PRACTICAL

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JULY 1988 £1.25

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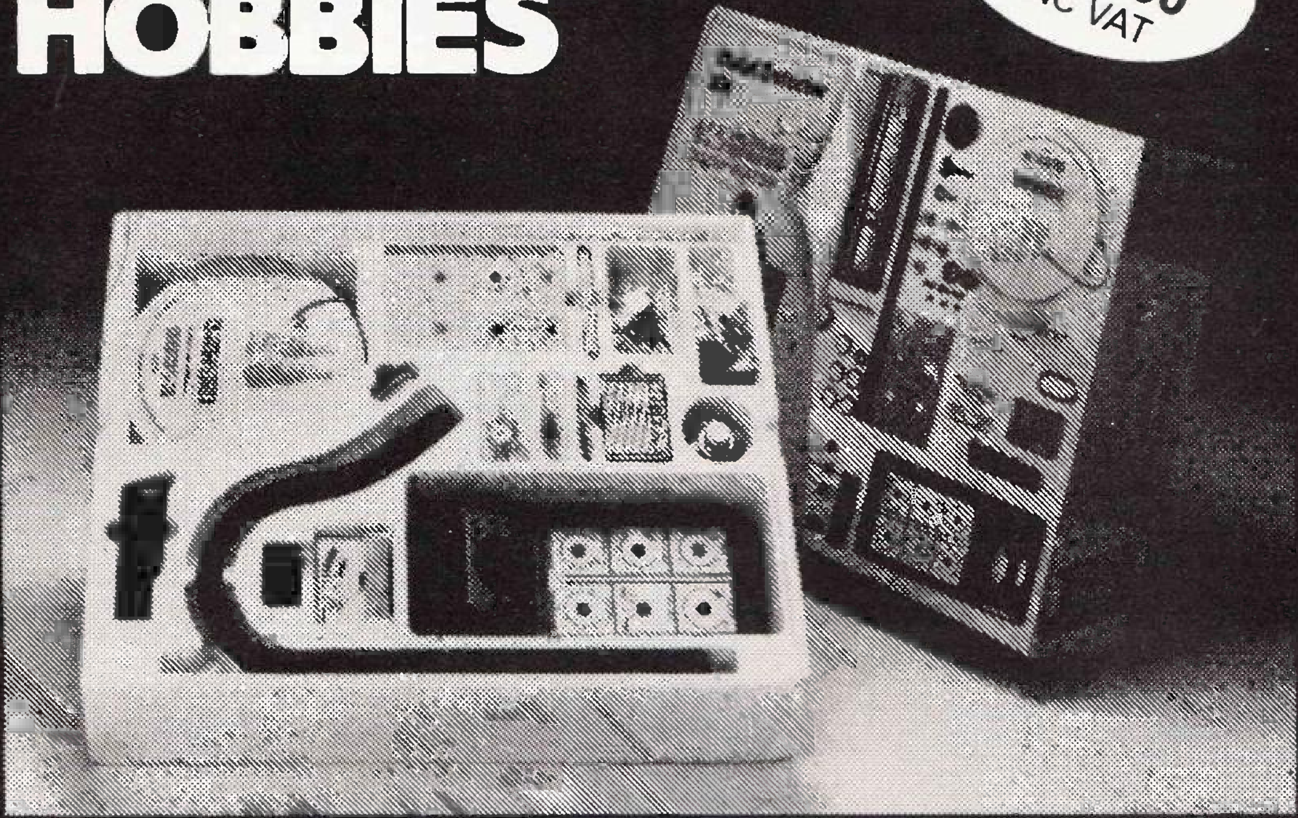

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The K5000 Metal Detector Kit combines the challenge of DIY Electronics assembly with the reward and excitement of discovering Britain's buried past.

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C-SCOPE

C-Scope International Ltd., Dept. PE
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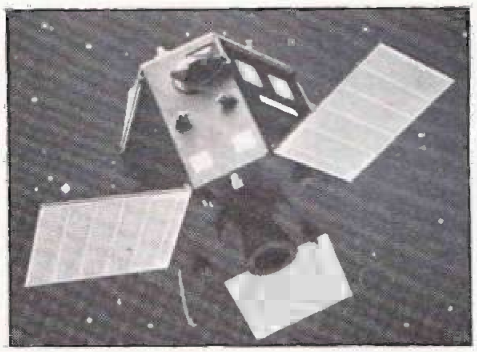
PRACTICAL ELECTRONICS

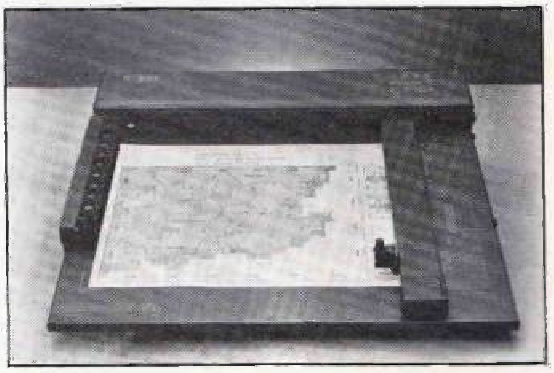
PE VOL 24 NO 7 JULY 1988

CONSTRUCTIONAL PROJECTS

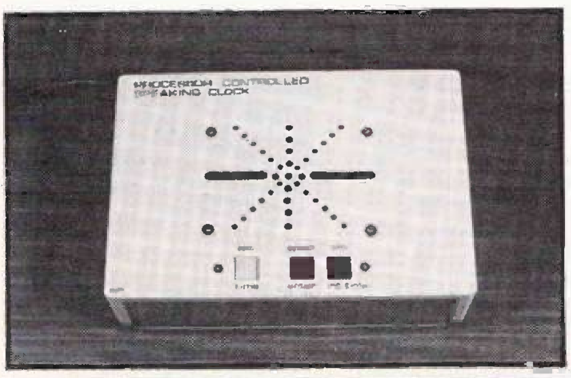
SPECIAL FEATURES



REGULAR FEATURES



PRODUCT FEATURES



NEXT MONTH . . .

LISTEN CLOSELY – IT'S NEARLY TIME TO BRING YOU –

A SPEAKING CLOCK • PROXIMITY DETECTORS • MORE ON CD TECHNOLOGY • EMERGENCY MAINS SUPPLY • A SIMULATED MOUSE (BUT NO MOUSETRAP!) • AND OUR REGULAR TOP LINE TOPICAL FEATURES •

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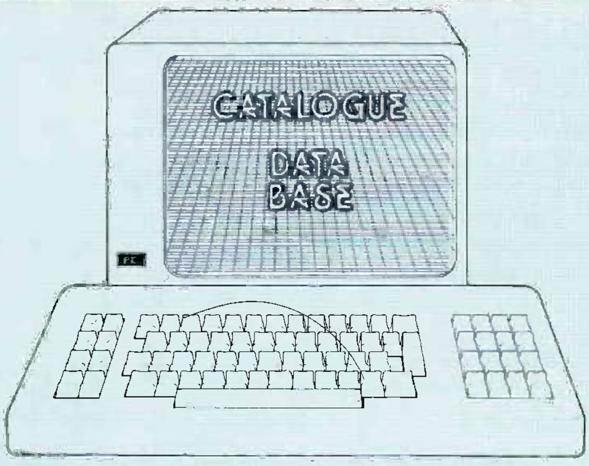
THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS ENTHUSIASTS



We have recently received the following catalogues and literature:

The Vintage Wireless Company have sent in their remarkable wad of listings sheets and the Antique Wireless Newsheet 122. For anyone trying to find **obsolete valves,** looking for a bygone datasheet, or just filled with nostalgia for **ancient audio equipment,** this is the company to contact – **The Vintage Wireless Company Ltd,** Tudor House, Cossham Street, Mangotsfield, Bristol, BS17 3EN. Tel: 0272 565472.

STC Electronic Services have a new six page full-colour brochure covering their **complete range of Seimens microprocessors,** controllers and peripherals. For details contact John Watson, **STC Electronic Services,** Edinburgh Way, Harlow, Essex, CM20 2DF. Tel: 0279 626777.

STC Instrument Services have produced a massive 320 page catalogue covering equipment ranging from **computers to scopes and speech design** products from over 65 leading suppliers. Anyone with a trade or other specific interest should contact Paul Channell. **STC Instrument Services**, Dewar House, Central Road, Harlow, Essex CM20 2TA. Tel: 0279 641641.

SRS have a new illustrated four page brochure outlining the entire range of **fixing and fastenings** associated with their 19-inch card frame systems. Contact Martin Deards, **SRS Products Ltd,** 19 Mead Industrial Park, Riverway, Harlow, Essex CM20 2SE. Tel: 0279 418401.

The Electronics and Instruments Directory has been released in a brand new edition. It styles itself as the complete electronics industry sourcing guide, and its extensive listings enable users to **locate products, manufacturers and distributors.** It is primarily intended for trade buyers, designers and engineers and costs £30.00. It is published by **Morgan Grampian Book Publishing,** 40 Beresford Street, London SE18 6BQ. Tel: 01-854 2200.

BSI have produced a Standard Code of Practice for **handling electrostatic sensitive devices.** Number BS5783: 1987, it has been prepared under the direction of the Electronic Standards Committee and will be of importance to anyone whose job involves the use of devices such as cmos chips. **Hobbyists need not be concerned** about obtaining this document as much of the information is industrially technical. **British Standards Institution,** 2 Park Street, London W1A 2BS. Tel: 01-629 9000.

Not Just The Ticket

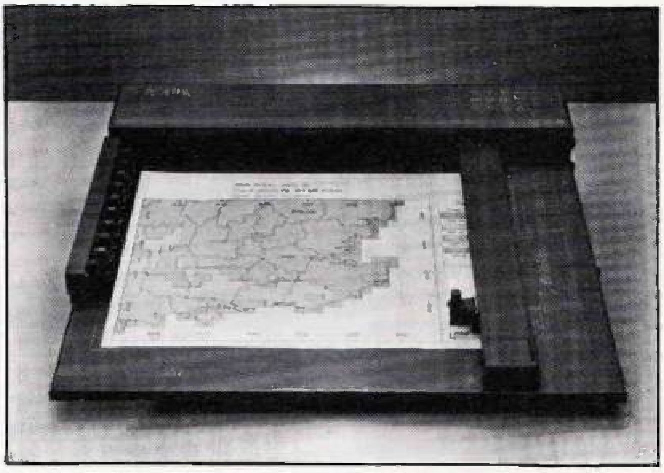
Epson have added a downward printing 132 dots per line card printer mechanism to their range of miniprinters.

The M260C has the ability to take a standard ISO card of up to 54mm x 86mm in dimension, print on it, and reverse feed the card back out. The miniprinter will therefore have applications in many multi-visit situations such as bus and train ticketing, membership passes, entry to pleasure park rides, security and with various gaming activities.

The M260C will print downwards up to 26 characters per line at 2.3 lines per second. It has an easy change ribbon cassette and a five solenoid shuttle head mechanism for graphics.

Contact: Epson (UK) Limited, Dorland House, 388 High Road, Wembley, Middlesex, HA9 6UH. Tel: 01-902 8892.

WHAT'S NEW



Penmate

Plotmate plotters have been enhanced with the addition of a ten pen automatic pen change facility which may be purchased as an up-grade kit. It can be fitted by the user or factory fitted by Linear Graphics.

It is now much easier to produce eye catching multi-colour plots for a wide range of uses for industry and business. Output colourful data presentation plots from a wide range of spread-sheets Lotus 123, Logistix, Symphony, or Ability. The multi-pen Plotmate is usable in a wide range of design applications, from plotting out a pcb layout, to designing your own dream house.

Plotmate's start at £420, and the multi-pen upgrade kits are £132.

Contact: Linear Graphics Ltd, 28 Purdeys Way, Rochford, Essex SS4 1NE Tel: 0702 541663/4/5.

Easiwire

As I am sure you will have seen from their adverts, BICC-VERO have launched a new wiring kit, the Circuigraph Easiwire, which offers the user a simple, versatile and low cost means of constructing electronic circuits without solder or chemicals.

Easiwire connections are made by winding the wire, fed from a special pen, tightly around the pins of each component to be connected in the circuit. The method is simple, clean and allows the user to change circuitry and re-use components without difficulty.

Although the method of wiring is easily and quickly learned, it can be applied to sophisticated circuits, as well as circuits that are straightforward. Additionally, the kit offers the advantage that the circuit can be connected exactly as the circuit diagram is drawn – a particular benefit to the less experienced user. Users also have the opportunity to wire on both sides of the board by using pins.

Easiwire includes a high-quality wiring pen that has a built-in wire cutter and carries a reel of wire which feeds through the pen in order to connect the components in the circuit (a spare reel of wire is also included in the pack).

The foundation of the kit is the flexible injection moulded wiring board, with tapered holes to give good component retention. Next comes the handy unwrap tool – this two-ended device is ideal for anchoring the wire at the start of wiring, and, as its name implies, for removing wired connections; the other end of it can be used to enlarge the holes in the board if necessary. Two double-sided adhesive sheets are also included – they are used to fix the wire in set positions and accept insulating material at crossover points. Last, but not least, come the spring-loaded terminals and jacks for power connections and the very clearly written instruction book which provides excellent guidance for the novice.

Contact: BICC-VERO Electronics, Flanders Road, Hedge End, Southampton SO3 3LG. Tel: 04892 88774.

C-Scope Competition

Metal detector manufacturers C-Scope have just launched a competition to help with the search for new projects in GCSE. The competition was introduced after a meeting at Norton Knatchbull School, Ashford, between The Kent Branch of the Educational Institute of Design, Craft and Technology, and C-Scope. The meeting was organised as a result of interest generated from a Hampshire school project, where pupils made and used a C-Scope metal detector provided in kit form, as part of their GCSE coursework. The company now aim to introduce metal detectors to the school curriculum in Kent.

The competition is open to all pupils of secondary school age who will be involved in GCSE coursework in the next academic year. Pupils may enter as a group or individually, and although entries must be submitted by the pupils themselves, consultation with tutors is recommended. The best designed project will win a C-Scope K5000 metal detector, worth £124.50 in kit form and over £200.00 made up. Ten runners up will receive 25% discount vouchers for the kit metal detector. Entrants should therefore include the construction of the detector as part of the project design. From there, ideas can be made relevant to any number of subjects across the curriculum.

Judging the competition alongside C-Scope will be Chris Burrowes, Head of Craft, Design and Technology at John Hunt of Everest School, Basingstoke, who has pioneered the use of the kit metal detector in GCSE coursework. Pupils at his school began by learning the circuitry and electronic principles while making the kit, which took the equivalent of one full week's work by two pupils, and then used the detector in joint projects within Humanities and Science. Details and easy to follow instructions accompany the kit and the pupils had no difficulty in its assembly. The end result is a powerful and easy to use detector, capable of good discrimination.

Children have always taken to metal detecting like fish to water. Studies of local and national history become far more interesting when researching discoveries and identifying interesting sites to search. The introduction of detectors to schools is therefore a logical resource for learning.

Entries and enquiries should be sent to: Schools' Competition, C-Scope International Ltd., Kingsnorth Technology Park, Wotton Road, Ashford, Kent TN23 2LN. tel: 0233 29181.
Closing date for entries is July 15th 1988.

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.

Regular courses for R.A.E., and also for Morse. Grafton Radio Society, Elizabeth Garrett Anderson School, Riseing Hill Street, London N1.

Regular weekly courses for Radio Amateurs Exam (C8G 765). Tuesday 7.30 to 9.30. Hendon College, Corner Mead, Grahame Park, Colindale, London NW8 5RA. Tel: 01-200 8300.

Jun 8-9. Infrared Technology. Wembley Conference Centre. 0799 26699.

Jun 26. Radio Society of Great Britain mobile rally. Longleat. *(No CBs!).* 0272 848140.

Jun 19. Denby Dale (Pie Hall) and District Amateur Radio Society mobile rally. Shelley High School, near Huddersfield, W. Yorks. 0484-602905. The Club also meets every Wed at the Pie Hall, Denby Dale at 8pm.

Jul 1-2. Minster School Science Fair, displaying the most up to date products in school science equipment, books, software etc. Local and national industries will also demonstrate the relevance of science education in their own fields. M. Bossard, The Minster School, Nottingham Road, Southwell, Notts NG25 0HG. Southwell 814000. *PE like to publicise events of this nature.*

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.

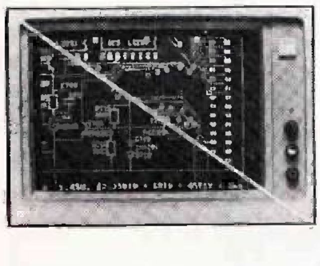
Sep 27-30. DES. Design Engineering Show. National Exhibition Centre. Birmingham.

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

Oct 18-20. Internepoon. Electronic Packaging Show. Metropole Convention Centre, Brighton.

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.



Cadwallah

Continuing their theme of "making cad affordable", Number One Systems have launched EASY PC, a low-cost pcb design package that provides a comprehensive range of layout features, and has the added bonus of schematic diagram draughting in one combined package.

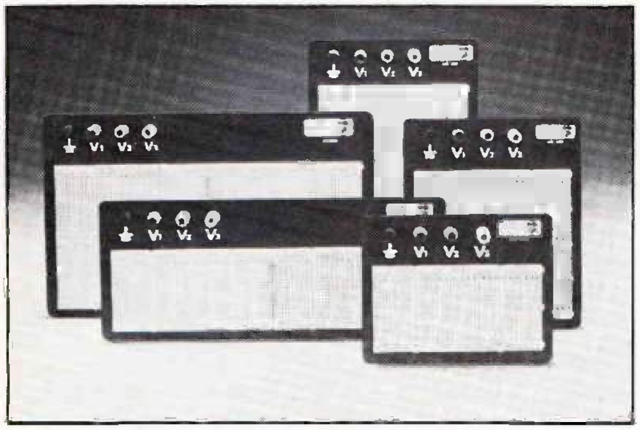
The package is for IBM PC compatibles (including Amstrad) with a minimum memory of 512K and CGA graphics. It handles multilayer boards with up to eight copper layers, and upper and lower silk screens. Camera ready artwork can be produced on an ordinary dot matrix printer. Drilling templates and solder resist details may be produced automatically from the layout information.

EASY PC has the capacity to layout and store dense designs, with up to 4000 pads in addition to those used in symbols, 12,000 track segments, 1500 symbols and 6000 text characters. Boards of up to 17″ x 17″ on a 0.1″, 0.05″ or 0.025″ basic grid, can be designed with or without snap. Eight active track widths can be selected from a choice of 128 with 16 active pad sizes chosen from a similar range. There a choice of 12 different basic pad shapes including circular, oval or rectangular.

Editing allows single items, or groups of items, to be re-locked, rotated, flipped, duplicated or erased. There are eight levels of zoom from x1 to x128. Auto-routing facilities are not offered, but other features such as rubber banding, auto vias, auto-save reminder to prompt the backing up of design changes after a period of working, and auto-snap to 45 degrees for neat tracking are included.

EASYPC is priced at just £275 + vat.

Contact: Number One Systems Ltd, Harding Way, Somersham Road, St. Ives, Huntingdon, Cambs. PE17 4WR Tel: 0480 61778.



HP Breadboard

New high-performance breadboards from OK are said to offer a number advantages, even including the fact that their round hole design in an off-white colour has been medically researched and proven to reduce eye strain.

High density configuration allows up to 25% more ic capacity, and all models have heavy gauge 2mm aluminium backplanes for increased board life, acetyl co-polymer insulation and phosphor bronze contacts. They are rated at up to 50MHz and the di-electric properties are said to substantially reduce cross-talk. Further, they are static resistant and cmos safe.

Four terminal posts per board allow multiple voltage levels for hybrid circuit design, and colour coding of terminal rows, together with column labelling, provide points of reference ideal when designing complex circuits. Board sizes range from 6.25in x 5in to 12in x 7in.

Contact: OK Industries UK Ltd., Barton Farm Industrial Estate, Chickenhall Lane, Eastleigh, Hants, SO5 5RR. Tel: 0703 619841.

Transputers Transcending

Britain's first DTI backed Transputer Centre has just celebrated a highly successful first financial year.

The Bristol Transputer Centre at Bristol Polytechnic was launched in 1987 to form a major bridge between the Academic and the Industrial worlds in the promotion of the Inmos transputer, a British invention and the world's first microprocessor specially designed for parallel processing.

The Bristol team are working with industrial and commercial partners to develop transputer based systems in such areas as intelligent process control, energy management systems, computer integrated manufacturing, robotics, financial modelling and forecasting, and decision support.

Transputer education is another major thrust of the Centre's activities, and the education team is running a successful series of short courses for industry on how to use transputers and how to develop their own research and development strategy.

"The transputer is now moving from being the best kept secret of the computing world to its rightful place as a piece of key innovation in helping us use computers in completely new ways", said Dr Mortimer, the centre's executive director. "British Industry has demonstrated that they are not lagging behind in developing this important technology. By their continued support of the Bristol Transputer Centre we can play an important role in keeping them at the forefront of developments."

Kilowatt Mosfet Amp

The all new Maplin 1kW high powered mosfet amplifier kit which is claimed to be equivalent to products selling at £800 to £900, is available at just £221.80 (including vat).

The amplifier is intended for use in halls, auditoriums or wherever the situation demands large scale audio amplification. Loudspeakers can be driven by the amplifier at full power before protection circuitry comes into effect. A feature of the monitor is that of preventing the amplifier from delivering power continuously into a short circuit.

The complete system is made up from four modules. Two form the power amp: a driver module and an output module; a monitor module and a power supply module.

For further information contact any of the Maplin shops.

CHIP COUNT!

This month's list of new component details received —

27C64A series. A new range of cmos eproms available both with and without uv erasure windows, and with a programming voltage of 12.5V. **(ML).**

2SJ160-162 series. A family of power mosfets optimised for use in audio power amps. Manufactured in silicon p-channel enhancement mode with a minimum drain source breakdown of 120V to 160V, and a maximum power rating of 100W at 25°C. A family of n-channel devices, the 2SK1056-1058, are also available allowing complementary pairs with closely matched characteristics to be used. **(HT).**

HA16654A. Pulse width modulation controller specifically designed to drive fast switching power mosfets. The chip contains a 5Vref, triangular waveform gen, pwm comparator, undervoltage protection circuitry and a high speed driver to control the power switch. **(HT).**

HD4608. 4-bit cmos microcontroller, with on-board eprom, optimised for telephone applications and containing a high precision dual tone multi-frequency (dtmf) gen, lcd driver-controller and two analogue comparators in addition to the opu, ram, timers, i-o ports and program memory. **(HT).**

HD63487. Multifunction memory interface and video attribute controller (mivac) that provides a complete interface between the HD63484 advanced crt controller (acrtc) and the frame memory buffer. **(HT).**

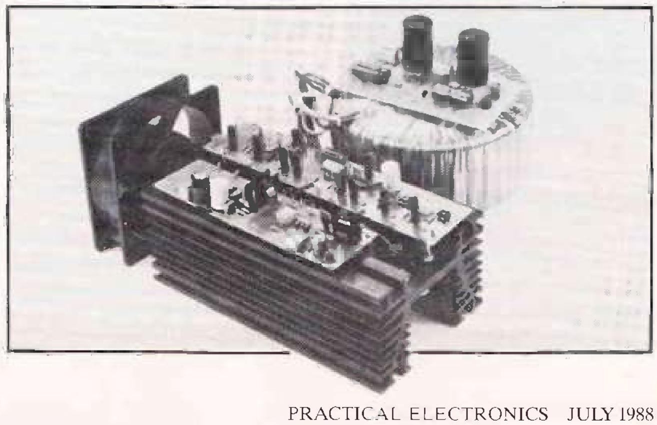
HM6787HP series. Three new 64K bicmos srams that are the world's fastest ttl compatible srams and are the first to meet the speed requirements of 20-30MHz microprocessors. **(HT).**

ISOTOP is the new plastic package introduced by Mullard for several ranges of their power semiconductors. Amongst the range are epitaxial and Schottky-barrier rectifiers, thyristors, gto (gate turn off) thyristors, darlingtons and switching transistors. This is the only plastic power package on the market that can handle over 1000V and carry current of 100A in a volume of only six cubic centimetres. **(ML).**

PCB83C451 and PCB80C451. Two new microcontrollers, with and without rom respectively, added to the cmos 8051 family and having 56 i-o lines and a mailbox. **(ML).**

Manufacturer's contact information: (HT) Hitachi, 21 Upton Road, Watford, Herts, WD1 7TB, 0923 246488. (ML) Mullard, Torrington Place, London WC1 7HD, 01-580 6633.

Mitsubishi have announced in Tokyo that they have developed and are now marketing Japan's first 2-megabit static memory module and having an access time of only 85 nanoseconds. We await more information.



Index Linked

Philips has launched a new Pocket Memo, the 292 Manager, which features indexing, previously only available on more expensive models.

The 292 Manager is a robust machine, measuring a compact 145mm x 62mm x 26mm. It is easy to handle and weighs only 213 grammes including batteries and cassette. All the functions – record, play, cue and rewind – are controlled by a side-mounted switch, to facilitate one-handed operation.

The single index system allows the user to put electronic pulses on the tape to mark the end of each document or highlight special instructions, thereby enabling the person transcribing it to locate any corrections or additions with greater ease.

Any of the Philips mini-cassette range of tapes can be used with the 292 Manager, to provide up to a full hour of recording time. These tapes are compatible with all of Philips' dictation and transcription machines.

The 292 Manager has a suggested retail price of £105.

Adcolation

Adcola's confidence in their all-British products has been confirmed by their announcement of an extended warranty.

They are implementing a two year guarantee that applies not only to the fume equipped soldering tools but to all equipment manufactured by them in the UK.

Adcola believe their quality has been the key-word in their success at considerably improving their world market share of hand soldering and production equipment related to the electronics industry, especially in America where the FumeX systems are their product leader. (FumeX systems are based upon a unique design for removing soldering fumes from the tips of soldering irons).

This warranty will not, however, be applied to long life soldering tips as a soldering tip life depends on it operating condition and temperatures.

Contact: Adcola Products Limited, Gauden Road, London SW4 6LH. Tel: 622 0291.

Home Taping

This is an excerpt from a statement issued by the International Federation of Phonographic Industries (IFPI) in support of the industries' campaign to place a levy on the price of blank cassette tapes:

The Canadian Independent Record Production Association (CIRPA) has released a study which graphically illustrates the threat of home taping to the music industry.

The report undertaken by the Music Copyright Action Group (MCAG) reveals that a staggering 63% of the Canadian population had home taped in the last year, each taper using an average of 9.5 cassettes in the year. The consequent loss to the Canadian music industry is estimated to be over $600,000,000 per year while sales of blank tapes have improved by nearly 50% between 1983 and 1986.

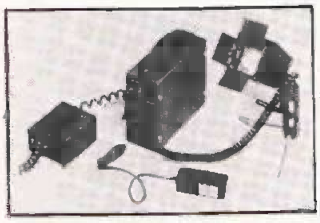
The report also recognises the dangers of readily available recording technology to both the Canadian and the worldwide recording industry. In Canada penetration of high speed dubbing recorders has reached 40% while dual dubbing machines has reached 55%. The European situation is described by Gillian Davies, Associate Director General of IFPI, in her report for the EEC: "In most EEC countries, over 60% of households have at least one tape recorder and the United Kingdom has the highest saturation level with 73%".

The consumer survey reveals that the majority of tapers who expressed an opinion favoured remuneration to right owners, with heavy tapers and those 'who taped to save money' being particularly keen on compensation for loss of income from home taping. The most popular method of compensation would take form of a royalty based on a percentage of the price of a blank cassette.

In order to address these urgent problems, CIRPA has tabled several solutions which are also applicable to the wider context of the world market. They recommend that a royalty to compensate creators should be levied on blank tapes and recording hardware. The amount of royalty to be negotiated between importers/manufacturers and copyright owners is in the form of a percentage of the price of tapes and recorders. The royalty payment should be distributed to copyright owners under a formula agreed by the copyright interests and allocated to foreigners on the basis of 'national treatment'. They also recommend the introduction of legislation making it a mandatory requirement for all new recording equipment for domestic use to contain an anti-copying device.

The conclusions reinforce the correlation between the upsurge in home taping and the decline of the recording industry. It is to be hoped the Canadian House of Commons will take note of these findings for the second phase of its copyright reform Bill, while in Britain the implications should not be lost on Kenneth Clarke and the Department of Trade and Industry. Already European countries such as the Federal Republic of Germany, France, Portugal and Spain have confronted the problems of home taping by legislating for royalties on blank tapes and/or hardware. Belgium, Italy and the Netherlands have legislation in progress. The study by CIRPA provides firm evidence why.

The IFPI Secretariat are at 54 Regent Street, London W1R 5PJ. Also see the Editorial on page 9.



Video Power

The new Polar Power Packs, have ben specially designed for video cameras, and to offer a less expensive and more versatile alternative to existing systems. Each pack comprises a 6 amp-hour battery with a small charger and an adapter lead which is fully adjustable to suit any voltage from 5 volt to 12 volt.

A range of heavy duty re-chargeable Polar Power Packs is also available. There are three versions: 24 amp hours (11kg.), particularly suitable for studio lighting, 10 amp hours (5½kg.) and 6 amp hours (3¾kg.), all at a 20 hour rate with periods for re-charge of six, four and three hours respectively. All versions possess sealed lead acid batteries, are internally fused and are circuit protected against over-discharge. The smaller extra-portable version may be carried from the shoulder.

These Power Packs can be re-charged from a vehicle alternator or from the complementary Polar Charger. This is a portable 6 amp 240/250 volt ac mains operated charger with thorough short circuit protection.

Contact: Jackson Brothers (London) Ltd., Kingsway, Waddon, Croydon CR9 4DG. Tel: 01-681 2754/7.

Far Sighted

A "de-luxe" version of the D-100 dx-tv converter system has recently been announced by the distributors, HS Publications of Derby.

The D-100 system, used by long-distance television (dx-tv) enthusiasts throughout the world, enables vhf and uhf reception of foreign tv signals on a standard uhf television receiver at full or reduced if bandwidth. The unit simply connects to the aerial input of the receiver. No internal modifications are necessary. Also, off-screen reception can be conveniently recorded using a normal video recorder.

Each unit comes complete with full operating instructions containing a useful tv systems map of Europe plus a vhf channel relationship plan for Bands I, II and III. The price, including carriage in the UK, is £89.99 via mail order only.

Further details about the D-100 systems, plus information about other dx-tv products, are available by sending two first class stamps or, for readers overseas, two irc's.

Contact: HS Publications, 7, Epping Close, Derby DE3 4HR. Tel: 0332 381699.

GLITCHED DROP OUTS

By Barry Fox
Winner of the 1987 UK Technology Press Award

OXYGEN TANKS FOR MICROS

Half a gnats' loss of mains power can wipe your ram and, worse, scramble your directories. It's no use telling the CEGB – independent action is necessary.

Recently, my lights went out. Every house in my street was being intermittently plunged into darkness, I was halfway through an article on a word processor, and lost a chunk of text and some database entries. The shut-down, without prior warning, was caused by a London Electricity Board engineer working in the local sub-station. The circuit breakers were wrongly labelled. He had tried to cure a fault by throwing one switch. When nothing happened, he threw several more in a panic. Another journalist, working at home over the road, lost two hours' worth of data, because he had not been regularly backing up onto disk.

When I found the sub-station and spoke to the engineer, his reply was interesting (to use neutral terms).

"What are you complaining about, the power was only off for a short time" he argued.

Later that day a senior LEB official called, to apologise, and explain the problem they have. If an engineer has been working on mains cables for the last thirty years, and has never used a computer, he knows about kettles and toasters but not volatile ram and the risks of shutting off the power to a computer while it is saving to disk. Ram loses all its data immediately the power is disconnected; if the disk drive stops while saving, you may end up with a garbled file directory, which effectively garbles all data on the disk.

"The problem is", said the LEB official, "that British mains are on the whole too good — we have grown to rely on them. But however good the statistics, there will always be some failures".

By law the mains voltage in Britain must be held stable to within ± 6% of the nominal 240 volt level. In practice engineers aim for a total swing of only 10%. Urban areas in the South East of England average an annual power loss or "outage" of only 30 minutes, with London 38 minutes. The national average for Denmark is 74 minutes, for Japan nearly 5 hours and for France 6 hours 42 minutes. Paris can expect to lose power for 88 minutes a year, Marseilles for 6 hours and Lomoges for over 11 hours.

None of this will console someone who has just lost several thousand words in a word processor. Also the Electricity Boards have no way of preventing users from injecting interference into the mains and thereby affecting their own or a neighbour's computer.

Mains voltage can dip by as much as 50% for a few Hz when a heavy duty inductive load, such as a lift motor, is switched on. A copying machine, arc welder,m refirgerator or vacuum cleaner can cause similar problems. There is an initial rush of current into the coils, of several times the normal working value. This saps power from other supply sockets on the premises. There may then be a voltage spoike which feeds back into the mains as the power rises and overshoots.

Top of the range computers are more like to have large, expensive, capacitors in the smoothing circuits of their power supply. These will store enough energy to bridge a gap of up to 5Hz, equivalent to a mains failure lasting 0.1 second. But budget computers, with small capacitors, may bridge only a 1Hz glitch, equivalent to a 0.02 second loss of power.

All this — and much more — has created a booiming industry for gadgets which are claimed to protect computers from vagaries of the mains. Like insurance, you hope you never have to rely on them. Unfortunately, as with any booming industry, there are cowboys on the bandwagon. They capitalize on fear, and get away with murder, because there is a good chance that what they sell will only later be put to a real test. Also some of the equipment sold, for instance to smooth spikes in the mains, may be redundant because it duplicates circuitry already incorporated in good computers. And spike suppression will do nothing to keep a computer running when the power fails.

Radio frequency interference, as for example fed into the mains by a sparking switch, can be blocked with a filter circuit of capacitors and inductors. But a filter will not block high voltage spikes. These must be diverted by a varistor, which offers high resistance to low voltages and low resistance to high voltages. But to be useful it must respond in nanoseconds to divert microsecond spikes.

An isolating transformer, with the primnary and secondary coils wound separately on a metal core, will also block interference and spikes. The core saturates with magnetic flux so it does not pass surges from one coil to the other.

Spikes do not travel past the street sub-station transformers, which damp them out. But the street transformers cannot do anything to cure spikes produced in the building in the street. Best bet is run your computer from a separate power line taken from as near the meter as possible. This isolates the computer supply ffrom other appliances in the building. Use screened leads to carry data signals between the computer and peripherals and separate them fom mains wiring, to avoid interference pickup.

None of this will save you from a mains failure which lasts longer than the capacity of the power supply capacitors. For this you need a stand-by, or better still, an uninterruptible power supply. Both have a battery and inverter, but in a ups these are always connected to the computer, so that the working supply floats free from the mains. A battery charger continually replaces the power which the computer takes from the battery. When the mains supply fails the computer sees no change. When the power returns, the battery re-charges. There is no switching, so no risk of data loss or corruption. Even if the batteries only last for five or ten minutes, it is enough to transfer valuable data from volatile memory to magnetic disk.

A ups also protects the computer from any mains-borne interference because there is no direct path from the mains to the computer, only to the battery. Telephone exchanges work on this same floating supply principle. Domestic phones need no extra power for basic operation. This is how BT can keep the phone system working even when there are widespread power cuts. But mains-powered cordless phones and fancy features like off-hook dialling go dead.

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SCOTCH THE NOTCH

We have recently been featuring reports about both dat and music piracy. The two are not unrelated.

In common with the recording industry I share the concern for copyright and profit protection, and wholeheartedly condemn professionals who copy recordings for illegal gain. I also recognise that many people make copies for their personal, non-profit making benefit, so theoretically reducing legal sales.

I do not agree that notching dat recordings is the right way to minimise Industry's losses. I have not yet heard dat, but I believe reports which say the notch can be audible. It seems downright crazy to spend millions perfecting recording techniques only to deliberately mutilate the results.

Copy-protect notches and copy-prevent circuitry are not going to stop any determined person from obtaining a copy, especially those who make their illegal living from tape piracy. Any security system can be broken by anyone with sufficient incentive.

And like it or not concerning home copying, many people do not regard it as wrong. Truthfully, how many of you have never copied a recording? If all else fails, a connection across the loudspeaker can tap a usable signal. Even though the copies will not be perfect, the quality may be acceptable to many people.

Legislation should naturally ensure that those making profits from piracy are heavily penalised. Legislation to prevent home copying is a non-starter. It can never be effectively policed. Look at how the Performing Rights Society are snubbed by amateur disc jockeys. Any dj is supposed to make payments to the PRS in respect of public performance of recorded music. I know that this requirement is blatantly ignored. It is not adequately monitored, nor can it ever be. Nor can home copying.

It is also lunacy to think that the introduction of laws to prevent the sale of dat equipment without copy protection will work either, for similar reasons. If such laws were to be passed, would it mean that if PE or other mags published contructional projects for dat recorders we would legally be required to include copy protection circuits? Would we then have to obligate readers to build them in? Or would we be prevented from publishing dat projects? I for one would fight such prohibition vigorously, as I am sure would other editors.

Industry and Government, show some common sense, don't tamper with technological perfection and don't use impractical legislation against home copyists. Tax them instead.

Put a levy on blank tape – it won't break the pockets of tape purchasers. Losses from non-sales of pre-recorded music can be buffered by the levy, even if admin needs slightly restructuring. But let's face another fact, there is no guarantee that one copy less would mean one recording sale more. More likely, and perhaps similarly detrimental in the long-run, many recordings might simply be less widely heard.

I don't condone home copying, but if dat is to be profitably accepted, this nonsense about notches should be scrapped.

THE EDITOR

VOCALS ELIMINATOR

BY GILES READ

CAPACITOR GOT YOUR TONGUE?

Just suppose you love the songs of Leonard Cohen, but can't bear the old gravel-voice... were born to boogie to Status Quo if it weren't for the little nasal whine... I would really groove to Wet Wet Wet if only they would shut up, up, up. Well, read on...

Almost every music-lover has a favourite track or two in which the lyrics really seem to spoil the music. A few years ago, there was a suggestion that 'sub-masters' of popular recordings might be issued in a four or eight track format. This would enable the suitably-equipped enthusiast to re-engineer classic tracks to his own personal taste. Similarly, fledgling bands or singers could use the backing of the original artists to practise against or to produce demo tapes. However, this idea has never got off the ground, mainly due to lack of demand and the inevitable copyright reasons.

Now, though, PE brings you the minor miracle of a Post-Recording Continuously Variable Singer-To-Backing Track Ratio Converter And Acronym Writer Defeater, or Vocals Eliminator for sanity. (*No, this is not a belated April Fool's joke. Ed*). The function of this curiously-named device is to enable one to vary the volume of a singer in relation to the accompaniment, or even dispose of the vocals altogether. But how is it done?

Most stereo recordings (well, of popular music, anyway) have the instruments carefully arranged in the stereo field, and the vocals slap in the middle. This is done by recording individual items (drums, guitar, vocals etc) on independant tracks on the master tape.

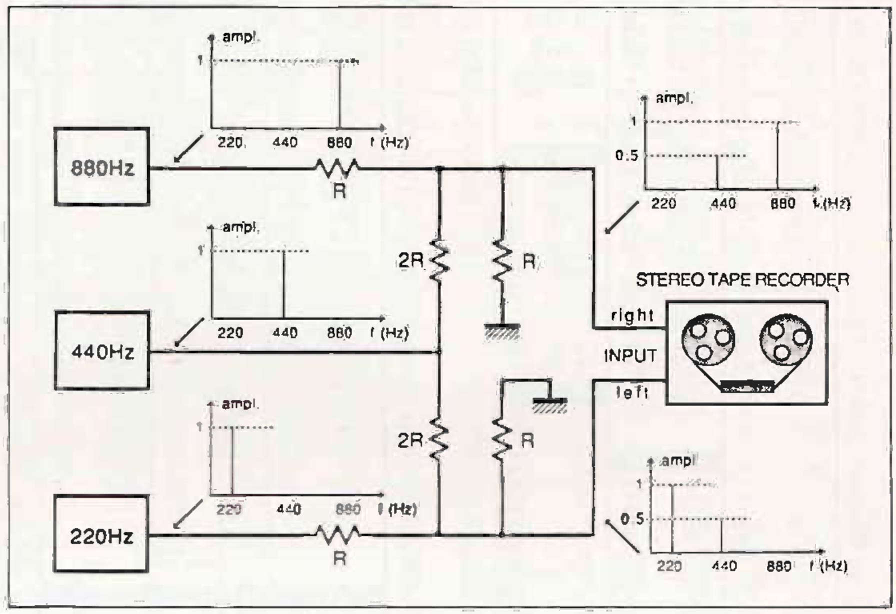

Fig.1 *Recording setup plus spectrum diagrams*

During subsequent mixing sessions, the final 'position' is determined by balancing the instrument between the left and right channels. Central positioning is achieved by having equal volume on both channels. To make the sound 'appear' from right of centre, slightly more signal is fed to the right than the left, and so on. There is rather more to it than that, but this explanation gives the essentials.

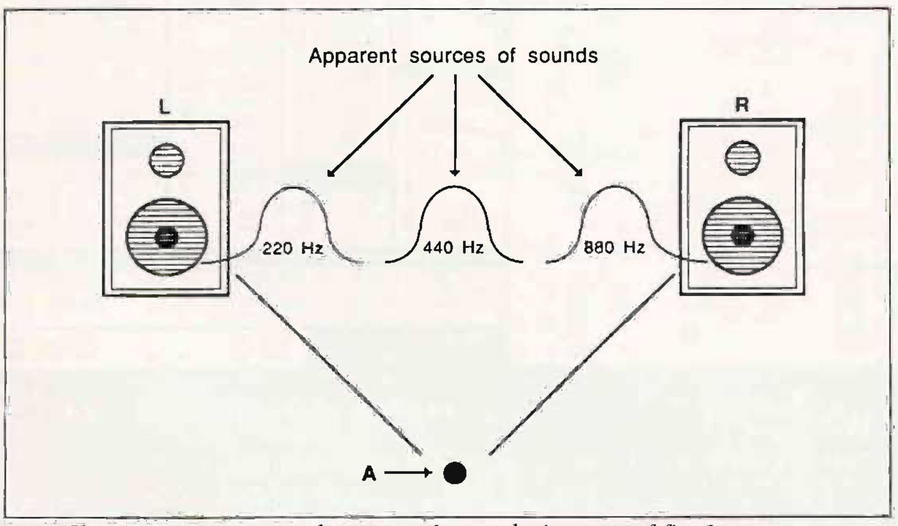

Fig.2 *Showing apparent sound sources when replaying tape of fig. 1*

ELIMINATION FOR BEGINNERS

Imagine a very simple stereo recording. Fig.1 shows three signal generators producing 220Hz, 440Hz and 880Hz at equal amplitudes. They are connected to a tape recorder via a simple passive mixer. The right channel will record 220Hz and 440Hz at half the amplitude of the 220Hz signal. Similarly, the left channel will record 880Hz and half-amplitude 440Hz. The spectrum diagrams show the frequencies and amplitudes at various points in the recording chain.

When the recording is played through speakers (Fig.2), a listener at A will hear the three tones at equal volume and correctly interpret them as coming from left, centre and right. Fig.3 shows how the spectrum diagrams add to confirm this.

If, however, we *subtract* the left channel from the right channel as in Fig.4, we end up with no 440Hz signal! In fact, the 880Hz signal also has a 180 degree phase change, but as we are only concerned with amplitudes and not

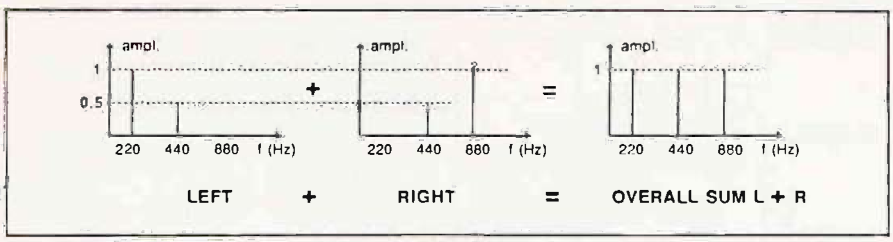

Fig.3 *Sum of two spectrum diagrams*

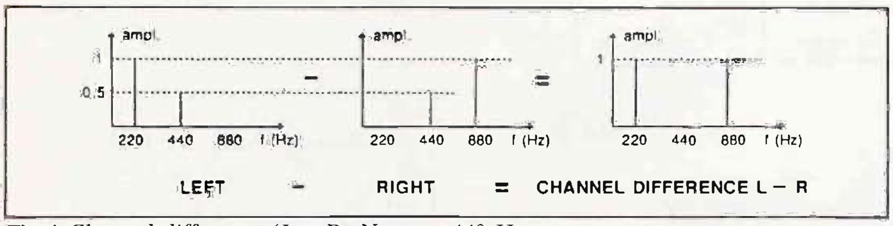

Fig.4 *Channel difference (L – R) Note no 440 Hz component*

phases, this is not shown. Subtracting the right channel from the left as well, we end up with the same frequency spectrum as in Fig.4, except that the phase of the 880Hz signals stays the same and the 220Hz signal suffers the phase change.

PHASERNATED

Unfortunately, there is a price to pay for removing the midddle of the signal: the resulting l–r and r–l signals are the same (but 180 degrees out of phase with each other), so we lose the stereo image. If our listener hitch-hiked over to point B in Fig.5 to hear the l–r and r–l signals, he would hear 220Hz and 880Hz signals appearing to the left of the left speaker and from the right of the right speaker. At this point he would probably ask if he could go and have a quiet lie-down somewhere to get rid of his headache, but that's another story......

Incidentally, fm stereo radio works by transmitting the l+r (sum) and l−r (difference) signals. The l–r channel is encoded on an ultrasonic subcarrier, and sent at the same time as the mono (l+r or sum) channel. This means that radios without a stereo decoder receive a mono broadcast, while a stereo radio can unscramble the l+r and recovered l–r into normal left and right stereo. That process deserves a whole article to itself, so we won't describe it here.

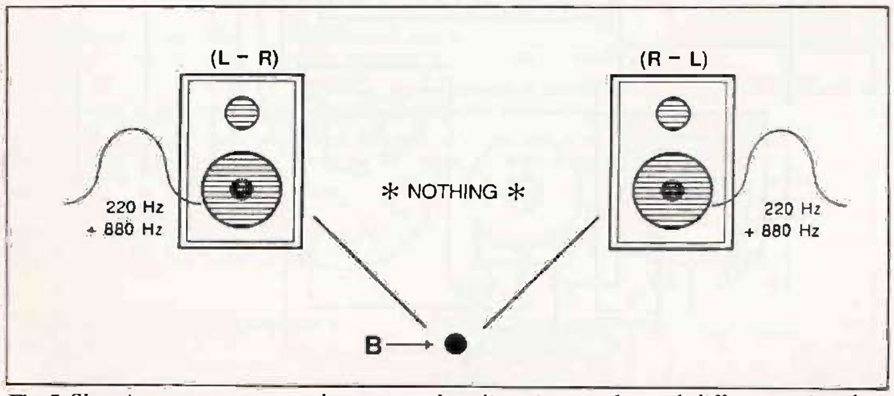

Fig.5 *Showing apparent sound sources when listening to channel difference signals*

PRACTICAL ELIMINATION

After that rather wordy description of the principles of stereo, a glance at Fig.5 will show that a quad op-amp is worth a thousand words. Fig.6 shows the basic principle of the Vocals Eliminator. Simple maths tells us 3 − 2 = 1 is exactly the same as 3 + (−2) = 1, and that is the basis of the circuit. The inverted left and right signals are each added to the (uninverted) opposite channel, thus producing l+(−r) and r+(−l). These two difference signals (with the 'middle bit' missing) form the circuit's output. It really is almost as simple as that!

While the Vocals Eliminator is a useful addition to any hifi chain, nobody really wants it in place all the time. Also it is sometimes useful to be able to fade the vocals slightly, rather than just have an 'all or nothing' switch. The circuit diagram (Fig.7) is a practical implementation.

CIRCUIT DESCRIPTION

As the circuit is symmetrical, only the signal path of the right channel will be described, to the left channel being very similar. C1 ac couples the input, and R1 provides a dc path to ground for the output side of the capacitor. IC1a, along with R3 and R5 form a unity-gain inverting amplifier, providing the (−r) signal. S1a either ignores this output, takes it directly or via VR1, through R8 to be summed with the univerted left signal connected via R109. IC1v forms a voltage follower to act as a buffer for the summed signal, and its output is taken to the output socket. Power is supplied to the circuit via S2, and decoupled by C3 and C4. Although ±12V is specified, anything from about ±3V to ±15V will work quite happily, as long as the supply is well smoothed. Current consumption is a miserly 8mA per rail, so you shouldn't have to feed the electricity meter too often on its account.

ELIMINATING CONSTRUCTION

Construction is pretty straightforward if the usual rules are obeyed. Specifically, start with the Veropins, then the ic socket, resistors and capacitors. Don't forget to observe the polarities of C1 and C2, and plug the ic in the right way round.

There is a reasonable amount of

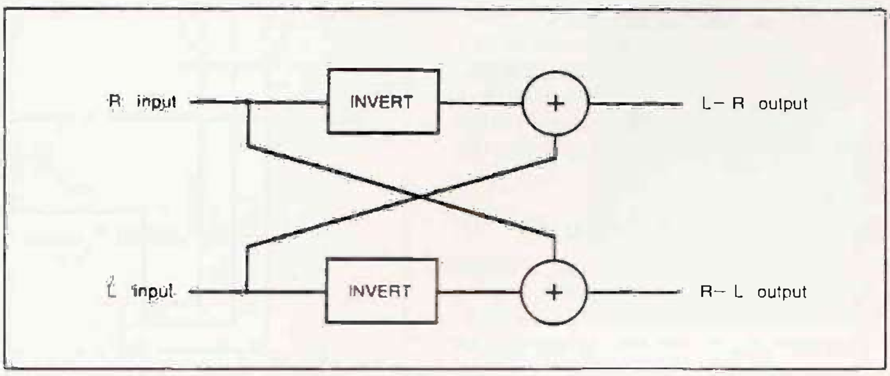

Fig.6 *Basic principle of vocals eliminator*

interwiring to complete, but it shouldn't present too much difficulty before installation. S1 must be converted from six positions to a three position device. Remove the fixing nut and washer and turn the spindle fully anti-clockwise. Now prise out the metal ring set into the body of the switch, and replace it so that the spigot slots into the hole marked 3. Replace the washer and nut, and check that the spindle now has only three stops. The pin numbers on the switch in the wiring diagram refer to Lorlin switches, as used in the prototype. Other types of switch may have different numbering, so beware. The pcb can

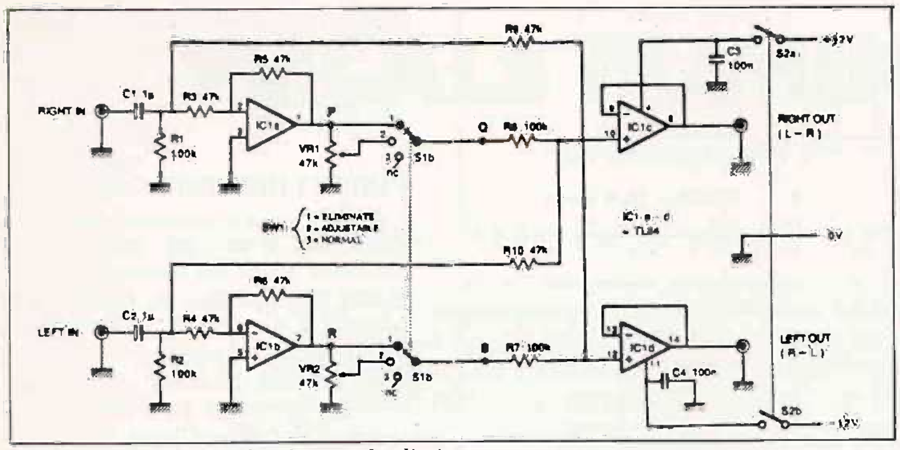

Fig.7 *Circuit diagram for the vocals eliminator*

RESISTORS	
R1,R2	100k
R3,R4,R5,R6	47k 1%
R7,R8,R9,R10	1M
CAPACITORS	
C1,C2	1μ 16V
C3,C4	0.1μ polyester
SEMICONDUCTORS	
IC1	TL084 quad op-amp
POTENTIOMETERS	
VR1,VR2	47k log
MISCELLANEOUS	
S1	2 pole 6 way rotary switch
S2	dpdt toggle switch

(14-pin ic socket, veropins (14 off), 3-pin din sockets (3 off) plastic case approx 150 × 80 × 50mm.

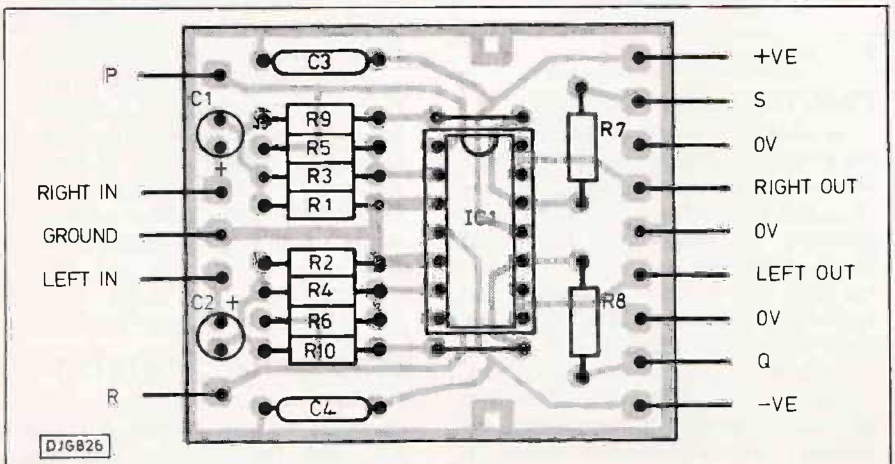

Fig.8 *Printed circuit board layout*

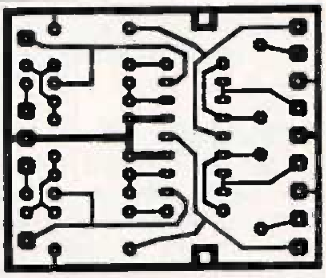
Fig.9 *PCB foil pattern*

either be secured in its case by a couple of bolts, or (again as in the prototype) held by a couple of self-adhesive pads. 3-pin din sockets are recommended for input andd output, and also for the power connection. Alternatively of course a couple of 9VPP3 batteries fitted within the case can be used to power the circuit.

ADVANCED ELIMINATION

The effectiveness of the Vocals Eliminator is heavily dependant on the stereo separation of the music source. Unquestionably, the best effect can be obtained from a compact disc recording, with the superb channel separation. Records and cassettes work reasonably well too, but don't expect the circuit to work from a mono source! The type of music also influences the efficiency. Practical experience shows that some effect will be observed with most types of music, but Queen, Dire Straits and Status Quo make good starting points. Start off with the circuit switched on and set to Normal. Start the music and wait until the artist starts singing and switch to Eliminate. Hey presto, no singing. Now switch to Adjust and check that the volume of the singing can be adjusted with VR1 and VR2. Happy Eliminating!

PE

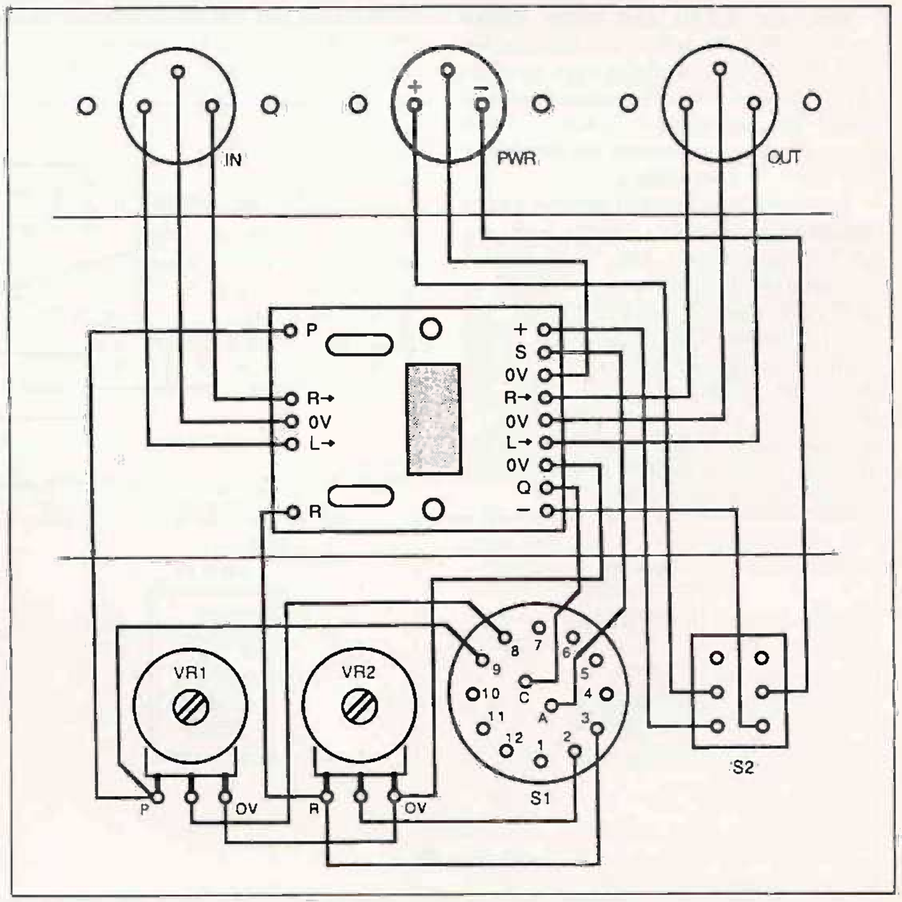

Fig.10 *Wiring diagram*

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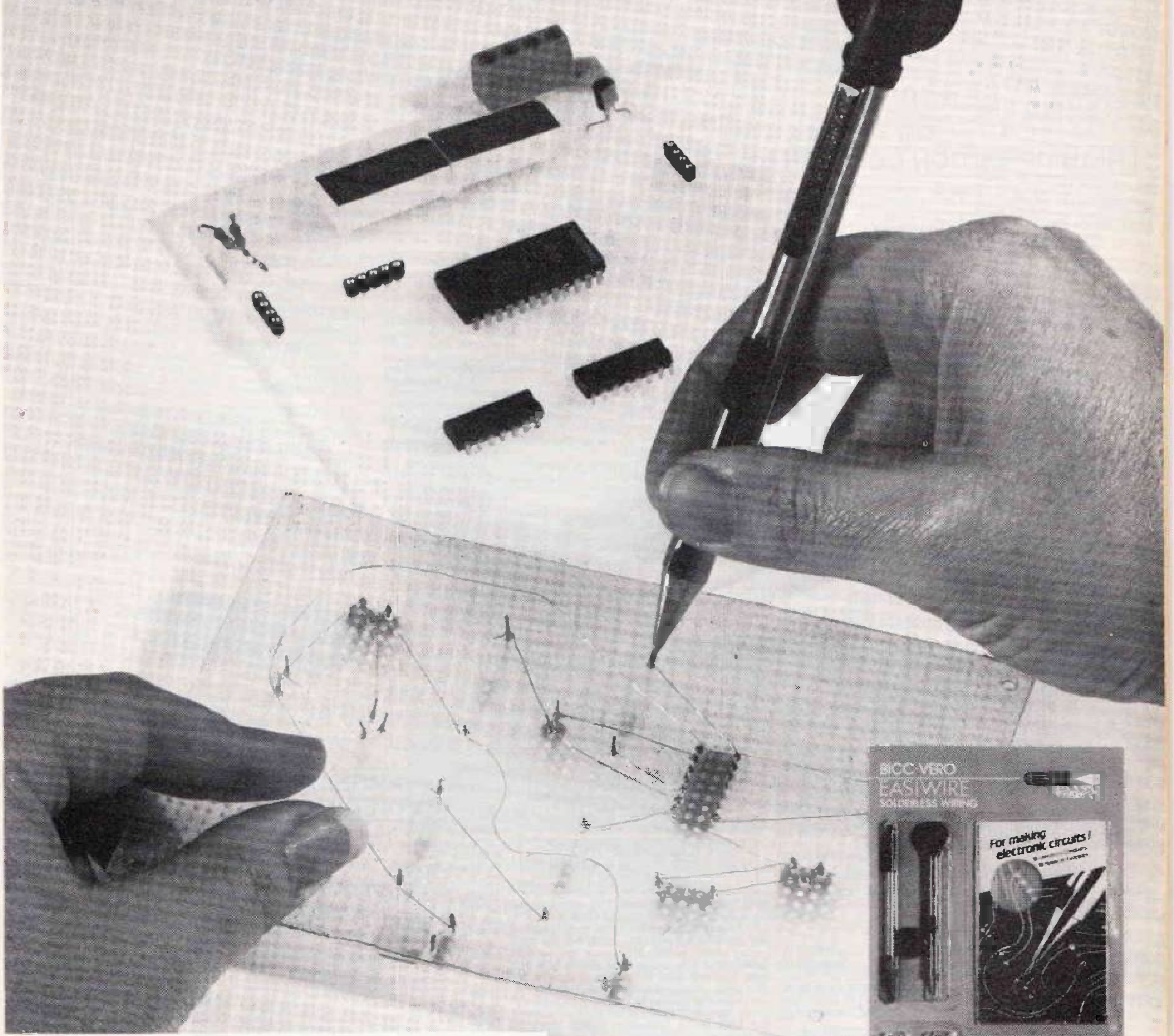

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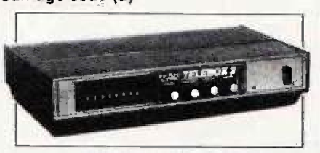

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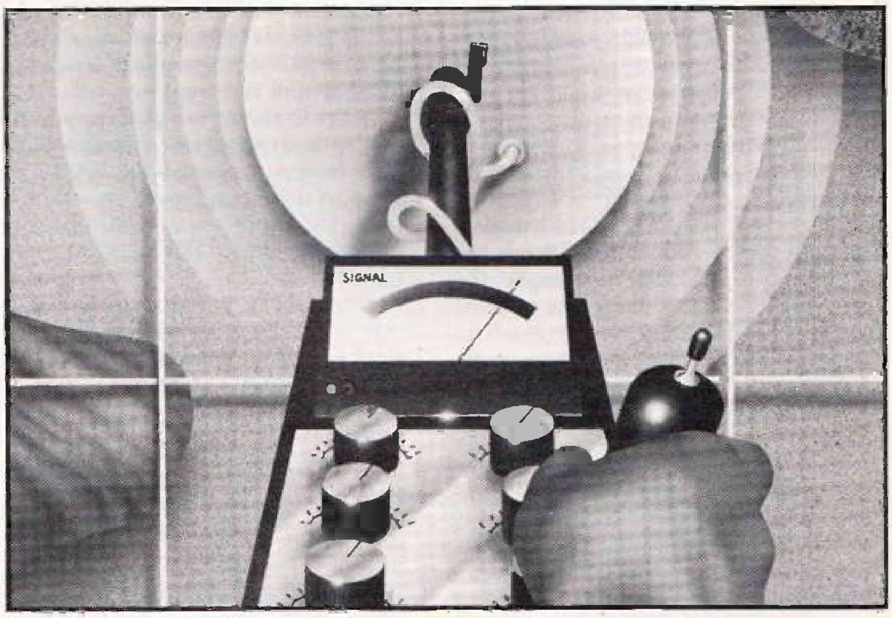
METAL DETECTION

BY THE PROF

PROSPECTING WITH A HOOVER

Metal objects "call out" to metal detectors as they sweep the ground by interfering with the detector's circuitry. Different detectors measure different aspects of the effect and convert them to audible or visual signals.



Although the "treasure" hunting craze of the seventies seems to have waned considerably during the eighties, metal detection still remains a popular aspect of electronics. It is also one that, perhaps after some over-kill in the past, has received very little attention in the technical press over the last few years. Even if you are not interested in going out into the wilds in search of buried treasure, the technology of metal detection still represents an interesting aspect of electronics. It is also potentially a very interesting line of pursuit for the electronics experimenter.

Most metal detector designs for the home constructor seem to be of either the bfo (beat frequency oscillator) or ib (induction balance) varieties, but there are actually many other types in existence. Although the term "metal detector" brings to mind images of treasure hunter style equipment, this type of equipment is actually used in a wide range of applications. These include things as diverse as pipe and cable location, airport and other security applications, medicine, and electronic ignition systems.

In this article we will consider a number of different methods of metal detection, including both the common and some of the more obscure systems. In most cases practical circuits with detailed descriptions are not provided, but a metal locator project will be provided in a future issue.

BEGINNINGS

Electronic metal detection has its origins further back in time than most people would imagine. In fact the first electronic metal detector was designed over one hundred years ago (in 1879 by Professor D.E. Hughes apparently). What is perhaps even more surprising is that the original design was of the induction balance variety. I own a sophisticated metal detector produced by a well known manufacturer of this type of equipment, and this is of the induction balance type. In fact many of today's more complex detectors seem to be of this type. This is not to say that modern detectors are simply refined versions of the original, and that no new techniques have evolved over the past hundred years or so. As we shall see, there are numerous types of detector currently in use.

Many of today's metal detectors are quite complex pieces of equipment, but the principles on which they operate are relatively straightforward. Much of the complexity of most detectors is in the "bells and whistles" rather than in the main detector part of the circuit. Virtually all methods of detection rely on a pick up coil or coils, and the effect on the electrical characteristics of the coil that a piece of metal in reasonably close proximity is likely to have. However, some detectors have coils which detect changes in a radiated signal, rather than directly detecting the metal. As far as I can ascertain, all normal forms of metal detector use a search coil of some sort or other.

In this article I will provide basic details of all the types of metal detector that I have been able to locate. Most of these methods I have seen in operation, but with some of the less common types I am not reporting from first hand experience. An important factor to keep in mind is that there is usually more than one way to exploit each basic method of detection. Consequently, the block diagrams provided here to illustrate the way in which each type of detector operates are only intended as examples. Not all metal detectors of each type will operate precisely as described here, but they will be based on the same fundamental principle.

BFO

The bfo (beat frequency oscillator) method of detection is one of the most simple, and has been much used at the low cost end of the detector market. Most of the early home constructor units were also of this type, and I would guess that many readers of PE have built one of these. The block diagram of Fig.1 shows the general make-up for a unit of this type.

The search coil forms part of an L – C tuned circuit which acts as the frequency selective circuit in an oscillator. The detected metal could be regarded as being analogous to the adjustable core in an i.f. transformer, and it causes a shift in the frequency of the oscillator. The oscillator could operate at an audio frequency so that

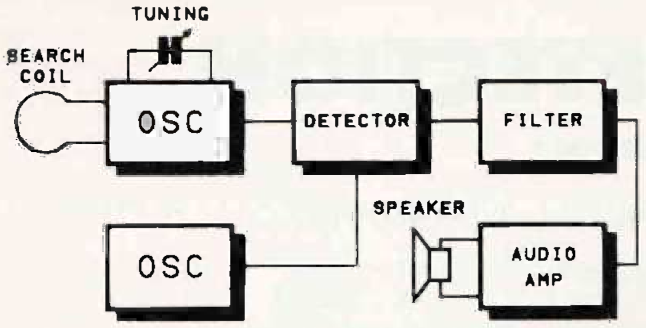


Fig.1. *The set up used in a BFO detector*

the shift in frequency would be audible, but this would give totally inadequate sensitivity in practice. The problem is simply that the shift in frequency is not very great, and with direct audio operation not even a well trained ear would be able to detect it.

A high operating frequency and the heterodyne principle are used to give improved sensitivity. The output from the search oscillator and a second oscillator are fed to a detector and rf filter. The output from the filter is the "beat" note, which is merely the difference between the frequencies of the two oscillators. These are tuned so that the beat note is a low audio frequency. If, for example, the search oscillator operates at 199kHz and a metal object produces a 0.01% reduction in frequency in absolute terms this represents a shift of 10Hz. This is not very much, but if the beat note was set at 50Hz, this would give a 20% reduction in output frequency, with an actual output frequency of 40Hz. This would be clearly detectable by the human hearing mechanism. By contrast, direct operation at 50Hz and a 0.01% shift in frequency would given an inaudible shift of just 0.005Hz!

SENSITIVITY

For optimum sensitivity a high search oscillator frequency and low beat note are required. In practice a high operating frequency is not possible due to legal requirements, but drift in oscillators would probably preclude the use of operating frequencies of many megahertz anyway. With this type of detector the output is normally in the form of an audio tone from headphones or a loudspeaker, but the change in output frequency can be used to give some other form of indication with the aid of some additional circuits. Most bfo detectors only seem to give the standard audio output though. Unfortunately, some people are literally tone deaf, and the straight audio output is not something that everyone finds usable.

I suppose the main attraction of this type of detector is that it is cheap, rather than being highly sensitive or easy to use. In the hands of an experienced operator quite good results can be obtained, and this method of detection provides discrimination between ferrous and non-ferrous metals. One category gives an increase in the output tone while the other produces a reduction (which type metal has which effect depends on how the unit is set up).

A drawback of bfo detectors is that they suffer from ground effect problems. This is where placing the search coil close to the ground gives an indication from the unit even with no metal present. In theory this does not matter provided the coil is kept a constant distance above the ground, but in use this is virtually impossible even with relatively flat terrain. Fortunately, the ground effect problems can be practically eliminated with the aid of a Faraday shield. This is a metal sheath placed over the coil, but broken at some point so that it does not quite form a complete ring. In my experience this dramatically improves results with this type of detector, and for a home constructor unit something as basic as a sheath of aluminium foil will work wonders for the user-friendliness of the unit. Multi-layer search coils are sometimes used with bfo detectors in an attempt to improve sensitivity at larger depths.

DROP-OUT DETECTOR

There are types of detector which are even more simple than the bfo variety, and which offer a similar level of performance. They seem to be relatively unknown and little used in practice though. A very simple method that I have found to be quite effective is to have an oscillator which includes the search coil in its L-C tuned circuit, and to also have an accurate voltage monitoring circuit of some type included in the unit. When metal is brought near to the coil it produces a change in the operating frequency, but probably of greater importance in this case, it alters the Q value of the coil. The voltages in an oscillator are not exclusively under the control of the bias network, and in many cases the bias circuit exerts very little control. The change in Q and operating frequency will give small voltage shifts with many oscillator designs, and these can be detected by the voltage monitoring circuit.

Vast numbers of metal locators must have been manufactured over the last ten to fifteen years, and one might reasonably expect that there would be several special integrated circuits for this purpose. This does not seem to be the case though, and the commercial detectors I have seen have had circuits based on 741Cs and the like. The only chip designed for this application that I have been able to locate is the intriguingly named CS209 "stud detector" from Cherry Semiconductors. This device is primarily intended for detecting studs and nails in walls, but it is suitable for other metal location applications. Fig.2 shows in somewhat simplified form the general arrangement used in the CS209.

Once again, we have an oscillator with the search coil acting as the inductor in its L-C tuned circuit. The feedback level must be carefully adjusted to the point where the oscillator only just manages to sustain oscillation. The oscillator is sensitive to changes in the Q value of the coil, and the effect of a metal object close to the search coil is to produce a drop in the amplitude of the output signal. The output is demodulated and fed to a level detector circuit. The latter detects the drop in signal level and activates two output stages. The two outputs are both current sinks which can handle currents of up to 150 milliamps, but one is normally switched off while the other is active under stand-by conditions.

Simple arrangements of this type are capable of quite good results, but can also be disappointing in practice due to stability problems. The CS209 seems to offer good performance in this respect

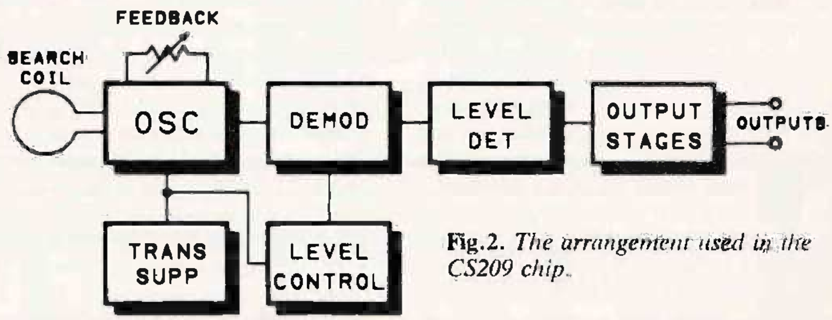


Fig.2. *The arrangement used in the CS209 chip.*

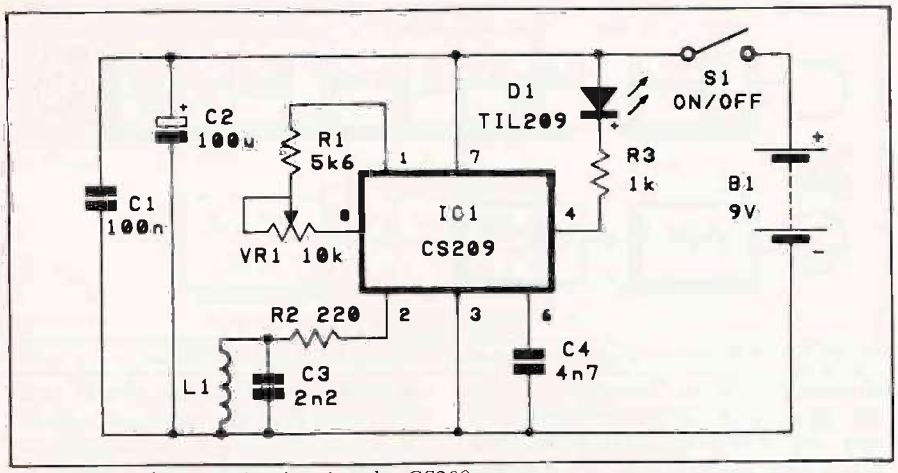


Fig.3. *Basic detector circuit using the CS209*

as it has a high quality built-in voltage regulator and a transient suppressor circuit. Another potential flaw in circuits of this type is the strong innate hysteresis. In this case it occurs due to the reluctance of the oscillator to restart once oscillation has been allowed to drop-out completely. In the CS209 this problem is minimised by a level control circuit which ensures that the oscillator can not cease oscillating even if a very large piece of metal is placed close to the search coil.

For those who would like to experiment with the CS209 the basic metal detector circuit of Fig.3 is provided. The data sheet for this device recommends a value of about 100ΩH for L1, but its exact value does not seem to be critical. VR1 must be carefully adjusted for the highest resistance that does not result in D1 switching on. In fact it might have to be backed-off slightly from this setting, since D1 might otherwise tend to hold in the on state when the unit is activated. The automatic level control circuit minimises the amount of hysteresis, but it does not totally eliminate it. Although in this basic circuit only led D1 is switched on when metal is detected, obviously an audio alarm or other form of indicator could be controlled by the circuit. The normally on output, incidentally, is at pin 5 of IC1.

IN THE BALANCE

The induction balance system requires two coils, or what in practice may be three coils with some tappings. For the moment we will only consider the basic twin untapped coil arrangement as depicted in the block diagram of Fig.4.

We have the familiar oscillator and search coil, but this time with a second coil feeding into an amplifier. Although a strong coupling from the coil driven by oscillator to the second coil would be expected, careful positioning of the two coils provides what is a very inefficient coupling with no significant output from the pickup coil. This sounds difficult, but is achieved merely by partially overlapping the two coils. A piece of metal close to the coils produces an imbalance and gives a strong output from the amplifier stage.

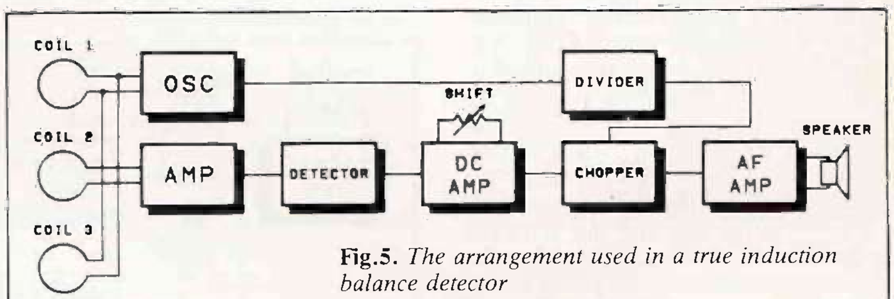


Fig.5. *The arrangement used in a true induction balance detector*

There must be endless ways of converting this rise in signal level into some form of indication to the operator of the equipment, but the general method shown here seems to be a popular one. It provides an audio output tone that rises in volume when metal is detected. This form of indication is generally much clearer than the varying tone produced by a bfo detector.

The output from the amplifier is fed to a detector circuit that gives a dc output level which is proportional to the output level from the amplifier. If meter indication is required, the meter can be driven from the detector stage via a buffer amplifier. For an audio output the next stage is a dc amplifier which incorporates a shift control that can be used to raise the quiescent output voltage above its normal level of close to zero. In practice this control sets the volume of the output tone under stand-by conditions, and results are generally better with a quiet tone rather than having zero output under quiescent conditions. This control is sometimes (rather confusingly) referred to as a "tuning" control incidentally.

The next stage is a "chopper", which is merely an electronic switch that gates the output of the dc amplifier on and off. This generates a squarewave signal having a peak to peak amplitude equal to the output voltage from the dc amplifier. Accordingly, the volume of this audio signal rises and falls in sympathy with the signal level received by the pickup coil. Most people find a change in volume easier to work with than the change in pitch provided by bfo type detectors, but by using a voltage controlled oscillator (vco) a change in pitch could be obtained if preferred. The chopper could be driven from an audio oscillator, but it is often controlled by the main oscillator via a divider stage. Unlike bfo designs, ib circuits often work at quite low frequencies (typically about 15 to 20kHz).

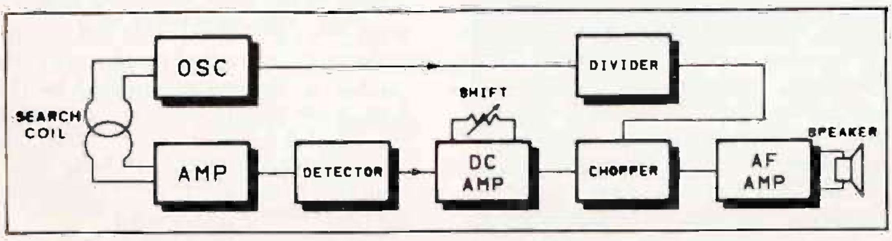


Fig.4. *An induction balance detector arrangement*

A three coil induction balance circuit uses the arrangement shown in Fig.5, which is what some metal detector experts consider to be the only true ib setup. It is virtually identical to the slightly simplified type described previously, and it differs only in that two coils are driven from the oscillator. In practice these two coils are carefully positioned and phased so that there is zero output from the third coil, with the pick-up from coil 1 coil being cancelled out by the pick-up from coil 3. The standard search head arrangement is to have coil 2 sandwiched between coils 1 and 3, with coils 1 and 3 having the same number of turns but being wound in opposite directions.

This type of detector operates in what is essentially the same manner as the two coil ib type, with metal in the vicinity of the search coil upsetting the balance of the system, and producing a stronger output from the amplifier. With both types it seems to be normal to have the system adjusted so that under quiescent conditions there is considerably less than perfect balancing. This enables the unit to discriminate between ferrous and non-ferrous metals. The latter give a decrease in coupling whereas the former produce increased coupling.

Many of the more up-market ib designs have quite sophisticated discrimination capabilities. This generally takes the form of a control that enables the unit to be nulled on a piece of metal, and it will then fail to respond (or at least be very insensitive to) any pieces of that particular metal in the search area. A typical use of the discrimination facility is to render the detector insensitive to aluminium foil, which is found in large quantities in many popular types of hunting ground. Note that discrimination means the ability of a detector to ignore certain metals: it does not mean the ability to ignore everything but (say) gold or silver. In my experience the discrimination facilities of metal detectors are less worthwhile than much of the advertising literature would have you believe. There is often a penalty to pay in the form of reduced sensitivity, and setting up a machine which has adjustable discrimination and other advanced features can make setting up a video recorder to automatically record a programme look like child's play.

Induction balance metal detectors suffer from ground effect problems. Some ib detectors now have a facility to "tune" out the ground, but variations in soil moisture etc can make frequent re-adjustment necessary. A very useful facility is an automatic nulling circuit, which, over a period of a second or two always adjusts the circuit for zero output. On the face of it this cures the ground effect problem, but renders the detector insensitive to everything else as well! However, in use the detector is swept quite rapidly over the earth, and if the search head passes over any metal the unit will produce a clear indication before the nulling circuit has a chance to rebalance the circuit. Having used this method to roughly locate an object, the unit is switched to the ordinary mode so that it can be pin-pointed.

IB OR NOT IB

There seems to be some lack of agreement as to which detectors are ib types, and which are t/r (transmit/receive) units. The general consensus seems to be that the types described above are forms of ib detector, while the system depicted in the block diagram of Fig.6 is the t/r type.

This system is very similar to the ib type, and it has one coil driven from an oscillator and a second one feeding into an amplifier. The amplified signal and some of the output from the oscillator are fed to a mixer. The signal from the amplifier is coupled to the mixer via an inverter, or perhaps some other form of phase shifter circuit. The idea is to have the signals at the mixer out of phase so that they cancel each other out. The signal from the oscillator is fed to the mixer by way of a potentiometer so that the signal level can be adjusted for precise cancelling. As for the ib type, metal close to the search head alters the strength of the signal from the pick-up coil, giving an imbalance in the signal levels fed to the mixer and producing an output from the mixer. This signal is fed to a detector stage, and the resultant dc signal is amplified before being applied to a meter. Of course, the dc signal can be fed to a chopper and audio amplifier if an audio indication is required as well.

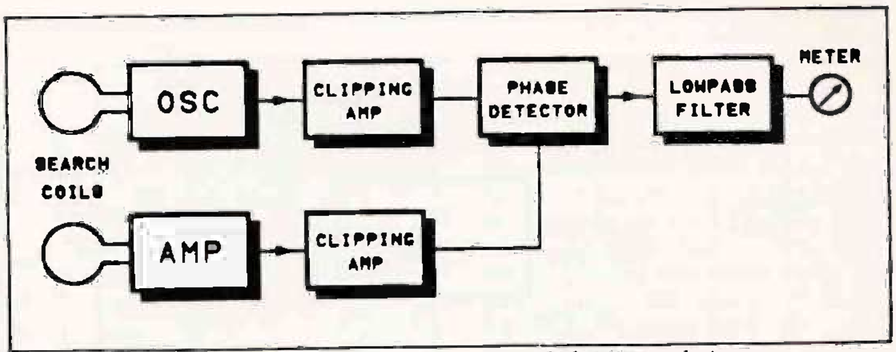


Fig.6. *The T/R system is another one which uses a balancing technique*

As the t/r type of detector operates on what is really the same principle as the ib type, it has very much the same advantages and drawbacks.

OFF-RESONANCE

This seems to be a little used type of detector, and it utilises the setup shown in Fig.7. It is another type of detector that relies on a balancing process, but the operating principle is not the same as the ib and t/r types. In fact it is much more like the bfo type of detector in this respect.

A signal generator feeds a signal to a buffer amplifier and detector circuit by way of an L-C tuned circuit that incorporates the search coil. Some of the direct output of the search coil is fed via a balance control to another buffer amplifier and detector circuit. The output signals from the detectors are fed to a differential amplifier, and under quiescent conditions the balance control is adjusted for zero output from this amplifier. As with a bfo locator, metal near to the search coil causes a shift in the resonant frequency of the tuned circuit. In this case the tuned circuit is used as a filter, and the signal generator is tuned just off-resonance where the filter has a rapid roll-off rate. The shift in resonant frequency therefore gives a change in signal level that gives an imbalance at the differential amplifier, and a consequent meter deflection.

Compared to a bfo type detector this system has the advantage of providing meter indication, or an audio signal of varying volume if suitable output circuitry is included. In other respects it should perform as well (or as badly as) an equivalent bfo design.

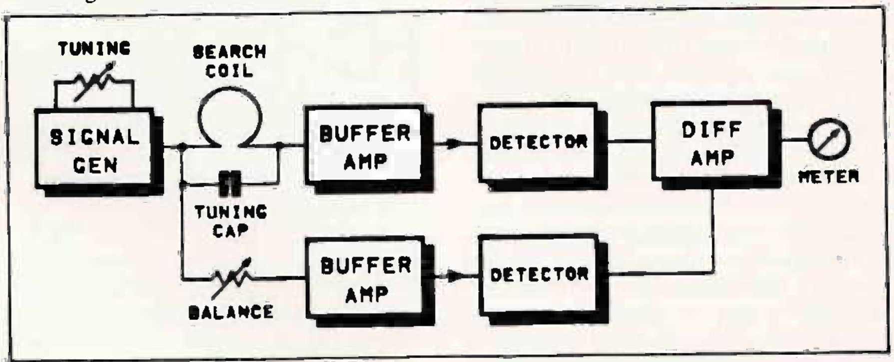


Fig.7. *The system used in off-resonance detectors*

PULSE TYPE

Pulse induction detectors operate on a principle that is completely different to ib and bfo style detectors. Fig.8 shows a somewhat simplified block diagram for a pulse induction detector.

The principle of operation may be different, but a search coil is still central to the operation of the system. A pulse generator supplies brief pulses to the coil, and this generates a magnetic field around the coil. On the trailing edge of each pulse the magnetic field collapses and generates a reverse voltage across the coil. The coil must be damped (electrically that is!) so that the reverse voltage spike decays quite rapidly. If there is a piece of metal in the vicinity of the coil it will either produce an eddy current or become magnetised by the field of the coil, depending on whether the metal is non-ferrous or ferrous. As far as the effect on the reverse pulse from the coil is concerned, in either case the pulse becomes stretched.

Turning the elongated pulse into a

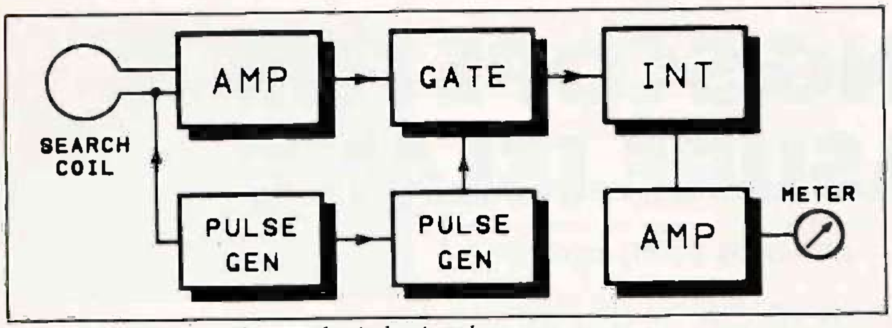


Fig.8. *Block diagram for a pulse induction detector*

clear visual or audible indication is usually done with the aid of a gate and an integrator. The gate is opened by pulses from a second pulse generator, but this circuit is triggered from the main pulse generator. Remember that it is the reverse pulse generated across the coil that must be allowed to pass through the gate circuit, and not the signal from the main pulse generator. The second pulse generator is therefore triggered on the trailing edge of the signal from the main pulse generator. In fact it is the part of the reverse pulse where it nears 0 volts that is really of interest, and the gate pulse can usefully be delayed slightly so that the initial part of the waveform is cut out. The integrator generates an output voltage that is a product of time and input voltage, and the stretched pulses give a higher output voltage. This signal is amplified and fed to a meter, and the output from the amplifier can be used to drive some form of audio indicator circuit if desired.

This system has definite advantages over the other types described so far, including its immunity to ground effect problems, and what is generally much better stability than other types of detector. It is not without drawbacks though, such as an inability to differentiate between ferrous and non-ferrous metals, and what is often a relatively high level of power consumption (although some other types of detector tend to be so packed with circuitry that they also consume large amounts of power). A point that has to be borne in mind with this type of detector is that it gives absolute rather than relative detection. In other words, whereas it is possible to adjust other types of detector to nullify the effects of any metal which forms part of the detector itself, this is not possible with a pulse induction type. It is therefore important to have metal-free construction in the search head and at least the lower part of the detector's "stem".

VLF PHASE ANGLE

This is an interesting type of detector, but I can not say that I have ever encountered a unit which utilises this technique. It is reminiscent of a simple ib or t/r detector in that one coil is driven from an oscillator, while a second coil is used as a pick-up that drives an amplifier. Note that the coils are not arranged in such a way as to give zero output from the pick-up coil. Operation of this system relies on a reasonably strong output signal being obtained from the pick-up coil. The output signal of the oscillator and the output of the amplifier are fed to squaring circuits, as shown in the block diagram of Fig.9.

The effect of metal close to the search head is to produce a phase shift in the output from the pick-up coil. Linear or digital circuits could be used to detect this phase change and convert it to some form of visual or audible output indication, and the digital approach is probably the more simple but effective method. In fact an ordinary logic gate can operate as an effective phase detector. Things would normally be arranged so that the two signals are normally in phase, and move out of phase when metal is detected. This gives zero output or very brief pulses from the phase detector under stand-by conditions, but longer pulses as metal is brought close to the search head. A lowpass filter is all that is needed to convert the pulses into a dc output signal, or perhaps some form of digital pulse duration measuring circuit could be used to provide a visual indication on a digital display.

A unit of this type could be designed to operate at virtually any frequency, but it is advantageous to use a very low frequency as this apparently avoids problems with the dreaded ground effect.

CONCLUSION

There are several different types of metal detection circuit currently in use, with each type having its advantages and disadvantages. Clearly the perfect metal detector has yet to be invented. People who have never used a metal detecor tend to have an exaggerated idea of the sort of performance that can be obtained. It takes a good unit to detect a 2p coin at a depth of 150 millimetres or so, and few units can detect even quite large pieces of metal at much more than two or three times this figure. Super high sensitivity is not necessarily an asset anyway, and it can simply provide confusing results with every speck of metal being detected. When using my detector at full sensitivity it often detects what turns out to be a small patch of rust!

Ready made metal detectors of fair performance seem to be quite expensive, and this is one aspect of electronics where it is certainly possible to build a unit that will cost considerably less than buying a "real one". There is plenty of scope for anyone wishing to try their hand at designing this type of equipment. One last point is that an operating license is no longer needed in order to operate a metal locator in the UK, but it is only legal to use detectors that fall within certain (not especially stringent) specifications. PE

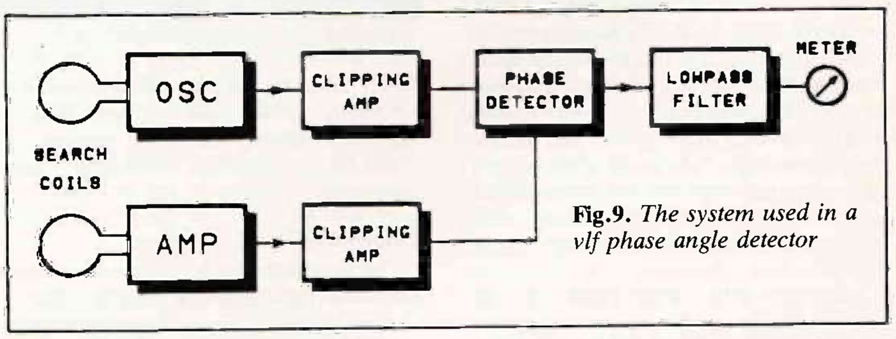


Fig.9. *The system used in a vlf phase angle detector*

BAEC PUZZLE SOLVED

The British Amateur Electronics Club has had periodic publicity through PE's news pages. The address previously quoted was that of the Hon Sec to whom several readers wrote asking for membership details. Receiving no reply they contacted your Ed who, loving a challenge, made more enquiries. It seems that Hon Sec moved but Hon Printers didn't update BAEC's Hon Mag.

Hon Ed chatted with Hon Chairman who says that membership enquiries eventually come to him anyway so suggests readers should contact him directly: Mr C. Bogod, 'Dickens', 26 Forrest Road, Penarth, South Glamorgan, tel. 0222 707813.

It's a club worth joining if you're looking for electronic companionship and an interesting quarterly magazine-newsletter full of ideas, circuits, information and sources of discount electronic goods. But please be good to Mr Bogod and send a stamped addressed envelope with any letter to him. **Ed.**

SEEING SCOPE FOR TREASURE ISLAND

BY LONG JOHN BECKER

THE PROOF OF THE PROBING IS IN THE KITTING

What your editor is trying to tell you is that he has been given a make-it-yourself metal detector to play with! Wooden leg optional...

While reading through Robert Penfold's article on metal detection, completely by coincidence, a press release from C-Scope about one of their several metal detectors arrived on my desk.

My curiosity being what it is I rang them to see how their designs related to RP's observations. Kate d'Lima, to whom I spoke, was extremely helpful with information and also suggested that I might care to examine one of their detector kits, the K5000. Never having used any sort of metal detector before, I jumped at the opportunity.

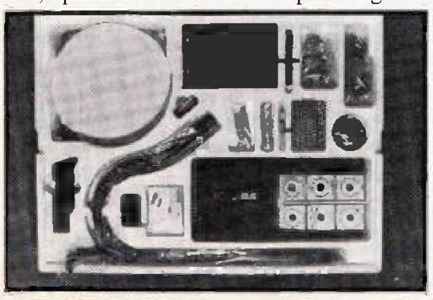
An ideal educational or hobby project

PRESENTABLE

A few days later a large well packed box arrived. Opening the wrapping I was immediately impressed by an attractively illustrated box and by the way in which everything inside has been packed and presented.

The interior was lined in specially sculptured polystyrene foam with various parts and packages neatly inserted into it. All the hardware parts were protected by polythene wrappings, and all the electronic components had been put into a selection of sealed polythene bags. Obviously this kit has been designed with the presents market in mind – and anyone receiving it as a gift would certainly be delighted by the appearance.

Accompanying the parts is an illustrated 34 page A4 size assembly and operation manual. Following a brief preface about C-Scope and the kit, a page is devoted to an itemised contents list, split into nine sections pointing me to an introduction, parts list checking, soldering, pcb assembly, mechanical assembly, wiring assembly, setting up procedure, trouble shooting and operation.



FORWARDS

The introduction describes the K5000 kit as having been designed to offer a challenge to an electronics enthusiast while being detailed enough for a novice to understand and complete successfully. It goes on to say that the kit requires no prior knowledge of electronic components or assembly techniques, and that it can be completed with a minimum number of tools. While assembling the kit I had these statements in mind and I certainly conclude that they are true.

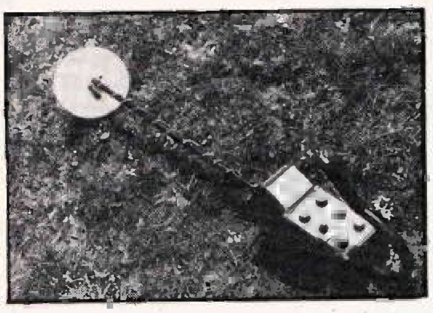
The tools suggested are a 1.5 Allen key screwdriver, a Phillips quarter inch blade screwdriver, wire cutters, long nose pliars, junior hacksaw, soldering iron, ruler, 5.5mm and 14mm box spanners. In fact I did not use an Allen key or the box spanners, but instead used a modelmaker's screwdriver and a pair of heavy duty pliars.

EASY AS PCB

The parts list checking section is thorough. It leads you through details of what resistors, capacitors and ics look like, even colour codes and component outlines are shown. There is a complete list of all the parts and in which bag to find them. Apart from tools, the only items not supplied are batteries, of which you will need to buy 12 of the HP7 type, or similar.

For the complete novice, half an illustrated page is devoted to instruction on soldering. Then comes the first of the exciting parts – the pcb assembly.

As far as was possible for an addicted assembler, I followed the instructions in detail and I feel sure that novices will find it very straightforward. A step-by-step approach is taken, using words and



pictures to tell you precisely what each component looks like and where it goes. It is almost impossible to put a component in the wrong place.

At this point I would make a few suggestions to C-Scope. First, it would be useful if in the pcb assembly section they explained the best way to remove any soldered component if it had been put in the wrong place.

PLUGGING SOCKETS

Secondly, from many years experience connected with kits I recommend that the ics should not be soldered in but instead should be used with sockets, so allowing easy removal if necessary. If someone was careless and soldered in an ic the wrong way round it would be difficult for an inexperienced constructor to remove it. The use of ic sockets is definitely preferable.

Another suggestion is that the insertion of ics should be left until after all the electronic and mechanical assembly has been done. Although the mos ics are less prone to static electricity problems once they are physically within a circuit, I still feel it is best if the risk of handling them is minimised by leaving their insertion till last.

LENGTHENED

A further comment is that although the manual appears to give all the necessary information to identify electronic components, I noticed that some capacitors only had their manufacturer's coded identities on them. Experienced constructors probably won't be confused by this, though a novice might, even though the identities can be intelligently deduced. As C-Scope already go to such lengths to make things easy, I suggest that additional code clarification here would make it even easier.

Although the pcb is solder protected in non-connection areas and the risk of solder shorts is minimal, I would suggest that the advice about checking soldering is put immediately following the pcb assembly section instead of, or as well as, in the trouble shooting section.

Incidentally, I could have done with a bit more solder supplied – the connecting tags really like to drink it. Another metre would probably do. Of the connecting ribbon cable there was no shortage and I only used about two thirds.

It was interesting for me to assemble another designer's pcb kit, and in the two hours it took me I enjoyed doing it. I was impressed by the overall thoroughness of the explanation.

TEXTURED HARDWARE

Mechanics are not as familiar to me as electronics, and on the hardware assembly I can truly say that I approached it as a novice. In retrospect, I am surprised at myself for finding one or two parts initally perplexing and I can admit now that in some instances I was guilty of not reading the words or studying the pictures properly.

Somehow, though, I got the feeling the authors of the electronics and mechanical stages were different people and that some of the explanation about the hardware was not so detailed as that for the pcb assembly. I am sure that everyone will find the answers, like I did, but a little extra detail would be even more helpful.

I felt, too, that the attachment of the detector head and the full length of handle would have been best left until after the wiring had been completed – my overcrowed workbenches didn't leave much clear space for satisfactorily balancing the head, handle and control box.

It would have been preferable for the control spindles to have had flattened sides and that the knobs had either been push-ons or used grub screws that would accept a small electrical screwdriver. Most people will have the latter, but Allen keys to suit the knobs supplied are not part of everyone's tool kit.

CHECKING PROCEDURE

After spending two and half hours doing the mechanical and wiring assembly I proceeded straight on to the setting up – you know how keen one can be to try out something new.

There are only three minor adjustments to be carried out to preset controls on the pcb. Adjusting the first two produced the required changes as stated in the text and I found that the detector recognised when coins were passed close to it. The third preset, the ground-exclude trimming capacitor C3, can simply be set midway and adjusted more precisely in the light of experience. I'm pleased the unit has been designed so that the controls can be set without the need for a meter or other test gear.

The trouble shooting section I didn't need to use, but it appears to be comprehensive, covering each stage of the circuit in turn. The complete circuit diagram shown will be of interest to anyone with technical knowledge.

CONTROLLED OPERATION

An eight page section is devoted to operating the metal detector. It covers the theory of detection, how the detector can discriminate between various objects, accepting or ignoring them depending on the control settings. There are six controls on the panel allowing for adjustment of sound volume, tuning, sensitivity, ground exclusion, discrimination level, and switched seventh control in the handle is in effect a type of memory recall and discrimination function selector.

Care and maintenance of the detector are covered, and then a lengthy guide to techniques for treasure hunting is given. A few detailed examples of searching would perhaps be useful here – like how to get the detector to recognise a specific item knowingly presented to it, using different items so that one can learn from controlled experiments.

EBULLIONT

Within five hours of starting to assemble the kit, I was succesfully 'finding' various things that I was deliberately 'losing'. My interest has been aroused to try searching for 'treasure' more earnestly now that summer is supposed to be with us. Following successful field trials I might just see if Brink's Mat or Fort Knox need any help...

I am very impressed by assembling and briefly using this detector. As I have not used one before I cannot compare it with others, but one thing is certain, the K5000 is a very well thought out metal detector kit.

The few suggestions I have made here should not be taken as serious criticisms; they are intended as helpful observations for minor improvements to an excellent kit. Congratulations to C-Scope.

PIECES OF EIGHT

The price of the K5000 metal detector kit at the time of going to press is £124.50 including vat. There is a full after-sales repair, maintenance and spare parts service. The detector can also be bought ready built direct from C-Scope for an extra £40. The kit is available from good hobby and electronics shops, or from C-Scope International Ltd, Dept PE, Wotton Road, Ashford, Kent, TN23 2LN. Tel: 0233 29181.

C-Scope are also running a competition with K5000 kits as prizes – see page 5. PE

POPULAR BAKERS DOZEN PACKS (Still available)

All packs are £1 each. If you order 12 then you are entitled to another free. Please state which one you want. Note the figure on the extreme left is the pack ref number and the next figure is the quantity of items in the pack, finally a short description.

BD2	5	13A spurs provide a fused outlet to a ring main where device such as a clock must not be switched off
BD7	4	in flex switches with neon on/off lights, saves leaving things switched on
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BD11	1	6½" speaker cabinet ideal for extensions, takes your speaker. Ref BD137
BD13	12	30 watt reed switches, it's surprising what you can make with these – burglar alarms, secret switches, relay etc etc
BD22	2	25 watt loud speaker two unit cross-overs
BD29	1	B.O.A.C. stereo unit is wonderful value
BD30	2	nicad constant current chargers adapt to charge almost any nicad battery
BD32	2	humidity switches, as the air becomes damper the membrane switches and operates a microswitch
BD34	48	2 meter length of connecting wire all colour coded
BD42	5	13A rocker switch three tag so on/off, or change over with centre off
BD45	1	24hr time switch, ex-Electricity Board, automatically adjust for lengthening and shortening day. Original cost £40 each
BD49	10	neon valves, with series resistors, these make good night lights
BD56	1	mini uniselector, one use is for an electric jigsaw puzzle, we give circuit diagram for this. One pulse into motor, moves switch through one pole
BD59	2	flat solenoids – you could make your multi-tester read AC amps with this
BD67	1	suck or blow operated pressure switch, or it can be operated by any low pressure variation such as water level in water tanks
BD91	2	mains operated motors with gearbox. Final speed 16rpm. 2 watt rated
BD103A	1	6 750MA power supply, nicely cased with input and output leads
BD120	2	stripper boards each contains a 400v 2A bridge rectifier and 14 other diodes and rectifiers as well as dozens of condensers etc
BD122	10m	twin screened flex with white pvc cover
BD128	10	very fine drills for p.c.b. boards etc. Normal cost about 80p each
BD132	2	plastic boxes approx. 3" cube with square hole through top so ideal for interrupted beam switch
BD134	10	motors for model aeroplanes, spin to start so needs no switch
BD139	6	microphone inserts – magnetic 400 ohm also act as speakers
BD148	4	reed relay kits you get 16 reed switches and 4 coil sets with notes on making c/o relays and other gadgets
BD149	6	safety cover for 13A sockets – prevent those inquisitive little fingers getting nasty shocks
BD180	6	neon indicators in panel mounting holders with lens
BD193	6	5 amp 3 pin flush mounting sockets make a low cost disco panel
BD196	1	in flex simmerstat – keeps your soldering iron etc always at the ready
BD199	1	mains solenoid very powerful has 1" pull or could push if modified
BD210	5	Keyboard switches – made for computers but have many other applications
BD210	4	transistors type 2N3055 probably the most useful power transistor
BD211	1	electric clock mains operated put this in a box and you need never be late
BD221	5	12v alarms make a noise about as loud as a car horn. Slightly soiled but OK
BD242	2	6" x 4" speakers 4 ohm made from Radiomobile so very good quality
BD246	2	tacho generators, generates one volt per 100 revs
BD252	1	panostat, controls output of boiling ring from simmer up to boil
BD259	50	leads with push on ¼" tags – a must for hook ups – mains connections etc
BD263	2	oblong push switches for bell or chimes, these can mains up to 5 amps so could be foot switch if fitted into pattress
BD268	1	mini 1 watt amp for record player. Will also change speed of record player motor
BD275	1	Guitar mic – clip on type suits most amps
BD283	3	mild steel boxes approx. 3" x 3" x 1" deep – standard electrical
BD293	50	mixed silicon diodes
BD296	3	car plugs with lead, fits into lighter socket
BD305	1	tubular dynamic mic with optional table rest

Most other packs still available and you can choose any as your free one.

5A BATTERY CHARGER KIT – all parts including case only £5 add £1 postage.

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A classified list of these packs and our latest "News Letter" will be enclosed with your goods, and you will automatically receive our next news letter.

THIS MONTH'S SNIP

ACORN COMPUTER DATA RECORDER (ref ALF03) this is a mono data recorder with switchable motor control intended for use with the Acorn Electron or BBC computers but also functions with almost any other computer and can be used for normal record and play back of music and speech.

Six key controls give "PAUSE" "PLAY" "STOP" and "EJECT" "CUE/FAST FORWARD" "REVUE/REWIND" and "RECORD", fast forward and rewind (100 seconds for C.60). Also tape counter with reset button. Input signal range 5mV to 500mV. Input impedence 40k ohm. Can be battery operated but is supplied with a mains adaptor. Brand new in manufacturer's wrapping. £6 Order Ref: 6P18 add £2 post.

AN ALLADIN'S CAVE We have opened another shop in Hove, the address is number 12 Boundary Road which is between Hove and Portslade fairly close to the seafront. When you want to see before you buy and when you want to brouse around the special bargains available, this is where you should make for as the Portland Road shop in future will be just mail order. You can of course collect from Portland Road but you should bring in an order complete with reference numbers so that the stores can attend to it easily.

9" MONITOR

Ideal to work with computer or video camera uses Philips black and white tube ref M24/306W. Which tube is implosion and X-Ray radiation protected. VDU is brand new and has a time base and EHT circuitry. Requires only a 16V dc supply to set it going. It's made up in a lacquered metal framework but has open sides so should be cased. The VDU comes complete with circuit diagram and has been line tested and has our six months guarantee. Offered at a lot less than some firms are asking for the tube alone, only £16 plus £5 post.

CASE FOR 9" MONITOR We have arranged with a metal worker to make cases for the 9" Monitor. Delivery promised for the end of May and the price £12 + £2 post. The case will be made from coated sheet steel, overall size approx. 10" × 10" × 7" high which will give ample space for the Power Supply and external controls if you fit them.

PROBLEM SOLVED! We have obtained from the manufacturers of the 9" monitor the TTL converter which makes it composite input suitable to work with any computer. We have had the printed circuit board made and have all the components and can supply this converter in kit form price £6. Our Ref: 6P4

CHINNON 3½" F.D.D. 80 track 500K. Beautifully made and probably the most compact device of its kind as it weighs only 600g and measures only 140mm wide, 162mm deep and has a height of only 32mm, other features are high precision head positioning – single push loading and eject – direct drive brushless motor – Shugart compatible interface – standard connections – interchangeable with most other 3½ and 5¼ drives. Brand new with copy of makers manual, at £28.50 post and VAT included.

CASE – adaptable for 3½" FDD, has room for power supply components price only £4 includes circuit of PSU. Our Ref 4P8

POWER SUPPLY FOR FDD – 5V and 12V voltage regulated outputs, complete kit of parts will fit into case 4P8 price £8 or with case £11

DOUBLE MICRO DRIVES as fitted to many ICL and some Sinclair computers complete double units with 2 drive motors tape heads, and 2 PCBS each with plug in ULA, Ref. 2G007ES. Price only £5. Ref. 5P113

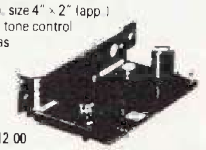
SWITCH AC LOADS WITH YOUR COMPUTER this is easy and reliable if you use our solid state relay. This has no moving parts, has high input resistance and acts as a noise barrier and provides 4kW isolation between logic terminals. The turn on voltage is not critical anything between 3 & 30v internal resistance is about 1k ohm. AC loads up to 10A can be switched. Price is £2 each Ref. 2P183

MULLARD UNILEX AMPLIFIERS

We are probably the only firm in the country with these now in stock. Although only four watts per channel, these give superb reproduction. We now offer the 4 Mullard modules – i.e. Mains power unit (EP9002) Pre amp module (EP9001) and two amplifier modules (EP9000) all for £6.00 plus £2 postage. For prices of modules bought separately see TWO POUNDERS

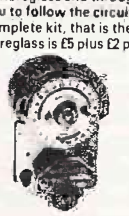
MINI MONO AMP on p.c.b. size 4" × 2" (app.)

Fitted volume control and a hole for a tone control should you require it. The amplifier has three transistors and we estimate the output to be 3W rms. More technical data will be included with the amp. Brand new perfect condition, offered at the very low price of £1.15 each, or £13 for £12.00



LIGHT BOX

This when completed measures approximately 15" × 14". The light source is the Philips fluorescent 'W' tube. Above the light a sheet of fibreglass and through this should be sufficient light to enable you to follow the circuit on fibreglass PCBs. Price for the complete kit, that is the box, choke, starter, tube and switch, and fibreglass is £5 plus £2 post, order ref 5P69



Ex-Electricity Board Guaranteed 12 months.

VENNER TIME SWITCH

Mains operated with 20 amp switch, one on and off per 24hrs. repeats daily automatically correcting for the lengthening or shortening day. An expensive time switch but you can have it for only **£2.95** without case. metal case – **£2.95,** adaptor kit to convert this into a normal 24hr. time switch but with the added advantage of up to 12 on/offs per 24hrs. This makes an ideal controller for the immersion heater. Price of adaptor kit is **£3.20.**

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Generates approx. 10 times more IONS than the ETI and similar circuits. Will refresh your home, office, shop, work room etc. Makes you feel better and work harder – a complete mains operated kit, case included. £11.50 + £3 P&P.

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NEW ITEMS

Some of the many described in our current list which you will receive with your parcel.

13A PLUGS good make complete with fuse, parcel of 5 for £2. order Ref. 2P186.

13A ADAPTORS Takes 2 13A plugs, good British make, packet of 3 for £2 order Ref. 2P187

8" GREEN SCREEN MONITOR Complete, cased and ready to work. Composite input so just right to use with Acorn or other computers or camera. Requires only 15 volt D.C. Has been used for a short period but we have tested and give six months guarantee. Price £17.50 plus £3 post etc.

MAINS TO 15VOLT SWITCH MODE POWER SUPPLY with multiple outlets intended to power up to 6×8" Green Screen Monitors. Slightly used but tested and guaranteed working. £20 each plus £2 post.

FREE POWER! Can be yours if you use our solar cells – sturdily made modules with new system bubble magnifiers to concentrate the light and so eliminate the need for actual sunshine – they work just as well in bright light. Voltage output is .45 – you join in series to get desired voltage – and in parallel for more amps. **Module A** gives 100mA Price £1 Our Ref. BD631 **Module C** gives 400mA Price £2 Our Ref: 2P199 **Module D** gives 700mA Price £3 Our Ref. 3P42.

SOLAR POWERED NI-CAD CHARGER 4 Ni-Cad batteries AA (HP7) charged in eight hours or two in only 4 hours. It is a complete, boxed ready to use unit. Price £6 Our Ref: 6P3.

50v 20a TRANSFORMER 'C' Core construction so quite easy to adapt for other outputs – tapped mains input. Only £25 but very heavy so please add £5 if not collecting. Order Ref: 25P4.

EQUIPMENT CASES Originally part of GPO equipment. these are rather large but maybe just the thing you are looking for. In good condition made of sheet steel sprayed grey.

Our Ref. 10P40 measures 19" × 12½" × 8" deep. Price £10 + £3 carriage
Our Ref. 15P10 measures 24" × 16" × 11½" Price £15 + £8 carriage

15A PANEL METER These have been stripped from Government's surplus battery charger units made originally for army use. Unused, tested but of course rather old, diameter 2" can be surface or flush mounted. £3 each Our Ref. 3P40

METAL PROJECT BOX Ideal size for battery charger, power supply etc; sprayed grey, size 8" × 4¼" × 4" high, ends are louvered for ventilation other sides are flat and undrilled. Order Ref: 2P191 Price £2.

20v-0-20v Mains transformers 2½amp (100 watt) loading, tapped primary 200-245 upright mountings £4. Order Ref. 4P24 add £1 post.

MOST USEFUL CASE constructed entirely from heavy gauge aluminium size approx. 7½" wide 5¼" high and 16" long. But its construction is such that it is a very simple job to reduce the length to your own requirements. The long top and both sides are flat and completely free from holes. One end has mains input socket – fuse switch – the other end has output plug – in brand new condition. Price £10 plus £3 postage, Ref 10D35.

12V DC FAN made by the famous PAPST company, these are brushless so are ideal for cooling computers without causing any electrical interference, size approximately 3½ x 3½ x 1½, all brand new. Price £10, our ref: 10P33.

AXIAL FANS very quiet running and purpose designed for cooling instruments etc mady by the famous German PAPST Company – these are 4½" square approx. 230v mains operated and metal bladed os O.K. in sunbeds and other hot spots – price £8 each. Our Ref: 8P8.

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3 CORE FLEX BARGAIN No. 1 Core size 5mm so ideal for long extension leads carrying up to 5 amps or short leads up to 10 amps. 15mm for £2. order Ref. 2P189

3 CORE FLEX BARGAIN No. 2 Core size 1.25mm so suitable for long extension leads carrying up to 13 amps – or short leads up to 25A, 10m for £2. order Ref. 2P190

ASTEC P.S.U. Switch mode type so very compact. Normal 230V input. Has 3 outputs – +5V at 3.5 amps, +12V at 1.5 amps and –5V at 0.3 amps. Should be ideal to drive floppy disc units. Regular price around £30, our price only £10 although brand new and unused. Order our ref 10P34.

24 HOUR TIMESWITCH 16A C/O contacts, up to 6 on-offs per day. Nicely cased for wall-mounting. Price £8.00. Ref. 8P6.

CAPICITOR BARGAIN Axial ended 4700 uf at 25V. Superior Jap make, normally 50p each, you get 4 for £1.00 Ref. 613.

AGAIN AVAILABLE – 12" mini fluorescent tubes – Price £1 each. Ref. BD314

MINIATURE BCD THUMB WHEEL SWITCH – Matt black edge switch engraved white on balck – gold plated, make before break contacts – size approx. 25mm high 8mm wide 20mm deep – made by the famous Cherry Company and designed for easy stacking – Price £1 each. Ref. BD601.

PIEZO ELECTRIC FAN an unusual fan, more like the one used by Madame Butterfly, than the conventional type, it does not rotate. The air movement is caused by two vibrating arms. It is American made, mains operated, very economical and cause's no interference. So it is ideal for computer and instrument cooling. Price is only £1 each. Ref BD605.

SPRING LOADED TEST PRODS – heavy duty, made by the famous Bulgin company. Very good quality. Price four for £1. Ref. BD597

TELEPHONE BELLS – these will work off our standard mains through a transformer, but to sound exactly like a telephone, they then must be fed with 25 hz 50v. So with these bells we give a circuit for a suitable power supply. Price 2 bells for £1. Ref. BD600.

CASE WITH 13A PRONGS – to go into 13A socket, nice size and suitable for plenty of projects such as car battery trickle charger, speed controller, time switch, night light, noise suppressor, dimmers etc. Price – 2 for £1. Ref. BD565

ALPHA-NUMERIC KEYBOARD – this keyboard has 73 keys arranged in two groups, the main area is a QWERTY array and on the right is a 15 key number pad, board size is approx. 13" × 4" – brand new but offered at only a fraction of its cost namely £3 plus £1 post. Ref. 3P27

TELEPHONE EXTENSIONS – it is now legal for you to undertake the wiring of telephone extensions. For this we can supply 4 core telephone cable, 100m coil £8.50. Extension BT sockets £2.95. Packet of 500 plastic headed staples £2. Dual adaptor for taking two appliances from one socket £3.95. Leads with B.T. plug for changing old phones. 3 for £2.

WIRE BARGAIN – 500 metres 0.7mm solid copper tinned and p.v.c. covered. Only £3 + £1 post. Ref. 3P31 – that's well under 1p per metre, and this wire is ideal for push on connections.

INTERRUPTED BEAM KIT – this kit enables you to make a switch that will trigger when a steady beam of infra-red or ordinary light is broken. Main components – relay, photo transistor, resistors and caps etc. Circuit diagram but no case. Price £2. Ref. 2P15.

3-30V VARIABLE VOLTAGE POWER SUPPLY UNIT – with 1 amp DC output. Intended for use on the bench for experimenters, students, inventors, service engineers etc. This is probably the most important piece of equipment you can own. (After a multi range test meter). It gives a variable output from 3-30 volts and has an automatic short circuit and overload protection, which operates at 1.1 amp approximately. Other features are very low ripple output, a typical ripple is 3mV pk-pk, 1mV rms. Mounted in a metal fronted plastic case, this has a voltmeter on the front panel in addition to the output control knob and the output terminals. Price for complete kit with full instructions is £15. Ref. 15P7.

TRANSMITTER SURVEILLANCE (BUG) – tiny, easily hidden, but which will enable conversation to be picked up with FM radio. Can be housed in a matchbox, all electronic parts and circuit. Price £2. Ref. 2P52

BATTERY DRIVEN MAINS AND HT CONVERTERS

PART ONE BY GEORGE KERRIDGE

HOW TO GET HIGH WHEN YOU'RE RUNNING LOW

Don't be caught powerless by a storm – put your batteries to better use and brighten up your darkest hour. We look at a range of circuits for boosting voltages from one level to another.

Your Editor tells me that at any time of the year there is a trickle of reader's letters asking about operating mains powered equipment from batteries. The reasons fall into two categories. Firstly, that the writer is about to go on holiday, and has some piece of electrical apparatus that needs 240 volts ac to drive it, but the boat, caravan or tent will be inaccessible to a mains source. The second is that the writer wants to have an alternative supply available in the event of a power failure.

STORM FORCE

For some time after the storm of October 1987 when the winds in the south east of England caused extensive and prolonged power breakdowns, the letters received by PE became a minor flood.

The Editorial of January 1988 lamented upon some conveniences that can be lost when mains power fails. The situations quoted were only a small proportion of those that can occur, but in reality many of them can be avoided since much of the electrical apparatus necessary to modern living is also available in battery operation versions. I think of things like radios, cassette machines, shavers, television sets, water heaters, clocks, lights, multimeters, soldering irons and so on. Indeed many mains operated items are available that can also have their own batteries inserted to which one can switch when necessary.

It is even possible to buy some equipment that can be run from a butane gas source. Such equipment includes camping stoves, heaters, lights and even soldering irons.

Still, how many people actually think about owning multi-powered equipment? I for one don't have a full complement, though I do rely heavily on the camping gas equipment when necessary.

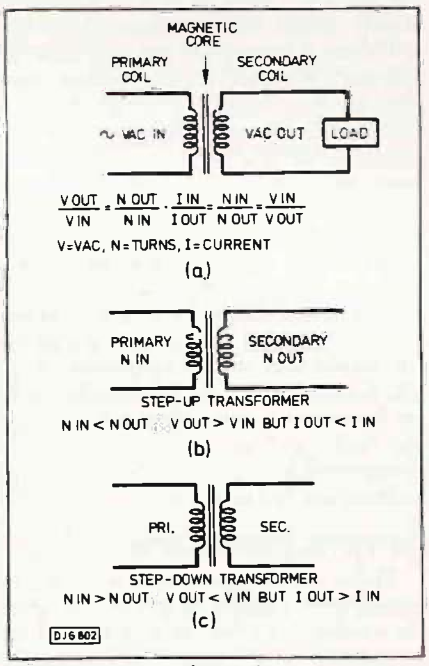


Fig.1. *Basic transformations*

POWERFUL AIMS

The intention of this article is to offer assistance to those who have equipment that can only be powered from 240Vac, and who have an adequate source of battery current. Whether the battery is 6V, 12V, 24V, or whatever, the principles I shall describe are common to all dc sources. Since part of techniques involve increasing one voltage level to another, I shall also have a look at other high voltage supplies as well. The article does not claim to be all-inclusive in its illustrations, but it will show some of the thinking necessary for readers to be able to modify the circuits to suit their own needs.

Changing the level of ac voltage is perhaps a convenient place to start. The use of a transformer is one of the most common methods, though not the only one.

BASIC TRANSFORMATIONS

If an alternating current, of whatever voltage, is passed through a wire coiled around a magnetic core, some of the energy passing through the wire will be induced into the core. The stored energy can be tapped by another wire coiled around the core and used to power a suitable piece of equipment. (Fig.1a). The amount of energy available is relative to the power passing through the first coil, and to the magnetic properties of the core material. The full theory of transformers is beyond the scope of this article, but certain facts are pertinent to what follows.

The three main factors are voltage transfer, current transfer, and degree of efficiency. It is not possible to achieve a 100% transfer of all the energy, and various losses occur, though an 80% to 90% transfer is a reasonable expectation for many transformers.

The energy available is of course the product of the supply voltage and the current flowing through the input (primary) coil. The voltage across the primary will usually be that of the power supply. The voltage then available across the output (secondary) coil is directly proportional to the number of turns for each winding. Ignoring losses and currents:

$$\frac{Vout}{Vin} = \frac{Nout}{Nin}$$

where N= the number of turns, and V= the voltage.

In other words, if both windings have the same number of turns, then Vin will equal Vout. If though, the secondary winding has ten times as many turns as the primary, then ten times the voltage will be available across the secondary. (Fig.1b). Putting it another way, in order to achieve an output of 240Vac from a 12Vac source, the secondary winding must have 240/12 = 20 times as many turns of wire as the primary winding.

It also follows that if the number of turns on the secondary is fewer than on the primary, a voltage reduction will occur. (Fig.1c). This will be the case in the more familiar transformer type of, say, 240Vac input and 12Vac output, where the number of secondary turns is one twentieth of the number of input turns. (Note that transformer output voltages may differ from quoted values with respect to the current drawn. As a guide, less load may mean a higher output voltage and viceversa).

It should now be obvious that a transformer can be used in either direction. If the secondary turns are fewer than the primary, then it is known as a step-down transformer. If there are more primary turns then it is called a step-up transformer. Which ever way round the transformer is used, the terms primary and secondary always relate to the direction of the current transfer. The input is always called the primary, and the output is always called the secondary. To emphasis this point further, if the transformer is marked as having, say, a 240Vac primary and a 12Vac secondary, and it is used in the opposite direction, then the 12Vac winding becomes the primary, and the 240Vac winding becomes the secondary.

CURRENT FACTORS

Beware, though, a factor relating to the amount of current flowing raises its head. Do not assume that a transformer intended for step-down mode from 240Vac to 12Vac can be used connected in step-up mode from 240Vac in order to get 20 × 240 = 4800Vac.

For one thing, the insulation of the transformer may not withstand this very much higher voltage. Sparks could well and truly fly across the winding, killing the transformer, and probably not doing you much good either if you are touching it.

When a manufacturer designs a transformer, he needs to know the maximum current that is to be allowed to be taken from the secondary as much as he needs to know the voltages involved. Whereas voltage output is directly proportional to the windings ratio, current output is inversely proportional to them. In other words:

$$\frac{Iout}{Iin} = \frac{Nin}{Nout}$$

where I is the current.

So, if the voltage is being stepped down to one twentieth, the current available from the secondary can be twenty times that at the primary, ignoring inefficiency factors, and the manufacturer will have chosen the gauge of wire used accordingly. Consequently, if the transformer is turned around to make the 12Vac winding the primary, 240Vac will try to pass through at a far greater current than intended. Things are going to get a bit hot, and rapidly. Windings may melt, and fuses die.

There are only two types of winding that should be connected to a particular power input — one that is intended for use at the stated voltage, or one that is intended for a higher voltage. In general, if a winding intended for a significantly lower input voltage is connected to higher voltage level, the winding is likely to be overloaded beyond its design criteria.

Of course, if a winding has a voltage rating higher than the level to which it is connected, then the input to ouput voltage ratios may be wrong. If, for example, a transformer having a 240Vac primary and a 12Vac secondary has its primary connected to 120Vac then the output will only be 6Vac since the ratio is still 20:1.

ISOLATION

In the transformers mentioned so far, the output winding is separated from the primary. Where a transformer is needed to provide isolation from the original mains supply the separation of the two windings is essential to safety. Unless the transformer suffers a catastrophic breakdown, there is no way that the secondary can allow full access to the original voltage and current. Even in the case of a mains transformer having a one-to-one ratio of winding turns, although the output voltage will be equal to the input, the maximum current that can be drawn will depend upon the power transfer. If such a transformer has been designed to only deliver a maximum of perhaps 100mA then that is the maximum current that it will deliver at the stated voltage. Should an attempt be made to draw more current, either intentionally or accidentally, the output voltage will fall as a result.

AUTOTRANSFORMERS

There are situations where a voltage needs to be transformed from one level to another but isolation is not required, or perhaps is provided by a preceeding isolation transformer. In this instance transformers can be used that have only one winding. These are frequently known as autotransformers. A very simple example is shown in Fig.2.

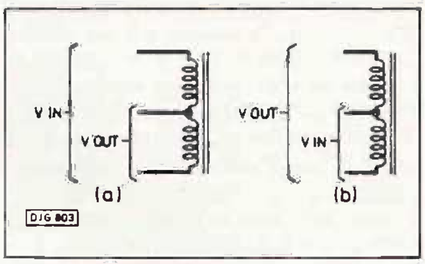


Fig.2. *Simple auto transformer*

If in the course of winding the correct number of turns suited to 240Vac the manufacturer brings an extra wire out from the half way point, then the voltage available at that tapping will be half that across the full winding. In this instance with a 240Vac input, the tap will provide 120Vac. Likewise other taps can also be

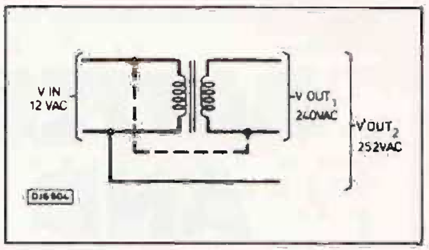


Fig.3. *Twin windings as auto transformer*

inserted so that different ratios occur with equivalent voltage levels. Stepping up can also be achieved in this way. If 120Vac is connected across the lower half of the winding, then 240Vac will be available across the whole winding.

Such an arrangement opens up several possibilities. One is the use of a variable contact that can be turned making connection with different tappings as it rotates. This can permit an almost infinite number of voltages to be selected, from zero up to the maximum. Another possibility is the use of a transformer with multiple input taps making it suitable for a variety of supply voltages.

An ordinary twin winding transformer may also be used as an autotransformer, simply by connecting the two windings together. In Fig.3 a 12Vac transformer is shown in step-up mode, normally producing 240Vac at its secondary. If the link shown is included, then the output will also have the original 12Vac added to it, making 252Vac. Care must be taken though, to ensure that the direction of the windings remains the same. If they are coiled in opposite directions then the currents will oppose each other. In this case instead of 252Vac we would get only 228Vac.

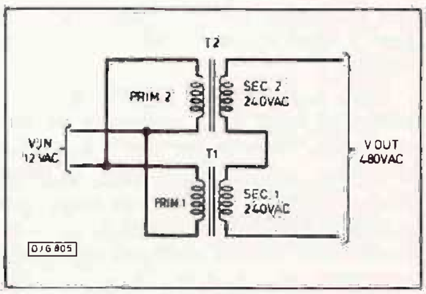


Fig.4. *Two transformers with outputs in series*

We can also couple several transformers together in order to achieve a much higher final output. Taking two 12Vac to 240Vac transformers coupled as in Fig.4, the 12Vac is applied to both primaries. Both secondaries will produce 240Vac across them, but the secondary of one is connected to the secondary of the other, therefore the total voltage across them is 480Vac.

ALTERNATING ONLY

Transformers will only allow energy to be passed from one winding to another if the input current alternates in direction. It is no use putting a battery across the primary and expecting to see a voltage across the secondary. The battery only puts out a dc voltage and all that will happen is that the battery will discharge through the winding, but without a current transfer to the output winding.

To use a battery to obtain a higher level of voltage from a transformer, we must first convert the direct current into an alternating current. Dc to ac converters are sometimes known as inverters, but basically they are only oscillators.

In Britain the alternating current supplied through the National Grid oscillates at a rate of 50Hz. This frequency and its phase are in fact far more precisely controlled than the actual voltage level. In order to produce an ac voltage suitable for powering mains equipment from a battery there are three principle considerations, voltage ratio, current transfer and frequency.

For some items of mains driven equipment, the precise frequency may be unimportant, things like light bulbs and some radios for example. Indeed a light bulb can quite happily be run from a dc supply if necessary. Other equipment, though, may have motors or other circuits that require synchronisation from the 50Hz frequency, and for these greater frequency control is required.

FREQUENCY GENERATION

For those items that do not need accurate frequency control, there are many oscillator circuits from which one can choose, and if the current requirement is only very low, many of them can drive a transformer directly.

Though mains transformers are normally used at 50Hz (or 60Hz in some countries), they can readily accept other frequencies and still produce a satisfactory output voltage, even though the conversion efficiency may suffer. In some circuits I have used frequencies as high as 3kHz to drive a 'mains' transformer in step up mode. The shape of the waveform is not necessarily critical either, and though mains waveforms are sinusoidal, other waveforms such as triangle, square, sawtooth and even pulses can be used, though at varying degrees of efficiency. A small selection of possible oscillators is shown in Figs.5 to 7.

The simplest of the circuits is Fig.5. Here a single opamp, such as a 741, is

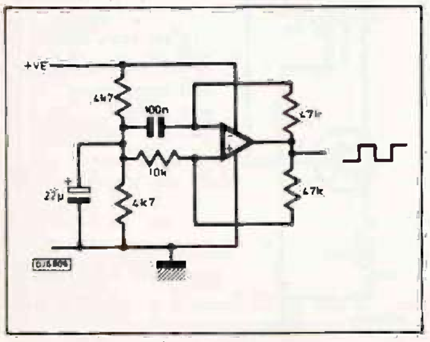


Fig.5. *Simple dc to ac converter*

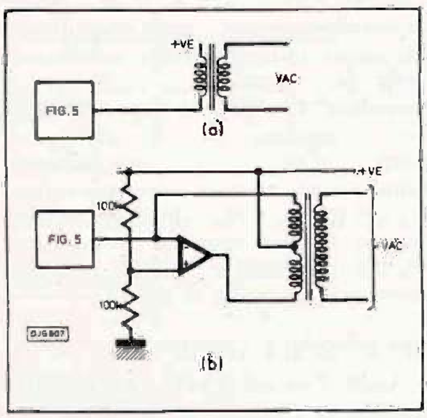


Fig.6. *Op amp driven transformers (a) single winding (b) push-pull. The centre tap may be taken to ground in both cases*

configured as a squarewave oscillator. The frequency is set by the value of the capacitor, and the ratio of the two feedback resistors. The output drives directly into the primary winding of a very small step up transformer. It is not very efficient, may drift in frequency, and can only supply a small current. There is the additional drawback that the output swing of the opamp is less than the power line supplying it.

If a 741 is powered from a 12Vdc line and it is feeding into about 1K resistance the output can only swing between about 1V and 11V. The swing will fall even further if the resistance into which it feeds is reduced.

PEAK TO PEAK

This now raises the question of whether we are trying to achieve voltages expressed as peak to peak swings, or those expressed as rms factors. The latter means that the voltage level is expressed as the root of the mean square of its swing value, and it is a value lower than the actual p-p. It is in effect an average value relating to the overall power available. In the case of a sinewave quoted as 240Vac rms, such as found on the mains supply, the waveform is swinging by equal amounts to either side of a midway level. If you look at it on a scope you will see that the swing of the p-p values is about one and a half times greater than the rms value on each side of the axis. The actual value is normally taken as 1.414 and since an equal swing occurs each side of the axis, the full p-p value is 240 × 1.414 × 2, or about 680Vp-p.

This means then, that when converting a 12Vdc supply to 240Vac 'mains' the step up ratio is not 12:240 but 12:680. However, since the output of an opamp like the 741 probably only achieves a 10V swing for a 12Vdc power line, the ratio becomes 10:680.

PUSH-PULL

One way that we can reduce this ratio is to use a transformer having two primaries connected as in Fig.6, and to use two opposing waveforms to drive them. This configuration is known as push-pull, since one waveform pushes, while the other one pulls. In this way double the power goes into the transformer, and twice the voltage appears across its output. The ratio for the example given thus falls to 10:340.

Another factor also comes to our aid — one property of an inductor. There will be a separate article published in PE in the near future discussing inductors, so I won't go into full detail now, but just quote a relevent effect.

One of the properties of an inductor is that if power is pulsed into it, there can be an effective increase in the amplitude of the voltage at the expense of the current available. I have generated over 600 volts from a 9V battery by feeding a squarewave into a ferrite inductor.

A transformer is of course one category

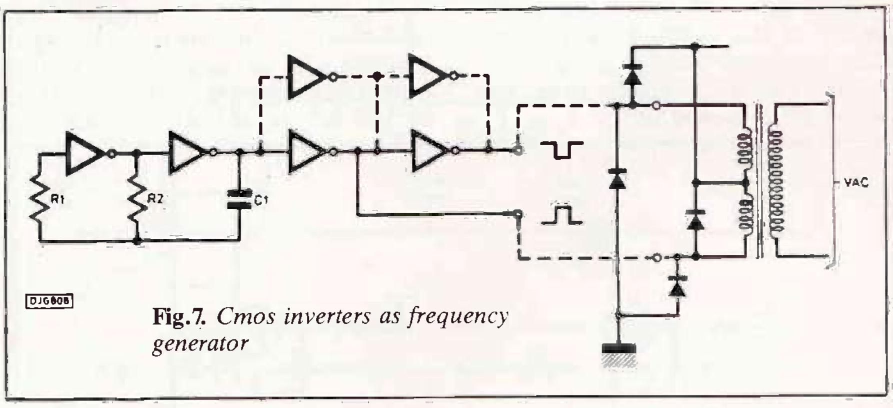


Fig.7. *Cmos inverters as frequency generator*

of inductor, and if the input and output impedances are satisfacory, pulsing it with a push-pull 10Vac will allow the turns ratio to be reduced. Providing the current drawn from the secondary is within bounds, it is therefore reasonable to expect a 340V p-p voltage to be available from the output of a 12:240 ratio transformer. The current transfer will not be that expected from the turns ratio, but will be lower by about the ratio of the expected to actual voltages, ignoring normal power losses.

Another possible circuit for producing a squarewave output is shown in Fig.7, and consist of several cmos inverters. The frequency is set by the capacitor and R2. This circuit will produce a full power line level swing, providing the load is within limits for the chip used. For a 4069 this is about 10mA, though other cmos inverters are available that can deliver a greater current. It is also possible to put two inverters in parallel so that the current drawn can be doubled. If this circuit drives a transformer or other inducter directly, it is essential that the diodes shown are included to prevent inductive peaks from damaging the inverters.

POWER REQUIREMENTS

It must now be obvious that the problem in hand is not as simple as it would appear at first sight. In some ways a compromise output voltage will have to be acccepted, and in relation to the current required. Let's then look at current requirements, as these may dictate other types of voltage control as necessary.

If we want to power a load of say 1 watt, we need to select a transformer that can supply this wattage from its output. It also follows that the input wattage must be at least this value, but 1 watt is a far greater power than the poor 741 can supply. It is well within the capabilities of many transistors though.

TRANSISTOR DRIVE

We now have a couple of choices, either use the frequency generator output to drive a transistor, or to use transistors to act as both the frequency generator and the transformer drive.

For the former we simply select a transistor that can conduct the necessary current at the required voltage and which has a gain suited to being driven by the current available from the oscillator. Figs.8a and 8b.

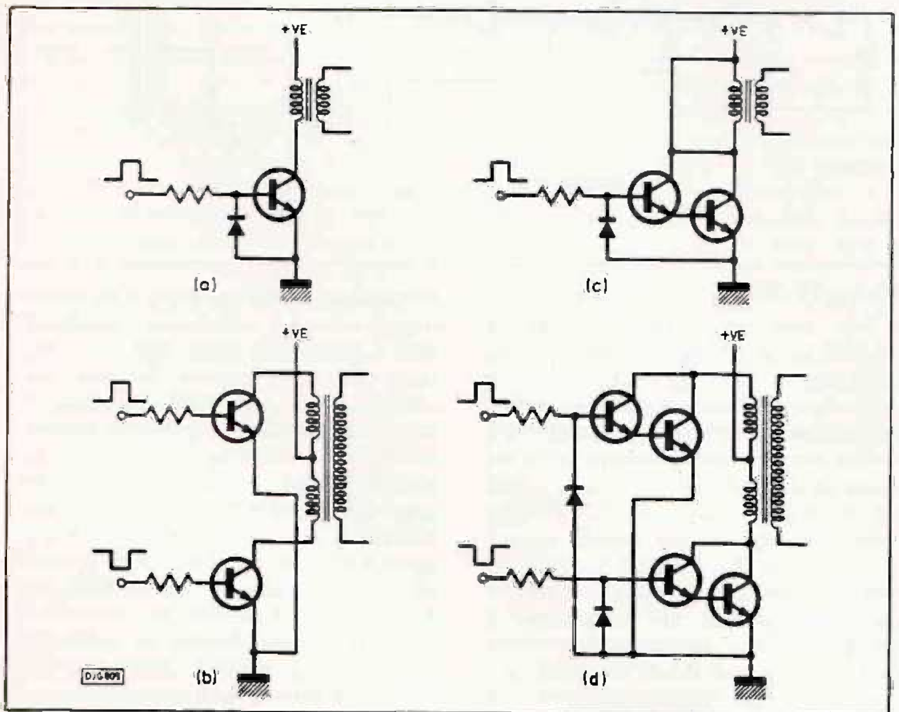


Fig.8. *Four methods of driving transformer windings. (a) single transistor, single primary (b) twin transistor, push-pull (c) Darlington, single primary (d) Darlington, push-pull*

If the output load requires a much greater current than a single transistor or the output of the oscillator can control, then the control current itself can be amplified. This can be achieved using two transistors in a darlington configuration, or better still, using a semiconductor that is a darlington within a single package. The controlling current can be further amplified by inserting another transistor prior to the darlington, as in Figs.8c and 8d.

SELF OSCILLATION

Another choice is to use the primary winding of a transformer as part of the frequency generating circuit, such as in the configurations shown in Figs.9 and 10.

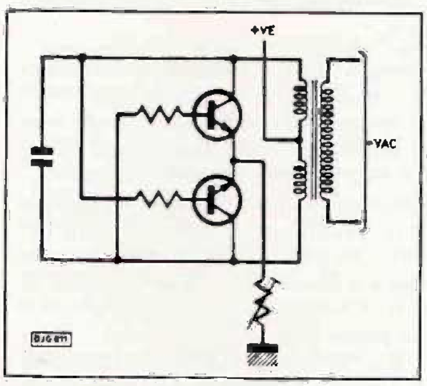


Fig.9. *Self-oscillating push-pull drive circuit*

Fig.9 uses two transistors cross-coupled to the split primary winding of the transformer. The frequency of operation is determined by the inductance of the winding, and by the capacitance across them. One advantage of this set up is that the oscillator

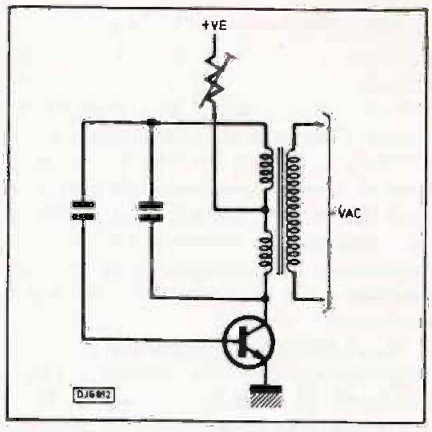


Fig.10. *Single transistor self oscillating circuit*

operates in push-pull mode, both halves of the cycle transferring equal power to the secondary. Here the voltage level can also readily be controlled by the resistor in the common emitter path. The greater its value, so the smaller the voltage drop across the primaries, equivalently reducing the output level. One draw back of this circuit is that the basic current consumption is quite high. This may make it inefficient in situations where a high voltage output may be needed at only a very few milliamps.

In the latter instance, the circuit of Fig.10 is better. Just one transistor is used and the frequency is controlled by the inductance of the transformer and C2. The current transfer only occurs through the winding in the collector path. The other winding is in effect another secondary, which, via C1 triggers the transistor on and off. The voltage level is controlled by the resistor in series with the transformer centre tap. With the values shown an average circuit current of less than 4mA can be achieved to produce over 250V p-p from a 9V battery. The circuit in Fig.9 with the components shown can draw over 20mA for the same output.

The circuit in Fig.11 is another variation on the theme. It consists of a

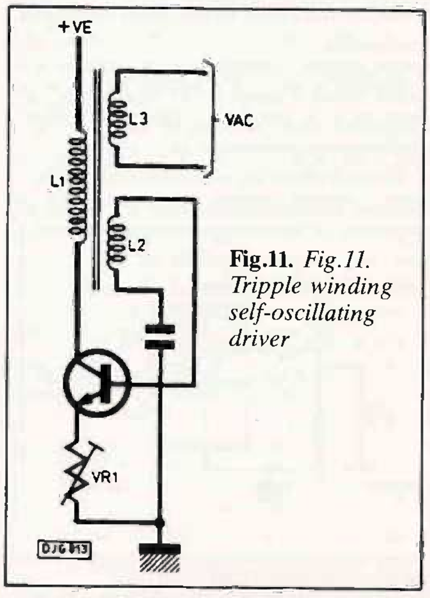


Fig.11. *Fig.11. Tripple winding self-oscillating driver*

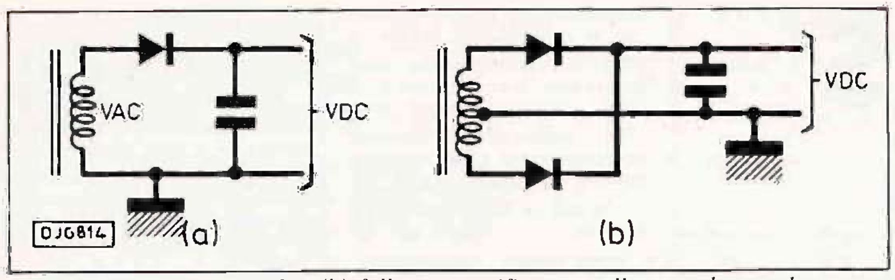


Fig.12. *(a) half wave rectifier (b) full wave rectifier, centrally tapped secondary*

transformer having three separate windings with L1 as the primary. L2 is a step-down winding providing the trigger that turns TR1 on and off at a frequency set by the inductance of the winding and the value of the capacitor. L3 is the step-up secondary winding, the voltage across which is governed by the voltage across L1, as set by VR1.

HIGH VOLTAGE DC

Before moving on to a circuit suitable for powering mains type equipment from a stepped up ac voltage, it is only a short detour to look at using the above circuits for generating high level dc voltages.

Note that peak voltages quoted will only occur when there is no load across the output. Increasing output loads will decrease the voltage level.

The simplest way of achieving this is to put a diode in series with the transformer output, and to feed it into a storage capacitor. (Fig.12). The resulting dc voltage will attain half the level of the full peak to peak swing. Other forms of rectification can alternatively be used, such as bridge rectifiers. (Fig.13). The latter will also produce a dc output roughly equal to half the full peak to peak swing.

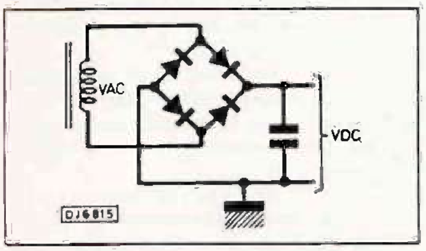


Fig.13. *Full wave bridge rectifier*

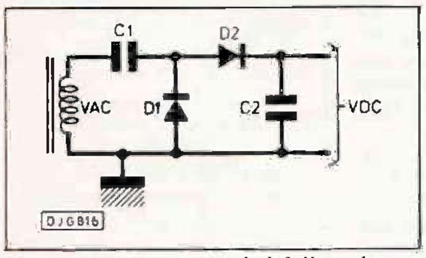


Fig.14. *Capacitor coupled full-peak rectifier*

One way to achieve a full p-p dc level is to insert a capacitor, C1, in series with the output, followed by a diode, D1, from ground, and another to rectify the ac to dc, D2, as in Fig.14. Here the bottom of the ac waveform will be at ground potential so the full swing will pass through the rectifying diode. The current transfer, though, will depend on the coupling capacitor value in relation to frequency. A high current will need a large capacitor.

VOLTAGE MULTIPLIERS

Ac voltage transfer via a capacitor can be taken a step futher in order to give voltage doubling. (Fig.15). If we follow C1 by C3, the ac swing will appear at the output of C3. If the preceding dc voltage at C2 is added to this swing via D3, and the two rectified by D4, the dc voltage then available at C4 will be the total of the two ac swings.

There is a choice of position for the storage capacitors, as shown in Fig.16.

In Fig.16a the total storage capacitance value for the chain is the sum of the capacitances, and each must have a voltage rating at least as high as the increasing dc level at each point. In Fig.16b the capacitors are in series, so the total capacitance reduces at each stage, but each capacitor need only have a rating suited to the voltage immediately across it. For long chains the latter circuit is preferable.

Since the end product of circuits like this is a smooth dc voltage, high frequency oscillators are preferable. These enable the capacitors in the chain to be of a lower capacitance value — a saving in both size and cost.

None of the above voltage adding circuits (sometimes known as voltage multipliers) need to be fed by a transformer, and may be coupled to any oscillator than can supply enough current.

Negative voltages can be produced simply by reversing the polarity of all the diodes. (Fig.17). The latter, irrespective of polarity, must all have a rating suited to the ac voltage level.

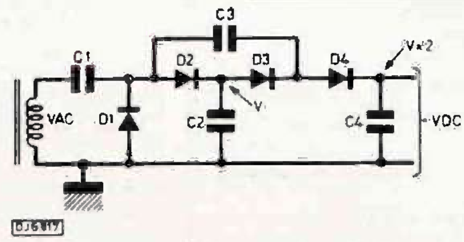
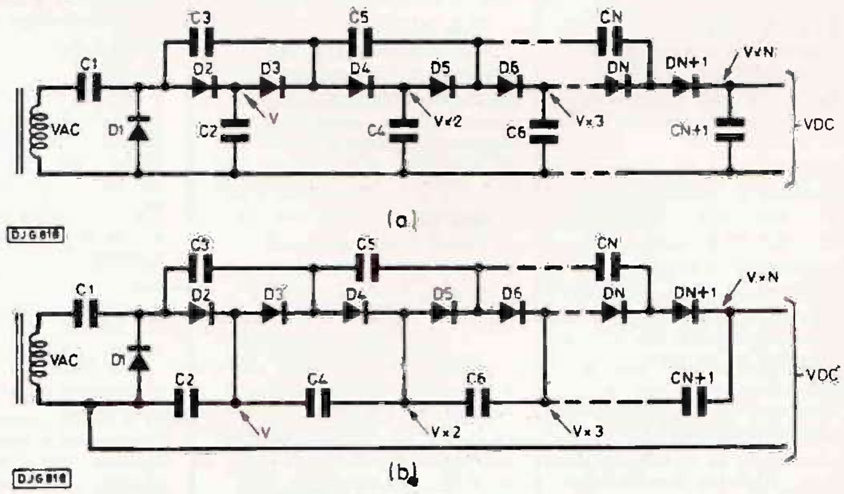


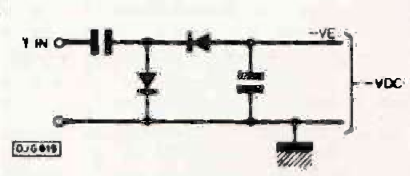
Fig.15. *(left) Voltage doubler*

Fig.16. *(below) Multi-stage voltage adders. (a) storage capacitors in parallel, (b) in serial*

Fig. 17. *(far bottom) Negative voltage generation*



This chain can be extended as many times as necessary to obtain very high voltages. There will be a small drop in the dc level at each stage due to the forward voltage drop across the diodes, of about 0.7V each. The current available will also drop with each stage since the coupling capacitors are in series. The effective total capacitance value can be calculated in the normal way for capacitors in series. Each of them must also be able to accept the p-p voltage generated across the transformer secondary.



Next month in Part Two we look at the construction of a practical battery to mains converter. PE

READERS' LETTERS

WELL FOUNDED

Dear Ed,
I have been an avid reader of PE since its early years. I have a few copies from 65 and 66 and every copy since 67.

I first became interested as a teenager, using ex-govt field telephone generators to jam my grandmother's radio. That was about the time that Sir Clive was painting red spots on scrap transistors. His little circuit books were good though.

After ten years as a morse maniac in the Royal Signals, spending my time building Micro 6s, Q14s and the like, they refused my applications to become a technician (maths not up to it). So I left and trained as a tv engineer. It was, and still is PE and other similar publications which encourage that experimental "suck it and see" method of circuit investigation, which makes all the difference between technicians who theorise and the one who actually make the circuit work.

Your excellent series on Experimental Electronics, and recently Real World Interfacing, for example, require development input from the reader and is not just putting together an "off the peg" project.

PE is my reference library, even the very old ones. Keep it up.

P. Wraith L.C.G.
Senior Lecturer,
Bristol.

We appear to share a comparable history and outlook. Much of my early interest and knowledge came from taking PE since its inception — and look where it got me! I've previously said that projects have the dual role of instructional inspiration and practical usefulness and I like to know that people still love experimenting. Nice to have heard from you.
Ed.

ADDING APPRECIATION

Dear Mr Becker,
I am writing to express my appreciation of the excellent write-up you gave my company on your news pages in PE May 88.

The format is just right and should give the business a healthy boost which could result in the need for a larger advertising space than we have recently occupied. If this turns out to be the case you may rest assured that PE will figure prominently in my advertising budget.

Once again, my appreciation of your courtesy and attention.

J.R. Ayliffe,
Quinton Tool Supplies,
52 Grayswood Park Road,
Birmingham.

I am fully sympathetic to the interests of advertisers, and it's good to have confirmation that our news pages work for you.

Any advertiser is welcome to send information about a particular product or service that is being newly introduced and I will be pleased to highlight it in the news pages. Please also send a suitable photograph if you have one.
Ed.

CLEAR VIEW

Dear Ed,
It's a pity that clear film artworks are not available for pcb layouts. Surely you could print them on tracing paper at little or no extra cost?

S. Beale, Somerset

Dear Ed,
Would it be possible to produce your pcb tracks as etch resistant rub down transfers?

N.R. Davison, South Shields

Another reader recently asked if we could print track layouts on pages which were blank on the other side. Yes, we could use other techniques, but the cost is probably more expensive than you realise, making it more realistic for readers to buy their pcbs from the PE PCB Service rather than buy clear artwork. Rub down tracking would be even more costly. I am reluctant to leave the pcb page blank on the other side as I feel that most readers would prefer not to pay for blank pages. I gave a similar published answer to the previous reader, and invited other readers to say that I'm wrong in my opinion – no-one has yet told me that I am wrong.

The photocopy and transparentiser method of producing your own boards from the published tracks as suggested on the Track Centre page is a very workable technique. I use it for many of my own prototype boards. Certainly the tracking can sometimes be a bit thin, but running solder over it is usually a quite satisfactory solution.
Ed.

DUAL TRACING

Dear Editor
I want to convert a single beam oscilloscope into a dual beam unit. Can you help me?

C.F. Steventon, Merton Park

Later this year we hope to publish an article in which such a technique will be shown. In the meantime you might consider one possible approach.

Install a second "Y" amplifier, preferably identical to the existing one. Feed the amps to twin gates which are alternately opened and closed by a clocking signal. The clock can either switch the gates so that each signal's trace is alternately drawn across the screen. Or the switching can be done at a high frequency rate chopping between each signal as a single trace passes across. In the latter mode the crt trace should ideally be "blanked" at the moment of transition between each gate to prevent the switch trace also being shown on the screen. In the first method additional blanking is unnecessary if the trace is correctly synchronised to switch immediately prior to the start of the trace.

In both methods additional panel controlled variable dc biasing must be employed so that the two traces can be positioned for different parts of the screen. The two methods are better suited to high and low frequency signals respectively.
Ed.

MUSAC

Dear Ed,
I am looking for a source of piped music systems as used in hotels and supermarkets. I turn to you as I find your magazine so informative and interesting.

Noshir B. Photographer,
Dubai, UAE.

What a marvellously picturesque name you have. As it happens I live almost within earshot of Redifussion Reditune Ltd who I believe are responsible for much of the canned music heard around the public places. Their address is Cray Avenue, Orpington, Kent. Tel: 0689 32121.

I believe there may be another company, possibly called Musac, but I cannot locate their whereabouts.
Ed.

SCHOLARSHIP

Dear Mr Becker,
We wrote to you last October seeking your advice on a suitable circuit for a game that we had designed in connection with North Yorkshire's Design and Make competition.

We are writing to you now to thank you for replying to our letter and for enclosing a suitable circuit diagram. You will be pleased to hear that our solution was judged the overall outstanding entry for its age range.

We enclose newspaper cuttings that publicise our completed project. Thank you once again for your help.

Janine Scarth, Emma Galloway,
Eskdale, Whitby, N. Yorks.

I am really delighted to hear of your success and we all send our congratulations to you for your ingenuity and achievement. I hope that your talents will lead you into a successful career in electronics or computing.
Ed.

ELEGANT LEGPULL

Dear Sir,
All Fools Day had passed when I received the April PE and unsuspectingly I started reading your Bio-chromatic feature. I felt uneasy over the 'digitalis multiflora' but as foxgloves are called something else here I was unable to check and pressed on.

Fortunately 'preposterosa' stopped me in time from phoning the great news to a computer-addicted grandson. It is unseemly for schoolchildren to be able to take the mickey out of gullible grand-dads.

Your photo hardly does justice to the authoress. While her dress is tastefully digital one suspects that other aspects are pleasingly analogue.

What a pity that this fairy tale isn't true. By the way, did Editor Becker get many enquiries out at Orpington?

I thank you for a most entertaining article and elegant legpull.

Ken Jones, Udine, Italy.

Whichever way you look at it Rekceb-Rotide is well pleased with the congratulatory response, though no-one has yet commented on the latent nature of the formula quoted.
Ed.

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

MORE LETTERS

BRIGHTER READING

Honourable Editor
I hope you will maintain the present style of PE, and I would like some more articles with detailed electronic information as in the GCSE series. But, I do not like the shiny paper you use, which makes reading difficult due to reflection.
Mehtab Ahmed, Karachi, Pakistan

We have another GCSE series starting in the Autumn which should brighten PE even further. Some glossy mags do use paper that excessively reflects the light, but the paper we use has been chosen for its reduced reflective properties while being of a quality suited to a quality publication. We appreciate your forthright comment, though we have no plans to issue free polarised sunglasses as yet.
Ed.

USER FRIENDLY

Dear Ed,
I don't like PE because it's written in English and not Swedish – a 'plus' for the easy English you use though! I do like PE because of its many building projects, Spacewatch, Industry Notebook, and News and Marketplace.
S.O. Svensson, Sweden

We'd love to be as multilingual as you are.
Ed.

TIME SHARING

Dear Ed,
Seven people read my copy of PE – it's better than Belgian tv!
P. de Cominck, Belgium

In that case, wouldn't you all prefer your own copies? – see page 9 for the subscription service!
Ed.

GI'S A JOB!

Dear Ed,
How about a jobs page in PE?
L. Charlton. W. Mids.

I'm looking into it.
Ed.

STAR STRUCK

Dear PE,
I feel that it is now unnecessary to have a monthly double-page feature on astronomy. I would have thought that any astronomy enthusiast would buy PE's sister magazine, Astronomy Now, since I am sure that the quality of that magazine is as high as that of PE.
V. Hamlyn, Southborough.

Am I wrong in thinking that those interested in electronics will also be interested in other aspects of science and technology? I find all related subjects fascinating, and although I read Astronomy Now, I still appreciate Patrick Moore's brief report in PE. The intention of columns like Spacewatch, Leading Edge and Industry Notebook is to give brief information to those who have broad interests, but not to the point of being devotees of a particular subject.
Ed.

POSITIVE FEEDBACK

Dear Ed,
It's good to know that PE responds to reader's queries, unlike many magazines and, regretfully, even suppliers.
J.G. Nevison, Liverpool

I try to give helpful answers to any reader who rings or writes, though time is too short to permit lengthy answers. If you have a query or comment to make, you are welcome to contact me.

When writing to suppliers, all of whom I am sure wish to be helpful, remember that for them writing may be expensive, needing someone to dictate an answer, and probably someone else to type it. The answers to many questions posed by customers are frequently to be found in suppliers' catalogues and price lists. Other questions are often answerable in a quick phone call, so where possible phone rather than write. If you have to write, be courteous and send a stamped addressed envelope. If you live outside Britain, send an addressed envelope and international reply coupons to cover the cost of postage. Please also do the same if you are writing to us.
Ed.

TRIFFID RADIO

Dear Ed,
I am interested in experimenting with the Ferranti radio chip ZN414 and understand that PE published an article on this entitled "PE Triffid", by Mr Heath of Ferranti, in the February 1973 issue. Is there any chance of obtaining a photocopy of this article? Any other information you can offer would be appreciated. Many thanks.
D. Davis, Argyll

1973 is too far back for the photocopy service I regret – three years back is really about the limit we prefer. However, the ZN414 is still in production. It is quite likely available from many sources if you study adverts, though I know that both RS Components and Electromail have it and may be able to supply a data sheet for a nominal sum. But ask our regular advertisers first.
Ed.

ELUSIVE

Dear Ed,
I sometimes have difficulty finding parts for projects, please can you quote sources in the text.
D. Rocke, Glasgow

Before publishing projects we ensure that parts are available from suppliers. If the occasional part is not widely available then we quote a source for it. For common components, though, you should read the adverts and catalogues of suppliers. It would not be fair for us to recommend particular suppliers for common parts as the list could be lengthy, and we would offend any advertiser whom we omitted to mention.
Ed.

STARTING POINT

Dear Ed,
I know very little about electronics but would like to be able to build PE projects. Have you any advice on where to start?
A. Robertson, Aberdeen

The key to successful project building is knowing how to solder. It's not hard to do it properly if you practice, starting say, on a really simple project. Begin with the simplest circuit you can find, even though the design may not be exactly what you want. Far better to boost your confidence by successfully building a small project than be disappointed by building a large one without previous experience.

Secondly, get hold of some elementary electronics books. There are five in the PE book service that might interest you. BP117, BP118, BP104, NT1 and the new "Electronics: Build and Learn". A good browse round a large bookshop may also pay dividends. You could also read the recent GCSE electronics series of which back issues or photocopies can be supplied. They are £1.50 and £1.00 each respectively, per issue/article, including postage in the UK.

And naturally, keep on reading PE.
Ed.

WEATHER RECORDS

Dear Mr Becker,
I have read your Weather Centre article with great interest, particularly since I have been recording weather features for some years. Your project enables weather aspects to be monitored at any time — would it be possible to integrate the outputs of any or all of the detectors so that cumulative values could be read off at any time? This would enable comparisons to be made over a period.
Herbert Jones, Hove

If you use the computer control described in part three additional program lines can be inserted so that data is fed out to disc or tape. The data may then be recalled at any time and analysed in whatever fashion you prefer, printing out the results to screen or printer. Just make sure when recording the data that each byte is correctly identifiable, otherwise your weather could be more changeable than you thought!
Ed.

UNDERDONE

Dear Eg.
Your challenge in the March issue for readers to tell you in which copies of PE other egg timers have been published has been met! Prior to the one in the Jan 88 issue, I find that on page 50, Aug 85 is a quote – "the circuit of a Digital Timer (which can be used as an egg timer) is shown in Fig.12". While not in the title of the article, the function is suggested in this line.
I came across it while backtracking on modem articles. Do I qualify for a free autographed copy of PE?!
C.F. Cole, Swansea

No! My heart is as hard as the eggs I boil. It's not specific enought to be an egg timer article. But I've relented slightly and sent you a free colour code chart for your efforts! My challenge remains open . .
Eg.

"INGENUITY UNLIMITED"

A selection of novel ideas

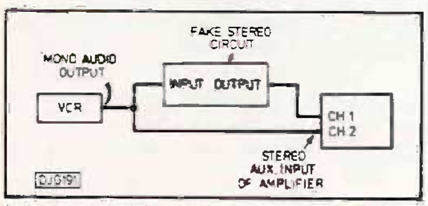
BY ENTHUSIASTIC READERS

Fake Stereo for Video

THIS circuit takes the mono audio signal from a video cassette recorder and provides a 'fake' stereo signal for the auxilliary input of an amplifier.

Rather than use a normal design of providing a 180° phase shift, this circuit lets bass signals stay in phase, but varies the phase shift of the treble frequencies, giving a good spacious stereo effect from a mono signal.

The circuit is built around a Dual BiFet Op-Amp. which provides very low distortion over the audio range and consumes very little power.



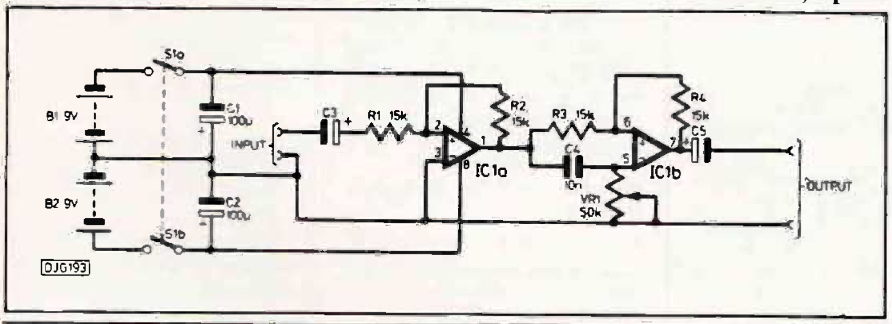
IC1a inverts the mono audio signal, which is then fed to the inputs of IB1b. C4 blocks bass frequencies so IC1b inverts these, and so provides no overall phase shift through the whole circuit as far as bass frequencies are concerned.

At higher frequencies, C4 couples these to the -ve input of IC1b and so reduces the phase shift through IC1b. This leads to a variation of phase shift through the whole circuit as far as treble frequencies are concerned. This output is then fed to one channel of a stereo aux. input of an amplifier, the other channel being fed directly from the original mono signal from the vcr.

VR1 brings the phase shift into effect, and is adjusted to give the best audio results from the listeners point of view.

In use it was found that the unit greatly enhanced the sound of not only music videos but also of film sound tracks.

Eric Williams, Epsom



Mains Remote Control

THIS ultrasonic remote control link enables a mains load to be switched on or off. It has numerous applications from the switching of a tv or radio set to controlling a garage door lock.

The signal from the transmitter is picked up by the ultrasonic receiver RX1 which is strongly resonant to ultrasound of frequency 40kHz, but is virtually unaffected by sounds of other frequencies. The signal from RX1 is amplified by TR1 and TR2 with R3 providing negative feedback. The output is then passed to the next amplifier stage TR3 with C3 adding some noise immunity. The output from the collector of TR3 is then rectified by D1, and smoothed by C4. R8 and C4 also provide a 'debouncing' action for the transmitter switch. The signal is then passed to a comparator IC1, the output of which is either high or low indicating the presence of ultrasound. The sensitivity of the receiver can be adjusted by VR1. IC2 forms a simple toggle switch with TR4 providing logic levels favourable to ttl. The relay is driven by TR5.

The transmitter circuit consists of an astable multivibrator which drives the ultrasonic transducer TX1. The frequency of the astable multivibrator is tuned to 40kHz by adjusting VR2.

M. Essa, Ilford.

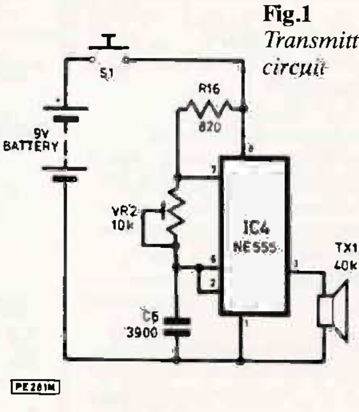


Fig.1 *Transmitter circuit*

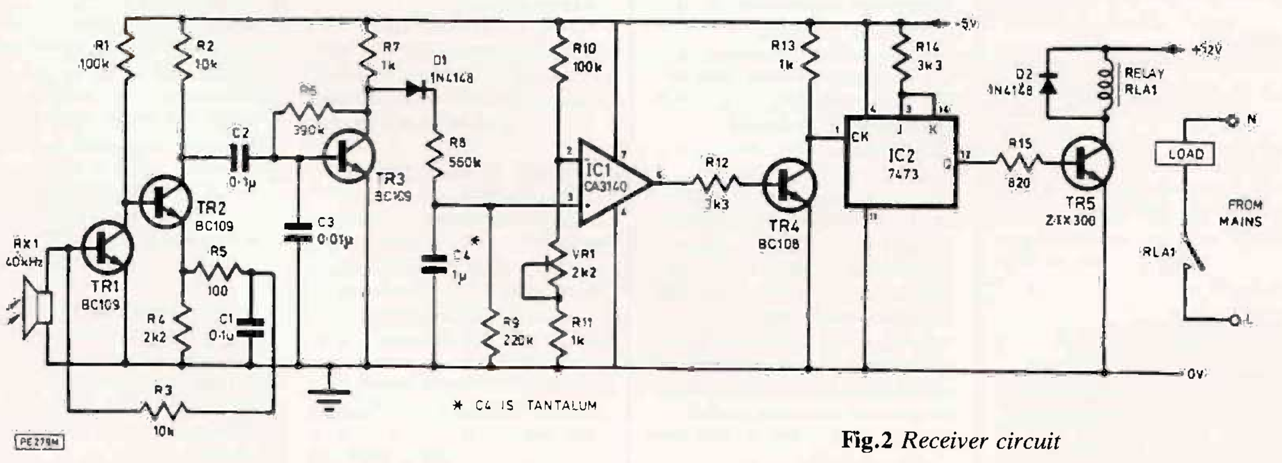
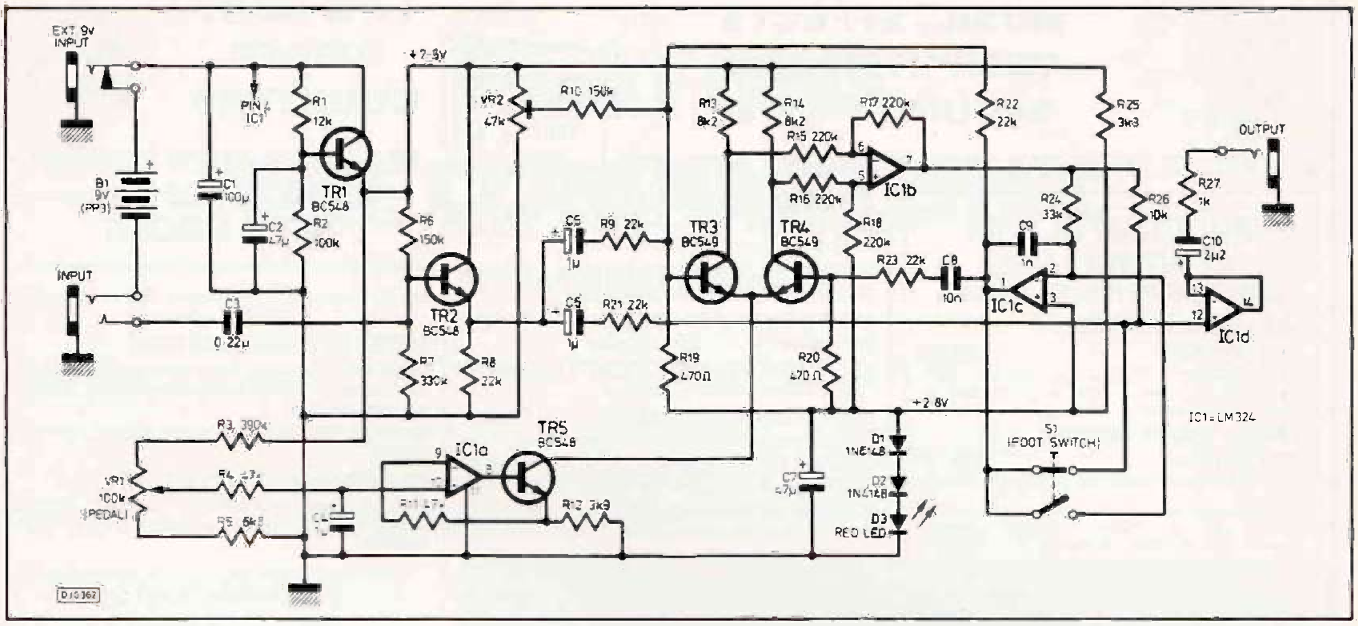


Fig.2 *Receiver circuit*



WAA-VOL EFFECT PEDAL

THIS circuit was designed to act as a waa-waa effect pedal and as a volume or 'swell' pedal. Switch S1 is operated by pressing the front of the pedal down hard, and normally switches the waa-waa effect on and off, but in this circuit it is used to switch between the two effects.

Power is applied when a jack is plugged into the (stereo) input socket TR1 provides a stable 7.5 volt supply for the circuit (assuming a 9V battery level). The input signal is buffered by TR2 and fed to a current-controlled amplifier (cca) built around TR3, TR4 and IC1b. The gain of this amplifier is controlled by the pedal pot VR1, via a voltage to current convertor (IC1a, TR5).

With S1 in the waa-waa position (shown in the diagram) the circuit is configured as a low-pass filter. The output buffer IC1d takes it's signal from the integrator IC1c. R22 provides negative feedback in order to limit the gain of the circuit. There is also some positive feedback through C8 and R23 to give a peak in the filter response at higher frequencies. The speed of the integrator, and hence the cut-off frequency of the filter, depends on the gain of the cca.

When the unit is used as a volume control, IC1c is effectively switched out of the circuit by shorting C9, and as it's output is also disconnected from the input of IC1d, the signal from the Cca gets through instead, via R26. Some of the original signal is added at this point through R21, in order to reduce the variation in gain to about 3:1. This was found to give a useful change between 'accompaniment' and 'solo' playing levels when the unit was used with an electric guitar, but R21 could be increased or omitted if greater variation is required (up to 16:1).

D1 to D3 provide a stable mid-rail at about 2.8V. If a high-brightness led is used for D3 it can also be used as a power-on indicator. Transistors TR3 and TR4 should ideally be a matched pair, and R15 to 18 should be 1% tolerance resistors, to minimise variations in output voltage with movement of the pedal. VR2 should be adjusted for minimum change in dc voltage at IC1 pin 14 when the switch is pressed (with VR1 at max.), or until no click is heard at the output.

C. Dancer, Merseyside.

Attenuator Dividers

ATTENUATOR ladders are frequently found at the input to test gear. Circuits similar to Fig.1. and Fig.2. are both common, and both use some resistors of non-preferred values. The 11.111ohm resistor is often approximated by 10R and 1R in series.

I use the circuit of Fig.3. For the addition of one resistor we can now make the ladder using only preferred values – the parallel pair of 150R and 12R (or its appropriate decade multiples) giving exactly the required value of 11.111R, as accurately as the tolerance of the resistors chosen.

C. Finn, Beverley

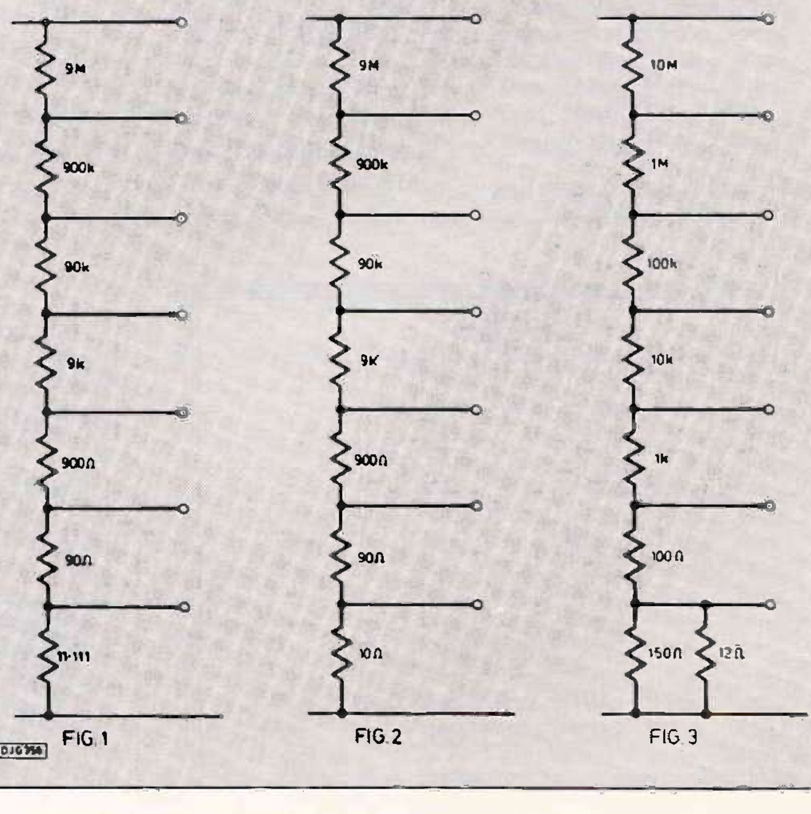


FIG.1 FIG.2 FIG.3

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PLAYING THE COMPACT DISC

BY VIVIAN CAPEL

BUMPS ON THE LANDSCAPE

The little audio discs don't rely only on high resolution and speedy revolution – they are played upside down and inside out, and have error checks on their error checks.

The shining silver discs with the crystal clear sound are becoming increasingly familiar. It remains a mystery to many though, just how the information is abstracted from the disc and in particular how the playback head manages to follow the recorded track, seeing that there is no physical contact between them. This is especially astonishing when the dimensions are considered. The track pitch is 1.6μm, and the track width a mere 0.6μm. In comparison the groove of an lp record is at its narrowest about 50μm wide.

The digital data is recorded as a spiral track of pits starting from the inside of the disc and ending near the outer edge. This is the opposite of the lp. Another opposite is that the disc is played on the underneath surface instead of the top, so to the pick up head it is travelling anti-clockwise.

Rotation speed of the lp is constant, which means that the modulations are cramped together at the centre where the groove circumference is small thereby increasing distortion, and expanded at the outer grooves thus wasting space. The compact disc rotates with a constant track velocity of 1.2 m/s, which means that the rotational speed is variable, slowing from 500 to 200 rpm approximately from start to finish.

The disc is made of plastic polycarbonate which is stamped or injection moulded to the required size and shape with the billions of modulation pits. The pitted surface is silvered in a mist of ionised aluminium which deposits a layer of some 0.04μm thick. Then the silvered surface is coated with a hard lacquer to seal and protect it. The modulations are read by a beam of light from a laser, but as it does so from the other side through the transparent disc material, the pits appear to it as humps.

All disc dimensions must be to extremely close tolerances. The thickness which is 1.2mm has a tolerance of ± 0.1mm; the disc flatness to 0.6° and the pit edge position to ± 0.05μm. The centre hole is 15mm in diameter but must be very accurately positioned. An eccentricity of 0.1mm would cause a beam deviation across 60 tracks! The disc has a small pilot hole drilled for the initial stages of manufacture, but the main hole is punched at the final stage. It is determined optically by a laser beam and is the exact centre of the track spiral, not necessarily of the disc perimeter. If after three attempts the laser cannot determine the centre, the disc is scrapped.

Photograph by courtesy of Morphy Richards CE Ltd.

DISC DIMENSIONS

Diameter	120mm
Thickness	1.2mm ± 0.1mm
Centre hole	15mm
Programme start radius	25mm
Programme finish radius (max)	116mm
Rotation	Anticlockwise to laser
Maximum recording time	60 minutes
Channel number maximum	4 with reduced playing time
Track pitch	1.6μm
Pit width	0.6μm
Pit or space length per digit	0.3μm
Minimum pit or space length	0.9μm
Pit depth	0.12μm±0.01μm

SCANNING BEAM

It is necessary that the scanning light beam focus down to a spot comparable to the dimensions of the humps otherwise more than one hump would appear in the spot at the same time and it may even spread over to an adjacent track. To get a light spot that small is difficult due to the effects of chromatic aberration. This is the appearance of coloured rings around an object due to the different angles of diffraction through a glass lens, of light of different wavelengths.

Achromatic lenses are made by combining elements of different types of glass so that the diffraction differences of each are cancelled, but these are very expensive. A further problem is that the

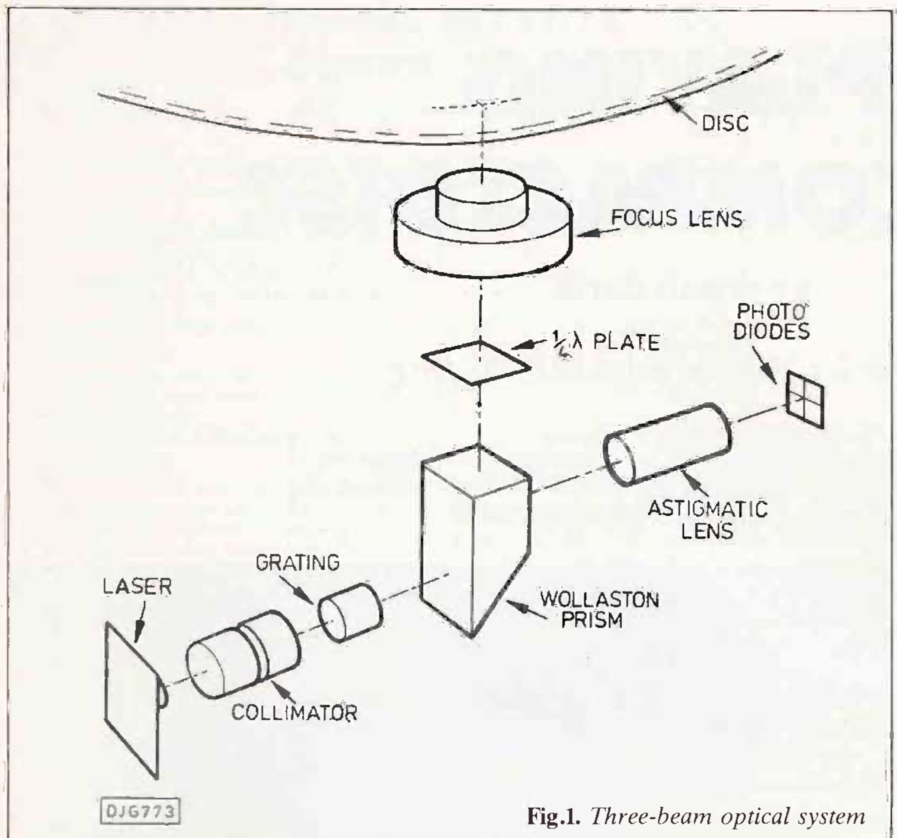

Fig.1. *Three-beam optical system*

humps must appear dark compared to the surrounding disc space (called *land* in CD terminology) so that they will effectively modulate the reflected light beam.

Both these problems are solved by using a laser. Having a single wavelength, there is no chromatic aberration and a relatively cheap lens can be used to produce a very fine spot. As laser light is coherent, that is all the waves are in step and in phase, light reflected from the hump which is raised about a quarter wavelength from the surrounding surface, is displaced half a wavelength compared to that from the surface. Cancellation occurs thus resulting in a darkening of the reflected beam. The hump width of 0.6μm is less than the laser wavelength of 0.8μm, so there is a degree of diffraction and light scattering which gives a further darkening effect.

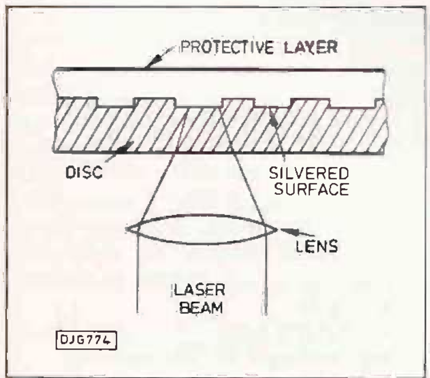

Fig.2. *Refraction of beam through transparent disc material*

Laser technology has improved considerably on the old gas lasers which were large and expensive. Those in current use are solid state, of aluminium gallium arsenide, and operate at low voltage which is another advantage. A further feature with some models is that the laser together with part of the optical system is contained in an easily replaceable plastic arm. However, replacements should be rare because life expectancy is now some 25,000 hours, which is quite a lot of playing time, nearly 3 years playing 24 hours every day!

THREE-BEAM SYSTEM

There are two basic optical systems, the three-beam and the single-beam. The operation of the single beam type can best be followed if we consider the three-beam one first. (Fig.1)

From the laser, the beam passes through a device called a collimator lens which ensures that the sides of the light beam are parallel and do not diverge. From there it travels through an optical grating which splits the beam into three. The light intensity of these is 50% for the main central one, and 25% each for the two side beams.

Next, the three beams are intercepted by a Wollaston prism which deflects them through a 90° angle and also performs a vital function on the return journey. From there, they pass through a quarter wavelength plate which rotates the plane of polarisation through 45°. This too is also necessary for the return pass.

Finally on the outward journey, comes the focusing lens which concentrates the beams into three tiny spots on the underside of the record.(Fig. 2). The point of focus is not at the disc surface through which it passes, but on the silvered layer above it. Thus the lower surface is out of focus which thereby reduces the effects of any surface blemishes on it.

After reflection from the silvered surface and modulation of the main beam by the humps it encounters, the beams pass back through the lens and again encounter the quarter wavelength plate. They are thus rotated a further 45° which means they are now 90° different from the forward going beams.

From there, the beams once more reach the Wollaston prism. This actually is a quartz device containing three elements which produce reflections that are dependant on the polarisation angle. As the returning beams have a different polarisation from the outgoing ones, they are reflected along a different path from this point on, and so do not return back through the grating to the laser.

Instead they travel through an astigmatic lens which produces a round spot when in focus on the photo-diode array. The reason for this lens we shall see later. Finally, the photo diodes convert the light and dark modulations into an electrical data stream.

THREE-BEAM TRACKING

The pickup assembly is moved over the underside of the disc by a servo motor. As beam tracking error must be within 0.1μm, the tracking must be extremely accurate and can only be controlled by the track itself. This is where those two auxiliary beams come into the picture.

They produce spots, one 20μm in advance and the other 20μm behind the main spot, on the silvered surface, but they are offset so that when the main spot is centered on the track one auxiliary is reading along the left hand edge of the track while the other reads along the right. (Fig.3).

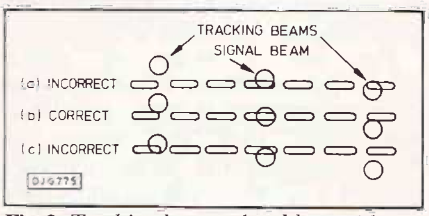

Fig.3. *Tracking beams should run either side of track (b). If incorrect one reflects a darker beam than the other so producing an error signal*

While the array is centered, the amount of modulation reflected from each auxiliary spot is equal. But if it strays to one side, one spot starts reading more of the track so reflecting a darker beam, while the other reads more of the space between the tracks, thereby returning a brighter beam.

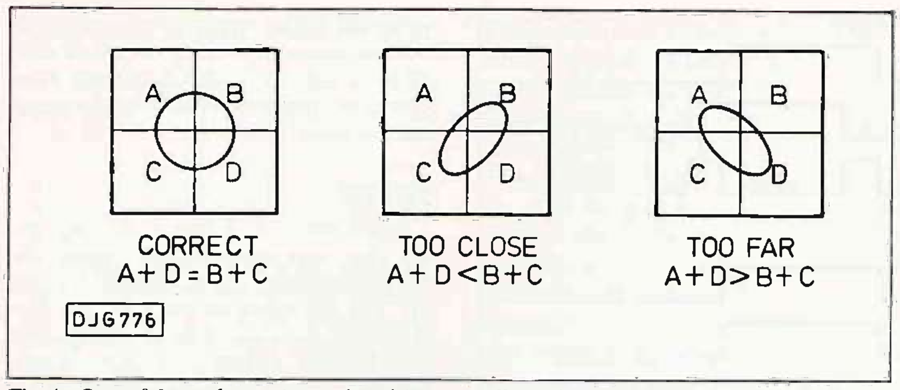

Fig.4. *Out of focus beam is rendered into an ellipse by the astigmatic lens. This illuminates diagonal pairs of photodiodes unequally. These are compared to produce a focus control signal*

The two beams are focused on their own respective photo diodes and the output from these are compared so that an error signal is produced when they are unequal. This is used to control the tracking motor. If either of the tracking beams are obscured temporarily by a disc surface blemish, the motor stops and the pickup remains stationary until both beams are again sensed. If this was not done, the circuit could generate a large spurious error signal due to the blacked out beam and so swing the pickup way off course.

Every track contains information as to its track number and timing from the start of the disc, so the decoder 'knows' what track is being read at any instant. This information can be displayed, or instructions can be given by the user to seek a particular track. This instruction puts the tracking motor into a fast mode which reverts to normal speed when the desired track number is detected. Just how that track and other information is recorded we will see in the next article.

FOCUSING

Focusing is another important function. Spot size is 1μm which is achieved with a lens aperture of 0.45 and a laser wavelength of 0.8μm. Defocusing enlarges the spot which could thereby read more than one hump at the same time causing corruption of the data signal.

The depth of focus of a 0.45 lens is 4μm, which makes focusing very critical, but here it is aided by the beam passing through the material of the disc. The material has a refraction index of 1.5, which is the ratio of the speed of light through a material compared to that through a vacuum. Resulting refraction increases the depth of focus. An advantage of a small depth of focus is that as the disc surface is 1,200μm from the silvered layer, it is a long way out of focus and so surface blemishes cast only a diffused image. They are thus less likely to cause errors.

Focusing error must be within 0.5μm, yet disc warp may cause a displacement of the surface of up to 500μm. Focus must therefore be continuously and automatically variable. The lens system which consists of four elements has a concentric coil surrounding it, and it is free to move vertically between the pole pieces of a permanent magnet. Movement is caused by current passing through the coil in the same manner as a loudspeaker cone.

There are four signal photo diodes arranged in a square block configuration. The spot reflected from the disc is focused at the centre of the four and when the system is in focus the spot is round so illuminating equal portions of all the diodes. If it goes out of focus, the spot develops into an ellipse due to the presence of the astigmatic lens, and thereby illuminates a greater area of one diagonal pair than the other.

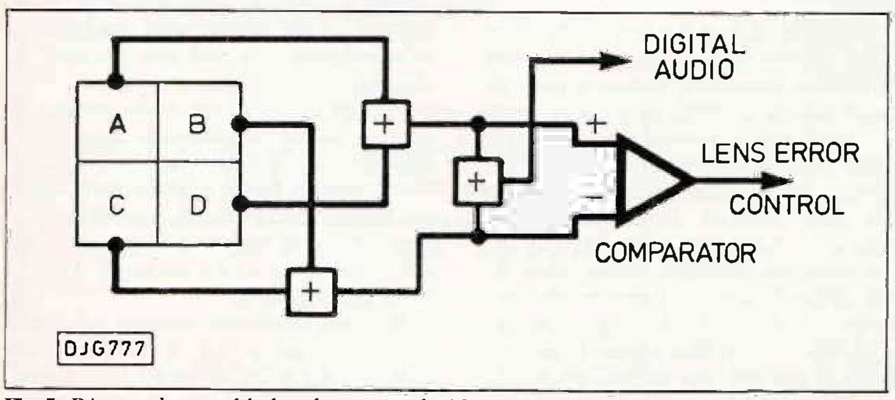

Fig.5. *Diagonals are added and compared with opposite pair to derive focus correction signal. All four photodiodes are summed for main audio data signal*

When the disc surface is too close, the ellipse lies across the second and third photo diode (B and C in Fig. 4) but when it is too far it straddles the first and fourth (A and D). So, the four are connected so that the output of each diagonal pair is added and compared to that of the other diagonal. (Fig. 5).

The comparator thereby produces an error signal which is amplified and fed to the lens coil. The polarity of the error signal, hence the direction of the lens movement, depends on which diagonal pair has the greater illumination. All four are summed to produce the main data stream signal.

SINGLE-BEAM SYSTEMS

If the two tracking beams are dispensed with the optical system can be simplified. The optical grating, Wollaston prism and quarter wavelength plate can be eliminated. The complete optical system can be contained in a simple, easily replaceable plastic-cased unit which can be swung across the disc on a pivot like a pick-up arm. A linear carriage is needed for three beams to maintain their tangential alignment. Furthermore, the whole energy of the laser is applied to the signal beam instead of 50% as with three beams. There are two methods of focusing and tracking. (Fig. 6).

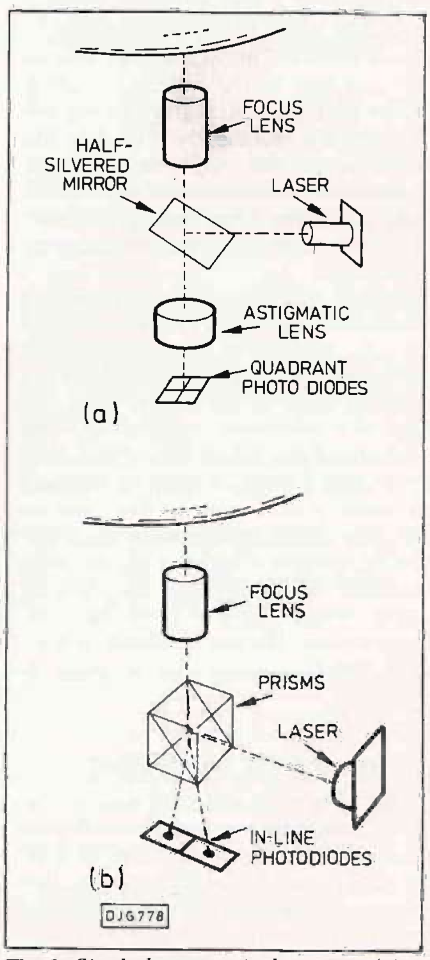

Fig.6. *Single beam optical systems (a) Quadrant diodes (b) In-line diodes*

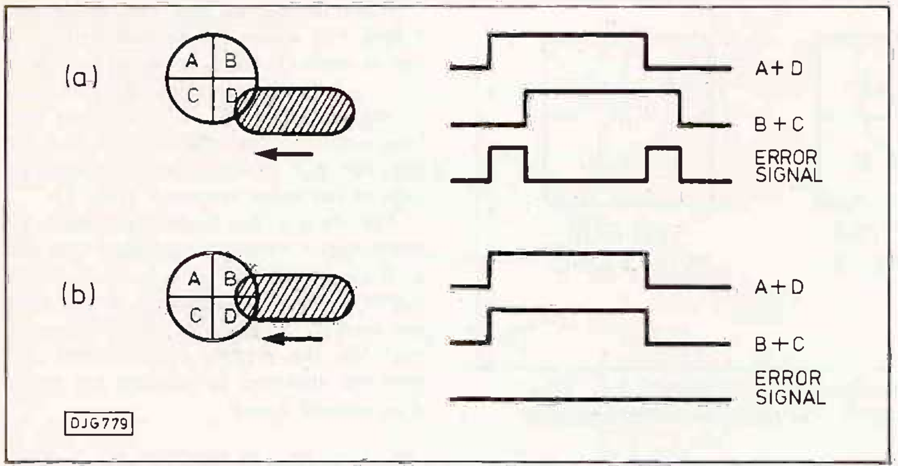

Fig.7. *When hump encounters an off-line spot, diagonal pair A+D is affected before B+C. Voltage at the comparator is thus in advance of B+C and a pulse is produced which is used as an error signal (a). When the spot is on-line (b), both diagonal pairs are affected simultaneously and no pulse appears*

Optical Path. The laser beam is reflected by an angled half-silvered mirror through the focus lens. After reflection from the disc it re-enters the lens, passing through the mirror and final lens to the photo diodes.

Quadrant Diode System. With this the focusing is the same as with the three-beam system, but the four quadrants of the detector are also used to detect deviation of the spot from the centre of the track.

This is how it is done. If the beam is off-course, one half of the spot reads the humps while the other reads the land so that one half of the reflected beam is darker than the other, and likewise the spot produced on the photo diodes. But as the quadrants are connected diagonally, both have one quadrant reading humps while the other reads land. Hence the output from both pair of diagonals is the same.

There is a difference though, and that is in the timing. (Fig. 7). A hump reaches the top quadrant of one pair before it encounters the bottom quadrant of the opposite one. So the output from one pair of quadrants arrives at the comparator just before that of the other, resulting in a pulse. Its polarity depends on which pair is affected first, and so indicates to which side of the track the spot has deviated. An error signal is thus produced which controls the tracking motor. When the spot is on line, the hump reaches the top quadrants of both pairs simultaneously, and no pulse is generated.

IN-LINE DIODE TRACKING

The difference with this system and the quadrant one is that the reflected beam from the disc is split into two by the final prisms in the optical path. Two prisms are combined, the exit one having a wedge shape which divides the beam. Their joint surface is half-silvered by an evaporated film that serves to reflect the incoming laser beam up through the

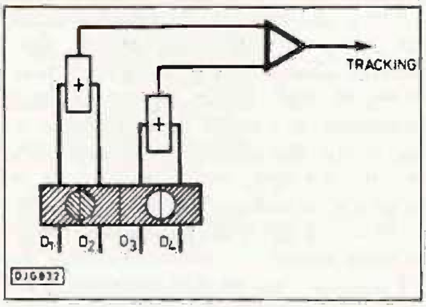

Fig.8. *Light spots fall equally on in-line diodes D1 and D2, D3 and D4. When off-centre one spot becomes darker than the other. Outputs of each pair are added and compared to provide tracking error signal*

focus lens. Although split into two, the system is termed single beam because only one beam is applied to the disc.

Both beam halves fall on four photo diodes which are arranged in a row. (Fig. 8.) One falls equally between D_1 and D_2, and the other between D_3 and D_4. If the spot on the disc is off-centre, the side of the beam reflected from the adjacent land is brighter than that reflected from the humps. So the two beam halves differ in brightness and there is a difference in output level between the diodes $D_1 + D_2$, and $D_3 + D_4$. This is used as an error correction signal.

However, dirt on the lens or prism, or other defects could produce permanent brightness inequality between the two beam halves resulting in tracking error. To avoid this a second tracking error signal is generated by a applying a 600Hz current to the tracking coil. This makes the arm oscillate from side-to-side, displacing the beam by $\pm$ 0.05μm. As any deviation from true centre varies the respective brightness between the two beam halves, both are thereby modulated by a 600Hz signal. If the spot drifts to one side, the signal increases in one pair of diodes and decreases in the other.

Summing the signal from both pairs produces either a positive or negative control signal depending on which side of the track the spot has strayed. This serves to 'fine tune' the first and main control signal.

FOCUS

When the spot is sharply focused on the disc, two sharp images appear on the photodiodes, one in between D_1 and D_2, and the other between D_3 and D_4. If the spot goes out of focus, the images also become diffuse and move closer together or further apart depending on the direction of the focus error. Fig.9. Thus the inner pair of diodes D_2 and D_3, have a different illumination level than the outer pair D_1 and D_4. A comparison provides a difference error signal that is applied to the focus coil.

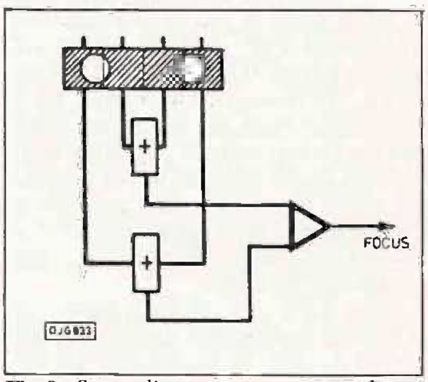

Fig.9. *Spots diverge or converge when beam is out of focus. Inner and outer pairs are added then compared to provide the focus error signal*

MOTOR SPEED CONTROL

The disc motor runs more slowly when scanning the outer tracks, than when the inner ones are read. Thus the data comes off the disc at constant speed. But unlike gram motors which need to be speed controlled to very fine limits to avoid wow and other pitch fluctuations, the cd motor speed is not particularly critical.

After emerging from the decoders the data is loaded into one end of a memory. It is clocked out at the other at constant speed by a quartz clock generator and fed to the d/a converters. It doesn't matter much if the input to the memory varies in speed as long as it is not too fast and so fills the memory completely to overflowing, or too slow so that it empties it.

The situation is rather like making regular weekly withdrawals from your bank account, the input may be irregular but as long as there is always sufficient to keep you in the black it doesn't matter very much. In that case of course it is not a bad thing to put so much in that the balance piles up!

With the cd output memory it is kept about 50% full so that there is room in both directions for adequate regulation. The amount it contains is continually measured and if it begins to fill up beyond the 50% level, this indicates that the motor is running too fast. Or if the level drops, the motor is too slow. A correction signal is thereby derived and used to change the motor speed.

So minor speed fluctuations are of no consequence, as the output frequency is firmly controlled by the quartz clock. Wow is therefore non-existent with a cd player.

We have come to the point where the light modulations produce corresponding electrical signals from the photodiodes. It may be thought that these are just digital signals that correspond to the original audio, and that all that is now required is to feed them to a d/a converter to recover that audio.

There is much more to it than that. The signal must be converted so that it can be read by a spot much larger than the smallest digital unit. (like using a gram stylus several times larger than the record groove). Correction elements must be included so that if parts of the signal are missing or incorrect there is no audible effect. Track numbering and other data needs to be included. and the two stereo channels must be combined in one track in a manner so that they can be parted with a much larger separation than is possible with an lp record.

How is it all done? Watch out for next month's issue and find out! PE

PE BAZAAR

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Pocket Computer. Casio Pb-110. Printer cassette interface expansion module. Tape recorder software. Manuals. £150 ono. Tel: 0734 730874.

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Q1 model C68 computer with MSU 500 disk drives (2 Shugart 8 inch DSdd drivers, controller, power supply and fan). Plus Richo 1600 daisy wheel printer friction and tractor drive plus lots of disks, software, manuals etc. £400 or exchange IBM equipment. Why? Ian Doble, Wickham, Quay Road, St. Agnes, Cornwall TR5 0RP. Tel: 0872 553609.

Ex. Govt. Smiths English clocks MKIV. Timing mechanism 0-26 weeks, 0-24 hours, 60 seconds. For sale £5.Mr. Preistley 0274-593382.

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Wanted: circuit diagram for GEC Soundeck Music Centre. 5 Spectrum power supplies 9V 1-4 Amps. £15 postage paid. J. Bakewell, 21 Newbarns Road, Barrow-in-Furness, Cumbria LA13 9SG.

Sinclair QL computer, joystick, lead, Micro-drive, cartridges, magazines from 1984 to 1988. All for £100. Richard Coles, 20 Priorsfield, Marlborough, Wilts SN8 4AQ. Tel: 0672 52014.

Wanted: Tandy TRS-80 pocket computer zip case. Reasonable price paid for reasonable condition. Tel: 061-973 3559.

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Projector turns any size TV into a 7Ft screen! £15 kit form. Nir Gendler, 6 Tnuat-Hameri Street, 55-286 Qiryat-Ono, Israel.

Wanted: oscilloscope. Watford 32K Shadow RAM - £40.00. Small electric guitar - £135.00 ono. Telephone after 6.00 pm please. Milan Lad, 64 Horton Grange Road, Bradford. Tel: 0274-575484.

Wanted: circuit diagram or information Texas silent 700 printer model 733 with modem (Harlow) 0279 33074.

Wanted: If you have any old components that you want to give away free, send to: S. Khan, 137 The Crescent, Slough, Berkshire SL1 2LF.

Wanted: Enterprise 64 H/ware and S/Ware. Also any contacts. Ian Joes, 21 Dene Street, Pallion, Sunderland, Tyne and Wear SR4 6JB.

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TIME AND MEASUREMENT

BY ANTHONY H. SMITH

PART TWO: THE UCT : SIGNAL PROCESSING AND THE INPUT CIRCUITS

Our series on universal counter timer continues with an examination of the important aspects of trigger signal conditioning and input protection.

Before the digital processing circuits of the Universal Counter/Timer (uct) can begin to measure the frequency and time parameters of an electrical signal, it is first necessary to convert the signal to digital form. This is the task of the input conditioning circuits which constitute the analogue processing section of the uct.

A digital signal is basically a series of rectangular pulses having the same constant amplitude. However, the shape and size of the input signal may vary enormously from one signal source to the next; furthermore, the presence of noise and interference may grossly distort the fundamental waveform.

Consider, for example, the signal shown in Fig. 1, where we wish to measure the period τp. Feeding the signal directly to the main gate would almost certainly prove disastrous due to the 100V dc offset voltage. AC coupling can remove this offset, but the signal amplitude itself is too large for the digital components to handle.

However, attenuating the signal by a factor of ten will bring the amplitude down to a safe level; we can now feed the signal to the main gate and take a reading — right?

Wrong! The uct is just as likely to measure the time $\tau \chi$, caused by the noise spike, as it is the correct parameter, τp. It might also display τy, the period of the superimposed signal, or may even attempt to measure all three time periods, resulting in a randomly changing readout. Fortunately, further processing such as filtering and trigger level adjustment enables the counter to "pick out" the required parameter from the mass of superfluous information.

Obviously, the more sophisticated the input circuitry, the more selective becomes the instrument's operation, enabling us to measure a wide variety of signals — hence, the "universal" counter/timer.

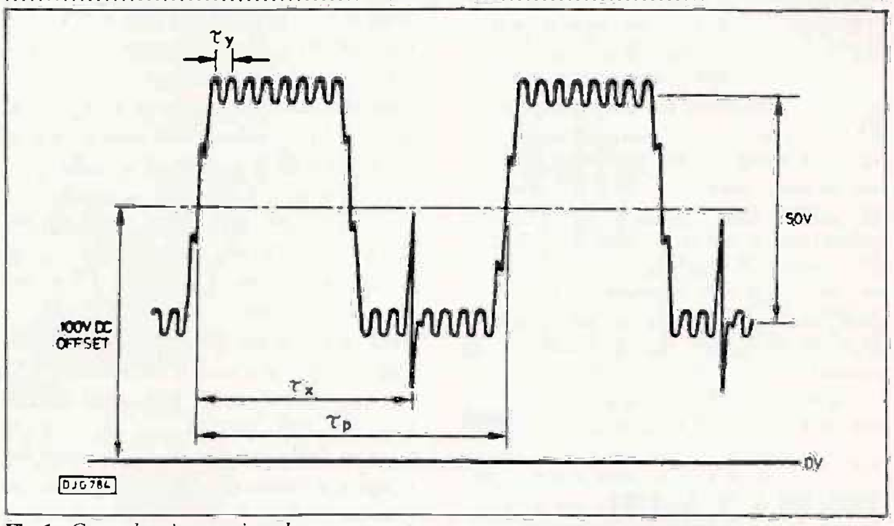


Fig.1. *Complex input signal*

INPUT CIRCUITRY

A comprehensive input processing circuit is represented in Fig. 2. This arrangement is capable of conditioning signals in the frequency range dc–100MHz, and is typical of the analogue circuitry found in good quality counters.

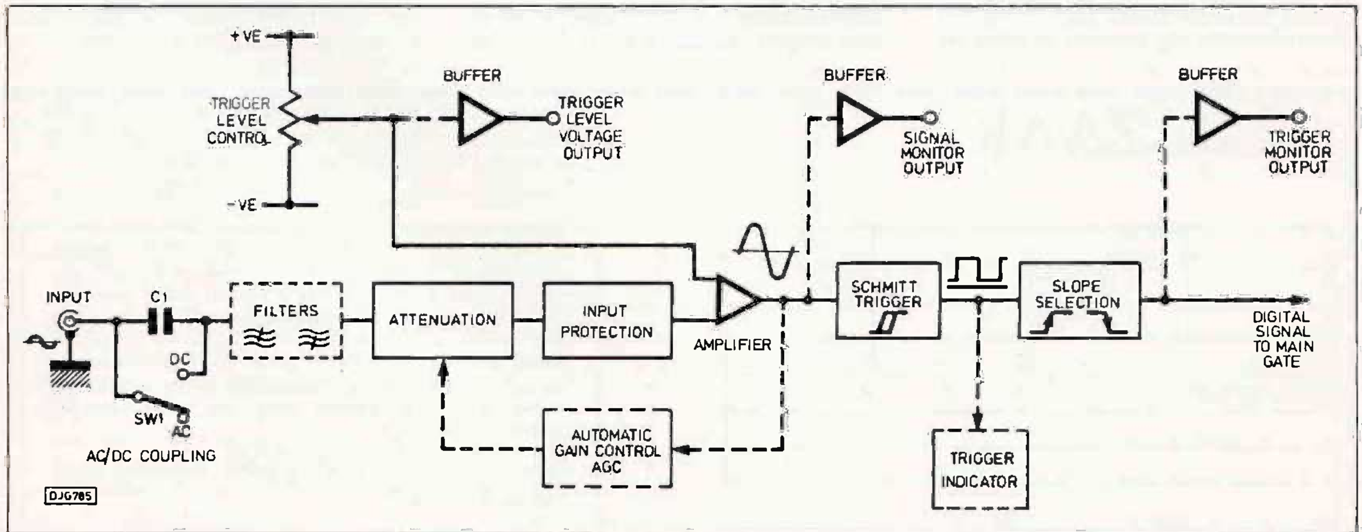


Fig.2. *Typical dc – 100MHz input processing circuitry*

Circuits may differ from one model to the next, but they should all provide adjustable attenuation, protection components to guard against overload, an amplifier, and a Schmitt trigger (to convert the analogue signal to digital form). Additionally, the trigger level and slope controls are necessary for selecting the precise points on the input waveform where the measurement begins and ends.

HYSTERESIS

The Schmitt trigger is a voltage comparator with hysteresis, an essential property which allows it to "ignore" the noise content of a signal such that only the fundamental waveform itself is converted to digital form.

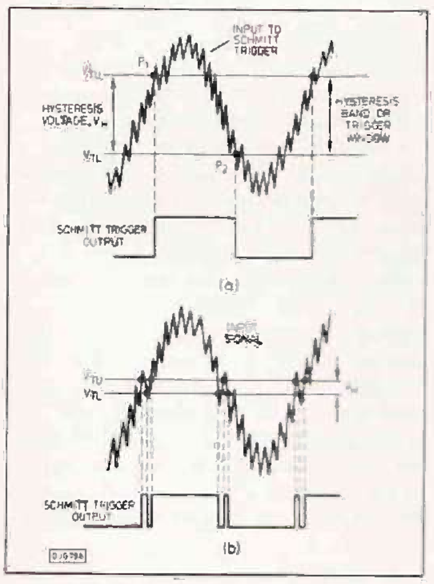


Fig.3. *(a) Schmitt trigger operation (b) Narrow hysterisis band*

The purpose of the trigger is to produce a step output when the input signal crosses one of two threshold voltages — see Fig. 3a. For example, when the input crosses the upper threshold voltage, V_{TU}, at point P_1, the Schmitt output rapidly changes state. However, subsequent crossings of this threshold due to the superimposed noise have no effect, and it is not until the signal crosses the lower threshold voltage, V_{TL}, at point P_2, that the output changes state again.

The difference between the upper and lower threshold voltages is the hysteresis voltage, V_H, sometimes called the "hysteresis band", or "trigger window". Note that the input signal must cross *both* threshold levels for the Schmitt to produce a corresponding digital output signal. Obviously, if the trigger window is too narrow, as in Fig. 3b, the noise itself will trigger the output and cause erroneous measurements.

The question is then, how wide should we make the trigger window? The situation of Fig. 3b suggests it be made as wide as possible so as to minimise the effects of noise (the trigger window is sometimes referred to as the "noise immunity band"). However, the wider the trigger window, the greater must be the input signal amplitude in order to cross both thresholds: in other words, increasing the hysteresis voltage has the desirable effect of increasing the noise immunity, but at the expense of diminished input sensitivity. (The sensitivity of the uct is the smallest signal amplitude which can be detected).

Unfortunately, the situation is further complicated by the conflicting requirements of frequency and time measurements. When measuring frequency, the hysteresis voltage should be just less than the peak-peak voltage of the input signal — in this way, signals buried in noise can be detected and measured.

However, for certain time measurements the trigger window should be very narrow to reduce the errors caused by differences in the input signal rise- and fall-times. This is illustrated in Fig. 4, where the parameter of interest is the pulse width.

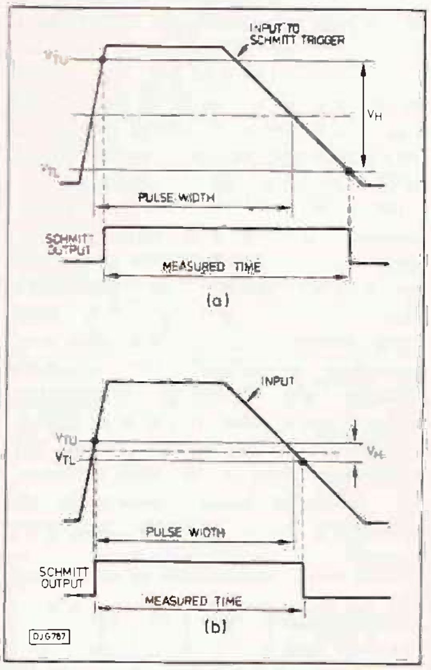


Fig.4. *Time measurement errors*

In Fig. 4a, the wide hysteresis band leads to a measured time which is considerably longer than the actual pulse duration. However, by narrowing the band (Fig. 4b) the Schmitt output is made almost equal to the pulse's width.

An obvious solution to these problems would be to provide a variable hysteresis band which could be adjusted to suit the prevailing signal and measurement conditions. However, an assortment of components is usually responsible for setting the threshold levels, and so a simpler alternative is to vary the input signal amplitude, noise and all, by means of attenuators. Obviously, reducing the signal amplitude has exactly the same effect as *increasing* the hysteresis band. Consequently, the upper and lower Schmitt thresholds can now be fixed such that the hysteresis band is constant, and is symmetrical about zero volts.

The magnitude of the hysteresis band dictates the sensitivity of the instrument: a hysteresis voltage of, say, 10mV would allow signals as small as 10mV peak-peak (3.5mV rms) to be detected. However, the thresholds cannot be set too close together or the trigger will become unstable due to ageing, supply-voltage drift, and temperature changes. Furthermore, any offset voltage at the trigger input may significantly bias a small hysteresis voltage. Consequently, most triggers have a relatively large hysteresis band, but are preceded by an amplifier to achieve the same sensitivity: for example, a hysteresis voltage of 100mV (ie, V_{TU} = +50mV, V_{TL} = −50mV) and an amplifier gain of ten result in a sensitivity of 10mV peak-peak.

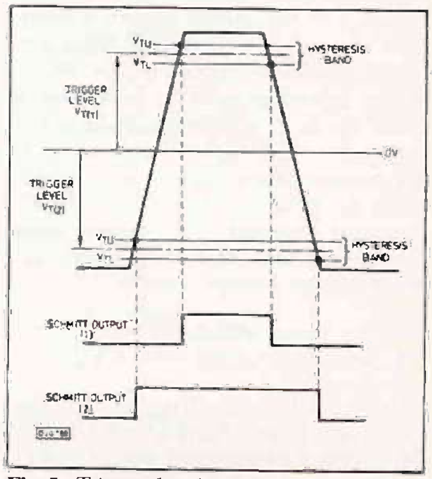


Fig.5. *Trigger level variation*

TRIGGER LEVEL

The analysis of the Schmitt trigger has assumed the trigger level (the mid-point of the hysteresis band) to be fixed at zero volts. However, many time measurements require that we "shift" the trigger level relative to the input signal, such that the trigger points can be fixed at almost any place on the waveform. This is exemplified in Fig. 5, where the trigger level is initially set positive, $V_T(1)$, and then negative, $V_T(2)$, to measure the pulse width at different places on the input signal.

Varying the trigger level is equally useful for eliminating the problems caused by large-amplitude noises, such as the spikes seen earlier on the signal in Fig. 1.

Often, the simplest way to vary the trigger level is not to shift the hysteresis band, but instead to shift the amplifier output signal while keeping the hysteresis band symmetrical about zero volts. This is achieved by adding a dc offset to the amplifier output: for example, shifting the output signal *negative* by two volts has exactly the same effect as moving the hysteresis

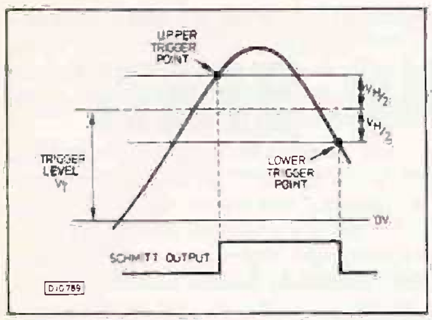


Fig.6. *Triggering occurs at the trigger points*

band *positive* by two volts, ie, a trigger level of +2 volts.

This ability to locate the trigger points anywhere on the waveform is all very well, provided we know just where we are setting them. Indeed, the precision of time measurement (such as that in Fig. 5) depends mainly upon the accuracy with which we can set the trigger points, rather than on the accuracy of the measurement circuitry itself. Remember, also, that triggering occurs not at the trigger *level*, but at the trigger *points* — see Fig. 6. Ideally, it would be best to measure directly the trigger point voltages. However, this is not possible since they do not exist as nodes anywhere in the circuit; instead, we must measure the trigger level voltage and then add or substract half the hysteresis voltage. That is:

Upper Trigger Point = $V_T + V_H/2$
Lower Trigger Point = $V_T - V_H/2$.

In several ucts, a voltage equal to the trigger level (for example, that at the wiper of the trigger level pot) is output such that V_T can be read directly on a dvm. Knowing V_H (which should be given in the counter's specifications) we can now establish the exact trigger points using the equations above. Incidently, some of the more sophisticated ucts incorporate the dvm into the instrument itself; for example, the Philips PM6652 uses a special technique known as "hysteresis compensation" such that the trigger points themselves can be read directly from the instrument's display.

The trigger level range is an important specification which differs considerably from one counter to another. Obviously, the greater the range the more versatile a measurement can be. Varying the trigger level over a ± 5V range is usually more than adequate; however, on some models the range may be as small as ± 1V, or less.

When making frequency measurements on signals symmetrical about zero volts, the trigger level offset is not required since the best sensitivity is obtained with the hysteresis band centred on zero volts: consequently, many trigger level controls have a detent, or "preset", position which sets the trigger level at exactly zero volts.

THE AMPLIFIER

Provided the trigger window is not excessively wide, an amplifier gain in the region of 20dB is usually sufficient to provide an input sensitivity of around 5mV rms (a typical value for most good-quality counters). However, the gain must be very carefully set if we are to have any confidence in adjusting the trigger level. (This important requirement will become clearer when we look at the input attenuators).

Furthermore, the gain must remain stable over the counter's frequency range, ie, we require a flat frequency response, otherwise the sensitivity will deteriorate at those frequencies where the gain falls. Since most counters have a frequency range from dc to at least 10MHz, the amplifier must be a wideband device: additionally, a very high slew-rate (at least 100V/Ωs) is essential for good pulse response. However, fast slewing alone does not guarantee a perfect pulse output, and the amplifier must be carefully compensated to avoid excessive overshoot and ringing.

Several other demands are made of the amplifier. For example, it must be a low-noise design, especially if very small signals are to be detected. Also, since the amplifier is dc coupled to the Schmitt trigger, any unwanted offset voltage at the output must be very small so as not to bias the trigger level voltage.

The amplifier's output voltage swing dictates the dynamnic input voltage range of the counter. This important specification defines the amplifier's *linear* range of operation. Any input signal which forces the amplifier into saturation is outside the counter's dynamic range. However, because the dynamic range refers to the *input* signal, it does not necessarily equal the saturation limits: as we shall see later, the amplifier gain and selected attenuation must also be taken into account.

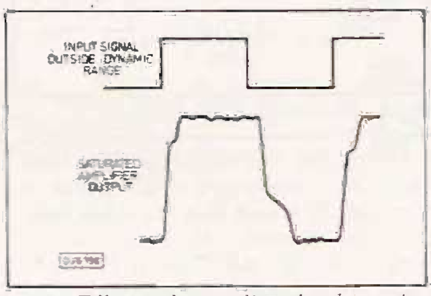


Fig.7. *Effects of exceeding the dynamic range*

Typical effects of exceeding the dynamic range are shown in Fig. 7, where the distortion caused by amplifier saturation will corrupt a variety of measurements, particularly pulse width, time interval, and transition time. Note, also, that the dc content of an input signal may cause saturation, *unless* ac coupling is selected.

Like oscilloscopes and voltmeters, the uct must have a high input impedance so as to minimise the load on the signal source, and consequently the amplifier input must have a high resistance and low capacitance. For most counters, an impedance of 1M in parallel with 30pF or less is typical; however, because the amplifier is a wideband device, the high input impedance makes it particularly sensitive to noise, and careful screening of the input circuitry is necessary to minimise false triggering.

HOW MUCH ATTENUATION?

The purpose of the input attenuators is two-fold: firstly, they allow large-amplitude signals to be reduced such that they are within the dynamic range of the counter; secondly, they provide a means of varying the signal amplitude in relation to the trigger window. Unfortunately, the amount of attenuation required varies considerably with the input signal amplitude and the type of measurement being made.

Consider, for example, making a measurement on a signal with a peak-peak amplitude of 5V, and assume the input amplifier has a gain of ten and a maximum output voltage swing of ± 5 volts. Obviously, feeding the signal directly to the amplifier will cause it to saturate. However, if the signal is first attenuated by a factor of ten, the "overall gain" (ie, the amplifier gain combined with attenuation) will be unity, and the amplifier output will have the same amplitude as the input signal. In this case, the dynamic input range is 5V p-p, and the trigger level range is ± 5V.

If, now, the attenuation is increased to x100, the overall gain is reduced to 0.1, and the dynamic input range and trigger level range are increased to 50V p-p, and ± 50V, respectively. In other words, any trigger level in the range − 50V to + 50V can be set on an input signal having a maximum amplitude of 50V p-p.

In general, the dynamic range equals the magnitude of the trigger level range (although on some models the trigger level range is somewhat less than the dynamic range) and:

$$\text{Dynamic Input Range (volts p-p)} = \frac{\text{Amplifier Output Voltage Range}}{\text{Amplifier Gain}} \times \text{Attenuation Factor}$$

Note that the trigger level range (and the dynamic range) *relative to the amplifier output* remains constant irrespective of the attenuator setting, and this should be borne in mind if the trigger level is output and read from a voltmeter. Note, also, that the amplifier gain and the attenuation factor must be accurately set in order to establish the

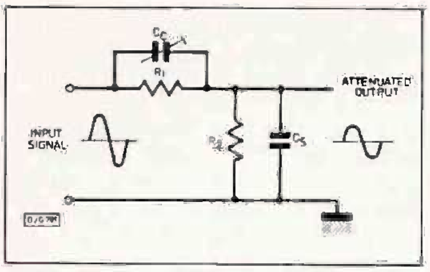


Fig.8. *Compensated attenuator*

corresponding dynamic and trigger level ranges.

Frequency compensated step attenuators are particularly suitable since the attenuation factors can be precisely set and remain constant at all frequencies. An example is shown in Fig. 8, where R1 and R2 form a simple potential divider. These resistors are chosen not only to give the desired attenuation, but also to provide the correct input resistance to the counter. For example R1=900k and R2=100k result in an attenuation of x10, and an input resistance of 1M. For x100 attenuation, R1 would need to be 990k, and R2 10k.

In practice, some stray capacitance, Cs, always exists in shunt with R2. For sinusoidal inputs, this results in increased attenuation at high frequencies since R1 and Cs effectively form a low-pass filter.

For high-frequency pulse inputs the effect is more dramatic: Fig.9 shows how Cs integrates the input pulses leading to gross signal distortion.

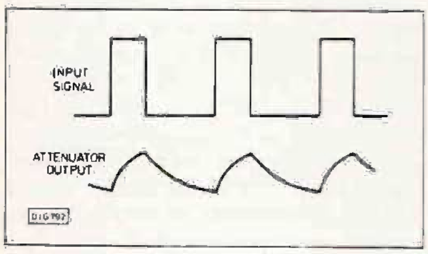


Fig.9. *Pulse distortion due to Cs*

To compensate for the effects of Cs, a trimmer capacitor, Cc, is added in shunt with R1. By adjusting Cc such that the ratio of its reactance to that of Cs is equal to the ratio of R1/R2 (ie, XCc/XCs = R1/R2), the attenuation is made frequency independent. Consequently, all signals are passed with constant attenuation, and the rectangular shape of pulse inputs remains intact whatever the frequency.

Note that Cc in series with Cs constitute the counter's input capacitance, which should not exceed 30 – 40pF for any attenuator setting. In this way, the counter's input impedance remains constant, even though the attenuation may be switched from x1 to x10 to x100, etc.

Although step-type attenuation is best for measurements requiring precise setting of the trigger level, it does have drawbacks. Consider, for example, a counter which has x1, x10, x100 attenuation with corresponding dynamic ranges of 500mV p-p, and 50V p-p, respectively. If the input signal is 600mV p-p, which attenuation setting do we choose? Obviously, x1 attenuation (ie, no attenuation) will not do, since the corresponding range is too small. Consequently, x10 attenuation must be chosen, even though most of the dynamic range (5Vp-p) will be "wasted" on the small input signal.

This example introduces an important consideration, namely that increasing the attenuation is equivalent to *increasing the trigger window relative to the input signal.* In this respect, decade attenuation is often too severe: this is exemplified in Fig.10, where x1 attenuation produces false counts, and x10 attenuation results in no measurement at all.

where the amplitude can be gradually reduced until only the fundamental signal itself crosses the hysteresis thresholds.

In order to get optimum measurement conditions, many ucts offer both continuously variable and step-type attenuation. An interesting example is found on the Philips PM6670 range of counter/timers. These models feature a switchable x10 attenuator, along with a potentiometer type which doubles as the trigger level control when making time measurements.

Note that whichever type of attenuation is employed, the instrument sensitivity varies accordingly: for example, a counter with 10mV sensitivity at the x1 attentuator setting will not be able to detect signals less than 1 volt when x100 attenuation is being used.

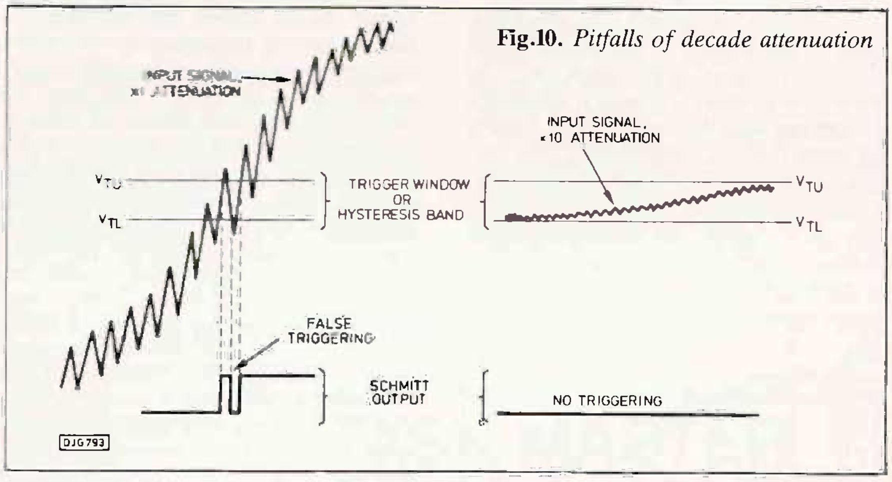


Fig.10. *Pitfalls of decade attenuation*

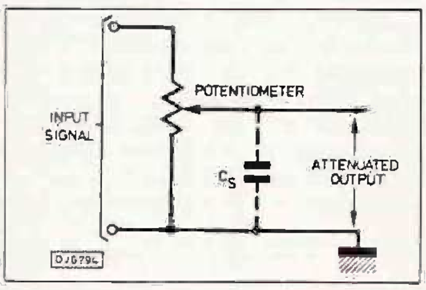


Fig.11. *Variable attenuation*

Obviously, some kind of continuously variable attenuation is required, such as that provided by the potentiometer in Fig.11. Unfortunately, this attenuator also has limitations. Firstly, it is practically impossible to compensate for the stray capacitance, Cs; consequently, more high-frequency roll-off is introduced as the attenuation is increased. Secondly, there is no way of knowing the exact relationship between the trigger level voltage and the input signal, since the relationship varies as the potentiometer is adjusted.

For these reasons, the variable attenuator is of little use for most time measurements. However, for sinusoidal frequency measurements (where the trigger level is usually zeroed, anyway) the potentiometer comes into its own, especially for extremely noisy signals

INPUT PROTECTION

With x1 attenuation selected, the input signal is fed directly to the amplifier, making some form of overload protection essential. A voltage limiting scheme typical of many counters is shown in Fig.12. This is a simple voltage clipping circuit when an excessive input signal causes D1 or D2 to become forward biased. Consequently, the amplifier input voltage, V_{IN}, cannot increase beyond either supply rail, and practically all of the large overload voltage is dropped across R1.

Obviously, the resistance of R1 must be large enough to limit the input overload current which flows through the parallel combination of D1 (or D2) and the amplifier input impedance. If R1 is, say, a 120k, 0.5W component, the input current caused by a 250V rms overload will be limited to a safe value of 2mA rms (3mA peak).

With the counter set at x1 attenuation, $R1+R_A$ is effectively the counter's input resistance, typically 1M. Thus, if R1=120k, R_A must be 820k. However, if the amplifier has fet inputs, R_A may be several hundred megohms, making the amplifier highly vulnerable to noise: consequently, a shunt resistor must be added across R_A to bring the counter's input resistance down to 1M.

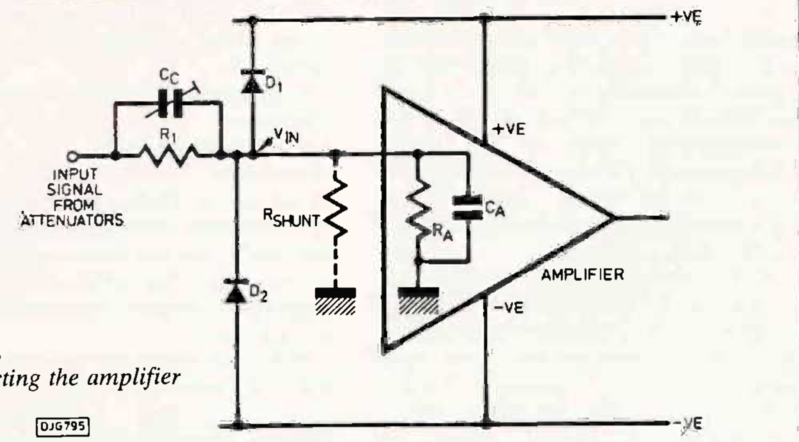


Fig.12.
Protecting the amplifier

Note that R1 forms a potential divider with R_A such that the input signal is slightly attenuated; this is easily remedied by increasing the amplifier gain accordingly. However, the amplifier's input capacitance, C_A, is more of a problem, making it necessary to compensate the network by adding Cc across R1. Unfortunately, the low reactance of Cc at high frequencies means the protection afforded by R1 is lost; as a result, the maximum input voltage becomes frequency dependent, as shown in Fig.13.

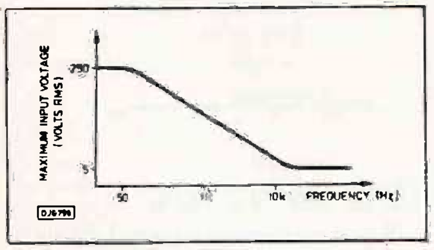


Fig.13. *Frequency dependent protection*

Most instrument manufacturers specify the damage level (the maximum tolerable input voltage) for various frequencies, or may illustrate it graphically as in the figure.

Fortunately, the frequency dependence is rarely a problem since most high voltages are confined to the mains frequency range, although care must be taken when working with the likes of high-power, high-frequency transmitters.

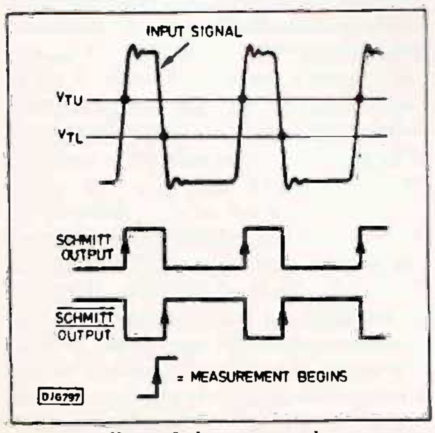


Fig.14. *Effect of slope control*

SLOPE SELECTION

The slope control is a two-position switch which allows the operator to choose whether the measurement begins on the rising or falling edge of the input waveform — see Fig.14. Basically, the switch position determines whether a true or inverted Schmitt output is fed to the main gate; although this has no effect on frequency and period measurement, it provides considerable versatility when measuring pulse width or the time interval between two events.

AC OR DC COUPLING?

AC coupling is required when measuring a signal with a relatively large dc offset, and is achieved by opening S1 (Fig.2) such that only the ac component is coupled via C1.

However, the combination of C1 (typically 0.1μF) and the counter's input resistance, R_{IN}, effectively forms a high-pass filter; consequently, ac coupling cannot be used on signals which vary slowly with time, since these are greatly attenuated and/or distorted.

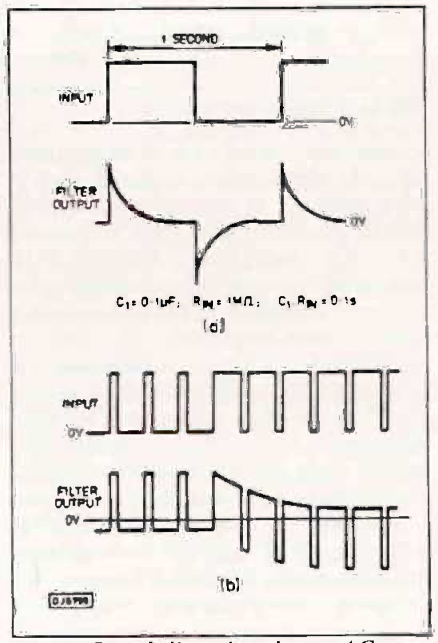


Fig.15. *Signal distortion due to AC coupling*

AC coupling can have serious effects on digital signals. Consider the example in Fig.15a, where the period of the input is much longer than the time constant ($C1.R_{IN}$) of the filter. Note how the filter differentiates the signal, making it difficult to measure anything but the frequency or period of the input.

With AC coupling, any change in the digital signal which affects the average dc level (such as changes in duty cycle or transition time) may cause considerable signal distortion. Fig.15b shows how a change in duty cycle makes it impossible to set constant trigger points on the ac coupled waveform.

Obviously, great care is needed when a digital signal is ac coupled, and in many cases the correct measurement can only be made by combining dc coupling with judicious use of the trigger level control.

It is for the above reasons that all sections of the input circuitry are *dc coupled*.

ADDITIONAL FEATURES

As well as the fundamental conditioning circuitry described so far, many counters feature additional sections to enhance the signal processing or to provide some degree of user feedback.

FILTERING

A typical example is the use of filters which may be switched in to help "clean up" the input signal. These filters reject a particular range of frequencies, and are usually first-order rc types with 20dB per decade roll-off. For example, a low-pass filter with a 3dB-frequency of 50kHz is useful for removing high frequency noise from audio signals.

A high-pass filter, on the other hand, might have a break frequency around 1kHz such that 50Hz mains interference can be removed. A typical application for this filter is shown in Fig.16, where a high frequency signal is superimposed on the large-amplitude mains hum: the hf signal can only be measured by filtering out the 50Hz interference.

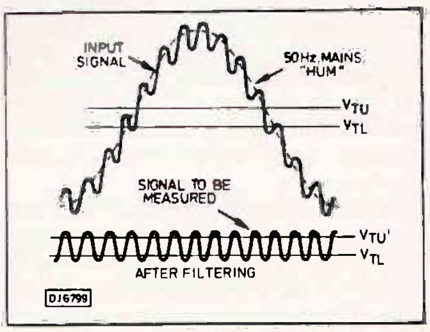


Fig.16. *Effective use of filtering*

VISUAL FEEDBACK

The commonest form of user feedback is the trigger indicator. In its simplest form, this is a led driven by the Schmitt output. In the presence of an input signal large enough to cross the hysteresis thresholds the led flashes at a rate equal to the input frequency; for small signals (or none at all), the led is extinguished.

An improvement on this theme is the "tri-state" led, which not only indicates input triggering, but also gives information about the trigger level. With the input correctly triggered the led flashes at a constant rate (typically about 3Hz); however, with the trigger level set too high or too low, the led is continually off or on, respectively. This is summarised in Fig.17.

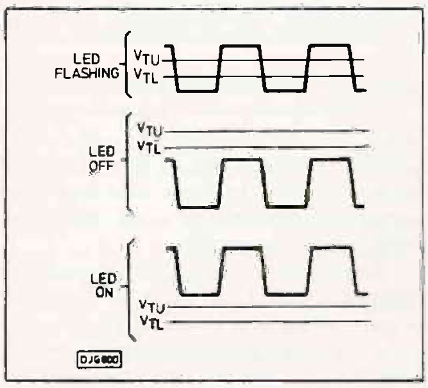


Fig.17. *Tri-state trigger indication*

Some of the more sophisticated ucts provide signal and trigger outputs (usually derived from a buffer with short-circuit protection) allowing the amplifier and Schmitt trigger signals to be monitored on an oscilloscope.

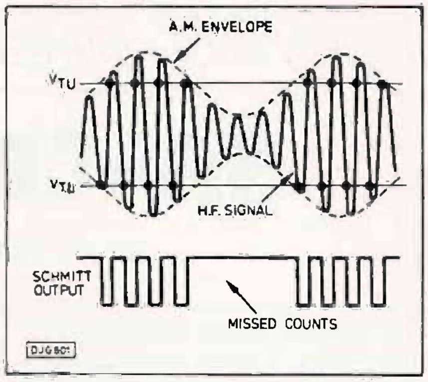


Fig.18. *Agc circuit – possible problems*

Superimposing the two signals gives a direct visual indication of trigger level adjustment, thus making it extremely easy to set the desired trigger points. Furthermore, the effects of ac coupling, filtering, and attenuation are also plainly visible.

AGC SIMPLIFIES OPERATION

Automatic gain control behaves as a "hands-off" sensitivity control, and is particularly useful when measuring the frequency of noisy inputs. By monitoring the amplifier output, the agc circuit automatically alters the input attenuation (or adjusts the amplifier gain) such that the signal level at the Schmitt trigger input is just greater than the hysteresis band. In this way, the overall gain is kept low enough to avoid false triggering due to noise.

However, agc does have limitations, particularly at low frequencies (50Hz or less) where it may respond "too quickly", effectively cancelling out the input signal.

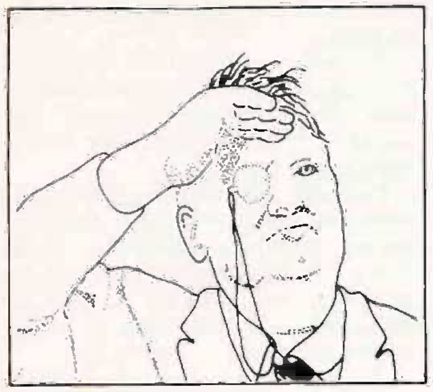
Problems can also be encountered when measuring the carrier frequency of an amplitude modulated signal. Instead of following the hf signal, the agc loop may lock-on to the am envelope, such that many of the hf counts are missed — see Fig.18.

To avoid problems of this kind, the agc loop must be switched out, so that control of the attenuators is returned to the operator.

VERSATILITY AND ACCURACY

By now you may be a little surprised at the diversity and complexity of the input processing circuitry, and one could be forgiven for wondering whether it is all really necessary.

Remember, however, that appropriate signal conditioning is needed not only for versatility, but also for accuracy. We shall see in a future article that even the simplest uct time base oscillator can have an accuracy better than one part in 100,000: obviously, such accuracy is meaningless if the input signal cannot be correctly digitised. PE



OUR REGULAR LOOK AT ASTRONOMY

SPACEWATCH

BY DR PATRICK MOORE

Titan, Saturn's largest moon, has an atmosphere capable of supporting life – alas, it's no refuge for we Earthlings

Of all artifical satellites, the most durable is undoubtedly the IUE or International Ultra-Violet Explorer. It was put into a geosynchronous orbit on 26 January 1978, so that it has been in space almost as long as the Voyagers to the outer planets. It has maintained observations with its spectrograph-equipped 17-inch telescope, and an amazing amount of research has been undertaken with it: hot gas around cool stars, mass-loss of cataclysmic variables, the interstellar medium, quasars, supernovae and – much nearer home – Halley's Comet. It is still working well. The really interesting point is that it was designed to operate for three years only, so that its performance has been nothing short of incredible – and it may continue functioning for a long time yet.

Another satellite, Hipparcos, has yet to be launched; it is an ESA venture. It weighs one ton, and has a 12-inch telescope Hipparcos is an astrometric satellite, designed to survey the exact positions of the brightest 120,000 stars; the accuracy should attain 0.002 of a second of arc. An additional 400,000 stars will be measured to an accuracy of 0.03 of a second of arc. Tests are going well, and there seems to be no reason why Hipparcos should not be launched on schedule. It is designed to function for 2½ years – but after the IUE triumph, anything may happen!

(On a more bizarre note, there was an odd episode on 2 April this year – it might have been more appropriate to April the First. A Pan-American jet-liner picked up what he took to be SOS signals, and then signals were heard from a Russian satellite which should not have been transmitting at all. It transpired that the trouble came from the house of a Mrs Mathers, in Wales, who had fitted up an electronic mouse scarer which had 'triggered' the statellite...)

Something very interesting seems to have happened to Asteriod No 2060, Chiron. Chiron is a very odd little world – several hundred miles across – which spends most of its time between the orbits of Saturn and Uranus, far beyond the main asteroid belt between the paths of Jupiter and Mars. Nobody knows quite what to make of Chiron. Normally it is of magnitude 18, but it seems to have brightened up abruptly by almost a magnitude. It does not seem to be a comet-like outburst; Chiron's spectrum

The Sky This Month

All through the first months of 1988 Venus has been a superb object in the night sky. Now, however, the apparition is coming to an end. The planet can still be seen in the west after sunset at the beginning of June, but it passes through inferior conjunction on the 12th, so that for a while it will be out of view. It will reappear as a morning object, low in the east, for the last ten days of the month. Venus appears telescopically as a slender cresent.

An inferior conjunction, Venus is more or less between the Earth and the Sun, so that its dark side is turned towards us. If the lining-up is exact, Venus is seen as a dark spot passing slowly across the brilliant solar face but these are unusual – the last was that of 1882, the next will not be until 2004. Surely there can be nobody now living who can remember a transit of Venus!

Of the other planets, Mercury also passes through inferior conjunction (June 13) and is out of view. Mars, magnitude −0.5, is a morning object, and is brightening steadily; its apparent diameter is almost 13 seconds of arc at the end of the month. Jupiter is a morning object, low down. Saturn, in Sagittarius, reaches opposition on 20 June. It is then visible throughout the hours of darkness, but is well south of the celestial equator, so that to British observers it is inconveniently low down.

The evening sky is dominated by what I have called "the Summer Triangle" (Vega in Lyra, Deneb in Cygnus and Altair in Aquila). Vega, brilliant and steely-blue, is near the zenith after sunset. It is one of the stars found by IRAS, the Infra-Red Astronomical Satellite, to have "an infra-red excess", due to cool material which may well be planet-forming. Deneb, which looks more than a magnitude fainter than Vega, is a particularly luminous supergiant, around 70,000 times as powerful as the Sun. Also on view is the orange star Arcturus, lined up with the 'curve' of the tail of the Great Bear, which is actually marginally brighter than Vega. It is the leader of Boötes, the Herdsman, and adjoining Boötes is the little semicircle of stars marking Corona Borealis, the Northern Crown. Inside the 'bowl' is the variable R Coronae, which is usually easy to see with binoculars, but which periodically develops clouds of soot in its atmosphere and becomes very faint for a while.

Ursa Major, the Great Bear, is in the north-west. Low in the south look for Antares in Scorpius (the Scorpion), which, like Altair, has a fainter star to either side. Scorpius is a magnificent constellation, but is too far south to be well seen from Britain, and part of it never rises at all. Following it round is Sagittarius, the Archer, which has no first-magnitude star, but contains the star-clouds which hide our view of the centre of our Galaxy. Much of the southern aspect is occupied by the large but rather faint constellations of Ophiuchus, Hercules and Serpens, but it is worth seeking out Messier 13, the globular cluster in Hercules, which contains around a million stars; it is dimly visible with the naked eye as a fuzzy patch, and binoculars show it easily. A moderate telescope (say a 3in refractor) will resolve its outer parts into stars.

shows no sign of emission lines, and there is no detectable coma. For the moment the mystery remains, but certainly it is clear that Chiron is even more exceptional than has been thought since its discovery more than ten years ago.

TITAN

With Saturn at opposition this month, it is a good time to look for Titan, the planet's senior satellite. This is easy enough with almost any small telescope, and I even know a few people who have glimpsed Titan with powerful binoculars. During June it is due east of Saturn on the 16th, and due west on the 4th and 20th.

Titan is not much less than 3000 miles in diameter, and is the largest satellite in the Solar System apart from Ganymede in Jupiter's family. As long ago as 1944 G.P. Kuiper reported that it had an atmosphere, which makes it unique among known planetary satellites, but not much else was known before the flight of Voyager 1. Voyager was deliberately programmed to survey Titan from close range, because it was thought that there might be features of unusual interest.

There were! I was in Mission Control at the Jet Propulsion Laboratory, in California, when the Voyager pictures came through. They showed nothing apart from an orange disc. Titan's atmosphere was much thicker than expected, and 'clouds' in it hid the surface completely.

The real surprise came when it was possible to find out the composition of the atmosphere. Most of it is nitrogen, which of course makes up 78% of the air that you and I are breathing; much of the rest is methane. In fact, all the ingredients for life exist there. The main drawback is the low temperature, which is such that methane could exist as a solid, a liquid or a gas – just as H_20 can do on Earth as ice, water or water vapour. On Titan there could be oceans of liquid methane, cliffs of solid methane, and a methane rain dripping down all the time from the orange clouds in the nitrogen sky. It is a fascinating picture.

Unfortunately, we can hardly hope to find out more until the next probe goes out to Saturn, and this will not be for some time yet. America's Cassini mission, which will survey Titan in detail, will not now be launched until well into the 1990s, if then, and as yet the Russians have shown no sign that they are ready to send vehicles out to the remoter reaches of the Solar System.

When the Sun leaves the Main Sequence and turns into a red giant star, in perhaps 5,000 million years hence, the Earth will almost certainly be destroyed, and life here will unquestionably perish.

As the Sun will be around 100 times as luminous as it is now, more heat will reach Titan. Alas – this means that Titan's atmosphere will escape, because higher temperature means that the molecules move faster, and Titan's low escape velocity will not be sufficient to retain them. So there is no chance of a mass migration to Titan; but long before then, men may have landed there, and in any case we must agree that Titan is one of the most intriguing worlds in the Solar System. PE

WEATHER BEAMS

ESA, the European Space Agency, has awarded Ferranti a contract to study ways in which high power lasers might help in weather forecasting. Over a 30 month period Ferranti will examine the feasibility of using a CO_2 laser as the transmitter for a wind 'Lidar' (light detection and ranging) sensor.

The intention is to project a laser beam from a satellite and to measure wind movement by sensing the doppler shift when the beam reflects back from particles in the atmosphere.

Lidars have already been successfully used in sensing wind shear, a localised down draught which can affect the air-speed of an aircraft during takeoff and landing. Mounting the laser in a satellite or other spacecraft could enable wind measurements to be made on a planet-wide scale.

Ed.

SEMICONDUCTORS

PART 8: THYRISTORS AND TRIACS (THEORY)

BY ANDREW ARMSTRONG

BIDIRECTIONAL TRIODE THYRISTORS

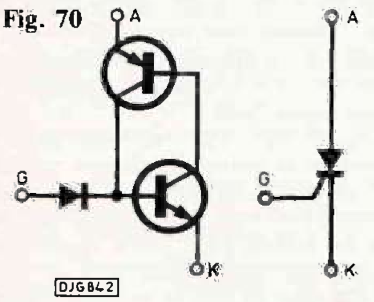
Thyristors and triacs are used to control ac power in a more useful way than relays. Used properly they can be versatile and reliable, but used incorrectly they can fail expensively.

Back in the mists of time, before the transistor, was the valve. The thyristor also has its vacuum tube forebear, the thyratron. This is a cold cathode device which contains a gas.

When the gas is made to ionise by application of a trigger voltage to the control terminal it permits conduction between the main electrodes in the device. Conduction is maintained as long as there is sufficient current flowing to maintain the ionisation. The triggering process is similar to the triggering of a xenon flash tube.

The thyristor works remarkably similarly to the thyratron, but most thyristors require less control signal than thyratrons. The semiconductor structure of a typical thyristor is shown in Fig.69, and an equivalent circuit illustrating the two transistors included in it is shown in Fig.70. As you will observe, a diode is also included in the equivalent circuit, as is the effect with most thyristors.

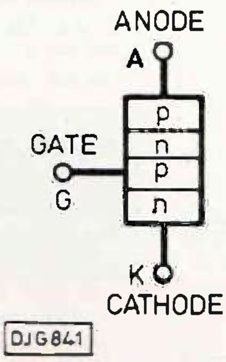
Fig. 70



TRIGGERING

When the gate terminal is raised to a positive voltage sufficient to make a current flow, the lower transistor is switched on. This switches on the upper transistor, which holds on the lower transistor. Only a small current is required to trigger this self multiplying effect. The practical problem exists that too small a trigger current will start the process too slowly and local power dissipation will damage the device before it has switched on properly. Many such switching cycles will eventually cause total destruction, giving rise to the surprised comment "Why did it fail now, after working for weeks?"

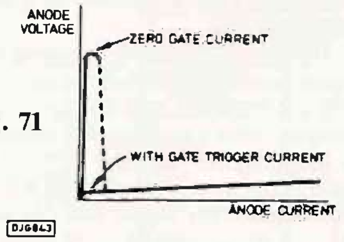
Fig. 69



An associated point to look out for in triggering a thyristor is the di/dt rating. When the device is triggered the current starts to flow over a limited area of the junction, and then spreads over the whole junction. If the load is such that the maximum rated current of the thyristor will atteempt to flow immediately after triggering, then repetitive switching cycles will overheat and destroy an increasing circle of junction, until the device fails.

A typical triggering characteristic is shown in Fig.71. Also shown on this graph is the phenomenon known as breakover, which simply means that the thyristor switches on if excessive voltage is applied. Depending on the nature of the load, this effect will normally protect the thyristor from destruction due to overvoltage.

Fig. 71



It is possible for a thyristor to be falsely triggered by a voltage well below the maximum rated voltage, if the voltage is applied rapidly enough, perhaps as a spike on the supply. There is a maximum dv/dt rating (rate of change of voltage) that a thyristor can withstand without falsely triggering, possibly in a damaging fashion. Too rapid a rise of voltage on the anode will trigger the device because self capacitance will cause a trigger current to flow.

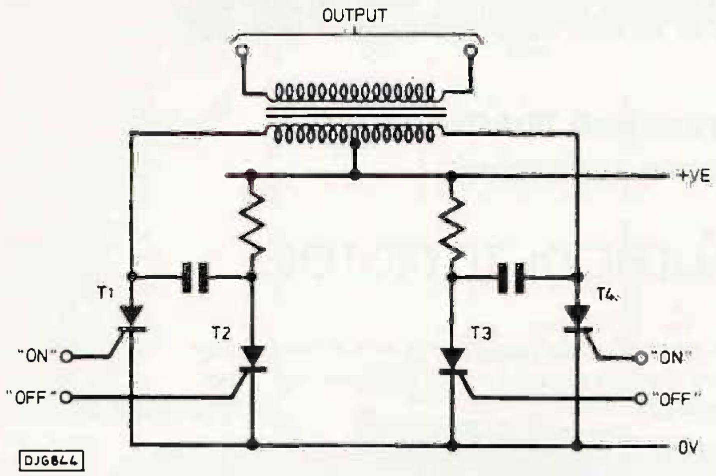
For the reasons above, thyristors are normally used with series inductance and an rc snubber network for protection against any fault conditions known to be possible in the circuit in use. The choice of these components will be considered in more detail as they apply to triacs.

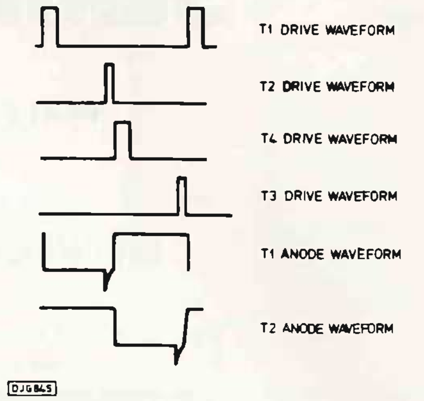
GATE TURN OFF

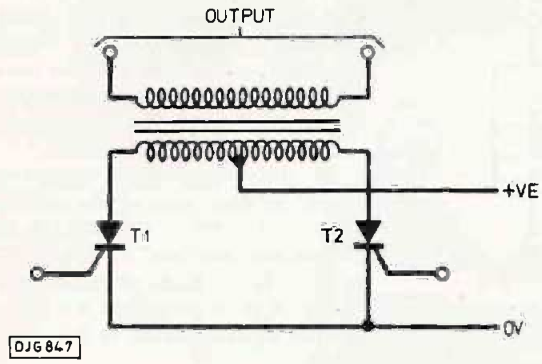
Most thyristors, when switched on, will remain switched on until the current falls below the level required to maintain the avalanche effect which maintains conduction. Certain special devices more recently available can be switched off with a reverse voltage applied to the gate. These devices are known as gate turn off thyristors, or gtos. They are intended for use in some lower frequency switched mode power supplies, inverters, tv deflection circuits etc.

With this type of device it is much easier to use thyristors in dc applications. It may seem strange to wish to do so when transistors are available for the purpose, but thyristors are very efficient in some types of switching applications.

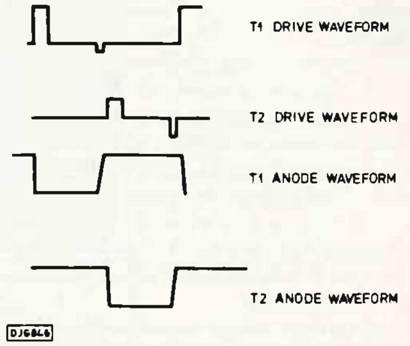
Fig.72 shows a typical method of switching ordinary thyristors in an inverter. The commutation thyristors are normally off, and are switched on when the associated load carrying thyristor must be switched off. When the commutation thyristor is triggered a voltage step from load voltage to 0V appears on its anode. A corresponding negative going step appears on the other side of the capacitor, which pulls the anode of the load carrying device negative, and hence switches it off smartly. The capacitor then charges up, due to the load current, which perforce stops. The current through the resistor is enough to reset the charge on the capacitor over a cycle, but not enough to hold on the commuta-







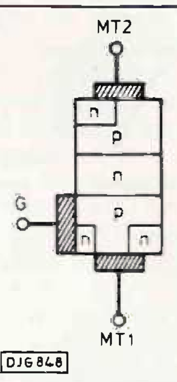
Top left: Fig. 72
Top right: Fig. 73
Bottom left: Fig. 74
Bottom right: Fig. 75



tion thyristor. The drive waveforms are illustrated in Fig.73.

The circuit and waveforms for a gto controlled inverter output stage are shown in Figs.74 and 75. See how much simpler this is. At present conventional thyristors have higher maximum power ratings than gtos, but increasingly powerful gtos are regularly developed.

Fig. 76



TRIACS

The home constructor has few applications for thyristors, which conduct only in one direction. Much more widely used is the triac, or "bidirectional triode thyristor" as some data manuals quaintly call it. Its semiconductor structure is shown in Fig.76. As you can see, between MT1 and MT2 there is a path through a pnpn structure as well as an npnp route. This means that the device can conduct in either direction, but because the path taken by the current is different in either case, a reversal of the applied voltage will switch off the device.

Because both the gate and MT1 are connected to both the p and the n layers at one end of the device, either polarity of gate drive will generate current flow across the pn junction and thus generate charge carriers which will commence the process of switching on the device. However, the mechanism of switch on is more direct and assured if the polarity of the gate drive is the same as that applied to MT2, because in this case the mechanism is the same as that of a simple thyristor.

The more complicated triggering arrangements of a triac reduce the efficiency by which triggering current is used, so the triggering current required for a triac is approximately ten times higher than for a thyristor of a similar current rating.

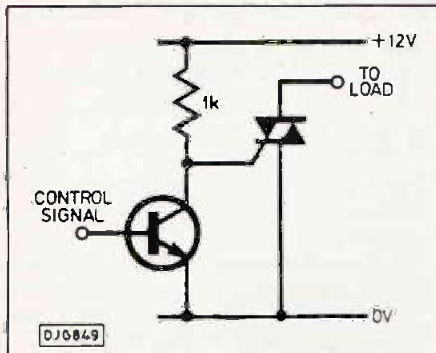
Though triacs can be triggered by a signal opposite in polarity to the voltage being controlled, not all types can be triggered with a positive gate voltage and a negative voltage on MT2. Many samples of triacs not specified to trigger in this quadrant will in fact trigger, but the triggering may be of such a nature as to damage the device because the current buildup is too slow to limit localised heating of the junction. Triacs used in this way may fail after many hours of operation.

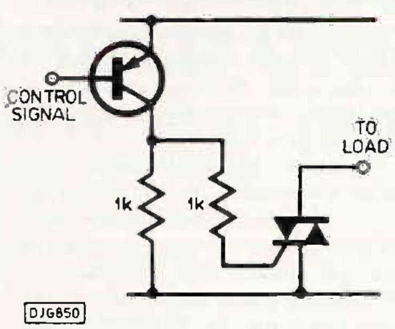
I have encountered a case in which equipment incorporating a substitute for the specified triac has shown over a 20% failure rate in the first month after installation due to this very cause. Apparently the specified device was temporarily unavailable, and someone experimented with various triacs in the bits box until one appeared to work. No one read the data sheet, and as a result items of equipment installed all over Europe started to fail, with high attendant repair costs.

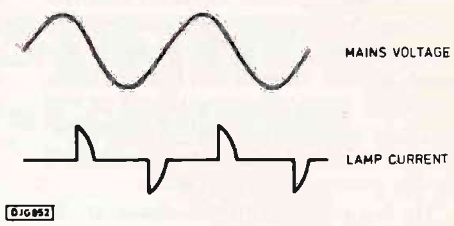
Admittedly the penalties for an amateur construction project are less severe, but it can be a serious embarrassment if your new disco lighting unit fails in the middle of a party. There is an immediate loss of street cred.

The rate of rise of current through triacs and of voltage across them must be limited for the same reasons as with thyristors. Because of the more complicated structure of the triac the limitations are more severe. In addition, because the gate can conduct in either direction, heavy fault currents can flow from the gate terminal if a voltage spike causes false triggering of the device.

This can be a problem, as illustrated by the triac triggering circuit shown in Fig.77. In this circuit, the resistor provides triggering current unless the transistor is switched on, in which case the current flows into the collector of the transistor rather than the gate of the triac. Spurious triggering of the triac can







Left: Fig. 77
Centre: Fig. 78
Right: Fig. 79

cause enough gate current to flow to destroy the gate structure of the triac and the transistor. On the other hand, a triggering circuit such as that shown in Fig.78 will not be damaged by occasional spurious triggering.

This point is not purely theoretical. In one particular industrial installation a series of control units employing the circuit of Fig.77 failed, most exhibiting transistors whose plastic case had cracked due to the heat of the breakdown, and some with just three legs standing where the transistor used to be. Replacement of the unit with one using the circuit of Fig.78 halted the series of failures, even though severe voltage spikes were sometimes present.

MODES OF OPERATION

Perhaps of the most familiar use for triacs is in light dimmers. In this application the triac is retriggered each half cycle of the mains to adjust the amount of power received by a lamp, while minimising flicker. This is illustrated in Fig.79. A power level of considerably less than a quarter is illustrated, because the power delivered to the load is proportional to the area under a graph of V^2 bounded by the firing point.

The lamp current waveform shows very fast rise, and therefore contains very high frequencies capable of causing interference with radio reception. The normal way to minimise this problem is to connect an inductor in series with the load to limit the rate of change of current. A capacitor is often used as well to help filter out high frequencies. This arrangement is illustrated in Fig.80. Note that the capacitor connected between load and neutral is a class X capacitor, specially rated for use on 240V mains.

If short term constancy of power is not important, such as in a heater, then instead of using variable phase angle triggering to control the power, burst firing is used. This type of power control switches the power on and off for several half cycles at a time. A typical period for one switching cycle might be two seconds. To limit interference the triac is normally switched on only close to the mains zero crossing, so that there is no spike of current and hence no interference.

Burst fire control is ideally suited to controlling heating elements, but is useless for lighting control because the lights flash on and off. The average level is correct, of course, but that is like saying that with your head in the oven and your feet in the refrigerator you are comfortable on average.

SNUBBERS

To protect the triac from damage due to voltage spikes on the mains supply a snubber network is normally used. In Fig.80 the snubber network consists of C1 and R1. The value of R1 is chosen to damp the resonance of the inductor and capacitors. Without R1 in the circuit resonant ringing could cause false triggering of the triac.

In applications using burst firing or simply using a triac to switch a load the filtering components are not needed but the snubber network is still required. If the load to be switched is highly inductive, for example a relay or contactor, or a solenoid, then the choice of component values in the snubber network is important to prevent serious ringing. A snubber network with the wrong component values can be worse than none at all.

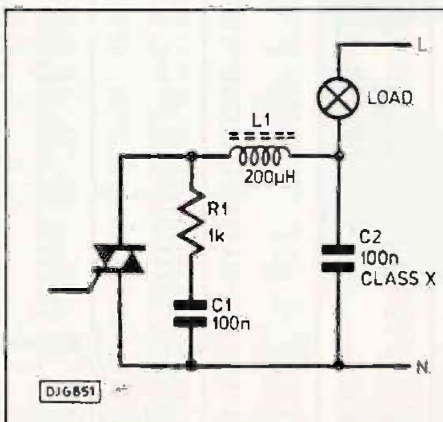
This may seem surprising, so consider the example of a triac controlling a solenoid load with 5H inductance and a power factor of 0.3. This means that the current phase lags the voltage by 60°. When the triggering current for the triac is switched off, the triac will switch off the next time the current reaches zero. As illustrated in Fig.81, the voltage is then at a value of approximately 295 volts positive or negative (assuming 240V mains). Because the current through the load is zero at this point, the situation is equivalent to suddenly applying 295V a series lcr circuit.

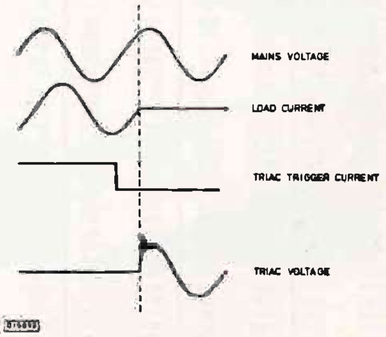
Clearly the voltage on the triac will rise to at least 295V, but it won't stop there. By the time the capacitor has charged to 295V a significant current is flowing in the inductor, and this current con-tinues to charge the capacitor. If the resistor value were very low then the peak capacitor voltage, and hence the peak voltage on the triac, would be 2*295 = 590V. This would definitely trigger a 500V rated triac into breaking down to protect itself, while the normal 400V rated devices used on the mains would not stand a chance.

If a suitable resistor value is used to damp the ringing caused by the sudden voltage step applied to the circuit, then the overshoot will be much less, though of course the resistor limits the ability of the snubber to prevent spurious triggering or damage in the presence of voltage spikes on the supply. If the load is highly inductive, however, this will serve as adequate protection.

One might imagine, therefore, that no snubber network at all would be a reasonable solution. This is not so because in the absence of a snubber network the rate of rise of voltage across the triac when it switches off and 295V appears across it almost instantly is enough to exceed its di/dt rating and cause false triggering anyway. A compromise of components is needed to avoid both these problems.

Here is a reasonable rule of thumb.





Left: Fig. 80
Right: Fig. 81

Choose the capacitor value so that the resonant frequency of the snubber capacitor with the load inductance is in the range 1000 to 10,000 Hz. Then calculate a resistor value to bring the Q of the resonant circuit of the snubber capacitor and the load inductance to 1, and then choose nearest preferred value.

The frequency of an lc resonant circuit is given by the formula:

$$f = \frac{1}{2 \times \pi \times \sqrt{L \times C}}$$

When the resonant frequency is known, calculate the resistance by using the formula Q = 2*π*f*L/R turned around to read R = 2*π*f*L/Q.

For example, if the load inductance is 1H, and the load is mainly inductive so that the resistive part can be ignored for rough calculations, a capacitor of 10nF would be suitable, giving a resonant frequency of approximately 1.5 kHz. The calculated resistor value to meet the stated criterion is 10k, and experiments have shown that this value is effective in the type of case described.

SUMMARY

The important practical rules for using triacs effectively are as follows. Always make sure that the device is specified to trigger under the conditions in which it is to be used. Make sure that the amount of trigger current is suitable, ideally a little above the minimum guaranteed trigger level, but below the maximum permissible gate current.

If the triac is triggered directly from a low level signal circuit, always feed the gate drive in via a resistor. This will avoid heavy gate fault currents in the event of overvoltage causing false triggering.

When using phase angle control, use a filter inductor to minimise radio interference, as well as a snubber network to protect the triac.

If the triac is to be used with an inductive load having a low power factor, choose the snubber network components carefully, and if necessary use a triac rated at a higher voltage than would normally be required for the mains voltage in use. This will enable it to withstand larger rings on the snubber network without false triggering.

Remember that some loads take a substantially greater surge current at switch on than they take when operating steadily. Make sure that the triac is rated to withstand the longest surge which the load will impose on it.

Next month I will show some practical circuit building blocks using triacs, including information on using pulse transformers and opto-triacs for triggering purposes. PE

BOOTING BATTERIES

There is a new discovery by BASF that turns conventional ideas about plastics on their head.

Normal plastics, unless specially impregnated, have good insulation properties. This new plastic has the electrical and thermal characteristics of the best conducting metals. It also has elastic properties, as was shown when a demonstration roll of the fabric was stretched to twice its length.

It is presently being used experimentally to make batteries. A possible application could be moulding the bootlid of a car as a self contained battery. Camera and instrument cases could likewise become their own power source.

Other applications might include the replacement of metal connections in electrical and electronic equipment by plastic circuits, with the obvious advantage of weight reduction. BASF also foresee that plastic containers for food might be given integral self-heating systems. Later this year they intend to launch a battery of postcard size and only three times as thick.

The plastic is apparently made from a family of organic chemicals known as polypyrolles. I claim ignorance about what these are but feel that the standard battery may come in for some battering from this new technology. **Ed.**

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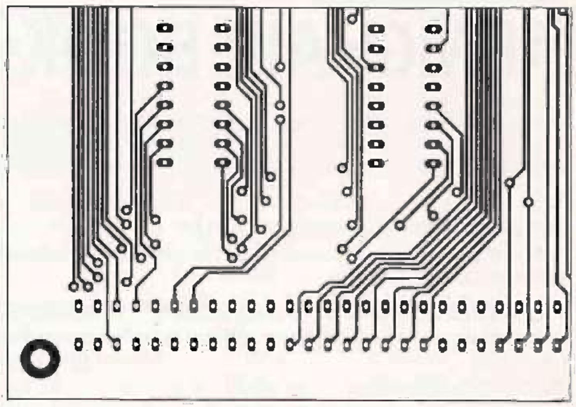

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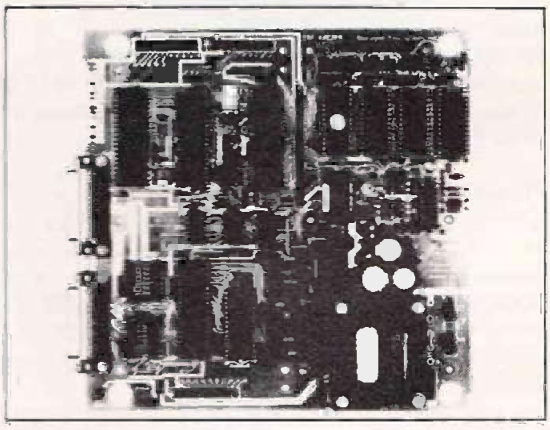

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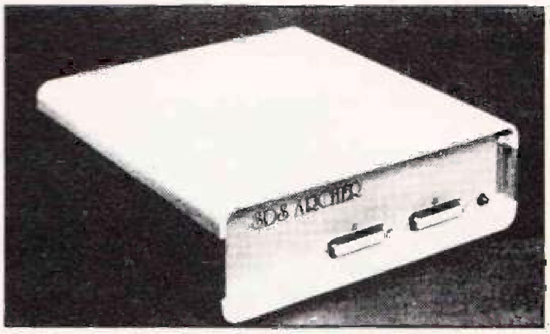

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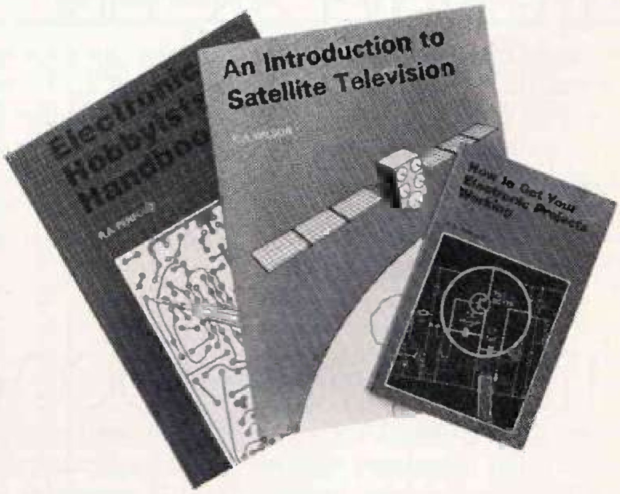

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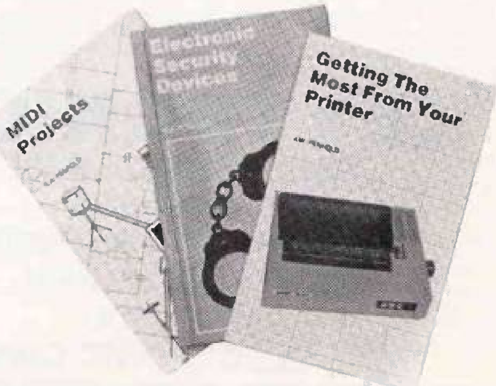

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MISSIONARY MEDIA

BY TOM IVALL

THE TRUTH, AND NOTHING LIKE THE TRUTH

Access to information confers power – if it is the right information. But it is difficult to avoid political bias when powerful nations are broadcasting to the less powerful.

"Why do we always have to listen to the gringos to find out what's happening here in our own backyard?" demanded one contributor to a radio phone-in programme in Honduras. It was during the military crisis in that country earlier in the year, when Nicaraguan troops had crossed the border, the Hondurans were rushing to chase them out and American paratroopers were dropping into the country from the sky. And in a Honduran newspaper a cartoon showed a peasant on a horse galloping away and shouting "I'm off to Washington to find out what's happening in Honduras!"

This was just one example of a situation that prevails all over the world in the acquisition, control and transmission of information. It's very much a one-way traffic, from the rich, industrialised nations to the poorer, developing nations. Whenever something important happens in a Third World country, the news media descend on it like a swarm of bees, strip it of what they consider to be interesting information, send back their reports over telecommunications networks, then disappear as abruptly as they arrived.

Subsequently the people of the country concerned hear about themselves and their doings — through radio, tv, news agencies etc — predominantly as seen by foreign observers. The interpretation is essentially what has been selected as interesting to the audiences in the industrialised countries from which the news teams were sent.

And, of course, this one-way flow of information is not confined to news reporting. It operates through many other channels of communication — entertainment, trade, advertising, education, economic aid, technology transfer and so on. Much of the information delivered through these channels is of direct practical use to a developing country. Unfortunately it also conveys the implied or inferred message: "By this token you are dependent on a superior form of society."

Thus the recipients of this information learn to see themselves perforce not as they feel and think themselves to be but through the distorting lenses of alien perceptions. They experience a form of mental subjugation, to an imposed picture of what life is supposed to be like. They have been edited. It may not always be deliberate — except in the case of political propaganda or unprincipled advertising — but nevertheless has the effect of indoctrination.

The process occurs because the industrialised countries are dominant not only in economic power but in communications as well. First they are able to acquire much greater quantities of information, in all the categories mentioned above, than is possible for the developing countries. Secondly they possess much more highly developed means of disseminating it — books, newspapers, news agencies, magazines, films, telephones, data transmission, broadcasting, sound and video records and so on.

Electronics miniaturisation, for example, has made possible 'satellite news gathering' with the 'fly-away' satellite earth terminal. If an important news event occurs in some remote part of the world, a broadcaster can pack one of these portable terminals in a private aircraft or in the hold of a scheduled airliner and immediately fly to the nearest available landing point. From here the terminal can be taken by road or even caried by humans to a suitable transmission site. Television and sound signals are fed in and uplinked to a communications satellite, which relays the pictures and sound straight back to the broadcaster's home base. Only the richest and most technically advanced broadcasting organizations can own and operate such equipment.

All the modern apparatus of communications started to build up from the late 18th century onwards. It was both an outcome and a necessary part of industrialization. At the same time this apparatus was used for colonial administration, which at its best was enlightened and at its worst repressive.

Now, in the 20th century, the colonies have become the developing nations. Having gained political autonomy, they are struggling to secure the rights that go with this autonomy — national sovereignty, economic independence and cultural integrity. But achieving these goals is extremely difficult, not only because these new countries are economically weak. To a great extent they are still colonised — through information and its cultural and intellectual side-effects.

In theory the peoples of the developing countries are not being influenced to think or feel in any particular ways. They are just presented with information and allowed to make up their own minds. But in practice their situation corresponds to what happens within the industrialised countries themselves. Broadcasting, newpapers and other media cannot tell us what to think. But through selection of information they do control what we think *about*.

In totalitarian countries the flow of information is largely controlled by the state. In market economies it tends to become an industry run for profit. Both systems exploit the media and can lead to distortion, conformism and the production of stereotypes. In the extreme, persons become objects managed by professional communicators. They are manipulated and mentally homogenized. They devolve into mere consumers of packaged information products to which they have in no way contributed. These processes strengthen the position of the dominant groups and the established orders.

On the principle of 'what we have we hold' the industrialised nations have done nothing to change the situation. This still leaves us with a need for a greater democratisation of communication. Information should not only reach but emanate from all parts of the world's population, including minorities and disadvantaged groups. Regardless of economic and military power, there should be a dialogue between equal partners instead of a one-way transmission from the rich and powerful to those whom they wish to influence or exploit.

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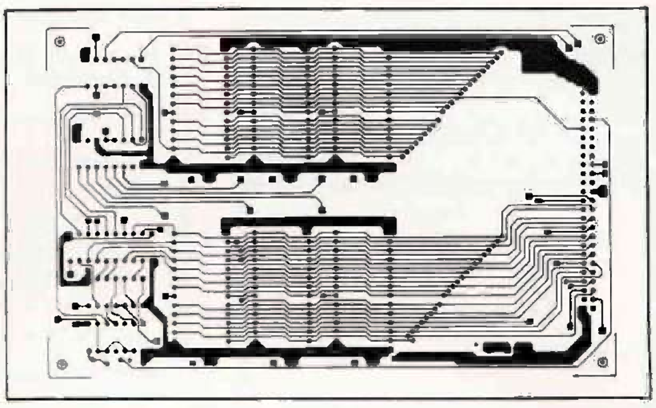

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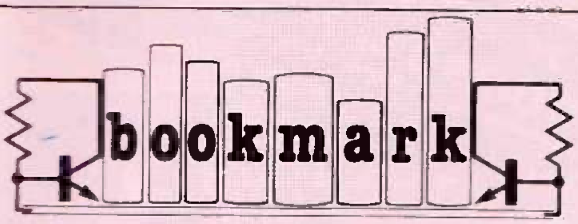
MAINS MODEM	174	£4.27

THIS MONTH'S BOARDS

JULY 88		
VOCALS ELIMINATOR	175	£4.31



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

Tv Dx for Beginners – 2nd Edition. Simon Hamer. HS Publications. £2.95 inclu UK post, £3.75 airmail worldwide. How to receive foreign tv broadcasts in simple and practical terms with our satellite tv receiver. 24 pages of useful guidance to assist anyone with their first attempts at long distance reception. HS Publications have other books (and equipment) on dx and satellite tv – send two first class stamps or two ircs for details.

Logo for Beginners. J.W. Penfold. Babani BP193. £2.95. ISBN 0-85934-167-4. An introduction to the programming language Logo, and also to computing more generally as it assumes no previous knowledge of either. It starts with the famous turtle graphics, explores mathematical and logical aspects of Logo, and finally looks at list processing, on which many aspects of artificial intelligence are based.

Getting the Most from Your Multimeter. R.A. Penfold. Babani BP239. £2.95. ISBN 0-85934-184-4. Definitely a book that any serious electronics enthusiast, however experienced, would do well to read. If you know how to use a meter fully many component and circuit tests can be carried out without more expensive gear. A multimeter is the first essential piece of test equipment you should buy, so get the most from it through the help of of this book – which is also available from the PE Book Service.

Introducing Digital Audio. Ian R. Sinclair. PC Publishing. £5.95. ISBN 1-870775-05-8. The subject of dat, cd and sampling is still surrounded by a certain amount of mystery and PE is currently clarifying the subject in a series of articles. This book in many ways compliments the PE series by discussing the basic principles and methods while intentionally avoiding the more technical and mathematical aspects of the subject. We have included the book in the PE Book Service.

Practical Midi Handbook. R.A. Penfold. PC Publishing. £5.95. ISBN 1-870775-10-4. Midi is the control protocol used for interfacing musical instruments. Robert Penfold has written much on the subject in PE and has expanded his thoughts on the subject in this excellently informative book. He does not give constructional circuits for Midi add-ons, but he thoroughly explains Midi's nature, what it can do, and how you can exploit its potential more fully. All the common Midi instruments are covered. Computer music software has its own section, and guide lines for programming are included. This book is now in the PE Book Service.

Prentice Hall have advised us of a number of books on transputers that they are publishing during 1988 in association with Inmos, the originators of the transputer:
Transputer Reference Manual. £19.95. ISBN 13-929001-X.
Transputer Instruction Set: A compiler Writer's Guide. £19.95. ISBN 13-929100-8.
Transputer Development System. £24.95. ISBN 13-928995-X.
Digital Signal Processing. £19.95. ISBN 13-212804-7.
Communicating Process Architecture. £19.95. ISBN 13-629320-4.
Transputer Technical Notes. £19.95. ISBN 13-929126-1.

Publishers' addresses in case of difficulties –
Babani Books, The Grampians, Shepherds Bush Road, London W6 7NF (who also have good catalogue FREE on request). HS Publications, 7 Epping Close, Derby, DE3 4HR. 0332 381699. PC Publishing, 22 Clifton Road, London N3 2AR. Prentice Hall, 66 Wood Lane End, Hemel Hempstead, Herts HP2 4RG. 0442 231555.

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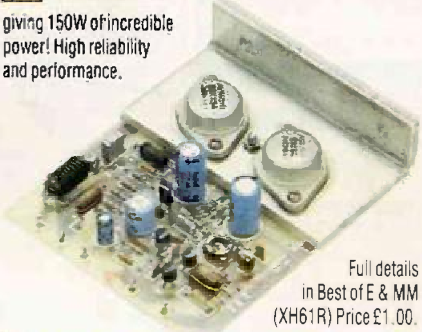

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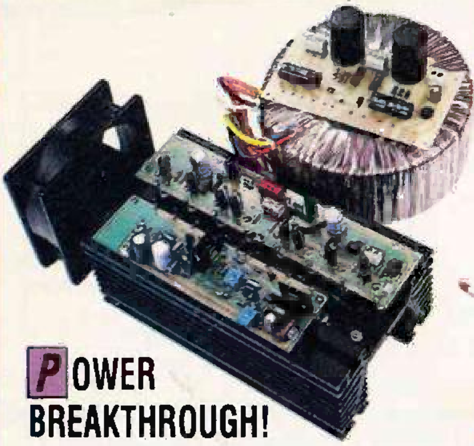

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