PRACTICAL

ELECTRONICS

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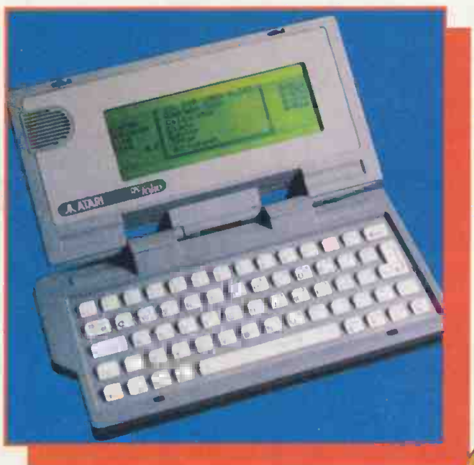

PROJECTOR SYNCHRONISER

Build a slide show magic marker

ENCRYPTION

The science of linguistic security

ELECTRONIC THUMB

Don't be caught red-handed in the workshop!

DIGITAL ELECTRONICS

The software for hardware control

PLUS AN EASI-BUILD WORKSHOP PSU!

Page 61 ▲ **▼ Page 4**

Page 49 ▼

NEXT MONTH

Whether you are receiving satellite tv signals or music from a pop radio station, the principles are similar - we examine the hows and whys of radio transmission. Stepper motors provide precise computer controlled movement, from plotters and printers to buggies - our new multimode driver circuit doubles the stepping precision. And there'll be a bumper bundle of other radiant features in the next power packed issue - step into your newsagents on time and make sure a copy's reserved for you.

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PRACTICAL ELECTRONICS

VOL 25 NO 7 JULY 1989

CONTENTS

COMPETITION

CONSTRUCTIONAL PROJECTS

SPECIAL FEATURES

REGULAR FEATURES

PRODUCT FEATURES

PE TAKES TECHNOLOGY FURTHER - BE PART OF IT!

TRIPLE POWER

The recently released Thandar TS30238 is a laboratory quality triple output power supply. Two outputs each provide 0 to 2 Amps at 0 to 30 Volts and can be switched to independent tracking; the third output provides up to 4 Amps at 4 to 6 Volts for logic circuits. All outputs have remote sensing.

Both 0-30V 2A outputs have 0.5 inch 3.5 digit liquid crystal displays which simultaneously display output voltage and output current. With the output switch off the display can be used to preset the output voltage and current limit prior to connection of the load. The power supply operates in constant current or constant voltage modes with automatic cross-over. A display annunciator indicates constant current mode. Coarse and fine controls permit the output voltage to be set within 5mV and the current limit control is logarithmic to give good resolution at low current settings. Load and line regulation are better then 0.01% with ripple and noise typically better than 1mV. The two supplies can be switched to be independent or tracking.

The 4-6V 4A output has a single 0.5 inch 3.5 digit lcd which displays either output voltage with the output switch off or output current with the output switch on. A display annunciator indicates current limit. The output voltage is set by a calibrated control and over-voltage protection is provided.

All outputs are protected against forward or reverse voltages. The power supply has a steel case, rubber feet and integral mains lead.

The TS3023S sells at £385.00. For further information, please contact the Sales Office at Thandar Electronics Limited, 2 Glebe Road, Huntingdon, Cambridgeshire, PE18 7DX. Tel: 0480 412451.

SERVICEABLE PROGRAMMER

Designed for ease of use and protability, the new Digelec model 834 programs all ee/eproms up to the latest 1Mbit devices and Intel single-chip microcomputers without any adaptors. Complete with its own built-in uv eraser and carrying handle, and housed in a moulded impact-resistant case this light-weight instrument is ideal for the service engineer or for use in the laboratory.

The 834 features a standard ram of 256K Bytes and can program any ee/eprom up to 1Mbit in one cycle. By using the "Set Mode" two 1Mbit devices can be programmed in just 4 keystrokes. The latest fast programming algorithms enable the unit to bring speed and reliability to programming.

Full editing facilities are provided for data manipulation both via the keyboard and by remote control. It has a wide range of communications formats for interfacing with various computers whilst the remote driver software provides remote operation from personal computers. All Setup functions are stored in non-volatile ram, which together with the Signature Recognition capability ensure the programmer is highly suitable for service use.

Contact: Microtel Systems Limited, Glanty House, The Glanty, Egham, Surrey, TW20 9AH. Tel: 0784 39881/35364.

CATALOGUE DATABASE

We have recently received the following literature:

If you're craving for even more **books to add to your technical library,** the book catalogues received from both Babani and PC Publishing will be of great interest. **Bernard Babani (Publishing) Ltd** are at The Grampians, Shepherds Bush Road, London W12 7NF. **PC Publishing Ltd,** have their offices at 4 Brook Street, Tonbridge, Kent, TN9 2PJ.

Anyone after **audio mixers** should include K-Tek on their shopping list. They have informed us that they have released a new catalogue which includes **plans, circuits, components,** faders and kits for mixers, compressors, noise gates, exciters, sweep equalisers and 48V psus. **K-Tek,** PO Box 172A, Surbiton, Surrey, KT6 6HN. Tel : 01-399 3990.

A very wide range of audio products, ranging from personal stereos to CD Midi systems and video equipment is imported by the Crown Corporation. Crown are a Japanese company who have recently built a new 1.3 million sq ft factory in China. One of their products that caught my eye in the catalogue is a very **neat portable cd singles player.** If you contact their London office, they will be pleased to advise you of the whereabouts of your nearest local stockist. **Crown Corporation (UK) Ltd,** 346 Kensington High Street, London W14 8NS. Tel : 01-602 9292/6.

A catalogue to rivet the attention of any self-respecting diyer is the new Tool Book from STC. It has 128 pages packed with **practically every tool and workshop accessory** you can imagine. In one section there are pliers, cutters, screwdrivers, wrenches, metal working tools; in the assembly aids section you'll find component testers, storage equipment, assembly jigs and vices, lamps and magnifiers; another section of production materials includes fasteners, labelling products, adhesive tapes, computer cleaning and service aids. A final section includes batteries of numerous types, and battery chargers. What is more, **you can use any of the four major credit cards** to purchase any of these superb products. Contact **STC Electronic Services,** Edinburgh Way, Harlow, Essex, CM20 2DF. Tel : 0279 626777.

Another publication **worthy of workshop attention** is the latest full colour 336-page equipment catalogue, available from another division of STC. This includes multimeters, oscilloscopes, converters, psus, counter-timers, and logic analysers, just to mention a few. One section of the catalogue is dedicated to **books on component data, theory and applications.** It also covers computer topics, communications and control. **STC Instrument Services,** Dewar House, Central Road, Harlow, Essex, CM20 2TA. Tel : 0279 641641.

HOME AUTO-HEATING

Two new electronic central heating controls for the home have been introduced by Landis and Gyr.

The Microgyr 40 is a daily electronic programmer for domestic central heating designed to provide more flexible control of central heating systems and domestic hot water. In conjunction with appropriate thermostats and motorised valves, it can be used in any type of wet domestic heating installation.

The controller offers a wide choice of programming options and accepts up to three on/off switching periods per day. This feature is particularly welcome for very cold periods when a short midday 'boost' can be programmed into the central heating for added comfort. The programmer can also be set to extend past midnight, ie, the last OFF can be almost 24 hours after the first ON.

A feature of the programmer is the battery back-up which maintains the unit's timing function in the event of power cuts or mains disruption.

Attractively designed and compact in size, the Microgyr 40 can be easily installed in any convenient position in the home. Its 'simple to operate' instructions are printed on the inside of the hinged cover. The baseplate is the same as that used for the Landis & Gyr RWB2 programmer (also known as the Potterton Mini-Minder and Glow-Worm Matermind) and when the Microgyr 40 is used as a direct replacement, no re-wiring is necessary.

The Microgyr 50 is a microprocessor based timeswitch designed to operate a single circuit within a 24 hour period. It is ideal for use with combination boilers, ducted warm air systems and solid fuel installations and offer a wide choice of programming options with three on/off periods per day and the ability to programme past midnight. It, too, has a battery back up.

For further information please contact: Leon Price, PR Executive, Comfort Control Group, Landis & Gyr Limited. Tel: 01-992 5311.

RECEIVING METEOSAT

ICS Electronics have announced a new low cost, high quality receiver for use with the Meteosat satellite – currently in orbit above West Africa. It gives noise free visible and infra red pictures of Europe every half hour with 24 hours per day coverage.

Accompanying software and interfaces are available to run on the Commodore Amiga, Archimedes, IBM-PC and Atari computers. Suitable antennas and connecting cables are also available.

This high quality SHF receiver is intended for use with the current generation of weather satellites which are in fixed geostationary orbit. Excellent, noise free pictures can be obtained with a one metre diameter dish antenna (or equivalent).

For the ultimate in performance, the MET-1 can power a remote antenna pre-amplifier (such as the MET-1a) via the coaxial cable. No other connections are needed. Ten metres or more of UR67 cable can be used between the receiver and pre-amplifier.

Overall, the MET-1 combines simplicity of use and excellence of performance. It certainly appears to be a dependable way to obtain superb satellite cloud cover pictures day after day. The price is £399.95 for the receiver and £119.95 for the matching preamp (including UK vat).

Contact: ICS Electronics Ltd., Unit V, Rudford Industrial Estate, Ford, Arundel, BN18 0BD, West Sussex. Tel: 024 365 655.

EVENTS DIARY

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

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

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

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

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

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

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

Jul. 24-26. Vacuum Microelectronics – 2nd International Conference. Bath. Contact Dr R.A. Lee, GEC Hirst Research Centre, Wembley, Middx, HA9 7PP. 01-908 9000.

Aug. 25-Sep 3. International Audio and Video Fair. Berlin. 01-408 0111.

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

Sep. 12-14. Optical Systems. Ramada Inn, London.

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

Sep. 26-28. British Laboratory Week 89. Incorporating Computer Aided Sciences. Olympia, London.

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

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

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

CRYPTIC BUG WARS

However concerned you are about security, Eskan Electronics can offer you many devices which will give better control over secrecy.

They have sent us several pages from their colour brochure covering many security-associated products. For example, they have a couple of bug detectors, both of them very easy to use and capable of detecting any transmitters or bugs. One of them indicates the presence of a bug by means of a bar graph and is fitted with a gain control. This not only provides details of the bug's exact location but also the signal strength. The other unit has similar features but in addition has an audio bleeper designed to change tone as the bugging device is approached.

For those concerned about phone tapping Eskan have a specially designed phone which will ensure that your conversations remain private. They have other monitoring units that can be used with your existing phone to provide the same effect. A warning light on all models will indicate if your phone is being tapped or if any extensions are off the hook.

On the other side of the scale, they have products which enable you to unobtrusively make security recordings. One such product is their recording briefcase. It looks like a high quality leather briefcase but has a microelectronics system hidden inside allowing discreet recordings of an extremely high quality to be made. It is entirely silent while in operation, with an invisible switching device operating the recording facility.

Other products in their range include several vhf transmitters, one of which looks just like a fountain pen. They also have a selection of automatic telephone recorders and transmitters.

For the cryptic lowdown contact Eskan Electronics Ltd, 172 Caledonian Road, London, N1 0SG. Tel: 01-278 1768.

ENCRYPTIC LOCKING

The New IC Type TEA5500 from Philips is designed to operate as either the encoder or decoder in security locking systems. It was originally developed for central door locking systems in automotive applications and is currently used by a number of leading car manufacturers. It protects the car by only allowing access through one out of 59047 combinations.

The chip has obvious applications in similar lock/unlock systems in a whole range of industrial and consumer applications.

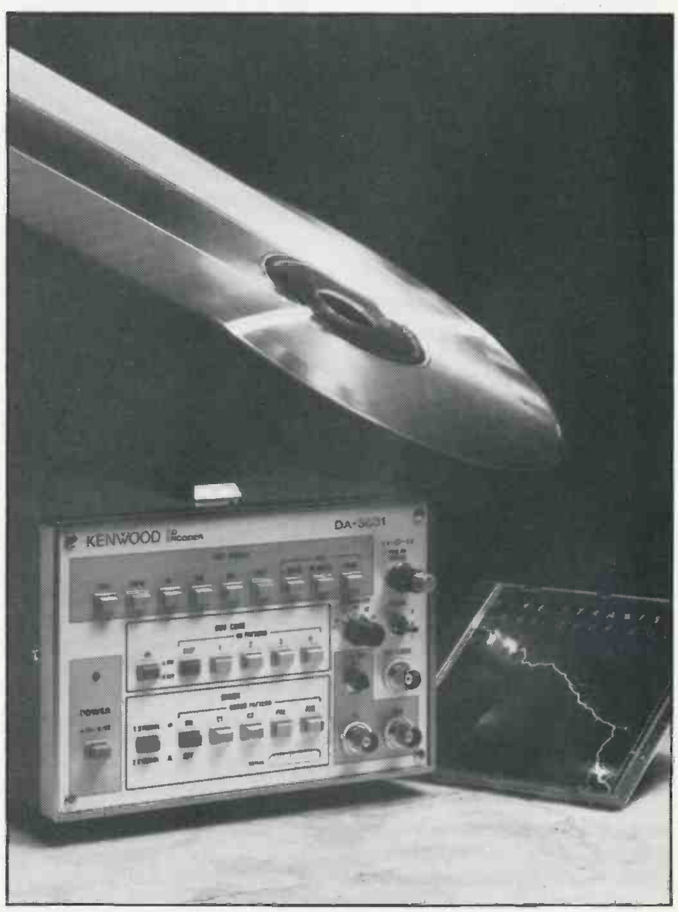
For further information contact: Philips Components Ltd, Mullard House, Torrington Place, London, WC1E 7HD. Tel: 01-580 6633.

ENCRYPTIC ANALYSIS

The Kenwood range of compact disc test equipment is now available from Thurlby Electronics and includes encoders and decoders, together with jitter analysers and a subcode generator. A cd test disc is also available.

The two cd encoders available are the DA3531 and DA3500A. The DA3531 is a reference signal generator used to evaluate cd players. The more sophisticated DA3500A generates EFM signals, performs CIRC processing and adds complete subcodes including R-W codes. It can generate a complete set of simulation signals, including those for optical transmission.

For further information contact: Thurlby Electronics Ltd., Burrel Road, St. Ives, Huntingdon, Cambs, PE17 4LE. Tel: 0480 63570.



MINI ASTRA DISH

Sir Clive Sinclair's Cambridge Computer Company has announced that it is planning to produce a new smaller, flat, square satellite receiver dish to receive signals from the Astra satellite.

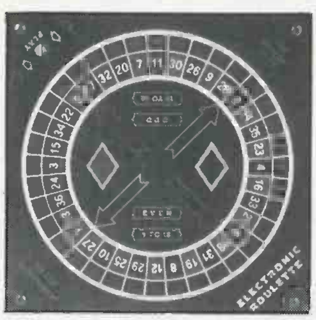
At a press conference held at the Cable & Satellite Exhibition in London, where Cambridge was showing its new 60cm receiver system to the public for the first time, Sir Clive announced plans for a new 45cm receiver dish that will be available from this Autumn.

"The original 60cm Cambridge satellite receiver design has performed significantly better than expected, and it is for this reason that we have been able to use its advantages over other designs to make it still smaller and shallower," said Sir Clive.

"Our technology is now proven and from the Autumn we shall introduce a new flat, square 17 inch dish only 5 inches deep. This we know will work in the Midlands and the South but, until further tests are carried out, people north of this region will only be able to use our 60cm dish."

The 60cm version of the Cambridge satellite receiver was the prize won by three PE readers following our February 1989 competition. The receiver is also commercially available in two system configurations: one with remote control and stereo sound output for £199.95, and a top-of-the-range system with remote control and a stereo amplifier for £259.95. The new 45cm receiver systems, available from the Autumn, will retail at the same prices as the 60cm systems. All prices include VAT.

For further information, please contact: Mark Mellor, Countrywide Communications (London) Limited, Bowater House East, 69 Knightsbridge, London, SW1X 7LH. Tel: 01-225 0311.



HIGH STAKES

The new Maplin Super Electronic Roulette Kit practically brings Las Vegas to your home. The kit aims to electronically simulate what is probably the most popular of games played in gambling casinos, Roulette.

The traditional roulette wheel is essentially a random number generator where a ball is thrown over the spinning wheel, which eventually comes to rest at a number. The chances of landing on any one number is approx. 9.842112 x 1039 to 1! In this version, the wheel is produced by a ring of leds which flash in succession producing a spinning effect; this rate eventually slows down and stops.

Although the real game is played for very high stakes, this project is intended to be used purely for the fun of playing the game. The kit comes complete in every detail, including a plastic front panel, printed circuit board and a small buzzer which simulates the sound produced by a ball on a spinning roulette wheel.

High Stake note: Playing chips are not included in the kit!

Low Stake note: The Roulette kit, number LM67X costs just £14.95, including vat. It is available from the Maplin nation-wide shops, or by direct mail from Maplin Electronics, PO Box 3, Rayleigh, Essex, SS6 8LR. Tel: 0702 554161.

CHIP COUNT!

Highlighting details of some recently released chips.

ADVANCING THIRTY TWO

Of particular interest to our more advanced readers are two new 32-bit devices from Hitachi. Both are additions to their H-series of advanced micro-processor products.

The HD641016CP-10 is a 10MHz version of the H16 embedded controller. It is built in 1.3 micron cmos technology and contains a full 32-bit cpu, 1K bytes of fast on-chip sram and a comprehensive set of peripheral circuits.

Apart from parallel i/o and external memory, the H16 contains all the peripheral functions required in the majority of applications, providing a major reduction in component costs and an equally significant increase in reliability. Two 16-bit timers and three serial ports are provided, while interrupts, dma and dram refresh are all handled by built-in controllers. The dmac has four independent channels for performing high speed data transfer without cpu intervention. Additionally, the H16 is directly compatible with low cost standard i/o devices from the 6800 family.

The chip's architecture has been specifically designed to support C and other high level languages. As well as the standard techniques used in earlier 32-bit devices, the chip includes a unique ring bank mode that greatly reduces the time taken to enter and return from procedures. The H16 therefore allows easier software development, shorter development time and other benefits of high level languages to be obtained without the traditional performance penalty.

SUPPORT TOOLS

Ideal for use in high performance embedded systems or as the central processor in a system containing several intelligent peripherals, the HD641016CP-10 is supported by a full range of development tools. These include an emulator, an evaluator and development software from Hitachi, as well as a wide range of third part tools.

To extend their own range of H-series support tools, Hitachi have additionally introduced the SO16SIMPC. This is a simulator/debugger that allows software for the H16 microprocessor to be developed on an IBM PC or compatible system. The device's powerful features allow H16 programs to be developed, tested and debugged before target hardware has been developed, allowing hardware and software design to progress in parallel.

The major benefits of the chip include symbolic debugging, i/o simulation and session logging, where command sequences and results are recorded for subsequently analysis. By including facilities to simulate memory-mapped i/o and functions such as interrupts and ASCII data transmission, realistic simulation of the target hardware is made possible.

Other features of the chip include complex breakpoint conditions, dynamic modification of registers and memory, a single line assembler/disassembler and the ability to use the entire address space for user programs. As well as the full simulator program, which is suitable for all H16 applications, Hitachi can also supply a demonstration version which is ideal for initial evaluation of the H16's unique architecture.

For further information on these two important new 32-bit products contact Sue Jenner at **Hitachi Europe Ltd,** 21 Upton Road, Watford, Herts. WD1 7TB. Tel : 0923 246488.

RATING DATA LINKS

BY BARRY FOX
Winner of the UK Technology Press Award

We have Integrated Digital Access. Now let's work out how we're going to use it . . .

You will be reading a lot about ISDN over the next few months. Officially ISDN stands for Integrated Services Digital Network. Unofficially it stands for "I still don't know".

ISDN was conceived in the 1970s as a way of improving telephone speech quality by providing digital links, each with 64 kilobit per second capacity, between telephone exchanges. The idea then evolved of providing customers with direct access to the digital paths.

In June 1985 British Telecom started a trial service, in the City of London – called Integrated Digital Access – which carried a 64bit/s data path, an 8Kbit/s signalling stream and an 8Kbit/s second data path into offices on a single pair of copper wires. There are now around 1000 IDA customer lines around Britain, used by large businesses including BT. Many of them use the service to send graphics art work from computer to computer, instead of using the mail or couriers.

Practical experience with IDA showed that the second, low data rate path was inadequate. So the CCITT, International Telegraph and Telephone Consultative Committee, set a higher standard, known as the I-420 interface. This specifies that each ISDN service link should offer two separate 64Kbit/s paths plus one control data path running at 16Kbit/s, making a total of 144Kbit/s. This is known as the 2B+D service.

France introduced a test 2B+D project in 1988. British Telecom will launch a 2B+D service this summer. The 2B+D format is called the Basic Rate Interface.

West Germany created a blaze of publicity by inaugurating an ISDN service (with 2B+D paths) to coincide with the giant CeBIT computer and telecommunications exhibition held in Hannover early in March. This service covers eight cities and the German Post Office, or Bundespost, claims that by the end of 1989 70,000 subscribers will have access to ISDN – with the whole country being able to subscribe by 1993.

Both France and Germany have accused British of trailing with ISDN, saying that commercial competition between BT and Mercury has sapped energy from the ISDN push. BT denies this, arguing that it has deliberately waited to introduce a service which conforms with the latest I-420 standard. The German service, says BT, was tailored, mainly by Siemens, to an older version of I-420.

Also BT fears that the Bundespost is making the same mistake which the Bundespost made with its Btx viewdata service – offering a high technology solution looking for a problem.

BT should know. It made exactly the same mistake with Prestel.

Although in theory it is a nice idea to have a single phone on a desk, with two 64Kbit data paths, in practice no-one is quite sure how these paths will be used or whether an ISDN connection can – as promised by Germany – cost no more than a conventional speech line.

Yes, ISDN lets Group 4 fax machines transmit an A4 page in ten seconds, without glitches.

Yes, ISDN lets a video telephone transmit jerky colour pictures at the same time as speech.

But with Group 3 fax machines now costing less than £1000 and most people not wanting to see who they are talking to by telephone, the high cost of a Group 4 fax and videophone starts to look very unattractive.

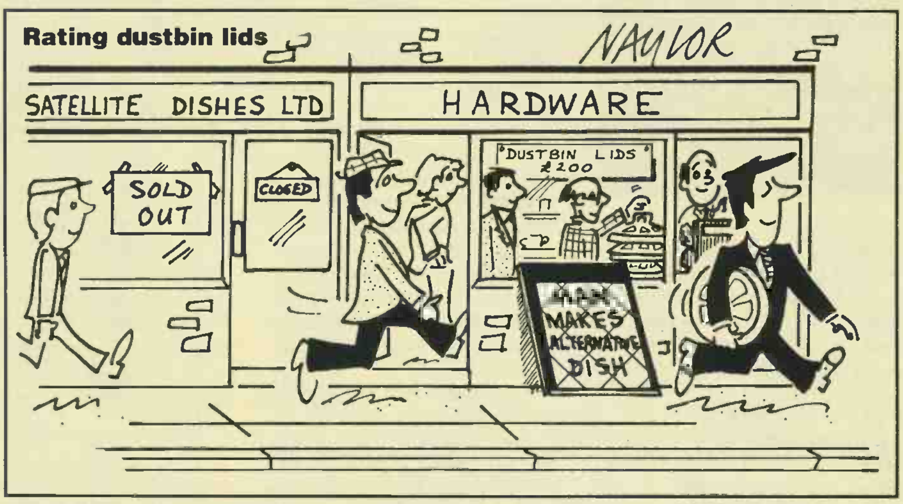
Remember how Prestel offered the public the chance to access all manner of information, and the public responded with a loud yawn? The Bundespost seems to forget that its Btx service fell flat for exactly the same reason.

BT thinks there may be more mileage in providing office telephone exchanges with a 2 megabit/s ISDN link, equivalent to 30 separate 64K bit paths. This would let large businesses with offices round the country link their computer networks as if they were in the same building. BT has already built 20,000 of these 2 Mbit ports into exchanges round Britain.

The 2 megabit service (more accurately 2.048 megabits per second) is known as the Primary Rate Interface. The spare capacity over and above the 30 channels at 64K is used for control data.

Here again standards are lagging progress, and there will be no international agreement on PRI until the 1990s. So services introduced now are unlikely to be fully compatible with similar services introduced in other European countries ahead of standardisation.

None of this bodes well for the European Commission's dream of a single ISDN service linking all Europe in time for the community wide markets in goods and services promised for 1992. PE



Describing the picture quality as ASTRA nomical, a certain Stan Bacon has discovered that some dustbin lids can be used as Sky satellite TV aerials. He denies this reflects the quality of the programmes!

PRACTICAL
ELECTRONICS

EDITORIAL

Exhibitions are an adven-ture! There is such a great sense of exploration and investigation right from the time that you pass through the ticketturnstile. The crowds, the noise, the colours, the jungle of displays, the alleys and byways and corridors that lead off to yet more revelations, all generate such excitement and anticipation that must surely rival that sought by Livingstone, Burton, Becker, et al. (Yes, your Ed's great-uncle Horace was an explorer - until he disappeared in Darkest Africa!)

The All Electronics Show is the latest adventure from which I have just emerged, overwhelmed by inspiration for new circuits to design, longing for products for which mortgages are needed, and weighed down by brochures and catalogues galore. Held in London at Olympia, it was indeed an Olympian challenge to do justice to each and every stand. It was, perhaps not unexpectedly, similar in content to Electronica 88 on which I reported in PE Feb 89. In the six months since that exhibition, the state-of-the-art does not appear to have changed sufficiently to justify a full scale report, but I was particularly impressed by the even greater emphasis being placed on the equipment and techniques for testing and quality control.

It was especially interesting to watch some of the demonstrations in which highly complex assembled, and often multilayered, pcbs were subjected to computer controlled diagnosis. With many of these, great forests of tiny probes were automatically placed in contact with significant track points and the signal flows analysed by preprogrammed software routines. One demonstration that held my attention for quite some time was that of a huge, highly sophisticated pcb track-integrity analyser.

The machine is previously programmed with data for a given track layout, which may be several feet in area. The etched pcbs are then placed within the machine which examines every single track and pad, checking the observed data against the memory store. Using a metal to non-metal detection technique, even the minutest flaws of only milli-fractions of an inch can be detected, whether they are scratches, shorts, open circuits or missing pads, and irrespective of their colouring. After fifteen seconds or so, the board is ejected from the machine and a plotter pen marks any points found to be substandard. This allows another operator to carry out restorative work on the problem sections. As the demonstrator pointed out, it is essential to determine track faults before multilayered panels are sandwiched in the final assembly.

Though these are not the sort of procedures that lend themselves to homebased diy electronics, you all would admire the mechanical ingenuity and analytical programming skills of those who have designed the equipment which helps to ensure reliability of the products on sale in the shops.

Of equal importance to you are the conversations I had with a few component manufacturers. As a result, I have lined up more top level feature articles written by leading experts. Also of interest was the chat I had with a pcb equipment manufacturer. I know how keen so many of you are on making your own pcbs and this manufacturer is actively investigating the possibility of producing low cost pcb etching tanks especially for PE readers.

So watch out for even more exciting electronic adventures within our pages!

THE EDITOR

Editor:
John Becker
Sub-Editor:
Helen Armstrong
Technical Illustrator:
Derek Gooding
Advertisement Sales:
Sarah Holtham
Business Manager:
Mary-Ann Hubers
Circulation:
David Hewett
Publisher:
Angelo Zgorelec
Editorial and Advertising Address:
Practical Electronics,
Intra House, 193 Uxbridge Road,
London W12 9RA
Tel: 01-743 8888
Telecom Gold: 87: SQQ567
Fax: 01-743 3062

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Despite the advent of videotaped presentations great use is still made of the slide-tape presentation. The use of a number of colour slides, linked with a taped commentary and/or music still remains a very effective and popular means of presentation. The main difficulty in mounting such a show is often the need to synchronise the slide changes with the taped sound. True this can be achieved by following a script with the slide change cues marked on it (but what if the tape is purely music?), or by timing it.

Both systems are feasible but rely on having an operator present to control the slide changes by hand. When the tape-slide sequence has to be shown repeatedly these methods become impractical. A more effective method, invariably used in professional presentations, is to make use of marker tones recorded on the audio tape in synchronism with the sound track. These tones are then used to trigger the control mechanism of a slide projector fitted with an automatic or remote control slide change mechanism.

PROJECTOR SYNCHRONISER

BY CHRIS BOWES

Concealed on your sound track – the magic marker that rolls in the pictures on cue. We present the project that plugs up the sync with chips.

The Projector Synchroniser described in this article is designed to allow any slide projector fitted with a non-manual slide change mechanism (ie, one which is operated by pushing a button as opposed to manually pushing a long bar in and out) and any stereo tape recorder to be used to mount such a presentation,which will not require constant attention during the performance.

To avoid the audience being aware of the marker tones, the audio soundtrack is recorded on one track of a stereo tape and the control codes are recorded onto the second track of the tape. When the marker tones are replayed into the projector synchroniser they are passed through a narrow band pass filter which ignores all other frequencies and operates the slide change mechanism only when the correct tones are detected.

CIRCUIT DESCRIPTION

The circuit for the Projector Synchroniser can be divided into a number of separate sections, which fit together as shown in Fig. 1. The full circuit is in Fig.2.

The slide change marker pulses which are placed on the tape are sine waves (to avoid distortion within the record/playback process) at a nominal frequency of 1kHz. The signal is produced by IC1, a RS8038 waveform generator chip. This ic produces square, triangular and sine wave outputs but in this application we are only concerned with the sine wave output, available at pin 2. The output frequency is governed by the values of VR1 and C1 according to the formula:

$$f = \frac{0.15}{R \times C}$$

(Where f is frequency in Hz, R is in ohms and C is in farads)

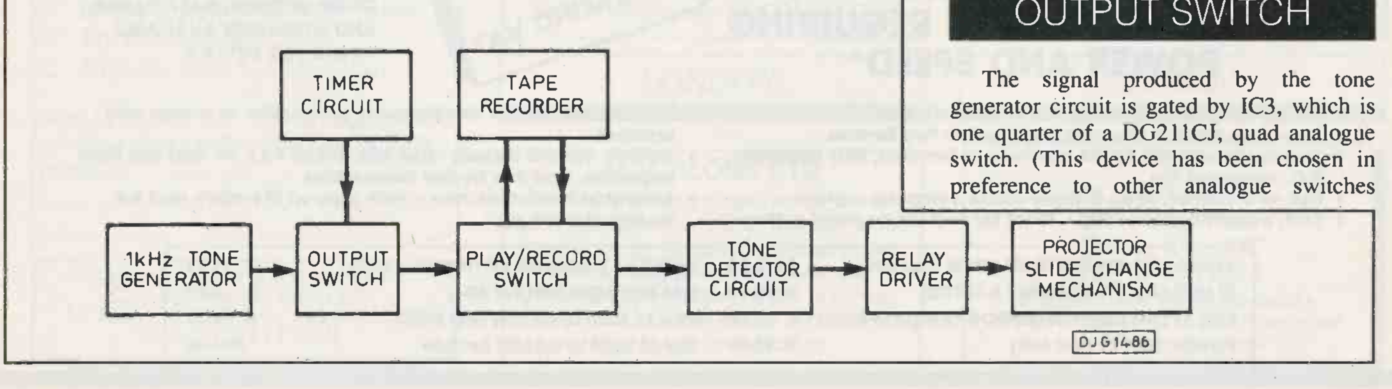
VR1 allows the output frequency to be adjusted to accurately match the centre frequency of the active filter circuit.

The 'sine wave purity' of the output from pin 2 of IC1 is adjusted by VR2. Both VR1 and VR2 are adjusted when setting up the circuit under test. The sine wave output from IC1 is taken to the non-inverting input (pin 3) of IC2a, which is one of the four independent op-amps within the LM324 quad opamp. IC2a is configured to give unity gain and act as a simple, but effective, buffer. The output from IC2a pin 1 is attenuated by VR3 and is ac coupled via C2 to the non-inverting input (pin 5) of a second amplifier (IC2b). This amplifier provides a fixed gain at a magnitude set by VR3 to give the most suitable signal strength for input to the tape recorder. Typically this would be approximately 500 mV.

OUTPUT SWITCH

The signal produced by the tone generator circuit is gated by IC3, which is one quarter of a DG211CJ, quad analogue switch. (This device has been chosen in preference to other analogue switches

Fig.1. Block diagram for the projector synchroniser



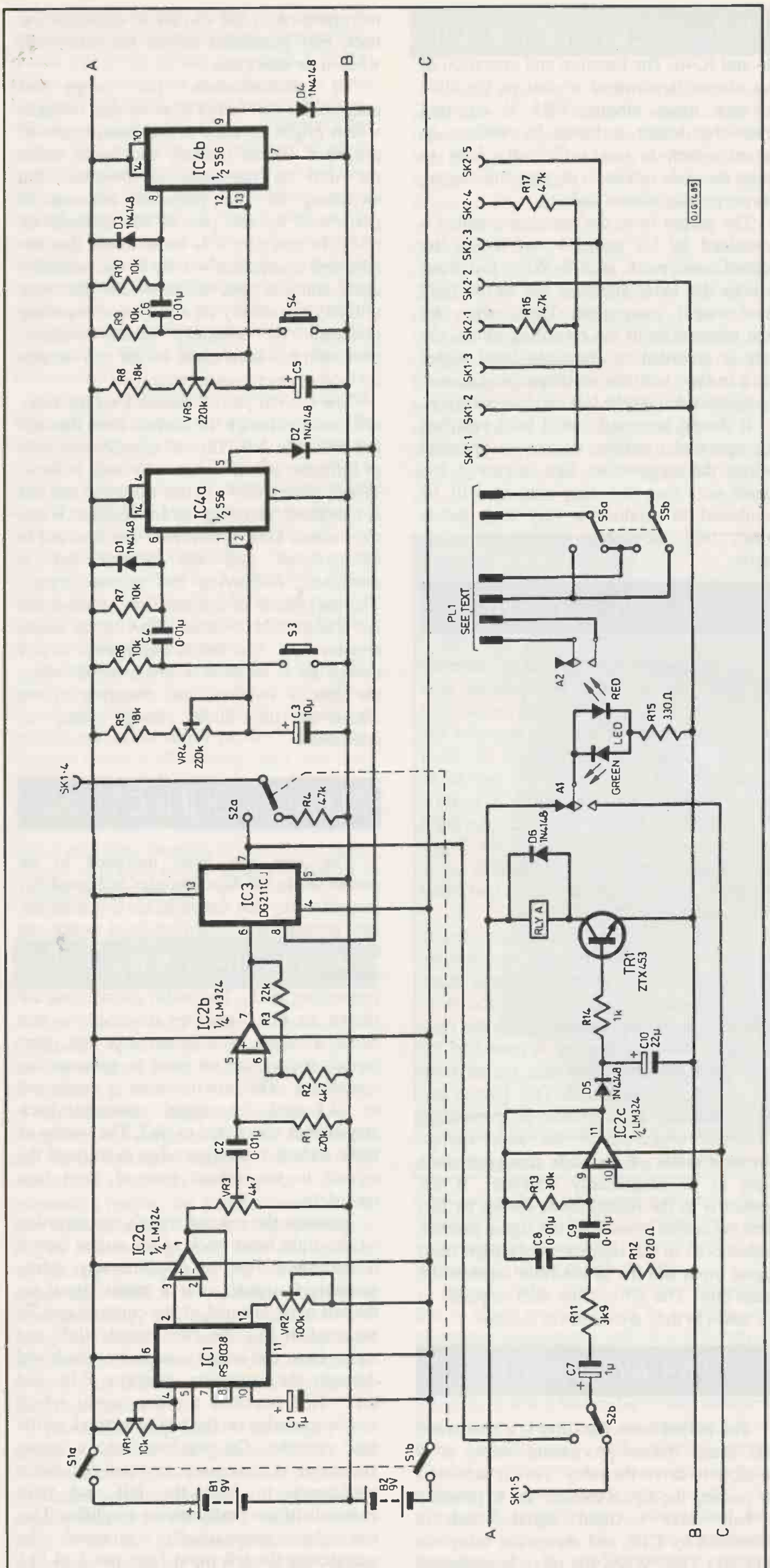


Fig.2. Circuit diagram for the projector synchroniser

because, paradoxically, the cheapest version of the family of analogue switch circuits is the quad version.) The sinusoidal 1kHz signal is constantly present at the source input (pin 6) of IC3 but is prevented from proceeding further by the almost infinite resistance of the internal circuitry for as long as the control node (pin 8) of IC3 is at the logic 0 state. When the node voltage level is raised to the logic 1 state, the gate's internal resistance falls to typically 200 ohms. This allows the signal to pass virtually unattenuated through the ic to the drain output at pin 7. The gated output signal is then routed by S2 to the tape recorder's right hand signal input connection and also, if S2 is in the record position, to the input of the active filter.

SLIDE CHANGE TIMER

In most modern slide projectors the direction in which the slide change operates (ie advancing the slide carrier to the next slide or reversing it to repeat the previous slide shown) is determined by the length of time for which the slide change button is operated. The usual method of operation is to make a short pulse advance the slide and a longer pulse reverse the slide carrier back to the previous position. To prevent erroneous operation the projector synchroniser has been designed so that the signal from the tone generator is gated for one of two predetermined durations, depending on which of the two slide change switches (S3 or S4) is actuated. Each switch is connected to its own identical monostable circuit made up of one half of a 556 timer (IC4 and IC4b).

When S3 is operated, the voltage at the junction of R5 and C4 is pulled down to 0 volts. This causes a short negative-going pulse to be generated at the trigger input (pin 6) via the ac coupling circuit comprising C4, R7 and D1. The trigger pulse causes the output at IC4 pin 5 to go high for a period of time set by R5, VR5 and C3. The output pulse duration is determined by the formula:

$$T = 1.1 \times (R5 + VR4) \times C3$$

(Where T is in seconds, R in ohms and C is in farads.)

VR4 allows the duration of the slide advance pulse to be adjusted to ensure reliable operation.

The ac coupling is necessary to restrict the length of time during which the trigger input remains at 0 volts. Since the timer output cannot return high until after the trigger input has returned to high state. (If the trigger input was dc coupled pressing S3 for a longer time than required to advance the slide change mechanism would cause the slide carrier to be reversed instead of advanced!)

Intentional slide reverse function is provided gating the control tone for a longer period of time than for the advance slide tone. This is achieved by means of the

COMPONENTS

RESISTORS

R1	470k
R2	4k7
R3	22k
R4, R16, R17	47k (3 off)
R5, R8	18k (2 off)
R6, R7, R9, R10	10k (4 off)
R11	3k9
R12	39 ohms
R13	30k
R14	1k
R15	330 ohms

All resistor 1/4 W carbon film5%

POTENTIOMETERS

VR1	10k preset
VR2	100k preset
VR3	4k7 preset
VR4, VR5	220k preset (2 off)

CAPACITORS

C1, C7	1µF 16V electrolytic (2 off)
C2, C4, C6, C8, C9	10n polyester (5 off)
C3, C5	10 µF 16V electrolytic (2 off)
C10	22µF 16V electrolytic

SEMICONDUCTORS

D1-D6	1N4148 (6 off)
LED1	bicolour led (red/green)
TR1	ZTX453 or similar npn
IC1	8038 waveform generator
IC2	324 quad opamp
IC3	DG211CJ quad analogue switch
IC4	556 dual timer

MISCELLANEOUS

RLA	6 volt pcb mounting dpco relay
S1, S2	dpst switch (2 off)
S3, S4	spst push to make switch (2 off)
S5	dpdt centre biased off switch
Sk1, Sk2	5 pin DIN 180° socket (2 off)
Pl1	plug to suit projector control connections (a socket to match might also be required).

Battery holders for PP9 battery (2 off), case to suit, multicore cable for linking unit to Pl1, screened cable to link Sk1 to Sk2, grommet for connecting cable, P-clip for connecting cable, pcb, standoffs (4 off).

The PCB is available through the PE PCB service.

second, identical monostable timing circuit, comprising S4, R8, C5, R9, VR4, C6, R10, D3 and IC4b. The function and operation of this circuit is identical to that of the slide advance timer circuit. VR5 is adjusted when the device is tested to produce an output which is just sufficiently long to cause the slide carrier to reverse and display the previously shown slide.

The output from the two monostables is combined by D2 and D4 and fed to the control node, pin 8, of IC3. When this input is high the 1kHz signal is fed to the right hand output connection. Thus, when the tape recorder is in the recording mode, the tone is recorded on the right hand signal track in sync with the accompanying soundtrack, recorded on the left hand signal track.

It should be noted that if both switches are operated together, or one is operated before the monostable first triggered has timed out, then the two outputs will be combined to produce a very long pulse, which will inevitably reverse the slide carrier.

ACTIVE FILTER

For the synchroniser to operate correctly the slide changer must be operated only when the control tones recorded on the right hand signal track of the tape recorder are detected, without being triggered by other signals. This is achieved by the use of an active filter circuit, comprising C7, R11, R12, C8, C9, R13 and IC2c, and having a narrow pass band, centred on 1kHz. When the 1kHZ control tone is present it is amplified and appears at the active filter output, pin 8 of IC2c.

The filter and relay circuits are used to operate the slide change mechanism irrespective of whether the system is being used to record or playback a sequence. If S3 is in the play mode the signal from the right output of the tape recorder is routed to the filter input and the gated tone output from the switch ic is inhibited. This feature has been included as a means of preventing erroneous triggering of the slide change circuit if either of the slide change buttons were to be accidentally activated. If the system is in the record mode (as set by S2) then the output tones from the signal gate are routed both to the tape recorder's right hand signal input and the active filter input at the same time. The active filter then responds to the tones as they are output to the tape.

RELAY SWITCH

The output from the filter is a sine wave and needs further processing before it is suitable to drive the relay. This is achieved by passing the signal through D5 to produce a half wave rectified signal which is smoothed by C10, and drives the relay via R11 and TR1. When the relay is energised it changes over the contacts and operates the slide change mechanism. D6 is incorporated in the circuit to dissipate the back emf generated across the relay coil when it de-energises.

To accommodate the range of magnitudes and forms of switching voltages which might be used in the many types of projector on the market, and hence make the unit as universal as possible, the switching of the projector controls is performed by one pair of the contacts on relay. In practice, it is most likely that the required connection will be to the normally open contacts but, to allow for the very unlikely possibility of a projector requiring operation by normally closed contacts, provision has been made on the pcb for this method of operation as well.

The second pair of contacts on the relay are used to change the current flow through the indicator led. This is actually two leds of different colours connected back to back. When current flows in one direction one led is energised, showing the first colour. When the current flow is reversed the first led is extinguished and the second led is energised, displaying the second colour. The magnitude of current flow through the led is restricted to about 10mA by the series resistor R15. The led is configured in this design so as to show a green output when the unit is switched on, changing to red whenever the slide change relay is energised.

AUDIO CONNECTIONS

The unit has been designed to be connected to the tape recorder and amplifier in such a way that the projector synchroniser, tape recorder and amplifier/signal source can be linked together simply by means of two standard (not mirror) 5 pin DIN audio connecting leads. The audio connections are shown in Fig.1 and are designed so that either a mono or a stereo tape (or other signal) source can be used to generate the soundtrack. The tape recorder is connected to Sk1 and the signal source/playback amplifier is connected to Sk2. The wiring of these sockets is configured so as to route the signals to the correct pins of most tape recorders.

Because the control signals are recorded on the right hand track of the stereo tape it is necessary first to combine any stereo soundtrack signals into a mono signal on the left hand channel of the control tape. To accomplish this the two signals (left and right) from the sound source are combined through the summing resistors R16 and R17. This provides a mono signal which can be recorded on the left hand track of the tape recorder. On playback into a stereo system it is necessary to feed the mono soundtrack to both the left and right channels of the performance amplifier. This can be automatically achieved by connecting the left input from pin 3 of Sk1 to both pin 3 and pin 5 of Sk2 within the unit.

Photocopies of the pcb track layout are available from the Editorial office, please send a stamped addressed envelope.

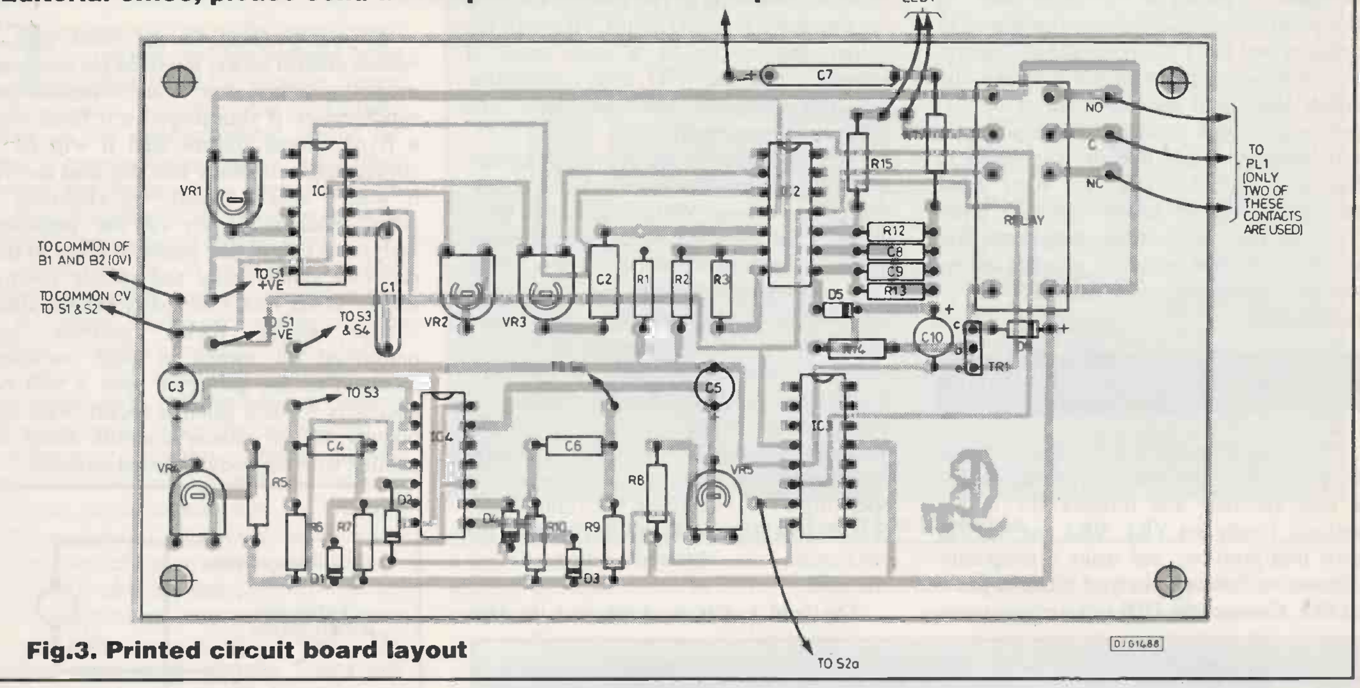


Fig.3. Printed circuit board layout

CONSTRUCTION

The greater part of the circuit is built on a single sided printed circuit board the component layout of which is shown in Fig.3.

After drilling, the components, with the exception of those mounted on the control panel, are inserted into the board and soldered in place. Although this process can be carried out in any convenient order, you will find that it is easier if the components are inserted and soldered in ascending order of size.

The ics are best accommodated in sockets which are soldered in place along with the other components. The ics should be inserted as the last task before testing out the unit.

CONTROL PANEL

In addition to the control switches and the amp and tape connector sockets, the front panel also supports the two battery holders. The front panel should be completely made, including lettering and drilling before any components are mounted. In addition to the holes required to accommodate the control switches and connector sockets it will be necessary also to drill and countersink the four holes with which the battery connectors are mounted onto the panel. After the preparation the panel mounting components should be fixed in place and connected together as appropriate. At this point you should note that R16 and R17 are mounted on the front panel by directly connecting them to the appropriate pins on Sk2, as shown in the photograph.

The use of a short length of screened cable between the junction of R16 and R17 and pin 1 of Sk1 and between pin 3 of Sk1 and pins 3 and 5 of Sk2 is recommended in order to prevent stray inductive pickup of the 50 Hz mains signal from any mains cables in the vicinity. This should preferably be accomplished by means of two core screened cable. If only single core screened cable is available then care must be taken to prevent the formation of an "earth loop". This is most easily achieved by connecting the screen of the cable linking pins 3 and 5 of Sk2 to pin 3 of Sk1 to link pin 2 of Sk1 to pin 2 of Sk2. The screen of the cable linking pin 1 of Sk1 to the junction of R16 and R17 should be connected only to pin 2 of Sk1. Pin 2 of Sk1 should also be connected to one of the mounting screws of Sk1 and to the 0 volt connection of the two batteries. It is not necessary to screen the cables carrying the control tones since the active filter will discard any signals so far removed from the 1kHz control tones. R4 is also mounted on the front panel and is connected between the appropriate contact on S2 and the 0 volt connection of S3.

SYNC LINKING

The interlinking between the synchroniser and the projector is accomplished by means of a cable fitted with an appropriate plug, connecting to a suitable socket mounted on the body of the projector. In some projectors the manual remote control unit will be attached to the projector by means of a plug and socket connection. In this case all that is necessary is to purchase a suitable matching plug and to deduce the correct connections for the slide change and the focus connections. This might require you to gain access to the interior of the projector if the details are not given in the projector handbook. *(But not when it's switched on! Ed)*

All that is then required is to connect the slide change pins and focus connections of the connector to the relay connections and S5 through a suitable cable, which exits from the case through a grommet fitted into a hole drilled in the side of the Projector Synchroniser case. (The cable can be securely held by means of a "P-clip" mounted on the side of the case adjacent to the grommet.)

TESTING

Once all the connections have been made the pcb should be carefully checked for broken tracks, solder blobs and incorrectly placed components to ensure correct polarity, and the unit tested.

The unit can then be tested without being connected to the projector.

If you have access to an oscilloscope you will find it easiest to start by examining the output of pin 12 of IC1. Firstly set VR1, VR2 and VR3 to their mid positions. Turn on the unit with S1 note that the led should glow green, although you might observe that the relay is energised (and the led glows red) for a short period of time. If this happens do not worry unless the relay remains energised permanently. Examine the waveform displayed and adjust VR2 until you obtain the most symmetrical sine waveform possible. Next make a temporary connection between pin 6 of IC3 and pin 5 of Sk1 and connect the oscilloscope probe to pin 8 of IC3. With S2 in the record position adjust VR1 until you obtain the maximum output. This will ensure that the signal generated by IC1 is centred on the bandpass frequency of the active filter. At this point you should observe that the relay operates and led 1 changes colour. Transfer the oscilloscope probe to pin 5 of Sk1 and adjust VR3 until an output signal of 500 mV peak to peak is obtained. The projector synchroniser should then be connected to the tape recorder and the right hand recording level set to the optimum level. You can then remove the temporary link between Sk1 and pcb, and proceed as for the test sequence without access to an oscilloscope.

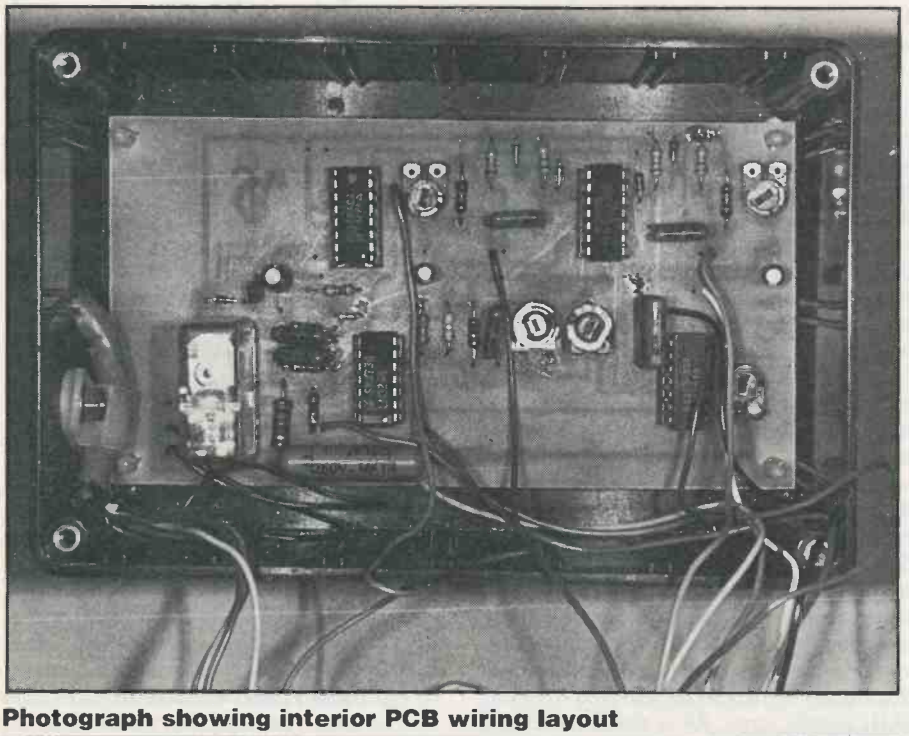
SCOPELESS TESTING

If an oscilloscope is not available it will be necessary to connect the synchroniser to a tape recorder and monitor the output audibly. Firstly set VR1, VR2 and VR3 to their mid positions and make a temporary connection between pin 6 of IC3 and pin 5 of Sk1. Connect the DIN input of your tape recorder (usually marked RADIO) to the tape connection (Sk1) of the synchroniser, set the recorder and synchroniser to the record mode and monitor the right hand signal of the recorder.

Set the input level of the tape machine to a comfortable level and make sure that a signal is being output from the synchroniser. At this point you might observe that the relay is energised. Rotate VR1 back and forth noting the extremes at which the relay "drops out", both when the value of VR1 is increased and as it is decreased. Set VR1 so the mid point between these two extremes. Set the tape recorder input to a normal recording position and observe the reading obtained on the recording level meter. Adjust VR3 until the recording level meter shows the optimum recording level. Finally listen to the sine wave tone and adjust VR2 until the output appears to be a pure tone. If necessary readjust VR3 after completing this test. Remove the temporary link between Sk1 and the pcb.

The remainder of the testing procedure is the same irrespective of which method was used to set VR1, VR2 and VR3. Connect the projector to the synchroniser, leave S2 in the record mode and operate S3. The relay should energise for a period of time which is adjustable by VR4. Adjust VR4 to give a definite operation of the relay which is sufficiently long to advance projector control mechanism without it being long enough to reverse the mechanism when S3 is actuated. Similarly test and set the slide reverse function by operating S4 and adjusting VR5 until a tone of sufficient duration to reliably operate the mechanism is obtained when S4 is operated.

The final test is to check that the tape recording function is correct. With the recorder and projector synchroniser set to the record mode, record on to tape a number of control tones, both forward and reverse, by operating S3 and S4 in a known sequence, using the tape counter to note where the tones were recorded. Rewind the tape and set the function switches to the play mode. Replay the tape and ensure that the slide change mechanism operates correctly, according to your predetermined sequence. Finally check that the input signals to the left channel from your chosen sound source are recorded as a mono source on the left channel of the tape and replayed as a mono source on both the left and right channels of your amplifier.



Photograph showing interior PCB wiring layout

MODIFICATIONS

If your projector is not fitted with a remote control socket it will be necessary to modify your projector to accommodate the synchroniser. If your projector is fitted with a fixed remote control lead it will be a simple matter to break into this lead and fit it with a socket (ideally by mounting a panel mounted socket on the projector body) and connecting identical plugs to the projector synchroniser and remote control cables. If no such lead exists but the slide change and/or focus functions are performed by means of push switches mounted on the projector body it will be necessary to fit a suitable socket, with the outputs to the remote controls wired in parallel with the body mounted switches.

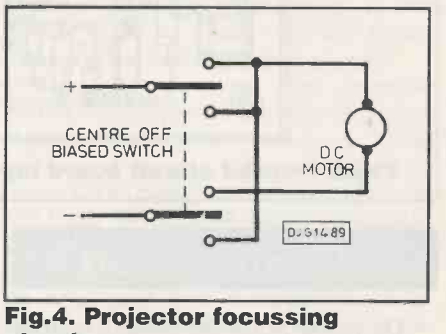


Fig.4. Projector focussing circuit.

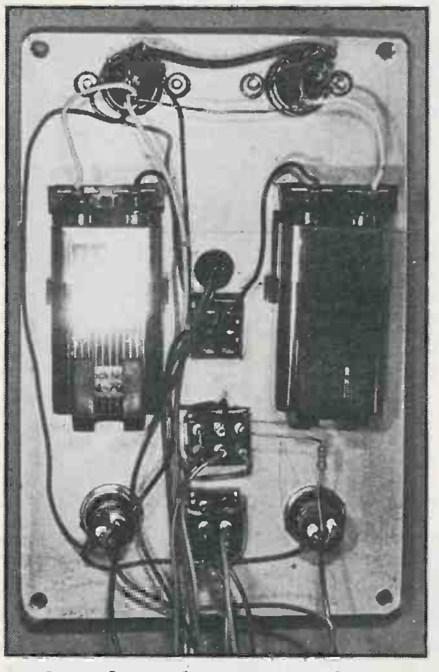
In most cases it will be necessary to gain access to the interior of the projector **WITH THE POWER OFF** and investigate the connections. Usually the slide change mechanism is operated by means of a solenoid which is energised by the slide change switch. This is usually a push to make type. The modification required here is simply a matter of connecting the slide change terminals so as to provide power to operate the solenoid when the projector synchroniser relay is activated. The focus control (if fitted) usually consists of a simple dc motor which is connected to a centre off, push to change over switch, wired up as shown in Fig.4. This is arranged so that when the switch is in the centre position the motor is totally disconnected. When the switch is pushed either way it causes current to flow through the focussing motor in the appropriate direction. In all cases the simplest method of connecting the extension socket is simply to make the required connections so that they are wired in parallel with the switches mounted on the projector body.

Six connections have been shown in Fig.1 for the connecting plug (Pl1) but in practice they may not all be required as the power connection used for the slide change switch is often common to one of the connections to the focussing switch. It is advisable, however, to ensure that the socket used for the projector control is dissimilar to that used for any other connections to avoid confusion and cross connection with disastrous results.

If your projector is not fitted with electrical focussing the connections to S5 can be dispensed with and the switch omitted.

SYNC USING

By the time that you have completed the testing sequence you should have a good idea of how the unit works. The basic method of operation is that the soundtrack should be made first. If your tape recorder can be set to record and playback independently on each channel then the soundtrack can be recorded, via the projector synchroniser if necessary, onto the left channel of the master tape. This is then replayed, through the synchroniser (which must be set to the record mode) and the slide change switches operated at the appropriate points. The synchroniser is then switched to the play mode and the slide changes should occur in sync with the soundtrack. If your tape recorder is not capable of being switched to record on the tracks independently then it will be necessary to create the soundtrack and then play it through the projector synchroniser onto the master tape and, at the same time, record the control tones. The focus control is active at all times, irrespective of the setting of S2, and can be used to focus the projector as desired while projecting the slides.



Inside view of component layout on the box lid.

You will probably have noticed that when the projector synchroniser is first switched on the relay will initially be energised for a short time. Because of this it is advisable to wait for the relay to de-energise before connecting the unit to the tape recorder or projector. PE

POINTS ARISING

PC MULTIPORT (PE April 1989)
In Fig.3, the following links are required: Hole adjacent to IC 9 pin 4 goes to hole adjacent to IC 10 pin 13. Hole adjacent to IC 10 pin 13 goes to hole adjacent to IC 10 pin 4. Hole adjacent to IC 10 pin 5 goes to hole adjacent to +5V. Hole adjacent to IC 8 pin 1 should go to digital ground, anywhere will do. In Fig.2, A32 should read A31, B15 should read B13.

KIRLIAN CAMERA (PE May 1989)
Fig.3. C1 polarity should be reversed. PCB point B should read as T1 common, PCB point C should just read as "T1+." in Fig.1. The coil output arrow should be marked as "EHT to plate." In Fig.5. the connection marked GND should go to PCB point A. The EHT plate and glass may be replaced by copper-clad fibreglass with a one inch strip of the copper removed from the edges.

REMOTE-A-BELL (PE May 1989)
In Fig.2. the polarities of D1 and D2 should be reversed. IC1 pin 1 is at top left. R1 should be inserted in place of link wire D to M, but taking it to L instead of M.

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Access

ENCRYPTION

Htuhjuyinyt - Ceauinhtoukx nehtinvcoh!

BY MIKE SANDERS

Encryption is not new. Ever since man stopped wandering the earth and started congregating in groups, secret messages have been whispered. The slaves in ancient Greece had their heads shaved, a message written, and when the hair grew again, the slave was sent to his destination to have his hair shaved again. This method is too slow and insecure for modern business needs.

New methods grow out of old and although the older, classical, methods of encryption would not stand up to modern methods of cryptanalysis (code breaking) it is worthwhile to explore the underlying principles.

After a survey of old methods, a modern method called the Data Encryption Standard will be explored. The key for encrypting a message is vital to both sender and receiver and methods of managing these will be discussed.

CIPHER SECURITY

Encoding a message may appear to be sufficient security, but there is nothing to stop an eavesdropper from recording the meaningless garble, and transmitting it again and again at a later date. This will cause confusion and inconvenience to the communicating parties, and may well do worse. This is where authentication comes in, to prove the origin of the message.

With large volumes of business done by data communication electronic mail spewing out of printers is replacing the handwritten word. This causes a problem since there is no signature to important contracts. The digital signature comes into its own here.

The security of a cipher, or code, can never be proved. The proof is more by default, that is, the longer it remains uncracked, the more confidence people have in it. Attackers come in all shapes and sizes, from the programmer with a good deal of inside information to the genuine cloak and dagger military spy.

Both commercial as well as military espionage is big business but espionage may not be motivated simply by financial gain. There is always the employee bearing a grudge against the firm or the undergraduate student who regards encryption as a challenge.

In most instances the attackers' (or hackers as they are known) time is unlimited and uncosted. And the excitement at drawing first blood often leads to more ambiguous ventures. On the other hand, those whose job it is to guard the data are usually paid by a firm and work office hours.

DEFINITIONS

Key management is the process of choosing keys and ensuring they are distributed to authorised users only.

The key space is a domain from which the key values are chosen. For instance, old methods of encryption used the 26 values of the alphabet giving a key space of factorial twenty-six (26!). Modern methods would use about 20 decimal digits giving a key space of 10^{20}. If on the other hand 20 binary digits are used, the key space is 2^{20}.

Codes used to encipher a string of characters without breaking them up are called stream ciphers.

HISTORY OF CODING

The earliest form of coding was steganography which means covered writing as in the case of writing on slaves' heads. The other form was cryptography which means hidden writing as in the case of substituting letters of the alphabet. Cryptography took the form of substitution as well as transposition.

Substitution was usually a prearranged scrambling of the alphabet whereas transposition involved scrambling the alphabet by means of a key. Examples will make the differences clear later.

A type of code called nomenclators were used around 1380. This method replaced the names of people and places so as to disguise the sentences. Twenty years later word groups like "in the" were also replaced. One of the weaknesses of a cipher in any language is the number of times certain letters and words repeat.

The users of nomenclators were aware of this drawback and used other equivalents which they called homophones. Even though nomenclators was not such a clever system it survived till the 19th century when stronger codes became necessary. Also telegraph transmission meant that lengthy messages were out of place.

STEGANOGRAPHY

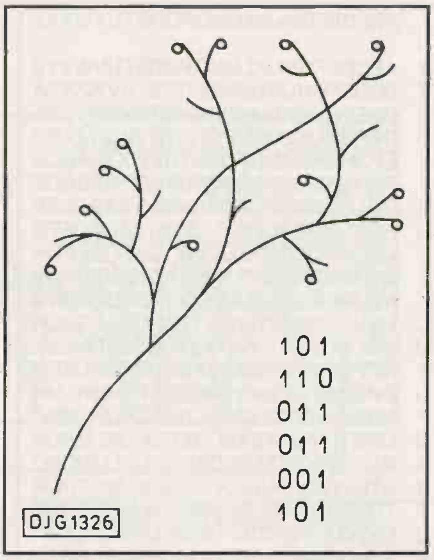


Fig.1. Fruit tree steganography

One form of steganography is to draw a picture of a tree with fruits on it, Fig.1. Then reading the code from the trunk and reading clockwise the recipient puts down 1 for a twig with fruit and 0 for a twig without fruit. Enclosed areas are ignored.

The parties could agree that the binary digits be grouped in threes and whether enclosed areas will be included or left out. Steganography is practised in modern ciphers when blank spaces are filled with random letters or numbers.

CAESAR CIPHER

This is an example of a substitution cipher where the alphabet is displaced by three letters as follows:

Plaintext A B C D E F G H I J K L M
N O P Q R S T U V W X Y Z
Cipher Y Z A B C D E F G H I J K L
M N O P Q R S T U V W X

Slightly better is a randomly jumbled alphabet, for instance:

Plaintext A B C D E F G H I J K L M
N O P Q R S T U V W X Y Z
Cipher X A W C B Y H V D E G U F
S Z T R L M Q I P J K O N

Then to encipher a message the plaintext is read off against the cipher as follows:

Message C A E S A R H A S B E E N
M U R D E R E D
Enciphered W X B M X L V X M
A B B S F I L C B L B C

Spaces are always left out between words. It is bad enough having particular letters repeating themselves in a given language, but putting in spaces as well is a dead giveaway. In the English language for instance, the letter E appears 13% of the time and the letter T appears in 9% of a long enough text.

Code books of this nature are not useful for modern applications. Apart from the fact that the code is not strong enough, code books are slow to look up and it is also slow work to change the code. In addition there is a security risk in printing and distributing the books.

The number of different ways it is possible to jumble the English alphabet is 26! or about 4×10^{26}. It appears good but that is a false sense of security. The main drawback is the frequency with which certain letters come up if one can guess at the language being used. In addition sentences contain many superfluous (redundant) words.

Once the frequent letters have been deduced, the rest can be guessed, like reading a garbled radio message. The above code is called a monoalphabetic substitution since letters are substituted individually. It may seem that enciphering a message twice in this fashion using two different ciphers will double the security. Unfortunately this is no different from enciphering the message once using a cipher which is an equivalent of the first two ciphers.

As people get more clever and as computers become more powerful for codebreaking purposes, ciphers have to be made stronger. One of the requirements for modern encipherment is that changing even one bit of the encipherment key should produce a large change in the enciphered message. This means that if a cryptanalyst (a codebreaker) guesses some of the bits in the key, he is still unable to solve the code.

THE VIGENERE CIPHER

In 1586 Vigenere invented a table, Fig.2. This was to be used in conjunction with a key chosen by the communicating parties. For instance if the keyword is COMET a message can be encoded by reading each letter of the message from the top row of letters above the table and the corresponding letter of the key from the vertical alphabet.

For instance:

Message	TENSTICKSOFDYN AMITE
Key	COMETCOMETCO METCOME
Enciphered	VSZWMKQWWHHR KRTOWFI

From the letter T in the top row of the alphabet, a vertical line is drawn downwards and from the letter C in the side column of the alphabet a line is drawn horizontally. The lines meet at the letter V and the enciphered text is obtained similarly for the other letters.

This code is harder to break and one of the best methods of attack on a Vigenere code is the probable word attack. That is, if a word is known to exist in the message, this is a good starting point.

	ABCDEFGHIJKLMNOPQRSTUVWXYZ
A	ABCDEFGHIJKLMNOPQRSTUVWXYZ
B	BCDEFGHIJKLMNOPQRSTUVWXYZA
C	CDEFGHIJKLMNOPQRSTUVWXYZAB
D	DEFGHIJKLMNOPQRSTUVWXYZABC
E	EFGHIJKLMNOPQRSTUVWXYZABCD
F	FGHIJKLMNOPQRSTUVWXYZABCDE
G	GHIJKLMNOPQRSTUVWXYZABCDEF
H	HIJKLMNOPQRSTUVWXYZABCDEFG
I	IJKLMNOPQRSTUVWXYZABCDEFGH
J	JKLMNOPQRSTUVWXYZABCDEFGHI
K	KLMNOPQRSTUVWXYZABCDEFGHIJ
L	LMNOPQRSTUVWXYZABCDEFGHIJK
M	MNOPQRSTUVWXYZABCDEFGHIJKL
N	NOPQRSTUVWXYZABCDEFGHIJKLM
O	OPQRSTUVWXYZABCDEFGHIJKLMN
P	PQRSTUVWXYZABCDEFGHIJKLMNO
Q	QRSTUVWXYZABCDEFGHIJKLMNOP
R	RSTUVWXYZABCDEFGHIJKLMNOPQ
S	STUVWXYZABCDEFGHIJKLMNOPQR
T	TUVWXYZABCDEFGHIJKLMNOPQRS
U	UVWXYZABCDEFGHIJKLMNOPQRST
V	VWXYZABCDEFGHIJKLMNOPQRSTU
W	WXYZABCDEFGHIJKLMNOPQRSTUV
X	XYZABCDEFGHIJKLMNOPQRSTUVW
Y	YZABCDEFGHIJKLMNOPQRSTUVWX
Z	ZABCDEFGHIJKLMNOPQRSTUVWXY

Fig.2. Vigenere table

TRANSPOSITION CIPHERS

In this method letters are exchanged or scrambled according to a key. The Greeks used this method by wrapping a narrow strip of parchment around a scytale (staff). The message was then written along the length of the staff and when the parchment was unwrapped there was a meaningless jumble of letters.

The main disadvantage was that the parchment had to be rewrapped very carefully around a stick of the same length and diameter.

An example of a transposition cipher is:

Message	SENDINGFIFTYTO NSOFGOLD
Enciphered	NDSEGFINTYIFNS TOGOOFABLD

3	4	1	2	Key
N	D	S	E	
G	F	I	N	
T	Y	I	F	
N	S	T	O	
G	O	O	F	
A	B	L	D	

A key is chosen of say four digits, then jumbled say in the form 3412. Now the message is grouped in four letters and each group numbered 1234. After that it is a simple matter to place each letter under its corresponding number in the key to form the rows. For instance SEND (1234) becomes NDSE (3412) and so on.

The enciphered message then becomes all the rows joined together. If there is a shortage of letters in the message, random letters are used instead of unusual ones like Z. In this example two blank spaces would have been left in the block under the key so the random letters A B were tagged onto the end of the message.

In the transposition cipher, it is easy to remember the key if it is a word rather than numbers. If ORANGE is the key then the letters are numbered in the order in which they occur in the alphabet:

O	R	A	N	G	E
5	6	1	4	3	2

A is 1 and since there is no B, C, D, then E is 2, etc. The message is then numbered as before.

Message
WHENTHESAINTSGOMARCHINGINCFEKJ
123456123456123456123456

The last five letters are random and the groups are now arranged under the key.

O	R	A	N	G	E
5	6	1	4	3	2
T	H	W	N	E	H
N	T	E	I	A	S
A	R	S	M	O	G
G	I	C	N	I	H
K	J	N	E	F	C

The final enciphered message is a string of all the rows:

THWNEHNTEIASARSMOGGICNIHKJNEFC

The Nihilist cipher is a combination of row and column re-arrangements by the application of a keyboard horizontally and vertically. For example:

Message:
THEQUICKBROWNFOX
1234123412341234

		M	I	N	T
		2	1	3	4
M	2	H	T	E	Q
I	1	I	U	C	K
N	3	R	B	O	W
T	4	F	N	O	X

Using the keyword MINT, the letters are arranged as before according to the keyword at the top. But when the rows are finally strung together, they are joined together in the order dictated by the vertical keyword. That is IUCK is transmitted first, followed by HTEQ, etc as follows:

Enciphered: IUCKHTEQRBOWFNOX

THE JEFFERSON CYLINDER

The US President Thomas Jefferson is said to have invented this cylinder around 1790. There were 36 discs, each with a jumbled alphabet and the discs were numbered so that the order in which they were inserted onto the spindle could be changed.

The number of choices in which 36 discs can be assembled in 10^{41} and this is the key domain. The discs were rotated so that the message lined up against an index bar and then the enciphered message was found by moving the index bar to one of the other 25 positions.

The received enciphered message was lined up against the index bar and the message appeared somewhere on the cylinder. The US Navy adopted this method from 1920 onwards for several years.

THE WHEATSTONE DISC

The Wheatstone disc, Fig.3, was invented by Wadsworth in 1817 and developed by Wheatstone in 1860. Basically it consisted of an inner and outer disc with two pointers. The outer disc had 26 letters and a space and the inner disc has 26 letters without a space.

The gear on the pointers is arranged so that when the long pointer (outer disc) has travelled over 26 letters, the inner one has travelled over only 25. This means that the pointers will be one letter out of step after the first revolution.

In order to encipher a message, the longer pointer is moved to the alphabets clockwise and space is included as a character. The enciphered message is then read off the inner disc. Because space is treated as a character on the outer disc but not on the inner disc an interesting thing happens. A change of alphabet takes place at the end of each word and this also happens when letters are repeated within a word since the longer pointer must make another revolution. This is called chaining and has important implications in modern methods.

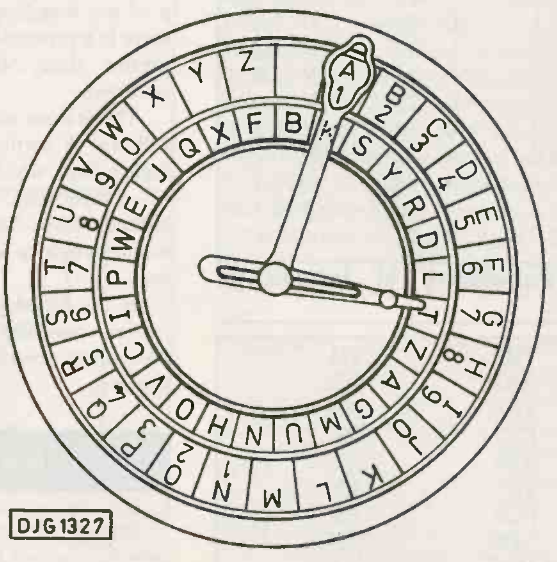
THE ENIGMA

The Enigma was the name given to the machine used for encoding German military messages during the second World War. It was a Dutch invention of 1920 and worked like a mileage recorder on a car. There were three rotors each with twenty-six positions and turning on the same shaft.

A later model used four rotors. Alphabetic substitution was achieved by cross connecting the rotors and the drive to the rotors was either electric or pneumatic. Two people were required to operate the machine, one to type the message on a keyboard and another to read the indicator lamps and write the encrypted message.

A stock of rotors was held and whenever these were changes, the new combination was transmitted as header information. This was a serious drawback and the Germans changed the method twice. In spite of that, the Allied forces broke the code regularly in

Fig.3. The Wheatstone encryption disc.



France, Poland and at the Government Code and Cipher School in Bletchley Park.

Attempts to automate codes by using a printer go back to 1880 with a printer invested by De Viaris. The famous M209 of Boris Hagelin was also used in quantity during the Second World War. The Siemens and Halske telegraph cipher was used as an on-line (real time) machine from 1930 to 1945 and used ten wheels of size 47, 53, 59, 61, 64, 65, 69, 71 and 73 characters.

LETTER FREQUENCIES

If a cryptanalyst wants to break an alphabetic code, the first thing to do is decide which language is being used. This is done with a letter frequency count assuming the text is long enough. Fig.4 shows the percentage of time that the most popular letters feature in English and German.

For instance the letter O features highly in English but low in German. On the other hand the letter Q is used a lot in Italian and French but very little in German and English. Once the language has been guessed the next thing to do is find the most popular letters. Once again tables come in handy and assuming the languages is English, Fig.5 shows how often each letter is used in a long enough text.

The most popular letters and the least popular letters are the most useful in breaking the code. The next useful item in breaking the code is combinations of two and three letters called diagrams and trigrams shown in Fig.6. So the art is well understood and modern techniques must resort to more sophisticated methods.

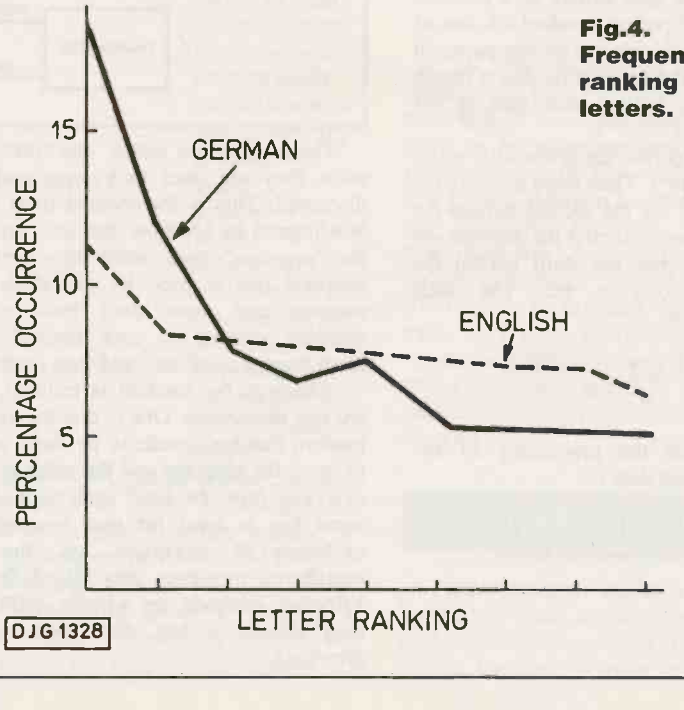


Fig.4. Frequency ranking of letters.

%		%		%	
E	13.1	D	4.1	G	1.4
T	9.0	L	3.6	B	1.3
O	8.2	C	2.9	V	1.0
A	7.8	F	2.9	K	0.4
N	7.3	U	2.8	X	0.3
I	6.8	M	2.6	J	0.2
R	6.6	P	2.2	Q	0.1
S	6.5	Y	1.5	Z	0.1
H	5.9	W	1.5		

Fig.5 Popularity of letters in English

THE	TH
AND	HE
THA	AN
ENT	IN
ION	ER
TIO	RE
FOR	ES
NDE	ON
HAS	EA
NCE	TI

Fig.6 Popular English trigrams and digrams

MANY HAPPY RETURNS

How many people are required so that it is likely that two people will have the same birthday? The answer is 23 and is often known as the birthday paradox because the figure is so low. Of course, by likely we mean a greater than 50% chance or 0.5 in probability theory.

This has important ramifications in calculating the security of a code or key domain. Just because a key is chosen from a large domain does not make it vastly more secure than one chosen from a smaller domain.

To prove the birthday paradox, suppose r people were chosen at random and the n (365) days of the year written on a piece of paper. Now each person is asked his date of birth and the date crossed on the paper in order to assess the probability that a match does not occur, ie the same date is not crossed out twice.

For the first person the probability of no match is 100% or 1. Then there are only (n-1) days left and for the second person the probability of not matching the crossed out data is (n-1)/n. For the third person the probability is (n-1)/n, etc. The total probability is now:

$$\frac{n}{n}, \quad \frac{n-1}{n}, \quad \frac{n-2}{n}$$

For r people the probability of not getting a matching date is:

$$P = \frac{n\,(n-1)\,(n-2)......(n-r+1)}{n^r}$$

$$p = \frac{n!}{(n-r)!n^r}$$

Substituting r=23, n=365, the probability p of not matching works out as 0.493. So there is a probability of 1-0.493 = 0.507 (or greater than 50%) that a match has occurred.

The lessons to be learnt from this are as follows: A sorting operation needs only r log2 r steps which is a great deal less than r2 comparisons. Therefore if one were looking for a key one would look for a match within a set or match between two sets.

In the birthday paradox, the sorting was carried out with r against n instead of comparing every single r against every single n.

STREAM CIPHERS

Stream ciphers are required when a communications link is transmitting from a source that does not have storage facilities. The Vigenere cipher is an example of a stream cipher and the Vernam cipher is a modern cipher of the same kind except that one uses characters and the other uses bits. The Enigma machines also operated in the stream cipher mode.

In 1917 Vernam was working for the US company AT&T on ciphers for telegraphy when he decided to combine random characters with the plain text, Fig.7. This was done in an exclusive-OR fashion. If loops of tape with random numbers are used only once at each end then it is almost impossible to break the code.

LINE TAPS

Talking of spies, foreign powers often listen to each other's microwave transmission by instructing their embassies to eavesdrop and make recordings. Although such traffic does not carry military information in unencrypted form, there is enough commercial and social gossip that can be used to advantage.

There are active and passive taps. Just listening is classed as a passive tap, and listening to radio transmission is one of the easiest since one does not have to physically hook up to the transmission path.

An active tap on the other hand means physically interfering with the transmission, (Fig.8), to divert, change, or repeat the messages. In the days of telegraph it was a simple matter to introduce a wire tap on the line. Today the choice of modulation and data protocols make a physical tap more difficult. However, a tap is not impossible, particularly if the transmitter and receiver are allowed to establish contact before the eavesdropper interferes.

NETWORK ENCIPHERMENT

In a communications network which may include the public telephone network, the systems engineer has to decide how much of the network should be encrypted.

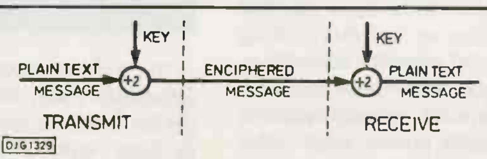


Fig.7. (above) Stream cipher
Fig.8. (below) Active line tap

These tapes are called 'one time' tapes since they are used only once and then discarded. This is the method used in the Washington to Moscow 'hot-line' and also the 'one-time' pads used by spies. An identical pad is used by the sender and receiver and these pads have random numbers printed on each tear-off sheet. Each sheet is used once and then destroyed.

Although the method is brilliant, there are two drawbacks. One is that the key (the random number) needs to be large enough to carry the message and the other is that a new key must be used each time. If the same key is used for two messages, an exclusive-OR operation on the two enciphered messages gets rid of the key. Effective methods are usually brilliant in their simplicity, but often have a small drawback.

Fig.9 applies equally if a network is wholly private or if parts of it are public.

Encryption may be carried out:

a) Line by line between nodes, eg node B to C.
b) Within nodes only.
c) End to end, eg terminal 3 to terminal 5 as shown by the dotted line in Fig.9.

A modern algorithm like the United States DES relies on a secure key for coding since the algorithm is public. It is quite possible to investigate the electronics within an encryption module to find out how it is done. This is not a giveaway since a public standard is required in any case so as to communicate across the various public and private networks.

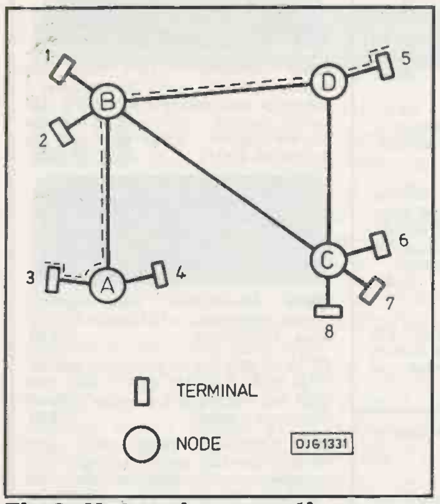


Fig.9. Network encryption

DATA ENCRYPTON STANDARD

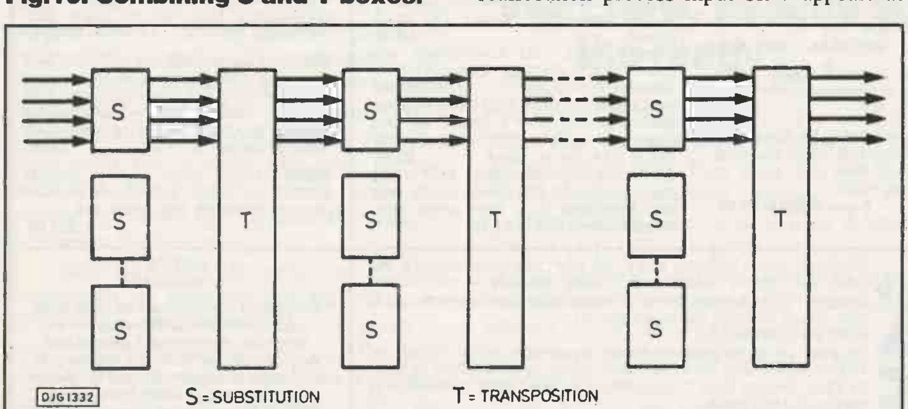
The National Bureau of Standards (NBS) within the US Department of Commerce was given the job of establishing a standard. In 1973 the NBS invited ideas for an algorithm but the response was poor and in 1974, there was a second invitation for ideas.

The IBM system called Lucifer seemed like a good one. It was invented in 1970 for an autobank teller machine (atm). Lucifer is product cipher, ie a combination of substitution and transposition. In 1975, IBM agreed to issue a free licence so that Lucifer could be used in the DES.

Shannon showed that weak ciphers could be made strong by combining substitution and transposition. Fig.10 shows how these are combined. Of course, a machine is required to encipher and decipher since humans would be too slow and inaccurate. Shannon called substitution 'confusion' and transposition 'diffusion'.

Lucifer uses 4 bit substitution (S) boxes in the input whereas DES uses 6 bit S boxes. Both use 4 bit S boxes in the output. The Lucifer block size is 128 bits, but DES uses a 64 bit key and accepts data in 64 bit blocks.

Fig.10. Combining S and T boxes.



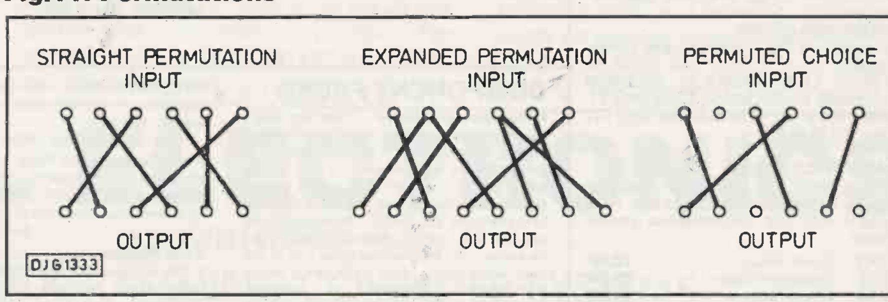
The code can be strengthened if each stage of S box Fig.10, is different. If each S box operates on 4 bits then $(2^4)!$ different S boxes are obtained. An S box contains a read only memory (rom) and a block of 128 bits would require 32 S boxes (128÷4).

This rom would need to store 16 words of 4 bits each and the information required to obtain an invertible transformation of 4 bits in $\log_2(16)! = 44.2$. Sixteen stages of S and T boxes make the key size 32x44x16=22,528 bits. This is much too big and only two different S boxes are used bringing the key size down to 512 (32x16).

This is reduced to 128 bits since each key bit is used four times. The key is also involved in a module 2 operation of certain bits in the key, a process called interruption in between the substitution and transposition processes.

The 128 bit key size and data block size of Lucifer gives 2^{128} different ways of mapping a message into a cipher. This is much smaller than $(2^{128})!$ Which is the number of different ways of mapping 128 bits into a 128 bit field.

Fig.11. Permutations



It is not intended to delve too deeply into the DES algorithm but the basic processes are permutations, module 2 additions and substitutions. There are three types of permutation, Fig.11:

i) the straight permutation where every input bit is changed to a different output bit.

ii) the expanded permutation giving more output bits than input bits.

iii) the permuted choice where only some of the input bits are changed.

In order to ease the implementation of the algorithm the DES carries out an initial permutation, as in Fig.12, which is not really part of the encryption process. In this reallocation process input bit 7 appears as output bit 64, input bit 4 appears as output bit 16 and so on.

58	50	42	34	26	18	10	2
60	52	4	36	28	20	12	4
62	54	46	38	30	22	14	6
64	56	48	40	32	24	16	8
51	49	41	33	25	17	9	1
59	51	43	35	27	19	11	3
61	53	45	37	29	21	13	5
63	55	47	39	31	23	15	7

Fig.12 DES initial permutation

Fig.13 Weak keys

01	01	01	01	01	01	01	01
FE	FE	FE	FE	FE	FE	FE	FE
IF	IF	IF	IF	OE	OE	OE	OE
EO	EO	EO	EO	FI	FI	FI	FI

Similarly output bit 8 corresponds to input bit 2, output bit 24 corresponds to input bit 6 and so on.

Keys used in the DES algorithm have one or two pitfalls and as long as these are known and avoided, no harm is done. There are weak keys and semi-weak keys known collectively as dual keys by the NBS. The weak keys are shown in Fig.13 in hexadecimal.

From the main key, the algorithm calculates sub keys K_1 to K_{16} and if the main key contains all zeros or all ones then the effect of applying encryption to a message is the same effect as applying the deciphering command. Stated another way, if the encryption process is applied twice to a message text, the original message appears again as plain text. This feature is called involution.

The semi-weak keys are alternate ones and zeros (0101) contained in one of the shift registers.

Another weakness in the DES algorithm is a feature called complementation. This means that if a complement of the plain message is encrypted with the complement of the secret key, a complement of the enciphered message is obtained.

PE

NEXT MONTH:
We continue examining DES modes and hardware, then take a close look at public key ciphers including a matter close to all our pockets – ATMs and PINs.

Anyone who takes up electronics construction soon becomes particularly sensitive to that 'expensive smell of burning'. Sooner or later an incorrect connection or an unsuspected short circuit leads to a device taking a current far larger than that for which it is rated. A well-trained nose is a great help, since the first signs of overheating are usually the generation of a scorching smell. If the power is switched off (*before* the smoke starts to rise!), it may prove possible to save the unfortunate component from serious damage. The problem now is 'which component is getting too hot?'. And the usual way of answering this is to touch each transistor and ic with a thumb or finger. Doing this can endanger your health! A nasty skin burn can result from touching a component that is at a temperature of 150°C or more. The Electronic Thumb is designed to take over from the human thumb and help you locate overheated components in comfort.

This project has other applications in detecting excessive temperature, particularly for high temperatures in the range of 100°C to 400°C.

At last! – the workbench aid that takes the soreness out of electronics construction

ELECTRONIC THUMB

BY OWEN BISHOP

THERMO COUPLE SENSOR

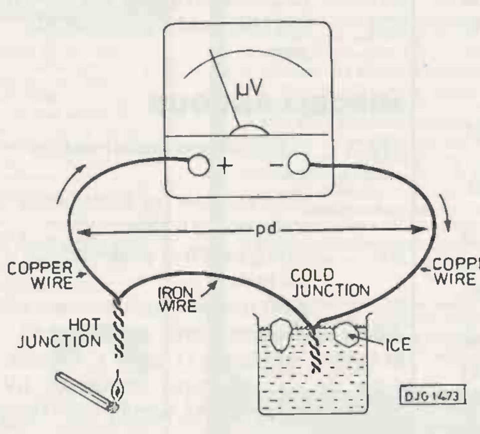
The sensitive element of this circuit is a thermocouple. These do not often feature in electronic circuits nowadays since temperature can more conveniently be sensed by semiconductor devices such as thermistors, diodes, and special temperature-sensing ics. However, a semiconductor sensor may itself become damaged by over-high temperature. A thermocouple can withstand over 1000°C so is better suited to this application.

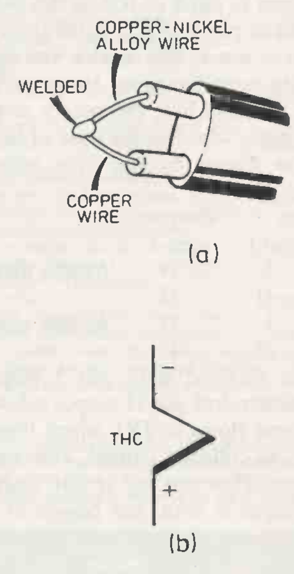
Since this device may be new to some readers, we will briefly describe its action. A thermocouple is formed when two dissimilar metals are in contact. The simplest way to make a thermocouple is to twist the ends of two lengths of wire together. The essential point is that the wires must be of *different* metals or alloys. For example, iron wire may be twisted with copper wire (Fig.1).

A thermocouple has two such junctions, referred to as the *hot junction* and the *cold junction*. If the cold junction is kept cool (at room temperature or in melting ice), and the hot junction is made hot (in warm water or in a flame), a potential difference (pd) of a few microvolts in generated. This is known as the *thermoelectric effect*. It is a simple though not very practicable way of generating electricity. The pd generated depends on the *difference* in temperature between the two junctions. The bigger the difference, the bigger the pd. This makes the thermocouple useful for measuring temperature, particularly high temperatures. A thermocouple made from platinum and a platinum-rhodium alloy can be used to measure temperatures up to 1750°C. Let's hope that your ics never get *that* hot!

In the Electronic Thumb circuit, the hot junction is formed by welding together wires of copper and of copper-nickel alloy. The junction is very small, about 1mm across, giving a spherical tip ideal for use as a temperature probe (Fig.2). The cold junction is the point at which the copper-nickel wire of the thermocouple is soldered to the copper strip of the circuit board or to a copper wire. The cold junction is at room temperature. When the hot junction is heated, the pd generated is 42µV per degree Celsius.

Fig.1. (below) A thermocouple. Fig.2. (right) Thermocouple junction (a) enlarged view; (b) symbol.





HOW IT WORKS

The device is designed to flash its warning led whenever the temperature of the probe (the hot junction of the thermocouple) exceeds 100°C. If room temperature is 25°C, the hot junction is 75 or more degrees hotter than the cold junction. Thus the pd generated is just over 3mV. Fig.3 shows that we measure the pd by using an operational amplifier as a comparator. It has a single 6V supply. As a comparator, the output swings high (more than 3V) if the potential at the non-inverting input (pin 3) is greater than the potential at the inverting input (pin 2). This is when the hot junction is warm enough to generate a suitably large pd. The function of R1 and R2 is to make the action of the comparator more positive. It is less affected by small pds such as might be caused by short spikes on the supply lines, or when the probe is touched by hand. Moreover, once triggered, the amplifier output stays high until the pd has returned to a low level.

The temperature at which the output goes high is set by adjusting VR1. This is the offset null resistor, which is normally used to set the amplifier to give a 'half-way' (3V) output when there is no pd between its inputs. Such is the nature of the amplifier circuit in the CA3140 ic that there is a small *offset voltage* (or pd) between its input terminals. It *appears* to the amplifier that there is an external pd between the two inputs when there is not. By adjusting VR1, this apparent pd can be cancelled out or 'nulled' and the amplifier then responds to

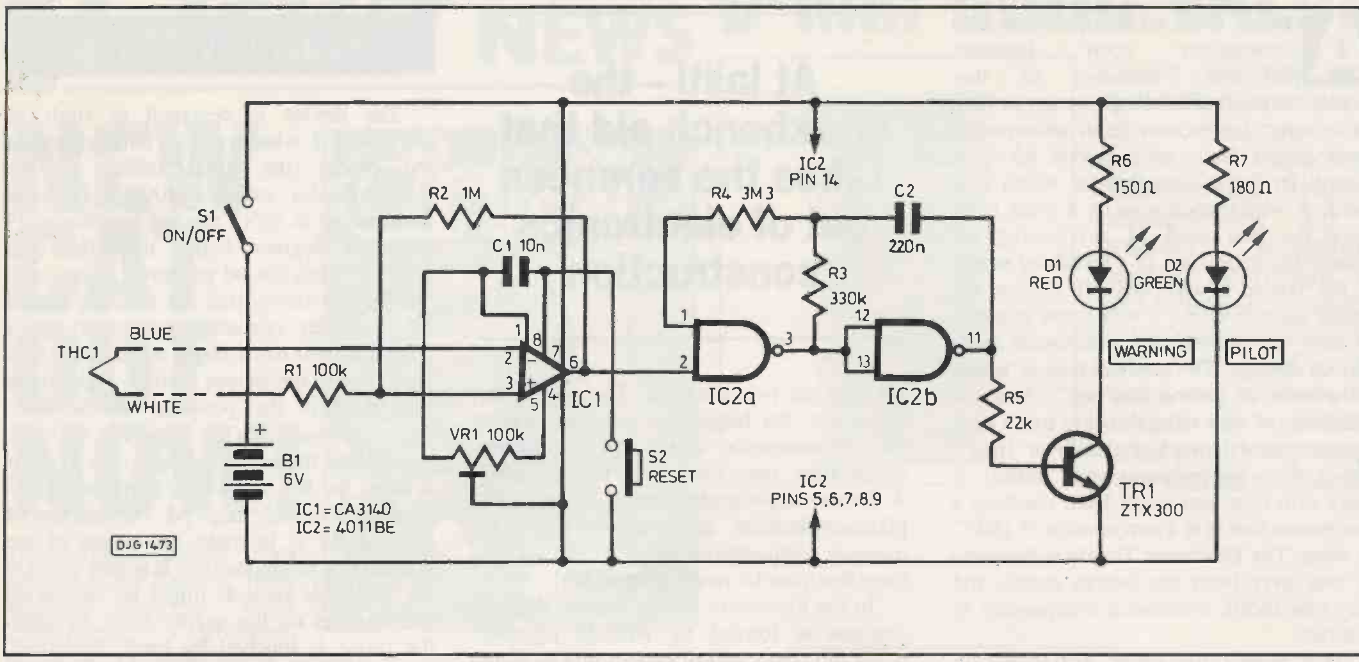


Fig.3. Circuit diagram of the Electronic Thumb

the true pd applied externally to its inputs. In this circuit we use the offset null resistor to cancel out not only the amplifier's own offset voltage but also the small voltage produced by the thermocouple when its temperature is less than 100°C (or any other temperature we choose). In this way we arrange for the output to be low (less than 3V) for temperatures of 100°C and over.

The mention of low and high outputs points to the fact that the output stage of this amplifer is compatible with cmos logic circuits. Its output levels count as logic lows and highs for the next stage of the circuit. The next stage is an astable multivibrator constructed from two NAND gates. The frequency of the astable is determind by the value of R3 and C2. The values shown give a frequency of about 6Hz, which is suitable for flashing the warning led D1. The astable is controlled by the input to pin 2 of IC2. If this is high, the output at pin 3 of IC2 is the inverse of the input at pin 1. The astable can change state in the normal manner. However, if the input at pin 2 is low, the output at pin 3 remains high, whatever the state of input at pin 1, as shown by the truth table for NAND:

Inputs		Output	
pin 2	pin 1	pin 3	
L	L	H	Astable disabled
L	H	H	
H	L	H	Astable enabled
H	H	L	

In the disabled state, pin 3 output is high, and therefore pin 11 output is low. No base current flows to TR1 which therefore conducts no collector current. The warning led is out. Thus the led is out when the thermocouple is cool, but begins to flash when the temperature exceeds the set level of 100°C.

COMPONENTS

RESISTORS

R1 100k
R2 1M
R3 330k
R4 3M3
R5 22k
R6, R7 180 (2 off)
All resistors 1/4W carbon film 5%

POTENTIOMETER

VR1 100k horizontal preset

CAPACITORS

C1 10n polyester
C2 220n polyester layer

SEMICONDUCTORS

D1 red led
D2 green led
TR1 ZTX300 npn transistor
IC1 CA3140 fet opamp
IC2 4011BE quad 2-input NAND gate

MISCELLANEOUS

THC1 copper/copper-nickel welded-tip thermocouple (eg Electromail stock no. 151-259)
S1 SPST switch or push-on/push off button
S2 push-to-make push-button
ABS case (approx 85mm x 55mm x 40 – or larger), stripboard 11 strips x 31 holes, 8-pin dil socket, 14-pin dil socket, 6V battery-holder (4xAA), battery clip, 1mm terminal pins (6 off).

CONSTRUCTION

Without the pilot led, the circuit takes only 1.5mA when quiescent and an average of 15mA when the warning led is flashing. It is feasible to run it from 4 button-cells and to construct it as a hand-held unit. However, there are fewer constructional problems if it is built into a static case with a mobile probe. This allows the use of 4 pen-cells in a battery-holder and, with the extra power thus made available, the addition of a pilot led to indicate when the device is switched on.

Fig.4 shows the circuit-board layout. Build and test the amplifier first, including the reset button, S2. The diagram shows the blue-covered wire of the thermocouple as being the negative lead and the white-covered wire as being the positive lead. This is a fairly standard colour code, though it is possible that the thermocouple you use could be different. The thermocouple is normally supplied with about 2 metres of lead. This can be shortened to about 30cm for convenience. Thread the lead through the barrel of an old ball-point pen (having removed the ball-point and ink tube) and secure it with a suitable adhesive, such as epoxy resin. Alternatively, since the thermocouple lead may be rather too stiff for convenient handling of the probe, you may prefer to cut the thermocouple lead short and join it to the circuit board by a pair of more flexible wires. Cut the lead so that the soldered joints lie within the barrel of the probe. Wrap insulating tape around each soldered connection.

This part of the circuit is most easily tested by using a cup of hot water as the heat source. Monitor the output of the amplifier (pin 6) with a voltmeter. Start with the thermistor at room temperature and turn the wiper of VR1 clockwise so that it lies at the 'pin 5' end of its track. Output is 'low' (close to 0V). Now turn VR1 slowly anticlockwise until the output rises suddenly to 'high' (about 4.25V – the CA3140 does not swing fully to the positive supply level). Once triggered to high, the output does not fall to low again when VR1 is turned in the reverse direction. Try pressing S2; this is the strobe input which *forces* the output to go low. When the button is released, the output may swing high again. If it does, turn VR1 a little way clockwise, toward the 'pin 5' end, and press S2 again. You soon reach a point at which the output *remains low* after S2 has been pressed and released. Now touch the tip of the thermocouple against the hot outside of the cup. The output goes high almost immediately (unless you have turned VR1 *too* far, or the water has cooled).

Adjust the position of VR1 in this way until the output goes high as soon as the probe is made hot and, provided that the probe has been removed from the heat, goes low when S1 is briefly pressed. The circuit has now been set to trigger at a temperature rather lower than 100°C, which is sufficient to show that it is working correctly. Setting it to operate at a higher temperature is left until later.

Next build the astable circuit, based on IC2. Note that some of the copper strips beneath the board are *not* cut. These make direct connections between the opposite pins of the ic, instead of wired connections. When the power is switched on, the warning led remains unlit. Warming the probe starts the led flashing and it continues to flash until S2 is pressed.

Finally, mount the circuit in its case. The prototype is built in what is probably the smallest case that will hold the circuit board, two push-switches and a 6V battery holder. Holes in the case are required for the two leds, the two switches, and for the lead from the probe. A hole bored in the case allows screwdriver access to VR1. S1 and S2 are connected on short flexible leads and are the first components to be inserted in their holes. The board is then slid into grooves in the sides of the case. Before attempting to do this the leads of the leds are splayed apart (like a bandy-legged person) to bring the leds closer to the board. This prevents them from fouling against the side of the case as the board is slid into position. Once the board is in position in the grooves, the leds are pushed into their holes, straightening their leads again.

Repeat the adjustment of VR1, as described earlier, but use boiling water this time (beware of scalding!). The Electronic Thumb is now ready to trigger at temperatures exceeding 100°C, the temperature at which things begin to get dangerously hot for electronic components – and for the human thumb! PE

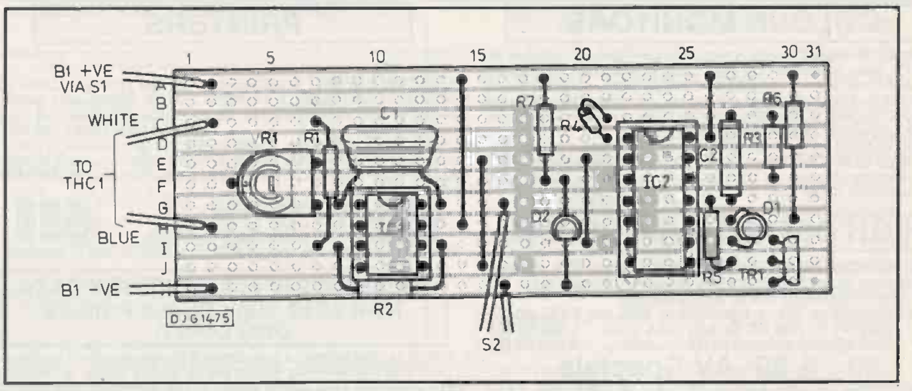


Fig.4. Circuit board layout. Carefully note the track cuts and solder blob links between some tracks.

MULTIPURPOSE POWER SUPPLY

Your Editor proves his well regulated stability and encourages you to join the board in his power game!

BY JOHN BECKER

This month my Easi-Build circuit is a simple but very effective variable stabilised power supply. It's a circuit I have been using in my own workshop for many years and is highly reliable.

PREREQUISITES

A well stabilised power supply is a prerequisite for any electronics experimenter, however experienced. There are probably hundreds of ways in which a stabilised workshop psu can be designed and implemented. Some of them will offer extremely wide ranges of voltage output, either under switchable or continuously variable panel control. Others will additionally have control over the amount of current that can be allowed to flow, so minimising the risk of mortal currents being sunk by erroneous circuit assembly.

Different readers will have different opinions on which type of psu is the best, but in reality it really boils down to an individual's personal needs. By and large, over the many years that I have been experimenting and designing, my own needs have been for stabilised voltages switchable for +5V, +9V, +12V and +15V, and the same ranges for negative voltages. In most instances the maximum current required has been less than 1 amp.

The circuit I describe here can be configured in several different ways to select any of the above positive voltages, and with the addition of a second identical circuit, to achieve the same range of negative voltages, or to increase the range of positive selections. The maximum current permissible is about 1A.

CHOICE COMPONENTS

Fig.1 shows the basic circuit diagram. It consists of a mains transformer having two 12Vac windings, each delivering about 500mA. If your likely current needs are less than 1A a transformer with a lower load capacity is quite permissible. As you see, I have coupled the two windings together in parallel, so that in effect I have a single 12V winding at 1A. The 12Vac is rectified and smoothed by C1. The voltage to be found at C1 will depend rather on the current being drawn from the circuit, but under no-load conditions you can expect to see around 17Vdc.

TERMINAL STABILITY

Stabilisation is carried out by IC1. Conventionally, and for a fixed power supply output voltage, IC1 would be selected for the fixed voltage required. In the normal 1A series of regulators with the 78 prefix, the options are for 5V, 6V, 8V, 12V, 15V, 18V and 24V, represented by the 7805, 7806, 7808, etc, respectively. The most common of these are the 7805, 7812 and 7815. For these specific applications the common terminal would be taken directly to the 0V line, and the input terminal would be supplied with a voltage of at least 2Vdc above the required stabilised output level.

However, it is equally permissible to raise the common terminal voltage above the 0V level. The final output voltage is then regulated against the raised reference level. So, if you have a 7805 regulator and raise its common terminal to, say, 4V, the output voltage will be regulated at 5V plus 4V, ie, 9V. There is the additional requirement, though, that in order to maintain at least a 2V drop across the input to output terminals, the input voltage must be similarly raised by at least the additional 4V reference level. In other words, for a 7805 to be configured for an output of 9V, a minimum of 11V must be smoothly present at its input. I emphasise the word *smoothly*, for if any ripple on C1 is at less than the required minimum input level, the output will not be fully stabilised.

REGULATED REFERENCES

For a fixed regulated supply above the chip's design voltage rating, the reference level could be created by inserting a resistor and zener between the common terminal and 0V. For adequate zener stability, the

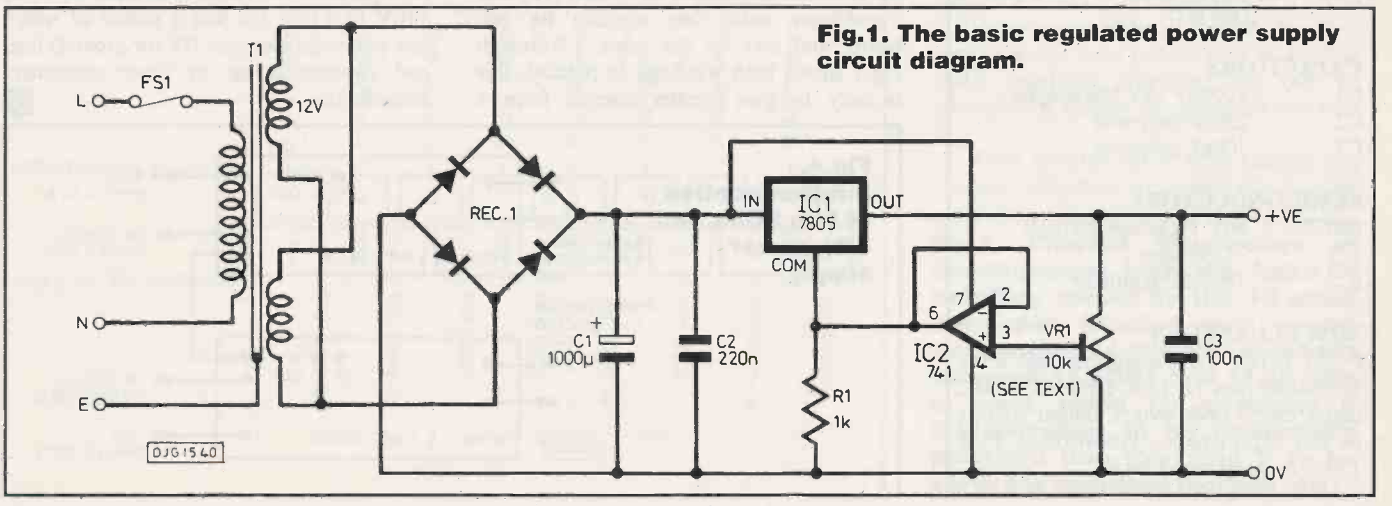


Fig.1. The basic regulated power supply circuit diagram.

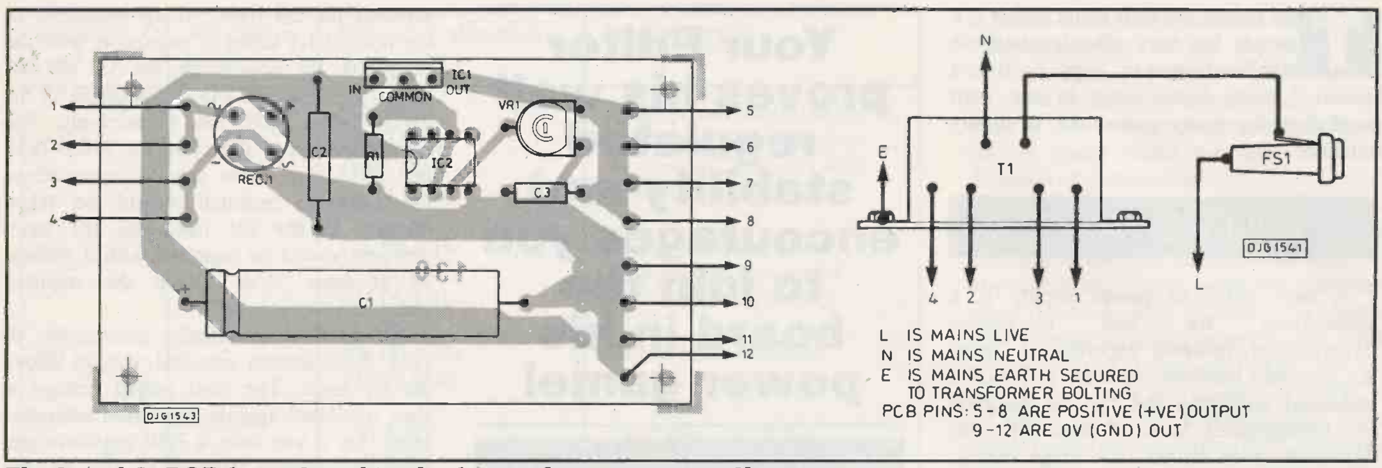


Fig.2 and 3. PCB layout and typical transformer connections

resistor should allow around 10mA to flow through the zener. Alternatively, we can replace the fixed reference level by a variable one. In this circuit we achieve it by tapping the final output voltage and feeding it back to the common terminal.

VR1 is connected across the output lines, and its tapped voltage is first fed to IC2, which is simply configured to act as a buffer. Whatever voltage is present at its input pin 3 will appear at its output pin 6, so providing the desired reference level.

It will appear at first glance that VR1 will allow the output voltage to be varied right from maximum right down to a minimum of 5V, the rating of IC1. In reality IC2 has a minimum voltage input requirement of about 2V, consequently the controllable output range starts at around 7V. The maximum fully stabilised output will depend upon the maximum smooth voltage from C1.

There is a choice of options for VR1. You could use a preset pot mounted on the pcb to set the desired fixed voltage. For example, this circuit can be used to produce a fixed 9V stabilised output in order to substitute it for a 9V battery. (So far as I know, there have never been fixed 9V regulators.) Alternatively, a panel mounted pot can be used instead of the preset, so allowing for panel selection of any voltage within the range. Thirdly, VR1 could be replaced by a series of fixed resistors as a divider chain. In this case a switch could then select the required control voltage available at any of the resistor junctions.

If you are switch selecting the voltage, another option exists. The switch can also be connected to take the common terminal of IC1 direct to 0V, so allowing the chip to act as a normal 5V regulator. You should also ensure that this latter switching simultaneously disconnects the output of IC2 from the circuit. Although the 741 opamp has overload protection, it's preferable not to take undue advantage of the fact. You will need to make a cut on the pcb to allow for this latter switching option.

COMPONENTS

RESISTORS

R1	1k 0.25W 5% carbon film
VR1	10k lin preset or rotary pot (see text)

CAPACITORS

C1	1000µF 25V electrolytic
C2	220nF polyester
C3	100nF polyester

SEMICONDUCTORS

REC 1	50V 1A bridge rectifier
IC1	741 opamp
IC2	7805 5V regulator

MISCELLANEOUS

0-12V 0-12V 1A transformer (see text), fuseholder plus 1A fuse, 8-pin dil socket, mains on-off dpdt switch, output sockets to suit requirements, Phonosonics' PCB 130A, box and wire to suit.

STACKED SELECTION

Now come the other options. For these you will need to build two identical circuits. The choices then come from the way in which you make use of them.

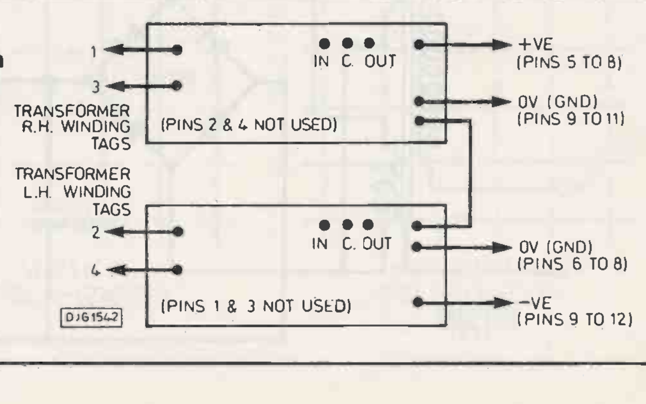
In my own main workshop unit I have kept both circuits separate and have a selection of sockets and switches on the panel so that I can select and intercouple as the situation demands. I have used only one transformer, using one winding for one board, and one for the other. Although Fig.1 shows both windings in parallel, this is only to give greater current from a smaller transformer; you can equally well use a basically more heavy duty transformer, keeping the twin windings separate, and still achieve a similar load capacity. You could also use a separate transformer for each of the circuits.

RELATIVITY

For a positive/negative supply, the +ve is taken from the conventional output of the first board. This board's 0V line is connected to the conventional output of the second. This connection forms the common 0V line for both boards. What was previously the 0V line of the second board thus becomes negative with respect to the common 0V line. You thus have your split power supply. Furthermore, each half of the supply can be set for different outputs. So, you could have a supply set for +13V/0V/-5V, for example, or +9V/0V/-15V, or any combination between minimum and maximum settings.

The next option is to regard the latter -ve line as 0V, then the common line between the two boards will be positive with respect to 0V at the level set, and the output from the first board will be the sum of its set output plus that of the lower level board. If each board is basically capable of a supply range from +5V to +15, in this stacked configuration the range selectable becomes +10V to +30V. It's just a matter of which line you regard as your 0V (or ground) line, and connecting up to other equipment accordingly. PE

Fig.4. Interconnection of two PCBs for +/0/- power supply



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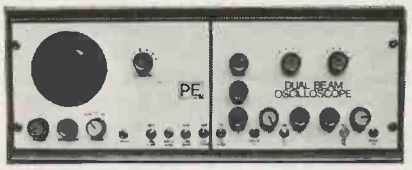

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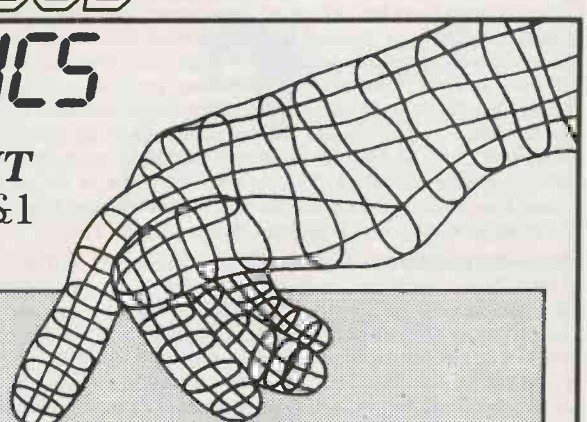

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Your Ed looks at some of the new books recently received.

Make Money from Home Recording. Clive Brooks. PC Publishing. £5.95. ISBN 1-870775-25-2. This book is aimed at recording enthusiasts and musicians, and it's packed with money making ideas. It covers setting up a studio, the equipment needed, how to sell your services, obtaining publicity, hiring out the studio, and a review of the business background. It concludes with a lengthy list of useful addresses for cassette duplication, magazines, manufacturers and other organisations. I could not find any reference to the author's background apart from the implication that he is connected with the Sound Workshop at Southampton, but he appears to know his subject inside out. If you fail to make money from the ideas given you've got the wrong abilities and ambitions.

Synthesizers for Musicians. R.A.Penfold. PC Publishing. £6.95. ISBN 1-870775-01-5. First a rebuke - let's keep British English as British as practical and avoid Americanisms such as using 'Z' in place of 'S' in synthesisers. It's not RAP at fault I'm sure so I guess it must be Philip of PCP - really Philip! Having said that, Robert (one of our elite contributors) is at his expected best and has written a book that will find immediate appeal with modern musicians. He explains all the current popular forms of synthesis, including linear arithmetic as used by Roland, phase distortion as used by Casio, Yamaha's frequency modulation, and sampling. He describes how the instruments are adjusted to produce various types of sound, such as strings, brass, percussion etc. The theory of synthesis is treated in a simple, understandable way that will guide you through what you need to know to use your instrument effectively. If you're tired of randomly pushing buttons without really knowing what you're doing, go out and get this book.

Experiments in Gallium Arsenide Technology. D.J.Branning and Dave Prochnow. Tab Books. £13.20. ISBN 0-8306-9352-1. Congratulations to Tab Books for this publication, its contents are welcome. Gallium arsenide technology has several advantages over that of silicon, and devices using it will become increasingly familiar. GaAs can carry electrons up to six times faster than silicon, it's more temperature tolerant, less power hungry, more resistant to radiation, and both emits and absorbs photons. Its present drawbacks are its expense, its low density component capacity, and its difficulty to test in production. This book covers products, manufacturers and the technologies of GaAs micro- and optoelectronics. It explores ten separate devices with a chapter to each, and describes practical diy circuits to build using them. A list of American component suppliers is given, but though no British suppliers are quoted, it would seem that many of the parts needed should be available in Britain. But this book is probably worth its price just for the information alone, even if you don't build anything in it.

Superconductivity. Jonathan L.Mayo. Tab Books. £10.00. ISBN 0-8306-9322-X. Superconductivity is probably the most revolutionary development in electronics technology since the transistor and laser. Already there are many applications to which it is being put. There are also some areas where it has almost become part of mythology in terms of what it may eventually achieve. This book takes an interestingly presented look at the present facts, and the future realistic possibilities. It is well illustrated with many drawings and lots of photographs. The text is written in easy to follow terminology and covers the nature of superconductivity, and its applications in power systems, electronics, science, medicine, and transportation. A short glossary is included.

Radio-Electronics Guide to Computer Circuits. by its editors. Tab Books. £7.75. ISBN 0-8306-9333-5. This books is described on its cover as "a collection of the best articles featured in Radio Electronics Magazine". Well, if that is so, I am even more glad that it's PE that I edit! What disturbs me straight off is that many of the diagrams are drawn as very sloppy freehand sketches. Although I approve of informality as a way of speaking *to people* rather than *at* them, diagram sloppiness detracts from informative clarity rather than aiding it. Tab Books are a large enough organisation to know better than to use sketches, and they must surely have the financial resources to have them drawn properly. It is obviously not practical for review purposes to test the circuits and their descriptions for shortcomings - they appear to be satisfactory but the diagram sloppiness leaves me somewhat concerned. The word "guide" in the title should also be noted - much more information will need to be sought elsewhere if you want to learn more comprehensively about computer circuits. However, I accept Tab's decision to publish the book since it does cover several microprocessor types and gives working examples of some situations in which they might be used.

50 CMOS IC Projects. Delton T.Horn. Tab Books. £13.20. ISBN 0-8306-2995-5. I am pleased to recommend this book as a source of useful experimental circuits for those wishing to explore the possibilities of a variety of standard cmos chips. The book begins with a general introduction to digital electronics, following it with chapters covering circuits in the general categories of : binary, control, test, flashing, sound and music generating, counting, time keeping, games, plus a few miscellaneous circuits. Circuit diagrams and parts lists are given though constructional layouts are not. The book is more suited to intermediate experimenters than to raw beginners.

How to Make Printed Circuit Boards. Calvin Graf. Tab Books. £12.70. ISBN 0-8306-2898-3. Of the 200+ pages in this book, about 21 are devoted to the actual techniques of designing and making your own pcbs. The basic principles described will be of interest to any would-be pcb maker, although some of the materials referred to are probably only available in the USA. By and large, though, equivalent materials are available in Britain through various suppliers, with the possible exception a special pcb imaging film for use with photocopiers. This film is not vital to pcb making and the other techniques described are equally suitable. I feel that more information could have been given on designing and making pcbs, but the text gives a reasonable insight into what can be a very straightforward process. The remainder of the book covers the general principles of construction, electron theory, components, circuit diagrams, tools, various wiring boards, and details of 17 interesting projects to build. There is another chapter on commercially available kits, but these appear to be relevant only to those living in the US. The book is well illustrated with diagrams and photographs, and will be a useful addition to any hobbyist's bookshelf.

50 Powerful Printed Circuit Board Projects. Dave Prochnow. Tab Books. £12.40. ISBN 0-8306-2972-6. This is a nicely thought-out book with a good variety of simple projects. Taking a few at random, there are flashing lights, speech synthesisers, radios, amplifiers, music generators, a robot, and a time bomb! PCB layouts are shown for each project, each printed on pages with nothing on their reverse side, so simplifying the transfer to pcb materials. Pinouts for selected ics are shown separately and a brief glossary is given. All the parts quoted should be readily available in Britain.

Improving TV Signal Reception. Dick Glass. Tab Books. £12.40. ISBN 0-8306-2970-X. Practical solutions to tv reception problems are offered by this book. It explains in simple direct terms the three basic reception setups used for transmitting signals to tv sets. It supplies technical data and formulae, describes tools and troubleshooting techniques for determining specific problems in antenna setups, and offers advice on solving particularly difficult reception problems as well as tips on safety. Reference charts are given for carrier frequencies and satellite numbers though these and the directory of antenna installers appear only to be applicable to those in the USA. Much of the information otherwise given should have universal appeal, including the numerous quizzes included.

Experiments in CMOS Technology. Dave Prochnow and D.J.Branning. Tab Books. £11.25. ISBN 0-8306-9362-9. This book is little more than a selection of abbreviated cmos data sheets. Although the pinouts shown will be of use to experimenters, the heavy emphasis placed on parameters such as propagation delays and transition times at selected psu voltages probably will not. There are some useful experimental circuits, but by no means as many as I would have hoped for in a book of this title. The projects include such circuits as a cmos logic tester, a-d converter, motor speed control, eprom programmer, binary counter, and a few others. PCB layouts for the projects are included. I can't help but feel readers might be better off buying a separate comprehensive and dedicated data sheet book and another book containing only experimental circuits.

How to Design Solid State Circuits - 2nd Edition. Mannie Horowitz and Delton T.Horn. Tab Books. £13.20. ISBN 0-8306-2975-0. In over 360 pages this book takes an in-depth look at four major categories of semiconductor: diodes, transistors, ics and thyristors. It is directed to circuit designers, engineers, technicians and students, and provides a wealth of information on semiconductors, their performance in many applications and operation in a manner that will ensure reliability. It is well illustrated, and though it uses mathematics in essential places, the equations and formulae are pretty straightforward and should be no problem to more experienced constructors and designers. This is the sort of book for which I feel Tab deserve credit.

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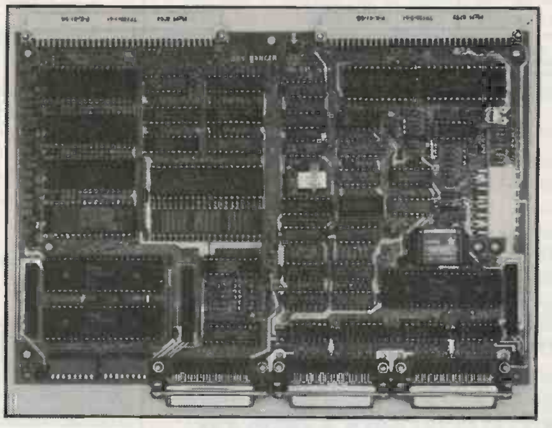

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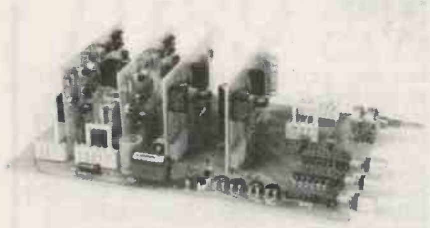

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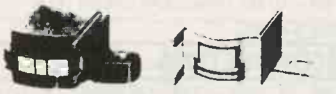

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SATELLITE FUNDAMENTALS

BY TOM IVALL

Part 3 – More characteristics of satellite signals – frequency, polarisation, modulation and coding

Just looking at a satellite television receiver in a shop or elsewhere gives you a few clues to the other signal characteristics we have not yet discussed. Probably the most prominent thing you'll see is a numerical display, showing a number for the tv programme channel to which the set is tuned.

You tune the receiver to a particular channel by pressing buttons labelled with single-digit numbers (0 to 9) – probably on a hand-held remote control unit. Usually two such buttons have to be pressed, for example '27', and this two-digit number appears on the display.

But this number itself is not significant from a fundamental point of view. It's just an arbitrary code or label identifying a particular channel transmitted from a particular satellite – say the Premiere film channel coming from a transponder in Intelsat VA-F11 (see Part 2). The receiver is already programmed so that, when you select this arbitrary code number, the set automatically tunes to the transmission frequency of the channel thus identified.

Yes, *frequency* is the fundamental characteristic we are now concerned with, after satellite position and signal power (Part 2). For a start, in talking about the 'frequency' of a satellite tv channel above we have been referring to the centre frequency of the channel. As an example Fig.1 shows the centre frequencies of the sixteen available channels of the Astra satellite. They range from 11.21425 GHz to 11.4355 GHz.

But, as can be seen from the 16 small blocks or envelopes in this diagram, each channel actually comprises a small band of frequencies. For example, channel No 9 (which carries Eurosport) occupies a band of frequencies from 11.31925 GHz to 11.34525 GHz. All the sixteen Astra channels have this same width, namely 26 MHz. This is the frequency bandwidth of the satellite transponders (see Part 2).

You'll see that in Fig.1 the channel centre frequencies are spaced along each row at intervals of 29.5 MHz. The difference between this spacing and the 26-MHz channel width is a small amount of frequency spectrum that has to be kept vacant between channels. Called a guard band, its purpose is to prevent the transmissions in adjacent channels in the same row from interfering with each other. The significance of the two separate rows of channels, labelled 'horizontal polarisation' and 'vertical polarisation' will be explained later.

FREQUENCY BANDS

Let's now look at the satellite frequency situation a bit more generally.

The idea of channels, as strictly defined bands of frequencies allotted to particular transmissions, may seem pretty obvious nowadays. But it wasn't always so. In the earliest days of radiocommunication, tuning had not been invented and all transmissions spread heedlessly over much of the whole frequency spectrum. Naturally, as more and more systems came into service the complete absence of selection meant that they started to interfere with each other. Everyone realised that some tidying-up was essential.

The arrival of tuning (then called 'syntony') put transmissions on specific carrier frequencies and so allowed them to be kept separate in the spectrum. But modulating a carrier frequency with a speech or other signal generates bands of side frequencies below and above the carrier. Everyone then realised that the carrier frequencies had to be carefully spaced so that these sidebands would not overlap and also cause interference between the different transmissions. Thus a carrier frequency plus its necessary sidebands forms what we now call a channel.

These physical requirements led to international frequency planning (from 1903 onwards) to ensure that different services and systems could work simultaneously without interfering with each other. Starting with terrestrial radiocommunication, this planning eventually expanded to include radio and television broadcasting, radio amateurs, radar and the rest. The first space conference, dealing specifically with frequencies for satellites and other spacecraft, was held in 1963.

So the satellite services, coming several decades after much of the terrestrial system planning, had to be fitted into whatever frequency spectrum was left. Fortunately there was plenty of spectrum still available in the microwave region – the super high frequencies (shf) from 3 GHz to 30 GHz – and this is where most of the satellite frequency allocations are to be found today, as can be seen from the table. Even so there are a few lower frequencies as well, from several MHz upwards, and some of these are listed in the table for illustration.

In general the lower frequencies – at hf, vhf and uhf – cannot be easily made directional and focused into narrow beams. But this does not matter a great deal as they are mainly used for the short transmission distances of LEO satellites (see Part 1). The microwave frequencies, however, do allow narrow beams to be formed with reasonably small parabolic antennas that can be conveniently carried on spacecraft (see Part 2).

When satellites act as relay stations (eg, comsats and dbs) it's important that the

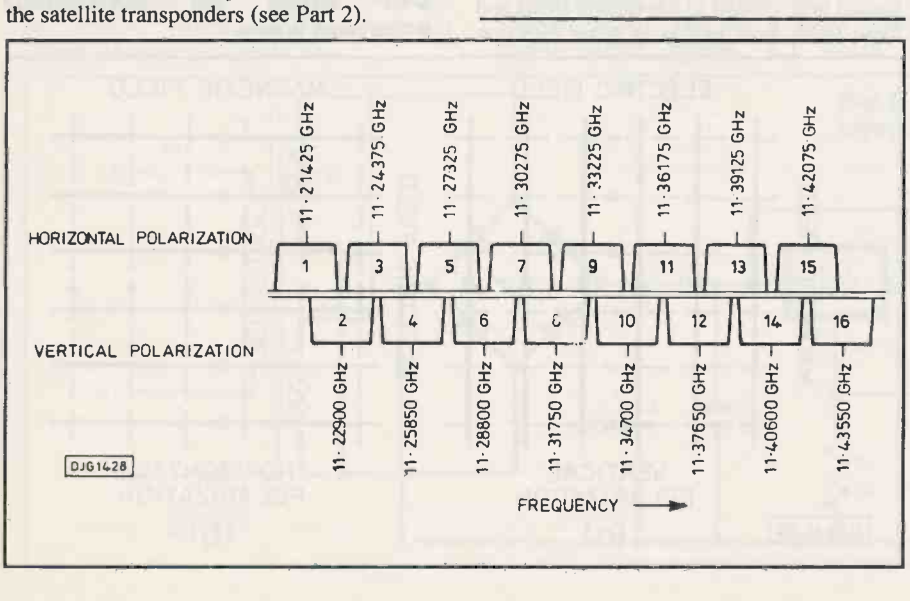


Fig.1. Channel frequencies of transmissions from the Astra tv satellite, shown by the 16 small envelopes labelled with centre frequencies. Available spectrum between 11.2GHz and 11.45 GHz is used twice by arranging 8 transmissions to be horizontally polarised (top row) and 8 to be vertically polarised (bottom row).

Frequency band	Microwave band	Frequency allocation (lower limit)	Type of service
		7.00 MHz	Amateur sat. transmissions
		14.00 MHz	Amateur sat. transmissions
hf		18.06 MHz	Amateur sat. transmissions
		19.99 MHz	Research sat. downlinks
vhf		121.50 MHz	Rescue beacon uplinks
		138.00 MHz	Research sat. downlinks
		144.06 MHz	Amateur sat. downlinks
uhf		406.00 MHz	Rescue beacon uplinks
		430.00 MHz	Amateur sat. uplinks
		1.21 GHz	Navigation satellites
		1.26 GHz	Amateur sat. uplinks
	L	1.53 GHz	Mobile satcoms downlinks
		1.56 GHz	Navigation satellites
		1.63 GHz	Mobile satcoms uplinks
		1.67 GHz	Meteorological satellites
	S	2.50 GHz	Community sat. broadcasting
	C	3.40 GHz	Fixed satcoms downlinks
		5.92 GHz	Fixed satcoms uplinks
	X	7.25 GHz	Military satcoms downlinks
shf		7.90 GHz	Military satcoms uplinks
		10.70 GHz	Fixed satcoms downlinks
		11.70 GHz	Dbs transmissions
	Ku	12.50 GHz	Fixed satcoms downlinks
		12.75 GHz	Fixed satcoms uplinks
		14.00 GHz	Dbs feeder uplinks
		17.70 GHz	Fixed satcoms downlinks
	Ka	22.50 GHz	Dbs transmissions
		27.00 GHz	Fixed and mobile uplinks
ehf	Q	37.50 GHz	Fixed satcoms downlinks
		40.50 GHz	Dbs transmissions

Table: A short selection of satellite frequency allocations for illustration.

satellite's transmitter for the downlink should not work in the same frequency band as the satellite's receiver for the uplink. Otherwise the satellite transponder would interfere with itself, feeding signals from its transmitter back into its own receiver. For this reason the uplink and downlink frequencies allocated to satellite services are kept well apart. In C-band telecommunications systems, for example, the uplinks are at about 6 GHz while the associated downlinks are at about 4 GHz.

POLARISATION

A domestic satellite tv receiver gives you another clue about the fundamental characteristics of satellite signals. It will have a switch marked 'polarisation change' (or 'polarity change'). Roger Bowyer, the technical manager of Rediffusion Satellite Systems, explained to me that this switch allows the whole receiving equipment to be set up to handle different directions of field in the incoming electromagnetic waves. A given, constant direction of field in an e-m wave is known as its polarisation.

All e-m waves, including light and radiant heat, consist of alternating fields and these fields must extend in some direction or other. Often the direction is varying. But electromagnetic waves, as the name implies, have two fields – electric and magnetic – which lie at right-angles to each other as the waves propagate. So which one do we mean when we talk about the direction of polarisation?

It's purely a matter of convention that the *electric* field direction has been chosen and agreed upon to represent the direction of polarisation. Thus a 'vertically polarised' wave means a wave in which the electric field extends vertically as in Fig.2(a), while a 'horizontally polarised' wave has the electric field lying horizontally as in 2(b).

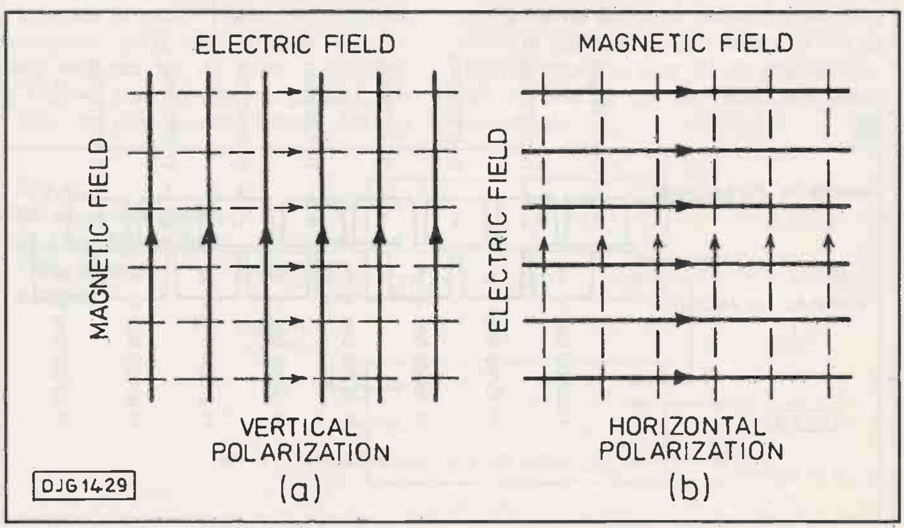
Some satellite transmissions have vertical polarisation, others have horizontal polarisation, and yet others have a third kind – circular polarisation. In the last-mentioned the fields are rotating continuously at a rate of one complete revolution per cycle of the radio frequency. At the transmitter the direction of rotation can be made either clockwise or anticlockwise. The two modes are actually identified as right-hand and left-hand circular polarisation.

But why does the direction of polarisation matter in satellite transmissions?

The answer is, briefly, to make more economical use of the limited frequencies available for satellite systems. There is a permanent, insistent demand from operators and users of all radio systems – not only in the satellite sector – for more space in the frequency spectrum. They want these frequencies in order to expand existing services and to set up new ones. The spectrum itself is a limited natural resource, and there are engineering difficulties in trying to exploit higher and higher frequencies in the mm-wave bands.

But a given frequency can be used by

Fig.2. Illustrating wave polarisation of an rf transmission, as defined by the direction of the electric field (solid lines) in the e-m wave: (a) vertically polarised e-m wave; (b) horizontally polarised wave.



more than one system, without mutual interference between systems, if this is done at different times or in different places. The principle is known as frequency re-use. A third possibility is to re-use a given frequency by making it available with different directions of polarisation, which separate the transmissions from each other. Hence the different polarisations adopted in the satellite field.

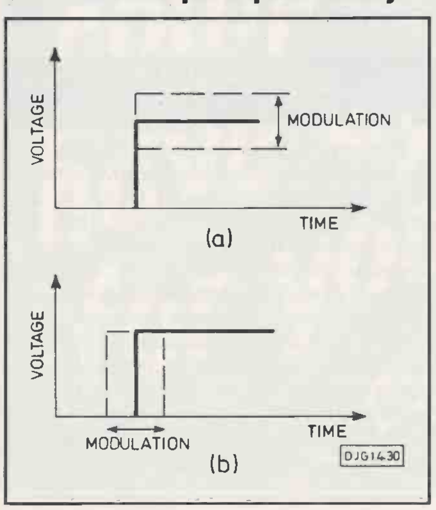
Fig.1 shows, for example, how sixteen 26-MHz tv channels have been packed into a frequency band (11.2 – 11.45 GHz) which, without different polarisations, would only be able to accommodate eight channels. As can be seen, the sidebands of the vertically polarised eight channels (even numbers) overlap in frequency the sidebands of the horizontally polarised eight channels (odd numbers). But because their directions of polarisation are different there is no mutual interference between channels in the frequency overlap regions.

MODULATION

For a radio frequency (rf) transmission to carry useful information – speech, images, data etc – there has to be some way of impressing this information on the rf oscillation. The process is called modulation. There are two basic ways of achieving it, and many variants of these.

An oscillation is an electrical quantity, say voltage, which is changing with time in a regular, repetitive sequence. Fig.3 shows just a single change taken from a repeating sequence – the solid-line graph. One basic modulation method is to vary the extent, or amplitude, of the change, as shown at (a). This is called amplitude modulation (am). The second basic method is to vary the time

Fig.3. The two basic principles of modulating a periodically changing voltage: (a) in amplitude; (b) in time. Normally the changing voltage is a sinewave (eg an rf carrier) but here we have taken a part of such a wave and distorted it into a step function just to show the two principles clearly.



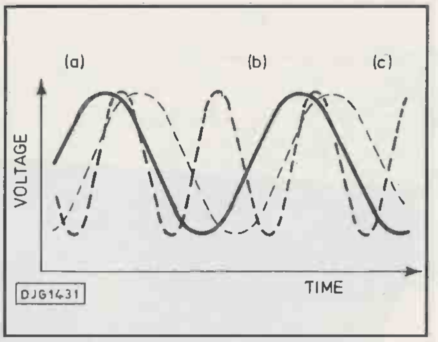


Fig.4. Illustrating the difference between frequency and phase modulation. Sinewave (b) has a different frequency from sinewave (a), while sinewave (c) has the same frequency as (a) but a different phase (displacement in time).

at which the change takes place, as shown in (b). This is called angle modulation and is the underlying principle of two methods widely used in the satellite field – frequency modulation and phase modulation.

In practice the rf oscillation is a sinewave, as shown in Fig.4(a). By using the time-changing principle of Fig.3(b) the frequency of this oscillation can be swung continuously above or below its normal value, in proportion to the speech, vision or other signal voltage to be transmitted. Waveform (b) in Fig.4 shows the result of a frequency swing of (a) to an instantaneous higher frequency. The maximum swing for a particular system is called the frequency deviation.

Suppose now that waveform (a) is being phase modulated instead of frequency modulated. Here the time-change principle is used to displace the waveform in time rather than to vary its frequency – see waveform (c) in Fig.4. The time displacement is varied in proportion to the modulating signal.

In analogue phase modulation this variation is continuous, but in satellite communication systems carrying digital signals the time displacement is done abruptly, between two distinct phase conditions. This is called phase-shift keying (psk), from the idea of keying in Morse code signalling. Mike Sanders's article in the April 1988 issue shows an example of this in Fig.5 on page 20. The signal is a stream of binary digits, and the psk switches the rf carrier oscillation between two distinct phase conditions in accordance with the signal binary digits 0 and 1.

Because there are just two binary numbers and corresponding phase states, this digital modulation scheme is called binary phase-shift keying (bpsk). A more advanced digital system doubles the communications capacity of bspk by making it possible for a single carrier to transmit, over the same time, four binary numbers, such as 00,01,11,10. For each of these the carrier goes into a particular phase state.

This method is called quaternary phase-shift keying (qpsk) and is used extensively in satellite communications. It has the advantage that, for a given transponder bandwidth, it allows transmission at twice the digital data rate of bpsk. This doubling of communications capacity can be used either for data messages or for digitised analogue signals (eg digital sound).

But, because more information can be sent in a given time and given bandwidth the signal-to-noise ratio has to be increased to achieve the same accuracy of transmission. This is an example of 'trading' between time, bandwidth and s:n ratio, as illustrated by Fig.5.

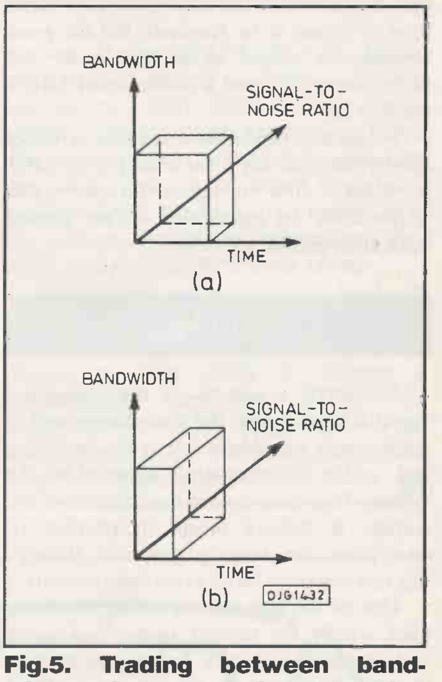


Fig.5. Trading between bandwidth, time and signal-to-noise ratio. The two boxes have equal volumes, representing a given quantity of information (bits), which is transmitted in the same bandwidth in (a) and (b). If, as in (b), the information rate is increased (ie the same number of bits transmitted in less time), the signal-to-noise ratio must also be increased to achieve the same accuracy of transmission as in (a).

You may well ask: why do satellite systems use these complex systems of modulation instead of the much simpler am principle in Fig.3(a)?

Frequency modulation (fm) is the preferred method for sending tv, sound and telecomms speech signals because it overcomes noise more effectively than am – as in terrestrial vhf/fm radio broadcasting. Noise modifies the amplitude of an am signal by directly adding or subtracting spurious voltages to or from the rf waveform: it therefore interferes directly with the amplitude modulation. In an fm signal the noise still affects the amplitude of the rf waveform, but since the signal information is being conveyed by the *frequency*, not the amplitude, of the rf carrier this noise doesn't interfere with the signal in the same way.

Satellite signals received on the ground, or ground signals received in the satellite, are in general much weaker than signals in terrestrial systems. A given level of noise will therefore have a worse effect on the signal – lowering the s:n ratio – in the satellite case. Hence the special need for fm in satellite systems. Much the same argument recommends the use of phase modulation in this field.

In practice the fm carrier power need only be just above the noise power for some kind of signal to be received, but for good reception it should be at least twice the noise power (c:n ratio a minimum of 3 dB – see Part 2).

Frequency modulation requires a wider bandwidth than am – for example 26 MHz in Astra – but in return for our extra 'expenditure' on bandwidth we are getting back an improved s:n ratio.

Satellite television receiver RSR 50 from Rediffusion Satellite Systems, with remote control unit in front. On the right is a numerical display for the channel selected. At the extreme left is the antenna positioning control (see Part 2), while next to it is a polarisation changing switch. The receiver is programmed through a microprocessor and a 50-channel memory which stores the fre-quency, antenna position, polar-isation and other operational data for each satellite channel re-quired. When a particular channel is selected on the remote control unit, the appropriate data is recalled and automatically sets up the receiver for that channel.

CODING

Coding is a process of organising the signal information at the transmitting end to get the best possible result at the receiving end, within the constraints imposed by the system. It is done before modulation of the carrier. It doesn't mean enciphering or encryption for secrecy purposes (though this can certainly be an extra requirement).

One of the best known coding methods, used widely for satcom systems, is pulse code modulation (pcm). To begin with, note that 'modulation' here doesn't mean direct modulation of the rf carrier, as discussed in the previous section. In fact pcm is a coding method often used in conjunction with the qpsk modulation scheme (see above).

Its principle is to convert an analogue signal into a stream of binary digit pulses. Its purpose is to overcome amplitude variations affecting the transmission process, such as noise and rain fading. This is achieved because the amplitude of the transmitted digit pulses – when converted into phase or frequency shifts by the modulation – doesn't matter very much. What is responsible for the information is purely the ability of the whole system to distinguish between a '0' digit and a '1' digit. This distinction can be made very reliably because it is the simplest possible choice, even though the binary pulses, or equivalent modulation changes, are badly distorted in transmission.

In sending tv and sound signals by satellite, the coding we are talking about is the format of the baseband signal before it modulates the carrier. The PAL system of coding is being used in the first Astra channels but MAC will also come into operation, certainly on the BSB direct broadcasting satellite. Other forms of coding are applied to compressing the bandwidth of both vision and sound signals. (For details, see my article on hdtv in the February and March issues.)

Finally, an advanced form of coding which is coming into increasing use is based on the principle of randomising the signal information. It is changed into a 'pseudo-random' sequence of numbers. In a truly random number sequence there is absolutely no discernible pattern – the randomness goes on for ever – but this would be impracticable for communication purposes because decoding would be impossible. So practical systems use a random sequence of finite length, which is repeated after a very long time, and this is called a pseudo-random sequence.

There are several applications in satellite systems. One is to scramble tv pictures in subscription or pay-per-view schemes, so that unauthorised (non-paying) viewers cannot unscramble the pictures and display them. Another is to provide secrecy and immunity to jamming in military communications and navigation systems. In both of these fields, of course, the coding is used specifically for encryption.

A third application of pseudo-randomisation is to conserve space in the frequency spectrum where an allocation is strictly limited. A number of different signals can occupy exactly the same band of frequencies without mutual interference as long as each is encoded into an individual pseudo-random sequence. This is a form of multiplexing. The effect of each coded signal when it modulates the rf oscillation – typically by psk – is to generate a band of frequencies occupying the full space available. This can be hundreds of kHz in some systems or several MHz in others. Consequently the method is known as spread-spectrum transmission.

At the transmitting end the code is generated by a digital circuit called a pseudo-random binary sequence (prbs) generator. Its output changes the original, uncoded, signal, which is in binary data form, by digitally multiplying this data. At the receiving end the encoded signal is decoded by digitally multiplying it by the output of a prbs generator, which has a random number sequence identical to that of the transmitter's prbs generator. PE

AIR POWER

A North American aluminium company has developed a battery that lives on air, according to a report from the Patents Office. In the battery, electricity is produced by the electrochemical coupling of a reactive metallic electrode, in this case aluminium, to an air electrode through an electrolyte in the fuel cell.

Light weight is one major advantage of an air cell. In recent tests two were installed in a small pilotless aircraft and the total weight was just under 3kg. The cells delivered 250 watts continuously for more than two hours. Military reconnaissance is one obvious application, but there are bound to be many others.

DIGITAL ELECTRONICS

BY OWEN BISHOP

PART 10 – PROGRAMMING COMPUTER SYSTEMS

Owen Bishop is not content with telling you what a computer is, and how many bytes it has. He wants you to start writing in assembler – and start now. Pencils at the ready . . .

PROGRAMS IN STORE

We shall now look at the way the cpu is instructed to perform its varied and complicated tasks. The instructions are stored in memory, either rom or ram. To make the description simpler we shall assume that the cpu is a Z80 microprocessor, but other microprocessors and the more complicated cpus of mini-computers and main-frames operate in much the same way.

The cpu begins with a memory address in its *program register*. In this example we assume that it begins at address &4000, though it could begin elsewhere. Fig.8 is a diagram of part of a memory chip (rom or ram) in which the circles represent the memory cells. Each circle might be a flip-flop or similar unit, which is reset (logic 0) or set (logic 1), or it might be a capacitor which is uncharged (logic 0) or charged (logic 1). Note that the cells, representing data *bits*, are arranged in groups of 8, representing a data byte. Each *group* or byte has its own address, from &4000 upward. When an address is put on the address bus and the control bus tells the memory chip that the cpu wants to read data, the data at that address is put on the data bus.

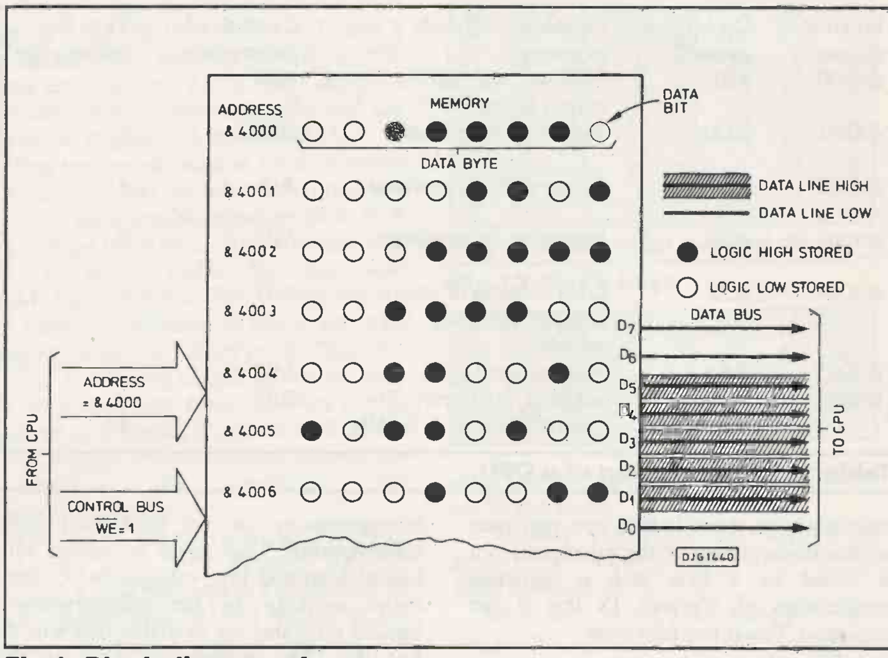


Fig.1. Block diagram of a computer system

In Fig.8, address &4000 is being read from and the data lines D1, to D5 are high. Other data lines are low. This data is read by the cpu, and stored in its *instruction register*. The cpu now has to act on this instruction. When the instruction register holds 00111110 (&3E) the cpu knows that it is going to have to load a value into its *accumulator register*. It also knows that the value is to be found in the next address of memory. So it increments its program register by 1, giving &4001, and puts this on the address bus. The memory chip then puts the contents of the second byte on the data bus. The cpu reads this data (00001101, or &0A) and puts it in its accumulator register. This completes the first operation of the program. Note that the instructions for this operation were contained in two bytes of memory. The first byte holds the *op-code* (the code for the operation that is to be done), while the second byte holds the *operand* (the value to be used in the operation).

Continuing with the program, the cpu increments its program register again, to &4002. The data (00011111, or &1F) is stored in its instruction register. This op-code causes the cpu to perform a simple operation on the contents of the accumulator. This is known as 'rotate right', in which the bits are shifted one place to the right. The effect of this is to divide the accumulator contents by 2. The accumulator now holds 00000110 or &06, the original right-most '1' having been lost. No operand is needed for this op-code since the value operated on is already in the accumulator. so this is a one-byte instruction, which is thus complete.

The next op-code is at address &4003. This is 00111100, or &3C, and causes the cpu to increment by 1 the value held in the accumulator. The accumulator now holds 00000111, or &07. Again, this op-code needs no operand, and makes a one-byte instruction.

At &4004 the cpu finds the op-code &32. This code means 'Load the contents of the accumulator into memory at the following address'. Obviously, this op-code needs an operand – the address where the cpu has to store the data. Since addresses have 16 bits, we need *two* bytes for the operand. These are found in the next two bytes of memory, at &4005 and &4006. The value in &4005 is &B4, and the value in &4006 is &13. By convention, the low byte of an address is stored first and the high byte last. The address represented by these two bytes is &13B4. This must be a ram address, not a rom address, otherwise it would be impossible to store anything there. Having stored the op-code and operands in its registers, the cpu puts &13B4 on the address bus, puts &07 on the data bus and makes the write-enable line low. The data is stored at the required address.

Let us sum up the action of the cpu in a table, stage by stage; as in table 1.

The total time required for this program is 28 cycles of the clock. If the clock is running a 4MHz, the total time is 7 microseconds.

The second column of the table shows the program as we could write it down in hex. Remember, a microprocessor does not understand hex (do you?). A micro-processor is a logic circuit – it understands only logic '0's and logic '1's, which result from reset or set flip-flops or from uncharged and charged capacitors (as in Fig.8). For any given combination of lows and highs in a byte the microprocessor is

Program counter	Op-code or operand	Meaning of op-code or operand	Contents of accumulator	Time in microcycles
&4000	&3E	Load acc. with data at next address	&00	
&4001	&0D	The value to be loaded	&0D	7
&4002	&1F	Rotate right accumulator	&06	4
&4003	&3C	Increment accumulator	&07	4
&4004	&32	Load contents of acc. into the following address	&07	
&4005	&B4	Address (low byte)	&07	
&4006	&13	Address (high byte)	&07	
		Data &07 stored at &13B4		13

Table 1. Typical action of a CPU.

built so as to make it take one particular action. Every action of the microprocessor is coded by a byte with a particular combination of '0's and '1's that it can recognise. This is *machine code*.

PROGRAMMING

It would not be easy for a person to program a computer by thinking in terms of the pattern of logic levels as shown in Fig.8. Indeed it is difficult for anyone to remember that 001111100 or &3E means 'load the accumulator with the data at the next address'. The Z80 for example has 158 different op-codes. Who can expect to remember which is which? Tables of op-codes help and it is *possible* to write programs in machine code using such tables, but one is very likely to make mistakes. Instead, programmers can use short-hand versions of the instructions, which are easier to remember. The program above can be written out like this:

Short version	What it means
LD A,&OD	Load accumulator with &0D
RRA	Rotate accumulator right
INC A	Increment accumulator
LD (&13B49),A	Load memory address &13B4 with the contents of the accumulator.

With a little practice it becomes easy to write programs in the short form. But the microprocessor can not understand these abbreviations! They must be turned into logical high and low voltages before they mean anything to the microprocessor. Special programs are available that will do just this. The programmer keys in the abbreviations, data, addresses, etc, just as in the first column of the table, and the program *assembles* a sequence of bytes that the microprocessor can understand. This sequence of bytes is set up in the computer's memory and can then be stored to tape or disk for future use. The corresponding code, in hex, can also be printed out as a permanent record of the program. A program which does this is called an *assembler*. The short abbreviations are usually known as *mnemonics*, since a mnemonic is something which makes it easier to remember things.

INSTRUCTION SET

In this section we look at some of the more frequently used instructions that the cpu obeys. For convenience these may be divided into groups:

Load and store: two examples of this group have been described above.

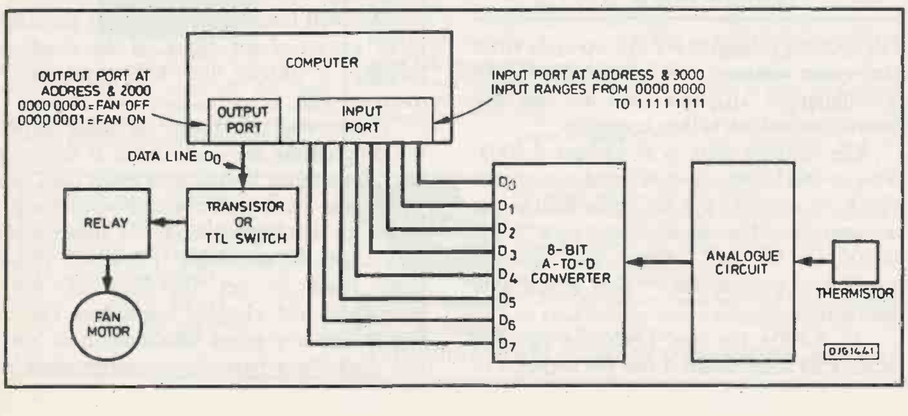
Increment and decrement accumulator: increment has been described above; decrement is the reverse. In most microprocessors the result of incrementing or decrementing may alter the value of one of the bits in the 'flag' register. For example, decrementing &01 produces &00. In this event the 'zero' flag bit is set to indicate the production of a zero result in the accumulator.

Compare: Compare a given value with the value in the accumulator. The value may be given as the operand, or it may be a value already stored in one of the other registers of the microprocessor. The value is taken away from the value already in the accumulator. This does not affect the values held in the accumulator or other registers, but the *result* of the subtraction affects certain flag bigs, such as the 'zero' flag (set to 1 if the result is zero, reset to zero if not) and the 'sign' flag (set to '1' if the result is negative, reset to zero if it is not.

Jumps: These make the computer jump to some other part of the program. Instead of just incrementing its program register when it has completed an operation, it loads a new value and goes to the new address so indicated. A jump may be *unconditional*, in which case the cpu immediately jumps to the new address. The new address is specified by giving it as a two-byte operand. A *relative* jump tells the microprocessor to jump (eg 20 bytes forward, or 46 bytes backward).

Jumps can also be *conditional*. This means that the jump is made only if a given condition is fulfilled. For example, the jump is to be made only if the zero flag bit is set. The mnemonic for this is JP Z, 'jump if zero'. If it is not set, the microprocessor continues to the next byte. The opposite condition is possible, ie JP NZ, 'jump if *not* zero'.

Fig.9. System for controlling an electric fan.



PROGRAM EXAMPLE

This shows how we use some of the simple instructions mentioned above to build up a program. The program is to control an electric fan, turning it on when the temperature exceeds 20°C, and turning it off when the temperature is less than 18°C. A possible digital system for this purpose is shown in Fig.9. Fig.10 is a flow-chart of the program. We begin by switching the fan off. This is because, supposing the temperature stays between 18°C and 20°C anyway, we do not want the fan to be running unnecessarily. Next the temperature is read. The a-to-d converter gives a readout in the range 0 to 255. In this example we assume that the reading is the actual temperature in degrees Celsius. If the reading is greater than 20, the fan is switched on. The program loops back to read the temperature again. If the temperature is *not* greater than 20°C, the value from the a-to-d converter is compared with 18. If it is less than 18, the fan is switched off. If it is 18°C or more (but not more than 20°C) not action is taken) – the fan remains off or on. In either event the program loops back to read the temperature again.

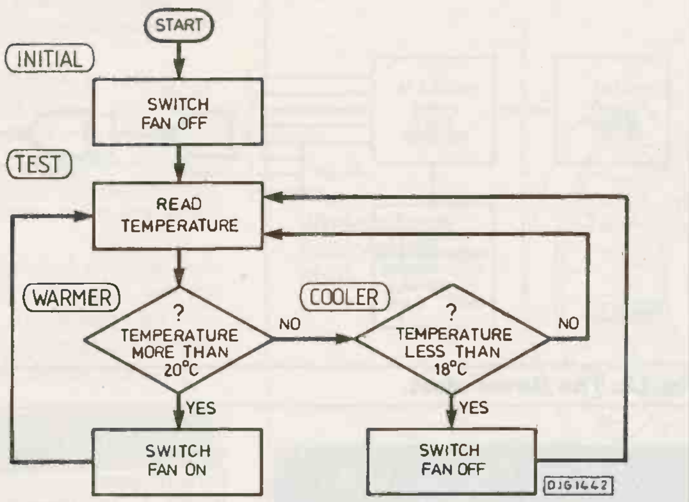


Fig.10. Flow chart of the fan control program.

Let us see how this program can be written in assembler language. To identify various parts of the program we give them *labels*,. Switching the fan off is simple:

Label	Assembler	Meaning
INITIAL	LD A, &0	Load accumulator with 0.
	LD (&2000), A	Load &2000 (fan motor control output port) with 0

This program assumes that the cpu has no instruction for loading a memory address directly. First the accumulator is loaded with 0 and then its contents loaded to the port address. This is typical of the way a microprocessor does everything in small simple steps.

Now we read the temperature:

TEST LD A, (&3000) Load accumulator with the contents of address &3000 (the a-to-d converter)

This puts the temperature in the accumulator. Is the temperature more than 20°C?

WARMER	CP &14	Compare accumulator with &14 (=20 decimal), ie subtract 20 from the value in the accumulator
	JP M, COOLER	If the 'sign' flag is minus (M), ie taking 20 from the temperature gives a negative result. Jump to the COOLER label. A conditional jump.

Jump if the temperature is low, continue if it is not.

	LD A,&1	Load accumulator with 1.
	LD (&2000),A	Load &2000 with contents of accumulator, to switch fan on.
	JP TEST	Jump to TEST label to re-read temperature. An unconditional jump.

This completes what is to happen if temperature is too high. If it is less than 20°C we proceed as follows:

COOLER	CP &12	Compare with &12 (=18 decimal). Remember that the previous compare in the WARMER routine did not alter the value in the accumulator. It is still there and may be compared again.
JP P,TEST		If the 'sign' flag is positive, (P) ie taking 18 from the temperature gives zero or a positive result re-read temperature. Conditional jump.
	LD A,&0	Load accumulator with O.
LD (&2000),A		Load &2000 with contents of accumulator, to switch fan off.
	JP TEST	To re-read temperature. An unconditional jump.

An assembler program would turn this all into machine code. It would also calculate the lengths of jumps required to reach the various parts of the program indicated by the labels.

One further point about this program is that the action of switching the fan off occurs twice. The code for this is short, so the repetition does not really matter. However, if a long routine is required two or (possibly more) times in a program, it is more economical of memory to treat it as a *subroutine*. This is set out as a separate part of the program. The cpu is made to jump to this subroutine by using the CALL instruction. It performs the subroutine and then jumps back into the main program, to the point from which it jumped. Here is the program again set out more compactly and using the subroutine OFF to switch off the fan:

INITIAL	LD A, &O	Load accumulator with 0.
	CALL OFF	Jump to subroutine to switch fan off.
TEST	LD A, (&3000)	Read the a-to-d.
WARMER	CP &14	Compare accumulator with &14.
	JP M, COOLER	If the 'sign' flag is negative
	LD a,&1 LD (&2000),A)	) Switch fan on
	JP TEST	Jump to TEST label
COOLER	CP &12	Compare with &12
	JP P, TEST	If the 'sign' flag is positive.
	CALL OFF	Jump to subroutine to switch fan off.
	JP TEST	Jump to TEST label
OFF	LD A,&0 LD (&2000),A)	) Switch fan off
	RET	Return from subroutine to main program

This short example is not intended to teach you how to program a micro-processor. It is simply meant to show how some of the operations listed earlier can be put together to do something useful. There is a parallel between computers (hardware) and programs (software). The computer consists of many complicated circuits, but it is built up from the simple logical units that we studied in previous issues – NAND gates, NOR gates, flip-flops etc. Similarly, a computer program, though it appears to do very complicated things, is built up out of simple logical operations – load, increment, jump etc.

RISCING IT

Microprocessors are able to perform a hundred or more different operations, and so their circuits have to be able to recognise over a hundred different op-codes before taking the appropriate action. Their circuits have to be designed so that they are capable of performing these hundreds of different operations. Yet, in practice, a few of these operations are used a lot and many of them are hardly ever used at all.

A microprocessor which performs only the more commonly-required operations is simpler to build and, more important, is much faster in action. Such devices are called *Reduced Instruction Set Chips*, or *RISC* for short. One of these microprocessors is featured in the BBC Archimedes microcomputer.

The operations that a RISC microprocessor can not perform in one step have to be performed using several operations. This takes longer than with a conventional microprocessor, but such operations are relatively rare. Overall, programs run considerably faster on RISC devices, often as much as 10 times faster. RISC computers thus represent another major development in computing.

TEST YOURSELF AGAIN

(Answers at end)

7. Which part of a cpu is used to store the address of the instruction the cpu is currently working on?

8. What do we call the first byte of an instruction?

9. What do we call the part of an instruction that consists of a value or part of an address?

10. Give an example of an instruction that has a one-byte operand.

11. How many operands has the 'increment accumulator' (INC A) instruction?

12. What is a mnemonic? Give two examples.

13. What does an assembler do?

14. Fig.11 is the flow-chart of a 'delay' routine. It keeps the computer waiting while the microprocessor decrements the accumulator 255 times. Try to write out an assembler program for this routine.

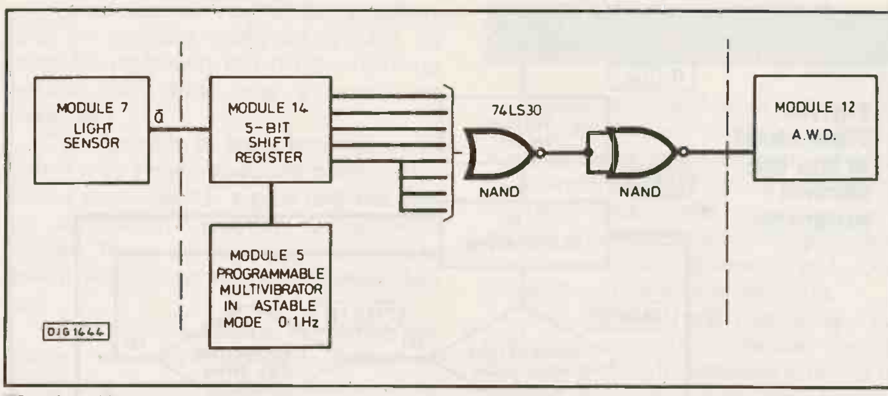


Fig.12. The dawn alert.

MODULES OF THE MONTH

MODULE 13 – *SOUND OPERATED SENSOR*

This sensor (Fig 13) responds to claps, whistles and explosive voice sounds. It uses cmos ics so be sure to observe the usual precautions against static charges when building and using this unit. The output Q, normally low, goes high when a sound is detected. The led comes on to indicate the output state. The output comes from a SR bistable so, once triggered, it stays high until the bistable is reset. There is a push-button for resetting, though you could wire in a connection for resetting by logic. There is an alternative output Q_0 from the pin at E24. This is the direct output which is normally low and goes high only while sound is actually being detected. This could be useful in applications in which the duration of sound has to be analysed. To set up the module, turn VR1 clockwise until the led comes on. Then turn it anticlockwise a little at a time, pressing S1 at each step. When pressing S1 turns the led off, the correct setting has been reached. Once the module has been set, a slight noise turns the led on; pressing S1 turns the led off. The module requires 3.5mA when not activated, and 18mA when it has been triggered.

Parts required

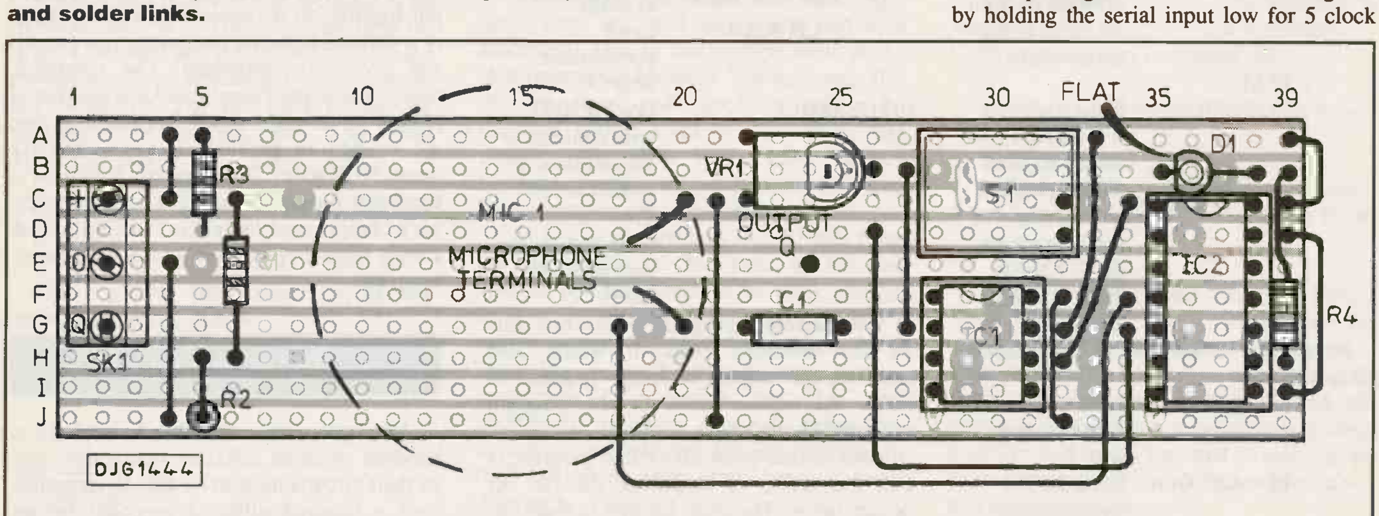
R1,R2	1k carbon 5% (2 off)
R3	15k carbon 5%
R4	180 carbon 5%
VR1	1M present miniature horizontal potentiometer
C1	100n polyester layer capacitor
D1	TIL209 led
IC1	7611 cmos operational amplifier
IC2	74HC00 quadruple 2-input NAND gate
S1	small click switch and cap
MIC1	microphone 'insert'
SKT1	pc terminal 3-way

8-pin dil socket
14-pin dil socket
1mm terminal pin
Stripboard 10 strips by 39 holes

MODULE 14 *5-BIT SISO SHIFT REGISTER*

This shift register has one more bit than the one we looked at last month. This makes it more useful for demonstrating shift register action, and gives an additional bit for multiplication by shifting. The 74LS96 is actually a pipo register, with a serial input. We are not using its parallel loading facilities in this module, as this would entail having too many terminal sockets. The module requires a clock input to terminal C. This can be provided by Module 5 in its astable mode. R1 holds the clear input high. You can clear the register by holding the serial input low for 5 clock

Fig.13. Sound operated sensor. Carefully note positions of the track cuts and solder links.



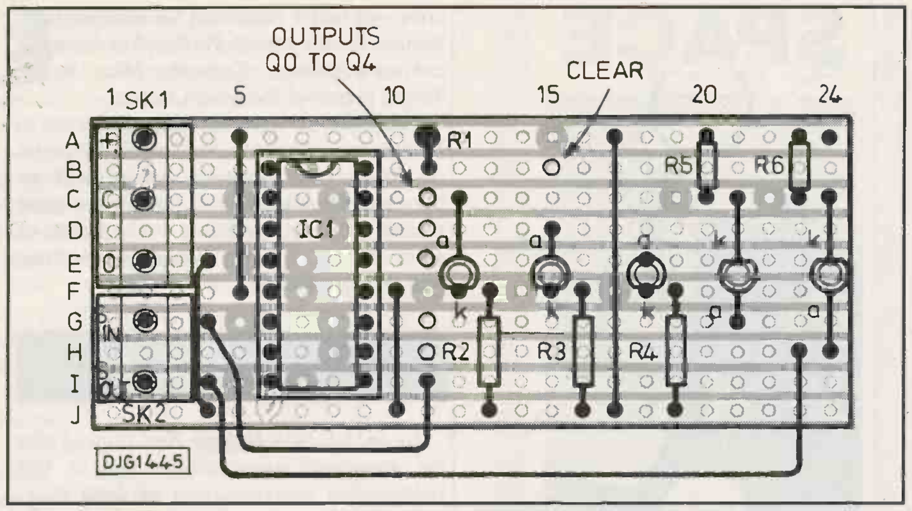


Fig.14. 5-Bit shift register. Carefully note track cuts and solder links.

pulses. Alternatively, wire a push-button between the 'clear' terminal pin (at B15) and the OV line. Pressing the button clears all registers at any state of the clock. The state of each register is displayed on the row of leds, and shifting operates from left to right. The output from each register is available at the terminal pins Q_0 to Q_4. The module requires 10mA for the ic and 10mA for each led, a total of up to 60mA, depending on the state of the lamps.

Parts required

R1	1k carbon 5%
R2-R6	180 carbon 5% (5 off)
D1-D5	TIL209 led (5 off)
IC1	74LS96 5-bit shift register
SKT1	pc terminal 3-way
SKT2	pc terminal 2-way
16-pin dil socket	
1mm terminal pins (6 off 9)	
Stripboard Vero 14345	

SYSTEM OF THE MONTH

Dawn alert

This is designed to wake you up at sunrise. It lets you sleep longer on a dull morning. The output of the light sensor module is normally low, but goes high when the light exceeds a set level. The sensor is placed in a window, preferably a north-facing window, so as to avoid the direct light of the rising sun. The output of the light sensor is stored in the shift register which is driven by a slow clock. The clock runs at 0.1Hz, so the state of the output is registered every 10 seconds. When the output has been high on *five successive occasions* (ie for at least 50 seconds) the 74LS30 gate output goes low and the second NAND gate output goes high. This sounds the alarm. The idea of using the shift register is that an occasional high output from the sensor, such as might be caused by the headlamps of a passing car, or a flash of lightening, does not trigger the alert. Only a continuous period of light can do this.

The system could have Module 3 connected in place of the second NAND gate. This would allow the alert to be reset by pressing a reset button.

Another version of this system has Module 13 instead of the light sensor. Us the Q_0 output of the module. This makes the system suitable as a phone alarm or baby alarm. It is not triggered by occasional noises within the room. If the phone rights for more than 50 seconds, or baby makes more than a few slight whimpers, the alarm is sounded.

ANSWERS TO QUESTIONS

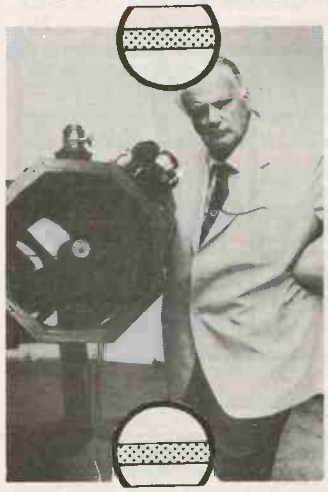
(Questions 1 to 6 were posed last month).

1. It processes data automatically.
2. The central processing unit (cpu)
3. The memory
4. Address, data, control.
5. A program that instructs the computer what to do when it receives an interrupt signal.
6. See the examples quoted in the text.
7. The program register, also called the program counter or instruction counter.
8. The op-code.
9. The operand.
10. &3E, meaning load accumulator with the value in the next address of memory.
11. None.
12. Something that makes it easier to remember things. 'LD A,n' for &3E plus its operand, 'RRA' for &1F, 'INC' for &3C, 'LD nn' for &32 plus its operand. Other subjects have mnemonic too – in physics, 'VIBGYOR' helps you remember the colours of the rainbow, in reverse order.
13. It takes a program written in mnemonics and produces machine code.
14. This is one of several possibilities – depending partly on what microprocessor is being written for:

INITIAL	LD A,&FF	Load accumulator with &FF
LOOP	DEC A	Decrement accumulator by 1
	JP NZ,LOOP	Jump back to LOOP as long as the accumulator does not hold zero (&00)
END		Accumulator has been decremented to zero after 255 times round the loop, so delay is over.

PE

SPACE WATCH



BY DR PATRICK MOORE CBE

Herstmonceux and Phobos 2 – two landmarks lost to us through human error?

The fact that the three outermost giant planets are so close together in the sky has a rather sad note: the man who first gave the clue to their true nature, the great scientist Sir Harold Jeffreys, has died at the age of 97. For many centuries the giant planets had been regarded as miniature suns, with violently heated surfaces, sending out enough radiation to heat their satellite systems. It was Jeffreys' series of papers in the 1920s which showed that this is not so. The gaseous surfaces of the giants are bitterly cold; they are not 'failed stars', and are not nearly massive enough for thermonuclear processes to be sparked off inside them.

Those who like visiting the grounds of Herstmonceux Castle will be disappointed; the Castle is now closed to the public, and the Royal Greenwich Observatory is moving out to its new office block in Cambridge. The future of the Herstmonceux telescopes remains in doubt. The fact that the Science and Engineering Research Council sold the Castle to a developer without safeguarding the telescopes is a major mystery.

Still on a depressing note, there seems no hope of reactivating the Russian probe Phobos 2. Contact with it was lost at the end of March, and all efforts to recover it have failed. It had joined Phobos 1, its twin, as a 'lost satellite'. In the case of Phobos 1, the failure was due to human error – a faulty command transmitted from Earth – but the loss of Phobos 2 is due to an unknown cause. Certainly Mars is the 'bogey planet' of the Soviet Union.

However, we have the Magellan probe to Venus; and of course Voyager 2 continues on its way to Neptune, which will be bypassed in August. So far, all the giant planets have provided us with plenty of surprises. It is hardly likely that Neptune will be any exception.

GALACTIC DANCE

In 1923 Edwin Hubble first showed that the so-called 'starry nebula' are in fact independent galaxies, most of them many millions of light-years from us; even the closest of the fairly large systems, the Magellanic Clouds, are over 170,000 light-years away. Our Milky Way galaxy is a member of the so-called Local Group, other members of which are the Magellanic Clouds, the Andromeda and Triangulum spirals, and more than two dozen smaller systems, plus possibly a large elliptical, Maffei 1, which we can see only vaguely because it is heavily obscured by dust lying in the galactic plane.

Our knowledge of the evolution of galaxies is still rather sketchy. It is not now generally believed that a spiral system

THE SKY THIS MONTH

The planetary enthusiast has restricted opportunities this month. Mercury is theoretically a morning object, but from Britain it will probably not be seen with the naked eye. Jupiter passes through conjunction on June 9, and so on is to all intents and purposes out of view throughout the month. It is in Gemini, not far from Castor and Pollux, but the magnitude has now dropped to +1.8, so that it is fainter than either of the Twins. Venus is emerging in the evening sky, but will set only about half an hour after the Sun; it too is in Gemini. The phase is over 95 per cent. However, Venus will be on view for most of the rest of the year.

This leaves the outer planets. Saturn, Uranus and Neptune are all in Sagittarius, while Pluto is near the borders of Virgo and Libra.

Saturn reaches opposition on July 2, so that during June it is visible for almost all the hours of darkness. The problem for British observers is that it is very low down, though to compensate for this the ring system is wide open; a small telescope will show it well, and look also for the brighter satellites – Titan at least is a comparatively easy telescope object.

Uranus, roughly between the stars Lambda and Mu Sagittarii, is on the fringe of naked-eye visibility. The magnitude is about 5.7, and even a small telescope will show that it is not like a star; it shows a pale, rather greenish disk. We knew much more about Uranus than we used to do before the flight of Voyager 2, which by-passed the planet in January 1986, but it still provides us with plenty of puzzles. Why, unlike the other giant planets, has it almost no internal heat-source? Why is its rotational axis inclined to the orbital plane by more than a right angle – and why is the magnetic axis tilted to the rotational axis by 60 degrees? In many ways Uranus is the 'odd one out'.

Neptune, at magnitude 7.7, is within binocular range, but it does look very like a star. We know it to be slightly smaller than Uranus, though more massive. Voyager 2 is on its way there – and if you want to locate Neptune, you have a good chance this month, as it is close to Saturn in the sky. On June 25 Saturn and Neptune are only one-third of a degree apart. But take care not to confuse Neptune with a Saturnian satellite!

There are no eclipses this month, but there may be some meteors from the rather sparse Ophiuchic shower. Incidentally, we may have a naked-eye comet later this year – Brorsen-Metcalf, which has a period of 70 years – but I will say more about this later; during June it is still a very faint object.

The Moon is new on the 3rd, first quarter on the 11th, full on the 19th, and at last quarter on the 26th.

The Earth reaches the summer solstice on June 21, but is not at aphelion (152,000,000 km) until July 4. The Sun is nearing the peak of its cycle of activity; as many people know, we had a giant sunspot group, together with a splendid display of aurora, on March 13 – and we may have aurora at any time, though of course the view of them is restricted during the short summer nights.

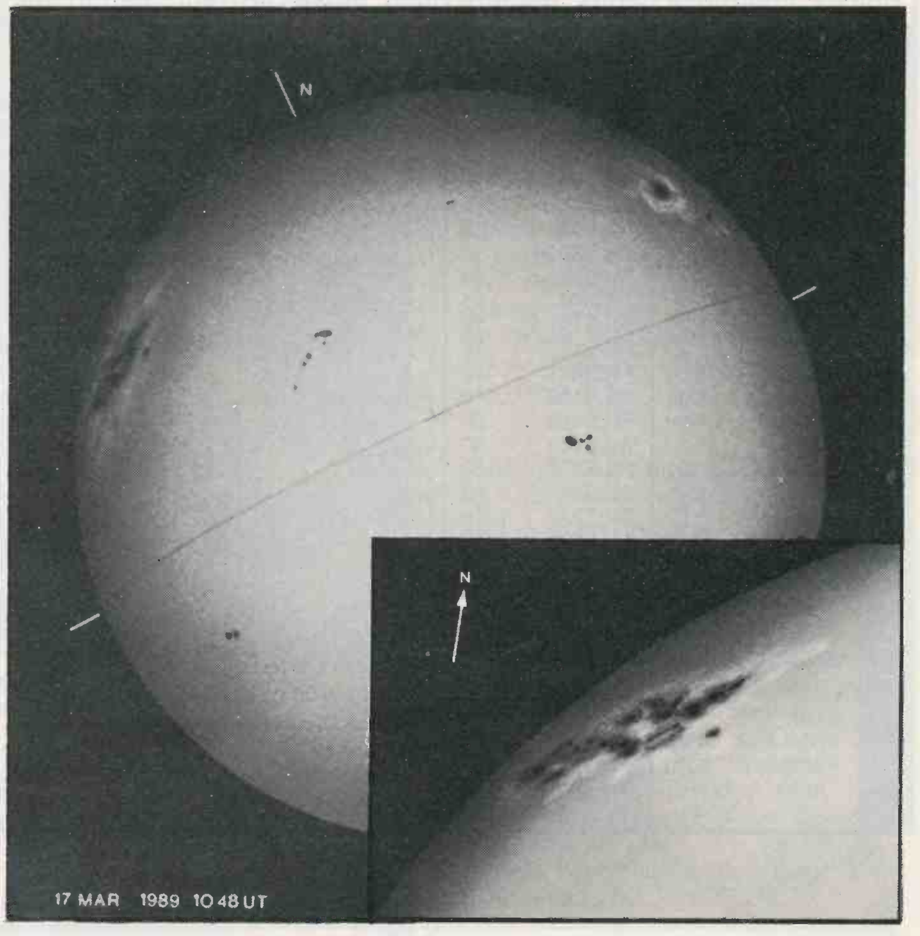
The starlit sky is now dominated by the "Summer Triangle" of Vega, Deneb and Altair; Vega is near the zenith during June evenings, and is easy to identify because of its steely-blue colour. (Some writers have questioned this description of it. I can only suggest that you go and look for yourself.) The brilliant orange Arcturus is to be seen in the north-west, with the Square of Pegasus starting to come into view in the east. Low down, look for the star-clouds of Sagittarius, which mask our view of the centre of the Galaxy. Sagittarius itself has no definite outline (I for one have never been able to make out the familiar 'Teapot' nickname), but of course the presence of Saturn this year makes it easier to find. If you have binoculars, sweep around those lovely star-clouds; the view is so magnificent that you will not be dissppointed.

evolves into an elliptical, or vice versa. But in America, Dr Joshua Barnes has produced a new and startling theory. By using computer simulations, he has suggested that clusters of spiral galaxies may eventually merge to form large, blob-like eliptical systems with a few surrounding starry remnants.

If this is so, then could the members of the Local Group eventually come together to make up one vast system? We know that the members of the group are not moving apart (at present the Andromeda Spiral is actually coming toward us), but it had always been maintained that they would retain their separate identifies permanently. If Barnes is right, this may not be so. The Magellanic Clouds, the Andromeda and Triangulum Spirals, and the dwarf members of the Local Group may all come together – in which case the sky many hundreds of million of years hence may look very different from the sky of today.

Of course, this is only a theory; it may well prove to be wrong, as so many theories have done in the past – but at least it must be taken seriously.

PE



Drawings made at the telescope by Paul Doherty of the major sunspot group which caused the aurora display of March 13th to 14th.

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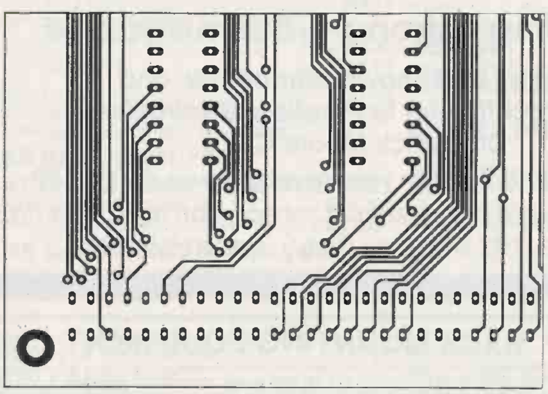

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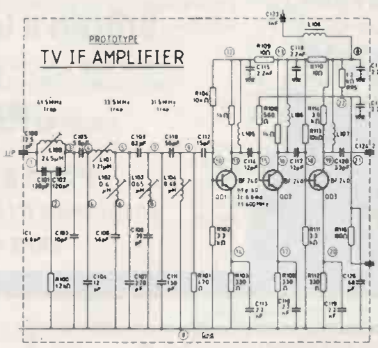

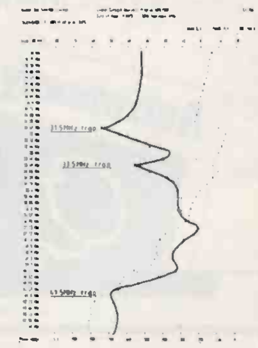

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BOATING REVOLUTION

PART TWO
BY JOHN BECKER

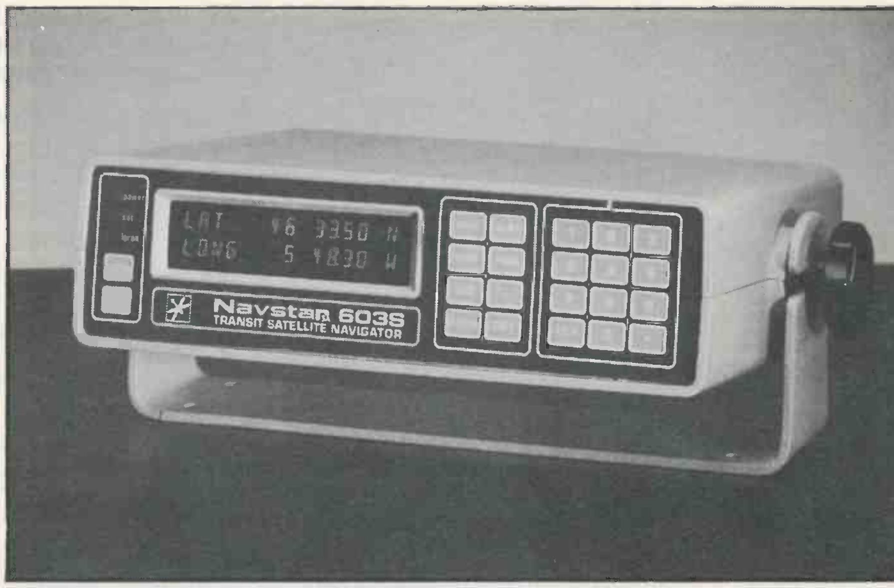
Whatever your craft, microelectronics brings precision and safety to your seafaring

TRANSIT SATELLITES

Scientists studying radio transmissions from the first satellites launched in the late 1950s noted the apparent change of transmission frequency due to Doppler shifting as the satellite orbited around the globe. It became obvious that if a satellite's position was known to a high degree of precision, then land or sea positions could be accurately determined in relation to it.

During 1964 the US Navy put a series of "Transit" navigation satellites into orbit as part of the Navy navigation satellite system (NNSS) intended for use with Polaris submarines. The system was released for commercial use in 1967 but has only become a practical reality since the introduction of microprocessor circuitry which allowed greater sophistication, reduced physical size, and lower power consumption. By 1987 the NNSS consisted of seven satellites, each in a circular polar orbit at an altitude of 600 nm.

The orbit takes approximately 107 minutes and a satellite passes above any one point on the earth at an interval of 12 hours. The satellites continuously transmit timing and orbital data in two-minute segments, using a transmission frequency of 399.968MHz (400MHz). When a satellite is visible above the horizon, the distance between the satellite and the receiver is measured by successive Doppler counts according to a sophisticated mathematical algorithm, and the craft's location displayed.



A compact satellite navigator from Navstar

SATELLITE NAVIGATORS

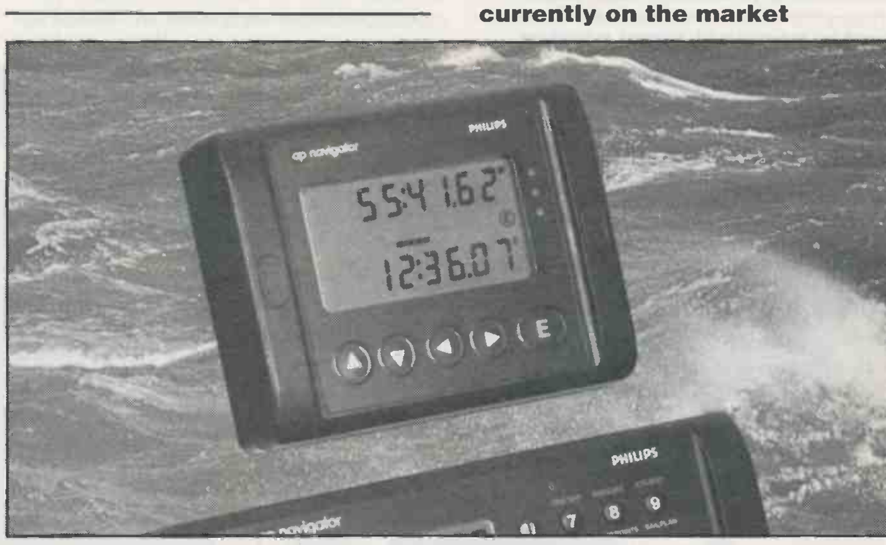
Several companies produce navigating equipment that uses the Transit satellites. Taking the Furuno FSN90 model just as an example, this is an all weather global satellite navigator with a wide variety of functions and parameters. It automatically acquires the satellite signals and displays the ships position in latitude and longitude, calculates range bearing, set and drift, and distance run. The accuracy is to within 0.1nm.

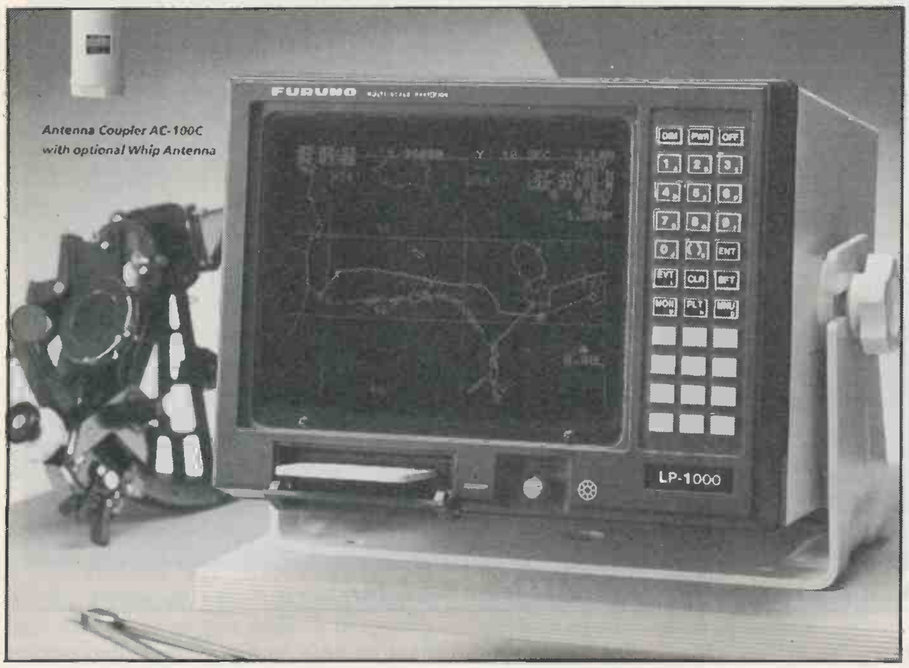
It uses a large alphanumeric display of 16 characters and three lines, touchpad prompted command menus for different functions, all acknowledged by a bleep when selected. It has ten auto-selected Rhumbline segments (too complicated to explain here!), 57 manual entries, and can function on GMT or local time. One hundred points along the course (way points) can be plotted, including 30 recorded entries of times and positions for selected events ranging from lobster pot placing to man-overboard. The navigator interfaces to Loran and GPS, video plotter, gyro or fluxgate compass, and log or paddle wheel sensors. High accuracy is ensured by corrections for speed log, magnetic compass deviation and variation, and the world geodetic system (wgs). During periods when the satellites may be out of range the system automatically uses dead-reckoning calculation to keep track of positions.

DECCA AND LORAN NAVIGATORS

Since World War Two, the names of Decca and Loran will, for many readers, be synonymous with landbased radio navigation aids both at sea and in the air. The Decca system, which originated in Britain, uses several strategically placed groups of four

The smallest Decca navigator currently on the market





An integrated Loran navigator

linked transmitters. Each group consists of a master and three slaves, each transmitting on harmonically related frequencies in the range 70-129kHz. The four signals are monitored by precision receivers and the phase relationship between them is constantly compared. From this data the craft's position can be calculated, either manually from specially notated charts, or more particularly since the advent of microelectronics, by a dedicated micro computer system. Loran began life as the equivalent American system principally for long range navigation – hence the name. It too has benefitted from technological advances.

Many companies produce navigators tuned for Decca and the Loran C systems, and capable of displaying practically every conceivable variety of course parameters, combined with built in alarm systems. Various models can automatically select the optimum master and several secondary tracking stations while travelling at speeds of up to 80 knots. Compensation can be made for magnetic variation, and up to six notch filters can be set to eliminate interference. Models have sensitivity as good as 1μV/m, with differential dynamic range of 80dB allowing for an achievable TD resolution of 0.1μs. Accuracies for lat/long can be within 0.01 minute, and range determination to around 0.01 nm. Some satnavs have separate outputs for feeding to printer, video plotter, course plotter, scanning sonar, colour video sonar, and autopilot. Others incorporate some of these facilities into the complete unit.

Quoting Furuno as an example, their LP1000 has a Loran C receiver and track plotter featuring a high resolution 7-inch yellow-green crt with a flat face and reduced glare. Chart scales can be varied from 0.15 nm to 385 nm, or as factors of 1:2000 to 1:5,000,000. The ship's track is calculated on two pages for instant switching between scales of the same course. It uses Mercator projection, and is usable between 85°N and 85°S. The built-in ram can retain a courseline with 1800 points, and 1524 event points dividable into 2, 3 or 6 blocks, each superimposable on each other, and backed up for three years without external power. An additional rom card is available for recall of factory digitised charts.

Philips have the smallest Decca navigator currently on the market. It is especially designed for small craft and has a security code function to disable it against use by non-authorised personnel.

Combining navigation with boat performance, Hercules have a model which seemingly caters for every eventuality through 46 data channels. Calibrations can be set to suit the boat, including type of rig, rating, leeway, log on port and starboard tacks, windspeed, masthead error correction, mast twist, depth datum, centreboard position, and even engine temperature and pressure. Parameters can be entered by keyboard or external computer interface (RS232C), and the unit has two serial inputs and two serial outputs conforming to NMEA (National Maritime Electronics Association). It can connect to Decca, Loran, GPS and Satnav receptions, and can be used as an autopilot.

An insight to some other electronic hardware considerations is offered by Kelvin Hughes. Their 603D employs a Z80B microprocessor with a 32K eprom and 4K of memory. The cw/mp receiver operates on the four bands 70-72kHz, 84-86kHz, 112-115kHz and 126-129kHz. A monopole aerial is used, containing a preamp/filter unit powered via the aerial cable from a switchmode power supply. Another interesting point is that the model uses a 16-character 15-segment vacuum fluorescent tube display.

PLOTTERS

Various chart plotters exist which can show full screen displays of coast lines, complete with lines of lat/long. Some have dynamic navigation window displays which can be zoomed to show entire oceans or just one's own marina.

There's nice little personal chart plotter designed particularly for the sailing market. It's from Navstar and has a high definition lcd screen with 260,000 optets. The display can be zoomed from 1:49,000,000 to 2 metres per pixel. The size is just 127 x 225 x 43mm.

Navstar personal chart plotter

Dynamic Puck Plotter

Another Navstar model, as well as updating position, also scrolls and pans to match. The zoom facility goes from 3-32,000 metres per pixel, and is equivalent to radar ranges of 0.5-4000 nautical miles. The non-volatile memory can hold up to 700,000 chart points, 20 way points and 300 nm of tracks with 20 markers. It tracks course, leg and total distance, true and compass heading, has a variable range marker, an event marker and an autopilot interface. It allows for magnetic variation, compass deviation, position calibration, depth contours, navigational aids, and has easy access to port plans. They say it is equally ideal for fishermen or long distance navigators. I should think it ought to be with all these facilities!

Colour video display plotters abound. With one in the Furuno range, plots can be drawn in any of seven colours, and can be erased of recalled at will. The display is on a high resolution colour crt, with a pixel count of 640 x 480 dots. Map scales can be selected between 1:1000 and 1:9,500,000, and are shown as Mercator projections. Data may be held on a ram card or on 3.5 inch 640 Kbyte floppy discs. This model can be connected to Satnav, Loran, GPS, a Satnav-Omega hybrid, or to other navigation equipment.

Furuno have another model which also utilises radar and echo plotting, and allows water temperature and depth sensors to modify the colour of the plotted course line. There is a choice of showing one's own craft moving in true speed while the coast lines stay on, or with one's own craft at the centre while other plots move relatively. Plots can be stored on a data recorder or cassette recorder, and an additional useful feature is that of a joystick remote control.

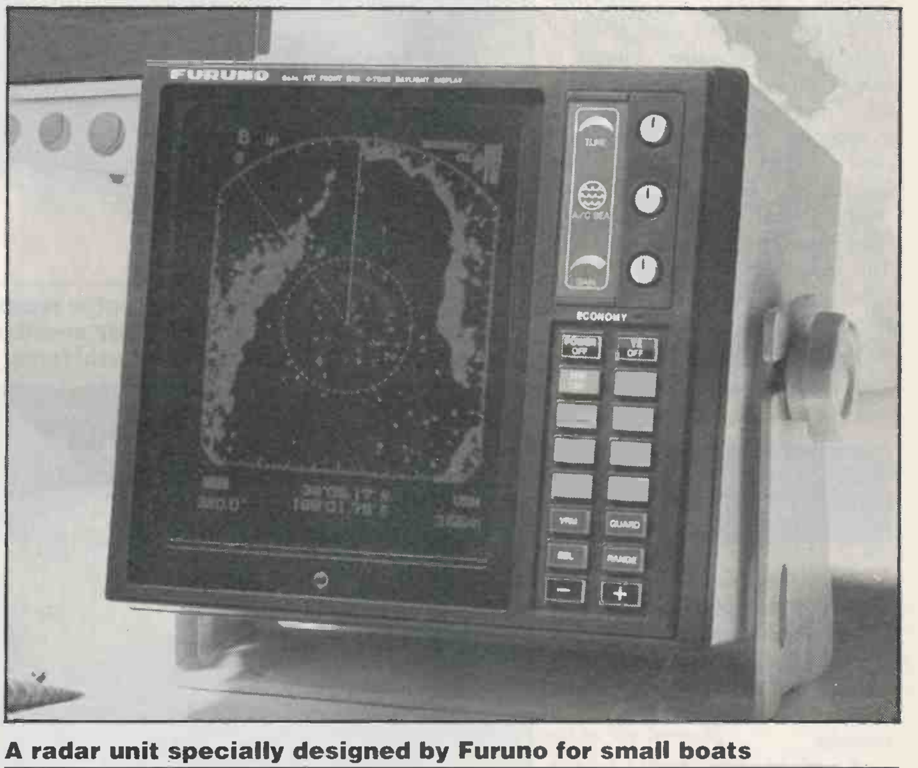
PUCK-DUCK PLOTTING

The Yeoman chart plotter (Navstar again) supposedly replaces parallel rules. It uses a moving dynamic puck, the nautical equivalent of a mouse (a duck?). In addition, it consists of an electronic digitiser connected to a computer, a waterproof pad, an lcd screen, and takes half-size admiralty charts. After selecting a chart and carrying out a simple referencing routine, the Yeoman works out its own lat/long on the chart. Accurate plotting of ranges and bearings can then be instantly carried out by simply moving the puck/duck across the chart. It is capable of providing dead reckoning, and can be interfaced to a navigation receiver. The memory can store data for 99 charts and can retain it for three months without external power. It is obviously ideal even for novices.

The ECPS Map Scan from Ampro is a unique patented navigation tool. The electronic chart positioning system consists of a pressure sensitive pad and a computer. The chart is placed on the pad, a pencil used to press on the chart at desired positions, and the coordinate is read off from the screen. It can be interfaced to Decca, Loran and other navigators.

RADAR BACKGROUND

It was apparent to early experimenters in radio transmission that radio waves could be reflected by objects in their path. By World War II this fact was being developed as a means of detecting enemy aircraft and shipping. The technique was given the name of Radar, a short-form way of saying "radio detection and ranging". To achieve satisfactory interpretation of reflected radio signals, they are transmitted as pulses via highly directional rotating aerials. The pulsed rf beam travels at about 186,000 miles per second, the same rate at which light travels. By measuring the time taken for a pulse to be reflected back to the sender, the distance travelled can be calculated and displayed on a screen. By synchronising the aerial rotation with the display, the echo pulse can be shown as a relatively placed location marker.



A radar unit specially designed by Furuno for small boats

Conventionally, cathode rays tubes have long been used as the display medium, but with improvements in solid state displays, these are increasingly taking over from crts.

Indeed, radar is yet another technology that is being revolutionised by sophisticated electronics and control software. Whereas in the 1960s, for example, radar was in widespread use with commercial and military shipping, it was a luxury for leisure mariners. Now that so many areas of electronics have been miniaturised and given greater capabilities, the cost has proportionately been reduced. It is probably true to say that pleasure boat radar as a navigational tool represents one of the most remarkable breakthroughs in modern marine history. Radar is now very much within the purchasing powers of the majority of yachtsmen and small boat owners. As a result, their navigation has been simplified and their safety at sea much improved.

RADAR TRANSCEIVERS

Of particular interest is the way in which radar signals are now processed, both for content, and for clarity of display on lcd and crt screens. The transmission frequency produced by the magnetrons is 9410MHz, ±30MHz, though different manufacturers use different pulse lengths and repetition rates, typically ranging from 0.08-0.3µs at 1184kHz. Intermediate frequencies vary from 38MHz to 60MHz, with bandwidths of around 3MHz to 7MHz. Beam widths are in the region of 5°, quite tight, but the vertical coverage is usually about 25°, so allowing craft to acquire signals even in heavy sea conditions. Antenna lengths and types vary from around 1.8 to 8 feet, and come as either open or closed radomes capable of handling wind speeds up to about 100 knots. The quoted peak powers go from 3kW to in excess of 25kW. With the exception of the magnetron and display screens, all circuits seem to be fully solid state, many of them using scrs in the modulation stages. Kingfisher quantify the hardware attributes a little further - they use a rotation speed of 25 rpm, the antenna is a centrefed slotted waveguide array enclosed in a radome, and is horizontally polarised.

Of the small marine radar models, the Swiftech seems fairly typical. Its scanner weighs only 7.6kg, and its display a further 4.5kg. It uses a 6-inch green crt, suitable for daylight viewing, and has sea and rain clutter controls to remove most of the scatter echoes leaving larger targets more clearly defined. Its direction generator is rotary encoded and an output of up to 3kW finds a range of 0.25 to 12 nm.

Still for small craft, Furuno have an ultra-compact radar with a high resolution 640 x 480 pixels display, a customised microwave integrated circuit receiver, and uses dual pulse lengths and repetition rates. Its range covers 35 metres to 16 nautical miles and has a bearing accuracy of 1°. In their words, "bells and whistles" are also included, such as variable range marking and a guard zone which can be set to give warning of objects within it.

Coming further up the scale, the Furuno 8050 shows an echo to assess targets for speed and course. Controls for off-centre and zoom are included for closer examination of areas of interest. Like all Furuno radars, this model uses multilevel quantisation (mlq) of incoming echoes, utilising eight levels to produce detailed and accurate image representations. Furuno comment that single levels of quantisation often allow images to fade in and out, whereas mlq prevents this happening. Their software incorporates routines enabling echo stretch and averaging, plus interference rejection to inhibit "rabbit tracks" typically caused by other radars operating within the area. This model can be interfaced with a video plotter that allows the radar picture to be overlaid with a geographic position plot.

COLOUR RANGING

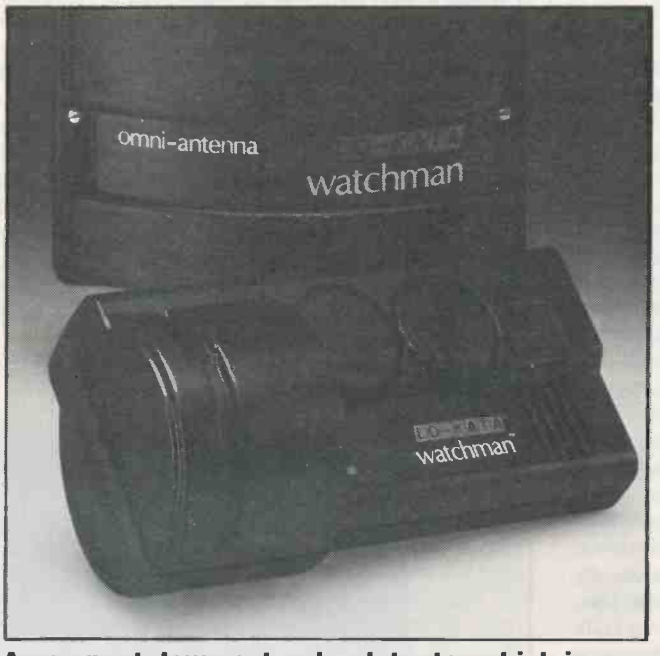
Many companies have colour radar which use rasterscan tubes of up to 20 inches diagonally and show echo strengths in several colours, typically red > yellow > green. The images can usefully be fed to a video recorder.

Some models have joystick controls enabling targets to be pin-pointed for origin, range and bearing. They can acquire several simultaneous targets in this way and, using electronic plotting, can present all the parameters pertaining to particular targets with selected symbol shapes. Some include picture freeze facilities allowing for detailed examination.

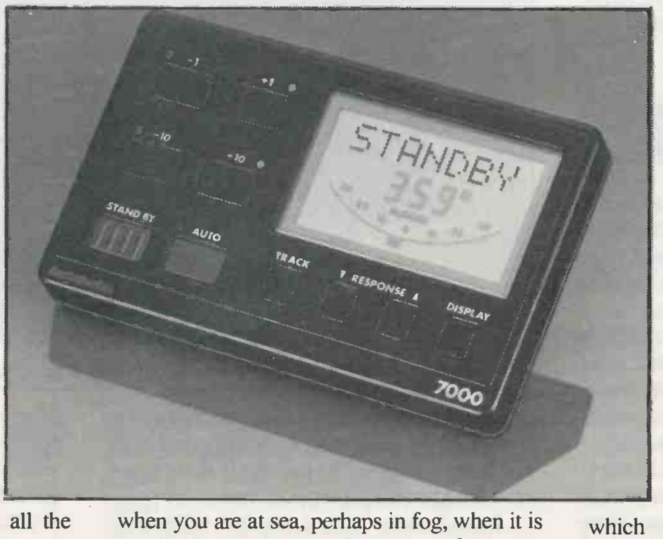
Variations and additional improvements on facilities are found on many other models, including north-up and course-up options, and true motion detectors which distinguish moving from static targets. Many can be interconnected to radio navigation systems such as Loran, GPS and Transit Satnav. Interfacing to fluxgate compasses is another option allowing the ship's bearing to be displayed on the screen.

RADAR DETECTOR

It is unlikely that you could use this next unit to detect lurking police cars on the radar prowl (which use continuous wave transmission), but it has very practical uses if you're wave-bound. For many small boats it's neither necessary, nor economic to own a radar transceiver. However, there can be times



A compact, low-cost radar detector which is ideal for very small craft. Also for smaller craft is the powerboat autopilot from AutoHelm.



when you are at sea, perhaps in fog, when it is good to have warning of a large craft bearing down on you. Lokata have just the model - it visually and audibly warns of the proximity of all large and small vessels with operating radars. Once alerted, you use the handheld direction finder to locate and monitor the movements of approaching vessels within a five mile radius. When there is more than one local radar the rdf gives an individual identifiable sound signature to each one, so avoiding confusion. It only responds to the primary radar signal and ghost echo reflections are ignored (no chance of avoiding the Flying Dutchman, it seems ...).

AUTOPILOTS

The ability to leave a craft to safely navigate for itself is of obvious importance to many seafarers of all types and persuasions. The first automatic pilots from which modern electronic units can trace their origins came about in the late 1940s. Since then there have been many significant improvements. One of them is the sensitivity that can be achieved in counteracting the effects of sea and weather. Modern autopilots are now more efficient than a helmsman in holding to prescribed courses. Commercially, this greater accuracy produces significant fuel savings. For the leisure market, boat owners and crew can enjoy the cruise in a more relaxed fashion. Perversely, I actually get a kick out of manually taking the tiller - but then my sea-scene is on a smaller scale (dinghies and inflatables!)

Autohelm claim to be the leaders in autopilots for pleasure craft; in the last 13 years more than 120,000 have been steered by their equipment. Their powerboat autopilot, the ST7000, only requires you to steer onto the desired heading and then press the Auto button, that's all. Furthermore, it seems that a real tiller could be obsolete - for changing course you simply press another button. For example, to make a 30° change to starboard, a "+10" button is pressed three times; to change by 2° to port, press "-1" twice. This really takes the use of automation to amazing levels.

However, it seems that powerboat owners cannot always depend on an autopilot to hold a reliable course while heading north at speed. If the boat makes a rapid course change or is buffeted by heavy waves, the dip in the earth's magnetic field and the force acting on the compass affects the autopilot's sense of direction. Seafarer quote that in these conditions a 20ft long powerboat loses effective control at only 10 knots, and a 50ft craft at 20 knots (no wonder my powerboat friend traverses sand banks!). Seafarer's patented solution is the use of an additional rate gyro which produces an electronic signal proportional to the rate of turn. Special software routines then use the rate gyro signal for short term control, and the compass signal for longer term control.

You dial in the course you need and set the sea state control with the Cetrek 727. Control is via a 16-bit microprocessor, fluxgate compass, plus a rudder reference and drive unit. It uses fets in a pulse width modulation drive circuit for very precise motor control in conjunction with a military specification potentiometer and an electronically operated friction clutch. Rudder feedback is incorporated since Cetrek believe that this is essential to maintaining accurate rudder position. They believe that though some manufacturers claim they can simulate rudder position, errors can occur and are cumulative. Nonetheless, Cetrek use a "ghost rudder" software simulation which will get you home in the event of a feedback failure. A two-level watchdog facility constantly checks the system integrity. Their model 737 additionally has two radio navigator interfaces, one for Satnav and the other for hyperbolic navigators.

UNIQUE COURSING

I was disturbed to read that Cetrek claim to use a unique data communications format. I hate to hear about "unique" data protocols - I'm all for standardisation and interconnectability between different manufacturer's equipment. Look at the mess we got into over computer protocols until IBM became the standard. Most maritime manufacturers seem to have standardised on NMEA protocols, though even with these there seem to be different dialects around. Still, it could be that Cetrek may have valid arguments since their fluxgate compass was used on Virgin Atlantic Challengers I and II during the Transatlantic speed record attempts.

Navico have an autopilot which reportedly has the fastest tiller hard-over time and, conscious of power conservation, they make use of variable deadband control. This can be set anywhere between 1.5° and 8° so minimising the amount of work done by the autopilot in rough seas, drawing only about 150-180mA when engaged, and 40mA on standby. The compass associated with this model is one of those that uses the Hall effect principle.

A patented drive approach is taken by Autohelm, one of whose units uses a precision servo motor to drive the wheel directly. There is an additional remote control operating via a signal cable link; infrared and ultrasonic techniques are no doubt unreliable at sea.

Robertson have a unit which can learn automatically how the rudder responds to its commands and so eliminates overshoot during steering. It can also be programmed to compensate for offset drag experienced by fishing boats hauling nets and tugs towing loads.

I was surprised to note that Neco use a conventional magnetic compass card with one model, though the data text implies that sensor coils are available for signal pick-off use.

RADIO TELEPHONES

Many companies are involved in this area of marine electronics and the range of variations on the theme is wide. I'll just give a few examples.

The RT650 manufactured by Seafarer covers all international vhf channels and is expandable by up to nine additional channels as new or private frequencies become available. It is preprogrammed for the UK Marina channel, Channel M (37), is under microprocessor control, has touch tuning, uses an lcd display, and has a selectable transmission power of 1W and 25W.

A handheld r-t is available from Swiftech, their Blackhawk LH1. It too has an lcd display, has full scanning facility over 55 international channels, plus chan 37, and the equivalent US channels. Sailor's r-t range includes facilities for 100 quick-select channels, all ITU telephony channels, and ten operator programmable scans with up to 128 channels in each. Other functions include flywheel tuning, keyboard controls, lcd readout, eprom memory, and frequency synthesis with a resolution of 10Hz. (You may recall that Robert Penfold looked at frequency synthesis in PE June 87.)

Naturally, Marconi are one of the companies with r-t equipment. Amongst other items, they have a neat multipurpose communications centre that looks similar to a slightly oversized modern telephone.

Seafarer's VHF radio telephone is designed and built in Britain

RADIO TELEX

Radio telex is a facility readily available via Navtex, an international system which will ultimately be extended to provide navigational and meteorological information to vessels sailing within 200 miles of all coasts worldwide. The system is sponsored by the International Meteorological Organisation (IMO) and the Hydrographic Organisation. Transmissions are timeshared on a common international frequency (518kHz, fsk), the service is free to users and no license is required.

CAS offer a model designed for use with an IBM PC compatible computer, a compact ARQ telex modem and a software package. Their Castor-1 will decode Navtex broadcasts, supports ARQ, FEC and Selfec modes of operation, and can print out hard copy. If the PC is in use for other purposes the model can continue to receive messages, storing them until required. PE

Due to lack of space in this issue the conclusion to this article is held over until next month.

A Radio-telex model from Lokata uses automatic error-correction routines

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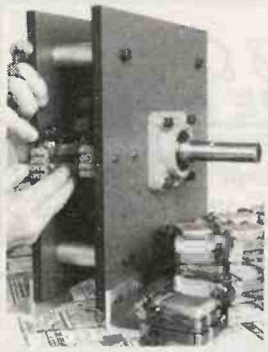

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NOTEBOOK

IN THE IMAGE OF HIS CREATION

BY TOM IVALL

Welcome the machine in its own nature, not as a rival and reflection of ourselves. We can be neighbours.

"In due time, I believe that the application of Artificial Intelligence will swamp in magnitude all other applications of computing" said Brian Oakley, the chairman of Logica, in a recent lecture. As he was also the director of the UK's Alvey Programme on information technology for five years he should be in a position to make an authoritative comment on the subject.

If this forecast turns out to be true we can expect AI to have a considerable effect on our lives one way or another. How this takes place will probably not be at all obvious or striking. AI will most likely infiltrate the existing applications of computing, through both hardware and software, in a very gradual way. Its initial purpose will be to enhance and expand the abilities of the conventional Von Neumann type of computers through new forms of software. We see this happening already with expert systems (which I discussed in the July 1986 issue). Applications are developing in medicine, economics, business, aviation, military surveillance, scientific research and engineering design.

Some of these expert programs – which rely on databases of knowledge derived from accumulated human experience – are used in independent information processing systems. Others, as I discovered from a recent IEE conference, are now being linked, in an on-line fashion, to conventional electronic digital signal processing systems. The idea is that the database of empirical knowledge helps the signal processing system to cope with incoming data from the real world which is somehow inadequate – distorted, incomplete, erratic, unpredictable and so on. It embodies perhaps years of previous human experience in dealing with such difficult material by making use of patiently acquired rules of thumb. These rules are codified into software in the knowledge base.

When eventually the average person becomes aware of AI it will probably be in a casual, incidental way. He or she may discover, for example, that a doctor's diagnosis or a reply to a telephone enquiry has been made with the aid of a knowledge-based system. But then eventually will come a general dawning of awareness of what has been going on behind the scenes – just as it was with conventional computing.

I wonder what the psychological effect of all this will be on human beings. Will it increase their feeling of power in a collective sense, rather like a nationalistic fervour? Or will it make them feel even more like helpless cogs in a vast machine which grinds on regardless?

Much depends on how the presence of non-human, alternative forms of intelligence will affect man's image of himself. Already simple muscle power has been devalued by industrial machinery. Human mental power in certain tasks like arithmetic calculation, manipulation of data and control of machines has been devalued by electronic computing systems. Now, the uniqueness of our power to exercise intelligence in solving problems seems to be under threat. And this is coming perilously close to the core of the human personality.

The challenge to the self-image arises from our technological ability to produce these clever systems. In earlier times man understood himself as a creature, made in the image of his creator – God (at least according to the Christian bible – Genesis 1, verses 26, 27). Nowadays, in the age of advanced machines, man is beginning to see *himself* as the all-powerful creator – and in the image of his own creation, the machine. Science has already taught us that we are made of the same atoms as everything else in the world. Our bodies function according to the same laws of physics, mechanics and chemistry as inanimate objects and systems. It's a reasonable inference that we are in fact machines, albeit of a very complex order.

The crucial question is: whether we are *nothing but* machines. Most people are repelled by the mere idea of this possibility. It has given rise to the age-old philosophical problem of free-will versus determinism. Machines are deterministic in that their future behaviour can be completely predicted from present knowledge of their structure and initial conditions. If humans are nothing but machines, their future behaviour can be determined in advance and free-will is an illusion.

Most of us reject the reductionist concept because it denies what we believe to be our truly human characteristics – of purpose, freedom, individuality, subjectivity and moral choice. But AI, by simulating human intelligence, further strengthens the position of inanimate machines relative to ourselves. In so doing it chips away a bit more of our belief in man's apartness from the rest of nature. The self-image is modified. Some psychologists, indeed, consider that we are already suffering from a modern neurosis as a result of unthinkingly adopting the image of the machine and allowing this to undermine our experience of ourselves as responsible beings.

It seems to be a problem with which we shall have to grapple. An optimistic approach to a solution for us is suggested by the philosopher and psychologist Margaret Boden in her book *Artificial Intelligence and Natural Man*. She thinks that human beings suffer a neurotic distress in this situation because they see "an unbridgeable metaphysical gulf between themselves and machines." She says that this "assumption of total incompatibility between mechanism and humanism" is mistaken.

I take this to mean that we shall be happier if we avoid a hang-up on this emotional question and accept the new machines – whatever their nature – as compatible with ourselves, in something like an ecological sense. They should not be regarded as dangerous rivals but as other creatures sharing the same environment which, after all, we are partly responsible for making.

Professor Boden also thinks that computional models of intelligence are markedly more "human" than the behaviourists' models of mankind that have been widely accepted for years. And computational ways of thinking about thinking, she says, are more encouraging to those who are struggling to learn than is the common view of intelligence as a mysterious attribute which one either has or doesn't have. PE

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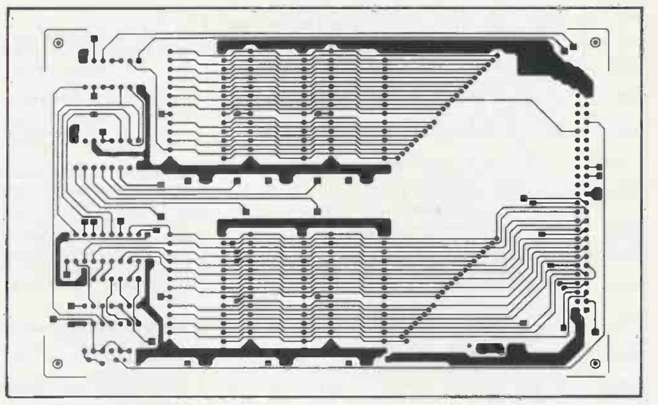

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