ETI
ELECTRONICS TODAY INTERNATIONAL

THE ELECTRONICS, SCIENCE & TECHNOLOGY MONTHLY

NOVEMBER 1988 £1.50

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■ TLX700 — Micro size telephone transmitter. Connects onto line at any point and requires no batteries. Clearly transmits both sides of conversations on both incoming and outgoing calls. Undetectable by phone users. Fully tuneable output covering FM band. Range up to 1000m. Measures just 20mm x 20mm **£9.95**

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■ XML900 — RF Bug Detector/Locator. Wide band input circuitry detects presence of RF field and triggers flashing LED and piezo bleeper. Variable sensitivity enables source of transmission to be pinpointed to within 6 inches. Max sensitivity will detect MTX or similar transmitter at around 15-20 feet. 9V operation. Measures 55mm x 55mm **£21.95**

All kits come fully documented with concise assembly and setting-up instructions, high quality fibreglass PCB and all components necessary to complete the module. All prices are inclusive but please add £1.50 to cover P&P. Orders over £50.00 post free. Please state requirements clearly and enclose cheque or PO to cover.

Phone orders on ACCESS or AMEX accepted. Tel: 0827 714476

NOTE: It is illegal to operate a transmitter in the UK without a licence

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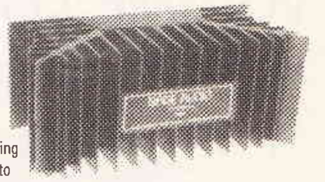

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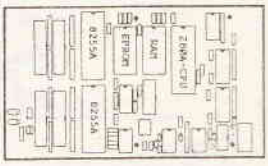
THE ORIGINAL SUPERMOS MODULES 50-150W **£65 plus (£1.50 p&p)**

Send to:- SAGE AUDIO Wendy (Sales Dept.), Construction House, Whitley Street, Bingley, W. Yorks, BD16 4JH England. Tel: (0274) 568647, Tlx: 517783, Fax: (0274) 551065

Interak 1



Bare Board £17.50 (plus postage and VAT)

SINGLE BOARD COMPUTER "SBC-1"

A computer doesn't have to look like you'd expect a computer to look. It doesn't have to have a keyboard and a screen and floppy disks and so on.

The SBC-1 has the bare minimum of chips a Z80 computer can have and still be a computer: A 4MHz Z80A-CPU chip, an EPROM chip (up to 32K), a static RAM chip (up to 32K) and a pair of 8255A I/O (input output) chips giving 48 individual lines to waggle up and down. There are one or two additional "glue" chips included, but these are simple "74LS" or "HC" parts.

A star feature is that no special or custom chips (ie PALs, ULAs, ASICs etc) are used — and thus there are no secrets. The Z80A is the fastest and best established of all the 8-bit microprocessors — possibly the cheapest too!

Although no serial interface is included, it is easy for a Z80A to waggle one bit up or down at the appropriate rate — the cost is a few pence worth of code in the program: why buy hardware when software will do?

Applications already identified include: Magnetic Card reader, mini printer interface, printer buffer, push button keypad, LCD alphanumeric panel interface, 40-zone security system, modem interface for auto sending of security alarms, code converter (eg IBM PC keyboard codes to regular ASCII), real time clock (with plug in module), automatic horticultural irrigation controller.

By disabling the on-board Z80A-CPU this card will plug into our Interak I CP/M Plus disk-based development systems, so if you don't fancy hand-assembling Z80 machine code you don't have to!

The idea is (if you are a manufacturer) you buy just one development system and then turn out the cheap SBC-1 systems by the hundred. If you are really lazy we can write the program for you and assemble the SBC-1 cards so you can get on with manufacturing your product, leaving all your control problems to us.

Greenbank

For more details write or phone us:
Greenbank Electronics, Dept. (T11E), 460 New Chester Road, Rock Ferry, Birkenhead, Merseyside L42 2AE. Tel: 051-645 3391.

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November 1988

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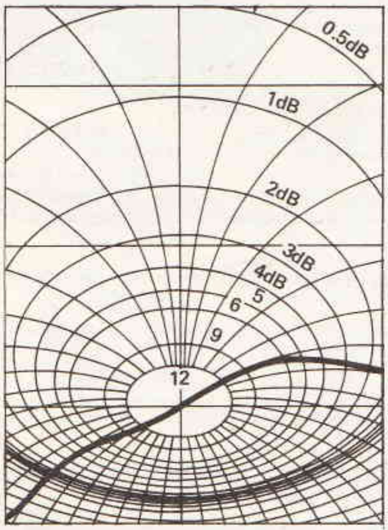
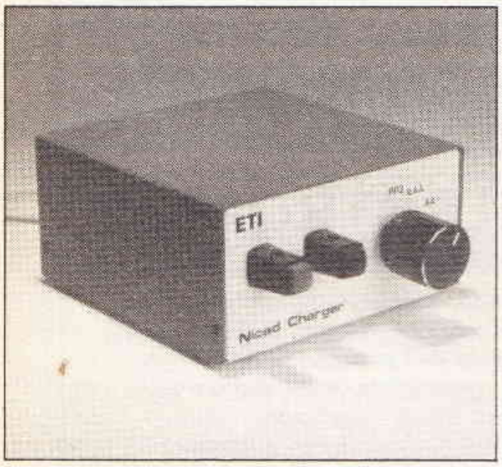
Page 12



Page 35



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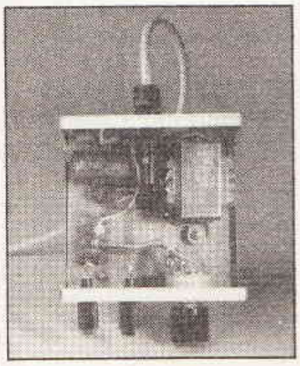
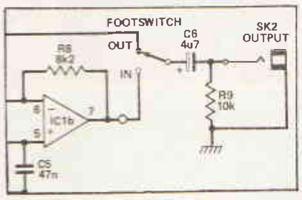
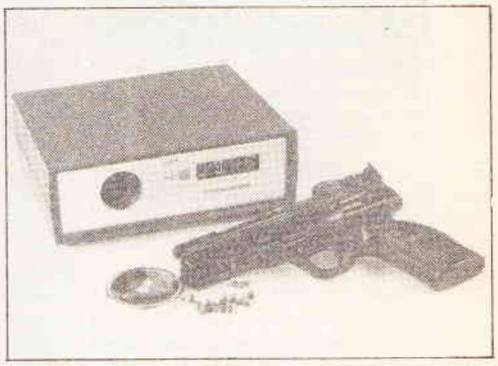
TODAY INTERNATIONAL

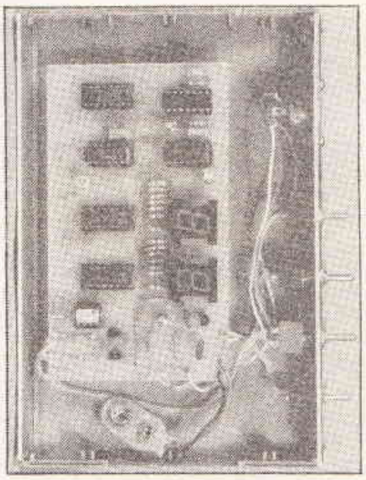
FEATURES/PROJECTS







Page 43



Page 29

Page 38

NEWS

THE PRICE IS UP

It is with great regret that we have to announce a 10p rise in the price of your favourite electronics mag, as of this month.

Despite our continued success since the new-look ETI was launched in April, our man with the desktop calculator and sharpened HB in his mouth tells us that the price of trees has risen something shocking this season.

We deeply apologise and hope that you will consider the extra coin to be money well spent.

DOMESTIC ARGUMENT

Government intentions to allow large industrial electricity users to sign direct contracts with generating companies will lead to increases in domestic charges, warns a new report from economist Dr Dieter Helm.

In order to compete with these direct sales the area distribution boards would have to reduce industrial prices and raise domestic charges to balance the equation.

Dr Helm details the importance of getting the details of regulation (and preferably the regulatory body itself) established quickly and before privatisation, to examine contracts in the period before the splitting of the CEGB and creation of the area boards.

The report *Regulating the Electricity Supply Industry* costs £5 and may be obtained from Blackwells, 108 Cowley Road, Oxford.

FLIP-TOP TV

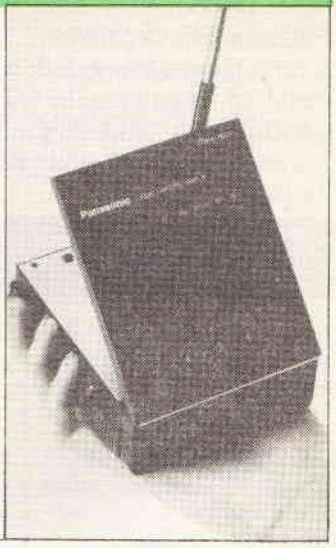
Panasonic has produced Minivision, its new compact portable TC-L3 colour television with a flip-top screen to make use of environmental lighting.

The unit is battery powered though can be powered from the mains or from a car battery (perhaps not the safest place to watch it . . .).

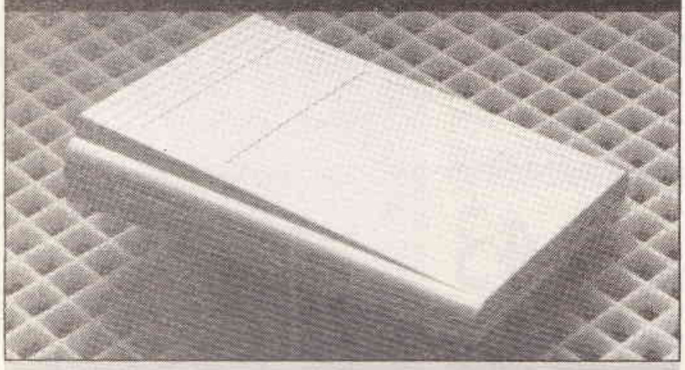
The 3in screen achieves a sharp clear picture thanks to Panasonic's Active Matrix technology — liquid crystal display with a thin film transistor on each LCD segment to control over 100000 pixels.

The TC-L3 should be available this month at a retail price of £329.95.

For more information contact Panasonic Consumer Electronics, 300-318 Bath Road, Slough SL1 6JB. Tel: (0753) 34522.



SLIMLINE TONIC

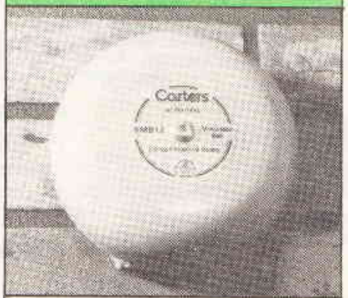


West Hyde has introduced a new slimline case designed for use with membrane keypad switches. The case is sealed to standard IP65 so that with hermetically sealed membrane switches the whole unit can be safely doused with Nescafé.

West Hyde has also announced significant price reductions particularly on Teko, Internorm and Combicard 500 products which are benefiting from exchange rates and higher production quantities.

For full details contact West Hyde, 9-10 Park Street Industrial Estate, Aylesbury HP20 1ET. Tel: (0296) 20441.

ALARM



With burglars to bust this month, Carters has introduced a very reasonable motorised bell which produces a 95dB ringing tone when triggered. The enclosure for the motor is fully weather protected and the bell dome is fitted with anti-tamper clamp screws.

The bells are available for two voltages: 12V at £7.60+VAT and 24V at £7.90+VAT.

Contact Carters, A&G Security Electronics, Wrigley Street, Oldham, Greater Manchester OL4 1HW. Tel: 061-633 3033.

CD-INFO

Pergamon's launch of the CD-ROM version of the 10-volume *International Encyclopaedia of Education* includes a free Hitachi CD-ROM drive with every copy. The Hitachi drive is for IBM compatible computers and has been left undedicated so that other CD-ROMs may also be read.

The software for the encyclopaedia attempts to be as simple to use as possible so that casual use in libraries and schools can be encouraged. Search topics are defined in the user's own words rather than being picked from the indexing system. Figures and illustrations are included and all displays may be printed out.

Meanwhile Nimbus is embarking on a series of discs aiming to place the entire World Heath Knowledge Base onto CD-ROM. First in the series is an AIDS information and expert system, with a diagnostic aid to examine symptoms and identify diseases that a physician should consider treating. Further details of such treatment can then be accessed.

For details of Pergamon's CD-ROM operation contact PCS, Headway House, 66-73 Shoe Lane, London EC4P 4AB. Tel: 01-377 4918. Nimbus Records is in Wyestone Leys, Monmouth NF5 3SR. Tel: (0600) 890682.

MAIL ORDER

A new mail order service for components, tools and equipment is being offered by EES from their Southampton address. There is to be no minimum order and all normal credit cards can be used for telephone or written orders.

A catalogue is under production and can be obtained by ringing the number below.

One handy service that EES is offering is one-off customised sheet metal working for enclosures, including hinging, panel cutting and silk screening.

For full details and the catalogue contact ESS, Harrison House, Harrison Road, Swaythling, Southampton SO2 3TL. Tel: (0703) 671166.

FREEBIES

A vast selection of literature and lists are up for the price of a stamp this month.

Omni's new mail order catalogue of components, tools and accessories is now available for two 18p stamps. Tel: 031-667 2611 or visit the shop at 174 Dalkeith Road, Edinburgh EH16 5DX.

Welwyn has produced a comprehensive guide to its SM resistors (Tel: (0670) 822181) and Multicore has written a trouble-shooting wallchart identifying the problems of SM soldering (Tel: (0442) 233233).

Hitachi has published an excellent 16-page guide to its CMOS and biCMOS gate arrays and also a short brochure on combo codec ICs. Contact Hitachi, 21 Upton Road, Watford WD1 7TB. Tel: (0923) 224422.

Rittal is giving away a thermal management slide rule to stop your enclosure overheating (Tel: (0909) 567871) and Instrumex has issued the first update to its Instruments for Industry Blue Book. Tel: (0753) 44878.

Handy for Chip In, Hamlin Electronics has a 16-page catalogue of the company's magnetic proximity sensors. Tel: (0379) 644411.

Topax has a full colour brochure of industrial mains conditioners (Tel: 01-977 0055) and lastly Axion Electronics has a free guide to CMOS special functions from Turnpike Road, Cressex Estate, High Wycombe HP12 3NR. Tel: (0494) 461616.

MISSION OF SUCCESS

Following up our education special last month, a Lancashire-based company is offering a collection of learning and project packages for schools, colleges and home constructors.

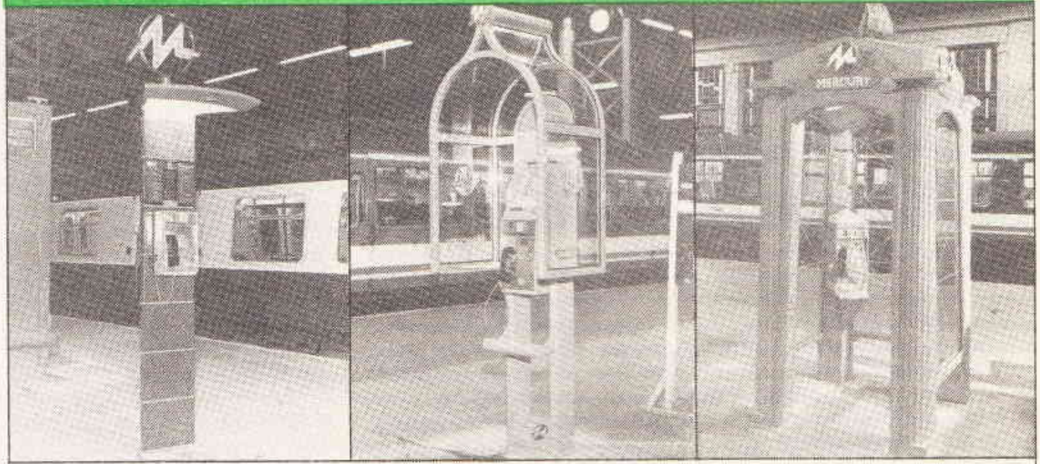
Electronics Success Ltd is an unusual company. It has been set up by a group of christian electronics and computing engineers to generate capital for a schooling project in the Far East. The vision is to run two schools: one as a fee-charging residential computing school, and the other as a free school for those unable to pay, supported by the fees from the first.

It is an ambitious project and Electronics Success are hoping to generate the initial capital over the next two years.

There are five packages ranging from the £30 *Elementary Learning Package* (containing 125+ components, 2 books and 2 wallcharts) to the £280 *Complete Constructors Package* (with 15 books, 3000 components, test instruments, 20 tools and soldering iron).

For full details contact Electronics Success, PO Box 10, St Annes on Sea, Lancashire FY8 1SA.

MERCURY DESIGNER KIOSKS



Mercury has opened its offensive on the UK public payphone market with 26 callboxes in London's Waterloo station. The units are cash-free with payment made using Mercury's own phone card, the Mercurycard. Unlike BT's Phonecard boxes, the kiosks can also accept Access, Visa, Amex and Diner's Club cards.

The design of the boxes has been the subject of some criticism. Mercury invited proposals from ten design houses and has selected three final kiosks to be adopted. A range of kiosks provides a 'sympathy with environment' not available with the single BT kiosk, says Mercury.

The three designs are an art-deco totem, a Gothic glass canopied standing kiosk, and a dreadful classically columned box that is unlikely to be 'sympathetic' anywhere beyond the gates of the British Museum.

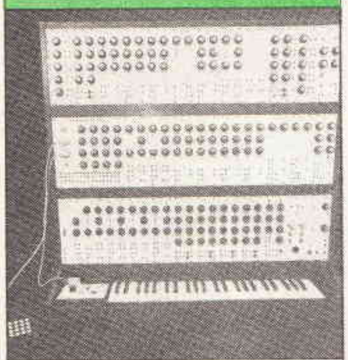
However Mercury can be proud of its technology and price structure. Every kiosk is directly connected to Mercury's digital optical fibre network — although this does limit new payphone sites to areas already covered by its own network.

The payphone unit itself, supplied by GPT, is sensibly laid out with simple instructions on LCD display and the useful addition of a volume control. All units will be serviced daily and are self fault reporting.

The charges are also lower than BT callbox rates by an average of 5% (inland) plus the major advantage of phonecard units being 5p rather than BT's 10p, which will halve the cost of brief local calls.

For more details contact Mercury, 90 Long Acre, London WC2E 9NP. Tel: 01-528 2000.

GOLDEN OLDIE



The Digisound Modular Synthesiser projects that appeared in ETI back in 1980 are now available in kit form again.

The original modules are available in improved form together with a range of new units including a keyboard controller and a sound sampler. Also available are analogue and digital VCOs, a profusion of filter modules, processors and effects units.

From these can be constructed a modest monophonic instrument or a TanDram special like the one pictured here.

The variety of components makes price listing a lengthy business but a catalogue with kit information and price lists is available free from Digisound, 16 Lauriston Road, London SW19 4TQ. Tel: 01-946 0467.

DESIGNER AWARDS

The Young Electronic Designer Awards sponsored by Texas Instruments and Cirkit have grown over the years into quite a major event.

This year's awards ceremony was held in a plush London conference centre with 'personalities' in attendance and Education and Science Minister Kenneth Baker handing out the prizes of cash, certificates, trophies and TI calculators to the winners in the three age groups.

In the under 15 age group the winner was Nicolas Adams (14) who had designed an effective pillow vibrator alarm to alert deaf people that other alarms (clocks, smoke detectors, burglar alarms, etc) were sounding.

The 15-19 group winner, Paul Dagley-Morris (17), also won last year. This year he again concentrated on the disabled market with a radio linked panic button for existing alarm systems in retirement homes and so on.

Hugh Mair (20) won the 19-25 category with a 20MHz digital storage oscilloscope add-on for a PC along with some impressive software.

The cash prizes ranged from £50 for the runner up in the youngest category to £500 for the 19-25 winner along with £600/annum course sponsorship, vacation employment and a guaranteed job with TI after graduation.

MATRIX MANAGEMENT

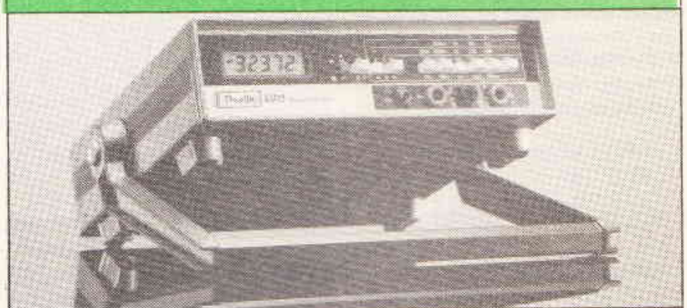
Professional prototyping using a customised version of a standard board is the service being offered by Matrix Systems.

The initial board uses the Intel 8052AH BASIC together with an on-board EPROM programmer, 8K of EPROM, 8K of static RAM, various ports (for VDU, printer and so on). Further hardware is then built on to the board (plenty of space is available) either by the user or by Matrix who offer production assistance form ASIC design through to case design.

As an example of the ability of such a system, a CPU card, bus card, I/O card and ADC card can all be replaced by one Matrix board plus three additional ICs to give 16-channel 8-bit data sampling with 24 relay control lines.

For more stuff contact Matrix Systems, 356 Silbury Boluevard, Milton Keynes MK9 2LR. Tel: (0908) 604848.

BENCH METER UPGRADE



Thurlby is marketing a new high accuracy bench digital multimeter, an improved version of the successful 1503.

In addition to normal functions the unit measures frequency up to 4MHz (7MHz with overflow ignored) with 100Hz resolution, and 0.0025% full-scale accuracy.

Resolution for normal multimeter functions is 10μV, 10mR and 1nA. The unit can be powered from mains or batteries and costs £185.00 + VAT.

Contact Thurlby Electronics, New Road, St Ives, Huntingdon, Cambridgeshire PE17 4BG.

READ\WRITE

PARTICLE ARTICLE

With reference to your article on particle physics in September, may I expound an alternative view?

It is well known that when an electron meets a positron the result is mutual annihilation with formation of two gamma photons, each with energy of 0.51MeV. Conversely a pair of photons at or above this energy can interact to form an electron/positron pair. The logical explanation is that an electron therefore consists of a 0.51MeV photon constrained into a circular path by its own relativistic field. A path length equal to the wavelength gives a circle radius of 3.863×10^{-13}m with toroidal symmetry.

Further, if the photon's plane of polarisation rotates 360° with one wavelength then its field becomes consistent with that of a magnetic dipole (perhaps with a small gyrational component). How the dipolar electrical field of a free photon becomes a unipolar field when constrained into a circular path I cannot yet explain.

Neutrinos are similar but have no magnetic dipole or unipolar electric field — my guess is that these are analogous to AC rather than DC, with their fields constantly inverting.

I also propose that quarks are simply leptons (electrons and neutrinos) travelling at such high speeds that almost all their mass is relativistic in nature.

Henry Earle
Nottingham

*Yes and no. Yes, $E=mc^2$. Yes, an electromagnetic field can become a matter field and vice versa. But they are not the same thing. The 9.11×10^{-31}kg rest mass of an electron **can** be released as a 0.51MeV photon but the electron is not merely a photon in disguise. Photons only travel at the speed of light because they have zero rest mass — a phrase which should not be interpreted as meaning they might have mass in some other circumstances.*

$$m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}}$$

No matter what circular path you constrain them in, photons are massless. Electrons cannot therefore be made of electromagnetic energy and the points about toroidal symmetry and so on do not follow. You cannot make matter out of photons without changing them into something else — in which case the other arguments don't really work.

RANDOM ERRORS?

I cannot see how the Random Number Display (August 1988) can work. After every ten clock cycles a single digit will be back to its original state with the same interval between it and the next digit. After ten states the 'random' numbers will wrap around.

Adding time delays before a digit is latched simply alters the intervals between the digits.

The only way for the circuit to work is as a single counter from 000 to 999 stopped at random (or with a delay) by the Tripetrimmers Committee.

A Thorne
West Morrs, Dorset

You have assumed that all three counters are locked in phase. In practice even if the oscillators were the same frequency they would drift in phase so that all combinations of 000-999 could be obtained.

EAN MEANS BEANS

I have often wondered about the bar code on my beans and was looking forward to the solution to your puzzle. I am quite at home with binary, hex and checksums but after reading your solution I still have no idea how to decode my beans (I don't even know what EAN stands for). Is this the best your staff writers can do?

While my blood is up, there is another thing. Although an occasional jest is welcome, I find your schoolboy compulsion to squeeze a pun into every other line tiresome. Imagine trying to find Mike Barwise's Brought to Light series from the index in two year's time. Any editor that allowed that piece to be published without laser or diode in the title should be tarred, feathered and hung out to dry, head downwards, from the top of Nelson's Column on a thin piece of string.

Niel Mackay
Hastings, East Sussex

OK we give in. The profusion of letters demanding a detailed explanation of bar code encryption are answered on page 21. It took a whole page to explain — the original solution simply did not have enough space to go into detail.

As for the indexing, all articles are cross referenced and appear under both title and subject to avoid just this problem. Please put that thin piece of string away!

SPEAKING FOR OTHERS

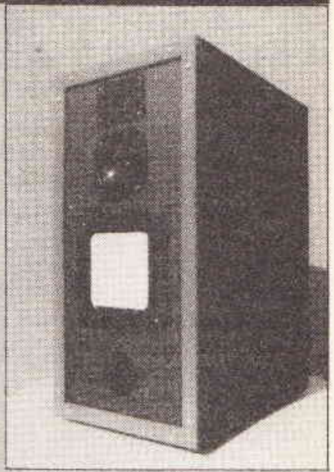
I have just read the article by Malcolm Walms *Speaking For Yourself* in your September issue and cannot let his remarks pass without comment.

Speaker kits are 'only to be found in obscure electronics dealers and through obscure mail order firms'. We are in our 30th year and with a £1M turnover are hardly obscure.

I have sent you a copy of our DIY speaker catalogue which may help to bring Mr Walmsley up to date. Our 'Total' kits include cabinets in flatback form. These are accurately machined from 18mm MDF with baffle apertures, rebates, etc ready cut. We can supply iron-on veneer for the cosmetic finish of the cabinets. Constructors often send us photographs of the completed speakers — usually beautifully done and the finish is superior to all but the very best of the ready-mades.

Edge glued ¾in chipboard without battens and then covered with vynide. Yuk — weak construction and probably not airtight. It's enough to put potential constructors right off the idea.

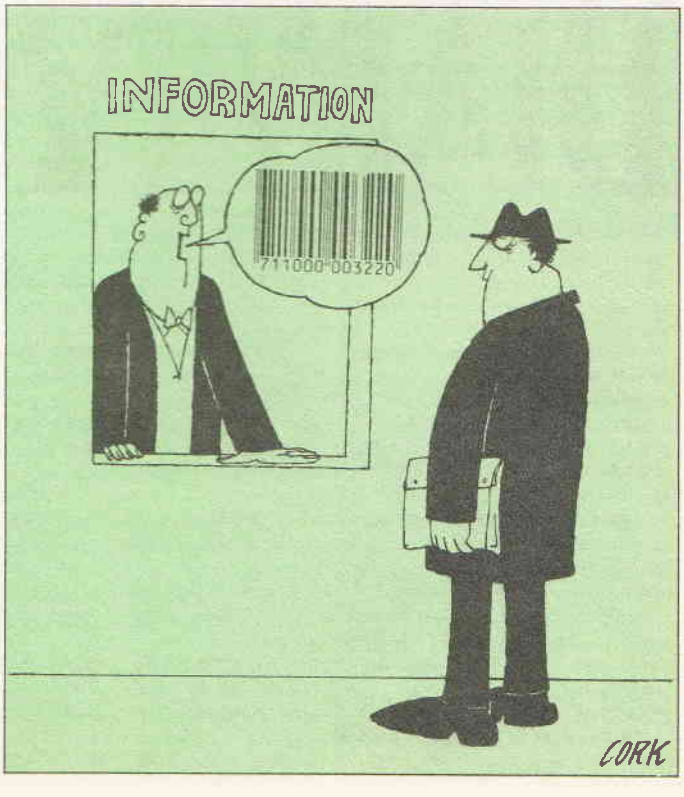
Dick Stephens
Managing Director
Wilmslow Audio



Malcolm's obscurity comments in his review of Maplin's speaker kits were directed at the apparent lack of speaker kits in the high street hi-fi dealers today. There was a time when most hi-fi dealers sold speakers in kit form as well as ready made. We accept that Wilmslow Audio has been trading for 30 years and are happy to hear of your excellent turnover, however, the fact remains that to the vast majority of the audio-buying populace speaker kits are nowadays conspicuous by their absence.

*Malcolm's chipboard cabinets are certainly airtight and strong. Most commercial speakers are still made of chipboard and even without the ubiquitous battens, the cabinet we had in the ETI office for photography was strong enough to survive a fall down the stairs (sorry Malcolm!) without a scratch. As to the finish, Malcolm could well have purchased some veneer to make his speakers look like everyone else's but the vinyl covering and wood front frame was chosen as a tough and durable finish which looks both attractive and **different**. The materials chosen are also commensurate with the low price of the Maplin units.*

We appreciate the extra ease of construction of your Total kits (although the expense is correspondingly greater) and we (or Malcolm) would be happy to build up a review pair of one of your models in the future.



INSIGHT

Japan's electronics industry is presently in a period of painful readjustment to the outside world.

The willingness of major manufacturers to expand and relocate production facilities in Western Europe and America is not simply to facilitate the harmonious global electronics industry — as promoted in the literature of the EIAJ (Electronics Industries Association of Japan).

Japan's exports are suffering badly from the continuing strength of the Yen against the American dollar and the move away from home production is a direct result.

Trade contracts are conducted almost exclusively in dollars so that products made with Yen capital are more expensive on the world market. Manufacturing abroad allows the Japanese companies to compete with foreign firms on equal terms, (although this damages Japan's balance of payments). Many products, particularly consumer electronic equipment, are now being sold back to Japan by Japanese companies but are manufactured in Asia, Europe or America.

The advantages for other countries are obvious — capital investment, employment opportunities since most of the workforce will be local, not to mention a major reduction in Japanese imports. Japan, in the guise of the EIAJ, carefully takes into account local communities and industries to ensure mutual prosperity and minimising of any initial resentment of the Japanese working practices.

However, the rising yen is not the only problem facing the Japanese economy. There is also the increasing competitiveness of countries in Asia such as Taiwan and South Korea — the NIEs (Newly Industrialising Economies).

Products from Asia are not only gaining global market ground but are beginning to encroach on Japan's home territory. Combined with attractive prices courtesy of the yen, Japanese imports of video equipment for instance rose by almost 300% last year, colour televisions by almost 900%. While they remain as only a fraction of the vast Japanese production, gains of this magnitude need little time to make significant inroads. The climate that is promoting imports to Japan shows no signs of change and the Government can do little in the face of continuing international demand for improved access to Japan's home market.

In 1987 the home market for consumer equipment in Japan exceeded the export market for the first time. This is mainly down to the export market being lost to NIEs and the effect of the strong yen, as well as it being supplied by Japanese manufacturers abroad. Export reductions — particularly to the US, now at half their 1985 levels — led to an 11% decline in home production. The reversal in relative importance of imports and exports marks a major change to the structure of the industry.

Home demand has been boosted both by some strong stimulative measures taken by the government and by the introduction of new products — HDTV, digital audio, CD video and DBS receivers. The decreasing likelihood of HDTV being accepted as a global standard will reinforce the domestic market as the major driving force for consumer equipment in the next few years.

In contrast, performance in the field of industrial electronic equipment shows less cause for Japanese concern. Production rose by just under 10% last year with computer peripherals (US markets) and wire communications doing especially well. Domestic demand for the former is also booming and this sector of electronics seems to be relatively trouble-free.

Thirdly comes the component industry. Although exports of all components increased (ironically often through use by those NIE consumer equipment manufacturers), the demand for each area is unstable, with the exceptions of PCBs and LCDs.

There has also been a good deal of trade friction in recent years regarding dumping and subsequent pricing regulations of memory chips between Japan and the US. The semiconductor industry suffers from painful cyclical supply shortages and gluts (we are at present in a DRAM memory famine with prices more than four times their 1986 levels).

Japanese companies lost perhaps $4 billion in the early eighties by continuing production while US and European companies were moving to other areas. The reward was to massively enlarge the Japanese share of the market and to give them what is now estimated as a two year lead in processing techniques.

With memory demand now booming again only the Japanese have been able to meet demand and large profits have resulted. The Japanese are however well aware that the future is far from assured. Motorola and Siemens are re-starting memory production and NIEs, notably South Korea, are biting increasing large chunks from the market. The future seems to be clouded by political issues to a far greater extent than in the early years of the decade.

For more information contact the EIAJ, 1 Deans Yard, Westminster, London SW1P 3NR. Tel: 01-799 9811.

DIARY

BBC Radio Show — 30th September -9th October
Earls Court, London. 'Spectacular extravaganza' to celebrate 21 years of BBC Radio 1, 2, 3 and 4. Exhibition, live shows, etc. Contact BBC Radio Show, PO Box 100, Chatham, Kent ME5 BLJ

Electronic Displays 88 — October 4-6th
Wembley Conference & Exhibition Centre, London. Contact Blenheim Online on 01-868 4466

Computer Graphics 88 — October 11-13th
Wembley Conference & Exhibition Centre, London. Contact Blenheim Online on 01-868 4466

Digital Signal Processing Seminar — October 13th
Heathrow Penta Hotel, London. Contact ERA Technology on (0372) 374151

Desktop Publishing Show — October 13-15th
Business Design Centre, London. Contact Database Exhibitions on 061-456 8383

ASIC Awareness Seminar — October 17th
London. One of three dates in UK section of tour. Contact organisers and sponsors LSI Logic on (0344) 426544

Satellite Systems For Mobile Communications And Navigation — October 17-19th
IEE. London. Conference organised by IEE. Contact IEE on 01-240 1871

Internepcon — October 18-20th
Metropole Exhibition Centre, Brighton. Contact Cahners Exhibitions on 01-891 5051

Southern Electronics Show — October 18-20th
Brighton. Contact Trident International Exhibitions on (0822) 614671

Testmex 1988 (Electronic Testing & Measurement) — October 18-20th
Business Design Centre, London. Contact Network Events on (0280) 815 226

ASIC Awareness Seminar — October 17th
Cambridge. One of three dates in UK section of tour. Contact organisers and sponsors LSI Logic on (0344) 426544

IC Outlook — October 19th
Centre Point Building, London. Market overview seminar. Contact Dataquest on 01-583 9171

ASIC Awareness Seminar — October 17th
Manchester. One of three dates in UK section of tour. Contact organisers and sponsors LSI Logic on (0344) 426544

Commercial Awareness And Business Skills For Young Engineers — October 21-23rd
Strand Palace Hotel, London. Contact IEE on 01-240 1871

SMECTS 88 — October 24-25th
Surface Mount Electronic Components Seminar. Post House Hotel, Heathrow, London. Contact Components Technology Institute on (0425) 73578

INTRON (Irish Electronics Exhibition) — October 26-28th
RDS Main Hall. Contact SDL Exhibitions on Dublin 01-900600.

Instrumentation Wembley — October 26-27th
Wembley Conference Centre, London. Contact Trident International Exhibitions on (0822) 614671

ITEX 88 — November 1-3rd
Barbican Centre, London. Information Technology Exchange backed by DTI. Contact Cahners Exhibtions on 01-388 9871.

Engineering Products And Technology — November (date to be finalised)
Exhibition and Conference Centre, Doncaster. Contact Trinity Exhibitions on (0895) 58431.

Electronic Information Delivery — November 8-9th
Tara Hotel, London. Contact Blenheim Online on 01-868 4466.

Next Month in

ETI
ELECTRONICS TODAY INTERNATIONAL

December ETI — out — November 4th

A Touch Of Spring For Winter

The December issue of ETI continues some of the themes in this month. There's the next part of the Burglar Buster free project with the constructional details and the PCB free on the cover. To continue the speed measuring theme (see the Chronoscope in this issue) we have the first DIY radar speed gun. Good for both vehicles and fast moving friends, this portable unit gives direct readout in miles per hour.

For those dark winter nights there's an all-electronic thermostat to drag your central heating system into the eighties. A simple wire-in replacement for most of those yukky mechanical jobs, the ETI thermostat gives you accurate heating contol and even tells you the temperature.

Is that all? Of course not. The December ETI is brimming over with goodies to make the winter seem shorter. There's the usual favourites — Chip In and Circuit Theory plus the News stories that matter, the readers' letters that natter and reviews that are really good (well you try and think of a suitable work to rhyme with 'atter'. Answers on a postcard, please. . .)

Winter wouldn't be the same without ETI. Don't miss your copy.

The articles mentioned above are in preparation but circumstances may prevent publication

Make A Date

It's competition time again — and time is the right word (as are date and year) because this month ETI has teamed up with Maplin to give away six of Maplin's 200 year calendar clocks to lucky readers who can solve the cryptic puzzle below.

These clever and stylish clocks feature 12 or 24 hour time display along with date and year and a complete calendar for the current month. There's an alarm built-in too with a four minute snooze.

It's an ideal way to keep track of time and a certain way to be sure you never miss that all important first Friday of the month when ETI is published!

Winning one of these clock/calendars couldn't be simpler. All you have to do is to match up the ten dates below with the ten cryptic descriptions on the entry form. So, if you think that 'Old long since' is referring to 4th November write '4/11' next to the first clue. When you've matched up all ten dates in the list, fill in your name and address and send the coupon, to arrive no later than 7th November, to:

ETI Clock/Calendar competition
1 Golden Square
London W1R 3AB

The first six correct entries out of the editor's deerstalker will win a clock/calendar each.

1/4	24/12	31/10	14/2	19/6
4/11	31/12	1/5	5/11	11/11

Maplin

Old Long Since	/	Remember, Remember	/
Massacre	/	Fools	/
Great Ending	/	Next ETI	/
Red	/	Spooky	/
Silent Night	/	Garfield's Birthday	/

Name ....

Address ....

CONTROL STRATEGIES

Although micros now seem to rule our lives, they can't do everything. Keith Brindley shows how analogue techniques in systems control will never be overtaken by those nasty little bits

Fortunately for us, most things in the real world are analogue. Digital techniques can only be utilised to good advantage in the *approximation* of how they function. Analogue techniques still need to be considered, even if a digital representation is to be the final result.

Control

Any electronic system requires control of some sort. Whether it's a simple power supply or a guided missile, some internal part controls the output. In the power supply, voltage regulation and stabilisation ensure

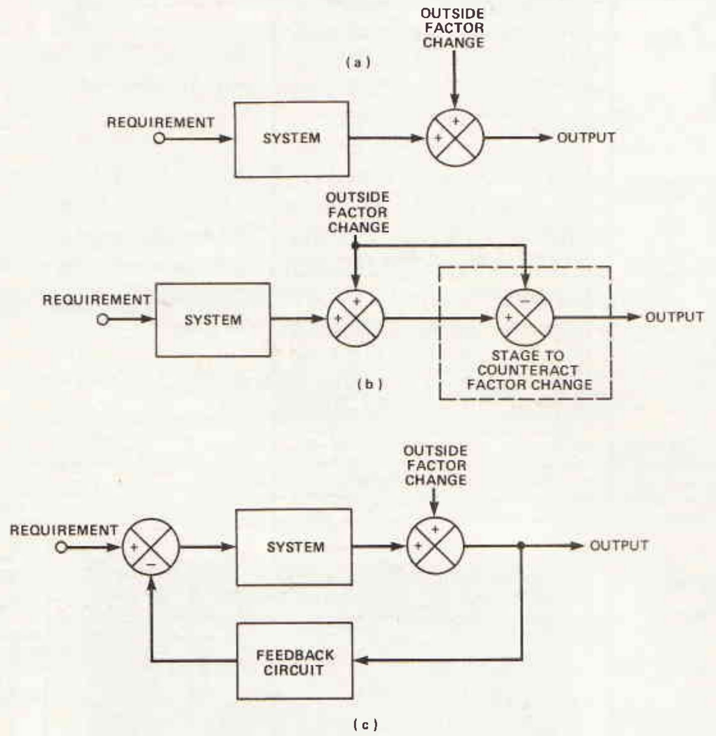


Fig.1 Three control strategies (a) open-loop control (b) feedforward control (c) closed-loop control

smooth DC voltage output. In the guided missile some technique ensures the missile hits the target.

There are three basic strategies used in any controlled system. Readers will probably be familiar with the strategy names although it's still worth summarising what they are. First is *open-loop control*, shown in Fig.1a. It's a sort of 'point and shoot' method in which the output of the system is specified and the system merely attempts to achieve it. If all things remain equal, open-loop control will produce the required output. However, open-loop control does not take into account factors which may change — load in the case of the power supply, or wind direction in the case of a guided missile.

Second is known as *feedforward control* shown in Fig.1b where factors which might change are monitored and actions are taken to counteract the effects of the changes. This method is still a 'point and shoot' procedure but the system is adapted according to the factor changes.

Finally, Fig.1c shows *closed-loop control* sometimes called 'feedback control' in which part of the final output is compared with the requirements and a control signal (sometimes called an error signal) adjusts the system.

Of the three strategies, the closed-loop one is arguably the best because it alone measures the *effects* of the outside factor changes. Feedforward control measures the factor change itself, re-aligning the system to suit. Open-loop control, of course, takes no effects into account at all.

This is not to say that feedback control *must* be used as the control strategy. Far from it, feedforward control is very effective as long as only a few factor changes occur — and can be a lot cheaper than equivalent feedback control systems. The problem arises when there are too many factor changes (so that measuring and correcting circuits become too involved and expensive) or when unforeseen factors change and no correcting circuits exist, or when gain variations occur. Often, a combination of feedback and feedforward methods is used.

Defining Feedback

Most readers will be aware of feedback (it's how all op-amps function) but a quick definition of terms involved wouldn't go amiss. Fig.2 shows a general block diagram of a feedback system and can represent anything from a single op-amp circuit to a complex stage in a large control system. The amplifier has a gain of G and the feedback has a gain H. The input i is summed with the output of the feedback loop f, such that an error signal e is produced, where:

$$e = i - f$$

Note that the error signal is input *minus* feedback. This means that the system is a 'negative feedback' system. The minus sign can be thought of as signifying that the output signal has been inverted, or turned through 180°. This is an important point. Positive feedback systems exist of course but are usually only used in oscillators and such like.

We can work out, that:

$$f = oH \text{ and } o = eG$$

so:

$$e = i - eGH$$

which, rearranging, gives the system error:

$$e = \frac{i}{1 + GH}$$

If the quantity GH (known as the 'loop gain' because it is the overall gain of the closed loop) is large then the 1 in the denominator is irrelevant, so $e = i/GH$. Conversely, the input $i = eGH$.

Now, the output $o = Ge$, which means we can generalise the system gain (because gain = output/input) as: Ge/eGH or $1/H$. That is, so long as the loop gain is large, the system gain becomes entirely independent of the amplifier gain. So, the general closed loop feedback system can be represented by a single block, as shown in Fig.3.

The fact that gain variations can be made virtually irrelevant is the real reason why closed loop feedback systems represent the most versatile control strategy.

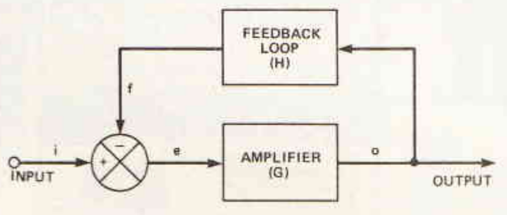


Fig.2 A general closed-loop feedback control system block diagram

CONTROL

Fig.3 With a high-gain amplifier the general closed-loop feedback system simplifies to a single stage effective system

Stability

In a simple system comprising one or even two feedback stages, stability (or rather lack of it) is usually no problem but in more complex control systems, with perhaps three or more stages, a potential exists for instability. The problem is that any closed loop feedback system has a phase shift between input and output. Further, this phase shift is not constant but varies with applied signal frequency.

Generally, instability will occur if at any particular frequency a total phase shift of 360° occurs *when overall gain is equal to or greater than unity.* At a phase shift of 360°, the negative feedback has, in effect, turned into *positive* feedback and so the system will tend to instability, oscillating or even locking up at the frequency at which it occurs. If we remember the introduction to negative feedback given previously, we know that *negative* feedback is the equivalent of a 180° phase shift in the feedback loop, so only a 180° phase shift in the overall system will create a total of 360° phase shift.

How can the designer tell if a system is going to be unstable except by building the thing and turning on? Well, there are complex mathematical methods of modelling system performance but there is an extremely simple graphic approach which will do equally as well. This concerns Bode plot diagrams, which many readers will be familiar with. These show a circuit's performance in two graphs — one of gain variation in decibels with frequency and one of phase shift with frequency. Fig.4 shows an example. It's the fact that any frequency phase shift as well as gain is represented that allow the Bode plots to be of use.

Initially, the whole closed-loop system has to be considered without its feedback loop — as an open-loop system. Fig.5 shows an example of a three-stage control system without its feedback loop. Fig.6 shows Bode plots of all three stages, plotted on one pair of Bode plots. Let's say that the Bode plot of the first stage of Fig.5 is that of a second-order high-pass filter (it has a roll-off of 40dB per decade and phase shift up to 180°). The second stage is a perfect amplifier, with gain of 7.5dB and a bandwidth greater than the limits of our Bode plots, so no phase shift occurs. The final stage is a first-order low-pass filter with a roll-off of 20dB and phase shift up to 90°. None of the individual plots show any tendency to instability because the phase shift in any single plot is never as high as 180° with unity gain (0 dB).

Now, with series coupled gain stages (as these three stages are) the overall gain can be calculated simply by multiplying together the individual gains. However, because the first of the two Bode plots has a vertical axis of gain in dB (it is logarithmic) the overall gain can be plotted *linearly* simply by *adding* the three gains together. Similarly, as the vertical axis of the second of the two Bode plots is a linear measurement of phase the overall phase shift can be calculated by adding the three phase shifts.

The final pair of Bode plots becomes that of Fig.7. This shows that a phase shift of 180° occurs at a frequency of 2.2kHz, when the gain is unity. That, plus the 180° phase shift of the negative feedback loop itself when the feedback loop of Fig.5 is closed, means that a total of 360° of phase shift occurs. So, according to this estimate, when the feedback loop is closed, the system experiences positive feedback at that frequency and will oscillate!

That's all well and good you may say, but this estimate is based on an open-loop. So how do we *really* know what will happen to the system when the feedback loop is closed? Is our estimate good enough?

Fortunately, control engineers have evolved another graphical method of interpreting theoretical results. It is known as the *Nichols chart,* which is simply a collection of open-loop gain and phase shift data, corresponding to the resultant closed-loop gains and phase shifts. A Nichols chart is shown in Fig.8 where the horizontal axis is of open-loop phase shift, while the vertical axis is of open-loop gain. On top of these perpendicular axes are superimposed a large number of plots of closed-loop phase shifts and gains.

Its use is pretty simple, although tedious. From the results of the final pair of Bode plots from the previous example, plot a line of points corresponding to gain and phase shift at a number of frequencies.

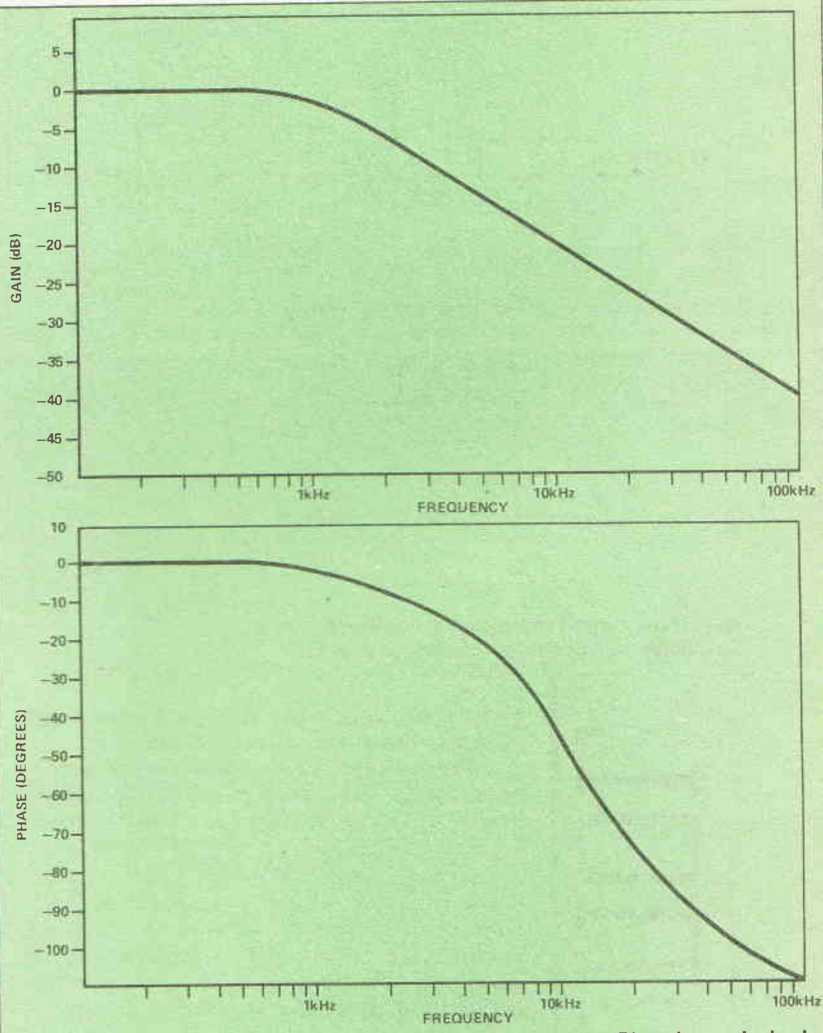


Fig. 4 A possible pair of Bode plots. The upper plot has gain (in dB) as the vertical axis with frequency as the horizontal axis. The lower plot has phase shift (in degrees) as its vertical axis

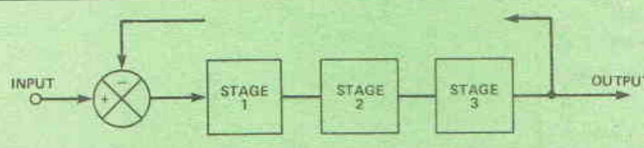


Fig.5 To model a control system, it is necessary to initially consider the system as an open-loop control system without its feedback loop

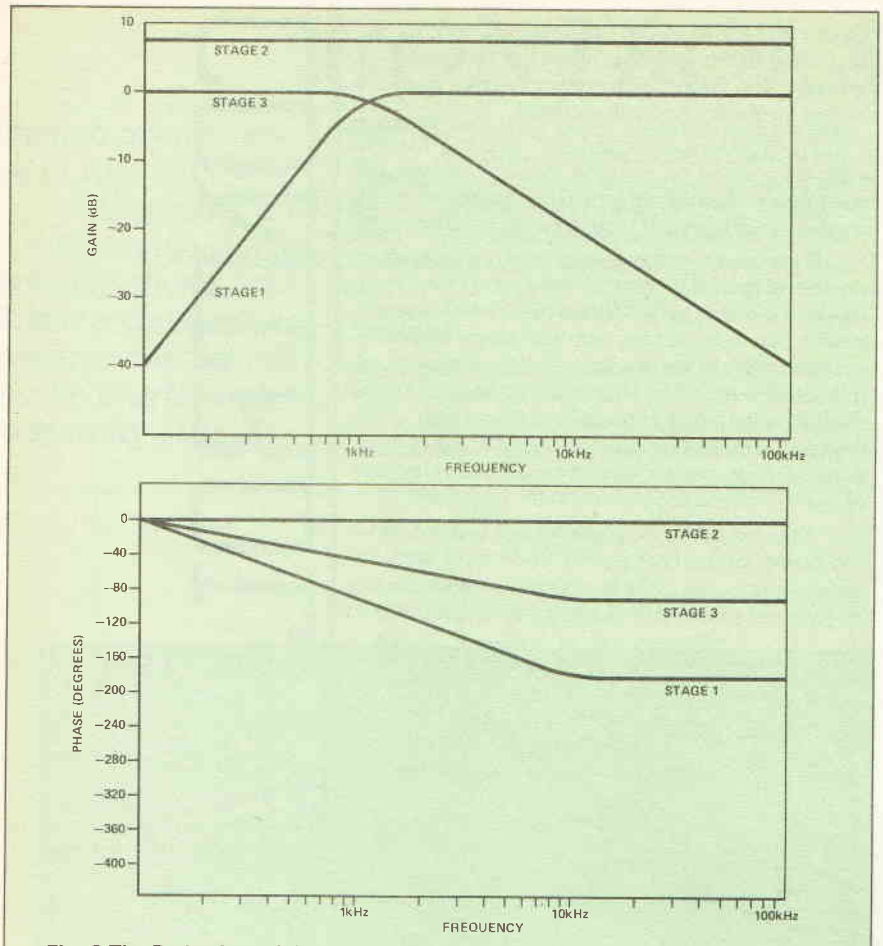


Fig. 6 The Bode plots of the three stages of the system of Fig. 5

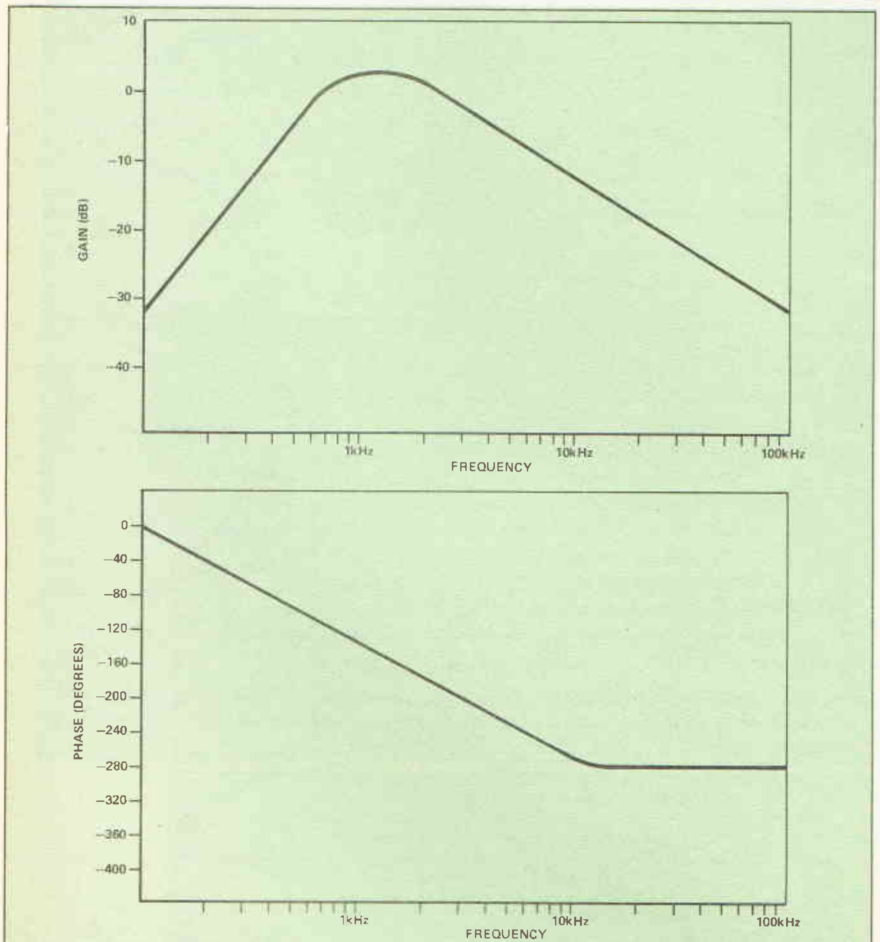


Fig.7 Estimate of final pair of Bode plots of the system in Fig.5, found by adding together gains and phase shifts of all three pairs of plots at each frequency

This is shown in Fig.8. Generally, you should always mark the frequencies on the Nichols chart, too. But as room is limited here, frequencies aren't marked in Fig.8 but the direction of increasing frequency is — this is important, as we'll see later.

Now from the closed-loop axes, take off measurements of gain and phase shifts at those frequencies and re-plot them onto a new pair of Bode plots, as in Fig 9, to see what the closed-loop frequency response is really like. As we would expect, the phase shift amounts to 180° at 2.2kHz, when the gain is a few dBs above unity gain. So, this method proves the system will be unstable too.

Incidentally, control engineers have a rule-of-thumb when using Nichols charts which alleviates the need to re-draw the closed-loop response on a final Bode plot. This is: if the closed-loop frequency response phases to the right of or intersects the 0dB/−180° open-loop intersection when viewed in the direction of increasing frequency, the system is unstable. In the example of Fig.8, the curve intersects the intersection, so we know the system is unstable. However, if stage 2 of the system had a lower gain then the curve would have passed to the *left* of the intersection and so the system would have been stable. With experience, control engineers can read information from a Nichols chart as easily as from a Bode plot.

The amount by which a stable system's response passes to the left of the intersection can be referred to as a 'gain margin' — the amount of gain which, if added to the system, would cause the response curve to pass through the intersection. Alternatively, it can be referred to as the 'phase margin' — the amount of extra phase shift which, if added to the system, would cause the curve the pass through the intersection.

Controllers

In the simple systems we have looked at so far, stages have been little more than amplifiers or filters. There are many more types of stages used in control systems. For example, often a stage may follow a mathematical equation of an integrator, in that the output is an integral of the input. The stage could be modelled by the expression:

$$\text{output} = \frac{1}{T_i}\int_0^T \text{input dt}$$

where T_i is the integral time of the controller, generally adjustable with front panel controls or presets.

Other types may be 'proportional' — the output is simply the input multiplied by a constant factor (a simple amplifier is a proportional controller), again adjustable with controls.

Others may be 'derivative' in that the model is one of mathematical differentiation, following the expression:

$$\text{output} = T_D \frac{di}{dt}$$

Some controllers are combinations of more than one type, the most common probably being the 'proportional plus integral' controller, also known as the 'P+I' controller or simply the 'PI' controller and may be modelled by the expression:

$$\text{output} = K(\text{input} + \frac{1}{T_i}\int_0^T \text{input dt})$$

Similarly, the 'proportional plus integral plus derivative' controller or P+I+D or PID controller is common. In fact, generally speaking, any mathematical model can be used as a control system stage, given that the electronic circuit equivalent can actually be made.

Which controller to use in any given system depends largely on the system, of course, and it's the

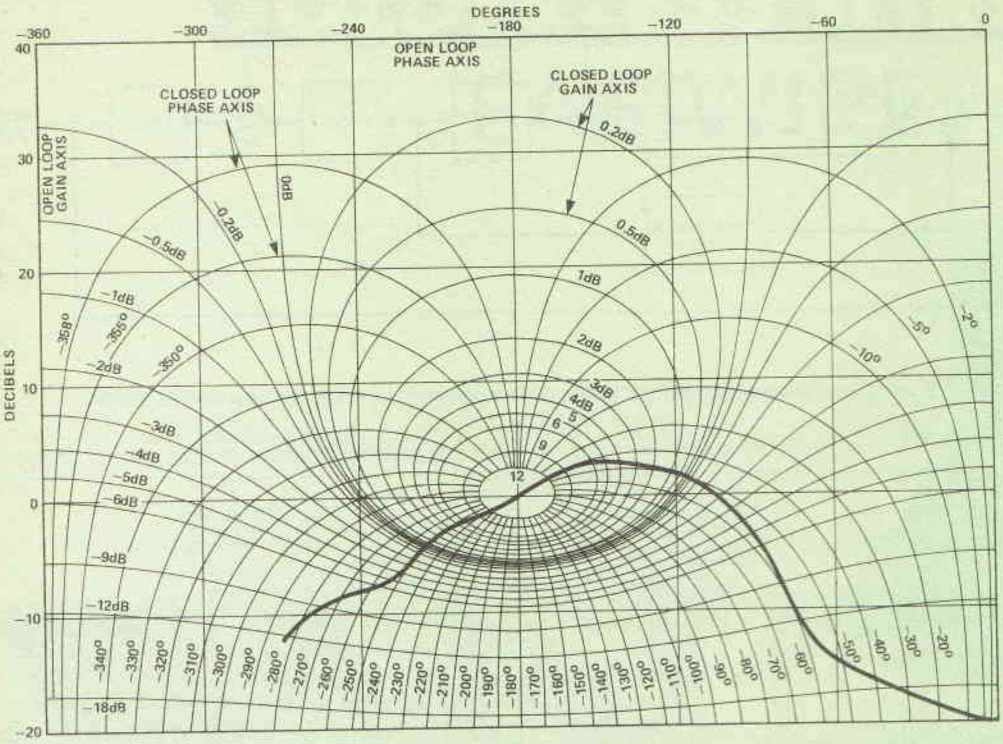


Fig.8 A Nichols chart showing open and closed-loop gain and phase shift axes with a frequency response curve, taken from the results of the Bode plots of Fig.7, transferred onto a Nichols chart

engineer with skill and experience who must design the control system to suit.

Loop De Loop

Single-loop closed-loop control systems, as we've seen, can be complicated enough. Sometimes, the engineer has to resort to a more complicated version of the closed-loop strategy.

The problem arises because the single-loop system is sometimes affected by disturbances within the control loop. Thinking back to the general closed-loop feedback system of Fig.2 and 3, the stage gain is specified as 1/H as long as the amplifier gain G is sufficiently high. In reality other factors matter too. The simplified expression relies on applied signals being within a specified bandwidth and disturbances at some places within the loop have a greater effect than at others. Also, it's not always the case that a sufficiently high gain is available or possible within the bounds of the overall system performance.

The answer to the problem is constructing multi-loop closed-loop systems. Such methods are often used where disturbances would otherwise be uncontrollable. Fig.1 shows 'cascade control' in which two control loops exist, one within the other. Two controllers are used, one for the inner loop and one for the outer. Of course, cascade control is only possible if there is some intermediate stage capable of being controlled. Large disturbances within the inner loop can be effectively reduced, particularly as the loop gain of the inner loop may be very much higher than that of the outer loop without affecting overall system performance so the disturbance may then come within the bounds of controllability of the lower gain outer loop.

Often cascade control is used to reduce the time constant of a part of the process, although the inner loop should generally only be placed around the component with the smallest time constant.

Overall benefits of cascade control are a wider bandwidth, with significantly greater reduction of

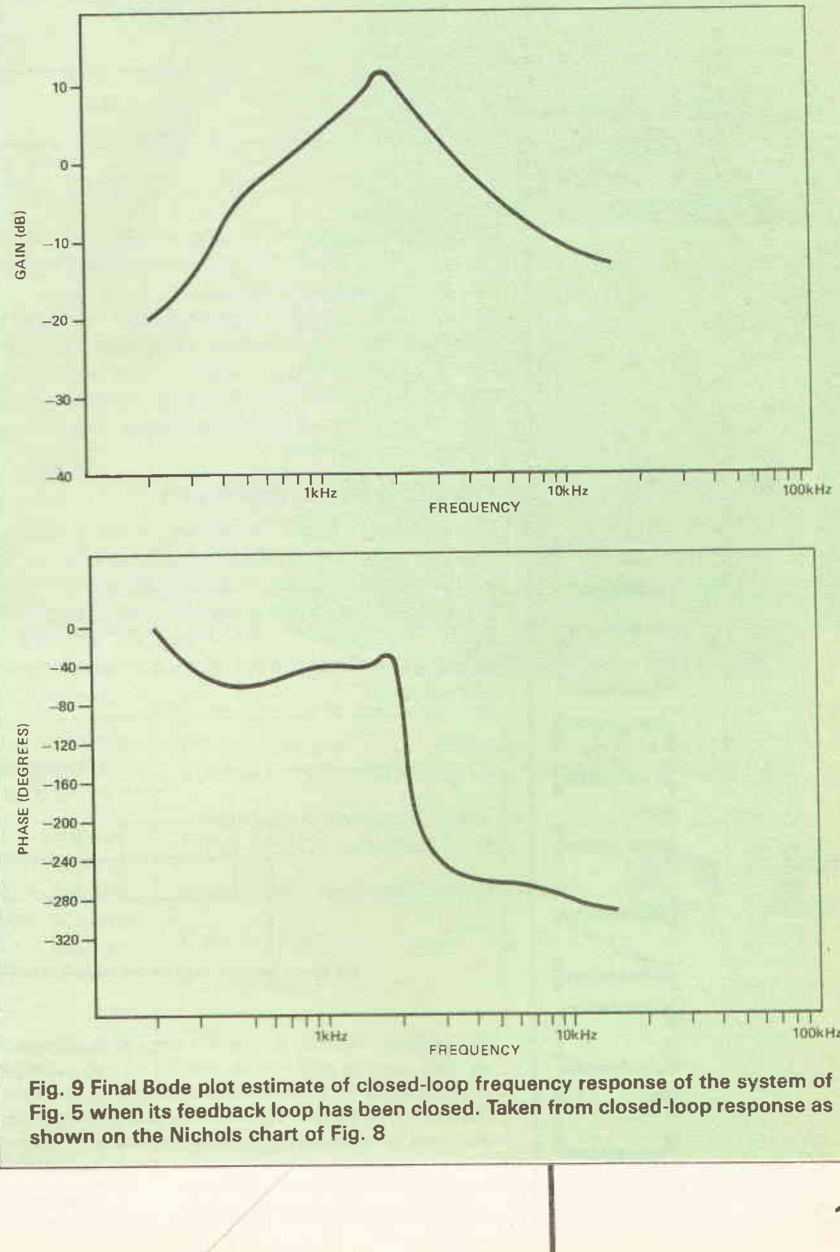


Fig. 9 Final Bode plot estimate of closed-loop frequency response of the system of Fig. 5 when its feedback loop has been closed. Taken from closed-loop response as shown on the Nichols chart of Fig. 8

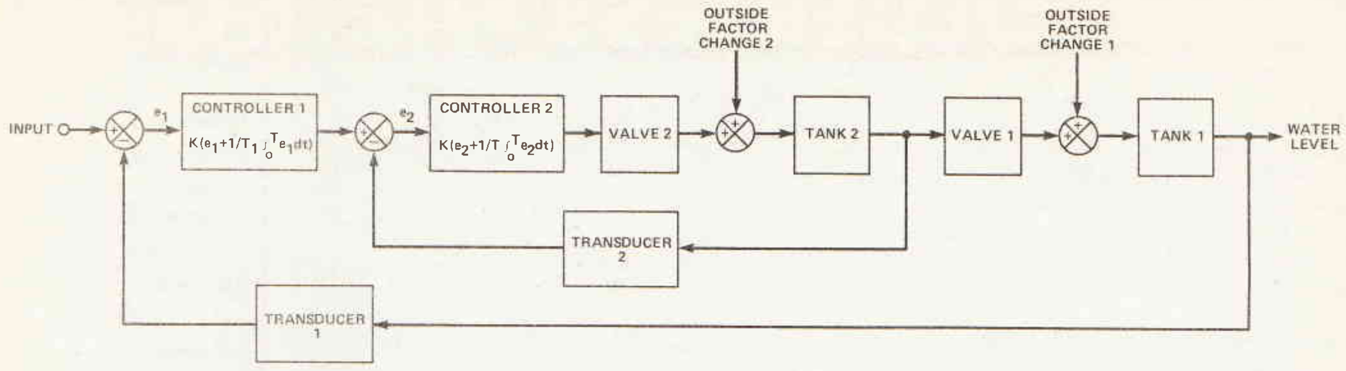


Fig.10 An example of cascade control, a multi-loop closed-loop control strategy. Disturbances in the inner loop may be greatly reduced by cascade control

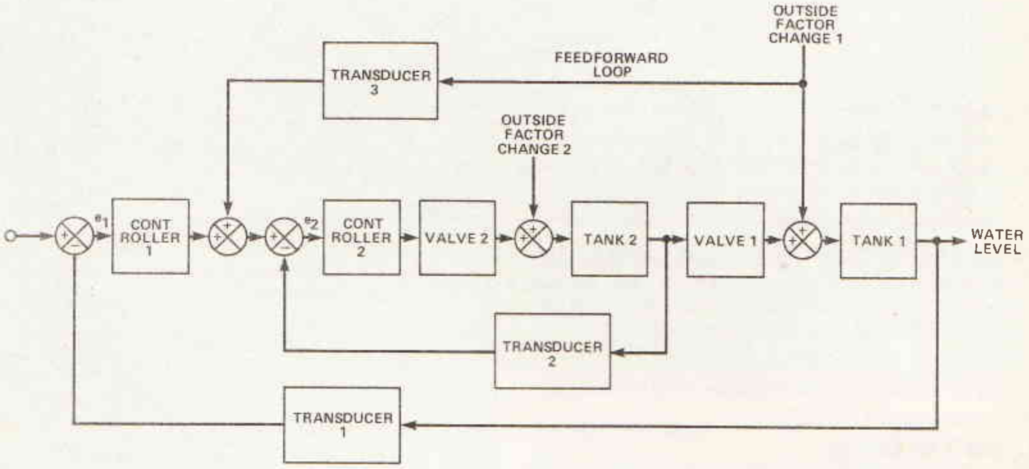


Fig. 11 Feedback control, used with the cascade control example of Fig. 11 to reduce the effects of disturbances which take place outside the inner cascade loop

inner loop disturbances. More and more loops can be used, if enough intermediate stages exist. However, each cascade as you might expect makes the engineer's job more difficult in that modelling of the system and consequent stability forecasting become increasingly complex.

Feeding More Forward

Finally, let's not forget feedforward control, where a disturbance is measured before it has an effect on the control system and counteracting measures are taken. Coupled with a cascade control system such as in Fig.11, feedforward control can be effective in reducing the effects of a disturbance outside the inner cascade loop.

One specific example of feedforward control is 'ratio control'. Here a control system is used to maintain the ratio of two variables. A possible system might exist in a car's fuel injection system, where the ratio of fuel to air must be strictly maintained so as to ensure the correct mixture is always taken into the engine's combustion chamber. Fig. 12 illustrates such a system. The mass of air being sucked into the engine is measured, the amount of fuel required to give correct fuel-to-air ratio is then calculated by a controller and a valve (the fuel injector) ensures exactly the right amount of fuel is added.

ETI

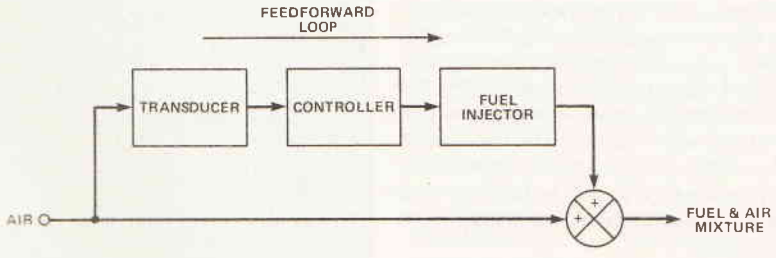


Fig.12 Ratio control. A specific case of feedback control used to control the ratio of two variables in a control system. The example shown is of an automobile fuel injection system in which the incoming air mass is measured and from this measurement a controller calculates the length of time a fuel injection valve must be opened to present the correct amount of fuel to the combustion cylinder such that exactly the correct ratio of fuel-to-air is sucked into the cylinder

CONTROL

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THE NORTON DIFFERENCE

Ray Marston presents the first part of his guide to the current differencing op-amp

Most popular op-amps (Fig. 1a) give an output proportional to the difference between their two input terminal voltages and are thus known as voltage-differencing amplifiers or VDAs. There is however a type of op-amp which gives an output voltage proportional to the difference between the *currents* applied to its two input pins.

These devices are known as current-differencing amplifiers or CDAs. Figure 1b shows the standard symbol of the CDA, also known as a Norton op-amp.

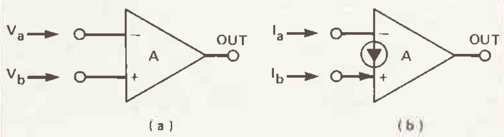

Fig. 1 (a) A conventional op-amp. (b) A Norton op-amp

The two best known Norton op-amps are the LM3900 and the LM359. The LM3900 is a low-cost medium performance IC that houses four identical op-amps in a 14-pin PIL package (Fig. 2) and can operate from a single-ended 4 – 36V power supply. Each of its op-amps has a unity-gain bandwidth of 2.5MHz with an open-loop gain of about 70dB, and gives a large output voltage swing. This IC is particularly useful in DC and low frequency applications where several op-amp stages are needed in single-ended supply circuits.

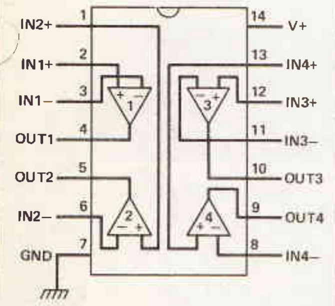

Fig. 2 Connections of the LM3900 quad Norton op-amp

On the other hand, the LM359 is a very fast dual Norton amplifier in which each op-amp has a unity-gain bandwidth of 30MHz with an open-loop gain of about 72dB, and in which most of the op-amp parameters are externally programmable. This IC is particularly useful in video and high frequency amplifier/filter applications.

The LM3900 and LM359 operate in a very different way to conventional op-amps and require the use of special biasing techniques. We will first take a look at the LM3900 and next month we'll move on to the faster LM359.

Inside The Box

The LM3900 incorporates four identical current-differencing op-amps, each having the circuit shown in Fig 3. To aid understanding of the complete circuit, Fig. 4 shows six simple stages in the development of the final design.

Figure 4a shows a basic inverting amplifier circuit. Q1 is a common emitter amplifier with a high-impedance (constant-current) collector load, and gives a high-gain inverting action. Q2 is an emitter load. The high frequency response of the complete amplifier is rolled off by C1, to enhance circuit stability.

Note that the output of this circuit can swing to within a few hundred mV of both zero and the positive supply rail voltage, and that its overall current gain equals the product of the two transistor current gains.

Figure 4b shows how the current gain of the above circuit can be increased with little loss of available output voltage swing, by adding PNP transistor Q3. The output of this circuit can typically source up to 10mA (via Q2) but can sink only 1.3mA (via Q2's constant-current generator).

Figure 4c increases the sink current by wiring Q4 so that in over-drive conditions it gives class-B operation.

Figure 4d shows transistors Q5 and Q6 used as constant-current generators (biased via a network that is built into the LM3900 IC).

Current Mirrors

The Figure 4d circuit forms the basis of each of the LM3900 amplifier stages, but gives an inverting action. The non-inverting LM3900 requires the assistance of the current mirror circuit of Figure 4e, which is made up of two matched and integrated transistors and simply draws an output current that is almost identical to the input drive current.

The input current is fed to the bases of both Q7 and Q8. Let's say both have current gains of ×100, and both are drawing base currents of 5µA. In this case both collector currents are 500µA plus both base currents. The input and output currents of the circuit are thus almost identical (within a few percent), irrespective of the input current magnitude.

Figure 4f shows the current mirror circuit connected to the basic Fig. 4a circuit to give the current-differencing action of the Norton amplifier. The mirror circuit is driven via the non-inverting input terminal, and the mirror current is drawn from the inverting input terminal. also connected directly to the base of the Q1 amplifier stage. Consequently, the base current of Q1 equals $I^- - I^+$. This is the difference between the two input currents. The complete amplifier (back in Fig. 3) thus gives the current-differencing op-amp action already mentioned.

Note that since both input terminals of the op-amp are connected to transistor base-emitter junctions, both inputs act (in voltage terms) as virtual-ground points. Consequently, these CDA circuits can be made to act like conventional voltage-differencing op-amps by wiring high-value resistors in series with their input terminals, so that the input currents are directly proportional to the input V/R values. When this technique is used, there is no upper limit to the

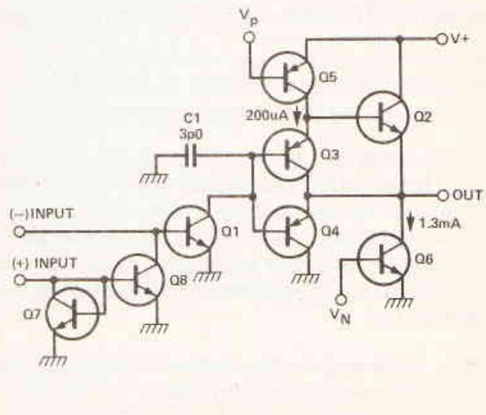

Fig. 3 Circuit of each of the four identical op-amp stages of the LM3900

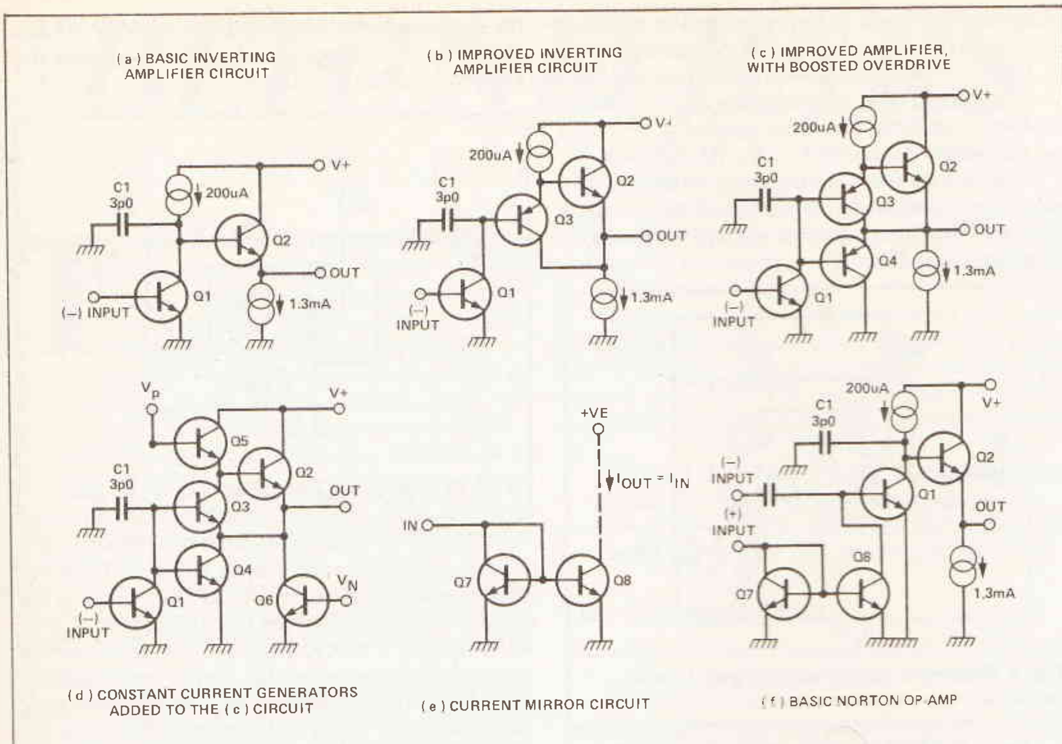

Fig. 4 Development of the LM3900 op-amp circuit

available input common-mode voltage range of the LM3900 op-amp.

Biasing Techniques

The basic amplifier stages of the LM3900 have high current gains, and the output of the amplifier starts to swing down through the half-supply point when the input bias current of Q1 starts to rise above 30nA or so. This input current is normally equal to the difference between the two input terminal currents, which should normally be restricted to the range 0.5μA to 500μA (ideally about 10μA).

In linear applications an op-amp is normally biased so that its output takes up a quiescent value of half-supply volts to accommodate maximum undistorted signal swings, and Fig. 5a shows how the LM3900 can be biased to meet this condition.

R1, R2 and C1 generate a decoupled half-supply reference voltage, which applies a reference current to the non-inverting terminal via R3, and a negative feedback current is applied from the op-amp output to the inverting terminal via R4. The basic action is such that the op-amp output automatically adjusts to such a value that the two input currents equalise and hence reduce the internal Q1 base current to near-zero (about 30μA) — in Fig. 5a this occurs when V_{out} equals V_{ref}. In practice, the single reference voltage source can be used to apply biasing for several op-amp stages.

A variation of this biasing system is shown in Fig. 5b. The non-inverting terminal is biased from the positive supply rail via R1, which has a value approximately double that of R2, causing the output to bias at a quiescent value of half-supply volts. A minor defect of this biasing technique is that it allows supply line ripple to break through to the output, with gain of 0.5.

Note that in Figs 5a and 5b, the input signal is shown connected to the inverting terminal of the amplifier, but in practice the signal can be connected to either input.

Figure 5c shows an alternative biasing technique that can be used when the op-amp is to operate only as an inverting amplifier. In this case the non-inverting terminal is disabled, and feedback potential divider R1, R2 is applied between the output and the inverting terminal. Consequently, since the inverting terminal acts as a transistor base-emitter junction (V_{be}, about 0.55V at 10μA bias), the output automatically takes up a quiescent value of $V_{be} \times (1+R1(R2))$. This is about 6V with the component values shown.

Linear Amplifier Circuits

Six ways of using the LM3900's op-amps as linear amplifiers are shown in Figs 6 to 11. In Figure 6, R2 and R3 bias the output to a quiescent half-supply

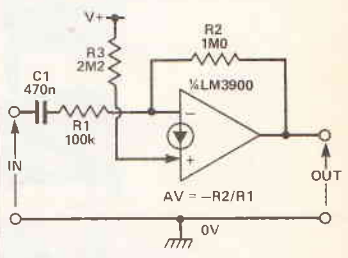

Fig. 6 Inverting AC amplifier with supply-line biasing

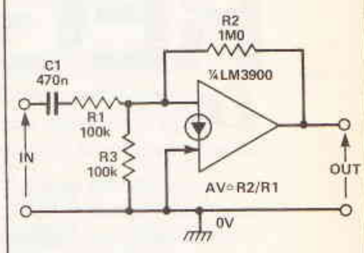

Fig. 7 Inverting AC amplifier with N×Vbe biasing

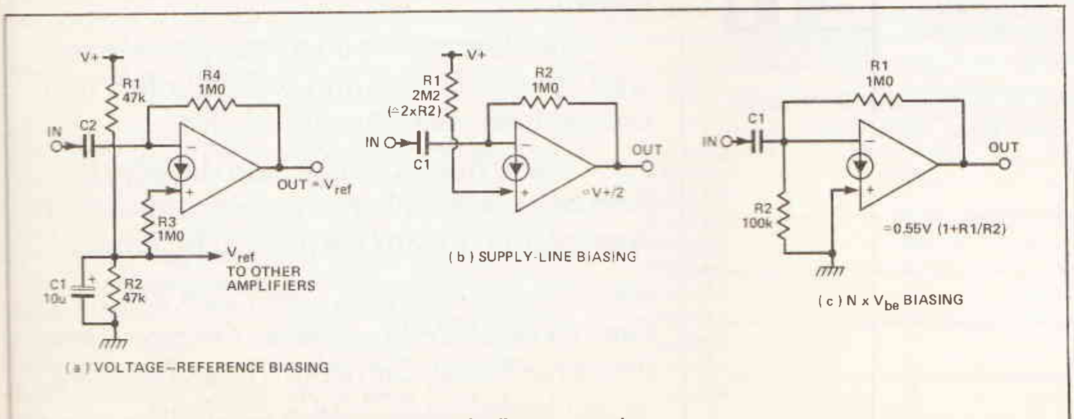

Fig. 5 Methods of biasing LM3900 op-amps for linear operation

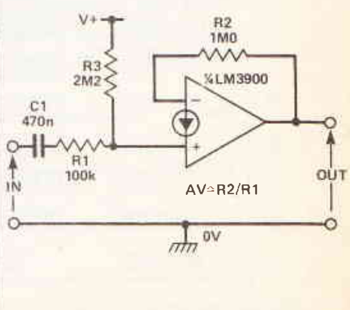

Fig. 8 Non-inverting amplifier

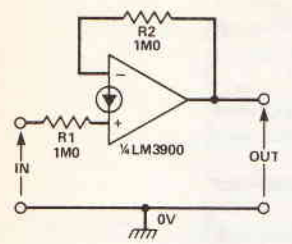

Fig. 11 DC voltage-following buffer

value, and the input signal is fed to the inverting terminal via R1. The voltage gain is determined by the R1, R2 ratio — this acts as a ×10 inverting amplifier.

Figure 7 shows an alternative ×10 inverting amplifier, in which biasing of the type in Fig. 5c is used and the gain is determined by the R1, R2 ratio.

Figure 8 shows a non-inverting amplifier with a gain of approximately ten. Supply-rail biasing is again used, but the input signal is applied to the non-inverting pin via R1.

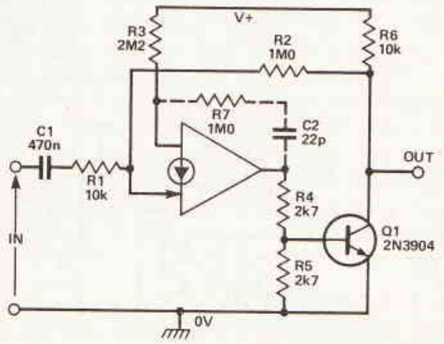

Fig. 9 Wideband (200 kHz) high-gain (×100) amplifier

The LM3900 op-amps are fairly slow devices with slew rates of only 0.5V/μs, and thus very limited useful bandwidths. Figure 9 increases the useful bandwidth by connecting an external common emitter transistor to the output and transposing the input connections of the standard amplifier. This makes a ×100 'compound' amplifier with a 200kHz bandwidth.

Because of its very high overall gain, this circuit may be unstable if care is not taken in layout. R7 and C2 can be used to slightly reduce the bandwidth and enhance stability if required.

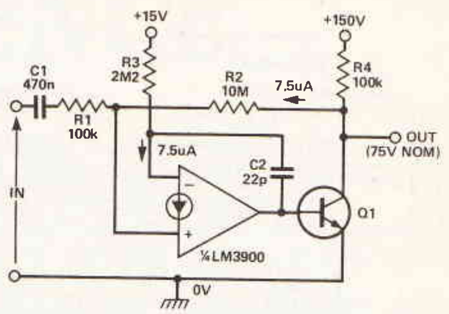

Fig. 10 High-voltage amplifier with ×100 gain

Figure 10 shows the same circuit modified to give a peak-to-peak output voltage swing of 150V (or whatever voltage is used to power Q1). Note that the output voltage of this circuit has a quiescent value of 75V, causing 7.5μA to be fed to the non-inverting terminal of the op-amp via R2. To give correct biasing, R3 (powered from the 15V supply rail of the op-amp) must also apply 7.5μA to the inverting pin of the op-amp, as shown.

Finally, Figure 11 shows how to connect an LM3900 op-amp as a unity-gain non-inverting amplifier or voltage following buffer. The input is connected to the non-inverting terminal via R1 (giving the non-inverting action) and R1 and R2 have equal values thus giving unity gain (note that the circuit would give a gain of ×2 if R1 were half the value of R2).

ETI

BEHIND BARS

EAN13

By popular demand Malcolm Brown reveals the truth behind the pretty patterns on your groceries

The bar code competition of the July 1988 issue caused quite a response. Not only did many readers enter (and most got somewhere near the truth) but it stirred up an inquisitiveness among many as well. It seems there is a strong desire to know how to read a can of baked beans and so this short article will describe how the EAN13 bar code system works.

A European Article Numbering (EAN) code is now printed on just about every item you are likely to buy in a high street store. These codes uniquely identify an item for use both by the manufacturer and shipper and by the retail store. The codes do not themselves contain price information but merely identify the item for the retailer's point of sale computer which can then look up the price and description of the article.

There are four EAN code systems in use. The EAN8 system contains just eight digits and is used mainly for in-factory tagging, quality control and the like by manufacturers.

The EAN13 system has 13 digits and it is these codes which are to be found on the proverbial baked bean tin.

Of the 13 digits the first two or three classify the code into broad categories. Codes starting with 978 and 979 for instance are books as these prefixes identify the International Standard Book Numbering (ISBN) system.

Most of the prefixes identify the country of origin of the product. Each country operating the EAN system has its own regulating body to assign the rest of the code. In the UK the body is the Article Numbering Authority (ANA) and the UK prefix is 50. The ANA assigns five digits to the manufacturer and five to the item identifier. You will also see a number of codes starting with numbers between 20 and 29 as this signifies an in-store code.

Breaking The Code

So how are the numbers actually encoded? Well — extremely complexly! This system is far more complicated than the simple black/white on/off system used in the Bar Code Lock project in the July issue.

The 13 digits are represented by 12 groups of seven equal width bars (either black or white). It is in effect a 7-bit code. From the first six of the 12 digits this produces, a 13th digit is decoded. This is usually written below the bars at the start, outside the bar pattern. The last digit of the 13 is always a checksum.

The two 'fields' (the groups of six digits) are separated and surrounded by a 'guard pattern' of two black bars separated by a white bar (the centre guard itself is surrounded by white bars as well). These do not contribute to the code itself but serve to initialise each read and to determine the speed of movement of the reader over the barcode or vice versa.

The first field is made up of code patterns from either of two sets, set A or set B (see Table 1). Set A patterns are odd parity with bar seven black, bar one white and either three or five black bars in total. Set B patterns are even parity with bar seven black, bar one white and either two or four bars black. The second field is made up of codes from set C. These are also even parity with bar one black, bar seven white and either two or four bars black in total. Set C is in fact the reverse of set A.

The choice of the sequence of set A or set B patterns for the digits of the first field determines the derived first digit. Table 2 gives the set patterns for the derived digits 0-9. The second field is relatively straightforward with all six digits taken from pattern set C.

The final digit of the code is the checksum. This is calculated by the following complex formula:

$$C = (10 - ((3 \times (D2 + D4 + D6 + D8 + D10 + D12) + D1 + D3 + D5 + D7 + D9 + D11) \text{ MOD } 10)) \text{ MOD } 10$$

The Competition

The July competition barcode (as you will all know by now) represented the digits

45 54 49 65 74 69

which are the ASCII codes in hexadecimal for ETIeti. The derived digit was therefore 4 and from Table 2 it can be quickly seen that this requirs a pattern set sequence of ABAABB. The checksum is:

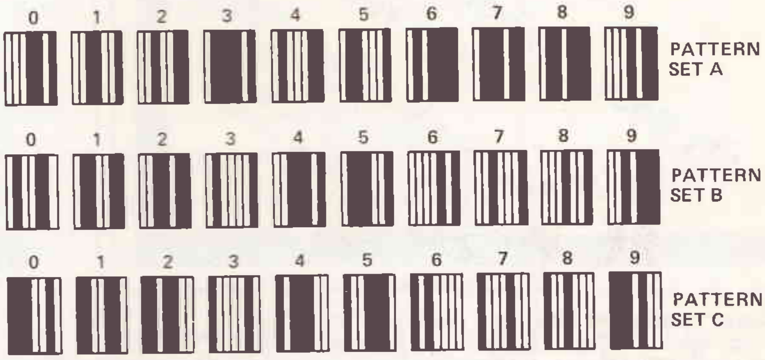

Table 1 The three pattern sets used in the EAN system

$$\begin{aligned} C &= (10 - ((3 \times (5+4+9+5+4+9) + 4+5+4+6 \\ &\quad +7+6) \text{ MOD } 10)) \text{ MOD } 10 \\ &= (10 - ((3 \times 36 + 32) \text{ MOD } 10)) \text{ MOD } 10 \\ &= (10 - (140 \text{ MOD } 10)) \text{ MOD } 10 \\ &= (10 - 0) \text{ MOD } 10 \\ &= 0 \end{aligned}$$

Table 1 can now be used to determine the bar patterns required for each digit (as shown in Table 3).

So there you have it. It may seem like an awfully complicated method of labelling your groceries (and so it is) but at least now you can wander around the supermarket impressing the shoppers by picking up a can of beans and announcing proudly 'Aha! This is a can of beans!' — Saturdays will never be dull again.

Set sequence	Derived digit
AAAAAA	0
AABABB	1
AABBAB	2
AABBBA	3
ABAABB	4
ABBAAB	5
ABBBAA	6
ABABAB	7
ABABBA	8
ABBABA	9

Table 2 The set patterns for the derived digit

DERIVED	4
GUARD	
SET A	5
SET B	5
SET A	4
SET A	4
SET B	9
SET B	6
GUARD	
SET C	5
SET C	7
SET C	4
SET C	6
SET C	9
SET C	0
GUARD	

Table 3 The competition barcode revealed

BACK NUMBERS

- Missed part one of your favourite project?
- Lost that all-important article on circuit design?
- Desperately need that Tech Tip to get your latest masterpiece going?
- Pining for that one issue to complete your valuable collection?

ETI Backnumbers Department to the rescue!

Please note that backnumbers are only held for 12 months. Articles published previous to this must be obtained through our photocopy service.

Please supply the following backnumbers of ETI.
Note: Backnumbers are held for 12 months only
(complete in block capitals)

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Month .... Year .... Month .... Year ....

Month .... Year .... Month .... Year ....

Month .... Year .... Month .... Year ....

I enclose a cheque/postal order made out to ASP Ltd. to the value of £1.90 per issue ordered.

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MAKING SENSE

CHIP IN

Mike Barwise turns his attention to the enormous range of sensors available

With increasing automation and computerisation of tasks in all fields of engineering from design, testing and production through to the control of everyday appliances like washing machines and cars, a vast variety of sensors and detectors has come into being. These are the fundamental mechanisms by which computers and controllers observe the outside world and without them no control system could operate.

There are two basic sub-divisions into which all sensors fall — the continuous or static state monitors and the transition or event detectors. The first group (group A) provide an output which indicates the current state of affairs at any given moment and which is able to track with changing input.

The second group (group B) provide no output at all until the monitored state changes. When this happens an output is provided, which indicates that *something* has happened but gives no information about the size or degree of change.

Within each of these two categories there are many alternative sensing techniques and it is in many cases even possible to make the same device operate in either mode. There is also a third category (a rather grey distinction, however) which delivers information about the order of change (group C).

The Great Detectives

We will now look at some real world things we can detect and at a selection of commercially available devices for detecting them. The following is a random list of detectable phenomena:
sound, light, heat, magnetic field, electric current, speed, proximity, motion, acceleration, position, frequency, displacement, pressure. This list is not exhaustive but it shows the variety of stimuli available to the properly designed robot or automation.

Let's look at each in turn, bearing in mind that many overlap in mechanism or purpose. Sound can be detected by means of a microphone within certain frequency limits (say, 20Hz-20kHz). The microphone converts airborne pressure waves into electrical energy by electromagnetic means (moving coil or dynamic microphones and ribbon microphones) or by piezoelectricity (crystal microphones).

The former method delivers a current output and the latter a voltage. The output of either device may be measured continuously via an amplifier (group A) or *integrated* (averaged) (group C), or it may be used to trigger a *comparator* set at a critical threshold to provide a group B event detector.

Sound can, however, also be used as a detection medium for other events such as distance and speed and as a communication channel for more complex information transfer. Typical devices are the ultrasonic transducer and detector and the doppler module.

The ultrasonic transducer and detector are a 'loudspeaker' and 'microphone' designed to operate at frequencies above the audible range (30-60kHz), with normally very narrow operational bandwidth. Instead of the 1000:1 frequency range of the conventional microphone and loudspeaker, you can expect a range of say ±10%. Working at these frequencies and narrow bandwidth has the advantage of being inaudible, not being affected by normal environmental sounds and being very *directional*. The higher the frequency, the less the sound waves disperse, which is why 'tweeter' units in hi-fi systems are frequently so complex and expensive (as we don't want high directionality in a hi-fi tweeter).

Distance is measured by emitting a stream of short 'bleeps' and measuring the time before the bleep is reflected back from the target (the echo time). This is how ASDIC and SONAR work. The directionality of ultrasound is useful here, as it allows comparatively accurate target selection. For this purpose, the frequency of emission is relatively unimportant but the bleep length must be short and the echo delay timer has to be very stable. A block diagram is given in Fig. 1.

Speed along the transmission axis can be measured by doppler shift using the same kind of transmitter with a more sophisticated detector which has a wider detection bandwidth. A continuous signal at a very stable frequency is emitted towards the target and the frequency of the reflected signal is measured. If the target is moving towards the sensor, the

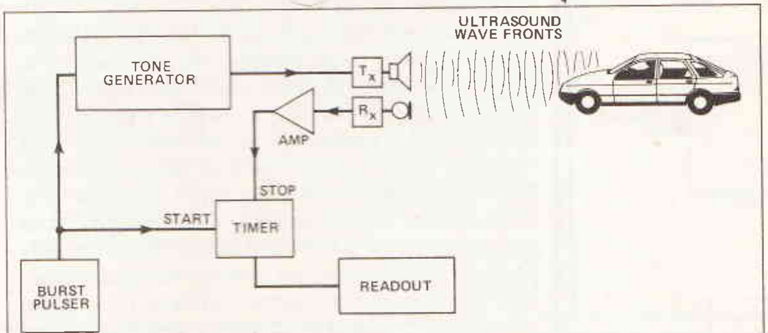

Fig. 1. The principles of sonar detection

wavelength of the return signal is compressed, raising the frequency. If it is moving away, the wavelength is stretched, resulting in a lower frequency. Relative speed between the sensor and target can be very accurately determined in this way (Fig. 2).

As a communication channel, ultrasound has several advantages. It passes through dense, opaque and electrically shielding media (water, concrete, plastics and so on), it is easily detected and coding is simple. Its disadvantages are short link distance and low data rate. The two most common communication techniques are pulsed carrier (the transmitter emits a series of discrete bleeps) and frequency modulation or FM (the transmission is continuous but the frequency varies with time). Amplitude modulation is not a recommended method as it is prone to fading (just like AM radio).

Light is another very familiar sensing medium. Some months ago I introduced the optical interrupter

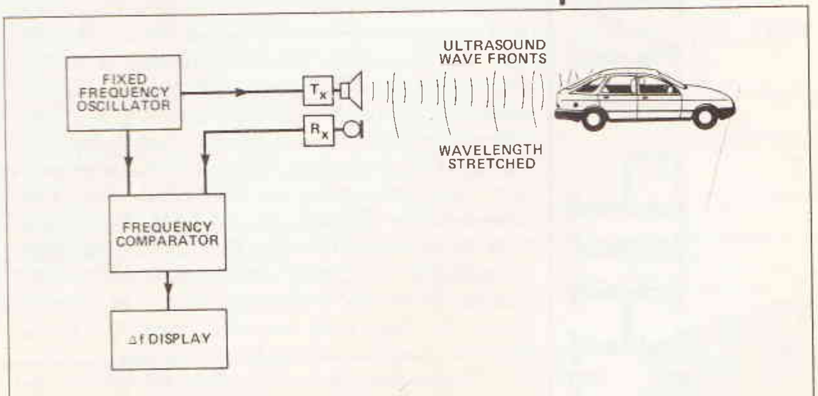

Fig. 2. Doppler shift speed measurement

and we have recently been discussing the esoterics of fibre optic sensors. However, in the real industrial context, there is a plethora of alternatives. The mechanism of the reflectance interrupter can be modified by the inclusion of a lens system to allow operation over distances or 300mm or more, while the transmittance interrupter can be split into two separate boxes and used over distances of several metres in burglar alarms and so on.

However, there are many more subtle and sophisticated optical sensors. A direct spin off from the ordinary interrupter is the optical fluid level sensor. In place of the free path between the emitter and detector there is a piece of glass or plastic which has a refractive index such that the light from the emitter falls on the detector via the reflected path while it is dry. If some other medium (a fluid) covers this material, the resultant change in its refractive properties causes the light to escape without falling on the detector (Fig. 3).

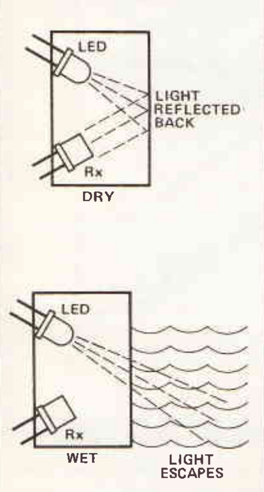

Fig. 3. A refractive fluid level sensor

Of course, photocell light meters are well known and used for many light monitoring tasks from photography to health and safety, and in level detectors such as burglar alarms but there are some tricks up our sleeve still to come.

There has been a recent fashion for domestic exterior lighting which switches on when someone approaches, rather than just when it gets dark. These lighting units use a device known as a pyroelectric detector. This consists of an element made of a complex metallic doped ceramic which exhibits a change in conductivity when exposed to *changing* infra-red flux. Under constant conditions, no output is obtained so this is a group B sensor. It is remarkably sensitive and can detect the change in flux due to body heat as a person moves across its field of view. These devices need quite a lot of care in handling, as they are subject to damage by over-intense illumination and are prone to some unwanted effects such as piezo-electric action (they are vibration sensitive). However they are very useful for the detection of thermally emissive bodies. A typical detection circuit is given in Fig. 4.

One of the more sophisticated applications of the pyroelectric sensor is the sorting of objects of differing temperatures. For this, a 'chopper' is required. Although the sensor only detects changes in intensity, the magnitude of the output change is proportional to the intensity change. A rotating vane set (a 'windmill') between the sensor and the objects to be monitored rotates at a constant speed (Fig. 5) and the sensor monitors the objects and the vane set alternately. A continuous sequence of comparisons is made between the vane temperature and the object temperature. The vanes must of course be maintained at a constant temperature.

The detection of heat is a field where some rapid progress has been made in recent years. The earliest and most common heat sensors with electrical output are thermocouples. These are twisted or welded junctions of dissimilar metals which generate a voltage proportional to the temperature of the junction. They come in various types with differing characteristics and all have the advantages of general robustness, small size and the ability to withstand very high temperatures. However, they are not very linear in their response and their signals require considerable amplification for normal uses. Most common applications are furnace temperature control and the like where the fairly long response times (>0.1s) and ±0.5°C precision are not limiting factors.

Next to thermocouples, thermistors are the next oldest group A or continuous temperature sensors. These are in effect resistors with a large linear or non-linear temperature dependency. They are positive or negative working — the resistance increases or decreases with temperature — and can be obtained with a sharp transition temperature between cold and hot resistance, as well as a linear characteristic.

Thermistors have severe limitations on accuracy and tolerance but they serve well in applications such as inrush limiting in high current circuits (high wattage negative linear characteristic), over-temperature protection (low to medium wattage positive rapid transition characteristic) and the like. They can also be made very small and can substitute for thermocouples in many applications.

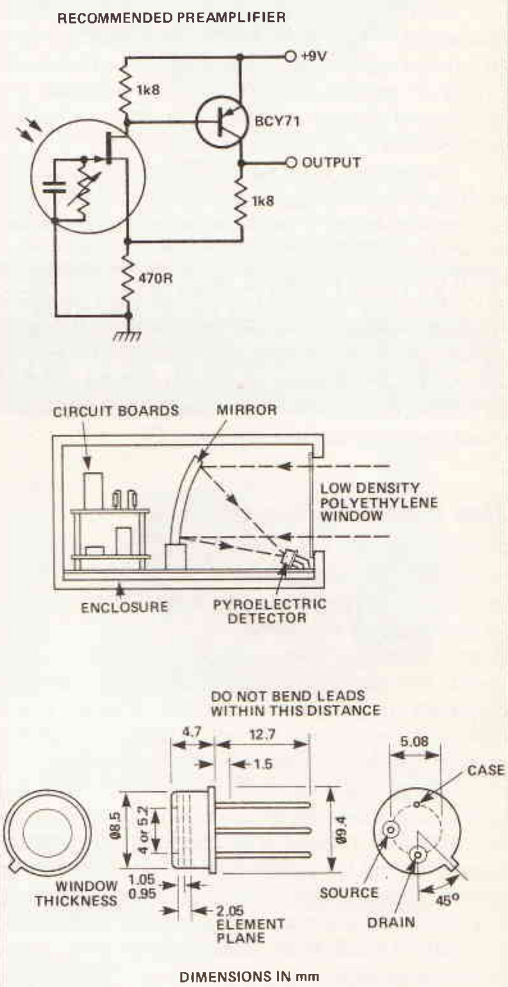

Fig. 4. Pyroelectric detector, a typical circuit and detector unit construction

It is well known (and frequently complained about) that semiconductor reference diodes are temperature dependent. Typically, a two-terminal current reference will have an output current which drifts linearly with temperature. I suppose this characteristic struck some clever person as interesting and they came up with the temperature sensor. The current drift with temperature has been increased and rendered more linear, until we get a device (such as the RS590) which delivers an output current proportional to absolute temperature over the range −55 to +150°C. Thus 0°C is represented by 298.2μA, as the device is referenced to Absolute temp. Feeding this current through a transimpedance amplifier or measuring the voltage drop across a fixed resistor carrying this current gives us a voltage proportional to temperature.

The capacitive proximity detector works on a similar principle, except that the other component of the tuned circuit is influenced by the detected object, and working distances are generally smaller.

Motion and acceleration are two of the most tricky things to detect and measure. There are so many kinds of motion! Demands range from shaft rotation speed to linear velocity, to displacement versus force, to tracking the erratic path of a randomly moving object. A whole issue of ETI would not be large enough to cover the subject in depth, so next month we will pick a few simple systems.

In the meantime, examples of all the sensors discussed here should be available from decent component stockists.

Even more clever is National's LM35 which is a direct temperature to voltage sensor. This has a power pin, a ground pin and an output pin, the two versions have working ranges of 0 to 100°C and −40 to + 110°C respectively. These devices are quite simply foolproof and in addition have no offset.

The final sort of temperature sensor to be mentioned is the assortment of mechanical devices — thermostats and thermal switches. These depend mainly on bimetallic elements, wax filled bellows, gas expansion and so on. They are widely used as emergency limiting devices but they are really too slow and too inaccurate to be considered in the same context as the other sensors mentioned here.

Magnetic field and current sensors have long been based on conventional electromagnetic effects — a current carrying conductor is surrounded by a magnetic field proportional to the current flowing. The commonest technique has been to cause the magnetic field to influence an inductive component in the detection circuit, altering the resonant frequency of a tuned circuit or directly inducing a current which can be measured.

However, some time ago a gentleman called Hall discovered the Hall effect whereby the behaviour of certain semiconductor devices is influenced by magnetic fields. Small devices (the size of TO220 transistors, for example) are now available, which are influenced by quite small magnetic fields, such as can be induced by a bar magnet about 4mm by 12mm. The Hall effect sensor delivers an output voltage proportional to the magnetic flux or field strength and although the sensitivity of individual devices varies quite a lot, the response is pretty linear and the devices are very robust. One possible use could be for key pressure sensing in keyboards. There are also Hall effect sensors which have inbuilt logic circuits to provide on/off switching.

Having already looked at speed sensing in terms of doppler shift techniques (sound), let us move on to proximity detection.

Industrial proximity detectors are generally based on inductive, capacitive and optical techniques. We have discussed the optical devices, so let's look at the others. The inductive proximity detector works very like the metal detector used by treasure hunters. An LC tuned circuit changes its frequency of oscillation when a conductive material is brought close to its inductive component. These sensors are normally used to detect presence or absence of objects, rather than their distance or position and they have working ranges of 1-20mm depending on the design and the material being sensed. They are generally packaged in boring cylindrical housings and frequently come with dedicated control circuitry.

ETI

OP-AMPS

Paul Chappell continues to look at op-amps used as differential amplifiers

Carrying on from last month's investigation of a simple differential amplifier, we now have the turbo-charged versions. The first pretender to the title of Ultimate Differential Amplifier is shown in Fig. 1.

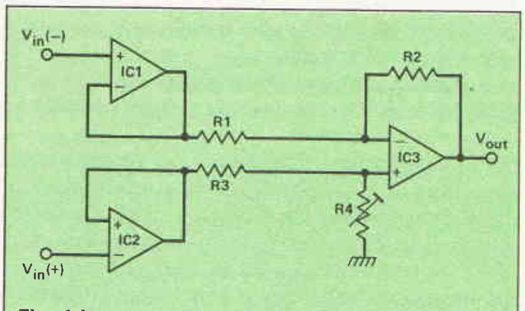

Fig. 1 Last month's circuit with added front ends

This circuit arises from a bull-at-a-gate approach to the problems I mentioned last month. If you remember, the main shortcomings of IC3 and its associated resistors as a differential amplifier were its sensitivity to the output impedances of the drive circuit and the critical dependence for good common mode rejection (CMR) on the matching of R1/R2 to R3/R4. Attacking these defects directly, what do you do? Buffer the inputs and trim the resistor match, of course!

It's easy to be unkind about this circuit, but you have to remember that it arose in the early days of op-amp ICs when designers were still much more in tune with discrete component circuits than with plastic packaged amplifiers. If your discrete instrumentation amplifier is affected by source impedances, what more natural than to use a FET or Darlington to buffer the inputs? Figure 1 is the result of applying the same instincts to an op-amp circuit. But if you have three whole op-amps at your disposal, there's a darn sight more effective way to use them than this!

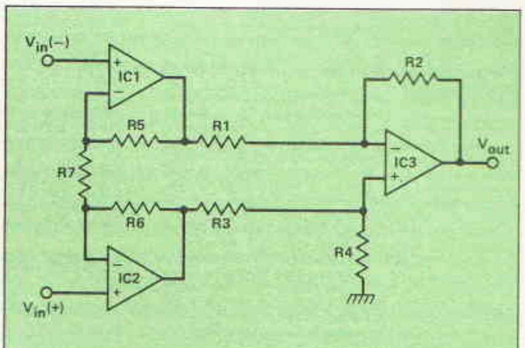

Fig. 2 The improved 3 op-amp circuit

Figure 2 shows the most common high performance configuration. The only difference between this and Fig. 1 is the addition of three resistors, but what a difference they make!

The first thing to notice about the circuit is that because IC1 and IC2 act to maintain their respective input terminals at the same voltage, the voltage at the top of R7 will be $v_{in(-)}$ and at the bottom will be $v_{in(+)}$. The second thing to spot is that any current which flows through R7 must also flow through R5 and R6.

Suppose the circuit is driven by a pure common mode input — that is to say, the inputs $v_{in(-)}$ and $v_{in(+)}$ change in voltage by exactly the same amount. The voltage across R7 will remain constant and so will the current through it. If the current is unchanged, so will be the voltage across R5 and R6. The result is the input voltages, the − input terminals of IC1 and IC2 and the outputs of IC1 and IC2 all move up and down in unison. The signal is passed to the outputs of ICs 1 and 2 without alteration.

Now picture the situation where the two inputs are varying differentially. Since the input voltage appears across R7, by Ohm's law you can easily calculate that any difference in voltage is magnified by $1+(R5+R6)/R7$ by the time it appears at the outputs of ICs 1 and 2. The values of R5,6 and 7 are often chosen to give front end gains of 1000 or more in instrumentation amplifier circuits.

The situation we have, then, is that IC3 and its associated resistors form a differential amplifier which is no better than the one described last month. To be

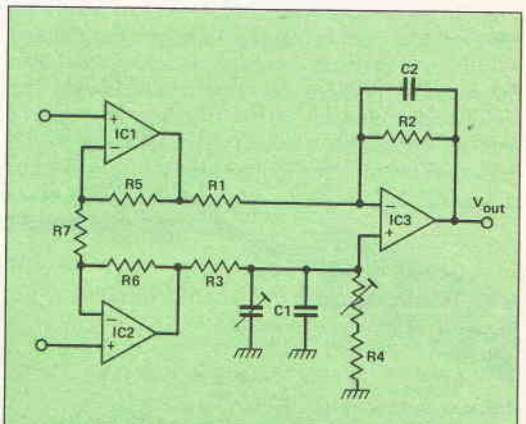

Fig. 3 Additional trimming capacitors for frequency compensation

more accurate — it's exactly the same! The difference is that, with the front-end turbo charger in place, the differential component of the signal is already 1000 times bigger in comparison to the common mode component by the time it hits R1 and R3. This means that, in theory at least (and not so far off in practice), you can add 60dB to the CMR figure that would be achieved by IC3 alone!

If you think I'm about to tell you that the values of R5,6 and 7 have to be chosen to some absurdly tight tolerance, you're wrong! For reasons which won't be apparent from this simple analysis of the circuit, it's a good idea to make R5 and R6 the same value but matching them to 1% is more than enough. In pre-packaged instrumentation amps (ICs or hybrid cir-

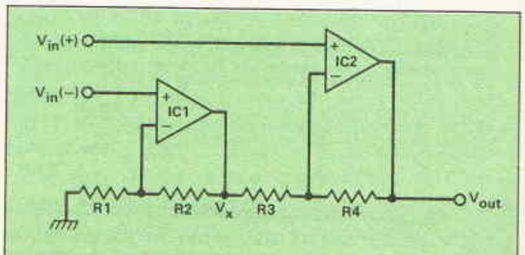

Fig. 4 The 2 op-amp compromise circuit

CIRCUIT THEORY

cuits) R7 is usually an external resistor chosen to set the gain of the circuit and (within reason!) can be any value you like.

The requirement that R1 and R3 should be driven from low resistance sources is settled by the very low output resistances of ICs 1 and 2. In op-amp and resistor versions of the circuit, final tweaking of CMR is usually made by trimming the value of R4.

The circuit still has the requirement that the output resistances of the circuit generating $v_{in(+)}$ and $v_{in(-)}$ should be very low in comparison with the input resistances of the differential amplifier. The input resistances we are dealing with this time though are those of IC1 and 2 which will be several orders of magnitude higher than those resulting from the resistors in last month's circuit. One thing you have to watch is not to spoil this advantage with the bias resistors to the +input terminals of IC1 and 2. In Fig. 2 I haven't shown any bias resistors at all. The ideal situation is that the input op-amps should draw their bias current from the driving circuit. If this is not possible, you've got a bit of juggling to do to make sure that the resistors are large enough to have negligible effect on the CMR but not so big as to cause excessive offset voltage at the output of IC3.

One thing to be aware of with this circuit is that if you aim for huge CMR figures, the calculated values will only be achieved at low frequencies. When I say low, I mean *low!* Try for 110dB, for example, and you will probably find the CMR beginning to fall at frequencies in the 10s of Hz. The main reason is unequal phase shifts of IC1 and 2. This can be compensated for, to some extent by including a pair of capacitors to trim the CMR at higher frequencies (Fig. 3). If you use the circuit for (say) audio rather than instrumentation purposes, the general scheme is to settle for a lower differential gain (otherwise you'll have frequency response problems), to aim for a lower CMR (otherwise you'll be disappointed!) and to trim the low and high frequency CMR individually.

The next circuit (Fig. 4) aims to achieve similar results to Fig. 2 but with only two op-amps. It's not often seen but is an excellent compromise between the cheap 'n' cheerful single op-amp circuit and the full blown instrumentation amplifier.

If last month's circuit was a pair of scissors, this one is a nutcracker! Figure 5a shows the situation where the two inputs are at the same voltage, and it's fairly clear that the condition for the output to remain at 0V under these conditions (and therefore for any common mode component of the input to cancel) is: R2/R1=R3/R4.

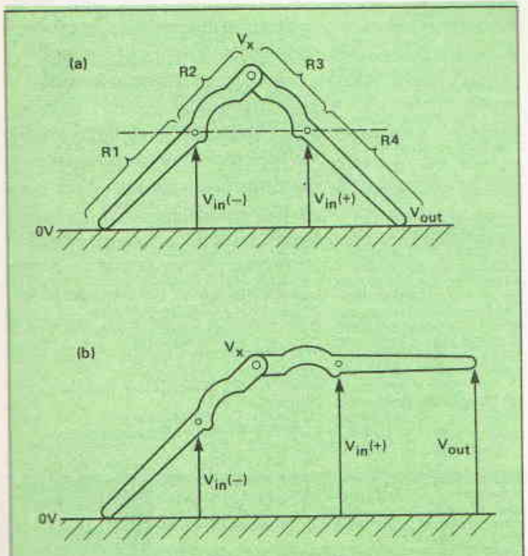

Fig. 5 The nutcracker analogy for Fig. 4

Figure 5b shows how an output is generated when the inputs are at different voltages. As with last month's scissors, you can push the analogy as far as you like if you find it helpful.

The circuit has Fig. 2's advantage of high input resistance but also two of the serious flaws associated with the single op-amp circuit: there's no way to trim the gain and CMR independently and the CMR is critically dependent on the matching of two resistor ratios.

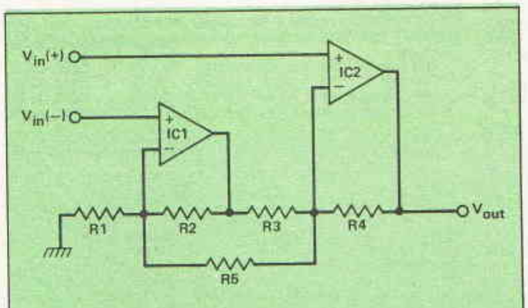

Fig. 6 The improved 2 op-amp circuit

Both of these defects can be overcome by the addition of a single extra resistor, as shown in Fig. 6. The action of R5 is very similar to that of R7 in Fig. 2. The differential input voltage appears across it by the action of IC1 and IC2 maintaining their + and − inputs at the same voltage and it allows you to 'steal' extra differential gain from the circuit without affecting the CMR trim.

That completes our tour of differential amplifiers but before I go I'd like to show you one more circuit. It's not a differential amp but it's another circuit which relies on the matching of two resistor ratios for its performance, which you're probably becoming rather wary of by now! You may also be able to spot some similarities between this circuit (Fig. 7) and last month's subtractor.

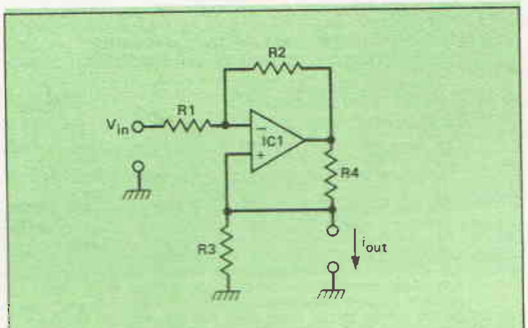

Fig. 7 Not a differential amplifier but a circuit with many faults in common

The idea is that if R1/R2=R3/R4, the output current will be directly proportional to the value of v_{in} and will have a value independent of the resistance of the load. In other words, the circuit is a voltage to current converter.

My reasons for showing it to you are threefold. It's another example of a circuit which works well on paper but not so well in practice (in fact, this one is so bad that I've only once seen it used!). The reason for its shortcomings are the same as those for the differential amps, it's another circuit where the problems are caused by the configuration rather than the quality of the op-amp. It is also (I think, anyway) fairly inscrutable so you might like to exercise your brain cells by trying to come up with an intuitive explanation of why it works! Working out the 'formula' is easy enough but how would you convince someone with no algebra whatsoever that it does (in theory, anyway) do what it's supposed to? You have ten minutes, starting . . . NOW.

ETI

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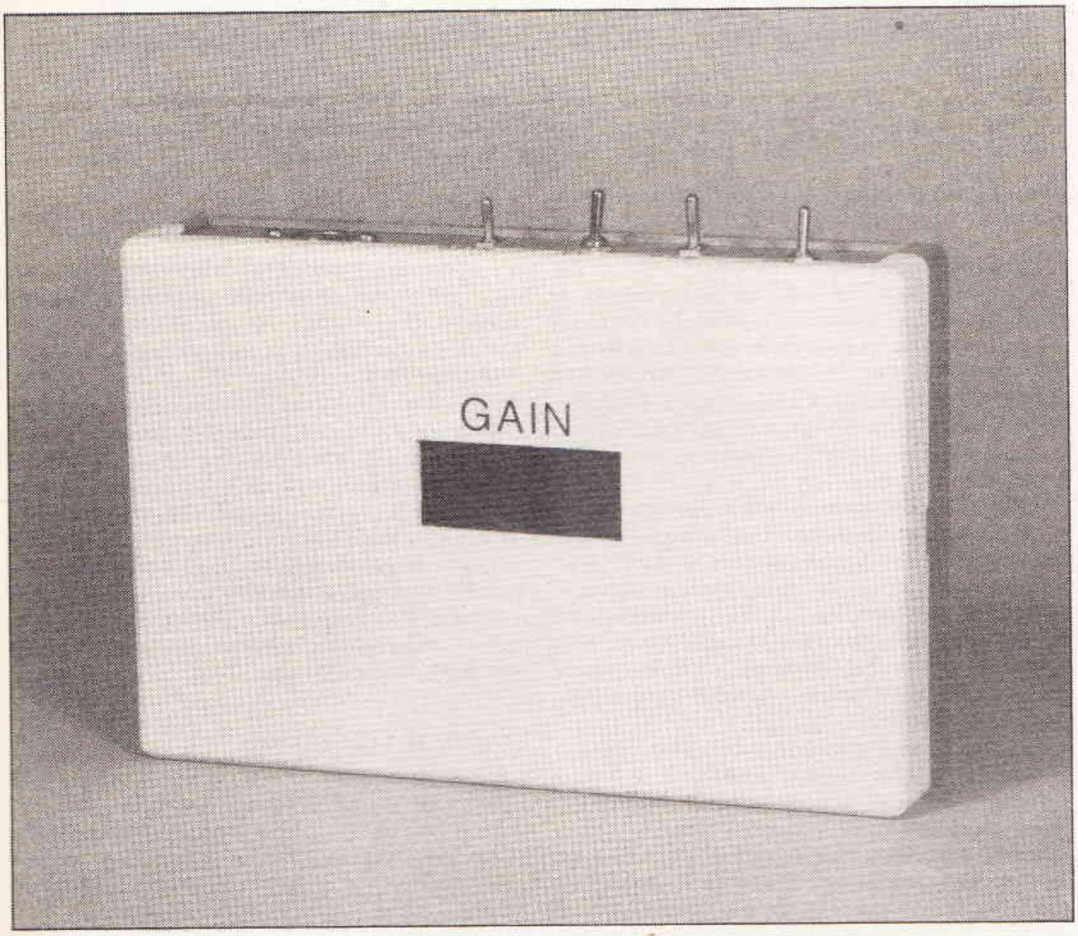
DIGITAL TRANSISTOR TESTER



Robert Penfold scorns the analogue and lets his digits do the testing

This transistor tester was developed to fulfil the need for a unit that would provide a quick and convenient means of testing DC current gain (h_{fe}) and leakage, Some other testers are inexpensive to build but provide only basic go/no-go checking or are relatively slow and difficult to use.

There are also some simple but effective circuits based on moving coil meters but the relatively high cost of meters these days makes these designs less attractive than they once were. On the other hand, an equivalent circuit using a digital readout is substantially more complex but not necessarily much more expensive. A 2-digit display gives better accuracy than most of the moving coil meters currently on sale and certainly more than adequate accuracy for this application.

This design has proved to be quick and easy to use in practice. It can test both NPN and PNP devices and has two gain ranges 0-99 and 0-990. This enables reasonably accurate checks to be made on anything from low gain RF and switching devices through to very high gain audio devices.

An over-range indicator is included on the 2-digit LED display and simple leakage tests can also be made using the unit. Power is obtained from an internal 9V battery.

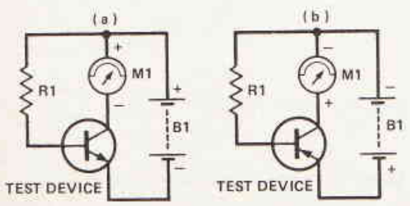


Fig. 1 Basic test circuits for NPN and PNP transistors

Testing Theory

Most simple transistor testers operate using the basic test set-up of Fig. 1a. Battery B1 supplies power to the test device with the correct polarity and meter M1

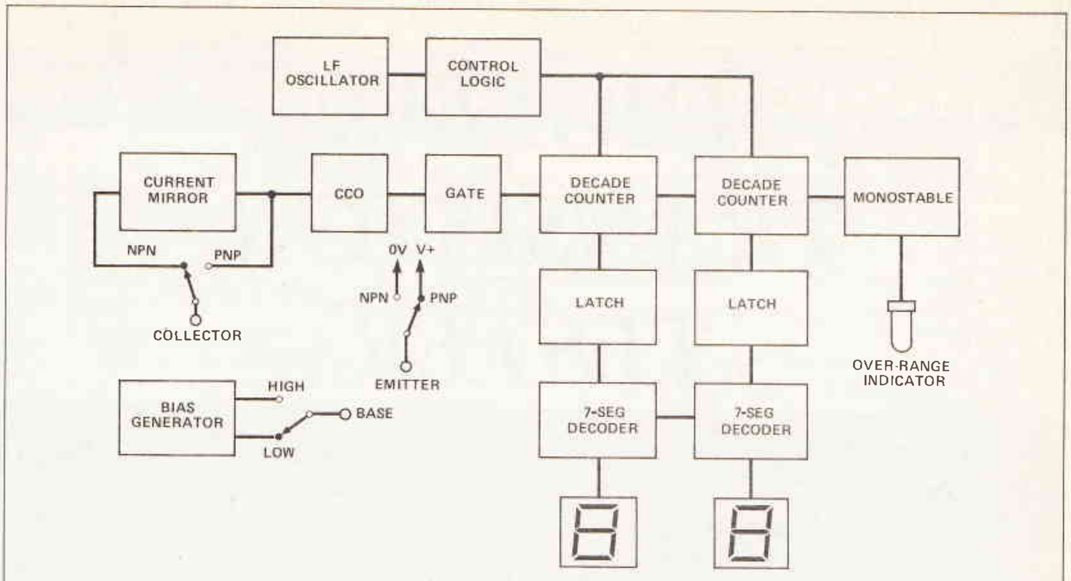


Fig. 2 Block diagram of the digital transistor tester

registers the flow of current in the collector circuit. The current flow from the collector to the emitter is normally very low and would typically be about one microamp or less for a silicon device. This is termed the 'leakage' current. Providing a small forward bias current to the base terminal results in a much larger flow of current in the collector circuit. The current gain of the transistor is equal to the collector current divided by the base current.

In this case R1 provides a small reference current to the base of the test device. The higher the gain of the device, the greater the collector current that will be registered on M1. In fact the circuit can be arranged so that M1 provides a readout direct in current gain. For instance with the value of R1 chosen to give a base current of 1μA and M1 having a full scale value of 1mA (1000μA) M1 would accommodate a current gain range of 0-1000.

This assumes the leakage current is very low and is not inflating the collector current flow but as explained previously, with silicon devices the leakage current is almost invariably insignificant.

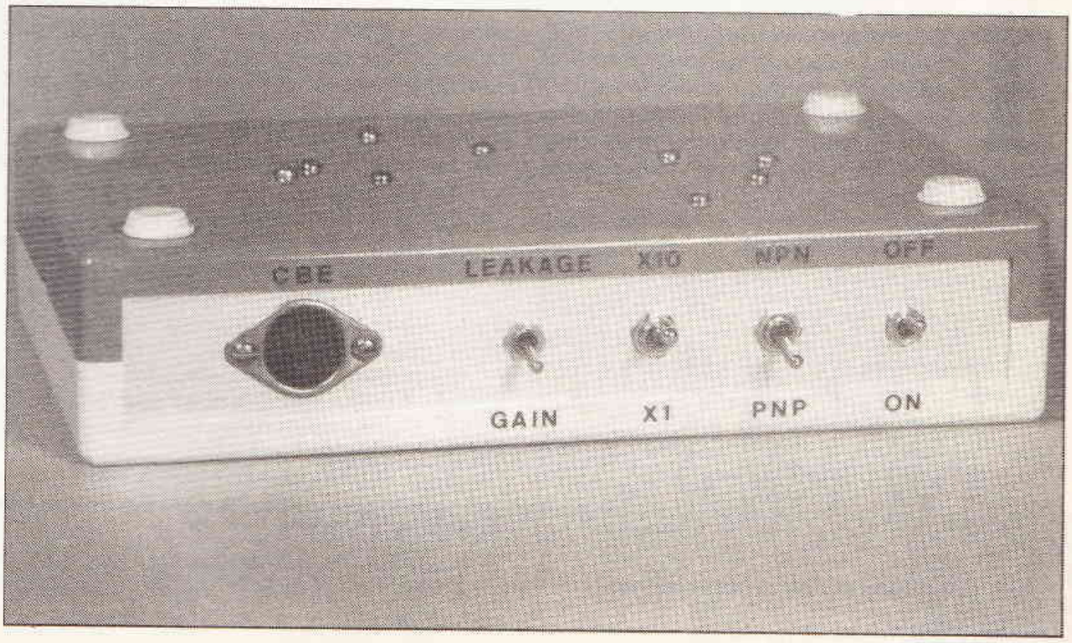
Fig. 1a shows the test setup for NPN transistors but the arrangement for PNP testing is essentially the same and is shown in Fig. 1b. It is just a matter of reversing the polarity of the battery and the meter.

This type of testing has a slight flaw in that it is not checking the gain at specific collector currents and voltages. These both vary according to the gain of the test component (high gain giving increased collector current and reduced voltage). The uncertain collector voltage is not of great importance as quite large variations in this factor have a minimal effect on the gain of test components. Variations in collector current have a greater (although still fairly small) influence on current gain. Results are perfectly acceptable in practice provided test components are not tested at very low collector currents. The use of two or more measuring ranges ensures that low gain devices can be checked at an acceptable current and also that they will give a high enough reading to provide reasonable good accuracy.

System Operation

The block diagram of Fig. 2 shows the general arrangement used in this transistor tester. The unit breaks down into two distinct sections, one providing the display and the other converting current gain into a suitable driver signal for the display circuit. The bulk of the circuit is used to provide the display.

The display section is a simple frequency counter



PROJECT

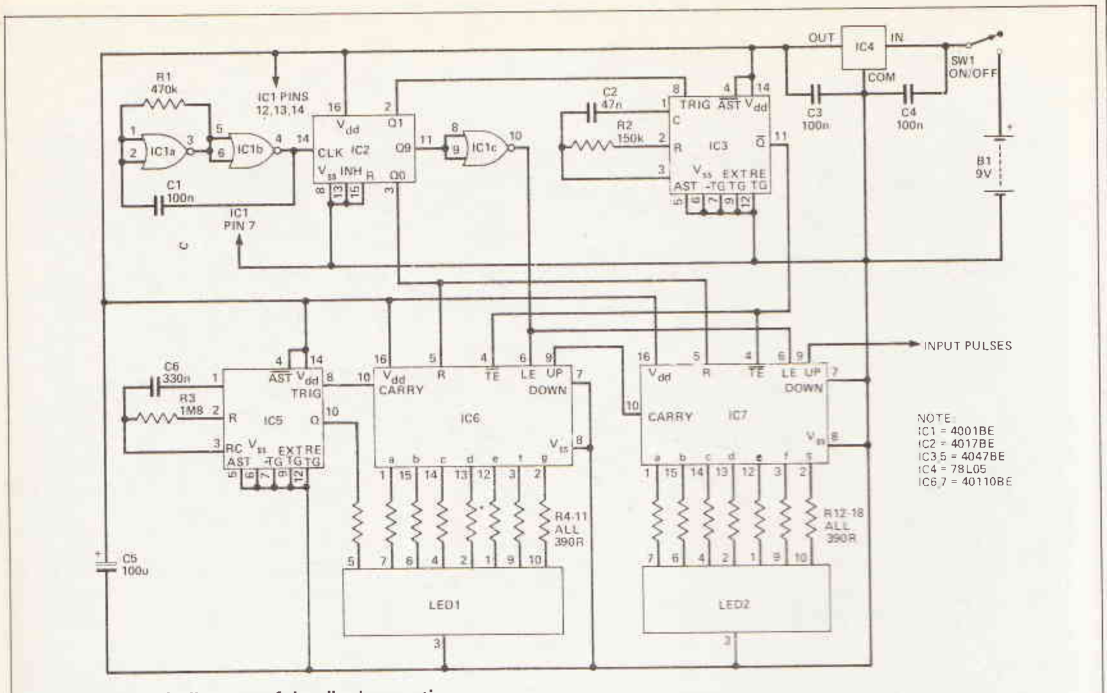


Fig. 3 The circuit diagram of the display section

HOW IT WORKS

The display section (Fig. 3) is built around two CMOS 40110BE integrated circuits which each contain a decade counter, latch and 7-segment decoder/driver. They also have 'toggle enable' inputs that effectively give a built-in gate that avoids the need for an external gate circuit. The 40110BE is actually an up/down counter but in this application it is only used as a straightforward up counter.

Unlike most CMOS devices, these have a high output current capability and they directly drive the common cathode LED displays via current limiting resistors. The carry output of IC6 is used to drive a positive edge triggered monostable based on IC5 and a trigger signal is only provided to IC5 if an overflow occurs. IC5 then activates the overflow indicator LED for just over one second, giving clear warning that the main display reading is erroneous. The overflow indicator is the otherwise unused decimal point segment of the most significant display digit.

The low frequency oscillator uses two gates of IC1 wired as inverters and connected in the standard basic CMOS astable configuration. The oscillator operates at approximately 20Hz but due to a divide by ten action in the control logic circuit this equates to only about two readings per second.

The control logic circuit is built around IC2, which is a CMOS 4017BE one-of-ten decoder. Output 0 (pin 3) going high resets the counters to zero and output 1 (pin 2) going high generates the gate pulse. It does so by triggering monostable multivibrator IC3. This generates a negative gate pulse of about 17ms at its $\overline{Q}$ output which is used to drive the gate inputs of IC6 and IC7.

With this type of display circuit both gate inputs must be driven and not just the one belonging to the least significant digit. Output 9 drives the latch inputs of the counter chips and latches the new reading prior to a new cycle commencing and the counters being reset. IC1c is used to invert this signal so as to give the negative latching pulse required by IC6 and IC7. Note that outputs 2 to 8 of IC2 as well as its carry output are left unused. Also, one gate of IC1 is left unused but its inputs are tied to the positive supply rail in order to prevent spurious operation.

Power is obtained from a 9V battery but a small 5V regulator provides a well regulated 5V supply for the entire circuit. This ensures the unit provides consistent results as the battery voltage drops.

In the input circuit (Fig. 4) R19 and R20 form a centre-tap on the supply lines and this drives the base terminal of the test device via one of two switched current limiting resistors (R21-R22). These provide the unit with its two measuring ranges and SW2 is used to select the desired base feed resistor. By driving these resistors from the mid-supply voltage there is no need to bother with any NPN/PNP switching in the base circuit. SW3 can be used to cut off the base bias current so that leakage checks can be made.

Q1 and Q2 form a conventional current mirror circuit, with R23 and R24 providing current limiting in the event of any accidental short circuits or closed circuit devices being checked.

There is no need to switch out the current mirror in the PNP mode and NPN/PNP switching can therefore be achieved using just a DPDT switch (SW4).

In theory, Q1 and Q2 should be a matched pair to obtain an accurate 1:1 ratio of input to output current. In practice, quite wide differences in their gain did not produce any great discrepancies between the NPN and PNP modes. One way of ensuring really accurate results is to use any two BC559s for Q1 and Q2 initially and to then use the unit to select two reasonably well matched transistors from a batch of (say) half a dozen devices. However, this is by no means essential and unmatched devices should suffice. It is advisable to use transistors from the same gain group (say, two BC559Bs).

The CCO is just a 555 astable circuit. No resistor is used between pins 6 and 7 in order to keep C7's discharge time as short as possible. This makes the period of each cycle almost totally dependent on the charge current and ensures good linearity. A TLC555CP is specified for the IC8 position as this gives a much lower current consumption than the standard 555 and it also seems to be somewhat faster in operation (which again aids good linearity). The collector current at which the devices are tested is dependent on their current gain but is typically around one or two milliamps.

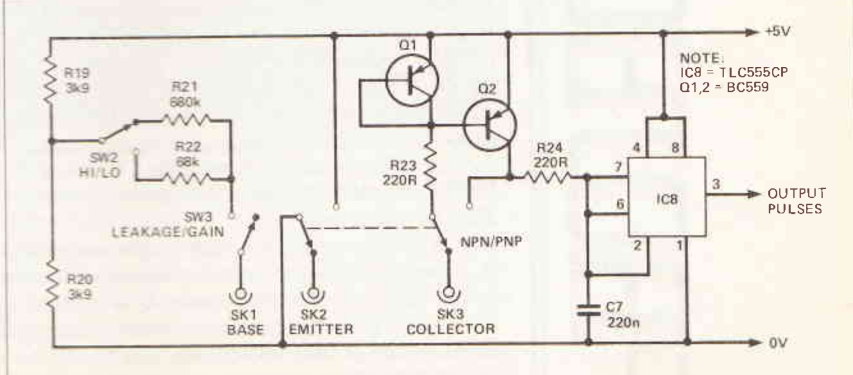
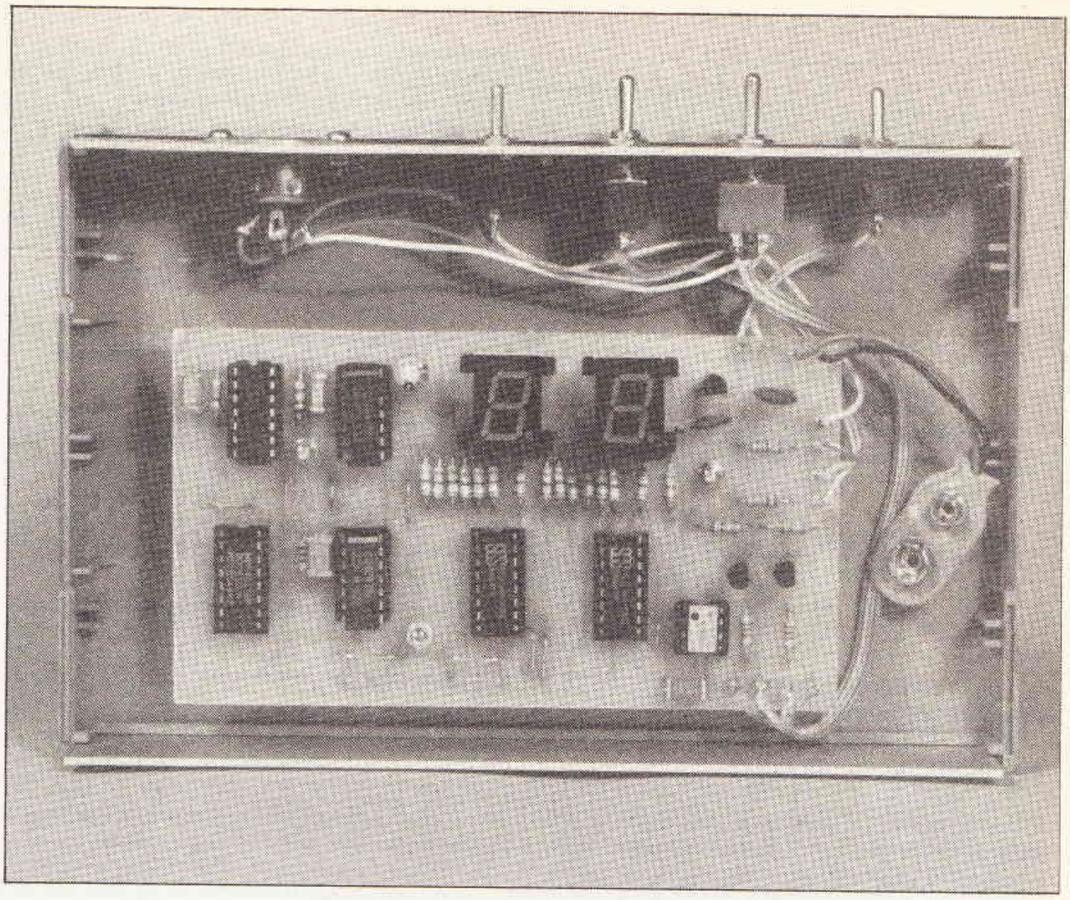


Fig. 4 The circuit diagram of the input section



circuit. This is controlled by the low frequency oscillator and a simple logic circuit. First the two decade counters are reset to zero and then a gate at their input is activated. Input pulses then flow into the 2-digit counter circuit until the gate pulse ends. Another pulse from the control logic circuit then activates the two latches, which store the count and feed it through to two 7-segment decoder drivers. The 2-digit display therefore shows the number of pulses received during the gate period.

This cycle is then repeated, with the decade counters being reset again. Note though that resetting the counters does not affect the latches and the old count is displayed until a new one has been taken and has been fed into the latches. The unit accordingly provides a continuous readout which is updated approximately twice per second. If the count goes beyond 99, this is detected by a monostable driven from the second counter, and this activates a warning LED.

The display circuit requires the collector current of the test components to be converted into a proportional frequency. This is not difficult and all that is needed is a CCO (current controlled oscillator) having a reasonably linear control characteristic. This leaves a slight problem in that the CCO operates as a current sink which will operate properly with PNP devices (which act as current sources) but is incompatible with NPN transistors which act as current sinks and must be fed from a current source. The solution to the problem is to drive the CCO direct from PNP transistors but to drive it via a current mirror for NPN transistor testing.

A current mirror is a very simple circuit which provides an output current that is equal but opposite to the input current it receives. One pole of the NPN/PNP switch connects the collector test socket to the input of the current mirror or the CCO, as appropriate. The other pole connects the emitter test socket to the appropriate supply rail. A bias generator provides two switched base bias currents and these provide the unit with its two measuring ranges.

Construction

Apart from the usual off-board components (controls, sockets, and battery) all the components fit onto the printed circuit board, as detailed in Fig. 5. All the ICs are CMOS types and the usual anti-static handling precautions should be observed when dealing with these. In particular, they should all be fitted in sockets but should not be plugged into the circuit until the unit is complete in all other respects.

It is also advisable to fit the displays in sockets. Apart from eliminating the risk of them sustaining heat damage when they are fitted to the board, this is also advantageous in that it raises them clear of other components on the board. Remember that the displays must be positioned just behind a window cut in the front panel and this will not be possible if other components protrude significantly higher above the board. 0.5 and 0.56in displays are compatible with the PCB layout but the larger type generally seem to offer slightly higher brightness for a given LED current. The displays must be common cathode types.

A dozen link wires are required and these can be made from the leads trimmed from the resistors. Fit single-sided pins at the points where connections to off-board components will be made.

A plastic and metal case having approximate outside dimensions of 180×120×39mm will comfortably accommodate all the components. This assumes a reasonably small battery such as a PP3 is used. The current consumption of the unit is quite high at around 65µA and if a small battery is used it must be a 'high power' or nickel-cadmium rechargeable type.

The four controls and the test sockets are mounted on the front panel but the case is used vertically so that this effectively becomes the top panel. I used a 3-way DIN socket for SK1-3 and most small

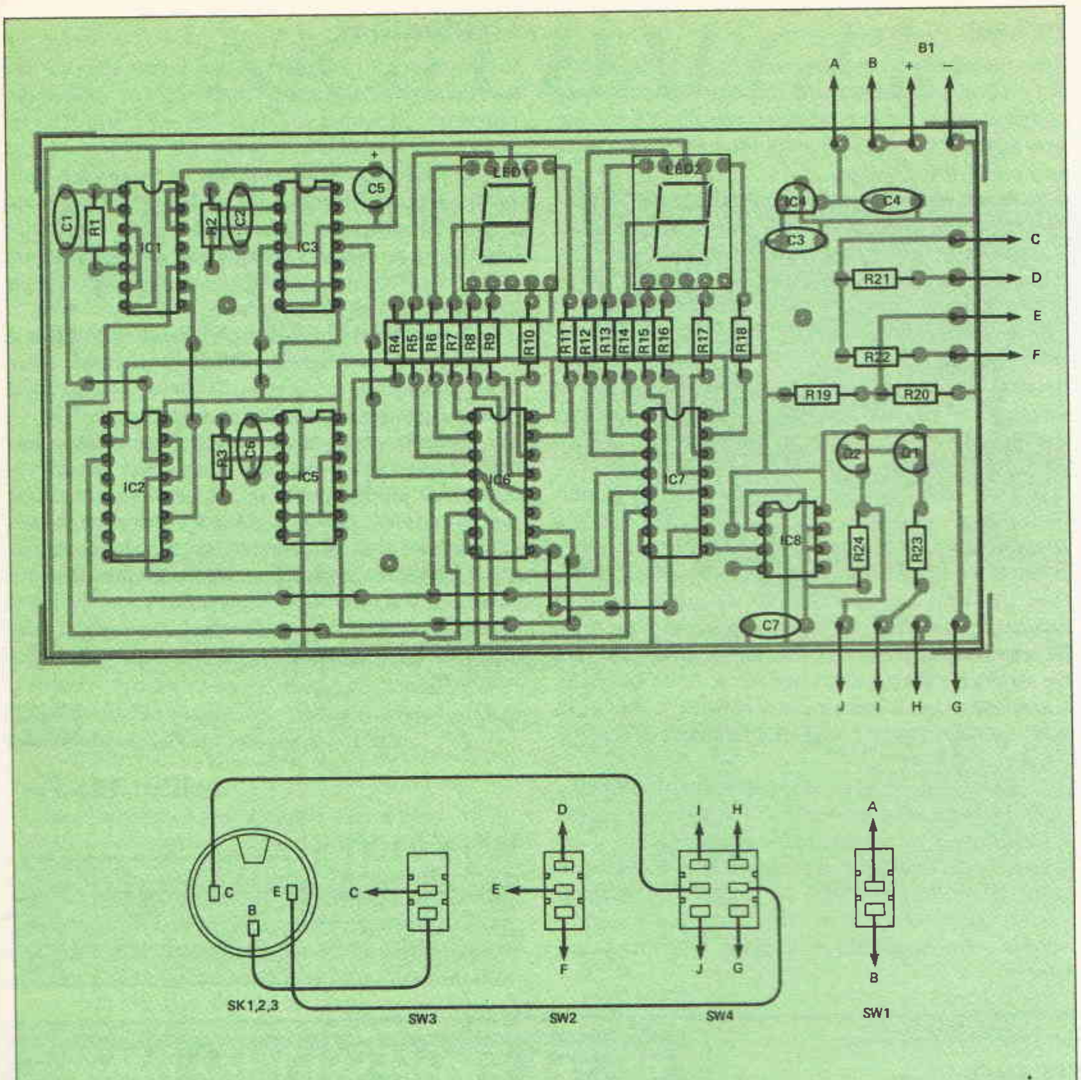


Fig. 5 Component overlay and inter-wiring diagrams for the digital transistor tester

PARTS LIST

RESISTORS (all ¼W 5%)		IC2	4017BE
R1	470k	IC3,5	4047BE
R2	150k	IC4	78L05
R3	1M8	IC6,7	40110BE
R4-R18	390R	IC8	TLC555P
R19,20	3k9	Q1,2	BC559
R21	680k	LED 1,2	0.5/0.56in common cathode 7-segment display
R22	68k		
R23,24	220R		
CAPACITORS		**MISCELLANEOUS**	
C1	100n polyester	B1	9V (PP3) battery
C2	47n polyester	SK1-3	3-pin DIN socket
C3,4	100n ceramic	SW1,3	SOST toggle
C5	100µ 10V radial electrolytic	SW2	SPDT toggle
C6	330n polyester	SW4	DPDT toggle
C7	220n polyester		
SEMICONDUCTORS		PCB. Case (180×120×39mm). Battery clip. IC sockets. Connecting wire. Nuts and bolts.	
IC1	4001BE		

transistors will connect satisfactorily with one of these. An alternative would be to use three 1mm sockets mounted in the same triangular pattern. Either way, a set of test leads terminated in small crocodile clips will be needed in order to make connections to unco-operative devices.

The printed circuit board is mounted on the rear panel (base) of the case, using 12mm stand-offs so the fronts of the displays are brought suitably close to the front panel. A window for the displays must be cut in the front panel. This is not too difficult using a coping saw or fretsaw to make a rough initial cutout and then carefully filing this out to precisely the required size. Some red display window material is then glued in place behind the cutout.

To complete the unit the hard-wiring is added as detailed in Fig. 5. This is all pretty straightforward and should not give any difficulties.

In Use

After giving the wiring the usual final check, switch the unit on and observe the display. This should an initial random number, followed about half a second later by 00. If this does not happen, switch off at once and recheck the wiring.

Assuming all is well, try connecting a few test devices to the input sockets, remembering to select NPN or PNP, as appropriate. It is unlikely that any damage will occur to silicon devices if the wrong setting is inadvertently tried but greater care should be exercised when dealing with germanium devices. With silicon transistors the leakage currents are generally so low that a 00 display should always be obtained when making leakage tests. Any other reading almost certainly indicates that the device under test is faulty.

The situation is less straightforward with germanium transistors, where quite high leakage currents are not unusual. Leakage readings of up to about 8 are quite normal but anything much higher than this would suggest the device under test is of dubious quality. Remember that gain readings must be adjusted downwards by the apropropriate amount if a significant leakage level is detected. For example, if a transistor has a leakage level of 6 and a gain of 45 is measured on the x1 range then the true gain of the component is only 39.

The tester can be used to check diodes. With the cathode terminal connected to the collector socket and the anode connected to the emitter socket, there should be an overflow indication with the unit set to the PNP mode. With SW4 set to the NPN position, the display should read zero for silicon diodes and a very low reading should be obtained with germanium types.

Calibration

In common with many transistor testers, this one has no means of adjusting readings for calibration purposes. Provided C2, C7, R2, R21 and R22 all have tolerances of 5% or better, the unit should give good accuracy. The vagaries of transistor gain parameters are such that there is little point in getting too pedantic about the accuracy of a simple transistor tester. Also, to calibrate the unit it would be necessary to have a reliable transistor tester or reference devices having accurately known gains.

Beware of the transistor checkers built into some multimeters. The accuracy of these ranges often seem to be unspecified and the h_{fe} range of my analogue multimeter seems to under-read by about 50%!

The best calibration source is probably a few transistors which have had their gains accurately checked by feeding them with accurate base currents, measuring the resultant collector currents and then reaching for the calculator to work out the current gains. This is the method used to derive the optimum values for the prototype. If you wish to calibrate the finished unit, despite the difficulties involved, trim the value of R2 to give the unit the correct level of sensitivity.

ETI

BUYLINES

None of the components used in this projects should cause particular problems. All are available from usual suppliers. The PCB is available from the ETI PCB service as detailed in the back of this issue.

PROJECT

NiCd CHARGER

1st CLASS

Batteries flat? Find out what shape they should be with Keith Brindley's simple charger.

Most readers will know the benefits of nickel cadmium cells — they are secondary cells and, as such, may be recharged when flat. Their only real disadvantage (the high purchase price when compared with primary cells) is more than outweighed when you consider that they can be recharged over 500 times during useful life.

Naturally users of NiCds need a charger, many of which are available over the counter. The ETI NiCd Charger has one advantage over most of these commercial counterparts in that the cell type is selected with a rotary switch, so that most available types (in fact, *all* popular types) may be recharged.

This switched selection means those cells and batteries of lower capacity (PP3, AAA,AA) can be recharged at a higher than usual charge rate, thus reducing the time till charged. This can be most useful if you're in a rush — a PP3-sized NiCd battery can be charged from flat in a little under 20 minutes! Details of charging procedures are given later.

Construction

Two methods of construction are offered: PCB or stripboard. Neither method creates any particular problem but the usual procedures and care should be taken, depending on your chosen method.

The PCB component overlay is shown in Fig.3 while the stripboard layout is in Fig.4. There's nothing difficult in either. Solder in the links first (there's only one in the PCB) followed by circuit board pins if you use them (we recommend them!). If you're building your project on stripboard, now is the time to make all the track cuts. Next, solder in passive components, ensuring capacitor C1 is inserted the right way round. Finally, insert and solder bridge rectifier BR1 and integrated circuit IC1, making sure they are both the right way round.

Now, drill the case to mount the circuit board.

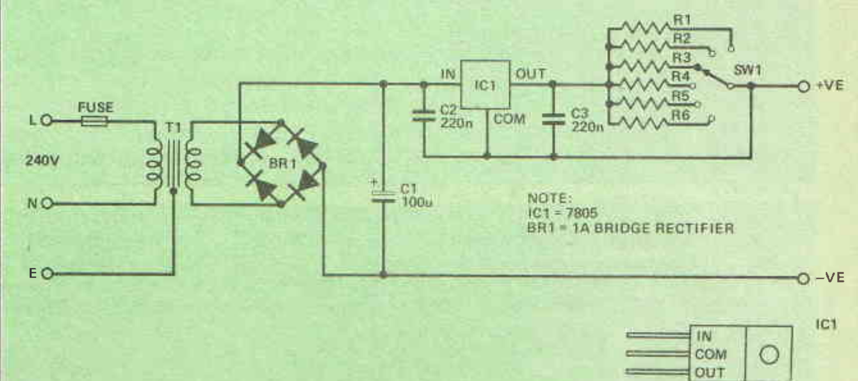


Fig.1 Circuit of the ETI NiCd Charger

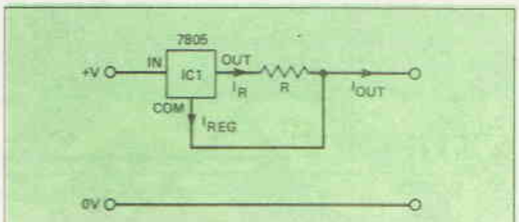


Fig.2 Showing how a 7805 voltage regulator IC may be configured as a constant current generator, suitable for recharging NiCd cells

HOW IT WORKS

Full-wave rectification of the transformer's 12V AC output is performed by bridge rectifier BR1 (see Fig.1). The resultant DC voltage is smoothed by capacitor C1 to around 17V ($12 \times \sqrt{2}$).

Integrated circuit IC1 is a 7805 voltage regulator which, under normal circumstances, would regulate this to a highly stable and regulated 5V DC output. However, the connection of a resistor between the IC's output and its common connection changes its operation from a voltage regulator to a constant current generator (Fig.2). Output current of the constant current generator is given by:

$$I_{out} = I_R + I_{reg}$$

but,

$$I_R = \frac{V}{R}$$

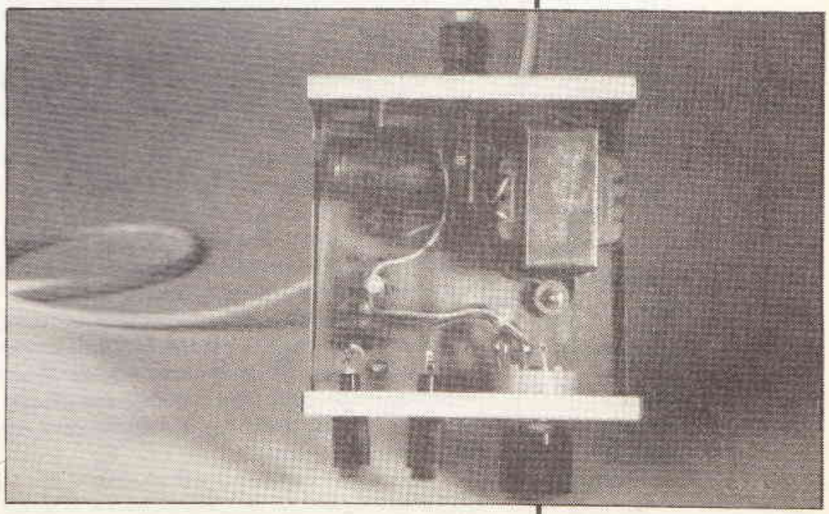
where V is the regulator nominal voltage. So:

$$I_{out} = \frac{V}{R} + I_{reg}$$

By switching into circuit different values of resistor, different constant currents may be generated. Resistor values are calculated by rearranging the above formula, so that:

$$R = \frac{V}{I_{out} - I_{reg}}$$

Table 1 shows how the denominator is calculated for the required charge currents in the ETI NiCd Charger.



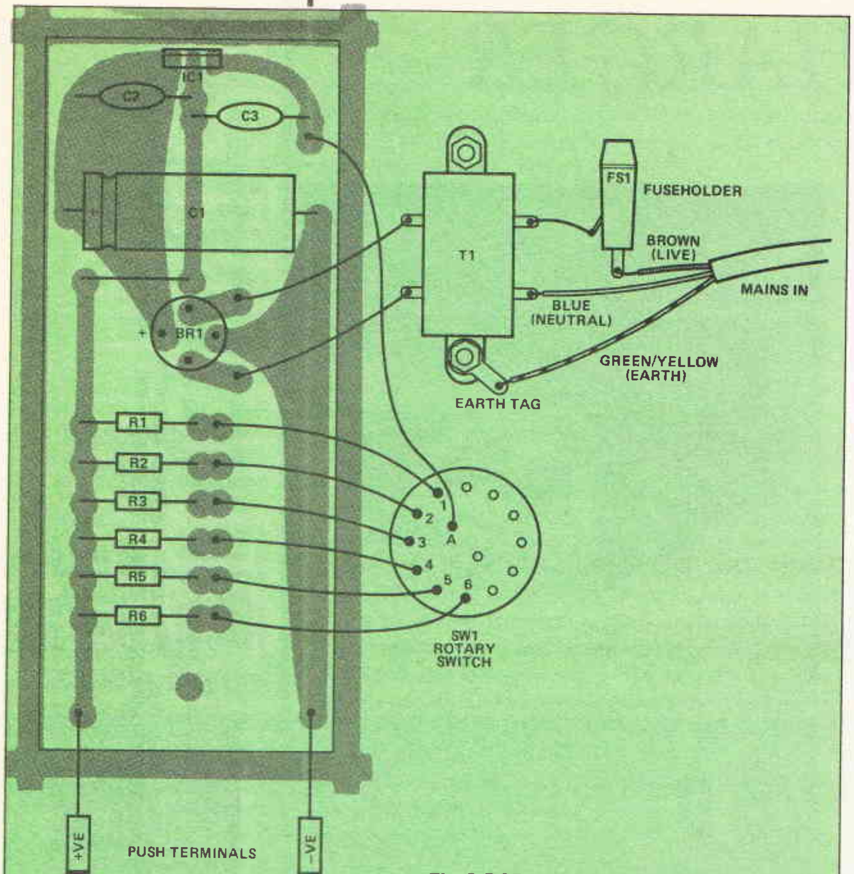


Fig.3 PCB component layout and wiring

NiCd type	Capacity (mAh)	Current at 10h charge rate (mA)	$I_{out} - I_{reg}$ (mA)	Calculated resistance (R)	NPV (R)	Practical current (mA)
PP3	110	11	6.5	770	820	12
AAA	180	18	13.5	370	390	48
AA	500	50	45.5	100	120	48
PP9	1200	120	115.5	43	47	115
C	2200	220	215.5	23	27	200
D	4000	400	395.5	12.5	15	340

Table 1 Listing NiCd cell/battery types, capacities, charge rates and calculations for resistances used in the ETI NiCd Charger

switch SW1, terminals, fuseholder, grommet and transformer. Case markings should be applied now.

Mounting the circuit board depends on which constructional method you've chosen. The PCB is best mounted with a fixing bolt and spacer on the bottom of the case. The stripboard can be fixed using self-adhesive pads. Integrated circuit IC1 needs to be bolted to a heatsink or, if you use a metal case like us, to the back panel of the case. As well as eliminating the requirement for a heatsink , bolting IC1 to a metal case provides a second fixing point for your circuit board, too. Mount all the remaining parts.

Following the wiring layout in Fig.3 or Fig.4, wire up your project. This is where circuit board pins come in useful — your circuit board is fixed in position, and it is a relatively simple job to make all interconnections between parts.

No setting up is required but a check can be made on operation if you possess that most useful piece of test equipment, a multimeter. You'll also need at least one NiCd cell (a low resistance resistor — say, 1R0, provides an adequate simulation). Connect the multimeter and the cell(s) or resistor in series and set your multimeter to read at least 350mA FSD. Turn on and check that current values correspond approximately to those given in Table 1 in the *practical current* column. If differences of more than just a couple of percent are found, check all components for polarity and value.

In use, you'll need a cell holder of some description, depending on which size of cell, and how many, you want to charge. At the charge rates used (a maximum of 340mA) no problems will be encountered if you want to use cheap plastic cell holders. PP3 and PP9-sized batteries can be connected to the Charger with simple battery connector clips.

THEORY

NiCd cells are rated by capacity – the total amount of electrical energy expressed in Ah or mAh – which can be obtained from them from a fully charged state. In common with other forms of secondary cells, this capacity (given the notation C) depends on the rate of discharge, so it's best to express C under fixed conditions – usually the rate which brings the cells to an end-point of 1V in five hours – the *five hour rate*.

From this capacity we can calculate rates of charge so that the cells will not be damaged by excessive currents. A couple of rules-of-thumb help here. First, a totally discharged cell can be recharged by a current for a given length of time, calculated from the capacity. Thus a cell with a 1Ah capacity can be recharged from fully discharged by a 1A current for 1h or a 100 mA current for 10h or a 10A current for 6 minutes (0.1h) and so on.

Problems can arise, however, because you cannot always be sure a cell is fully discharged, so the cell may become overcharged before the calculated recharge cycle time has elapsed.

Under certain conditions, an overcharge may not cause damage. Many cells (most single cells, such as AAA, AA, C and D-sized cells) are vented so the gases given off when overcharged are released to the atmosphere. Some cells, on the other hand (button cells used in the construction of PP3 and PP9-sized NiCd batteries) are not vented and will explode if overcharged.

This is where the second rule-of-thumb comes in. If a cell or battery is charged at a rate of C/10, no damage will occur if the charge cycle time is extended by, say, 50%. At a charge rate of C/16, most single cells can remain permanently on charge. Button cells, however, can only remain on charge permanently with a charge current of C/100.

The ETI NiCd Charger is set by resistance values to give a charge rate of C/10 to connected NiCd cells or batteries, thus ensuring an overnight charge is sufficient to give a full recharge. Nearest preferred resistances used in the project, however, mean that a charge of slightly more than 10 hours is required – around 12 to 16 hours, in fact.

Saying all that, it is still perfectly feasible to recharge NiCd cells much more quickly than this, as long as you're sure they are fully discharged! A fully discharged PP3-sized NiCd battery, for example, may be recharged by charging it at the D-cell charge rate (340mA), for a shorter period of time. A quick calculation:

$$\frac{110}{340} \times 60 = 19.4$$

tell us the battery can be recharged in a little over 19 minutes. If you're going to do this, mind you, keep checking the battery temperature, particularly towards the end of the cycle. And for the sake of your living room's decoration, don't forget the battery's on charge!

PARTS LIST

RESISTORS (¼W 5%, unless stated)

R1	820R
R2	390R
R3	120R
R4	47R
R5	27R,1W
R6	15R, 2W

CAPACITORS

C1	1000µ, 25V electrolytic (axial for PCB, single-ended for strip)
C2,3	220n polyester

SEMICONDUCTORS

BR1	W005, or similar, 1A bridge rectifier
IC1	7805 5V voltage regulator

MISCELLANEOUS

FS1	500mA fuse & holder
SW1	6-way rotary switch
T1	12V 6VA mains transformer

PCB or stripboard. Case. Knob. Terminals. Battery holder. Wire.

BUYLINES

None of the components used in the project is difficult to obtain and all should be found at your local outlet or mail order store. The PCB is available from the ETI PCB Service.

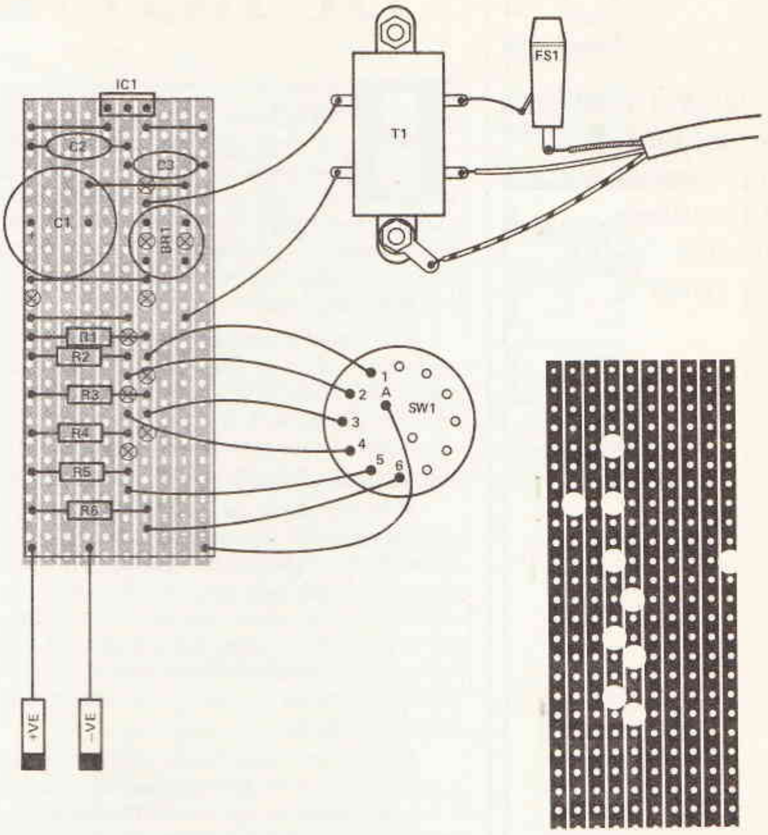


Fig.4 Stripboard layout wiring, and track cuts on reverse

BURGLAR BUSTER

Paul Chappell stands by to repel burglars with this simple alarm to use the free components on this month's cover

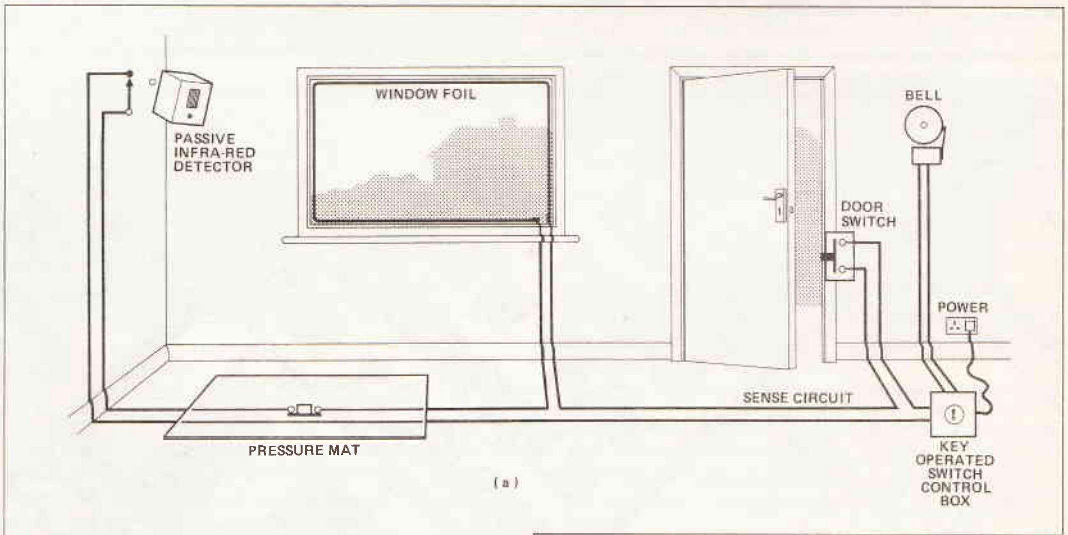
PROJECT

By this time next year, if statistics are anything to go by, over five hundred ETI readers will have become victims of burglary. I don't mean to imply that there are civil service bureaucrats beavering away somewhere over ETI-related crime figures, I'm just assuming that electronics enthusiasts have about the same chance of being burgled as anybody else, and doing my sums accordingly.

The aim of this project is to make sure that our readers are no longer a representative sample of the population. If most of you build the alarm system (and since the components and PCB are free, there's no excuse not to!) then perhaps only a hundred or maybe only ten or possibly none at all will suffer burglary!

A simple alarm circuit with some of the more popular detection devices is shown in Fig. 1a. The sense circuit consists of a complete loop of wire which visits each of the detection devices in turn. As long as all the switches remain closed, the control box sees the loop as a short circuit. If any single switch opens, the loop is broken and the control box causes the bell to sound. Cutting the wire in the sense loop also sounds the alarm.

For this very basic circuit, all you'd need in the control box would be a relay and a mains transformer. If the relay drew its coil current via the sense loop, breaking the loop would cause its contacts to open.



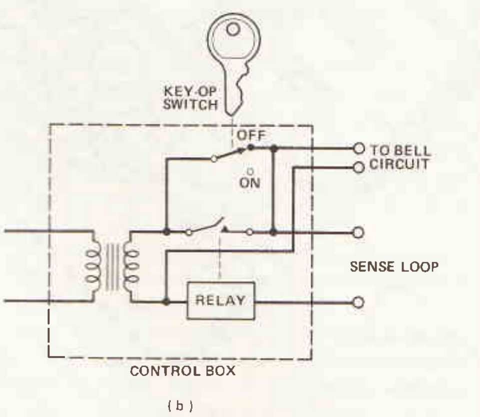


Fig. 1 A typical alarm system. (a) The detection loop. (b) The simplest possible control circuit

Figure 1b is about the simplest circuit you could get away with. I'm assuming here that the bell is self-powered and regards the situation where it has the transformer's secondary voltage applied to it as 'normal' and looks upon losing that voltage as a signal to ring. The reason for doing things this way around is to make sure the alarm rings if someone cuts its wires or yanks out the control box mains plug.

When the key switch is in the 'off' position, the bell is always supplied with a voltage and the relay can pull in and drop out to its heart's content as people open and close the doors in the house. When the switch is turned to the 'on' position, as long as the loop is closed the relay will be energised and its contact will be closed.

As soon as the loop is broken, the relay drops out, its contact opens to withdraw power from the bell and the alarm rings. Since the contact is also in series with the loop and the relay's own coil, restoring the

PROJECT

loop won't stop the alarm from ringing. It must be turned off with the key.

With little more than a relay (and another relay and some batteries for the bell) we already have a working circuit with a certain amount of resistance to being tampered with. What more can be added? The answer is that it depends just how secure you want to be and how much you want to spend on the alarm. Most systems have more sophisticated anti-tamper arrangements (although Fig. 1b won't stand for having its loop wires cut, shorting them together will knock out every switch downstream of the short!) Some have several loops, so that if one is out of action the others will still be on the alert. It's simply a matter of anticipating possible weaknesses and doing all you can to overcome them.

One little problem with Fig. 1b is how do you get out of the house once the alarm is turned on? You have the choice of either leaving the front door without a loop switch or of putting the key switch outside the house. Both put a point of weakness in the system — the first for obvious reasons, the second because any self-respecting burglar could lay his hands on the tools to uproot the switch and could then de-activate the alarm without difficulty.

Most alarms overcome this problem by allowing time for entry or exit through one particular door. Once you turn on the alarm you have maybe thirty seconds to leave the house and close the front door before the switch is armed. When you come back in, you have the same amount of time to dash to the control box and turn the alarm off.

The ETI alarm, using just the free PCB and components, is a two loop system: one sense loop and one anti-tamper loop. There is also space on the PCB for timed entry and exit circuitry which you can add if you wish. The resulting alarm can be used with just about any commercial detection apparatus from pressure mats and window foils to infra-red beams and body heat sensors. Heaven help the poor burglar who comes within range!

The Circuit

The alarm circuit you can build with the free components is shown in Fig. 2. It has two loops — one to sense any attempt to break into your house, the other to detect interference with the wiring or fittings. Both loops must be closed to prevent the alarm from sounding.

In the 'off' position, the key switch supplies 17V to the alarm sounder and allows the relay to pull in whenever both loops happen to be closed. In the 'on' position the relay will only remain energised as long as both loops are intact. As soon as anything is disturbed, the relay drops out, removes the 17V supply to the alarm sounder and also breaks the circuit to its own coil so it can't pull in again even if the loops are restored. The only way to stop the alarm from ringing is to turn it off with the key.

Figure 2b shows a suitable power supply (you can use any 12V mains transformer) and Fig. 2c is a simple alarm sounder. Under normal conditions the sounder's relay will be energised and the battery will charge via D1 and R2. As soon as the control circuit removes the power from the sounder, the relay drops out (D1 prevents the battery from holding it in) and the battery becomes connected across the bell.

In the control circuit, R3 drops the surplus 5V not needed by the 12V relay, R2 and C1 help to avoid accidental triggering of the alarm by interference picked up on the loops, R1 sets a suitable loop current and base drive for Q1 and D1 protects Q1 from the high voltage that would otherwise be generated on removing current from the relay coil.

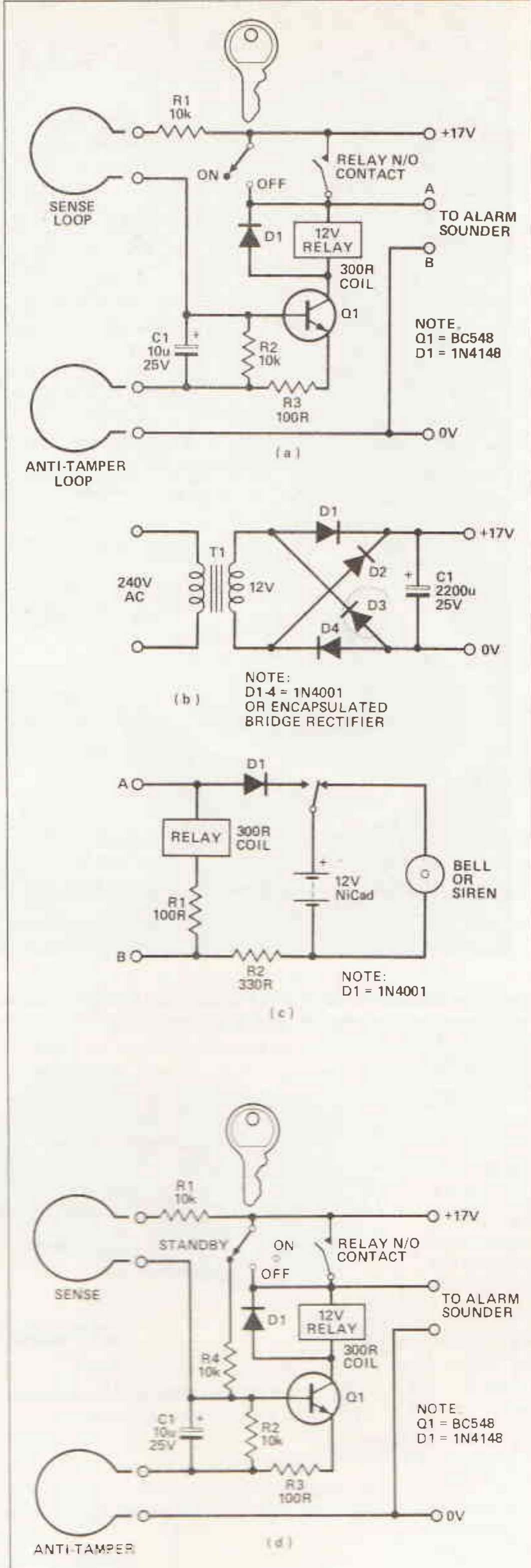


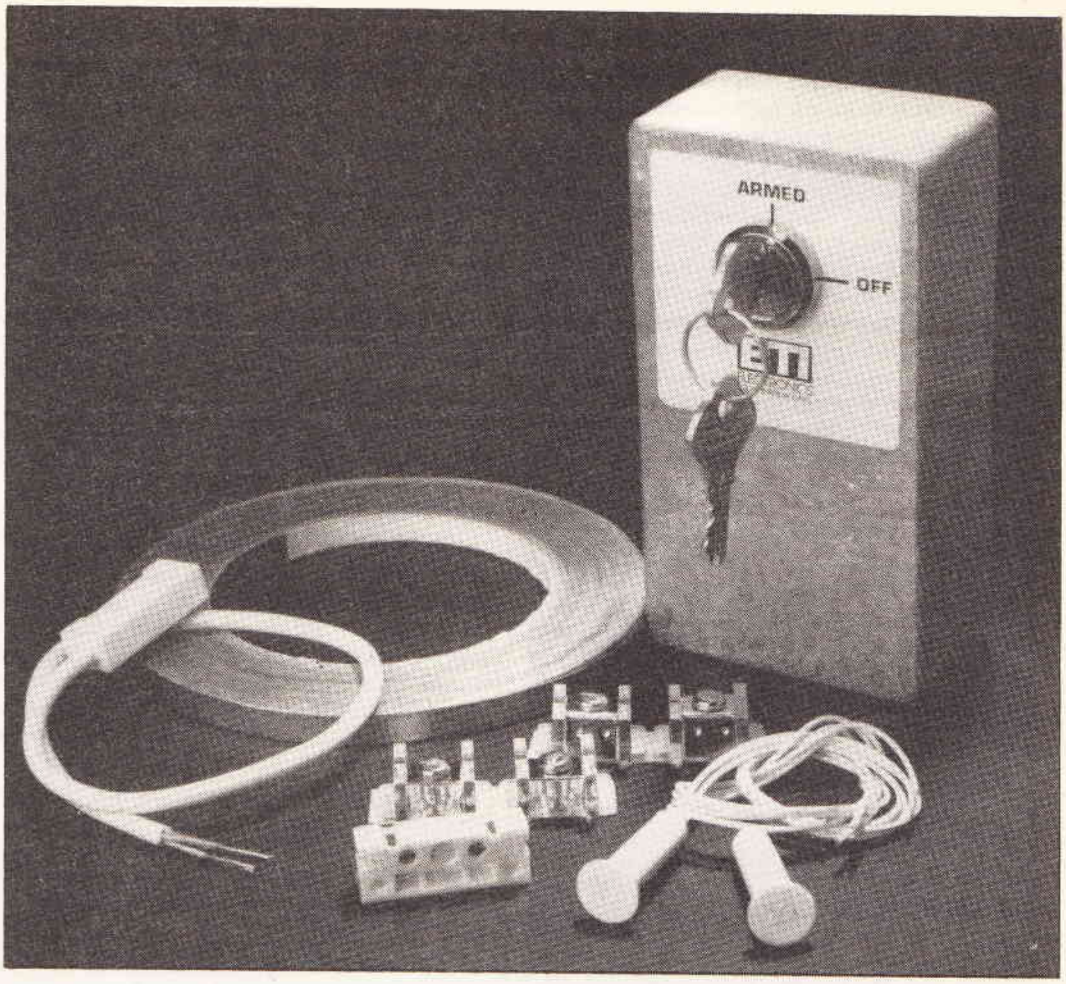
Fig. 2 The Burglar Buster circuit. (a) The main control box. (b) A suitable power supply. (c) A simple alarm sounder. (d) Alterations for an always-on anti-tamper loop

Instead of de-activating the alarm entirely, you might prefer to leave the anti-tamper loop running at all times. Figure 2d shows how this is done: the extra 'standby' position on the key switch disables the sense loop but keeps the anti-tamper circuit in operation.

The Anti-Tamper Loop

The usual way to wire an alarm system is shown in Fig. 3 and since all commercial fittings are intended

PROJECT



to be used this way, it's as well to stick to it! Both pairs of loop wires travel together along a single four-core cable. Whenever a detection device is to be fitted, the cable enters a junction box. (Some of the more complicated devices such as infra-red sensors and so on will have an internal junction strip but the principle is exactly the same). The wiring inside the junction box looks complicated but the idea is just to allow the sense loop to be broken by the detection device and the anti-tamper loop to be broken if anybody removes the cover to interfere with the wiring.

If a burglar attempts to interfere with the wiring

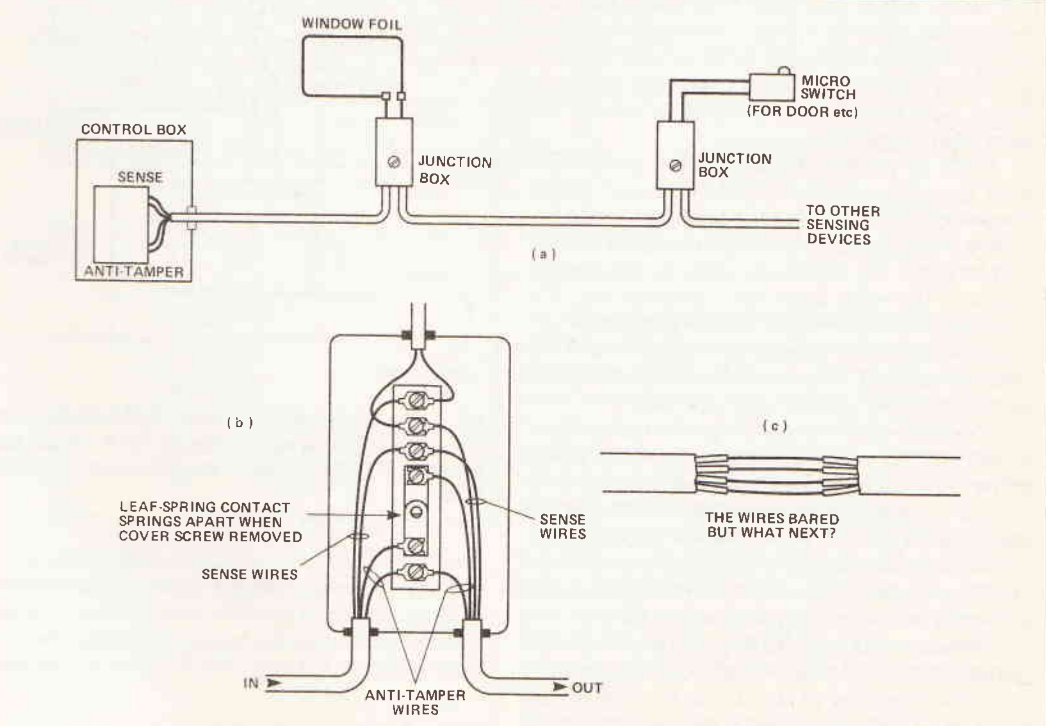


Fig. 3 The anti-tamper loop in action. (b) Wiring a standard detector unit. (c) The stripped wires in the loop tell a would-be burglar nothing

elsewhere, he will be faced with four wires (Fig. 3c). What does he do? Cutting any one of them will sound the alarm, and so will shorting either of the sense wires to either of the anti-tamper wires. Will he risk shorting two wires together to see what happens? Not if he's got any sense!

The control box can protect itself against attack in the same way — a micro switch held closed by the lid can be wired in series with the anti-tamper loop to prevent anybody getting at the insides. Another pair of wires on the same circuit can run up to the bell just to confuse the issue if anybody has a go at the wiring but unless the burglar carries a 17V power supply in his tool kit he's not going to be able to do much harm there.

Parts and Equipment

Just about any electronics catalogue will offer a range of burglar alarm parts: junction boxes, suitable wire, proximity detectors, pressure mats, window foils, and so on. Much of the equipment you can make yourself quite easily. To wire up doors, for instance, you could simply use a micro switch in the door frame (on the hinged side of the door) mounted so that the plunger is held down when the door is closed. It's usual to fix a metal plate to the door to prevent the plunger from digging a hole in the wood.

Proximity detectors (in this case, a posh name for a reed switch and magnet) are considered to be more reliable than micro switches and once again you can fix up a reed in the door frame and magnet on the door without having to go for the commercial versions (which come encapsulated in plastic but apart from that are exactly the same).

The most important thing is to get all the doors and windows wired up. Once you've done that, you can add more exotic devices at your leisure. I hardly need point out that you'll find all kinds of alarm-related projects if you flick through the pages of your back numbers of ETI.

Key-operated switches are readily available from component suppliers but if you're keen to save money you could nip down to your local car breakers (no, not the type who say 'ten-ten till we do it again' or whatever, I mean the ones who sell odds and ends from old cars) and buy an old ignition switch. As long as they've also got the key, that is!

The relay needn't have a coil resistance of 300R on the dot — a common resistance for small relays seems to be 280R and that's just fine. If the resistance is too far out, you'll have to change the value of R3 to suit. Calculate the current taken by the coil at 12V, then choose R3 to drop 5V at the current you've just calculated. Even easier — make R3 about 5/12 of the coil resistance, to the nearest preferred value, or perhaps one notch below to allow for the voltage drop across Q1 and the supply voltage drop under loaded conditions. Try to avoid coil resistance below about 250R — it increases the dissipation in Q1 and R3 unnecessarily.

Next Month

There's not much point in starting on the construction right now — you haven't got the PCB yet. It will arrive on the cover of next month's mag, so start queueing at your newsagent right away! (Or take out a subscription . . .)

I will also be telling you how to adapt the circuit to give timed exit and entry — there's room on the PCB for this too. There will be a bleeper to let you know that you have thirty seconds to escape from the house before the alarm erupts and deafens you . . . and all kinds of things besides. Don't miss it!

ETI

CHRONOSCOPE

PROJECT

Paul Brow shoots off about an ingenious device to measure the speed of air gun pellets.

A chronoscope is a device for measuring the velocity of an air gun pellet. Those of the shooting fraternity will realise how useful a chronoscope can be, to check the consistency of the gun, monitor its power output and compare how different pellets perform.

Commercial products are available but as usual they are expensive! This unit can be built for less than half the cost and perform equally as well.

The chronoscope is basically a counter with start and stop sensors. A pellet passes through the start sensor triggers the counter, covers a measured distance and halts the counter by passing the stop sensor. The pellet velocity can then be calculated from the display reading. Pellet velocities cover a wide range but typical values are 500 feet per second (0.22 calibre) or 800 feet per second (0.177 calibre).

Infra-red LEDs and photodiodes are used in two groups of three to detect the moving pellet. Three sensors are used to ensure that the small diameter of the pellet is reliably detected by providing a large detection zone (see Fig. 1). 0.177 calibre pellets are smaller, faster and more difficult to detect but this arrangement works well.

The chronoscope is mains powered, although it can easily be modified for battery operation. The display is a four digit LED type with a separate LED as an overflow indicator (counter exceeded 9999). The display units are 0.5 μs counts of frequency 2MHz, this value being convenient for the formulae described later.

Construction

The chronoscope has been designed to maximise the use of printed circuit boards to ease construction. Only two components (infra-red emitters) are mounted separately. Following the component overlays (Fig. 3, 4 and 5) assemble each PCB with the smallest components first — wire links, then resistors, IC sockets, capacitors, transistors with regulators and the transformer last.

Double check polarities. Use reasonable caution when soldering semiconductors. Don't keep the iron on the joint too long. Do not insert the ICs yet. Note the regulators require a substantial heatsink which should be made up as shown in Fig. 6.

The digital display is designed to plug on to the main board using 0.1in pitch PCB connectors. Wire links could be used but are not recommended.

On the subject of wire links, make sure that you solder the three links *under* the displays before inserting them in place. The display board is secured to the main board with small right angle brackets using the holes marked. The same type of brackets secure the sensor board vertically next to the plastic sensor tube.

The LED on the display board should stand slightly off the board to match the seven segment displays — a transistor mounting pad can be used here. The sensor board needs special attention when mounting the six infra-red photodiodes. These are soldered on the track side of the PCB and must be *exactly* six inches apart (no metric units around here!) centre to centre. Use the component overlay to align the photodiodes, as shown. Ensure the sensitive face is to the PCB track side when soldering to the board (see Fig. 7 for photodiode details), with the type markings to the component side.

The preset potentiometers are not the usual 0.4in standard type and may be difficult to obtain (see *Buylines*). Solder the 4-way ribbon cable to the sensor

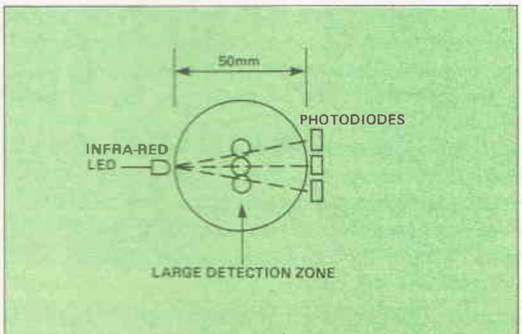


Fig. 1 The enlarged detection zone

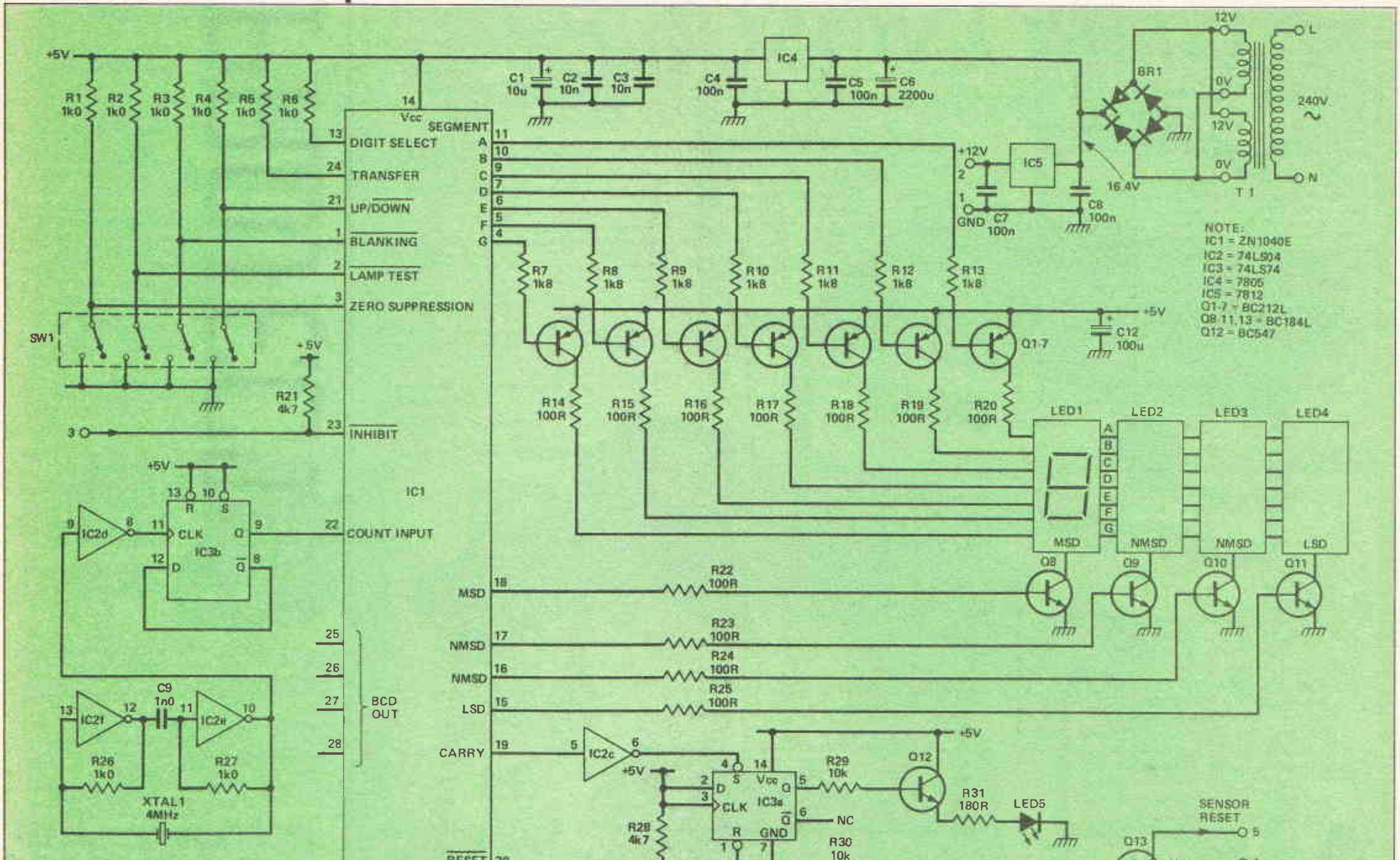


Fig. 2(a) The circuit diagram of the chronoscope main board

HOW IT WORKS

The heart of the chronoscope is the ZN1040E counter. This provides all the counter logic and display multiplexing. Two inverters of IC2 form a simple crystal oscillator with a frequency of 4MHz.

This is divided down to 2MHz by bistable IC3b, which supplies IC1 counter input (pin 22). While IC1 inhibit (pin 23) is held low, IC1 will not count. The inhibit input is toggled by the sensor board whenever a pellet is detected. If the counter overflows, the carry output (IC1 pin 19) is used to set bistable IC3a indicated by LEDs. IC3a is reset by SW5, which also zeros the counter IC1. R28 and C11 provide power on reset. SW1 selects various options on the counter IC1. SW1a ON enables leading zeros. SW1b ON provides a segment test on the display. SW1c ON blanks the display (really useful?). SW1d forces IC1 to count down (well, 4-way DIL switches are easy to obtain!)

Q1-7 are the segment drivers. Q8 and Q11 are digit drivers (multiplexing).

The sensor board controls IC1 inhibit. Six very high gain operational amplifiers together with their associated photodiodes form the detectors. Infra-red light from LED6 causes a current flow in D1-3 holding the non-inverting inputs below the bias voltage set by RV1.

If light to any photodiode is interrupted momentarily, the non-inverting input rises above the bias voltage, causing a high output. The outputs feed an OR gate IC7b. Any one causes bistable IC8a to be set driving IC1 inhibit high via Q15 and starting the counter. An identical arrangement IC9, IC7, IC7a will reset IC8a and stop the counter. IC7a OR gate allows reset from SW5. Q14, D10 and Q16, D11 monitor the bias setup, both LEDs set just off, for maximum sensitivity.

C15 are power supply decoupling to suppress unwanted spikes and noise.

The power supply is a standard bridge rectifier capacitor arrangement, supplying two voltage regulators IC4 and IC5 for 5V and 12V respectively. C1-8 provides decoupling for the ICs.

board. This then plugs on to the main board with a 0.1in PCB connector (SK4).

Solder twin ribbon cable to the infra-red LEDs and again use PCB connectors to plug on to the sensor board, observing polarity. The LEDs are fitted to the specially made brackets (see Fig. 8) using standard LED clips.

The main counter PCB is fairly straight forward but note the transformer pinout arrangement. I have noticed variations among suppliers. The DIL switch SW1 is optional and can be replaced with links to save costs. Secure the regulators to the heatsink with suitable nuts and bolts.

The boards must be mounted in a case for mains safety and to enclose the photodiodes from external light sources. A suitable tube, 5⅝ inches long was used in the prototype to protect the electronics from stray pellets and to give the unit a more professional finish. A piece of plastic gutter downpipe (2in diameter) is idea. The tube, infra-red emitter brackets and sensor board are secured to a base plate, made from plain SRBP, aluminum or fibreglass.

Secure the tube centrally to the baseplate and then position the sensor PCB and LED brackets to mark the fixing holes. See Fig. 9 for the case layout. Secure the sensor chassis and main board to the case with small self tapping screws. Fig. 10 shows the panel drilling details. The sensor hole in the front and rear panels is large (1½in). I used a Q-Max hole punch for this but if you don't have one, then drill small holes inside a marked circle and file to finish (you'll wish you had bought a Q-Max punch!)

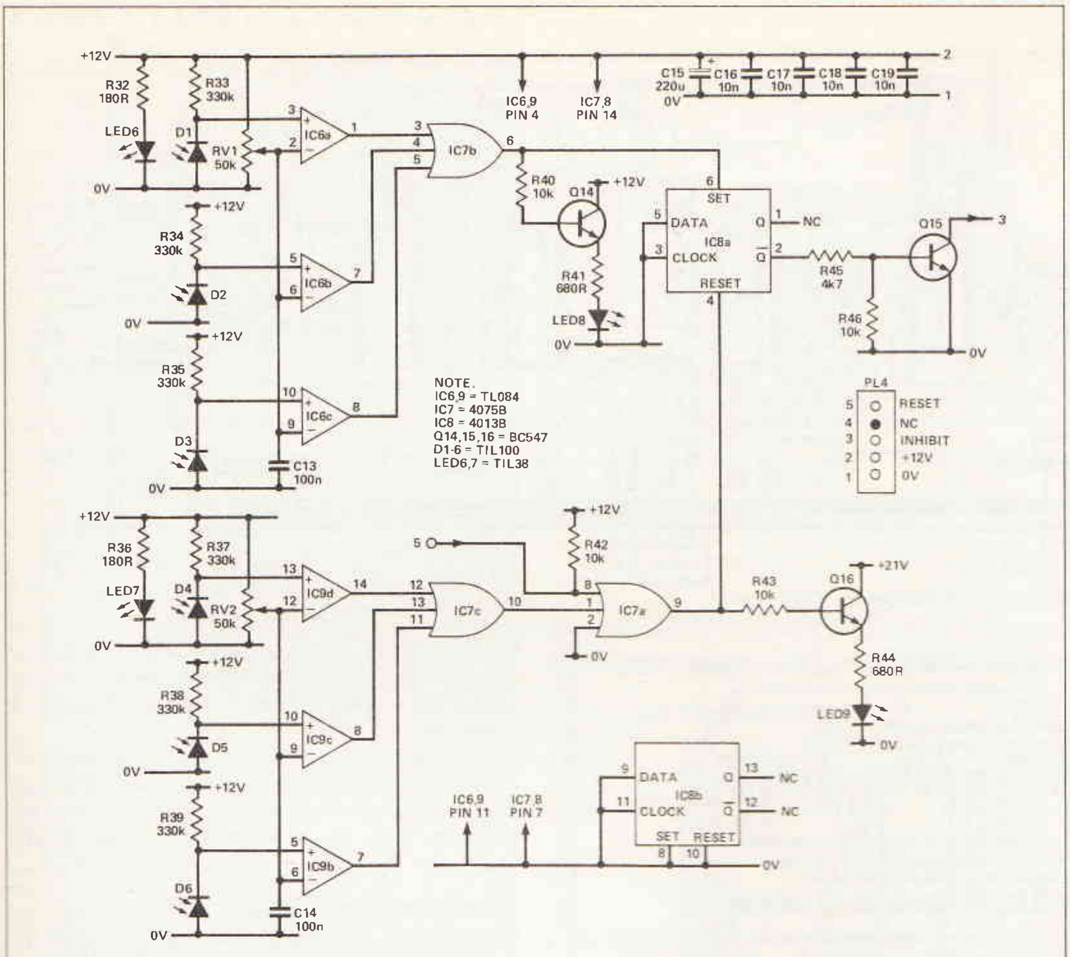


Fig. 2(b) Circuit diagram of the sensor board

Unfortunately, the rectangular hole for the display must be drilled out and filed laboriously, unless you also have a suitable rectangular punch. Paint the inside surface of the front and rear panels near the sensor hole with matt black paint to limit stray light. Fit a red diffuser (any piece of red transparent plastic film) behind the front panel to enhance the display digits. Slide the panel into the case slots — you will have to 'bow' the panel slightly to clear the *reset* switch.

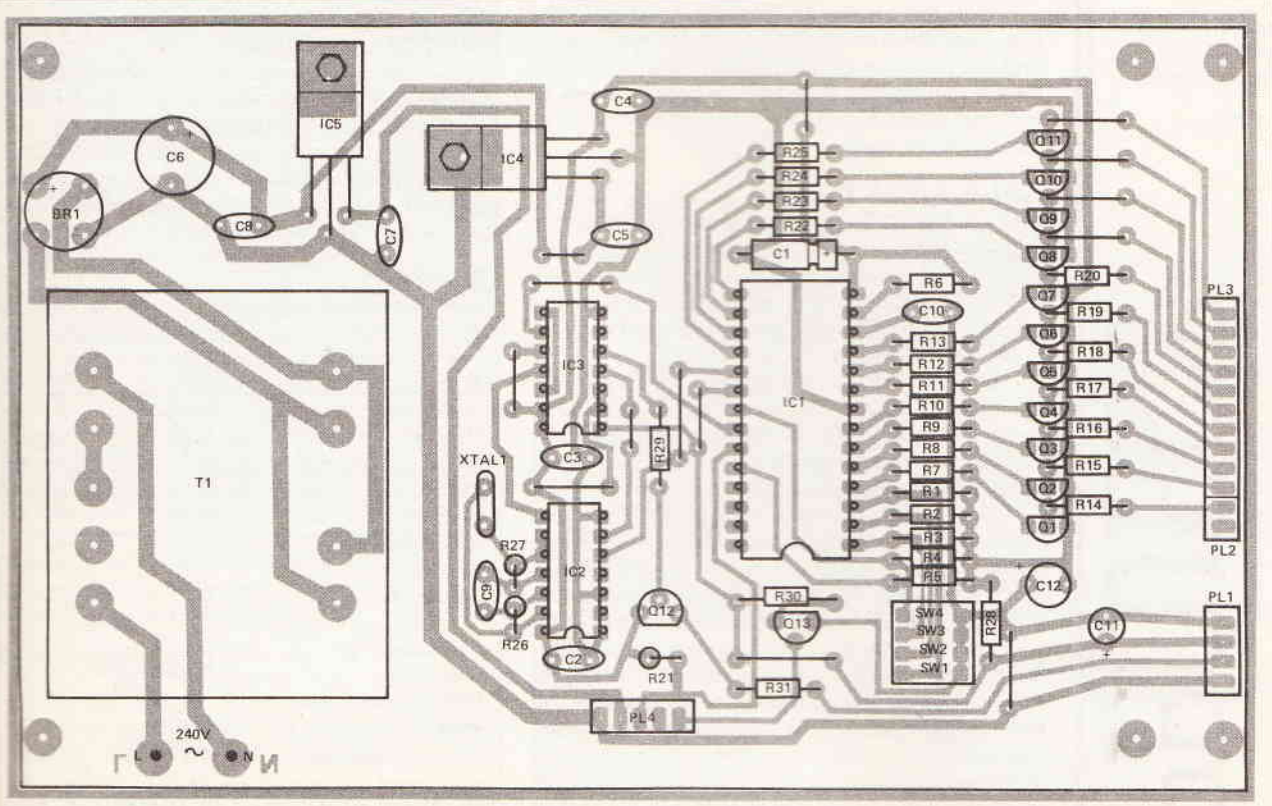


Fig. 3 The component overlay for the counter PCB

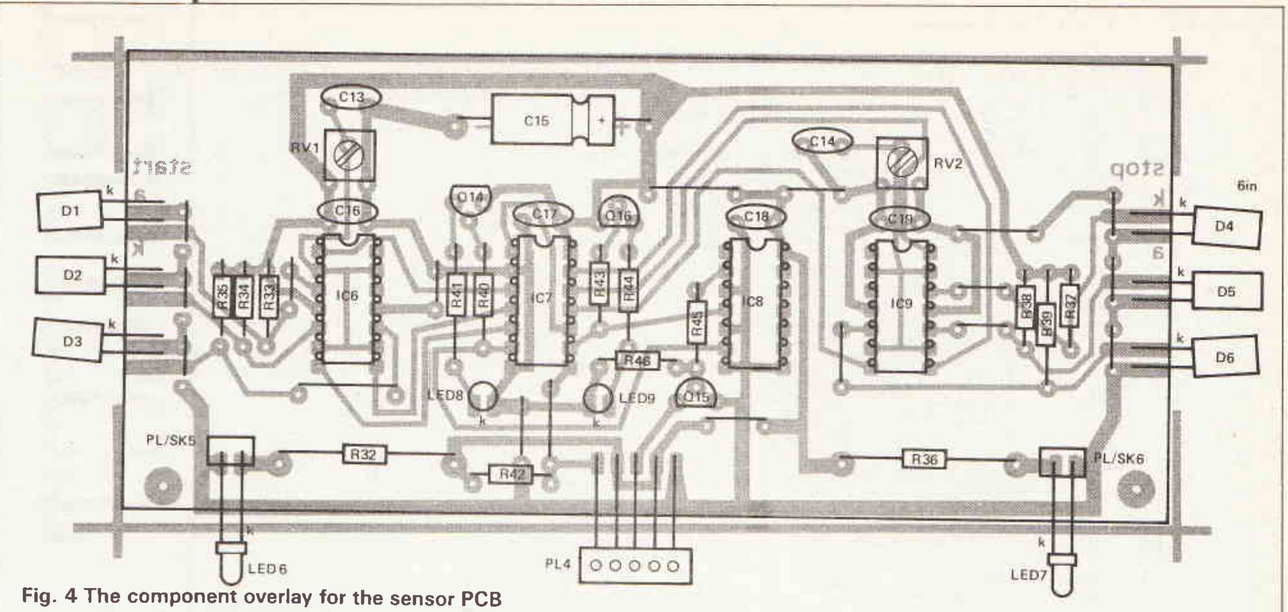


Fig. 4 The component overlay for the sensor PCB

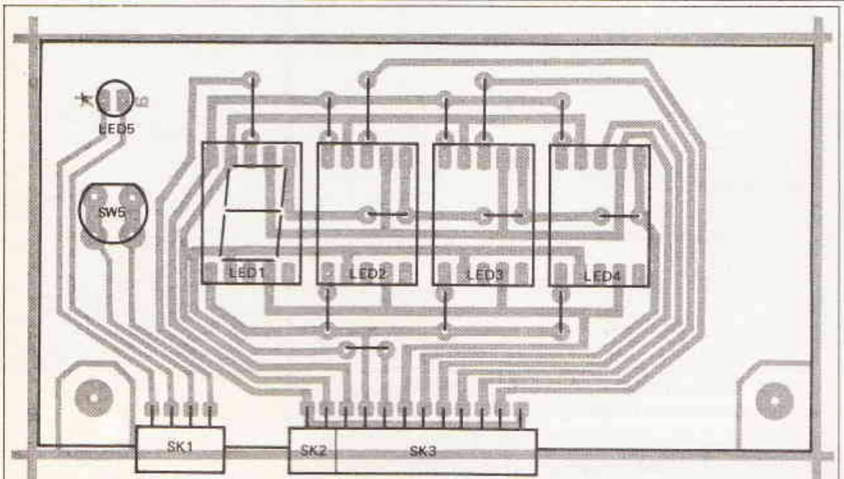


Fig. 5 The component overlay for the display PCB

PROJECT

Note that a mains on/off switch is not used. The Live/Neutral wires are soldered directly to the board and exit via a grommet in the rear panel. Cut a slot for the grommet so that the rear panel can still be removed easily. Finally, a mains plug fuse of 3A or less should be fitted.

Set-up And Testing

Caution! The PCB tracks near the transformer are live! Before inserting the ICs, check all the connectors are made and power up. Check that 5V is present across IC1 pin 14 and IC1 pin 8. Check that 12V is present across C15 on the sensor board. Power off and if all is OK, insert the ICs.

Set the 4-way switch bank all off. Power up and the display should illuminate. If you have an oscilloscope, you could check the clock circuit. There should be a 4MHz square wave (roughly!) at IC2 pin 8 and 2MHz at IC3 pin 9.

Set up the sensors in normal light conditions (with no strong direct sunlight and shield them from artificial lights). Adjust RV1 and RV2 so that LED8 and LED9 just go off. Press RESET and the display should now zero. Interrupt the infra-red beam at D1-3. The counter should clock happily and overflow! Interrupt the beam at D4-6 and the counter should stop. If all is well, fit the cover and prepare for the final testing with an airgun. Be careful! Air weapons are inherently dangerous and should be used with care! If you have a pellet trap, fine — if not, make one! A cardboard box with an opening 4in square, with a thick (1in to 2in) piece of wood (or ¼ steel) in the end, stuffed with old rags should be OK. Place this behind the chronoscope pellet 'exit' within a foot or so. This will catch your pellets safely and avoid shooting next door's cat.

Fabricate a mount for the rifle muzzle so that it rests centrally and straight, at the chronoscope 'inlet'. Zero the unit and fire a pellet through the tube, into the trap. You should obtain a reading without overflow.

Trouble Shooting

If the unit does not trigger, check that stray light is not interfering with the sensors and re-adjust RV1 and RV2. If this fails, suspect the IC2,3 clock circuit.

If the clock is started but will not stop, re-adjust RV2. (Check you are shooting straight, too!) No display at all means the 5V supply is missing or that SW1c is on.

A corrupt display shows a fault around Q1-7 or IC1 and a missing digit signifies a fault in Q8-11 or IC1.

Battery Operation

To use the chronoscope with a 12V battery for portable, on-the-range operation, omit Q1, BR1, C7, C8 and IC5 and link the two outer pads of IC5. Connect the battery to the + and − pins of BR1.

A 12V rechargable battery is recommended due to the fairly high current consumption of the chronoscope (typically 450mA).

Results

The chronoscope display actually shows only the number of clock cycles measured between the pellet

Type	Cal.	Grains
Eley Wasp	0.22	14.55
Hustler	0.22	12.4
Milbro Caledonian	0.22	13.0
RWS Superpoint	0.22	14.34
RWS Superdome	0.22	14.33
RWS Hobby	0.22	12.2
Bulldog	0.22	13.9
Barracuda	0.22	20.7
Eley Wasp	0.177	7.2
Silhouette	0.177	9.15
Milbro Caledonian	0.177	7.85
RWS Superpoint	0.177	7.9
RWS Superdome	0.177	8.3

Table 1 The pellet weight for a selection of types

PARTS LIST

RESISTORS (all ¼W 5%unless othewise stated)	
R1-6,26,27	1k0
R7-13	1k8
R14-20, 22-25	100R
R21,28,45	4k7
R29,30,40, 42,43,46	10k
R31	180R
R32,36	180R 1W
R33-35, 37-39	330k
R41,44	680R
RV1,2	50k horiz preset
CAPACITORS	
C1	10µ 16V axial electolytic
C2,3,10,16, 17,18,19	10n polyester
C4,5,7,8, 13,14	100n polyester
C6	2200µ 25V radial electrolytic
C9	1n0 polyester
C11	47µ 16V radial electrolytic
C12	100µ 16V radial electrolytic
C15	220µ 25V axial electrolytic
SEMICONDUCTORS	
IC1	ZN1040E
IC2	74LS04
IC3	74LS74
IC4	7805
IC5	7812
IC6,9	TL084 OR TL074 quad op amp
IC7	4075B
IC8	4013B
Q1-7	BC212L
Q8-11,13	BC184L
Q12,14,15,16	BC547 (BC107 or similar)
LED 1-4	FND500 ½in 7-segment display
LED 5,8,9	Red LED
LED 6,7	TIL38 infra-red LED or similar
D1-6	TIL100 or similar
BR1	W005
MISCELLANEOUS	
PL1	4-way PCB connector
PL2,5,6	2-way PCB connector
PL3	10-way PCB connector
PL4	5-way connector
SK1	4-way angled PCB connector
SK2	2-way angled PCB connector
SK3	10-way angled PCB connector
SK4	5-way PCB connector
SK5,6	2-way PCB connector
SW1	4-way DIL switch
SW2	push button SPST
T1	0-12 0-12V 0.5A PCB mounting mains transformer
XTAL1	4MHz crystal

PCBs. Case. IC sockets. Display filter. 2in drain pipe. Cable. Nuts and bolts.

passing the front and back sensors. To calculate the speed of the pellet or the power of the gun, some calculations must be performed.

$$\text{Velocity} = \frac{\text{distance}}{\text{time}}$$

$$= \frac{\text{counter frequency} \times \text{measured distance}}{\text{display reading}}$$

The measured distance is 6in (½ft) and the clock frequency is 2MHz, so:

$$\text{velocity (ft/s)} = \frac{2000000 \times 1/2}{\text{display}}$$

$$= \frac{1000000}{\text{display}}$$

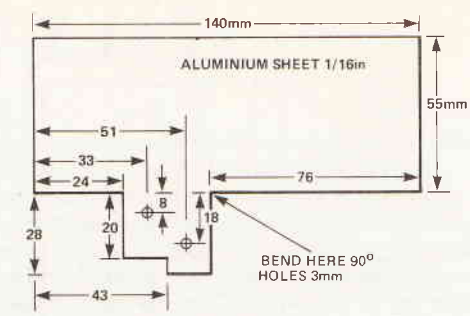


Fig. 6 The heatsink for IC4,5

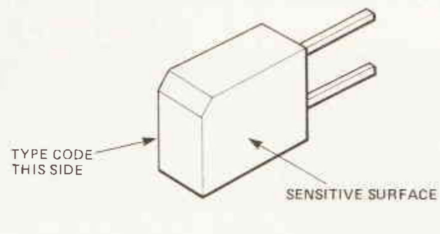


Fig. 7 The TIL100 photodiode

PELLET TYPE:	ELEY WASP (7.2 grains)
READINGS:	1188, 1178, 1194, 1180, 1177, 1182, 1176, 1209, 1207, 1163.
AVERAGE OF ABOVE READINGS:	1185

$$\text{VELOCITY} = \frac{1,000,000}{1185} = 843\text{ft/s}$$

$$\text{POWER} = \frac{843 \times 843 \times 7.2}{450240} = 11.36$$

Table 2 Typical results obtained by the author

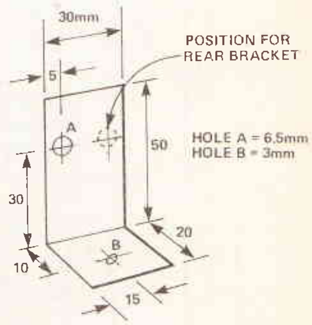
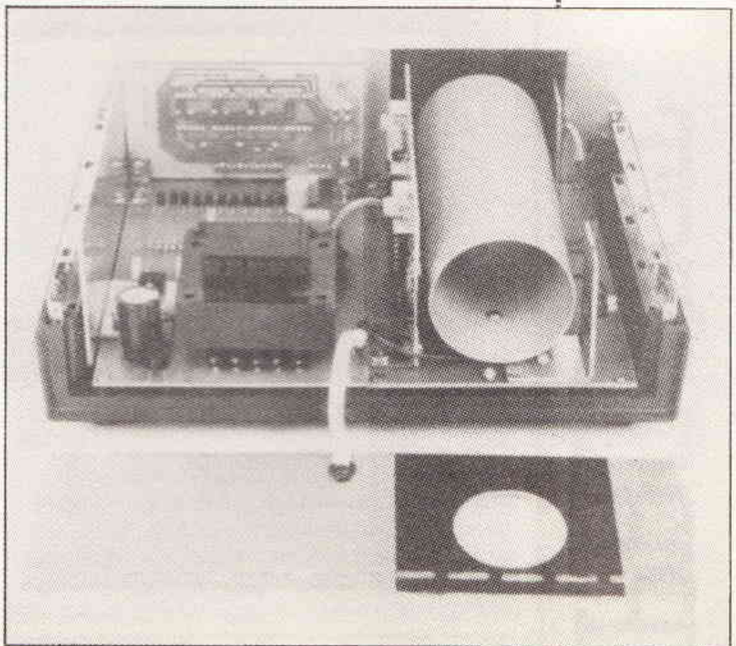


Fig. 8 The bracket to hold the sensor diodes in place (front shown)



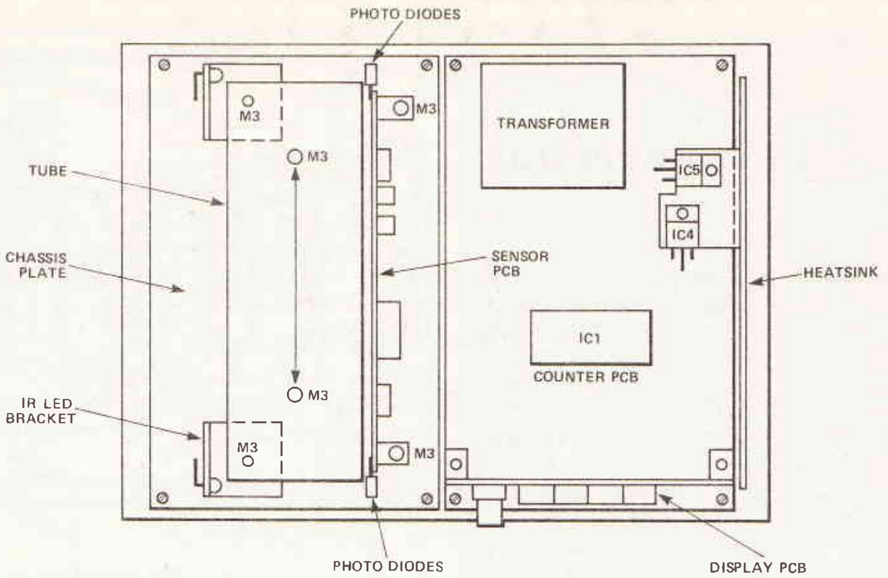


Fig. 9 The layout of the major parts of the prototype chronoscope

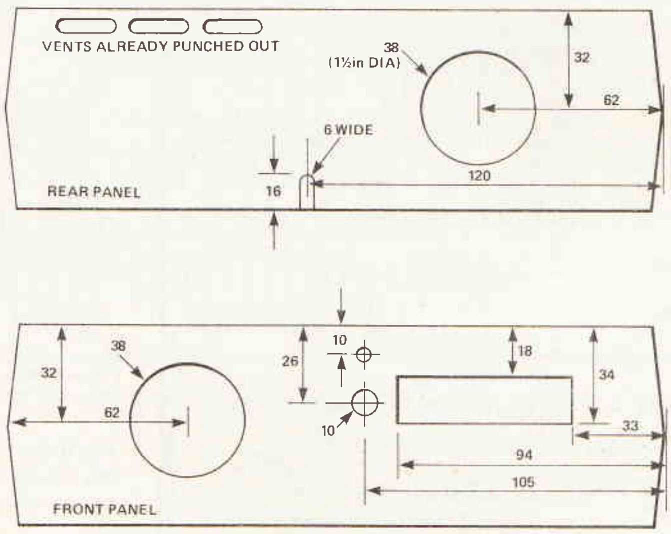


Fig. 10 Case cutouts for the recommended case

The power output of the gun can be calculated with:

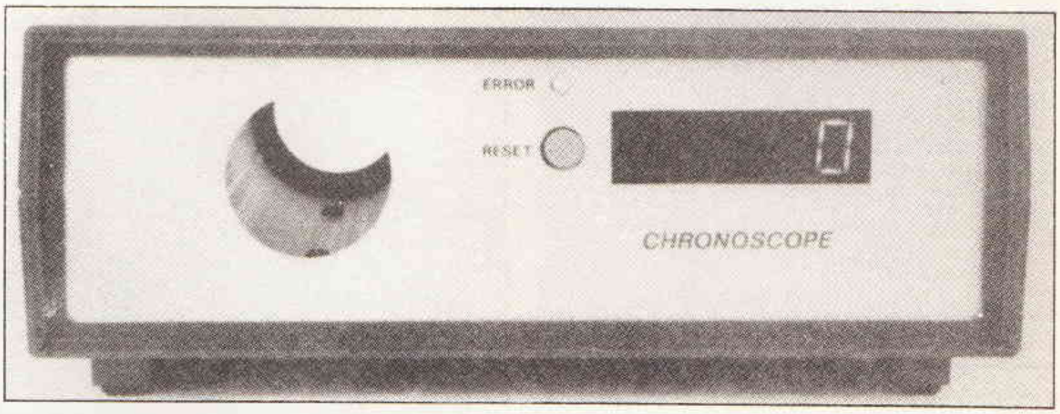
$$\text{power (ftlbs)} = \frac{\text{velocity}^2 \times \text{pellet weight}}{450240}$$

The pellet weight is in grains (438 grains = 1 ounce). If you don't know the pellet weight your local airgun stockist should be able to help. Some are given in Table 1. Alternatively, the author can supply a list for common pellets (see *Buylines*).

Typical results are shown in Table 2, obtained using a BSA Mercury S 0.177 calibre air rifle. Note that the legal power limit for an air pistol is 6ftlbs and for a rifle 12ftlbs, above which you need a firearms licence.

To conclude, we should stress again the care that must be exercised when firing guns and rifles through the chronoscope. *Always* use a pellet trap of some sort.

ETI



BUYLINES

Most of the components are readily available. Rapid Electronics (Tel: (0206) 272730), Maplin (Tel: (0702) 552911), Electromail (Tel: (0536) 204555) and Farnell (order from Trilogic on (0274) 684289) can supply the more unusual parts.

The transformer is available from Farnell as part 141-481 as are the presets. The 7-segment displays are available from Maplin (FR41U) or Rapid (57-0115). IC1 (the ZN1040E) is available from Electromail as part 306-285. The case used for the prototype is a Retex RE3 type available from Rapid as part 30-0910.

The author is able to supply any or all parts for the Chronoscope. Send a SAE to ETI Chronoscope, 40 Victoria Avenue, East End Park, Leeds LS9 9DG for a price list. For a list of the weights of pellets, send a SAE to the same address.

TECH TIPS

8-way Stereo Selector

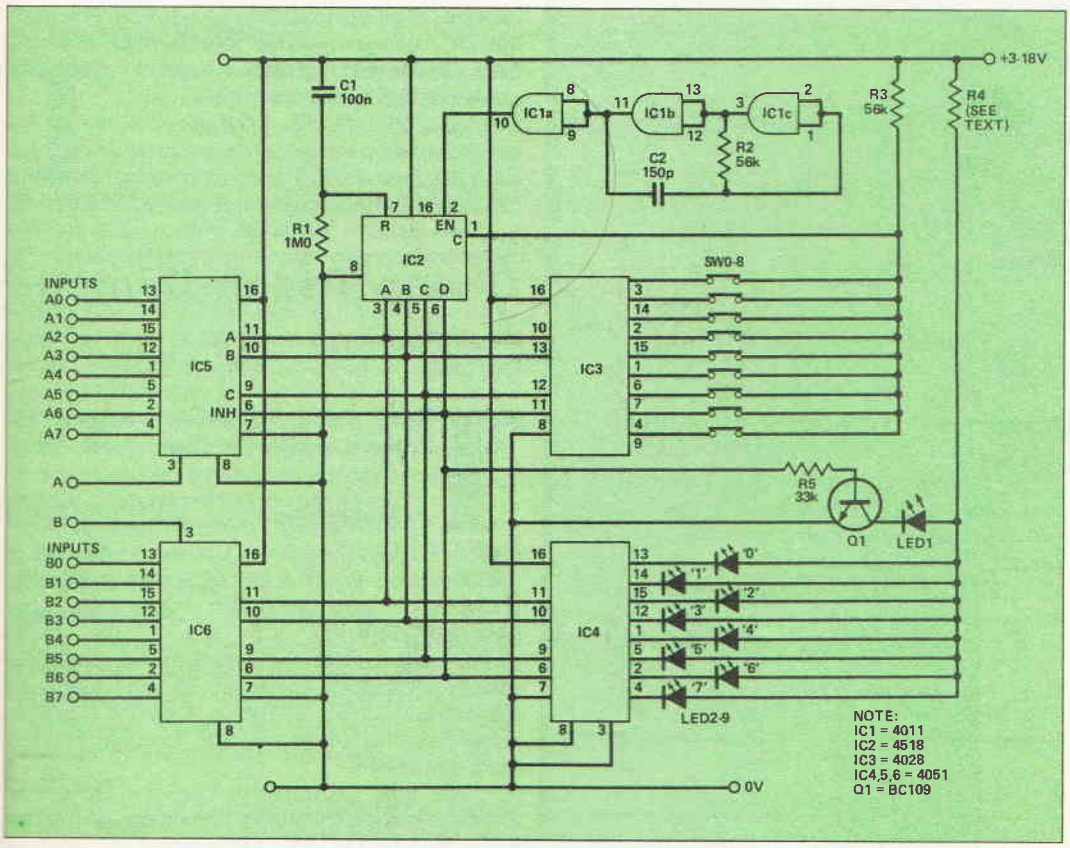
D. Ian
East Molesey

This circuit provides noiseless remote selection and routing of eight audio signals, either stereo or balanced pair mono, using simple non-locking push-switches.

The BCD counter IC2 is disabled from counting IC1's 1MHz clock rate by the wired high on pin 1. A momentary closure of SW2, say, is sufficient and the switching action is effectively debounced. The code 0010 is now present on all the ICs so that LED 2 on IC4 is now lit and inputs A2 and B2 are connected to the outputs of IC5 and IC6.

SW8 selects BCD 1000 inhibiting the 4051s and providing an 'off' facility. ICs 5 and 6 may, of course, be remote from the selection and indicating circuitry — advantageously sited with respect to the audio signal paths.

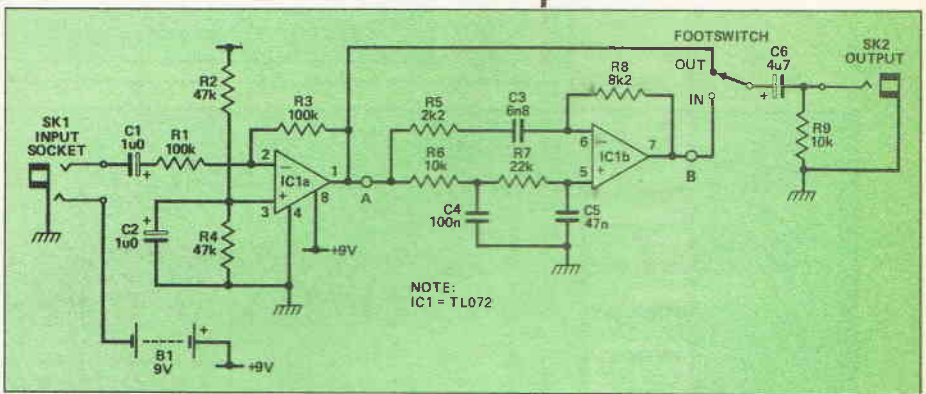
The power requirement is only about ½mA above that required by the LEDs. Select R3 to suit the supply voltage assuming 25mA for the LED (so 140R for 6V, 260R for 9V, 380R for 12V, 500R for 15V and so on).

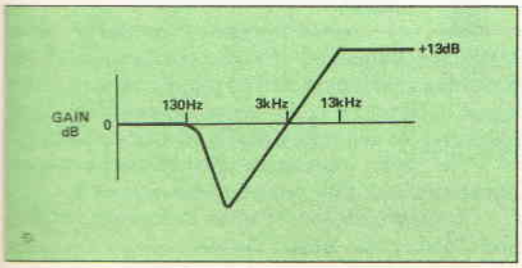


Guitar Preshaper

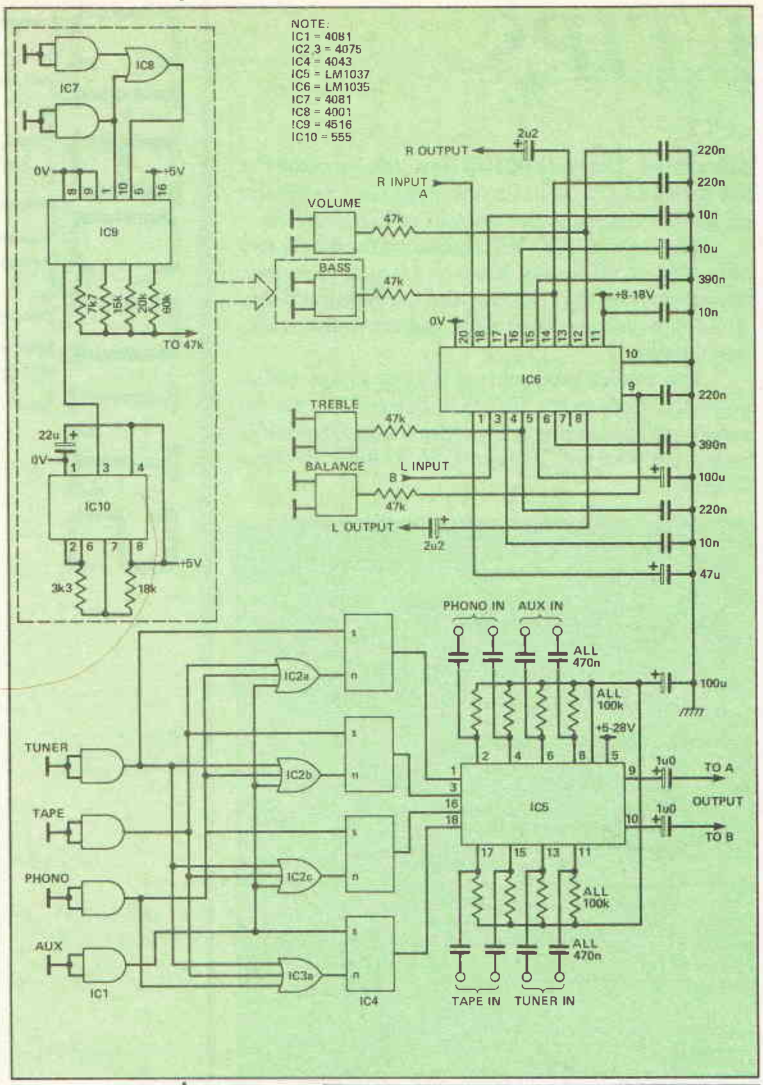
I. Harvey
Hastings

Some upmarket bass and guitar amps are fitted with a preset tone circuit to give an instant clean modern sound without the tedious EQ setting. In this circuit IC1b filters high and low frequencies then recombines them to produce a frequency response approximately as shown. This produces a clean bright sound for either 6-string guitar or bass.





The circuit can be built as a footpedal powered from a PP3 (no power LED is included to extend battery life). If fitted in your amplifier between preamp and power amp then the buffering and level shifting circuitry can be omitted leaving just the components between A and B.



Touch Controlled Pre-amp

A J Bird
Walsall

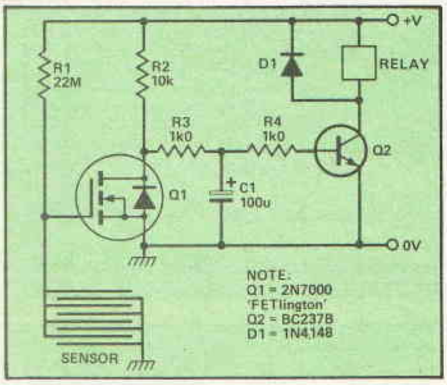
A touch controlled pre-amp with touch plate selection of inputs and volume, bass, treble and balance can be easily constructed with the help of the LM1037 and 1035 audio control ICs.

The touch plate sensors rely on the tied inputs of the AND gates (IC1, 11, 21, 31, 41) floating low and being taken high by a touch on the plate.

IC2, 3 form a latching arrangement so that each touch on an input selector plate will set the relevant flip-flops and reset the others.

The four flip-flop outputs are used to switch on a pair of inputs to IC5 through to IC6. This uses the DC voltage from the four identical volume, bass, treble and balance circuits to filter and attenuate the stereo channels.

The DC control voltage is obtained by weighting the 4-bit output from up/down counter IC13 (23, 33 and 43). The counter is clocked by the 555 timer in astable mode and enabled to count up or down by IC11 and IC12.



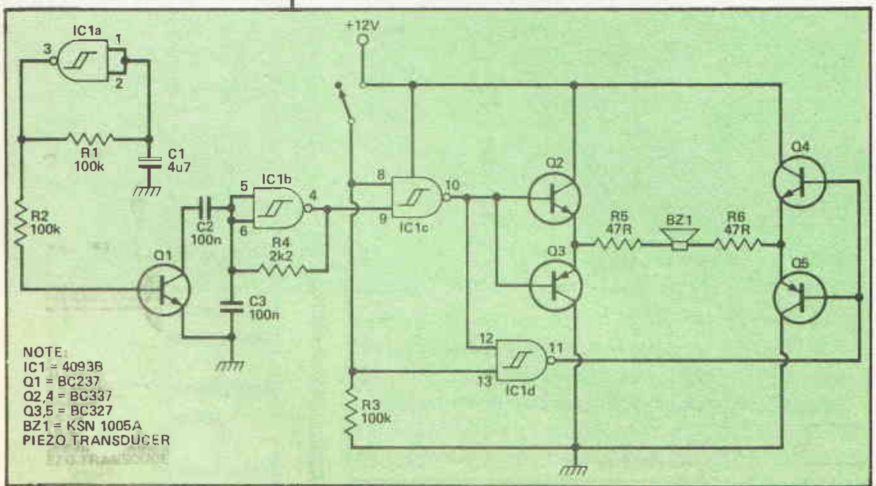
Cheap Touch Switch

R J Fletcher
Penzance

This circuit, originally designed as the switch of an alarm system for a disabled person, takes advantage of the high input impedance of the 2N7000 'FETlington.' The high value resistor R1 pulls the gate of Q1 to the positive rail. If the operator's finger is placed across the sensor contacts, the gate voltage falls close to zero. This switches Q1 off.

Q2 acts to invert the signal from Q1 and so the relay is normally de-energised. R3 and R4 provide the correct voltage at the base of Q2. C1 adds some delay to overcome any 'contact' bounce from the sensor.

The type of transistor used for Q2 is not critical and nor is the supply rail voltage. R1 may be reduced to 10M to reduce sensitivity. With a value of 22M it was found the switch could be activated by breathing on the sensor! For the prototype a small piece of stripboard was used for the sensor.



Low Current Siren

G Landry
South Africa

This efficient circuit provides an output of 10V RMS (approx 103dB at 1m) at a current consumption of only 30mA.

Low frequency oscillator IC1a varies the frequency of audio oscillator IC1b by switching in and out C2. The rapidly varying audio signal is gated by IC1c to output amplifier stage Q2,3 and an inverted signal is passed to Q4,5.

The piezo transducer is connected between the stages with 20V peak-to-peak across it.

Resistors R5 and R6 serve to limit the current and stabilise the output stages.

Super Woofer

Philip Day,
Ponteland, Tyne and Wear.

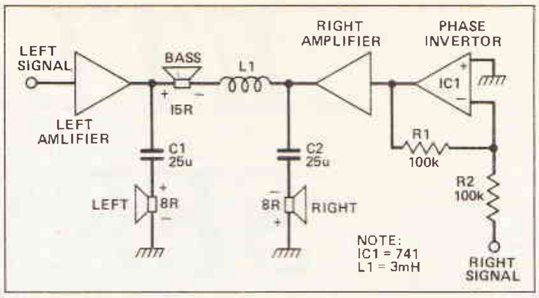
This circuit enables a single centrally placed woofer to be added to a stereo system. This gives a cost effective bass enhancer which still preserves the stereo picture via the original speakers.

The right channel is driven in antiphase and the right hand speaker is reverse connected to restore the phase.

C1 and C2 as shown give a crossover at about 800Hz — other values could be tried.

The single bass speaker is bridge connected across the antiphase outputs via inductor L1. This has the incidental advantage of cancelling out in-phase hum and vertical turntable rumble.

Note that for a system playing records only, the inverting IC circuit could be removed be reversing one half of the stereo cartridge.



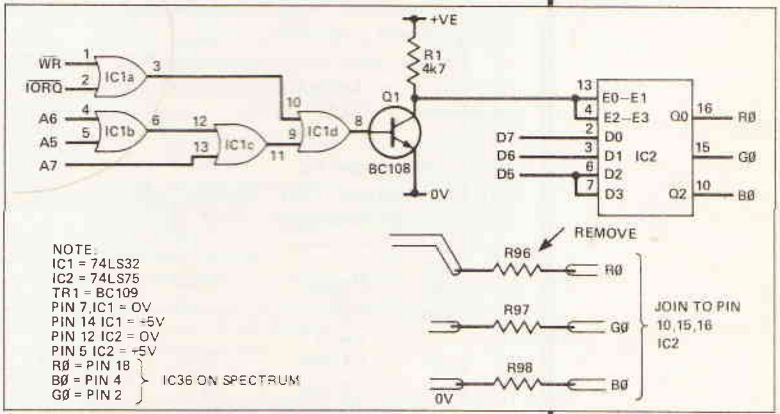
Spectral Spectrum 128

K. D. Hedger,
Gt Yarmouth, Norfolk.

This circuit modifies the Spectrum 128 to allow selection of any one of eight different palettes, each with eight colours. This makes full use of the 64 colours available from the Spectrum 128's video chip, the TEA2000. The palettes are selected by a simple 'OUT' instruction from either BASIC or machine code.

Inside the Spectrum 128, you will see that the three unused inputs of the TEA2000 (IC36) are tied to ground with R96,R97 and R98. With these resistors carefully removed, this circuit ORs $\overline{WR}$, $\overline{IORQ}$, A6, A5 and A4 together to detect an 'OUT 31' instruction. The corresponding data is latched from D5,6 and 7 onto the outputs of the enabled IC2. These outputs (R0,G0 and B0) connect to the right hand pads of the removed resistors and so to the colour inputs of IC36.

The four components fit on a small piece of stripboard which can sit in the Spectrum case.



Envelope Generator

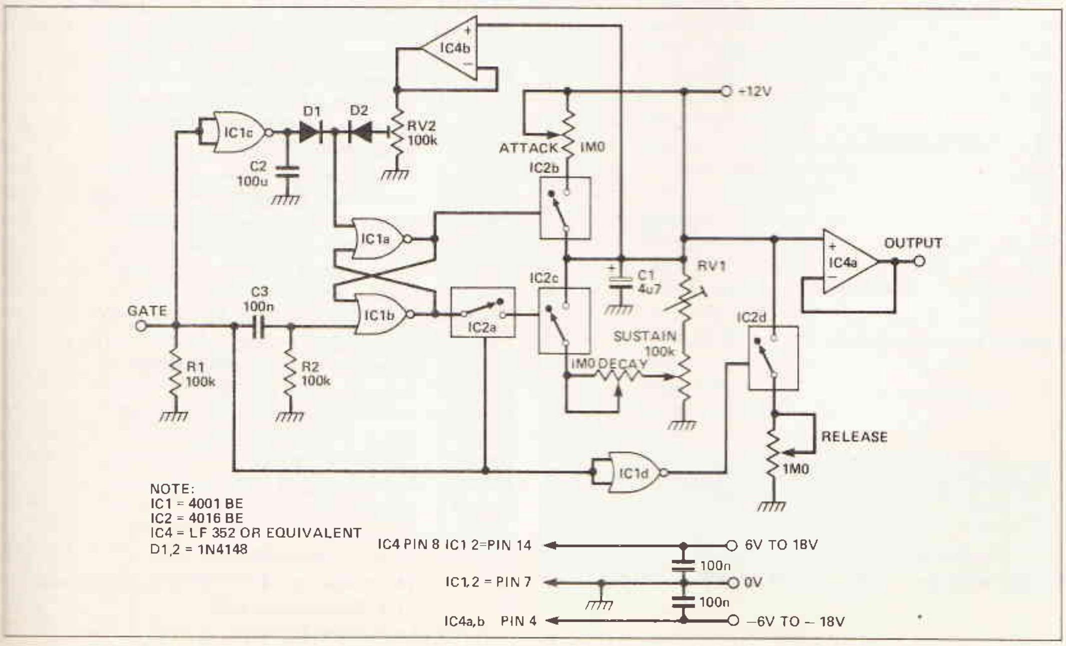
T. Allgood,
Hornchurch, Essex.

This envelope generator was designed to boost the performance of my ancient monophonic synthesizer which came equipped with only one. This way I can control either the VCA or VCF with each generator. It's a no frills ADSR generator and it's small and cheap.

C1 charges at a rate set by the attack pot when the gate goes high (at the start of a note). At a certain voltage (set by RV2), the flip-flop of IC1a,b resets and C1 discharges at a rate set by the decay pot until it reaches the voltage set by the sustain pot. When the gate is removed (note off) C1 discharges through the release pot.

RV1 sets the maximum sustain level which should be set to match the voltage controlled device. IC4 buffers the voltage across C1 for the output.

I used this circuit with a Moog Rogue with excellent results.



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E8202-5	MM Stage Disc Pre-amp (Tilsbrook)	G
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E8208-1	Playmate Practice Amp (3bds)	K
E8212-1	ELCB	F
E8301-2	Analogue to digital conv ZX81/Spectrum)	E
E8305-3	Dual Audio Power Supply, Linsley Hood	G
E8305-3	Balanced Input Preamplifier	F
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E8311-1	Mini Drum Synth	F
E8311-8	Moving Coil Pre-Pre-amp	F
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E8402-2	Modular Pre-amp Disc Input Mono	F
E8402-3	Modular Pre-amp Stereo Output	F
E8402-4	Modular Pre-amp Relay, PSU	F
E8402-5	Modular Pre-amp Tone Main Mono	F
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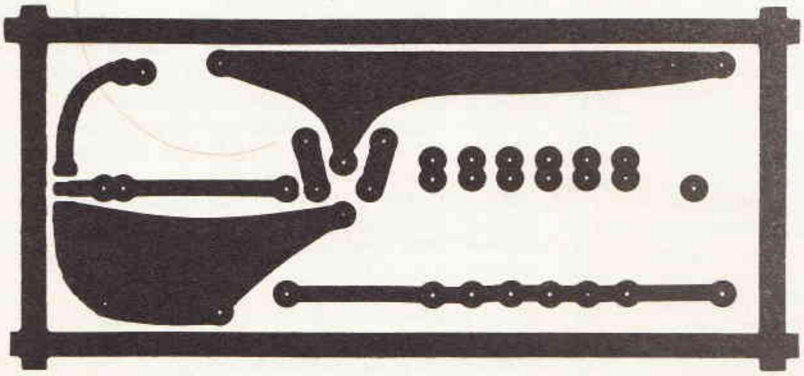
E8402-7	Modular Pre-amp Balanced Output	F
E8402-8	Modular Pre-amp Headphone Amp	F
E8404-2	Mains Remote control Receiver	F
E8405-1	Auto Light Switch	F
E8405-2	ZX81 EPROM Programmer	N
E8405-3	Mains Remote Control Transmitter	H
E8405-4	Centronics Interface	F
E8405-6	Drum Synth	F
E8406-1	Oric EPROM Board	O
E8406-2	Spectrum Joystick	E
E8406-3	Audio Design RIAA Stage	G
E8406-4	AD Buffer/Filter/Tone	H
E8406-5	AD Headphone Amp	F
E8406-6	AD Preamp PSU	K
E8406-7	AD Power Amp	H
E8406-8	AD Power Amp PSU	J
E8406-9	AD Stereo Power Meter	F
E8406-10	AD Input Clamp	C
E8407-1	Warlock Alarm	M
E8408-2	EPROM Emulator	N
E8408-3	Infra-red Alarm Transmitter	E
E8408-4	Infra-red Alarm Receiver	F
E8409-1	EX42 Keyboard Interface	F
E8409-2	Banshee Siren Unit	F
E8410-1	Echo Unit	F
E8410-2	Digital Cassette Deck	N
E8410-3	Disco Party Strobe	H
E8411-5	Video Vandal (3 boards)	N
E8411-6	Temperature Controller	D
E8411-7	Mains Failure Alarm	D
E8411-8	Knite Light	D
E8411-9	Stage Lighting Interface	F
E8411-10	Perpetual Pendulum	E
E8412-1	Spectrum Centronics Interface	F
E8412-4	Active-8 Protection Unit	F
E8412-5	Active-8 Crossover	F
E8412-6	Active-8 LF EQ	F
E8412-7	Active-8 Equaliser	F
E8501-3	Digital Delay (2 bds)	T
E8502-1	Digital Delay Expander	N
E8502-2	Data Logger	J
E8503-1	Combo Preamplifier	F
E8503-2	THD Meter mV & oscillator boards (2 bds)	K
E8503-3	THD Meter Mains PSU	F
E8504-1	Framestore Memory	M

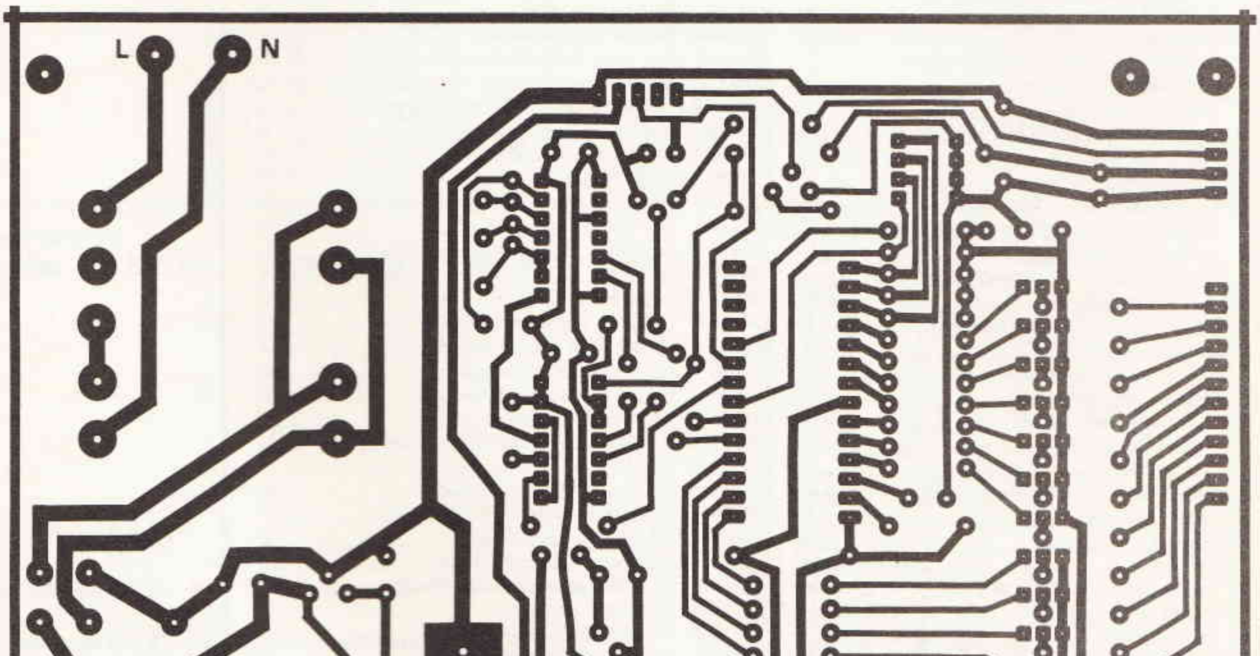
PCBs

E8504-3	Framestore Control	N
E8504-4	Buzby Meter	E
E8504-5	CCD Delay	F
E8505-5	Stereo Simulator	F
E8506-1	Audio Mixer Main	J
E8506-2	Audio Mixer PSU	F
E8506-3	Audio Mixer RIAA	D
E8506-4	Audio Mixer Tone Control	D
E8506-5	EPROM Prog MKII	O
E8507-1	Noise Gate	H
E8508-1	RCL Bridge	N
E8508-2	EX42/BBC Interface	E
E8508-3	EPROM Emulator	L
E8509-1	Spectrum EPROM card	F
E8509-2	Direct Injection Box	E
E8510-9	Sunrise Light Brightener	K
E8511-1	MTE Waveform Generator	H
E8511-2	Millifaradometer	H
E8511-3	Cymbal Synth	J
E8511-5	Chorus Effect	H
E8511-7	Enlarger Exposure Meter	F
E8511-8	Switching Regulator	E
E8511-9	Second Line of Defence	M
E8512-1	Specdrum Connector	F
E8512-2	MTE Pulse Generator	H
E8512-3	Specdrum	L
E8601-2	Walkmate	L
E8601-3	MTE Counter-timer	M
E8602-1	Digibaro	O
E8603-2	Programmable Logic Evaluation Board	H
E8603-3	Sound Sampler Analogue Board	R
E8604-1	JLLH PA PSU	H
E8604-2	Matchbox Amplifier	C
E8604-3	Matchbox Amp Bridging Version	C
E8604-4	MTE Analogue/Digital Probe	M
E8605-1	Microlight Intercom	E
E8605-2	Baud Rate Converter	M
E8605-3	Baud Rate Converter PSU Board	C
E8605-4	Portable PA	H
E8606-1	MIDI-CV Converter Board	H
E8606-2	MIDI-CV Converter PSU	D
E8606-3	Troglograph	F
E8606-4	80m Receiver	H
E8606-5	Sound Sampler	R
E8607-1	Direction	E
E8607-2	Upgradeable Amp, MC stage (Stereo)	G
E8607-3	BBC Motor Controller	F
E8608-1	Digital Panel Meter	G
E8608-2	Upgradeable Amp, MM stage (mono)	H
E8609-1	Mains Conditioner	E
E8609-2	Experimental pre-amp	F
E8609-3	Upgradeable amp, Tone board (mono)	H
E8609-4	Upgradeable amp, Output board (mono)	F
E8610-1	Audio Analyser Filter Board	L
E8610-2	Audio Analyser Display Driver	K
E8610-3	Audio Analyser Display	H
E8610-4	Audio Analyser Power Supply	F
E8611-1	Audio Switcher (2 bds)	H
E8611-2	PLL Frequency meter (4 bds)	Q
E8611-3	Upgradeable Amp PSU	J
E8611-4	Call meter, main board	O
E8611-5	Call meter, interface board	N
E8612-1	Bongo Box	J
E8612-2	Biofeedback monitor (Free PCB)	E
E8701-1	RGB Converter	F
E8701-2	Mains Controller	D
E8701-3	Flanger	H
E8701-4	Audio Selector main board	M
E8701-5	Audio Selector PSU	H
E8701-6	Tacho-Dwell	F
E8702-1	Ratemeter main board	K
E8702-2	Ratemeter ranging board	F
E8702-3	Photo Process Controller (3 bds)	O
E8702-4	LEDline display board (2 off)	K
E8702-5	LEDline PSU and controller (2 bds)	G
E8703-1	Capacitometer	F
E8703-2	Geiger Counter	L
E8703-3	Credit Card Casino	E
E8704-1	BBC micro MIDI interface	L
E8704-2	ETIFaker patch box	H
E8704-3	24Hr Sundial	E
E8705-3	MIDI Keyboard keyswitch boards (3 bds)	W
E8705-4	Batlite	C
E8705-5	Budget Power Meter	E
E8706-1	Hi-fi Power Meter	N
E8706-2	MIDI Keyboard CPU	U
E8706-3	MIDI Keyboard Front Panel	O
E8706-4	Flame Simulator	G
E8707-1	MIDI Keyboard PSU	H
E8707-2	Telephone Alarm	J
E8707-3	Nuclear Strategy Simulator	J
E8708-1	Remindalite	F
E8708-2	Rear Wiper Alarm	G
E8708-3	Rev Counter	F
E8708-4	Car Alarm	F
E8708-5	Knight Raider	J
E8709-1	Boiler Controller	G
E8709-2	Amstrad Sampler (2 bds)	P
E8709-3	Portable PA	G
E8709-4	EEG Monitor (2 bds)	L
E8710-1	Concept CPU board	N
E8710-2	Concept Power board	K
E8710-3	Concept display board	G
E8710-4	Hyper-Fuzz	F
E8710-5	Big Digits digit board	N
E8710-6	Big Digits minute board	F
E8710-7	Big Digits battery board	G
E8711-1	Quiz Controller	E
E8711-2	256K Printer Buffer	N
E8712-1	Heating Management System	O
E8712-2	SWR Meter	H
E8712-3	Dream Machine (free PCB)	D
E8801-2	Passive IR Alarm	H
E8801-3	Deluxe Mains Conditioner	G
E8801-4	RGB Dissolve	L
E8802-1	Electric Fencer	E
E8802-2	Telephone Intercom	L
E8802-3	Transistor Tester (2 bds)	L
E8802-4	Spectrum Co-processor CPU	N
E8803-1	Co-processor RAM board	N
E8803-2	Beeb-Scope (3 bds)	O
E8803-3	Jumping Jack Flash	E
E8804-1	Spectrum Co-processor Interface Board	N
E8804-2	Combo-lock	E
E8804-3	Kitchen Timer	E
E8805-1	Virtuoso 2U PSU	M
E8805-2	Virtuoso 3U PSU	N
E8805-3	Bicycle Speedometer	F
E8805-4	Dynamic Noise Reduction	E
E8806-1	Universal digital panel meter	L
E8806-2	Universal bar graph panel meter	K
E8806-3	Virtuoso power amp board	N
E8806-4	Virtuoso AOT board	G
E8806-5	Metal detector	E
E8806-6	Bicycle dynamo backup	D
E8807-1	Bar Code Lock (2 bds)	N
E8807-2	Analogue Computer Power Board	L
E8807-3	Bell Boy	F
E8807-4	Logic Probe	C
E8807-5	Updated FM stereo decoder	J
E8807-6	Breath Rate display board	F
E8808-1	Breath rate main board	H
E8808-2	Breath rate switch board	C
E8808-3	Telephone recorder	D
E8808-4	Analogue computer main board (2 bds)	M
E8808-5	Random number display	O
E8809-1	Spectrum EPROM Emulator	M
E8809-2	Frequency meter (2 bds)	P
E8809-3	Travellers' Aerial Amp	E
E8810-1	Gerrada Marweh Bikebell	E
E8810-2	Peak Programme Meter (2bds)	N
E8810-3	Variat-Ion ioniser	K
E8810-4	TV-to-RGB converter	E
E8810-5	Electron RGB buffer	C
E8811-1	NiCd Charger	E
E8811-2	Chronoscope (3 bds)	P
E8811-3	Digital Transistor Tester	G

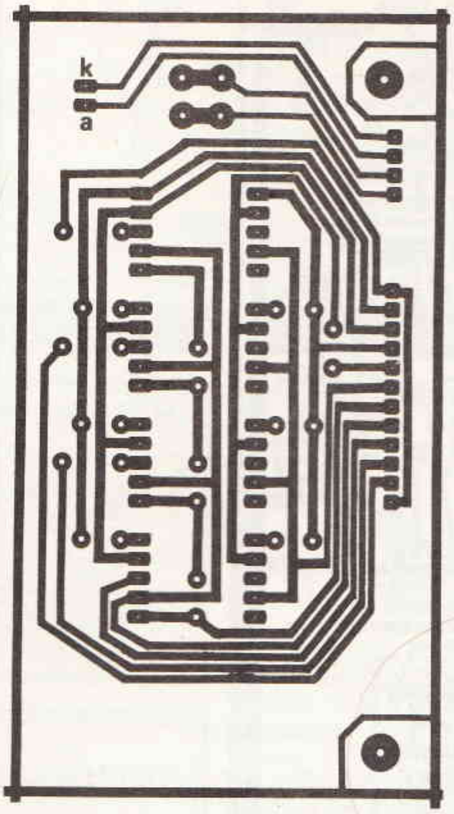
PCB FOIL PATTERNS



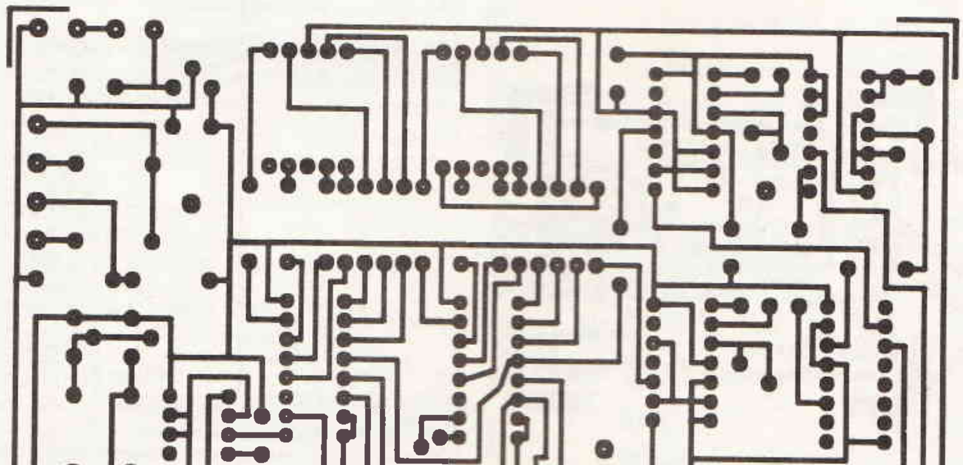
The 1st Class NiCd charger PCB

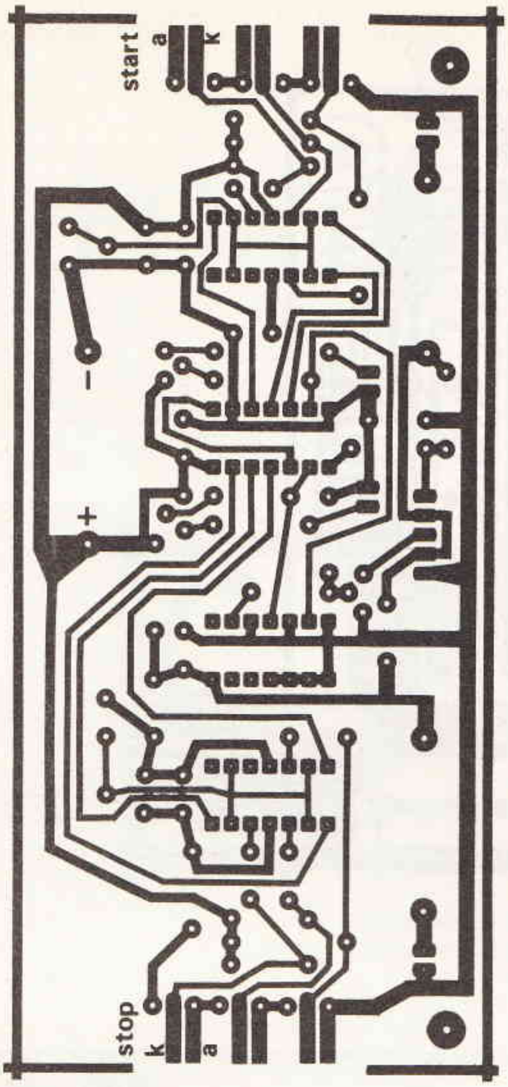


The Chronoscope counter PCB

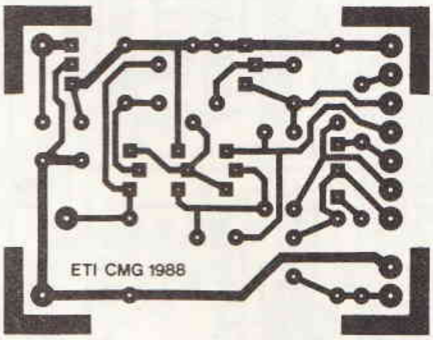


The Chronoscope display PCB


The Digital Transistor Tester PCB



The Chronoscope sensor PCB



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OOPS!

Dream Machine (December 1987)
The transistors used in this project are ST1702. BC108s can be substituted.

Heating Management System
(December 1987)
A 4116 is not a suitable alternative to the 6116 specified. A 4016 RAM chip will suffice. In Fig. 1 the junction of R1/D5 should connect to D1-4/C1 and not cross. The zener diodes above the temperature sensor ICs (IC16-19) should be deleted. C4 should be 220n and not 220μ. C7-10 should be 10μ. Q2-7 should be 2N3904 and not BC3904.

RGB Auto-Dissolve (January 1988)
In Fig. 5 there are marked two D6's. The right hand one should be D5 (they are both 1N148's anyway). In the text the reference to zener diode D5 should read ZD1.

Power Conditioner (January 1988)
There is confusion between the values of R7 and R8 in the Parts List and Fig. 1. These should be: R7-27k, R8-10k and not as given in the Parts List. In addition, ZD1 is incorrectly orientated in Fig. 3. The positive terminal should be at the southern end.

Passive Infra-Red Alarm
(January 1988)
Fig. 2(a) shows the base of Q1 connected to ground and to R14. It should be connected only to R14.

Transistor Tester (February 1988)
The foil pattern for the main board was printed reversed left-right on the foil pages.

Spectrum Co-processor (March 1988)
Mogul Electronics, given in the Buylines as suppliers of the RAM chips, have moved to: Unit 11, Vestry Estate, Sevenoaks TN14 5EU. Tel: (0732) 741841.

Dynamic Noise Reduction (May 1988)
The LM1894 is no longer available from the sources listed but it can be obtained from the author. Please address orders to Manu Mehra, 88 Gleneagle Road, Streatham, London SW16 6AF.

QL Output Port (Tech Tips May 1988)
Several problems with the diagram for this one. A5 should read AS — that is, address strobe. Pins 22 and 24 should be connected to +5V and the junction of the (only) resistor and diode connected to VPA on the QL.

QWL Loudspeakers (August 1988)
Some dimensions were missing from Fig. 7. The bass driver port centre should be 3¾in above the base of the baffle panel. The notches in the side of the tweeter cut-out are ½in wide. The top plate is missing from the cutout diagram (Fig. 6). This is 7 × 4⅝in.

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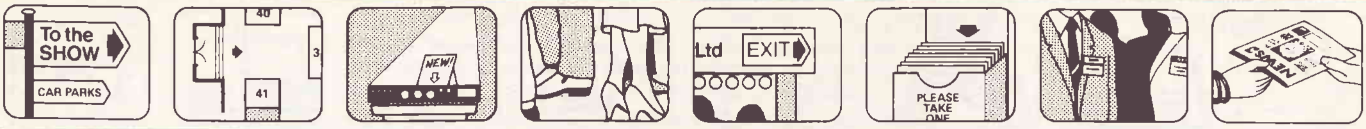
BRITISH MUSIC FAIR REPORT



Who played at Wembley this year? Apart from the mega-gigs that have been so prominent in the news over the summer, some 120 exhibitors were also at the Wembley Conference Centre to show off their latest wares in this year's British Music Fair. All the big names in musical instruments were there as well as most of the lesser known companies, although it was not always easy to find who you were looking for, big or small, as the conference centre has a rather confusing layout.

What this venue does have is around 6,700 square feet of air-conditioned exhibition space which allowed a less cluttered layout thus avoiding some of the claustrophobic scenes from last year at Olympia.

Who's Got What?

Let's start with the big boys shall we? Yamaha had a wealth of new products to show from all the divisions. At the pro end of the market we have two new synths designed to make FM synthesis easy for all — the YS200 and the cut-down 8-track sequencer-less YS100. Both are multi-timbral and feature 5-octave touch sensitive keyboard, pitch and modulation wheels and a control panel that looks like a Crazy Golf course. £790 for the 200, £700 for the 100.

From the portable keyboard wing comes the PSS-680 (below) — a 5-octave mini keyboard complete with pitch bend wheel, eight drum pads and MIDI capabilities all for just £250. Also into this category comes five expander boxes to enhance the sound of porta-keyboards that have come in for some stick in the past. The EMQ-1 Sequencer (£299), the EMT-1 and EMT-10 voice expanders (£220 and £300 respectively), the EMR-1 Drumbox (£220) and the EME-1 Reverb unit (£220).

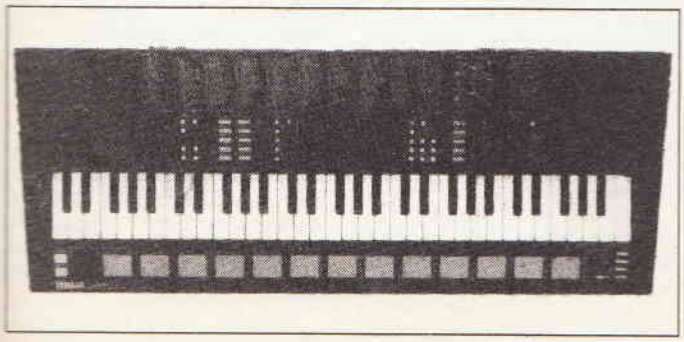
Obviously Yamaha see the portable market as one to get serious about.

I'll Be Blowed!

By contrast, Casio seem to be taking the pro market by storm with products like the DH-100 Digital Horn (see photo) which allows wind instrumentalists access to all the electronic sound he wants for just £99.

Following on from the success of their DG-20 MIDI Guitar Casio have now launched the PG-380 which, if the demos on the stand were anything to go by, gives the most demanding of guitarists an armada of sounds (up to 192) tracked perfectly.

What's nice is that the sounds and ROM cards are compatible with another new product from Casio, this time the keyboardist (just in case you were all feeling left out). The VZ-1 flagship synth certainly leaves a keyboard player with no complaints as far as performance controls and options go. The sounds aren't bad either. Furthermore, for the master keyboard devotee, you can buy the VZ-1 in rack mounted format as the VZ10-M.



Back In LA

Roland's main push on their stand was behind the E-20 and the E-10 keyboards which seem to be straddling two markets. This idea seems to be that these two keyboards will give pro musicians the benefit of all the little tricks that portable keyboard owners have enjoyed all these years. So now you can have the combination of the sounds of a D-20 synth without the programability but with some rather clever auto accompaniment routines which can be stored in the on-board sequencer and dumped onto RAM card for long-term storage.

I can see what they're getting at because a lot of musicians would like to work out songs and arrangements at home but don't want the hassle of turning a room into a small studio.

Also of interest was the T-110 sampled sound module which won't record sound samples but plays ROM cards of ready-made samples which are available thanks to the S-10 series. As the majority of sampler users just play with presets anyway this would sound like a good investment to a musician at around £600.

What A Combination

This is the first year the UK has seen any evidence of the Yamaha aquisition of Korg. The new catalogue proves interesting reading with the launch of Korg's Professional Performance series spearheaded by the M1 MIDI Workstation — a full spec master keyboard multi-timbral sampler, digital effects processor and eight track sequencer for around £2000. To add to your sound library, Korg also has two sound modules with specific tasks. The P3 is a sampled piano module with two types of piano onboard (titled Piano 1 and 2!) however it will accept ROM cards as well. Symphony is the other expander from Korg and it has several internal orchestral type sounds and, once again access to that Korg ROM Library.

Street Cred Kawai

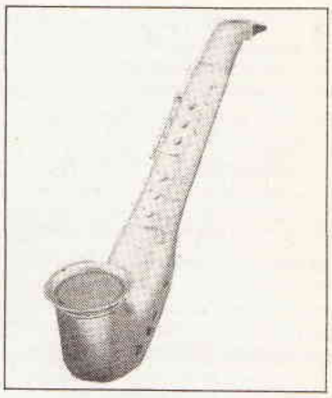
It's only in the last two years that Kawai have gained the credibility it needed in the pro market. This year it has done it once again with the K1 synth and the keyboardless K1m expander. Although without the sequencing frills of its rivals it is certainly the most easily programmed and usable as an expander for someone who wants performance control and a bit more than presets.

Akai — Hard To Beat?

Not a whole heap new at the Akai stable. There's the S1000 top of the range sampler which features 16-bit stereo sampling and a 2Mb memory for £2899. For rhythmists the ME35T Drum Pad to MIDI interface was being thrashed by some prospective customers — price nearly £260. To compliment this the XE8 drum expander for £500, gives any MIDI instrument a further eight 16-bit sampled drum voices which can be changed via cartridges (wot! No ROM card?).

Akai launched one of the first master keyboards — the MX 73 which is still popular today. However, they have wisely decided not to sit on their laurels and have come up with the MX76 which has an extra three keys on the keyboard, is weighted and has both velocity sensitivity and after-touch along with four programmable sliders which could, for example, be used to control tempo, portmento rate, volume and so on all via MIDI.

Akai also had a rather unusual use for low cost sampling technology. Instead of shoving it into a mini keyboard and putting kids off sampling for life, they have put it into the U4 phase trainer. This is a sort of sampler cum pitch shifter which allows you to sample a riff and slow it down without altering the pitch. It could be useful for a musician who needs to practice a riff as he can slow it down to learning speed and keep repeating it, speeding up as he gets better. The audio bandwidth is none too hot, so serious



musical applications are out. DJs, Rappers and Housemasters may find them useful for effects.

Typically Tropical

Cheetah gets the prize for the most tropical stand at the show with the sounds of the jungle sound effect record, the astro turf presumably nicked from the local greengrocer and of course the inflatable gorilla. Not a lot new, though — just what's been advertised for the last five months.

Sound Effects

Sound Technology, the UK distributor for Alesis effects and analogue synth masters Oberheim had new things for both at the show.

Alesis had two new additions to its Micro effect series which are the Micro EQ and the Micro Cue Amp, both £125. Planned for the Autumn is the sequel to the excellent Midiverb and the Midiverb 2, the Quadraverb with 100 programmable effects which can be chained together in fours which will get over the problem that most multi-effect units have.

From Oberheim comes the Matrix 1000, a sound expander with 1000 presets on it. The unit is six voice but no mention is given to it being multi-timbral. Nevertheless £450 is still good value for that many options.

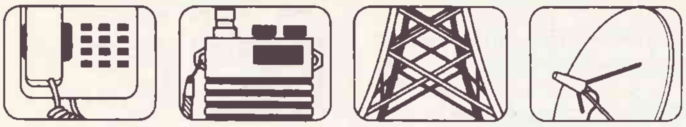
Additional Highlights

Having trolled round the big names you may well be forgiven for thinking that that's all that there was of interest. Nothing could be further from the truth.

The Farfisa stand was showing the Midimic — an audio-to-MIDI converter which not only receives a mono sound source from the in-built microphone but also has a line level input for non-MIDI instruments such as guitars, saxophones or even old keyboards. From the demo I received the tracking is excellent and at £200 means anyone who can even whistle a decent tune can now get into professional music.

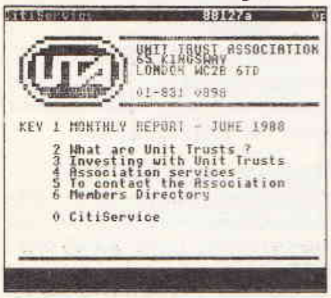
Darrin Williamson

OPEN CHANNEL



The potential UK videotex market is huge. There are, after all, well over 50 million of us living on these fair isles and if even only a tenth of this potential is tapped, there's many a fortune to be made.

Yet the present state-of-the-art here in Britain is ridiculously small. Only a few hundred thousand terminals are in use and the aim of the services appears to be primarily towards the business sector. I would strongly suggest this is a short-sighted attitude and one which must change.



The Prestel service is hardly a service at all. At the risk of being contradicted (I would dearly love to be, if anyone can tell me otherwise) cost is basically prohibitive to all but the keenest of private users and uses of the service are limited such that it is hardly worth the bother, anyway.

This is a preposterous situation. We have, potentially, an extremely good system — on its initiation back in 1979 (yes, nearly ten years ago) it was the best of its kind and should have been constantly developed to remain so through the years. British Telecom, back in the days of the Post Office, thought it would increase telephone revenue and were at that stage reasonably happy to put funds into it.

However, once developed, Prestel was (and still is) allowed to rot and so now falls at about the bottom of the pile compared with other systems. Where Prestel's task was to increase the public's use of the telephone system (it didn't, and still doesn't) other later systems such as France's Minitel have taken videotex to new heights with every year of their use.

The British problem is one of sheer mis-management and poor marketing. Where UK users have to fork out our hard-earned pennies (well, hundreds of pounds, actually) to buy a terminal or buy software to convert a computer into a terminal, the French equivalent of BT (France Telecom) *gives* the damned terminals away to interested users at the rate of *one million terminals a year*! France Telecom expects to give everyone a terminal by the end of the century.

Further, whereas we have Prestel and its limited existing uses, France's Minitel is based around an electronic adaptation of the telephone directory. Instead of looking in a paper directory or phoning Directory Enquiries (that is if you can actually reach Directory Enquiries) French users merely use their free terminals. This electronic directory automatically ensures the terminals will be adequately used and will even pay for themselves given time.

Apart from a few technical details (Minitel is a much easier-to-use system than Prestel — it's menu-based rather than the difficult page-based Prestel) other services remain similar — electronic shopping, travel agencies and so on, although a number of new services have arisen due to Minitel's wider acceptance by the public.

Incidentally, just in case you're a bit suspicious about whether the terminals can pay for themselves, France Telecom estimates each terminal given away pays for itself in the extra revenue generated, *within a year*!

Minitel presently generates some 70 million calls a month, which translates to some 84 million hours connected to the service and that means a lot of money — more even than I get paid by ETI for writing this column! Only around 3.5 million terminals have yet been given away, too. The final figure, when everybody has a terminal, will make BT executives' faces (and, I suspect, those of the Government) go positively green with envy.

Not Cricket

Now come on! Can't we take a lesson from all of this? What are we thinking about? I know it's not cricket, but who said we were playing a game, anyway!

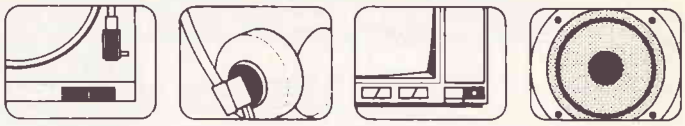
We who invented the hovercraft, the jet engine, the computer (there must be others but for the life of me I can't think of any more, offhand) can't even seem to get our act together on this one. Yes, I know the Prestel system doesn't lend itself to the same sort of things that Minitel can do but what the heck!

If Prestel's no good scrap it and let's do it right. We've got ten years experience (give or take a few months) of how our system doesn't work and isn't much good.

Now, let's do it right.

Keith Brindley

PLAYBACK



Even in today's hi-tech world there remains plenty of scope for the hi-fi hobbyist to improve his system by paying meticulous attention to detail. Indeed, there is many a way in which systems may be 'tweaked' — all in the name of enhancing the musical experience!

Over the years such techniques as tightening-up cartridge bolts, employing rigid and spiked loudspeaker stands and using good quality interconnection end speaker cables have evolved into a thoroughly logical upgrading process.

However, acting as a foil to these perfectly sensible 'tweaks' there exists a stubborn fringe element insisting on employing quite ludicrous methods to improve audio performance.

One of the silliest ideas to emerge in recent years involves sticking little black squares of metallised polyester over everything in sight. Now, in some cases this process might effect a *change* in the sound of a system though whether such differences are actually improvements has as much to do with the placebo effect as rational science.

I shall return to this subject at a later date but for now I would like to highlight a particularly illogical and potentially damaging 'tweak' that has surfaced in the hi-fi arena.

This latest concept concerns the use of shorting plugs to load the coaxial digital outputs of the more up-to-date CD players. Apparently by terminating the output in this fashion, the overall sound quality of the CD player is said to be improved. Daft but true.

The tentative rationale for this improvement is thought to be that the plug somehow stops electricity from leaking out the hole!

Most manufacturers employ transistor-transistor logic (TTL) to drive this digital output either via a resistive pad or transformer that isolates the digital and analogue ground lines. Now, whether this digital output is shorted or open circuit there will always be a degree of mistermiation that results in signal reflection, so perhaps these outputs are best loaded with plugs that match the universal output impedance of 75R.

According to the Red Book standard, the peak voltage of a digital output should be set to 0.5V with a master clock frequency of 5.65MHz, a signal that will be injected directly into the earth line if a shorting plug (loaded or unloaded) is employed.

As you might expect from TTL, stages could be permanently damaged by this inappropriate loading. In the case of a shorting plug this peak voltage could realise a current of up to 6.66mA which will itself set up voltages across common earth lines due to small series inductances.

Of course, this effect will depend very much on the layout of the PCB but with interference set up between digital and analogue earths it is not difficult to imagine jitter effects being exacerbated.

In addition, a greater demand will be placed on the integral power supply as more current is drawn just as fairly significant RF (5.6MHz) magnetic fields may also be developed. The subjective consequences of RF interference are becoming more widely appreciated by the more sane elements of the hi-fi industry and it is likely that this situation will snowball once we enter the 'RF conscious' European Market.

Early research work indicates that down-band products of very high-order difference intermodulation may be responsible for certain grainy and coarse high frequency colourations observed during critical listening tests. Certainly my own experiences of a vast number of CD players point to them sounding *worse* once the digital output is shorted — a logical conclusion considering the added stress this imposes on the player.

Other enthusiasts, unaware of the electronic consequences of their actions, may expect a change in sound quality and this 'difference' may inadvertently be interpreted as an improvement. I am quite sure that if CD players were manufactured with shorting plugs in place then the fringe element would currently be proposing their removal . . .

The ideal situation is presented by those up-market players which enable the user to switch the TTL output on or off when required. Nevertheless, if the presence of localised RF fields is undesirable from the subjective point of view then an unterminated digital output is likely to be preferable to one that is shorted. I now wait with baited breath for someone to suggest we short out any redundant *analogue* outputs as a way of improving sound quality!

Paul Miller

This column is a service to readers to provide electronic designs to order. Many a project never gets further than the drawing board because of difficulties with one small part. If you are stuck for a circuit or a technique, let the ETI expert help you out. Send your requirements, with as much detail as possible, to ETI Blueprint, 1 Golden Square, W1R 3AB.

The request for a Blueprint design this month comes from Herbert Jones of Hove, Sussex.

I would like to build an integrating current meter which, linked to a solar cell, would give a reading of average daylight intensity over a period. I have seen a paper describing a device which integrates current by plating metal from one electrode to another. The electrodes have to be weighed to obtain a measurement. A digital readout would be much more useful.

There is a practical way to make a digital integrating meter. The most versatile solution would be to use a microprocessor but this would take far too much time to write the program in machine code. Also, many people do not have EPROM programmers. The circuit in Fig.1 uses 4000 series CMOS to achieve the aim and uses so little current that a battery can be used to power it.

The system shown here uses a voltage controlled oscillator (VCO) to convert an analogue signal to a frequency. The clock pulses from the VCO are counted and the total is displayed when required.

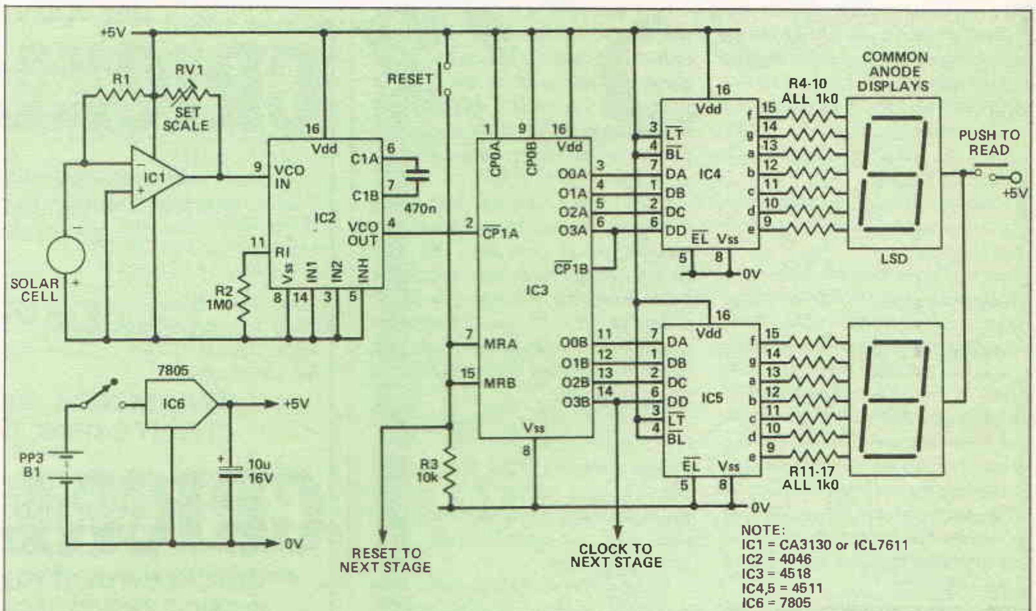


Fig. 1

The Circuit

A solar cell converts light into electricity by means of incident photons giving up their energy to an electron on an individual basis. That is to say, the energy of the electron freed from the atom depends on the energy of the photon which it has absorbed. Silicon solar cells have certain bands of possible energy levels for 'bound' and 'free' electrons and they can only absorb photons having an energy corresponding to a jump between levels in the requisite bands. This means the voltage generated by a solar cell depends on the energy band structure of the cell, rather than on the incident light (assuming the incident light includes photons of the right energy range).

Although the electron energy is not a good indication of the incident light level, the short circuit current is a reasonable indication. This is because the number of electrons raised to the conduction band depends on the number of photons in the right energy range which fall on the cell. This correspondance is not perfect because the cell will have defects but it is very good.

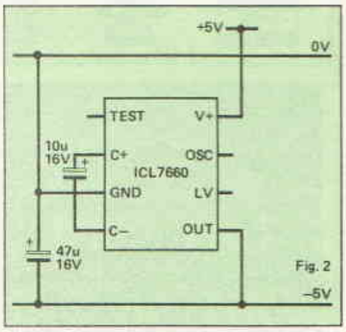
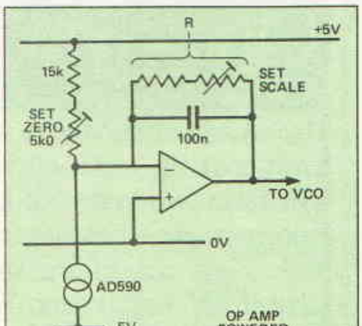


Fig. 2



OP AMP POWERED FROM 0V & +5V

1mV/°C	1k0
10mV/°C	10k
200mV/°C	200k

Fig. 3

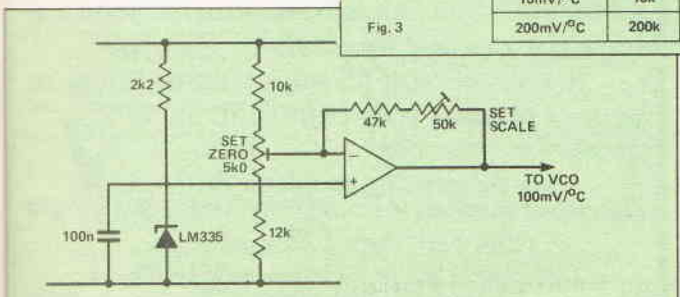


Fig. 4

In The Right Light

To make use of this characteristic of solar cells, the cell is connected to a current-to-voltage transducer. In this circuit, so long as the op-amp is not overloaded, feedback keeps the voltage across the cell almost at zero. The current from the cell all flows in R1 and RV1, so the voltage output of the current-to-voltage transducer can be calculated by Ohm's Law if you know the current output from the cell.

All this only works if the cell is connected the right way round. If it is not, the output of the op-amp will remain stubbornly at 0V, trying but not succeeding to reach a negative potential.

The output from the current to voltage transducer feeds the VCO control input of a 4046 phase locked loop IC. The frequency of the VCO is proportional to the control voltage. A slight error will be introduced here because the relationship is not perfectly linear but the error is only small.

Out For The Count

The VCO output is fed to a dual decade counter and from the first decade counter to as many cascaded stages of counting as may be required to count the total number of pulses from the VCO.

The counter outputs are fed to BCD-to-seven segment decoder/drivers and thence to 7-segment displays. If a long series of counters is to be used, it may be unnecessary to use displays and drivers on the least significant digits.

For many purposes, adequate resolution would be provided by using displays on the four most significant digits (assuming that measurements in the same range are needed). More displays on less significant digits would, however, display a useful reading with shorter measurement periods. The displays have been shown with a push-to-read switch to minimise battery consumption.

Other Applications

Clearly, the integrating meter part of the circuit can be used to integrate any analogue voltage measurement having a range of approximately 0-4V. With the circuit shown, the limitation on converting some types of signal source to suitable range is the lack of a negative power supply.

Fig. 2 shows a suitable means of generating a negative power supply, and Fig. 3 shows a temperature measuring circuit which uses the negative supply. As an alternative, the more complicated circuit shown in Fig. 4 does not need a negative supply to measure temperature.

Both of these circuits are assumed to be Celsius reading. The temperature sensors provide a Kelvin scaled output but this is unlikely to be of use to determine the difference between a warm day and a cool one.

Andrew Armstrong

ONCE OVER

The welcome associated with the glow of a home must be as old as are glowing homes. In the days when the glow was caused by the roaring hearth there was not a lot you could do to automate the glow so it would be there on your return and not wasting fuel all day.

Come the advent of electricity (and more importantly, electronics) and things changed.

Now it is quite possible to have a light at your doorstep which comes on to greet you or visitors only when someone approaches and only when the sun has set. You can't go much further in the way of automated welcomes and there can't be a much more economic solution either.

It is just such a unit that Maplin has been selling for a while now. Called the *Nite Sentry* on the box and simply the *Outdoor PIR* in Maplin's catalogue it has the order number XG96E and a price of £39.95.

The catalogue name gives the game away. This is yet another ingenious application of the passive infra-red detector idea based on a pyro-electric sensor.

The Nite Sentry is mains powered and connects up just like any outside light. It is similar in many ways to the passive infra-red alarm project of the ETI January 1988 issue.

Body heat from the visitor is collected by way of a special Fresnel type lens onto a concave mirror where it is focused onto the pyro-electric sensor. The mirror angle can be easily altered to change the height of the detection area over a range of about 15°.

The sensor responds to *changes* in radiated infra-red heat received. The Fresnel lens creates a pattern of detection zones so as a visitor crosses the area covered by the unit, he will move into and out of the array of sensitive zones, triggering the unit.

So it is much like any passive infra-red alarm. In this case, however, rather than connect the unit up to an alarm system (such as the Burglar Buster!) it connects a built-in light socket (up to 100W) to the mains and powers an auxiliary output too for extra lights (up to 600W).

Once triggered, the light stays on for a preset period from about ten seconds to 15 minutes. The Nite Sentry even includes a photosensitive cell to disable the unit during the hours of daylight. The photocell is sensibly mounted on the underside of the unit to receive ambient light only and not direct sunlight.

The whole thing — detector and lamp — is encased in a slightly weird cream coloured ABS box with a pearled light cover. It is entirely waterproof and easily mounted on a wall with the mains cable entry through the rear.

Once on the wall it looks rather like a 1960's attempt at bringing the carriage lamp up to date! However, it is not too obtrusive and certainly warrants a position on the wall.

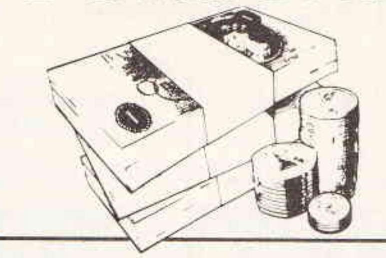
The sensor is rated with a range of a quarter circle 10m in radius. Once up over the front door, the effective range seemed to be nearer 5m but as most front gardens are about this length and passing cars can trigger the detector, this reduction in range is probably a good thing.

Otherwise the unit performed perfectly. It is easy to install. An add-on angled mount is provided if necessary and even a sticker for the photocell is included so the unit can be tested in the daylight. It takes only about 15 minutes to put up, it means you'll never have to leave the light on again and even acts as a mild deterrent to unwelcome visitors. What more can you ask for £40?

Malcolm Brown

In next month's ETI there is a chance to win one of three Nite Sentry units in a free competition.

FAME & FORTUNE



That's what an incredibly small number of people have achieved by contributing articles to ETI. The rest of us have had to make do with total obscurity and enough money for a couple of pints. Nevertheless it's all worthwhile and we need your contributions now!

FEATURES

If you know what you're talking about and it hasn't all been said before, we want you to add to our wide ranging and informative features. If you have a great idea for a feature or two, send in a brief resumé. If you don't have the ideas but you think you have a commanding knowledge of a suitable subject area we want to hear from you too.

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