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Improve your workshop and enhance your experimenting with our triple function test gear project - combined LCD frequency counter with separate audio and digital logic signal generators. And add hi-tech security to your home with our sophisticated microprocessor controlled alarm system monitor. Owen Bishop will continue his discussion of practical theory in the Digital Electronics series, and ... well, you'll have to wait and see what other interesting features we've lined-up. They'll be worth waiting for, that's for sure! Start the count down now - it's not long till our next edition is hot off the press ...

* DON'T MISS THE SEPTEMBER 1989 ISSUE
* ON SALE FROM FRIDAY AUGUST 4TH
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PRACTICAL ELECTRONICS AUGUST 1989
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The imagewise/pc real-time Video digitiser/display board can digitise any NTSC, PAL or SECAM video source. It has a wide potential in industrial, security and desktop publishing applications.

The system can grab a single video frame and digitise it to a resolution of 256x255 with 256 grey levels. The board provides composite video output and digitised pictures can also be shown on an ega or vga monitor. A digitised picture, grabbed or software generated, can be applied as a caption or mask on a live video signal.

For more information contact: J.B. Designs & Technology Ltd, 15 Market Place, Cirencester, Glos, GL7 2PB. Tel: 0285 68122.

FUSED FOR SAFETY

As part of their current safety campaign, TMK Instruments have announced the availability of fused test prods. Designed and manufactured in the UK, the new prods are compatible with most test and measuring equipment. Safe and reliable, they comply with the requirements of the Health and Safety Executive and the Electricity Council's Engineering Recommendation Standards.

Manufactured using a tough, high impact nylon casing both the red and black prods have moulded finger grips and guards for additional safety. Internal contacts, assemblies and tips use solid brass, phosphor bronze and silver plating. The 4mm banana plugs have safety shrouds with a smooth spring loaded action which helps when changing over to the moulded crocodile-clips. Easy multi-turn access to the fuse assembly allows simple replacement of the recommended 500mA fuse.

Supplied as a pair in a plastic wallet, these fused probes offer the user a safer working environment.

The price of the fused test prods, in a wallet, is £24.95 excluding vat. (Crocl-clips are available at an extra cost.)

For further information please contact Mike Dixon of TMK at Building 3, GEC Estate, East Lane, Wembly, Middx, HA9 7PJ. Tel: 01-908 3355.

CATALOGUE DATABASE

We have recently received the following literature:

We've been inundated with catalogues from many of our advertisers - we start them here in alphabetical order, and shall continue next month.

Barrie Electronics specialise in transformers and allied products, with a range exceeding that shown in their usual advert. They will also wind transformers to your specification if they don't already have one to suit you straight off the shelf. In addition, they have a good range of components available, including semiconductors, resistors, pots, capacitors and connectors. And don't overlook the range of transmitting and receiving valves stocked, nor the very wide selection of workshop tools. Boat owners will be especially interested to know of Barnes Powerverter dc-ac marine inverters. Barrie Electronics Ltd, Unit 211, Stratford Workshops, Burford Road, London E15 2SP. 01-555 0228.

J and N Bull's catalogue has always been an Aladdin's cave of fascinating products. The range is too great to even cover briefly, but I'll highlight a few interesting items - acoustic chamber, battery operated laser, electronic spaceship, gardener's friend (time and temp module), 12V siren, ioniser for cars, golf trolley charger, and so it goes on .... Ask for your own copy of the amazing offerings and bargains from J and N Bull Electrical, 250 Portland Road, Hove, Sussex, BN3 5QT. 0273 734648.

On a personal note, I am sorry to learn that Jessie Bull has decided to retire. I've known for some time that he has been considering it, but he has announced in the newsletter he sent me that he is actively looking for someone to take over the business. For anyone with the right interest, and the willingness to make a capital investment, taking over the business should be a very rewarding opportunity. Jessie Bull has been in the surplus electronics business for around 43 years and during that time has made many friends in the trade. I hope that he readily finds one of those friends to take over from him. If anyone is interested, give him a personal call in the afternoons, preferably after 4pm, on 0273 734648.
**EQUAL HARMONY**

The introduction of a Dynamics Processor module and remote panel to the Harmonia Mundi BW102 system, further extends its creative capabilities. This new addition offers the comprehensive digital audio processing functions of level (mixing) control, parametric equalisation, compression, limiting, expansion, noise gate and reverb functions.

With the new module, a wide range of attack/release times are possible. The release time can be set manually or automatically, with the automatic function permitting the choice of two different releases times, for fast peaks and mean level. A unique feature of the BW102/34 dynamics processor is its pre-delay function. The pre-delay, again set manually or automatically, enables the processor to look into future time, anticipating level changes, thus avoiding overshoots and distortion. Automatic level compensation is also provided to make life easier during mastering and post production.

F.W.O. Bauch, who, you probably know, handle Revox products as well, have already delivered five tailor-made BW102 systems over the past few months to CBS Studios London, Fine Splice Limited, Battery Studios, Townhouse Studios and Audio FX Camden. All of the systems include processing with equalisation and all systems have been installed in mastering suites, while the unit held by Audio FX is available for hire purposes.

**CONTACT:** F.W.O. Bauch Limited, 49 Theobald Street, Boreham Wood, Hertfordshire, WD6 4RZ. Tel: 01-953 0091

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**DEMANDING CASE**

B.K. Electronics have at last succumbed to a real demand to case their OMP mono mos-fet chassis amplifiers, and have started by casing their MF100 and MF200 modules.

The new cased amplifiers will be known as the CA110 and CA210 slave amplifiers. All the advanced features of the mos-fet chassis amplifiers, including the toroidal transformer power supply, have been retained. These features have been combined with a led vu meter and an input level control, and are housed in a purposely designed black anodised aluminium case.

Both amplifiers have an input sensitivity of 50mV for full power output. The CA110 provides 115 watts into 4 ohms and 105 watts into 8 ohms, whilst its larger brother boasts 215 watts into 4 ohms and 150 watts into 8 ohms (All power being watts rms). The power bandwidth (-3dB) is 1Hz-50kHz. Both models are realistically priced at £79.00 + £4.00 P&P for the CA 110 at £99.00 + £5.00 P&P for the CA210, inc. vat. The amplifiers are available direct from B.K. Electronics, Unit 5, Comet Way, Southend On Sea, Essex, SS2 6TR. Tel: 0702 527572.

The power band will be simultaneously monitor up to 16 pins. Functioning as a logic monitor and ic test clip it is a convenient circuit troubleshooting tool. Its logic threshold is 1.5V +/-0.34V and voltage range is 3.5-1.5V Bandwidth is 1MHz and current load 11mA.

For further information contact: OK Industries UK Ltd, Barton Farm Industrial Estate, Chichester Lane, Eastleigh, Hants, SO5 5RR. Tel: 0703 619841.

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**SAFE CLIPPING**

The new LC-160 logic clip from OK, said to be the first electrostatic discharge safe logic monitoring instrument, will
Deborah's Tribute

Deborah Gardner, aged 17, of Whickham Comprehensive School in Gateshead, is pictured with her YEDA trophy and her school's new Texas Instruments electronic time teaching aid for primary school children.

With less than a month to go the deadline for 1989 entries, Whickham's headmaster, Bill Smith, invited Texas Instruments' corporate communications manager, Richard Mann, to inaugurate the prize. Deborah was the first recipient of the Young Electronic Designer Awards. Her project was an electronic time teaching aid for primary school children.

The combination of a high resolution, dynamic pointer and digital displays provided the RAC with an unexpected bonus. The clear digital read-out in 10.5mm high numerals has enabled them to use the meter to interrogate the computer-based Electronic Control Units (ECUs) found on many modern cars. CONTACT: Kate Grenshaw, Megger Instruments Limited, Archcliffe Road, Dover, Kent, CT19 9EN. Tel: 0304 202620.

Optical Pole Vault

The equivalent of 25,000 simultaneous telephone conversations have been carried over a single optical fibre link in British Telecom's network, in a record-breaking demonstration of a technique which offers even bigger increases in capacity in the future.

The demonstration was carried out on a fibre in the optical submarine cable between the Cumbrian coast and the Isle of Man. The system, which came into service last summer, operated without regenerators over its entire 94km length.

British Telecom is the first to use optical wavelength division multiplexing over its operational network, by sending light at different "colours" or frequencies simultaneously along the same hair-thin optical fibre.

The microchip lasers, which produce the separate light outputs at slightly different wavelengths, were developed by British Telecom scientists at the company's research laboratories at Martlesham Heath, near Ipswich.

The demonstration was part of British Telecom International's assessment of the impact of new technologies on future submarine systems.

"It will enable such systems to be readily upgraded in the future at minimum cost to provide direct increases in capacity. And this benefit will apply with equal force to longer systems incorporating optical amplifiers, which are able to handle multiple transmissions without difficulty."

For those of you who have a craving for hi-tech facts and figures: The is the first time that WDM transmission has been used in the field using fully packaged and commercially available components. The demonstration was part of British Telecom International's assessment of the impact of new technologies on future submarine systems.

"It will enable such systems to be readily upgraded in the future at minimum cost to provide direct increases in capacity. And this benefit will apply with equal force to longer systems incorporating optical amplifiers, which are able to handle multiple transmissions without difficulty."

SAFETY AT WORK

With health and safety at work receiving greater attention than ever before, TMK Instruments have introduced a new portable appliance tester. Designed in the UK, Model TEM 4600 can be used by non-technical personnel after brief training. Ideal for suppliers, hirers and users to check the electrical safety of appliances, tools, equipment and extension wiring for compliance with the Health & Safety at Work Act.

Two fault simulators are supplied for earthed appliances, the other for suppliers, hirers and users to check the electrical safety of tools, equipment and extension wiring for compliance with the Health & Safety at Work Act.

CONTACT: TMK Instruments, Building 3, GEC Ind. Estate, East Lane, Wembley, Middx, HA9 7PJ.
two versions of J.P. Designs' new eprom eraser are available, with or without switch selectable timer. The basic construction is the same for both versions: an anodised aluminium unit, featuring a sliding drawer section with high density anti-static foam into which the eproms are placed for erasing. It is possible to erase up to 40 eproms at one time and when the drawer is closed it becomes almost light tight. Erasing is performed by a lower power 6 watt lamp, which keeps the unit cool whilst emitting the correct light level to the eproms. Erasing takes between 20 and 30 mins. The unit is compact at 320 x 87 x 60mm and the tube is totally enclosed. All units are supplied with 1 metre mains cable and lamp fitting instructions. The timer version also features an led indicator and times of 10, 20 or 30 mins can be selected. For your safety the casing is earthed and carries a warning label. These erasers are available at the low cost of £54.95 for the basic version and £64.95 for the timer version.

For further information contact: J.P. Designs, The Old School, Prickwillow, Ely, Cambridgeshire, CB7 4UN. Tel: 035 325/455.

PHAXSWITCH

The latest product from The Switch Electronics stable is the BIT PHAXswitch which enables a phone and a fax to operate, problem-free, on a single telephone line. Thought to be ideal for small businesses or use at home, the unit is convenient, fully automatic and cost effective. Convenient, because it can be installed in seconds by the user (no waiting for the telephone company to install a new line) and because it can be easily moved from one location to another. Taking work home at the weekend? Simply take your fax and PHAXswitch with you. Automatic, because it is able to identify whether an incoming call is from a fax machine wishing to transmit or a person wishing to speak - and directs the call accordingly. Calls from non-automatic fax machines are also accommodated - in most ingenious and simple manner. After two rings the caller is greeted with a friendly, digitised voice which says: 'This is a BIT PHAXswitch answering your call. If you wish to send a fax, please say 'fax' after the tone. Otherwise, please wait until the phone is answered.' A time delay of three seconds, for the caller to say 'fax', is utilised to determine which way the call should be directed. The PHAXswitch can also be used in manual modes; for example, when a call from a friend is expected and the user does not wish him to be greeted with the recording message. Comments Steven Wickens of Switch Electronics: 'This new device provides an invaluable automatic switch-over for fax machines and dramatically increases the scope of a single telephone line. It's no wonder that the BIT PHAXswitch walked away with the 1988 Best New Product award in its category at the prestigious Telecom Asia exhibition in Hong Kong.'

For details of the further benefits of the PHAXswitch contact Switch Electronics, 241 Desborough Road, High Wycombe, Bucks, HP11 2QW. Tel: 0494 465352.

CHIPPING OUT

Two versions of J.P. Designs' new eprom eraser are available, with or without switch selectable timer. The basic construction is the same for both versions: an anodised aluminium unit, featuring a sliding drawer section with high density anti-static foam into which the eproms are placed for erasing. It is possible to erase up to 40 eproms at one time and when the drawer is closed it becomes almost light tight. Erasing is performed by a lower power 6 watt lamp, which keeps the unit cool whilst emitting the correct light level to the eproms. Erasing takes between 20 and 30 mins. The unit is compact at 320 x 87 x 60mm and the tube is totally enclosed. All units are supplied with 1 metre mains cable and lamp fitting instructions. The timer version also features an led indicator and times of 10, 20 or 30 mins can be selected. For your safety the casing is earthed and carries a warning label. These erasers are available at the low cost of £54.95 for the basic version and £64.95 for the timer version.

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For details of the further benefits of the PHAXswitch contact Switch Electronics, 241 Desborough Road, High Wycombe, Bucks, HP11 2QW. Tel: 0494 465352.

CHIP COUNT

This month we highlight the new TL030 and TL050 series of enhanced jfet-input opamps introduced by Texas Instruments. They are of immediate relevance to many PE readers since the chips are improved and direct replacements for the familiar TL060, TL070 and TL080 series.

TL030 AND TL050 OPAMPS

With the introduction of the first jfet family in the late 1970's, jfet-input opamps have become firmly established as low cost, high speed amplifiers.

In applications where dc precision, in addition to ac performance is required, a trade off generally exists between the two. Texas Instruments, with its advanced design and processing, believes it has solved the problems of dc precision in jfets with the release of the TL030 and TL050 series. The new jfets combine, and even improve on, the excellent slew rates of the first generation jfet devices with a step function improvement in dc precision.

Jfet employ junction field effect transistors in the differential input stage of what is in effect a bipolar opamp. The result is higher slew rates and lower input bias currents that bipolar opamps. System designs using jfet-input opamps generally rely on these two key parameters: high slew rates for good ac performance and low bias currents for high impedance interfacing.

Many applications require both good ac performance and steady state precision. Bipolar opamps can offer excellent dc precision in terms of input offset voltage (Vio) and gain, but at the expense of ac performance. Furthermore, jfet-input opamps with good dc precision have been especially difficult to produce as a result of shifts in Vio caused by package induced stress. Existing jfet technology opamps, when assembled in plastic such as the familiar dual-in-line package, typically exhibit a 300 microvolt shift in Vio, often moving Vio out of specification.

For this reason TI has, over the last few years, evaluated the possibility of a low offset jfet while retaining the characteristic ac performance. The result is the new TL030 and TL050 series. The new jfets are also more stable with time - precision applications drift with time can cause significant problems and result in continual recalibration. The new designs have reduced the 300µV average shift down to 60µV.

Unity gain bandwidths remain unchanged, with between a 25% to 85% increase in slew rate for the TL050 series when compared with the TL070 series. The TL050 series are improved versions of the TL070 and TL080 series, and the TL030 series are improved versions of the low power TL060 series. They are all plug-in replacements.

For further information contact: Texas Instruments Ltd, Manton Lane, Bedford, MK41 7PA. Tel 0234 270111.

PRACTICAL ELECTRONICS AUGUST 1989
It does now look as if the firms trying to sell the idea of satellite to the British public may fail, with catastrophic cash losses all round. Much of the damage is self-inflicted. Instead of joining forces to try and educate the public on a very muddled field of new technology, rival factors have fought in public and created even more confusion.

This is the current state of play. When (if?) launched this autumn, BSB's satellite will hang at a completely different place in the sky from the Astra satellite which already carries Sky and W H Smith (31 degrees West for BSB, 19 degrees East for Astra). One aerial cannot pick up both signals, unless it is an expensive and difficult-to-install beast which moves under remote-controlled motor power. In most cases it will be easier and cheaper to have two aerials, or use one aerial and forget about the other service.

BSB will use a completely different transmission system from Sky, D-MAC instead of PAL. BSB will also use a different scrambling more accurate, encryption system from Sky, Eurocrypt instead of Videocrypt (previously called Palcrypt). Eurocrypt was developed by General Instruments, in the USA, from the Videocrypt system which is the de facto standard in North America.

**W H Smith** still threatens to switch from PAL to D-MAC and adopt yet another scrambling system, called Eurocrypt. This had prevented the owners of the Astra satellite from launching a generic advertising campaign for all programmes available from the same source.

BSB will only supply its descrambling equipment to four selected suppliers of BSB receivers - Ferguson, Philips, Tatung and Salora. So Sky receivers made by other firms cannot be modified to receive BSB. This is why the Evening Standard cancelled its competition with supposedly "future-proof" Grundig receivers as prizes.

So, the total kit needed to receive all programmes promised for the end of this year becomes an absurd two aerials and four set-top boxes costing up to £1000 to buy and install, and gobbling subscriptions at the rate of around £30 a month. Because there is no agreed electrical interface standard between dishes and receivers, it is impractical to mix and match.

Compare that with the price of a BBC tv licence (£66) and the simplicity of a conventional TV aerial and video recorder.

A full eight months after BSB scored extensive publicity by unveiling its squarish flat dish aerial (without actually explaining that it was only unveiling a wood and plastic}

### MAC SCRAMBLING

**BY BARRY FOX**

**WINNER OF THE**

**UK TECHNOLOGY PRESS AWARD**

**Satellite TV - will it end up in the crypt, or just turn out to be a cypher?**

Whatever the shape of the aerial, DIY dish fixing is to be recommended only to electronics hobbyist. Even then it is downright dangerous to learn by trial and error how to connect, align and then secure an aerial on a high ladder or sloping roof.

Although the government has ditched its scheme for a £10 dish licence, because it cost more than £10 to process each piece of paper, the Department of the Environment's planning regulations set a limit of one dish (of less than 90cm) per building. The Home Office's Cable and Broadcasting Act, 1984 flies in the face of this. The Cable Authority is duty-bound to enforce clauses in the Act which make it a criminal offence for even two flats to share a dish without becoming a licensed cable station.

**DUTCH COURAGE**

When Philips signed with BSB, in February, to become the fourth supplier of set-top D-MAC receivers, the Dutch company was put in a very difficult position. The position got even worse when, less than a month later, Philips signed to supply descrambling equipment for Sky too.

The decisions were pragmatic and commercially sound. Unfortunately they were covered in face-saving fudge which only adds to the general confusion.

The original MAC system (C-MAC) and the British variant to be used by BSB (D-MAC) will not work on the Continent, because the eight channel digital sound signal has too broad a bandwidth to be distributed by their extensive cable systems.

This is why Philips has so far backed D2-MAC, which was half the number of sound channels and half the bandwidth.

Two years ago Philips and Thomson (with software company Logica) formed the Euromac consortium to develop a scrambling and encryption system for MAC. In 1988 it crystallised into Eurocrypt. The decoder is controlled by a smart card (credit card with built-in computer). This is the system W H Smith plans to use with D-MAC.

Fearing delays in availability of the vital chips, BSB signed with ITT Intermetall to produce D-MAC chips and with General Instruments in America to provide Eurocrypt encryption modules.

But Philips cannot bear to admit the hard truth - that it has had to turn against both D2-MAC and Eurocrypt, and use D-MAC and Eurocrypt instead.

With unbounded optimism Philips satellite boss Peter Groenenboom has told the UK Government what it should do; adopt a common MAC standard and a common scrambling system by January 1st 1991.

This is technical nonsense, as well as astonishing cheek.

The Eurocrypt and Eurocypher systems are quite different. Whereas Eurocrypt needs a smart card reader in the receiver, Eurocypher sends all the necessary decoding and subscription validation signals over the air. And there is no compatibility between dedicated D and D2-MAC systems.

Now Philips has signed with Sky to produce the PAL Videocrypt decoders which will be needed to receive scrambled movies.

Quite simply everyone in the satellite game is betting on all competing systems - which could simply ensure that none of them win.
EDITORIAL

Practical Electronics, at the above address and telephone number.

Readers' Enquiries

All editorial correspondence should be addressed to: The advertisement department, Practical Electronics, at the above address and telephone number.

We regret that lengthy technical enquiries cannot be answered over the phone.

they continue to be in charge of what goes on in their homes".

The Big Brother concept is of concern to me, and is obviously of concern to many others, particularly those who are better informed about computer-based systems. The fear is that home automation will permit invasion of privacy. Consequently, the report concludes that collation of and dealing in information derived from home-based transactions may need strict regulation to forestall consumer resentment and fear.

Fear of the unknown is a common human condition, and is a factor to be addressed regarding home automation products and services. If these can be presented in such a way that they can be perceived as an extension of something with which consumers are already familiar, they are more likely to be accepted. The same is true if they provide a solution to an already recognised problem. The report rightly concludes that perception that an item falls into one of these categories can have a major effect on its evaluation. In this context, familiarity is likely to breed contentment, not contempt.

Another issue highlighted is that home automation arouses concern among many consumers about a deterioration in the quality of their lives. The reason given is that passivity, isolation, de-skilling and atrophy of mental and imaginative functions are all to some degree feared. This, to me, is indeed an unexpected finding. One of the primary motives for introducing automation to the home is surely to enhance one's life style. That has usually been the case presented for many domestic devices, and it seems reasonable to extend that case to include the newer concepts emerging under the general title of home automation.

Although I do not overlook the profit motive driving manufacturers concerned with this infant technology, I am convinced that there will be true benefit to society in general arising from widespread implementation of home automation.

THE EDITOR

PRACTICAL ELECTRONICS AUGUST 1989

9
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PLTV EXPRESS AUGUST 1989

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2 x 500 way £1500

2 x 500 way £1500

2 x 1000 way £2000

2 x 1000 way £2000

2 x 2500 way £5000

2 x 2500 way £5000

2 x 5000 way £10000

2 x 5000 way £10000

2 x 10000 way £15000

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This article describes a new stepping motor driver IC M5804 which offers higher power and more operation modes than the commonly used SAA1027. A full practical design is given to allow this chip to be used in all modes driven either from a computer or a simple pulse generator.

**STEPPER MOTORS**

Stepping motors are becoming more and more popular as a means of providing precise computer controlled movement. Their applications in plotters, printers, buggies, and scanners are well known, but there are many other applications - for example, greenhouse vent controls, and antenna positioning systems, where stepping motors are ideal. In the hobby and educational fields low cost stepping motors find practically unlimited applications, particularly in technology, and cdt projects.

In order to drive a stepping motor from a computer output port, some form of interface is needed. The simplest is a set of four power transistors (usually high gain Darlington types) each connected between one output port line and one motor winding connection. The computer is then programmed to switch the windings on and off in the correct sequence to rotate the motor. The necessary sequences for the various modes of motor drive are shown in Table 1. Although the hardware is simple, they operate in other modes - particularly half-step mode, limit its use. One difficulty with this IC is that it needs unusually high logic levels (logic 1 = 7.5V) on its inputs to perform correctly. High logic levels were once commonly used in industry because they provide higher noise immunity than normal 5V circuits. To raise 5V levels to these higher levels takes additional circuitry.

Many stepping motor applications require higher performance drive circuits which are capable of half-step operation as well as the usual two-phase (full step) mode and can provide higher output power. Even simple applications benefit from half-step drive which gives smoother running as well as halving the step angle (doubling the number of steps per revolution).

The M5804 IC introduced in this article is able to handle up to 35V and 1.25A per phase (50V 1.5A peak) and has three motor drive modes: half-step, one phase, and the standard two-phase. The inputs to the IC are compatible with standard CMOS, PMOS, and NMOS circuits and with the addition of

![Fig.1. Simplified circuit of the M5804 stepper motor control IC.](image)

**TABLE 1**

**STEPPING SEQUENCE TABLES**

**WAVE-DRIVE SEQUENCE**

<table>
<thead>
<tr>
<th>Step</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>2</td>
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<td>ON</td>
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<tr>
<td>3</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
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</tr>
<tr>
<td>4</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
</tbody>
</table>

**TWO-PHASE SEQUENCE**

<table>
<thead>
<tr>
<th>Step</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
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<td>OFF</td>
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<tr>
<td>2</td>
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<td>OFF</td>
</tr>
<tr>
<td>4</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
</tr>
</tbody>
</table>

**HALF-STEP DRIVE SEQUENCE**

<table>
<thead>
<tr>
<th>Step</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
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<td>4</td>
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<td>OFF</td>
<td>ON</td>
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<tr>
<td>8</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
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</tbody>
</table>

**DEDICATED CHIPS**

A better approach is to use a dedicated interface IC which works out the correct switching sequence for the motor and has four high power outputs which drive the motor directly. This approach simplifies the computer's job so that only two output port lines are required, one sets the direction of rotation and the other is programmed to change state each time a step is required. The most common dedicated IC for this job is the SAA1027 which handles up to 400mA at 12V on each output and provides bi-directional full step control.

In many applications this IC is adequate, but its low output capability and inability to

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**BY MARK STUART**

*The new M5804 becomes a very versatile single-chip stepper interface.*

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PRACTICAL ELECTRONICS AUGUST 1989
Fig.3. Input circuit details

appropriate pull-up resistors, t1 and t2. This means that the ic can be connected directly to any computer parallel output port and drive a wide range of motors directly. Another excellent feature of this ic is internal thermal protection circuitry that disables all outputs when the chip temperature exceeds approximately 165° and re-enables them at 145°.

FUNDAMENTALS

A simplified circuit of the ic is shown in Fig.1. Four output transistors drive the motor windings. Each transistor is actually made up as shown in Fig.2, consisting of a standard power Darlington pair with a reverse connected parallel diode and another diode linked to a separate pin to be connected to the positive motor supply. The first diode clamps any negative voltage swings and so prevents the base-emitter junction of the output transistor from becoming forward biased. Without this, energy from the output can very easily be coupled to the input drive circuits – with dire consequences. The second diode provides an alternative path for the inductive motor winding current to flow as it decays when the transistor is turned off. This is an identical function to the familiar connection of a diode across a relay coil, it prevents high voltage spikes from breaking down the collector-base junction. The two diodes are sometimes called “ground clamp” and “flyback” diodes respectively.

The input circuits are the same as standard cmos logic as shown in Fig.3. These have the usual series protection resistor and shunt clamping diodes.

Fig.4. Zener stabilised logic supply.

The supply voltage to the logic section of the board can be separate from the motor drive supply and must not exceed 7V. As only 30mA (maximum) is drawn by the logic circuits it is likely that most computer systems can be tapped for the necessary current from their 5V rails. Alternatively a simple zener diode stabiliser can be run from the motor drive supply as shown in Fig.4.

Fig.5. IC connected to motor. R = series resistors (see text)

MOTOR CONNECTIONS

A circuit of the ic connected to a motor is shown in Fig.5. Most standard unipolar stepping motors, such as the MD200 and MD35, have a pair of centre tapped windings. One winding connects to pins 1, 2 and 3, while the other connects to 6, 7 and 8. It does not matter which winding connects to which three pins, and provided the centre taps are connected correctly the two ends of each winding can be connected either way round. To make things simple, Fig.6 gives the lead colours for the popular MD200 and MD35 motors.

SERIES RESISTANCE

In many applications it is adequate to connect the motor supply directly to the winding centre taps, and operate the motor at, or even below its rated voltage. This arrangement gives adequate performance for many applications but does not extract anywhere near the full potential from the motors. When higher acceleration and speed are required it is possible to make substantial improvements by raising the supply voltage and fitting series resistors as shown in Fig.5. The higher voltage forces the motor current to rise more quickly. If left unchecked this would lead to excessive current and a very hot motor, but the series resistors prevent this, so that the current rises much more rapidly, but stops rising when it reaches the motor's maximum rating.

Fig.7 shows the current in two cases for the MD35 and MD200 motors derived from actual oscilloscope measurements on a single winding. In the first case the motors are powered directly from 12V, and in the second case from 25V via a 33 ohm 5 watt...
series resistor. In both cases the final current is the same, but the rate of increase is more than doubled. This rapid increase gives much higher performance from both motors. The penalty for this, of course, is wasted power in the series resistance which may equal or exceed the power reaching the motor. The method is simple though, and for small motors the improvement may be well worth the extra power. Only two resistors are required because the two halves of one winding are never on together (if they were, the opposing currents would cancel and the motor would draw its usual current but develop no torque – a condition which can occur if the two windings are mixed up).

**OPERATION**

Fig. 5 shows that the ic has five input pins. Pin 15, the output enable pin, turns off the output transistors when held at a logic 1. Its operation is completely independent of the stepping logic: in normal operation it would be connected to 0V. This pin can be used to reduce current consumption when the motor is stationary. Its main purpose is to allow the ic to be used with sophisticated chopper current control circuits.

Pin 14 sets the direction of the step sequence and hence the direction of motor rotation. Logic 0 produces one direction and logic 1 the other. Note that the actual direction of rotation depends on the way the motor windings are connected and can be changed simply by reversing the connections to one winding. This is sometimes more convenient than altering the computer program if the motor is found to rotate the wrong way.

Pins 9 and 10 are used to select the stepping mode. Table 2 is a truth table showing the circuit logic. Normally the levels on these pins will be fixed for each application to give full-step or one-phase drive. When both are held at a logic 1 (Step Inhibit) step pulses (pin 11) are ignored. This feature is useful in some situations where two motors are being driven at the same speed but need to be stopped and started independently.

Step pulses can be applied to both motor drivers together from a single computer output line or oscillator and by using the step inhibit feature either or both motors can be stopped or started simply. In some circumstances it is desirable to change the stepping mode while in operation. This can be done by connecting each of the two pins to a computer output line, and setting the logic levels accordingly. Note that these lines and the direction control line (pin 14) must only change state when the step input (pin 11) is in the low state. This is necessary to prevent disruption of the step sequence which would result in lost or extra steps. It is easy to attend to this when driving the ic from a computer, but some sort of gating arrangement may be necessary when simpler drive methods are used.

Pin 11 is the Step Input pin. The outputs will advance one sequence position each time this pin changes from a logic 1 to logic 0. The minimum pulse width required is 500ns, there is no maximum limit but it is advisable to keep the pulse rise and fall times reasonably short (as with all logic circuits) to avoid problems caused by output transients being picked up by the input circuits.

**STEPPING SEQUENCES**

The step sequences for all three operating modes were shown earlier, in table 1. In each case the states (on or off) of the output transistor are given. Fig. 8 shows a simplified motor with just four steps per revolution. Practical motors have multipole rotors and stators but the principles are the same. Windings are energised by switching the four terminals to 0V according to the sequence in table 1 while the positive supply voltage is applied to the winding centre taps. For each step the rotor aligns with the energised stator poles as shown in Figs. 9a, b and c. Unmarked poles are not available. The characteristics of each mode are as follows:

**ONE-PHASE (or Wave Drive)**

In this mode just one winding is energised at a time and the motor executes one full step for each pulse (Fig. 9). The current consumption is lower than any other mode, and the available torque is correspondingly less. Acceleration and maximum stepping rate are low.

**TABLE 2**

<table>
<thead>
<tr>
<th>CONTROL LOGIC TRUTH TABLE</th>
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<tbody>
<tr>
<td>PIN 9</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>TWO-PHASE</td>
</tr>
<tr>
<td>ONE-PHASE</td>
</tr>
<tr>
<td>HALF-STEP</td>
</tr>
<tr>
<td>STEP-INHIBIT</td>
</tr>
</tbody>
</table>

PRACTICAL ELECTRONICS AUGUST 1989
TWO-PHASE (or Full Step)

As the name suggests, in this mode the windings are energised in pairs so that the rotor aligns between the energised pair of poles (Fig. 9). Since two poles are energised at a time, the torque and hence the acceleration and maximum stepping rate are higher, and the current consumption is double that of one-phase drive. The motor executes one step per pulse.

HALF-STEP

By alternating between the above methods the rotor can be moved to alternately align with the poles and between them (Fig. 9). This doubles the number of rotor positions so that the motor now executes one half step per pulse. This mode is very popular because it gives finer resolution (96 steps with a 48 step motor and 400 steps with a 200 step motor). It also gives much smoother running and freedom from resonance effects which can cause unstable running under certain speed and load conditions in the other two modes. The current consumption changes between alternate steps and averages three-quarters of the full-step mode.

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**Fig.8. Diagram of simple 90° per step motor showing relationship of coil terminals to poles.**

**Fig.9. (a) Wave drive-one phase, (b) Full step-two phase, (c) Half step mode.**
POWER-ON RESET

When power is first applied to the logic section of the ic the states of the outputs are automatically set to those shown as step 1 in the tables. If a separate motor power supply is used this can be turned on and off freely without affecting the logic states.

CONSTRUCTION

A single small pcb design is all that is required for this ic as it requires few other components. Fig. 10 shows the component layout diagram. The ic may require heatsinking in some applications, and this can be achieved by soldering copper "wings" to pins 4, 5, 12 and 13. I have operated all of Magenta’s standard motors (drawing up to 1A total at 12V) without heatsinks of any kind, and the ic has stayed quite cool. A single capacitor on the board is provided to decouple the logic supply.

On the input side of the board, a row of eight 0.1 in pins are provided for connection of the logic power supply and control inputs. Next to these pins, a row of holes are provided so that any of the inputs can be linked either to supply or ground for the particular application.

The output side of the board has a row of 6 pins, four of which connect to the output transistor collectors, with the other two being the connections to the two pairs of flyback diodes. Provision is made on this side of the board for two resistors to be fitted if series resistance operation is required. In most cases the necessary resistor power rating makes it preferable to mount the resistors away from the ic, connected to the board with flexible wire links.

TESTING

When completed, the board can be tested by connecting four leds (with series resistors) between the four output pins and the logic supply. The functions of the circuit can then be checked one by one by linking the appropriate input pins to ground or supply. Note that the logic supply should be between 4.5V and 5.5V (max 7V) and that the circuit will need 30mA plus the led current. As the inputs are cmos, they must not be left floating in any circumstances.

Computer programming to drive the ic can be very simple indeed as it is a matter of writing numbers to the computer output port. The simplest program can be written in basic and just consists of a timing loop and Two instructions to write to the output port. The time delay must be long enough to give a stepping rate that the motor can follow. This is best determined by trial and error and depends on the load and motor inertia. A good idea is to start at a slow rate, such as 50 steps per second, and gradually decrease the time delay until the highest practical stepping rate is achieved. There is a stepping rate (called the pull-in rate) above which the motor will not start from a standstill. It is possible however to accelerate the motor gradually to higher speeds by smoothly increasing the stepping rate while it is running. The programming for this is more complicated, but very interesting, especially as the motor also must also be decelerated gradually. For many applications it is better to take the soft option and stick to constant but lower speed running.

MORE MOTORS

Magenta have a range of stepping motors in stock, all of which can be driven by this interface.

Two types are featured in this article: MD 200:200 steps per revolution £16.80 inc. vat
MD 35:48 steps per revolution £12.70 inc. vat
The interface will drive any other motor provided its ratings are not exceeded, and that the motor has 4-phase unipolar type windings.

about 30% of their potential pay-as-you-view income because of pirates selling illegal decoding equipment which enables viewers to receive encoded or scrambled signals. Sky TV, which intends to introduce pay tv channels later this year, will issue smart cards to subscribing viewers. They are the thickness of an ordinary credit card and have a built-in microprocessor. Inserting them into the set-top decoding boxes will unlock the unscrambling equipment allowing normal viewing. The smart card microprocessor will allow Sky to cut off any viewer who has not paid the monthly subscription.

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High frequency (hf) radio relies on radio waves being bent through the atmosphere for the signal to reach the distant end. The demarcation between low, high and very high frequency radio is a demarcation by frequency as shown in Fig. 1, and although hf radio will be concentrated upon here, the other forms will be touched on for completeness.

### RADIO WAVE PROPAGATION

Radio energy can be visualised as rippling away from a point source like water rippling away when an object is thrown into a pond. The only difference is that radio energy ripples away three dimensionally, i.e., in the shape of a spherical front unless deliberately suppressed in the backward and sideways directions so as to concentrate the energy in the forward direction.

Therefore the power decreases by the square of the distance as given by the formula

\[ P = \text{Total power radiated} \times \frac{1}{4\pi r^2} \]

Where \( P \) is the power at distance \( r \).

The wavefront consists of an electrical component and magnetic component at right angles to each other which is referred to as a transverse electro-magnetic (tem) wavefront. The plane of the electric field determines whether the wave is horizontally or vertically polarised, Fig. 2.

In general, electro-magnetic waves travel in straight lines except where the earth and atmosphere change the path. There are three methods of propagation:

1. The ground or surface wave
2. The sky wave
3. The space wave

### HF RADIO

**The first in a series on practical radio propagation, from aerials to atmospherics.**

In the earth's atmosphere, where the pressure is lower (100km to 300km up), free electrons are produced as a result of ionisation by energy from the sun. From measurements of electron density the atmosphere has been divided into layers D, E, F1 and F2 as in Fig. 3. At night the F1 and F2 layers combine into a single layer.

The D layer depends on the latitude of the sun and disappears at night. It reflects vlf and if waves but does not affect hf much. The E layer also disappears at night like the D layer owing to de-ionisation in the absence of the sun. The E layer helps mf propagation and reflects some hf.

Sometimes a thin layer of high density ionisation appears with the E layer and remains through the night. Although it does not assist long distance communication, it gives unexpectedly good reception.

Of the two F layers, F2 is the more important for reflecting hf radio and it persists at night. The height and ionisation density of the F2 layer vary with the time of day, season of year and sunspot cycle.

HF waves are returned to earth not by reflection but refraction, Fig. 4. The wave is gradually bent so that it finally emerges from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth.

### Fig. 2. Polarisation

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<th>Frequency</th>
<th>Wavelength</th>
<th>Application</th>
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<td>Very low frequency (VLF)</td>
<td>3-30kHz</td>
<td>100,000-10,000m</td>
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<td>Low frequency (LF)</td>
<td>30-300kHz</td>
<td>10,000-1,000m</td>
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<td>300-3,000kHz</td>
<td>1,000-100m</td>
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<td>High frequency (HF)</td>
<td>3-30MHz</td>
<td>100-10m</td>
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<td>30-300MHz</td>
<td>10-1m</td>
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<td>300-3,000MHz</td>
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<tr>
<td>Super high frequency (SHF)</td>
<td>3-30GHz</td>
<td>10-1cm</td>
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### THE GROUND WAVE

For horizontally polarised waves the electric field is short circuited at the earth's surface, therefore this method of propagation occurs only with vertical polarisation. The wave loses some of its energy to the earth and is therefore attenuated. The amount of energy lost depends on the terrain. For instance this is greater over rocky land than over the open sea.

Propagation by this means is limited to low frequencies 20kHz to 2MHz since attenuation increases with frequency.

### THE SKY WAVE

In the earth's atmosphere, where the pressure is lower (100km to 300km up), free electrons are produced as a result of ionisation by energy from the sun. From measurements of electron density the atmosphere has been divided into layers D, E, F1 and F2 as in Fig. 3. At night the F1 and F2 layers combine into a single layer.

The D layer depends on the latitude of the sun and disappears at night. It reflects vlf and if waves but does not affect hf much. The E layer also disappears at night like the D layer owing to de-ionisation in the absence of the sun. The E layer helps mf propagation and reflects some hf.

Sometimes a thin layer of high density ionisation appears with the E layer and remains through the night. Although it does not assist long distance communication, it gives unexpectedly good reception.

Of the two F layers, F2 is the more important for reflecting hf radio and it persists at night. The height and ionisation density of the F2 layer vary with the time of day, season of year and sunspot cycle.

HF waves are returned to earth not by reflection but refraction, Fig. 4. The wave is gradually bent so that it finally emerges from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth. The refractive index of the layer reduces from the atmosphere and returns to earth.

### Fig. 3. Ionisation layers

PRACTICAL ELECTRONICS AUGUST 1989
Above 30MHz, the ground component is greatly attenuated and refraction in the ionosphere does not take place. Therefore propagation is direct, or line of sight, between transmitter and receiver. However the radio horizon is slightly greater than the optical horizon.

In the troposphere, Fig. 5, the lower part of the atmosphere, the temperature and density of air decrease with height. Therefore the radio waves travel slightly faster in the upper atmosphere compared to closer to the earth. The results in a curved propagation path and an increase in the effective horizon.

If at the open circuited end the wires are parted, Fig. 8a, a little energy is radiated. However, the radiation from the top wire cancels that from the bottom wire and only energy that is not reflected back at the open circuit escapes as radiation. However, the radiation from the top wire cancels that from the bottom wire and only a little energy is radiated. If at the open circuited end the wires are parted, Fig. 8a, to give a horn shape, more energy is allowed to escape. Maximum energy radiates when the wires are bent at right angles to give what is called a dipole, Fig. 8b.

If the total length of the verticals is equal to half a wavelength, the aerial is called a half wavelength dipole. The horizontal radiation pattern of a vertical dipole is a circle, Fig. 9a, and the vertical pattern is a figure of eight, Fig. 9b, since the dipole radiates in both the forward as well as backward direction.

Resonant aerials could be described as opened out transmission lines such that the aerial is a half wavelength or a multiple of a half wavelength.

It was mentioned above that the vertical radiation pattern from a half wavelength dipole is a figure of eight. The vertical patterns for increasing lengths of aerial in free space are shown in Fig. 10. As the

**THE SPACE WAVE**

Communications over distances greater than implied above and at frequencies in excess of 30MHz can be obtained by a phenomenon known as scatter propagation. This is because both the troposphere and ionosphere are in a continuous state of change. Consequently the refractive index of the atmosphere changes, scattering radio energy, Fig. 6.

The useful frequency range for troposcatter links is 400MHz to 5GHz and distances of 800km have been achieved. The penalty of course is that rapid fading is possible due to multipath delay and the signal strength is lower than that usually achieved by a direct line of sight link.

Ionospheric scattering is also possible as a result of changes in ionisation of the E layer. The useful frequency range is 30MHz to 70MHz over a ground distance of 200km, with the same penalties as for a troposcatter link.

**THE WORK OF MARCONI**

Guglielmo Marconi was born in Bologna, Italy in 1874 and died in Rome in 1937. He was a physicist and is accredited with much of the early work on radio. His early experiments with radio communication succeeded in detecting a signal 6km across Salisbury Plains and 14km across the Bristol channel.

He founded a company which was renamed the Marconi Wireless and Telegraph Company in 1900. In spite of mathematicians who said that the curvature of the earth would limit radio communications to 322km, Marconi sent a signal from Poldhu in Cornwall to St John's in Newfoundland in 1901.

In 1918 he had improved his transmitters and receivers sufficiently to send a signal from England to Australia. His work also extended to the higher frequencies employing dish aerials for line of sight communications.

**AERIALS**

If an open circuited length of transmission line is considered, Fig. 7, forward and reflected waves combine to form a standing pattern as shown. The wave energy that is not reflected back at the open circuit escapes as radiation.

**Fig.4. Refraction in the ionosphere**

The dead space not served either by the ground wave or the sky wave is called the skip distance.

**Fig.5. Atmospheric bands**

Communications over distances greater than implied above and at frequencies in excess of 30MHz can be obtained by a phenomenon known as scatter propagation. This is because both the troposphere and ionosphere are in a continuous state of change. Consequently the refractive index of the atmosphere changes, scattering radio energy, Fig. 6.

**Fig.6. Troposcatter link**

**Fig.7. Open circuited transmission line. Fig.8. (a) Horn shape, (b) Dipole. Fig.9. (a) Horizontal radiation pattern of vertical dipole. (b) Vertical radiation pattern of vertical dipole.**
length of the aerial is increased the pattern builds up more lobes and the larger lobes come closer to the aerial.

Non resonant aerials on the other hand can be likened to non resonant transmission lines which are correctly terminated and therefore do not have standing wave patterns. Most of the forward energy is radiated and the remainder is dissipated in the termination, Fig. 11. Therefore the radiation pattern of the non resonant aerial is similar to that of the resonant aerial except that the former has only half the angle made by the two half power points of the main lobe, Fig. 12.

The beamwidth can then be defined as the angle made by the one half power points of the main lobe, Fig. 12.

**EARTH EFFECT**

The earth may be thought of as a reflecting surface, Fig. 13, and some rays will be bounced off. Therefore the energy arriving at a particular point may be made up of a direct ray as well as a reflected ray and if these are in exact antiphase, no signal is picked up by the receiver at that point.

In considering reflected rays it is sometimes easier to visualise these as coming from a mirror image of the aerial, ie, an aerial located below the earth's surface.

**LOW FREQUENCY AERIALS**

These are restricted to frequencies up to 300kHz and therefore a vertical radiator is sufficient. If the previously described dipole of overall half wavelength is connected to a transmitter or receiver as in Fig. 14 so that one end is earthed, it has a voltage and current distribution as shown.

Although the aerial is theoretically resonant at a height of a quarter of a wavelength, in practice this occurs at a height of slightly less than $\lambda/4$ (where $\lambda =$ wavelength).

Assuming that the resistance is negligible, the impedance of the aerial is capacitive for heights up to $\lambda/4$ and inductive between $\lambda/4$ and $\lambda/2$.

For economic reasons the height of the aerial may be limited to $\lambda/4$. For instance at 300kHz, this would be 800 feet which is quite an expensive tower. Since the aerial is capacitive for this height, it can be tuned by a series inductance.

Capacitance is deliberately added to the top of low frequency aerials and is achieved by turning the top half into an inverted 'L' or 'T' shape. The additional capacitance produces a uniform current distribution on the aerial and also reduces the overall capacitance of the aerial making a smaller tuning inductor possible.

**MEDIUM FREQUENCY AERIALS**

One of the most important applications of medium frequency aerials (used between 300kHz and 3MHz) is for broadcasting in the range of 550kHz to 1600kHz.

Early aerials for broadcasting in the 1920s were 'T' shaped with a piece of wire between two masts but insulated from the masts. There were many areas of fading where the ground wave neutralised the sky wave and therefore increasing the radiated power did not achieve anything.

It was left to Ballantine to show that there is a maximum height of aerial for maximum ground wave radiation. This led to the construction of a steel tower which acts as an aerial. It is on a ball and socket joint and insulated from earth, with stays to support the mast.

Fig. 15 shows the effect of increasing the height of the mast. At $5\lambda/8$ a secondary lobe appears and predominates over the ground wave. Therefore in practice such aerials are limited to around $\lambda/2$. 

**GAIN AND BEAMWIDTH**

Since practical aerials are designed to radiate in the required direction some means must be found of assessing their gain and beamwidth.

This is achieved by comparing the energy with that radiated by an isotropic radiator, ie, a theoretical aerial radiating uniformly in all directions.

The beamwidth can then be defined as the angle made by the one half power points of the main lobe, Fig. 12.

**Fig. 10. Pattern for increasing length of dipole.**

**Fig. 11. The non-resonant aerial.**

**Fig. 12. Beamwidth.**

**Fig. 13. Effect of the Earth.**

**Fig. 14. An earthed dipole.**

**Fig. 15. Aerial directivity with height.**
The aerials described up to now have been likened to an open circuited transmission line radiating energy. Another class of aerials may be considered, terminated in its characteristic impedance. One example is the rhombic aerial, Fig. 18a.

It is made of four straight lengths of wire suspended from posts and the rhombus is parallel to the earth. The lengths may be from two to eight wavelengths long and the angle between them from 80 degrees to 150 degrees. The angle \( \theta \) in Fig. 18b decreases as the lengths of wire increase and is 20 degrees for wires six wavelengths long.

For the frequency being transmitted, if the lengths of wire and the angle between them are chosen correctly, the angle \( \theta \) in Fig. 18b disappears and one main lobe is produced which radiates along the diagonal from the feeder.

The rhombic aerial is used for both transmission and reception and is widely used in the hf range for point to point working. These aerials have replaced broadside arrays to a large extent because the input impedance and radiation pattern remain fairly constant over a wide range of frequencies.

A rhombic aerial also produces minor lobes and about half the power is dissipated in the termination. These problems are overcome by using two or more rhombics in parallel either on top of each other or side by side depending on the radiation pattern required.

The aerials may also be connected in series as shown in Fig. 19. Alternatively they may still be in a straight line but connected separately to a receiver as in Fig. 20. If these can be steered to vary the angle \( \theta \) then the signal to noise ratio is improved since the down angle of short wave signals varies throughout a twenty-four hour period. Such a system is called a multiple unit steerable antenna (musa) and helped the early days of transatlantic telephony.
Thermal noise has a uniform spectrum up to $10^{13}$Hz, as white noise does. This can be likened to white light which has all colours. The noise voltage through a metallic resistor is given by:

$$V^2 = 4kTBR$$

where $B$ = bandwidth in Hz

$$k = \text{Boltzmann's constant}$$

$$T = \text{temperature in Kelvin}$$

The above equation implies that minimum bandwidth must be used to transmit the signal in order not to degrade the signal to noise ratio.

**THERMAL NOISE**

For the series circuit of Fig. 23

$$Q = \frac{\omega L}{R} = \frac{f}{B}$$

where $B$ is the bandwidth.

In the parallel resonant circuit of Fig. 24, the same equation applies:

$$Q = \frac{f}{B} = \frac{wCR}{2\pi L C}$$

**RESONANCE AND ENERGY COUPLING**

Resonance may occur in series or parallel tuned circuits. In the series tuned circuit of Fig. 23, resonance occurs when

$$\omega L = \frac{1}{2\pi LC}$$

or $f = \frac{1}{\sqrt{LC}}$

Bandwidth is defined as the two frequencies on either side of the resonant frequency, at which the power drops to half or by 3dB.

The Q of a circuit is a figure of merit and the general definition is:

$$Q = \frac{\text{energy stored in the circuit}}{\text{energy dissipated per cycle}}$$

**Resonance and Energy Coupling**

The Q of a network can never be greater than the Q of the coil. For air cored coils the Q is 100 to 200 and for ferrite cores the Q is 50 to 100. In the vhf range (30MHz to 300MHz) helical resonators with a Q of 100 are used.

Capacitors behave as series LC circuits because of the internal inductance of the leads, and radio frequency coils behave like parallel LC circuits because of the distributed capacitance between the windings.

Since radio frequency chokes present a high impedance, the resonant frequency of the circuit needs to be less than the resonant frequency of the choke. The cores are usually iron, ferrite or phenolic.

The coupling of energy from one stage to another is usually by transformers particularly around the intermediate frequency (if) stages. The double tuned transformer is mostly used around the if stage with the single tuned transformer used around other stages like the rf stage.

The equivalent circuit of a single tuned transformer is shown in Fig. 25 and the coupling co-efficient ($k$) is given by:

$$k = \frac{M}{L_1 L_2}$$

The equivalent circuit of a double tuned transformer is shown in Fig. 26 and the coupling co-efficient is given by:

$$k = \frac{M}{L_p L_s}$$

**In the next part we shall look at the essential parts of a radio receiver.**
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Magenta supply Full Kits: Including PCB's (or Stripboard), Hardware, Components, and Cases (unless stated). Please state Kit Reference Number, Kit Title and Price, when ordering.

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PRACTICAL ELECTRONICS AUGUST 1989
Probably even before primitive man discovered the techniques of producing harmonic sounds with wind and stringed instruments, he would already have known that his body was a multipurpose musical instrument. With our mouths and vocal chords we can produce an astonishing range of musical tones, and with our limbs can create an equally varied range of percussion sounds.

**APPLAUSE**

One of the most frequent sounds we produce, whether we are musical or not, is created by sharply bringing our hands together, the act of clapping. By clapping we can signify many states of emotion, ranging from approval or disapproval to rhythmic accompaniment. Strangely, approval and disapproval are differently interpreted by different races. In some countries the synchronised clapping by an audience signifies approval, whereas in others it can be a sign of derision. In Britain we seem to prefer slow synchronisation for expression of dissatisfaction and fast non-synchronisation, randomness, for approval. All cultures, though, seem to be in agreement about the use of clapping as a rhythmic expression of musical beat.

**MONOTONY**

Producing an electronic simulation of hand clapping is not very complex, although it takes a fair number of components since we ideally need to also create ambience, echo and tonal variation. However, I shall avoid the philosophical conundrum of attempting to simulate the sound of one hand clapping!

In its most basic form the sound of two hands coming together as a clap can be created by regularly feeding sharp transient pulses into a loudspeaker. In other words all you need is a click generator. This can be readily formed by designing an oscillator that produces pulses on a regular basis. If the pulse generator is made to produce clicks at different rates, the sound, though uninteresting on its own, can serve as a

allowing the noise to decay in volume after the end of the click. We can even cater for the simulation of different clap reverb times by making the decay and amplitude variable.

**HAND CLAPPER**

**SYNC AND DELAY**

We can also create an even greater approach to reality by simulating echo as well as reverb. The same technique will also give the impression that more than one pair of hands is clapping on the same beat. Naturally precise synchronisation of several pair of hands will never occur and so the simulation can be enhanced if there is a brief delay between the claps. In our circuit then, we must have a sequence of pulses, occurring one after the other, all triggered by a common cause. This train of pulses is then mixed together, accompanied by the white noise ambience, or reverb, signal. In our full circuit we shall want to allow for the clapping to be repeatedly cycled through under automatic control, or for it to be triggered from an external source.

**DIGITAL REPEATS**

For the digital approach I could use a gated oscillator and a counter such as in Fig. 1. The oscillator output is fed to a
SOUND EFFECTS PROJECT

Fig.1. Digital pulse train generator.

gate which is controlled by two sources, the original starting pulse, and the final output of the counter. Each counter output has its pulse differentiated by the resistor-capacitor networks which are fed through to a mixer. The gate opens in response to a starting pulse, either from another, slower running, oscillator, or from an external trigger source. When open, the state allows pulses from the main oscillator to pass through to the counter. Each pulse triggers the counter on by one stage, each stage producing its own output click. When the counter reaches a predetermined output, in this case output five, the output causes the gate to close. Naturally, no more pulses will pass through, and no more clicks will be heard. On receipt of the next trigger pulse, the counter is reset, the gate reopens, and the cycle is repeated.

ANALOGUE COMPARISON

The analogue technique I have enclosed here instead shows how a series of comparators can be used to achieve the same results. Fig. 2. There are four main comparators used, each having a different reference level trip point. Each comparator output is fed through differentiators through to a mixer, as in the digital approach. The different reference levels are set by a chain of resistors coupled as a series of potential dividers. The voltage level at each resistance junction is of course different, becoming higher as we move up the chain from the bottom to the top. Consequently, each comparator will only change its output state when the input voltage is greater than the reference level. If the input voltage were to be a sudden change from minimum to maximum voltage, all four comparators would change state practically instantaneously. However, if we slowly increase the input voltage, there will be a delay between each comparator being tripped. Consequently, the output pulses will be heard as separate clicks. What we need, then, is for the starting pulse to initiate a ramped change in voltage level.

Fig.2. Analogue pulse train generator.

RAMPING SAWTOOTH

Each of the five generated pulses are summed at the junction of D4 to D8, and increasingly charge up C4. Between

EXTENDED TRAINING

This pulse creates the first of the clicks, being differentiated by C5 and R13 to pass via D4 to IC3. We'll look at IC3 presently. When the output of IC1a goes high in response to the trigger pulse, it also goes via D1 to charge up C2. The purpose of this capacitor is to extend the effective length of the trigger pulse so that we have time to make full use of its swing. Although the charge will eventually leak away via R39 it will remain high long enough for it to be fed via VR1 and R5 to charge up R3. The rate at which C3 will charge can be varied by VR1. The chain of reference level resistors consists of R6 to R10. As C3 charges up so its voltage level successively passes each trip point set by the resistor chain. Consequently, each comparator trips in a delayed sequence as discussed above. Each of the four outputs is differentiated and fed via diodes to IC3. Each trigger pulse thus creates five pulses to be delivered to IC3.

IC3 is a voltage controlled amplifier. Ignoring for the moment its other control and input sources, IC3 will only open when a suitable voltage level appears at its control node pin 5. The output will then swing in sympathy allowing any signal input to pass through to C11 and the volume control VR2. The output from VR2 is intended for feeding to any normal amplifier system.

Fig.3. Block diagram of clapper effects unit.

RAMPING SAWTOOTH

Each of the five generated pulses are summed at the junction of D4 to D8, and increasingly charge up C4. Between
Fig. 4. Full circuit diagram of the clapper effects unit.

Each pulse received, R13 causes C4 to slightly discharge. Thus the voltage level at the junction looks like an increasing level sawtooth, and the output from IC3 will vary accordingly.

The sawtooth voltage also charges up C20 via D10. IC2a then buffers the level, and also feeds to the control node of IC3 at a level set by VR5. The result is that even after the sawtooth has ended IC3 will remain open until C20 has discharged sufficiently via R41.

When all the comparators have tripped we need to reset them so that the next trigger pulse can repeat the sequence. Thus both C2 and C3 have to be discharged. The output from the final comparator, IC2d, is fed via C15 and D11 to charge up C19. This causes TR2 to be turned on which discharges C2 and C3 via R37, D2 and D3. The value of C19 has been chosen to let TR2 remain open long enough to allow adequate discharge of C2 and C3. Without C19 you will see that TR2 could remain open only until IC2d had reverted to its low level state, a situation which would not necessarily sufficiently discharge C2 and C3.

Time now to see just what it is that the pulse train allows IC3 to pass through to the output. For a start, of course, it will effectively pass the pulses themselves. In the absence of a sufficiently high current on its control node pin 5, via either R23 or R24, the output at IC3 pin 6 will be low. As soon as the current reaches sufficient level, the output voltage will rise in sympathy. Consequently, the pulse sequence will be heard as a sequence of clicks, the separation between them set by VR1 controlling the ramp rate at C3.

We said earlier that we also want to introduce a certain amount of reverb, or ambience simulation from a white noise
source. Obviously, IC3 is the place at which we introduce it.

**AMBIENCE**

Many of you will know that a reverse biased transistor will produce a certain amount of noise in response to its non-lethal distress under such conditions. Some types of transistor will behave more noisily than others, but in general an npn transistor such as the BC549 and its related families can be quite noisy under reverse biasing. Note though that the noise level can vary between types, and even between individuals of the same batch.

TR1 is the source used here, feeding the white noise through C14 to the filter and amplifier IC1B. The selected frequency band of noise is set by C16 and C17, and is additionally variable by VR3. The latter allows for panel control of the ambience tone. The output is fed to the input of IC3, with VR6 allowing for preset control of the level.

As IC3 is progressively opened by the clapper from external to internal control causes a trigger pulse to IC1a, so initiating the pulse train. At the end of the train, when TR2 opens to discharge C2 and C3, it also discharges C18 via D9. During the pulse train this has been held charged via VR4 and R35. As the charge on C18 drops below the reference level set by R34 and R36, the comparator IC2a changes its output level state. It remains in this state until TR2 has closed and C18 recharged at the rate set by VR4. When C18 has passed the trigger level in the opposite direction, so IC2a again changes state, sending another trigger pulse to IC1a, and so the cycle goes on repeating until S1 is once more switched to external mode.

**LIKE THE CLAPPERS**

Construction of the circuit is very straightforward and it shouldn’t take long to put together. Ensure that the correct polarities of diodes and electrolytic capacitors are observed, and that ICs and TRs are in the correct way andpolarities appropriate to the supply voltage used. The only setting up needed is the adjustment of VR6 to allow the white noise through at the desired level. The panel controls allow for selection of the other levels, relative clap rates, spacing and tone. The power supply needed is ideally suited for 9V battery use, though voltages up to 15Vdc could be used instead.

I am sure you will find this circuit an interesting addition to your effects line up. As a final suggestion, try feeding it into a separate echo or reverb unit as well – the results are astounding.

**TRIGGER CHOICE**

For control of the clapper from external sources, the pulses can be generated by a variety of devices. One possible source is from a microphone. In this instance plugging a mic into the input and then clapping above it will trigger the automatic clap response. Alternatively, the pulses could come from a signal generator or other repetitive pulse producer. And naturally, the pulses could come from the output of a computer or a midi instrument.

It is also possible to use the clapper as a self contained unit by switching over to automatic recycling mode. In this mode S1a is switched to the output of IC2a and S1b is open. The act of switching from external to internal control causes a pulse to be generated across IC1a, so initiating the pulse train. At the end of the train, when TR2 opens to discharge C2 and C3, it also discharges C18 via D9. During the pulse train this has been held charged via VR4 and R35. As the charge on C18 drops below the reference level set by R34 and R36, the comparator IC2a changes its output level state. It remains in this state until TR2 has closed and C18 recharged at the rate set by VR4. When C18 has passed the trigger level in the opposite direction, so IC2a again changes state, sending another trigger pulse to IC1a, and so the cycle goes on repeating until S1 is once more switched to external mode.

**Handclapper Project**

Don’t miss our new workshop frequency counter and dual sig-gen test gear project next month!

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**Fig.6. Control wiring details.**

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**PRACTICAL ELECTRONICS AUGUST 1989**
If you have any comments, criticisms or suggestions, write and let us know. We are interested in what you think and say.

PITCH IN TIME

Dear Mr Becker,

As a long time reader of PE and dabbler in some of your projects over the years, I was interested to see your Editorial on vacuum tubes in PE Mar 89. I used to run one of the departments making valves at GEC and little thought to see them making a comeback some 30 years later, albeit in a rather different form.

It has prompted me to write to you for some advice concerning a small project which my family has been agitating me about for some time, but which may require someone of 40+ to solve because of the technology.

I have many tape recordings of our wedding and other family events, such as the children when young, made on a now-departed reel-to-reel tape recorder bought during the late 50s. Wishing to transfer them to modern cassettes, I recently bought an old 3-speed Collaro tape recorder at a jumble sale. Having tried my recordings on this and other recorders it appears that the original machine must have been running at the wrong speed. At 3.75 ips the voices are pitched too low, and at 7.5 ips they are too high. Is there some way I can modify the playback speed?

E.R. Goodwin, West Drayton, Middx.

EASI ON THE EAR

I am an aging gastronome whose hearing is not as good as it used to be, particularly where high notes are concerned. To make up for this I tend to adjust the tv volume to a higher level than that preferred by my wife. In addition I have somewhat bizarre programme preferences such as Open University maths and similar arcane subjects which similarly distract my good wife's train of thought. Have you ever published a circuit that will allow personal listening without domestic discord?

Dr R. Parfitt, Croydon, Surrey

BINGO ITALIANO

Dear Ed,

Your friendly magazine prompts me to write, somewhat belatedly, in response to a letter published in PE Mar 88 concerning automatic bingo callers.

Bingo halls do not exist here in Italy, but at festive times of the year the family 'tombola', as we call it, is a tradition. A random number generator by itself is unsatisfactory for serious bingo and would never content our bunch of hyper-critical moppetts! I agree with you that a computer provides a better solution than a dedicated circuit design.

The generator must be capable of extracting only integral random numbers (no decimal fractions allowed) and each number only once during any game (too duplications of drawn numbers), as well as keeping within the limits set by the cards. In Italy, tombola has limits of 1 to 90. Our answer is to use a short Basic program, which we run on a Spectrum.

Thank you for a monthly 'read' of so many topics in the electronic environment (satellites to solder tags) where there always seems to be something for everyone.

Ken Jones, Udine, Italy.

ETHIOPIAN APPEAL

Dear Sirs,

It is unfortunate that my prodigious interest to have access to your monthly publications has failed due to the problem of getting foreign currency, which is restricted to exchange by the government here in our country.

Since I can obtain your publications only intermittently (and if not taken by others) from a British Council Library here in Addis Ababa, I am not always able to enter your competitions. Can you advise me of any way in which I can obtain your publication on time?

Moges Belete, Ethiopia.

We recognise that there is an exchange problem for a few countries. Some readers with this problem have friends in other countries who are able to send payment on their behalf. With some
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Excellent value at £12.00

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Z8852 Keyboard: Superb brand new keyboard. 392 x 181 with LCD displaying 1 line of 10 characters and a further line with various symbols. 100 keys, inc separate numeric keypad. Chips on board are 2x77HO5, 80C48. LCD + driver chips are easily removable from board. Looks like it was used with a comms package. Has anyone any more info?

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Z8857 High quality Alphameric keyboard on aluminium frame 314 x 150mm. Contactless keys good for 20 million operations. Originally sold at over £100 each, they were used in a 'Printcom' portable terminal. Fully ASCII encoded output. Power supply +5v and -12v @ 35mA supplied with comprehensive data.

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Z4140 New complete set for ZX Spectrum unboxed. (They were bulk packed)

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Z4142 Speech 64 for the C64 computer. Better than the Spectrum version as no software needed, and can be programmed in plain English! We only have the bare boards but these are new and working. A photocopy instruction book is included.

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NAUTEX AND SEA FAX

A dedicated video navtex receiver from Nasa Marine edits and sifts the information, accepting and storing messages only of the types of information and from which stations you have defined. The system has a high contrast data display screen and is based on a 68000 series microcomputer using the latest version of Alnor error correcting software. Lokata have a model using software routines which error-correct all messages before printing, and ensure that no message already received is reprinted.

The error correcting software seems as though it must be incredibly intelligent and sophisticated - I wonder how garbled messages are correctly interpreted without semantic error? Even the word processing software with which I'm writing now needs human intervention on its spell checking routines (especially for its Americanisms - hal).
frequency of 121.5MHz is constantly monitored by commercial aircraft, the search and rescue satellites Cospas and Sarsat, and the majority of RNLI rescue craft which are also fitted with vhf/rd equipment. In an hour, a Nimrod aircraft can visually search only 1800 square miles; with radar it can cover 65,000 square miles, but if a distress beacon is being sought 384,000 square miles can be covered.

The Cospas/Sarsat system was put into operation in 1982, additionally monitoring on 406MHz, and typically offers a beacon distress location finding accuracy to within 2-5km. The system has the capability for a satellite to simultaneously monitor 90 beacons within its view.

Globally, mariners in distress can transmit directly to the satellites which retransmit the call to ground receiving stations, known as local user terminals (LUTs). In the UK, one is based at Lasham. The ground station processes the signal, records the location and passes it on to a mission control centre (MCC). In the UK it is at Plymouth. MCC then sends the location to the appropriate land/sea rescue coordinating centre (RCC), and the rescue operation is commenced!

**DISTRESS CODING**

In 1979 the World Administration Radio Conference (WARC-79) recognised the limitations of the 121.5MHz channel and allocated the new distress frequency channel on 406MHz. The channel is very stable and uses pulses which are phase modulated with digitally encoded messages. The transmission signal itself enables a distress location to be established, but in addition, the coded messages can provide information such as the vessel’s country of origin and the nature of the distress. For example, (1) fire/explosion, (2) flooding, (3) collision, (4) grounding, (5) listing/capsizing, (6) sinking, (7) disabled and adrift, (8) abandoning ship.

Jotron’s distress beacon, Tron 30S, operates on the 406MHz channel but also has the option for transmitting on the homing frequencies of 121.5MHz and 243MHz. It has 90 hours operational time, and incorporates a flash light. Lokata have their 406P(X) beacon which includes the unique user selectable message capability, and also has the 121.5MHz homing signal for air/sea rescue services. Swiftech’s GL500 operates only on the 121.5MHz channel but can be detected at 30,000 feet within a 200 mile radius. It is small enough to be attached to a life jacket or linked to a crew member by a lanyard, and it floats. It is lithium battery powered, with a shelf life of up to ten years.

**INMARSAT**

The International Maritime Satellite Organisation, Inmarsat, operates a system of satellites to provide telephone, telex, data and facsimile, as well as distress and safety communications services, to the shipping, aviation and offshore industries. Unlike some other communications systems, Inmarsat’s links are unaffected by storms, sunspots, ionospheric or other radio propagation conditions, or congested traffic lists. With this system it is not only virtually impossible to eavesdrop on the content of transmissions, but also competitors cannot tell when or from where you are transmitting. (In the maritime business, often the ability of the competition to detect and locate a radio transmission is sufficient to give your secret away!)

Inmarsat began operations in 1982 and by the end of 1988 over 7700 ship earth stations or transportable versions were using the system. In the Standard-A system, Inmarsat operates via eight satellites in geostationary orbit, located above the Atlantic, Pacific and Indian Oceans at an altitude of 36,000kms. They provide coverage of almost all of the world’s surface, except the extreme polar regions. Of these eight, three are prime operational satellites and the others are maintained as ‘hot’ spares.

Inmarsat is about to acquire a second generation of satellites, the first four of which are to be launched during 1989, and will become part of the new Standard-C system.

Standard-C will use a new range of microterminals. These will be light weight, of only a few kilos, and compact enough to be fitted to aircraft, vessels and land-based vehicles of any size. Some units are planned which will be small enough to be handheld, and fit in the pocket or handbag. As well as being of obvious benefit to commercial users, Standard-C units will have a powerful impact for office and personal users. In addition to offering position reporting data, they will enable two-way communications between mobile users and their homes or offices, on a global basis.

Information on the handheld units is not yet available, but at least one company has Standard-C terminals for marine users. Thrane and Thrane have a low cost unit, the TT3020A, which applications range from merchant ships to private craft.

With the introduction of the new Standard-C service imminent, marine and land-based communications are on the threshold of one of the most exciting developments for many years.
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Cirkit NEWS

JUNE 1989

NEW CAT OUT NOW!

Over 3,000 product lines feature in the Summer 1989 edition of the Cirkit Constructors' Catalogue, available from most larger newsagents or direct from the company priced at £1.50. The latest books, an RF frequency meter, two new PSU designs and a 3.5MHz converter are among the innovative new kits this issue, while our construction project - a 2 Watt stereo amplifier - is bound to prove an absorbing activity for dedicated constructors. In the test equipment section there's a whole new range of multimeters, a bench DVM and a triple output PSU.

For eagle-eyed readers who enjoy a challenge of a different sort, there is the opportunity of winning an audio signal generator worth £180.00 in the latest fiendish competition. All prices now include VAT for quicker, easier ordering; and Cirkit's same-day despatch of all orders, combined with value-for-money discount vouchers, makes the line-up even more attractive.

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DSX900 Sub-carrier decoder unit for monitoring CTX900. Connects to radio. £15.95

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The Data Encryption Standard allows for operation in four different modes:

a) Electronic Code Book (ECB) which is a simple encipherment on a block by block basis, sometimes called the 'native' mode since it is so fundamental.
b) Cipher Block Chaining (CBC) where the algorithm is used to scramble the blocks together.
c) Cipher Feedback (CFB) which enciphers a string of characters dealing with each character as it appears, as from a teleprinter. This is a type of stream cipher.
d) Output Feedback (OFB) which is another type of stream cipher.

Since electronic code book is the simplest, in 64 bit blocks, repeating a block would reveal useful information to an eavesdropper. For instance computer messages often repeat and worse still they are in a very standard formats with messages and headers always in the same place.

In addition, protocol designers usually leave large blank spaces so that various facilities can be incorporated if required for a customer. If some of these facilities are not required, the spaces are left blank or filled with constants.

Therefore, ECB is not advisable for transmitting more than one block and a simple application is for transmitting a key since a key contains 56 bits of random digits. Short messages like acknowledgments can be sent but the IV must be padded out to 64 bits otherwise the contents may be obvious. The padding can be carried out by including a serial number or stamping the acknowledgment with the date and time. The date and time occupy 48 bits, so there is still room for 16 bits of data.

In cipher block chaining, Fig.14, each block before encoding, is added to the cipher of the previous block. This makes the nth encrypted block Cn a function of the previous plain message block L1 M2 M3...Mn.

The problem is that for the first block, there is no 'previous block' so an initializing variable (IV) is sent but the IV must be random, otherwise an eavesdropper can analyse it.

One big disadvantage of CBC is that errors in one block are extended into other blocks because of the chaining. This is called error extension and in the case of speech, produces clicks or in the case of pictures, produces spots. Since speech and pictures have redundancy (excess of bit rate over information rate) error extension is only just a nuisance, but in data transmission, the data could be corrupted excessively.

In order to prevent data corruption, error checks must be carried out and this must be carried out directly on the enciphered bit stream, Fig.15, not on the plaintext message, Fig.16.

Cipher feedback, Fig.17, is employed for chaining when the message is operated on in bits or characters. But instead of chaining whole blocks, cipher feedback chains characters and is often known as "m-bit" cipher feedback where m is any number between 1 and 64.

In older message transmission systems 5 or 6 bit character codes were common, but present day systems use 7 or 8 character codes. The ISO (International Standardisation Organisation) 8 bit (octet) is a popular method. This comprises 7 information bits and 1 parity bit.

Fig.17 shows how the octets are added module 2 (XOR) to the output of the DES algorithm. For an on line system of this nature, each octet must be enciphered immediately by the transmitter and deciphered as soon as it is received by the receiver. CFB suffers the same problems of error extension as CBC does.

Fig.14, Cipher block chaining.
If OFB loses synchronisation, the synchronisation process must be restarted by placing a new initialising variable (IV) in the shift registers. The IV does not have to be encrypted since it does to reveal the pseudo-random stream if intercepted by an eavesdropper.

The pseudo random stream is not a truly random number like that generated from a noise source but an artificially generated one using shift registers and XOR functions hence the name pseudo-random.

The pseudo random stream must not repeat. If it does then an eavesdropper can easily eliminate it by a simultaneous equation as follows:

Let X be the pseudo random stream
Let M be one plaintext message
Let N be another plaintext message
Then the first enciphered message is X + M

The second enciphered message is X + N

To eliminate X these two enciphered messages are added module 2 giving M + N which is the same as enciphering M with N.

The pseudo-random stream is also called the key stream.

**DES HARDWARE**

The transpositions required in present day ciphers are difficult to implement in terms of hardware. A small telephone exchange would be required to implement all the permutations of an algorithm. An alternative is to write a computer program, but this is slow and therefore inefficient.

Therefore, the state of the art at present is to use hybrid methods employing operations like shift, add and XOR acting on whole words.

There are several manufacturers of DES chips. The Burroughs MC 884 is an n-channel ttl compatible chip employing silicon gates. The clock speed is from 0.5MHz to 1.25MHz and there are 32 different clock speeds which are required by the algorithm. A second lsi chip MC883 is required to control the MC884 and encryption or decryption takes 25us to 64us.

Motorola makes the MC6859 with a 2MHz clock and an encryption time of 10μs. Western Digital makes the 3 chip set WD 2001E/F, WD 2002A/B, WD 2003 using n-channel silicon gates. And advanced Micro Devices makes the AmZ8068.

The DES algorithm can also be implemented in microprocessor form. The Intel 8294 uses a microcode stored on a prom (programmable read only memory). American Microsystems makes the S6894 which is a 2 chip microprocessor, and Texas Instruments makes the TMS 9940 with a 5MHz clock. Rockwell Collins and Motorola supply circuit boards for interfaces and key management.

**PUBLIC KEY CIPHERS**

In a symmetric cipher, the key is secret and is known only to the communicating parties. In an asymmetric cipher the sender has his own key and the receiver has his own. The latter are called public key ciphers and were developed by Diffie and Hellman in 1976.

Fig. 19 shows how a public key cipher works. For enciphering the message, key e and the algorithm E is used and to decipher the message, key d and algorithm D is used. A seed or starting key is used to derive keys e and d using algorithms F and G. The algorithms D, E, F, and G are all public knowledge since anyone can buy the encryption boxes and study them anyway.

In order for the recipient to be the only one to decipher the message, he must be the one to derive both keys e and d using algorithms F and G. He then announces key e and keeps key d secret. The first publications did not detail the algorithms D, E, F and G to produce a working model.

It was left to Rivest, Shamir and Adleman in 1978 to produce the first working model and it is now the well known RSA method. F is known as a one way function since knowledge of the key e must not enable an unauthorised person to calculate keys s and d. E is also a one way function since knowing the ciphertext should not enable calculation of the plaintext x.

Since e is now a public key, authentication is not provided since there is no point in proving that the sender is genuine.

The two key public method can be illustrated as follows. With reference to Fig.20a, suppose company A wants to send company B a message in a case without sending the key. They apply padlock A to the case and send it with a courier, without sending the key. When it gets to B Fig.20b
company B also apply their padlock and return the case to company A, who remove their padlock Fig. 20c. The case then travels to company B who remove their padlock B, Fig. 20d, and read the message.

It may seem longwinded but when it is remembered that data travels up and down a communications link quite quickly, it is no problem to transfer it back and forth for the sake of security.

The RSA method is based simply on a number which is a product of two very large prime numbers. Suppose this product is \( m = xy \), the recipient is the one who chooses \( x \) and \( y \) and then announces the number \( m \) which will be used as part of the public key.

Of course, \( m \) is of no use if it can be easily factorised and if \( m \) is small, it can be easily factorised. On the other hand if \( m \) is large, the factors are difficult to find. This is a well known problem in mathematics so it has been given considerable thought.

### LEKTOR

In the Lector system developed by British Telecommunications, the large prime numbers \( x \) and \( y \) are up to 128 bits in length. The number \( m \) is then up to 256 bits in length and is called the modulus. The numbers \( x \) and \( y \) are called relative prime, i.e., they cannot be factorised and their divisors are only themselves and one.

Since the public key cipher method is slow it is usually used only to distribute the session key. The parties can then revert to a faster real time transfer of data like B-Crypt also developed by British Telecommunications. In addition, Lector has facilities for using DES for those who prefer DES.

Lector employs user tokens in the form of a physical key and pin numbers as used by cash tills. Lector can also be used to encode facsimile (still picture) transmission.

### KEY MANAGEMENT

The distribution of keys and the control of keys is an art in itself since the security of a modern system depends not on the algorithm but on the keys remaining secret. If \( s \) is a key used to encrypt data for only one session it is called a session key. In order to send the key through the network, it is encrypted with another key \( t \) called a terminal key. Key \( t \) is used more often than key \( s \) so it is stored at the host computer under the care of a master key.

In order to generate the master key, a very intensive method is used. A dice is rolled or a coin is tossed in order to select each digit. This may seem a labour intensive method of generating a random number but it is reliable and in any case, a master key is not changed often.

In order to generate keys below the master key level a pseudo random number generator or a random bit generator is employed. The latter could use a resistor as a noise source and a wideband amplifier for switching a gate on and off. Zero crossings of the signal are used and the output is sampled to give a 1 or 0 at fixed intervals.

Terminal keys can also be distributed by a courier and a key module the size of a pocket calculator. The module is plugged into the host computer and the key is loaded. Actually loading the keys into the destination computer must be carried out in the presence of reliable personnel.

The module presents a number of problems. An unreliable courier could copy a key or insert a false key. Copying the key can be defeated by arranging that reading the key erases the key from the module memory. Therefore is say three terminals require the same key, this key must be loaded three times into the module.

Installing a false key can be overcome by the use of a password, and it could be arranged such that say more than three attempts at guessing the password, activates the module so that the keys are erased.

### AUTHENTICATION

It is interesting to note that enciphering data only prevents an enemy from adding new data. But there are other forms of active attack like:

- a) deleting blocks of data
- b) altering the sequence of blocks
- c) repeating previous blocks
- d) altering the destination
- e) falsifying an acknowledgement
- f) making the recipient think that the data originated at a location other than its true origin

So a fair bit of mischief can be perpetrated without actually breaking all of the code.

The need for authentication may well be questioned when one is using a secret key. However, there are many instances when encipherment may be inconvenient and the parties may rely on occasional authentication checks only.

For instances point to multipoint broadcast may be in progress as from a taxi-cab base station to all its mobile units. This may be in plain English for convenience with only one receiver checking the authentication digit fields to ensure someone is not sending out false messages.

Another instance may be a computer with a heavy work load. Here time wasted in deciphering every step of a program could be spent in running the program itself. Therefore, cipher security may be exchanged for an authentication field so that the computer can carry out a quick check and assure the programmer that all is well.

In the cipher block chaining mode of the DES, the authenticator is calculated from the final output block by taking the most significant m bits. In the USA, the authenticator is called the Message Authentication code (MAC) or the Data Authentication Code (DAC).

For financial transactions it is recommended that the MAC be greater than 32 bits long and for telecommunications, the MAC should be greater than 24 bits. Authentication protects the communicating parties against a third party but not against each other. For protection against each other, the parties require digital signatures, which will be dealt with later.

### IDENTIFICATION

Identification is an essential part of data security. This is achieved by many methods some of which are more suitable than others for electronic scanning. Passwords for accessing computers and pin numbers for accessing cash bills are two such methods.

Personal characteristics which are highly individual can also be used for electronic scanning but are usually unacceptable for one reason or another. Such characteristics include finger prints, the voice, retinal patterns and the handwritten signature.

Passwords are of several kinds:

1. The most common are those that are unique for each person.
2. Those that are not unique but aid identification, e.g., pin numbers.
3. Passwords that are known to a group of people.
4. Passwords which are used only once.

When a computer terminal fails to recognise a genuine person, this is called a Type I error, and when it gives access to a false individual, keying in the wrong code, this is called a Type II error.

If people were permitted to choose their own passwords, the most common choices would be:

- a) words spell backwards
- b) car numbers, telephone numbers and social security numbers
- c) town names and street names
- d) surnames and first names
- e) false individual, keying in the wrong code
- f) making the recipient think that the data originated at a location other than its true origin

A recent survey showed that about 85% of passwords could be cracked because they fell into one of these simple categories when people chose their own passwords.

The most common form of identification on paper documents is by a signature. Forgeries are of three kinds: improvised, copied and traced. An improvised one happens when someone finds a cheque, and because the owner’s name is now printed on each cheque, the forger makes a guess at what the signature might look like. This may fool a shopkeeper but not the owner’s bank.

A copied signature is one where the forger has a copy of the owner’s signature and after a few practice attempts, has a go at signing a cheque. A traced signature is the hardest to detect but for the copied signature, Nagel and Reosenfeld have
invented a machine which compares the angles of slant and dimension ratios with a specimen of the true signature.

A signature verification system called VERISIGN has also been developed by the National Physical Laboratory. This uses a pad called CHIT and is made from two membranes which touch when the pen is pressed down on the surface. The x and y co-ordinates of the signature are then plotted by sampling at the rate of 50 times per second.

Ten different characteristics are assessed such as velocity and acceleration, turns, slopes and loops and the number of contacts. The time taken for an individual to sign his name varies very little and this in itself is a good check.

A voice verification system has been developed by Texas Instruments. The candidate is required to utter 16 words containing vowels and from this the machine produces 32 sentences. By sampling at 10ms intervals, a Fourier analysis detects the large amplitude regions and bands are selected in the range 300Hz to 250Hz. The information is stored and compared with samples from later visits. However, a cold or stress changes the voice and even asking the candidate to repeat words could lead to stress.

Finger prints are also highly individual. The arch, loop and whorl, Fig.21, and finger printing has developed by Sir Edward Henry in 1897, the Metropolitan Commissioner of Police.

Fig.21. Loop, whirl and arch.

Unfortunately, fingerprints are connected with crime and the public is not likely to embrace such a system, even though an ink-pad is not involved. The person requesting access has merely to place his fingers on a sheet of glass, and a light from underneath reflects off the fingertips.

The retinal pattern is also unique to individuals and provides another means of identification. Eyedentify of Oregon have invented an infra-red scanner which detects the pattern of blood vessels on the retina when one looks into the binocular eyepiece. The nodes and branches within the scanned area is then registered.

The standards for pin management expect organisations to use pin numbers between 4 and 12 digits long. In practice, typical pin numbers are 4, 5 or 6 digits long perhaps to assist people to remember them without writing them down.

A pin number can be derived from an account number as shown in Fig.23. Using zeros or constants, the account number is padded out to 16 decimal digits. The 64 bit number produced is then enciphered using DES and a secret key and the 64 bit output is examined in groups of 4 bits starting at the least significant bit end. Those groups whose decimal equivalent is less than 10 are accepted and the required M digit pin number is obtained. In practice a slight adjustment is made if too many or too few decimal digits have been produced.

PIN numbers are typed by printers without ribbons so that an unscrupulous person cannot steal the ribbon and read it afterwards, hence security is improved. Instead a carbon type of paper which is already inside a sealed envelope is inserted into the printer and this envelope is posted separately from the plastic card.

Another method of choosing a pin number could be by a visit to the bank where customers would have the facility of typing their chosen number onto a computer terminal. Although the local bank staff may not see the pin number, it could be assessed by the systems operators.

A recent development is the so called smart card which is active and can, therefore, handle a certain amount of
processing. (Smart cards were discussed in Home Automation, PE May '89 Ed) Its storage is 250 bytes compared to the 100 bits of the ordinary card. The information can be stored in a hologram and is used for such things as paying for phone calls and transport and viewing television, and the number of credit units held in the hologram is decremented each time it is used. The active card did not appear earlier because the requirements were to maintain the durability and dimensions of the previous card, therefore, fragile chips would have been unsuitable. Nevertheless cards with chips are also in use as well as cards with magnetic stores.

**ELECTRONIC FUNDS**

The Society of Worldwide Interbank Financial Telecommunications (SWIFT) was set up to speed international payments. It is a non-profit bank owned by 1000 shareholding banks in 50 countries. Passwords are used only once and tables of passwords are despatched in two halves so that if one half is intercepted, no harm is done.

There is no point in developing an international system if a national system does not exist to aid and support the international system. For this purpose the Clearing House Interbank Payment System (CHIPS) was established in the USA and Clearing Houses Automated Payment System (CHAPS) in the UK.

DES in the CBC mode is the authenticator used in CHAPS, and CHAPS operates over the part of the public telephone network called packet switchstream (PSS). The interface of CHAPS software with the banks software is called the gateway, Fig.25. The gateways must be reliable and the PSS network must have a high availability.

Both these aspects are essential since CHAPS offers same day settlement of accounts which is vital to those who are moving house for instance. On the final date called 'completion' the seller wants to be sure of receiving the money since he is also vacating the house. Thirteen settlement banks in London are linked into CHAPS and about 300 banks in the UK including foreign banks.

**DIGITAL SIGNATURES**

On paper documents, a signature has always been the ultimate authority. In electronic communications, authentication is useful against third parties, but does not provide security between the communicating parties.

Both sender and receiver have scope for cheating in the absence of a digital signature. For instance the sender could delay instructions to his broker if the shares suddenly look unfavourable. A receiver could cheat by altering the amounts and frequency of payment to himself.

A digital signature is a number which depends on all the bits of the message and also on the secret key. A digital signature can be checked by means of a public key whereas an authenticator requires a secret key.

A public communications system provides either authentication or secrecy and if both must be combined then signature methods as well as encipherment must be used.

A symmetric cipher can also be used for digital signature but an arbitrator must be employed. The arbitration service is called the 'authentication server' by Needham and Schroeder and is probably better suited to internal communications in a large firm.

The arbitrator must be trusted by all parties to time and date stamp all messages. A random number or serial number in the transmission is also checked to ensure no one interferes with the message.

If the sender has lost his key or believes it has been stolen, he can recall all his messages. This may give rise to a fraud dispute but it is no worse than any other fraud dispute. If a sender is careless enough to lose his keys, he is likely to lose business and if he only pretends to lose his key, he is also likely to lose business.

So he can hardly continue the masquerade particularly if he stands to gain by pretending to lose his key. In general digital signatures are more reliable than handwritten signatures, since they are automatically checked whereas handwritten signatures are accepted at face value. Therefore, digital signatures help automate business processes.

Enciphering used to require human skill and intuition and was an art. Now, computing can break the classical methods by brute force, first to identify the type of cipher and then to break into the combinations. In addition to finding the key and cracking the algorithm, the modulation of the transmission system and the plaintext language must also be found.

**CIPHER STRENGTH**

In estimating the strength of a cipher if the cryptanalyst does not have any idea of the plaintext and has only the ciphertext to work on, this is called a ciphertext only attack. It is impossible to find the key if the message is very short and without redundancy.

If there is redundancy like an arbitrary string of constants or known preamble as in computer or satellite communications then cryptanalysis becomes easier. This is called the known plaintext attack, and is possible in more situations than one would expect.

For instance political unrest would lead to a message from an embassy to its home country and spectacular changes on the stockmarket would cause a high activity of messages between banks and stockbrokers.

A bombing run on a lighthouse during World War II led to the word leuchttoune appearing in Enigma messages. This was predictable and is called the chosen plaintext attack. If the attacker is crafty enough he can use his agents to slip his own words into his enemy for encipherment and this in another case of a chosen plaintext attack.

In modern ciphers the key and not the algorithm is the all important item. Suppose 1lsi hardware is used to search for the key and that the key is found after exploring only half the key space, Table 1 shows the time taken to search keys of varying size.

Table 1 also shows a machine beyond our present technology capable of doing a million tests in parallel and searching separate parts of the key space. Whereas the lsi is capable of 1LS per test, the imaginary machine does a million tests in the same time and even a 64 bit key becomes insecure.

**TABLE 1**

<table>
<thead>
<tr>
<th>Key Size</th>
<th>Single Tests</th>
<th>One million tests in parallel</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>35 minutes</td>
<td>2.15ms</td>
</tr>
<tr>
<td>48</td>
<td>4.46 years</td>
<td>2:35 minutes</td>
</tr>
<tr>
<td>64</td>
<td>107 days</td>
<td></td>
</tr>
</tbody>
</table>
Shannon put security in two classes: unconditionally secure and computationally secure. One time taps with random keys or very short messages contained in a key are unconditionally secure since no amount of computing power can break them.

Those ciphers which are computationally secure are those which cannot be broken by today's computing power but may be broken in the future. If a step is defined as the work that lsi hardware can carry out in ljs, then today's technology cannot cope with more than $10^{24}$ steps.

Certainly, time can be cut down by large money stores and parallel processing, and these will be used increasingly in the future. To be on the safe side, assessment of cipher strength must assume conditions which favour the enemy like a chosen plaintext or known plaintext.

Shannon defined the 'unicity distances' as the minimum length of text which will provide a unique solution. That is, the redundancy in the plaintext must be greater than the information in the key.

Taking monoalphabetic ciphers as an example, the key size is 26! and log$_2$ 26! is 88. Assuming that English is 80% redundant, each character provides 3.8 bits of redundancy. Hence a cipher with 88/3.8 or about 23 characters is the unicity distance.

Therefore, a text with more than 23 characters will contain redundancy. Shannon's calculations take into account text with spaces, therefore, text without spaces will need a bit for monoalphabetic substitution.

The DES algorithm can be strengthened by increasing the key space, but then the hardware would be more expensive. In a good algorithm the output is not linearly related to the input and changing, even one bit in the key would produce a bit change in the output.

Various estimates have been produced for the cost-time trade off of a machine capable of carrying out a search for a DES key. Cost estimates ranged from 20 to 200 million dollars an the time from 20 hours to 11,000 years. But it is not worth the time or effort since DES machines carry commercial, unclassified information.

To meet the challenge of improving technology the permutations, S boxes and keying methods can be improved in addition to changing the key size, data blocks and sub key generators.

Conducting an exhaustive key search on the 128 bit Lucifer system would take 10$^{19}$ years, assuming one key is tested per picosecond, since there are $3 \times 10^{38}$ keys.

Ultimately, both a thermodynamic limit as well as a limit on the storage must defeat an exhaustive key search. Suppose each step requires energy KT where K is Boltzman's constant and T is the absolute temperature. Assuming that the calculations will take place at 100k and from calculations of the sun's rays heating the earth, $3 \times 10^{48}$ calculations will take 1000 years.

The other important requirement is memory space. Assuming one binary digit needs only 10 atoms of silicon, $10^{46}$ bits will cover all the dry land to a height of 1km. Alternatively a satellite of similar mass will have to be put in orbit.

When machines become too expensive for code breaking, more mundane methods will be adopted like merely stealing a card and pin or bribing a person in a position of trust.

## CONCLUSIONS

Early ciphers depended on substitutions and transpositions, but when the two are combined, machines are required otherwise humans would be too slow and inaccurate. The DES was described as an example of a modern cipher where the emphasis has changed from secrecy of the algorithm to secrecy of the key. With this change in emphasis, key management then becomes an art in itself.

Together with public key ciphers, other improvements have been introduced such as identification, authentication and digital signatures, all of which are essential for automating business using atms and CHAPS.

The security of a cipher is never guaranteed and hackers, when they are caught, do not have the same guilt feelings as those who steal money. Society probably looks on them with mild amusement and curiosity. However, damage of a varying extent can be caused by unauthorised people accessing medical records, financial records and military networks.

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high potentials may be in the room or near the walls. Many have been described with wooden and plastic objects.

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The planety observing. Observations have mixed fortunes this month. Mercury is to all intents and purposes out of view. Mars is visible low in the western sky after sunset, but it is now little brighter than the Pole Star, and no telescope will show much on its shrunken disk. We will not see Mars well again until late next year. Note, though, that Mars as well as the Earth has been having unusual weather. The great dust-storms which usually occur there late in Martian summer have simply not formed, and even when the planet had moved far away from the Earth it was still able to see the dark markings on the disc which are generally hidden.

Venus is a brilliant object in the western sky after sunset. If you have a telescope or binoculars, look at it on July 23. It is within 1/2 degree of the bright star Regulus, and the two make up a beautiful pair. Venus is now drawing away from the Sun in the sky, and is brilliant in the east before dawn; later this year it is hoped that the Galileo space-probe will be launched toward it, though unfortunately the journey will be a protracted one, and Galileo will not arrive near the region of Jupiter until 1995. Finally there is Saturn, which comes to opposition on July 23; it will be 1,350,000,000 kilometres away. The rings are wide open, so that a small telescope will show them as well as several of Saturn's satellites.

Saturn is in the constellation of Sagittarius (the Archer) and is inconveniently low down as seen from Britain. The two outer giants, Uranus and Neptune, are also in Sagittarius. Uranus is just visible with the naked eye, if you know where to look for it, but Neptune requires optical aid. At the moment Voyager 2 is still on course for Neptune, and the rendezvous, next month, will be fraught with interest. Do not forget Pluto, which comes to perihelion this year. It is in Libra, but as the magnitude is only 14 you need a fair-sized telescope to see it. We now know that it has an extensive, if tenuous, atmosphere; its surface has a coating of methane ice, whereas the coating of its companion, Charon, appears to be water ice. It is a pity that no current space-probe is scheduled to go anywhere this strange little system.

An interesting periodical comet is coming into view. This is Brorsen-Metcalf, which has a period of 72 years—not very different from Halley's. However, Brorsen-Metcalf is not bright, and even at its best, in the early autumn, it is not likely to be above the fifth magnitude. Telescope owners may care to look for it: the calculated position for July 23 is RA 07h 31m, dec. +41°55'.2, with magnitude of about 10. I will say more about it in the next Spacewatch.

July is the best time of the year to look at the lovely star-clouds of Sagittarius, which mask our view of the centre of the Galaxy. They are low down, but this year the presence of Saturn in the same region makes them particularly easy to identify. On a dark, moonless night they are superb; if you have binoculars, sweep around and enjoy yourself among the rich star-fields.

Vega in Lyra, the brilliant bluish star, is almost overhead; look for the other members of the unofficial 'Summer Triangle', Deneb in Cygnus (the Swan) and Altair in Aquila (the Eagle). Arcturus in Boeetes (the Herdsman) is dropping in the north-west, while the Square of Pegasus is making its entry in the east late in the evening. The Great Bear is in the north-west, still well above the horizon, from Britain, of course, it never sets.

At the end of July we will start to see the first of the Perseid meteors, which reach their maximum on August 12. Generally the Perseids can be relied upon to give a good display, and there is no reason to suppose that 1989 will be exceptional in this respect. Because the Sun is now rising to the peak of its 11-year cycle of activity, we may well have some displays of aurora, though one can never be sure, and we will be lucky to have another display as good as that of March 13 this year, which was seen from much of Britain.
should prove to be among the most informative of the space-craft.

We know a good deal about Saturn itself, but not nearly so much about Titan, its senior satellite, which will be Cassini’s main target. Titan, larger than our Moon and almost as large as the planet Mercury, has a dense atmosphere which is made up chiefly of nitrogen, with a good deal of methane. Organic compounds no doubt exist, and the main objection to the existence of life is the very low temperature.

But has Titan a liquid surface? This may well be the case. Of course, the liquid will not be of water, but it may be that much of the satellite is covered with a methane ocean, in which case Cassini’s ‘lander’ may have to be capable of floating. Whether we will be able to find out before the probe is launched remains to be seen, but at any rate the Titan mission is something to which astronomers look forward with considerable eagerness!

The photograph shows the New Technology Telescope in the workshops of INNSE at Brescia, Italy prior to being installed at the La Scilla Observatory in Chile. The photo is reproduced by kind permission of Astronomy Now to whom it was supplied by courtesy of the ESO Information and Photographic service.

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Chances are that the first answer to come to mind will be, "A Dalek". Perhaps, after a little more thought, fans of Star Wars rather than Dr Who will offer, "R2D2", or maybe "C3PO". The voice of Hal, the deranged computer in 2001, might also be another response.

**VOCAL ROOTS**

Though I too become enthralled by Star Wars, and 2001, on each viewing, my mind certainly thinks of the infamous and exterminatory Daleks as the root for all mechanical voices. There's something about the vibratory clipped accents of the Daleks which, for me, makes their voices synonymous with robots.

Poor old R2D2, though capable of communicating with other computerised devices, could not communicate directly with Humanity. And the technology that created the voices of Hal and C3PO produced speech as perfect as that from any human, so in terms of novelty effects units for 1989, the Dr Who sound effects creation. He told me that one of the engineers involved in their voices are really non-starters. So in terms of novelty effects units for 1989, speech as perfect as that from any human, the voices of Hal and C3PO produced

Humanity. And the technology that created communicating with other computerised devices, could not communicate directly with Humanity. And the technology that created the voices of Hal and C3PO produced basically created by three processes. First, an actor speaks the words into a microphone and the signal is duly amplified. It is then passed through a ring modulator to produce a metallic sound, and finally subjected to amplitude variation to give it its vibratory effect.

Ring modulators are really fascinating units to work and play with. The theory was
directly created by three processes. First, an actor speaks the words into a microphone and the signal is duly amplified. It is then passed through a ring modulator to produce a metallic sound, and finally subjected to amplitude variation to give it its vibratory effect.

Rather, the process both adds and subtracts the two frequencies to and from each other, producing an output signal containing upper and lower harmonics of the originals. The technique, though, is beyond the scope this simple project, which is based upon just the vibratory effect associated with the Dalek-type voice.

**CLIPPED ACCENTS**

In Fig.1 you will see that the circuit consists of four opamps, contained in one package, and a transistor. The purpose of IC1a is to control the gain of the input voice signal. Most ordinary high output crystal microphones will produce a signal strong enough to suit the circuit. Lower output level microphones will need to have their signal preamplified first before being sent through the unit. The output signal from most cassette recorders is likely to be sufficiently strong to suit the unit without additional preamplification.

The input signal strength can be given a small amount of gain by VR1. As I am sure

many readers will be aware, the gain is related to the value of VR1 plus R3, divided by the value of R2, plus 1. In this case the maximum gain is ((10k + 500k) / 10k) + 1 = 52.

However, I have included two diodes, D1 and D2 in the feedback path across IC1a. These have the effect of restricting the maximum output level to about 0.6V peak to peak. In other words they clip the signal, giving it a squarish shape if viewed on an oscilloscope. The effect is a harsher sound than wouldotherwise be experienced, and one which is more consistent in level. C2 is used to filter out some of the upper frequencies of the voice signal, so also changing its quality.

**HIGHER EXTERMINATION**

The signal is then fed through the section associated with the modulation process to the filter circuit around IC1b. This also modifies the frequency characteristics and the resulting sound quality. Although all of the components associated with IC1b play their part in the filtering process, C4 and C5 are the principle controllers. Increasing their value will decrease the frequency range, and viceversa, but it is preferable, though not essential, to keep their values within the same ratio.

From IC1b the modified signal is simply taken via C6 to the output level control VR3. From there it can be fed to any normal amplifier.

**VODALEK**

BY JOHN BECKER

examined in my constructional project published in PE Nov-Dec 84. In essence, an input signal is mixed with a secondary signal of a variable frequency, but not in the manner associated with ordinary mixers.
COMPONENTS

RESISTORS
R1, R2, R3  10k (3 off)
R4-R6, R13, R14 100k (5 off)
R7  510k
R8-R11  4k7
R12  75k
R15  330k
CAPACITORS
C1  220n polyester
C2, C5  470p polystyrene (2 off)
C3, C12  15n polyester (2 off)
C4  1n polystyrene
C6  1μF 63V electrolytic
C7, C9-C11  22μF 16V elect (4 off)
C8  100n polyester

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VR2  100k skeleton preset
VR3  1k log mono rotary
VR4  10k lin mono rotary
VR5  1M lin mono rotary

SEMICONDUCTORS
D1, D2  1N4148
TR1  2N3819 fet
IC1  324 quad opamp

MISCELLANEOUS
FP3 battery clip, pcb supports (4 off), knobs (4 off), 14-pin ic socket, mono jack sockets (2 off), spst switch, Phonosonic's PCB type number 155A, box to suit, connecting wire and solder.

WOBBLATING

The modulating oscillator consists of the circuit around IC1c and IC1d. You've no doubt seen many circuits with oscillators that look similar to this one. If you haven't you can add it to your list of possible candidates for frequency generator sources. I gave two other types in the Wheeby-Jeeby project of PE June 89. The circuit oscillates at a rate set by the value of C8 and the feedback resistance across R14 and the rate controller VR5. I showed and described a similar circuit in the Oscilloscope articles of PE Nov 88 to Jan 89. The circuit oscillates because each time the output of IC1c rises above or drops below the reference level at the comparator IC1d, the comparator changes output state, so reversing the direction of charge for C8. You will see a more sophisticated variation on this theme in the forthcoming Combined Frequency Counter and Twin Signal Generator (scheduled for the Sept 89 issue).

The output at IC1d is a squarewave, which in this instance we don't need. What we are interested in is the triangular waveform produced at the output of IC1c. It is taken via C11, through the level control VR4, and to the amplitude controller around TR1.

TR1 is a field effect transistor (fet) whose resistance between source and drain is controllable by the voltage or current present at its gate input. Here the basic resistance is preset by the voltage supplied via VR2. As the current via C10 increases and decreases in sympathy with the triangle wave from IC1c, so the resistance across TR1 also changes. Since the signal between IC1a and IC1b passes through R4 on its way to IC1b, the changing resistance across TR1 causes the signal level at the junction of R4 and TR1 to vary up and down. And this of course is just the amplitude modulation that we need for a robot type voice.

A modulation of about 30Hz is the rate I find most suitable for creating the robot effect, but there is wide range to either side of this controllable by VR5.

The circuit will run from any dc voltage between 5V and 15V. A 9V battery is ideal.

Fig. 2. (top) Printed circuit board layout.
Fig. 3. (above) Suggested box and controls layout.

SETTING THE ACT

Setting-up is very straightforward once you've assembled and checked the pcb assembly. Apply a suitable signal to the input and adjust VR2 until the signal is heard to modulate smoothly when plugged into an amplifier. You will soon find which settings for the panel control pots are best suited to different effects needs.

Final points - VR1 at too high a setting will also allow any noise near the microphone to be amplified and cause it to be modulated as well as the speech. Also note that if the unit is plugged into an amplifier having a good bass response it may be necessary to reduce the bass control on the amp to cut out the sound of the modulator, which might otherwise be heard in quiet passages. For the best overall robot-type effect, you should speak in a monotone, slowly, and with long drawn out words.

So, have fun with this Vodalek. Play the part, utter your words of doomng extermination, and even Time-Lords might tremble!
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Congratulations and happy hi-tech telecomms to all of you!

THE ANSWERS

With questions one to three these are the answers for which I was looking:

The first communications satellite was launched in 1962 and was called Telstar. Alexander Bell is credited with inventing the telephone.

Most entrants had these three answers correct, though a fair number believed that 1955 was the launch date. A few suggested that 1969 and 1975 were the correct years. Almost unanimously Telstar was given as the answer to question two and only a very small minority believed that Astra and Buzbsat were the satellite names. Buzbsat is (so far as I know) a fictitious name invented by myself. Astra is the satellite recently launched for use by Sky Satellite TV.

Alexander Graham Bell seems to be universally acclaimed as the inventor of telephone. Very few of you fell into the trap of honouring Hans Fernsprecher or Gugliemo Marconi for the invention. Marconi, of course, should be honoured for the invention of wireless. Fernsprecher is a name I coined to confuse you - those who speak German may recognise the pun!

The answer to question four disturbed many of you. It also disturbed me! My source book for the date was a somewhat ancient and cheap volume claiming to be an encyclopaedia. It quoted 1861 as the year in which Bell invented the telephone. A totally fallacious assertion! As so many of you pointed out, 1876 is the date acknowledged by history. However, a fair number of you seem to possess equally fallacious documentation, claiming that your books variously gave 1871, 1873, 1875, and even 1856.

The truth appears to be that the microphone (albeit, a very crude one) was invented in 1861, by a certain Johann Philip Reis. Bell first demonstrated the telephone at the Philadelphia Exhibition of 1876, and this is the same year in which he filed his patent, believed to be on March 7th under US patent number 174465. It's conceivable that he actually invented the telephone before 1876, but this is the year I now accept as factual. If anyone knows differently, please tell me!

As far as the draw was concerned, both 1861 and 1876 were taken as valid answers.

Questions five to seven were survey queries and your answers played no part in the draw. Thank you all for your opinions.

Our thanks too to Shaye Communications for kindly making available the Forum Telepoint telephones.
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Carn Ellis Communications Ltd make a point of telling you proudly that all employees in their Watford, Herts, electronics factory have free access to computer terminals. To what extent this is utilised in the manufacturing processes I don’t really know, but it certainly has interesting social implications.

The company makes data communications equipment — modems, concentrators, multiplexers, switching systems and the like. It also builds local-area and other dataroom networks for customers. You may remember that it got into the news a few months ago during Mr. Gorbachev’s short visit to the UK. The Soviet president had asked to see a highly automated manufacturing plant while he was here. Lord Young, the DTI minister, took him to Case, partly because it is near London but mainly because the factory acts as a Government demonstration site for showing the application of computer-aided design (CAD) and testing and computer integrated manufacturing (CIM).

Case are using CIM for much the same reason as other manufacturers. There is pressure on them from their owners, the shareholding of the Dowty group, to sell their products at a good profit to keep up group dividends and stock market value. This means being able to sell the product at competitive prices, which in turn means manufacturing efficiently to keep the production cost of individual items (unit costs) to a minimum.

Basically this is done by reducing waste — of time and materials. Individual processes — like component insertion in pcb’s, flow soldering, board testing — are already speeded up by automatic machines. But there is still a possibility of waste occurring between these processes. In manufacturing generally this takes the forms of excessive inventory, work-in-progress and setting-up times, and rejected items and reworking. By integrating all the separate processes into a smooth overall flow without bottlenecks a company can minimise these sources of waste.

Nowadays this integration is achieved through the use of computer systems. CIM forms a bridge between CAD, the planning of manufacturing resources and individual computer-controlled machines (CAM — computer aided manufacturing). And here the ‘manufacturing’ in CIM embraces the complete range of a company’s activities — specification, design, buying components and materials, assembly, testing and despatch out of the factory gates.

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Using CIM reduces both the product development time and the time from the receipt of orders to the despatch of goods.

In discussing last month the possible impact of artificial intelligence (AI) on our lives I was really jumping the gun a bit. AI technology, which is largely based on non-numerical or symbolic computing, is farther into the future than current information technology (IT), which in the main uses conventional numerical computing. In fact IT is already affecting our lives, in the various ways I’ve been mentioning in previous reports over the years.

CIM is a particular application of IT which is likely to influence our lives not merely by its immediate effects on the kind of work done in factories but by modifying the very structure of industrialised societies. Way back in the Victorian era Karl Marx said that when new production technology comes into conflict with the existing social relations of production the conditions are set for social change. Whatever you think of Marxism as a political ideology, this particular observation has been borne out by events. Over two centuries it has been seen working through industrialisation (concentration of manufacturing), mechanisation and computer-based automation.

More than ten years ago the National Computing Centre concluded from a case study that the introduction of a computer-based system in a factory “can change roles” in ways that cause workers to form different attitudes to their tasks and to the management. Now that CIM has developed a lot more it has become the subject of deeper analysis. In the USA, for example, Professor Shoshana Zuboff has shown in a recent book (In the age of the smart machine) that IT is progressively changing the meaning of work, the identities of workers and people’s sense of themselves.

She says this is happening because IT cuts right across the traditional hierarchy of factory organisation. In the past managerial power to order things and people has rested on the distinction that managers do mental work (making decisions etc.), which is mainly carried out through communication with people, while factory operatives do largely manual work on objects. CIM is changing this organisational structure by making the work on objects more mental than manual.

All the hard graft and even the skill component is being provided by the computer-controlled machines. Information, no longer the exclusive property of managers, is made available to workers through vdu screens of computer terminals instead of being accepted through spoken or written forms of communication.

This new structure, according to Professor Zuboff, encourages employees to participate in the basis of information supplied by the computer terminals, rather than passively waiting for instructions from the managers. It will lead to more open and participative ways of working. But she also thinks it will require a lot of psychological adjustment. People won’t want to give up the traditional idea of management being achieved by instruction and command through a hierarchy of distributed power, from the top down.

Already the old Victorian concept of the manager as a boss who tells you what to do is going out. Increasingly the manager is being seen not as a superior who sits above you but as a professional who sits beside you. The jargon expression is ‘openly by dressing managers and workers in the same uniforms.

Undoubtedly CIM will accelerate this new trend in the social relations of the factory. But the ways we relate to each other anywhere are partly influenced by our occupations, and how these are perceived in the general pattern of an industrialised culture. So the effects of the new production technologies will certainly be reflected in the structure of society at large.

CIM AND SOCIETY

BY TOM IVALL

Full Marx, Karl - the manager shall sit down with the workers, and the worker with the machine

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PRACTICAL ELECTRONICS BOOK SERVICE

Here is your Editor's choice of books he thinks will be of interest to electronics and computer enthusiasts.

BEGINNERS AND EARLY STARTERS

- **Mini-Matrix Board Projects.** R.A. Penfold. 112 pages. £2.50. Order Code BP99
  Shows a selection of 20 useful and interesting circuits that can be built on a mini-matrix board of 24 holes by 10 copper strips in size - an ideal book for early experimenters.

  For the absolute beginner, clearly explaining the fundamentals behind the whole subject of electricity and electronics.

- **Electronic Projects for Beginners.** F.G. Rayer. 128 pages. £1.95. Order Code BP48
  Spcially for the newcomer to electronics who is looking for a book containing a wide range of easily made projects. Some circuits need no soldering and many others show actual component and wiring layouts.

- **Electronics Build and Learn.** R.A. Penfold. 128 Pages. £5.95. Order Code PC101
  Combining theory and practice, the book describes a circuit demonstrator unit that is used in subsequent chapters to introduce common electronic components and circuit concepts, complete with practical experiments.

- **Practical Electronic Building Blocks.** R.A. Penfold. There are two books - Book 1: 128 pages. £1.95. Order Code BP117
  Book 2: 112 pages. £1.95. Order Code BP118
  Book 1 is about oscillators and gives circuits for a wide range, including sine, triangle, square, sawtooth and pulse waveforms and numerous others from voltage controlled to customised ic types. Book 2 looks at amplifiers, ranging from low level discrete and opamp types to ic power amps. A selection of schematics, filters and regulations is included.

  Each project is designed for building on a Verobloc breadboard and is accompanied by a description, circuit and layout diagrams and relevant constructional notes. Many of the components are common to several projects. Book 1 covers linear devices, and Book 2 covers more logic chips.

  Shows the complete beginner how to tackle the practical side of electronics and includes simple constructional projects.

- **Oscilloscopes.** I. Hickman. £6.95. Order Code NT3
  Subtitle: How to Use Them, How They Work. The book is illustrated with diagrams and photographs and is essential reading for anyone who wants to know about scopes, from first principles to practical applications.

- **How to Get Your Electronic Projects Working.** R.A. Penfold. 96 pages. £2.50. Order Code BP110
  Essential reading for anyone who wants first-time success in project assembly. Covers tracing mechanical faults as well as testing for failures of active and passive components of most types.

TEST AND MEASUREMENT

- **Getting the Most from Your Multimeter.** R.A. Penfold. 112 pages. £2.95. Order Code BP239
  There's more to what you can do with a meter than meets the casual eye. The book covers the basics of what you can do with analogue and digital meters and discusses component and circuit testing.

- **Test Equipment Construction.** R.A. Penfold. £2.95. Order Code BP248
  Describes in detail how to construct some simple and inexpensive, but extremely useful, pieces of test equipment.

AUDIO AND MUSIC

- **Introducing Digital Audio.** I. Sinclair. 112 pages. £5.95. Order Code BP102
  A non-mathematical introduction to the new digital technology, discussing the principles and methods involved in devices such as cd, dat and sampling.

- **Electronic Music Projects.** R.A. Penfold. 112 pages. £2.50. Order Code BP74
  24 practical constructional projects covering fuzz, wah, sustain, reverb, phasing, tremolo etc. The text is split into four sections covering guitar, general, sound generation and accessory projects.

- **More Advanced Electronic Music Projects.** R.A. Penfold. 96 pages. £2.95. Order Code BP174
  Complementing BP74 by covering more advanced and complex projects including flanging, chorus, ring modulation, plus a selection of drum, vocal and synth circuits.

- **Computer Music Projects.** R.A. Penfold. 112 pages. £2.95. Order Code BP173
  Shows how home computers can produce electronic music and covers sequencing, analogue and MIDI interfacing, digital delay lines and sound generation.

- **Practical Midi Handbook.** R.A. Penfold. 160 pages. £5.95. Order Code PC103
  A practical how-to-do-it book for musicians and enthusiasts who want to exploit the capabilities of Midi. Covers keyboards, drums, sequencers, effects, mixers, guitars, and computer music software.

- **Midi Projects.** R.A. Penfold. 112 pages. £2.95. Order Code BP182
  Practical details of interfacing many popular home computers with Midi systems, and also covering Midi interfacing to analogue and percussion synths.

- **Electronic Synthesiser Construction.** R.A. Penfold. 112 pages. £2.95. Order Code BP185
  Even relative beginners should find the monophonic synthesiser described here within their capabilities if the book is thoroughly read. Individual aspects of the synth are dealt with separately and pcb designs are shown for the main modules.

SATELLITE TV

- **NEW* Satellite TV Installation Guide - 2nd edition John Breeds. £11.95. Order Code STV1
  Full of vital information for any competent DIYer who wishes to install a satellite tv antenna and obtain optimum reception quality.

- **An Introduction to Satellite Television.** F.A. Wilson. 112 pages. £5.95. Order Code BP195
  Informative answers to many of the questions about this communications revolution. The information is presented on two levels, one aimed at the complete beginner, the other at professional engineers and serious amateur enthusiasts.

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Microprocessor Systems and Circuits
F.A.Wilson. 256 pages. £2.95. Order Code BP77
A comprehensive guide to the elements of microprocessing systems, covering the fundamental principles behind this important subject.

Introduction to 6800/6802 Microprocessor Systems
R.J.Simpson and T.J.Terrell. 238 pages. £10.95. Order Code NT9
The book covers systems hardware, programming concepts and practical experimental work that will assist in understanding the 6800/6802 microprocessor, with additional information on the 6802 DEX evaluation system.

NEW An Introduction to 68000 Assembly Language.
R.A. and J.W. Penfold. 112 pages. £2.95. Order Code BP184
Covers the fundamentals of writing programs that will vary to the speed of 68000 based machines such as the Commodore Amiga, Atari ST range, Apple Macintosh, etc.

Getting the Most from Your Printer
J.W. Penfold. 96 pages. £2.95. Order Code BP181
How to use the features found on most dot-matrix printers from programs and popular wordprocessors, showing examples of what must be typed to achieve a given effect.

Micro Interfacing Circuits
R.A. Penfold. Two books, each of 112 pages.
Book 2: £2.25. Order Code BP131
Both books include practical circuits and useful background information though job layouts are not included. Book 1 mainly covers computer input/output techniques. Book 2 deals primarily with practical application circuits.

NEW An Introduction to 6502 Machine Code.
R.A. and R.W. Penfold. 112 pages. £2.50. Order Code BP147
Covers the main principles of machine code programming on 6502-based machines such as the Vic-20, Oric/1/Atma, Electron, BBC and Commodore 64. It assumes no previous knowledge of microprocessors or machine code and gives illustrative programming examples.

NEW A Z-80 Workshop Manual.
E.A.Parr. 192 pages. £3.50. Order Code BP112
A book for those who already know Basic but wish to explore machine code and assembly language programming on Z80 based computers.

Practical Digital Electronics Handbook
M.Tolley. 208 pages. £6.95. Order Code PC104

Electronic Science Projects
Owen Bishop. 144 pages. £2.95. Order Code BP104
A bumper bundle of experimental projects ranging in complexity and including a colour temperature meter, electronic clock, a solid state (red display) scope, an infra-red laser, a fascinating circuit for measuring the earth's electrical field strength, and many more.

Electronic Security Devices
R.A. Penfold. 112 pages. £2.50. BP56
Full of ideas for keeping your valuables safe. The circuits include designs for light, infra-red, ultrasonic, gas, smoke, flood, door and baby sensors.

R.A. Penfold. 112 pages. £2.95. Order Code BP190
Follows on from where BP56 leaves off and describes a number of more up-to-date and sophisticated projects, such as pyro-sensors, infra-red and doppler-shift detection, fibre-optic loops, and many others.

NEW Electronic Projects for Cars and Boats
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More Advanced Power Supply Projects
R.A. Penfold. 96 pages. £2.95. Order Code BP192
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NEW Popular Electronic Circuits.
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