deserving of a name as convoluted as Vector Synthesis. With regard to originality, the technique was possible on many modular analogue synthes, not unknown on DJ's mixing desks and not very dissimilar to the soundfield control Joysticks found on quadrophonic equipment.

Bruno Hewitt

Today, I took delivery of my new Mercury telephone. I ordered it less than a week ago from Mercury Communications Ltd, having made a few rough calculations based on the use of my telephone.

I will be able to use this telephone to connect me to the Mercury 2200 telephone network which now has some 59 access areas. The latest expansion incorporates my address.

Evenly, of course, the whole country will be covered but meanwhile it's worth checking with Mercury (the customer assistance number is 0800 424 194 and no answer made by BT for years, incidentally) to see if you live in one of the current access areas.

The savings in telephone charges by using Mercury 2200 can make the enquiry well worthwhile. For example, a standard rate trunk call via BT can cost around 12p per minute, whereas the same call via Mercury 2200 is less than 9p per minute.

Alternatives

Mercury's alternative telephone network to British Telecom's, unlike BT's, only a trunk network. In other words, you can't use the Mercury network to dial a local call. In fact, this is not strictly true — it is possible to use the Mercury 2200 network to make local calls by routing them out of the local area onto the trunk network then back into the local area but truly, it costs more than a BT local call anyway, so it's not worth the bother! So, to make a local call you must still be connected via a local line to the BT network.

However, any calls made which are longer distance and must be connected via a trunk network, can now be made via BT or Mercury. In fact, I have a choice of telephone networks for the very first time! At least, I will have a choice of network, when BT finally gives me a new socket.

Apart from a choice of network on trunk calls, I have a choice of prices. Needless to say Mercury's prices generally undercut BT's somewhat. As most of my calls are long distance, I calculate I will make savings of at least £70 per year by making all my trunk calls using my Mercury telephone.

I applied to BT to have their engineers call and fit me a new socket some seven weeks ago. At the time, I was told that a date eleven weeks after that was the earliest possible appointment to do the simple job — and telecommunications in Britain are supposed to be liberalised?

Do you think I will pay up if I send them a bill for £143.60 (which is 11/52 x £70), to make up for the lost savings in telephone charges which their slow service has caused me?

Looking At A Problem

Users of, potential users of or even just parties interested in, optical fibre communications would do well to get a copy of a new booklet published by BICC Electronic Cables Ltd called 'UFO's Explained'.

The UFO's in question are ' unidentified fibre optics'. The booklet is a well thought out, well written, and well put together tome (no, I had nothing to do with it) which starts at the beginning and ends at the end of the topic (shouldn't they all!) Somewhere in the middle is also a pretty fair description of optical fibre technology, in a non-technical yet thorough manner.

BICC has obviously seen that one problem in getting Joe Public to use optical fibres is the sheer reluctance to get to grips with the technology. Most people believe it to be too expensive and too technical for general cabling purposes. 'UFO's Explained' goes a long way to sorting this problem out.

A free copy of the booklet can be had from BICC Electronic Cables, Optical Fibre Technology Unit, Helsby Works, Helsby, Warrington, WA6 6JR. Tel: (0928) 3700.

TDF's DBS

French broadcasting body, Tele-diffusion de France, intends to launch the country's first direct broadcasting satellite (DBS) later this year. Problems have arisen in the satellite's launch, not because the satellite was not ready but because the launch rocket (Ariane) has been grounded following its failure some time ago.

However, now Ariane's technical problems appear to have been overcome and launch dates are currently being tentatively mooted. Meanwhile, it has been reported that Germany's DBS satellite launch, although agreed to have been via Ariane, and instead go ahead on a Chinese or Russian rocket if further problems with Ariane occur.

Keith Brindley
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E8611-4 Call meter, main bd.  
E8611-5 Call meter, interface bd  
E8612-1 Bongo Box  
E8612-2 Biofeedback monitor  

There should also be no OV connection to the top of R13 should be numbered 16 and 7, 8, 9 and 10 at the top of Fig. 3 should be flying leads are numbered incorrectly. Leads 1, 2, 3, 4 and 5 should connect the two pads to the left of C1. Q1 should be swapped.

In the circuit diagram (Fig. 2) the cathodes of diodes D3, D5 are shown connected to 0V. They should connect to the junction of R16, 17, 18.

In the overlay diagrams (Figs. 3 and 5) the flying leads are numbered incorrectly. Leads 7, 8, 9 and 10 at the top of Fig. 3 should be numbered 16-19. In Fig. 4, leads 6 and 8 from the top of R13 should be numbered 16 and 17. Numbers 9 and 10 from Q1 and Q2 should be 18 and 19. In addition the leads 11 and 12 should be swapped.

Capacitometer (March 1987)

The circuit diagram (Fig. 3) should show pin 1 of IC1 connected to 0V. The zener diode (ZD1) should be connected between the two pads below IC6. The zener diode (ZD1) should be connected between the two pads below IC6. The zener diode (ZD1) should be connected between the two pads below IC6. The zener diode (ZD1) should be connected between the two pads below IC6.

Power Meter (May 1987)

The foil for the power meter was given 50% full size on the foil pages. The correct size foil appeared in the June issue.
3-in-1 Reset

A.J. Holme
York

This circuit was designed for a 6502 controller board. It provides power-on reset, a TTL compatible input for externally generated resets, and a push button for manual reset.

A PNP output stage is used to prevent RES briefly going high at power-up, before the supply stabilizes at +5V. It is not strictly necessary and may be replaced by a NAND inverter if preferred.

The state of the EXT RES input is echoed at the RES output while the one-shot generator is in its stable state. There are two possible uses for this:

1. Driving EXT RES with a clock causes the processor to continuously repeat its power-on reset sequence. Provided suitable triggering can be arranged, this enables the processor buses to be viewed on an oscilloscope as steady, logic-analysers style traces.

- With the addition of the lower circuit shown a restart from crash facility may be added. Point X is connected to a signal which regularly changes during normal processor activity. The network on the output of the NAND inverter produces positive pulses which clock the monostable at every falling edge of X. This ensures that the mono is permanently in its triggered state. Should the processor crash (for example from mains-borne interference) these pulses will cease, causing the mono to reset. The resulting negative edge at Q is capacitive coupled to the EXT RES input and this generates a processor reset which recovers execution.

Some simple software support for this circuitry will be required to enable the processor to distinguish between warm and cold starts.

Simple Audio Limiter

R.J. Eggleton
St Ives

Audio limiters are useful in many applications such as recording, transmitting or public address systems where over-modulation would cause unwanted distortion.

This circuit has the virtues of simplicity, fairly low distortion and no need for adjustment.

Input voltages below the limit level are amplified by the op-amp eleven times to the output ((R7+R8)/R7). When the output level rises to the limit level of 775mV RMS the diodes conduct to the two limiting transistors and limit the level. Since the transistor limiters are inside the feedback loop of the op-amp, distortion is reduced significantly.

As the input is immediately limited before entering the op-amp, the circuit can withstand considerable overload. However distortion will rise above 40dB of limiting (approx 7 volts RMS input).
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WANTED: technical service manual, circuit diagram, details of expansion ROMs for Acorn Atom. Tel: (0422) 70270.

USED COMPONENTS for sale. Send SAE for list to 23 Dickens Court, Newtheworpe, Nottingham, NG16 3RG. Soon!

WANTED valve power amp circuit and board layout. Mr. J. Smith, 93 Breda Road, Belfast, BT8 4BW.

VARIAC type variable auto transformer, 5 amp rating. Enclosed. £20. Tel: Windsor (0753) 860889.

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SOLID STATE MULTIBAND TRS-30 receiver. Coverage 540kHz-12MHz, 30-50MHz, 88-173MHz. Details: Write to Victor McKaig, 15 Islandranny Road, Bushmills, Co. Antrim, N. Ireland, BT57 8YE.

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HELP. Does any reader have a copy of instructions for Quicksilva sound board? Tel: Jim Branston 01-200 7165.

CCT100-EXCELLENT terminal (DEC VT100 compatible). Very good condition. A great buy at £200. Tel: (0273) 203662.

MULTICORE light duty cable. Mostly 5-core, 100m reels. £5 a reel: Approx 20 reels available. Tel: 01-690 3131.

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SEIKOSHA GP-100A graphics, 80 column, dot-matrix printer. £65 ONO. Tel: Alan 01-866 4579.

CRIMSON S200 40W stereo power amp. £40. F. Richard- son, 20 Callerton Close, Ashington, Northumberland, NE63 9QJ.

FOR SALE: Pioneer cassette deck model CT-4. £55. Tel: 051-928 8011 evenings. Possibly deliver.

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The foil for the Nuclear Strategy Simulator.

The MIDI Master Keyboard PSU foil.

The Telephone Alarm PCB foil.
Please note: The MIDI Master Keyboard CPU foils given last month were shown 64% full size. Photocopies of the full size foils can be supplied on receipt of an SAE. Please send in to ETI MIDI Keyboard Foils, 1 Golden Square, London W1R 3AB.

The MIDI Master Keyboard front panel board foil held over from last month.
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K1682

This unique timer is in principle a 24-hour clock provided with 6 relay switched outputs and a programming period of 1 week. 20 switching programs can be memorized and via the membrane keyboard be programmed. Outputs or timing periods can be selected at random.

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