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PRACTICAL ELECTRONICS

PE VOL 24 NO 2 FEBRUARY 1988

COMPETITION

WIN A SATELLITE TV SYSTEM 61
Answer a few simple questions and have a chance to win a superb Connexions CX8520R satellite tv system, complete with motor driven dish, remote control, and twin channel output. Worth over £1200!

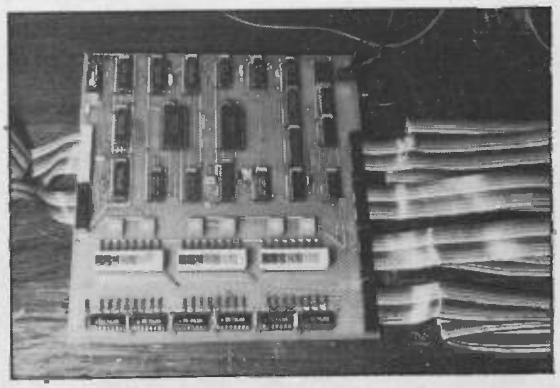
CONSTRUCTIONAL PROJECTS

LOGIC ANALYSER PART ONE by Michael Sweet 12
A very sophisticated unit for use with the BBC computer, enabling digital systems to be analysed at full operating speed.

TREMOLON by John Becker 24
A novel musical effect unit designed with low-tech and hard-up soloists in mind.

TEACHER TALKBACK PART TWO by Tim Pike 42
Chatterbox TP tells how masters and slaves can communicate along a GCSE project hot-line.

DC MOTOR SERVO by David Sanders 51
Practical real world interfacing for mobiles through a mixer and motor control system.



SPECIAL FEATURES

REAL WORLD INTERFACING PART ONE by Robert Penfold 17
Most things in nature produce analogue signals, so to control them by digital electronics, converting interfaces are needed.

HEAT SINKS by Stephen Knight 29
A cool headed look at the theory of why heatsinks are needed, and how their applications can be treated as circuit diagrams.

SEMICONDUCTORS PART FOUR by Andrew Armstrong 35
Uses for field effect transistors are growing rapidly, so it's vital to understand their pros and cons.

ELECTRONIC LOCKS PART TWO by The Prof 48
Still keyed up from last month's security discussion, the Prof describes an infrared controlled locking system.

REGULAR FEATURES

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Future British telecommunications
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NEXT MONTH . . .

WE'VE GIVEN MARCHING ORDERS TO –

A WEATHER CENTRE • SATELLITES • TEACHER LIGHTSHOW • AMSTRAD PRINTER PORT • DIGITAL TO ANALOGUE • AND WE'RE SNOWED UNDER WITH OTHER TIMELY FEATURES

SO HARE ROUND TO YOUR NEWSAGENTS FOR THE PE MARCH 1988 ISSUE ON SALE FROM FRIDAY FEBRUARY 5TH

THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS ENTHUSIASTS

We have recently received the following catalogues and literature:

Maplin appear set to conquer the Universe with their **Monster 1988 buyer's guide to electronic components,** or so it would seem from it's front cover. Could they be conquering time travel as well? – if you phone **0702 554161** before 5pm, they promise the same day goods despatch. Otherwise, write to **Maplin Electronics, PO Box 3, Rayleigh, Essex, SS6 2BR.**

Electroplan Rental have issued their 1987-88 catalogue of computing test and measurement **products that are available for rental.** Equipment may be rented for a minimum of one week, to over two years. Discount and purchase option plans are also offered. **Electroplan Rental,** PO Box 19, Orchard Road, Royston, Herts, SG8 5HH. 0763 47251.

IQD Ltd have announced their new 200 page quartz crystal catalogue. It's been completely redesigned around the **needs of electronic design engineers and buyers,** and is apparently the largest and most comprehensive frequency control catalogue on the UK market. **IQD Ltd,** North Street, Crewkerne, Somerset, TA18 7AR. 0460 74433.

IMO have sent their 1987-88 catalogue. They are well known for their **wide range of professional control equipment,** and their 300+ page catalogue confirms this reputation. **IMO** are at 1000 North Circular Road, Staples Corner, London, NW2 7JP. 01-452 6444.

British Amateur Electronics Club have sent another news letter **full of interesting electronics information,** and reader feedback. (How about looking into a low cost DTP system, chaps? It would work wonders with your drawings). For more info on the **BAEC,** write to the Hon Sec, 53 High Oaks Close, Locks Heath, Southampton, SO3 6SX.

Industry and Education is a quarterly journal, the first issue of which has recently been received. Its intention is to cover all aspects of developments **in collaboration between higher education and industry.** It is published by **Butterworth Scientific Ltd,** PO Box 63, Westbury House, Bury Street, Guildford, Surrey, GU2 5BH.

Midnight Express

Midland Bank has introduced Mid-Night Express, an electronic service for retailers that helps speed up and simplify the process of receiving payment for goods and services.

Mid-Night Express is the first in a series of electronic payment services to be introduced by Midland under the generic name 'MidlandTransact'. Based on the principals of EFT-POS (electronic funds transfer at the point-of-sale), it collects and distributes certain plastic card payments, without the necessity of the traditional sales vouchers.

The customer pays for goods and services by handing the retailer an acceptable card. Initially these will include Access and Visa. The retailer then 'swipes' the card through a small point-of-sale device. This reads the card and a receipt is produced. The customer confirms the transaction, usually by signing the receipt, and the sale is completed electronically.

WHAT'S NEW

Arriva Revox

FOLLOWING the successful introduction of the C279 compact audio mixer, Revox have launched a plug-in expansion module further enhancing this flexible unit.

The new unit gives the mixer four additional features: stereo noise reduction using dbxII processing (encoding/decoding); built-in test-tone generator for calibration at two levels 0dBu and +6dBu; fader start logic for all six inputs as well as the master channel; two phono inputs also with fader start logic.

Revox have also introduced a carrying case for the mixer which can be used whether or not the C279 is fitted with the expansion unit.

For more information about Revox Equipment, please contact F.W.O. Bauch Limited, 49 Theobald Street, Boreham Wood, Hertfordshire WD6 4RZ Tel: 01-953 0091

Soft Boards

CADsoft have announced the introduction of their new printed circuit board design program for the Amstrad range of computers.

It will operate on all Amstrad CPC computers without the need for expansion RAM. Draft or final quality printouts can be produced at 2:1 scale, using Epson compatible dot matrix printers, including the Amstrad DMP2000. Single and double sided boards up to 25 x 25 inches (63.5 x 63.5 cm) finished size can easily be accommodated, with up to 4000 structures (pads or tracks) on each board. 4 track widths and four pad sizes are available and can be freely mixed.

The program costs £19.99 on tape and £21.99 on disc and is available from: CADsoft, 18 Ley Crescent, Astley, Tyldesley, Manchester, M29 7BD.

Multi-Colour Panels

A new and non-hazardous system has been introduced by Mega, for the production of purpose-designed custom panels, signs and labels.

The Gedakop system offers the means of producing labels or panels quickly, economically and simply on standard formats ranging in size from 250 x 320mm, up to 500 x 1000 mm, with thicknesses from 0.125 to 3.0 mm. The end product is reproduced from the user's artwork on anodised aluminium sheeting and as many as 29 available dyes provide for a variety of multi-colour options.

The anodised aluminium sheeting is coated with an ultraviolet-sensitive, positive working photoresist. Once exposed to UV light via the positive film artwork, the sheeting is developed by spraying with water. There then remains an 'open-pore' positive image of the film, and this will accept any of the colour dyes. Excess dye and unwanted photoresist is removed by means of a stripping solution, and this results in the coloured design being set into the anodised aluminium image of the artwork. The complete process may take only about 10 minutes. If necessary, the image may then be sealed extremely simply, for protection against chemicals, scratching and adverse weather conditions.

Introductory kits are also available, for feasability assessment.

For further information contact: Mega Electronics Ltd, 9 Radwinter Road, Saffron Walden, Essex, CB11 3HU. Tel: 0799 21918.

DFB Laser Diodes

Hitachi is introducing two new DFB (Distributed Feedback) single-mode laser diodes which offer exceptionally high-speed and long distance data transmission characteristics. The HL1341 operates at a wavelength of 1.3 microns while the ML1541 operates at a wavelength of 1.55 microns for multi giga bit transmission speeds.

The major advantage of the new diodes is that they offer a single mode signal. More traditional multi-mode laser diodes suffer because different frequencies interact when sent through an optical fibre creating optical noise. This makes increasing the speed of optical transmissions difficult. The problem is overcome with the new single mode DFB laser diodes.

These new devices allow a transmission speed of 5 giga bit/second or more over a distance of 30 km, whereas the practical maximum for multi-mode lasers is 565 mega bits per second over this distance. Both of the new devices are available in 7 basic package variations.

The two new laser diodes employ a buried hetero-structure to offer both high reliability and a high-speed response, which allows for direct modification of 5 giga bit/second or higher. These products have opened the way to the realisation of the giga-bit system of optical communication.

Contact: Dave Redpath at Hitachi Electronic Components. Tel: (0923) 246488.

Trannies

THE OB (on board) range of miniature transformers available from Avel now conform to the requirements of seven of the world's most exacting specifications. The load ratings range from 0.8VA to 30VA, with the 0.8VA being claimed to be the world's thinnest transformer at only 10.5mm (0.413in) high. The flat height profile enables the 0.8VA version to be mounted where there is 0.5in board spacing. Others in the range are equivalently small, making them ideal for direct mounting on close spaced pcbs. Their low height profile and general small size enables a power supply to be an integral part of a particular board, or section of a circuit, rather than drawing power from a central psu.

Dual primary windings can be connected in parallel for 120Vac and in series for 240Vac nominal operation at either 50 or 60Hz. Seven dual secondary windings can be provided which give 5, 6, 9, 12, 15, 18 and 24V rms when parallel connected and 10, 12, 18, 24, 30 and 48 rms. when series connected.

Contact: Avel-Lindberg Ltd, South Ockenden, Essex RM15 5TD. Tel: 0708 853444.

Barry Fox Awarded

Barry Fox, one of PE's leading contributors, has received well deserved recognition in the fourth UK Technology Press Awards. He has won the features journalist category award, for contributions to *Practical Electronics* and *New Scientist*.

The awards were sponsored jointly by *The Times* and Hewlett-Packard, and were announced at the end of November during a ceremony held at Claridges. Judges for the awards included Doug Eyeions, director of the Computing Services Association, June Fraser of the Design Council, David Driver, design editor of *The Times*, and Jim Brooks, chief executive of the British Computer Society. Television presenter Cliff Michelmore hosted the ceremony.

Barry's feature article contributions that won him the award covered the future of optical storage, fibre optics, and the corruption of computer data. Regular followers of his monthly column in PE will be aware of the commitment Barry has to reporting current technological trends in a clear, concise and knowledgeable style. Readers will also remember his full length feature on Optical Fibres, Lasers and Communications, in the PE November issue.

It was in the early 1970s that Barry first began writing for PE, at that time publishing under the pen name of Adrian Hope. Since then his contributions to PE have been well respected, and we are proud to have his continuing

association with us. His monthly *Leading Edge* column has become a traditional part of PE, and we have further full length features from him lined up to bring you shortly.

The award confirms that top people in top places write and read PE. Congratulations Barry, and thanks.

Other contributors to PE have also found media attention during 1987. Tim Pike, author of the GCSE project series, received recognition through a report on his involvement with PE by a regional newspaper. He has since been approached by a national tv network in connection with educational television. Your Ed, John Becker had the geiger counter, that he designed for PE following the Chernobyl accident, demonstrated on BBC television, accompanied by good publicity for PE itself.

We are in no doubt that, through the quality of its authors, PE is definitely *the* science, technology and education magazine for those who are seriously interested in electronics. PE

CHIP COUNT!

This month's list of new component details received — mainly chips, but other items may be included.

83X3X. CHMOS multifunction periferals for 8-, 10- and 12MHz versions of 80286 PC-AT compatible designs. **(IT).**

H4808. Addition to the H400 series of single chip cmos 4-bit microcontrollers. Ideal for instrumentation, telephones, display modules etc. Features large program and data memories, integral lcd interface, time, interupt and flexible i/o structures. **(HT).**

NE-SA-SE5570. Controller for brushless 3-phase dc motors using pulse-width modulated (switch mode) drive from a serial bit stream. Can also deal with 60° or 120° commutation motors. **(ML).**

OM2000 series of low noise wideband hybrid ic amps for RATV, MATV and CATV systems in the 40 to 860MHz range. **(ML).**

PP12 series potentiometers. Small low cost modular pots with carbon or cermet tracks, for pcb mounting, vertically or horizontally, and which can be fitted with a snap in plastic spindle. **(ML).**

Manufacturers, and contact telephone numbers for further details: (HT) Hitachi, 0923 246488. (IT) Intel, 0793 696204. (ML) Mullard, 01-580 6633.

Breaking Down

A new device available from Hitachi provides the core of a residual current circuit breaker (rccb) in a space saving 8-pin sip package. The HA16636P contains a differential amplifier, a monostable and an scr drive circuit, along with a reference zener and clamping diodes, and includes temperature compensation, noise rejection and surge voltage protection circuitry to ensure reliable operation.

The chip connects directly to a conventional zero-phase current transformer (zct) which measures the sum of the currents flowing in the live and neutral wires to a load. Ideally, these are of equal magnitude but opposite sign, giving a net current of zero. If a shunt path is created between either wire and earth, the two currents become unequal and the residual current is detected. The output of the device then drives an external scr which activates a circuit breaker, isolating the load within 10s of milliseconds. The only other external components required are a diode bridge and a few passive components for timing and sensitivity control. The components can be chosen to allow the rccb to meet BS4293.

The HA16636P allows both the cost and physical size of rccbs to be reduced and is therefore ideal for use in mains-powered hand tools, domestic appliances and consumer products, as well as for replacing or augmenting conventional fuses in mains distribution panels.

Contact: Hitachi Electronic Components (UK) Ltd, 21, Upton Road, Watford, Herts. WD1 7TB. Tel: (0923) 246488.

Gas Soldering

IDEAL for field servicing use, in the laboratory or where electric mains connection is impractical, a new butane gas soldering tool from OK Industries can be used with or without a flame to enable it to double as a welder. It is supplied with three attachments to allow soldering with a tip, shrinking with a hot air nozzle and welding with an open flame with temperatures of up to 1300°C. When used for soldering and hot air applications a catalytic converter operates.

The amount of gas and temperatures is controlled by three adjustment rings, and the refined butane gas in the refillable cartridge allows for about 180 minutes operation.

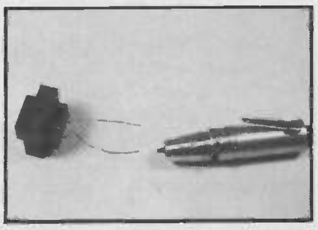
Contact: OK Industries UK Ltd., Barton Farm Industrial Estate, Chickenhall Lane, Eastleigh, Hants, SO5 5RR. Tel: 0703 619841.

Airstrip

Eraser International have introduced an all new air operated magnet and enamel wire stripper into their popular L series of strippers.

The L4 uses rotary inserts to strip most film insulations from round wires of sizes between 29 AWG and 4 AWG and can also be used for cleaning component legs and transformer pins. A clean lubricated air supply of 90 p.s.i. at 18 c.f.m. is required to operate the unit.

Contact: Eraser International Ltd, Unit M, Portway Industrial Estate, Andover SP10 3LU. Tel: (0264) 51347/8.



Tintinabulation

MEGA Electronics have announced the availability of a new powder-form tinning solution. It is the only one currently available that is capable of plating tin on tin.

Introduced as part of Mega's recently acquired Seno range of PCB processing chemicals and applicators, the Seno-tin solution embodies a number of unique features of importance in the PCB production environment.

In addition to its ability to plate tin on tin, Seno-tin is designed to work at room temperature. Once mixed with water it does not crystalise out, and deposits the tin in extremely small molecules to form a hard, bright and non-porous scratch-resistant surface.

The powder may be mixed in ordinary tap water, after which it has a shelf life of around six months; its shelf life in powder form is indefinite.

SENO-TIN is available in bulk, ex-stock, from Mega Electronics Ltd., at 9 Radwinter Road, Saffron Walden, Essex, CB11 3HU. Tel: 0799 21918.

Micro-Synth Sig Gens

ELECTRONIC Brokers have introduced the Marconi Instruments 2018A and 2019A AM/FM synthesized signal generators, two new microprocessor-controlled instruments covering the frequency ranges 80kHz to 520MHz and 80kHz to 104MHz respectively.

Microprocessor control provides simple and rapid operation by direct keyboard entry of settings, and the non-volatile memory, which can store up to 100 settings, further reduces measurement time. Powerful second functions enhance the operation of the signal generator and provide the user with valuable diagnostic aid facilities for use in maintenance and calibration.

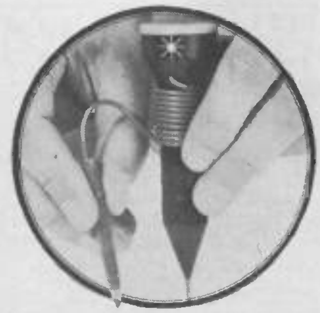
Contact: Electronic Brokers Limited, 140-146 Camden Street, London, NW1 9PB. Tel: 01-267-7070

Digital Radio Service

THE Department of Trade and Industry have announced a new agreement with the Electronic Engineering Association (EEA) on a work programme aimed at the introduction of a digital short range radio service by the early 1990's.

The use of all-digital techniques for voice and data is a UK first in this field.

The DTI has commissioned a report on the economic costs and benefit of short range radio which is **available free of charge from:** Radiocommunications Division Library, Department of Trade and Industry, Waterloo Bridge House, Waterloo Road, London SE1 8UA.



Scribbled

A continuity tester with a difference has been introduced by JASP Internatinal. The EEH 75H incorporates accoustic and LED indicators to faciliate testing procedures, and additionally has a push-in writing probe so that notes can be written done immediately after making tests.

The voltage on the test probe is only 2.6V, minimising the risk of destroying components under test. The unmistakably loud tone resulting from satisfactory connections is produced by a peizo-electric buzzer. Simultaneously a LED is illuminated.

The probe measures just 19mm x 120mm, runs from two 1.5V batteries, and is protected against external voltages up to 250Vac, providing each test takes less than 10 seconds.

It is obviously a handy tool to have around if a multimeter is not available.

Contact: JASP International, 14 Tudor Close, Wokingham, Berks, RG11 2LU.

Pico the Pulses

IBM scientists here have made and measured the world's shortest electrical pulses, an important step in designing the ultrafast electronic computer components of the future.

Using a laser and a very fast switch, the scientists produced electrical pulses lasting only one half of a picosecond. A picosecond is one trillionth of a second. Until this experiment, researchers had never broken the "picosecond barrier" with an electronic device.

Today's fastest experimental silicon logic devices can switch on and off in about 30 picoseconds; gallium arsenide devices in about 10 picoseconds. But to investigate the electrical behaviour of these devices, researchers must be able to measure pulses at least 10 times faster then these switching times.

The technique used to make the half-picosecond pulses can measure electrical pulses up to 20 times briefer than the switching times of the fastest present-day devices.

If you are organising any electronic, computing, electrical, scientific or radio event, big or small, drop us a line – we shall be glad to include it here.

PLEASE NOTE: Some events listed here may be trade only, or restricted to certain categories of visitor. Also, please check dates, times and other relevant details with the organisers before setting out as we cannot guarantee information accuracy.

Jan 27-28. Instrumentation Coventry. Trade only. Allesley Hotel, Coventry. 0822 4671.

Feb 24-25. Instrumentation Bristol. Trade only. Bristol Crest Hotel, Bristol. 0822 4671.

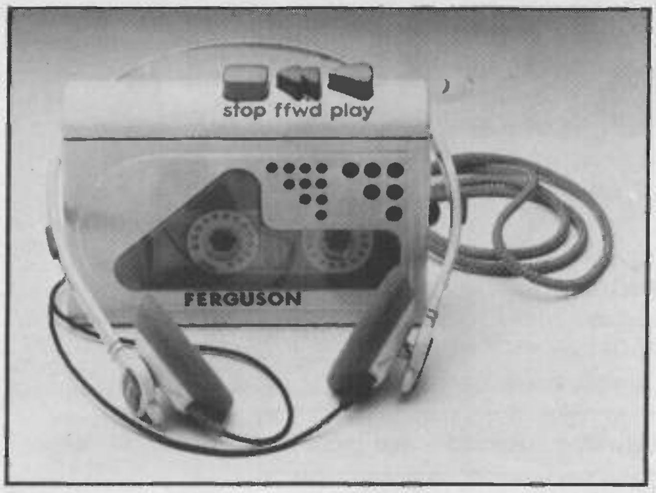
Mar 29-30. Instrumentation Harrowgate. Trade only. Harrowgate Exhibition Centre, Harrowgate, N. Yorks. 0822 4671.

Apr 13-14. Laboratory Cambridge. Kelsey Kerridge, Cambridge. 0799 26699.

Apr 26-28. British Electronics Week 88. Olympia. 0799 26699.

May 12-14. Compfest 88 – National Computer Festival. Telford Exhibition Centre. 0952 505522.

May 18-19. Laboratory Manchester. New Century Hall, Manchester. 0799 26699.



Fergi Bopper

THE Ferguson Bopper PSC01 is a brightly colourful personal stereo with a 'soft' and tactile features that should ensure an appeal to its target audience of children aged five and upwards.

The electronics are safely enclosed inside the bright canary yellow case to distract young prying fingers and it has chunky, bold coloured play, stop and fast forward buttons; simple slide volume control; automatic tape stop and large, easy to read graphics.

The Ferguson Bopper comes with removable carrying strap, belt clip and a pair of safety designed headphones, it runs off two AA size batteries and sells for around £19.99.

Contact: Ferguson, Cambridge House, Great Cambridge Road, Enfield, Middlesex EN1 1UL Tel: 01 363 5353

New links for Lancs

Electronic education at Lancashire Polytechnic has won important national recognition for its Higher National Diploma Course in Electronic Engineering.

It is the first course to be approved by the new Joint Academic Accreditation Committee which scrutinises courses and colleges for acceptability to the Institution of Electrical and Electronics Incorporated Engineers (IEEIE) and the Society of Electronic and Radio Technicians (SERT). All students who get HNDs in Electronic Engineering at the polytechnic will now automatically be eligible for registration as Technician Engineers (TEng) with the Engineering Council. After a spell of training and experience in industry they will be eligible for full membership of the IEEIE or SERT and able to use the TEng abbreviation after their names.

Professor Norman Burrow, Head of the School of Electrical and Electronic Engineering, said: "This vote of confidence by the two major professional bodies concerned with technician engineers confirms the national recognition of the quality of engineering education at Lancashire Polytechnic. It is a just reward for the staff and students who have worked hard to develop the courses in electronic engineering over the past few years. Students who come to Lancashire Polytechnic can be confident that their course is one of the best in the country and that it will help them to find exciting and well-paid employment."

For further information contact Prof. Burrow, or Bernadette Evans, at Lancashire Polytechnic, Preston, PR1 2TQ. Tel: 0772, 22141, Extns 2200 and 2231 respectively.

Jail House Rock?

THE hopes of a group of record pirates to profit from the tenth anniversary of Elvis Presley's death ended in a Dutch court recently. What are believed to be over a million units of lps, cassettes and compact discs were involved in a case brought against two Dutch companies. It was admitted in court that the recordings had been exported to 11 other European countries.

The cassettes were made in Holland, while the records were manufactured in Germany and the cds in Korea. The Presley recordings offered for sale comprised over 20 different titles, including *Hound Dog, Heartbreak Hotel, GI Blues, Blue Suede Shoes* and *Golden Hits Vol. 1, 2 and 3.* The president of the court said that the rights of record companies and performers were as important as those of composers, and since the product was obviously manufactured without the consent of the copyright owners, this was a clear case of piracy.

Transputer Centre

THE Bristol Transputer Centre, a major new initiative to exploit British technology has recently been opened by Professor Ian Barron the man behind the invention of the transputer at Inmos, and Brian Lodge of the DTI.

Bristol Polytechnic, Inmos and the Department of Trade and Industry teamed up to launch the centre at a cost of £500,000. The centre will provide a major link between industry, commerce, and the academic community. It has been established to supply information on transputers and their applications and will develop short courses, workshops, applications notes, and in-house training packs on this important new topic.

Underpinning this work is a flourishing research group investigating transputer applications in fields such as Intelligent Knowledge Based Systems and Databases for clients in both the industrial and financial sectors.

Initially the centre will have a forty transputer system and fifteen microcomputer based workstations supported by Inmos transputer development systems, together with a versatile selection of specialised boards for applications such as graphics, disk handling, signal processing and communications.

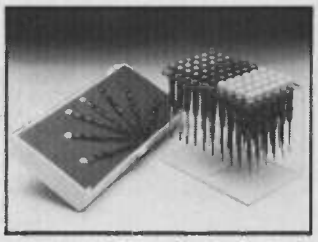
Contact: Mary Wright, Public Relations Office, Bristol Polytechnic, Coldharbour Lane, Frenchay, Bristol BS16 1QY. Tel: 0272 656261 ext 2208

Return Of The Jedec?

THERMALLOY has come up with an extruded heat sink design specifically constructed for use with Textool sockets which accept jedec Type A chip carriers.

Heat sinks in the new Thermalloy 2300 Series form a 'lid', which nicely covers the chip and then snaps into a 68-lead Textool 268-5400 socket, to provide a neat and efficient housing without need for thermal bonding.

Contact: MCP Electronics Ltd, 26-32 Rosemont Road, Alperton, Wembley, Middx HA0 4QY. Tel: (01) 902 1191.



Ceka Driver

AS an extension to its ranges of screwdrivers for the electronic, radio and tv industries, CeKa Works has introduced a new selection of small 'Micro' Screwdrivers for the most delicate tasks.

With self centering 'button' heads and ribbed turning grooves moulded into the handles, the drivers measure just 85mm from button to tip and are available in versions to suit slotted, recessed or 'Trox' screws: each type is clearly identified by its button colour and sizes are printed onto the handles.

Tip sizes of the four slotted drivers range from the minute 0.8mm to 1.8 mm, the recessed tools are sizes 000, 00 and 0, while 'Torx' drivers are in four sizes from 06 to 09.

Contact: Ceka Works Ltd, Pwllheli, Gwynedd, North Wales, LL53 5LH. Tel: 0758 612254.

Screen Printer

NEW from Electronic Brokers is a particularly handy and compact thermal video printer that can be used to record directly from any crt screen.

The Thander TP-35 is capable of printing a hard copy of any crt image – eg, from a computer, oscilloscope, spectrum or logic analyser. It operates very quickly; records are produced in only 16.7 seconds for a standard screen. It is fully compatible with most computer and measuring systems and, furthermore, there is no warm up time prior to use.

The printer has input terminals for composite video signals, separate video signals and composite synchronised signals. It can also be connected directly to any computer; no separate interface is required.

There is a choice of high or low resolution printing. Horizontal printing pitches are 6 dots/mm or 3 dots/mm, are switch selectable, and there is a user choice of positive or negative copies.

The TP-35 operates virtually silently, and also features simplified construction and built-in testing to assure reliability and peak performance for years of maintenance-free operation.

Contact: Electronic Brokers Limited, 140-146 Camden Street, London NW1 9PB. Tel: 01-267 7070.

THE LEADING EDGE

BY BARRY FOX

THE WIRES WON'T TELL

A new report says that all our information and entertainment could be piped to us through broadband optical cables by the year 2010. It could happen, but will it? IT can reveal anything — except the future.

Barry Fox has won a UK Technology Press Award – see page 5.

Soon after writing a feature for this magazine on the future of optical fibre wideband systems, I got a look at a new report prepared for the government.

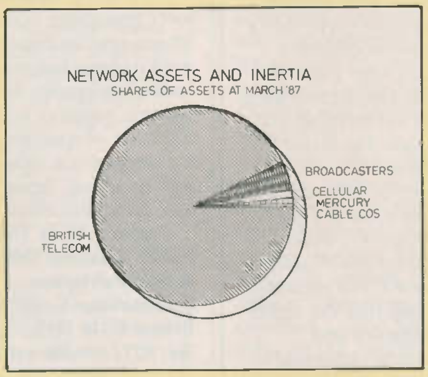
The department of Trade and Industry had commissioned the PA Consulting Group to research the 'Evolution of the United Kingdom Communications Infrastructure'. This followed a recommendation made in the Peacock Committee report on financing the BBC, published in July 1986. Peacock had said that BT and Mercury should be allowed to act as common carriers, and bring television programmes into the home as well as providing a telephone service. The DTI thought the government should know what the future looked like. Now PA has told them.

In a nutshell, no-one knows how Britain's telecommunications infrastructure will look in 2010! PA can only say it all depends on the people who commissioned the study, the Department of Trade and Industry. As it's an interim report, intended as a discussion document, the DTI still has time to shape the future. But don't bank on it.

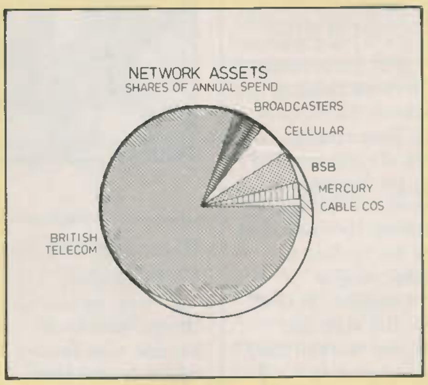
People in the Information Technology business have short memories. Kenneth Baker, who started the IT ball rolling and breathed fire into the DTI, has been through several different jobs since then. I fear there are people in the DTI now who would have difficulty remembering what the IT initials stand for. I doubt many of them recognise that the PA paper echoes forgotten recommendations made in 1982 to Prime Minister Margaret Thatcher and her Cabinet by another research group, the Information Technology Advisory Panel.

ITAP envisaged a wired society with an infrastructure of optical fibre cables carrying not just entertainment but interactive information technology and telecommunication services run by British Telecom and rivals. ITAP's plan fell flat when the firms licensed to provide new cable systems in Britain learned that the Government would not provide money, and investors saw the project as too risky. ITAP sank without trace, along with Kenneth Baker's plans for wiring up Britain.

According to PA the year 2010 *could* see 80% of homes and 95% of business sites connected to a high technology national telecommunications grid of wide band optical fibre links. On the other hand only one in ten homes may be connected to a low tech cable network.



Key player share of network assets (100% = £16,250M)



Annual investments in infrastructor (100% = £1,750M pa)

Six years after ITAP, the PA report is sure of only one thing; although fibre optic cable is already used in telephone trunk lines it will be 15 years before the hardware is cheap enough to run direct into British homes. After that, there will be a move towards optical fibre, and fixed links will replace radio and satellite transmission for everything except broadcast and mobile communications.

"The differences between scenarios are in the pace of this change, not in its direction", says PA.

Today's telecoms infrastructure is valued at £16.25 billion, of which BT's share is over 90%.

The Government, says PA, will be the most important player influencing the changing size of this share. Annual investment now runs at £1.75 billion with around 20% coming from Mercury, the broadcasters, cellular radio operators and cable tv companies.

"I feel sorry for people who retired from telecoms 5 years ago," Colin Davis, boss of the booming Cellnet cellular radio service, told me recently. "They missed out on all this".

PA comes up with a string of possible future scenarios. If competition is lightly regulated, and BT and Mercury continue to be precluded from carrying entertainment channels on their telephone network, and if local cable tv companies are allowed to carry telephony, there will be no incentive for BT to rip out existing copper cables and replace them with optical fibre. So only around 2 million homes will get even simple broadband links.

If the Government adopts a hands-off approach, and lets BT and Mercury carry entertainment tv by telephone wire, they could run optical fibres into seven million homes and half British businesses. This policy would be irreversible because of the high price of compensation.

If the government intervenes and helps wire Britain with a national IT grid, up to 16 million homes could be plugged into broad band fibre by 2010. This would make Peacock's dream come true, with widespread electronic publishing and very many people and organisations able to originate video material for wide distribution.

One way to achieve a grid, says PA, would be to compel BT to share its existing underground cable ducts with local franchises. If there is one thing in the telecoms industry you can be sure of for the future, it is that BT will fight this proposal tooth and nail. PE

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SPANNING HIGH TECH NOTES

In recent issues the Prof has demystifed some of the facts about MIDI. Those articles concerned the theory and simple practice behind a universal interface standard of multiple control for electronic musical instruments. In future issues, we shall be showing further practical ways in which this theory can be applied.

Music and effects control is a subject close to my own heart, and I know how important MIDI is for the modern musician. The Prof has written several books on the subject, one of which, 'Midi Projects', is available through the PE book service. It makes interesting reading.

High tech music interfaces are of considerable value for those who have the equipment and desire to use them. Instrument prices are really quite moderate considering the technology inside them, and you need not spend a fortune to equip yourself with one suited to MIDI control. If you build the interface yourself from a published project, it could cost even less.

However, despite the availability of high tech music making, it should not be forgotten that everyone does not necessarily want high tech facilities. There are many instrument players who are quite happy with their solo guitar or simple electronic organ, playing it purely for their own pleasure. Additionally, there are those who may belong to a small group for whom mobility is as important as technology. Let's face it, a lot of performers have only a rusty old low tech banger in which to stow their gear, and do not have space for sophisticated synths, samplers, mixers, equalisers and so on, as well as for guitars and a drum kit. All they have room left for is an effects box or two that can be slung in the boot somewhere.

From the letters received I know that the needs of these players are just as important as those who are high up the scale. The interest created by the Bright Fuzz in the May issue, as well as by some of my own simple effects designs published at various times, confirms my opinion.

Boxes that produce fuzz, phasing, flanging, tremolo, echo and chorus are frequently the only additional effects that many performers need. I see further truth of this when I travel on the London Underground to the PE editorial offices. Around the corridors and escalators of the central London stations there are solo musicians, playing everything from guitars, flutes, saxophones and synths, to harps! Many of them use electronically coupled small effects boxes, all only of the type just mentioned. I'm not suggesting you join them (though I think some are students from music colleges), but the sounds they produce with their equipment are well worth imitating.

With this is mind, I am pleased to publish another simple musical effects project as a contrast to higher tech MIDI units. I make no apology for its function being nothing new. I have designed several tremolos across the years, and this is simply a fresh approach using a different technique. It should fit in the boot nicely.

THE EDITOR

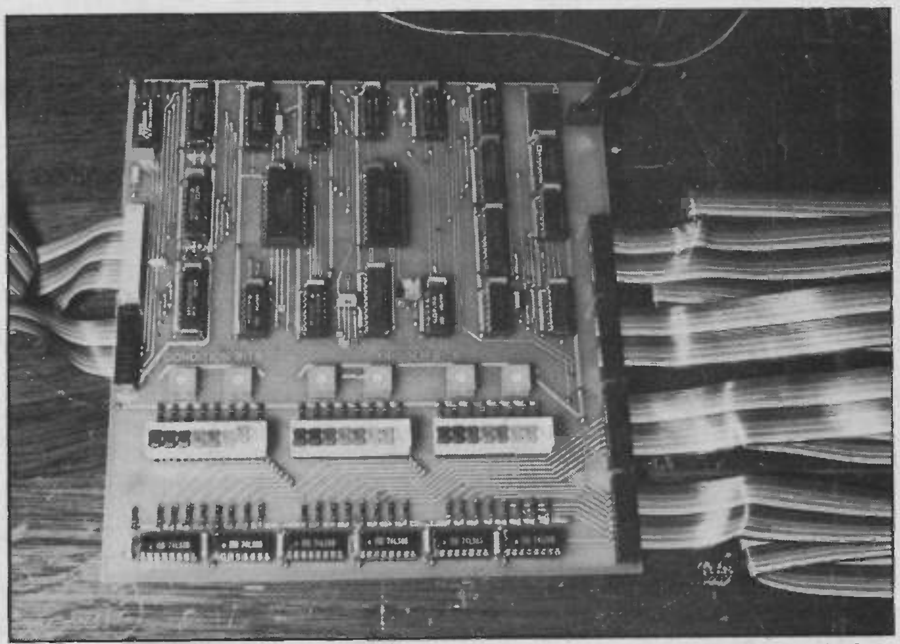
OUR MARCH 1988 ISSUE WILL BE ON SALE FRIDAY, FEBRUARY 5th 1988 **(see page 2)**

LOGIC ANALYSER

PART ONE BY MICHAEL SWEET

SAMPLE AND UNFOLD

This board is for use with the BBC microcomputer, and enables target systems to be analysed at full operating speed with logic level, cycle-by-cycle or disassembled displays.



THE Logic Analyser collects signals along eight data lines, sampling at regular very short intervals. The signals collected are ttl logic level voltages and are interpreted as 0 or 1 in the usual way. The user attaches probes to test points which he has chosen on the target system, these collect the test signals (data). The target system is the system whose operation the logic analyser is being used to test, and any number of test points up to the maximum of eight may be investigated simultaneously.

The sampling frequency may be chosen between 1MHz and 16MHz. The input data is stored in the on-board ram and is subsequently transferred to the ram of the host microcomputer, the BBC-B. The data extends to 2048 bytes and since this represents a short time interval at any of the sampling frequencies it is normally necessary to define when the sample should be taken in order to obtain useful information; a random sample covering a few microseconds is unlikely to reveal anything of interest. This definition is achieved by setting some or all of the 24 triggers and condition bits available on the analyser. Again the probes by which these signals are relayed to the logic analyser may be attached at chosen points on the target system. The logic analyser will "trigger" or collect the data sample only when *all* the trigger and condition bits correspond to the chosen settings. The data storage may be chosen by the user to be after the occurrence of the trigger condition (POST) or up to this event (PRE); this choice is by a prompted keyboard entry. Skilful selection of trigger conditions is important in obtaining useful results with this, and with any, logic analyser.

The collected information is processed by the BBC-B and the user has a wide choice of how the data is presented, again by prompted keyboard entry. The following article describes these options and also gives some examples of the use of the trigger and condition bits. The logic analyser is useful in achieving an understanding of the operation of a perfectly working target system as well as enabling both hardware and software errors in a faulty system to be pinpointed. The user-friendly software available for this device ensures an ease of operation unusual in logic analysers.

OUTLINE OF OPERATION

Essentially the device clocks data into on-board ram at a user chosen frequency between 1 and 16MHz. Data collection is started (or terminated) by the occurrence of a preset trigger condition depending on whether the user has chosen post (or pre) trigger mode. The source of the data and trigger signals is normally a microprocessor based system which is under investigation, henceforth referred to as the target system. Subsequently the contents of the on-board ram are downloaded to the BBC ram where it is then treated to create data in various useful forms which are discussed later: these may be used to fully explore the way in which the system under investigation has behaved at its operating frequency. The most powerful of the options is a disassembled listing of the steps taken during the full speed operation of the target system. Software is provided to allow signature analysis of each of the 8-bits comprising each data word.

The risk of spurious data occurring in the BBC ram is minimised by the buffering of all signals between the board and the BBC, the buffers being a high impedance state for all but the few microseconds necessary to transfer data following a data collection cycle.

While a Z80 version is available the 6502 version is the most advanced and reference to this is most often made.

The specifications are as follows:

SIGNAL INPUTS FROM SYSTEM UNDER INVESTIGATION

24 trigger inputs. Each has a *don't care* option.
1 synch pulse. The synch line *must* be connected to the 6502 pin 7.
1 clock qualifier.
8 bit data word input.

Each of the above is via buffered inputs.

SIGNAL INPUTS/OUTPUTS TO BBC MICROCOMPUTER

Buffered address and data lines to allow transfer of data from ram on the logic analyser board to BBC internal ram together with control signals. All via a rom socket connector.

Eight outputs and one input acting as control signals to ensure proper operation. All via a user port connection.

Michael Sweet is the Senior Lecturer in physics at Robert Gordon's Institute of Technology, Aberdeen.

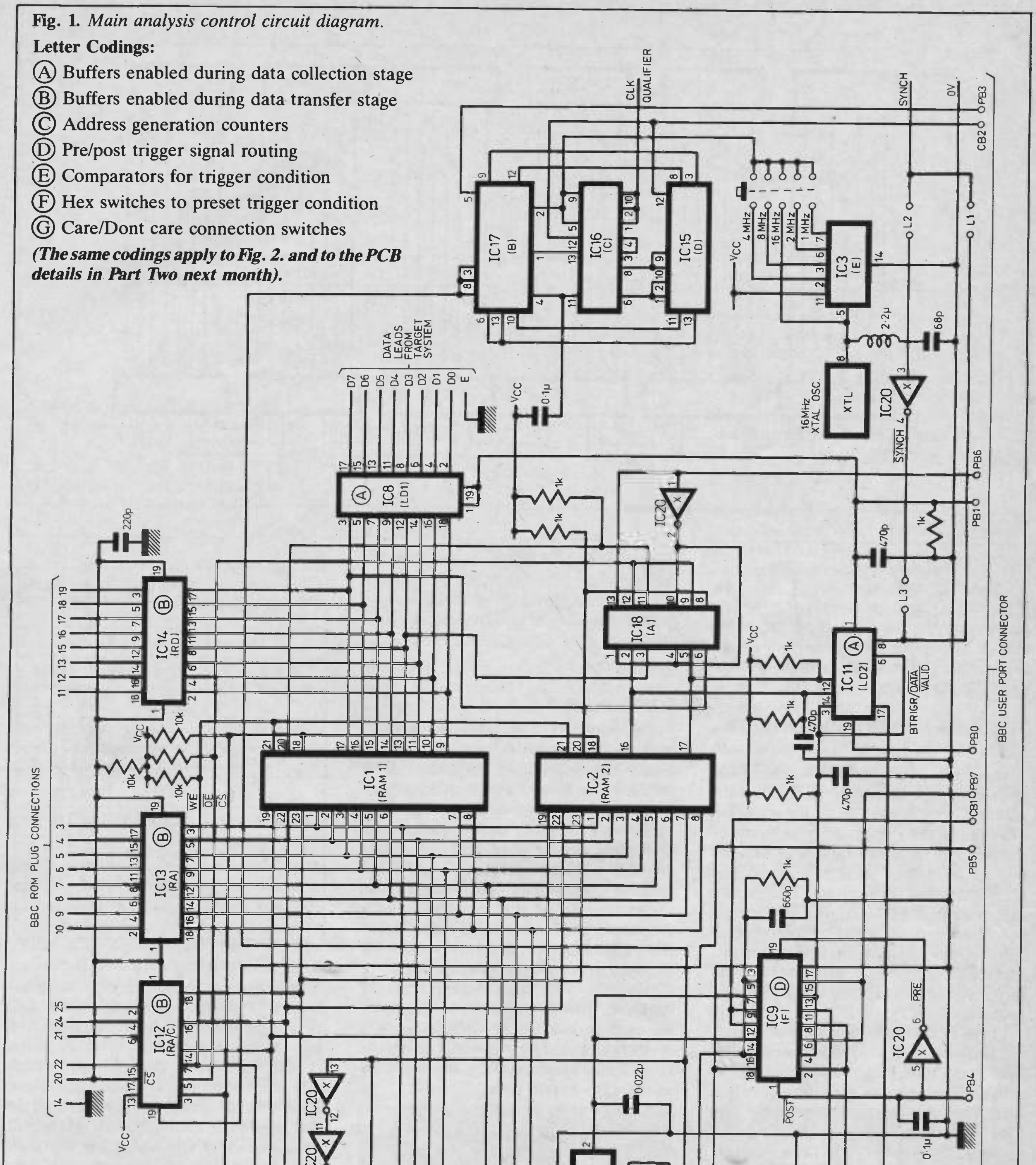


Fig. 1. *Main analysis control circuit diagram.*

Letter Codings:

- (A) Buffers enabled during data collection stage
- (B) Buffers enabled during data transfer stage
- (C) Address generation counters
- (D) Pre/post trigger signal routing
- (E) Comparators for trigger condition
- (F) Hex switches to preset trigger condition
- (G) Care/Dont care connection switches

(The same codings apply to Fig. 2. and to the PCB details in Part Two next month).

See also Table 1.

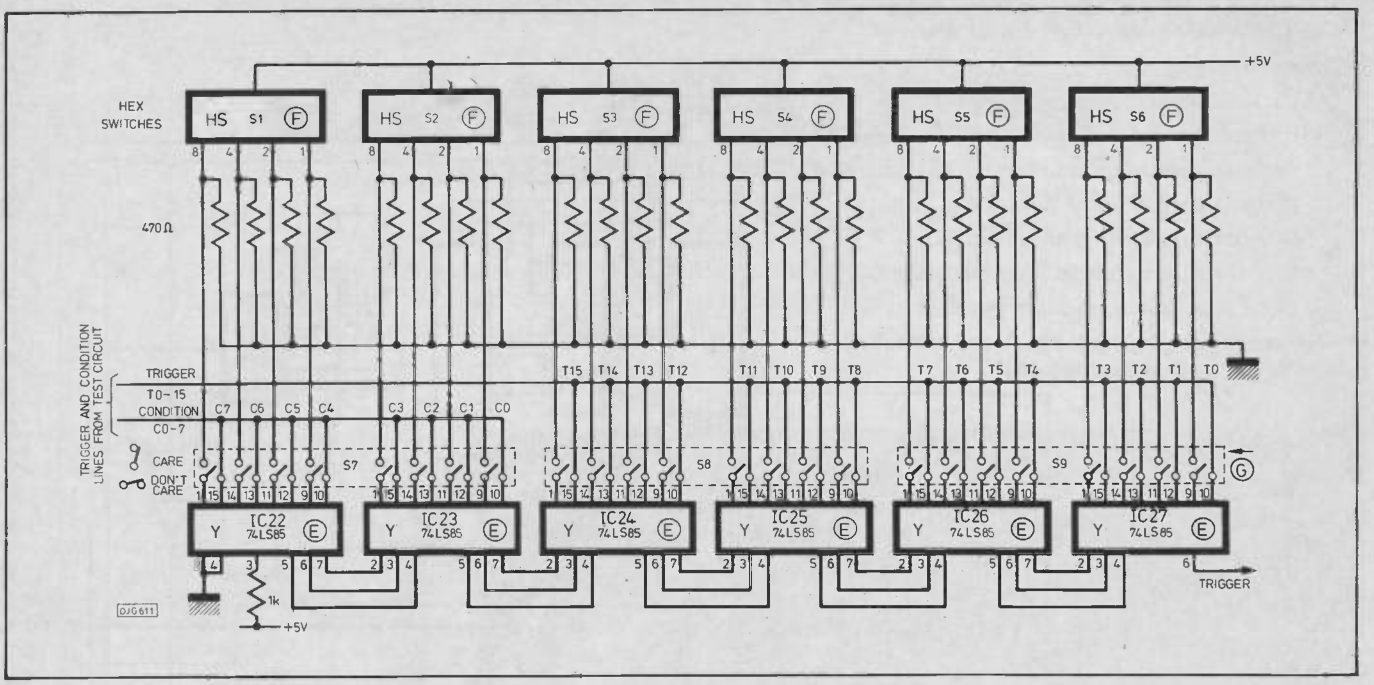


Fig. 2. *Trigger selection circuitry.*

ON-BOARD CLOCK

Choice of frequency 16, 8, 4, 2, 1 MHz. This range is very suitable for processors in the frequency range 1–4MHz. The lower frequency limit could be extended at modest extra cost. (For example, by an extra counter.)

TRIGGER CONDITION/STORAGE MEMORY

There are 24 trigger inputs, each with optional don't care setting. The recommended use is for 16 of these to be attached to the system address bus with the other 8 for other signals as desired but all 24 may be used in any way the user considers appropriate. The inputs are described as 16 trigger bits and 8 condition bits. For the recommended connections a plug-in connector to replace the 6502 microprocessor on the target system is available, which reduces problems with multiple leads.

There is also an 8 bit data word input normally connected to the data bus lines. This is the data which will be stored as 2048 × 8 bit words. Bits from the data word may also be used as trigger condition bits by connecting them in parallel to trigger inputs. This combination allows a wide range of data and trigger options and includes storage of 8 bit data on a 16 bit address trigger condition, which is a powerful option. The full 2048 × 8 bit storage may be chosen to be pre- or post-trigger condition.

DISPLAYS

Data as acquired, cycle by cycle data, disassembled code* or opcode only data* may be displayed on the BBC monitor a page at a time or sent to a printer. Alternatively the 2048 words of as acquired data may be displayed in logic level format 32 words at a time on the screen. Disassembled code with absolute address may be displayed or printed, as may also signature analysis data.

SOFTWARE

The supporting software is in BBC Basic with a judicious mix of assembly code for operations requiring high speed. The software is such that the user is taken step by step through the necessary choices and while the operating instructions and hardware/software details presented in later sections may help and extend the understanding of the instrument only Appendix 1 is *essential* and only then in the event that the interrupt vectors of the systems are unknown and accurate disassembly through interrupts is required. In this event the device may be used to find these vectors using a method detailed in Appendix 1; this is specifically referenced by the software at the appropriate point.

DISASSEMBLY/OPCODE LISTINGS OF DYNAMICALLY ACQUIRED DATA

The actual program as executed by the target system may be presented on screen or printer in disassembled form*. This allows a full check so that deviations from expected operation may be diagnosed. This is equivalent to a full processor speed single stepping facility but is more powerful as it is more efficient to operate and allows access to interrupt handling routines, a feature absent from manual single stepping. The full facility is available for the 6502 processor only at present but the software may be extended to include others. Available for all processors is the cycle by cycle listing which gives the data bus contents at each successive cpu clock cycle and enables the operator to follow the instruction sequence cycle by cycle.

These features make the device rather more oriented to the software engineer than most logic analysers and aims to bridge the gap between hardware and software personnel while remaining a powerful hardware tool. The features described also make it a powerful aid in the teaching of microprocessor principles.

***for 6502 and Z80 microprocessors only at present. Also for these facilities the 8 data inputs MUST be connected properly to the system data bus. A screen warning to this effect is given at the appropriate stage.**

Table 1

Labels	Types	V_{cc} pin	V_{ss} pin
RAC, RA, RD, F	74 LS 244	20	10
LD1, LD2, LA, LC	74 LS 244	20	10
E, L, M, H	72 LS 193	16	8
A, B	74 LS 125	14	7
C, D	74 LS 00	14	7
G	74 LS 27	14	7
X	74 LS 04	14	7
RAM1, RAM2	6116 P-2 or 3	28	14
Q	Newport 8450		1,14
Y	74 LS 85	16	8

V_{cc} & V_{ss} connections not shown, also each package has 0.1μF decoupling capacitors not shown

COMPONENTS

RESISTORS

R1–R4	10k (4 off)
R5–R12	1k (8 off)
R13–R36	470 (24 off)

All resistors ½W 2% metal oxide

CAPACITORS

C1	660pF polystyrene
C2–C4	470pF polystyrene (3 off)
C5	220pF polystyrene
C6	100pF polystyrene
C7	68pF polystyrene
C8	220nF miniature layer
C9–C36	110nF miniature laye (27 off)
C37	3.9nF ceramic

SEMICONDUCTORS

IC1,IC2	6116, 150ns or faster (2 off)
IC3–IC6	74LS193 (4 off)
IC7–IC14	74LS244 (8 off)
IC15,IC16	74LS00 (2 off)
IC17,IC18	74LS125A (2 off)
IC19	74LS27
IC20	74LS04
IC21	8450 Newport
IC22–IC27	74LS85 (6 off)

CONNECTORS

SK1–SK5	20 way DIL plugs, IDC (5 off)
SK6	26 way DIL plug, IDC
SK7	4 pin PCB header and 4 socket housing IOC or crimp tag type
SK8–SK12	20 way bump polarised IDC sockets (5 off)
SK13	28 pin DIL header plug, IDC crimp type

SWITCHES

Sw1-S6	hex encoded rotary switches (6 off)
Sw7–S9	SPDTERG spectra edge series changeover switches (ERG No. SDEC 8-013)

IC SOCKETS

24 pin	(2 off)
20 pin	(8 off)
16 pin	(10 off)
14 pin	(7 off)

Socket strip 16 pins SIL (6 off)

A 5V dc power supply is also required, capable of delivering 750 mA or more.

MISCELLANEOUS

Ribbon Cable	26 way, 0.7m 20 way, 0.7m 20 way, 0.2m (4 off)
Crystal oscillator	16 MHz, 4 pin package
RFinductor	2.2nH
Jumper pins	8 pairs of pin strip headers
Jumper sockets	(3 off)

PCP linking pins (if board used not through-hole plated)
Printed circuit board
Stick on rubber feet (4 off)
Logic grabber set (e.g. RS 611–313) at least 2, up to 4
PCB headers (e.g. RS 467-582) at least 2, up to 4
(The last two items are to enable attachment to system test points.)

The printed circuit board is available through the PE PCB Service.

Software and further details about the Logic Analyser are available direct from the author: Dr M.A.S. Sweet, Robert Gordon's Institute ofTechnology, School of Physics, St Andrew Street, Aberdeen, AB1 1HG. Tel: 0224 633611 Ext 443.

Finally it should be emphasised that the software may readily be user-extended to include features not presently included; the model provided by the existing software should aid this task in many instances.

CONSTRUCTION

For constructors making their own printed circuit board the minimum size is 207mm × 195mm, and the board is double sided. Boards which are not through hole plated require 0.8mm drilled holes for link pins, the locations for these are clearly shown on the component layout diagram. The 0.84mm link pins are forced in from the top side and soldered on both sides.

The next stage is to add all components which require top-side soldering, using (and identified by) the remaining solder pads on the top side of the board. Flux residue should then be removed from the top side, and constructors using in-house boards are advised to lacquer this side at this stage.

The remaining components, ic sockets and jumper pins should then be soldered in leaving connectors 1 to 6 till last. Sockets should NOT be used for the hex-switches as their pins are too fragile for forceful insertion, these should be soldered directly to the board. Connectors 1 to 6 are attached to appropriate (see components list) lengths of ribbon cable before soldering. The use of the recommended cable and connector types is strongly advised to minimise contact fault problems, even with these items and with care in assembly and use contact faults remain one of the most common error sources. Pins 1 and 28 are not used on the BBC-B rom socket, it is recommended that 26 way ribbon cable is used positioned so as to exclude these pins when squeezing together the dil header plug connector. Finally the 3.9nF ceramic capacitor should be soldered to the solder pads of pins 13 and 14 of IC21 on the underside of the board, and this side lacquered if appropriate.

Before using the logic analyser the links must be made; L1 and L2 if a 6502 microprocessor is on the target system or L3 if a Z80 or for general purpose working. The sample frequency selection is made by completing L4 (4 MHz), L5 (8 MHz) L6 (16 MHz), L7 (2 MHz) or L8 (1 MHz).

Connections to be made are:

SK13 to any rom socket in the BBC-B, ensure correct polarity.

SK12 to the BBC-B user port connector.

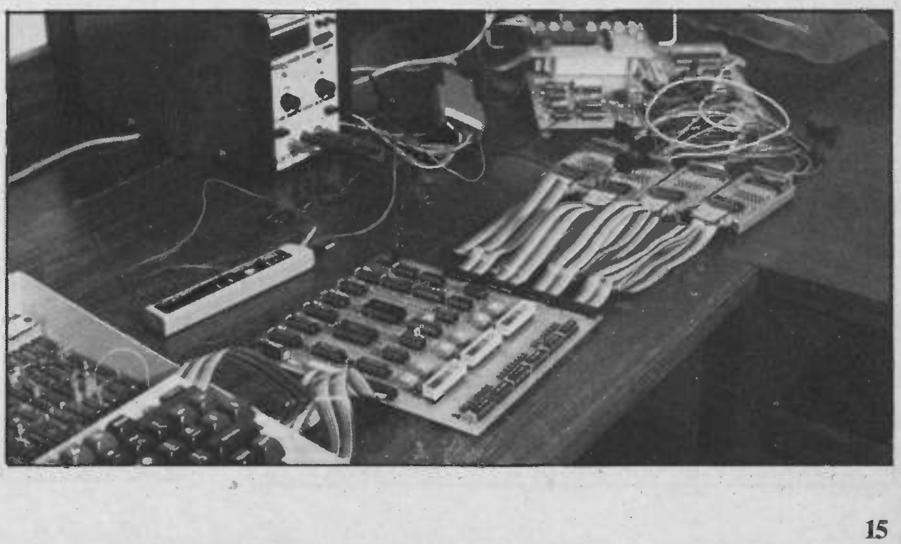
SK8 via a PCB 10-way header and logic grabber set to target system test points.

SK7 to the 5V dc power supply. ENSURE correct polarity. It is a good idea to remove one of the four pins in the header and to block off the corresponding socket hole to avoid careless polarity reversal.

SK11, and SK10/SK9 as required, via 10-way pcb headers and logic grabber sets to target system trigger/condition points.

The signal identification markings on the pcb overlay should assist in avoiding connection errors. PE

To be concluded next month.



REAL WORLD INTERFACING

PART ONE BY ROBERT PENFOLD

ANALOGUE INTO DIGITAL AND BACK AGAIN

A digital circuit cannot handle the infinite range of signal variations possible to an analogue circuit. The real world is analogue. This article looks at ways of bridging the gap.

Few people would doubt the advantages of digital electronics in many applications, and logic circuits are now commonplace in audio systems, cars, video equipment, etc. With much digital equipment there is a major obstacle that has to be overcome before the advantages can be exploited. This is simply that in the real world there are few things that are truly digital in nature. Most entities that are measurable or controllable can be interfaced to analogue circuits with little difficulty. In the field of audio for example, a microphone provides an output that can be directly fed to analogue circuits, and a loudspeaker can be directly driven from analogue devices. As far as I know there is no microphone that provides a digitised output, and no genuine digital loudspeaker!

Digital audio circuits work with conventional transducers, but only via special interfaces. Apart from simple on/off switching of motors, bulbs and the like, this technique of conventional analogue transducers plus an interface of some kind is the standard approach to real world interfacing. Even with something as simple as switching a light bulb or an audio signal on and off, the direct output from a digital circuit will not usually be able to fulfil the task without a little assistance.

In this two part article we will consider various types of digital interfacing, including such things as power and audio control, and measuring methods. The information has been deliberately made as general as possible, and circuits that will interface to a specific computer are not provided. It is assumed that the reader has some background knowledge of general interfacing techniques, and that he or she can get digital information into and out of their computer. It is the electronics that fits onto the parallel input/output port that we will be concerned with here. The purpose of this article is to provide a range of practical circuits rather than to delve deeply into the theoretical side of things. It is not possible to give a complete course in interfacing in two articles, but a wide range of circuits will be provided.

Photo: *Flight Electronics FLT 68K microprocessor trainer linked to a BBC computer.*

It is worth noting that digital interfacing does not necessarily mean using a microprocessor based system. There are a great many applications where digital electronics can be used to good effect, but where there would be considerable over-kill in using a microprocessor system. The circuits provided here should work perfectly well with simple digital systems.

D/A CONVERSION

In this first article we will consider a number of control circuits. Only low power circuits will be considered here, but the related subjects of power control and measurement will be covered in some detail in part 2. Some low power control applications require nothing more than on/off switching, and quite often the direct output from a latching output port will then surface. At most a simple driver or level shifter circuit will be required.

Most applications require some form of digital to analogue conversion so that precise control can be obtained. There are several types of digital to analogue converter, and in some applications a simple type based on an operational amplifier summing mode circuit might suffice. Simple digital to analogue converters can also be based on multi-way cmos analogue switches. However, the cost of high quality dac chips is reasonably low these days, and these usually offer a cost effective solution even if they are slightly over-specified for a given application.

Although they do not have "industry standard" status, the Ferranti dac and adc chips are much used, and are the most convenient devices of this type I have yet encountered. The dac converters are of the "R-2R" type, and this name refers to the resistor network on which they are based. Fig.1 shows the basic set up used, and the switches are, of course, electronic types which are operated by the eight bit parallel input. In theory the values used for the resistors is unimportant, provided all the "R" types are the same value, and the "2R" types are twice this value. In practice the values used must be low enough to give a reasonably low output impedance, but not so low as to heavily load the voltage reference. In the Ferranti chips the resistors have values of 10k and 20k.

For anyone familiar with Kirchoff's Voltage Law it should be apparent that this circuit will have roughly the desired

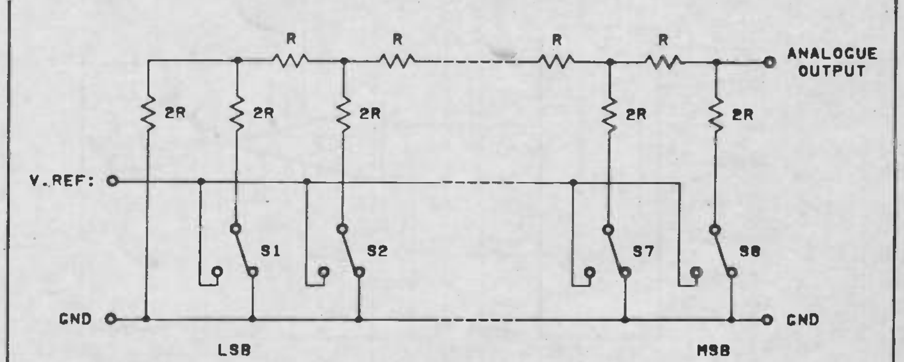


Fig. 1. *The basic arrangement used in R/2R D to A converter.*

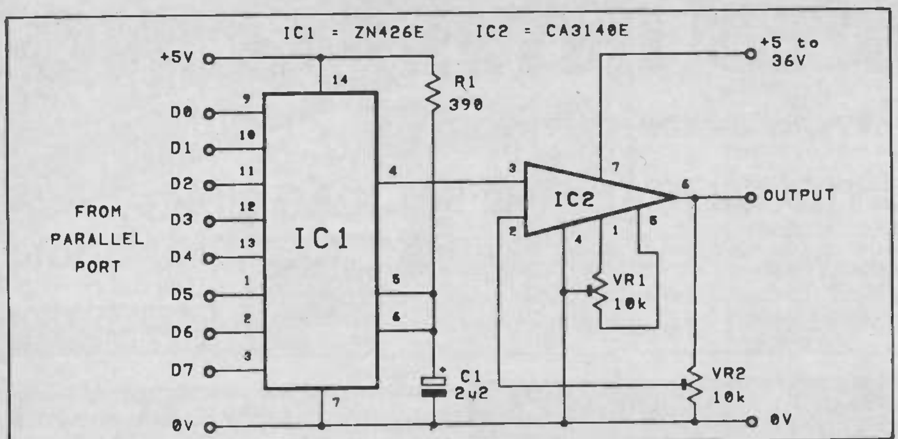


Fig. 2. *A simple D/A converter based on the ZN426E. This circuit must be driven from a latching parallel port.*

effect, with the msb switch producing a large increase in the output potential when it is set to the left hand position, and the switches controlled by the less significant bits having progressively less effect. Working out a few examples with two or three bit network will soon show that it has precisely the desired effect, with an output voltage that is proportional to the binary input value. The Ferranti digital to analogue converters have a built-in 2.55 volt reference source. They are 8 bit types which consequently have an input value range of 0 to 255 (decimal), or a convenient 10 millivolts (0.01 volts) per digit output voltage. A value of (say) 126 would therefore give an output voltage of 1.26 volts.

Two main dac converters in the Ferranti range are the ZN426E and the ZN428E. These would appear to be essentially the same device, but the former requires latched inputs whereas the latter can interface direct to the data bus of most microprocessors. Basic circuits for these two devices are shown in Figs.2 and 3 respectively.

Taking Fig.2 first, the 8 bit input can be driven from standard ttl logic outputs, as well as 5 volts mos and cmos outputs. The built-in voltage reference source requires discrete load resistor R1 and decoupling capacitor C1. The output will normally require buffering and amplification, and this is provided by IC2. VR1 is an offset null control which is used to optimise accuracy at low output voltages, and VR2 controls the closed loop voltage gain of IC2. With all the inputs set high VR2 is adjusted for the required full scale output voltage. The input value is then made much lower (around 5) and VR1 is adjusted for the correct output voltage. This procedure is repeated a few times until the output voltage tracks accurately over the full output range. The maximum output voltage can be anything from 2.55 volts to about 34 volts, but note that the supply voltage for IC2 must be at least 2 volts more than the required maximum output voltage.

Turning to Fig.3, the converter circuit is much the same as the one described previously, but there is an extra input ("LATCH"). This input would normally be fed from the output of an address decoder circuit. It must be high under quiescent conditions, and pulsed low when data is written to the converter. The data is latched into the device as this input returns to the high state. The ZN428E is effectively a ZN426E with an 8 bit transparent latch added at the input. The only other significant difference between the two devices is that the ZN428E has separate digital ground (pin 9) and analogue ground (pin 8) terminals. The device will operate properly with a voltage difference of up to 200 millivolts of either polarity between these two pins, but in practice they are almost invariably wired together.

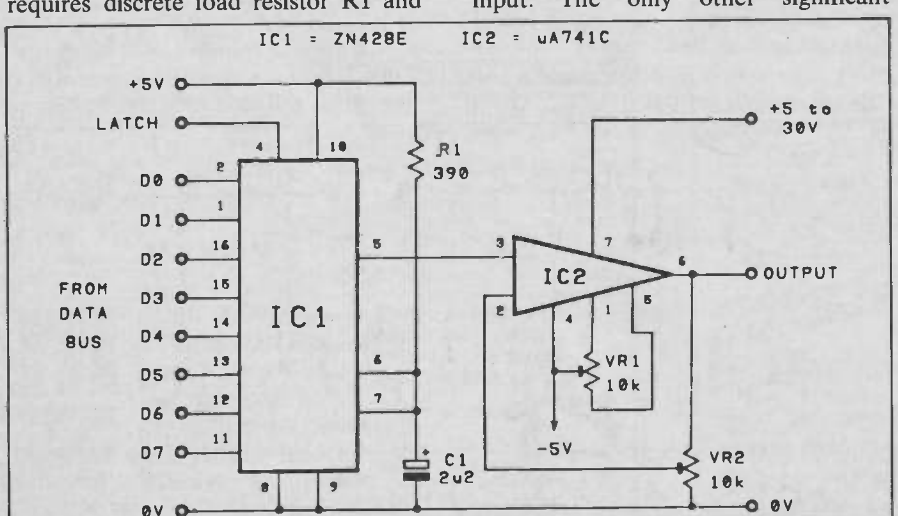


Fig. 3. *A basic D/A converter using the ZN428E.*

The circuit of Fig.3 shows a different output stage. This differs from the one featured in Fig.2 in that it uses a standard μA741C operational amplifier rather than the more expensive CA3140E. It requires a –5 volt supply though, and as the total supply voltage to the device must not exceed 36 volts, this reduces the maximum possible output voltage by 5 volts. The output stage of Fig.3 generally offers slightly better accuracy at low output voltages, and is the better choice in critical applications.

Both converter chips offer a maximum error of 0.5 lsb, or 5 millivolts in other words. The output of a dac converter does not switch instantly from one voltage level to another, and the time taken for the switch over is called the "settling time". For these converter chip it is 1μs for a 1 lsb change, or 2μs for a change from maximum to minimum (or vice versa). This is more than fast enough for most applications, including the more demanding ones such as audio waveform synthesis.

Some applications require lowpass filtering at the output in order to remove slight glitches that are often produced as the output moves from one value to the next. In audio waveform synthesis a lowpass filter is needed anyway, in order to remove the high frequency components generated by the almost instant switching from one level to another. Fig. 4 shows the circuit for a dac converter plus third order (18dB per octave) output filter. The filter has a cutoff frequency of about 10kHz, which is well suited to waveform synthesis. The cutoff frequency is easily changed though, and is just a matter of changing the values of the filter capacitors (C2 to C4). The relationship between the values of these capacitors must not alter significantly (eg C4 must be kept ten times higher in value than C2), and the values of all three must therefore be changed. Alterations in the values produce an inversely proportional change in the cutoff frequency.

With an output that shifts in 10 millivolts increments it is obviously not possible to produce highly accurate sinewave signals, or other waveforms which are of a non-stepped nature. This is a fundamental difference between digital and analogue circuits that must always be kept in mind. A digital circuit can not handle the infinite range of voltages possible with analogue circuits, but in practical applications there is a certain level of resolution that will give acceptable results. Sometimes 8 bit

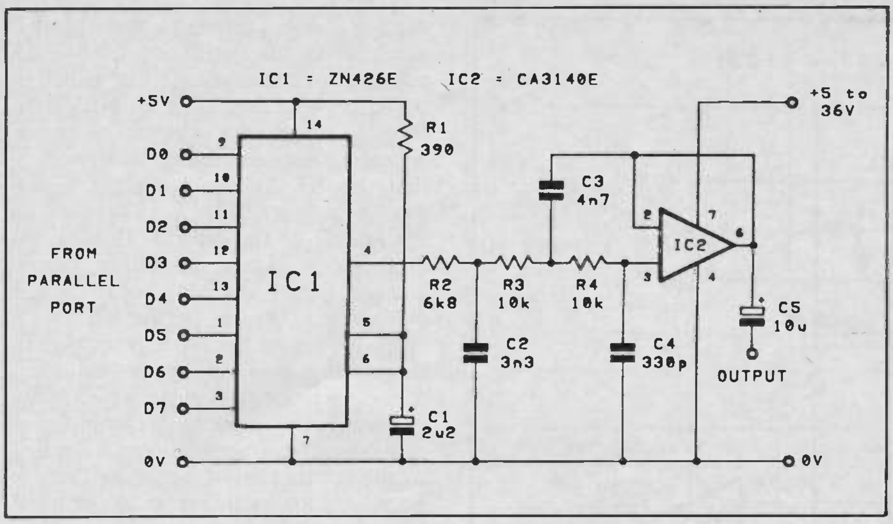


Fig. 4. *A D/A converter for audio synthesis.*

resolution is more than adequate, but on other occasions it is less than ideal.

For audio synthesis there is a definite advantage to 12 or even 16 bit resolution. However, 12 and 16 bit converters of adequate speed are quite expensive, and their extra performance can only be realised in practice if the hardware driving the converter is of adequate speed and sophistication. The distortion level obtained with 8 bit resolution is under 0.5%, but this assumes that the waveform uses the full 0 to 255 value range. It is therefore important to make sure that waveforms are synthesised using the widest possible range of values. More information about the theory of digital audio can be found in the "Signal Processing" article in August 1987 issue of PE.

MAKING THE SWITCH

Digital audio control can range from simple on/off switching through to precise level control and filtering. Taking on/off switching first, a low-tech but effective method is to use a relay, and a high speed reed type would be the normal choice for this type of application. This may seem like a rather old fashioned way of doing things, but there are a couple of advantages. The first of these is the total isolation between the relay contacts and the digital controller. The contacts can therefore be placed at any desired position in the audio circuit. The second advantage is a total lack of distortion through the contacts (or in deference to Graham Nalty, (PE Aug-Sept 87), perhaps that should be 'almost a total lack of distortion').

If a more modern approach is preferred, there are a number of semiconductor switching devices that can be used, including various types of transistor and numerous integrated circuit analogue switches. There are some quite expensive analogue switch integrated circuits available, but these are not particularly popular as there are much cheaper devices which seem to be capable of achieving a similar level of performance if used in the right way. In particular, the cmos analogue switches such as the 4016BE quad spst type are available for a matter of pence each, and can work very well.

The action of the 4016BE is for a switch to close if its control input is taken to logic 1, or to open if it is taken to logic 0. However, the switch can not be used quite as freely and easily as the contacts of a reed relay. The switch should only be used at signal voltages which do not stray significantly outside the supply rail potentials, and it should be borne in mind that the "on" and "off" resistance are not zero and infinite respectively. The "off" resistance is actually extremely high at hundreds of megohms or more, and the "on" resistance is generally quite low at between about 50 and 250 ohms.

Switching circuits based on these devices should take into account the fact that stray coupling around a switch can easily reduce the effective "off" resistance, and that the "on" resistance varies somewhat with the applied signal voltage. This second factor means that small but significant distortion levels can be generated, and that the signal voltage across the switch must be as low as possible in order to optimise performance. With any electronic audio switching circuit there is a strong danger of severe switching "clicks" being generated unless due care is taken with the circuit design.

Fig.5 shows a simple but effective method of using two cmos analogue switches plus an operational amplifier to provide low distortion, low breakthrough, and virtually "clickless" switching. IC2a is the main switch, and this is connected in the signal path. IC3 acts as a high input impedance buffer amplifier, so that when IC2a is turned on, the voltage drop through its series resistance is negligible. This ensures that it can introduce only minute amounts of distortion.

A drawback of IC3's high input impedance is that it encourages stray coupling through IC2a when it is switched to the off state. To ensure that no significant breakthrough can occur, IC2b is used to reduce the input impedance of the circuit to only about 100 ohms when the circuit is in the off state. This gives the circuit a massive amount of attentuation over the full audio bandwidth when set to the off state.

The two switches must be operated in anti-phase, and so IC2a is controlled via an inverter (IC1). The signal is allowed to pass when the control input is low, and blocked when it is high. Control IC2a direct and IC2b via the inverter if the opposite action is required.

Many applications for this type of circuit require a multi-way audio selector rather than a single on/off switch. Ideally multi-way switching would be achieved having several circuits of the type shown in Fig.5, with the outputs fed to a conventional audio mixer circuit. The desired channel or channels are then selected by taking the appropriate control input or inputs low.

This method provides excellent performance, but is probably too costly and complex to be practical in some applications. A low cost alternative is to use a multi-way cmos analogue switch, as shown in the 8 way selector circuit of

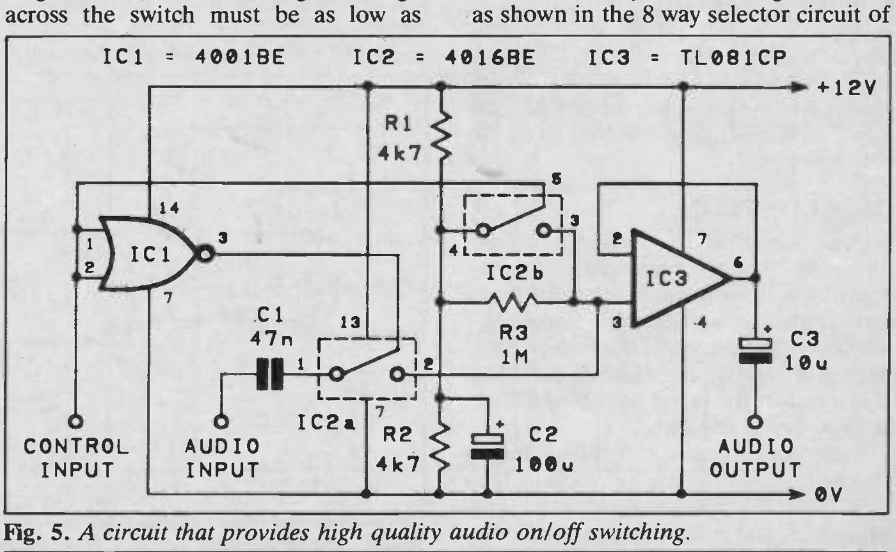


Fig. 5. *A circuit that provides high quality audio on/off switching.*

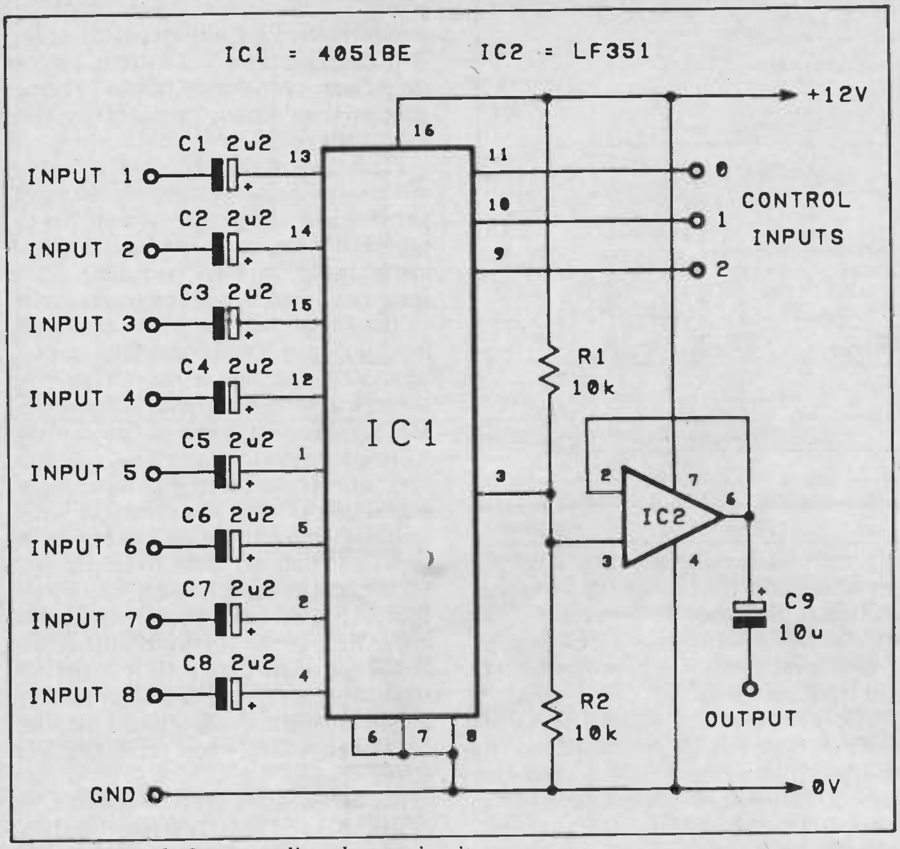


Fig. 6. *A simple 8 way audio selector circuit.*

Fig.6. IC1 is a cmos 4051BE 8 way single pole analogue switch. It is controlled by a three bit binary input, and in this circuit it simply switches the selected audio channel through to the buffer amplifier based on IC2. The input impedance of IC2 has to be something of a compromise. On the one hand it must be high enough to give reasonable distortion performance, but on the other hand it must be low enough to give no significant breakthrough on the channels that are switched off, even at high audio frequencies. The specified values for R1 and R2 give what seemed to be the best compromise, but they could be made lower in value if very low breakthrough is important, or higher in value if lower distortion is vital.

If less than eight inputs are required, simply ignore some of the most significant inputs and omit their input capacitors. Any unused binary inputs must, of course, be connected to the 0 volt supply rail.

GAIN CONTROL

Digital control of audio gain and filters has been commonplace in the world of electronic music for some time now. Digital audio control is finding its way into other aspects of electronics, and the use of computerised mixing consoles is just one of the many possibilities that are now being exploited.

There are digitally controlled audio attenuator chips available, such as the 7110 from RS. As yet these are quite expensive, and it is generally more cost effective to use a conventional vca driven from a digital to analogue converter. This is one application where 8 bit precision is not really needed. Human hearing can at best detect a 2dB change in volume, and a dynamic range of about 100dB is adequate for an audio attenuator. With a 6 bit converter there are sixty four output voltages available, and with these giving 1.5dB increments in gain an adequate 96dB dynamic range could be accommodated. Of course, an 8 bit converter can be relegated to a 6 bit type simply be connecting the two least significant inputs to ground, and then driving the other six inputs from the least significant bits of an output port.

The circuit of Fig.7 is for a good quality vca that will interface to the digital to analogue converter circuits described earlier. They should be set for unity voltage gain through the output amplifier as this circuit has a 0 to 2.55 volt control voltage range. The circuit is based on one section of an NE570 or NE571 compander chip. The main difference between these two devices is that the NE571 has a slightly higher distortion figure of 0.1% as opposed to the 0.05% of the NE570. The NE570 also has a higher maximum supply voltage rating of 24 volts, which compares to 18 volts for the NE571.

In this circuit the input is applied to the variable gain cell, and is then taken to the operational amplifier which really just acts as an output buffer amplifier in this case. The control voltage is applied to the rectifier input, although there is no processing by this stage as the input is always positive going, and the control voltage passes straight through to the gain control cell. Note that increased input voltage provides decreased gain. This could be altered by using an inverting amplifier ahead of the control input, but in practice there is unlikely to be any problem in writing the software to suit the natural control characteristic of the circuit. An excessive control voltage causes the gain to start to rise again. Therefore, with the output of the d/a converter at maximum, VR1 is adjusted for minimum gain. Around 100dB of attenuation should be possible.

VR2 is the distortion trimming control, and is merely adjusted for minimum distortion. In the absence of suitable test gear this can be adjusted by ear using a low frequency sinewave test signal, or R3, R4 and VR2 can just be omitted. The untrimmed distortion is typically 0.3% for the NE570 (0.5% for the NE571).

The numbers in brackets in Fig.7 are the equivalents for the other section of the device, and this can be used in a second vca.

SC FILTER

A digitally controlled filter can be implemented using a voltage controlled filter (vcf) driven from a digital to analogue converter. There is an interesting all-digital alternative in the

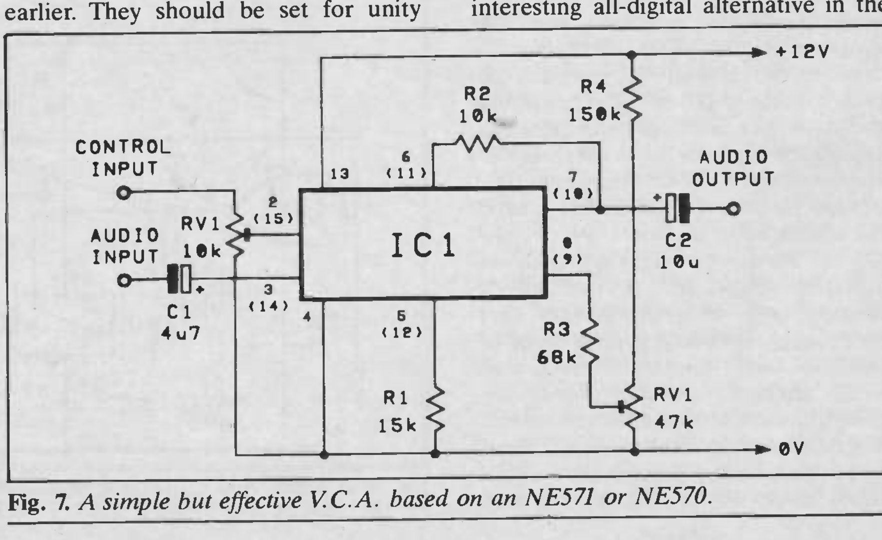


Fig. 7. *A simple but effective V.C.A. based on an NE571 or NE570.*

form of switched capacitor filters. These have an operating frequency that is controlled via a clock signal, and accurate clock frequencies can easily be generated by conventional digital circuits, or by microprocessor based designs. In the case of microprocessor based systems the clock frequencies can either be largely software generated, or special timer/counter chips can be used. An advantage of the switched capacitor approach is that it enables the operating frequency to be set with quite high precision; a factor that opens possibilities in the area of high quality computer controlled test equipment.

The only readily available switched capacitor filter chip is the MF10CN, which is a versatile device having an excellent specification. Fig. 8 shows a circuit based on the MF10CN, and having switchable lowpass, bandpass, and notch modes. This circuit uses IC1 in what the MF10CN data sheet refers to as "Mode 1a", which is one of nine possible operating modes. As shown in Fig.8 the operating frequency of the filter is nominally one hundreth of the clock frequency, but this can be changed to one fiftieth of the clock frequency by taking pin 12 high. There are actually two identical filters in the MF10CN package, and the numbers in brackets show the pin numbering for the second section of the device. The 50/100 control input is common to both filters, but they do have separate clock inputs. Dividing one clock frequency by two will therefore place the filter frequencies one octave apart. The clock signal can be at ttl or (5 volt) cmos logic levels. The Q of the filter if equal to R2/R3, and can be increased from its present level of 1 by increasing the value of R2.

Switched capacitor filters have definite advantages, but they do have a slight drawback in that the output is a form of digitised signal. It steps up and down in level in standard digitised audio fashion, and in many applications some output filtering will be needed in order to attenuate the high frequency components on the output. An input filter may also be needed to ensure that high frequency input signals do not result in heterodynes on the output.

A simple single stage passive filter will often be sufficient at the input, and a filter of this type (R1 – C2) is included in Fig.8. More comprehensive output filtering may be desirable, and in this circuit a third order active lowpass filter is included. The filters give a bandwidth of about 10kHz, but the cutoff frequency may need some adjustment to suit a particular application. A crucial point to bear in mind with this type of filter is that low filter frequencies (less than about 200Hz) require clock frequencies that fall within the audio range. Any significant breakthrough of the clock signal at the output is then likely to be clearly audible. At the other end of the

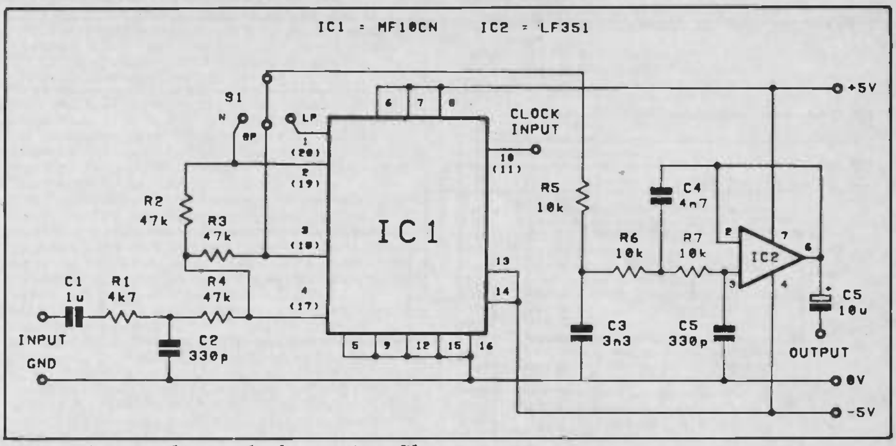


Fig. 8. *A versatile switched capacitor filter.*

frequency range, the MF10CN is guaranteed to operate at filter frequencies of up to 20kHz (typically 30kHz).

IN ISOLATION

Nine times out of ten there is probably no problem in connecting one piece of equipment directly to another, but there can occasionally be problems. I have only encountered such difficulties when dealing with two pieces of mains powered equipment where neither of them had an earthed chassis. The problem is the high voltage that can exist between the chassis of the two pieces of gear. This will be at a high impedance, but could still damage sensitive semiconductor components. I once destroyed the 6526 CIA in a Commodore 64 computer in this way!

There are plenty of circuits for isolating digital signals, but designs to handle analogue signals seem to be scarce. An isolation circuit that will accurately transmit a dc level with no offsets is a relatively difficult task. Isolation circuits are almost invariably based on opto-isolators, and these lack the high degree of linearity required for analogue applications.

A standard approach to audio isolation is to use an opto-isolator, but to feed the signal through it as some form of pulse modulated signal. As the isolator is only handling a pulse signal any slight non-linearity it introduces is of little significance. The performance of the system is largely governed by the quality of the encoder and decoder circuits. The circuit of Fig.9 is based on pulse width modulation techniques.

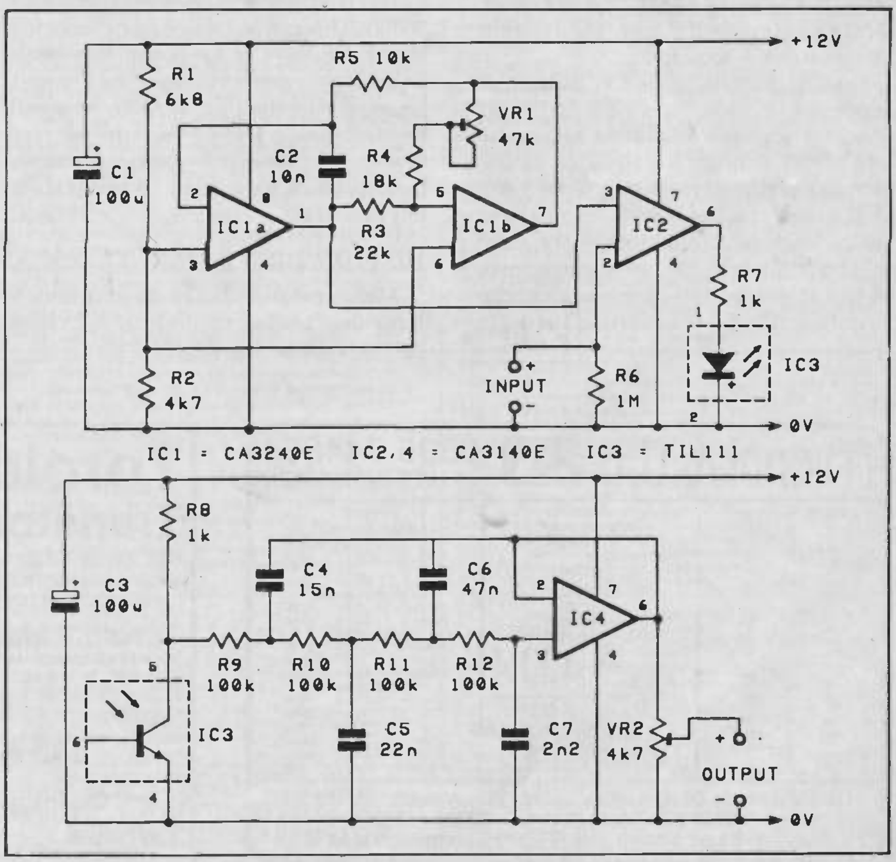


Fig. 9. *An analogue opto-isolator circuit.*

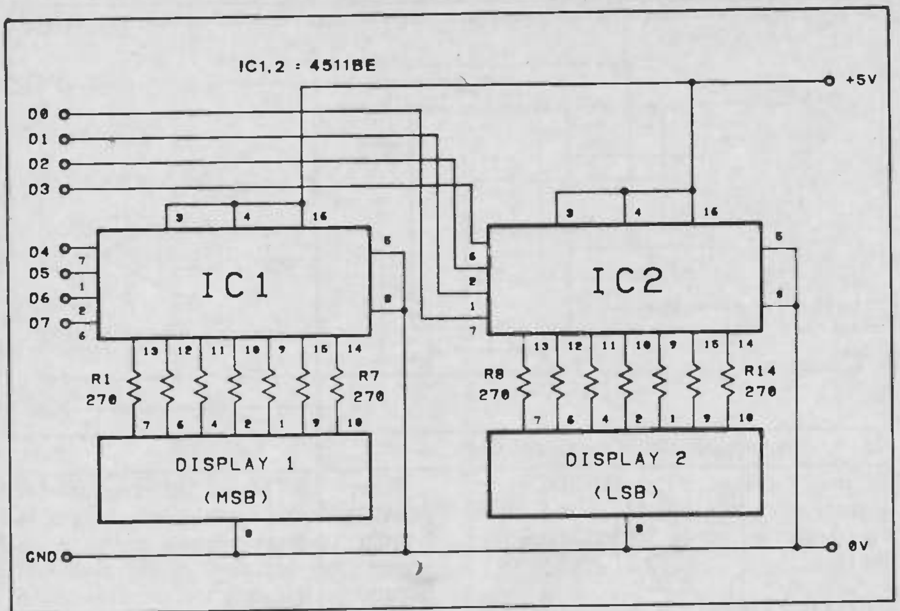


Fig. 10. *A circuit to drive two seven segment l.e.d. displays from an 8 bit output port.*

The basic idea is to conver the dc input level into a pulse signal having an average voltage that is equal to the input voltage. The pulse signal recovered from the opto-isolator is then processed by a lowpass filter to recover the dc signal level. In this circuit IC1 operates as a triangular oscillator and IC2 is a voltage comparator. This method of pulse width modulation is a well known one that is much used in a range of applications. Pulse width modulation has been covered in PE in the recent past in articles on class D audio and switch mode power supplies, and these articles should be consulted if more information on this topic is required.

For the circuit to work well it is important that VR1 and VR2 are set up correctly. Ideally VR1 should be a multi-turn preset. Initially it is adjusted so that the triangular output signal from pin 1 of IC1 just reaches 0 volts on negative peaks. The unit should then work quite well, but linearity at low voltages may be less than ideal. An improvement can be obtained by first connecting and input of a few volts to the unit, and then adjusting VR2 for the correct output level. Next use a much lower input voltage (about 20 millivolts) and adjust VR1 for the correct output voltage. Repeat this procedure a few times until no further improvement in accuracy can be made. When used with a Ferranti converter over a 0 to 2.55 volt range the prototype exhibited no significant degradation in performance. Note that the unit can be used both at the output of a digital to analogue converter, or the input of an analogue to digital converter.

The bandwidth of the circuit is about 100Hz. This can be increased by reducing the value of C2 to boost the clock frequency, and raising the cutoff frequency of the output filter. This will result in some loss of linearity at very low input voltages though, and a bandwidth of more than 10 to 20kHz is not practical.

DISPLAY DRIVING

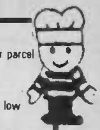
Microprocessor based circuits mostly have the familiar monitor or television display as the main means of supplying data to the user, but in some applications something more basic is all that is needed. In particular, applications that require the system to run for prolonged periods unattended are better suited to some form of display. Televisions and monitors should not be left unattended for any length of time as they represent a fire hazard.

Light emitting diodes can be driven from digital circuits without difficulty, and usually require nothing more than a current limiting resistor. A few individual leds can provide a useful status display, or the seven segment variety can be used where a slightly more sophisticated form of readout is required. One way of driving seven segment displays from a microprocessor based project is simply to drive each segment from one output of a parallel port, but this is doing things the hard way. A much better approach is to use a couple of binary coded decimal (bcd) to seven segment decoders, as in the circuit of Fig.10. This permits two displays to be driven from an 8 bit latching output port.

The pin numbering for the displays assumes that they are of the standard 0.5 or 0.56 inch common cathode type. Other sizes should work equally well, but will almost certainly have a different pinout configuration. The displays must be of common cathode variety and not the common anode type.

The decimal value sent to the port is not the value that will be displayed by this circuit. To find the right value to display a given number, simply multiply the most significant digit by sixteen, and then add the least significant digit to this. For example, to display "24", the value written to the port would be 36 (2 x 16 = 32, 32 + 4 + 36).

In part two next month, Robert Penfold looks at other aspects of real world interfaces, such as dc pulse controllers, triacs, and measurement techniques. PE



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5 – 3 flush electrical switches
7 – 4 in flex line switches with neons
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9 – 2 mains transformers with 6V 1A secondaries
10 – 2 mains transformers with 12V ½A secondaries
11 – 1 extension speaker cabinet for 6½" speaker
12 – 5 octal bases for relays or valves
13 – 12 glass reed switches
14 – 4 OCP 70 photo transistors
16 – 4 tape heads, 2 record, 2 erase
17 – 1 ultra sonic transmitters and 1 ditto receiver
18 – 2 15000 mfd computer grade electrollics
19 – 2 light dependent resistors
20 – 5 different micro switches
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41 – 6 Rocker Switches 10 amp mains SPST
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45 – 1 24 hour time switch mains operated (s.h.)
46 – 1 6 hour clock timeswitch
48 – 2 6V operated reed switch relays
49 – 10 neon valves – make good night lights
50 – 2 x 12V DC or 24V AC, 4 CO relays
51 – 1 x 12V 2C O very sensitive relay
52 – 1 12V 4C relay
53 – 2 mains operated relays 3 x 8 amp changeovers
55 – 1 locking mechanism with 2 keys
56 – Miniature Uniselector with circuit for electric jigsaw
57 – 5 Dolls' House switches
60 – 5 ferrite rods 4" x 5/16" diameter aerials
61 – 4 ferrite slab aerials with L & M wave coils
62 – 4 200 ohm earpieces
63 – 1 Mullard thyristor trigger module
64 – 10 assorted knobs ¼ spindles
65 – 5 different thermostats, mainly bi metal
66 – Magnetic brake – stops rotation instantly
67 – Low pressure 3 level switch
69 – 2 25 watt pots 8 ohm
70 – 2 25 watt pots 1000 ohm
71 – 4 wire wound pots – 18, 33, 50 and 100 ohm
73 – 4 3 watt wire wound pots 50 ohm
77 – 1 time reminder adjustable 1-60 mins
78 – 5.5 amp stud rectifiers 400V
85 – 1 mains shaded pole motor ⅞" stack – ¼ shaft
86 – 2 5" ali fan blades fit ¼" shaft
87 – 2 3" plastic fan blades fit ⅛" shaft
88 – Mains motor suitable for above blades
89 – 1 mains motor with gear box 1 rev per 24 hours
91 – 2 mains motors with gear box 16 rpm
93 – 4 11 pin moulded bases for relays
94 – 5 B7G valve bases
95 – 4 skirted B9A valve bases
96 – 1 thermostat for fridge
98 – 1 motorised stud switch (s.h.)
101 – 1 2½ hours delay switch
103 – 1 6V mains power supply unit
104 – 1 4½V mains power supply unit
105 – 1 5 pin flex plug and panel socket
107 – 1 5" speaker size radio cabinet with handle
109 – 10 ¼" spindle type volume controls
110 – 10 slider type volume controls
112 – 1 heating pad 200 watts mains
114 – 1 1W amplifier Mullard 1172
115 – Wall mounting thermostat 24V
118 – Teak effect extension 5" speaker cabinet
120 – p.c.b. with 2 amp full wave and 17 other recs
122 – 10 mtrs twin screened flex white p.v.c. outer
132 – 2 plastic boxes with windows, ideal for interrupted beam switch etc
155 – 3 varicap push button tuners with knobs
188 – 1 plastic box, sloping metal front. 16 x 95mm, average depth 45mm
241 – 1 car door speaker (very flat) 6½" 15 ohm made for Radiomobile
243 – 2 speakers' 6" x 4" 15 ohm 5 watt made for Radiomobile
266 – 2 mains transformer 9V ½A secondary split primary so OK also for 115V
267 – 1 mains transformers 15V 1A secondary p.c.b. mounting
330 – 2 6V 0.6V mains transformer .3A p.c.b. mounting
350 – 40 double pole leaf switches
365 – 1 7uf 660V 50hz metal cased condenser
453 – 2 2½in. 80ohm loudspeakers
454 – 2 2½in. 8ohm loudspeakers
463 – 1 mains operated relay with 2 sets c/o contacts
464 – 2 packets resin filler/sealer with cures
465 – 3 5A round 3 pin plugs will fit item 193
466 – 4 7 segment l.e.d. displays
470 – 4 pc boards for stripping, lots of valuable parts
473 – 1 5" 4ohm speaker with built in tweeter Radiomobile
480 – 1 3A double pole magnetic trip, saves repairing fuses
498 – 4 1000uf 25V axial electrolytic capacitors

TELEPHONE BITS

Master socket (has surge arrestor – ringing condenser etc) and takes B.T. plug	£3.95
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Cord terminating with B.T. plug 3 metres	£1
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100 mtrs 4 core telephone cable	£8.50

COMPACT FLOPPY DISC DRIVE EME-101

The EME-101 drives a 3" disc of the new standard which despite its small size provides a capacity of 500k per disc, which is equivalent to the 3½" and 5¼" discs. We supply the Operators Manual and other information showing how to use this with popular computers: BBC, Spectrum, Amstrad etc. All at a special snip price of **£27.50** including post and VAT. Data available separately **£2**, refundable if you purchase the drive.

DON'T FREEZE UP! – We have had the strongest winds for over 200 years and who knows we may be in for the coldest winter, so if you have not already protected your water pipes you should do so now – our heating wire wound around the pipes will do this and will cost only about 50p per week to run – 15 metres (minimum length to connect to 230/240 v mains). Price £5. Our Ref. 5P 109.

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3½ & 5¼ FLOPPY DISC DRIVES now in stock all are new and made by famous Epson company. All are double sided drives with storage capacity of 1 meg byte. They have standard connections and are fully compatible with conventional systems. Both are small size and light weight. Price – either model is £57.50 plus £3 post. Price includes copy operating data.

APPLIANCE THERMOSTATS – spindle adjust type suitable for convector heaters or similar price 2 for £1. Ref. BD582.

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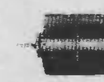
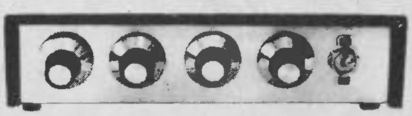
Made for use in cars, etc. these are very powerful and easily reversible. Size 3½" long by 3" dia. They have a good length of ¼" spindle –
1/10 hp £3.45
1/8 hp £5.75. 1/6 hp £7.50



SOUND TO LIGHT UNIT



Complete kit of parts for a three channel sound to light unit controlling over 2000 watts of lighting. Use this at home if you wish but it is plenty rugged enough for disco work. The unit is housed in an attractive two tone metal case and has controls for each channel, and a master on/off. The audio input and output are by ¼" sockets and three panel mounting fuse holders provide thyristor protection. A four pin plug and socket facilitate ease of connecting lamps. Special price is £14.95 in kit form.

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9" VDU OR MONITOR ideal to work with computer or video camera uses Philips black and white tube ref M24/306W. Which tube is implosion and X-Ray radiation protected. VDU is brand new and has a time base and EHT circuity. Requires only a 16V dc supply to set it going. It's made up in a lacquered metal framework but has open sides so should be cased (if you are handy with a drill and file you could make a case out of two of our 6½" speaker cabinets). The VDU comes complete with circuit diagram and has been line tested and has our six months guarantee. Offered at a lot less than some firms are asking for the tube alone, only £16 plus £3 post. We also have some that failed the line test, again brand new but offered without guarantee at £8 plus £3 post. We do a kit for the 16V 2A psu to operate this monitor price is £3 our ref 3P26

LIGHT BOX

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

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NEW ITEMS

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

£2 POUNDERS*

2P122 – 1 30a rotary switch, surface mounting with pointer knob
2P123 – 1 25a rotary switch, surface mounting, cover engraved, high, medium low and off
2P124 – 1 28kv .001mfd block condensor
2P127 – 1 30a bridge rectifier assembly on heat sinks
2P129 – 1 10rpm motor 115V so supplied with adaptor for 230V
2P131 – 1 Crouzet motor 230V fits the Crouzet gearbox
2P132 – 1 ceiling heat-stat for fire warning or protection
2P133 – 1 Circuit breaker 20a, Crabtree ref C50
2P134 – 1 9V 500mA psu, plugs into 13a socket
2P135 – 10m 10 conductor intercom cable
2P136 – 1 2½kw element made for tangential blowers
2P137 – 1 Thermo couple, stainless steel tipped for measuring internal heat
2P138 – 1 Mains transformer 20V-0-20V 1a upright mounting
2P141 – 1 rechargeable battery D size (4 AH) solder tag ended
2P142 – 10m 4 pair intercom cable White PVC outer
2P144 – 1 mains operated relay with 4 x 8a c/o contacts
2P147 – 1 10w 100ohm line matching transformer
2P148 – 1 Technical information on 3" FDD refundable if you buy fdd
2P149 – 5 diff battery operated model motors
2P150 – 1 PSU chassis with all components for 24V 2A d.c. unwired
2P151 – 1 Metal box 14½ x 14 x 4 with lid add £2.00 post
2P152 – 1 Motor start capacitor 80uf 250V
2P153 – 1 Two station intercom unused but line reject
2P154a – 1 Nicad charger — plug into 13a socket 5.2V .7UA output
2P154b – 1 Nicad charger — plug into 13a socket 6V .9VA output
2P155 – 1 Mains transformer giving 16, 17, 18 & 20V 60W
2P158 – 1 Oven thermostat with temp calibrated knob
2P159 – 1 9V 500ma cased with mains lead and output lead
2P160 – 1 13a plug adaptor fused takes 3 x 13a plugs
2P161 – 1 6" diagonal side cutters
2P162 – 1 Stereo Matrix PCB mounting deemphasis K35
2P163 – 1 AC Working capacitor 12uf 660V AC or 1500V dc
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£3 POUNDERS*

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3P8 – 1 24hr time switch Sangamo, new condition Guaranteed 1 year
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3P10 – 1 Mains transformer 50V 2A with 6.3 pilot light winding; upright mounting, fully shrouded
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SUPER WATER PUMP – Approx ⅓ hp mains operated originally intended to operate a £300 shower unit at a controlled pressure – but of course suitable for many other water or liquid moving operations – where a good flow at a constant pressure is required – Price £25 each V.A.T. and Post Paid. Our Ref. 25P2.

VERY USEFUL MULTI TESTERS – These have all usual ranges AC & DC volts – DC MA and OHMS etc but an unusual and very useful feature is a "low OHMS" range. Very useful for checking dry joints etc. They are ex G.P.O., and may have faults but we test and guarantee the movement to be O.K. Price £3 each. Ref. 3P30, or two, same make and type, Price £5. Ref. 5P110.

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

POWER PACK OR AMPLIFIER CASE – Size approx 10" x 8¼" x 4¾" plated steel – with ample perforations for cooling. Front panel has on/off swtich and E.E.C. mains inlet plug with built in RF filter – undoubtedly a very fine case which would cost at least £50 from regular sources, our price is £5 each and £3 post. Ref. 5P111.

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

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4P14 – 1 150w mains transformer "c" core 43V 3.5A secondary
4P15 – 1 powerful motor 2" stack fitted with gearbox final speed 60rpm mains operated, could operate door opener etc.
4P17 – 1 Uniselector 3 pole 25W, 50V coil standard size
4P18 – 1 Volt meter with digital display (DIGIVISOR)

£5 POUNDERS*

5P86 – 1 Transformer upright mounting 230/240V primary 2 x 100 1a secondary
5P88 – 1 Transformer in waterproof metal box 24V 5A add £2 post
5P89 – 1 4 bank heating element each 2kw ideal convector heater
5P90 – 1 18" long tangential blower with motor at one end
5P91 – 1 14" blower, motor in middle
5P92 – 10m Audio co-ax double screened 75ohm super low loss for TV
5P93 – 1 6" Alarm bell 24V dc or ac
5P94 – 1 Current transformer 14V out with 1a dc input
5P95 – 1 Vintage photo cell
5P97 – 1 Impedance matching transformer 0-4-5-8-160 ohm 100 add £150 post
5P98a – 1 0–90a ammeter for mounting outside control panel
5P98b – 1 0–180a ammeter for mounting outside control panel
5P99 – 1 Mains operated blower centrifugal output size app. 5" x 1½"
5P100 – 1 Mains splitter 45a switch 3 x 15a fused circuits
5P101 – 1 Model motor 1 rpm from 6V reversible

£8 POUNDERS*

8P1 – 1 Charger transformer 10a upright mounting 230/240 primary 16v 10a secondary
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10P25 – 1 100W audio transformer 50-0-50W primary 8 ohm secondary
10P31 – 1 7 day time switch 16a c/o contacts sep switches for each day
10P32 – 1 68 rpm 1/6th hp motor reversible

TREMOLON

BY JOHN BECKER

TRIM THAT TCA TO YOUR TASTE

Your editor does not like to be caught standing still, so hiding deep within this simple and economical tremolo unit are stranger sounds and a variety of choices for the constructor.

In these days of high tech music, it's easy sometimes to loose sight of the fact that not everyone wants or can afford the necessary equipment. Undoubtedly, the cost of sophisticated electronic musical instruments complete with computer and digital interfaces has been plummeting as chips become more complex, equipment becomes smaller, and more companies make their impact felt on the scene. Nonetheless, to those whose income may be less than ideal, or non-existent, even such competitive prices may be too expensive.

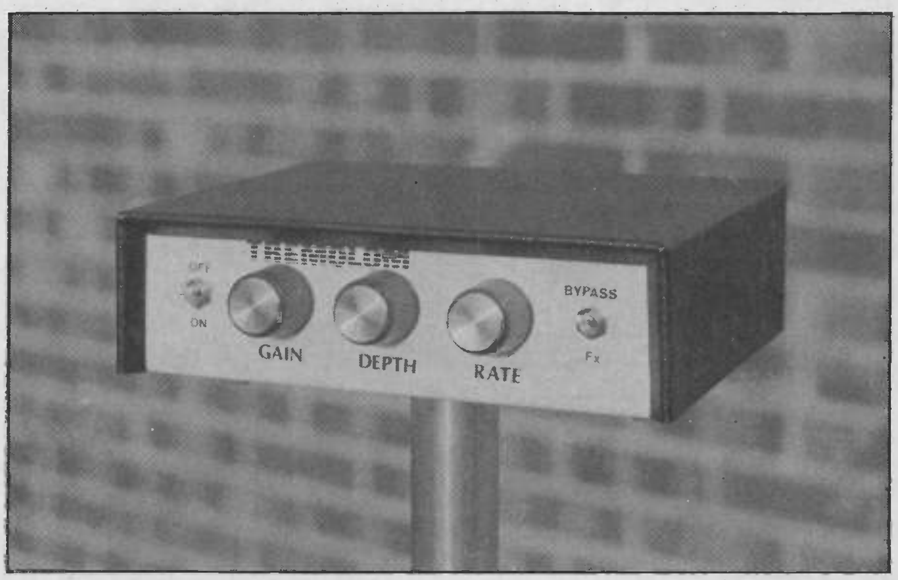
RHYTHM RIDDLED

This does not stop people from wishing to make music; those who are really stricken by the need to let tunes or rhythms pour forth, will do so irrespective of the facilities available. Hands beating on a tabletop, fingers plucking at a tuned rubber band, throats vibrating in song, all signs of the desire to make music. Music is part of human nature.

To those with a litte more talent, and perhaps with a few extra pounds, or generous relatives at gift times, guitars become an ideal instrument to play. Pleasure can be just as great whether the guitar is acoustic, or electronically powering into an amplifier. With the electric guitars, it is easy to plug in an extra box of some sort to also change the nature of the tone or character. In this way, greater interest can be created, and whole new realms of sounds produced. Some of these may even help a moderate musician to sound more adept!

POPULAR POPS BOXES

Of the units generally available at little cost, there are perhaps just half a dozen or so that are the most commonly used. Probably one of the more interesting boxes is one that gives echo or reverb, adding spaciousness to the music. Chorus, flanging, phasing and double tracking are also related to echo, and they too have their widespread appeal. Fuzz and heavy overdrive units have their addicts, though unconverted listeners may query why distortion is thought to be a sign of modern music maturity. Tremolo and vibrato as well are easy to produce via simple control boxes. Curiously though, vibrato seems less common than it deserves to be; it is after all the effect that any stringed or vocal musician will deliberately introduce to create mood.



The finished unit. No prizes for spotting the spelling error.

The two effects simplest to produce electronically, are fuzz and tremolo. Robert Penfold produced a superb little Bright Fuzz unit for the May 1987 issue of PE. To show just how easy and effective tremolo can be, I have designed this very simple Tremolon unit. It uses only one chip, and just a handful of other components, and is a valuable but low cost addition to anyone's effects line up. It's simple to make, cheap to buy, and interesting to use.

MISCONCEPTION

Before looking at the circuit, let's remove a misconception. From numerous conversations it is apparent that a number of people are confused about the difference between tremolo and vibrato. Certainly they both involve the imposing of a low frequency vibration, and in that sense tremolo is a vibrato effect. In reality though, the character of the two effects is widely different, both in nature and in operation.

VIBRATO

Vibrato occurs when the pitch of a basic note or notes is repeatedly and smoothly varied up and down. This change is not the same as simply shifting back and forth between two conventional notes at a fast rate. It is more subtle than that, and usually faster.

Much research has been carried out into what creates the best sounding vibrato, both in terms of frequency shift, and the rate at which it occurs. Analysis of the singing and playing of live musicians, and of those who now only live through their recordings, reveals interesting facts. Although some musicians may claim that they only sing pure notes, in reality, even they may unintentionally introduce vibrato. Instrument players, on the other hand, can be more self-controlled, and deliberately decide whether or not to add vibrato.

From the analysis, there seems to be a fairly consistent agreement on the pitch shift and its rate, a rate which also applies to tremolo. The pitch shift range usually depends on the basic note that is being played, and upon the emphasis required by the mood of the music. As a rough guide, a shift of about a quarter of a tone to either side of the ideal is common.

The rate at which the shift is created is also pretty consistent between performers, and lies in the range of about six and a half cycles per second. This too changes with mood and the emphasis required.

TREMOLO

Tremolo, although varied at similar rates and depths to vibrato, is fundamentally very different. It involves

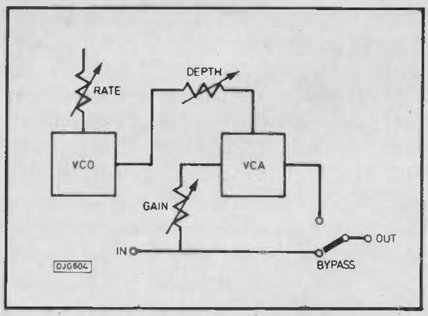


Fig. 1. *Block diagram of the Tremolon.*

changes in the amplitude, or volume, of the music. While a skilled musician may be able to create this effect without electronic assistance, electronics can produce some extremely marked and controllable effects. With even a simple unit it is possible to rapidly vary the level between nil and maximum, and at rates well to either side of the 6.5Hz ideal. All that is needed is an arrangement as seen in the block diagram of Fig.1.

CIRCUIT BLOCKS

The set up is basically a voltage controlled oscillator that modulates a voltage controlled amplifier. Both controllers are under manual control, so that rate and depth can be modified. There is also a signal gain control included, though this is not essential to the creation of tremolo.

Looking at Fig.2, the oscillator is formed around the components associated with IC1a. This is one of two identical circuits within IC1, though they are used very differently.

The functional name of the chip is dual transconductance amplifier, or tca. The way that it works is not essential to the understanding of the circuit. It is adequate to simply know that each half has two signal inputs, one inverting and the other non-inverting, and that the level of the signal passing through can be controlled by the current flowing into a control node.

The characteristics of the chip introduce a high amplification factor. This partly depends on the current flowing into the control node, but also is related to the current being drawn from its output. Within limits, the less current being drawn, so the higher is the gain. To maximise the availability of the gain, the tca is followed by a very high impedance buffer, IC1b.

The abilities of this particular chip allow the creation of numerous varying circuits, and I have used it in many applications. Most readers will know the potential versatility of the humble 741 and its associated family, but I thoroughly recommend the LM13600, or LM13700 to any experimenting constructor if even greater versatility is sought after.

OSCILLATOR

In common with other forms of oscillator, feedback and amplification are needed to create the conditions under which self-sustained oscillation can occur.

IC1a has a network of associated components that provide just these conditions. The essential timing component that governs the rate of oscillation is C3. Current flows into and out of this capacitor at a level set by the current at the control node. In this case it is variable by the potential divider VR1 and R3. The tapped voltage from the wiper of VR1 causes a current to flow through the limiting resistor R6. The higher the voltage level at the wiper, so the greater is the current flowing into the node through R6. Since the rate of charge of any capacitor is determined by the current flowing into it, so VR1 can vary the rate of charge into C3. R3 sets the minimum possible current.

IC1b is simply a very high impedance buffer stage consisting of two transistors in a darlington configuration, Fig.3. Its impedance is so high as to have little effect upon the charge rate for C3. As

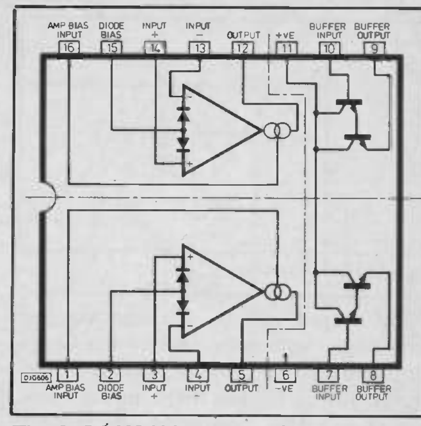


Fig. 3. *LM13600 transconductance amp.*

the voltage level on C3 rises, the threshold level of IC1b is reached. At this point, the darlington pair begin to conduct into R7. Since there is a feedback path along R5 as well, the increasing voltage level is fed back to the inverting input of IC1a. Once the bias level at this input starts to increase, so current begins to flow back through IC1a from C3. Eventually, the level will drop below that needed by IC1b, and once more the process will reverse, ad infinitum.

The process is additionally enhanced by providing positive feedback between C3 and the inverting input of IC1a, limited by the back-to-back diodes D1 and D2.

MODULATION LEVEL

The initial bias to IC1a comes via VR4 and R4 as well as that from R5. VR4 is used to preset the divided potential as seen at the negative input of IC1a, so predetermining the oscillation range, but more particularly setting its sweep amplitude. The waveform seen at the output of IC1b, is a rather shameful approximation to a triangle wave (Fig.4), though it's perfectly adequate for use as the modulation control of the next stage.

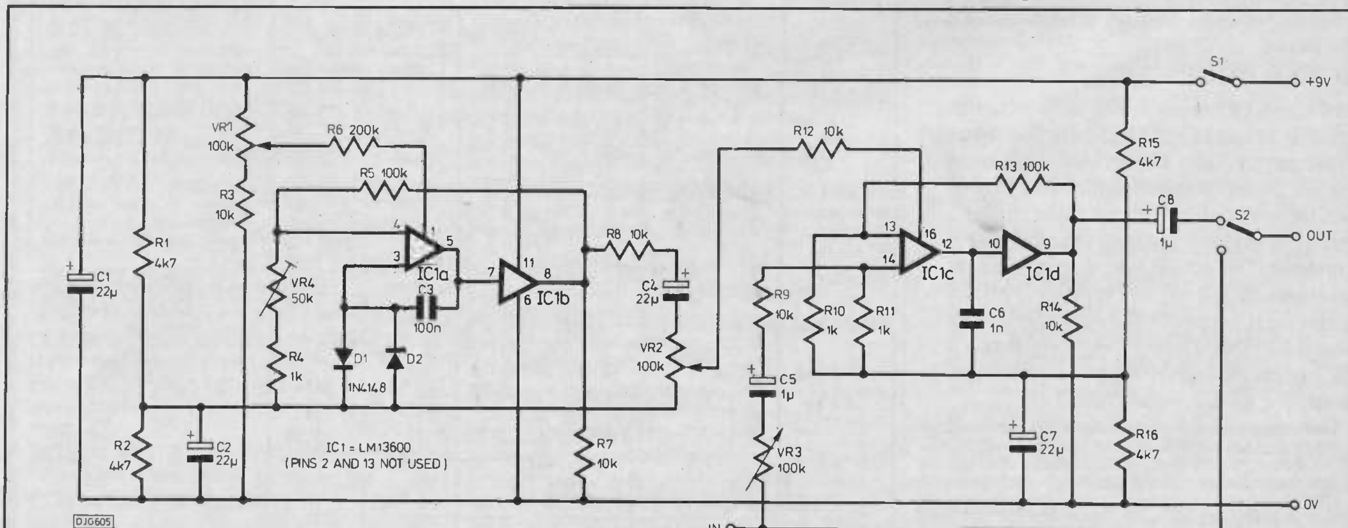


Fig. 2. *Complete circuit diagram for the Tremolon.*

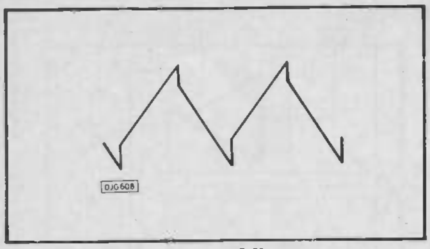


Fig. 4. *Waveform at ICIb*

The output voltage is taken via the decoupling capacitor C4 to the level control VR2. R8 is not essential to the circuit, but is simply there to limit the maximum level available at highest setting of VR2. The level tapped by the wiper of VR2 is taken via R12 and controls the current flowing into the control node of IC1c.

ALTERNATIVES

It might be expected that the amplitude control stage should consist of a voltage controlled amplifier. That is certainly the conventional way of doing things. But many of you will know by now that your Ed is sometimes prone to unconventional eccentricities. Here is a case in point, in which I shall show that there are usually more ways than one in which specific problems can be approached.

What I have chosen to do here is to show that by using a modulated filter we can produce a tremolo effect, and at the same time add a little more interest to the sound.

It is interesting to note that simply by changing one component, a voltage controlled amplifier based around a tca such as the LM13600 can be modified to become a voltage controlled filter. That component is the one on the output of IC1c. For the network around IC1c and IC1d to operate as a vcf, the component becomes a capacitor. For use as a vca a resistor would be used instead — a nominal value of between 47k and about 220k would be suitable. For a full gain span R13 should also be omitted in the vca mode.

SIGNAL PASSING

For use either as a vca or a vcf, the signal is brought into IC1c via the input level control VR3, C5 and R9. This level control is also somewhat unusual and is used as a variable resistor rather than a potential divider, though the end result is similar. The actual signal level seen at the input of IC1c is the tapped level set by the total value of VR3 plus R9 feeding into R10. Decreasing the resistance of VR3 causes a higher tapped signal level to appear at the input to IC1c.

The amount of signal that is allowed to pass through IC1c is of course determined by the current into its control node. Now, as we saw with the vco in stage one the current coming out of IC1c will charge or discharge a capacitor. If the output signal is an ac waveform, then the capacitor will mop up frequencies above the natural time constant set by the current and capacitance ratios. If the control current into the node is large, only high frequencies will be absorbed. If the current is progressively decreased, so the time constant will assume a larger value, and lower frequencies will be progressively mopped up. This process is additionally aided by feeding back some of the output of IC1d to the inverting input of IC1c, via R13. The result is that between them IC1c and IC1d behave as a low pass filter.

MOP MODULATING

We have already established that the current flowing into the control node of IC1c can be varied by the oscillator amplitude being output through VR2. It should now be apparent that the frequency response of the vcf stage to any input signal is going to vary with the control level at any given point in time. At that point, only signals having frequencies below the filter cut off region will be allowed to pass through to the output. Since the vcf response is constantly changing with the vco rate and level, so the effective amplitude of the signal will vary with its frequency. An amplitude variation is just what we want for a tremolo effect. Quod est nearly demonstrandum — almost QED!

The remaining point to notice is that the tremolo effect is not being applied to just any old signal, irrespective of its content. This would be the case with a normal tremolo unit, but here, as it is the upper frequencies working downwards that are progressively modified, so a more individual effect occurs varying with signal pitch. Additionally, if the input signal level is allowed to overload IC1c, an effect similar to a mild phasing will sometimes occur. At extremes of overload, and signal frequency, a slight 'wah' effect may also be noticeable.

COMPONENTS

RESISTORS

R1,R2,R15,R16	4k7 (4 off)
R3,R7,R8,R9,R12,R14	10k (6 off)
R4,R10,R11	1k (3 off)
R5,R13	100k (2 off)
R6	200k

All resistors ¼W carbon film 5%

CAPACITORS

C1,C2,C4,C7	22µ 16V(4 off) elect
C3	100n polyester
C5,C8	1µ 63V (2 off) elect
C6	1n polystyrene

SEMICONDUCTORS

D1,D2	1n 4148
IC1	LM13600
VR1,VR2,VR3	100k Lin rotary (3 off)
VR4	50k skeleton preset

MISCELLANEOUS

Printed circuit board 281A, pcb clibs (4 off), PP3 battery clip, box (150mm × 110mm × 45mm), mono jack sockets (2 off), spst toggle switches (2 off), wire and solder, knobs (2 off).

The PCB and a kit of parts are available from Phonosonics. (see advert)

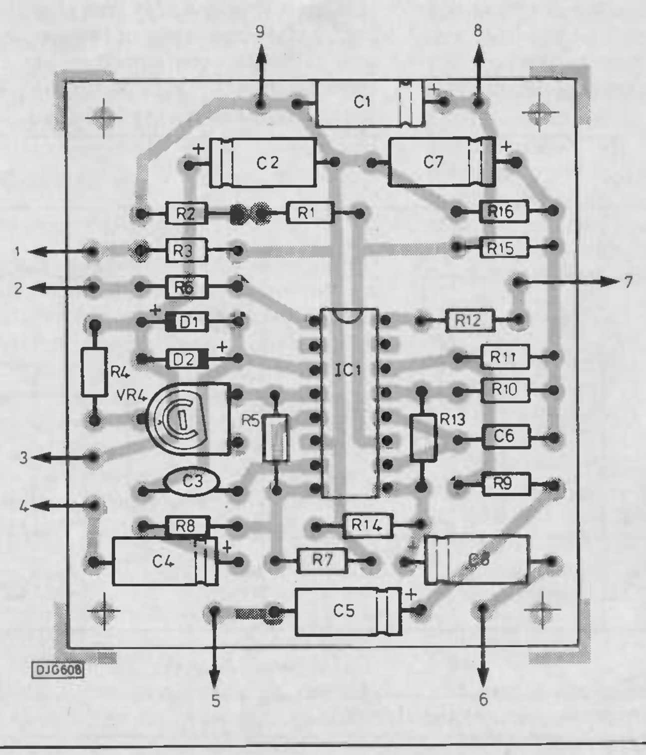


Fig. 5. *Printed circuit assembly details.*

Returning briefly to pure amplitude control, if you replace C6 with a resistor as mentioned above, only pure level variation will occur, without frequency modification. In this instance, by overdriving the input to IC1c, a fuzz effect can be produced.

The final output is taken via C8 to S2, and then to an amplifier in the normal way. S2 is included as a bypass switch, allowing the unmodified original input signal to pass to direct to the amplifier.

POWER SUPPLY

The unit draws very little power, and is very tolerant of voltage levels. A nine volt battery, such as a PP3, can quite readily power it. A 12V supply could be used instead, though the frequency characteristics of the two stages will vary in relation to the psu voltage used. For testing purposes, note that two basic bias levels are used, one for each function stage. Both split the psu level in half and consist of R1, R2, C2 and R15, R16, C7 respectively. However, providing you have assembled and checked everything adequately it is unlikely that you will need to do any testing. All that is needed is to set VR4 for the best sweep amplitude, and to use the unit.

ASSEMBLY

The printed circuit board layout is shown in Fig.5, and should be within the assembly capabilities of even a novice to electronic construction. Indeed, this is an ideal unit for GCSE students, or anyone else learning about electronics, to assemble. Even the wiring details shown in Fig.6 are very straightforward. There are so few components involved that it should not take long to put together, and not only will it give useful assembly experience, but also result in a worthwhile addition to your musical effects line up.

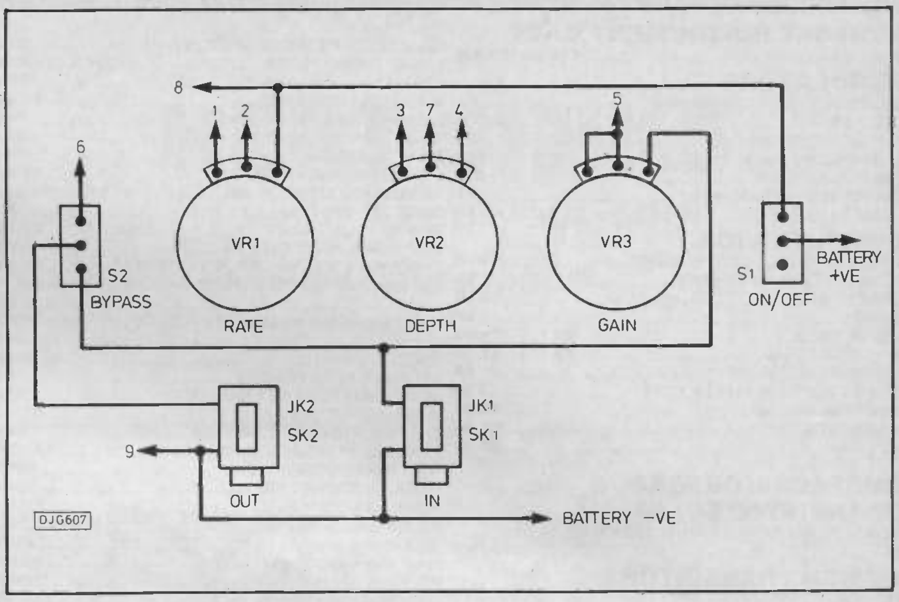


Fig. 6. *Control wiring details.*

TREMOLONWARDS

So, whether you are an escalating musician (to whom I refer in the Editorial!), an impoverished soloist, or an aspiring electronic enthusiast, have a bash at the Tremolon and raise your skill and thrill thresholds. PE

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300 x 133 x 217mm deep .... £10 ea (£2.20)

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7905/12/15/24 plastic .... 50 100+27p
CA3085 T099 variable reg .... 2/£1
LM338 5A VARIABLE £5

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27256-30 ex-eqpt £2.50
2764-30 .... £2
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6264-15 8k static ram £2.80
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In the white heat of electronic invention, it is easy to overlook the prosaically physical problem of heat dissipation. Until something goes phut...

HEAT SINKS

How to keep your cool

BY STEVE KNIGHT

When a transistor is working, power is not only delivered to the load, a loudspeaker for example (something we do want), but, like any other appliance, power is also dissipated inside the transistor itself, most of it at the collector junction (something we don't want). The worst case occurs in Class-A operation where, in the absence of a signal, the greatest power is dissipated at the collector.

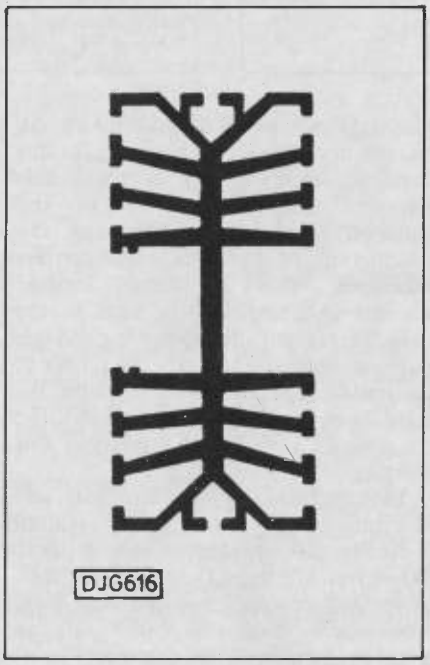
If the heating is very small, as it is in small-signal amplifiers, we can rely on air convection and the conducting paths provided by the connecting wires, and the copper on the printed board to which the wires are soldered, to remove the unwanted heat from the transistor as fast as it is produced. With power transistors, however, we cannot rely on this method because the heating generated is too great to be conducted away quickly enough. So we have to mount the transistor on a large area of metal plate (or use the metal chassis of the case), and this serves to get rid of the generated heat into the surrounding environment. Such a plate is called a "heat sink".

According to molecular theory, the temperature of a solid is a function of the extent of vibration of its molecules about their mean position. So when one end of a metal bar is heated the extent of the vibration of the molecules at this end is increased. These vibrations affect neighbouring molecules and cause them to vibrate in turn. Thus, heat is conducted along the bar until, assuming it is perfectly lagged and loses no heat by radiation, the whole bar reaches the same temperature.

The choice of a material for a heat sink depends upon its ability to conduct heat efficiently, that is, it must have a high "thermal conductivity" or a low "thermal resistance". As a general approximation, if a metal is a good conductor of electricity it is also a good conductor of heat. Copper and aluminium are both good conductors and most heat sinks used in the electronics business are made from one or other of these metals, most generally from aluminium.

AN ELECTRICAL ANALOGY

A convenient way of investigating heat sink problems is to relate the flow of



heat along a metal conductor to the flow of current along a conductor.

Electric current flows (in the conventional sense) from a point of high electrical potential (voltage) to a point at a lower potential. Similarly, heat energy will flow from a point at a high temperature level to a point at a lower temperature. We can make comparisons by looking at Fig. 1 (a) and (b).

As it flows along a conductor, electric current encounters resistance to the flow and Ohm's Law tells us that the current flowing depends upon the potential difference across the ends of the conductor. So

Voltage difference = current × electrical resistance

or $$V_2 - V_1 = I \times R$$

or $$R = \frac{V_2 - V_1}{I} \text{ volts per ampere.}$$

Hence, resistance is defined as the voltage difference (or voltage drop) per unit current (ampere). Electrical resistance, of course, depends upon the material from which the conductor is made and its physical dimensions.

In the same way, the flow of heat along a conductor also encounters "resistance" and this too is a function of the material and its dimensions, and, additionally in this case, of the surroundings of the conductor. Suppose we use the symbol θ to represent this thermal resistance. Then we may say that the heat energy flowing (P watts) depends upon the temperature difference $(T_2 - T_1)°$ across the ends of the conductor. So

Temperature difference = power × thermal resistance

or $$T_2 - T_1 = P \times \theta$$

or $$\theta = \frac{T_2 - T_1}{I} \text{ °C per watt.}$$

Hence, thermal resistance is defined as the temperature change (or temperature rise) per unit dissipation (watt).

See the analogous connection? If you keep this in mind, heat sink calculations are not problem at all.

THERMAL RUNAWAY

Why do transistors require heat sinks? If they want to get hot, why worry? In the old days, valves never required cooling in this way (not outside of large transmitters, anyway). Well, we can find an answer by looking at Fig. 2. Everything hinges fundamentally on the collector junction temperature T_j of the transistor being used. This is always higher than the surrounding (or

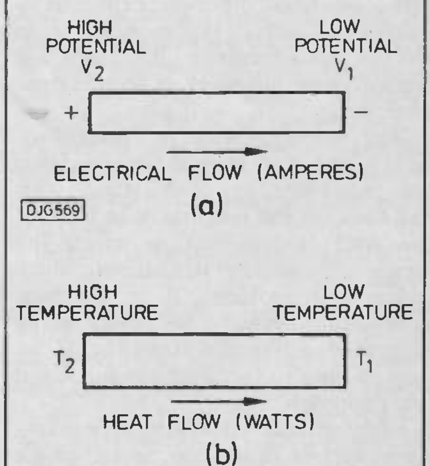


Fig. 1.

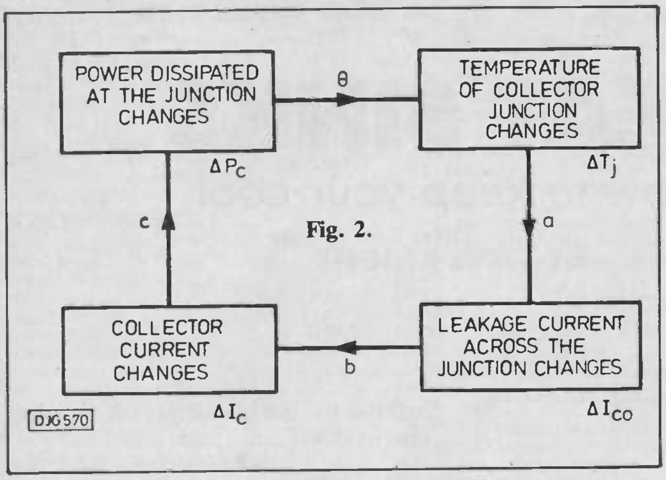


Fig. 2.

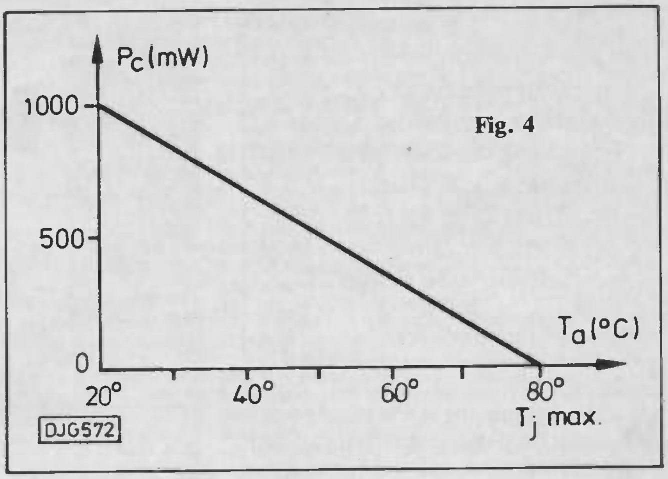


Fig. 4

ambient) air temperature T_{amb}, but it has an upper limit. There is a maximum permissible temperature above which the transistor must not go if damage or destruction is to be avoided.

Germanium transistors don't like working at temperatures above some 85°C; silicon transistors are hardier creatures but anything over about 180°C is not appreciated. These upper temperature limits are stated by the manufacturer of the transistor and are symbolised $T_{j\ max}$. They are decided by the physical properties of germanium and silicon, not by the manufacturers.

As temperature increases, more and more electrons are shaken out of their valence bonds by the increasing vibrational energy of the generated heat, and these thermally generated electrons become available as charge carriers, as do the holes which appear simultaneously. These "hole-electron" pairs as they are called are strictly unwanted carriers, and they form what is known as "leakage current". They are dependent upon the temperature of the junction inside the transistor and they are not under our control in the sense that the charge carriers produced by the doping of the semiconductor are under our control. We can only control them by paying attention to the rise in temperature. The collector current, which we should otherwise expect to be stable at whatever value we might set it, has the leakage current added to it and consequently increases as temperature increases.

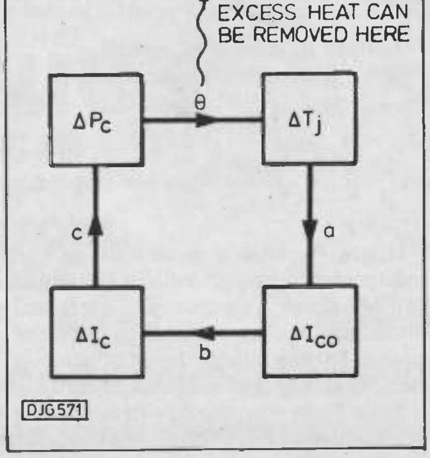
Well, we might argue that the answer to this one is to keep the temperature low and steady; don't stand your amplifier on the radiator or in front of the fire! But it isn't so much the surrounding ambient temperature which causes the problem, it is the heat generated internally by power being dissipated within the transistor. If we now go back to Fig. 2 we can figure out what happens.

Suppose our transistor is working away happily in its case, and then for some reason the internal dissipation increases – this need only be very slight. Call it ΔP_c where the Δ stands for a small change in the collector power P_c, in this case an increase. As soon as this happens, the temperature of the junction (T_j) rises slightly and the production of the unwanted carriers increases. This additional leakage current (ΔI_{co}) effectively adds to the collector current already flowing and this current increase (ΔI_c) lifts the power P_c dissipated at the collector junction. We have now worked our way around the diagram in Fig. 2 and arrived at our starting place.

From here on the process repeats, and the junction gets hotter and hotter until it finally exceeds the permissible limit. What you will need then is a new transistor and probably a better heat sink! The whole disastrous build up can actually happen in an extremely short space of time and is known as "thermal runaway". Hence thermal runaway occurs when the rate of increase in the junction temperature outpaces the ability of the transistor mounting to pass the heat safely away into the surroundings. This will always happen if the "gain" around the closed loop of Fig. 2 exceeds unity, that is, when we have thermal positive feedback. so, to put it in the form of a simple equation, the product

$$a.b.c.\theta < 1 \text{ for stability}$$

Fig. 3.



Now whereabouts around the loop can we get in to make sure that the product of a, b, c and θ is always less than 1? In other words, how can we get a negative feedback loop? Well, we can't do anything about links a or c because they involve physical facts which cannot be changed. Link θ is out best bet; if we can siphon off enough of the generated heat at the collector junction, the temperature of the junction can be kept below its maximum permissible limit. So by mounting the transistor on a large area of radiating surface, we can ensure that this happy state of affairs comes about. See Fig. 3.

INTRINSIC RESISTANCE

For a given temperature rise in the transistor, the heat generated can be radiated into the surrounding air more quickly if that air temperature is low. As the air temperature rises, the power dissipated in the transistor must be correspondingly reduced to ensure that the temperature rise doesn't exceed its maximum. A graph showing the permissible power dissipation against ambient temperature can be drawn for any transistor, and Fig. 4 is a typical example.

In this case the dissipation at 20°C (room temperature) is seen to be 1000mW, but at 50°C this has fallen to 500mW. Obviously, if the ambient temperature reached that of $T_{j\ max}$, here taken to be 80°C, no power dissipation within the transistor would be allowed, hardly a useful situation! We are actually here discussing the radiating properties of the transistor case as it is supplied to us, as so far we have not fitted it to anything.

The thermal resistance of the device itself is known as its intrinsic resistance, θ_i, and this is made up of two parts: the thermal resistance of the junction and the thermal resistance of the case to which the junction is attached. To keep θ_i small, power transistors have their collector electrode mounted in direct metallic contact with the case; TO5 and TO220 are familiar forms of this type of construction. This keeps the intrinsic resistance low, typically of the order of 1 to 2°C/W.

From Fig. 4 we can derive the intrinsic resistance of that particular transistor by dividing the temperature gradient by the power dissipated, i.e.

$$\theta_i = \frac{T_{j\,max} - T_{case}}{P_C}\ °C/W$$

Assuming that the case is maintained at, say, 20°C by some means, then

$$\theta_i = \frac{80 - 20}{1000}\ °C/mW$$

$$= 0.06\ °C/mW$$

As the graph is a straight line, it doesn't matter whereabouts we take the ratio of temperature to power, we will always get the same value for θ_i.

THERMAL DIAGRAMS

So the intrinsic resistance is built in to the device and there's nothing we can do about that. What we can do is "short-circuit" the high thermal resistance present between the transistor case and the surrounding air; call this θ_d for the direct air-to-case connection. Now we can sketch a resistance diagram as shown in Fig. 5A. The thermal resistances act in series, and the heat generated at the junction has to work its way to the ambient level through the total $\theta_i + \theta_d$. θ_i is relatively small, but θ_d is large, hence the drop in temperature across θ_i is going to be small relative to the drop across θ_d; think of all this in terms of ohmic resistance and voltage drops. Hence the case temperature T_c is not going to be far removed from the junction temperature T_j, and our transistor is probably going to overheat.

What we want to do is put a resistance of low thermal value in *parallel* with θ_d; this will then bring the temperature of the case down towards the ambient where, theoretically, we ideally want it. This parallel resistance is the heat sink, so when we have mounted our transistor on it, the diagram looks like Fig. 5B. In most cases, since θ_s will be very low compared with θ_d, we can simplify matters and neglect the effect of θ_d altogether. From diagrams like this, heat sink problems can be solved as easily as d.c. circuits containing ohmic resistance.

SOME EXAMPLES

Suppose we have a silicon transistor with a rated $T_{j\,max}$ of 150°C. We are told this transistor will dissipate 20W when its case is held at a temperature of 100°C. What is the intrinsic thermal resistance of this transistor?

Well,

$$\theta_i = \frac{T_{j\,max} - T_{case}}{P_C}$$

$$= \frac{150 - 100}{20}$$

$$= 2.5\ °C/W$$

Suppose now we bolt this transistor to a plate of aluminium which has a thermal resistance of $\theta_s = 2.0$ °C/W. If the ambient temperature is 20°C, what is the greatest collector dissipation the transistor will tolerate?

The total thermal resistance from junction to air is the sum of θ_i and θ_s which equals 4.5 °C/W.

The overall temperature drop this time is $T_{j\,max} - T_a$, which is 150 – 20 = 130°C. So

$$P_{c\,max} = \frac{\text{Temp drop}}{\text{Total resistance}} = \frac{130}{4.5} = 28.9\text{W}$$

Now it nearly always happens that we have to insulate (electrically) the transistor case from the heat sink itself. We do this with either a mica or a silicone impregnated washer, usually with the addition of a smear of compound to help reduce the additional thermal resistance that the washer introduces into the circuit. Fig. 5C shows the situation this time; we have ignored θ_d for reasons already stated.

What effect does a washer have? Well, we should expect it to reduce the power dissipation at the collector as it has introduced resistance in series with the thermal path. Suppose the transistor mentioned above has a washer introduced where $\theta_w = 0.75$ °C/W. Then the total thermal resistance now becomes

$$\theta_i + \theta_w + \theta_s = 2.5 + 0.75 + 2.0 = 5.25\ °C/W$$

For the same ambient temperature T_a = 20°C, $T_{j\,max} - Ta$ remains at 130°C as before.

$$\text{But now } P_{c\,max} = \frac{130}{5.25} = 24.76\text{W}$$

So we have lost something like 4W power dissipation.

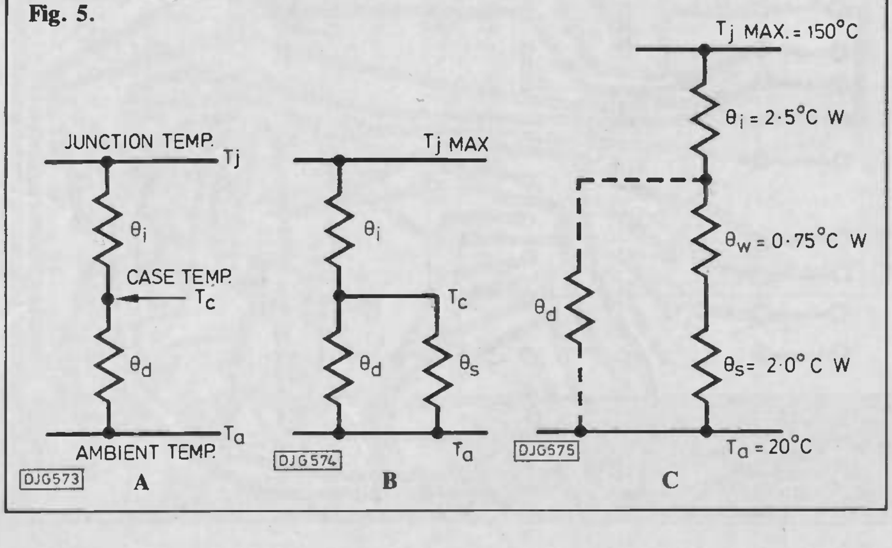
Things are helped if the heat sink is blackened. Most ready made heat sinks are blackened, but a home produced sink, besides being unfinned, will generally be made from a sheet of aluminium. It pays to spray the sheet with some matt black auto paint, but the areas where the transistor is bolted on are best left plain. If sufficient area of metal is involved, it makes spraying unnecessary. Thickness of the plate is not particularly critical. 16 gauge is adequate in most cases; it is the surface area which matters. And remember that *both* sides of the plate constitute the total radiating area.

As a rough and ready guide, a piece of 16 gauge aluminium measuring three inches square has a thermal resistance of about 8°C/W, while a piece measuring 6 inches square is about 3°C/W.

To get down to, say, 1.5°C/W you will need a piece of 14 gauge measuring eight inches square. All pieces are assumed to be blackened. If you use bright aluminium, you lose about 20 percent of the effective radiation. The sink doesn't have to be square as the above comments might have suggested; the area of the surface is the criterion. It is, however, advisable to make the sink so that the ratio of its sides is no greater than 2 to 1; that is, if you want a sink of area 50 square inches, it is O.K. to make it about 7 inches by 7 inches or 10 inches by 5 inches, but *not* 25 inches by 2 inches.

Finally, if you have to use an insulating washer, it is best to use the hard anodised aluminium washer or the silicone rubber reinforced with fibreglass washer as these have very low thermal resistances, typically 0.5 to 1.0°C/W compared with 1.5 to 2.0°C/W for mica. Mica washers also need heat sink compound which is not necessary with the silicone rubber type of insulator. PE

Fig. 5.



HOW TO USE THESE TRACKS

FIRST MAKE TRANSPARENT COPY

(We regret that we cannot supply transparent copies of PCB track layouts.)

Have a normal photocopy made, ensuring good dense black image. Spray ISOdraft Transparentiser onto copy in accordance with supplied instructions. ISOdraft is available from Cannon & Wrin, 68 High Street, Chislehurst, Kent. Tel: 01-467 0935.

NEXT PRINT ONTO PCB

Place positive transparency onto photosensitised copper clad fibre glass, cover with glass to ensure full contact. Expose to Ultraviolet light for several minutes (experiment to find correct time – depends on UV intensity).

Develop PCB in Sodium Hydroxide (available from chemists) until clean track image is seen, wash in warm running water. Etch in hot Ferric Chloride, frequently withdrawing PCB to allow exposure to air. Wash PCB in running water, dry, and drill holes, normally using a 1mm drill bit.

(PCB materials and chemicals are available from several sources – study advertisements.)

*** CAUTION – ENSURE THAT UV LIGHT DOES NOT SHINE INTO YOUR EYES. PROTECT HANDS WITH RUBBER GLOVES WHEN USING CHEMICALS.**

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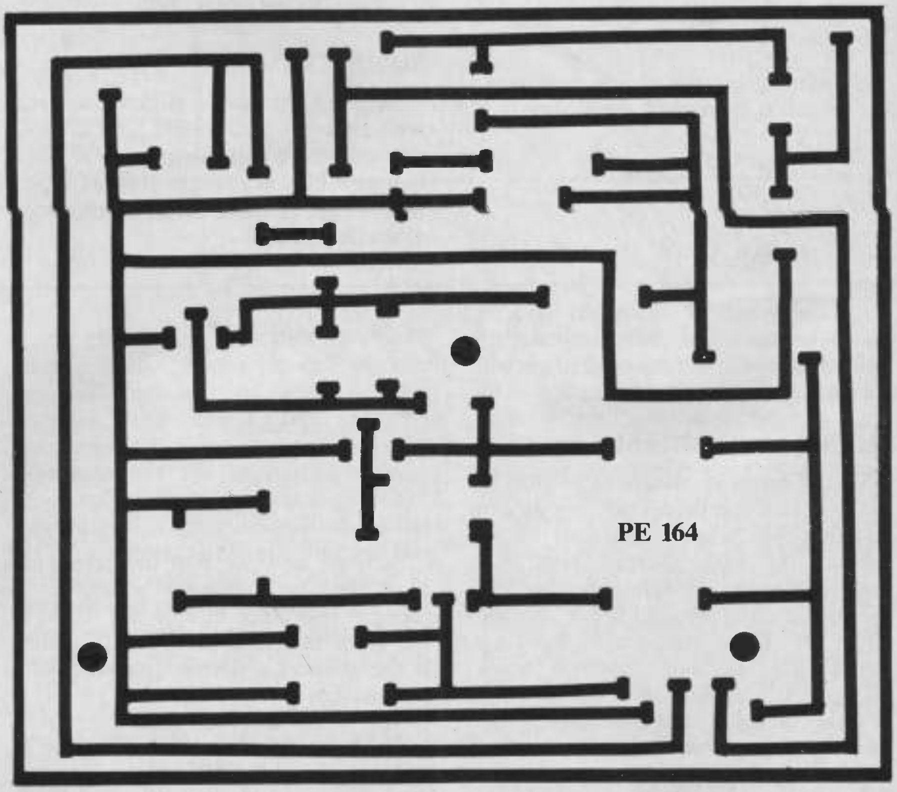

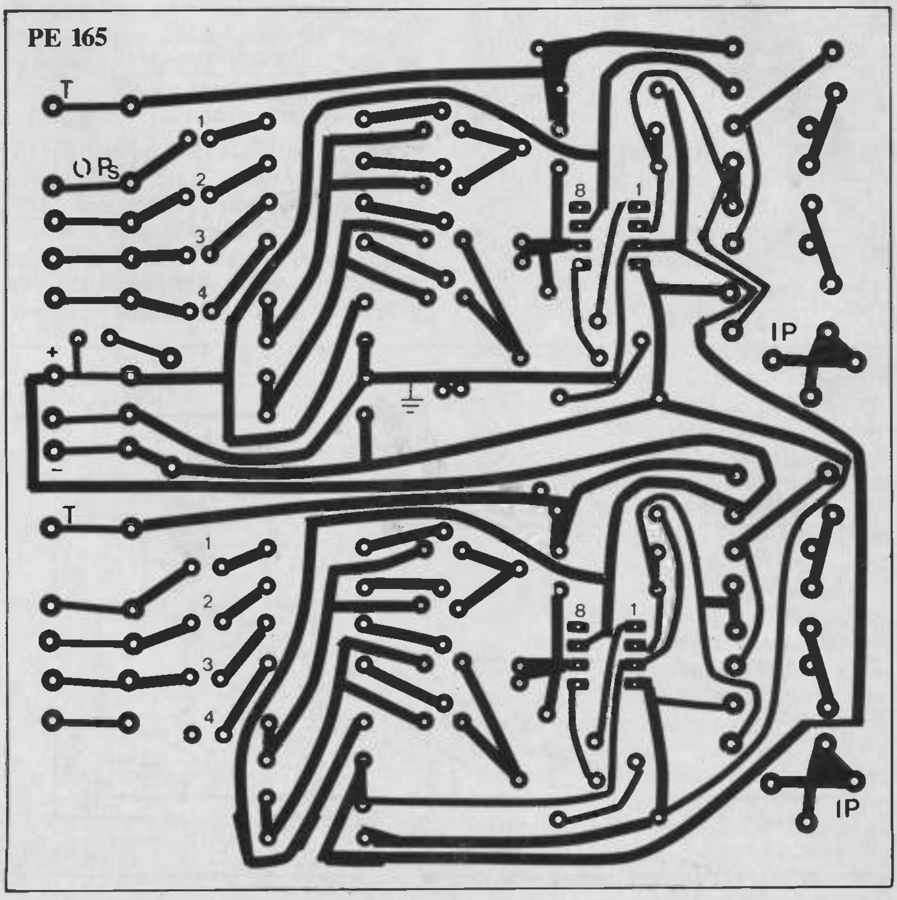

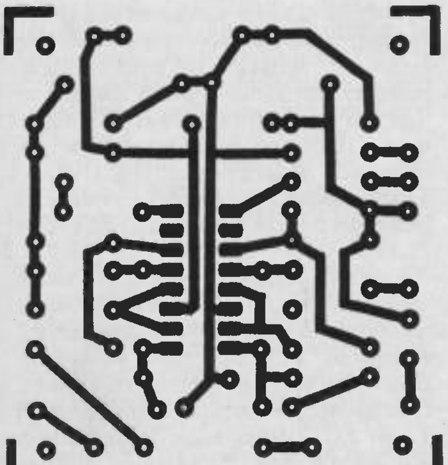

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BY ANDREW ARMSTRONG

THE THINKING PERSON'S VALVE

Fets score points over junction transistors in a number of ways, but in the post vacuum tube era few people really know how to get the best from them.

PARTS 2 and 3 of this series examined junction transistors and their applications. Field effect transistors (fets) receive the same treatment in part 4. As with part 2, some subjects must be covered very briefly or not at all to prevent this feature growing into a book.

Junction transistors have been in widespread use for a long time, and may be regarded as a mature technology. The rate of development of new devices has slowed considerably. The application of fets is still growing rapidly, and new improved devices are introduced on a regular basis. It is becoming increasingly relevant for the amateur constructor to understand the pros and cons of this growing range of devices as they begin to replace junction transistors in many applications.

FET TYPES

The classifications "small signal", "high power" and "low and high frequency" apply to fets and junction transistors alike. There are additional parameters which affect the choice of fets. A fet may be of the junction type, in which the gate is isolated from the channel by a reverse biased diode, or of the insulated gate variety in which the gate is isolated from the channel, normally by a layer of silicon oxide.

Junction fets are all depletion mode types, that is to say that they conduct if the gate voltage is zero, and the conduction is reduced by the application of reverse gate voltage (negative in the case of an n channel fet). Insulated gate fets, normally called metal oxide semiconductor field effect transistors (mosfets), may work on the enhancement or depletion principle. An enhancement mode fet is one which does not conduct at zero gate voltage, and starts to conduct on application of gate voltage (positive in the case of n channel mosfets).

In silicon technology most or all of the new devices recently introduced are mosfets, though some small signal high frequency gallium arsenide junction fets have been developed. Here we shall concentrate on silicon, and eschew further reference to gallium arsenide, indium phosphide and the like in the interest of brevity.

CHARACTERISTICS

Some readers may remember the days when glass bottles with electric fires inside were the mainstay of electronic equipment. Despite their inconvenience valves had some admirable characteristics, and fets share a number of the advantages of valves without the associated disadvantages. For example, though a junction transistor needs a continuous supply of base current to remain switched on, a fet simply requires a constant voltage applied to the gate terminal. The only gate current required in the normal course of events is that needed to charge the gate capacitance to the required voltage. The power gain available from fets of all types at moderate frequencies is much greater than that available from junction transistors just for this reason.

In most applications fets are inherently more linear than junction transistors. If a voltage signal is applied to the base of a transistor, the current flow in the base and in the collector is exponentially related to the applied voltage. In a fet on the other hand the drain current is proportionally related to the gate volt-age over a moderate range. The gain of a fet is expressed in terms of mutual conductance, represented by the symbol g_m, and expressed in microsiemens, millisiemens, or siemens (amps per volt).

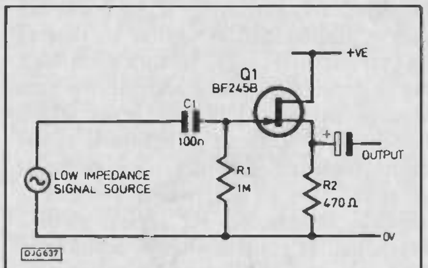


Fig. 35. *Source follower.*

Size for size most fets switch faster than their junction counterparts. There is no charge storage in the base because there is no base in which to store charge, so the switching time of a fet is largely governed by the charge and discharge time of the gate. This can be a limitation in large power devices because there may be a very high capacitance and a significant resistance in the gate.

There is another advantage to the use of fets in some applications. Because fets work on majority rather than minority charge carriers the mechanism of noise generation is different from that of junction transistors, and the overall noise can be lower if the input and output impedances are correctly matched. This is mostly of interest in rf applications, but some of the hi-fi fraternity would have you believe that because there are more electrons moving slower (in effect) in a fet than in a junction transistor at any given current, a type of subtle distortion which occurs in junction transistors should be much reduced in fets. The theory is that distortion is introduced by only being able to have either 1000 electrons or 1001, rather than, say, 1000.475, and that this is reduced in fets because the choice is between larger numbers of electrons. They may even have a point, but until we have perfect air molecules to transmit the sound I wouldn't get excited about it. *(Long live practical sanity! Ed.)*

THE DOWNSIDE

So far, it would appear that fets violate the law of the conservation of misery, but there are some snags. One problem is that fets have been more expensive and less available than their junction counterparts. This drawback is fast disappearing. There are also applications in which the current operated junction transistor is more useful than the voltage operated fet. In low voltage low impedance circuits fet cannot give of their best, and if only a 2V drive signal is available fets will not usually switch at all well.

Fig.35 shows a simple example of an application for which fets of any type are ill suited. In this application the most important characteristic is the g_m of the device. In order to provide a low output impedance, the gate to source voltage must not vary much as load current varies. A mutual conductance of 2ms will give a change of 0.5V/mA, or the equivalent of 500Ω in series with the source. This would only be a minor problem if this were the whole story, but the better linearity of the fet is only relative. The effective resistance in series with the source depends on the current and this gives rise to waveform distortion.

Biasing fets is difficult as well. A junction transistor has a more or less predictable base-emitter forward voltage drop regardless of its gain. For example, one method of voltage biasing, in which the base is biased to a level of base emitter voltage plus forward drop in emitter resistor. This works with emitter resistor voltage not much greater than forward base voltage because the base emitter voltage is about the same from transistor to transistor.

The gate voltage required for a given current in a fet is much different from fet to fet, so a circuit designed with fixed component values may be biased right with one fet but not with the next one out of the box. For example with junction fets (which are of course depletion mode types) there is a specific gate voltage at which the fet is turned off and no current flows. This is known as the pinch off voltage and it can be different by a factor of 3:1 for a given fet type. Another variable characteristic is the Idss, the saturation drain current. For a junction fet this is the current which will flow if the gate voltage is the same as the source voltage. For a 2N3819 n-channel fet this is specified as between 2mA and 20mA.

Most circuits using a 2N3819 would require a resistor to be selected on test, or alternatively would use a preset potentiometer to set the bias. Luckily there are many more recent devices whose parameters are a little more closely specified, and which can be used without adjustable bias in appropriately designed circuits.

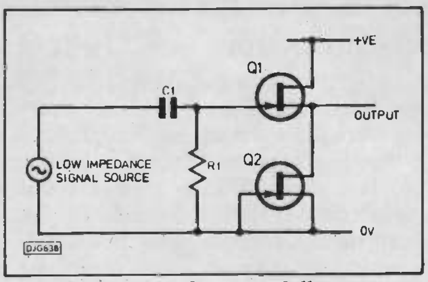


Fig. 36. *Improved source follower.*

JUNCTION FET APPLICATIONS

Perhaps the simplest possible linear fet circuit is the source follower. It is equivalent to the emitter follower configuration for junction transistors, but it is less effective. An improved version of the circuit is shown in Fig.36. In this configuration, the source resistor is replaced by a fet connected so as to provide a constant current, equal to the Idss of the device. As can be seen from the sample characteristic curves shown in Fig.37, so long as the drain-source voltage of a fet is high enough to clear the resistive region, the drain current changes very little with changes in drain-source voltage.

The use of a constant current source in this circuit removes the problem mentioned earlier, that the source

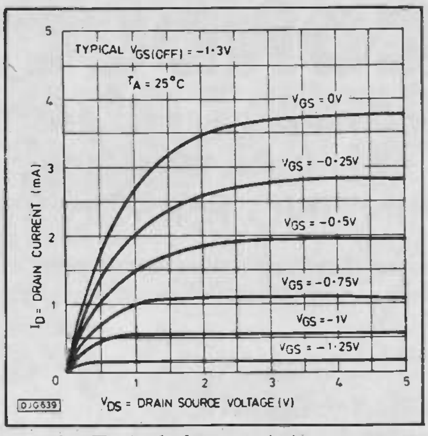


Fig. 37. *Typical characteristics curves.*

output impedance acts as part of a potential divider network of questionable linearity which attenuates and distorts the output signal. Of course, if a moderately low output load impedance is used, this advantage is nullified, so that all we really have here is a unity voltage gain buffer with a high input impedance and only a fairly high output impedance.

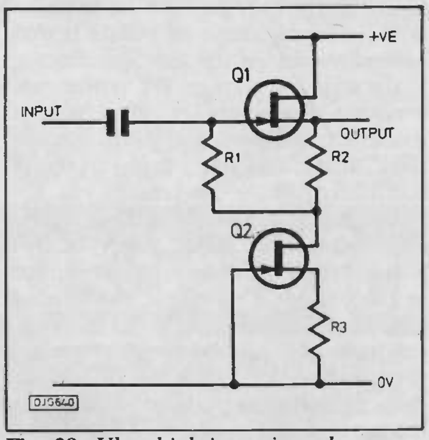


Fig. 38. *Ultra high input impedance source follower.*

This idea can be taken further to come up with something really useful, as shown in Fig.38. Here, the input impedance is extremely high, while the output impedance is similar to that of the circuit in Fig.36. In this ultra high input impedance configuration, the gate voltage is derived from a point which has almost the same signal on it as the input terminal. Hence, no significant current flows in R1, when a signal is applied. This makes R1 appear to be a much higher resistor than it actually is. The presence of R2 permits reasonable dc biasing, and provides just enough signal attenuation to prevent any danger of instability. In this circuit, the constant current sink, Q2, is biased to provide a current lower than its Idss by the addition of R3. This simple technique can permit a fet to provide a wide range of preset constant currents.

So far, the circuits we have looked at have not provided voltage gain. The circuit shown in Fig.39 provides a considerable ac voltage gain with high

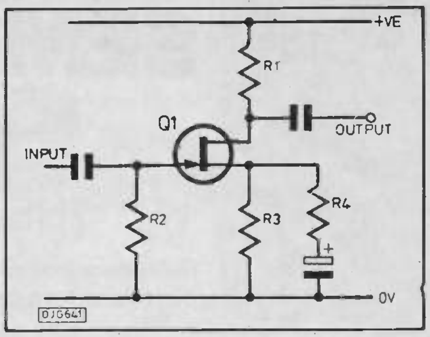


Fig. 39. *Inverting amplifier with voltage gain.*

input impedance, fairly high output impedance, and a moderate linearity. The ac gain is set by the ratio of R1 to R3 in parallel with R4. So long as this latter value is much higher than the source output impedance, the linearity is good. Once again, however, the tendency is for the limited g_m of most junction fets to limit the usefulness of this simple type of circuit.

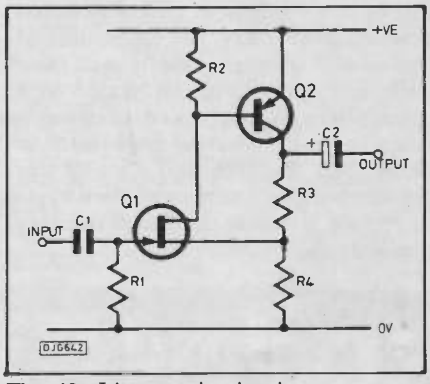
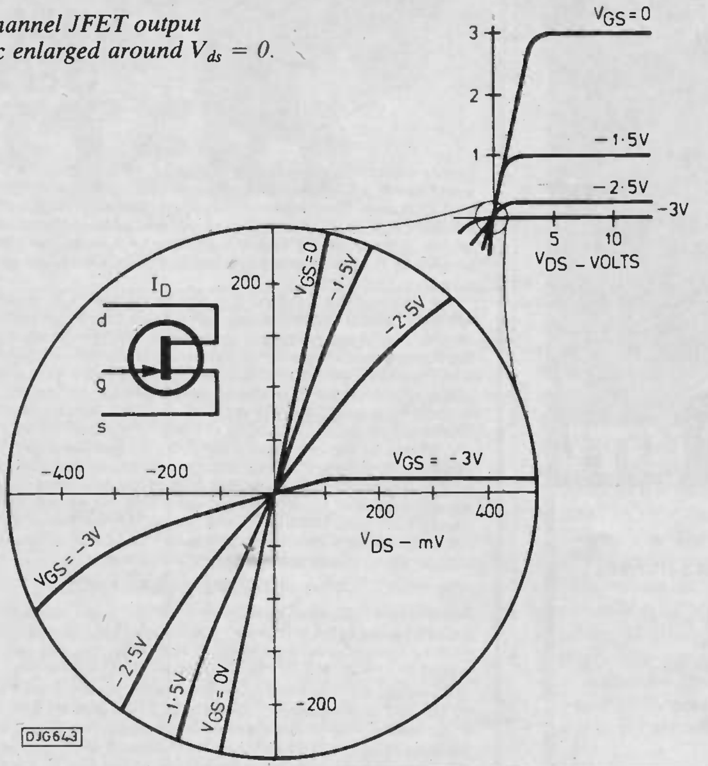


Fig. 40. *Linear gain circuit.*

Fig.40 shows a circuit in which a good voltage gain and linearity are provided, in which the bias point is accurately set, and in which the virtues of the fet are put to good use while the vices are minimised. The quiescent current of the fet is set by the value of R2 and the base/emitter voltage of Q2. Assuming that the gain of Q2 is reasonably high, so that its base current is fairly small compared with the current in R2, then the drain current of Q1 will settle to whatever level is required to produce approximately 0.6 volts across R2. The extra gain provided by Q2 allows a fair amount of negative feedback, so that the signal at the junction of R3 and R4 is virtually identical to the input signal. This presents a high impedance to the source of the fet, and hence makes it work linearly, setting the gain of the circuit to approximately (R3 + R4)/R4. This is very much like the formula for the gain of an op amp circuit, but it is less accurate in this circuit because the loop gain is less. Still, the action of the feedback gives a reasonable approximation if the current in R3 and R4 is much greater than the current in Q1. In this situation, the feedback lowers the output impedance on the collector of Q2 to quite a low level.

Fig. 41. *N-channel JFET output characteristic enlarged around $V_{ds} = 0$.*



VARIABLE RESISTANCE

Another difference between fets and bipolar transistors is in the performance at very low drain-source voltages. At voltages of up to a few hundred millivolts, fets pass a current proportional to the drain-source voltage, though bipolar transistors are non-linear. This characteristic allows fets to serve as analogue signal switches, voltage controlled attenuators, or in any other application in which a variable resistance is needed. The expanded section of fet characteristic shown in Fig.41. Applications of this principle are shown in Figs. 40 to 42.

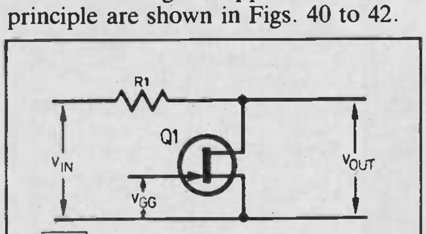


Fig. 42. *Simple voltage controlled attenuator.*

The simple attenuator shown in Fig.42 causes significant distortion, though there are some applications in which this would not matter. That there will be distortion is clear from a close inspection of Fig.41. The reason for the distortion is that increasing drain-source voltage tends to pinch off the channel, as illustrated in part 1 of this series. The incremental resistance of the device is actually increased by this effect, hence the distortion. This effect can be countered by feeding some of the signal to the gate, so that a rise in gate voltage will offset the rise in drain voltage.

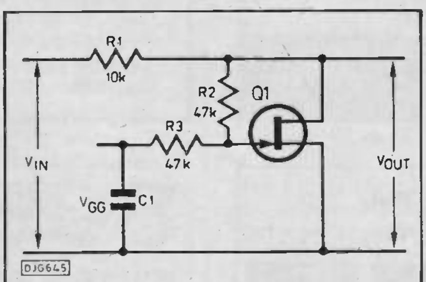


Fig. 43. *A linearised voltage controlled attenuator.*

A circuit employing this principle is shown in Fig.43. R2 and R3 are used to apply half of the drain signal voltage to the gate. The values of R2 and R3 are a compromise between loading the drain signal too much and having such a high impedance on the gate of Q1 that it picks up a lot of radiated electrical noise. The use of this circuit technique can reduce the distortion from 10% (mainly second harmonic) to approximately 1% with a particular signal level. Distortion level is of course signal dependent, but too low a signal level will give a poor signal to noise ratio, which will tend to nullify any advantages gained from lower distortion.

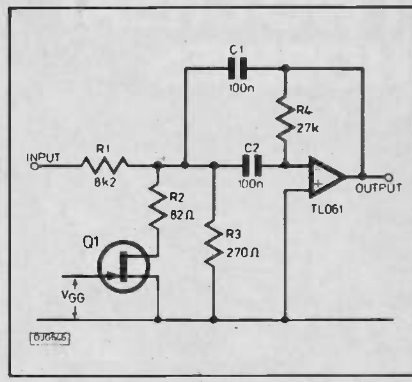


Fig. 44. *Voltage controlled bandpass filter. Q increases with frequency. F = 500Hz, Q = 6. F = 1000Hz, Q = 10.*

Fig.44 illustrates a voltage controlled filter which is tuned by varying the resistance of a fet. The maximum frequency is determined by the lowest possible fet resistance in series with R2, while the minimum is determined by the resistance of R3. The filter shape is affected by the fet resistance, but this is not too serious a problem over a modest tuning range — perhaps a maximum of an octave.

Apart from having a fairly linear characteristic at low drain-source voltage levels, junction fets really score in two specific ways: one is that they have a very high input impedance, and the other is that they have a very high inherent output impedance. Certain types of load benefit strongly from the high output impedance. These are the applications in which one might use a cascode circuit with ordinary junction transistors. For example, if a high Q tuned circuit is connected to the drain of a fet in an rf amplifier circuit, the high drain output impedance will not significantly load the circuit and hence reduce the Q value.

To illustrate this point, compare the bipolar if amplifier stages shown in Fig.45 with the fet stages shown in Fig.46. In the fet circuit, no impedance matching is required, and thus the design of the tuned circuits is simplified. The disadvantage associated with this is that the Miller capacitance (drain-gate capacitance) has more effect on performance, but in most applications this problem is not serious. Where it does matter, the solution is often to use a dual gate mosfet, which will be covered in part 5 in two months time along with power mosfets. PE

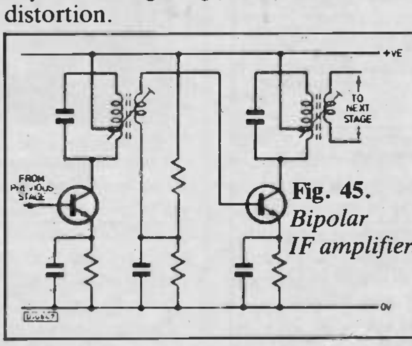


Fig. 45. *Bipolar IF amplifier.*

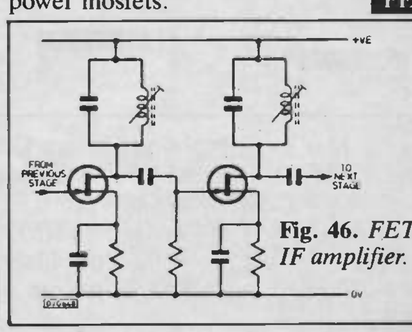


Fig. 46. *FET IF amplifier.*

READERS' LETTERS

HEARING AGE

Dear Editor

I was interested to read the item "Hear hear!" on page 4 of the August issue as this is a topic which has interested me for some time. I do not believe that age related hearing loss is the correct explanation for the complaints about the reduced signal to noise ratio inherent in many TV productions.

In the early days of information theory this situation was known as the "cocktail party problem". Although semantic content plays a part I believe the problem arises because of the loss of spatial information when listening to sound from a single loudspeaker. Normally our binaural hearing helps us to select the information of interest.

This is supported by a common experience. When listening to a public speaker there is little loss of information. If one listens to a tape recording of the same occasion however, the replay is marred by a host of other sounds — coughing, fidgeting, traffic outside the window, footsteps outside the room, etc. which were successfully filtered out in the live situation.

Also, in my experience, the quality of sound on many modern TV productions is inferior to older ones. For instance the sound on the recent showing of the 1930's Fred Astaire films was excellent, but that on the recent ITV serial "Floodtide" was very poor.

The reduced signal to noise ratio now also seems to be infiltrating the visual domain as well as the auditory one. Examples are the backcloth designs to many productions, for example the "Through the Keyhole" production on Channel 3 hosted by David Frost and the "So we bought a computer" series on Channel 4 which started at least with a large keyboard as a somewhat distracting backcloth.

I am collecting information to try to counter the view that these annoyances are age related and would be grateful if you would tell me an address for the group investigating the problem.

John C. Shaw Ph.D., Chidham

AN EDITOR'S SOUND-OFF

Dear Mr Shaw

As an ex-film editor I too was particularly interested by the report, and share some of your views.

Most certainly I believe that binaural focussing of attention is a key to selective separation of wanted and unwanted sounds. Visual understanding though is related to the simplicity of the two dimensional image, and to the length of time in which to study it.

Film makers often work to a golden rule that information should be imparted in as many forms as possible. (I have no experience of TV production, but it appears that similar rules apply.) There are five main methods of doing this, four of which are the most frequently combined.

To generalise, initially there is the visual content, which by its nature can impart information more rapidly than any other means. It is very true that 'a picture paints a thousand words'. The spoken word, either in the form of dialogue, or as a commentary, supplements the visual information, usually by adding further data or confirming that seen. Subtitles also serve a similar purpose, though are less generally used, except to replace the spoken word, as is done when foreign language films are screened.

The use of music is supposed to work upon the emotions to reinforce the message, and to set the mood. The whole character of a scene can be totally changed by different types of music. To a good film maker, the correct selection of music is of vital importance, and many hours can be spent ensuring that the most appropriate is chosen.

Sound effects are used to give reality to a scene, not just those coinciding with visual action but also the choice of 'off-screen' effects to broaden the depicted environment.

It is usually believed by film makers that maximum impact is achieved by enhancing the overall visual and auditory content of a production through combining these options. However, two principle points always bothered me about this, the first of which is related to equipment quality.

Film makers have at their disposal the highest quality equipment available, both for viewing images, and listening to multiple sound tracks in a mixing studio. Under these conditions, commentary, music and effects are mixed so that they sound correctly balanced to the technicians. Although mixed sound tracks may also be played through lower quality reproduction equipment as a check against how things might sound and look elsewhere, the equipment and the acoustics cannot cater for all conditions experienced by end users. It is assumed though, that if the quality starts off by being the best possible, then sub-standard equipment will give a reasonable imitation.

This may well be true in theory, but in practise "normal" conditions can muffle and distort the sound, possibly resulting in auditory confusion through the inability to separate the sounds. The confusion can be further aggravated by visual distortion, and also by mental perception problems.

Perception of filmic information is more complex than just the ability to separate 'cocktail party' chatter. Four or five levels of information are being imparted, through vision, commentary, sound effects, music and possibly subtitles. The brain is being expected to separate and understand all of these messages. Though some discrimination can be done subconsciously, vision, commentary and subtitles may all be giving separate, but essential information. It can be extremely difficult to concentrate on, and think about all the messages, as we are frequently expected to do, especially in documentary reports.

Add to this the shortcomings of the equipment and conditions under which this mental contortionism has to be performed, and it is not surprising that information is not always apparent to an audience.

My second concern is that the age factor does also come into it, on two levels. It is well established that the frequency bandwidth of the human ear decreases with age. As a result more information can be lost, and the audio content become muddled. Many older people find it necessary to increase the treble content of the sound by means of the tone control, to compensate for apparently muffled speech. They may well also need to increase the volume beyond that at which the equipment prefers to operate, resulting in electronically generated distortion. Further more, as people become older, their ability to rapidly analyse meaning can also become reduced. It is often necessary to talk to an older person at a slow rate so that not only can they hear you distinctly, but also have time to interpret and think about what is being said.

In addition to difficult audio conditions, if visual overloading is present as well, interpretation becomes even more complex. As many levels of sound data are used to create impact, so multiple visual data paths are also combined to emphasise a message. Apart from subtitles, split screen images are frequently used for this purpose, on occasion many of them appearing simultaneously. The intention here though, is not that all should be looked at and understood, but rather that they should give an overall impression of the message. Despite this, it can be confusing, and frustrating, to have interesting images in view, but not be able to study them in detail.

Your comment on older productions sounding clearer than recent ones interests me. The 1930s production mentioned would have been originally recorded on an optical (photographic) track, the bandwidth of which is inherently lower than obtainable with magnetic tape. I forget the figures, but I believe that the upper limit is well below 5kHz, and that the bass response was also well curtailed. This restriction, and the optical recording equipment used could also place severe limits on the overall fullness of mixed tracks. Consequently, your comment suggests that the simplicity of the sound track made it easier to hear, either through limitations of restricted hearing, or the abilities of the reproduction equipment.

It may be a sign that even editors age, but there are times when I too would welcome simpler audio-visual messages, even though in the past I have been guilty of attempting the multiple impact approach through film based information. I would also welcome a ban on vertically striped backgrounds, shirts and ties, since my own set is prone to vision-on-sound problems that cause even more aggravation!

To answer your question though, further information on the research group's activities can be obtained from Henry Price, BBC TV, Broadcasting House, London W1A 1AA.

Ed.

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

If you have any bright ideas that you think might interest other readers, why not send them, neatly drawns and type written, for possible inclusion in this section?

"INGENUITY UNLIMITED"

BY ENTHUSIASTIC READERS

A Combination Lock

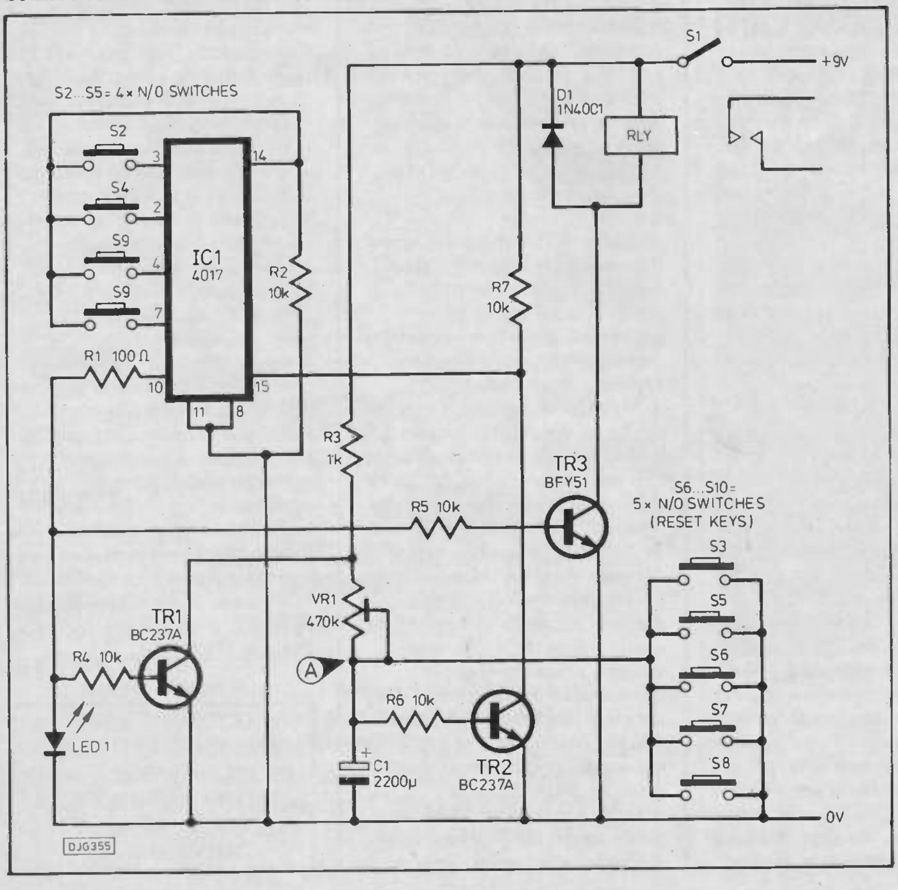
THIS circuit was designed in response to a request from one of my friends. He wanted to build a combination lock for his workshop, so that it will open the door when he keyed in the correct code. This circuit is a very simple design, based on the CMOS 4017 decade counter.

The keyboard has nine keys for the digits 1-9, (but more keys could be put in if required, using them as reset keys). Four keys are used to key in the code. One of each of the four keys' connection is connected to pin 3,2,4,7 of IC1 and the other connections are all connected to the CLK pin of IC1, pin 14. The position of these keys determines the sequence in which the code has to be keyed in. The circuit diagram shows the connection for the code number 2491. The rest of the keys are used as reset keys. So when any of these keys are pressed, it will reset the opening sequence of IC1. One of each of these keys' connections are connected to point 'A', (shown in diagram) and the other connections are connected to the ground.

The circuit automatically resets itself at switch on. This is so because C1 has to slowly charge up through VR1 and R3, and before C1 reaches 0.6V, Tr2 will be off, so the reset pin of IC1, pin 15, will be high. When Tr2 turns on, ie, C1 has reached 0.6V, pin 15 of IC1 will go low, so the code could now be keyed in. If the keys are pressed together, the reset keys will reset IC1. If the four code keys are pressed together, pin 14 will still be low because the only high output from IC1 will be pulled low by the other three outputs.

When the correct code is keyed in, in the right sequence, pin 10 of IC1 will go high, LED1 will light up and Tr3 and Tr1 will turn on. Tr3 will switch on the relay and Tr1 will ground the point at the junction between R3 and VR1. C1 will slowly discharge through VR1 and when 1T has discharged below 0.6v, Tr2 will switch off and reset IC1, ie, switch off the relay. The delay time could be varied by varying VR1.

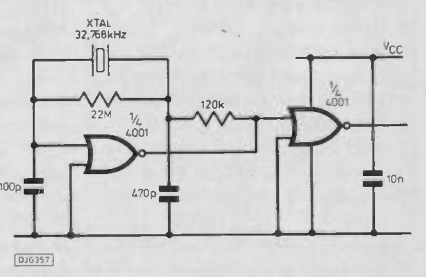
J. Lam, Dagenham



Crystal Oscillator

THE circuit shown here is a micro-power crystal controlled oscillator which was designed for use with CMOS circuitry. The circuit as shown requires only 45μA at 5 volts. The power consumption of CMOS devices is proportional to operating frequency. This is because power is consumed charging and discharging on-chip capacitances and because when switching there is a short time when both the n-channel and p-channel transistors are partially conducting. Bearing this in mind, a low power oscillator must operate at relatively low frequency, thus the 32kHz crystal in this design. The number 32,768 is 2^{15} thus the output of the oscillator may be divided down to 1 Hz using 15 binary dividers. Other frequencies are obtainable by changing the crystal. A decoupling capacitor should be mounted across the supply pins.

E. Hunter, Dundee



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Monica or Oboe RAF. Any info. most welcome, or old circuits relating to these receivers. Mr. H. Hatton, 6 Tuscan House, Knottisford Street, London E2 0PR.

Hitachi V222 Oscilloscope, dual trace, full industry specification, never used, boxed + probes + manual. £300. A. Cowell. Tel (evenings) Great Dunmow 5076

Tektronix type 564 storage oscilloscope: dual trace with screen store, probe included. £150 ono. R. Hollands, 56 Worlds End Lane, Orpington, Kent, BR6 6AH. Tel: 0689 57596.

Wanted. Ferrograph or capstan motor for ferrograph model 2A/NH. J. Taggart, 2 Sandown Lane, Wavertree, Liverpool L15 8HY. Tel: 051-734 1302.

Eproms for sale. 2716, 2516, 2732, all £1 each inc. postage and packing. D. Keene, 16 Leasowes Ave. Green Lane, Coventry, CV3 6BH.

247 PE Mags 67-88 offers to B.S. Hewson 35 Knox Road, Forest Gate, London E7. Tel: 01-555 3796.

Wanted: ZX Spectrum cheap or free, in any condition or bare PCB only. Please. I'll pay postage. R. Kaminsky, 90 Helston road, Penryn, Cornwall, TR10 8NG.

Murphy FM/LW/MW radio (boxed) £12 Five high quality amplifier modules & directions 50 Watt/£6 - 100 Watt/£8. Mr. Frost, 1 Regent Road, Ilkley, Yorkshire.

Wanted Oric Microdisk or compatible drive with DOS also BBC DOS listing and CBM 1551 drive. M.J. Last, 7 Peacock Rise, Ixworth, Bury St. Edmunds, Suffolk. Tel: 0359-30858.

BBC B OS1.2 40/80 SDD. Fitted ROMS wordwise, spellcheck £250. Printer £150. Phone after 6.30 pm. 0933 678970.

Wanted: LNC's for 12GHz SAT-TV reception. For sale: surplus components, schematics, instruments, various parts. Mr. Gebles Bela, Gorenjska 17A, 24000 Subotica, Yugoslavia.

For Sale: short range experimental video transmitter, use with computers & video games. Price £25. Contact Syed Shahid Raza, House No. 599, Block 20, Fedrac 'B' Area, Giulistan-e-Mustafa, Karachi-no.'38', Pakistan.

Maplin Reg. 2A PSU £35. Ultraviolet light box £40. Good condition. Will post. Mr. G.A. Hope, 72 Picket Close, Fordingbridge, Hants SP6 1JY.

MAP80 (VFC) Video and floppy card + CPM2.2 for NASCOM/GEMINIs £160 ono. GM802 64K RAM £45ono 75W PSU (switching) £35ono. Contact: I. Cullen, High Hill Farm, Nettlestead, Ipswich, Suffolk, Tel. (0473) 831353.

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Wanted: Info or equivalent supplier TMS 1600 SM 807. P.A. Hern, 2 Arthur Road, Bexhill on Sea, Sussex TN39 3PN.

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In part one some of the theoretical aspects of designing an intercom were discussed. This month the article is completed by describing a practical working two-station intercom.

TEACHER TALKBACK

PART TWO BY TIM PIKE

EVEN SLAVES CAN CHAT TO MASTERS

The only other practical improvement worthy of consideration is another look at the amplifier design. In developing the three stage circuit of Fig.6, no thought was given to the overall requirements of the circuit. We arrived at Fig.6 by adding more amplification through identical cascaded transistor stages. Although this simple approach will work, better results should be obtained if more specialised components are used.

Fig.14 gives a much better amplifier design although still based around three transistors. If you followed the *"Teacher Radio"* GCSE article in PE Dec. you will notice great similarities between the amplifier circuit used there for the radio and the heart of the unit suggested here.

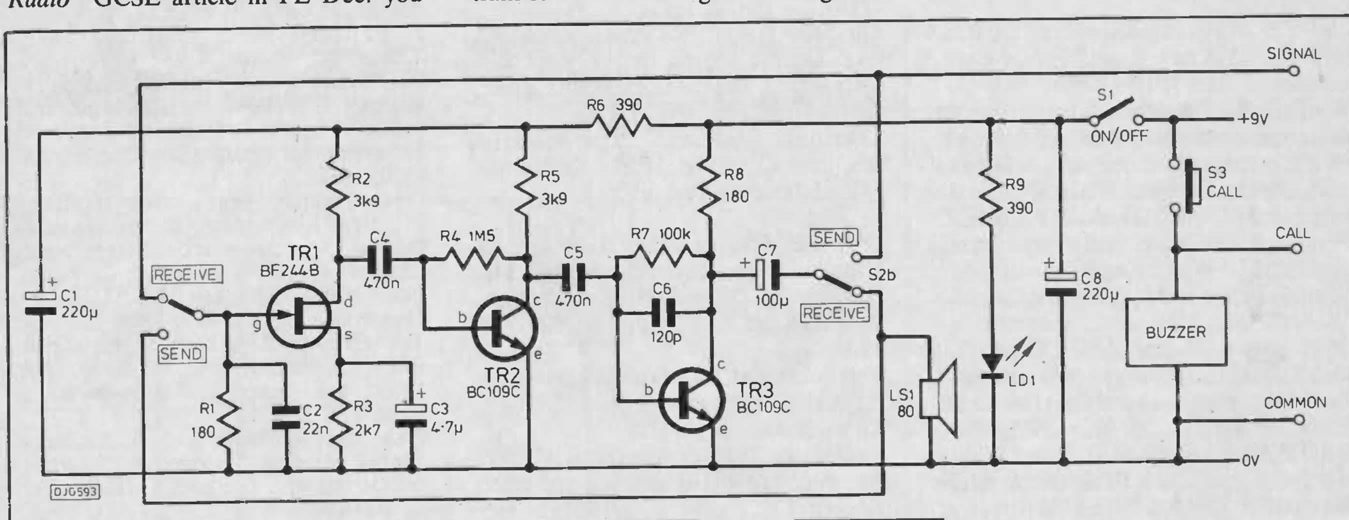
The input stage uses a field effect transistor (fet) to provide a low noise voltage gain of about 20dB – this corresponds to a linear gain of about 10 times. The fet itself has a very high input impedance of 100 M. The inclusion of the gate bias resistor R1 provides a dc path to the gate of fet under all conditions. Capacitor C2 provides some rf filtering which is important because high gain circuits of this type invariably suffer from RF breakthrough. This means that the circuit detects unwanted radio signals and amplifies them along with the desired audio information.

Although there is no diode detector in this circuit, there are other semiconductor devices (base-emitter junctions) which will serve this purpose. Unless we are careful the intercom can end up as a pretty good radio receiver!

Capacitor, C4 couples the output from the fet to the first bipolar transistor which is being used in common emitter configuration. Capacitor, C5 couples the output of transistor TR2 into the base of transistor TR3. This again is being used in common emitter configuration but with lower values of load resistor (R8) and bias resistor (R7) to allow for sufficient current to drive the loudspeaker. This is the same argument as was presented earlier when discussing Fig.8. The output power of the amplifier is only about 50mW but this is perfectly adequate for this sort of application.

Following the approach developed in the system diagram of Fig.13 we require four switches. S1 is a simple on/off toggle switch to disable the amplifier when the unit is not required to be left on. S2 is the double pole double throw selection switch which the master control operates to toggle between "send" and "receive". S3 and S4 are push-to-make "call" switches, one for each unit.

Notice that when S1 is switched off, no current will be flowing from either battery. The remote unit can operate its "call" button even when S1 is switched off. Both buzzers will sound when either call button is pressed. This serves as a battery test and would give the operators a good idea of battery condition especially as the batteries begin to reach the end of their effective life.



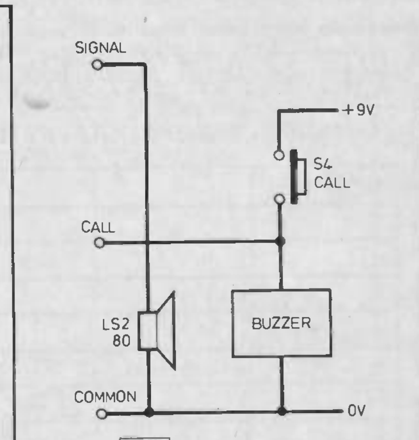


Fig. 14. *Above: Full circuit of the master Teacher Talkback unit. Bottom Right: Circuit for the remote station.*

off. Both buzzers will sound when either call button is pressed. This serves as a battery test and would give the operators a good idea of battery condition especially as the batteries begin to reach the end of their effective life.

Although not essential it is probably desirable if S2 is of the biased toggle type because it makes for easier operation.

Ideally the three-way cable needed to connect the units should be a two core screened cable with the screen braid being used for the 0V line. This again will help to ensure that rf breakthrough does not occur.

CONSTRUCTION AND TESTING

Low profile, sloping panel boxes are traditionally used for this sort of application. Although the remote station will house only the loudspeaker, the buzzer and the call switch, it is probably worth having two identical boxes. Certainly the result will look more professional if you keep the hardware uniform. Cable length is always deceptive and of course will change if you wish to relocate the system at any time. For this reason permanently wired connections are awkward. I would prefer to see a simple plug and socket arrangement at each end of the cable – a stereo jack and socket of the 0.25in type will do very nicely.

A suitable printed circuit design for the amplifier is given in Fig.15 but do try to develop your own designs. This is a relatively simple pcb to work on.

Testing is likely to be divided into two main areas. Firstly of course, the amplifier which could easily be tested independantly by injecting a very small signal from a generator, running at perhaps 1kHz, into the circuit at the gate of TR1. An oscilloscope would then be needed to trace the signal through its various stages of amplification and eventually to detect it emerging through capacitor, C7.

In some ways it is more likely that a total lack of response from the circuit is due to a problem with one of the many interconnections or switches. Each of these pathways must be checked for continuity if such a problem is suspected.

High impedance loudspeaker units (80Ω or 64Ω) will give much better results than 8Ω units.

Whichever one of the various designs given you decide to build, I wish you many hours of enjoyable 'chat' once you have your finished product. PE

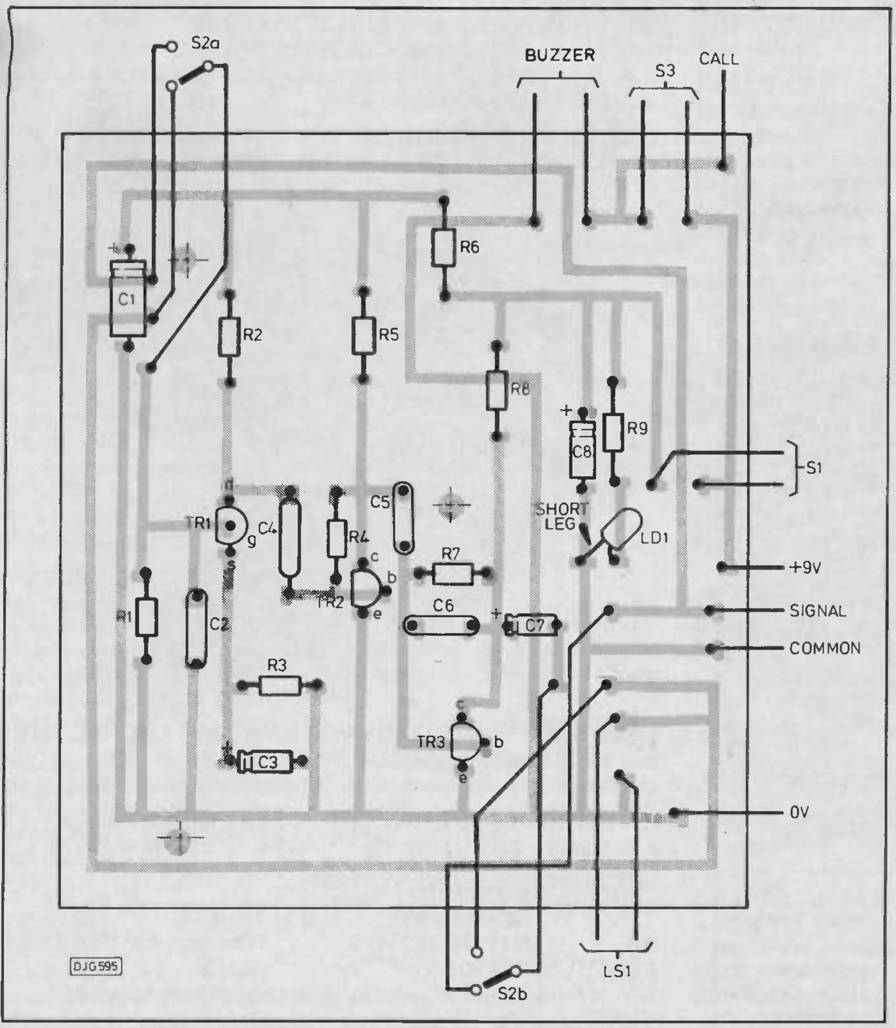


Fig. 15. *Printed circuit board layout details.*

COMPONENTS

RESISTORS

R1,R8	180Ω (2 off)
R2,R5	3k9 (2 off)
R3	2k7
R4	1M5
R6,R9	390Ω (2 off)
R7	100k

All resistors ¼W 5%

CAPACITORS

C1,C8	22μF 10V (2 off)
C2	22n plastic foil
C3	4.7μF 10V
C4,C5	470nF plastic foil (2 off)
C6	120pF ceramic plate
C7	100μF 10V

SEMICONDUCTORS

TR1	BF224B
TR2,TR3	BC109C (2 off)
D1	Red led

SWITCHES

S1	spst toggle
S2	dpdt biased toggle
S3,S4	Push-to-make switch (2 off)

MISCELLANEOUS

LS1,LS2	Miniature 80Ω loudspeaker (2 off)
BZ1,BZ2	Miniature 6V buzzer (2 off)

Two PP3 batteries and connectors, two boxes, two 0.25in stereo jack plugs and sockets, length two core screened cable, wire, solder, printed circuit board.

The pcb is available through the PE PCB Service.

Tim Pike is Deputy Headmaster of the Ramsden School for Boys in Orpington, Kent, and has taught Electronics to 'A' level standard for thirteen years.

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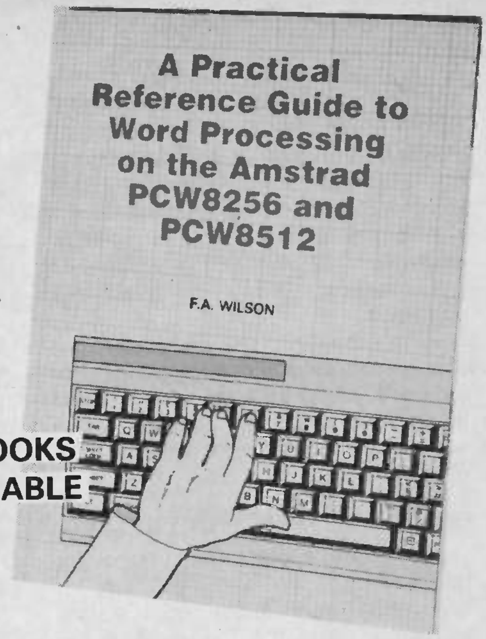

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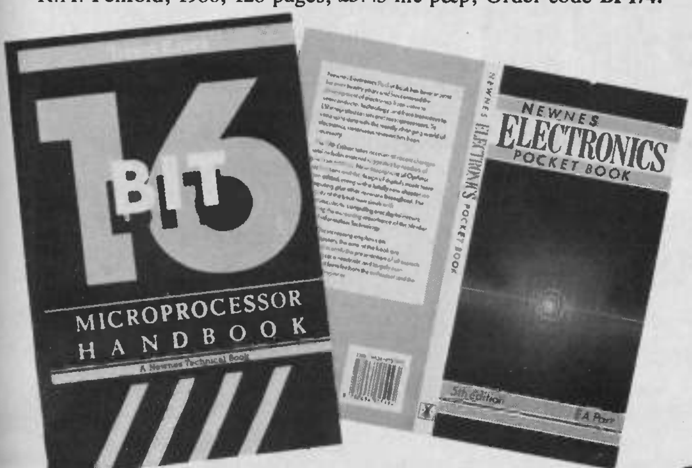

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OUR REGULAR LOOK AT ASTRONOMY

SPACEWATCH

BY DR PATRICK MOORE

Mars and more distant objects are providing food for speculation in the near future, and the variable star Mira Ceti will be visible to the naked eye for a while.

A new millisecond pulsar has been found, this time in the cluster M4 near Antares. The discovery was made by A. Brinklow, A. Lyne, J. Biggs and M. Ashworth, using the 250-foot Lovell Telescope at Jodrell Bank. The spin rate is 90 revolutions per second. It is generally believed that millisecond pulsars are old, and have been 'speeded up' by interactions with a companion star. This is only the second millisecond pulsar to be found in a globular cluster; I will have more to say about it in a future article.

Plans for the launch of the Russian Mars probe are well under way, and if all goes well the vehicle will be sent up during the coming summer. It is intended to explore not only Mars itself, but also the larger of the two dwarf moons, Phobos, which is below 20 miles in diameter, and is a dark, irregularly-shaped rock object. The 'descent module' will land on Phobos, attaching itself by a harpoon-like device; the 'frog' will literally hop around the surface of the tiny satellite. Of course, Phobos has a very weak gravitational pull, so that 'landing' there is really more in the nature of a docking operation.

Another satellite which will be very much in the news in 1989, if not 1988, is Triton, the senior attendant of Neptune. It is larger than our Moon, and, like Titan in Saturn's system, is believed to have a substantial atmosphere. Two American astronomers, M. Delitsky and W. Reid, now suggests that the surface may be partly covered with a sea of intensely cold liquid nitrogen and methane, on which floats a 'scum' of organic compounds. They even say that when Voyager 2 by-passes the satellite, in August next year, it will show "plains of white and coloured organic deposits and, maybe, the glint of a distant Sun reflected off a calm nitrogen sea". We must wait and see, but in some ways Triton may prove even more interesting than Neptune itself!

On the debit side, we greatly regret to report the death of one of Britain's most distinguished astronomers, Dr. D.H. Sadler of the Royal Greenwich Observatory and a Past President of the Royal Astronomical Society. Dr. Sadler was particularly well known for his work in the Nautical Almanac office.

The Sky This Month

As 1988 opens, both the two brightest planets are in the evening sky, and make a brave showing. Pride of place must go to Venus, which by the end of the month does not set until three hours after the Sun. Its magnitude is −4, so that it far outshines any other object in the sky apart from the Sun and the Moon. Yet lovely though it is as seen with the naked eye, Venus must be regarded as a telescopic disappointment; no telescope will show anything but occasional vague, cloudy markings, simply because all we are seeing is the upper part of the atmosphere. Below, we have found Venus to be a veritable inferno, and even the shining clouds contain large amounts of sulphuric acid. During January the phase decreases from 82 per cent to 77 per cent; not until March will the planet reach 'dichotomy', and appear as a half-disk.

Jupiter, magnitude −2.4, is in Pisces, and is visible all through the early part of the night. Telescopically it is more rewarding than Venus; look for its cloud belts, its bright zones, and its four main satellites. The Great Red Spot (now known to be a whirling storm) has not been in evidence lately, but no doubt it will soon become prominent once more.

Saturn is emerging into the dawn sky, and Mercury is an evening object; it may be glimpsed low down in the south-west at the end of the month, just after sunset. Telescopes will show it as a crescent, but no surface details will be seen. Of the other planets, Uranus and Neptune are out of view, but Mars can be observed in the south-east before sunrise. Its magnitude is +1.5, and its apparent diameter is less than 5 seconds of arc, so that telescopes will show little; but Mars is worth finding, because it is not far from the first-magnitude star Antares in Scorpius. It is easy to confuse the two, though Antares is lower down and is, at present, half a magnitude brighter. Of course Antares is a red star — its name means 'the rival of Ares' or Mars. It is sobering to reflect that while Mars has only half the diameter of the Earth, Antares is big enough to swallow up the whole orbit of the Earth round the Sun!

The Moon is full on January 4, and new on the 19th. The only major meteor shower this month is that of the Quadrantids, with its maximum on the 3rd; it is usually of brief duration, and this month the Moon will interfere. Bradfield's Comet is now fading, but telescopically it will remain observable for some time.

Of course the evening sky is dominated by Orion, with its two brilliant leaders (Betelgeux and Rigel), its Belt, and its Sword. Lower down, and further east, is Sirius, the brightest star in the sky, of magnitude −1.5. Sirius is pure white, but seems to flash various colours because of the effects of the Earth's atmosphere. Capella, in Auriga, is almost overhead; by it you can see the little triangle of stars nicknamed the 'Kids', of which one member (Epsilon Aurigæ, at the apex of the triangle) is a remarkable eclipsing binary, made up of a yellow supergiant together with an invisible companion which passes in front of the supergiant once every 27 years. The Square of Pegasus is setting in the west; Ursa Major, the Great Bear, is rather low in the north-east. Leo, the Lion, is coming into view over the eastern horizon.

MIRA CETI

This month the most famous variable star in the sky, Mira Ceti, should be an easy naked-eye object. It lies not far from the 'head' of Cetus, the Whale, and is on view in the south-west after dark.

Mira was the first variable star to be discovered. It was seen in 1596 by the Dutch observer Fabricius, but subsequently it was 'lost'. It was seen again by Johann Bayer in 1603, but again little notice was taken of it, and it was not until 1638 that Phocylides Holwarda realized that it is a genuine variable. The mean period is 332 days, but this is not constant; like all stars of its type — now known universally as 'Mira variables' — both the amplitudes and the period show changes from one cycle to another. There is none of the regularity of the short-period Cepheid variables.

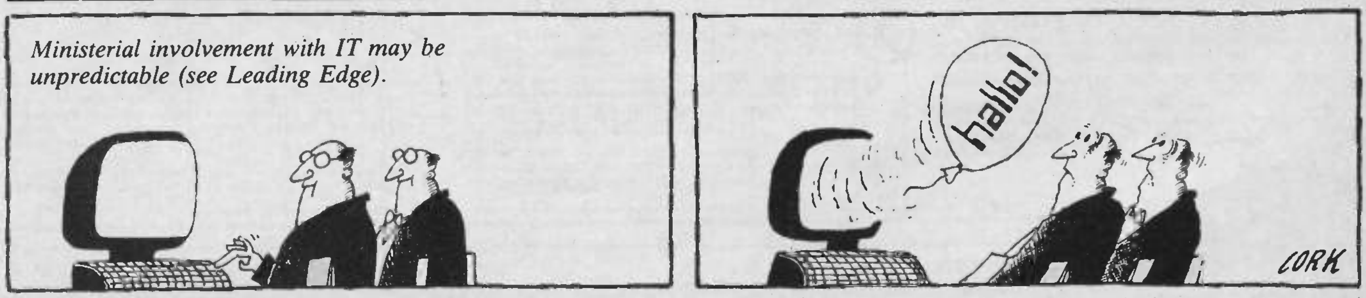
Mira is the closest of the variables of its type; the distance has been given as 95 light-years. (This is according to the authoritative Cambridge catalogue; other sources give it as rather more distant.) At maximum, the luminosity is 130 times that of the Sun. By stellar standards this is not very powerful; Betelgeux in Orion — also variable, but of different type — could match 15,000 Suns.

At its peak Mira may rise to magnitude 1.7, brighter than the Pole Star, but admittedly this does not happen often, and in most years the magnitude does not rise above 3. The 1987 maximum was fairly bright — I gave it as magnitude 2.3 — but whether 1988 will come up to expectations remains to be seen. In any case Mira will be easy to identify, because of its strong red colour. Its spectrum is of type M, which means that its surface temperature is only about 3000 degrees Centigrade — half that of the Sun.

Mira has a faint companion, known either as Mira B or as VZ Ceti. Its usual magnitude is 12, though it shows occasional short-lived flares up to magnitude 8. It may well be a white dwarf, but this month it will not be easy to see, because it is less than a second of arc away from the bright star (the actual separation is 0.8) and will be 'drowned' in the glare.

It is interesting to follow Mira throughout its cycle, though of course it is out of view for some time during the summer when it is too close to the Sun in the sky. My advice is to locate it now, when it is an unmistakable naked-eye object, and memorize the binocular and telescopic fields, so that you can find it again when it has dropped below naked-eye visibility. Binoculars will enable you to follow it for some time, but at minimum the magnitude falls to 10, so that a telescope will be needed.

Mira is only one of many red long-period variables, but it has a special place in the history of astronomy, and it is not surprising that its name means "Wonderful". PE



Ministerial involvement with IT may be unpredictable (see Leading Edge).

ELECTRONIC LOCKS

PART TWO BY THE PROF

RED LEADER TO CONTROL

Using an infra-red frequency beam and a filtered bandpass receiver circuit, keyless remote control is a practical proposition.

The circuit diagram for the transmitter appears in Fig.7, with the receiver circuit being shown separately in Fig.8.

A standard 555 oscillator forms the basis of the transmitter. VR1 is adjusted for the output frequency that gives optimum sensitivity. The timing resistors have been given values that provide a roughly squarewave output. Due to the frequency selective nature of the receiver circuit, short pulsed waveforms tend to be ineffective and a (more or less) squarewave signal gives better results.

High output currents are not required in this application, and IC1 can therefore directly drive the infra-red led via current limiting resistor R3. The LD274 specified for the D1 position is a narrow angle type which is well suited to a short range application such as this. A wider angle type such as an LD271 will work in the circuit, but the wider beam results in a signal of lower intensity.

Turning our attention to Fig.8, D1 is the detector diode. It is a large area type which is used here in the reverse bias mode. The pulses of infra-red radiation from the transmitter cause increased leakage current through D1, and the resultant pulses at its cathode are coupled to the input of the buffer amplifier via C2. D1 is a type which has a built-in infra-red filter, and it is not affected significantly by visible light.

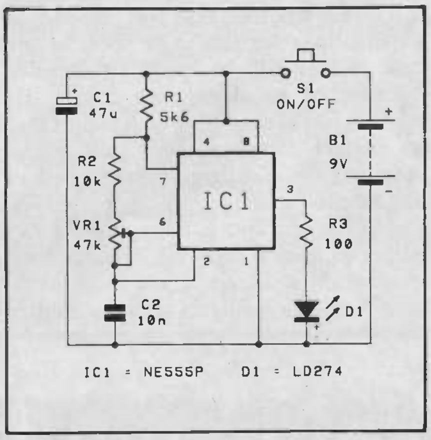


Fig. 7 *Infra-red "key" circuit.*

The buffer amplifier is an ordinary operational amplifier voltage follower which drives a simple operational amplifier bandpass filter based on IC2. The latter has a Q of just under 5, a voltage gain of about 34dB, and a centre frequency of just over 3kHz. The voltage amplifier is based on TR1, which is operated as a high gain common emitter amplifier. Together with IC2 it provides approximately 80dB of voltage gain, and gives the unit good sensitivity. A simple two diode rectifier processes the output from TR1, and the smoothed signal is fed to the input of a conventional operational amplifier Schmitt Trigger built around IC3. R14 provides a moderate amount of hysteresis which reduces the risk of spurious pulses being generated. The flip/flop is one section of a 4013BE CMOS dual D type, and this drives a simple relay driver based on TR2.

As this circuit has a fairly high level of gain, the component layout needs to be designed reasonably carefully so that any obvious paths for stray feedback are avoided. The only adjustment required to the finished unit is to be set VR1 in the transmitter for maximum range. The easiest way of doing this is to monitor the output level from IC2 at the receiver

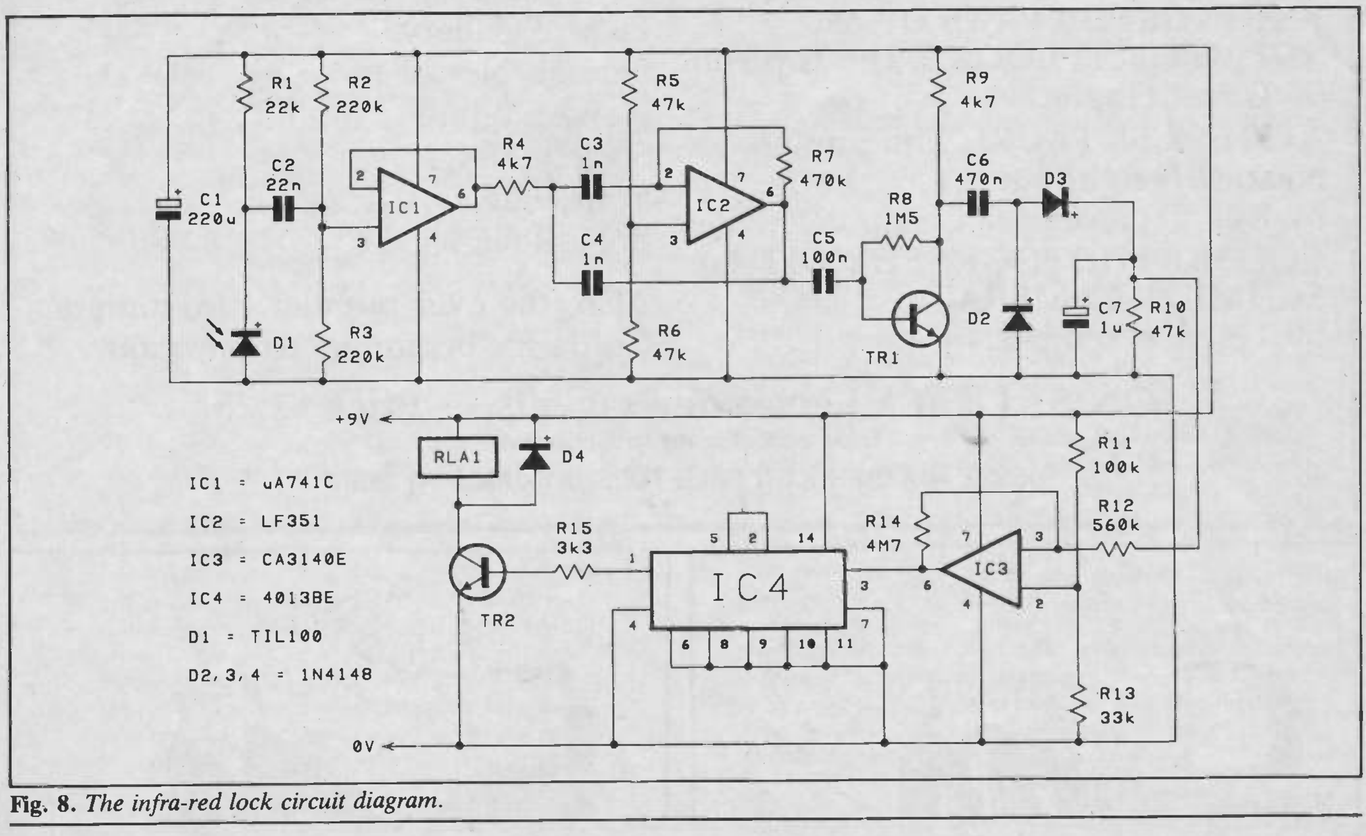


Fig. 8. *The infra-red lock circuit diagram.*

using an oscilloscope or a.c. millivolt meter. With the transmitter switched on and aimed towards D1 at the receiver, VR1 is then adjusted for maximum output from IC2. If IC2 becomes driven to the point where the output signal becomes clipped, increase the distance from the transmitter to the receiver in order to reduce the signal level. In the absence of suitable test gear, it is just a matter of trying VR1 at various settings in an attempt to find one that gives good results.

The unit works well at ranges of up to about 3 metres in free air, but the range is obviously reduced somewhat by the inclusion of glass or other partial obstructions placed in the beam from the transmitter. In practice a range of around half a metre should be satisfactory, and even allowing for factors that reduce the practical operating range, the system should be more than adequate in this respect. In some cases the range might be much more than is really needed. It is then advisable to reduce the gain of the receiver slightly as this improves the security of the system. The receiver's gain can be reduced by adding a resistor in the emitter circuit of TR1. The higher the value of this resistor, the lower the sensitivity of the receiver (a value of about 100 ohms should do).

Many of the circuits provided in this article use a relay. I have not specified a particular type, but in each case any type that meets the following criteria should suffice:-

1. It must operate reliably at slightly less than the nominal supply voltage.
2. The coil resistance should be about 185 ohms or more.
3. It must have contacts of the appropriate type and adequate rating for your particular application.
4. Not essential, but construction is generally easier using a modern miniature printed circuit mounting type.

DEVELOPMENTS

These circuits should serve to give you a good idea of the variety possible with electronic locks. They also make a good starting point for anyone who would like to experiment with this type of thing. All the circuits could be improved upon, and you may well be able to come up with a few novel designs of your own. A useful addition to units of this type is some form of tamper alarm. This sounds an alarm and (or) holds the lock in the off state for a period of time in the event of an incorrect "key" being connected to the circuit. With the infra-red alarm it would be possible to have a circuit that detected an infra-red beam at the wrong pulse frequency and sounded an alarm and (or) provided a hold-off. It would also be possible to have a coded signal modulated onto the infra-red beam. This could use the same basic circuit as the infra-red joystick design featured in a previous issue of this magazine (Nov 1986), or some remote control integrated circuits which permit quite complex coding of information onto the output signal.

When designing electronic locks try not to get carried away with over complex ideas. To be practical the system must not be so expensive that it costs more than the property it is protecting. It must also be convenient in use, and should not require a suitcase full of electronics to activate to lock. It must also be reliable. It is very easy to design systems that quite often fail to operate when the correct "key" is used. Do not make the classical mistake of having highly sophisticated locks that are easily bypassed simply by undoing a few screws, or leaning hard on a door or window. Good locks should be used in addition to secure windows and doors, and preferably backed up by at least a basic alarm system. Where electronic locks can probably be used most effectively is with electronic equipment that must not be operated by unauthorised users. For instance, with computers that are used to store sensitive information, or radio transmitters.

Your local police station will always be happy to offer advice on the best way to secure your property. Ed. PE

DC MOTOR SERVO

BY DAVID SANDERS

TWO MODULES GO A LONG WAY

Our author describes two tried and tested stages which can be built into a variety of servo and robotic systems: a non-linear mixer circuit, and a dc servo amplifier with four separate selectable voltage supplies.

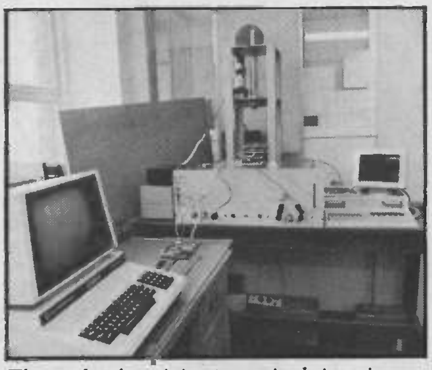
IN recent issues of PE Brian Brooks and Mark Stuart described the principles, characteristics and performance of basic dc motors and control circuits. In this article I intend to elaborate on the theme, and consider the various parts of a dc servo system.

All the designs were developed over the last year during robotics research at Portsmouth Polytechnic. Although the designs were originally for a cheap prototype robot, the circuits may be used for a wide range of applications and will extend the use of your home computer. The circuits are considered separately, and not as a complete servo system, so that individual circuits or parts of circuits can be used. The designs will allow interfacing and control of the outside world.

Here we shall consider a useful non-linear mixer stage and a novel but simple design for an efficient servo amplifier stage. In both cases, by sensible adjustment of resistor values, the circuit can be applied in any situation, not just in a dc servo system.

MIXER STAGE

The mixer stage is a non-linear circuit based on a TL081 operational amplifier. The TL081 has proved itself as a robust and reliable op amp for control applications, directly replacing standard op amps such as the 741. The mixer has two feedback paths, one of which is non-linear and only takes effect within predefined limits.



The author's unit in a practical situation.

The first dc servo-amplifier design is called the Billingsley amplifier, after Dr John Billingsley, Professor of Robotics at Portsmouth (more famous among electronics and computer buffs as the father of Micromaze and now, Robot Ping Pong).

Unlike more conventional "push pull" amplifiers, this design has four separate simple voltage supplies. Current supply to the dc motor in a forward or reverse direction is usually achieved with a single power supply. In the Billingsley amplifier, current is applied by four separate high impedance output stages. The design is highly efficient and largely overcomes the problems of crossover distortion and wasted power common in conventional servo motor power amplifiers.

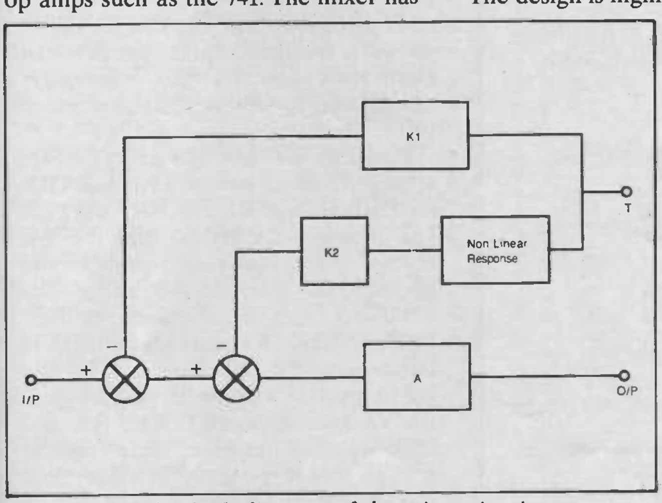
David Sanders is at the Portsmouth Polytechnic.

The block diagram of the mixer circuit is shown in Fig.1. The feedback signal is split into two paths, both providing negative feedback. The outer loop is a simple linear feedback loop, but the inner loop is non-linear. The gain and range within which the non-linear circuit takes effect is preset by the selection of suitable resistors and voltages. For most applications the outer loop would be "loose" (low gain), allowing high speed. The inner loop can be high gain, providing "tight" control within the limits.

The demand input to the mixer is an analogue voltage. If powered from a computer or microprocessor, the signal would be derived from a d/a circuit.

The tacho signal is optional and is only used when a speed/voltage signal is available. Tacho signals can be simple to produce with the help of modern chips and specific circuits will not be discussed here.

The tacho input is mixed with the demand input and fed to the TL081. This is connected as a standard mixer using the negative input.



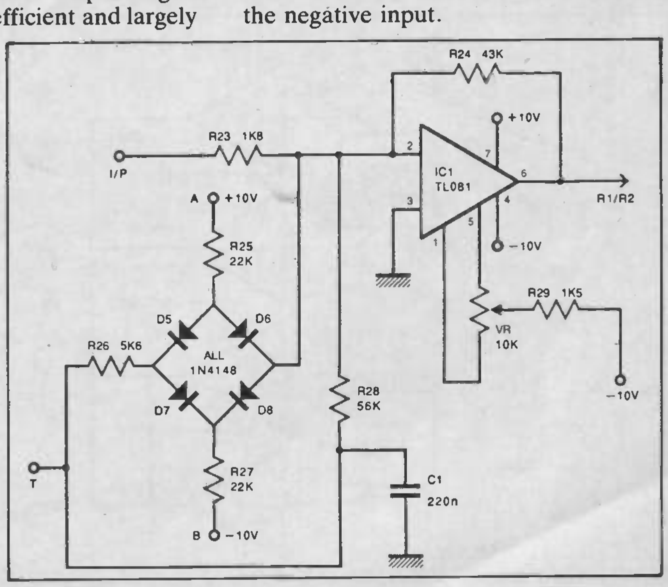


Fig. 1. *(Above) Block diagram of the mixer circuit.*
Fig. 2. *(Right) Mixer circuit diagram.*

MIXER CIRCUIT

The circuit diagram of the mixer is shown in Fig.2. R23 and R24 define the gain of the demand input, in this case:

Demand = R24/R23 = 43/1.8 = 24.

The tacho signal is separated into two paths. One path is high gain, for low velocities close to the demanded position and consists of the four diodes D3–D8 and resistors R25–R27. This inner loop only takes effect when the tacho-feedback signal is within the two supplies at A and B, in this case +/−10 volts.

A current flows from supply A to supply B. When the tacho input T is zero, half the current flows through D5 and D7, and half through D6 and D8. As the tacho input moves away from zero, say positive, the amount of current through D5 and R25 reduces and current through D7 and R27 increases. Thus, the voltage applied to the op-amp tends to increase in sympathy. The effect within the range is that the output to IC1 is via R26.

The high gain circuit only takes effect within the limits of A and B, since when the tacho input is outside this range, say positive, no current can flow through D5, which is reverse biased and the voltage across is constant. So R26 and R24 define the inner loop gain, in this case:

Loop gain = 42/5.6 = 7.8

A second path with a low gain for higher velocities where control is not so important, consists of a simple resistor, R28. A capacitor, C1, is included to remove noise from the feedback signal. R28 and R24 define the outer loop gain, in this case:

Loop gain = 43/56 = 0.78

The setting of these gains depends on the amplitude of the feedback signal in your particular application and may require modification.

Resistor R29 and variable resistor VR1 adjust the output of IC1 to zero for a zero input.

AMPLIFIER DESIGN

For rapid speed and fast responses, the amplifier must be capable of delivering a substantial current. In this novel design, large demand voltage signals may have current supplied from a higher voltage positive or negative supply. (Fig.3). This would occur at high speed or for torques associated with large changes of force. (Fig.4).

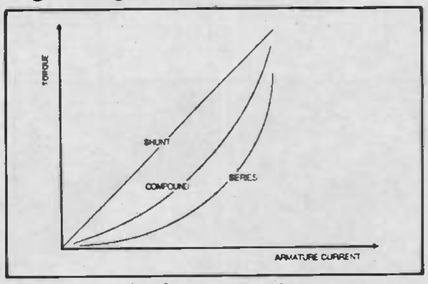


Fig. 4. *Graph of torque against armature current.*

For smaller inputs, current is drawn from two lower voltage supplies. This will be the case when the motor is at rest while sustaining a constant load. When stationary the mechanical efficiency of the dc motor is near zero and the power associated with the current drawn from the power supply must be dissipated in the motor winding or control circuitry.

Because lower voltage supplies are used whenever possible, a power saving is achieved. Considering supplies of ±40 volts and ±10 volts, the thermal dissipation of power in the controlling circuits will be less than one eighth of that in a conventional circuit of typically ±40 volts.

The amplifier circuits of a conventional twin supply output stage are configured to have a low output impedance and are liable to excessive common current if both are simultaneously driven into conduction. This transition characteristic is crucial in traditional amplifier design. Basic design provides for a 'dead band' in which no conduction occurs. Crossover distortion is then present in the output wave-forms.

The control circuits of the Billingsley amplifier are configured to have a high output impedance, giving an output current which during the conducting phase of each circuit varies linearly with the applied demand signal. These outputs may be safely connected without fear. The lower voltage circuits are biased so that over a central range of input control signal both circuits conduct. Outside the range, one or other circuit will be cut off. (Fig.5). Within the range, the rate of change of output current with respect to the input signal will be twice that outside the range and neither dead band nor discontinuity of current will occur.

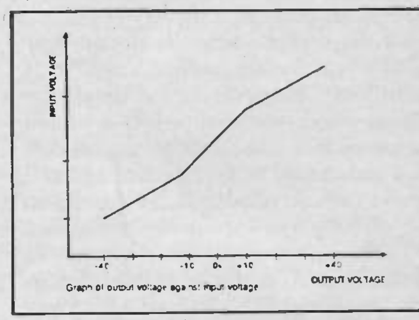


Fig. 5. *Graph of output versus input voltages.*

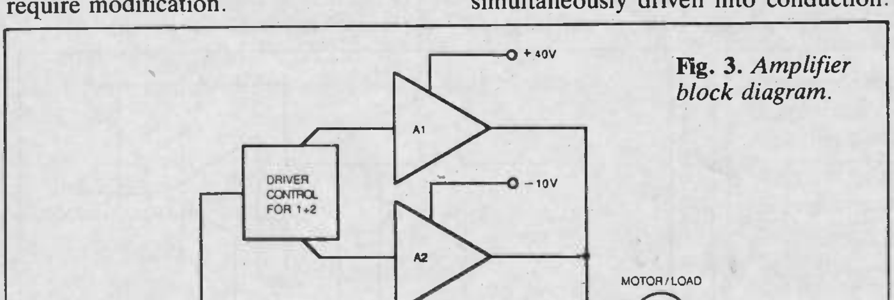


Fig. 3. *Amplifier block diagram.*

AMPLIFIER CIRCUIT

A block diagram of the circuit is shown in Fig.3. The four circuits are configured so that the higher voltage amplifiers will only conduct once the opposing low voltage amplifier has turned off. The amplifier circuit diagram is shown in Fig.6.

Two pairs of transistors control the four Darlington pair driver circuits. These are shown as TR1/TR2 and TR3/TR4 in the diagram. These pairs of transistors are configured so that neither pair can have both transistors conducting simultaneously. In the circuit shown, a change of input voltage at the emitters of about 1.4 volts is necessary to change from one state of conduction to the other.

Resistors R7 and R8 apply a bias voltage to the bases of TR1 and TR2. Similarly R9 and R10 bias TR3 and TR4. The resistors are set so that the low voltage drivers each conduct a moderate current, for instance 0.5 amps. The grounded base configuration of TR1, TR2 and TR3, TR4 causes the change in input voltage at the junction of R1 and R2 to result in a proportional change in the voltages across R11, R12, R13 and R14. If, as in this case, these resistors are selected to be equal in value, then the voltage changes are equal.

If the input voltage is steadily increased from zero then TR2 will

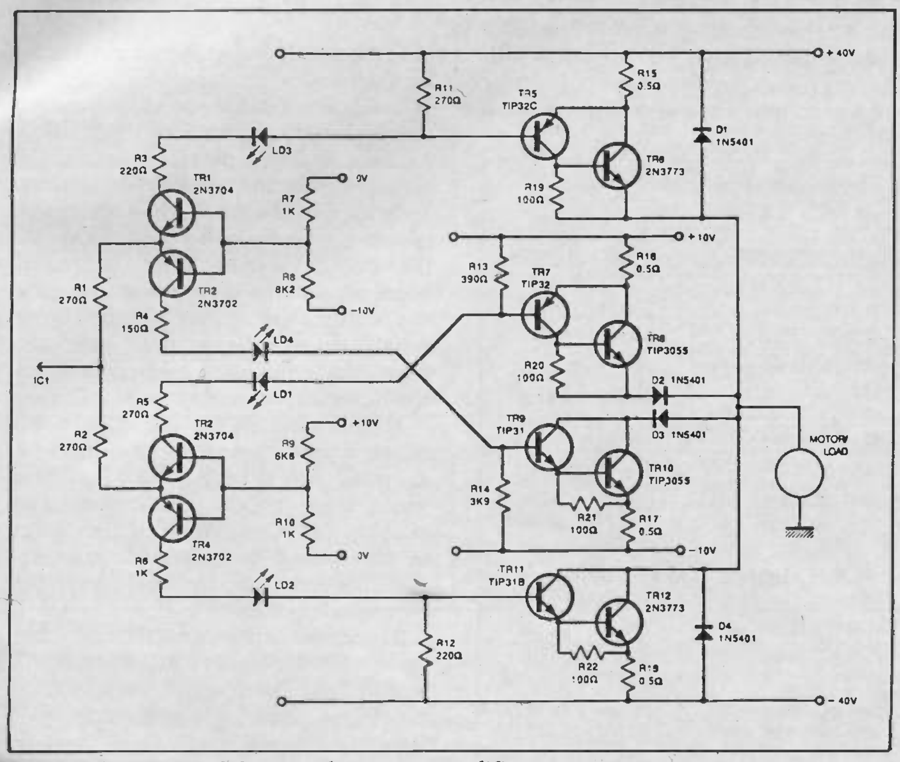


Fig. 6. The circuit of the complete servo amplifier.

increase its collector output while driver TR3 will decrease, in this example cutting off at an input of 0.25 volts. Thus, TR3, the transistor controlling the +10 volt supply, switches off completely before TR4, controlling the −40 volt supply, can begin to conduct. TR1 and TR2 operate in a similar manner. As the input voltage continues to increase, the output of TR2 continues to increase. Only when the input is in excess of approximately 3 volts will TR4 and the −40 volts supply begin to conduct.

CURRENT CONTROL

The four circuits for current control are formed by transistors TR5 to TR12 with their associated resistors. These circuits operate slightly differently, but are similar and only TR5 and TR6 will be considered.

TR5 and TR6 are connected as a Darlington pair, giving very high current gain. Resistor R15 carries a voltage proportional to the current supplied by its associated transistors. This voltage has a feedback effect, so that to a first approximation a voltage increase on the base of TR5 will result in an equal increase in the voltage across R15, and hence a corresponding output current. If, for example, the value of R15 or R18 is 0.5 ohms, a gain of 2 output amperes per input volt is obtained. In a similar manner, the other three circuits supply current to the load from +40, +10, −10 and −40 volts respectively.

Diodes D2 and D3 protect the lower voltage drivers from being reverse loaded and diodes D1 and D4 protect the output transistors TR6 and TR12 from the large reverse voltages which can be produced in the load.

The printed circuit board is available through the PE PCB service.

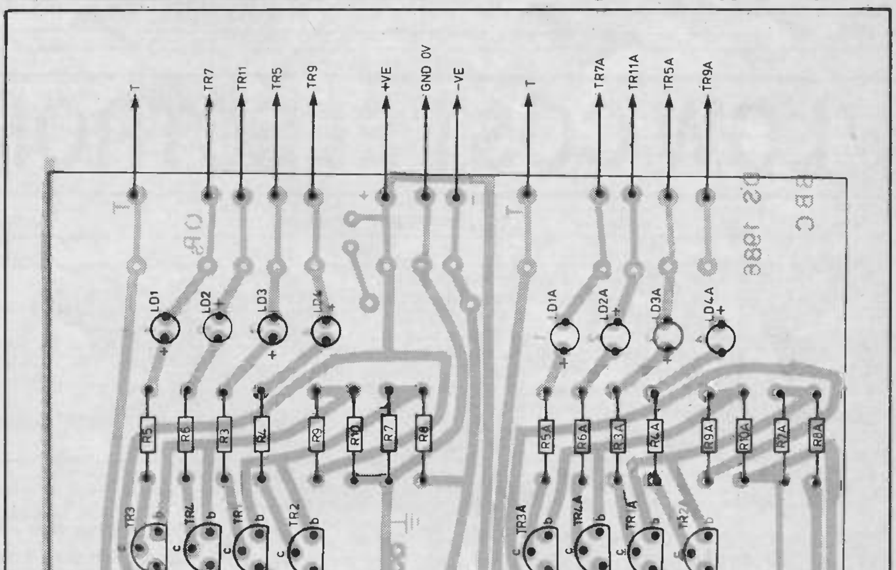


Fig. 7. *Printed circuit assembly details.*

MIXER PARTS LIST

RESISTORS

R23	1k8
R24	43k
R25,R27	22k (2 off)
R26	5k6
R28	56k
R29	1k5

CAPACITORS

C1	220n

POTENTIOMETER

VR1	10k lin

SEMICONDUCTORS

D5,D6,D7,D8	1N4148 (4 off)
IC1	TL081

CONSTRUCTION

The mixer and low power section of the servo amplifier need to be as close as possible to avoid noise in the low voltage connection, and in this case are mounted on pcb. (Fig.7).

The four high current circuits need to be constructed on a heatsink, and so that each transistor of each Darlington pair is close together. A typical layout is

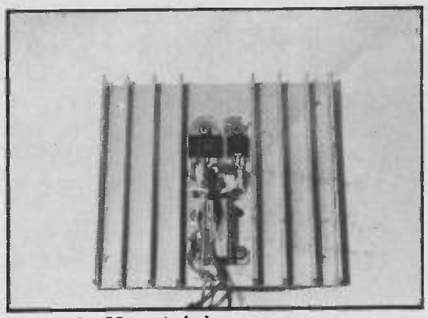


Photo 2. *Heatsink layout.*

shown in photo 2. This is not the only way to construct the amplifier circuit and your construction can be modified to fit your available space and type of heatsink.

A construction of this type can then be mounted with each amplifier above the other as shown in photo 3. Providing the circuits are mounted +, −, +, − with the low power circuits on the outside for safety, no problems should arise from overheating.

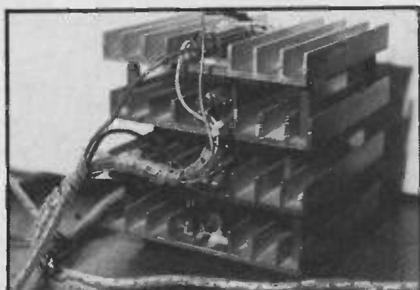


Photo 3. *Heatsink stacking.*

SERVO-AMPLIFIER PARTS LIST

RESISTORS	
R1,R2,R5,R11	270 Ω (4 off)
R3,R12	220 Ω (2 off)
R4	150 Ω (2 off)
R6,R7,R10	1k Ω (3 off)
R8	8k2
R9	6k8
R13	390 Ω
R14	3k9
R15,R16,R,17,R18	0.5 Ω (4 off)
R19,R20,R21,R22	100 Ω (4 off)
SEMICONDUCTORS	
D1,D2,D3,D4	1N5401 (4 off)
TR1,TR3	2N3704 (2 off)
TR2,TR4	2N3702 (2 off)
TR5	TIP32C
TR6,TR12	2N3773 (2 off)
TR7	TIP32
TR8,TR10	TIP3055 (2 off)
TR9	TIP31
TR11	TIP31B
LD1,LD2,LD3,LD4	Standard low power leds

FINALLY

Once the decisions have been made for the fixed power supplies and resistor values, only VR1 needs adjustment to give a zero output for zero input.

The only likely problems with these circuits will be in the earth connections and care must be taken when wiring the system not to create an earth loop. All the circuits should have one earth connection to the same point, including the motor and supply circuits. Any connection to a d/a circuit or computer should have the earth connection from the mixer circuit supply.

Motors are noisy things and any noise in the circuit from this source must be accepted. Any attempt to filter this noise will reduce circuit performance and possibly cause oscillation. If oscillation in the circuit is very bad, start by reducing your tacho feedback loop gains by amending R26.

The circuits are proving themselves as good work horses at Portsmouth Polytechnic and photo 1 shows the dc amplifiers powering a prototype robot base developed for Micro Robotic Systems in the Electrical Engineering Department. The circuits have now been used for over a year with little problem. I wish you the same success with your systems. PE

INDUSTRY NOTEBOOK

REPORT BY
TOM IVALL

MONEY FOR NOTHING – BUT THE CHIPS AREN'T FREE

The inevitable price of financial speculation is a market collapse. The ultimate victim is manufacturing — the process by which real wealth is created. Big firms are amalgamating in the struggle to survive.

MARKET AND OWNERSHIP CHANGES

If anything were needed to illustrate my remarks in August 1987 about the domination of use value by exchange value, you wouldn't find a much better example than the world-wide stock market crash in October. All electronics firms listed on the Stock Exchange were affected. Take Racal Electronics, for example. Between 16th and 28th October this enterprising company did nothing to worsen its own trading position and prospects. If anything, with the Racal-Vodafone cellular radio business pulling in more subscribers than expected, the company was on an upward swing from the low point it had experienced in 1986. Yet between those two dates — less than a fortnight — the capital value of Racal Electronics, as judged by the share market, fell by as much as 40% (the share price dropping from 330p to 198p).

This was patently absurd. In less than two weeks the use value of all Racal's products and services, its factories and capital equipment, couldn't possibly have changed so drastically. The exchange value of the company's shares was clearly way out of touch with reality. Either the initial valuation was unrealistically high or the later price was unrealistically low. Perhaps by the time this report appears some degree of stability will have emerged.

How can such a crazy situation occur? Because the people who buy and sell the company's shares, whether solid investors like pension funds and insurance firms or opportunists out for quick buck, simply do not understand the electronics business carried on by the company and its relationship to the world at large. In fact these people are not interested and don't care. When they see share prices going down generally for some external reason, they simply follow the herd and sell their shares in the company to recover their money, quite regardless of any sensible assessment of the company's true worth. Lacking knowledge, they are guided by nothing more reliable than the primitive emotion of fear.

When this process is repeated many times with numerous companies and investors, all looking over their shoulders at each other, it becomes a self-maintaining panic. And nowadays such a drop in share prices is accelerated electronically by world-wide data communications and programmed trading based on computers. Chancellor of the Exchequer Nigel Lawson was driven to comment to members of the Stock Exchange: "The electronic automation and globalisation of the herd instinct is not a pretty sight."

If the industry could simply sit tight and ignore such wild swings in its share prices everything would be fine. But unfortunately a drop in market value not only has a bad psychological effect but also reduces a firm's ability to raise money for capital investment and increases its vulnerability to a hostile take-over.

Talking of which, just before the stock market collapse Racal was reported to be considering a take-over of Ferranti. If this rumour were true it wouldn't be at all surprising, as Racal has conducted a consistent policy of expansion by acquisition over the years. It has purchased a whole series of small and medium-sized compaies, including such well known names as Chubb, Decca Navigator and Dana Instruments. But so far it has failed to swallow up any of its major competitors in general electronics and communications.

Meanwhile, in other parts of the playground or jungle (according to your point of view) there have been some quite substantial shifts in the pattern of ownership. Not only Racal but STC as well was said to be considering a take-over bid for Ferranti. In the event, Ferranti itself took over the American company International Signal and Control and thus made itself even bigger in the field of military electronics manufacturing. As a result of this merger the combined companies had a capital value of some £1 billion before the stock market collapse, with annual pre-tax profits of about £100 million. Thus it seemed that Ferranti thwarted any possible take-over by making itself too big and expensive to be swallowed by the likes of Racal or STC.

Although STC was founded in Britain, for several decades it was virtually under the control of the American giant ITT, which held a majority shareholding. In recent years, however, ITT has reduced its stake to only 24% so that STC has become predominantly British again. But now this remaining 24% has been bought by the Canadian firm Northern Telecom, which has also added a further 3.8% by purchasing STC shares on the stock market.

A positive development for Plessey has been an agreement between it and GEC to merge their telecommunications equipment manufacturing activities in a new, joint-venture telecomms company. By the time this report appears the new firm may well be in business.

You may recall that in early 1986 I reported on GEC's attempt to take over Plessey with an offer of £1.18 billion. The reason given by GEC was that they wanted to make themselves bigger in telecomms manufacturing in order to compete better in world markets. At the time GEC was 11th in the international telecomms league table and Plessey about 14th. As things turned out, the Government banned the proposed take-over on the advice of the Mono-polies and Mergers Commission. How-ever, although Plessey had rejected the GEC bid, they did say at the time that they would be willing to co-operate with GEC solely on the manufacture and marketing of telecomms switching equipment — notably System X. This proposal now seems to have come to fruition. It will give the UK a stronger foothold in the world telecommunications market, though the new company will still be only the eighth largest manufacturer in this field. PE

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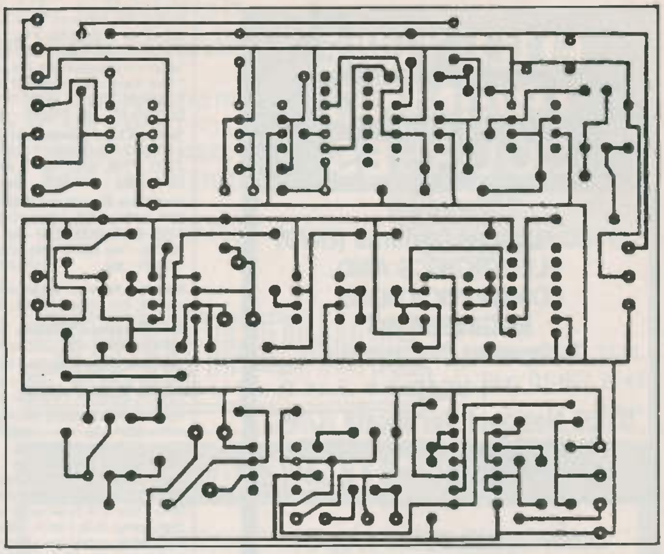

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