PRACTICAL
ELECTRONICS
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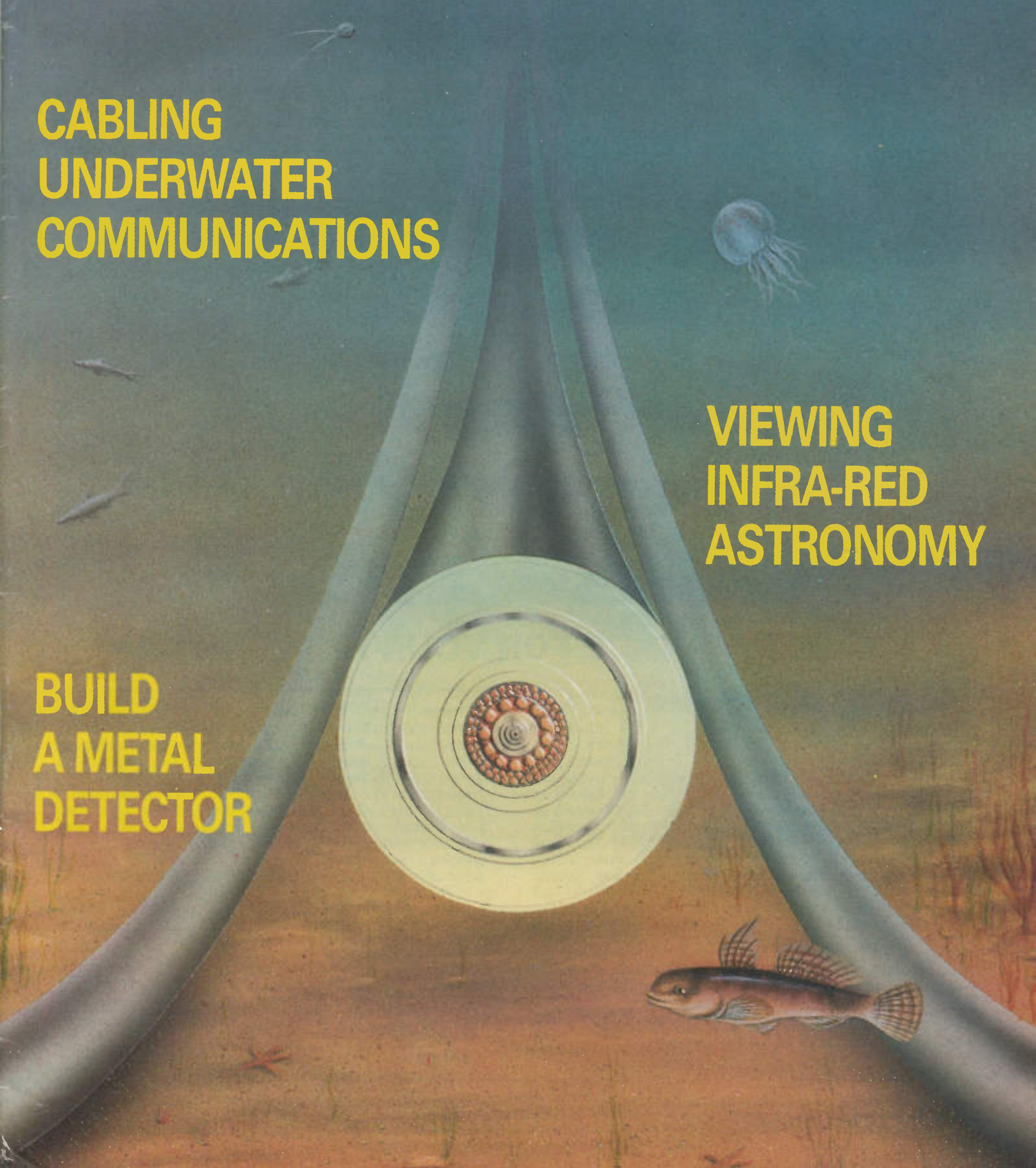
SCIENCE & TECHNOLOGY



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B **Realistic PRO-2021.** Features direct keyboard entry, search and scan in two speeds and two-second scan delay. Priority function will automatically switch to the priority channel when a call is received on it and individual lock-outs for temporarily bypassing channels. Scan up to 200 channels in these bands: VHF Lo 68-88 MHz, VHF AIR 108-136 Mhz, VHF Hi 138-174 MHz, UHF Lo 380-470 MHz and UHF Hi 470-512 MHz. Easy-to-read LCD channel/frequency display with electroluminescent back-lighting, squelch control and built-in speaker, telescoping aerial. Jacks for external speaker, external aerial, tape recorder and DC power supply. Size: $3^{1}/_{8}$ x $10^{1}/_{4}$ x 8". Includes mounting bracket for mobile use and DC power cord. Mains operation (or 13.8 VDC neg. gnd.). Memory back-up requires 9v battery. **20-9113** **£199.95**

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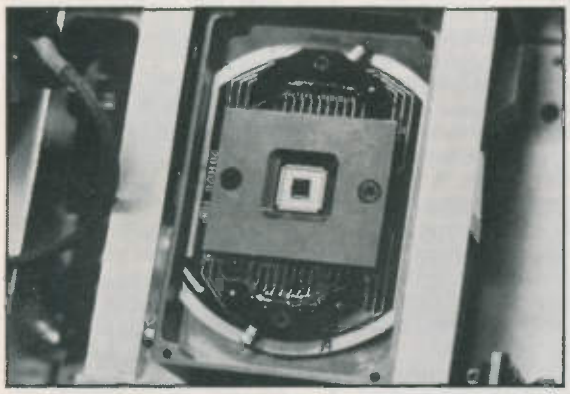
PRACTICAL ELECTRONICS

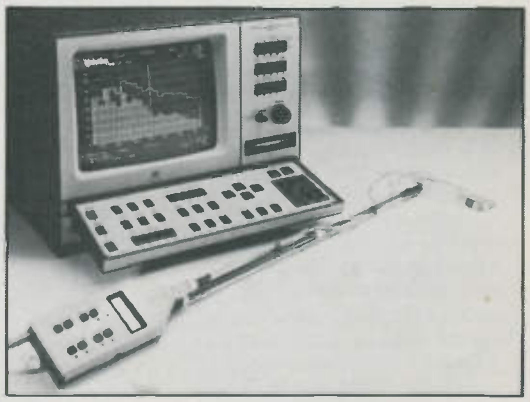
PE VOL 24 NO 10 OCTOBER 1988

CONSTRUCTIONAL PROJECTS

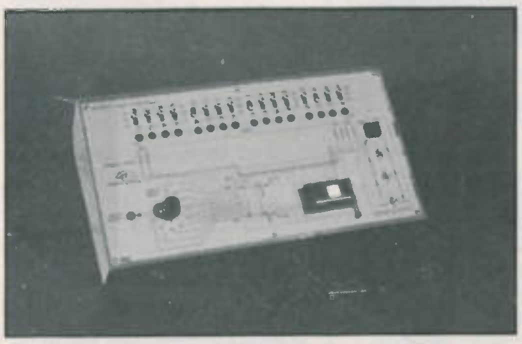
SPECIAL FEATURES



REGULAR FEATURES



PRODUCT FEATURES



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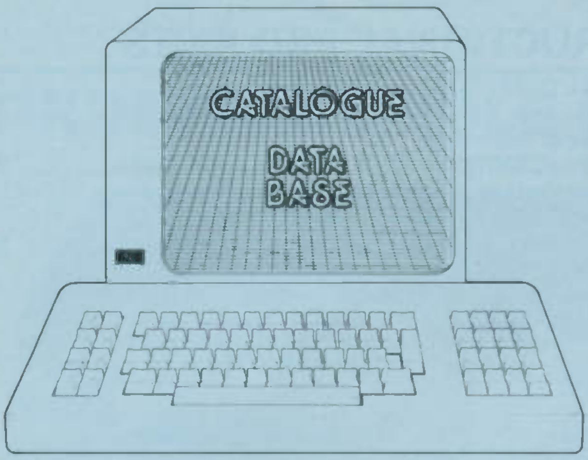
THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS ENTHUSIASTS



We have recently received the following catalogues and literature:

CATALOGUES

We have recently received the following catalogues and literature:

Omni's 56 page catalogue is tightly packed with the components and hardware **vital to anyone interested in diy electronics.** Omni offer a counter sales service from their shop as well as an efficient mail order delivery service, both accompanied by a **helpful, personal attitude** towards customers. **Omni Electronics,** 174 Dalkeith Road, Edinburgh. EH16 5DX.

Hitachi has published a 16-page brochure describing its **range of ZTAT semiconductor devices.** A ZTAT (Zero Turn Around Time) is a single chip microcomputer in which the mask rom is replaced by a cmos eprom that may be one-time programmed using a standard prom programmer. **Hitachi Europe Ltd,** 21 Upton Road, Watford, Herts, WD1 7TB. Tel: 0923 246488

Master Heat Tools have announced a new brochure on their full **range of butane powered soldering irons** and heat tools. Among the range is the Ultratorch soldering iron which is available in sizes ranging from a **miniature pen-clip pocket unit,** to a heavy-duty 3-in-1 heat tool for work on large power cables. **Master Heat Tools,** Unit M, Portway Industrial Estate, Andover, Hants, SP10 3LU. Tel: 0264 51347.

Ambar Cascom have an excellent selection of liturature covering many semiconductor **products relating to EPLDs,** their characteristics, design criteria, simulations and applications. This information will be of great interest to those who have been following our PLD and Microprocessor Development articles. **Ambar Cascom Ltd,** Rabans Close, Aylesbury, Bucks, HP19 3RS. Tel: 0296 434141.

ICW will be delighted to supply serious enquirers with a catalogue covering an extensive variety of **specialist capacitors,** ranging from miniature polycarbonates to high-voltage and high capacitance metal cased can-types. **Values of up to 400μF at 1500Vdc** are stocked. **Industrial Capacitors (Wrexham) Ltd, Miners Road, Llay Industrial Estate, Wrexham, Clwyd, LL12 0PJ. Tel: 097883 3805.**

Acrom has published a 24-page catalogue detailing its most recent **STEbus board, software and enclosure instructions.** Entitled 'The News', the guide covers their pc-compatible board set, including 8088 graphics, disk controller and serial-parallel i-o, a new 80188 cpu board for **low cost target systems,** and a general purpose colour video controller based on the ACRTC chip. **Arcom Control Systems Ltd,** Unit 8, Clifton Road, Cambridge, CB1 4WH. Tel: 0223 411200.

Epson have sent information about their printer mechanism range. They claim to have a **miniprinter for every application** and although they are basically intended for professional applications, anyone looking to make their own **custom-built printer** will find Epson's information of considerable interest. Epson also have a good **range of large lcd modules,** including a new Super TN high contrast version with 640 x 200 dots. The products are sold through Epson's distributors, details of which and the hardware available, can be obtained from **Epson (UK) Ltd,** Dorland House, 388 High Road, Wembley, Middx, HA9 6UH. Tel: 01-902 8892.

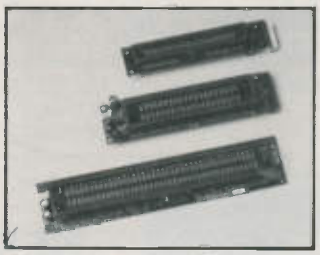
WHAT'S NEW

Top Analyst

A sophisticated new system of spectral analysis equipment has been announced by Bruel and Kjaer. It offers a wide range of facilities for noise and vibration measurement in real time, together with post-processing power and storage capacity to make a computer redundant in most applications.

The basis of the system is a powerful narrowband analyser suitable for coventional noise measurement or for accurate pinpointing of machinery noise and vibration sources. A second channel is added to offer the additional benefits to two channel and cross channel functions for measurement of sound intensity, particle velocity and the complex cross-spectrum. Bruel and Kjaer say this instrument is the most powerful intensity analyser on the market.

Contact: Alan Gibson, Bruel & Kjaer (UK) Ltd., 92 Uxbridge Road, Harrow, HA3 6BZ. Tel: 01–954 2366.



Super-slim

STC Mercator has launched a new 'super-slim' range of dot character display modules.

The CU-SCPB Series includes devices measuring just 176 x 44 x 28mm featuring an 8-bit bi-directional parallel data bus and user definable programmable fonts. Working from a 5V supply, power usage is 300mA for the 5-font 2 x 20 version and 70mA for the 2-font 2 x 40 device.

In the same series is a 'compact' 1 x 20 unit costing less than £40 and measuring 150 x 32 x 24mm. This has an 8-bit parallel and serial input (1200bps) and a command base 8-step dimming function. Other features include a user-programmable font; a uni-directional data bus; and a 5V, 100mA (typ) power requirement.

Contact: STC Mercator, South Denes, Great Yarmouth, Norfolk NR30 3PX Tel: 0493 844911.

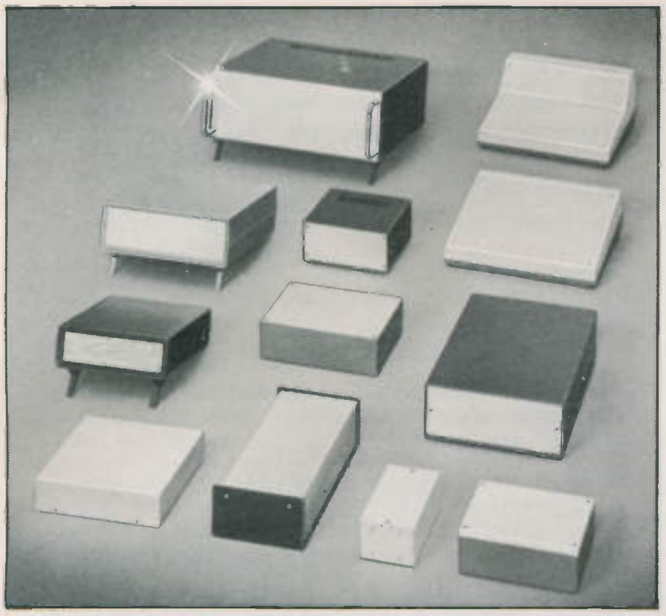
Switching Debits

A major new debit card scheme called 'switch', which enables customers to make payments electronically in retail outlets has been announced by three leading UK banks – Midland, National Westminster and The Royal Bank of Scotland.

The joint scheme is expected to be operating this autumn and to have at least ten million cardholders by the middle of next year.

It differs from other card systems as the processing will be entirely electronic, which brings the benefits of speed and convenience to customers and retailers alike by cutting waiting time at checkouts. It will also remove much of the paper and associated backroom work of alternative payment methods.

The system will involve ATM/cheque guarantee cards issued by the members being 'swiped' through point-of-sale terminals which store the details of the transaction after verification by customer signature. The information will be subsequently passed to the members on tape or via telecommunication links for the appropriate debits and credits to be completed in the normal cheque clearing cycle.



Retex Cases

Retex UK are now stocking the top quality instrument case range manufactured by their Spanish counterpart in Barcelona.

The ever increasing range has twelve desk console styles and fifteen instrument case styles in varying sizes plus a comprehensive Eurocard system. Included are three ranges with anodised aluminium front panels and moulded cases. The Abox desk consoles have single or dual front panels. Elboxes are rectangular with intergral tilt feet and Polyboxes are also rectangular with internal pcb guides.

To minimise transit damage and storage space, all of the large sized and some small desk consoles and instrument cases are supplied flat-packed.

Prices are very competitive and quality excellent because of the high level of automation in the Retex factory. Exports to many European countries, North America and Australia, already accounts for over 70% of their production.

Contact: Retex UK, Electronic Distribution Services, 8 Trehaven Parade, Woodhatch, Reigate, Surrey, RH2 7LL. Tel: 034284 2879.

Optical Waveform Analyser

The Photodyne 1500XP optical waveform analyser is a compact and versatile unit that converts optical input signals from lasers, leds and fibre optic cables, etc into electrical signals. These can be fed directly into a wide range of electronic measuring instrumentation such as oscilloscopes, waveform analysers, lock-in voltmeters, spectrum analysers, distortion analysers.

In the case of an oscilloscope, the optical waveforms displayed can be direclty calibrated in units of optical power: μW, mW,W. Frequency response is flat from dc to 200MHz.

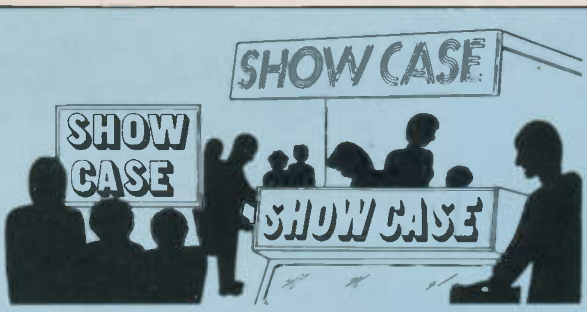
Each analyser is factory-calibrated at 820nm, and an accompanying detailed chart gives full information for applying correction factors enabling it to cover a wide variety of other wavelengths.

A large rod lens ensures easy and efficient input coupling while output is taken from a standard BNC connector. No tuning is required; the unit just needs switching on and one of four ranges selecte by pushbuttons.

The 1500XP is completely self-contained and powered by two 9V batteries. Measuring only 3.4 x 4.8 x 1.5in. (94 x 122 x 38mm) it weighs just 6lb (3Kg).

A range of threaded input adaptors is available as is an input attenuator giving 10,000X attenuation – especially useful when working with laser sources.

Contact: Lambda Photometrics Ltd., Lambda House, Batford Hill, Harpenden, Herts, AL5 5BZ. Tel: 05827 64334.



COUNTDOWN

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.

Sep 6–8. Coil Winding. Wembley Conference Centre. 0799 26699.

Sep 8–12. Sim-HiFi-Ives. International video and consumer electronics show. Milan. 02-4815541.

Sep 27–30. DES. Design Engineering Show. National Exhibition Centre. Birmingham.

Oct 11–13. British Laboratory Week. Grand Hall, Olympia. 0799 26699.

Oct 18–20. Brighton Electronics Show. Metropole Hotel, Brighton (filling the slot vacated by Internepcon). 0822 614671.

Nov 1–3. Custom Electronics & Design Techniques Show. Heathrow Penta. 0799 26699.

Nov 29–Dec 1. DMC-PC. Drives, motors, programmable controllers etc. National Exhibition Centre, Birmingham. 0799 26699.

Dec 11. Satro Annual Computer and Technology Show. Music Hall, Aberdeen. 0224 273161. Satro, the Science and Technology Regional Organisation is a non-profit making organisation dedicated to supporting and enhancing science and technology education. Profits from the show will be devoted to developing computer and electronics clubs. **We hope it will be well supported.**

1989

Apr 5–6. Laboratory Science and Technology Show, Kelsey Kerridge, Cambridge. 0799 26699.

Apr 25–27. British Electronics Week. Olympia. 0799 26699.

Super Power

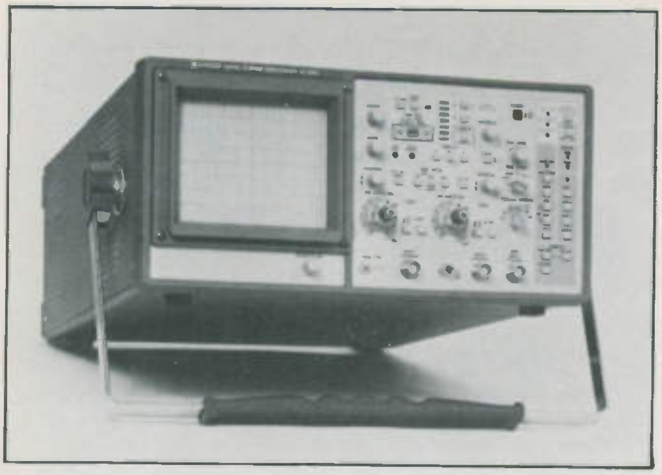
New from Bonar Advance is a range of up to 1800W single output SuperSwitcher power supplies which have ratings of 2V/200A up to 48V/36A and are designed to meet the tough safety and emission specifications of VDE, IEC, CSA, UL, and FCC.

Features include user selectable input voltage of 90-132 or 180-264V ac (47-63Hz); output voltages of 2-48V dc which are user adjustable via a front panel potentiometer; an efficiency of typically more than 75%; and overvoltage and thermal shutdown protection as standard.

The psus also have a line regulation of 5mV or 0.1% and a load regulation of 10mV or 0.2% at any load up to 100% of rated load with remote sensing. Ripple and noise are 1% or 50mV peak-to-peak, whichever is greater and the temperature coefficient is better than 0.02%/°C.

The Series 9 range of SuperSwitcher power supplies are supplied in industry standard case sizes and have an operating temperature range of 0-70°C.

Contact: Bonar Advance Limited, Raynham Road, Bishop's Stortford, Herts, CM23 5PF. Tel: 0279 55155.



100MHZ Storage Scope

STC has introduced the Hitachi VC-6165 digital storage oscilloscope which provides high-speed sampling of up to 100M samples/s via two channels simultaneously, and enables storage or single-shot events up to 25MHz.

Storage of repetitive events up to 100MHz (−3dB) by equivalent sampling is possible and the scope can be used for 100MHz bandwidth real-time monitoring with such facilities as delayed sweep, sweep time autoranging, trigger lock and crt readout.

Its many features include independent 4K word memories for both channels; two 4K word battery-backed memories which last for up to 72h from the last power on; an 'envelope mode' which enables the user to capture the glitch and to extract the envelope; an 'averaging mode' to permit observation of signals buried in noise; a 'roll mode' for continous observation of a stored waveform on the crt; post-trigger (1μs to 5s by time base B sampling) and pre-trigger (0 to 9.9div) facilities; a crt acceleration potential of approximately 17kV; and vertical system sensitivity of 2mV/div to 5V/div ±3%.

A built-in plotter interfaces can be used to provide a hard-copy of the waveform with the necessary scales and settings while the CP-IB(IEEE) interface and a switchable probe are standard.

Contact: STC Instrument Services, Dewar House, Central Road, Harlow, Essex CM20 2TA Tel: 0279 641641.

Atari Oscilloscope

K-Scope and K-Spect, two new products from Kuma Computers Ltd, enable Atari ST microcomputers to be used as an oscilloscope or spectrum analyser.

Both products consist of an interface box which connects to the rom port of the ST together with the relevant software. Both software packages operate under GEM, making control of the various settings and easy to adjust and clearly displayed.

K-Scope provides the necessary hardware and software to convert the ST into an audio frequency oscilloscope. The specification is: dual port (BNC), 3mV to 30V per division software selectable, ac/dc to 30KHz, signal invert, sync or trigger, X10 on timebase option, 1/256 vertical resolution. The primary purpose of K-Scope is to provide a route for displaying, capturing, analysing and manipulating repetitive audio signals.

K-Spect turns the ST into a low frequency dual channel Spectrum Analyser. The provisional specification is: Channel AB input (BNC) which can be used as A or B, A+B, B/A, coupled ac or dc, normal or inverted. The signal can be locked or free running with a frequency range: Fmax 1 to 35KHz in 1KHz steps, Fmin 0 to 24KHz in 1KHz steps, bandwidth (Hz) 781, 390, 195, 98, 49, 24, 12. Scale: Linear or Log.

Both K-Scope and K-Spect are available now, the price for each is just £149.95 including vat. The K-Spect software is available separately to K-Scope purchasers at a cost of £89.95 including vat.

Jon Day, Marketing Director of Kuma said, "These products are especially suited to educational establishments which need computing and scientific instrumentation, but have restricted funds. K-Scope and K-Spect give added functionality to an Atari ST purchase and give a unique price/specification combination."

For full details of these and the complete range of Kuma products for the Atari ST contact: Kuma Computers Ltd, 12 Horseshoe Park, Pangbourne, Berks, RG8 7JW. Tel: 07357 4335.

CHIP COUNT!

This month's list of new component details received.

AD639. Universal trigonometric function generator. A complete fully calibrated synthesis system including all standard functions of sin, cos, tan, cosec, sec, cot, arosin, arccos, arctan etc. and with a 1.5MHz bandwidth **(AD).**

AU2901-2904 series. Extended temperature range versions (−40°C to +125°C) of the LM2901-4 series of linear ics already used by the automotive industry for electronic engine management system circuits. **(PL)**

DH-OA32. A state-of-the-art hybrid thick film audio opamp designed for professional audio and precision instrumentation. **(DP)**

HA19214. Low power 10-bit video ADC that combines a 20 msps conversion rate with an unusually low power dissipation of only 900mW, and containing an internal s&h and ttl-cmos compatible i-o lines **(HT)**

HD153201 and HD153202. A pair of devices that simplify the design of high speed optical data links. Consisting of a codec and pll respectively, the pair can perform simultaneous conversion in both directions, at data rates up to 32 Mb per sec. **(HT)**

HD404808 and HD4074808. 4-bit ZTAT microcontrollers which combine an on-board, one-time programmable prom with 8K x 10 rom, an integral lcd driver-controller and three timers, including a watch clock. The HD404808 is a mask-programmed version. **(HT)**

HD63143. Universal pulse processor containing the UPP core, 1K x 8 ram, a microprocessor interface, 16 bidirectional i-o lines and two serial communications ports. **(HT)**

(AD) Analogue Devices – contact Verospeed, Boyatt Wood, Eastleigh, Hants. SO5 4ZY. 0703 644555. **(DP)** Deltec Precision Audio, 16 Claude Road, Roath, Cardiff, CF2 3PZ. 0222 482818. **(HT)** Hitachi, 21 Upton Road, Watford, Herts. WD1 7TB. 0923 246488. **(PL)** Philips Components, Mullard House, Torrington Place, London, WC1E 7HD. 01-580 6633.

Turbo Modem

The new range of Enterprise modems from Anglo Computers has been designed to cate for the needs of every user, from a simple V21/V23 version, to the top of the range 'Hayes' compatible V21/V22/V23 Enterprise II Turbo modem.

Unique features on most modules are auto-adaptive dialling, automatic Mecury log-on facilities (including a secret password store), 8K ram and an 80 entry battery backed number store, in addition to on-board speaker etc.

All modems are fully BABT approved for PABX and PSTN use, and use cmos technology for low power comsumption and cool continuous running. Prices range from £99.95 plus vat to £229.95 plus vat.

For Further Details Contact: Anglo Computers Ltd, Unit 3, Cefn Llan Science Park, Llanbadarn Fawr, Aberyswyth, SY23 3AH. Tel: 0970 624321.

Mainly Curly

A new range of mains sockets announced by Briticent features curly leads and meets the latest safety standards. They provide safe and portable power in commercial, industrial and diy applications. The British made products incorporate the best in quality, toughness and thoughtful design.

Curly cables are used on the entire range with two lengths options, 2.5 and 5 metres (extended). Four-square, fourline, twinline and monoline socket options are offered, providing wide applications potential. The four-and twin outlet sockets feature mains-on neon indicators and easy wire terminal covers. The four-in-line models are also switched and fused. All the sockets have mains cable grommets and are supplied with sleeved 13A plugs meeting the new BS1363/A.

Fully shuttered live and neutral terminals are standard and the socket bodies are designed to discourage the dangerous practice of inserting plugs from the wrong side of the socket (with just the earth pin inserted so as to open the shutters).

Contact: Trevor Parvin, Briticent International Limited, Crow Arch Lane, Ringwood, Hampshire, BH24 1NZ. Tel: 0425 474617.

Re-Recordable cd

Tandy have announced a revolutionary development on optical disc media, Tandy Thor-CD. With the introduction of this technology, it is now possible to record and erase digital information on a cd-compatible optical disc.

Using a laser beam, the system can repeatedly record, playback, store and erase music, data or video on a disc that can be used with all existing cd audio and cd-rom players.

Just as important, it is expected to be less expensive than alternative digital audio formats, including digital audio tape (dat).

Thor-Cd will have applications in several fields of electronics, stated John V Roach, Tandy's President, and its commercialisation in audio should be rapid. Its applicability in mass memory is long sought after, and it may have video applications as well.

Thor-CD playback technology follows the same technique used in conventional optical discs: using a laser beam to read a series of microscopic pits in a light reflecting disc.

What brings the technology breakthrough in optical media is that the pits, while environmentally stable and permanent in nature, can be erased, allowing editing and re-recording, over and over again.

Because the optically-formed pits resemble those in a conventional, molded cd in fit, form and function, the technique retains all of the extraordinary qualities of current cds.

The technology is the result of years of research and development at the Tandy Magnetic Media Research Center in Santa Clara, California. Exhaustive testing has confirmed Thor-CD's ability to record, erase and play back digital information that is vitually indistinguishable from the original source material. What's more, erasing a previously recorded signal instantaneously returns the media to its original state, ready for the next recording.

The first commercial use will be cd-audio, for which there appears to be a substantial market for a recordable cd disc. CD–audio is also the least demanding on the hardware and the media. The additional cost in electronics and drive mechanisms should permit play and record decks to be offered in the early years of development for under $500.

The next likely commercial product, Tandy believe, is a data storage device which requires greater precision and error checking capabilities. Thor-CD technology will fit well in the high-density storage field with storage capabilities in the hundreds of megabytes per five-inch disc.

Thermal Digitising

The new Therma B40 bench thermometers have been designed as general purpose mains operated units for the electronic engineer or technician who requires a digital thermometer which can measure a varible number of different thermocouples continuously, within a temperature range of –50 to +1150 degrees with one degree Celsius resolution, repeatability and accuracy.

By simply plugging in up to 12 temperature probes, the unit with its inbuilt selector can read any desired probe temperature. The instruments are housed in sturdy ABS cases and come complete with a dual purpose carrying handle/adjustable stand.

The price range is from £135.00 and a wide range of probes are available.

Contact: Electronic Temperature Instruments Ltd., PO Box 81, Worthing, W. Sussex, BN13 3PW. Tel: 0903 202151.

British Students Awarded

At the recent prize-giving ceremonies at the International Science and Engineering Fair in Knoxville, Tennessee, two British students won honours for their projects.

Nicole Ballantyne (aged 17) of Crosspool, Sheffield, South Yorkshire, received a second grand award in behavioual and social sciences for her project which is a music notation aid. Her prize is $350.

Nick Rose (aged 19) of Cublington, Leighton Buzzard, Beds, won two awards for his digital electronic map measurer – a second award in electrical engineering, worth $50, from the Patent and Trademark Office of the US Department of Commerce: and a third grand award in engineering, prize $200.

Nicole and Nick were among teenagers from six nations sponsored by Westinghouse Electric Corporation to participate in the 39th annual worldwide competition.

The UK students are selected from competitors in science and technology fairs and competitions throughout the UK by the British Association for the Advancement of Science.

Contact: Ruth Woodhead, Westinghouse PR, 13 Knightsbridge Green, London, SW1X 7QL. Tel: 01-581 4393.

No More Sore Fingers

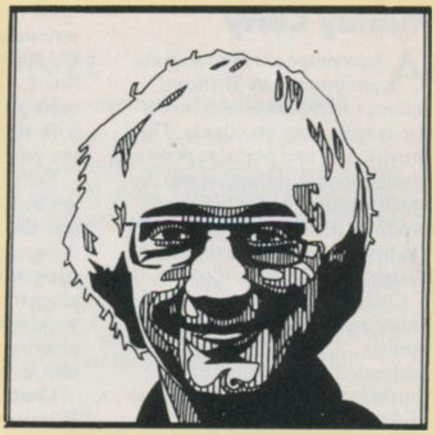
The new DCFT wire twister can be hand held or bench mounted with footswitch control and has its own set of fingers mounted on a centrigugal head to twist stranded wires neatly and pracisely all day long without the need to raid the medical cupboard for plasters.

Contact: Rush Wire Strippers, Unit M, Hunting Gate, Andover. SP10 3LU. Tel: 0264 51347.

SATELLITE BATTLES

BY BARRY FOX
Winner of the 1987 UK Technology Press Award

MAC PATENTS MISS OUT



As D-MAC flounders in a slough of politics and indecision, it looks as though dear, decrepit PAL is going to take the winners' stand once more.

In a classic case of free enterprise run riot, British Telecom is helping to split the previously agreed transmission standard for satellite broadcasting across Europe. On the very day when Rupert Murdoch announced that he was leasing four channels on Luxembourg's Astra satellite through British Telecom, and will start broadcasting this winter using the PAL transmission system and £199 dish systems made by Amstrad, British Telecom announced a deal with Murdoch's rival Robert Maxwell and W.H. Smith to offer a quite different package of programmes to be broadcast next year from the same satellite using the quite different D-MAC transmission system.

Murdoch's surprise move completely re-writes the rules of the satellite game and neatly avoids the tangled web of technical problems which are currently stymying the new MAC technology. But it pulls the rug from under Europe's carefully constructed plans to create a single pan European standard for direct broadcasting by satellite, lay the foundation for a future high definition tv system and use patents to shield Europe from a flood of low cost imports from the Far East. It also cripples Britain's own national satellite service, BSB, which is due to start broadcasting late next year and is compelled by the government to use the MAC tv system.

British Telecom is a partner to the Sky plan because BT International had previously bought control of 11 out of the 16 transponders on the Astra satellite. Previously BT had recommended that the new MAC tv system should be used on Astra because of its ability to carry digital data piggy back on the picture signal. The belt hedging spoiler plan by BT, Maxwell and W H Smith to transmit a rival package of programmes in the MAC system prefaces the Astra – BSB standards battle – and looks certain to end in tears for the Maxwell camp.

Although all parties refuse to discuss prices charged by Astra, BTI has been asking over £4 million per year per channel; by buying first and in bulk, Sky has secured four channels for the price of three. By buying first, Murdoch has secured the four transponders on Astra which will give the strongest signal for Britain.

The MAC system (multiplexed analogue components) was developed by the Independent Broadcasting Authority and adopted by the European Broadcasting Union as a standard for all satellite broadcasting in Europe.

MAC uses 625 line pictures, like PAL, but improves quality by transmitting the colour and black and white information separately. The sound is digitally encoded, with room in the bit stream for up to 8 simultaneous channels or a rapid stream of data, eg teletext or business information.

...on technical grounds Murdoch's approach offends, on commercial grounds he's a sure-fire winner...

The EBU and all European governments saw the adoption of MAC as a golden opportunity to set a single, improved quality, tv transmission standard for the whole of Europe. A Eureka project is already developing technology to upgrade MAC into a high definition wide screen system, while still retaining compatibility with conventional MAC. By spurning MAC for Sky channel, Murdoch, Astra and BT are also spoiling the plan to use patents on MAC to protect the European electronics industry against a flood of low cost imports from the Far East. The PAL patents were for 20 years used in this way, but are now dead and MAC was seen as their legal replacement.

A year ago the IBA, Thomson of France, Philips of the Netherlands and the French Government broadcasting research centre at Rennes, pooled their patents on MAC technology and set up a licensing authority in Paris called MAC Packet. Any manufacturer wanting to make MAC receivers must buy a licence, and they only get favourable terms if they manufacture in Europe.

A squabble between Britain and the Continent over which variant of MAC to use has delayed the supply of chips for receivers. There is also no agreement yet on a standard for encryption to let only paying viewers watch. D-MAC, as chosen by Britain, will not be ready until well after Astra starts broadcasting.

"MAC is a millstone round BSB's neck", says Marcus Bicknell, Commercial Director of Societe Europeenne des Satellites, the Luxembourg company backing Astra. "It's technology invented at a broadcasting conference ten years ago".

"PAL is the best existing technology available", says Rupert Murdoch. "The so-called wizard MAC technology is just a conspiracy amongst manufacturers to sell more tv sets".

"MAC doesn't exist", says Amstrad Chairman Alan Sugar. "If you wish to enter the market quickly, you should do it via PAL".

Alan Sugar says he hopes the 60cms metal dish can be made in Britain and he is negotiating with Marconi to make the amplifier and frequency converter which must be built into the dish. The set top tuner will use components made in Japan, with final assembly in Britain.

The Astra satellite is due for launch on Ariane rocket Flight 27 on 4 November and should be ready to start broadcasting by the beginning of 1989. Rather than wait for MAC receivers and de-scramblers Sky decided to fund all four channels with adverts and broadcast all four channels "clear" and in PAL. So anyone can watch on a conventional tv set equipped with a dish aerial and set-top turner.

Amstrad will make 100,000 dish and tuner systems a month, to sell through Dixons and Currys high shops for £199. Rupert Murdoch predicts that by the time his rival BSB starts broadcasting, at least a million homes in Britain will be equipped with PAL systems to watch Sky on Astra. They will not then be interested in buying a second dish aimed at a different satellite, with MAC electronics and de-encryption circuitry, for the chance to pay a subscription and watch BSB's 3 channels. In all standards battles someone always wins in the end. Although on technical grounds Murdoch's approach offends, on commercial grounds it makes him the sure fire winner.

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SAFELY DOES IT

The editorial desk is the focus for many tales – of pleasure and delight, of woe and distress, and of errors and thoughtlessness.

A reader rang me not so long ago about his drinking problem. His beer mug was on top of the PE Minisonic he'd built many years back. He'd knocked the tankard over, stumbled while trying to retrieve it – and collided with the synthesiser. Falling, the machine pulled on its mains lead, which he'd not secured properly inside. The internal live lead detached itself and touched the low voltage circuitry. Fuses blew, but not before the chips were cooked at 240Vac. Where, he asked, could he buy a new set of components, and could he still get hold of the pcbs?

Another fellow, ignorant of Telecom's restrictions to the contrary, had been experimenting by trying to couple his computer to the telephone line. He had breadboarded the circuit and was using a high impedance interface. But he'd built up a good bird's nest of components and in making a component change had managed to touch a Telecom 50V lead to a computer input lead. Buzby seemed not to notice, but a ttl port doesn't like voltages over about 5V and the VIA chip died. At least they're cheap – he's lucky to have got away so lightly.

Someone else was repairing a scope. He thought it was switched off. It was, but in connecting a bare metal croc-clipped meter probe to the eht point on the tube he had forgotten to allow time for the capacitively-stored voltage to discharge naturally. He had his other hand on the chassis. The current was only small, and the charge soon ebbed, but even a momentary 2000Vdc across you can be a provocative surprise. Irrespective of other considerations, maintenance of high voltage circuits should be done with one hand in a pocket, not on an earth point.

A most potentially horrendous situation was recounted by a school pupil. He'd rung to ask why his circuit board layout had spat sparks and hot metal at him. On questioning, he revealed that he was building a mains ac ammeter. Assembling his circuit on Veroboard, he plugged it into the mains. Inadequate cleaning and removal of solder debris from the board had caused a direct short across the tracks. They had reacted like a fuse, and had vaporised. At least he wasn't touching it. I pointed out the dangers of having live mains open to public view, and of not checking solder tracks. Then I was amazed to learn that the circuit idea had his teacher's approval, and that he was intending to produce a project capable of monitoring 100 amps at 240Vac. The mind boggles, even though an ordinary UK mains plug will normally restrict current flow to 13 amps max.

I applaud experimentation and diy construction, but it must be done within the bounds of common sense safety precautions.

THE EDITOR

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	0.1	0.156
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BY THE PROF

THE SOUND OF XNORING

The Prof's experimental design irons out the ground effect, but can't quite grind out the iron effect! Using very low frequencies (for a metal detector) it uses small phase shifts in the search signal to trace useful objects.

Producing a new metal detector design for the home constructor is not an easy task these days. There have been a large number of metal detector projects published in the last fifteen to twenty years, making it much easier to come up with a revamped circuit than one of a totally new type. I will not claim that this detector relies on a totally new system as it works on a principle that has certainly been known for many years. On the other hand, I have not seen a previously published design of this type. The basic requirements for this project were as follows:–

1. It should not be of a "standard" (bfo, ib, or pi) type.
2. It should be free from the "ground" effect without using any special shielding. The ground effect is one that results in an indication being produced by certain types of detector even when no metal is present in the ground. To combat this effect either the search coil must be suitably shielded, or the coil must be kept a fixed distance above the ground.
3. Construction of the search coil should be non-critical, and any electronic setting up should be simple and straightforward.
4. The unit should be easy to use, having a method of indication that is very obvious even for someone without a good sense of pitch (many designs indicate the presence of metal by giving a small change in the pitch of an audio tone).
5. It should have a level of performance at least as good as most simple bfo and ib designs.

PHASED OUT

When looking at the available options, the only kind of detector which seemed likely to fit these requirements was the very low frequency (vlf) phase detector type. This operates by detecting small phase changes in the signal in the search coil when metal is brought near to the coil. "Very low frequency" in metal detector terms generally means a frequency at the upper end of the audio spectrum, with something around 17kHz being quite typical. The point of using relatively low operating frequencies in

metal detectors is that it avoids problems with the ground effect.

Practical experiments with vlf phase detector circuits proved quite encouraging, and the final design is quite simple but effective. In terms of performance it falls some way short of a kit-built ib unit that I have, but it can be built for what I would estimate at little more than a tenth of the price of this commercial unit. The higher sensitivity of ultra-sensitive detectors is often unusable anyway, due to problems with small amounts of iron or other metals in the soil giving a sort of pseudo-ground effect.

The performance of the unit is quite good for such a simple design. It will detect a 20p coin at a maximum range of about 60 to 80 millimetres. Larger pieces of metal can be detected at longer ranges, with a 50p coin being detectable at about 100 to 150 millimetres. Large chunks of metal can be detected at a maximum range of around 500 millimetres. This is better than most bfo designs, but is perhaps a little inferior to some simple ib circuits. This design is more simple than an ib design though, and in particular, the search coil does not need to be made very accurately. In this respect the unit is even less critical than a bfo design. Sensitivity is certainly high enough to provide good results. Note that the quoted sensitivities were obtained from "in-air" tests. Performance in practice depends on the characteristics of the soil, and the exact orientation of many objects seems to significantly affect how well (or otherwise) they are detected.

The block diagram of Fig.1 shows the arrangement used in this detector. The search coil is actually a twin type, and is really a form of transformer. An audio oscillator drives the primary winding by way of a buffer amplifier. The purpose of the buffer is to ensure that metal close to the search coil does not "pull" the oscillator and affect the phasing of its output signal. It is not to produce a high drive current in the search coil, which only requires a very low drive level. A (more or less) squarewave signal is produced by the oscillator.

The output from the secondary winding is fed to a high gain amplifier and then to a trigger circuit. This gives a roughly squarewave signal at logic compatible signal levels. A form of mixer circuit processes the output of the audio

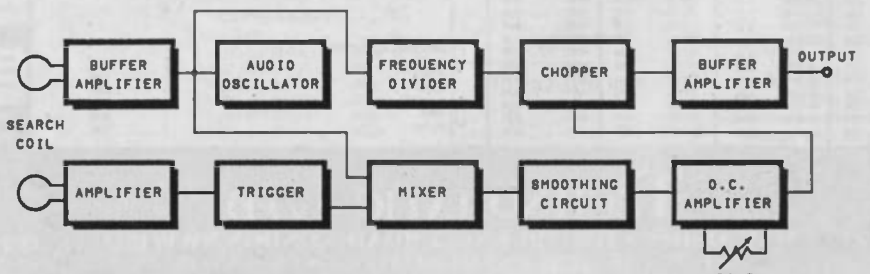


Fig 1. *Block diagram for the VLF phase detector.*

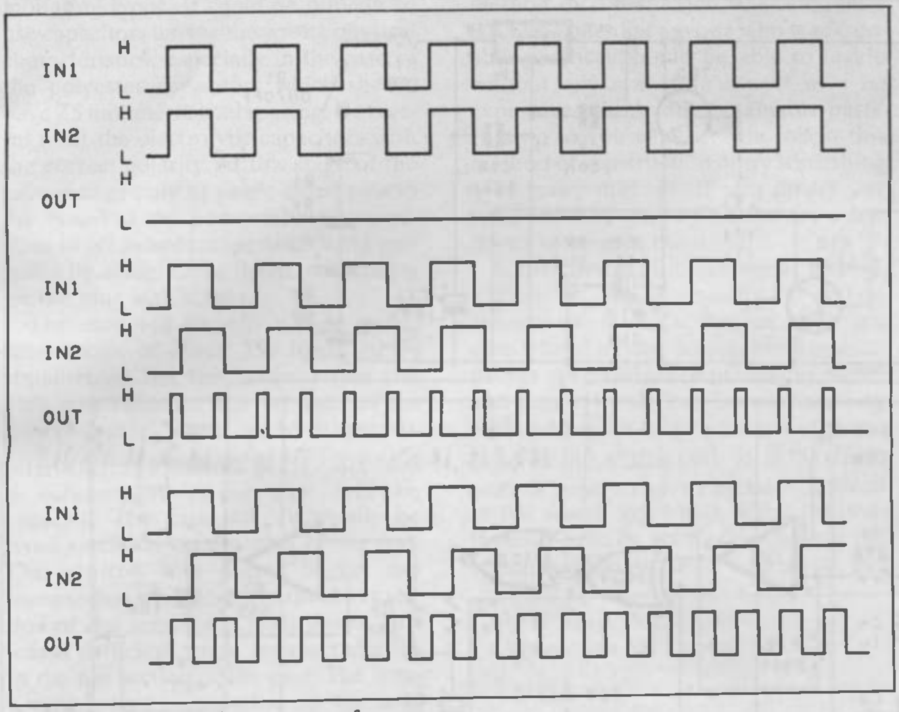


Fig 2. *XOR phase detector waveforms.*

oscillator and the output of the trigger circuit. This mixer is actually a 2 input xnor gate. XOR and xnor gates are probably the least used types, and some readers may not be familiar with their operation. An ordinary nor gate has an output which goes low if either input 1 OR input 2 is taken high. The output also goes low if both input AND input 2 are taken high. An xnor gate differs from a nor type only in that taking both inputs high does not take the output low. An xnor gate therefore provides what could reasonably be regarded as the true nor action.

What we require in this application is a mixer circuit that converts phase lag into a proportional output voltage, because the output from the secondary winding slightly lags the input signal, but if metal is brought near the search coil the phase lag increases and decreases for ferrous and non-ferrous metals respectively. XOR and xnor gates may not seem to be of much use as phase detectors, but they can in fact operate very well in this mode. The waveforms in Fig.2 help to explain the way in which this type of detector operates. Here we are assuming that an xor gate is used.

The top set of three waveforms are those obtained with the two input signals perfectly in-phase. Both inputs of the gate are low, then they are both high, then low again, and so on. A state is never reached where the inputs are at opposite states, and so the output goes continuously low. In the middle set of waveforms the second input lags the first one by about 45 degrees. The two inputs are now at opposite states twice on each cycle, although only briefly. The output is high for about 25% of the time, giving an average output voltage of around one quarter of the supply voltage. In the bottom set of waveforms the phase lag has been increased to 90 degrees. This lengthens the periods during which the input signals are at opposite states, and gives longer output pulses, still with two per input cycle. The average output voltage is increased to about 50% of the supply voltage. By taking the two input signals 180 degrees out of phase the two signals would always be at opposite states, and the output would go permanently high. An xnor gate is effectively an xor type with its output inverted. Results using an xnor gate are therefore essentially the same, but the output is of the opposite logic state.

By smoothing the output pulses to obtain a reasonably ripple-free output equal to the average output potential, the required phase lag to voltage conversion is obtained. However, the phase changes produced by even quite large pieces of metal very close to the search coil are quite small. At most they seem to be just a few degrees, and small target objects more than a few millimetres from the search coil produce a phase shift of only a fraction of a degree. A high gain dc amplifier is therefore needed in order to produce a reasonably strong output signal to drive the subsequent stages. There is quite a large phase lag under stand-by conditions, giving a strong quiescent output voltage from the unit. A variable bias circuit in the dc amplifier enables this quiescent output voltage to be nulled.

The output stages of the unit are used to produce an audio tone that rises or falls in volume when metal is detected. Even people who have a good sense of pitch generally find a change in volume much more noticeable than a change in pitch. The output from the dc amplifier could be used to drive a panel meter if this method of indication is preferred. However, in my experience it is necessary to concentrate on control of the search head, making any form of visual indicator difficult to use properly.

A tone at a frequency of a few hundred Hertz is obtained by feeding the output of the audio oscillator stage through a frequency divider circuit. This drives a chopper circuit which produces an audio output signal having a peak to peak amplitude equal to the output voltage from the dc amplifier. This signal is fed to a buffer stage which drives the output socket. A crystal earphone and most types of headphone are suitable for use with this project.

CIRCUIT OPERATION

The full circuit diagram for the "Phaser" metal detector appears in Fig.3. The audio oscillator is a humble 555 astable circuit. A low power version of the 555 (the TLC555CP) is used in the IC1 position in order to reduce the current consumption and extend the battery life. The operating frequency of the circuit is roughly 16kHz. The primary of the search coil (T1) is driven via an emitter follower buffer stage based on TR1. R3 limits the drive current to just a few milliamps. Both the primary and secondary windings of T1 are fitted with parallel "tuning" capacitors, and these seem to be essential if reasonable sensitivity is to be achieved. IC2 amplifies the output of the secondary winding, and the high gain of this amplifier gives a severely clipped output signal. VR1 is adjusted to give an output waveform having a suitable mark-space ratio.

This signal is processed by IC3a which is a cmos xnor gate which functions here as a simple inverter stage. IC3b is the xnor gate which functions as the phase detector, and it is fed from the outputs of IC1 and IC3a. Its output is smoothed to a reasonably low ripple dc signal by the single pole lowpass filter comprised of R6 and C6. IC4 acts as the basis of the dc amplifier, and this has a voltage gain of around 300 to 400 times. I cut down the voltage gain from its original level as I preferred lower drift to increased sensitivity. If you prefer higher sensitivity, then R7 can be made higher in value and (or) R8 can be replaced with a shorting link. Remember though, that the increased gain will result in any drift being amplified by a larger amount, and more frequent readjustment will be needed in order to keep the circuit adjusted for optimum sensitivity. Also, accurate adjustment of the bias controls becomes more difficult. These controls are VR2 ("fine") and VR3 ("coarse"). C7 provides additional filtering which provides a very low ripple dc output signal.

The frequency divider is a cmos 4040BE 12-stage binary type (IC5). In this circuit only five stages are used. This gives a divide by 32 action, and an output

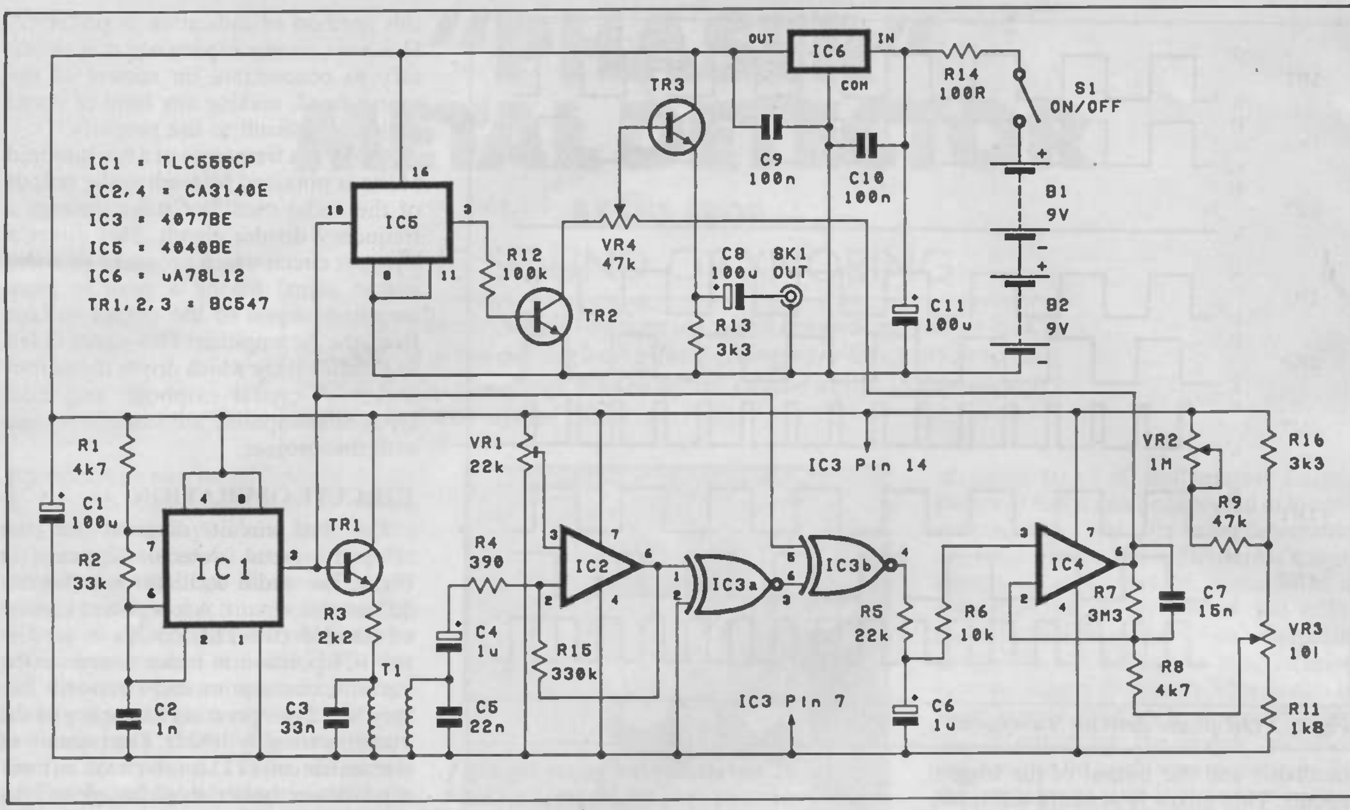


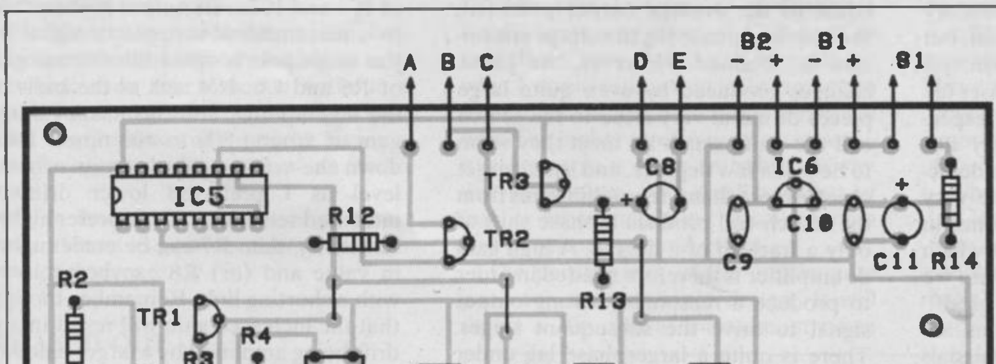
Fig 3. *The full circuit diagram for the "Phaser" metal detector.*

frequency of about 500Hz. This signal is used to drive common emitter switching transistor TR2, which chops the output of IC4. VR4 is the collector load for TR2, and this acts as the volume control. TR3 is an emitter follower output stage.

A very stable supply in the range 9 to 15 volts is required. A single 9 volt battery is unsuitable as it would provide totally inadequate stability. Instead, two 9 volt batteries wired in series are used to provide a basic 18 volt supply, and monolithic voltage generator IC6 then provides a well stabilised 12 volt output from this. R14 reduces the dissipation in IC6 slightly, so that it operates slightly cooler and gives a more stable output. The current consumption of the circuit is about 17 milliamps. This can be provided by two high power PP3 size batteries or rechargeable PP3 size nickel-cadmium batteries. If the unit is likely to receive a great deal of use it would probably be better to opt for higher capacity batteries, such as two sets of six HP7 size cells in plastic holders.

CIRCUIT BOARD

Fig.4 shows the component layout for the printed circuit board. IC1 to IC5 are all mos types and consequently require the normal mos anti-static handling precaution to be observed. Note that IC1 has the opposite orientation to ICs 2, 3, and 4. Three link wires are required, and these can be made from 22 swg tinned copper wire (or trimmings from resistor leadout wires). The capacitors are all miniature printed circuit (vertical)



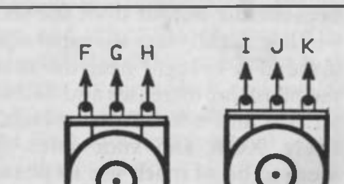


Fig 4. *(left) Printed circuit board details.*
Fig 5. *(above) Pots and socket wiring details.*

mounting types. It could be difficult to use capacitors having the wrong physical characteristics, especially in the case of the polyester capacitors which should have 7.5 millimetre lead spacing. Be careful to fit the electrolytic capacitors with the correct polarity. At this stage of the proceedings only fit single-sided pins to the board at the points where connections to off-board components will eventually be made. Once fitted, generously tin the pins with solder.

The unit will fit into a case having dimensions of about 150 by 80 by 50 millimetres, but this assumes that two PP3 size batteries will be used as the power source. If you opt for larger batteries such as a number of HP7 size cells a substantially larger case will be required. The case will eventually be fixed vertically on the stem of the unit. The controls and output socket are mounted on what becomes the lower section of the removable front panel. This leaves sufficient space for the batteries in the top section of the case. The component panel is mounted on the rear panel of the case using M3 or 6BA fixings, including some extra nuts or short spacers to hold it slightly clear of the rear panel. Note though, that printed circuit board can not be finally fitted in place until the case has been mounted on the stem of the unit.

All the point-to-point style wiring is quite straightforward and should not give any great difficulties. Fig.5 in conjunction with Fig.4 shows the interconnections between the three potentiometers, the output socket, and the circuit board. SK1 is a 3.5 millimetre jack socket on the prototype. I use the unit with a crystal earphone, or "Walkman" type headphones having their original (stereo) plug replaced with an ordinary mono type. The latter, with the two earphones wired in series, seem to give better volume and better results than a crystal earphone, and are probably worth the extra cost. Of course, rather than fit a different plug to the phones you might prefer to fit a stereo 3.5 millimetre jack in the SK1 position, but sockets of this type can be difficult to obtain. The unit seems to work with most types of headphone, incidentally. For low and medium impedance types it is best to use series connection, but for high impedance headphones parallel connection will probably be better. A low impedance magnetic earphone is unlikely to give satisfactory results.

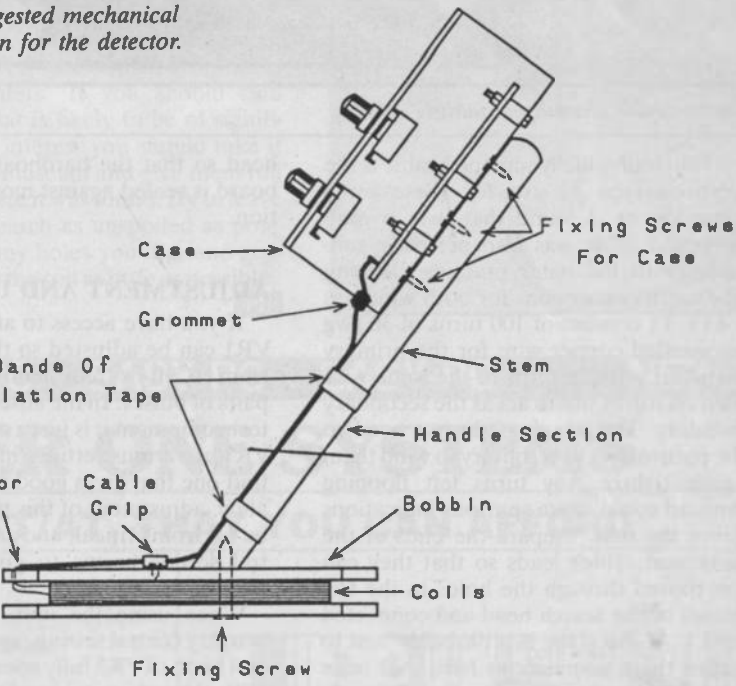
MECHANICAL CONSTRUCTION

Mechanically, construction of the detector is non-critical. You can opt for a fairly basic method of construction (as I did), or adopt more advanced techniques to give a more professional finish. Results using the unit will be exactly the same either way, and it is only the quality of finish that will be different. The method of construction suggested here is a basic one that anyone who is reasonably practical should be able to tackle without any real difficulty. It uses inexpensive and readily obtainable parts. It is up to you whether you follow this method of construction or try something a bit more difficult. If you do try out some ideas of your own there are a few points to bear in mind.

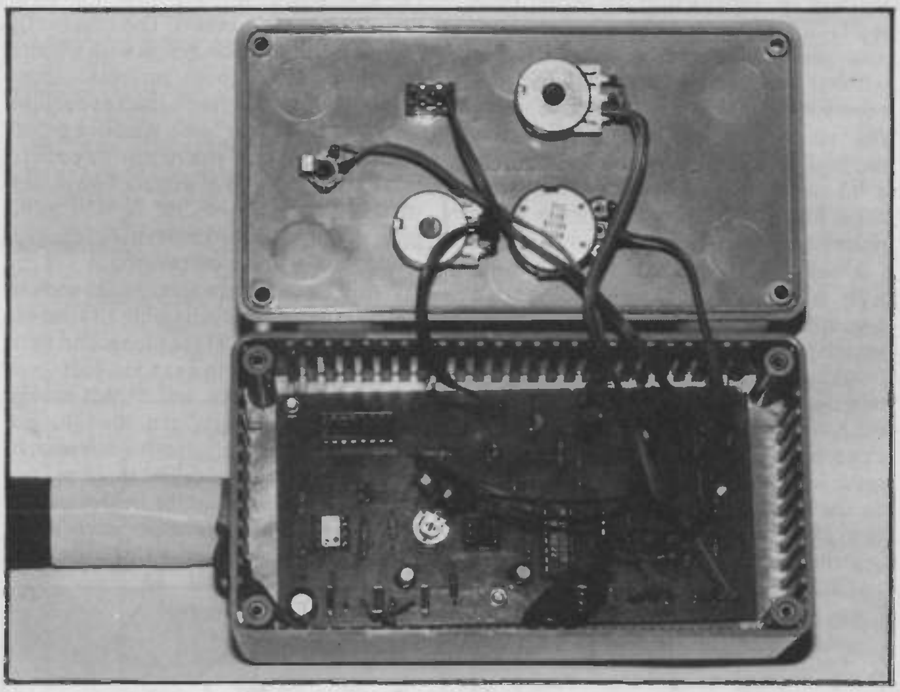
Unlike some types of metal locator, with a vlf phase detector a certain amount of metal within or near the search head is quite acceptable. The electronics can be adjusted to null this metal, and there is no obvious loss of sensitivity even with quite large amounts of metal close to the search coil. It is therefore quite in order to have a metal stem fixed to the search head by a metal bracket. It might even be acceptable to have the search head constructed from metal, but I have not tried this and cannot guarantee that it will provide satisfactory results. Physical balance is important as the unit will be difficult to use for long periods if it is top or bottom heavy. It is possible to produce a very neat search head using fibreglass, but as I know from previous experience, this can result in a very bottom heavy and unwieldly finished unit. If you use a heavy-weight material for the search head use as little of it as possible! The handle should be as close to the centre of balance as possible.

The method of construction I adopted is as outlined in Fig.6. The stem is a piece of wooden dowel about 20 to 25 millimetres in diameter and around 1.2 to 1.3 metres long. Suitable dowels are readily available as replacement broom handles! The bottom end of the stem is angled at about 55 degrees to the search head, and it must be cut at the appropriate angle. The search head is made from thin hardboard or particle board. The material I used was thin particle board with a white plastic veneer on both surfaces. Apart from giving a neat finish the veneer also helps to make the unit weather-proof. The search head is really just an outsize bobbin on which T1 is wound. Two pieces of the board about 200 by 150 millimetres form the top and bottom cheeks, while one or two pieces about 140 by 100 millimetres form the middle section of the bobbin. It is advisable to trim off the corners of the larger pieces and then round them off using a sander. This gives a neater appearance and avoids having sharp corners which can tend to get tangled in the undergrowth when searching overgrown ground. The three or four pieces of the bobbin are held together by a good quality adhesive such as an epoxy resin type. Drill three or four small holes (about 1.6 millimetres in diameter) well towards the front of the top panel. These are where the leads of the connecting cable will pass through the top panel. The search head is fastened to the stem using a woodscrew and some epoxy resin adhesive.

Fig 6. *Suggested mechanical construction for the detector.*



The case is fixed at the top end of the stem using three small woodscrews. The case must protrude slightly beyond the end of the stem, or the stem will get in the way and make it impossible to fit one of the circuit board's mounting screws in place. Having the case as high up on the stem as possible is a good idea anyway. It gives a better balance and keeps the case clear of the handle section of the stem (the section just beneath the case). An entrance hole for the cable which connects T1 to the circuit board is required in the bottom panel of the case, and a grommet should be fitted into this hole.



Case interior showing mounting details.

Twin individually screened cable is the obvious type to use for these interconnections. I found that twin overall screened cable was also perfectly suitable, with the outer braiding carrying the earth connections for both windings of T1. T1 consists of 100 turns of 36 swg enamelled copper wire for the primary winding, with 25 turns of the same wire laid on top of this to act as the secondary winding. The windings do not need to be particularly neat, but try to wind them quite tightly. Any turns left flopping around could cause spurious indications from the unit. Prepare the ends of the screened cable's leads so that they can be passed through the holes in the top panel of the search head and connected to T1. At this stage it is probably best to leave these connections bare, but once the unit has been tested and is fully working it would be advisable to use some fibreglass filler paste or epoxy adhesive to cover them over and protect them. A cable grip secures the cable to the top of the search head, and some tape can be used to cover over the cable and produce a neat finish.

Some bands of insulation tape are used to fix the cable to the front edge of the stem. If you have a suitable tool for the purpose it would be a good idea to make a groove for the cable in the front edge of the stem. About half a dozen bands are sufficient to hold the cable in place. I used a couple of layers of tape over practically the entire stem in order to give a neat finish and a degree of weather-proofing. I used white tape for most of the stem, with black for the handle section. To finish off the unit, thread the twin screened cable through the hole in the case and connect it to the printed circuit board, and paint or varnish around the edges of the search head so that the hardboard or particle board is sealed against moisture absorption.

ADJUSTMENT AND USE

If you have access to an oscilloscope, VR1 can be adjusted so that the output from IC3b is reasonably symmetrical pairs of pulses. In the absence of suitable test equipment it is just a matter of trying VR1 at various settings in an attempt to find one that gives good results. Fortunately, adjustment of this preset seems to be far from critical, and any roughly central setting seems to give satisfactory results.

When using the unit, set VR2 at a roughly central setting, and turn the control knob of VR3 fully counter clockwise. With the volume control well advanced, adjust the control knob of VR3 slowly in a clockwise direction until a loud tone is heard from the headphones. Then adjust VR2 to reduce the volume of the tone so that it is quite quiet but still clearly audible. Placing the search coil close to a metal object should result in the tone increasing or decreasing in volume. Conventionally, the detector should be set up so that the tone increases in volume for non-ferrous metals, and decreases in volume for ferrous types. This is the action that will be obtained if you have the windings of T1 connected in-phase. I preferred to have items of interest (which mostly means non-ferrous metals) produce a drop in volume, as I found a small drop in volume to be much more apparent than a small increase. I therefore wired the windings of T1 out-of-phase (ie, one "start" lead earthed and one used as the non-earthy lead). You might like to try out the unit one way, and then reverse the connections to one winding of T1 so that you can try it out the other way, to see which system you find easiest to use.

As a point of interest, I found that ferrite rods and pieces of iron had the opposite effect to most other metals, but steel (which I would have thought counted as a ferrous metal) usually did

COMPONENTS

RESISTORS

R1,R8	4k7 (2 off)
R2	33k
R3	2k2
R4	390
R5	22k
R6	10k
R7	3M3
R9	47k
R10,R13	3k3 (2 off)
R11	1k8
R12	100k
R14	100R
R15	330k

All resistors ¼ watt 5% carbon film.

POTENTIOMETERS

VR1	22k sub-min hor preset
VR2	1M lin carbon
VR3	10k lin carbon
VR4	47k log carbon

CAPACITORS

C1,C11	100μF 25V radial elect (2 off)
C2	1n polyester (7.5mm pitch)
C3	33n polyester (7.5mm pitch)
C4,C6	1μF 63V radial elect (2 off)
C5	22n polyester (7.5mm pitch)
C7	15n polyester (7.5mm pitch)
C8	100μF 10V radial elect
C9,C10	100n ceramic (2 off)

SEMICONDUCTORS

IC1	TLC555CP
IC2,IC4	CA3140E (2 off)
IC3	4077BE
IC5	4040BE
IC6	uA78L12 (12V 100mA pos reg)
TR1,TR2,TR3	BC547 (3 off)

MISCELLANEOUS

B1,B2	9 volt (high power PP3 size, 2 off)
S1	spst sub-min toggle
SK1	3.5mm jack
T1	36 swg enamelled copper wire (see text)

Plastic case about 150 × 80 × 50mm, printed circuit board, control knob (3 off), 8-pin dil ic holder (3 off), 14-pin dil ic holder, 16-pin dil ic holder, battery connector (2 off), twin screened lead, insulation tape, wooden dowel, hardboard, cable grip, fixing screws, etc (see text).

not. Note that for optimum sensitivity you must keep VR2 adjusted so that the tone from the earphones is fairly quiet under stand-by conditions. The unit inevitably drifts slightly, and VR2 will accordingly need to be periodically trimmed in order to keep the unit at optimum sensitivity. Eventually you will find that very frequent adjustment of VR2 and VR3 is required, and this indicates that the batteries are nearing exhaustion.

There seems to be no problem at all with the ground effect. If an area of ground always gives a small indication from the unit, this indicates that the soil has a significant metal content. This phenomenon is not as rare as you might think, and can occasionally make an effective search very difficult.

FINALLY

There are a few final points that it is worth mentioning. I believe that licenses are no longer needed for metal detectors. To be legally usable in the UK they must fall within certain restrictions, but to the best of my knowledge this design falls comfortably within all these restrictions. Constructors outside the UK should ascertain that the unit can be used legally in their country, and should obtain any necessary permit prior to constructing and using the unit. You should obtain permission before searching any land that you do not own. Any sites of historic interest are out-of-bounds to treasure hunters. If you should find something that is likely to be of significant historic interest you should take it to your local museum and give them full details of where it was found. Try to leave places you search as unspoiled as possible. Fill in any holes you dig, and generally disturb the soil as little as possible. PE

SUBMARINE CABLES

PART ONE BY MIKE SANDERS

THE SEA CAN HEAR YOU FROM HERE

They say sound travels well underwater. So does light, power, data, anything that can be carried by cable. Here's the proof.

Submarine cables are not used for reeling in submarines as I was led to believe in my school days.

Submarine cables are used to carry telephone circuits from one continent to another or power from a mainland to an offshore island eg. UK to the Isle of Wight.

Any cable immersed in water is a submarine cable so in addition to communicating across oceans, submarine cables find useful application inland if a river has to be crossed. Many countries have large lakes and it is quicker to lay a cable on the bed of the lake than to try to circumvent it.

It all started in 1819 when it was found that a magnetic needle was deflected by current carried in a nearby wire and that was the beginning of electrical transmission as we know it today. This fascinating story covers more than a century and is now giving way to optical transmission, ie information carried on light waves instead of electric waves.

In 1837 Charles Wheatstone and W.F. Cooke patented a communications system using five pointers and six wires. At this time Samuel Morse also patented a telegraph system using the Morse code. Things moved quite rapidly from this stage. Having communicated inland, man wanted to communicate overseas to prove that no man is an island.

In 1850, the first submarine cable was installed between England and France. This cable was 46 km long and was made water resistant by gutta percha – a combination of hessian fibres and gum from the Malayan rubber plant. *(I thought it was a fishing term! Ed)*. This cable did not have armour protection and was cut by a fisherman's anchor in the same year.

The next year, another cable was laid between England and France, this time protected by layers of galvanised wires. Other cables around Britain and the Mediterranean soon followed and survived many years.

In 1866 the first transatlantic telegraph cable was laid and at this stage it was even possible to grapple for the ends, if a cable was severed, and reattach them. By 1888, the world had already spent more than £40 million on cables.

Preliminary submarine cable laying activity. Reproduced by kind permission of British Telecom.

Submarine cable is quoted as two quantities, the ratio of the weights of conductor to insulator per nautical mile (6080 feet or 1.852km). For instance 107/140 means 107lb of copper to 140lb of gutta percha per nautical mile.

It can be seen that the insulator is the greater weight but as the insulation techniques improved, this trend was reversed and in 1881 130/130 cable was used. The 400/360 was introduced in 1888 and the 175/140 in 1889.

CABLE AND TRAFFIC

Submarine cables may be divided into power cables and communications cables. Power cables are usually short, between two and twenty kilometers and carry thousands of volts.

Communications cables on the other hand may range from a hundred miles to thousands of miles and link several countries and even continents. These cables carry telegraph, telephony, data, music programmes and even television.

To understand how communications cables work, it is necessary to understand the nature of the signals carried. Television is not usually carried by submarine cables. It is more convenient to set up a television link via satellite since such links are 'occasional', ie serving a particular purpose, like Olympics coverage, coronations, etc.

Television links are unilateral, ie. the transmission is in one direction only and usually required in a hurry to cover some event like motor racing. That is why it is quicker to set it up via satellite. However there are television-carrying cables and the typical bandwidth of a tv signal is about 6 MHz, Fig. 1.

By comparison a speech circuit needs only about 4kHz including the guardband, ie spaces between adjacent channels, Fig. 2. Most of the power in speech is contained in the frequencies between 300Hz and 3400Hz, therefore this bandwidth is sufficient for intelligible communications. These circuits are called 4kHz circuits.

On a cable that crosses the oceans, bandwidth is expensive and every effort is made to utilise bandwidth as

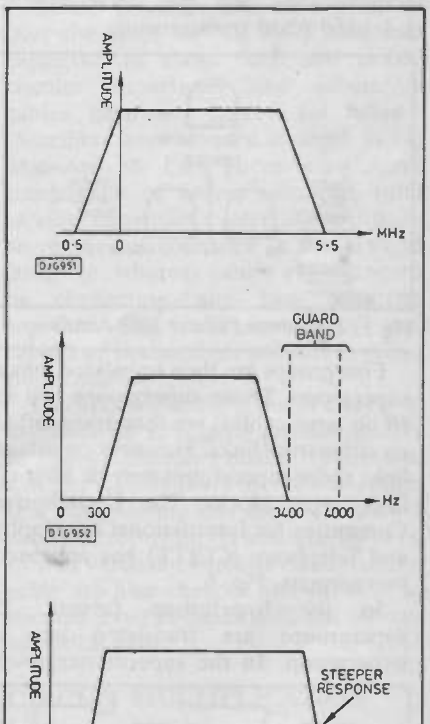


Fig 1. *(Top) Television bandwith*
Fig 2. *(Middle) 4kHz speech bandwith*
Fig 3. *(Bottom) 3kHz speech bandwidth*

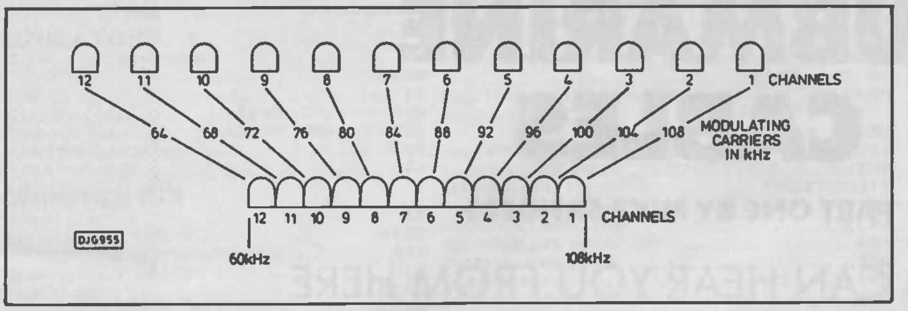


Fig 4. *Translation of channels into a group*

economically as possible. Therefore in some instances, cables carry what are called 3kHz circuits where by a filter design the cut–off is made sharper than for 4kHz circuits, Fig. 3. In addition the speech band is from 200Hz to 3050Hz.

Twelve 4kHz channels are translated into a group 60kHz to 108kHz. If 3kHz channels are used, sixteen of these fit into the same group bandwidth of 60kHz to 108kHz. The term translation is only another term for modulation where each channel is modulated by a carrier to give it its rightful position in the larger bands, Fig. 4. Allocating portions of a frequency spectrum in this manner is called frequency division multiplex (fdm).

Modulation produces upper and lower sidebands Fig. 5. Only one sideband is chosen to save bandwidth but in radio applications both sidebands may be transmitted to overcome fading. The former is called single sideband (ssb) transmission, and the latter double sideband (dsb) transmission.

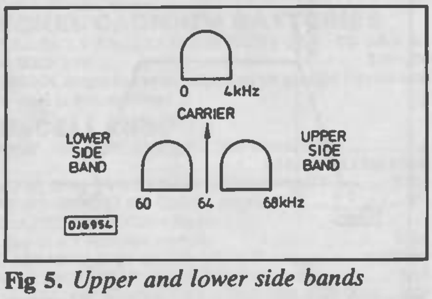


Fig 5. *Upper and lower side bands*

Five groups are then translated into a supergroup. These supergroups (up to 69 on large cables) are then transmitted on submarine links. However on inland links these supergroups may be built up into larger blocks. The Consultative Committee for International Telegraphy and Telephony (CCITT) has approved two formats, Fig. 6.

In the hypergroup format, 15 supergroups are translated into a hypergroup. In the supermastergroup, five supergroups are first translated into a mastergroup. Then three mastergroups are translated into a supermastergroup.

To summarise then, the basic format is 12 or 16 channels into a group and five groups into a supergroup. After that 15 supergroups make a hypergroup or five supergroups make a mastergroup and three mastergroups make a supermaster group. A hypergroup and supermaster-group are both roughly 4MHz wide if 4kHz channels were used as basic building blocks.

Equipment which translates 3kHz channels into groups also has facilities for carrying music and sound programme circuits. The channel filters are bypassed and the group bandwidth 60kHz to 108kHz, ie 48kHz is chopped into four programme circuits each approximately 12kHz wide. These can be used to carry music in stereophonic sound.

Data is carried at speeds of 50, 120, 200, 600, 1200 and 2400 bit/s. These can be carried over a 4kHz channel and require modems at the customer's premises and the exchange to convert the digital signals back to analogue signals, since the present network carries analogue signals, mainly. Higher bit rates require wider bandwidths, eg 48Kbit/s requires a group bandwidth of 48kHz.

Telegraph circuits are also carried by submarine cable and though the man with the sun visor tapping out a telegraph message is a thing of the past, telex machines transmit much the same signals.

The five unit Murray code is used, Fig. 7. Five units gives 32 different combinations (2^5). These 32 combinations are required to cover all the letters of the alphabet as well as punctuation marks. In addition to the information code, a start signal of one pulse width is added and a stop signal of one and a half pulse width.

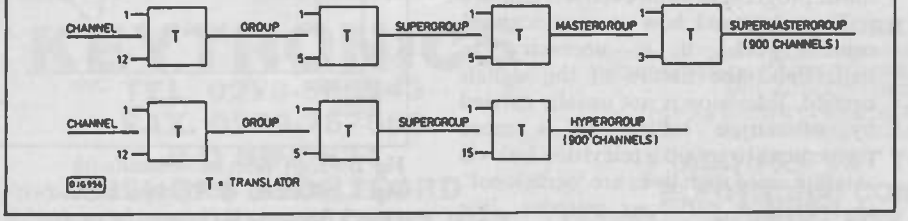


Fig 6. *Supermastergroup and hypergroup formats*

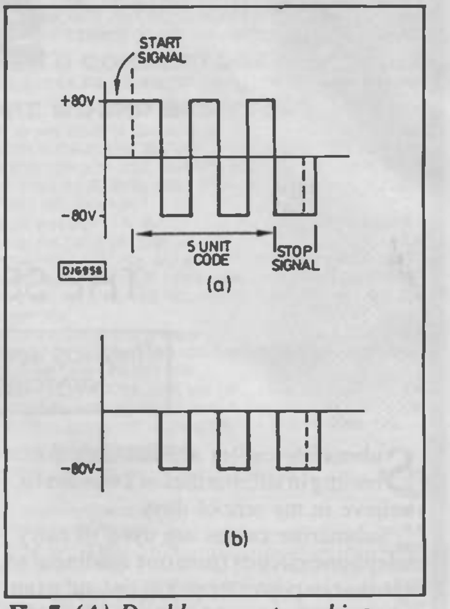


Fig 7. *(A) Double current working (B) Single current working*

The mark to space ratio is 1:1 and each is 20ms long. The waveform in Fig. 7a is known as double current working where the positive pulses represent the space and negative pulses the mark. Fig. 7b shows single current working where zero voltage represents spaces and negative voltage represents marks. Although double current has opposite polarities, the transition from mark to space is more distinct.

UK TELEPHONES

In 1868 a lot of private companies were competing in the field of telegraph communications. Then in 1870 an Act of Parliament unified all the telegraph companies. But it was not until 1912 that the National Telephone Company was absorbed giving a united telephone service.

The size of the UK telephone network in 1982 was 6600 exchanges with 28 million telephones serving 18 million customers. This massive network handled more than 280 million outgoing international calls and 20 billion inland calls in 1982. From the UK one can dial more than half the 220 different countries.

SUBMARINE CABLES

The first cable across the Atlantic was TAT 1, in 1956, and carried 36 circuits. In 1959 TAT 2 was laid and both TAT 1 and TAT 2 had one cable for each direction of transmission. In 1961 CANTAT 1 used the same cable for both directions of transmission by sharing the available bandwidth.

TAT stands for Trans–Atlantic and CANTAT for Canadian Trans–Atlantic. The TAT cables land in the USA and the CANTAT cables land in Canada. The European ends land in the UK, Spain and France.

TABLE 1: SOME SUBMARINE CABLES AND CAPACITIES

SG = Supergroup, MG = Mastergroup, C = Circuit

SYSTEM	TERMINALS	NAUTICAL MILES	CAPACITY	DATE
CANTAT1	Oban – Cornerbrook (UK-Canada)	2072	80c	1961
CANTAT2	Widemouth-Beaverharbour (UK-Canada)	2800	23SG	1974
TAT3	Widemouth-Tuckerton (UK - USA)	3518	138c	1963
TAT4	St Hilaire-Tukerton (France-USA	3596	138c	1965
TAT5	Spain - USA	3461	845c	1970
TAT6	St Hilaire-Greenhill (France-USA)	3396	4000c	1976
TAT7	Lands End - Tuckerton (UK - USA)	3277	4200c	1983
UK-Germany 2	Winterton - Leer	251	2 SG	1964
UK-Germany 3	Winterton - Leer	251	2 SG	1964
UK-Germany 4	Winterton - Fedderwarden	28	21 SG	1971
UK-France 1	Eastbourne - Courseulles	107	43 SG	1976
UK-France 2	Eastbourne - St Valery	60	14 SG	1978
UK-Netherlands 8	Aldeburgh - Domburg	83	21 SG	1972
Netherlands 9	Broadstairs - Domburg	83	23 SG	1974
Netherlands 10	Lowestoft - Alkamaar	119	14 MG	1979
Netherlands 11	Aldeburgh - Domburgh	84	14 MG	1984
UK-Belgium 2	St Margarets Bay - La Panne	48	7 SG	1964
UK-Belgium 3	Broadstairs - Ostende	64	21 SG	1972
UK-Belgium 4	St Margarets Bay - Venue	59	14 MG	1977
UK-Denmark 2	Scarborough - Thisted	381	21 SG	1973
UK-Denmark 3	Winterton - Romo	296	13 SG	1980
UK-Norway 2	Scarborough - Kristiensand	392	8 SG	1968
UK-Portugal 1	Goonhilly - Sesimbra	951	8 SG	1969
UK-Spain 1	Goonhilly - Algorta	482	8 SG	1971
UK-Spain 2	Goonhilly - Sopelana	465	23 SG	1975
UK-Spain 3	Lands End - Rodiles	430	69 SG	1980
UK-Faroes 1	Gairloch - Torshavn	288	23 SG	1963
UK-Faroes 2	Lerwich - Torshavn	230	8 SG	1971
UK-Channel Is 4	Tuckerton Bridge - St Helier	137	8 SG	1968
UK Channel Is 5	Tuckerton Bridge - St Peter Port	89	29 SG	1972
UK-Channel Is 6	Stoke Fleming - St Helier	109	23 SG	1982
Kirkwall-Lerwick	Same as system name	108	8 SG	1971
Barrow-Lancaster	Same as system name	20	8 SG	1971
Lancaster-Colwyn Bay	Same as system name	72	2 SG	1962
Colwyn Bay-Douglas	Same as system name	77	2 SG	1962
ATLANTIS Sect 1	Dakar - Recife	1846	1380c	1982
ATLANTIS Sect 2	Dakar - Lagos	1532	43 SG	1982
SECOM 1	Singapore - Hong Kong	4080	80 c	1964
SECOM 2	Australia - New Guinea	3005	160c	1966
TRANSPAC 1	Hawaii - Japan	5282	142c	1964
TRANSPAC 2	Hawaii - Japan	5015	845c	1976
COMPAC	Canada - Australia	8233	80c	1963
COLUMBUS	Venezula - Canary Is	3239	1840c	1978
TRIBEN	Tripoli - Benghazi	376	900c	1979
MERIDIAN	Veurne - Rodiles	720	43 SG	1983
TEPAL	Tel Aviv - Palo	1470	1320c	1975
MAT1	Italy - Spain	986	640c	1970
Florida-Bahamas	Florida - Bahamas	222	1380c	1972
USA-Bermuda	USA - Bermuda	750	80c	1962
Denmark-Netherlands 3	Romo - Leeuwarden	171	9 MG	1983

TAT 3, 4 and 5 followed quickly and then CANTAT 2 carrying 1840 circuits of 3kHz bandwidth. CANTAT 2 used 900 tons of aluminium, 600 tons of copper, 7000 tons of steel in the core to act as a strength member and 6000 tons of polythene insulation and sheathing.

Table 1 shows some of the cables that have been installed over the years and how the capabilities have grown. Typical bandwidths are 1.2, 5, 14, 25, 29.5 and 45MHz carrying circuits ranging from about 100 to over 5000.

Fig. 8 shows some of the cables landing in the UK and Western Europe. During the 1970s cable bandwidths tripled from 5MHz to 12MHz. This represents a tripling of circuits from 480 (4kHz) to 1380 circuits. Present day 45MHz circuits can carry 4140 4kHz circuits or 5520 3kHz circuits.

A cable must have repeaters along its length to amplify the signal and therefore overcome cable attenuation. It is a fact of life that the greater the bandwidth, the greater the amplification required to maintain the signal level. This can be achieved by more powerful amplifiers or amplifiers spaced closer together.

Since the amplifiers (repeaters) are dropped on the seabed it is necessary to keep the number to a minimum to reduce the fault liability. Therefore the 45MHz systems have come to be associated with short haul routes, eg UK to Europe, and the 14MHz systems with long haul routes UK to the USA.

However, with improving technology, the distinction between long haul and short is becoming less important. What matters is the demand for traffic. For instance TAT 7 carries 4200 circuits and TAT 8 will be optical fibres. Up to now electrical techniques have been used but optical fibres will use light technology which offers much larger bandwidths and larger spacing between repeaters.

CABLES V SATELLITES

Of the satellites that have gone up over the years Intelsat IV, V have had capacities of about 5000 and 10,000 circuits respectively and submarine cables have not lagged far behind. (Satellites were covered in depth in PE Mar–Apr 88. Ed.) There is no direct comparison of course since the total satellite capacities quoted above usually serve several countries in the area of coverage, whereas cables are restricted in connecting any two countries together. Any traffic coming off one cable and destined for another is called transit traffic.

The above illustrates the flexibility of satellites for setting up circuits quickly to geographically distant countries. Circuits via cables are useful when there is a gale blowing and the earth station aerial for receiving via satellite has to be stowed vertically. Circuits via submarine cable are also cheaper and promise to become even cheaper with the advent of optical fibre.

CIRCUIT MULTIPLICATION

Circuits via cables and satellite can both be multiplied. This is achieved by installing circuit multiplication equipment (cme) at the terminals to take advantage of the silent periods in speech. If two people are holding a conversation, Fig. 9, one speaks and the other listens, therefore at any given moment one path is redundant or spare.

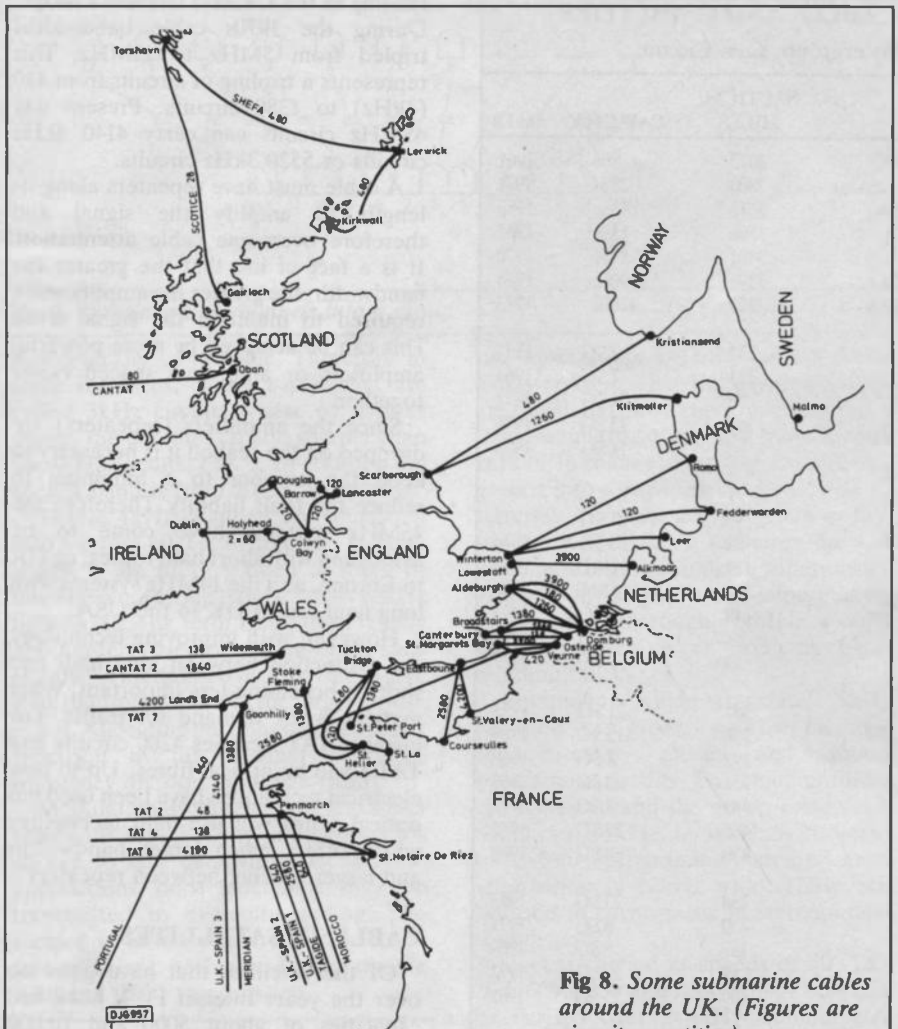


Fig 8. *Some submarine cables around the UK. (Figures are circuit quantities)*

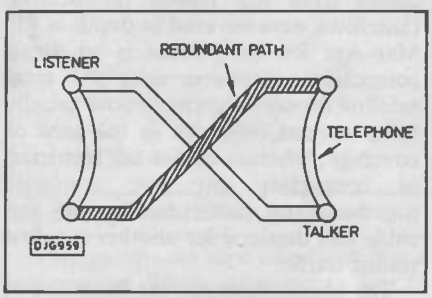


Fig 9. *Redundant speech path*

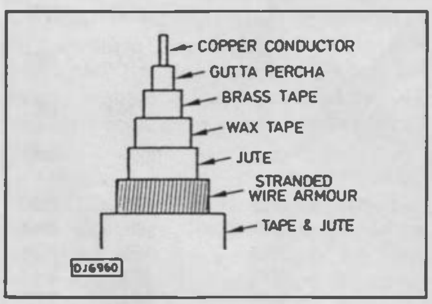


Fig 10. *Telegraph cable*

The cme snatches this path and allocates it to another talker. The cme computer is fast enough to snatch a path even during pauses in conversation and this means that twice as many people can use the speech paths. This is said to give a 2:1 advantage at little cost. For instance if a transatlantic cable provides circuits at £35,000 each then instead of running a new cable when this one is full, cme will provide extra circuits at only £3000 each.

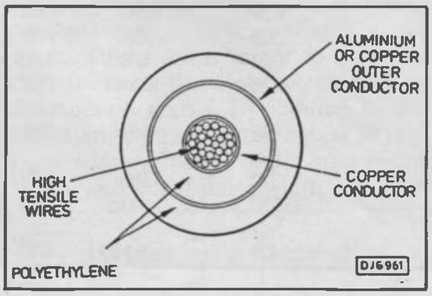


Fig 11. *Lightweight telephone cable*

EARLY CABLES

Fig. 10 is a diagram of an early telegraph cable. In comparison Fig. 11 shows the construction of a modern lightweight telephone cable. Both used the technology of the day and it can be seen how the wax tape and gutta percha has given way to polythene.

One of the disadvantages of having two metal conductors separated by an insulator is that a capacitor is formed. The inner and outer conductors of a coaxial cable with the separating insulation gives rise to capacitance which leaks away signals.

A British mathematician and physicist, Heaviside, showed in 1866 how this capacitance could be reduced, by loading a cable at regular intervals along its length with inductors.

In 1951 the UK Post Office developed the unarmoured cable of Fig. 11. On continental shelves, in fishing areas, in the English Channel or any other shallow water area of intense shipping activity, armoured cable is used. These cables have steel strands on the outside as well as in the core.

Unarmoured cable is used to span the oceans and has torsionally balanced steel wires in the centre. Armoured cable tends to loop on the sea bed as a result of water pressure. These loops cause kinks and damage the cable ultimately. Whereas the armoured cable would twist by one turn per fathom of depth, the unarmoured one twists by only 0.0001 turn.

Coaxial cables replaced wire pairs around 1937 and a submerged repeater was first used during the Second World War.

TAT 1 and TAT 2 have already been mentioned. CANTAT 1 was the first cable to use the lightweight, unarmoured design, and in 1964 transistorised repeaters were used for the first time.

TABLE 2: COMPARISON OF CANTAT 1 AND CANTAT 2

	CANTAT 1	CANTAT 2
Circuits	80	1840
Year In Service	1961	1974
Cost per circuit	£100,000	£16,500
Lengths	3636 km	5620 km
No. of repeaters	90	490
Power	9.5kV, 415mA	12kV, 500mA

Table 2 shows the difference between CANTAT 1 and CANTAT 2 and how technology had progressed over 13 years from 1961 to 1974. Wideband amplifiers were developed and there was also the traffic demand to justify 1840 circuits for CANTAT 2.

CANTAT 2 is about 25% longer but the number of repeaters is five and half times more to cope with the bandwidth. CANTAT 2 used transistors whereas CANTAT 1 used valve amplifiers.

Thermionic valves did not have sufficient gain at the high frequency end of the bandwidth required for CANTAT 2. This would have required more repeaters which meant that line voltages of the order of 20kV would have been required to feed the whole string of repeaters. It can be seen from Table 2 that the valve repeaters of CANTAT 1 required about 100V each whereas the transistor repeaters of CANTAT 2 need only around 20V each.

Continued Next Month. PE

ELECTRONIC BAROMETER

PART TWO BY JOHN BECKER

SCREENING THE MILLIBARS

Proportional representation displays a programmed solution to grading degrees and pressure fronts.

Last month we looked at some of the facts about atmospheric pressure and described the circuit for an electronic pressure sensor. We concluded the project with details of setting up and use.

SETTING UP

First, a few words of **VERY STRONG CAUTION**. The pressure transducer has a hole in one face that allows atmospheric access to its interior. **DO NOT POKE ANYTHING INTO THIS HOLE**. It is very tempting to do so, but the interior is very fragile and could be punctured, so destroying the sensor. Out of curiosity I did poke a wire in to one sensor to see how the voltage output changed under applied pressure. Unaware of the fragility at that time, I killed it. Unfortunately, these sensors are not cheap.

Start off the setting-up by adjusting the temperature level. Switch on the unit, and leave to warm up for 10 to 15 minutes. Assuming that you are using a computer to control the unit, and that the program is running, adjust VR2 until the screen shows a decimal readout corresponding to the known room temperature. A Fahrenheit thermometer is better suited for this cross checking, firstly because it has a wider scale, and secondly because the gain given to the signal is intended to give a single digit change for each °F.

If you are omitting the adc circuits, monitor the output of IC1d with a voltmeter, and adjust VR2 until a reading of 2.5V is obtained.

It is important to set the temperature control first since any subsequent adjustment will have an effect upon the alignment of the pressure sensing circuit.

Next, with a meter, monitor the output of IC1a, and adjust VR1 until a reading of about 2.5V is obtained. Then set VR3 to about midway, and monitor the output of IC1b, either by meter, or direct on the computer screen. Very delicately readjust VR1 until the output of IC1b is showing pretty close to 2.5V on the meter, or about 64 on the screen.

FINE TUNING

So far, that's all very straightforward, fine tuning though needs a little patience. It is necessary to fractionally readjust both VR3 and VR1 in the light of experience. VR3 needs adjusting until the opposing temperature changes of the diode D1 and the sensor are balanced. For any change in VR3, it is likely that a fractional change of VR1 will also be needed to return the output of IC1b to the midway point. For better precision, 15-turn presets for all of VR1 to VR3 would be preferable, but they are more expensive than ordinary skeleton ones and I did not feel that the expense was justified. With care, the skeleton presets can be adjusted to a precision that is close enough for practical purposes. If, subsequently, readings are found to be slightly out of line, corrective program statements can be written in to compensate for them. This is a cheaper method than using precision components.

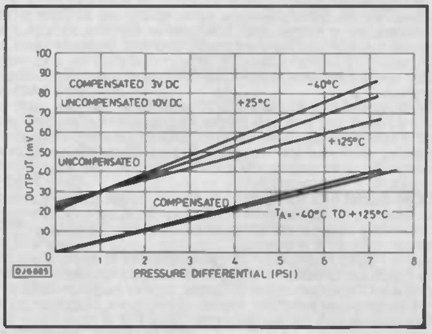


Fig 17. *Output voltage versus pressure differential as a function of temperature for compensated and uncompensated pressure sensors.*

Incidentally, Motorola produce temperature compensated versions of their pressure transducers, but even they do not fully overcome temperature variation factors (Figs. 17 and 18). I also felt that the price was higher than I wished to pay.

For setting up my own unit I used a low power fan heater to help in the temperature alignment. Using a digital meter I monitored the outputs of IC1a and IC1c while blowing warm air on the sensor, D1 and a mercury thermometer. Though the diode and the sensor have slightly different rates of response, I was able to establish figures for the respective temperature changes. From these I calculated the necessary gain to be given to the counterbalancing by D1. I then get VR3 for a resistance value that would give me this gain through IC1b.

If you don't have a digital meter then the presets will have to be set by trial and error. Remember though, that it is not vital to achieve absolute accuracy since any reasonable deviation can be compensated for by writing a corrective program line.

A low cost aneroid barometer was then used as the reference against which I carefully adjusted VR1 until the screen showed a realistic corresponding figure. Over several days I then observed the aneroid barometer and the screen readout, noting the respective figures. Ultimately I established a simple corrective formula line for insertion into the program to compensate for the observed deviations. Using the unit constantly over several weeks, the computer readout showed consistent conformity with the aneroid barometer, the mercury thermometer, and with the details given on the BBC tv weather charts. The resulting figures showed a change of close to one decimal digit for each °F, and approximately two decimal digits for each millibar.

LONG TERM RECORDING

The program has been written so that data is also sent out to a disc drive enabling long term records to be kept.

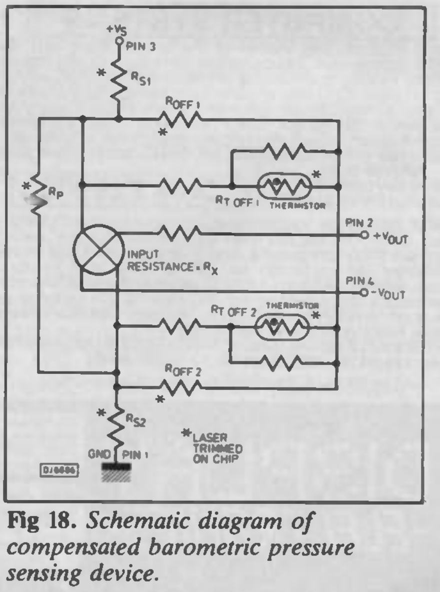
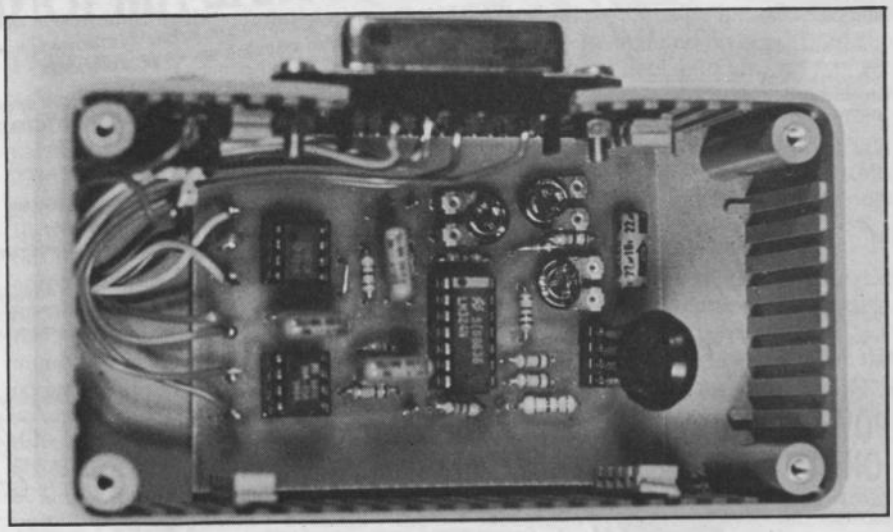


Fig 18. *Schematic diagram of compensated barometric pressure sensing device.*

```
100 PRINT"□BAROMETER"
110 PP=1
120 REM "□" = CLEAR SCREEN
130 DOPEN#8,("P"+STR$(PP)),D1,W
140 IFDS>20THENPP=PP+1:DCLOSE:GOTO130
150 DRT=59459:IN=59457:OUT=59471:V$=""
160 GOSUB600
170 POKEDRT,1OR128:POKEOUT,128
180 FORA=1TO128:POKEOUT,1:POKEOUT,0
190 D=PEEK(IN):B=B+(DAND2):C=C+(DAND4)
200 NEXTA:B=128-(B/2):C=128-(C/4)
210 C=C+9:REM  TEMP CORRECTION
220 GOSUB340:IFLEFT$(TI$,3)=V$THEN250
230 T$=TI$:PRINT#8,T$;B;C
240 V$=LEFT$(T$,3)
250 B=0:C=0:GOTO180
260 PRINT"□REPLAY":GOSUB600
270 DOPEN#8,("P 4"),D1
280 IFDS>19THENPRINTDS$:DCLOSE:STOP
290 INPUT#8,A$:T$=LEFT$(A$,6)
300 B=VAL(MID$(A$,8,2))
310 C=VAL(RIGHT$(A$,3))
320 GOSUB340:IFST<>64THEN290
330 DCLOSE:PRINT:PRINT:STOP
340 F$=STR$(C)+"  "
350 REM CELCIUS CONVERSION
360 DC=INT((C-32)*5/9*10)/10
370 DC$=STR$(DC)+"  "
380 REM MILLIBAR CONVERSION
390 MB=1012+((B-64)/2):MB$=STR$(MB)+"  "
400 IFB>PTHENM=2
410 IFB<PTHENM=1
420 IFC>TTHENN=2
430 IFC<TTHENN=1
440 IFB>HPTHENHP=B:HP$=MB$
450 IFB<MPTHENMP=B:MP$=MB$
460 IFC>THTHENTH=C:HC$=DC$:HF$=F$
470 IFC<TMTHENTM=C:MC$=DC$:MF$=F$
480 PRINTLEFT$(DN$,5)T$
490 PRINTTAB(48)MP$;TAB(17)MB$;TAB(26)HP$;
500 PRINTTAB(36)M$(M)
510 PRINTTAB(48)MF$;TAB(17)F$;TAB(26)HF$;
520 PRINTTAB(36)M$(N)
530 PRINTTAB(48)MC$;TAB(17)DC$;TAB(26)HC$;
540 PRINTTAB(36)M$(N)
550 PRINTTAB(B+80)" ":PRINTTAB(C+80)" "
560 PRINTLEFT$(DN$,13)
570 PRINTTAB(B)"*":P=B
580 PRINTLEFT$(DN$,16)
590 PRINTTAB(C)"#":T=C:RETURN
600 DN$="SQQQQQQQQQQQQQQQ"
610 REM CURSUR HOME, 15 X CURSOR DOWN
620 PRINTLEFT$(DN$,5)TAB(9);
630 PRINT"MIN        NOW        MAX      +/-
640 PRINT:PRINT"PRESSURE"
650 PRINT:PRINT"TEMP F"
660 PRINT:PRINT"TEMP C"
670 PRINT:PRINT:PRINT"PRESSURE"
680 PRINT:PRINT:PRINT"TEMP"
690 M$(1)="-":M$(2)="+":HP=0:MP=256
700 TH=0:TM=256:RETURN
710 :
720 BBC PORT CODES
730 DRT=&FE62 IN=&FE60 OUT=&FE60
740 C64 PORT CODES
750 DRT=56579 IN=56577 OUT=56577
760 NOTES
770 THIS PROG IS WRITTEN IN PET BASIC4
780 TI$ IS TIME CODE FOR PET & C64
790 FILE HANDLING CODES SUCH AS
800 DOPEN#8 INPUT#8 PRINT#8 MAY NEED
810 CHANGING TO SUIT EQUIPMENT
820 TAB CODES MAY ALSO NEED MODIFYING
830 :
840 THE SIMPLEST PROG WITHOUT SCREEN
850 AND TIME HANDLING ETC IS -
860 DRT=59459:IN=59457:OUT=59471
870 POKEDRT,1OR128:POKEOUT,128
880 FORA=1TO128:POKEOUT,1:POKEOUT,0
890 D=PEEK(IN):B=B+(DAND2):C=C+(DAND4)
900 NEXTA:B=128-(B/2):C=128-(C/4)
910 PRINT"P=";B,"T=";C
920 B=0:C=0:GOTO880
```

A second section of the program then allows for these results to be reinput and displayed. Since the changes in temperature and pressure will occur slowly, in recording mode the program only requests a data conversion routine once a minute. This rate could of course be changed to suit your own needs. On replay, each sample takes about half a second to display. Consequently, the temperature and barometric samplings are played back at over 100 times the rate of recording. In other words, two hours of data are compressed into about one minute of display. The data could of course, be put out to a cassette recorder or printer instead. The necessary program lines can be inserted into the listing. I regret, though, that neither PE nor I can offer information for devices other than the disc drive I use, the Commodore 8050. You will need to refer to your own handbooks for this information.



Interior view of barometric pressure sensing project.

CONCLUSION

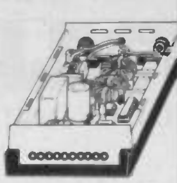
This electronic barometer and thermometer will cost you more to build than buying conventional non-electronic devices. However, the great benefit of using an electronic unit to do the monitoring is the ability to record, replay and analyse data over considerable periods of time. Armed with this information, rudimentary predictions can be made, and trends analysed. Weather conditions are close to the hearts of many people, and this unit will provide an interesting source of information.

For those with a greater interest in the weather, a wide selection of books is available through libraries, and also through the London Weather Centre book shop at 284–286 High Holborn, London WC1V 7HX. They also provide a weather chart and advisory service. I found my visit to them most worthwhile.

We are grateful to the controller of Her Majesty's Stationery Office for permission to reproduce the Crown copyright weather charts used in Part One. PE

POWER CONDITIONER

FEATURED IN ETI JANUARY 1988



The ultimate mains purifier. Intended mainly for lowering the noise floor and improving the analytical qualities of top-flight audio equipment.

The massive filter section contains thirteen capacitors and two current balanced inductors, together with a bank of six VDRs, to remove every last trace of impulsive and RF interference. A ten LED logarithmic display gives a second by second indication of the amount of interference removed.

Our approved parts set consists of case, PCB, all components (including high permeability toroidal cores, ICs, transistors, class X and Y suppression capacitors, VDRs, etc.) and full instructions.

PARTS SET **£28.50** + VAT

Some parts are available separately. Please send SAE for lists, or SAE + £1 for lists, circuit, construction details and further information (free with parts set).

KNIGHT RAIDER

FEATURED IN ETI JULY 1987

The ultimate in lighting effects for your Lamborghini, Maserati, BMW (or any other car, for that matter). Picture this: eight powerful lights in line along the front and eight along the rear. You flick a switch on the dashboard control box and a point of light moves lazily from left to right leaving a comet's tail behind it. Flip the switch again and the point of light becomes a bar, bouncing backwards and forwards along the row. Press again and try one of the other six patterns. An LED display on the control box let's you see what the main lights are doing.

The Knight Raider can be fitted to any car (it makes an excellent fog light!) or with low powered bulbs it can turn any child's pedal car or bicycle into a spectacular TV-age toy!

The parts set consists of box, PCB and components for control, PCB and components for sequence board, and full instructions.

Lamps not included.

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Mono power meter	£3.90 + VAT
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FEATURED IN ETI AUGUST 1988

There's nothing quite so encouraging as having a quantifiable result to show for your training efforts. If you are not particularly fit, your resting heart rate will be around 80 beats per minute. As your jogging, aerobics or sport strengthens your heart, the rate will drop dramatically – possibly to 60bpm or less. With the S101, you can watch your progress day by day.

Breathing is important too. How efficiently do you take up oxygen? How quickly do you recover from 'oxygen debt' after strenuous activity? The S101 will let you know.

The approved parts set consists of case, 3 printed circuit boards, all components (including 17 ICs, quartz crystal, 75 transistors, resistors, diodes and capacitors), LCD, switches, plugs, sockets, electrodes, and full instructions for construction and use.

PARTS SET **£33.80** + VAT

Some parts are available separately. Please send SAE for lists, or SAE + £2 for lists, circuits, construction details and training plan (free with parts set).

THE DREAM MACHINE

FEATURED IN ETI DECEMBER 1987

Adjust the controls to suit your mood and let the gentle, relaxing sound drift over you. At first you might hear soft rain, sea surf, or the wind through distant trees. Almost hypnotic, the sound draws you irresistably into a peaceful, refreshing sleep.

For many, the thought of waking refreshed and alert from perhaps the first truly restful sleep in years is exciting enough in itself. For more adventurous souls there are strange and mysterious dream experiences waiting. Take lucid dreams, for instance. Imagine being in control of your dreams and able to change them at will to act out your wishes and fantasies. With the Dream Machine it's easy!

The approved parts set consists of PCB, all components, controls, loudspeaker, knobs, lamp, fuseholders, fuse, mains power supply, prestige case and full instructions.

PARTS SET **£16.50** + VAT

AVAILABLE WITHOUT CASE FOR ONLY **£11.90** + VAT

FEATURED IN ETI OCTOBER 1988

£24.80 + VAT

THE MISTRAL AIR IONISER

Air ions are as essential to life as food and drink. In sterile city environments the natural ions are wiped out by dirt, dust, pollution and traffic fumes with devastating results.

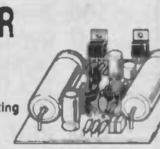
The Mistral is designed to restore the natural ion balance, and with it your sense of energy, health and vitality. A highly developed circuit combined with an efficient phosphor-bronze emitter fills the most spacious room with life giving ions. You'll feel the difference within hours!

- Variable ionisation potential for maximum ion rush
- Hundreds of phosphor bronze ion thrust points
- Built-in ion counter – see the output level at a glance
- Over 100 top grade components
- Power enough to drive five multi-point emitters
- Feel the difference within hours

Some parts are available separately. Please send SAE for lists, or SAE + £1 for lists, circuit, construction details and further information (free with parts set).

ARMSTRONG 75W AMPLIFIER

FEATURED IN PE JULY 1988



A.J. Armstrong's exciting new audio amplifier module is here at last!

Delivering a cool 75W (conservatively rated – you'll get nearer 100W), this MOSFET design embodies the finest minimalist design techniques, resulting in a clean, uncluttered circuit in which every component makes a precisely defined contribution to the overall sound.

You can read all about it in the July issue of PE, but why bother with words when your ears will tell you so much more?

Parts set includes top grade PCB and all components.

SPECIAL INTRODUCTORY PRICE FOR FULLY UPGRADED MODULES.

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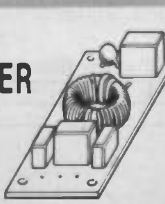
STEREO PAIR **£25.90** + VAT

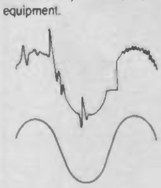
Please send SAE + £1 for data and circuits (free with parts set), including diagrams for matching pre-amp and power supply. This amplifier will not be available from your usual audio supplier – we produce the only designer approved parts set.

MAINS CONDITIONER

FEATURED IN ETI SEPTEMBER 1986



Cleans up mains pollution easily and effectively. You'll hardly believe the difference in your Hi-Fi, TV, Video, and all other sensitive equipment.



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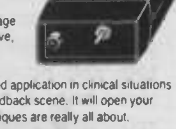
RUGGED PLASTIC CASE **£1.65** + VAT

BIO-FEEDBACK

FEATURED IN ETI DECEMBER 1986



Bio-feedback comes of age with this highly responsive, self-balancing skin response monitor! The powerful circuit has found application in clinical situations as well as on the bio-feedback scene. It will open your eyes to what GSR techniques are really all about.

The complete parts set includes case, PCB, all components, leads, electrodes, conductive gel, and full instructions.

PARTS SET **£13.95** + VAT

BIO-FEEDBACK BOOK **£3.95** (no VAT)

Please note: the book, by Stern and Ray, is an authorised guide to the potential of bio-feedback techniques. It is not a hobby book, and will only be of interest to intelligent adults.

POWERFUL AIR IONISER

FEATURED IN ETI JULY 1986

Ions have been described as 'vitamins of the air' by the health magazines, and have been credited with everything from curing hay fever and asthma to improving concentration and putting an end to insomnia. Although some of the claims may be exaggerated, there is no doubt that ionised air is much cleaner and purer, and seems much more invigorating than 'dead' air.

The DIRECT ION ioniser caused a great deal of excitement when it appeared as a constructional project in ETI. At last, an ioniser that was comparable with (better than?) commercial products, was reliable, good to build . . . and fun! Apart from the serious applications, some of the suggested experiments were outrageous!

We can supply a matched set of parts, fully approved by the designer, to build this unique project. The set includes a roller tinned printed circuit board, 66 components, case, mains lead, and even the parts for the tester. According to one customer, the set costs about a third of the price of the individual components. What more can we say?

Instructions are included

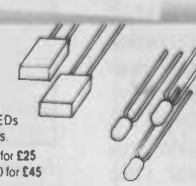
PARTS SET WITH BLACK CASE **£11.50** + VAT
PARTS SET WITH WHITE CASE **£11.80** + VAT

LM2917 EXPERIMENTER SET

Consists of LM2917 IC, special printed circuit board and detailed instructions with data and circuits for eight different projects to build. Can be used to experiment with the circuits in the 'Next Great Little IC' feature (ETI, December 1986).

LM2917 EXPERIMENTER SET **£5.80** + VAT

LEDs



Green rectangular LEDs for bar-graph displays.

50 for £3.50 — 500 for £25
100 for £6 — 1000 for £45

DIGITAL AND AUDIO EQUIPMENT LEDs
Assorted 3mm LEDs: red, green, yellow and orange.
25 of each (100 LEDs) for **£6.80**

Prices shown are exclusive of VAT, so please add 15% to the order total. UK postage is 70p on any order. Carriage and insurance for overseas orders £4.50. Please allow up to 14 days for delivery.

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BRAINWAVE MONITOR

FEATURED IN ETI AUGUST 1987

The most antonishing project ever to have appeared in an electronics magazine. Similar in principle to a medical EEG machine, this project allows you to hear the characteristic rhythms of your own mind! The alpha, beta and theta forms can be selected for study and the three articles give masses of information on their interpretation and powers.

In conjunction with Dr. Lewis's Alpha Plan, the monitor can be used to overcome shyness, to help you feel confident in stressful situations, and to train yourself to excel at things you're 'no good at'.

Our approved parts set contains case, two PCBs, screening can for bio-amplifier, all components (including three PMI precision amplifiers), leads, brass electrodes and full instructions.

PARTS SET **£36.90** + VAT ALPHA PLAN BOOK **£2.50**

SILVER SOLUTION (for plating electrodes) **£3.60** + VAT

Parts set available separately. We also have a range of accessories, professional electrodes, books, etc. Please send SAE for lists, or SAE + £2 for lists, construction details and further information (free with parts set).

MICROPROCESSOR BASED SYSTEMS DEVELOPMENT

PART TWO BY TIM WATSON BSc (HONS) AMIEE

EPROM EMULATION

The flexibility and low cost of EPROM emulation puts microprocessor system development within the grasp of anyone with programming experience and constructional enthusiasm.

The method of eprom emulation is a technique by which the target system eprom is removed from its socket and replaced by a dil socket with connecting wires to the host. The host then performs the functions of the eprom. The target will not be aware that when it accesses the eprom it is actually accessing the host and not a true eprom. Note that in the section on processor emulation the terms host and emulator were used, these terms will again be used, but in this section *emulator* will mean eprom and *host* is not the host of the previous section but a new host. The exact facilities provided by the emulator depends on the particular emulator; some are dumb systems, some are quite clever. Like processor emulators, eprom emulators are available as complete systems or as add-on units, to connect to a normal microcomputer via a parallel port or an RS232C interface. Eprom emulators lend themselves to be add-on units and this is perhaps the more popular way that they are implemented.

As well as considering typical features, the actual hardware implementation of eprom emulators will be discussed. In particular a hardware outline for an emulator will be given.

A typical eprom emulator setup is shown in Fig. 4. The emulator shown is of the add-on type. The general purpose host microcomputer requires a special software package to transfer data to the emulator unit, and if the emulator is of the more advanced type it may be necessary to send the emulator unit commands. This software package is normally available from the emulator manufacturer.

The sequence of operations to execute a program on the target is as follows. The program is written and assembled on the host microcomputer, using a normal editor and assembler (this may have to be a cross assembler, see later). The executable code is then transferred, by the host, to the emulator unit, using the special software package. The target system is reset, manually by the user, in order to start program execution from the reset address, and if all is well the target springs into life executing the program held in the emulated eprom.

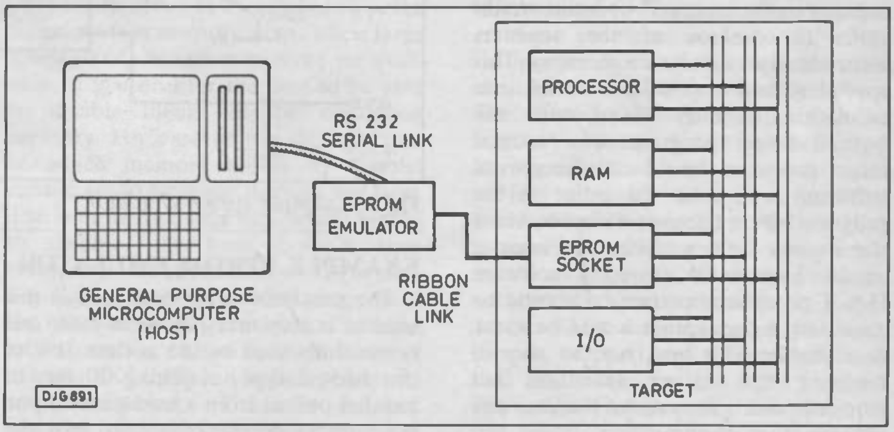

Fig 4. *Eprom emulation (add-on-type).*

FLEXIBILITY

Emulators vary in flexibility. The simplest type of emulator is tied to a particular type of eprom (such as a 2716), better emulators can emulate several different types and storage sizes. In the same way a processor emulator ties the user to a particular processor an eprom emulator ties the user to a particular type(s) of eprom. However, this not so restrictive because the number of different types of eprom commonly used (2716, 2732, 2764) are so small compared with the number of different types of processor used (eg 8085, Z80, 6502, 8088, 8086, 6809, 6800, 8031, 9900, the list goes on...). This is quite understandable because the function performed by an eprom is very simple and well defined; the eprom chip manufacturers would have difficulty making different eproms from each other.

Taking the concept of eprom emulation one stage further leads to a system which hooks onto the address, data bus, control bus etc. of the target and maps to anywhere in the target memory map. This type of system would then better be described as a memory emulator. Providing the emulator with access to the control bus signals allows the emulator more control over the target and potential for better debugging facilities. In practice hooking onto the address bus, data bus etc. may prove difficult if there is no convenient plug-in point. The advantage of a true eprom emulator over a memory emulator is that it plugs in place of an eprom and is thus easy to hook into the target, taking only seconds.

The hardware for an eprom emulator is similar to a cutdown processor emulator. Take the processor emulator shown in Fig. 3 of part one, remove the cpu emulation and emulation registers, leaving the emulation memory and the emulation interface logic, and what is left is a memory emulator. If this is further tailored to plug into an eprom socket, you then have an eprom emulator. Removing the above sections of hardware certainly saves some money. However, on the basis of "you can't get something for nothing" some facilities are lost.

Perhaps the most obvious point is that the target must now have a processor plugged in. What is more, this processor must be working correctly and the connections to the eprom, and hence emulator, must be correctly wired. This is not always the case when a new design is turned on for the first time! However, with the aid of an oscilloscope, continuity checker and multimeter it does not usually prove too difficult to get a target processor running. Once it is running the emulator can be used to help further debugging of the hardware.

The most significant disadvantages of a basic eprom emulator, compared with processor emulation, are lack of access to the cpu registers, lack of access to the target memory, and inability to set breakpoints. These problems can sometimes be alleviated by judicious use of target software. For example, with emulators that allow the emulation memory to be read and written by the host (not always the case, see the emulator example later), then the host may find out the processor's register values using a special software routine, running on the target. The routine would store the values of the registers somewhere in emulation memory. This special software would be loaded into emulation memory along with the normal target program. The normal target program should call the special software routine at the point in the program where the user wishes to know the register values. After the register values have been stored a software HALT or similar instruction should be executed; a breakpoint would be ideal, if available. The host has no way of knowing that target execution has stopped, and it is assumed the user can observe this in some way. When this happens the user can use the host to read the emulation memory, at the point where the register values were stored. The same type of method can be used to read locations in the target ram.

Though this type of method works it is very 'messy'. There are several drawbacks. Firstly the registers cannot be examined by the user at any point in the program. There has to be a CALL to the special software routine, and the program has to be modified to make this CALL. Also, since the special software must be written to run on a particular processor, the emulation system has become pro-cessor dependent. Not having a proces-sor dependent emulator is supposed to be one of the advantages of eprom emulation! What is worse is that the special software may have to be re-written for each different target, even when based on the same processor, this being necessary in order to avoid memory clashes with the normal target program. The more advanced emulators have extra hardware to allow breakpoints and other facilities without resorting to the 'messy' method.

To summarise, the facilities offered by eprom emulators range from very simple to good. They will never offer the facilities of a good processor emulator. However, eprom emulators are very easy to use, reasonably cheap, and usually provide enough facilities to allow development without a struggle.

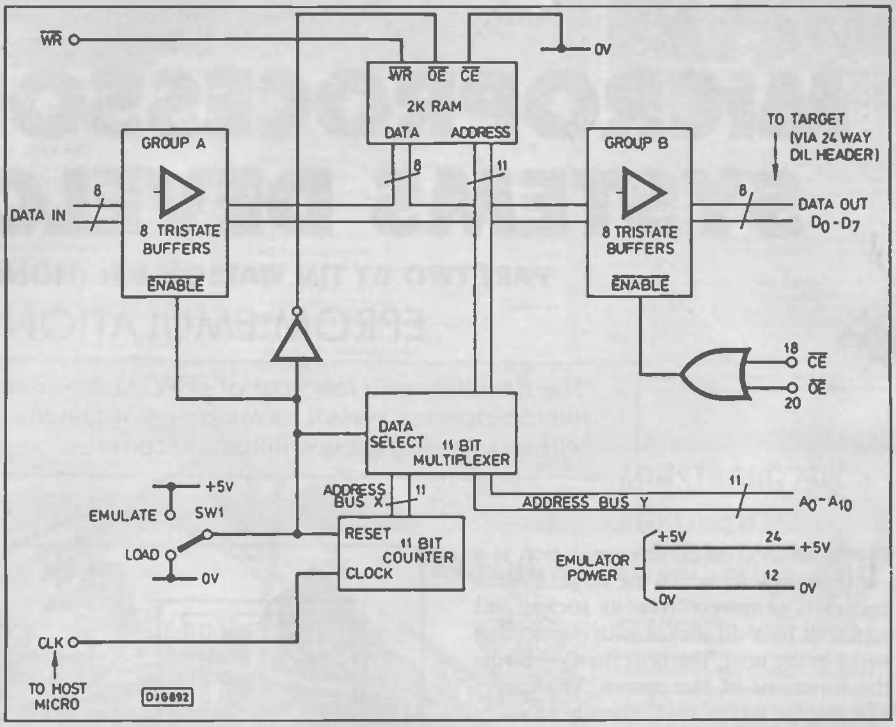

Fig 5. *Example eprom emulator.*

EXAMPLE EPROM EMULATOR

The emulator to be described in this section is one that has been built and successfully used by the author. It is of the add-on type, requiring 10 bits of parallel output from a host general purpose microcomputer. It falls into the very simple category, only being able to emulate type 2716 eproms, and provides absolutely no debugging facilities. However, the cost of this type of unit is so small that it is still good value for money. At the end of this section ways of expanding the emulator are considered.

The complete development system used by the author with this emulator was, for the host microcomputer a second hand Superbrain (Z80 processor, 64K ram, dual disk drives, integral keyboard and vdu, cp/m operating system) bought for £100, a parallel i/o card for the Superbrain (built by the author), software from the public domain, software written by the author, eprom programmer (built by the author), and the eprom emulator unit to be described here. The total set-up cost about £150.

A block diagram of the emulator is shown in Fig.5. The emulator is powered from the target system. The connecting wires to the target system, shown on the right hand side of Fig.5, were soldered onto a 24-way dil header, with the pinout of a 2716, to allow the emulator to plug straight into the target eprom socket. The signals which connect the emulator to the host microcomputer are shown on the left hand side of Fig.5. There is one switch on the emulator (S1), which switches the unit between two modes of operation, load and emulate. The load mode allows the host microcomputer to access the ram and hence load it with the target program, the emulate mode allows the target to access the ram and hence run the program. When in load mode the target system cannot correctly access the emulated eprom. The target system will crash causing unpredictable results. To avoid anything nasty happening it is best to keep the target permanently reset via its reset switch.

The circuit operation will now be described. Firstly, consider load mode. The group A tristate buffers are enabled so that the data from the host microcomputer is passed through to the 2K of ram. The group A buffers are unidirectional, that is the host microcomputer can only write to the ram, not read it (write only memory!). The ram data outputs are held permanently tristate by means of the output enabled (OE), which is driven from S1 through an inverter. The 11-bit ram address is driven from the 11-bit multiplexer. This multiplexer selects either address bus X or Y, depending on its data select input. In load mode address bus X is fed through. Address bus X is the output of an 11-bit counter. The counter provides the means by which the host microcomputer selects the ram address. The advantage of using a counter is that only one bit of output is required from the host microcomputer, instead of 11 bits for the full address bus. The disadvantage is that the ram addresses have to be accessed sequentially. In practice this is not a noticeable disadvantage because the host microcomputer only needs to access the ram when loading it with a target program, and this is naturally a sequential process. The counter is held

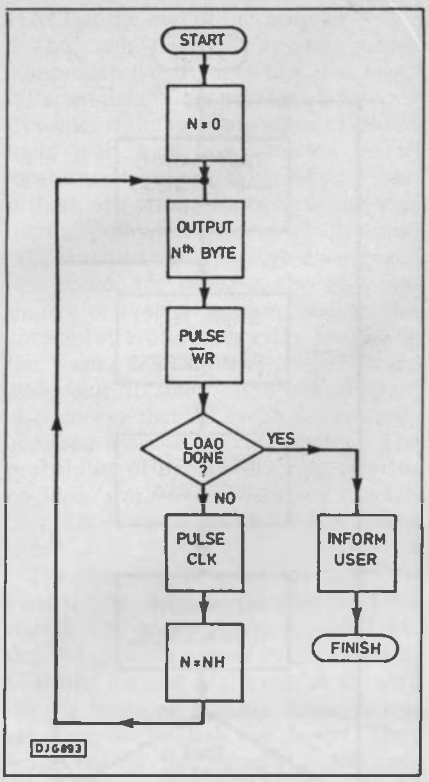

Fig 6. *Flow chart for loading emulator.*

reset by S1 when in emulate mode. Before a new load can begin S1 must first be switched to emulate in order to reset the counter. Special software is required on the host microcomputer to take a target program (perhaps from disk) and load it in to the emulator ram. In this case the special software is trivial. The flow chart in Fig.6 shows the required sequence of events.

When the program starts it assumes the 11-bit counter has just been reset, and therefore address bus X is zero. The host microcomputer outputs the first byte of the target program to the emulator unit via the data in bus. To write the data into the ram it must pulse the WR line, by taking it low and then back high. If all of the target program has been loaded the host microcomputer should inform the user of this fact, so that the user can switch the emulator into emulate mode. If the load has not finished the ram address must be incremented by pulsing the counter clock signal (CLK), taking it high, then back low. The next byte of the target program can now be loaded into the ram by repeating the above sequence, and so on ....

Once the target program has been loaded S1 can be switched to emulate mode. Group A tristate buffers are disabled, which stops the host microcomputer having access to the ram, and the ram data outputs are enabled. The data select input to the multiplexer is now high and so address bus Y is now passed to the ram address bus. Address bus Y comes from the target system eprom socket. When the target attempts to read the emulated eprom it takes chip enable (CE) and output enable (OE) low, which enables group B data buffers to drive the data out bus with the ram data. Group B data buffers are unidirectional, the target can only read from the ram. This is not unreasonable since an eprom can only be read.

The disadvantage with the above example emulator is that there are no debugging facilities or the ability to emulate larger eproms. Ways of expanding the hardware to provide more facilities will now be covered.

Adding the ability to emulate larger eproms is a straight forward matter. More ram should be added to the existing 2K ram, the amount depending on the maximum size of eprom to be emulated. Expanding the ram upto 32K would allow emulation for 27256 eproms. In order to avoid clashes in the target system memory map, when large amounts of emulation memory are available, it is useful for the user to be able to disable blocks of the emulation memory. For ease of use the selection of which memory blocks to disable/enable could be done through the host. The user instructs the host which blocks to disable, the host then in turn configures the emulator as requested. Fig.7 gives an outline block diagram of the hardware implementation. The emulation ram size shown is 8K and any of the four 2K blocks can be independently enabled/disabled. The 2-to-4 line decoder (demultiplexer) has active low outputs. It decodes the two most significant address bits. The decoder outputs are each ORed with an enable bit, E0 to E3. A ram chip is enabled only if its enable bit is low and its decoded output is low. The host selects which blocks to enable by setting the relevant bits of a byte (or to be accurate a nibble, 4-bits) low and writing the data to the enable latch.

To allow examination of the target from the host requires that data can be passed from the target to the host. The emulator shown in Fig.5 is write-only with respect to the host and read-only with respect to the target. Data can only be passed from the host to the target, the data that is normally passed is the target program. By making group A and group B buffers bidirectional, data can be passed both ways. Data is passed from the target to the host by the target writing the data into emulation ram, at predetermined locations, the host can then read the data from the locations.

This is a simplified description. Two obvious problems are: firstly, when does the host know that the data has been placed by the target in emulation ram? Secondly, the host and target must know which locations are to be used for the data passing and these locations must not be used for anything else. The first of these problems could be solved by using a breakpoint to alert the host that data has been placed in emulation ram. The second problem requires that the software routines on the host and target are organised to use the same locations.

Next consider adding a hardware breakpoint. This can be done by adding a value comparator. The comparator would compare the address bus with the value of the breakpoint address. If they are the same then the target processor must be stopped, and the host informed that the breakpoint has been reached. The method of stopping the processor will depend on the particular processor. Typically it will be done by means of processor inputs such as WAIT, BUS REQUEST or RESET. Using RESET has the disadvantage that when the break condition is removed (by the user) and RESET goes inactive, program execution will restart from the beginning rather than continuing from the break address. Fig.8 shows an outline of the hardware to implement a breakpoint.

The host sets the breakpoint address by writing the address to the latches.

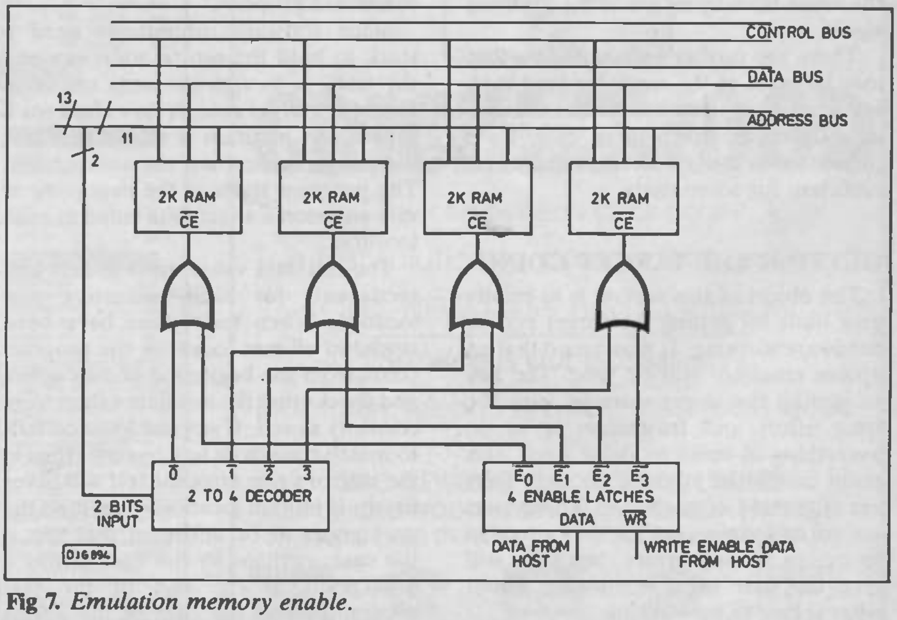

Fig 7. *Emulation memory enable.*

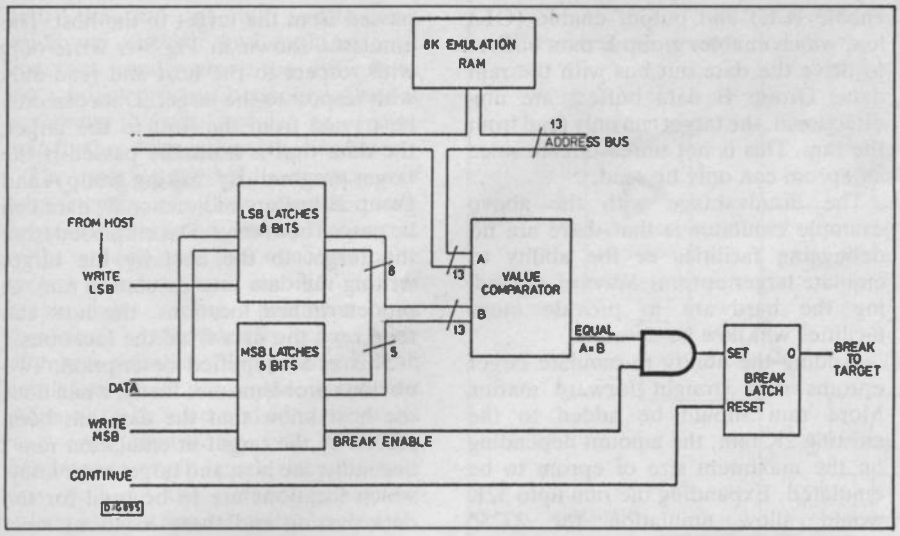

Fig 8. *Breakpoint circuitry*

Two sets of latches are used, this allows the data to be written in two bytes. First the least significant byte (lsb) then the most significant byte (msb). The msb latch also uses one bit to enable/disable the breakpoint, since the user may not want any breakpoints. If the enable bit is low (breakpoint disabled) then even if there is an address match no break will occur. If a match is found and the breakpoint is enabled then the break latch is set, the Q output goes high. This signal should be connected to the target processor and cause execution to stop. The break latch is required because the target processor may not service the request to stop execution until the end of the current instruction, the address bus value may change in this time. If the address value does change the value comparator will no longer indicate a match and without the break latch the request to break would be lost, and the target processor would not stop. If the user wishes to continue target program execution after a break has occurred then the host must be instructed to reset the break latch by means of the continue signal.

There are further enhancements that may be made to the emulator hardware. It is important to consider what the user actually needs. Even in its basic form the emulator is very useful, and may be sufficient for some users.

GETTING THE TARGET GOING

The object of this section is to briefly give hints on getting the target system hardware working. It is assumed that an eprom emulator will be used. The key to getting the target working with the least effort and frustration is to do everything in small modular steps, this point cannot be stressed enough. Tests are suggested at each step. These tests are not exhaustive, nor are they intended to be, in finding errors, but they will give the user some confidence about what seems to be working.

Since an eprom emulator is being used the first step is to confirm the target processor is running. To start with, using a scope, power supplies and the system clock should be checked. Next a short and simple test program should be written. This test program should perform an operation the user can observe and it should use as little of the target's hardware as possible, don't use any ram or i/o. The test program is run on the target using the emulator. An example of a test program for a Z80 based target is, a single byte program consisting of the HALT instruction. When a HALT instruction is executed the HALT line on the processor (pin 18) goes low. The user should be able to observe the result that when the processor is held reset the HALT line will be high, as soon as reset is released the HALT instruction is executed and the HALT line goes low. The HALT line can be observed using a meter or logic probe. If this test performs correctly confidence can be gained that the processor is running and the emulator is connected properly.

Since software subroutines need a stack to hold the return addresses and the stack is in ram the next test is to check the target ram. A flow chart for a simple test program is shown in Fig.9; the program must not use subroutines! The program starts at the beginning of ram and stores a test data value at each location.

The test data value starts at zero and increments for each successive ram location. When test values have been stored in all ram locations the program starts from the beginning of ram again, and checks that the test data values were correctly stored. If any one location fails to match the whole test restarts, thus in the case of a ram error the test will never finish. If all ram locations pass then the user needs to be informed that this is the case, perhaps by the user setting a breakpoint at the end of the test program, or in the case of the Z80 a

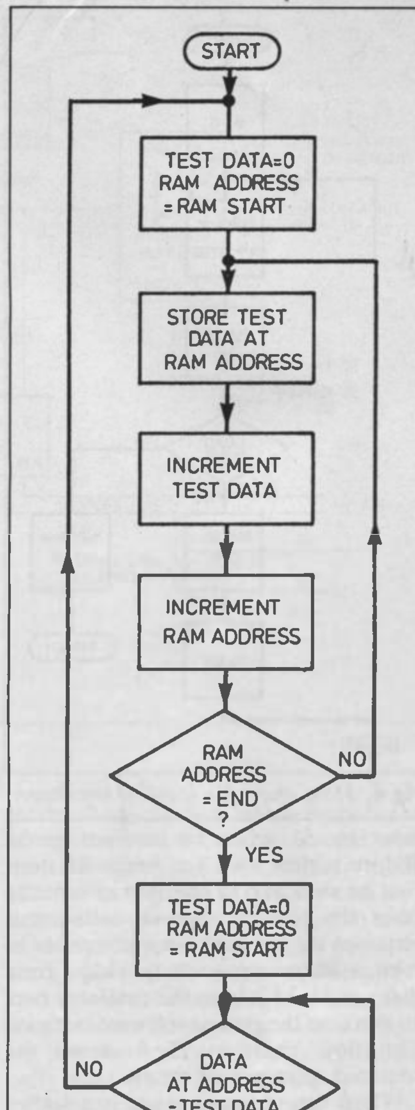

Fig 9. *Target ram test.*

HALT at the end of the program.

The ram test is by no means comprehensive. It does test that many different data values are stored correctly. Consider if the test data value of all bits logic high had been written to all locations, then the test would pass even if there was no ram, so long as the data bus had pull ups, because pull ups would take the data bus logic high during read operations. The program also tests that there is more than one ram location; this checks for a hardware error leading to the same location always being addressed. To some extent the program also checks that all locations are only accessed by one unique address. The probability of finding this type of error could be worked out, however it is felt that this depth of detail is not required here.

The next step is to test the target i/o. Firstly, the output circuitry will be tested. The exact test(s) required will depend upon the type of output circuitry. Consider the case of the output circuitry driving lamps on and off. A simple test program could flash the lamps. They would have to be flashed at a slow rate, otherwise the user would not be able to observe the flashing. Similar tests can be conducted for most types of output circuits. When the outputs have been tested the inputs can be tested. A simple test program could display the input values on the outputs (which have just been tested). Consider the case of the input circuitry being connected to a set of on/off switches, and the output circuitry as above. Each switch could be programmed to control one lamp. The user could manually switch the inputs and watch for the relevant lamps to turn on/off.

When the user is happy that all the hardware is working then software development can begin. Again this should be done in small modular steps, such that at each step a test can be conducted to confirm everything is working as intended.

ASSEMBLERS AND COMPILERS

So far it has been assumed that the target program has been written in assembler on the host machine, and the executable code is transferred to the target. There is a possible problem. What if the host is based on the 8086 processor and the target on a 6502? Clearly an 8086 assembler will not produce code which could run on a 6502. A normal 6502 assembler, which would produce suitable code for the target, will not run on an 8086 host. What is needed is a cross assembler. This is an assembler written to run on one type of processor but assembles to machine executable code for a different processor. Cross assemblers are commercially available.

If the speed of assembler is not needed then there is no reason why the target program should not be written in a high level language. The program would be written and compiled on the host. The executable code produced by the compiler would be transferred to the target, as normal. In the same way cross assemblers may be needed, so may cross compilers. Cross compilers are also commercially available. One further problem with normal compilers is that they will probably produce code which uses the resources of the machine upon which the compiler is running, for example assumptions of usable ram locations, CALLs to the operating system to perform some functions etc. This type of compiler is of no use. A special type of compiler is needed, a compiler specifically for the task of producing code for stand-alone systems. Such compilers are commercially available. So much more could be said about compilers that they need an article to themselves.

Finally, good luck with designing and developing your own stand-alone system. PE

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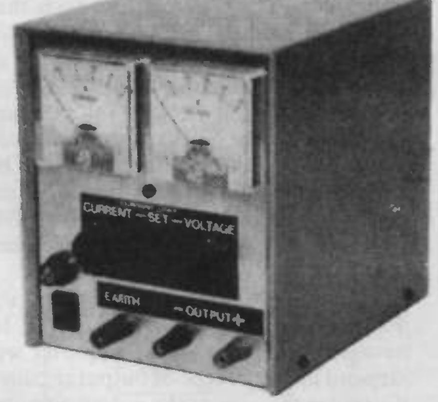

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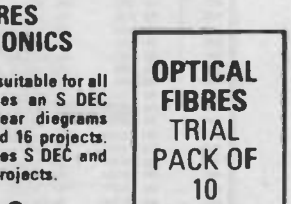

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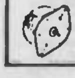

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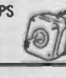

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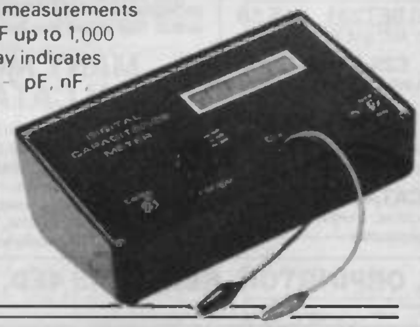

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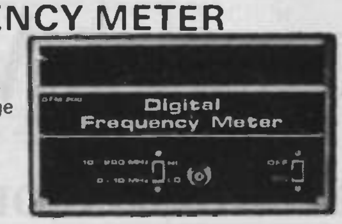

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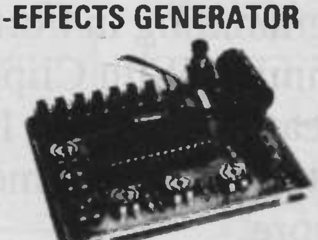

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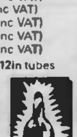

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DIGITAL ELECTRONICS

BY OWEN BISHOP

PART 2 — USING LOGIC GATES

IF informative AND fun THEN NOT put-downable!

This month Owen Bishop describes the different logic operations, shows how a gate is a box, a flip-flop can remember how to stop a computer going "AAAAAA" and what to do with a used-up biro.

The 7400 logic series described last month is one of the old originals, and is still popular today. Several other logic series have been developed since, and each has its good and bad points, as the table on the right shows:

The good points about each series are highlighted in the table. Weighing the advantages against the disadvantages, low power (LS) ttl is the best for experiments and demonstrations, while the HC series is the best for project-building, epscially for battery-powered projects.

SERIES NAME	Standard TTL	LS TTL	'4000'	HC/HCT TTL	AC TTL
Semiconductor type	Bipolar ('ordinary') transistors		CMOS field effect transistors		
Power required	Standard	Low (20% of standard)	Extremely low power		
Supply voltage	5V ± 0.5V		3V–18V	2V–6V	
Suitable power supply	5V regulated[A]		Mains PSU or battery		
Speed	Fast		Slow	Fast	Faster[B]
Handling	Easy		Liable to static damage (Fig.1) Needs extra operating precautions (Figs 2 and 3)		

Note A: they may work with a 6V battery.
Note B: but there can be problems in laying out the circuit.

FROM OUTPUT TO INPUT

The AND, OR and NOT gates we investigated last month are three of the basic units from which more complicated logic circuits are built. This idea of building up complicated systems from simpler ones is an essential part of digital electronics. If you can understand what the simple circuit units (the gates) do, you can understand what they do when they are connected together to make something more elaborate. Note that we said 'if you can understand what the simple circuit units *do*'. It's not necessary to understand *how they work*. Just treat them as black boxes and have fun building bigger black boxes from small black boxes! Let's begin by connecting two gates together in this month's first investigation.

TRUTH TABLES

As a reminder, here are the truth tables we discussed last month.

AND Inputs A	AND Inputs B	AND Output Z	OR Inputs A	OR Inputs B	OR Output Z	NOT Input A	NOT Output Z
0	0	0	0	0	0	0	1
0	1	0	0	1	1	1	0
1	0	0	1	0	1		
1	1	1	1	1	1		

0 = low = false 1 = high = true

Truth tables for AND, OR, NOT.

Owen Bishop is the author of many books on electronics and is a frequent contributor to many periodicals. This series of articles is scheduled to run for nine parts.

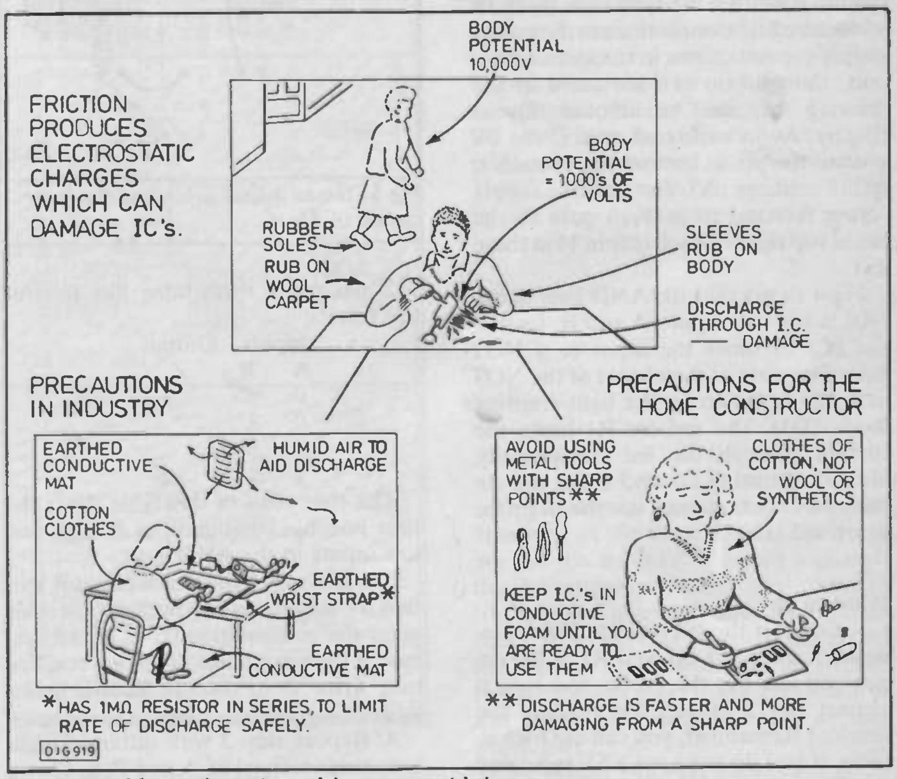
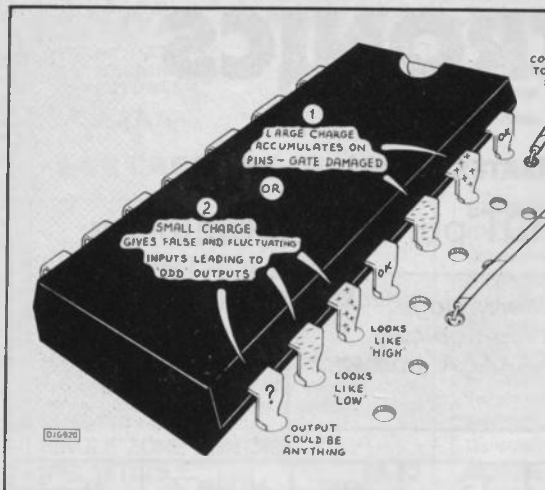


Fig 1. *Troubles with static and how to avoid them.*



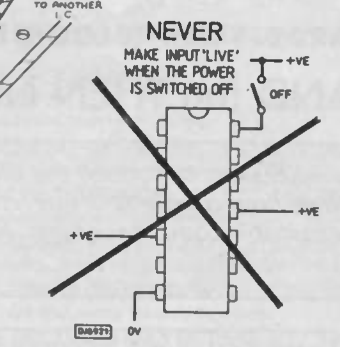


Fig 2. *(left) In cmos ALL pins must be connected to something. This is what happens if pins are left unconnected.*
Fig 3. *(right) With cmos always switch power ON FIRST, OFF LAST.*

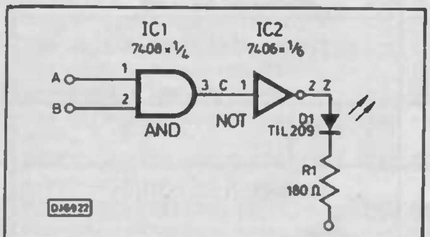


Fig 4. *AND followed by NOT.*

INVESTIGATION 1
Joining AND and NOT

Fig.4 shows the logic circuit. As before, we show the gates by their standard symbols though, to help you, we have written the name of the function below each gate symbol. Above the gate symbol is written the type of ic (both ttl in this circuit). Connections to the power supply are not shown in the circuit diagram, though you can see them in the drawing of the breadboard layout (Fig.5). As in nearly all ttl ics, the 0V goes to the pin at bottom left of each ic (pin 7 in these ics). The positive supply (often referred to as V_{CC}) goes to the pin at top right of each ic (pin 14 in these ics).

Fig.4 shows that the AND gate in the 7408 ic has two inputs, A and B. Its output (C) becomes the input to a NOT gate. The state of the output of the NOT gate (Z) is shown by the light-emitting diode (D1). The resistor R1 limits the current through the led. Incidentally, instead of having D1 and R1 in the circuit, why not build and use the ttl probe described later?

What to do

1. Connect the circuit as in Fig.5. (Instead of including D1 and R1 in the circuit you can use the probe, touching it against pin 2 of IC2 for reading the results.) Remember, you can use 6V batteries if you do not have a 5V regulated supply.

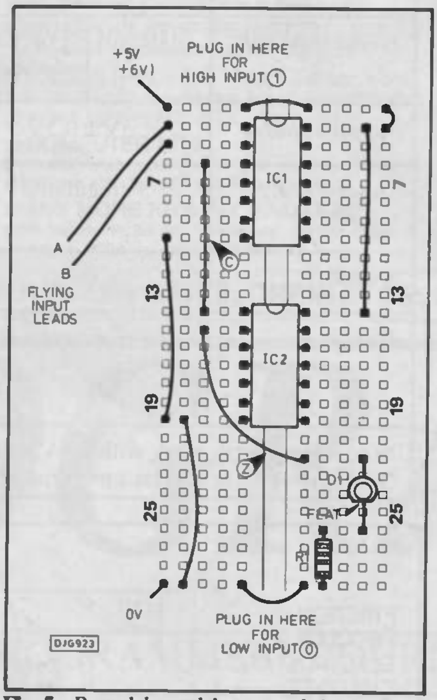


Fig 5. *Bread board layout of the logic circuit in Fig 4.*

2. Set out a truth table like this for the results:

Inputs		Output
A	B	Z
0	0	
0	1	
1	0	
1	1	

The four rows of this table cover the four possible combinations of high and low inputs to the AND gate.

3. Push both flying leads A and B into two 0V sockets in the bottom row. This gives the combination 00 as in the first row of the truth table. If the led remains out, write '0' in column Z; if it lights, write '1'.

4. Repeat step 3 with different high/low combinations of A and B as shown in the other rows of the truth tables.

5. When you have finished, compare this truth table with the truth table for AND. In what way is Z different from the Z in the AND truth table?

NOT AND

The circuit of Fig.4 peforms the NOT-AND operation, which is usually called NAND for short. To put the logic of NAND into a sentence in English, we begin with three statements such as these:

A 'The quality is poor'
B 'The price is high'
C 'I will buy it'

The NAND relationship is expressed by combining the three statements in one sentence (Fig.6):

Fig 6. *The logic of NAND.*

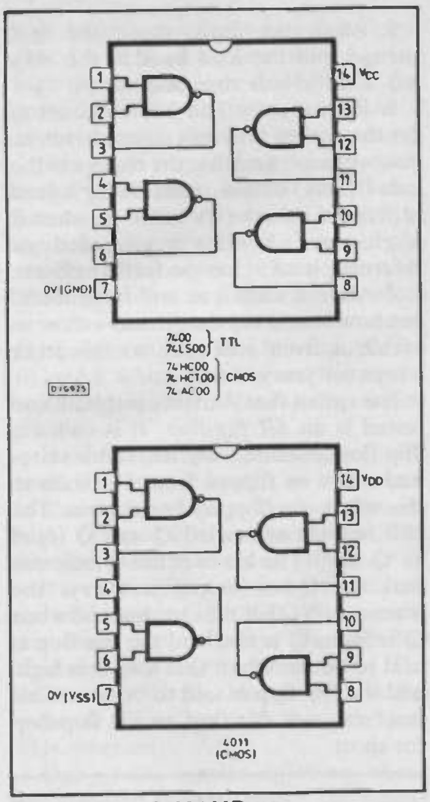


Fig 7. *ICs with NAND gates.*

IF the quality is poor AND the price is high, **THEN NOT** I will buy it'.

The last part of the sentence has the words in a slightly different order from that we usually find in an English sentence. Revise it to '... **THEN** I will **NOT** buy it'.

The NAND operation seems a little way-out when you first meet it but in fact we use it often in everyday life. It is very useful in electronic logic, too. You don't need an AND gate and a NOT gate to perform NAND, as NAND gates are available ready-made on the 7400 ic and its equivalents in the other logic series (Fig.7).

The symbol for a NAND gate (Fig.8) combines the symbol for AND with a small circle. The small circle indicates NOT, which we have already seen on the NOT gate itself.

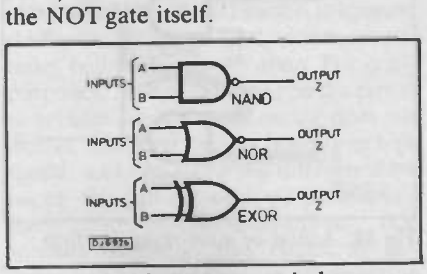


Fig 8. *Other logic gate symbols.*

MORE TRUTH TABLES

NAND			NOR			EXOR		
Inputs		Output	Inputs		Output	Input		Output
A	B	Z	A	B	Z	A	B	Z
0	0	1	0	0	1	0	0	0
0	1	1	0	1	0	0	1	1
1	0	1	1	0	0	1	0	1
1	1	0	1	1	0	1	1	0

0 = low = false   1 = high = true

FETs AND CMOS LOGIC

For readers who know about fets, the 'DD' in V_{DD} refers to the fact that pin 14 is connected to the *drain* terminals of the field effect transistors used in building the gates. Similarly, the 'SS' in V_{SS} shows that pin 7 is connected to their *source* terminals.

NOT-OR

The NOT-OR (or NOR) gate is obtained by taking the output of an OR gate and feeding it to a NOT gate. The circuit diagram and layout are the same as Figs.1 and 2, except you have an OR gate (from a 7432) instead of the AND gate.

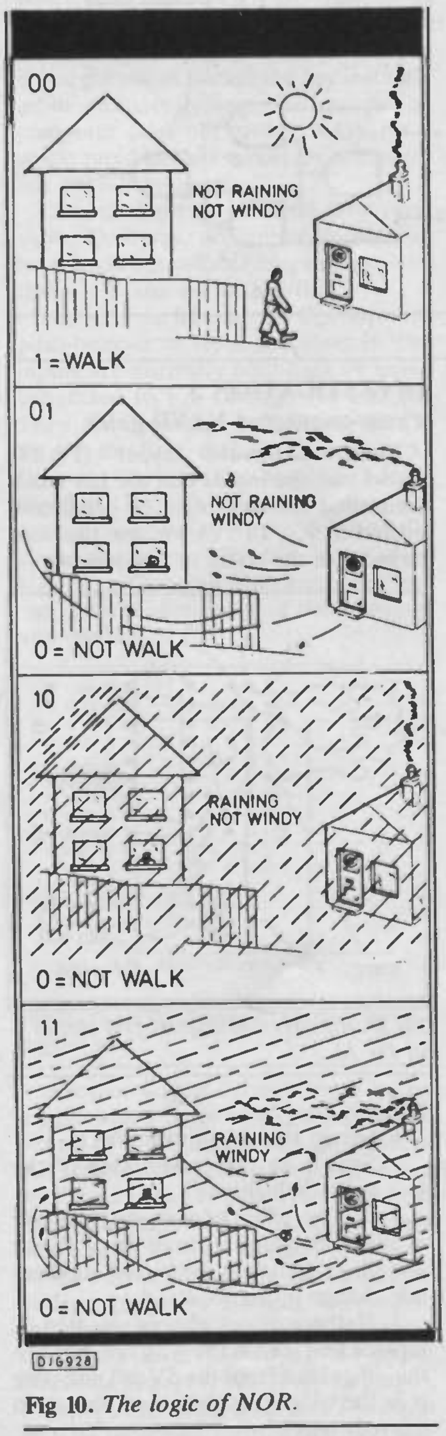


Fig 10. *The logic of NOR.*

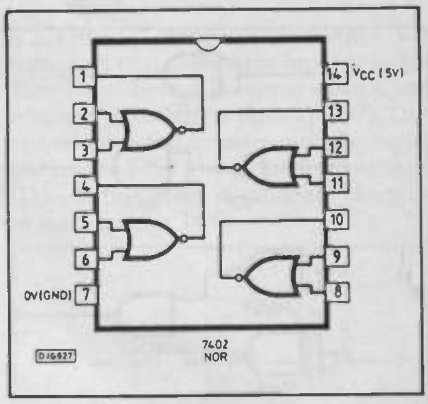


Fig 9. *TTL NOR gates.*

INVESTIGATION 2
Joining OR and NOT

Set up the circuit for NOT-OR, following the same procedure as in *Investigation 1*, and work out the truth table. Compare the results with those obtained by using a ready-made NOR gate, in a 7402 ic (Fig.9).

The NOR operation is illustrated by combining these statements (Fig.10):

A 'It is raining'
B 'A cold wind is blowing'
Z 'I will go for a walk'

Combined into a NOR statement, these make:

'**IF** it is raining **OR** a cold wind is blowing **THEN NOT** I will go for a walk'. A more grammatical ending to the sentence is '**THEN** I will **NOT** go for a walk'.

LOGIC GALORE

Fig.11 shows a collection of logic circuits that you can investigate, using ttl ics on a breadboard. For each circuit, set out a truth table ready to be completed as you try the various possible inputs. Circuits (a) to (c) have only one input; make this low, then high. Circuits (d) to (f) have two inputs, so the truth table has four rows, as in *Investigations 1 and 2*. Circuits (h) to (j) have three inputs. Their truth tables need 8 rows:

Inputs			Output
A	B	C	Z
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

This covers all possible high/low combinations of the three inputs. Try working out the truth table *before* you start the investigation, using the standard truth tables given on this page. Then check your working by using the actual ics. You may find that some of the circuits (made of many gates) have the same logical action as a single gate. If so, say which gate.

The results you may expect are given on p. 41.

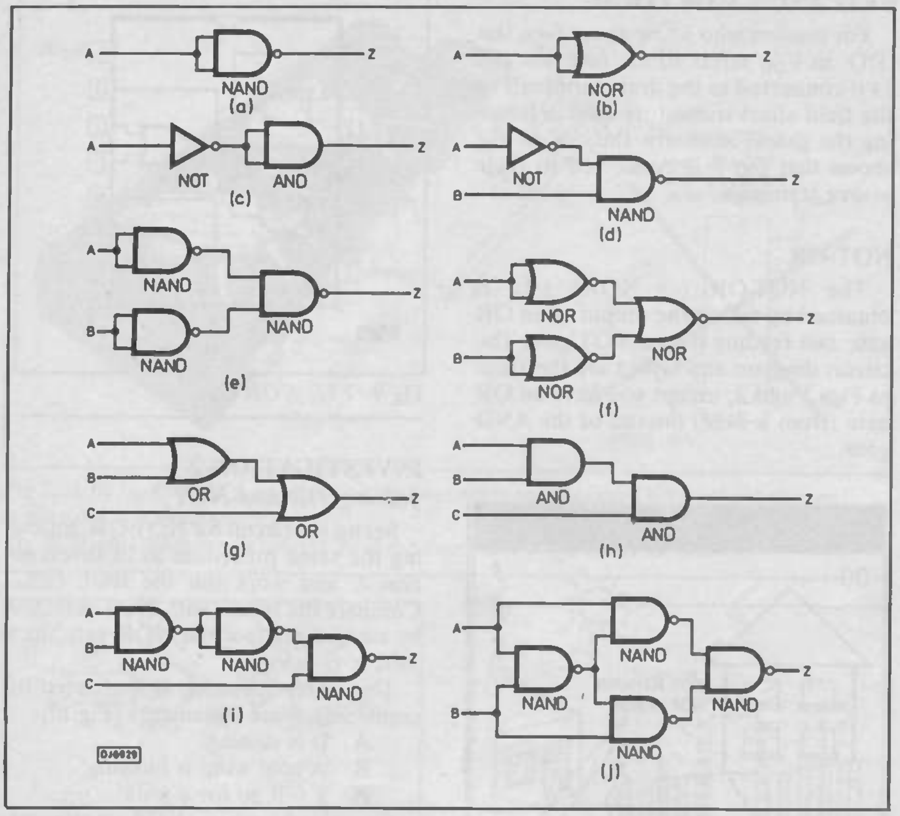


Fig 11. *Some logic circuits to investigate.*

Something else to think about: What do you notice about the numbers in columns A, B and C of the truth table above? Answer on p. 41.

EXCLUSIVE-OR

The exclusive-OR or EXOR gate is a variation on the OR gate. The output of an OR gate is high if A OR B *OR BOTH* are high. The output of an EXOR gate is high if A is high OR B is high, *but not if BOTH inputs are high*. So OR and EXOR differ in the last lines of their truth tables.

EXOR is sometimes called the 'same or different' gate. Its output is high if its inputs are different, but low if they are the same. This gate is therefore useful for making logical *comparisons*. The 7486 ic has four EXOR gates arranged as the gates in a 7400 (Fig.7).

CROSS CONNECTIONS

Fig.12 shows two NAND gates cross-connected so that one *input* of each gate is fed from the *output* of the other gate. The behaviour of this pair of gates is best examined by trying it out.

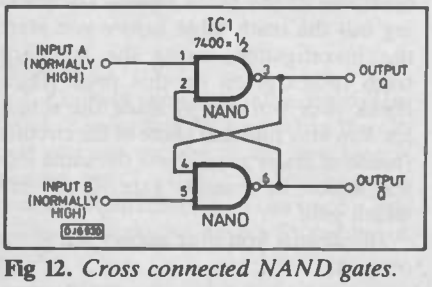


Fig 12. *Cross connected NAND gates.*

INVESTIGATION 3
Cross-connected NAND gates

The bread-board layout (Fig.13) shows that the inputs that are not cross-connected are held high, by being connected to V_{CC} (+5V). We use two leds to indicate the states of the outputs.

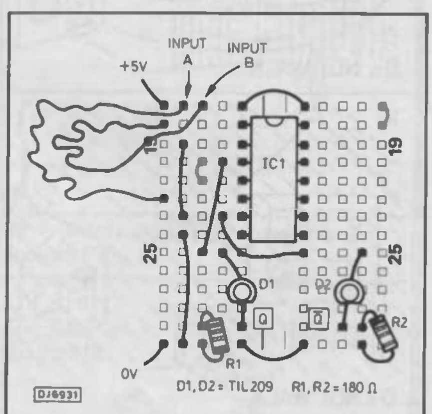


Fig 13. *Bread board layout of the circuit in Fig 12.*

What to do

1. Set up the circuit as in Fig.13.
2. Switch on the power. One of the leds lights. Which one?
3. Try the effect of removing any *one* of the leads (A or B) from the +5V rail and plugging it into the 0V rail. Is there any change in the leds?
4. If there is no change at step 3, replace that lead in the +5V rail; remove the *other* lead from the 5V rail and plug it in the 0V rail. Is there any change in the leds now?
5. When you have made the leds change, put the lead back in the +5V rail. Do the leds change now?
6. Repeat steps 3 to 5 a few times to get the feel of how this circuit behaves. You will soon find that the change in the leds (if any) occurs immediately a lead is plugged into the 0V rail — ie when it is *grounded*. Leaving it grounded, or returning it to + has no further effect.
7. After a while you will have found out how to control the circuit — how to switch it from one state to the other whenever you want to.

The circuit that you have just built and tested is an *SR flip-flop*. It is called a 'flip-flop' because it has two stable states and it can be flipped from one state to the other, or flopped back again. The two outputs are called Q and Q̄ (read as 'Q-bar'). The bar over the Q indicates that the Q-bar output is always the inverse or NOT of the Q output. So when Q is high, Q̄ is low, and the flip-flop is said to be *set*. When Q is low, Q̄ is high, and the flip-flop is said to be *reset*. This is a 'set-reset' flip-flop, or SR flop-flop for short.

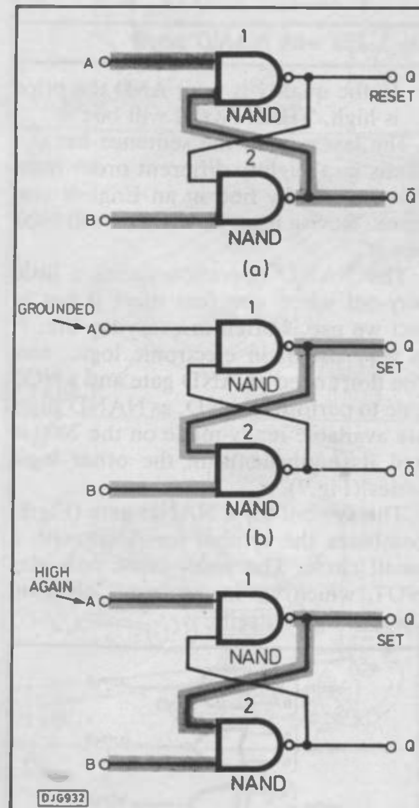


Fig 14. *Action of a set-reset flip-flop*

The way the flip-flop works is explained in Fig.14. Assume that it is in its *reset* state to begin with (Fig.14a) and inputs A and B are in their normal state, both high. Gate 1 has both of its inputs high, so its output Q is low. This low output is fed to one of the inputs of gate 2. Gate 2 thus has a low input (from gate 1) and a high input (B), so its output Q̄ is high (refer to the truth table for NAND if you are not clear about this).

This high output from gate 2 is fed to gate 1 which, as we have said, has two high inputs. The logic levels at the two gates conform with the logic for NAND so the circuit is stable in its reset state.

Now input A is grounded (made low), as in Fig.14b. As a result of this, Gate 1 has a low input and a high input (the input from gate 2 is still high *at this moment*). Its output Q changes to high. This high input is fed to gate 2 which now has two high inputs, so its output $\bar{Q}$ changes to low. This low input is fed to gate 1, which now has two low inputs, so Q remains high. The flip-flop is now *set*.

If we return input A to its normal high level (Fig.14c), it makes no difference to the output of gate 1, which remains high. So gate 2 is unaffected too. The flip-flop is stable in its set state.

If we make input A low *again*, this has no effect on the flip-flop. However, if we make input B low, the flip-flop changes back to its reset state. The description of the change-over is the same as before but with the gate numbers reversed.

One of the interesting things about the flip-flop is that, unlike the simple gate circuits of Fig.11, the output of the flip-flop does not just depend on what level the inputs are *at the moment*. They depend on what the inputs have been *in the past*. The flip-flop *remembers* what has happened to it. For this reason SR flip-flops, or other circuits working in a similar way, are used in the memory of computers and other devices that store information electronically.

CONTACT BOUNCE

Almost all switches or press-buttons suffer from *contact bounce*. If the switch is open and is then closed, the action is not simply 'open-closed'. Its contacts make and break contact several times before the contacts finally close firmly together. The action is 'open-closed-open-closed-...-open-closed'. Conversely, when a closed switch is opened, the contacts break and make several times before it is finally open. For many purposes, such as switching on the power to a radio set, contact bounce does not matter. But logic circuits operate at high-speed, and there is a big difference between the 'off-on' that we intend and the 'off-on-off-on-off-on-off-on' that actually happens. The circuit is fast enough to respond to every *off-on* action of the contact bouncing switch. For example, if you press the 'A' key on the keyboard of a computer briefly *just once*, you expect to see just 'A' appear on the screen. Actually the key may has made and broken contact several times for the single keystroke. If the computer responded to every make and break, as it could easily do, you would see 'AAAA' (or even more 'A's) instead. Programming or word-processing would be

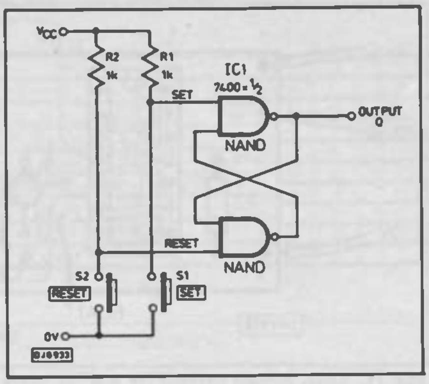


Fig 15. *Using the RS flip-flop*

impossible. Incidentally, we are not referring to the auto-repeat function which gives you 'AAAA etc' if you press *and hold* the key for an appreciable time. We are referring to what should happen if you press and release the key instantly as in ordinary typing. The reason the computer does not give 'AAAA' for a single rapid key-press is because the key has been *debounced*.

Debouncing can be done in several ways. One way, not generally used in computers but suitable for other applications, is to use an SR flip-flop.

In Fig.15 we have an SR flip-flop with push-buttons to set it and reset it. The inputs are normally held high by being connected to V_{CC} through R1 and R2. They are grounded by pressing S1 (to set the flip-flop, making Q high) or S2 (to reset the flip-flop, making Q low), flip-flop. If S1 is pressed, it does not matter how many times S1 actually closes and opens — the flip-flop changes state to 'set' when it *first* closes and stays 'set' for the remainder of the openings and closings.

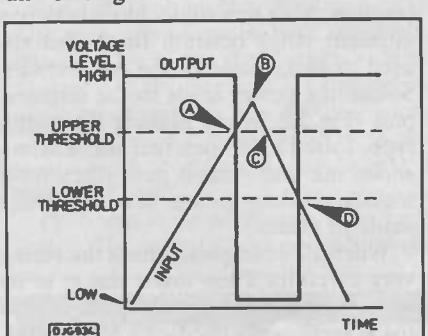


Fig 16. *Inputs and outputs of the Schmitt trigger gate.*

Another way of debouncing is to use a gate with a *Schmitt trigger* input. The action of a NOT gate with an input of this type is shown in Fig.16. Imagine that we have a circuit in which the input voltage can be increased or decreased *gradually*. The input is 0V to begin with (low) so the output is high. We raise the input voltage gradually. Nothing happens to the output at first but, when the input reaches a level known as the *upper threshold voltage* (point A on the graph), the output suddenly goes low. The input may be increased further (B) but there is no further change in the output. We then start to decrease the input voltage. There is no change in output when it has returned to the upper threshold (C). The output does not change until the input has reached the *lower threshold voltage* (D). At this point it suddenly changes to high again.

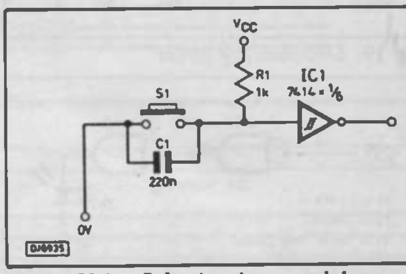


Fig 17. *Using Schmitt trigger to debounce a key.*

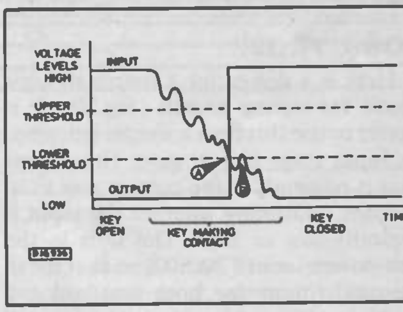


Fig 18. *Voltage chances as SI is pressed in Fig 17.*

Fig.17 shows the gate being used as a key debouncer. Fig.18 explains how it works. Normally capacitor C1 is charged by current flowing through R1. The input is high, and the output is low. When the key (S1) is pressed and makes contact, the capacitor is partly discharged. As the key goes 'on-off-on-off-on etc', the charge on the capacitor 'falls-rises-falls-rises etc'. The trend is down, as shown by the 'input' curve in Fig.18. As the input voltage falls past the upper threshold, there is no effect on the output of the gate. When it *first* falls below the lower threshold (point A) the output becomes high. Any further rises in voltage (as at B) can have no effect, since the capacitor never charges up fast enough to take the voltage above the *upper* threshold. This means that there is a 'once-for-all' action when the button is pressed.

When the button is released, the input voltage rises irregularly, but there is no change in output until it first reaches the upper threshold. At that stage it is not able to fall as low as the lower threshold, so again there is a clean changeover. The button is debounced.

The circuit in Fig.17 normally has a high output, changing to low when the key is pressed. The reverse action is obtained by connecting R1 to 0V and C1/S1 to V_{CC}. A similar circuit may be used with cmos, based on the 4093, which has Schmitt trigger 2-input NAND gates (Fig.19).

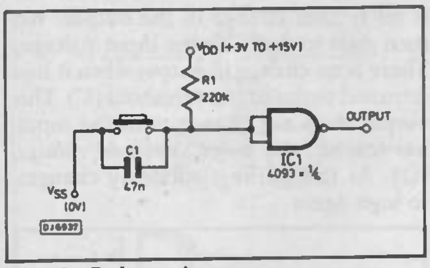


Fig 19. *Debouncing cmos.*

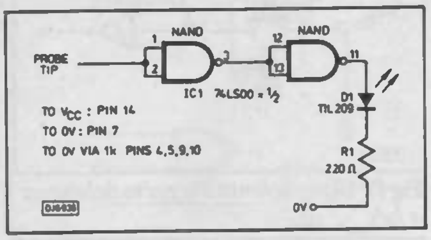


Fig 20. *Logic probe.*

LOGIC PROBE

Here is a design for a simple ttl logic probe for testing circuits (Fig.20). It is better to use this than a simple led, since its input stage is a ttl gate. This means that it responds in the correct way to ttl outputs, indicating whether the input is logically low or high. The ic is in the low-power series (74LS00) so that it can be used for testing both standard and low-power ttl circuits. It can also be used for cmos '4000', HC, HCT and AC if they are operating on a 5V supply. The input is fed to a NAND gate with its input terminals connected, so that it acts as a NOT gate. The output from the first gate goes to a second NAND gate, also wired as a NOT gate. Therefore D1 is on for a high input and off for low input. The probe takes its power from the power supply of the circuit under test.

Cut a piece of strip-board to the required size (Fig.21). Cut the copper strips beneath the board at the points indicated. Note that some of the strips beneath the ic are *not* cut. This is where certain pins on opposite sides of the ic are joined through the copper strips, so eliminating the need for wired connections. Solder the terminal pins, ic socket

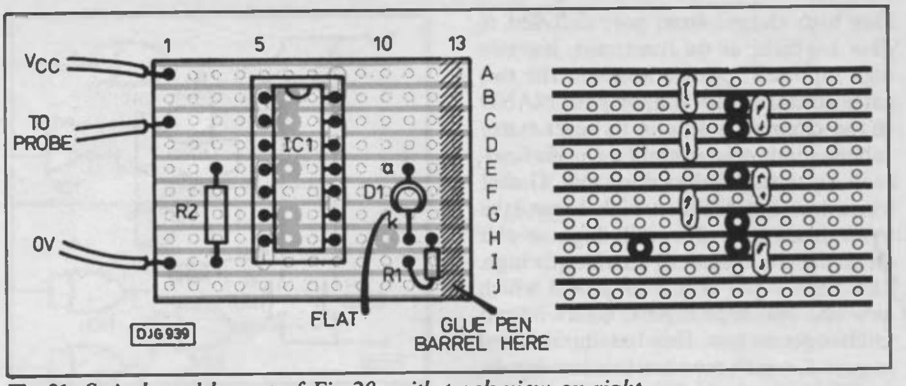


Fig 21. *Strip board layout of Fig 20, with track view on right.*

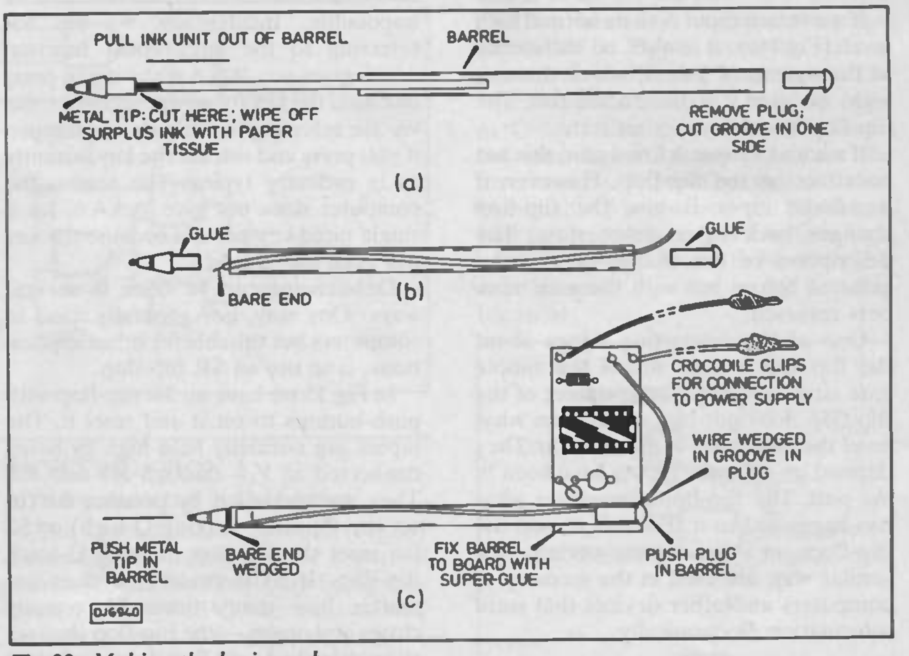


Fig 22. *Making the logic probe.*

and components (except for the ic) in position. Note that solder blobs between adjacent strips beneath the board are used to make some of the connections. Solder the power leads to the terminal pins (Fig.22). When making the prototype, I used a ball-pen that had a *metal-ended* ink unit (cheap pens often have metallic-*looking* points that are really made of plastic).

When all is complete, check the wiring very carefully. Then insert the ic in its socket. To test the probe, connect it to the power supply (+5V or a 6V battery). D1 lights, since the probe is unconnected and therefore acts as if it is receiving a high input. Touch the probe to high (+5V or +6V); D1 stays on. Touch the probe to low (0V); D1 goes off. If the device does not behave properly, check the wiring and soldering. If the led does not light, check that it is connected the right way round (the 'flat' side of the rim must be as shown in Fig.21). In use, the probe tip is touched against the point or terminal to be tested. The led is on if the input is high and is off if it is low. If the led lights, though not as brightly as usual, it is likely that the level is alternating rapidly between high and low (eg a stream of pulses).

COMPONENTS
LOGIC PROBE

RESISTORS

R1	180
R3	1k

Resistors all ¼W carbon

SEMICONDUCTORS

D1	TIL209 or similar led
IC1	74LS00 quad 2-input NAND gates

MISCELLANEOUS
14-pin dil socket, 2.5mm matrix strip-board (9 strips by 18 holes), 1mm terminal pins (3 off), miniature crocodile clips, pvc covered (1 black, 1 red), used ball-point pen.

MODULES OF THE MONTH

More circuit modules for building your own electronic systems.

3. SR flip-flop

This comprises *two* flip-flops operating side by side. One gives outputs Q and $\bar{Q}$, suitable for driving other modules. The other controls the led which indicates the Q output of both flip-flops. Power requirements are 10mA when set.

Parts required:

R1	180 ohm, 0.25W carbon
D1	TIL209 or similar led
IC1	74LS00 quadruple 2-input NAND gates
SKT1	pc terminal 4-way
SKT2	pc terminal 2-way

14-pin dil socket
Stripboard Vero 14345

4. Debounced push-button

The circuit is based on Fig.17, except that we use a 7413 which has two 4-input NAND gates with Schmitt inputs. There are 2 outputs. $\bar{Z}$ comes from the first gate (pin 6); it is normally low and goes high when the button is pressed. $\bar{Z}$ is inverted by the second gate to give Z at pin 8. The module requires 10mA.

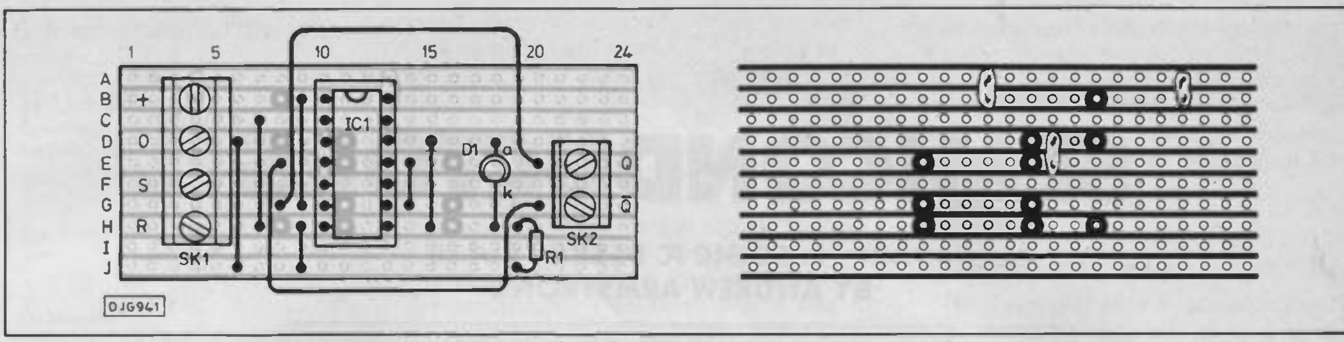


Fig 23. *Module 3. SR flip flop component layout and track view.*

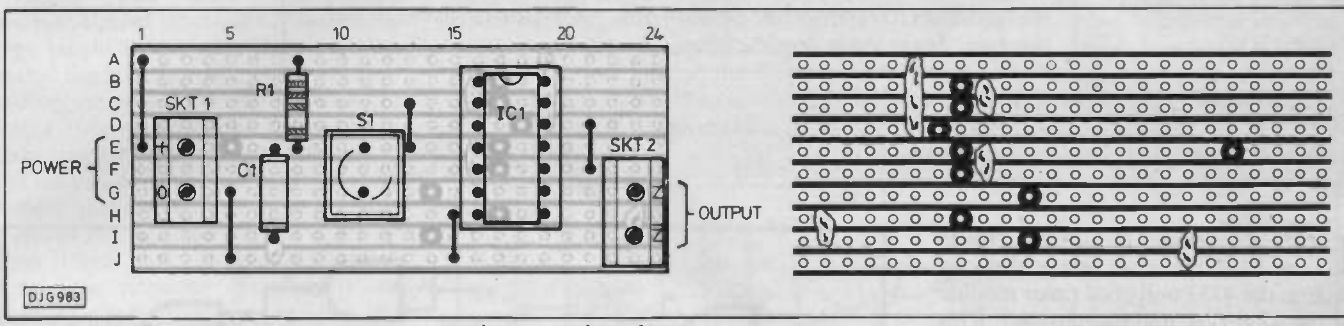


Fig 24. *Module 4. Debounce key component layout and track view.*

Parts required:

R1	1k, 0.25W
C1	22n polyester layer capacitor
IC1	74LS13 dual 4-input NAND Schmitt trigger gate
SKT1,SKT2	pc terminal 2-way (2 off)

14-pin dil socket, S1 push-to-make push-button (pin spacing 5mm), Stripboard Vero 14345

ANSWERS TO QUESTIONS

Don't look until you need to!

The truth tables of the logic circuits in Fig.11 are as follows:

(a) Same as a NOT gate. This is a way of making a NOT gate if you do not need as many as there are on a 7406, yet have a NAND gate to spare.

(b) Same as a NOT gate. Same comment as in (a).

(c) The output equals the input — a TRUE gate.

(d)

Inputs A	Inputs B	Output Z
0	0	1
0	1	0
1	0	1
1	1	1

(e) Same as an OR gate.

(f) Same as an AND gate.

(g) Same as an OR gate with three inputs. The AND, Or, NAND and NOR gates that we have used so far have only two inputs each. These gates can have more than two inputs. With a 3-input OR gate, the output is high when any one or more of the three inputs is high. Conversely, the output is low only when all three inputs are low (000). 3-input OR gates are not available on ttl so this is a way of constructing such a gate if you need one.

(h) Same as an AND gate with three inputs. The output is high only if all three inputs are high (111), otherwise it is low. A way of making a 3-input AND gate.

(i) Same as a NAND gate with 3 inputs. NAND gates with 3, 4 and 8 inputs are available on ttl.

(j) Same as an exclusive-OR gate. This is a simple way of making an EXOR gate if you need just one.

The other question: If read as 3-bit binary numbers the numbers in columns A, B, C are the equivalents of the decimal numbers 0 to 7. PE

Next month, Part Three covers the basic principles of multivibrators, including monostables and astables. We also take a look at the 555 timer ic, and a programmable multivibrator becomes the Project of the Month.

SEMICONDUCTORS

PART 10: LOGIC IC DESIGN RULES
BY ANDREW ARMSTRONG

Simply connecting logic ics together to form the required logic diagram sometimes works well, but can lead to problems. It is important to remember certain electrical design rules to get the best from your logic chips.

Logic chips come in all sizes. There are lsi (large scale integration) ics such as the 4753 universal timer module or the 4752V ac motor controller. This type of ic is unlikely to be of interest to the home constructor, though memory chips which are also classified as lsi may well be of interest.

The next size range down is msi, which includes such useful items as dual monostables, display decoder drivers, and counters. Some ics of these types are reasonably cheap, and quite practical for the home constructor to use. Even more economical and widely used are ssi (small scale integration) ics. This category refers mainly to ordinary gates, such as the 74LS00 ttl quad 2 input NAND gate, or the 4001 cmos quad 2 input NOR gate.

It is in the area of design with ssi that the home constructor has the greatest freedom of choice. LSI and to some extent msi chip are designed to be used in certain ways, and what you can do with them is constrained by their basic functions. Good design of the circuit is still important, but in some cases this can mean simply following the application circuits in the data book.

For this reason, I shall devote this section mainly to design using ssi, and I shall confine my examples to cmos ics because these are more widely used by the home constructor.

BOOLEAN ALGEBRA

If you know what the standard logic gates do, it is often possible to look at a logic circuit diagram and deduce what it will do. Equally, it is usually easy to draw a circuit to carry out a simple logic function just by using common sense. For the designs where this is not true, Boolean algebra provides a means of analysis and design much more powerful than simply looking at a circuit and saying "I think it will do this".

Even in a simple design, Boolean algebra can help. While you may be able to see a way to make a logic circuit using a NAND gate and an OR gate, this could mean that you use one quarter of two different ics. Simple Boolean algebra will tell you that the OR gate is not needed because the function can be synthesized from the remaining three quarters of the NAND gate. This is illustrated in Fig. 89, and the corollary using an AND gate and three NOR gates shown in Fig. 90.

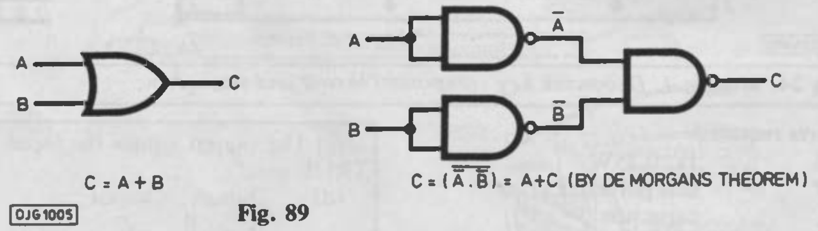


Fig. 89

Many readers will be familiar with Boolean algebra. For those who are not, here is a brief explanation:

(Readers will find Owen Bishop's digital electronics tutorial to be additionally helpful. Ed.)

In Boolean algebra, letters are used to represent logic signals rather than numbers, so the available values for a variable are logic 1 and logic 0. The operators are + meaning OR, . (dot) meaning AND, and the inversion symbol as in $B=\bar{A}$ (meaning that if A is logic 1, B is logic 0 and vice-versa). In addition to these basic logic operations, which can easily be used in Boolean algebraic operations, there are additional symbols + meaning exclusive OR, | meaning NAND (AND with the output inverted) and ↓ meaning NOR (OR with the output inverted).

In this case of two input gates, these logic functions have the following meanings:

OR – the output is logic 1 if one or both of the inputs is logic 1.
AND – the output is logic 1 if both of the inputs are logic 1.
EXOR – Exclusive OR – the output is logic 1 if either but not both of the inputs is logic 1, ie if the inputs are dissimilar.
NOR – the output is logic 0 if either or both of the inputs is logic 1.
NAND – the output is logic 0 if both of the inputs are logic 1.

Note the similarities between, for example OR and NAND. The OR gate output is logic 0 if both the inputs are logic 0, while the NAND gate output is logic 0 if both the inputs are logic 1. Simply inverting the inputs changes a NAND gate into an OR gate or vice versa.

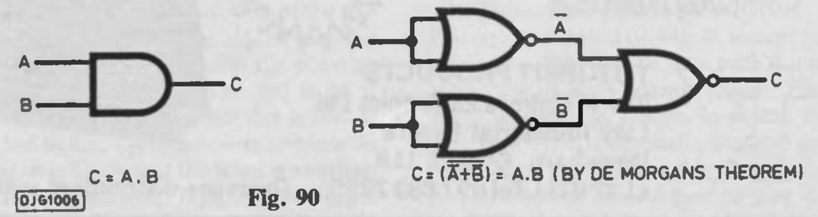


Fig. 90

Here are some of the laws of Boolean algebra:

Basic gating functions	$A.\bar{A}=0, A+\bar{A}=1$
Identity	$A.(A+B)=A,$
	$A=(A.B)=A,$
	$A.(\bar{A}+B)+A.B,$
	$A+(\bar{A}.B)=A+B$
Distributive laws	$A.(B+C)=(A.B)+(A.C),$
	$A+(B.C)=(A+B).$
	$(A+C)$
De Morgans Theorems	$\bar{A}+\bar{B}=\bar{A}.\bar{B}, A.B=\bar{A}+\bar{B}$

People who have encountered Boolean algebra in school have normally been taught to minimise the equations, so that the logic function can be written as simply as possible. In the real world of design, the aim is to fit the logic function to the standard ics which are available so that the design can be built as simply and cheaply as possible. Here is an example of an outdoor light intended to switch on when it gets dark, or when a detector signals the presence of intruders, or when manually switched on. For the sake of this example, the output is intended to switch an opto-triac via a transistor, and there will be separate switches for automatic operation or manual override.

In words, the requirement is as follows. The output must switch on if: Manual override is on OR automatic operation AND low light level are true OR automatic operation AND intruder detect are true. Let output = Z, manual override = M, automatic operation = A, intruder detect = D, low light level = L. As an equation we have Z = M+A.L+A.D

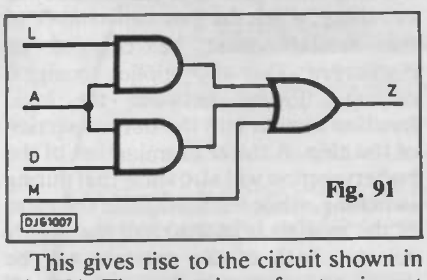


Fig. 91

This gives rise to the circuit shown in Fig. 91. The selection of gates is not convenient, so we will try to alter the form of the equations to minimise the number of different gates. To make this easier, signals which can be generated with either logic polarity will be used as true or inverse as is convenient. For example, if a signal is generated by means of a switch it does not matter whether the switch output is logic 1 for on or logic 0 for on. Z=M+A.L+A.D = M+A.(L+D). This is a hierarchical set of two input gates, which is a step in the right direction. Inversions are almost certainly required in the final implementation, so we could try fitting this equation into NOR or NAND form. Here are the two sets of reasoning.

NAND

$Z=M+A.(L+D) = M+A.(\bar{L}|\bar{D})$

$=M+(A|(\bar{L}|\bar{D})) = \bar{M}|(A|(\bar{L}|\bar{D}))$

NOR

$Z=M+A.(L+D) = M+ A.(\overline{\bar{L}\downarrow\bar{D}})$

$=M+(\bar{A}\downarrow(L\downarrow D)) = \bar{M}\downarrow(\overline{\bar{A}\downarrow(\bar{L}\downarrow\bar{D})})$

There isn't a lot to choose between the two final equations, but I think that I slightly prefer the NOR one. The polarity of the output signal does not matter in this case, because the sex of the drive transistor used can be chosen accordingly. I do think it is neater to have both the switch signals of the same polarity, preferably with the switch pulling a control line to logic 0 to switch on a function. Taking these ideas into account, the final inversion of the output is removed, and instead the fourth gate in the ic can be used to invert the M signal. This gives rise to the circuit shown in Fig. 92.

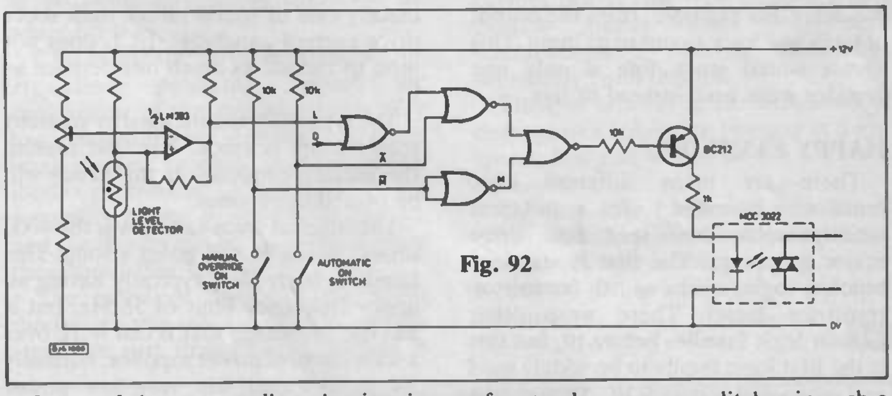


Fig. 92

Some of the surrounding circuitry is shown as well as the logic circuitry to illustrate the application more clearly. The D signal might well be derived from a passive infra-red intruder detector.

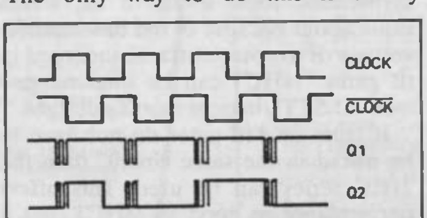
Of course, this example is simple and tells you little that was not obvious at a glance. The principals can be applied to much more complicated situations, where significant savings can be made. The only way to do this is to try transforming the equations in different ways to find one which is sensible. The hint that this is advisable is if a number of logic ics have unused sections, so that if the logic functions required matched the gates available the number of ics could be reduced.

WINNING THE RACE

The straightforward combinational logic design procedure is ok so long as speed is not a major consideration. In fast circuits with several signal paths, a delay in one signal relative to another can cause problems. In general it is bad practice to design a circuit in which the operation depends upon two signals arriving at the same time. Even minor discrepancies caused by differing lengths of pc track may cause glitches in such a design.

The effect of differential timing errors, often called pulse race hazard, is illustrated by the particularly gross example in Fig. 93. This is a circuit of a master/slave T (or toggle) flip flop. It contains two set/reset latches, and two of what are effectively transmission gate pairs. The two transmission gate pairs, labelled gate one and gate two in the diagram, are alternatively open and closed, so that information is transferred first from latch one to latch two and then from latch two to latch one. The feedback connections are crossed over so that the latches change state.

This is what happens in theory, but in practice this particular circuit cannot



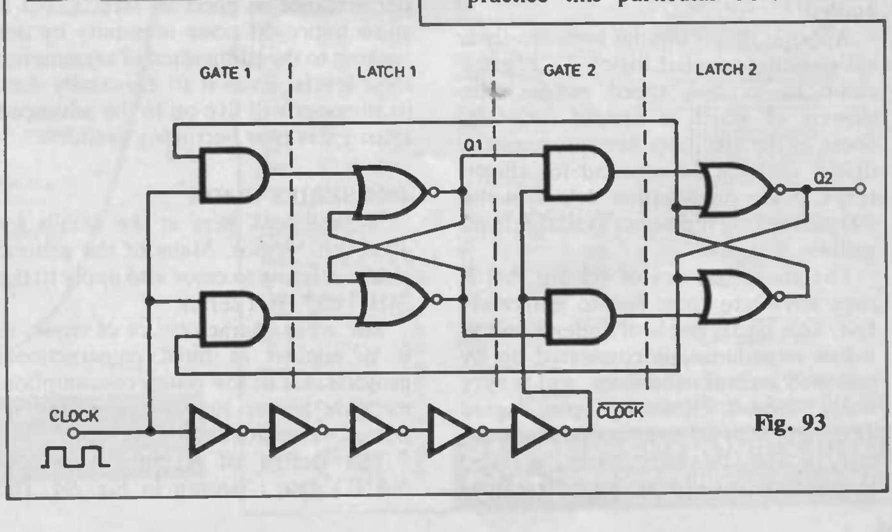


Fig. 93

perform in the way described, because there is too much skew in clock timing between the two gates. This skew is generated by the unnecessarily large number of inverters on the clock signal. Unless there was some strange buffering problem, one would normally only use one inverter for this purpose.

The timing diagram illustrates the problem. Each transmission gate pair changes state when its clock signal is high, and there is a significant period of overlap when both sets of transmission gates are open. This means that there is a path right round the feedback loop and oscillation can occur. The state in which the latches settle after this oscillation is indeterminate.

The timing requirement of the clock signals to prevent oscillation is that the skew is under three gate delays. This is the delay, for example, from the output of latch one back round to its input. This circuit would work fine if only one inverter were used instead of five.

HAPPY FAMILIES

There are many different logic families intended for different requirements. They split into three major groupings. The first is standard bipolar logic, such as ttl (transistor-transistor logic). There were other bipolar logic families before ttl, but this is the first logic family to be widely used and scattered around in circuits like liquorice allsorts. Standard ttl is now obsolete, but it lives on in all specialised variants.

The normal "vanilla" ttl is ls (low powered Schottky). For faster applications, there is als (advanced low powered Schottky), FAST, and Schottky. TTL has been viewed as a dinosaur which refused to die.

Briefly, ttl is reasonably fast, has medium to high power consumption, and tends to radiate interference to other parts of the circuitry because it is switching signals of several volts at high speed. TTL has fan-out limitations. This means that, because ttl inputs require drive current, the number of inputs that can be connected to any ttl outputs is limited.

Another major bipolar logic family is ecl (emitter coupled logic). ECL gates come in various speed ranges, the slowest of which is around 200MHz. Some of the fast gates have propagation delays under a nanosecond for silicon chips, while propagation delays in the 100 picosecond region are available from gallium arsenide.

The characteristics of ecl are that it runs anywhere from fast to extremely fast, uses signal levels of under a volt at a low impedance, is connected up by matched transmission lines, and is very watty indeed. Some people regard designing with ecl as a bit of a black art, but it can be very tame if used intelligently. As with ttl, ecl suffers from

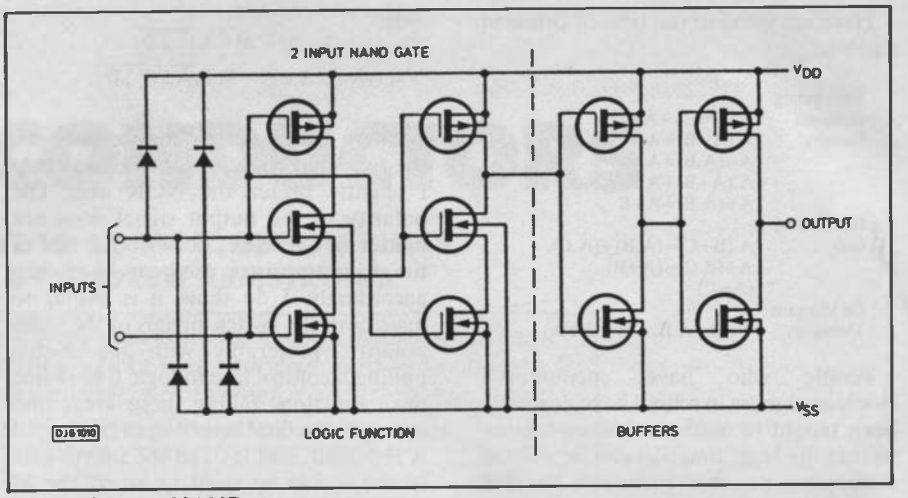


Fig. 94 *2-input NAND gate*

fan-out limitations, but the limit is usually one of speed rather than sheer drive current capability. ECL does not tend to radiate as much interference as ttl.

The type of logic most used by amateur constructors is cmos. For that reason, the greater emphasis of this series will be placed upon cmos.

The original cmos family was the 4000 series, which is still going strong. This family is fairly slow, typically having an upper frequency limit of 5MHz, but it has the advantage that is can work over a wide range of power supplies, normally 3V to 18V and has very low power consumption. For this reason, it is widely used in applications where speed is not critical. Because it has been around for some time, and has substantial sales, 4000 series cmos is relatively cheap. In other words, this is the one we all use.

Faster cmos has taken its cue from ttl. We have the 74HCTseries of cmos, which duplicates most aspects of ttl performance. It even uses the asymmetric logic levels of ttl, which came about because of the base/emitter voltage of the output transistors used in ttl gates. 74HCT can be interchanged with 74LSTTL in most existing designs.

If cmos and ttl gates do not have to be mixed in the same circuit, then the 74HC series can be used. This offers performance as good as 74HCT, but it gains improved noise immunity by not sticking to the ttl standard of asymmetric logic levels. Even if ttl eventually dies, its memory will live on in the advanced cmos gates now becoming available.

4000 SERIES CMOS

We will look here at the details for 4000 series cmos. Many of the general points relating to cmos also apply to the 74HC and HCT series.

The main characteristics of cmos, as it is applied in most constructional projects, are its low power consumption, its wide power supply range, and its notorious sensitivity to static electricity.

The design of a cmos two-input NAND gate is shown in Fig. 94. The design here is of a buffered gate which can drive more output current than unbuffered types. If the gate were unbuffered, the output would be taken from the output of the part labelled "logic function". A fair amount can be learned from this circuit. As you can see, the inputs are diode protected, but apart from that they go only to the gates of mosfets, so no input current is required to hold the input at either logic level. The specifications for input leakage current of a cmos gate are much higher than the levels achieved by almost all gates in practice. The input leakage current would normally be only the diode leakage, and this is very small, but the specification is higher to make testing easier.

The only time that a significant input current should flow in a correctly working cmos gate is at the moment of switching, when the gate capacitance of the mosfets must be charged or discharged. This also applies to signal currents flowing between the logic function section and the buffers section of the chip. A closer examination of the buffers section will also show that during switching, while the voltage on the gates of the mosfets is around half the supply voltage, both of the mosfets will be conducting current to some extent. All of these factors add together to make the ic draw gulps of current from the power supply every time it switches.

A typical formula for power dissipation of a cmos gate running at 10V is:

$$\text{Power } (\mu W) = 7700 * f_i + f_o * Cl * V^2$$

where f_i is the input frequency f_o is the output frequency, C_l is the output load capacitance, and V is the power supply voltage. This assumes that just one output and just one input are in use.

BUS DRIVERS

CMOS lends itself well to providing tristate outputs because it has a very high output impedance in the off state. Tristate outputs are largely used in

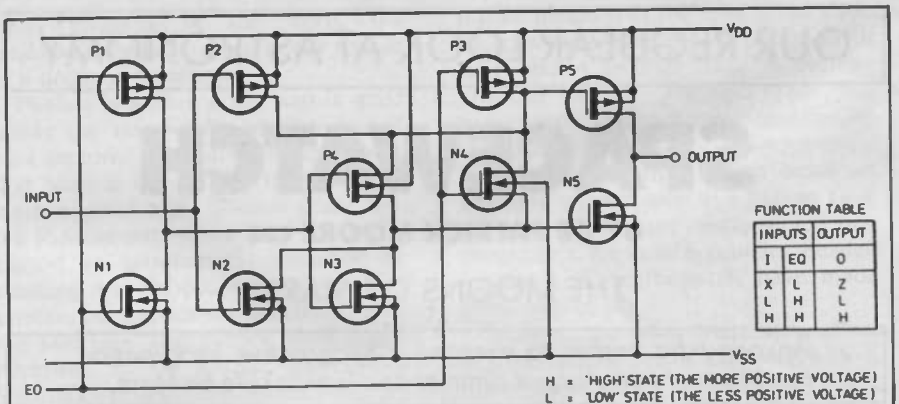


Fig. 95 *Tri-state output stage*

H = 'HIGH' STATE (THE MORE POSITIVE VOLTAGE)
L = 'LOW' STATE (THE LESS POSITIVE VOLTAGE)
X = STATE IS IMMATERIAL
Z = HIGH IMPEDANCE 'OFF' STATE

microprocessor systems, in situations where several chips must, at different times, put data onto the data bus. Fig. 95 shows a typical output circuit.

This is how it works: if the E0 input is at logic 0, then P1 is switched on and N1 is switched off. The output from this pair switch N3 on and P4 off, thus holding N5 off and disconnecting the output from Vss. At the same time, P3 is switched on and N4 is switched off by E0, so that P5 is switched firmly off, disconnecting the output from Vdd. In this situation the state of the input is irrelevant.

If E0 is at logic 1, on the other hand, N3 is switched off and P4 is switched on, so that the state of N5 is controlled by P2 and N2, which are controlled by the input. Equally, P3 is off and N4 is on, so that the gates of P5 and N5 are connected together, and the output stage is effectively the same as that of Fig. 94. while E0 is high.

CMOS inputs, as mentioned before, are diode protected. Though the capacitance of the mosfet gates is very low, cmos chips are sturdier than many small discrete mosfets, because of this diode protection. Nevertheless, the capability of the protection is limited, and the diodes can be damaged if more than about 10mA flows.

The effect of damaging the input diodes or some other part of the chip by static can vary from a slight increase in quiescent current to the total functional failure of the ic. In the latter case, the damage is very obvious, but in the former case it will only be apparent if the ic is used in a circuit in which the power consumption is critical. However, even the lower level of damage can cause an ic to fail after many hundreds of hours of operation.

One mechanism by which this delayed failure occurs is as follows: if a static discharge punches a hole through an insulating layer, a small amount of the interconnect metallisation may be deposited on the inside of the hole, rather like a plated-through hole on a pcb. The deposition of metal is likely to be so slight that, depending on circumstances, more metal may be deposited or the metal already there may be removed by ion migration as leakage current flows. This type of failure may explain rather more equipment malfunctions in service than has previously been thought.

There is one very clear indication of damage to a cmos chip running at a low speed: if it gets warm, then it has been damaged.

On that note I will end part ten of Semiconductors, and continue with the subject of cmos in the next part, where I shall be giving a number of practical circuits.

PE

OUR REGULAR LOOK AT ASTRONOMY

SPACEWATCH

BY DR PATRICK MOORE CBE

THE MOONS OF MARS

Anyone who wishes to exercise a hyperactive imagination can blame the sun for our summer and look for life on Mars.

The supernova which burst forth in the Large Cloud of Magellan last year continues to fade slowly, but is still an easy object with a small telescope (it is, alas, too far south to be visible from Britain). It is interesting particularly in-as much as its progenitor star was a blue giant, not a red star. This explains why it was underluminous by supernova standards; a blue giant is not so large as a red giant, and there is less 'surface' to expand. Whether the remnant will be a pulsar or a black hole remains to be seen.

Our own Sun has now passed its minimum, and during June and July we saw the greatest sunspot group for many years; it was also a very active group, and produced a major solar flare. Activity will no doubt go on increasing over the rest of this year, building up to the next maximum around 1990-1991, and solar observers will have an interesting time; so too will observers of aurora or polar lights, which are due to electrified particles sent out from highly active regions on the sun. Radio and television reception may be affected, and there will certainly be many magnetic storms. Whether sunspot activity has any direct influence on British weather is much less certain!

The Phobos Probe

The Russian interest in Mars has been highlighted by the launch of a space-craft not only to Mars itself, but to Phobos, the larger of its two midget moons. The journey will take 200 days.

Phobos is a true dwarf; it is irregular in shape, with a longest diameter of 27 km (just under 17 miles) and it is crater-scarred. The largest crater is 5 miles across; and has been named Stickney, the maiden name of the wife of Asaph Hall, who discovered Phobos in 1877. Phobos also shows remarkable features which seem like stress-marks, and there are hills and valleys.

The Russians hope to land two probes on Phobos, one of which will be static while the other will be able to 'hop' around. But, of course, the gravitation pull of the tiny satellite is so weak that one cannot speak of a 'landing' in the

The Sky This Month

The planetary scene this month is, of course, dominated by Mars, which comes to opposition on 28 September. It will then be a mere 59,000,000km away. This is less than 37,000,000 miles – almost as close as Mars can ever be – and for a brief period it will outshine every other object in the sky apart from the Sun, the Moon and Venus. The magnitude will be −2.8, as against −2.5 for Jupiter.

In fact, Mars will not again be so close for the rest of the century. Morever, it is within one degree of the celestial equator, so that over Britain it rises to a very respectable altitude indeed. The apparent diameter of the disc at opposition will be 23.6 seconds of arc, and the southern helmsphere will be presenteed. A small telescope will show the main dark markings, such as the V-shaped Syrtis Major (once known as the Hourglass Sea!) which was recognisably drawn by the Dutch observer Christiaan Huygens as long ago as the year 1659.

Venus is a brilliant object in the eastern sky before dawn; the magnitude is about −4.1. The phase increases from approximately 53 per cent at the beginning of the month to 68 per cent at the end (it is not possible to be precise, because of the well-known Schröter effect which I discussed earlier this year). Mercury is theoretically an evening object, but is badly placed for observers in Britain, and I doubt whether you will see it with the naked eye. Jupiter, in Taurus, is a prominent morning object in the general area of the Hyades and the Pleades; if you look at it with a telescope around 21.45 GMT on September 1 you will find that all its four satellites are out of view – either eclipsed, occulted or in transit. This does not happen often; almost always at least one of the "Galilean satellites" is visible. Saturn, magnitude +0.5, is still in the evening sky, and its rings are wide open, but it lies in Sagittarius, and is inconveniently low down.

The Moon is new on 11 September, and full on the 25th.

The Perseid meteors are over for this year. The only shower active during September is that of the Piscids, but the ZHR is not likely to be more than 10 – in other words, if you see more than two or three Piscids per hour you will be lucky – and the date of maximum is not at all well-defined.

The autumn constellations are now well in view, with the Square of Pegasus prominent in the south after dark. Look at its four main stars, and you will see that while three of them are white, the other – Skat or Beta Pegasi, in the upper right-hand corner of the Square – is orange; it is also variable, though it has a small range. Below the Square, almost at the southern horizon, look for Fomalhaut in Piscis Austrinus (the Southern Fish), which is a bright star but is never well seen from even South England; from North Scotland it barely rises at all. It is one of the stars found by the infra-red astronomical satellite (IRAS) of 1983 to be associated with a cloud of cool, possibly planet-forming material, and it is by no means far-fetched to think that Fomalhaut may be associated with a full-scale planetary system, though we have no direct proof.

The "Summer Triangle" of Vega, Deneb and Altair is still on view. Ursa Major, the Great Bear, is at its lowest in the north; the W of Cassiopeia is not far from the zenith or overhead point; the lovely star-cluster of the Pleiades is coming into view in the east – heralding the approach of winter, with its fogs and frosts!

usual meaning of the word; the rendezvous will be more in the nature of a docking operation.

Phobos is a dark body, and is quite unlike our massive Moon; it may well be a captured asteroid, bearing in mind that Mars is not so very far inside the main asteroid zone. Twenty years ago, the Russian astronomer Iosif Shklovskii caused an astronomical sensation by claiming that Phobos was not a natural satellite but a space-station launched by the Martians. This caused many raised eyebrows in the USSR; years later Shklovskii told me that his idea was put out as a practical joke, but whether or not he meant it at the time is not clear. At least the Viking probes of the 1970s have shown us that there is nothing artificial about Phobos. (In this connection, I cannot resist mentioning the 'face on Mars' – a rock photographed by the Viking lander which bears an uncanny resemblance to a human face. Shadow effects are responsible, but, predictably, the usual eccentrics, headed by the UFO enthusiasts, have made great play of it!)

Deimos, the other Martian satellite, is even smaller than Phobos, with a maximum diameter of less than 10 miles; it too is dark and cratered. If you have a reasonably powerful telescope, you should be able to see both as tiny points of light – electronic equipment will naturally be a help, but I can glimpse both satellites visually, under good conditions, with my 15-inch reflector.

Small though Phobos and Deimos are, they could be of great value to us in the future. Martian colonists will find them inadequate to provide any illumination at night (Deimos would appear no better as a light-source than Venus does to us). But they may act as ideal space-stations, and it does not seem improbable that robot stations will be established there within the next few years. PE

POINTS ARISING

Upstairs Alert (Mar 88)
(Ingenuity Unlimited). TR3 may be a ZTX 300 or similar.

Amstrad ROM Expansion (Jun 88)
IC2 is a 74LS374.

Semiconductors Part 7 (Jun 88)
Amend parts list so that R1 is 4k7. In Fig.68 the two 100 ohm input resistors should be 100k.

Vocals Eliminator (Jul 88)
Resistors R7-R10 should all be 100k. The symmetry of the pcb track layout has caused some confusion. It does not matter which way up it is printed providing IC1 is inserted so that the +V lead goes to its pin 4, and the 0V line goes to its pin 11.

INFRARED ASTRONOMY WITH ARRAYS

BY JOHN DAVIES

BY THE HEAT OF THE STARS

Semiconductor materials have the right characteristics to detect long-wave emissions from distant stars; infrared detectors can now be built into large arrays which can "snapshot" and spectrum analyse stars and galaxies, revealing new data.

Although satellites have opened up new frontiers in astronomy, ground based telescopes are also benefiting from new technology. Advanced electronic detectors are providing astronomers with powerful new instruments, and to an astronomer a better instrument is almost as good as a bigger telescope. Nowhere is this detector revolution having more impact than in the field of infrared astronomy.

INFRARED — INVISIBLE ASTRONOMY

Infrared radiation consists of electromagnetic waves just like those of visible light, but with slightly longer wavelengths. Human eyes are not sensitive to the infrared, but our bodies are, which is why you can feel the heat from an electric fire before the element gets hot enough to see. Your hand, acting as a crude infrared detector, is registering the heat radiation from the fire. The infrared region stretches from wavelengths of about 1 micron (a micron is one millionth of a metre) to one millimetre, although most of these wavelengths are absorbed by the atmosphere and can only be studied from space. Fortunately the atmosphere is transparent to infrared radiation in certain limited ranges, known as atmospheric windows, and it is through these windows that infrared astronomers study the Universe (Fig.1).

Because the type of radiation which things emit depends on their temperature, infrared astronomers can study different sorts of objects from their optical colleagues. Hot objects (like stars) with surface temperatures from about 10,000°C to 1500°C emit mostly visible light, material from about 1500°C to about −263°C (that's 10 degrees above absolute zero or 10K in scientific notation) emits mainly at infrared wavelengths. Infrared astronomers can study material too cool to see; for example they can map the dust in a comet's tail and probe cool shells of dust that surround young stars and which might one day form planets.

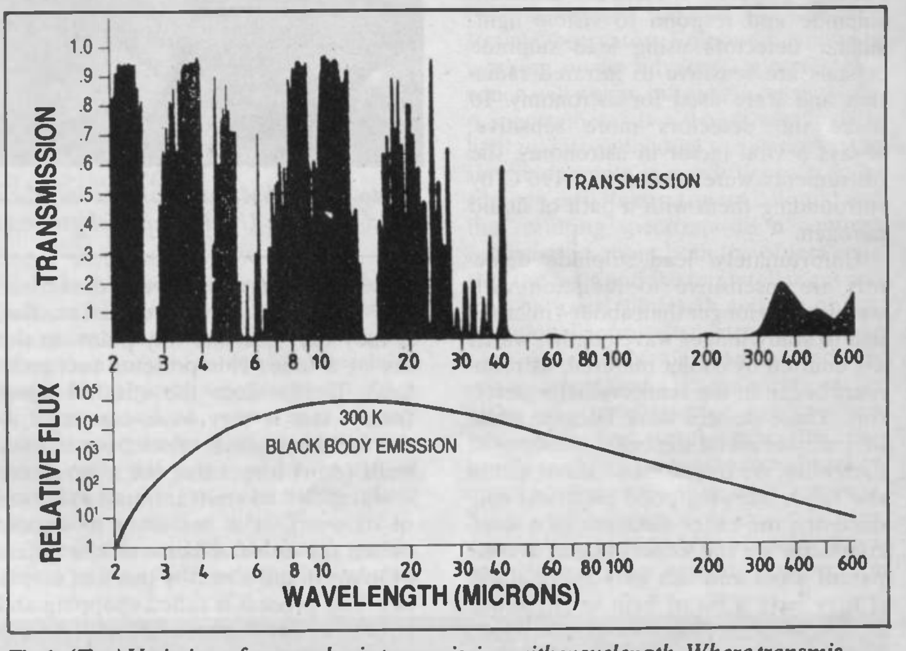


Fig 1. *(Top) Variation of atmospheric transmission with wavelength. Where transmission is high (close to 1.0) astronomical observations are possible from ground based telescopes. (Bottom) Amount of energy (flux) given out at different wavelengths by an object at 300K (27°C). The information in the diagram originated from the European Space Agency (ESA).*

Infrared radiation has another useful property: because of its longer wavelength it can penetrate clouds of dust which block ordinary light (Fig.2). This effect of increased penetration by light of longer wavelengths is exactly the same as that seen here on Earth at sunset. As the Sun sinks towards the horizon its light must travel almost parallel to the ground to reach you and so passes through a much greater thickness of air than it would if the Sun was almost overhead. During its journey the blue light, with its shorter wavelength, is scattered by dust in the atmosphere but the longer wavelength red light is less affected and so gets through to produce a red tinted sky. Infrared radiation is

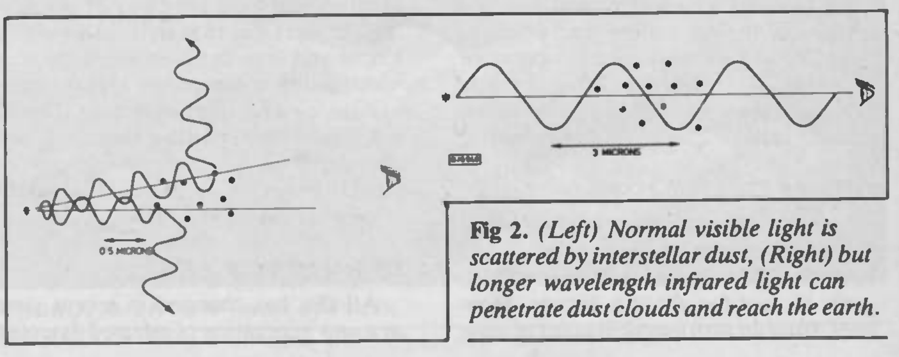


Fig 2. *(Left) Normal visible light is scattered by interstellar dust, (Right) but longer wavelength infrared light can penetrate dust clouds and reach the earth.*

even less affected and this penetrating power means that infrared astronomers can look inside the clouds of gas and dust where stars are born and probe towards the centre of our Galaxy where the dust is so thick that it blocks the view in normal light.

THE EARLY YEARS

The first infrared detections of the Sun and the Moon were made in the last century but it was not until the early 1970s that electronics enabled infrared astronomy to come of age. The new generation of detectors used the same principle as photographic light meters: light falling on a suitable crystal caused a change in its resistance and this change was measured by attaching a small battery across the crystal and monitoring the current passing. Exposure meters use cadmium sulphide and respond to visible light; similar detectors using lead sulphide crystals are sensitive to infrared radiation and were used for astronomy. To make the detectors more sensitive, always a vital factor in astronomy, the instruments were cooled to −196°C by surrounding them with a bath of liquid nitrogen.

Unfortunately, lead sulphide detectors are insensitive to radiation with wavelengths longer than about 4 microns and to study longer wavelengths, which are emitted by cooler material, astronomers began to use semiconductor detectors. These devices work because while in a normal metal the outer electrons of each atom are free to move about within the solid, allowing good electrical conductivity, the outer electrons of a semiconductor are still loosely bound to their parent atom and can only move about if they have a bit of help to get going. For certain semiconductors infrared radiation falling on the material is enough to liberate the electrons and allow a current to flow. What is more, by contaminating the semiconductor with suitable impuri-ties, a process known as doping, the material can be tuned to react to radiation in a specific range of wavelengths.

Astronomers began by using detectors based on germanium doped with either copper or mercury. These were sensitive to wavelengths from about 5–15 microns, but they were soon replaced by devices using germanium doped with gallium. A germanium/gallium detector is sensitive to all infrared wavelengths and is called a bolometer, but suffers one practical difficulty; it only works at a temperature of about 2K (2 degrees above absolute zero) and must be cooled by expensive, and difficult to handle, liquid helium.

ONE PEEP AT A TIME

Despite the practical difficulties of building detectors cooled by liquid helium, bolometers have been used with great success for about a decade. However, from an astronomical point of view, they suffer from an important drawback: they are single element detectors, that is they only see one tiny point on the sky at a time. This presents two problems. Firstly, since the infrared signal from a star is very weak compared to the radiation which arises from the sky itself (don't forget that the atmosphere is warm and so emits infrared radiation of its own), it is necessary to rapidly switch the detector between the object of interest and a nearby patch of empty sky. This process is called chopping and is done so that the background radiation from the empty sky can be subtracted from the radiation from the star plus the bit of sky around it. This subtraction leaves the tiny signal of the star behind and is done about ten times a second. The signal from the star is extracted electronically from the detector output using a phase sensitive amplifier linked to the chopping frequency.

The second problem is that while a single element detector is adequate for studying stars, which appear as points of light, it is not so good for looking at extended sources such as planets, comets, clouds of dust and galaxies. Until recently the only way of mapping such objects was to scan them a point at a time and then build up an image afterwards using a computer. This is rather like taking a lot of photographs through a keyhole then pasting them together afterwards to find out what the world outside looks like; it can be done, but it is very slow indeed.

HOORAY FOR ARRAYS

All this has changed in recent years as a new generation of infrared detectors has been developed. These are array detectors, an infrared equivalent to the ccd cameras described in last month's issue. The new infrared arrays cram together many dozens of tiny detectors by etching them onto a single semiconductor crystal. Each of the tiny detectors, sometimes called a pixel (short for picture cell), produces an electrical signal when exposed to infrared radiation. Furthermore the strength of the signal is dependent on the amount of energy falling on each pixel. When the array has been exposed to a source of infrared radiation it can be read out electronically via a conventional silicon microchip and the results fed directly into a computer for image processing.

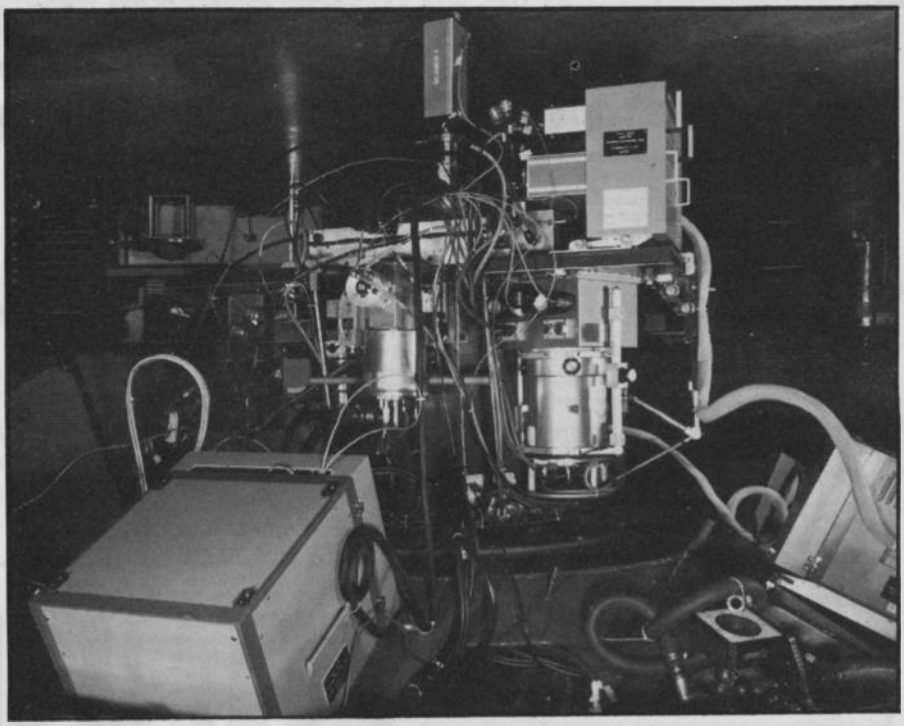


Photo 1. *IRCAM, some of its control electronics and other scientific instruments attached to the UK Infrared Telescope in Hawaii.*

IRCAM: AN INFRARED CAMERA

The most obvious use of an infrared array is to make a camera, an instrument able to make direct images of the sky without the need to scan an object point by point. Just such an instrument has been developed by the astronomers and engineers at the Royal Observatory, Edinburgh. Since the middle of last year, the IRCAM, in combination with the UK Infrared Telescope in Hawaii, has been producing stunning images of the sky with hitherto unbelievable speed and accuracy. The IRCAM, together with some of its control electronics, are shown in the foreground of Photo 1. Also visible are some other scientific instruments and, at the bottom, a tv camera that transmits a picture of the sky to a control room so that astronomers can operate the telescope without having to stand in the cold, darkened dome. More electronics, and the data processing com-

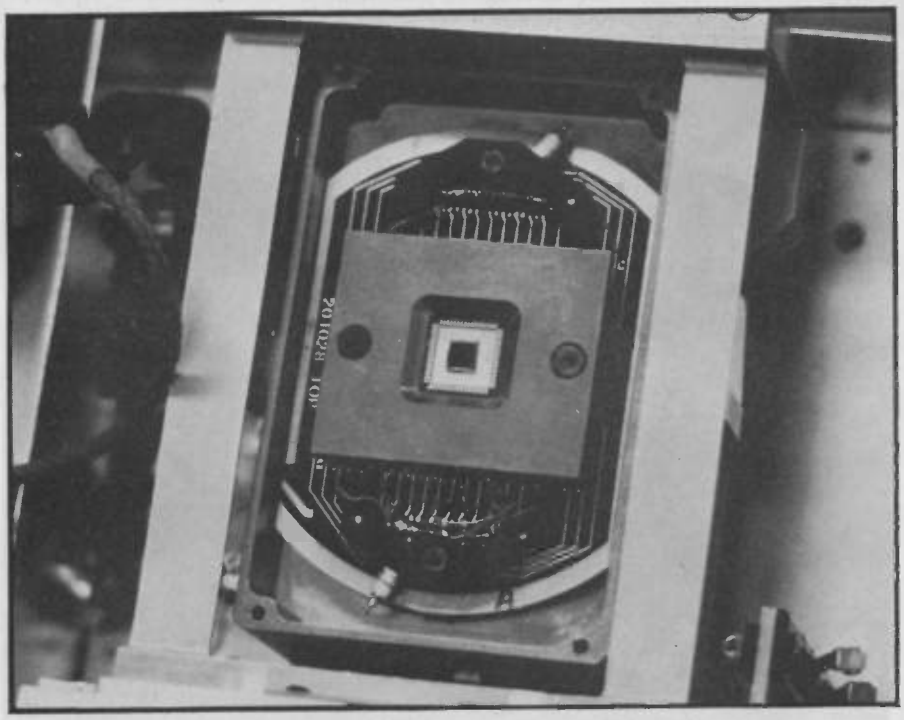


Photo 2. *The infrared array detector chip at the heart of IRCAM.*

puters, are located in the control room.

The heart of IRCAM is a 62 by 58 element array of indium-antimonide detectors packed onto a chip less than half a centimetre square. The array (Photo 2) was developed by the Santa Barbara Research Corporation of the USA, but the camera, much of its electronics and the mechanical and cooling systems were all designed and built at Edinburgh. The Santa Barbara detector works best at a temperature of 35K (−238°C) and, because no common gas has a boiling point near this temperature, IRCAM uses a cooling system which has the infrared array chip coupled by a sort of gas filled thermostatic switch to a reservoir of liquid helium. The balance between heat leaking in from the outside and the cooling produced by energy soaked up boiling away the liquid helium keeps the camera at the correct temperature.

When the camera is operating a beam of light from the sky is focused into it by the main telescope and, once inside, passes through lenses which define how big an image falls on the detector array. At maximum magnification the field of view is 1/120th of a degree in diameter and each element of the detector is viewing an area less than 1/5000 of a degree across. Wheels are used to place filters in the beam and restrict the energy reaching the array to a narrow range of wavelengths. By taking a series of images through different filters what amounts to an infrared colour picture can be produced in a matter of minutes and, as well as looking beautiful, these images contain a wealth of scientific information.

Photo 3 is an IRCAM picture of Saturn made by taking two images at different wavelengths and combining them electronically. When seen at a wavelength of 1.6 microns Saturn reflects light from both its upper atmosphere and from its rings. However, the planet's atmosphere contains methane gas, which absorbs wavelengths of about 2 microns and so, when seen at this wavelength, the body of the planet vanishes while the rings, which consist of icy particles not gas, continue to reflect and show up well at this wavelength.

Photo 4 is an IRCAM image of the Orion nebula, a cloud of gas and dust which is faintly visible to the naked eye as the middle 'star' in the sword of Orion. The Orion nebula is a stellar nursery but, because of the dust, most of the newly born stars are hidden from normal optical telescopes. The penetrating power of the infrared, together with the ability of IRCAM to produce direct images, has enabled British astronomers to map the entire nebula in a few hours, a project impossible before the advent of infrared arrays. Images like this will be vital to astronomers trying to understand how stars, including ones like the Sun, are formed.

AFTER IRCAM

Although a second IRCAM, operating at longer wavelengths, is already under construction, the value of arrays extends beyond infrared cameras; the Royal Observatory Edinburgh is already working on an advanced spectrometer which will use an infrared array detector. A spectrometer is a device which splits light up into individual wavelengths (the simple example is a prism which splits sunlight into its constituent colours) and the resulting spectrum often contains information about both the object emitting the light and the interstellar gas and dust between the Earth and the object. Traditional infrared spectrometers have used a single detector and measured only one wavelength at a time; a spectrometer using an array detector can measure many different wavelengths simultaneously enabling the spectrum to be taken much more quickly than ever before.

Using two dimensional arrays, like the one in IRCAM, spectra of many different regions of an extended object, for

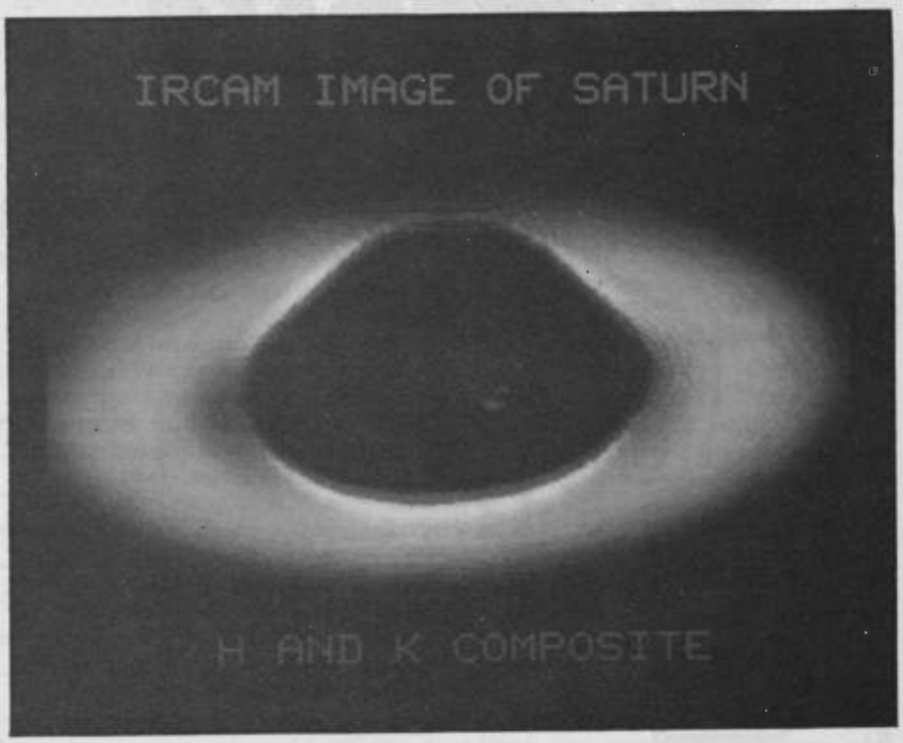


Photo 3. *An IRCAM image of Saturn.*

instance a distant galaxy, can be made at the same time. Such a spectrum might show differences between the central region of the galaxy and its outer edges, or between the head of a comet and its tail. This capability makes two dimensional infrared spectroscopy a powerful new tool for astronomy.

These instruments mark the beginning of a new era in infrared astronomy, one which will see the object make great strides forward in the near future. IRCAM and its successors will enable British astronomers to remain at the forefront of this fascinating subject, but ultimately the key to newer and still better instruments is the development and exploitation of evermore sensitive detectors. The production of such devices offers a great challenge to the electronics industry, but who knows where the experience gained may lead? PE

Dr John Davies is an astronomer and aerospace engineer at the Royal Observatory, Edinburgh. He is involved in the development of an infrared camera for a European astronomy satellite. The Project scientist for IRCAM is Dr Ian McLean.

The Royal Observatory visitor centre is open all year round and features displays of instruments such as those described here.

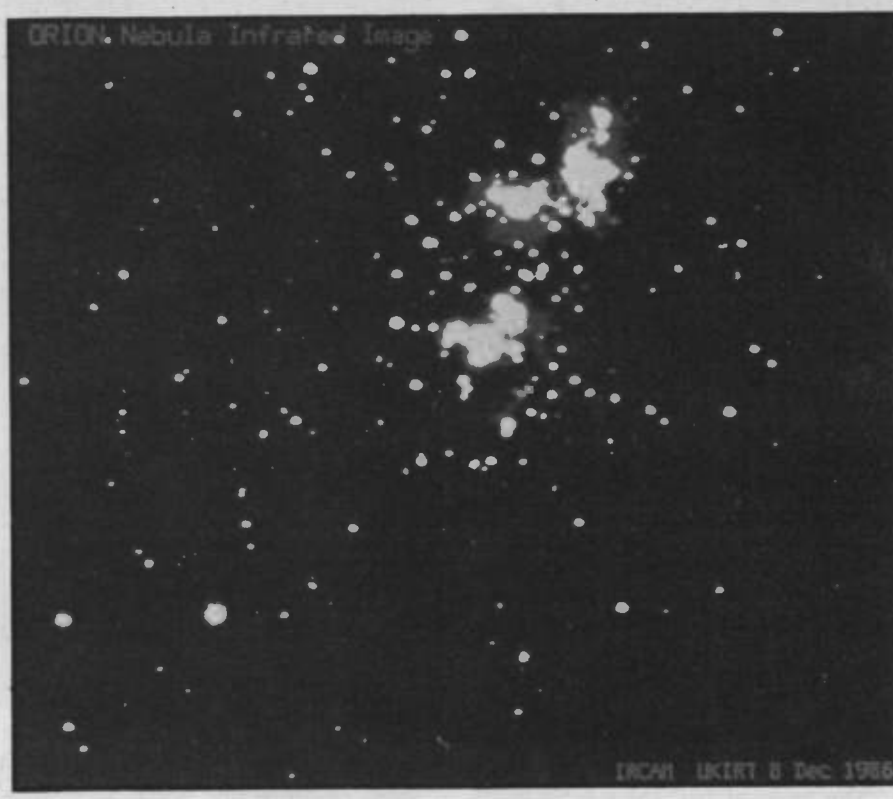


Photo 4. *IRCAM image of star forming region inside the Orion Nebula. Most of these stars cannot be seen in normal light, they are hidden behind clouds of gas and dust.*

We express our grateful thanks to the Royal Observatory Edinburgh for their kind permission to reproduce the photographs.

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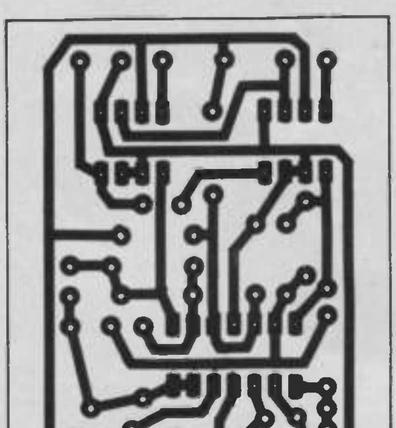

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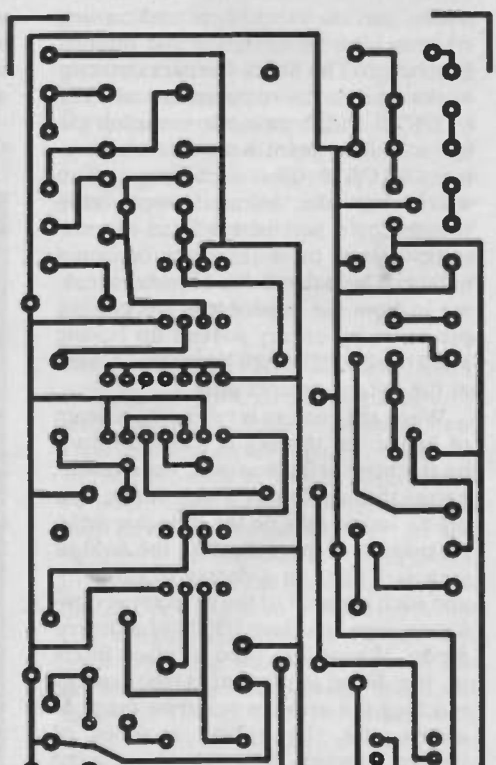

Metal detector

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Disabled F.A.S student seeks text book or literature on electronic digital watches, especially alarm type. Can anyone help? Cyril Nolan, 8 Rathmines Park, Rathmines, Dublin Ireland.

Telectric cost monitor £115.00. Heathkit working FM/AM 15watt stereo radio £80.00 and vocals eliminator no leads £9.00. G. Churcher, 15 Rosemary Hill Road, Streetly, West Midlands B74 4HL.

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Wanted: certain issues hobby electronics 1983, 84. State price. Michael J. McArdle, Big Ash, Knockbridge, Dudalk, Ireland.

Shugart and CDC 8inch disk drives and spares. DJ Harries, 46 Eliot Drive, Marlow 5978 SL7 1TU.

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Spectra physics multiline Argon laser with variable current supply, model 162C, good condition £1500 call John Spang, 47 Carleton Road, Chorley, Lancs PR6 8TQ Tel: 02572 75831.

Epson FX1000 printer. New still sealed £380. Also Dowty Quattro Modem V21/V23/V22/V22BIS £175. Tel: 0703 265344.

Books, 1948 BBC year book £10, 1929 electrical wiring diagrams by W. Perren Maycock £10. P&p 75p. Phone: 0908 564635. R and BA Foskett, 2 Boswell Lane, Deanshanger, MiltonKeynes, MK19 6HE.

Wanted: circuit diagram and operating instructions for 'Pye' Lynx camera. Phone: 0222 750008.

Transformer 2X 15-0-15V secondary 350VA eight tappings - primary suitable for amplifier power supply £14 inc. p&p. Mr. CA Lloyd, 22 Westwood Park, Newhall, Burton-on-Trent, Staffs DE11 0RS.

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Wanted: circuits and any GEM of the Armstrong Superegen, and other unusual receivers of the 1920s. LA Wilkinson, 2 Cragside, Lower Contour Road, Kingswear, Devon, TQ6 0AL.

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Wanted: ZX81 interface for disk drive and parallel Centronics type for printer. Mr. Dussiot, 25 Rue de Chanteloup, 91180 St. Germain les Arpajon, France. Tel: (33)-1-60833812.

Onyx s-ware, h-ware WANTED. Please contact Nick Hacking 9A Bowmont Terrace, Glasgow G12 0LP. Tel: 041-339 1575.

Wanted: circuit diagram or full info on voice synthesiser for use on car with interfacing. C J Jones, 187 Pullman Court, Steatham Hill, London SW2. Tel: 01-674 3365.

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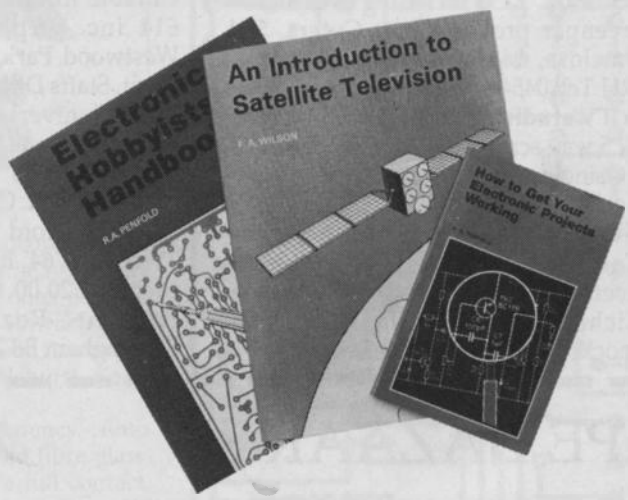

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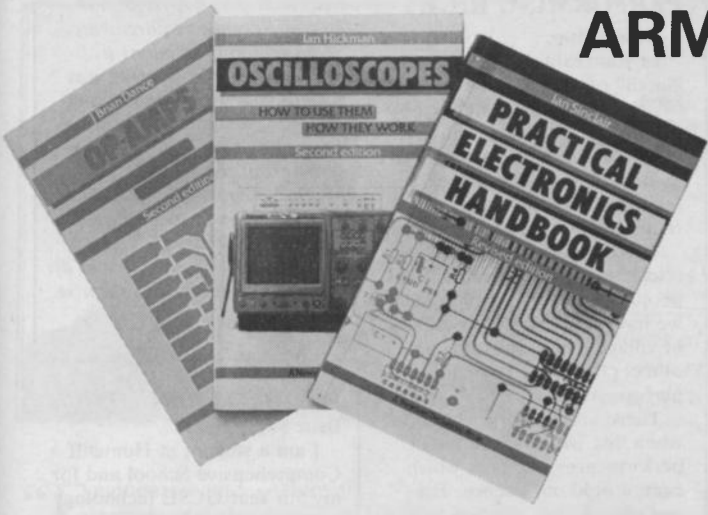

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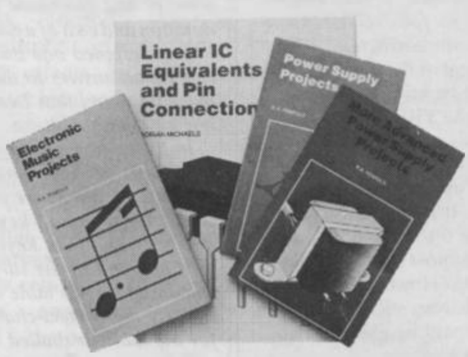

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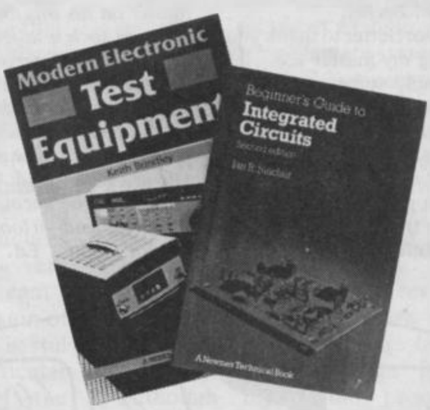

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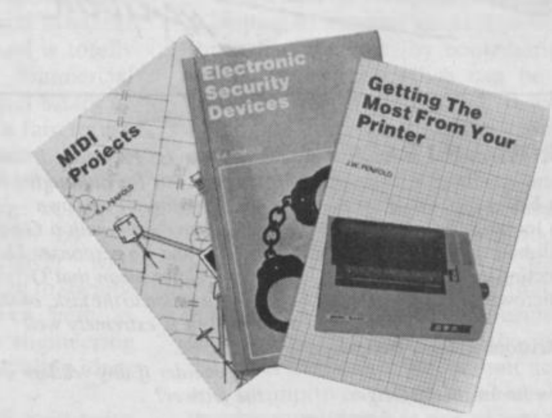

READERS' LETTERS

HOT DOGGITTY

Dear Mr. Becker,
Just a short letter to thank you for helping my master Ted Conolly build some car fans which attach to the window and switch on automatically when the car interior gets hot. (Clever these humans)! Please find enclosed a picture of one of the fan kits in the design stage.
Yours, Rufus of Haverfordwest.

Dear Rufus
Please congratulate your master on his ingenuity in devising such a hi-tech mod-con for your well deserved comfort. Now you've well and truly been given board *and lodging.*
This cool cat sends his best wishes to an ex-hot dog and his talented best friend. Perhaps others may be encouraged to follow his lead – it looks like Jim Naylor might... **Ed.**

MICROWAVE LEAKS

Dear Ed,
I am looking for information that will help me build a device for detecting microwave leakage from microwave ovens. Can you help?
Christopher Law, Doncaster.

I have heard that a Geiger counter may be able to detect microwaves. However, I cannot confirm this for although I have tried to monitor my own microwave oven with a Geiger, I have found no response. This could either mean that Geigers are not suited to the task, or that my oven is extremely well protected.
I wonder if any readers know the answer?
Ed.

PERFORMING RIGHT

Dear Editor,
In your Editorial "Scotch the Notch" of the July 88 issue you say that the PRS is snubbed by amateur disc jockeys who are supposed to make payments to us for public performance of recorded music but the requirement is blatantly ignored.
This is news to us. Our policy is to licence premises rather than people wherever possible and so we have licences for thousands of village halls, clubs, pubs and otheer places where disc jockeys perform.
There are a few occasions when disc jockeys give public performances in places which cannot hold our licence. For instance, a club function in a private home. For disc jockeys who undertake this sort of work we have a licence at a flat royalty of £47.90 (plus vat) per annum. This licence protects the dj, and the people who hire him, against accidental infringement of our rights, and quite a number of djs have one.
I must stress, though, that the licence will *not* cover a dj performing in a regular club, pub, hotel or other nomal place of entertainment.
It is also appropriate to point out the penalties for not complying with the regulations. Where we approach the dj for a licence before he has spontaneously asked for one, the royalty for the first year is 50% greater (£71.95). But if the dj is infringing our rights blatantly we may seek an injunction preventing the dj from further performances, and we may claim damages as well. It may also be of interest to your readers to know that the *deliberate* infringement of the copyrights of others can be criminal offence, although the PRS has never invoked this sanction and would need a great deal of provocation before doing so.
Frankly, it has been our experience that mobile djs are among the most law abiding music users. However, if there are any djs who still need a licence we will be glad to do business with them.
Michael Hudson, Licensing Controller, The Performing Rights Society Ltd, 29/33 Berners Street, London, W1P 4AA. Tel: 01-580 5544.

I am sure that the majority of djs who carry out their work on a regular basis know and abide by your regulations wherever they are working. However, I had in mind those who make money as a side-line by performing in unusual locations. Over the years it has periodically come to my attention that some of these djs neither respect copyright nor Inland Revenue requirements. From these observations it appeared that the practice was widespread. I also understand that in some cases the music performed has even been lifted direct from radio broadcasts – another area which I can see is hard to monitor, and which I wholeheartedly condemn.
I hope that any delinquent djs may be persuaded to regularise the administration of their activities. **Ed.**

PHONE TIMER

Dear Sir,
I am a student at Huntcliff Comprehensive School and for my 5th Year GCSE Technology project I intend to design and make a telephone timer. This will time how long someone has spent on the phone and, at the same time, display an approximate cost of the call using a digital display.
Have you ever published anything that might help me on this?
Lorraine Ketley, Gainsborough.

I regret to disappoint you but there are regulations which prohibit the connection of any unapproved equipment to Telecom's telephone lines. I have for some time been trying to discover just what specifications are required for equipment to qualify for approval and so far have drawn a blank.
In theory it is quite simple to detect the pulse from a telephone dial, and, with the aid of a computer and an electronic interface decode the dialled number and determine the duration and cost of a call. I have in fact designed one but until I can get an answer to the specs problem regret that I cannot release details of it.
In the circumstances your best solution is probably to use a computer as the timer and the calculator, manually keying in the dial code and then keying in the start and end of the call. A software look-up table can then identify the correct charge rates for the number dialled and the call duration. However, be prepared for a lot of thinking about the program, as I discovered when writing my own there is far more to the procedure than immediately meets the eye.
Ed.

IF YOU HAVE ANY COMMENT, CRITICISMS OR SUGGESTIONS, WRITE AND LET US KNOW. WE ARE INTERESTED IN WHAT YOU THINK AND SAY.

SHOULD ENGINEERS CARE?

BY TOM IVALL

BLIND MENS' BLUFF IN THE RAT RACE

Pressures of life make it simpler for engineers to feel that they are "only responsible for the job" – but how far can this go before all eyes are closed to the consequences?

"Engineers and scientists who introduce technologies do have a profound responsibility took at the social multiplier effects and propose constructive alternatives" writes Mike Cooley in the 1988 National Electronics Review. In an article entitled 'Using electronics to help society' he gives examples of how the technology is being used in socially beneficial projects. But this is not the main thrust of electronics in its impact on society, as Mr. Cooley points out. It is one of the technologies which affect us mainly through the economic mechanisms of the industrialised state.

"The gap between the potential of these technologies and the realities is developing into a chasm" he says, "as resources are concentrated on developing technologies which meet the sectional needs of the vast multi-national corporations and the military-industrial complex, while on the other hand the wishes, the needs, the aspirations and the dreams of ordinary people are increasingly ignored". By the term "social multiplier effects" Mr. Cooley means the effects in society brought about by technological change which multiply among themselves, like bacteria, seemingly out of proportion to the original cause. He gives as an example "... the drug-taking neurosis, interpersonal violence, the decline of inner city areas, and the illnesses which are directly related to unemployment".

Whether engineers do have a "profound responsibility" to pay attention to social consequences as Mike Cooley asserts is a matter for debate in the electronics sphere. I don't think this question can be settled by any objective enquiry because essentially it is not about facts but about values, not the 'is' but the 'ought'.

Some workers in this branch of technology, including myself, hold that each person is uniquely responsible for his/her own acts. Even if the person is physically or mentally deprived – say chronically ill or lacking in motivation or intelligence, or held captive by economic or psychological pressures – that person is still the author of what he/she chooses to do in these circumstances. To believe otherwise is to deny human dignity to the person, who thus becomes a passive object, a mere thing. And this point of view obviously extends into the realm of work. Undoubtedly many workers see themselves as mere cogs in the machine, without power or responsibility with an abstraction – the organisation, the system, the company, the powers-that-be etc – rather than with the reality of their own lives as sentient beings.

From this point of view the engineer is clearly responsible for his own work. And since engineering is essentially the practical application of science to human purposes he must therefore be responsible for the social consequences of his work. Even if he does a very specialised job as part of a large team – a common situation with the division of labour in modern industry – he is still the originator of that particular contribution. If the result of the collective engineering effort is a mass-produced object like a tv set, or a single system which is used by many people over a long period of time like a radar installation, the effect of the specialised, individual engineering contribution is magnified many times.

The opposite point of view is that electronics engineers are required to engineer nothing else. The individual is hired by a company to perform a specific task and his responsibility is confined to doing the job properly to a professional standard. His duty is first and foremost to his employer or client and is totally defined by the laws of commercial contract. He is paid a certain salary or fee and the hirer expects a fair return for this expenditure at the current labour market rates. Any responsibility for the effects of the engineering work on society must be shouldered by the company or other employer who supplies the product or system to society. Engineering ethics are seen here as matters like conforming to engineering codes of practice and not stealing ideas from other firms.

In situations where this second point of view prevails, the individual engineer who expresses concern about the wider effects of his work is regarded as a nuisance or a trouble-maker by his employers. If he discovers some technical or commercial deficiency and seeks to correct it by individual action he is branded as a whistle-blower or traitor to the collective interest. It's quite possible that the debacle of the Nimrod airborne early-warning radar project, which wasted about £1 billion of public money on an inadequate system, was the result of individual engineers fearing to step out of line and voice their misgivings. Those involved were bright enough to know what was going wrong.

These two opposed attitudes about responsibility seem to spring from two different ways of looking at the role of the engineer in society. The first emphasises that the engineer is helping to design and manufacture objects or provide services which are intended to be useful or enjoyable to people. Although the actual processes are complicated and indirect, to engineer is providing something particular for another person to use in a specific way – though this transaction may be multiplied many times by mass production. It can't be as direct as the independent craftsman making and selling a complete product to a customer whom he meets face to face. But underneath the complexities of manufacture and distribution the exchange is essentially the same.

In the second viewpoint the engineer is helping to increase general prosperity through commerce, by contributing to goods or services which can be sold. Basically he isn't interested in *what* is being sold as long as his employer succeeds in selling it, makes a profit, keeps the company in business and the engineer and his colleagues in employment. Even if the product is something trivial and customers have to be persuaded by advertising that they want it, the success of the business as such is the important thing because it increases the country's economic activity and so improves the material wealth of the community.

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

Key Techniques for Circuit Design. G.C. Loveday. Benchmarks. £6.95. ISBN 1-871047-00-5. The Benchmark Book Company is a small publishing house formed this year. Their aim is to produce good quality books to fill the gaps that they say exist in the technical domain, particularly in electronics at technician and junior engineer level. This book is the first in a series on all aspects of the design of electronic hardware. It tackles the problems of designing circuits from scratch, introducing the concept of target specifications, the design sequence, device selection, rules of thumb, and useful equivalent circuits. Many reader design tasks are set, all with solutions provided at the end of the book. Some understanding of basic electrical and electronic theory is assumed. There are not many illustrative circuit examples given but the text goes into a lot of detail about the thinking that is needed in order to solve specific design problems, while avoiding too great an emphasis on mathematics. A useful first book from this new company, though I think they may need to examine their page binding equipment as my copy began to shed pages.

Sensors and Transducers. Keith Brindley. Heinemann Newnes. £12.95. ISBN 0-434-90181-4. A thorough examination of numerous ways in which transducers can convert non-electrical physical quantities (measurands) into electrical signals, and vice versa. The book looks at basic transducer principles, their characteristics and the engineering implications. It covers, in separate chapters, thermal, solid, fluid, acoustic, optical and chemical measurands. A chapter on interfacing is included, and there is also a brief bibliography of related books. I welcome this book to my library.

Using the Triggered Sweep Oscilloscope. Robert L. Goodman. Tab Books. £19.00. ISBN 0-8306-2853-3. This is a book for the really devoted electronics constructor who wishes to get the most out of a scope. The book heavily features the Sencore SC61 waveform analyser, but many of the applications discussed appear to be usable with other types of scope. It covers oscilloscope features and specifications, and examination of the Sencore SC61, voltage measurement, several chapters relating to tv and video servicing, and a chapter on digital circuit trouble shooting. I recommend, though, that this book should be examined before purchase to ascertain that it is suited to your requirements.

Electronics Display Devices. Richard A. Perez. Tab Books. £31.70. ISBN 0-8306-2957-2. At this price the book is obviously aimed at the professional electronics designer. As such it goes into levels of detail which give a clear understanding of not only the purpose of various display devices, but also the way in which they function. It claims to be the first complete study of its kind to review all display technologies currently on the market - analogue meters, crts, leds, incandescent lamps, lcds, vfds, elds, and plasma displays. It also looks at what is on the horizon of developing electronic display devices of the future. An extensive glossary has been provided, and over 250 display device manufacturers are listed. However, as I have come to expect from Tab Books, who are an American company, most of the addresses listed (with a few welcome exceptions) bear little direct relevance to those living in the Uk.

Principles of Electronics. Barry Dowding. Prentice Hall. £14.95. ISBN 0-13-710104-X. The book sets out to develop, from first principles, an understanding of the properties, performance and operating capabilities of an extensive range of modern digital and analogue devices, circuits and subsystems. It is written by a senior lecturer at the City of Birmingham Polytechnic and is intended as an introductory electronics text for undergraduate students at colleges and universities. It requires a good knowledge of mathematics and is not an appropriate book for early beginners.

How to Test Almost Everything Electronic – 2nd Edition. Jack Darr and DeltonT. Horn. Tab Books. £6.95. ISBN 0-8306-2925-4. The title should not be taken too literally if you are wanting to find out why your diy-assembled project does not work first time. It is more a book on the use of test equipment generally, and a fair number of the examples given are related to testing valve-type equipment. Nonetheless it does give reasonable guidelines for using electronic test gear and discusses the basic principles of troubleshooting and interpreting test results. It covers psu and dc voltage tests, signal tracing, alignment, component and tv tests, in the course of which it looks at ammeters, voltmeters, oscilloscopes, logic probes and analysers etc.

An Introduction to Basic 2 on the Amstrad PCs. J.W. Penfold. Babani. £5.95. ISBN 0-85934-174-7. The aim of this book is to teach readers to program the Amstrad PC1512 and PC1640 in Locomotive Basic 2. It assumes no prior knowledge of computers or programming and tries to show that programming is not difficult and that it can be interesting and enjoyable. It is intended as an introductory book and the example programs do not cover all Basic commands, but all commands are illustrated in some form. A useful book for the early starter.

Build Your Own 80286 IBM Compatible and Save a Bundle. Aubrey Pilgrim. Tab Books. £13.20. ISBN 0-8306-3031-7. What a splendid title! This book explains how, if you are a real computer enthusiast, it is possilbe to buy a "bare bones" system of pre-assembled computer boards and hardware. Then, with the aid of pliers, screwdrivers and a set of instructions, the system can be assembled and tailored to your needs. UK readers should be prepared for detective work in locating the necessary parts, though the book quotes several addresses in the USA which may be helpful.

101 Solderless Breadboarding Projects. Delton. T. Horn. Tab Books. £12.40. ISBN 0-8306-2985-8. An ideal book for the novice and semi-experienced constructor. It emphasises the versatility of breadboarding in experimentation, and also shows how successful projects can then be made more permanent and incorporated into larger systems. The general chapter headings cover basic breadboarding, timers, opamps, comparators, audio amps, sound effects generators, digital gates and flipflops. It's 101 more ways of enjoying electronics.

The Beginner's Handbook of Amateur Radio – 2nd Edition. Clay Laster. Tab Books. £13.20. ISBN 0-8306-2965-3. Contains detailed coverage of specific information about the history of amateur radio, principles of electricity andd magnetism, radio communications theory, valves and semiconductors, fundamentals of transceivers and aerials. There are also chapters on operating procedures and licences, though since this book is from the USA, the information may not be of total relevance to UK readers.

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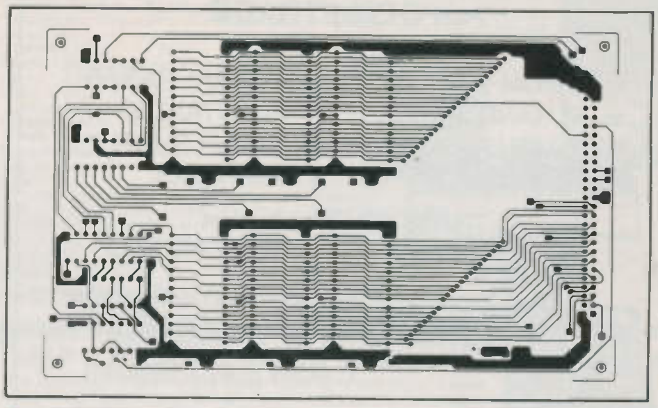

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