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THE ELECTRONICS, SCIENCE & TECHNOLOGY MONTHLY

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The Inside Story

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Infra-red Alert System

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Major New Series

WIN!
John Linsley Hood 80W MOSFET Amplifier Kit

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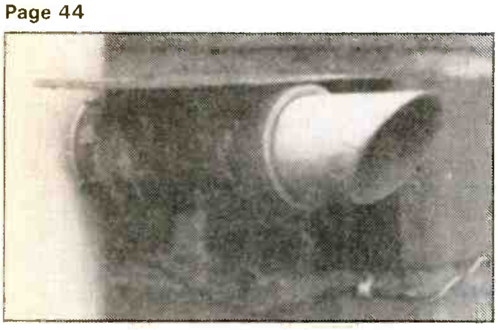

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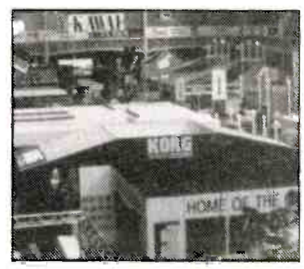

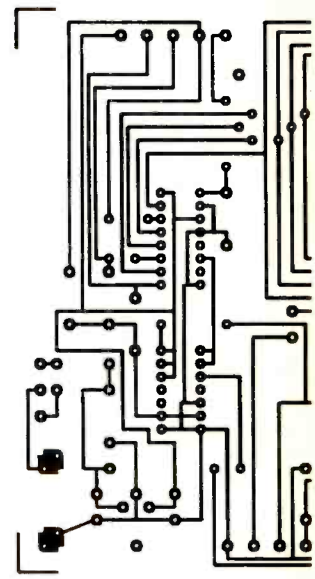

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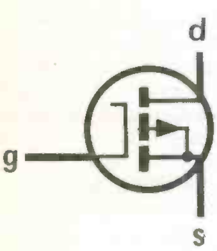
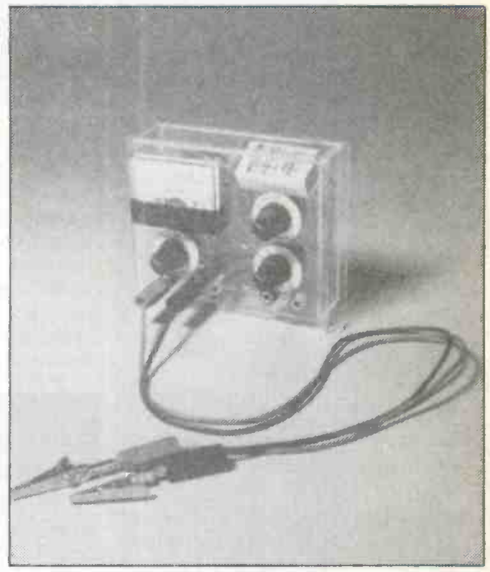
FEATURES/PROJECTS





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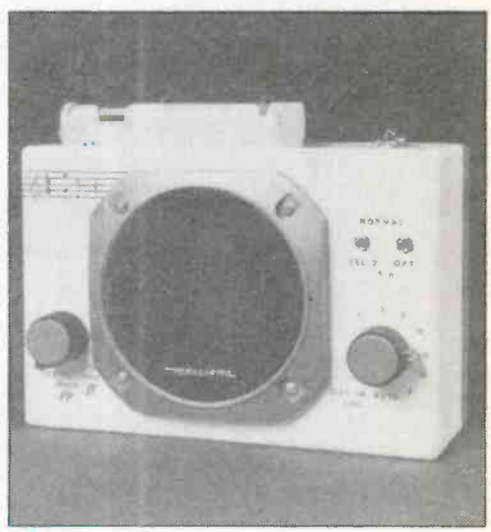

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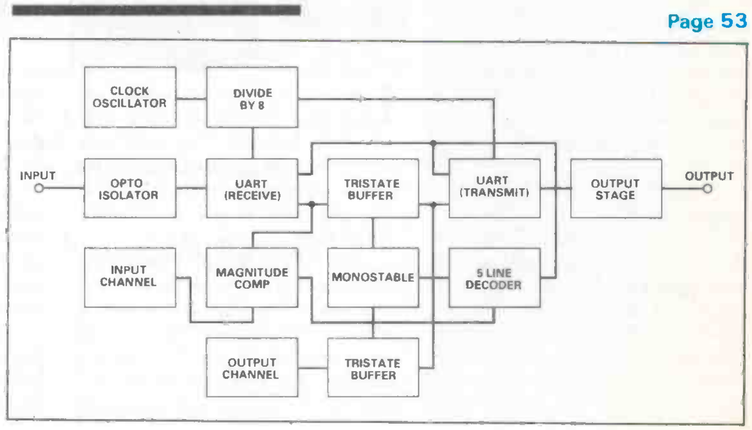


NEWS

NO SALE

The privatisation of the electricity industry will *not* include the sale of Britain's Magnox nuclear reactors, because of the huge costs associated with decommissioning.

The announcement came as the bill approached the end of its passage through the House of Lords and forced an embarrasing U-turn on Baroness Hooper, a junior energy minister and representing the Government in the House.

A proposal was made by Labour Energy Spokesman Lord Williams that the entire bill be held until the autumn session, in the hope that the Government might more reliably finalise its plans. "After all" he said, "we are talking nuclear power stations, not tiddlywinks".

The wisdom of including nuclear power in the sell-off equation has always been in doubt. The enormous costs of building nuclear plants and the inconceivable costs of compensation in case of accident would make it unlikely that private enterprise would ever commission new power stations. This would seem to directly contradict the Government's committment to the nuclear industry.

The Magnox decision only partly solves the problem. As Lord Ezra, former chairman of the National Coal Board, was quick to point out in the House of Lords, there has been no reason given as to why the exemption should not be extended to all nuclear stations.

His questions were later echoed by the Confederation of British Industry, which urged the removal of all nuclear power until the costs are more clearly realised.

There are fears in the industry that troubles with advanced gas-cooled reactors (AGRs) may extend many years beyond the anticipated run-in period. The costs of decommissioning and of reprocessing fuel are also expected to climb rapidly. Unless the Government makes firm guarantees of support, or removes nuclear power from the sell-off altogether, private industry and the free market is likely to spell the end of the British nuclear industry and the general concern will adversely affect the entire privatisation scheme.

It would appear that doubts over the nuclear inclusion are not limited to those in the industry. A recent National Opinion Poll commissioned jointly by Greenpeace and Friends of the Earth indicated that while 17% of interviewees were considering buying electricity shares, only half that number would do so if nuclear power formed part of the offer.

DAT FOR CHRISTMAS

The much awaited Digital Audio Tape machines will be generally available to the public throughout Europe by Christmas.

An agreement comes after argument between the recording and consumer electronics industries over the infringement of copyright issue. It now clears the way for the consumer to make near perfect copies of live or recorded material using DAT, but as a concession the manufacturers agreed that the tape machines will only be able to copy originals once — a condition the recording companies asked of the manufacturers before the boycott could be lifted. How this is to be achieved is not yet clear.

The recording companies will not receive a royalty for every DAT machine sold as compensation for the infringement of copyright. However, talks will have to start all over again when it comes to discussing the newest technology — the recordable compact disc.

AIR-SEA POWER

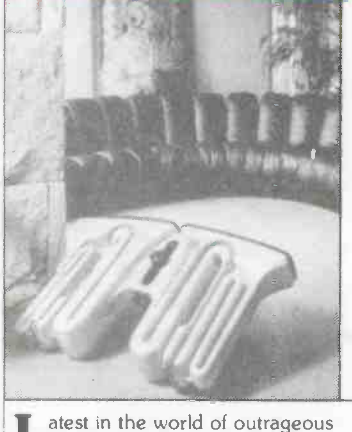
If the electricity privatisation bill is passed in its present form, one positive result should be the promotion of renewable energy sources such as wind and sea.

The Government has specified that within ten years of privatisation, some 600MW of the power fed to the grid from nonfossil fuel should come from renewable sources.

As a prelude to this, three experimental wind turbines are to be built under a £28m scheme announced by the CEGB, and to be funded by PowerGen and National Power (the two generating companies that will be formed from the CEGB) together with the Department of Energy.

The three sites are at Capel Cynon in Dyfed, in North Cornwall and in the northern Pennies. It is hoped that the first of these will be operational by 1991, using 25 turbines to produce between 7.5MW and 12.5MW.

SPEAKER TECHNIC



Latest in the world of outrageous speaker systems are these two units from Technics. They have been designed by Mr Technics himself, Mr Obata, using complex space simulation programs to give the designs shown here.

The SST-1 Sound Space Twin Load Horn appears more like a musical instrument than a speaker system. It uses two different sized horns folded and mounted on the back of the speaker with an acoustic filter for mid-range detail. The price is as spectacular as the appearance — not yet finalised but expected to be around £1000 a pair.

The SST25Hz and SST35Hz must be approaching the ultimate in subwoofer systems, a horn is folded back at the centre of its length with acoustic coupling in the upper portion. The tentative prices are £1000 for the 35Hz version and £1400 for the 25Hz.

For further details and sales contact Technics, Panasonic House, Willoughby Road, Bracknell, Berkshire RG12 4FP. Tel: (0344) 853205.

TOUCH TECH

A new company has been formed to meet the demands of the hi-tech touch screen industry.

Based at Eastleigh in Hampshire, Touch Screen Technologies Ltd will design and supply touch screens and interfaces, complete with software. It has entered into a joint venture with Gunze Ltd of Japan, to manufacture touch screens for the European market.

The conductive coated film is a metallic oxide coated polyester, manufactured in the US and Japan. With an overall thickness of only 0.75mm, the resistive touch screen is simple to use and has already been applied to the medical, process control and banking industries. They are also considered ideal for airlines, tour operators, hotels and any situation requiring general public access to computers. Touch screens in all shapes and sizes are finding their way onto calculators, personal organisers and into diaries.

For further information, contact Touch Screen Technologies Ltd on (0703) 629545.

FAX CHANGE

Ceefax, the BBC's teletext system, is about to commence a relaunch operation — or perhaps more appropriately a metamorphosis as the changes are taking place slowly.

An estimated six million viewers have teletext sets in this country and the process of finding what you want can be painfully slow at times. This is because data is sent serially through a few lines on the top of the screen of your TV set. Ceefax is now going to use more of these lines to convey the information a little faster. This will be done by increasing the number of pages available and reducing the number of subpages.

It is in the subpage area where access to information can take the time. At present 99 subpages are available, but only eight are used at any one time. You can imagine the eternity it would take to cycle through 99 pages!

Part of the change is that only three subpages will be used, to reduce waiting time. Subject areas of the magazine are to be renumbered as well, each getting its own 'hundred' catagory. The travel section, for example, is to be expanded and updated more frequently by the new BBC Travel service.

TV GRAPHICS

Conventional television pictures can now be combined with computer graphics on a fully interactive scale, thanks to a breakthrough in image processing from Videologic, a British company based in Hertfordshire.

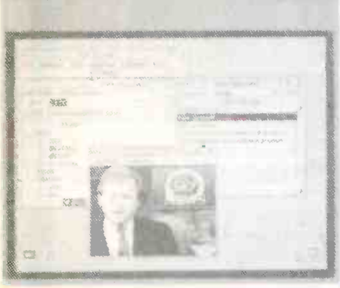
It is nothing new to overlay computer text onto a full-screen image displayed on a standard television screen. There has also been some success in digitising a continuous TV picture for display on a conventional computer monitor.

But the DVA4000 (Digital Video Adapter) goes further. It allows real-time processing of the signal as a binary array, enabling windowing, fades, layering and so on. An entire image could be reduced to icon size, to be selected when required and 'pulled' to the desired size. This form of video integration requires very fast processing — some 25Mbits per second when used with an IBM PS/2 machine.

The development of the DVA4000 has involved £1.5m research and design using the custom chip CAD facilities of VLSI in the US, and 8-layer PCB manufacturing in the Netherlands.

It supports all 17 VGA modes so needs no extra graphics card and uses a single expansion slot.

For more details contact Videologic, Home Park Ind. Estate, Kings Langley, Herts WD4 8LZ. Tel: (09277) 60511.



INDUSTRIAL CAMCORDER

A new Video 8 recorder/player is now available from Sony's new range of industrial 8mm audio and video products.

A growing number of Video 8 camcorders are being used in areas such as education, training, travel and research. With the growing acceptance of 8mm format and the ever increasing base of 8mm camcorders, Sony believes the new recorder/player will find a niche in non specialist areas within industry and commerce.

In the industrial sector, Video 8 is now being used for test bed recording, production line monitoring and operational analysis.

Its chief advantage is its small size. The Video 8 tape is no bigger than an audio cassette.

The EVO 520P is a rugged industrial version of its consumer counterpart and being a front loader, it can be rack mounted. The machine has an auto repeat function and in search mode, recognisable colour pictures can be followed with ease, a useful function. The player operates on AC or DC, and the low voltage DC gives the flexibility of usage in field work. The price tag on the EVO 520P is £795.00.

Further information from (0256) 474011 ext 3603.

CAD CIRCUITS

A machine code utility for designing and printing circuit diagrams for the Sinclair Spectrum (48k, 128k, +2) is now available from BESoft.

The software package offers facilities for drawing, editing, storing and printing of diagrams. The user friendly system includes 50 standard circuit symbols and associated logic gates with 400 more user-definable symbols. The symbols can be rotated or flipped to give the correct orientation and then moved into the correct position.

Labelling of text includes Greek characters and a magnifying facility gives four times the normal size around the area of the cursor. The printer interface options are ZX or Alphacom 32 type, Centronics Interface and Interface 1-RS232 output.

Prices are £17.50 (cassette version) £19.00 (microdrive). Both include postage and packing.

Further information from BESoft, 20 Ashfield Road, Leytonstone, London E11 4DT. Tel: 01-588 3469.

LASER WORM

Mitsubishi is introducing a new optical disc storage system into the UK.

The MW-5U1 is a laser action WORM drive (Write Once Read Many times) and comes complete with the standard small computer system interface (SCSI) for your PC.

Mitsubishi wants to target the package at places where high volumes of permanent storage are required. These include CAD graphics, database storage and archival systems for legal, financial, scientific and medical organisations. The disc drive can store 300MB on each side of the optical disc cartridge and the software allows standard DOS or MS-DOS read/write access to any PC.

The drive is said to be the fastest available anywhere with random access times of 80ms, track to track times of 1ms and average positioning times of 63ms. Data transfer rate is 5.5Mbits per sec.

The MU-5U1 package comes complete with a 600MB optical disc cartridge and retails at £2500.

For further information contact Mitsubishi Electric UK Ltd., Electronics Division, Travellers Lane, Hatfield, Herts AL10 8XB. Tel: (07072) 76100.

GIANT LEP FOR MANKIND

The Large Electron Positron collider, LEP, built in Geneva, is about ready to shoot its load. The accelerator has a 17-mile circumference and is 11ft wide, burrowing through the border between France and Switzerland — a truly international project funded by the 14 member countries of CERN, the European Centre for Particle Physics.

High on the list of priorities for LEP is a systematic study of the particles that transmit the weak nuclear force, the so-called Z particles.

These have been seen before but not in sufficient quantities to allow analysis.

There is also, as always, the hope of spotting new particles such as the elusive Higgs boson.

ROCKING ROBOTS

Rock Circus, a new permanent exhibition of static and animated rock stars, opened in London last month.

The Tussauds Group, famous for its wax figures, decided there was a need for an exhibition of rock music history.

To display such a vibrant part of our culture was a challenge, so they developed and patented the robotics or audio animatronics section of the show. Their movements, lighting, sound and effects are all controlled by two powerful computers.

Walking around the show, you can hear the full hi-fi sound through cordless infra-red headphones. Many spectacular effects await you on your journey through pop history. A full review of this and the exhibition will be given in next month's ETI.

The show is open daily 10am to 10pm at the London Pavilion, Piccadilly Circus. Prices are £4.20 for adults and £3.15 for children.

CHIP SPEAK

Cogent Technology's modular speech synthesis system can give you a microchip that can add a human voice to your products.

The system interfaces to machine I/O ports producing any number of different speech output combinations. It can give single words or sentences and react to real time situations. A simple system, using 10 to 20 key-words in different combinations will cost a few tens of pounds when produced in quanitities of a hundred or more.

The speech is stored on EPROM in the form of digitally recorded and compressed speech. The intonation and inflection of the male or female voice can be changed if required. As the package is miniturised it can be used in anything from a hand held meter to a large machine tool.

Contact Cogent Technology Ltd. Dock Lane, Melton, Suffolk IP12 1PE.

AUDIO PARTS

Graham Nalty, the man that gave you the Virtuoso Power amplifier way back in 1988 can supply you with a list of upgraded components for your JLH Audio Design amplifier through Audiokits Precision components.

A list of components is available from Audiokits, 6 Mill Close, Borrowash, Derby DE7 3GU. Tel: (0332) 674929.

YOUR CHANCE TO WIN!

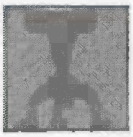
Subscribe to ETI and win a John Linsley Hood 80W MOSFET POWER AMPLIFIER.

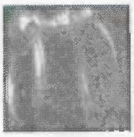
What better way is there of making sure you never miss another copy of ETI than by ordering an annual subscription for only £18.00*?

Each issue is delivered direct to your door at no extra cost. For a limited period you now have the chance to win, in our exclusive competition.
To win this complete kit, order your subscription using the coupon provided and study the four pictures below. Each is taken from the cover of ETI in the last six months. Simply write in the correct cover date next to the relevant letter on the coupon and you could be the winner of this spectacular prize.

John Linsley Hoods 80W Audio Design MOSFET Power Amplifier was featured in the May 1989 issue of ETI and the kit is produced by Hart Electronics as the flagship of its pedigree audio range. It combines the excellent performance one expects from a Linsley Hood design, with a versatility unusual in power amplifiers. The passive input stage with gain and balance allows direct imput not only from a pre-amp but from CD and tape decks direct.

This offer is also open to current ETI subscribers who wish to renew or extend their current subscription but they must do so using the order form provided. The lucky winner will be the first correct form drawn. A photocopy of the order form will be acceptable is so desired.



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A .... C ....

B .... D ....

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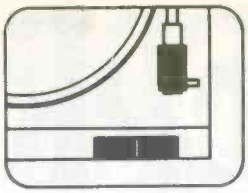
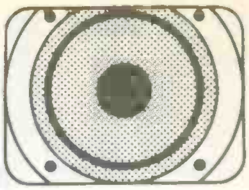
TERMS & CONDITIONS

This offer closes on Friday 29th September and is open to UK residents only. Subscriptions received using the order form provided and showing the correct competition answers will be entered into the DRAW. No cash alternative will be available to the winner. The winner will be announced in a future issue of ETI. The judges decision is final. Full details of the terms and conditions of entry into this promotion are available on request.

HART

PLAYBACK





Over the last couple of months I have introduced the concepts of Pulse Density Modulation (Philips) and Pulse Width Modulation (Technics) as applied to D/A reconstruction in modern CD players.

Well the pace of technology has not let up since, for no less than two new D/A convertors have been introduced in the last few weeks.

The first of these is a new 16-bit DAC from Philips who, for the time being at least, appears to be covering both multi and single-bit bases! First seen in the sub-200 CD610 CD player, this new 'economy' DAC has been integrated down to an 8-pin DIL package. Imagine, a dual-channel 16-bit convertor no larger than an NE5532 op-amp!

Technically the TDA1543, as it is known, falls behind the standards set by their top TDA1541 convertors yet some of its specs are quite remarkable. THD and noise typically fall in the −80dB range at peak level (as opposed to the TDA1541's <−100dB) yet in terms of amplitude linearity its −90dB error of just −2.4dB represents tough competition.

Oddly enough if the linearity of the TDA1543 were assessed in terms of s/n, as is the SAA7320 bitstream chip, then a figure of 13 bits would seem most appropriate. However in terms of amplitude its moderate low-level error implies a practical linearity of some 15.6 bits.

Expect to see this new DAC crop up in a number of budget players. Its low 5V supply rating also makes it an ideal candidate for portables and the like.

Of greater surprise this month was NAD's announcement of two new CD players, the 5320 and 5325, which have been designed around a new hybrid DAC from Sanyo. The LC7881 is another low-cost chip yet it combines the virtues of multi-bit operation with the simplicity of a PWM glitchless output.

The LC7881 incorporates two independent D/A convertors which latch the incoming 16-bit data stream and sub-divide it into three distinct bit-words. Specifically the first 9 Most Significant Bits (MSBs) are separated to control a series-ladder of 512 resistors ($2^9 = 512$). Acting as a 9-bit switch this DAC generates two output voltages, V1 and V2, that correspond to levels slightly above and slightly below that described by the 9-bit word.

For truly monotonic conversion the resistance chain of a 9-bit DAC demands an accuracy of less than one part in 512. In a conventional 16-bit DAC the 65536 available quantisation levels require an accuracy 128 times as great for monotonic conversion. This is all well and good but there is little to be gained by truncating the 16-bit code for simplicity of operation if the original 98dB linearity is still desired.

Sanyo has solved this problem by employing the 4 Least Significant Bits (LSBs) to control two variable resistors that are connected in series with the two ends of the 512R chain. These are used to trim the R-string 9-bit convertor outputs such that the total voltage across both variable resistors remains constant but that the unit resistance of the main R-string alters in steps of 1/128.

Having accounted for the nine MSBs and the four LSBs the remaining three intermediate bits are employed to generate eight different pulse widths ($2^3 = 8$) within the PWM output DAC. These eight different pulse widths determine the percentage of time occupied by each of the V1 and V2 voltages, necessitating a clock frequency able to accommodate up to 16 different widths.

The maximum data rate is therefore 16 × 176.4kHz (the latter derived from a 4x oversampling filter) = 2.8224MHz. However, as with previous PWM systems, each 176.4kHz conversion sample must be subdrived into nine equal time slices. This is necessary to accommodate the maximum pulse width (equal to 8x the least pulse width) plus one wait cycle (also equal to a least pulse width). Therefore the clock edge accuracy has to be within 9 × 7.8224MHz or 25.4016 MHz. Sanyo actually specify 8.4672MHz because they claim a total of 3 clock cycles per PWM conversion cycle.

Either way this is a cost-effective method of avoiding the non-monotonicity, zero-cross distortion and glitches suffered by conventional DACs. Perhaps other hybrid systems are on the horizon.

Paul Miller

BLUEPRINT

Dear Blueprint

This Blueprint and the one or two following are to be somewhat different from usual. ETI has received an enquiry from the Dyfed Wildlife Trust for help in providing an amplifier to play amplified recordings of bird calls in the hope of attracting migrating birds to re-establish a colony. The project is larger than would be normal for a Blueprint, but it is technically interesting and *A Good Cause* so I decided to see what can be done.

There is limited technical backup at the wildlife trust, so the plan is for ETI to provide the parts and for me to assemble the necessary modules, while explaining in print the rationale behind the design.

Shearwaters

Manx Shearwaters are sea birds which land only to breed, and they seem to do this at night. They nest in burrows, as a result of which the colony on Cardigan Island were exterminated in the 1930s when rats escaped from the wrecked steamer Hereford. Now that the rats have been eradicated from the island the Dyfed Wildlife Trust (sponsored by Cresta Holdings of the Isle of Man) are trying to encourage a new colony of Shearwaters to form.

Previous attempts have involved taking birds too young to fly and transporting them to the island in the hope that once they can fly they will return in the normal migration pattern. This has not worked apparently because the lack of a flourishing colony on the island has meant that the island is quiet and hence not attractive for their return.

The strategy now is to play recordings of the call of the shearwater in the hope of attracting birds to the island. If it works this would eventually become self sustaining, but some time might be required for the colony to build up to this point.

Power

The island is uninhabited and has difficult access. It is just about possible to land by boat, but impossible armed with tools and electronic equipment. Consequently any electronic equipment installed must be very reliable and able to function without intervention for long periods of time. The use of any power source requiring periodic attention is ruled out, which leaves wind or solar power as the two obvious choices. Power from such sources can vary greatly due to our renowned British weather.

The equipment will initially be delivered by helicopter but maintenance visits could be a problem!

A solar power system by BP Solar is being used. This can be guaranteed to provide 10AH/day at 12V over the period from January to October, with more available in practice over the middle part of the year if the weather is good. The original request was to provide 60W audio output for the whole night, a demand clearly beyond the capability of the power source. In addition it was initially thought that the signal source was to be a highly reliable environmentally sealed automatic tape machine provided by Racal Recorders, consuming 24W. Erk alors!

Subsequently they have provided a CMOS RAM store. The power consumption of this unit is too small to consider, so that what power is available will be able to be fed to the amplifier. Even so, it is quite possible that over 100W will be required to provide an output of 60W. The average power consumption depends on the waveform of course, and the current consumption will not be as much as if the output were a 60W continuous sinewave.

The exact time for which the unit can run over each period of 24 hours depends on the efficiency, but at least an hour should be possible. The ornithologist confirms that short periods of sound rather than continuous bird calls is likely to be effective, so that the project is now possible within the constraints of the laws of physics.

Now we get to the electronic questions. A pair of 8R horn loudspeakers are available, each rated at 40W. If these were connected in parallel the voltage required to provide a power of 60W would be 15.5V RMS, which translates to 43.8V peak to peak. Any practical amplifier which is to provide 43.8V peak-to-peak will need approximately a 50V supply to do it. As an alternative, one might deliver the required power to the loudspeakers by using a step-up transformer on the output of the amplifier and running the amplifier on the 12V supply.

The disadvantage of running the amplifier on a 12V supply is that, using tried and tested circuit techniques, one is unlikely to swing the output closer to the power supplies than within 2V. The waste of a total of 4V out of a possible output swing of 12V would lower the efficiency of the circuit too much.

Various compromise solutions, using bridge amplifiers for example, were considered and rejected. Some of the solutions considered were technically interesting but the prime requirement is that the equipment shall be reliable. It is simply not practical as an amateur project to design fancy circuits from scratch and be confident of leaving them to run unattended for months on end. For a project of this nature well known and understood technology is needed.

Inversion

The design stategy which I am following is to adapt, with his kind permission, a design done by John Linsley Hood. The April and May 1986 issues of ETI published his design for the 55W power amplifier to run from 12V. This has been carefully designed for the purpose and has probably had more design time applied to it so far than is available before the equipment is to be installed. John Linsley Hood makes the point that the sensible designer will look through his files of other people's designs to see what has been done in a particular area, and perhaps thereby avoid reinventing the wheel or falling foul of an unobvious snag. This is a case in point.

JLH's amplifier design is in two parts. First of all there is an inverter which increases the battery voltage to 55V, then in a separate module is a simple but sturdy single rail power amplifier. The modules could almost be used as they are designed but certain alterations can improve their applicability to the specific project. At the time of writing this I am hoping to be able to use the PCBs originally designed for the project courtesy of the ETI PCB Service.

One special requirement is that the amplifier system must be capable of being switched on and off automatically, perhaps at intervals of five minutes, without making any sort of power up thump which may startle the birds. It may therefore be necessary to add a slow startup circuit to the 55V inverter. Further, it is preferable if the volume rises over a period of several seconds rather than the sound starting abruptly, again to avoid startling the birds and defeating the object of the exercise.

The frequency range of the bird calls is rather limited, so a full bandwidth is not required from the amplifier. The range is 400Hz to 1.2kHz and for such a narrow range there may be some advantage to be gained by limiting the response of the amplifier. This should become clear on careful examination of the circuit.

As well (if it can be done simply), it might be a good idea to sense the battery voltage and to shut down if it falls too low. Deta/Leda batteries (DJ Batteries in Stoke) donated the solar batteries which are rated for deep discharge, but it would still be possible to damage them if they were utterly flattened and kept that way by too heavy a load. Lead acid batteries, used here for power storage, are vulnerable to the formation of lead sulphate, which is insoluble once formed. This removes lead and active electrolyte from any utility. In severe cases the crystals of lead sulphate can buckle the plates and cause a short circuit. Temperature cycling a partially discharged battery accelerates this process.

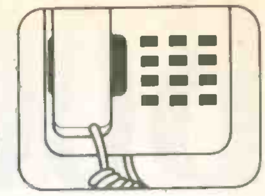
Wide temperature swings may be expected, and it is unrealistic to expect the batteries to be fully charged all the time, so they are specially designed to survive this kind of treatment. Nevertheless, their long term utility could be impaired if, due perhaps to a corroded connection to a solar cell, the batteries were flattened and left that way. Hence the consideration of a cutout circuit.

Next month I hope to cover such design adaptations as were necessary, and to report on tests of the modules.

Andrew Armstrong

The Blueprint column is a service to our readers to provide electronic designs to order. Many a project never gets further than the drawing board because of difficuties with one small part. If you're stuck for a circuit or technique, let the ETI expert help you out. The requests that are selected for publication are likely to be of possible general use or interest to other readers. Enquiries such as 'my oscilloscope is broken, how do I fix it?' are not really suitable for Blueprint. If you have an enquiry, send it with as much detail as possible to ETI Blueprint, Argus House, Boundary Way, Hemel Hempstead HP2 7ST.

OPEN CHANNEL



If all accounts are anywhere near true, British Telecom is about to forge ahead with a revised method of applying videotex. BT's own Prestel — the videotex originator designed and developed by BT long before anyone else had even considered videotex — has never even scratched the surface of potential in the UK.

Prestel is ten years old this year and hasn't changed much since it started. When it opened for service, it was the golden goose of the nation — but now it's more a lame duck. But I've argued this before I hear you say. Yes, back in the November 1988 issue of ETI I gave a lengthy sermon, aimed specifically at BT, showing it how to go about revitalising videotex.

In that text I showed how videotex *can* make good and indeed *has* in the French videotex system known as *Minitel*. The French equivalent of BT known, would you believe, as France Telecom, has more than four million Minitel terminals in use. Contrasted with Prestel's meagre eighty thousand terminals, this looks fairly impressive.

So what makes Minitel so much better than Prestel that four million French people want to buy it. Well, for starters, they don't have to buy it! Minitel terminals are *given away* by France Telecom — the terminals are a loss leader, which presumably can be written off against tax anyway. Terminals earn their real worth by increasing the the usage of the French telephone system, bringing in many more times their value in revenue created by the extra telephone calls which are generated. In more monetary terms, France Telecom has estimated that every terminal pays for itself in extra calls within a year. With everyone in the country expected to have a terminal by the end of the century, this means steady growth in telephone traffic (currently growing at over 20 per cent a year) and enormously increased revenue throughout.

Just to contrast with this situation, even BT's boss Iain Vallance has said that he expects the growth of British telephone traffic to slow down to nil over the near future. Something must be done to counteract this.

BT is currently in negotiations with a number of companies, including Alcatel (manufacturer of Minitel terminals) and Tandata (manufacturer of current Prestel terminals), all of which bodes well for UK videotex. Rumours abound that these terminals will be subsidised by BT to be a giveaway or at least very cheap. They'll need to be.

But giving terminals away is not the only thing required if Prestel is to be the figurehead for increased revenue. Even if the terminals are free, who would want to use Prestel? It's not a particularly nice videotex system, for a number of reasons.

First, the videotex services currently provided are virtually irrelevant to the majority of the British public. Minitel has many more services not yet found on Prestel. For example, the computerised French national telephone directory is available via Minitel. BT is always struggling to keep its dialled directory services up to the level of demand — particularly in the cities — so why not put it on Prestel? What about bus, plane and train timetables — local, regional, national and international? What about home shopping, home banking, business information? True Prestel does supply *some* of these services but it still hasn't got it right!

Second, technically Prestel is a page-based system which is extremely slow and unwieldy to get around — Minitel, in comparison, is menu-based.

Historically, Prestel has suffered because it was the first videotext system. Everyone else learned from our mistakes. Now it looks as though we're about to get a second chance. Please Mr Vallance, can we learn from everyone else's mistakes and make ours an even better system than theirs.

If we get it right, the public and BT will benefit. But getting it right means having the desired services and the terminals to use those services economically. If the services aren't the ones we need and the terminals are expensive, we'll end up with another useless videotex system. The phoenix arising from the ashes of Prestel may just be another lame duck!

Keith Brindley

BOOK LOOK

Electronics Engineers Handbook 3rd Edition
Edited by Donald G Fink & Donald Christiansen
Published by McGraw Hill
ISBN 0-07-020982-0
Price £79.95

The Electronic Engineers Handbook, revised in 1989, is a weighty tome covering everything from the basic physics and maths relevant to electronics to applications such as digital audio. It is written in twenty nine sections, grouped in four parts under the general headings:
Principles Employed In Electronics Engineering.
Materials, Devices, Components and Assemblies.
Electronic Circuits and Functions.
Electronic Systems and Applications.

Each section commences with a detailed contents list, which supplements the brief description at the front of the book. The book is well indexed and arranged to enable the reader to locate any topic quickly, a necessary point rendered more so as there is more in the book than in several ordinary textbooks.

It is not possible to do full justice to such a work in a short review, so I will examine sections which exemplify the standard of it. Section 1 starts by defining the subject of electronics and carries on to cover relevant aspects of particle physics. It also gives good coverage of electrostatics, magnetism and electromagnetic waves among other items. The derivations of formulae, so beloved of college professors, are not included. If you have some familiarity with a subject area then you will be able to use this book for reference. It will not, however, serve to teach a subject area from scratch.'

Clearly some sections have been more thoroughly or more recently updated or rewritten than others. There are a couple of valve circuits in the subsection covering audio amplifiers. This said, most of the information is either of a fundamental nature and thus becomes out of date slowly (if at all), or is up to date at the time of publication. Examples of the former would be the sections on mathematics or radio wave propagation, while the section on computer softwave is as up to date as is plausible for a book rather than a magazine. Even in this section, more weight has been placed on general concepts likely to remain valid even after specific programming languages have evolved or fallen out of use.

Who would benefit from this book? The beginner in electronics is unlikely to be able to make enough use of the work to justify its cost. There are no simple designs which the constructor can build or adapt easily. At the other end of the scale, the expert in one narrow field is unlikely to find the book of any use in his or her field of expertise, because it does not go deeply enough into individual topics to teach the experts.

Serious students of electronics, people who produce subtle and complex project designs, and above all engineers working over a wide range of disciplines are likely to find the book valuable. It is clearly designed as a reference book for the professional who may not to able to remember necessary information about a subject area which is only occasionally necessary to his work. The book has already proved its worth to me in this manner, though it contains some sections to which I shall probably never need to refer. I would recommend this book for committed students or for engineers who want a reference book covering almost everything they need to know and may otherwise have difficulty in finding out.

Andrew Armstrong

Lightwave Technology, An Introduction
Chaimowicz J C A
Butterworths Press
Price £27.50

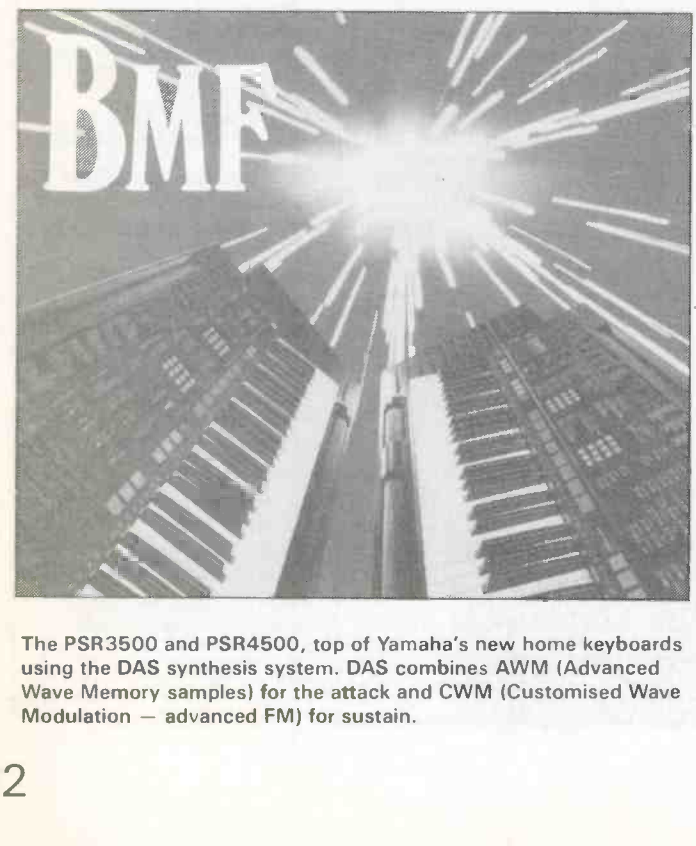
Seldom, in this age of book after book after book on technology, do I wax even faintly lyrical about any new title. I mostly find them very similar and somewhat lacking. It is most refreshing to discover a new book which breaks the mould.

In this case the mould has been well and truly smashed. The field of modern optics is generally considered to be abstruse and beyond the average man's comprehension. Here then is the antidote. In little more than 300 pages Mr. Chaimowicz takes us from basic concepts of light rays and lenses, via optical semiconductors, lasers, holography and fibre optics into the as yet uncharted fields of integrated optics. Throughout, he provides a wealth of real-world example, and the mathematics is mostly not even beyond me.

What makes this book specially exciting however, is the breadth of scholarship the author has brought to bear: not only are we presented with technology (fascinating though it is), but here and there we find derivations of terminology in half-a-dozen languages and notes on photosynthesis, plus historical background and industrial applications, all expressed in a delightfully readable manner which constantly challenges one to look further. What can one do but read on when presented with the initial proposition that "all light rays are invisible"?

All in all, an excellent book for interested amateurs and students to BSc level. Well worth its price, and guaranteed to stimulate further interest in modern optics. My only reservation is that for a couple of quid more, hardback binding would have stood up better to the use this book is likely to get — on my bookshelf at least.

Mike Barwise



The PSR3500 and PSR4500, top of Yamaha's new home keyboards using the DAS synthesis system. DAS combines AWM (Advanced Wave Memory samples) for the attack and CWM (Customised Wave Modulation — advanced FM) for sustain.

At the 1989 British Music Fair, Olympia was packed to the galleries with exhibitors bringing increasingly complex music technology to the marketplace at decreasingly frightening prices.

Nowhere was this more apparent than the arena of the budget keyboard. This is a market once held almost exclusively by Casio, more recently joined by Yamaha's tumbling-priced FM units. Yamaha now has some well turned-out units at most reasonable prices. The YS100 (£349) and YS200 (£449) have velocity sensitive keyboards and ten on-board digital effects to plump up those 4-operator sounds.

Those who have not yet rushed out to buy Yamaha's remarkable EMT-10 AWM sample expander (£250) might wish to examine the new AVS-10 before they do so. This has been produced to slot into the Electone Home Keyboard and consequently looks dreadful. The samples, however, are close to perfection — piano, choir, strings and timpani ruling the roost. The AVS-10 has 3-channel multitimbral operation and retails at £399.

But perhaps the most remarkable performances were handed in by Kawai. The technology that brought huge success last year to Kawai's K1 keyboard (and sons) has been blown wholesale into preset sound chips and released in a range of home keyboards.

The PH50 has some 200 of the K1's best sounds and allows you to layer them in the manner of the K1's multi-sounds — at a price of £299. And the technology has even gone into the kid's toys — press the big blue buttons and you can come out with an impressive string sound.

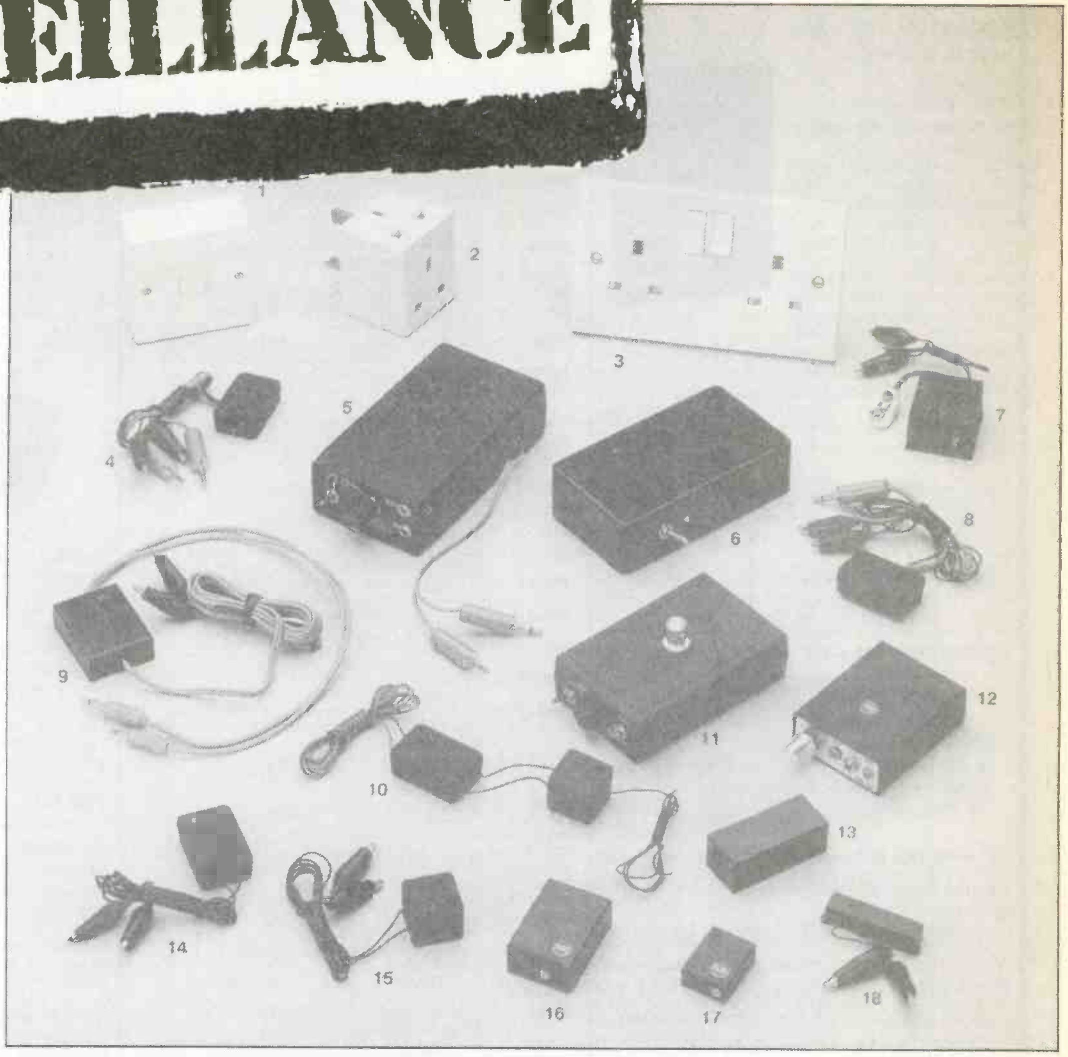
Lastly Roland deserves a mention for its computer-orientated expanders. Designed in 'IBM beige', the CM32L (£369) is similar to the MT32 but bigger, with 128 sounds, 32-voice polyphony and 9-channel multitimbrality. The CM32P (£445) contains 64 PCM sampled sounds and takes U110 ROM cards. It has 31-voice polyphony and 6-channel multitimbral operation. The CM64 (£789) has both in a single rather understated box.

Colin Cat

UNDER SURVEILLANCE

Paul Chappell lifts the blinds surrounding the problems and solutions in electronic surveillance

SURVEILLANCE



A selection of off-the-shelf surveillance equipment available from Lorraine Electronics Surveillance. 1-3 discreet transmitter housings; 4,8,9,13-15,18 telephone surveillance devices; 5,12 amplifiers; 6,7,10,11,16,17 transmitters.

1: Electronics Bugs: theory and circuits

Before the clamp down on the sale and use of bugging equipment in the USA, there were over sixty companies supporting themselves entirely by the sale of such things. It couldn't happen here, could it? To find the answer you won't need to join some underground organisation — look no further than the pages of the Exchange & Mart, for heaven's sake! There it all is, openly advertised for anyone to buy.

In this and the following articles I'll be looking at some aspects of the surveillance industry and, since this is a practical magazine, giving you some circuits to try out for yourselves. You should be aware that, according to how you use them, you may fall foul of the law. A Paul's eye view of the current legal position follows but although the facts are basically correct, there's no way we can help you if you do something silly and get caught doing it. Let's face it, most people don't take at all kindly to being bugged and if you plant one in your boss's office, he'll give you the boot and have every right to do so. You may end up in court too.

On the other hand, if you use the circuits for a bit of fun, as long as you don't Interfere with anyone else's reception of VHF broadcasts, nobody will bother you — legally they could, but they'll be unlikely to do so (this again is Paul's opinion, you understand). Enough of the lecture. You're all big boys now, so off you go and enjoy the rest of the article.

The Legal Position

Although the planting of bugs and tapping of phones theoretically contravenes all manner of rules and regulations, hauling the 'buggers' through the courts doesn't seem particularly high on anyone's list of priorities. This can be attributed to a very low public awareness of the subject — the general consensus seems to be that you have to be Russian, a member of CND or a brewer to qualify for a bugging. Since most people are none of these, they don't feel paricularly threatened by the prospect.

For room bugs, the current situation seems to be this: as long as you enter the premises by some legitimate means (that is, you don't resort to breaking and entering), plant your bug and then retire to a safe distance to listen, the naughtiest thing you have done so far is to contravene the Wireless Telegraphy Act.

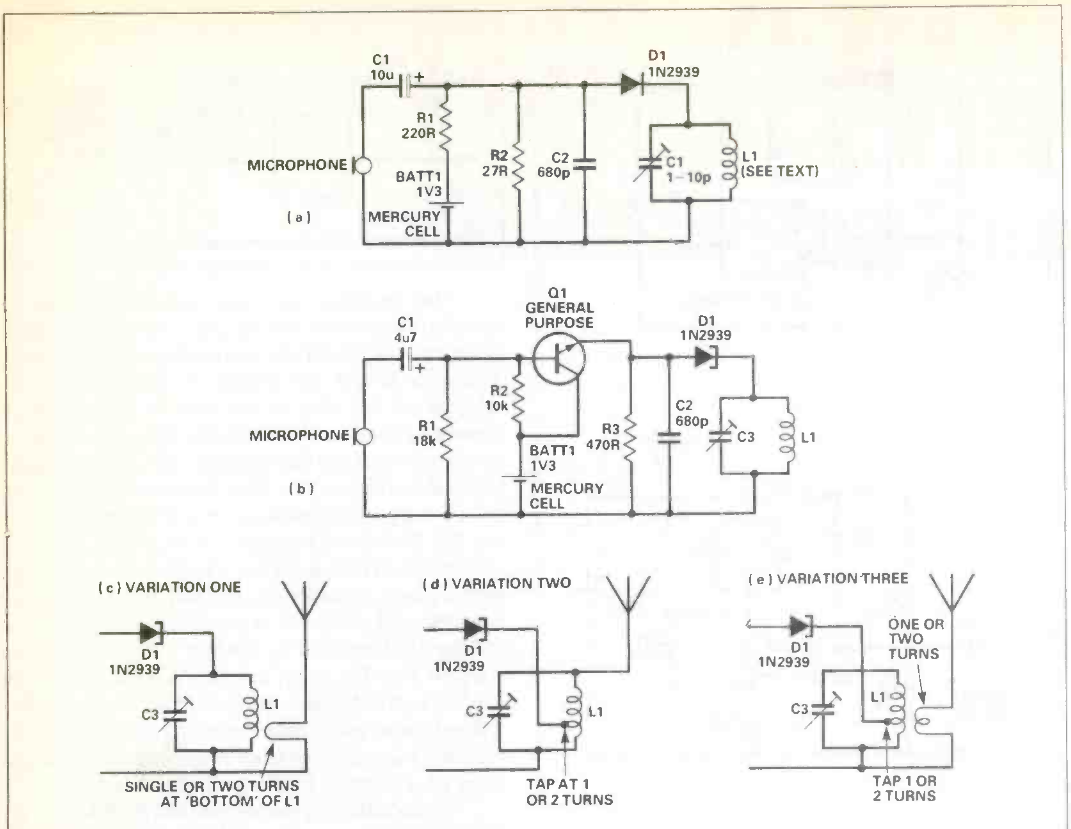


Fig. 1 (a) Tunnel diode microbug (b) Adding a buffer for a microphone (c,d,e) Variations on the circuit

If anyone is insistent enough to have you up in court, it's a slap on the wrist affair. A small fine and you're away.

The thing that is technically illegal is to make use of any information you acquire in this way. This is quite a tricky one because one of the semi-legitimate uses of bugging equipment is for internal investigations. If it is suspected that someone in a company is, let's say, giving away marketing plans to a competitor, the only way to prove it might be to bug his office or his home. The trouble is that if the information is used, even in court, there's the embarrassing question of where it came from. Those who use it are on the wrong side of the law too. The strategy of the good guys will probably be to confront the bad guy with the evidence and persuade him to pack his bags and go. It seems to work.

Tapping phone lines is another matter altogether. This comes under the 1985 Interception of Communications Act which protects letters, telephone calls and various other services licensed by the DTI — Vodaphone, for instance. The very installation of the equipment in the first place is illegal in the case of phone taps.

Having said that, the prospect of suffering the rigour of the law doesn't seem to deter those who make a living from such activities. One or two have even given blow by blow accounts of their activities for the TV cameras. No public outrage, no calls for a tightening of the law or the prosecution of the offenders. Just a mild curiosity at the wacky old things that some people get up to.

A recent development has been the attempt by James Cran to introduce a bill to control electronic surveillance devices. The yawns of his Conservative colleagues have been overwhelming, and although at the time of writing there's still the possibility of a second reading in a few weeks' time, for my money the whole thing will be gone and forgotten by the time you read this.

Room Bugs

These are the devices with the Hollywood superspy image — tiny microtransmitters, totally invisible if planted by the good guys, always leaving some telltale sign if planted by the bad guys. Somehow the Hollywood versions only pick up relevant information too. None of this 'What's for dinner?' or 'Have you seen the new Batman movie yet?' kind of chit chat. Always 'Right, let's talk about the secret plan. You know, the one where we drive into the nuclear widget plant at exactly ten o'clock tomorrow morning disguised as plumbers in the blue van, registration number ETI 1989 . . .' You know the kind of stuff.

Real life ain't like that. The first difference, often quite disappointing to those with romantic notions about the business, is that most bugs aren't all that small. The reason is obvious when you think about it. If the bugging operation is going to be worth the aggro, the transmissions have to carry for a reasonable distance. If they only carry to the next room, you might as well just put your ear to the wall or use a simple microphone and tape recorder set-up. If the transmissions are to carry for any worthwhile distance, the bug needs to poke out 10mW or so, which requires a fair sized battery to supply the juice. And if you need a big battery, there's not a lot of point in going all out to miniaturise the electronics.

Tiny bugs do exist — all kinds of ingenious methods have been devised to overcome the power problem and to some extent the deficiencies of the transmitter can be overcome by using a super-sensitive receiver — but they tend to be temperamental, expensive (by which I mean *very* expensive) and unreliable. Those who earn their beans on toast from planting the things will, for choice, go for the more substantial and reliable ones every time.

Having said all that, Fig.1 shows a circuit that gives scope for being made as small as you could ever want it, simply by virtue of having very few

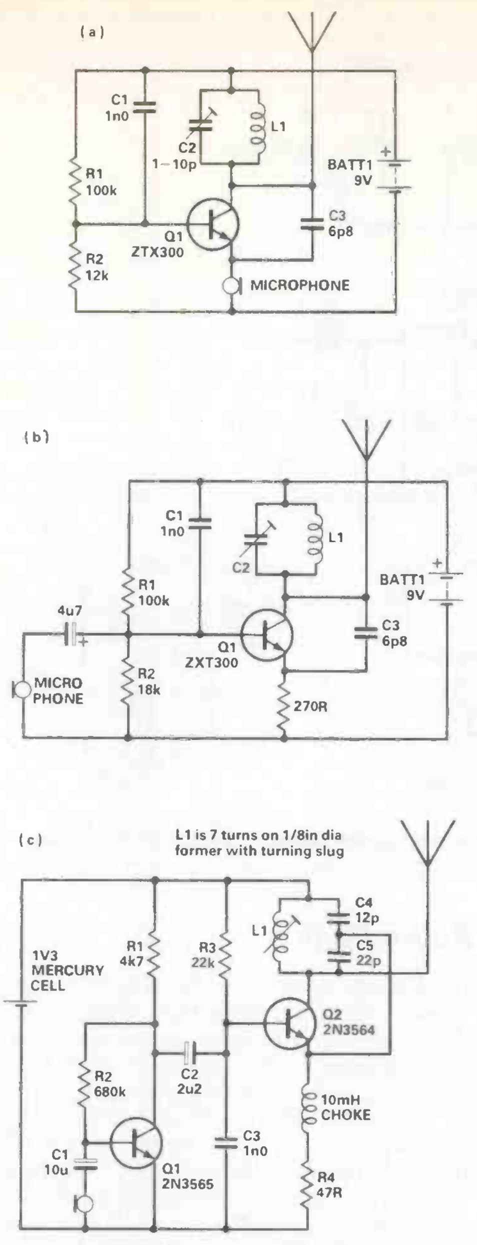


Fig. 2 (a) Simple single transistor bug circuit
(b) Improved circuit
(c) A commercial bug circuit, vintage late 1960s.

components. The RF oscillation is sustained by D1 which is a tunnel diode — it won't work with a 1N4148: R1 and R2 serve to bias the diode into the negative resistance region and the microphone modulates the signal by, in effect, shifting the bias point at audio frequency. The whole thing runs from a 1.3V mercury cell.

For the smallest possible size you could try tracking down a hearing aid microphone. These sometimes can be had from surplus component suppliers — if not, you'll have to go to a hearing aid manufacturer and pay the price of a new one. The tuned circuit C3/L1 can be made in a variety of ways. If you're building the thing into a fountain pen, for example, it may be possible to wind L1 around a former that slips into the body of the pen. At ⅜in diameter you'll need about five or six turns to hit the FM broadcast band. The rest of the circuit can be built long and narrow to slip inside L1. Otherwise, you can save a little space by making C1 a fixed ceramic capacitor of about 6p8 and using a small coil with a ferrite tuning slug for L1.

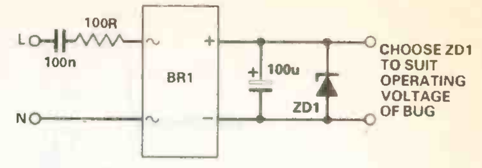


Fig. 3 Transformerless power supply

The antenna may need some experiment. A straight piece of wire will be fine — the output power will vary with the length, generally increasing as the wire gets longer but hitting various maxima and minima on the way as the ratio of wire length to wavelength varies. A few inches will do for a start. If you're going all out for small size, you can't worry too much about the niceties of tuning the antenna — you'll have to rely on any available metal surface to radiate the RF. The metal pen cap, for example.

If you decide to go for a longer antenna, begin with a piece about 2½ft long and snip small pieces from the end until you hit maximum output. Use an ordinary FM receiver for the test — tune it to a clear spot on the dial, then adjust C3 until you hear a feedback whistle. Because the circuit is very crude, it will radiate to some extent at multiples of the C1/L1 resonant frequency, so keep checking for better results even after hearing the first whistle.

When installing the long antenna version, try to keep the antenna straight and vertical if at all possible. If not, don't curl it around. Tape it in a zig-zag. For best range, don't plant it close to the floor — the higher the better. And, if possible, put it near an external wall of the building — the less masonry the signal has to travel through, the stronger it will be. One last thing: bear in mind that anything you can pick up on an FM radio, everyone else in the area can too — including the buggee. It might just give the game away if he tuned across the FM band and heard . . . himself! Best modify the receiver a little and use a frequency just outside the broadcast band.

Although the circuit of Fig.1a will work, a lot of improvements can be made without increasing the component count unduly. Buffering the microphone increases the modulation and so the sensitivity — a circuit for this is shown in Fig.1b. There are several ways of attempting to increase the output by tweaking up the matching between diode, tuned circuit and antenna. Figure 1c and onwards show various ways and means. They increase coil winding complexity but needn't increase the size of the bug unduly if you're careful. In each case the basic winding of L1 remains the same. Extra turns are wound over the top of the cold end for the antenna in variations one and three, and L1 is tapped at one to two turns in variations two and three. If you really want to go to town on the output stage, you can even add another variable cap

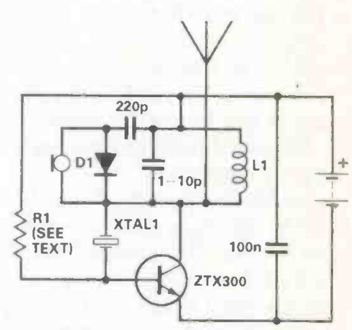


Fig. 4 Simple crystal controlled bug

across the antenna coil. The mods will all give varying degrees of improvement to the basic circuit, but if you're not an experimenter at heart, just stick to 1a or 1b. The circuit can be, and often has been, used in earnest.

Having gone into some detail over the tunnel diode circuit, here are a few transistor ones. For setting up, selecting an antenna and placing the bug, all the same comments apply.

First of all, Fig.2a shows the simplest possible circuit. Almost the simplest anyway — if you are willing to choose R1 by trial and error to suit the particular sample of Q1 you use, R2 can be missed out! The microphone has to be a dynamic of similar type — low impedance and low DC resistance — the latter because all Q1's current passes through the microphone itself. At the cost of an extra resistor and capacitor, Fig.2b is almost as simple.

Figure 2c shows a circuit that was commercially available in the USA until the hoo-hah over Watergate put a stop to such things. Legend has it that the whole thing, including battery, was packed into a volume not much larger than a sugar cube, which just goes to show how small components were in those days. With surface mount components it would just about be possible, although you'd need delicate fingers to wind yourself a tiny 10mH choke. Stick to the tunnel diode, I say.

With the higher voltage transistor circuits, you can do away with the antenna altogether by winding L1 around the edge of the PCB, or even by etching it onto the board. Two square turns about ¼in on each side will do the trick. The range won't be as good, but you'll avoid the problem of where to put the dangling wires.

Although pretty basic, circuits similar to the ones already described probably account for over 90% of the bugs that are ever used. Most of the time nothing more complex is required. There are those odd occasions, though . . .

For long term monitoring, the power supply problem raises its ugly head again. Every house and office has at least two sources of endless power: the mains wiring and the telephone line. If either of these can be tapped, the bug is there for good. The phone line I'll put aside for the moment. For the mains, Fig.3 shows a convenient way to derive power. A capacitor can be smaller than the smallest mains transformer. The basic bug can be any of the circuits shown so far and the complete circuit can be built into a plug adaptor, a light fitting or whatever. If you have access to the mains, there's no need for radiated RF: the wiring can carry the signal for you. Just use any of the mains intercom circuits that are published from time to time, or get hold of a data sheet on the LM1893 carrier current transceiver (National Semiconductors Linear Databook 3).

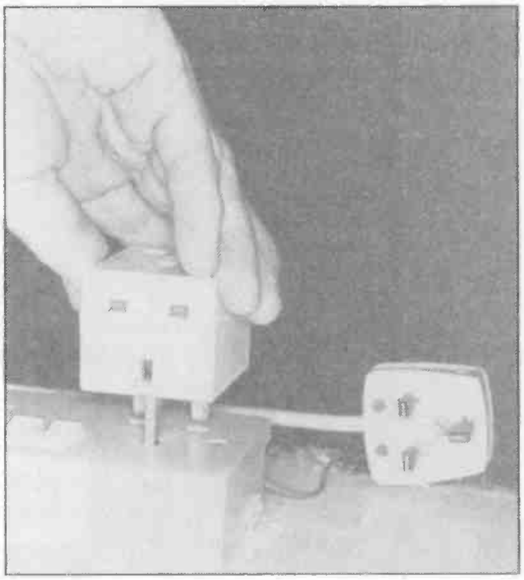
For those with sufficient money and resources to develop exotic and impractical devices, all kinds of power sources can and have been tried. As an example, one source of power is the output of commercial radio stations. In most areas you can suck enough power from the air to drive a crystal earpiece, so why not use that very same power to drive a bug? Because it will have a transmission range of about six inches is as good a reason as any not to bother. But suppose you incorporate a very low current standby switch, store up the power when the bug is not in use and turn it on when the sound exceeds a certain threshold. In conjunction with a highly sensitive receiver this might just be on the borderline of feasibility. The next stage is not to rely on the background RF but to generate a strong RF field yourself. Then you have the great holy grail of the surveillance industry: a completely passive bug. Undetectable because it sits there doing nothing unless activated from outside. No batteries to run down, so it's there for good. Worth the bother? That's not for me to say.

The other problem with long term surveillance is that the simpler bugs will drift off tune — either of their own accord, or because of a change in their environment.

The effects of somebody walking past might be enough to have you reaching for the tuning dial. Unless you have the patience of a saint and a massive coffee budget, you're not going to sit there with the headphones on just in case somebody speaks. Far better to have a tape recorder with voice operated switch and let the thing take care of itself. In this case a crystal controlled bug is called for — about the simplest circuit you can get away with is shown in Fig.4. Modulation is from a variable capacitance diode driven directly by a crystal microphone — not designed according to the highest standards, but it will work! R1 is best chosen on a trial and error basis (or select-on-test as we say in the trade — sounds much better, doesn't it?). Just pop a meter in series with the battery and select for a current of around 5mA. The battery can be any voltage from 1.3V upwards — the only component you'll need to change will be R1.

Beyond this you get to the real high tech stuff. Given access to any device known to man or the facilities and finances to develop bugs as complicated as you choose, there's no end to what might be done. There are very few occasions when anything more sophisticated than a plain radio microphone is really needed — the stakes are only raised when the buggee is aware of the possibility of being bugged and is likely to know how to track and destroy the things, or at least to detect their presence. In this case the battle can raise itself onto ever higher technical planes, with the bugs perhaps encrypting the sound — ideally to make it appear to be noise if picked up on an ordinary receiver — or perhaps lying dormant until activated by one event or another. Maybe it will transmit on a frequency which coincides exactly with that of a broadcast station, so that an RF frequency analyser in unskilled hands will not show anything out of the ordinary. The bug sound could then be recovered by subtracting the broadcast signal picked up by a second receiver from the sum of broadcast and bug picked up by one within range of the bug.

Next time around I'll be looking at the other side: how to detect and locate bugs if somebody is unfriendly enough to try bugging you.



ETI

UNDER SURVEILLANCE

2: The Inside Story

Helen Armstrong

Mankind has been eavesdropping on its neighbour since long before the eave was invented. A hollowed-out mammoth tusk pressed to the party wall of the cave in 20,000 BC perhaps, or a hand-picked slave planted as a bathroom-suite accessory in ancient Egypt. The first true eavesdropper probably fell out of the rafters onto a far conclave of Hittites, doubtless to face a decisive decommissioning by their counter-surveillance team.

And so to the present day, when several tons of SR-71 screaming at Mach 3 through the troposphere mimics the achievements of stealth and silence — get in, get the guff and get out before they see you coming.

ETI is grateful to Lorraine Electronics Surveillance and Suma Designs for their help in producing this article. Photographs are courtesy of Lorraine.

For further information contact Lorraine at 716 Lea Bridge Road, London E10 6AW (tel: 01-558 4226) and Suma at The Workshops, 95 Main Road, Baxterley, Warks CV9 2LE (tel: (0827) 714478).

More convenient ways of finding out what foes and relations are up to are available over the counter — available as you have seen in this very ETI indeed. Whether or not you wish to actively partake, covert surveillance devices — 'bugs' — have entered legend as surely as the Trojan horse and Watergate.

Where would a spy be without his briefcase of miniature radio transmitters, where foreign policy without its regular expulsions of diplomatic personnel for undiplomatic behaviour?

All this is in the hands of Governments and not for the likes of us, but then the likes of us still have our targets, say those in the business. For the business is in erring spouses and conniving associates.

Lorraine Electronics Surveillance develops and markets both 'surveillance tools' plus counter-surveillance tools and services, a combination which director David Benn is quick to rationalise. Not, you would think, that much rationalisation is needed for producing bugs and de-bugs (nobody is surprised when a computer programmer carries out a similar process, after all) but surveillance has an air of heroes and villains about it, and offering both services can look like wearing the black hat and white hat at the same time.

Suffice it to say that any de-bugging consultancy is likely to be looking for rival bugs, as well as its own.

"Contrary to common belief," says David Benn, "surveillance as such is rarely used for espionage or 'spying'. Industrial espionage has been going on since the year dot, mostly by bribing someone — say a secretary or a junior manager." Somebody who is under pressure to live up to a career image but doesn't earn enough and might weaken in the face of a brown envelope full of used fifties. Sound familiar? — "It's perhaps more prevalent today, when people in very responsible jobs need more money and where financial information is valuable. Loss of information is more dangerous than money or stock. Stolen information is invisible until your competitors have it."

Result: managements suspecting that confidential information is going astray need to know where, how, and by whom. In other words, businesses are more likely to bug their own premises than the opposition's.

Home Guard

"Out of thousands of customers, about 30% are large PLCs checking on the loyalty of their staff," Benn reckons. "Junior staff are the least of the problem. They may have directors leaving to set up independently and taking company secrets with them, or there may be corrupt buyers taking bribes."

He breaks operations down into three areas: "recording conversation under difficult conditions" — meaning without being observed; "environmental recording" — or monitoring whole rooms or offices; and telephone monitoring.

The concealed portable tape recorder is a spying staple. Let's call it a classic case: Lorraine's is built into a 'recording briefcase'. Eschewing the obvious false base or sides, the briefcase has most of its electronics, including a microphone and automatic level controlled amplifier, built into the frame. The owner can then choose between a small standard micro-format cassette recorder which tucks out of sight behind the document compartment, invisible to casual observation and standard security checks. Tapes are easy to get hold of that will record for up to three hours, attended or unattended, open or closed, before the tape needs turning. Recording can be started discreetly from outside the case by radio control, or by sound activation.

In other words, the executive to look out for is the one who takes his briefcase to the gents during the second coffee break to turn the tape over. It is a handy alternative to relying on the Minutes to record what was actually said.

Monitoring conversations that you are not supposed to overhear is easy if you can get access to the room in question. Small recorders can be hidden easily but there are maintenance problems, especally for long-term eavesdropping. Tape recorders can click or rumble, tape needs collecting and changing. Radio transmitters have the advantage that once in place they can be left almost indefinitely. Most bugs 'discovered' in buildings are long dead and abandoned, found by accident when the place is refurbished.

Lorraine supplies VHF and UHF transmitters built into solid-state desktop calculators, fountain pens, 13A mains sockets and adaptors, indeed any device which does not generate noise of its own (such as a typewriter). If hardware provides its own mains or battery supply, so much the better. The devices use typically around 5mW and, although 'domestic band' transmitters are available, these could be picked up on passing car radios.

"We advise clients to go up on the air bands where nobody will hear them," says Benn. VHF transmitters are available in the range 129.448 to 139.97 MHz and UHF transmitters are available in the range 390 to 450MHz.

Domestic band devices typically use the FM broadcasting band. The advantages are that the transmitter circuit will be very simple and receivers readily available. The disadvantage is that it is easy to check whether this sort of bugging is taking place. Also the transmitted signal occupies a wider bandwidth, making it more susceptible to detection, so it could appear on a local household radio set.

The air band transmitters have the advantage of being narrow band FM, and since the aircraft FM signals are only an echo, you can hear the planes but they can't hear you.

No Jam Today

One hears about radio stations and other transmissions being jammed by hostile agencies, but jamming is not used by respectable security agents, for good reasons. Besides being highly illegal and very antisocial, it's a dead giveaway.

"If you know what frequency you are jamming on, it is very easy", says Benn, "but if you are being bugged, the chances are you don't know what frequency and can only jam broadband, which will interfere with anything in the area. We would not do it, or allow our customers to do it."

Phone tapping is another area surrounded by myth, some of which is true. If you have a rash of calls which are wrong numbers, or have no apparent caller when you pick up the receiver, or a sudden apparent increase in the number of engineers or telesalespeople on the line, you may be being bugged. It is more likely that the lines are playing up, or the double-glazing world is having a sales push. Crackles or buzzing is unlikely to mean bugging, at least not by the police or government. On the contrary, official bugging is likely to guarantee you the cleanest line in the neighbourhood.

Tapping usually means an interface which switches on a tape recorder whenever the phone is in use. The tape recorder itself can either be triggered by the change in line current or voltage when the receiver is lifted or by vox — the voice itself.

'Bugging' implies a transmitter connected to the line, or mounted in the telephone socket itself. Drawing a significant current from the line to operate the transmitter would interfere with the proper operation of the telephone — doubly so if the current drain continued when the receiver was down. It is for this reason such devices must be very low powered. This, says Lorraine, restricts their range to about 100 feet (worst case). On the plus side, once installed they can be left to get on with it, and only operate when the telephone is in use. No batteries, no tapes.

An *infinity* device can operate over international line distances by holding the line open once the handset has been replaced, allowing the room beyond to be monitored without the occupant's knowledge.

A similar means of holding open the line for telephone lines serving high-sensitivity buildings is mentioned in certain recent 'spy-and-tell' memoirs.

The actual method and site chosen for a bug will depend much on whether the premises belong to the client (giving free access) or to an adversary where bugging must be done by stealth and with a minimum of after-sales service.

There are other ways of getting information. RF emissions from computer monitors, peripherals and cabling has received a lot of publicity recently. A van equipped with a fibre-glass top (or some other structure transparent to radio frequencies) and appropriate receiving equipment parked outside an office block can frequently pick up the exact image displayed on a computer inside the offices. This is a leak which has only come to light with the proliferation of desktop terminals.

'Tempest attack' is a name adopted for this actually non-invasive method. It usually involves picking up harmonics of the line and frame syncs from a monitor on a low frequency receiver, and picking up harmonics of the video on a VHF or UHF receiver. Sync frequencies of 50Hz and 15625Hz do not transmit far, but their harmonics interfere with radio reception, like it or not. Similarly baseband video, covering 50Hz to 5MHz typically, contains high frequency harmonics which transmit over a considerable distance.

Lorraine provides an EMDAR (Electromagnetic Data Analysing Recovery unit) which is not used for stealing information of course. It consists of a scanning receiver covering 25MHz to 2GHz with 100 memories which automatically store the frequencies of the strongest signals. There is also a display on which the strongest received signal can be displayed. In this way the offending computer can be identified. It is handy for demonstrating to customers that data can seep out in ways unthought of. The device costs £15,000.

"This is something that can only be used either for espionage or to prove espionage can be effected," says Benn. "We market it on restricted sale. All the customers who have bought this from us are bona fide security services or public bodies."

The idea is to find RF leaks, trace the source and then provide screening — from individual components to the whole room — to stop them. Companies can also hire the EMDAR and do a check on their own computers, and then call in the security company to carry out screening.

Tempest-proof terminals and PCs are available, according to trade press, but only to Government approved companies. The rest must devise their own security measures or risk data theft. Preventing unwanted radiation from a display is not as simiple as it might at first appear. The electronics can be housed in an earthed metal case and all wires in and out of the case screened. The screen for the cathode ray tube is a mesh — about the best protection possible without preventing anyone from seeing the display.

Other obvious means to minimise radiation would include band limiting signals to minimise harmonics and transmitting antiphase signals to cancel such radiation as remains. There must be more to it than this, or the availability of such terminals would not be restricted.

Debugging is an industry in its own right. William Parsons, who runs Lorraine's counter-surveillance service, reckons that there is no easy way to find the hidden ear.

"Counter-surveillance consists of going in with the correct equipment and looking for devices, checking for unusual cables, testing telephone wires and looking for transmitters or hard-wired microphones. The attitude of the person who heads the team — ours and the clients' — is crucial. For instance, we probably carry more equipment than the average counter-surveillance company, and I don't trust in equipment alone, so we do a full physical search as well." Finding electronics devices by electronic means is not straightforward at the professional level.

When high-level meetings are involved, the CS team will do a *sweep* first as described, and then monitor the location for RF signals during the meeting.

Many types of unauthorised device get attached to the telephone system. Lorraine now uses a telephone line analyser which was developed to try to detect or imply the presence of every kind of telephone tapper and bug known to Parsons, in one box.

"Most analysers are not geared to find everything accurately. This one has tests which people say don't find things, such as time domain reflectometry — they don't use them. I know it does: with the 500 metre version, a time domain used in the building will see any series device and 50% of parallel devices connected."

A time domain reflectometer sends a pulse down a line and looks for reflected echoes. A perfectly uniform transmission line which is properly terminated will give only a very low level echo, but if anything is attached to the line its impedance at that point will be changed, and a more obvious reflection will be generated. The time between the sent and received pulses gives an indication of how much cable is between test instrument and tap. This is only an indication, because the rate of propagation of a signal along a transmission line is influenced by the line characteristics, and may be about 70% of the speed of light.

The way to avoid a tap from being detected by a time domain reflectometer is to load the line very lightly with a very high impedance parallel load taking an indetectably small voltage and current, as a pure audio lift-off. Bearing in mind that a telephone line is not a uniform transmission line but has built in irregularities, such a load applied to the line will not be detectable. Of course, a series connected tap will almost certainly disturb the line enough to be detected.

The telephone bug detector also has a function for measuring line capacitance — an increase means that extra cable has been added. It also has a low frequency receiver, an active line test and a line sweep test. The receiver is to detect carrier signals transmitted along the line, and the active line test measures the line voltages with the phone on and off hook. A bug powered from the line may disturb these voltages. The line sweep test applies a voltage to a disconnected line. The voltage is varied from 0-10V and accurate voltage and current meters indicate if any devices start drawing power.

Export

Much of Lorraine's equipment is sold for export only, as most RF surveillance devices are not type approved, putting them beyond the necessary licensing required for RF in the UK. Likewise, attaching listening devices to the telephone system is in breach of various acts covering everything from interception of communications to interfering with BT wiring. It is not illegal to supply the stuff, only to use it. But clearly much is destined for home use. Do Benn and people like him get aggravation from *The Authorities* on this front?

"Authorities are among our customers as well," he emphasises. "We provide an excellent service for industry and commerce and this is recognised by certain people. There are certain situations in which electronic surveillance is the only option available." He can't be specific, only saying "I think there is a general recognition that we benefit managements rather than harm them."

Why isn't this stuff type approved? The answer will be familiar enough to anyone developing RF or telecomms equipment. "Because it would be horrific-ally expensive." But there is a simpler, more poetic explanation in the nature of the goods. RF equipment is restricted by law because it can cause catastrophic interference to other services. Bugs, by definition, must be invisible.

"If someone knows you're using it, you're not using it correctly," says Benn. "Surveillance devices, including those for telephones, are typically narrow band, about 5mW — nuisance-free. We sell devices across the board, but customers are strongly advised not to use broadband FM products. We advise customers never to use domestic frequencies."

What about the legality of eavesdropping?

"There are no privacy laws in the UK" — another subject of much public debate in recent months — "although the situation is different in the United States," Benn points out.

So you can eavesdrop to your heart's content, if you can get away without prosecution under the various Wireless Telegraphy and Communications Acts. And if you conceal a wholly legal tape recorder in a rival's premises, there is always *Theft of Electricity* and possibly *Trespass*. In practice, prosecutions rarely happen, for reasons we will shortly see.

Tim Jinks of Suma Designs provides design and consultancy on covert surveillance. He looks on international spying with a practical eye.

"It goes on. Ministries won't admit it, but it goes on in a big way and it's good for national security. It's mostly propaganda — we like to hear that everything's OK."

But the person in the street, he says, feels guilty about using bugs and doesn't like the idea until they have a specific problem which they are desperate to solve.

"It's like contraceptives. They won't come in and say I want to bug my business partner or I think my wife's doing this and that, but they do end up telling you quite a lot." If the company suspects unethical use, he says, they will decline to supply by winding the price up or claiming that their services are unsuitable.

Telephone conversations are best for monitoring, says Jinks. People feel vulnerable in the open and room systems must be voice or remote activated with the risk of noise from the machinery. People say more on the telephone — "most bad deals are done on the phone". Likewise RF transmitters are more trouble-free than local tape recorders, much easier to conceal and can be left for ever.

How easy are bugs to detect? I asked. "When was the last time you looked under your desk?" he countered, adding that I should be looking upwards under the rim, not downwards into the floor filing system.

Touché. This is the low end or cheap and cheerful approach — people are always talking about being bugged, but they rarely suspect it. In that respect, he says, people are gullible.

"The low end is easy to find visually, but the target is unlikely to try and find it. On the other hand, taps can be done in various positions along the line. In theory you don't have to go into the building — up a telegraph pole or into the street junction box." Yes, in theory, the chaps in overalls and hard hats poking about in the street junction box could be tapping your phone. "In that case, you have no chance visually."

Lorraine's less than innocent calculator and pen set

Open Door

On the other hand, most people at the 'high end' in the professional bugging category are wise to the possibilities. Many companies have their own counter-surveillance officers. Concealing room transmitters from people who are likely to be suspicious must be done with care. Cavity doors are a gift — just knock a piece out of the top rail, weight the aerial wire to that it hangs straight down, fix the thing in and leave it. There's an air gap at the top, acoustics are usually perfect. There is no real need to stop up the hole unless the housekeeper is going to check the top of the doors for dust.

Plasterboard ceilings could be called the modern equivalent of eaves where eavesdropping is concerned. Roll up the carpet, rip up a floorboard, gouge out the plasterboard until about 1/16in is left (something of an art) and leave the device. A transmitter could be on a board the size of a postage stamp, including batteries — it won't drop through the ceiling. Ideal. Coffee tables with false bottoms are good for meaty long-life battery packs, skirting boards are almost purpose-built for concealing extra wiring (especially when tack-down carpet-fixing strip is added), and clock radios provide not only their own mains power but aerials as well. Not so good when the radio is on, but otherwise ideal.

The home and office would seem like an audio paradise for the potential secret-snatcher. Except the bathroom. Running water is pure white noise, the perfect, no-nuisance, all-purpose jammer. Perhaps the most successful bad deals are done in the WC.

Ripping up floorboards is only a reliable option if the customer owns the building — even then, access can be a problem. "I've never been given a disguise other than a corporation name tag," says Jinks. "We say give us free time to install it. We mustn't be seen and we mustn't be working against the clock."

Sometimes the ethics have to be viewed at an angle.

"We were asked to do a house of ill-repute — saunas, solaria, the lot once," he admits. "We thought the client was the vice squad, but it turned out to be the owner checking if the girls were doing a bit of private business."

Recorded information will not be accepted as evidence by courts unless the recording was done on a sealed tape provided and signed for by a solicitor. Clients and targets rarely meet in court.

"Once somebody is confronted with the fact that somebody else knows what he's up to, they usually back down," says Jinks.

"They could probably prosecute the person who bugged them, but people don't know the law inside-out and if they do, there are usually things they want to keep hidden."

He tells of a man who bugged his wife and later confronted her with his findings. "She phoned the DTI and he was done under the Wireless Telegraphy Act. He got a stiff fine but the information he got enabled him to carry out investigations which saved him thousands of pounds in a divorce case."

A Hard Life

De-bugging premises is the real challenge.

"The bugger has it much easier than the de-bugger," Jinks says, once challenged by a television company to hide some bugs and then have a counter-surveillance company locate them — all on camera. The debugger failed.

Even when devices are activated, the power involved is very low and the frequencies in a sophisticated device are obscure, although 100 to 140MHz FM remains popular — "up to 90%".

A good commercial bug tracer uses a phase locked loop high frequency receiver to sweep across a comparatively narrow band, searching for harmonics of the lower frequency bands. If a signal exceeds the detection threshold, it gives a numerical code which the operator can then enter, locking the device in on the signal. Once locked on, the receiver can analyse the signal and demodulate AM or FM, and check for subcarrier.

Another device tunes slowly through the lower bands searching for the signal rather than its harmonics. It gives a click like a bat, which can be picked up and re-transmitted by a bug. The timing of the return click indicates how near the bug is to the tracer.

But Jinks has higher ambitions than installing his own bugs, "hard, dirty, boring, down-on-the-knees work," and winkling out other people's — he wants a better bug.

"Frequency hopping is the real challenge. Every time a transmitter is about to make a frequency jump, it sends a signal to lock its receiver on to a new frequency. You'd have a job catching that."

The real love of his drawing board is 'time slot transmission', where the transmitter monitors for 30 seconds and then compresses the information and transmits it in a millisecond. Properly synchronised, the receiver would hear a smooth conversation. "Nothing on earth can detect that".

What are the chances you are on the right frequency and, if you are, what do you hear?

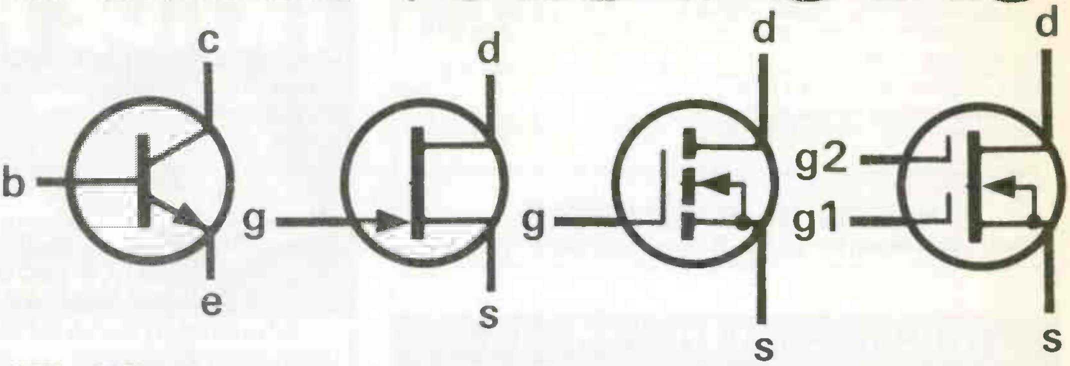
"You still have to decode it. The idea's still on the bench." He adds that the battery size will have to come down, as well. Of such things is electronic development made.

Like it or not, listening to other people's secrets clearly has a social role. Benn (who may be being optimistic) reckons that about 1% of products sold are mis-applied — used for theft of information that does not rightfully belong or appertain to the client. This provides a useful justification for the counter-surveillance consultancy, if any justification were needed. Company managements are more likely to be searching for outsider bugs than their own — the massed staff of ETI, for instance, have yet to march on Argus Towers searching for management bugs. In an open-plan office you can hear every blessed thing everyone says anyway.

This didn't stop me asking David Benn whether he would sell bugs to people like me. "Fleet Street?", he said (kindly), "they certainly rank among our more interesting customers. What would they do without us?"

ETI

...AND THEN THERE WERE TRANSISTORS



John Linsley Hood continues his semiconductor analysis with the evolution of the transistor

TRANSISTORS

Having dealt with the range of semiconductors and how they are produced, we now move on the basic p-n junction technology and how this has been extended to provide a whole family of amplifying and switching devices.

Point Contact Diodes And Transistors

The point contact diode is a device of venerable age, dating back to the 'crystal and cat's whisker' types of early radio receivers, and coming into commercial use with the small silicon and germanium diodes used in war-time radar gear.

The physics of its operation had been worked out during the 1930s and it was known that a metallic point in contact with the surface of a semiconductor would cause a 'depletion zone', especially if reverse biased. This is shown in Fig. 1a.

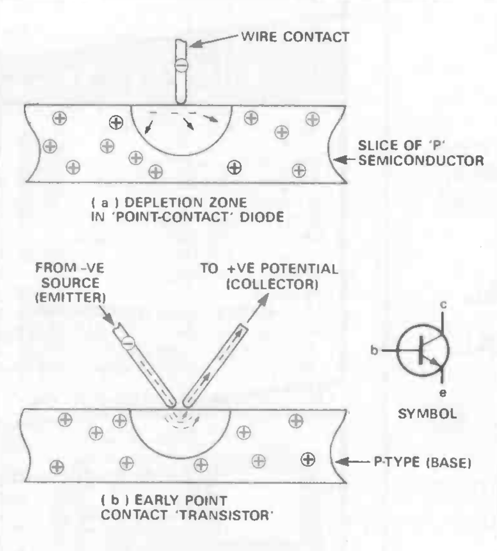


Fig. 1 Point contact devices

This led Bardeen, Brattain and Shockley of the Bell Telephone Labs to try the experiment of bringing another sharp edged conductor in contact with the base semiconductor slab, as shown in Fig. 1b, which happened to be next to a reverse biased probe. Lo and behold, the current which was injected by the emitter probe into the depletion region was swept up by the collector.

This has given us both the terms we use for the electrodes (emitter, base and collector) and also the circuit symbol we use. Point contact transistors were never much more than museum pieces, but once the idea had registered, better devices were soon made.

Junction Transistors

Although we use the same names for its electrodes and the same circuit symbol in drawings, the modern bipolar junction transistor is a very different device, and will usually be made as shown in Fig. 2, starting with a very high purity single crystal slice of silicon.

In the case of an npn transistor, the crystal slice will contain a carefully controlled proportion of an n-type impurity, usually either phosphorus or arsenic, and a further dose of n-type impurity will then be diffused into the rear surface too provide an n+ layer for the collector contact.

A thin p-type layer will then be 'epitaxially' (one sided) grown on to the upper surface. By a process of masking, etching and vapour phase diffusion, a series of fairly heavily doped n+ patches will be diffused into this upper face, which after metallising and slicing up into tiny dies (0.5mm square for a typical small signal device), will give individual transistors that look like Fig. 3.

If the collector is biased positively with respect to the p-type base region the depletion region will extend all the way through the base layer and because it is a reverse biased junction, only a very small leakage

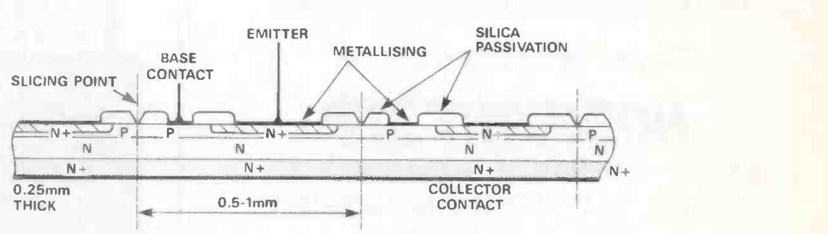


Fig. 2 Typical construction of modern epitaxial base npb transistor (prior to slicing)

current will flow.

However, if the emitter is made negative with respect to the base, or if the base is made positive with respect to the emitter (which amounts to the same thing once the forward voltage exceeds the pn junction potential barrier) electrons will flow from the emitter into the base, and nearly all of them will promptly be swept up by the collector.

With good geometries and careful control of impurity levels, upwards of 99% of the emitted electrons will be captured by the collector. Looking at it another way, less than 1% of the base current will control 99% of the collector flow. If the base is not forward biased with regard to the emitter, neither emitter nor collector current can occur.

The same argument will apply for pnp transistors if one substitutes the concept of 'holes' for electrons.

The way that the collector changes as a function of base voltage and collector voltage, for a typical junction transistor is shown in Fig. 4.

Junction Field Effect Transistors

In principle, this is just about the simplest semiconductor device there is. Its action depends upon the way the depletion zone at a pn junction will grow wider or narrower as the reverse voltage is inceased or respectively decreased.

So, if we take a thin slice of n-type silicon, connect a terminal at either end and diffuse a couple of p-type (gate) regions on either side of it, as shown in Fig. 5. The possible channel of non-depleted silicon (the only kind through which current can flow), can be made either wider or narrower by changing the negative bias applied to the gate.

This allows the current flow through the device to be controlled by the gate voltage, in just the same way as the anode current of a valve can be controlled by the grid voltage. Also like a valve, the gate electrode is normally non-conducting, unless it is biased in a 'forward' direction.

The only minor complication in this device is that the voltage at the 'drain' electrode will increase the reverse bias on the gate with respect to the drain, and make the shape of the depletion zone lop-sided, increasing in thickness at the drain end Fig. 5.

If more than a few volts is applied to the drain, the gate depletion regions will tend to increase so that they 'pinch off' the channel entirely. When this happens, the voltage drop due to current flow at the source end of the channel will disappear leaving only a narrow neck of channel as shown in Fig. 6, and then electrons will tunnel through this.

Because of the way in which the pinch-off becomes tighter as the drain voltage is increased, the drain current remains constant with increasing voltage, as shown in Fig. 7a. A fairly typical drain current vs gate voltage characteristic for an n-channel junction FET is shown in Fig. 7b.

Two final points about junction FETs. Firstly, the gate region is just a pair of quite normal junction diodes, they are *not* prone to damage due to static electricity any more than any other PN junction. Static is a problem only with insulated gate type MOSFETs.

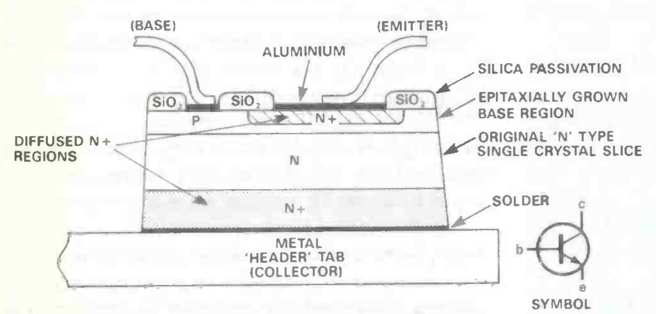


Fig. 3 Section through npn epitaxial base transistor

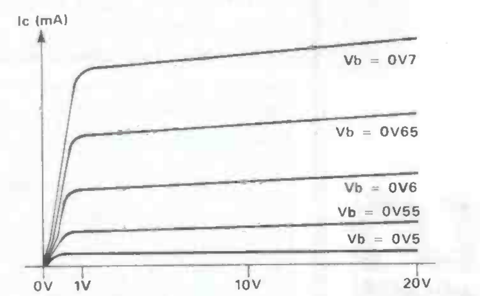


Fig. 4 Junction transistor b/c voltage characteristics

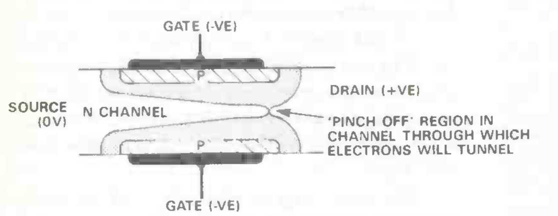


Fig. 5 Schematic layout of n-channel junction FET

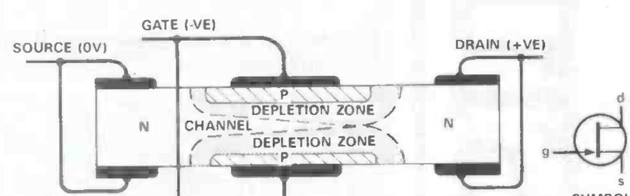


Fig. 6 Shape of depletion zone when FET is operated in 'pinch-off' conduction

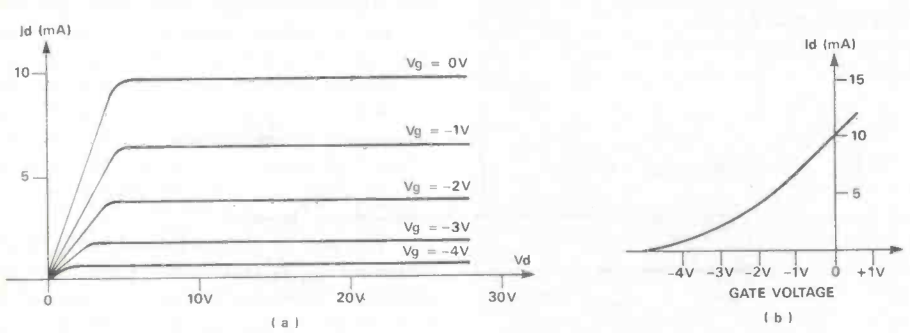


Fig. 7 Drain current/gate voltage characteristics of typical small signal junction FET

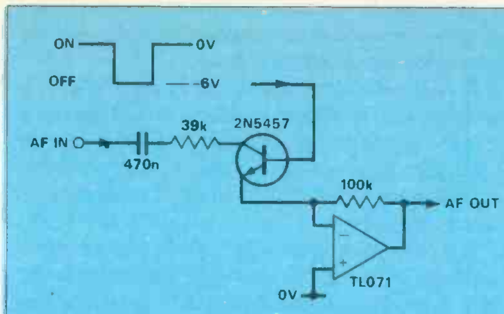


Fig. 8 Junction FET used as low distortion AF switch

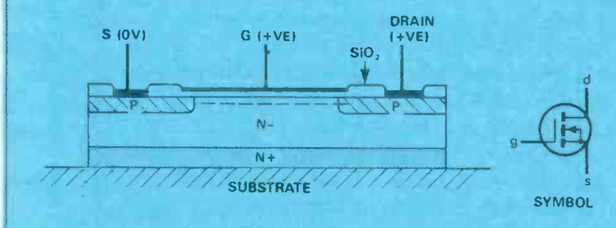


Fig. 9 Schematic layout of n-channel MOSFET

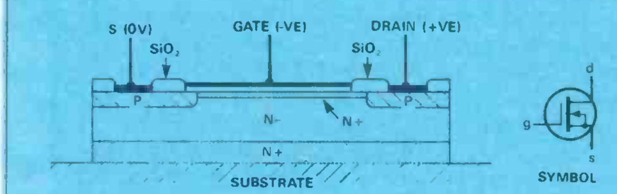


Fig. 10 Construction of n-channel depletion MOSFET

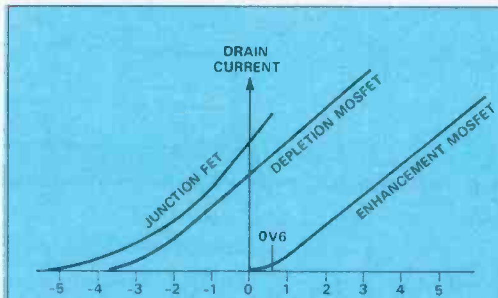


Fig. 11 Comparative characteristics of FETs and MOSFETs

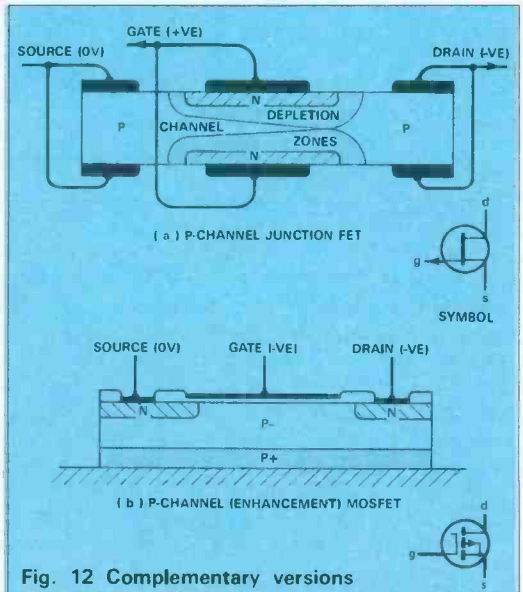


Fig. 12 Complementary versions of JFETs and MOSFETs

Secondly, the capacitance between gate and drain will be a few picofarads, but rather more between gate and source because the depletion zone width is less at this end. Like any other pn junction the depletion zone, which acts like the insulating dielectric layer in a capacitor, will vary with voltage — and so will the capacitance across it. This is a phenomenon which occurs in all reverse biased p-n junctions and is exploited in 'varicap' diodes.

Owing to the relatively long and thin conducting path from source to drain, the conducting resistance of junction FETs is fairly high. This varies from a few hundred ohms typically in the 'on' state, to many megaohms when turned 'off'. They can be used as switches in an audio channel but it is prudent to put a 'swamping resistance' in series with the source-drain channel to minimise the possible audio distortion which could be introduced, shown in Fig. 8.

Insulated Gate FETs (MOSFETs)

This is the most recent type of transistor and one which is growing in importance because of its very high input (gate) impedance, its very good linearity, and its high operating speed. Ironically, it was also one of the first types of transistor which the early experimenters tried to make. They were defeated because they were unable to produce semiconductor material of adequate purity, or surfaces adequately free of contamination.

The way these devices are made, in principle, is to take a slice of very lightly doped n-type silicon, and diffuse a couple of p-type zones into it at either end, to serve as 'source' and 'drain' connections, shown in Fig. 9. Normally, the source connector metallising is extended so that it connects to the substrate as well.

A thin layer of a good insulator, usually either silica or silicon nitrade, is then formed over the region between the source and the drain. A further metallised region (the gate) is applied on top of this insulator.

If the drain is made positive with respect to the source and substate, no current will flow, because the drain/substrate connection is a reverse biased p-n junction. However, if a sufficient positive voltage is applied to the gate electrode, it will induce a layer of negative charges (electrons) immediately underneath the gate electrode and these electrons will move, just like any other electrons would, towards the drain. So current will flow.

The very good linearity of this type of device arises because there is a direct relationship between the voltage applied to the gate and the amount of charge induced in the channel between the source and drain.

They are fast in action because the charge under the gate insulator will appear instantly the gate voltage is applied and will disappear again as soon as it is removed. The only practical problems are that if the gate insulation is too thick, it will take a lot of applied voltage to induce electrons in the source-drain channel, whereas if it is too thin it could easily break down if the gate voltage is too high — even briefly.

Also, the conducting path between source and rain is very thin, and consequently its 'on' resistance is very high indeed. The device has to be designed so that there are a lot of drain-source channels connected in parallel.

The sort of gadget shown in Fig. 9 would be described as an n-channel lateral enhancement MOSFET. 'n-channel' because the current flow is due to electrons (n-type carriers), 'lateral' because the current flow is from side to side across the chip, as distinct from downwards through the chip as would be the case in a junction transistor, and 'enhancement' because the current starts off at zero and increases as the gate is made more positive.

Finally, the 'MOSFET' term, which has now become almost universal as the type name for these devices, is derived from 'metal-oxide-semiconductor FET', because of the way that the early devices were made.

If a thin layer of more highly doped (n+) silicon is formed as a channel before the gate insulating layer is grown, this will conduct electricity from source to drain even without any positive voltage being applied to the gate. The current can then be turned off by a negative gate voltage which will repel the negative charges (free electrons) away from the channel. Such a device is shown in Fig. 10, and this is called an 'n-channel depletion MOSFET'. Comparative drain current vs gate voltage curves for a normal small-signal n-channel junction FET, an n-channel depletion MOSFET, and an n-channel enhancement MOSFET, are shown in Fig. 11. The junction FET will usually have the higher slope.

Both junction FETs and MOSFETs can also be made in 'complementary' p-channel versions by reversing the types of doping, as shown in Figs. 12a and 12b. However, because of the rather slower movement of holes compared with the motion of electrons, they are not quite as fast in operating speed.

Dual Gate MOSFETs

The very good high frequency response of MOSFETs makes their use as RF amplifiers an attractive proposition. Unfortunately, the gate/drain capacitance is much too high, at a few pF, for stability in RF applications.

A dual gate MOSFET with another gate junction interposed between source and drain, shown in Fig. 13, has therefore been introduced. In this, the gate/drain capacitance is only of the order of 0.02pF. These MOSFETs are always of 'depletion' type.

In addition to their usefulness as RF amplifiers, these transistors are very convenient as signal mixers, or signal switches, for both radio and audio applications.

Power MOSFETs

Because of their growing use in high quality audio amplifiers — for which, in my opinion, they beat junction transistors hands down — the actual construction and characteristics of these transistors has received quite a lot of attention in recent years, and I don't propose to add to this.

The only comment I would make here is that with the growing skills of manufacturers in making very precise diffusion and etching masks, the 'T-MOS' type of power MOSFET of the kind shown in Fig. 14, is becoming much more widely used. Here, the channel length is controlled as in the standard 'lateral' MOSFET by the spacings between the surface diffusion regions. The drain region is placed below the gate, so that the current flow is in a 'T' shape. Hence the name 'T-MOS'. The very lightly doped n-region which separates the gate from the drain proper is called the 'drift' region, and it is essential that the bulk of the source-drain voltage drop appears across this, otherwise the gate-drain voltage would exceed the breakdown voltage of the thin gate insulating layer.

This condition may not be met at very high drain current levels, because the drift region may contain secondary carriers due to collisions. So the combination of high drain currents and high drain voltages may cause gate breakdown, and the circuit designer should take care to avoid this possibility.

The big advantage of the 'T-MOS' design is that it allows both n-channel and p-channel devices to be made, though the higher voltage one are still more commonly of the n-channel type. 'T-MOS' transistors are a bit slower in operating speed than the original 'V-MOS' or 'U-MOS' types because of the time it may take the current carriers to get through the 'drift' region.

However, they are still a great deal faster than the best of the junction power transistors, and this shows in the clarity and transparency of the upper treble region in audio amplifiers in which they are used, in comparison with those based on bipolar junction transistors.

Thyristors And Triacs

All the devices discussed so far have been essentially linear amplifying components, though they can be used as switches. There is a wide range of useful components based on the same semiconductor technology. They are used as fast acting electronic switches in power control applications.

The first of these to come into widespread use was the 'silicon controlled rectifier' or SCR as it is most commonly known. It is also called a 'thyristor' — by analogy with the 'thyratron' valve which operates in a similar manner.

The SCR is basically a pair of transistors, one npn, the other pnp, connected as in Fig. 15. Clearly, if Q1 isn't conducting, no current flows from its collector into Q2 base and so Q2 doesn't conduct either. No current flows from its collector into Q2 base

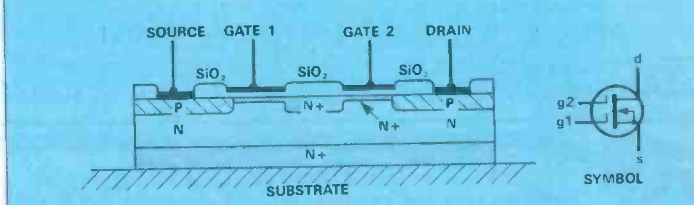
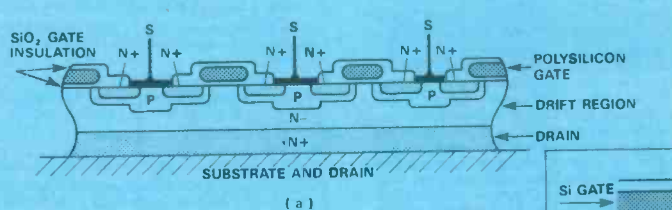


Fig. 13 RF dual-gate depletion MOSFET (eg 3N201)



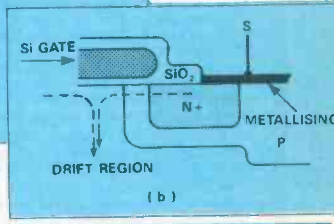


Fig. 14 Construction and current flow in T-MOS (or D-MOS) transistor

and so Q2 doesn't conduct either and no current flows from its collector into Q1 base.

If either transistor should be turned on, however briefly, then each will drive the other into conduction and both will then remain 'on' until either the supply voltage is removed or the base of one or other transistor is connected to its emitter to bypass its input drive.

This little circuit makes a very useful 'trip' mechanism, which can be put together from any available pnp/npn transistor pair. With normal transistors the cumulative loop gain will be so high that it is liable to trip inadvertently, so the resistors R1 and R2 are needed to tame its 'hair trigger' qualities.

Commercial SCRs are effectively two separate low-gain transistors merged together into a four-layer device, in the manner shown in Fig. 16a and 16b. The

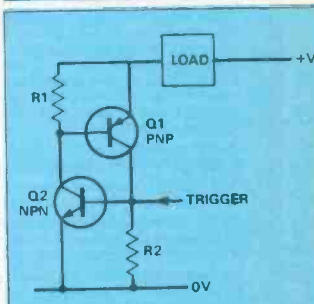


Fig. 15 Simple two-transistor 'thyristor' circuit

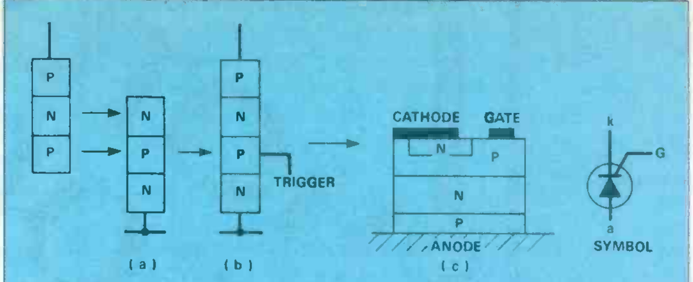


Fig. 16 Evolution of 4-layer thyristor or SCR

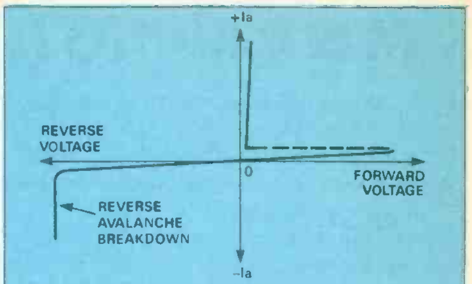


Fig. 17 Forward and reverse breakdown characteristics of SCR

actual construction of the device is more like that shown in Fig. 16c.

This is normally non-conducting in both directions but can be triggered into conduction in its forward mode if a brief pulse of input current is fed into its gate. This results in the kind of conduction curve shown in Fig. 17.

There is an AC version of this, which can be triggered into conduction in both directions, called a 'triac'. This is just a pair of SCRs joined together as shown in Fig. 18a and 18b, which results in the practical structure shown in Fig. 18c, and the type of conduction curve shown in Fig. 19. Triacs are very useful for light dimming and other forms of AC current control, but they are not available in quite such high power versions as SCRs.

Also, because the component 'transistors' within the triac or SCR are driven hard on, a lot of minority carriers (holes in the n-type region and electrons in the p-type) are produced, and current flow will not stop until all of these have recombined. This means that the high frequency switching performance of both types of these devices isn't very good — perhaps 15-20kHz at the most.

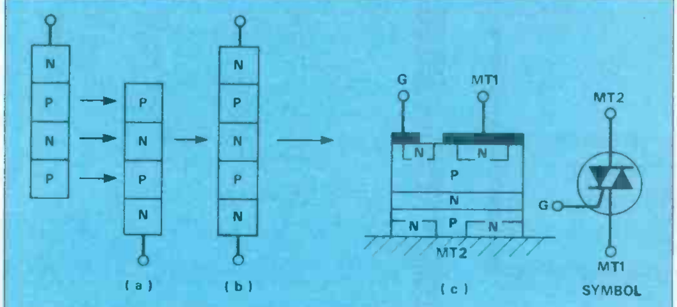


Fig. 18 Evolution of triac (bidirectional SCR)

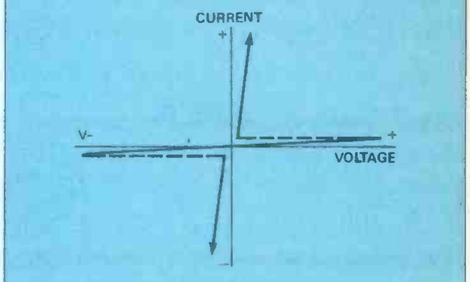


Fig. 19 Conduction characteristics of triac

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THE GOOD IC GUIDE

Paul Chappell announces the ETI Chip Of The Month Award and sees what this power op-amp can do

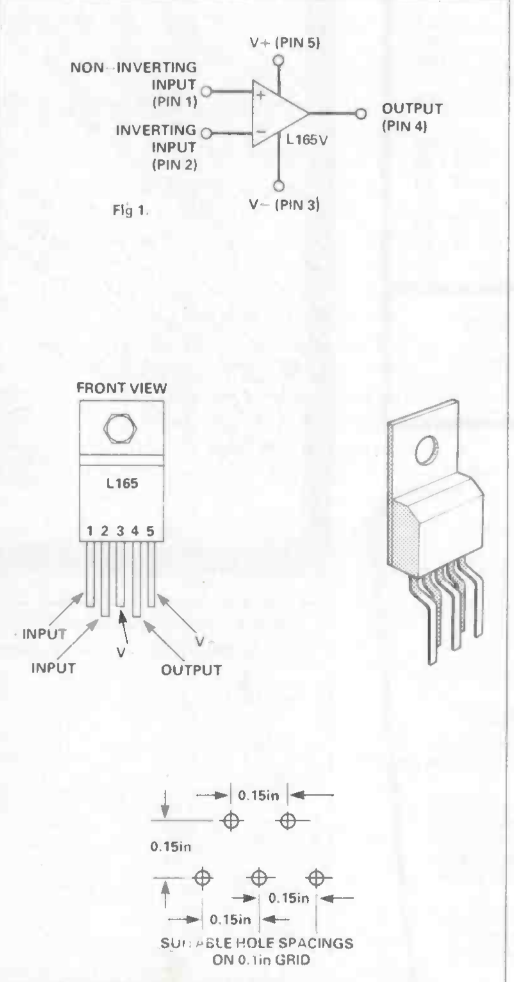

Fig. 1 L165V pin connections and spacing

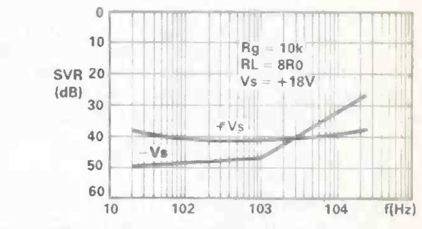

Fig. 2 The slew rate required to reproduce a sine wave depends on the amplitude of the wave

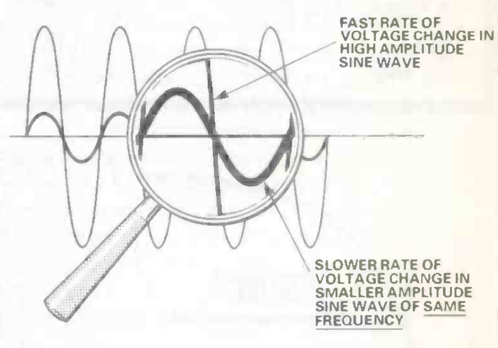

Fig. 3 Large signal frequency response of L165V

The L165V power op-amp is the IC for this month. Of all the power op-amps currently available, the L165V probably represents the best compromise between price and performance for a general purpose device. Its output current capability of ±3A makes it beefy enough to cope with most situations, and the price tag of a few pounds means you won't have to re-mortgage your house to buy one.

First of all, what's the competition? On the cheap 'n' cheerful side there are devices like the Fairchild μA759 with an output current capability of about ±300mA, general specifications similar to a 741 and a price tag not much smaller than the L165. On the upmarket side, you could have a National Semiconductors LM12 for around £25. This will give you the means to make an audio amp of hi-fi, though not super-fi, specifications. Downhill with the wind behind it, it might touch 150W RMS. What you have to weigh up is whether you could, by using discrete components, do the same rather cheaper, or do better for the same outlay. At the moment I'm sure you could, but the LM12 is relatively new and if it proves popular in industry the price is bound to fall. Keep an eye on that one!

The Data

An op-amp needs five connections: two for the power supply, two for the inputs and one for the output. The L165 has exactly that, no more and no less. The pin connections are shown in Fig. 1. The pin spacing, which you'll want to know for laying out PCBs, is illustrated in the side view of the IC. Pins 1, 3 and 5 are in a row about 0.15in ahead of pins 2 and 4.

The actual spacing between adjacent pins doesn't work out to anything sensible in any scale of measurement that I can discover, but the pins can be bent just a little without stressing the IC and the hole spacings shown will work out fine if you're laying out on a 0.1in grid. The pins are all bent towards the front of the IC so that it can be mounted at the edge of the

CIRCUIT THEORY

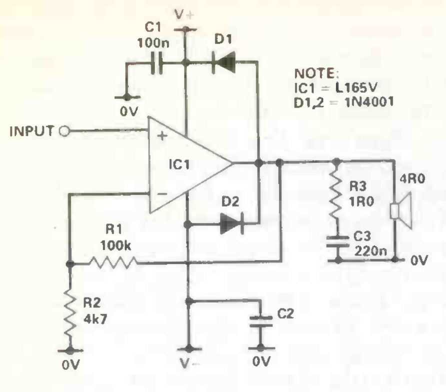

Fig. 4a Basic amplifier circuit

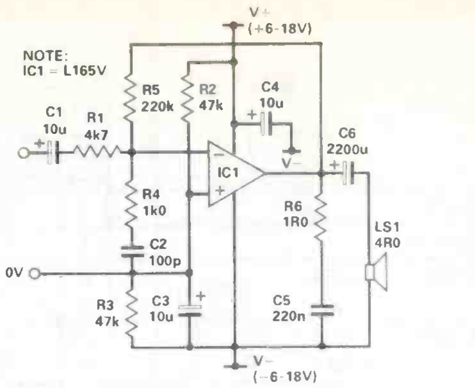

Fig. 4b Matchbox Amplifier circuit

board with the tab bolted to a vertical heatsink — possibly the wall of the case if you're using a metal one.

The first thing you'll find on the data sheet, after the obligatory 'Hey! Look what this IC (or some samples of it, anyway) can do!', is a list of absolute maximum ratings as in Table 1. These aren't intended as a guide to operating conditions, they're more by way of warning; exceeding these figures may damage the IC's health.

To some extent the figures are fairly arbitrary. The 36V rating for absolute maximum supply voltage, for instance, doesn't mean that at 35.9V everything is tickety-boo, but at 36.1V the IC smokes. What it does mean is that at anything over 36V the strain on the IC's insides rises very rapidly and is likely to cause an unacceptably high failure rate. Some ICs will fail if you stick exactly to the 36V, some will still fail if you never exceed 30V but it will be a darn sight fewer in the later case. Go up to 40V and you may find that, say, 10% pop immediately, and a large proportion of the rest fail within a fairly short time. Some may soldier on for the usual life of the equipment.

The point is, there isn't really any totally safe level. It's all a matter of statistics and the reliability level you're prepared to accept. Having said all that, exceeding the maximum ratings is asking for trouble and unless you're prepared to replace a lot of ICs, stay well within the quoted figures.

The differential voltage rating is, for most purposes, a technicality. The action of op-amp circuits is normally to maintain the two inputs at the same voltage, so unless you're using the IC as a comparator there's not much chance of the inputs being anything like 30V apart. It's possible to envisage situations where this has a chance of occurring: if you were to feed a very high amplitude signal at a frequency too high for the feedback circuit to deal with properly, the inputs just might end up being 30V apart. But you're not going to do that, are you?

On the next line you see that either input can go as high as Vs (which means to either supply rail) without harming the IC. As long as the other input is within 30V of it, that is.

The next line speaks for itself: if you try to take more than 3½A from the IC the internal limiting comes into operation and begins to remove drive from the output transistors. The IC has safe operating area protection, which means that it tries not to allow conditions which would lead to overstressing of the IC. Lest this should give you a false sense of security, let me say now that it's a good safety measure but by no means certain to keep the IC from harm no matter what. Under static conditions you can put just about any load on the IC, even a short circuit, and it should be OK. But under dynamic conditions it's possible for a situation to arise that the protection circuit can't cope with — bye bye IC.

The last two lines give an idea of the maximum power and temperature the IC can survive. Note that the 20W figure refers to the dissipation of internally generated heat, not to how much power it will deliver if used as, say, an audio amplifier. The 20W figure could, in fact, be derived from other information: the absolute maximum junction temperature is 150°C, the junction case thermal resistance (from Table 2) is 3°C, so for a case temperature of 90° you would calculate a maximum junction to case temperature difference of 150°-90°. The thermal resistance figure tells you that for each 3° temperature difference, 1W will pass from junction to case, so with a 60° temperature difference the dissipation will be $60 \div 3 = 20$W. And there you have it.

Table 2 is a different matter. The figures here are mostly measured at the recommended operating conditions, so you can take them as a guide to how to use the IC comfortably within its limits. The first line is self explanatory: if you use a supply of less than 12V,

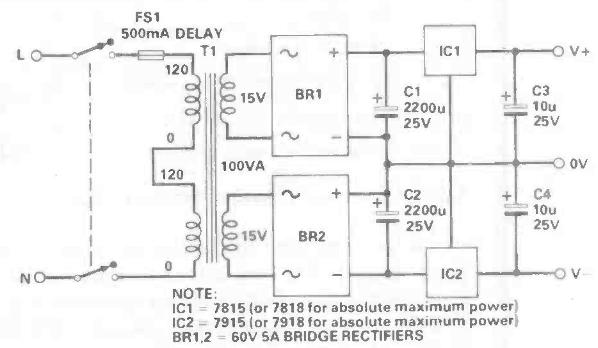

Fig. 5a Power supply for Matchbox amp

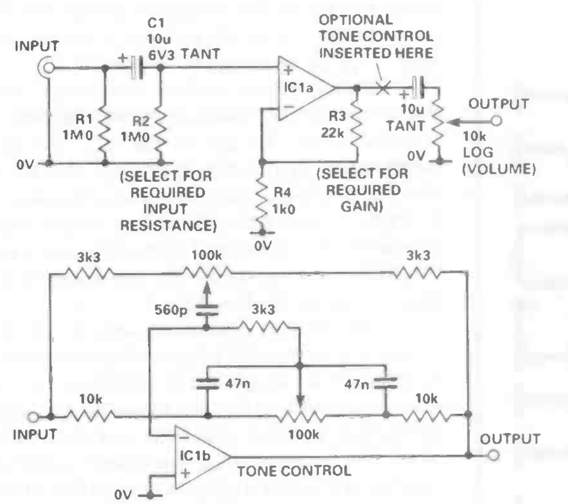

Fig. 5b Pre amplifier and tone control for Matchbox Amp

Parameter		Test conditions		Min	Typ	Max	Unit
V_s	Supply voltage			±6		±	V
I_d	Quiescent drain current	$V_s = \pm18V$			40	60	mA
I_b	Input bias current				0.2	1	μA
V_{os}	Input offset voltage				±2	±10	mV
I_{os}	Input offset current				±20	±200	nA
SR	Slew-Rate	$G_v = 10$			8		V/μs
		$G_v = 1$			6		
V_o	Output voltage swing	f = 1kHz	$I_p = 0.3A$ $I_p = 3A$		27 24		V_{pp}
		f = 10kHz	$I_p = 0.3A$ $I_p = 3A$		27 23		V_{pp}
R_i	Input resistance (pin 1)	f = 1KHz		100	500		KΩ
G_v	Voltage gain (open loop)				80		dB
e_N	Input noise voltage	B = 10 to 10000Hz			2		μV
i_N	Input noise current				100		pA
CMR	Common mode rejection	$R_g \leqslant 10K\Omega$ $G_v = 30dB$			70		dB
SVR	Supply voltage rejection	$R_g = 22k\Omega$; $V_{ripple} = 0.5V_{rms}$ $f_{ripple} = 100Hz$	$G_v = 10$		60		dB
			$G_v = 100$		40		dB
η	Efficiency	f = 1kHz	$I_p = 1.6A$; $P_o = 5W$		70		%
		$R_L = 4\Omega$	$I_p = 3A$; $P_o = 18W$		60		%
T_{sd}	Thermal shut-down case temperature	$P_{tot} = 12W$			110		°C
		$P_{tot} = 6W$			130		

NOTE: $V_s = \pm15V$; $T_j = 25°C$ unless specified.

Table 1 Absolute maximum ratings for L165V

Parameter		Max	Unit
V_s	Supply voltage	±18	V
V_5-V_4	Upper power transistor V_{CE}	36	V
V_4-V_3	Lower power transistor V_{CE}	36	V
V_i	Input voltage	V_s	
V_i	Differential input voltage	±15	V
I_o	Peak output current (internally limited)	3.5	A
P_{tot}	Power dissipation at $T_{case} = 90°C$	20	W
T_{stg}, T_j	Storage and junction temperature	-40 to 150	°C

Table 2 Electrical Characteristics of L165V

the IC won't perform too well (it won't stop working altogether — I've had one operating at 9V with tolerable results — but the results won't be too good). Usually, the maximum supply voltage in this table is also the absolute maximum supply voltage. It's more usual to specify a recommended operating voltage range and to put the maximum somewhat less than the *absolute* maximum to leave a safety margin for supply spikes and ripples, and so on.

Quiescent drain current comes next. This is just the current the IC takes to operate its own internal circuitry when it's not doing any amplifying or supplying any current to the load. The typical figure can be ignored: if you reckon up the size of your heatsink or the capacity of the power supply, or whatever, on the basis of typical figures, you'll wish you hadn't when you discover that the devices you've used are all above the 'typical'.

Now the bias and offset section. Once again, unless you belong to the groundless optimism school of design, you can ignore the typical figures. Take the worst case, assume that the actual IC you've got is as bad as they come and all your surprises will be nice ones! The bias current is the current supplied from outside to bias the input circuitry of the op-amp. In this device it actually flows *out* of the terminal. It's useful to know because you can immediately estimate the voltage drop across the bias resistors: if you're using resistors of the order of 1M0 for instance, they could drop about 1V each. The significance of the offset voltages and currents I delved into with the op-amps series last year, so go look it up!

Slew rate. This tells you how fast the output voltage can move if it's really in a hurry. Suppose you apply a voltage step to the input. In an ideal world there'd be a corresponding step at the output, but in a real L165 the output will move at a certain speed set mainly by the time it takes the output transistors to get their act together. In the case of a step resulting in a 10V difference in voltage between input terminals, the 'typical' slew rate will be 8V per micro-second. That is, if the output begins by being hard against the lower supply and has to make it all the way to the upper supply voltage, it could take 4μs to get there. Interestingly there are no minimum slew rate figures specified. I'm not sure whether this is because they are so embarrassingly low, or whether the production spreads are so wide that the manufacturers don't want to commit themselves.

The slew rate has a bearing on the large signal frequency response. Let's suppose we're trying to amplify up a 100kHz signal and really wham it out into the load at maximum voltage. Let's suppose the headroom is 27V (from the next line down in the table it would seem to be a reasonble figure). OK, so we're going to try our darndest to pump out 100kHz at 27V p-p into the load.

Just take a look at Fig. 2 if you've forgotten what a sine wave looks like. Where it crosses the axis it's moving at one helluva rate, and the higher the frequency, the higher that rate will be. It's a simple matter to calculate: for a sine wave of amplitude A and frequency f, the fastest voltage change anywhere on the wave is $2\pi fA$. In this case, bearing in mind that the p-p voltage is *twice* the amplitude, it works out to be about 8.5V per μs. Assuming that the slew rate is indeed 8V per μs, it's not quite going to make it.

Now, look at Fig. 2 again. The second sine wave is at a lower amplitude but still at the same frequency. And it doesn't shift quite so fast in voltage as it crosses the axis. So although the L165 can't quite cope with the 27V 100kHz wave, it may well manage one of the same frequency but slightly smaller amplitude. In fact, we should bet about 25½V maximum at 100kHz, which is in fact in fairly good agreement with the published large signal frequency response graph (Fig. 3), which is quite surprising bearing in mind all the assumptions I've made! You get the general idea, though. The large signal frequency response can be worse than the small signal one, and can vary with the load too.

I hardly need comment on the input resistance and open loop again. Noise voltages and currents I've had my say about quite recently. Which brings us to the common mode rejection. Ideally an op-amp should amplify *differences* in the voltage between the two inputs. Any voltage common to both should be ignored. The common mode rejection figure gives an indication of how well the IC manages it — there will always be some amplification of common mode signals, but the less the better. The figure of 70dB is quite respectable for an op-amp, although only a typical figure is given (very naughty) and, more worrying still, there's no indication of the frequency at which the measurement was made. A lot of ICs can turn in good figures at low frequency, but they're often pretty dire at any practical audio-type frequency.

Supply voltage rejection is a similar kind of animal: if ripple or noise appears on the power lines, the IC should ignore it. These figures tell you how well it manages it. Once again, a figure for a single

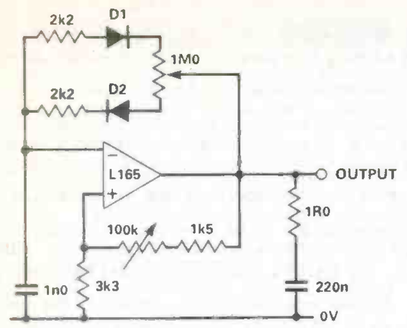

Fig. 6a Power oscillator circuit

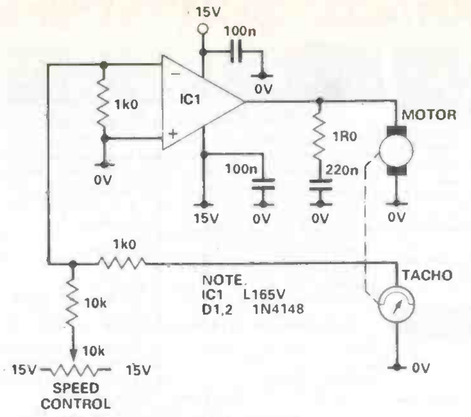

Fig. 6b Motor speed control circuit

frequency doesn't tell the whole story: at higher frequencies the rejection can fall off quite dramatically. Always decouple (my boy) no matter what those crafty IC manufacturers may tell you.

The efficiency figure essentially gives you an idea of how much power you can deliver to the load without overheating the IC. If it's popping out 18W at an efficiency of 60%, you can reckon on about two thirds of this figure (12W) for internal heating and arrange your heatsink accordingly. It also tells you how much extra oomph the power supply needs over and above the power delivered to the load. If the IC is going to get warm, somebody has to supply the power to heat it! In the 18W output case, it means you need a minimum of 30VA available from the supply, once you've added the extra 12W of heat.

The thermal shutdown temperature is once again something you need to know for choosing a heatsink. Let's do a rough calculation for an 18W audio amp. The IC has to get rid of 12W of heat and since we'd rather not have the thermal shutdown coming on let's keep the junction temperature to less than 100°C. At a junction to case thermal resistance of 3°C per watt, the case must be kept to 36° below the junction temperature — that is, to not more than 64°. Let's assume quite a high ambient temperature (it's been hot this summer!) of 28°. We need the whole heatsinking assembly to give a temperature difference between the IC cases and the surrounding air of not more than 36°. That is, we want a thermal resistance for the whole works of not more than 3°C/W.

That rules out any of the small PCB fixing heat sinks but, even allowing for a mica washer, should be a doddle for any of the larger heatsinks or a reasonable thickness of case metal. And we're being rather cautious anyway, unless you use your amp to reproduce maximum power sine waves, the heating will be very much less.

Circuits

The basic amplifier circuit, straight from the manufacturer's data, is shown in Fig. 4a. There's not much more to it than an ordinary op-amp non-inverting amplifier. R1 and R2 are the usual feedback resistors, C1 and C2 decouple the supply rails at higher frequencies than the rejection can cope with, D1 and D2 prevent the output from going beyond the supply voltage if an inductive load is connected, R3 and C3 serve to make an inductive load look more resistive and to smooth out impedance changes, and LS is the loudspeaker. That's all there is to it.

Figure 4b shows a practical version of the same circuit — ETI's Matchbox Amplifier from way back in April 1986. With a 32V supply and four ohm speaker, it will pump out about 20W and makes an excellent bench test amplifier of hi-fi module. And yes, it *can* be made to fit in a matchbox if the IC is bent parallel to the board!

A suitable power supply for the amplifier module is shown in Fig. 5a. This will allow the full 20W to be used and will power two modules, but if you're not interested in going to maximum power just about any old supply from 12V to 36V (if you want to risk it) will do. If you use an unregulated supply, bear in mind when you do your sums that the smaller transformers will give a substantially higher voltage than you expect — perhaps 15 to 20% higher — under lightly loaded conditions. The output voltage will usually be specified for full load, and the difference between this and the lightly loaded voltage will be much greater for a small transformer than for a large one. Just to complete the picture, a simple flat response pre-amplifier is shown in Fig. 5b. Now you've got a complete audio amplifier. Go for it!

Figures 6a and 6b are both borrowed from the data book, to give an example of some non-amplifier applications. There's an oscillator, not much different from the standard op-amp one that appears again and again. This one does have the added sophistication of a duty cycle control, which works by putting a different resistance in the charge and discharge paths of C1.

Then there's a motor speed controller. The idea is that RV1 provides a voltage to the inverting input of the IC which slams the output against one or other of the supply rails. The motor then accelerates smartly, or shudders to a halt and zips back the other way depending on what it was doing previously and carries on accelerating until the tacho output cancels out the RV1 voltage and everything settles down to a nice, steady speed. Or so goes the theory. It looks to me like one of those circuits that works fine on the bench and oscillates like crazy if you try to do anything useful with it. Do remember to connect the tacho the right way around or the motor will go screaming off into ultrasound!

Although the L165 has been around for some time, there still doesn't seem to be that many enthusiast suppliers willing to supply it. To make things easy we've arranged a little deal with Specialist Semiconductors: they will supply the IC, with a data sheet too, at £2.90, which includes postage and VAT. Their normal all-in price for the IC is £5.40, so this sounds like a bargain to me! A complete parts set for the Matchbox Amp module is available from the same source at £8.40 inclusive. Orders to: Colette Marshall, Specialist Semiconductors, Founders House, Redbrook, Monmouth, Gwent NP5 4LU. Tel: (0600) 3715.

Maplin do the L165 as well at a catalogue price of £3.10. Tel: (0702) 554161.

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LESS LOGIC

Andy French takes his NAND is his hand and NORs his way through to the simplest solutions

Combinational logic is the wonderful world of AND, NAND, OR and NOR where Boolean algebra is king. Whereas sequential logic produces outputs that are a function of time, combinational logic outputs are purely a function of the input values and change immediately the inputs change. If you get up to enormous speeds, things get tougher as gate propagation delays get involved, but otherwise things are eminently easy to handle.

As a result of its relative simplicity, most enthusiasts adopt an 'intuitive' attitude to design, building up gate by gate. The outcome of such cobbling will rarely be the optimum or cheapest solution to a problem. Here we will look at the techniques that can check a circuit's operation and minimise the number of gates used.

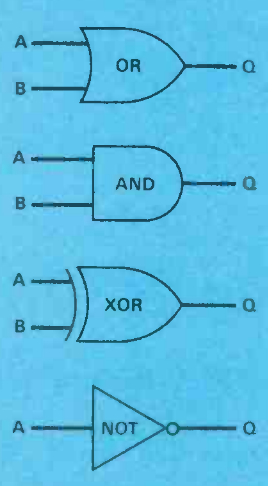
Boolean Algebra

Don't worry! Boolean algebra is really no more difficult than ordinary arithmetic, although as with ordinary arithmetic there are a few symbols to be learned first — four of them to be exact.

These symbols are best described in terms of the logic gates that they represent, as shown in Fig. 1. There is nothing magical about the symbols used, they are just a convenient form of logical shorthand.

In a digital logic system there are only two valid states, high or low voltage. We choose to represent these two states with a 1 or a 0 respectively.

Now looking at the truth tables of Fig. 1 you will see that there are columns on either side of a vertical dividing line. Those on the left represent the input information and those on the right the outputs. So for the OR gate you will see that the output is low when both inputs are low, and high when either input A or B is high. The OR function is exactly the same as the ordinary English language or, and is sometimes called 'inclusive' OR.



A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

A	Q
0	1
1	0

Fig.1 Logic gates — their symbols and truth tables

The other type of OR is the 'exclusive' OR, often abbreviated to XOR. With this, the output is high when either input goes high but you exclude the case where they are both high. Because of this, the XOR gate is often used as a comparator to test if two inputs are the same.

Boolean expressions can represent only one of two values — *TRUE* or *FALSE* — so don't confuse the symbols with those used in ordinary arithmetic. It is convenient to write the Boolean values as 1 or 0, representing logic high (true) and logic low (false) respectively, giving the familiar truth tables of Fig.1. Using our Boolean signs with variables A, B and so on, we can write equations to represent digital logic systems.

For example, the circuit of Fig.2 can be described by the equation:

$Q = AB + CD$.

Note that it is common to omit the AND dot, just as the multiplication dot is often omitted from ordinary arithmetic. Note also that the Boolean operators have a strict order of priority, so all NOT functions should be interpreted first, followed by AND and finally OR and XOR (equal priority).

So, is $AB+C$ the same as $A.(B+C)$? No it isn't. If in doubt, use brackets — purists may raise their noses but at least your equations will be correct.

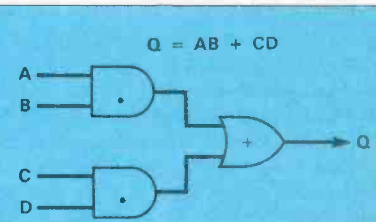


Fig.2 Simple logic circuit

It's The Law

So we can now express logic systems in terms of Boolean equations. This is where the clever bits come in. Using the list of laws in Table 1, equations can be reduced to use less Boolean signs (which implies less gates, less space, lower power consumption, less cost and so on).

It should be noted that the laws are not all independent — some are implied by or may be derived from others. The laws in the right column are said to be the 'duals' of those on the left and may be obtained by replacing 1 with 0, 0 with 1 and + with . .

Communication Law	$A+B=B+A$	$A.B=B.A$
Identity Law	$A+0=A$	$A.1=A$
Idempotency Law	$A+A=A$	$A.A=A$
Inverse Law	$A+\bar{A}=1$	$A.\bar{A}=0$
Universal Bounds	$A+1=1$	$A.0=0$
Associative Law	$A+(B+C)=(A+B)+C$	$A(B.C)=(A.B)C$
Absorption Law	$A+(A+B)=A$	$A(A.B)=A$
Distributive Law	$A+(B+C)=(A+B)+(A+C)$	$A(B.C)=(A.B).(A.C)$
De Morgan's Law	$\overline{(A+B)}=\bar{A}.\bar{B}$	$\overline{(A.B)}=\bar{A}+\bar{B}$
Involution Law	$A=\bar{\bar{A}}$	
Negation Law	$0=\bar{1}$	$1=\bar{0}$

Table 1 Boolean laws

Most of the laws are quite obvious and easy to prove. De Morgan's law is less so but is a very useful law to know and it is worth working through the truth tables as shown in Fig.3.

LOGIC

INPUT A	B	$\bar{A}$	$\bar{B}$	$\bar{A}.\bar{B}$	A+B	$\overline{A+B}$
0	0	1	1	1	0	1
0	1	1	0	0	1	0
1	0	0	1	0	1	0
1	1	0	0	0	1	0

INPUT A	B	$\bar{A}$	$\bar{B}$	$\bar{A}+\bar{B}$	A.B	$\overline{A.B}$
0	0	1	1	1	0	1
0	1	1	1	1	0	1
1	0	0	1	1	0	1
1	1	0	0	0	1	0

Fig.3 Truth table proof of de Morgan's law

The best way to become familiar with these laws and manipulating Boolean algebra is to practise. A sound understanding here will help you understand what is going on later.

Try following my example simplification in Table 2. If you think you can understand how I obtained the result, then try covering up my working and deriving it for yourself.

As you can see, the end result is far less complex, and is in fact just the exclusive OR function. You can prove it by drawing the truth table.

Getting On The Map

Boolean algebra is fine for proving the validity of a solution system but it is not very practical as a method of reducing logic systems. For a start, as the number of variables (inputs) increases, it becomes more and more likely that that an error will be made. Also, how do we know when we have got the simplest solution and can stop seeking further reductions?

Karnaugh mapping is an ingenious technique which takes the hard work (and algebra!) out of simplification. The Karnaugh map is a pictorial representation of the Boolean equation, similar to a truth table. The empty grids for two, three or four variables are shown in Fig.4.

For each square or 'cell' of the map, the required result with that particular set of inputs is inserted. This is made easier if a truth table is drawn first. (Beware of transposing the inputs when you fill in the map, a common error with disastrous consequences!).

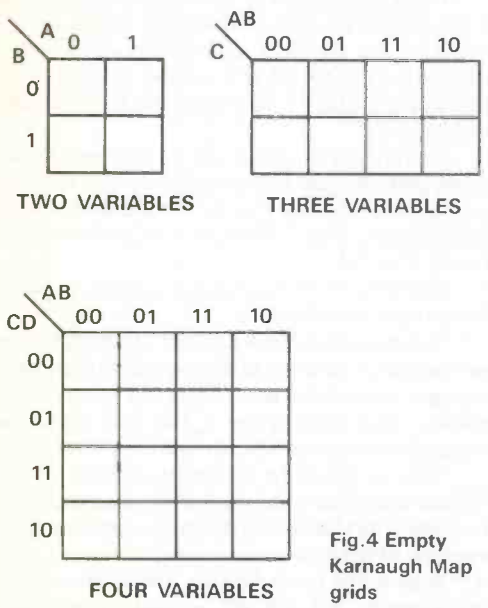


Fig.4 Empty Karnaugh Map grids

Now that you've got your nice two dimensional map, you should think of it as a three dimensional surface! All this really means is that the right most column should be thought of as being next to the left most column. Likewise, the top row is next to the bottom row. This 'edgewise adjacency' is important to remember.

Now groups of cells can begin to be made into clusters. Where ever there is a group of 1s together, they should be circled in groups of one, two, four or eight (powers of two). The idea is to circle all of the ones into the largest groups possible. The example in Fig.5 should clarify this.

The actual minimisation has now been performed and all that remains is to form the resultant Boolean equation for the Karnaugh map. Each of the groups of circled ones can be represented as an AND term, which are ORed together to give the function. In the four variable examples of Fig.5, the circled group in the top row has the variable values B=1, C=0, D=0, and A can be either. The AND term for this group is therefore $B\overline{CD}$.

	$Q = \overline{\overline{AB}.A} . \overline{\overline{AB}.B}$
By de Morgan's Law	$Q = \overline{AB}.A + \overline{AB}.B$
Now expand the brackets	$Q = \bar{A}A + A\bar{B} + \bar{A}B + B\bar{B}$
And finally cancelling the redundant terms using the Inverse Law gives	$Q = A\bar{B} + \bar{A}B$

Table 2 Example of de Morgans calculations.

CD \ AB	00	01	11	10
00	0	1	1	0
01	0	1	0	0
11	0	1	0	0
10	1	0	0	1

$$Q = B\bar{C}\bar{D} + \bar{A}BD + \bar{B}C\bar{D}$$

Fig.5 Demonstration of Karnaugh grouping

In some applications, 'don't care' values occur where the circuit specifications dictate that either a particular set of input values cannot occur, or the output state is irrelevant. An example of this is a BCD to 7-segment display decoder. Input values above nine are illegal and so the output is meaningless. When 'don't care' values arise, a 'd' is initially inserted into the appropriate cell of the Karnaugh map. As the 1s are grouped, it will become desirable to change this to either a one or a zero, whichever produces the least number of groups.

Also it sometimes happens that there are many more ones than zeros in a Karnaugh map. If the zeros are then grouped instead of the ones, the resulting function will often be much simpler. Because the zeros are grouped, the resulting function will be the complement of the required function. An inverter will be required at the output to obtain the valid function.

It is advisable, initially at least, to draw a truth table of the simplified function and compare it with the original to check the validity. A few moments longer with pencil and paper can save hours with a logic probe. Finally, note that the Karnaugh mapping technique minimises the number of gates used in a design, but that gates are usually packaged with several others on a single chip. Therefore, unless designing custom chips, the resulting design may leave redundant gates. These gates can be put to good use in reducing the chip count as we will see later.

The Quine-McCluskey Method

The Karnaugh map is a simple and powerful method of reduction which should be adequate for the needs of most hobbyists. However, as the number of input variables increases the size of the Karnaugh map increases rapidly making the chances of errors occurring also increase. For those of you planning to build your own microprocessors from discrete TTL, there is another method.

The Quine-McCluskey method is a tabular technique based upon the inverse laws. It is methodical, but tedious and error prone and so makes ideal computer fodder. Describing the process is, as with many things in life, more difficult than actually performing it, but once understood you will have a very powerful design tool so here we go. . .

ABCD	Q
0000	1
0001	0
0010	1
0011	1
0100	0
0101	1
0110	1
0111	0
1000	1
1001	0
1010	d
1011	d
1100	d
1101	d
1110	d
1111	d

0 0000✓	00-0✓	-0-0
1 0010✓	-000	-01-
1000✓	001-✓	--10
2 0011✓	0-10✓	
0101✓	10-0✓	1--0
0110✓	1-00✓	1-1-
1010✓	-011	11--
1100✓	101-✓	
3 1011✓	-101	
1101✓	110-✓	
1110✓	-110	
4 1111✓	1-10✓	
	11-0✓	
	1-11✓	
	11-1✓	
	111-✓	

$$Q=\overline{BCD}+\bar{B}CD+B\bar{C}D+BC\bar{D}+\overline{BD}+\bar{B}C+C\bar{D}+A\bar{D}+AC+AB$$

Fig.6 Tabular example of the Quine-McClusky method

First of all, draw up a truth table for the function you wish to simplify. Pick out all of the input combinations that result in either a 1 or a *don't care* at the output and sort them into groups according to the number of 1s they contain. Write these in a vertical list such that any combinations with no 1s go into group zero, those with one 1 go into group one and so on. Each group should be labelled and separated from each other by horizontal dividing lines as in Fig.6. Don't worry if any group has no entries — just leave it blank.

Now for every entry in each group compare it with all of the entries in the group immediately below. If any pair of entries differ by just one digit then they are combinable. The terms are combined by replacing the differing digit by a dash, so that 0010 and 0110 would be combined as 0—10.

A new column is made for the combined terms, again in groups according to the number of ones. As the two terms are combined a tick is made next to their entries in the original list. If two identical entries arise in the new column then one of them may be crossed out.

In a similar way the second column entries are now compared with each other, but remember that the dashes must be in the same place if the entries are to be combinable. Make a third column of combined entries and tick those that were combined.

Continue this procedure creating new columns until either only one group exists in a column or none of the terms are combinable. Now for all of the entries that have not been ticked a Boolean term must be formed. This is done in much the same way as it is with the Karnaugh map, but a dash means the term is missing. 01-0 would therefore become $\overline{A}B\overline{D}$.

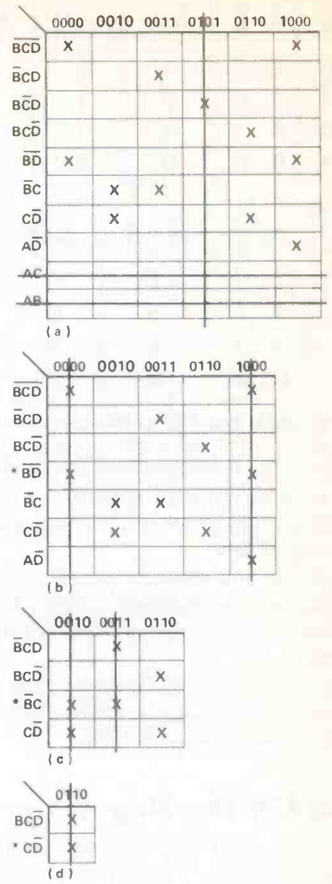


Fig.7 Reducing the prime implicants

The Boolean expressions so obtained are called prime implicants and some may be redundant terms. To obtain the fully minimised 'irredundant polynomial' we use diagrams known as prime implicant tables which enable us to find and eliminate the redundant terms.

These tables (see Fig. 7) are square grids with a horizontal line for each of the prime implicants and a vertical line for each input combination that is required to generate a 1 at the output (taken from the original truth table — do not include the 'don't care' combinations).

Go through the table row by row and at each intersection of a row and column, check if the input combination is covered by the associated horizontal Boolean term. If it is, then mark the intersection with a cross (Fig. 7a).

The bottom two rows have no crosses, so we can delete them as redundant.

Now select a *column* with just one cross (if there aren't any then move on to the next stage). The prime implicant associated with that cross is said to be *essential* and will appear in the final minimised irredundant polynominal, so mark it with an asterisk.

You can delete the column with the cross (Fig. 7b) plus any other columns that have a cross in the row belonging to that essential prime implicant (there are none of these in our example).

Repeat this procedure for any other columns with a single cross. It is not necessary to redraw at every alteration unless you feel the table is too messy for reliable interpretation.

The next stage is to take the row with the *most* crosses, mark this with an asterisk as an essential, and delete all the columns implicated by the crosses (all these input combinations are covered by this binary expression).

Note in our example we could have picked several rows — it doesn't matter. As a rule pick the simplest Boolean expression first. Note also that picking $\overline{BD}$ leads to the deletion of the left and right columns. This leaves two rows without any crosses — $\overline{BCD}$ and $A\overline{D}$. These rows can also be dumped, leading to Fig. 7c.

Here we repeat the procedure, picking this time $\overline{B}C$, taking out the left two columns, emptying the top row also, giving Fig. 7d. We choose the simpler term and empty the table, completing the analysis.

Collecting up the prime implicants we have asterisked as essential gives us the simplified result:

$$Q = B\overline{C}D + \overline{BD} + \overline{B}C + C\overline{D}$$

Checking this with a truth table proves that the result is correct.

Having explained the process it is worth mentioning the property of domination, particularly useful if you intend to program a computer with limited memory to perform the process. A row is said to be dominated by another if all of its crosses are duplicated in another single row. Likewise, a column is said to be dominated if all of its crosses are duplicated in another single column. If a row or column is dominated then it may be crossed out immediately. This can reduce computer array sizes, making computation much faster.

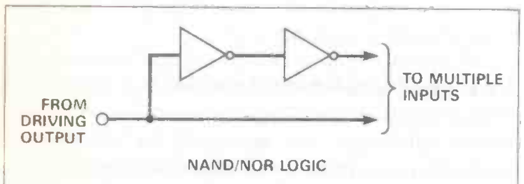


Fig.8 Buffering to avoid fan-out problems

Real Gates

It should be noted that all of the above methods of logic design assume that we are using ideal gates. In practise there is a limited fan out. When a single gate is trying to drive too many other gates, the excessive load pulls the output voltage towards ground and into the illegal range between logic high and logic low. Most logic probes will not be able to diagnose the problem correctly and extensive voltage checks with a high impedance voltmeter, or better still an oscilloscope, will be required.

It is better not to try driving too many more inputs than the manufacturers recommend. Instead use a buffer stage consisting of two inverters to drive half of the inputs, as shown in Fig. 8. Of course, other gates could be used in place of the inverters, depending on what are left over from the main design. Waste not, want not!

Waste Not, Want Not

Using the 'left-over' gates to implement different types of gates to be used in the main circuit can result in a dramatic reduction in the number of packages required for a circuit. Any logic system can be implemented using NAND or NOR gates alone. All of the common combinational logic elements are shown in Fig. 9 and could easily be extended to provide more inputs if required.

To implement a function using NAND logic, first reduce it using either a Karnaugh map or the Quine McCluskey method, then draw a circuit diagram for the resulting Boolean expression. Next, redraw it replacing all of the AND and OR gates with their NAND equivalents. Wherever two inverters are immediately in series they may be cancelled. Redrawing again omitting the cancelled gates will give the final circuit.

Doing It Discretely

Other tricks can also reduce the number of packages. These days most people leap to ICs when it comes to logic, but discrete component logic gates can also be useful. For instance, inverters generally come in six packs but Sod's law states that the number required for any design is a multiple of six plus one left over. A common emitter stage (Fig. 10a) can be employed to good effect as an inverter, though the savings will probably be in space only since the cost of a 7404 is roughly the same as that of a transistor and the two resistors.

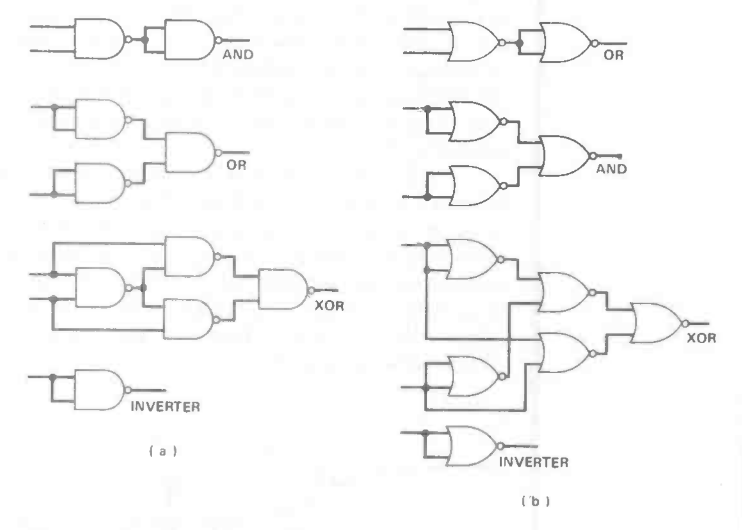


Fig.9 Making any gate from (a) NAND gates and (b) NOR gates

Need a multiple input AND gate? A fist full of diodes (Fig. 10b) can be cheaper than using many integrated AND gates in cascade and they don't draw any power. OR gates can be constructed in a similar manner (Fig.10c). One caution though, the passive gates should be used to drive active ones or else the logic levels will sink into the illegal region. Also, use diodes with a fairly low forward voltage drop such as common or garden 1N4148s, definitely not rectifier diodes as these tend to have forward voltage drops in excess of 1V and will almost certainly cause problems. Diode gates were used quite extensively in days gone by when logic ICs were still very expensive, but the two-a-penny cost of TTL and CMOS logic today makes the financial savings less of a consideration except in very high fan-in applications.

An even cheaper AND gate can be constructed if you're using open collector gates. It only requires a single resistor, you just connect all of the inputs together and connect them to the output, using the resistor to pull the output up to the positive supply rail — phantom AND gates (Fig. 10d). Don't try this with ordinary totem pole output gates or else the circuit's life will be short if not spectacular!

So to sum up this article, although standard procedures can help you achieve a correctly working logic circuit, a little extra time spent trying to achieve the best possible utilisation of the available gates can give rise to dramatic savings.

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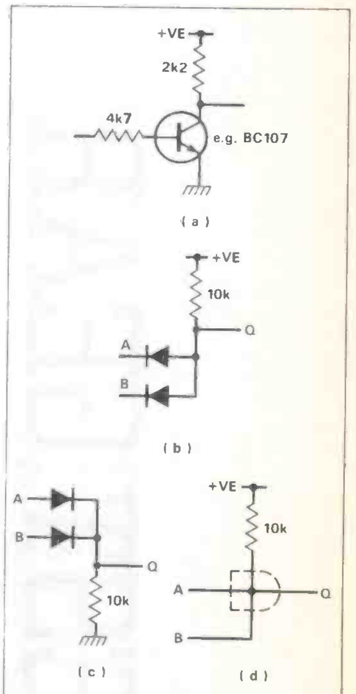

Fig. 10 Discrete gates (a) inverter (b) AND (c) OR (d) multiple AND

TESTING TESTING

1: THE BASICS

Mike Barwise returns with a series explaining the correct way to handle test gear from the humble probe upwards

In this series I will be describing electronics test gear and how it is used, together with any pitfalls or special techniques for getting reliable results. Far too frequently the assumption is made (even by highly trained specialists and research workers) that all their equipment is 100% accurate, reliable and transparent to their experimental data. *WRONG!!!*

The first, second . . . and last point to note is that no test gear is infallible. If there were letters gleaming gold twenty feet high on the front, this could not be emphasised enough. It is not sufficient to be able to take readings when using instruments, you must know how to interpret the readings. Time and time again we will come across situations where the test gear contributes to an error in your results and it is vital to be able either to quantify the error or to find a way of cancelling it out.

The generic name for experiment-induced error is *artefact*. This term will crop up with boring regularity as we proceed to discuss measurement techniques. However I don't mean to put you off — artefact can be cancelled out very successfully using a wide variety of techniques. Most of them are tricks of the trade which you won't find in the majority of textbooks, which are biased towards theoretical principles. The general assumption in theoretical work (in order to simplify problems) is that components are perfect and test gear transparent. This is right and proper when you are learning background theory for exams and so on, but in the real world things are never quite that neat.

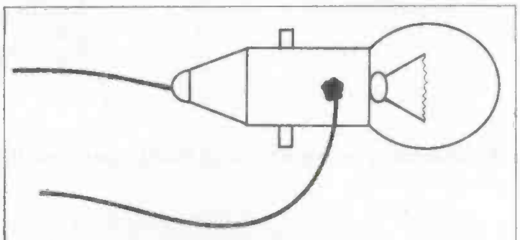

Fig. 1 Car mechanics lamp probe

Defining Terms

Before we start, there are two or three terms we must define: *resolution*, *accuracy* and *precision*. These all relate to sources of error inherent in even the very best instruments.

Resolution is the number of divisions on your scale. It is normally expressed as a percentage: 100 marks between zero and maximum equals 1% resolution. Good resolution has nothing inherently to do with high accuracy or high precision.

Accuracy amounts to how much of the resolution you can ignore: if your needle wobbles a total distance equal to two divisions at 1% resolution then it is accurate to 2%, more normally expressed as ±1%.

Precision is a measure of how reliably your instrument reading accords with the truth. If your meter reads 99mV when the input voltage is 100mV, its precision is −1%, so long as it always reads 99mV. Precision is the least troublesome of the three sources of error in instrumentation — so long as it is constant and not grossly deficient.

You will commonly find these terms used at random in mail order adverts: the most common being the use of accuracy where resolution should be used. This tends to make very ordinary gear sound more attractive, so watch out!

Common among cheap and bad instruments (not always the same thing!) is variability of any or all of these parameters with age, temperature and other outside influences. You are lost if the variation is significant, as your results will always be unpredictable.

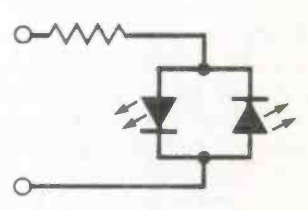

Fig. 2 Back to back LED probe

Maplin's range of multimeters

TEST GEAR

Thus, rule one: never assume new test gear is good. Check it! Neither should you assume that borrowed test gear is good — even if the guy you borrowed it from tells you so, even if he is an incredibly experienced engineer. He is most probably just used to its idiosyncrasies and automatically compensates for them mentally. This is one of the tricks I am going to show you.

Nothing For Nothing

Step two in understanding test gear artefact is the fundamental principle that you get nothing for nothing. Detection of signals is detection of *energy*, and you can only detect energy by stealing a bit of it. The amount you steal and how you steal it determines whether you significantly alter the signal you are testing or not.

Remember that every time you apply a test probe, even a non-contact probe like a compass needle beside a wire carrying a current, you draw a bit of energy from the thing you are investigating.

Let us take a very crude example (perfectly realistic though!) to demonstrate how things can go wrong. The gear in question is the automotive engineers' test prod. This consists of a 12V lamp (about 2W or 180mA consumption) connected to a pair of flying leads (Fig. 1). It is used to test for open circuits and live terminals among the guts of your car: you connect one lead to either the battery positive or negative and then the lamp lights when the other lead contacts a point of opposite potential. The mechanic is very happy because his test probe is reliable, robust and simple to use.

Now you come home to find that your computer won't talk to your modem and you can't get onto your favourite bulletin board service. OK, whip round to your friendly mechanic and borrow his test probe. After all, you have a hazy memory (head, not micro!) that RS232 works at 12V. You disconnect your modem cable, connect one lead of the test probe to

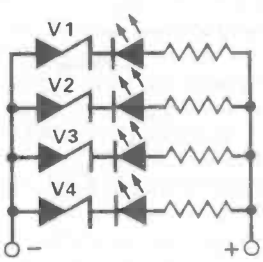

Fig. 3 Zener/LED probe

a good ground point and probe around the RS232 connector with the other. Nothing . . . nothing . . . *nothing* at all! You are convinced your RS232 port has blown up and you go out and spend lots of hard earned loot on a new one. However . . .

The real problem lay with your choice of test gear. It's perfectly true that RS232 works at 12V (+/−12V nominal to be precise), but any output can only supply about 50mA and still remain at +12V or −12V. Drawing any more current than this causes the output voltage to fall towards 0V. By the time the output is trying to cope with the 12V lamp (about 30R cold thus a little over 300mA) its voltage is very low indeed and the output is just incapable of lighting the lamp.

This does not mean that current is not flowing: just that you can't detect it. Fortunately, although you have not done any good, you have done no harm either (this time). RS232 outputs are designed to withstand continuous short circuit. Now, if you had tested your hard disk controller in this way, you would have finished up with a bit of smoke and a very big bill indeed.

What does this silly example tell us? Quite simple: when you take your measurements, you must take out much less energy than is in the system. Quite apart from any consideration of damage, a 10% drain into your test gear will produce at best a 10% error in your reading (probably more). It is normally considered reasonable to draw not more than a thousandth (10^{-3}) of the power in the circuit under test. As most affordable general purpose test gear resolves to about 1%, you are always one order less intrusive than you will notice. In special cases this criterion can be tightened. In many modern instruments, tested signal drain (probe current) is vastly less due to advances in technology.

Your next step is to give the lamp back to your mechanic and look for a more suitable test probe. You can cheat a little, because I have just told you that RS232 works at ±12V and can deliver about 50mA without problems. Yes — an LED! If you substitute an LED for the lamp, you just might be on the right lines. An LED will light up at a current of 5-25mA depending on the flavour: lime and lemon mostly need more current for a given brightness than cherry. 50mA will blow most of them up, so a series resistor will be needed (say 1k0) which will pass about 10mA.

A refinement would be a second LED back to back with the first (Fig.2) as LEDs are diodes (they only conduct one way round). This would indicate whether the RS232 line was high (LED1 on), low (LED2 on) or dead (neither on). This is in fact the basis of the majority of cheap (here I mean overpriced) RS232 testers. Well done! However . . .

The functional RS232 tester we have just developed has a major limitation. It only registers top-notch signals as it is a representative RS232 load. A good output (insufficient voltage swing, low current or a host of other faults) just registers as dead. You can go further: in order to establish what is wrong in more detail, we must think up something a little more sophisticated!

A first line of attack could be to design a monitor which shows at least approximately the voltage swing of the RS232. An obvious solution would be a set of zener diodes (defined reverse breakdown characteristic) and a set of LEDs (Fig.3). This circuit has just one minor problem. It doesn't work.

The zener diodes are fine — not very accurate, but fine. What screws up the performance is the LEDs. An LED has a threshold voltage (minimum for conduction and light output) called Vt of about 1.2 to more than 1.7V, depending again on the type (this is a very variable value from device-to-device). The Vt of each LED would have to be added to the zener voltage, and each pair would need individual testing and tuning. Also, even if you got this right, the higher the RS232 voltage the more LEDs are on, so the higher the current drawn from the circuit under test, the greater the voltage drop at the point under test (the old problem again).

A much better solution (it actually works) is shown in Fig.4. Here, the zener diodes drive transistors which carry the LED current when they are in conduction. Only half the circuit (the positive-going detector) using npn transistors is shown for simplicity but obviously a similar circuit using pnp devices (conducts when base negative) would be included for testing RS232. This test probe will show not only whether the RS232 is functioning but also how good its voltage swing is, with limited precision. Furthermore, the probe draws less than 1/100th of the power from the circuit under test compared with the simple LED of Fig.2.

This is about as far as you can go with simple probes with lights on. Mostly people build probes themselves, but the next step in test gear is the *meter* (multimeter, DVM, DMM and so on). These, you buy. There are two main categories: the *analogue* and the *digital*. It is a common idea that since the invention of the digital meter, the analogue meter is dead and useless. This is not so. Each has its uses, and the experienced electronics engineer usually has a couple of each to hand.

The Analogue Solutions

In the old days, before the advent of cheap A to D converters (the guts of the DVM), people used moving coil and moving iron ammeters and voltmeters and valve voltmeters. Clever engineers still use them sometimes.

They all work on the principle of electromagnetic attraction and repulsion between a coil of wire and a piece of magnetised iron against the restoring force of a small spring: in some the coil, and in others an iron armature, moves. Over the years, a considerable level of sophistication has been reached in their design and they are remarkably accurate under the right conditions.

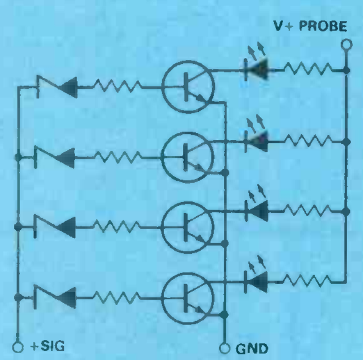

Fig. 4 Zener-transistor-LED probe

Firstly, let us look at the difference between an ammeter (Fig. 5a) and a voltmeter (Fig. 5b). The ammeter measures current passing through it and so does the voltmeter. The only difference is that the voltmeter has a very precise known resistor in series with it, and its scale is calibrated in terms of the voltage required to pass specified currents though it. The resistance of the ammeter has to be negligible in comparison with the circuit it is connected in series with (see Fig. 5c) and the resistance of the voltmeter plus its resistor must be very high compared with the circuit it is connected across (Fig. 5d).

Both these requirements fulfil the rule we have just learned — take as little energy from the system as you can. The ammeter in series with the circuit dissipates energy proportionally to its resistance, and the voltmeter in parallel with the circuit, in inverse proportion, to its resistance.

Moving coil ammeters are sold as 0-5A, 50-0-50mA and so on but in most cases, the actual coil in the meter has quite a high resistance and a significant needle deflection is caused by quite a small current passing through it. The range selection is accomplished by adding a substantial wattage resistor in parallel with the meter coil (Fig. 5e). If the coil resistance is N ohms, and the resistor has a value of 0.11N ohms (N/9), the current range of the ammeter will be multiplied by 10. The advantage of this approach is that it is much easier to produce a reliably sensitive delicate mechanism than one chunky enough to carry the whole current you are measuring once you get above about 100mA or so. The best ammeter movements have full scale ranges in the region of 50-100μA.

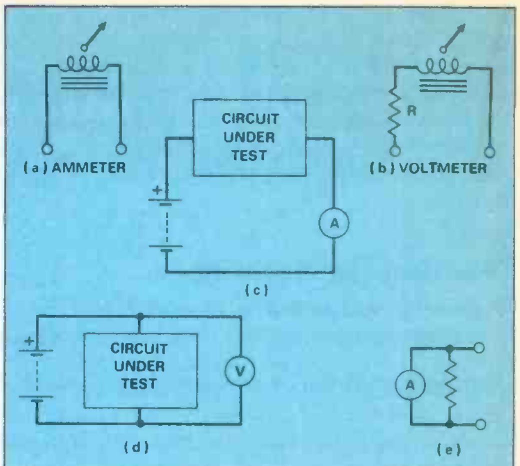

Fig. 5 (a) ammeter (b) voltmeter (c) ammeter series connection (d) voltmeter parallel connection (e) resistor for range selection

Moving coil volt meters are classified in terms of the current they draw in ohms-per-volt. This is a measure of the total resistance of the meter and its series resistor in terms of the full scale deflection of the meter. Thus a typical value of 20,000 R/V (a good quality general purpose voltmeter) would have a total resistance of 20k for a 1V range, 200k for a 10V range and so on. The current drawn by the meter will vary over its range with the applied (measured) voltage but this specification assures us that the maximum current which can be drawn from the circuit under test is 50μA.

Simple moving coil meters have one drawback — you can only use them to obtain sensible readings of DC systems. If you apply AC, the needle will jitter about, changing direction with the AC polarity, and you may shake the movement to pieces. There are solutions using additional external components (more later) but for general purpose chunky AC signals (power supply monitoring and so on) the moving iron movement is most suitable.

This consists of a fixed electromagnet formed of the coil wound on an iron core and an armature made from magnetisable material (carbon-free iron) which does not retain its magnetism well. This, like the keeper on a toy magnet, is attracted to the electromagnet in proportion to the strength of the field, but it does not care about the polarity of the fields the armature has no north or south pole. Even in the presence of an AC magnetic field, the armature will be attracted in proportion to the field strength.

This has an interesting spinoff. In the presence of an AC field, the moving iron voltmeter will tend to display the AC RMS voltage (a measure of the average power capability) rather than the peak-to-peak swing of the AC. For a sine wave, RMS is about 0.7 times the peak voltage and is actually a more useful parameter in many cases. It amounts to the theoretical DC potential you would get if you integrated the AC via a lossless full wave rectifier.

Moving iron meters are, however, rather crude. They are much less linear than moving coil meters, and are remarkably insensitive. In order to improve measurement at low AC signal levels, the valve voltmeter was invented. This is what we shall start by examining next month, in the second part of this series.

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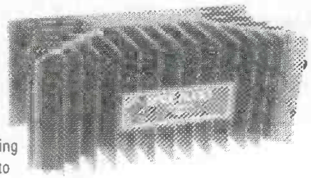

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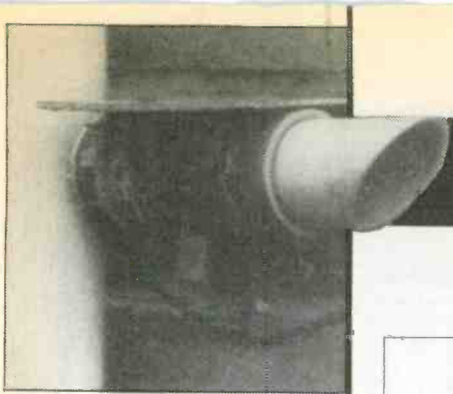


INTRUDERBEAM

Felons should think twice before crossing the path of Geoff Phillips, thanks to his active infra-red alert system

In these days of high crime figures a burglar alarm for the home is a sound investment. Most alarms however operate on the principle whereby the felon has to actually break into your home before the alarm is triggered. He may be frightened off or a brave burglar may grab something before he runs. Meanwhile costly damage has been done to a window or a door, leading to drawn out insurance claims and the hastle of arranging for the repairs to be carried out. Your property may be in an insecure condition in the meantime.

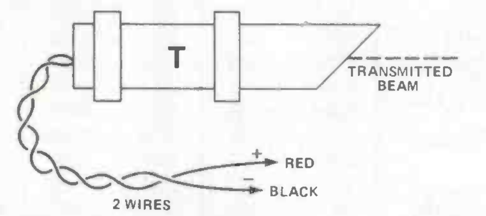


Fig. 1 Mounting the transmitter

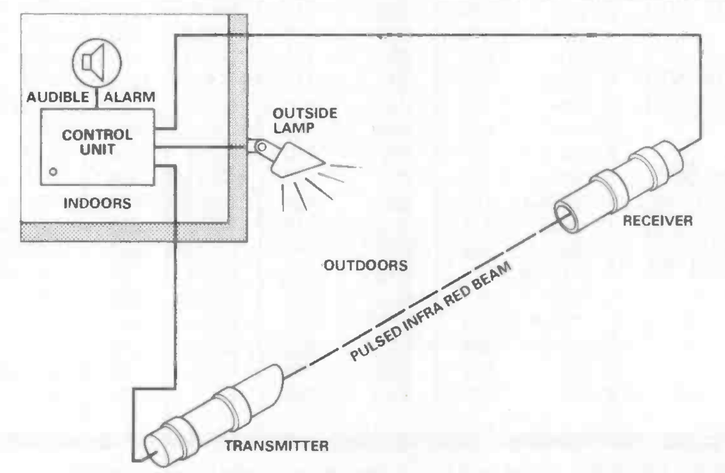


Fig. 2 Operating arrangement for the Intruderbeam

The *intruderbeam* system utilises a pulsed active infra-red beam which is installed outdoors to monitor the most vulnerable areas around the doors and windows of your property.

If, during the hours of darkness, the infra-red beam is broken by a prowler the system switches on an internal house light to fool the burglar into thinking he has been spotted and the householder is coming to investigate. In addition, an audible alarm may be sounded to scare the prowler away further. The audible alarm channel is selected manually when required but the internal house light channel is arranged to self-prime at dusk — the householder does not have to remember to switch it on.

It is highly probable that most burglary attempts will be thwarted by the light channel in which case the householder sleeps through the whole event. The system is completely tamper-proof in that any attempts to mask off the transmitter or receiver or to cut any of the wires will trigger the alarm.

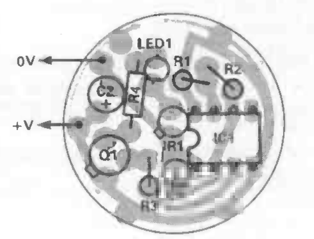


Fig. 3 Component overlay for the circular transmitter PCB

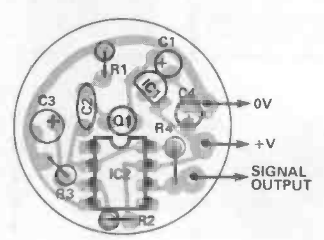


Fig. 4 Component overlay for the circular receiver PCB

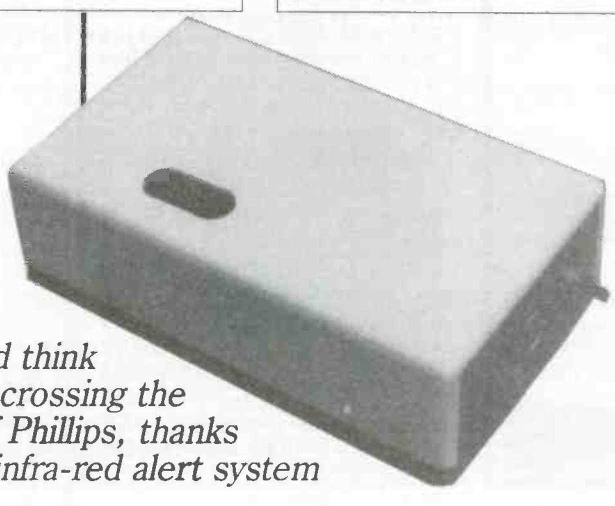
Transmitter And Receiver

The system comprises an infra-red transmitter and infra-red receiver and a control unit. Short pulses of infra-red of 900nm wavelength are used for the beam rather than a continuous signal which would be wasteful on energy and difficult to differentiate from the relatively constant infra-red content of daylight. Both the transmitter and receiver are fitted with LEDs to aid alignment.

The control unit is designed to be mounted indoors but as the infra-red beam is outdoors it is essential that the transmitter and receiver are completely waterproof. A perfect solution to the problem was to mount the transmitter and receiver electronics in 1½in plastic waste-water pipe fittings on the principle that if they are designed to keep water in, the pipe fittings will certainly keep water out.

Small circular printed circuit boards are used for the transmitter and receiver circuits which fit into a pipe end blank of the type used where a kitchen sink waste pipe emerges from the outside wall of the house. (The end blank is screwed and allows a plumber to gain access to the section of pipe which leads to the gully grate if a blockage in the pipe occurs.)

The collimating lens for the transmitter or receiver is mounted in a section of pipe which is joined to the end blank section by an in-line pipe join (see Fig. 1). The complete unit can then be mounted to a wall with the operating arrangement as shown in Fig. 2.



PARTS LIST

CONTROL UNIT

RESISTORS (all ¼W 5% unless stated)

R1	100k
R2	330k
R3	15k
R4	8k2
R5	820R ½W
RV1,3	1M0 horizontal skeleton preset
RV2	100k horizontal skeleton preset
LDR1	ORP12

CAPACITORS

C1	4.7µ 35V aluminium electrolytic
C2	2.2µ 35V aluminium electrolytic
C3,4,6	100µ 16V aluminium electrolytic
C5	220µ 25V aluminium electrolytic

SEMICONDUCTORS

IC1	LM324 quad op-amp
IC2	4011 quad NAND gate
IC3	7812 12V regulator
Q1	BCY71
Q2,3	BC107
BR	W01 1A bridge rectifier
D1-4	1N4148
ZD1	BZY88 C5V1
LED1	5mm red LED
LED2	5V flashing LED

MISCELLANEOUS

T1	3VA transformer 12V, 12V
RL1,2	Vertical format 12V DC relay dual changeover contacts
SW1	DP toggle switch

Plastic case. Mains plug and socket. 3-pin 180° DIN plug and chassis socket. Audible alarm.

TRANSMITTER

RESISTORS (all ¼W 5%)

R1	100k
R2,3	100R
R4	10R

CAPACITORS

C1	4µ7 35V aluminium electrolytic
C2	100µ16V aluminium electrolytic

SEMICONDUCTORS

IC1	CMOS 7555 timer
Q1	BC640
LED1	5mm red LED
IR1	TIL31 IR transmitter

MISCELLANEOUS

PCB. 1.5in plastic pipe fittings. Bland end. Pipe (approx 80mm). Straight coupler. Watchmaker's eyeglass 31mm focal length.

RECEIVER

RESISTORS (all ¼W 5%)

R1	2k7
R2	1k0
R3	10k
R4	2M7
R5	820R

CAPACITORS

C1,4	22µ 16V aluminium electrolytic
C2	100n polyester 5mm lead pitch
C3	100µ 25V aluminium electrolytic

SEMICONDUCTORS

IC1	78L12 12V 100mA
IC2	741
Q1	TIL81 IR receiver
LED1	5mm red LED

MISCELLANEOUS

PCB. 1.5in plastic pipe fittings: blank end, pipe (approx 80mm), straight coupler. Watchmaker's eyeglass 31mm focal length.

Control Unit

The control unit is designed to supply the necessary DC power to the transmitter and receiver and to process the voltage pulses from the receiver. The unit is powered from 240V AC and must be mounted indoors away from rain and moisture.

The unit constantly monitors the voltage pulses from the receiver and if the pulses disappear (the beam is interrupted) then one or two alarm channels may be activated — the light channel and the audible alarm channel.

The light channel may be used to power an outside floodlamp to really throw light on the scene of the crime or the channel may be used to turn on an internal house light to fool the burglar into thinking someone is coming to investigate.

During the hours of daylight a light dependent resistor senses the ambient light level and inhibits operation of the light channel. This has the advantage that the householder does not have to remember to turn on the alarm at night and off next morning. When 24-hour protection is required, the audible alarm channel may be activated by means of a switch. Either a mains powered alarm may be used or a 12V DC piano sounder. (The weirder the alarm sounds the better. If the brain does not recognise a sound it is thrown into confusion and this adds to the deterrent aspect of any burglar alarm.)

The control unit is fitted with an LED which indicates when the beam is established so that the householder can confirm that there is nothing blocking the beam before he activates the audible alarm channel. A flashing LED is also fitted to remind the owner that the audible alarm channel is set to avoid him accidentally setting off the alarm himself.

Construction — Transmitter

Ensure that the circular PCB (see Fig. 3) will fit into the plastic pipe blank end before fitting the resistors, capacitors and semiconductors. Solder the positive and negative supply leads to the rear of the PCB. The leads should be of a suitable length to run from the required location of the transmitter outdoors to a junction box indoors. Supply cables can then be run from the junction box to the control unit.

Connect the leads to a 12V DC supply to confirm that the circuit operates correctly and the LED is seen to flash at about 3-4Hz. The circuit can then be fitted to the blank end by drilling a hole in the rear of the blank end, passing the leads through the hole and then sealing the whole blank end assembly with silicone rubber or other suitable potting compound.

The PCB may be held in place with adhesive tape while the compound is solidifying. The

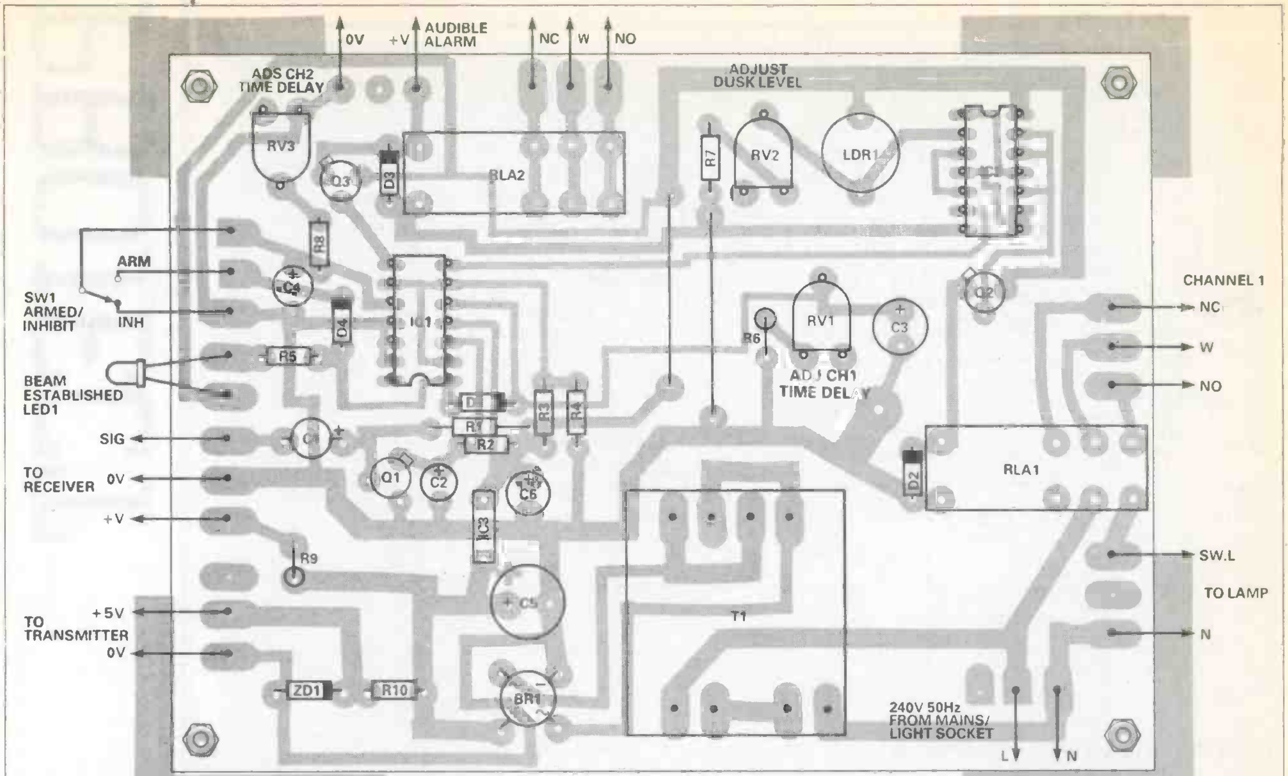


Fig. 5 Component overlay for the control unit PCB

completed assembly can then be screwed into the other section of the blank end which in turn can be inserted into the straight coupler.

A watchmaker's eyeglass of focal length 31mm is used as the collimating lens. Choose an eyeglass which has an outside diameter which is slightly larger than the outside diameter of the plastic pipe (cut according to Fig. 3). The eyeglass is secured to the end of the pipe with sealant or adhesive and when the adhesive is dry, the eyeglass body may be filed until it is flush with the outside diamter of the pipe. The whole assembly can then be inserted in the straight coupler.

The position of the collimating lens with respect to the infra-red sensor can be adjusted by sliding the pipe/lens assembly in and out of the coupler until the infra-red sensor is at the focal point of the lane. It may be necessary to smear the rubber O-ring in the coupler with Vaseline to make this operation easier. The final position of the lens may be set when the complete system is commissioned.

Construction — Receiver

Construction of the receiver (see Fig. 4) is similar to the transmitter. Only the LED is fitted so as to protrude

HOW IT WORKS

Control unit

Transistor Q1 and associated components (see Fig. 6) are connected as a missing pulse detector. As long as 0V going pulses are being received at C1, C2 is repetitively discharged by Q1. The output of IC1 is normally 0V and thus the 'beam established' LED is illuminated via R5.

If the pulses at C1 cease then C2 charges up to 12V via R2. When the voltage at C2 exceeds that set at pin 2 of IC1a by R3 and R4, the output of IC1 goes high. This causes C3 to be quickly charged up via D1 thereby triggering the 'light channel' alarm circuit.

IC1b, RV1, R6 and C3 function as a monostable circuit which dictates how long the light remains on once the alarm has been triggered.

The light is only turned on during the hours of darkness however and this function is controlled by the quad NAND gate IC2. At dusk, the resistance of the LDR starts to increase. When the voltage at the junction of the LDR and RV2 falls below the switching threshold of IC2a pin 2, then pin 3 goes high and so the two logic 1s at pins 5 and 6 of IC2a cause its output to go low and the light is turned on via IC2c, Q2 and RL1.

IC2d prevents the light from being turned off again when its own light falls on the LDR. The time the light remains on once triggered may be adjusted by RV1.

If the audible alarm channel is required then SW1 must be placed in the *Armed* position. If the infra-red beam is interrupted and IC1a goes high, then the monostable formed by RV3, R8, C4 and IC1c is triggered and the audible alarm is energised via Q3 and RL2. A 12V DC audible alarm may be connected between the emitter of Q3 and 0V, but if a mains powered unit is used then the normally open contacts of RL2 may be used.

A second pole of SW1 is used to connect the 5V supply at ZD1 to a flashing LED. This reminds the user that the audible alarm channel has been activated. If the alarm is triggered when the householder is at home, the quick discharge of C4 by SW1a when the switch is operated ensures that the alarm is quickly silenced and does not continue for the time period set by RV3, R8 and C4.

Receiver

The circuit diagram is shown in Fig. 7.

IC1 provides a stabilised 12V supply for the infra-red receiver Q1. Pulses from the receiver are AC coupled by C2 to IC2 which is connected as a comparator. When the amplitude of the pulses exceeds the offset between pins 3 and 2 produced by R2, R3 and R5, the output of IC2 goes from positive to negative saturation. An indication that a pulse of infra-red has been received is given by the LED driven by Q2. This is a very useful facility when attempting to align the receiver to the transmitter.

Transmitter

The circuit is as shown in Fig. 8.

IC1 is connectd as an astable multivibrator which produces narrow 0V going pulses at pin 3 of a repetition frequency of a few Hz. Current gain is provided by Q1 so as to drive the infra-red transmitter in series with the LED. The LED gives a brief pulse of light in synchronism with the infra-red pulses and is useful to indicate operation of the transmitter when commissioning the system.

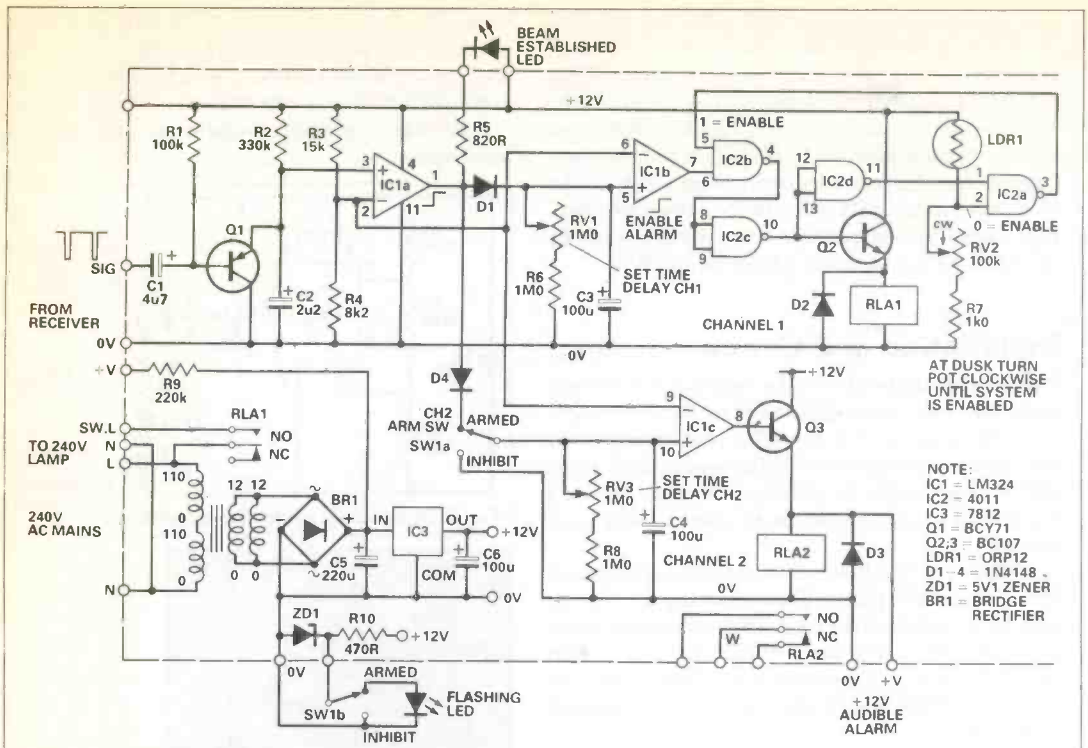
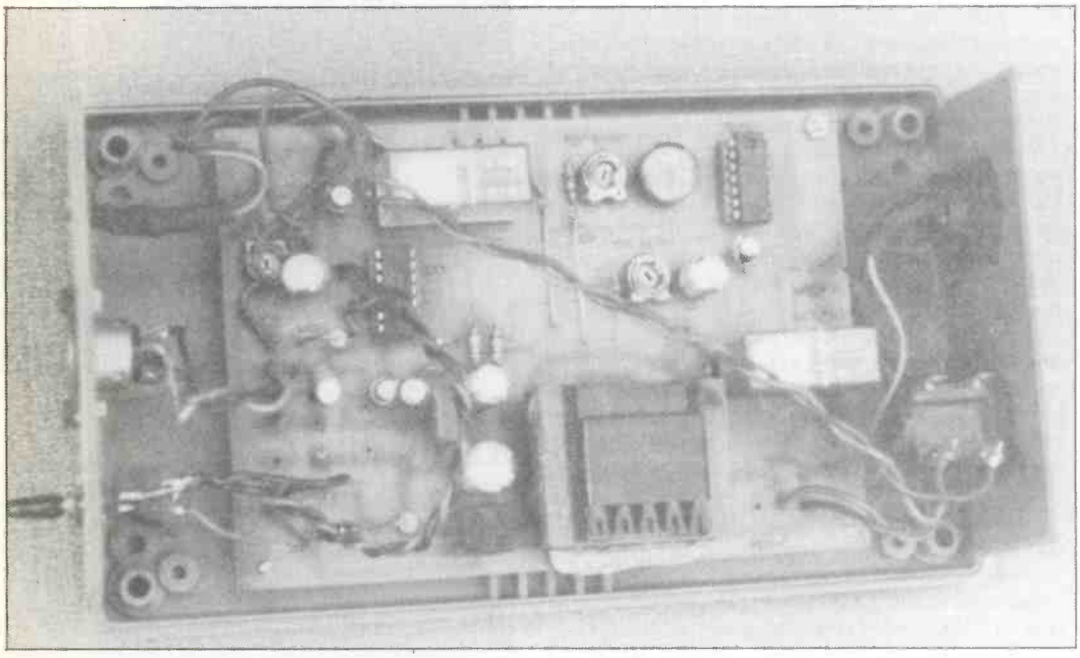


Fig. 6 Circuit diagram for the control unit



through a second hole in the rear of the blank end. The receiver can only be checked by lining it up to the infra-red pulsed beam produced by the transmitter and checking that the LED on the receiver flashes in sympathy with the transmitter pulses.

Control Unit

The component overlay is shown in Fig. 5.

Fit the power supply components first and test this section before fitting the remainder of the components. It is wise to fit sockets for the integrated circuits so that they may be inserted one at a time.

The control unit PCB should be tested before it is fitted in its case as follows. Temporarily connect the receiver and the transmitter to the control unit and align them so they point directly at each other. Insert IC1 into its socket and check that the "beam established" LED on the control unit is lit. Interrupt the beam and check that the LED extinguishes.

Insert IC2 and simulate darkness by masking off

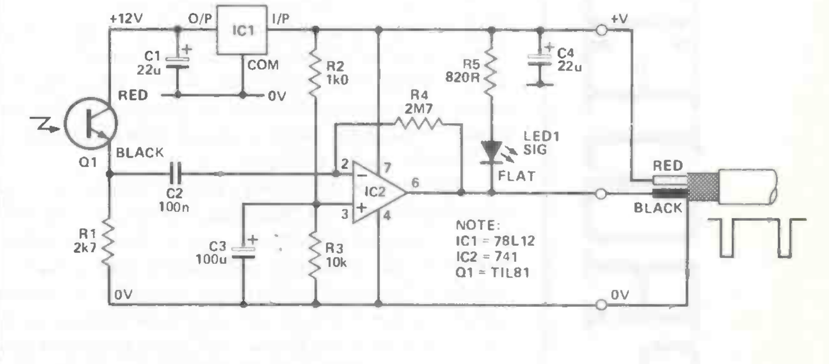


Fig. 7 Circuit diagram for the receiver

the LDR with dark-coloured tape or Plasticene. Check that the relay RL1 operates when the beam is broken and remains energised for a time period adjustable by RV1. The relay should fail to operate if the masking from the LDR is removed and the ambient light level is above the threshold set by RV2. The audible alarm channel may be tested by connecting a link on the PCB to simulate SW1 being in the armed position. RL2 should operate when the beam is broken and stay operated for a time delay adjustable by RV3.

Installation and Commissioning

The installation should only be started when all three units have been thoroughly tested on the workbench.

The transmitter and receiver should be sited so that the beam covers the required area close to doors and windows as the psychological effect is greater if the alarm is triggered when the prowler is close to your property.

The mounting brackets for the transmitter should be adjusted in two planes. This is to enable the receiver and the transmitter to be aligned for maximum signal. The cables should be passed through holes in door or window frames to junction boxes indoors (in case one of the units develops a fault and has to be replaced or repaired).

An ideal siting for the control unit is above an entrance door in the room where the light fitting is to be coupled up to the light alarm channel. The live neutral and switched live will be available at the ceiling rose of the light and these three connections are all that is required to both power the control unit and facilitate the light alarm channel.

Power up the control unit and align the transmitter to the receiver by eye. Confirm that the transmitter is functioning correctly by observing the flashing LED through the collimating lens. Adjust the angle of the receiver for maximum brightness of its flashing LED at the back of the unit. It may then be necessary to adjust the position of the transmitter, although two people may be required for this step — one to watch the receiver LED and the other to adjust the transmitter. If an oscilloscope is available, the amplitude of the pulses at the control unit may be monitored while fine adjustments are made to the positions of both the receiver and transmitter until the pulses are at their maximum amplitude.

Once their positions have been optimised the transmitter and receiver should be securely clamped so that they cannot be easily moved. Check that the 'beam established' LED is lit on the control unit and is seen to extinguish when the beam is interrupted.

The light alarm channel may be tested by temporarily masking off the LDR with tape. After testing, remove the tape, turn RV2 fully anti-clockwise and interrupt the beam with an opaque object. When the ambient light at dusk has reached the level at which operation of the light channel is required, turn RV2 slowly clockwise until the room light being controlled, illuminates. The audible alarm channel is simply tested by throwing the switch to the 'armed' position. By experimentation, set RV1 and RV3 to the desired time delay periods for the light channel and the audible alarm channel.

Remember than any burglar alarm is only effective if someone responds when it is triggered. Many people leave their homes protected by an alarm system while on holiday and assume that someone will act if the alarm is triggered. In reality not many people can be bothered and alarms are heard to ring for hours until a neighbour can't stand the noise any longer and telephones the police. By then the thieves could have made off with the entire contents of the house. The Intruderbeam resets after the time period set by RV3 so incessant noise from the alarm is less likely, nevertheless it is wise to ask a friendly neighbour to at least have a look over the fence at your property is they hear your alarm sound when you are away from home.

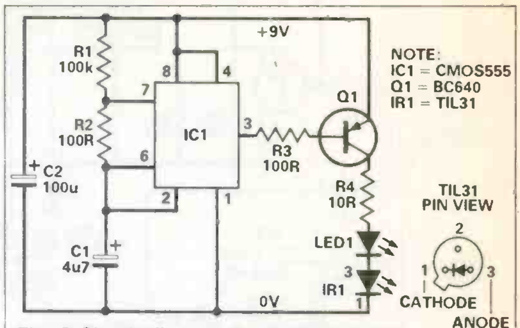
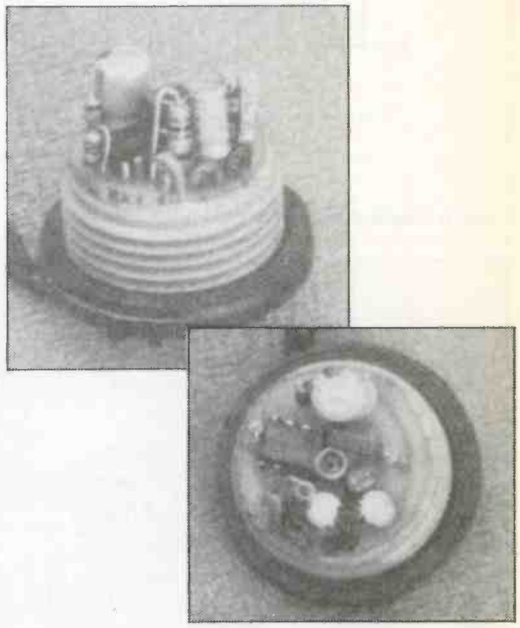


Fig. 8 Circuit diagram for the transmitter



THE TRANSMITTER-RECEIVER

When connected to 5-9V DC the transmitter gives short pulses of infra-red light at about 900nm wavelength, collimated into a narrow beam which is aimed at the receiver.

A light emitting diode gives pulses of visible red light in sympathy with the infra-red. A quick test can thus be made by looking directly into the lens.

The transmitter will operate satisfactorily at any DC voltage between 4V and 10V. Ensure that the correct connections are made otherwise the transmitter may be damaged.

The transmitter should be securely mounted on a wall or similar rigid structure and aimed at the infra red receiver. It is desirable to mount the unit at waist height so that cats and dogs do not interrupt the beam.

The receiver will operate satisfactorily at any DC voltage between 8V and 25V. Ensure that the correct connections are made again. The purple lead gives the output signal of voltage pulses.

The receiver should not be mounted such that strong sunlight can shine directly into the lens aperture.

The angle should be slowly adjusted until the LED at the rear of the casing is seen to flash at regular intervals. Make fine adjustments of the angle in both planes (vertical and horizontal) until the flashes are at their brightest.

The transmitter-receiver combination has been tested and proved to be satisfactory at distances of up to 60 feet. Once the transmitter-receiver combination have been accurately aligned they should be securely clamped so they cannot be accidently mis-aligned.

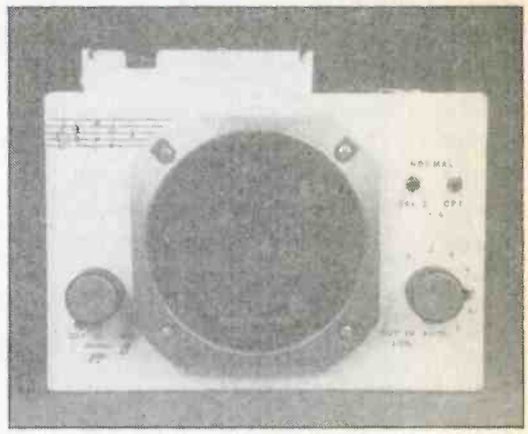
POLYBEL TUNEWARE

HOW TO SERENADE IN HEX

Trevor Skeggs explains the Polybel Operating System — PBOS — and teaches his polyphonic programmable doorbell to sing a new tune

The September issue of ETI saw (heard?) your Polybel Programmable Music Generator built and tested (I hope) and now you find you're no longer inviting people around on any excuse merely so that they can press your door-push and go gosh. You're bored! Or perhaps the music is too square/hip/sedate/brash? Time to re-program!

There will be three categories of owner amongst you. Firstly those who, as long as it plays a 'toon', couldn't give a damn . . . these may as well proceed to the next article. Then there is the EPROM owner who wants to 'have-a-go' — you may either skip to the encoding section, or read the next bit jealously. Lastly there is the lucky EEPROM owner, anxious to find out why he's paid extra for it . . .



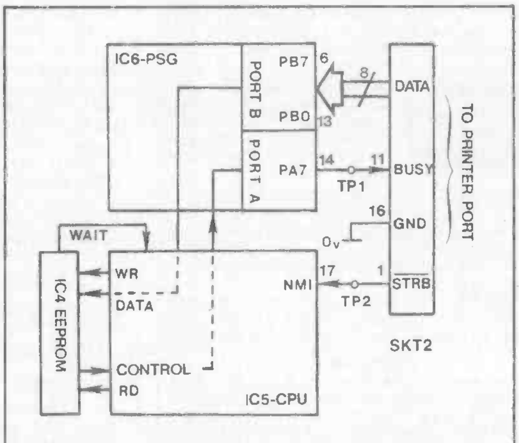


Fig. 1 Transferring data from computer to Polybel

Printing to Polybel!

As stated last month, Polybel accepts data over an 8-bit bus from a home computer. This means that Polybel must try to impersonate a printer. This masquerade is exposed in Fig. 1.

The data from your computer arrives at the Centronics socket over a standard cable (Fig. 2). Here the 8-bit data bus is wired (via the rotary switch — which *must* be open-circuit — and the DIL header SKT1) to the Programmable Sound Generator (PSG). The active-low *strobe* is taken via a separate wire to the Non-Maskable Interrupt of the Z80 (test-point near C11 on supplied boards or if not fitted then on the lower-end of R12).

The acknowledgement *busy* is taken, via a separate wire, from test-point TP1 near SKT1.

PIN 1 - STROBE	PIN 13 - SELECTED	PIN 25 - (OV)
PIN 2 - DATA 0	PIN 14 -	PIN 26 - (OV)
PIN 3 - DATA 1	PIN 15 -	PIN 27 - (OV)
PIN 4 - DATA 2	PIN 16 - GND	PIN 28 - (OV)
PIN 5 - DATA 3	PIN 17 -	PIN 29 -
PIN 6 - DATA 4	PIN 18 -	PIN 30 -
PIN 7 - DATA 5	PIN 19 - (OV)	PIN 31 -
PIN 8 - DATA 6	PIN 20 - (OV)	PIN 32 - /FAULT
PIN 9 - DATA 7	PIN 21 - (OV)	PIN 33 -
PIN 10 - /ACK	PIN 22 - (OV)	PIN 34 -
PIN 11 - BUSY	PIN 23 - (OV)	PIN 35 -
PIN 12 - NOPAPER	PIN 24 - (OV)	PIN 36 -

Fig. 2 Connections on the Centronics socket SK2 (rear)

Procedure

How you enter programming mode on the Polybel is dictated by the characteristics of your computer.

Most computers will check *online*, *no paper* and *error* via the *fault* line. Sometimes this will float high (no fault) if not connected whilst others may require sourcing to +5V. This may be checked by attempting to print a character with the printer disconnected. In the event of an error, it may be possible to link this to +5V at the computer socket, else to +6V at SKT2 via a diode and resistor.

Similarly, most computers will check *busy*, and this may or may not require an active current. If it does, then the printer will appear 'ready' when disconnected — when Polybel is off it will accept the first byte. Again, you can test this (having solved the 'fault' problem) by seeing if you can print into free space.

Polybel enters programming mode by either a negative-edge on NM1 after having powered-up (that is printing to it when it is active), or by a zero byte on Port B at power-up (that is sending a null byte before it becomes active).

Here then is a possible procedure. Firstly write a data file by any means available to your computer, using the codes detailed in the next section. Preface this file with:

(a) One or more null bytes.
(b) Start-code byte, &AA.
(c) The start address in hex divided by 8 (eg &B0 for &580).
(d) The length, from 1 to 256 (represented by zero) bytes.

The operating system in pages 0 and 7 must not be overwritten, so keep the address code between &20 (buffer 1) and &C0 for safety.

Connect the printer cable to Polybel, which should be off. Set all switches open-circuit (position C). Send the first (null) byte of the data file, probably with PRINT CHR$(x). Trigger the unit. Polybel should respond with a 'peep'. Send the data file. Polybel should respond with a 'peep' if the start and address bytes are acceptable, or a raspberry if not.

Tuneware

The operating system interprets buffer codes and manipulates the PSG accordingly. Like a microprocessor instruction set, these codes may be one, two

PROJECT

or three or more bytes in length. Again like a micro, most instructions are single-byte and explicit. The tinted box of instructions lists them all and what they do.

Pitch

The AY-3-8910 PSG chip has one major shortcoming: the clock is pre-scaled by 16 before being divided by the divisor of our choice. In practice this renders the top octaves (smallest divisors) too inaccurate for serious work, especially at 1MHz.

To circumvent this problem, the unusual step of using the *'just scale'* has been taken. This means that all notes have a relatively simple numerical ratio to each other and some musicians do not like this because, for example, the note 'G' would contain the same frequency as the 3rd harmonic of 'C'. The look-up table at &0D0-0DF (Listing 1, September) may be replaced by any scale you wish — such tables are often to be found in home-computer BASIC manuals.

Figs. 3 and 4 show the codes for setting the most-used pitches. They are not called 'notes' here because they do not necessarily by themselves create sound (the channel volume or envelope must be enabled). Sharps, flats, higher and lower octaves are obtained by direct manipulation of the PSG registers.

Channel A is usually reserved for the bass because of its extra filtering. Channel C therefore carries the treble or melody line, and Channel B the alto (stop me if I get too musical for you). Although Channel B can descend into the bass regions (codes &30-&3A), these tend to sound raspy because of insufficient filtering.

Timing

Benefitting from experience of other music programs, where tempo is a matter of trial-and-error and triplets are out of the question, Polybel's Operating System (PBOS) has very precise timing.

The tempo is expressed as beats per quarter-minute (converted to hex) if the meanings of Fig. 5 are to be used (where 1 beat = code &57, &67 or &77). Thus the code for a tempo of 60 beats/minute is 60/4 = 15 = &0F (preceded by &FE, the 'set tempo' byte). One beat will then give a precise delay of one second.

In practice this is too slow even for a death march. A more practical list of tempo codes is given in

INSTRUCTIONS

SINGLE-BYTE CODES

&00 and &FF	These do precisely nothing – they are ignored! Strangely enough, this makes them invaluable for EPROM users as the NOP code (&FF) can be liberally sprinkled throughout your code wherever uncertainty exists (tempo or envelope period etc). Then when changes are required, the original code can be rubbed-out (&00) and the blank codes re-programmed without erasing the PROM under UV light. (Do remember, when apparently getting the wrong tune played that the operating system will scan through blank buffers!)
&01-&4F	These codes select various notes for channels A, B or C. See *Pitch* in the main text.
&70-&7F	Produces one of sixteen tempo-related time-delays. See *Timing* in the main text.
&50-&5F	A special tremolo (mandolin-like) version of code 7x (only for channels enabled in auto-envelope mode).
&60-&6F	Initiates auto-envelope then behaves as delay-code 7x.
&80-&8F	Manual volume of channel A.
&90-&9F	Manual volume of channel B.
&A0-&AF	Manual volume of channel C. Cancels auto-envelope mode for that channel and forces volume from off (&x0) to maximum (&xF).
&C0-&CF	Sets the envelope period for the auto-envelope Has a restricted range from short clunk (&C1) to medium (piano/guitar). Longer envelopes are obtained by manipulation of register 14.
&D0-&DF	Initiate certain attack/decay envelopes. See AY-3-8910 data manual for full details.
&E0-&E3	Set the bits of Port A which control the filters. For example &E2 sets pin 20 high to turn on the bass filter. Codes &E4 and &E8 are free for you to experiment with (setting spare pins 19 and 18).
&F8-&FA	Put channels A, B or C into auto-envelope mode. The envelope is triggered by delay-code 6x, provided that a suitable envelope period has been set.

DOUBLE-BYTE CODES

&B*r dd*	Put data byte *dd* into PSG register *r*. Direct manipulation of any PSG register serves as a general-purpose fill-in when no shorter code will suffice. The AY-3-8910 handbook is essential for this.
&F0 *nt*	Amplitude decay on channel A.
&F1 *nt*	Amplitude decay on channel B.
&F2 *nt*	Amplitude decay on channel C.
&F4 *nt*	Frequency sweep on channel C.
&F6 *nt*	Noise-frequency sweep (flange). The PSG has only a single auto-envelope, which can control the decay of any or all channels together (for a chord). For polyphonic (non-chordal) music the software must provide additional envelopes. This is done by decrementing the volume register after each minimum time interval (⅛ beat) for the duration *t* specified. Function *nt* takes any of the forms defined for codes &50-&7F.
&F5 0*r*	This specifies a second register to be simultaneously decremented, allowing any two of the above functions together, such as a rising pitch of decaying amplitude. Cancel with &F5 80.
&F7 *aa*	Next buffer-code to be interpreted is at address *aa* within the same page. A sort of 'jump' instruction.
&FB 76	Stop – all buffers must end with this code if you value your batteries!
&FC *aa*	Optional 'jump'. If the option switch is open, this command is ignored; else behaves like 'jump' code &F7.
&FE *tt*	Set tempo. See Timing section in main text. Caution: if deleting a tempo, ensure both codes are deleted – a tempo of zero will hang you up forever!

MULTI-BYTE CODES

&F3 *aa bb*	Define User Function (advanced users only).
&FD *aa bb*	'Recall'. Repeat the buffer-passage from address *aa* up to and including address *bb* within the same page. The passage recalled cannot itself contain a recall, or a 'jump'.
&FB 21 *aa p*	'Leap' – the next buffer code to be executed is at address *aa* within page *p* (&0*paa* where *p* = 1-7). Code &FB actually causes the CPU to quit the Operating System and to start executing Z80 code. Advanced users only! The *stop* command &FB 76 is in fact the Z80's *halt* instruction. The *monitor* mode uses this technique to break out of the buffer and increment the 'number of callers' location in EEPROM. Similarly, the *tell-tale* mode breaks out to check this location before deciding whether to sound a number of peeps or a raspberry!

Fig. 6, where 112 beats/minute is represented in 'normal tempo' as &FE 1C. If the music we were transcribing had an awful lot of 'tails' on the notes we could just as easily use double-tempo (&FE 38) and let code &67 represent one half-beat.

Triplet Timing

A triplet is a group of notes with the number '3' over them. They are to be played at the rate of three notes per two beats. Whereas other music programs give up on this problem, PBOS has three solutions.

1. Use the approximation for a tripleted beat (&66 in Fig. 5).
2. Use the normal codes for a beat or half-beat (&67, &63) to represent the tripleted notes. Use code &6B or &65 for their 'normal' versions (see 'Among Triplets' in Fig. 5).
3. Temporarily up-rate the tempo to one-and-a-half times (Fig. 6).

Method — Making Music

First catch your music!

Legally one should be careful of pinching copyright music, but since The Performing Right Society has, as yet, no special tariff for charging polyphonic programmable doorbells and is on the whole more concerned about rounding up Britain's coach companies and breweries, it is unlikely you'll get a licensing officer appearing on your doorstep!

So, pick your tune. It should ideally have no sharps or flats in the key signature. Else the scale will not sound right (one sharp is acceptable). The music chosen should not be chordal (clumps of notes), but one voice should move with another stationary. The relevance of this was discovered when the original recipients could hardly tell that Polybel was polyphonic!

A dummy example is shown in Fig. 7. This will be allocated as Tune 5, Bank 2, so at start address &580. Divide the music up into horizontal events — bar-lines are irrelevant.

Event zero starts by setting-up control register 7. Your should always use the code as given, until you can learn *not* to output to the switches! Event zero continues with setting tempo, pitch, channel modes and so on until the first code that produces sound.

The tempo is given here, which we look-up in Fig. 6. If it is not given then you hum the tune whilst counting (in hex) the number of times you tap your foot in 15 seconds!

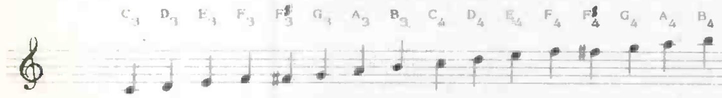
The 'rest' of event 2 implies sudden quiet, so we kill everything by allocating all channels a manual volume of zero for one beat.

Event 3 shows that we need separate envelopes, since the channels take-on different timings. Here we will arbitrarily allocate channel C to the automatic envelope of the PSG. We will 'assign' register 9 (channel B volume) as the second register for software decay and use the timing-codes that control decay of channel A (& F0 5x or F0 6x).

Event 4 shows a requirement for a note not shown in Fig. 3. This is 'between' codes &4D and &4E. Listing 1 (last month) shows the look-up at &0DD and &0DE to contain &50 and &48; we average these and inject the value directly into register 4 (frequency control for channel C).

At event 7, we end if the 'option' switch is set. Events 7, 8, 9 are the same as events 2, 3, 5 and so we use the 'recall' function before ending.

Best wishes as you encode into the wee hours . . . send me your best masterpiece and I'll send you the current library!

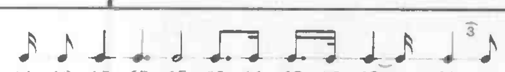


	C3	D3	E3	F3	F♯3	G3	A3	B3	C4	D4	E4	F4	F♯4	G4	A4	B4
Channel C:	40	41	42	43	44	45	46	47	48	49	4A	4B	4C	4D	4E	4F
Channel B:	20	21	22	23	24	25	26	27	28	29	2A	2B	2C	2D	2E	2F
Channel A:		01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F

Fig. 3 Treble pitch codes

	C1	D1	E1	F1	F♯1	G1	A1	B1	C2	D2	E2	F2	F♯2	G2	A2	B2
Channel A:	10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D	1E	1F
Channel B:	30	31	32	33	34	35	36	37	38	39	3A	3B	3C	3D	3E	3F

Fig. 4 Bass pitch codes



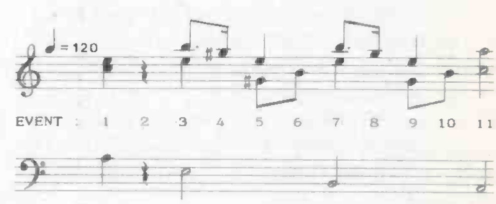
Auto Attack	61	63	67	6B	6F	65	61	62	60	69	66 (Note 1)	
As Tremolo		53	57	5B	5F	55	--		--	59		
Among Triplets	X2	X5	XB	(Note 2)			(X = 5,6, or 7)				X7	X3
As Rest/Delay	71	73	77	7B	7F							

Note 1: approximate timing
Note 2: use multiple codes

Fig. 5 Useful timing codes

Beats Per Minute =	88	92	96	100	104	108	112	116	120	124	128	132	134
= 6F (Double Tempo)	2C	2F	30	32	34	36	38	3A	3C	3E	40	42	44
= 67 (Tempo X 1.5)	21	--	24	--	27	--	2A	--	2D	--	30	--	33
= 67 (Normal Tempo)	16	17	18	19	1A	1B	1C	1D	1E	1F	20	21	22
= 63 (Half-Tempo)	0B	--	0C	--	0D	--	0E	--	0F	--	10	--	11

Fig. 6 Tempos

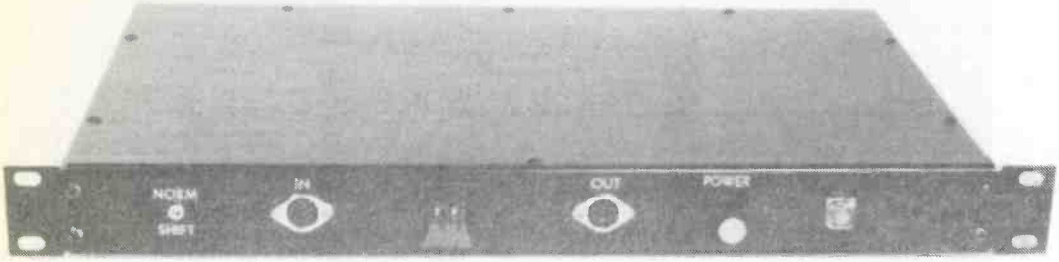


Event	Addr	Hex Code	Comment
0	0580	B7 78	Configure ports. Noise off
	0582	FE 1E	Tempo = 120
	0584	FF FF	Spare for tempo change
	0586	F8 F9 FA	All channels on Auto
	0589	CF E3	Medium decay. Filters on
	058B	1E 28 4A	Notes A2.C4.E4
1	058E	67	One beat with attack
2	058F	80 90 A0	Silence....
	0592	77	.... for one beat
	0593	FA	Channel C on Auto again
	0594	F5 09	Ch. B allocated so
	0596	1A	Bass E2 for Channel A
	0597	2A 4F	E4,B4 for Channels B & C
3	0599	8F 9E	Volumes for Bass & Alto
	059B	F0 65	Auto attack & Soft decays
4	059D	B4 4C	G-sharp in Channel C
	059F	F0 61	Re-start Auto envelope
5	05A1	B2 9A 9E	G3. New soft envelope
	05A4	4A F0 63	E4. Restart Auto envelope
6	05A7	27 9E	B3 . New soft envelope
	05A9	F0 73	All 3 decays continue
(11)	05AB	FC B2	Optional jump to Event 11
7	05AD	17 8F	Else new B1 bass, otherwise
(10)	05AF	FD 97 AA	Repeating 3-6 ($597-$5AA)
	05B2	F8 F9	All Channels auto again.
	05B4	16 28 4E	Final chord
11	05B7	6F FB 76	2 beats, then shut-down.

Event	Addr.	Hex Code	Comment

Fig. 7 A worked example of Tuneware

MIDI MAPPER



Robert Penfold can change channels in mid data stream with his MIDI mapping rack unit

In an ideal MIDI world I suppose there would be no need for add-ons such as a MIDI mapper. In the real world there are plenty of MIDI instruments and other MIDI equipped equipment which have what is only a fairly basic MIDI specification. These days manufacturers of electronic music equipment give most of the current equipment a fairly comprehensive specification — mode 4 operation with multi-timbrality is now the order of the day even on budget synthesisers and samplers. There is usually a great deal of control over which voice of an instrument operates on which MIDI channel.

This contrasts with many instruments of the past, including some of the most popular ones. A common failing of these is the ability to transmit data only on MIDI channel 1, which can be a bit limiting especially if your setup contains more than one instrument of this type. A simple way around this problem is to feed the output of the instrument through a MIDI mapper such as the unit featured in this article. The basic action of this device is to pass most MIDI data unaltered. However, data received on a certain MIDI channel can be retransmitted on a different channel. Both the input and output channels are user selectable via a couple of switches. In our example of a synthesiser restricted to transmission on channel 1, by setting channel 1 on the input selector switch, the data would then be output on any desired channel, as set on the output selector switch.

There are other ways of using the unit, but a certain amount of care needs to be exercised as things might not always work out as you might expect.

The unit can be used in what is effectively the opposite way to the one described above, where it is added at the input of an instrument which can only operate on channel 1, so as to make it respond to data sent on a different channel. Bear in mind though, that this unit only provides channel switching, it does not give MIDI filtering (which is a rather more complex function than one might think). Although it will convert messages on channel to any other desired channel, messages received on channel 1 will be passed straight through to the output, still on channel 1. This might not matter, but it could prevent the desired action from being obtained. If, for instance, you have two mode 3 instruments which are restricted to operation on channel 1, adding this unit ahead of one of these instruments would not permit them to be sequenced separately. However, building a doubled-up version of the unit with two mappers would permit independent operation of the units on any desired channels, except channel 1 which would become a 'no-go area'.

The lack of filtering could be used to good effect with a little ingenuity. With two instruments on channel 1, and the mapper being added ahead of one of them, both instruments would respond to messages on channel 1. If the mapper was set for channel 2 as the input channel, then messages sent on channel 2 would only be received by this instrument. This would permit solo operation using channel 2 or layering of the instruments by using channel 1. Not fully independent operation but a definite advance on having only layered operation of the instruments.

There are other possible ways of using the unit. As explained in the *How It Works* section, it can be set up to effectively filter out certain types of MIDI data. However, it would be naive to expect a simple device of this type to provide all the functions as a highly sophisticated micro-based design costing hundreds of pounds.

Construction

Refer to Fig. 5 for details of the printed circuit board. Apart from IC4, all the DIL integrated circuits are CMOS types and require the usual anti-static handling precautions. I would recommend the use of a socket for IC4 as well — it is not a static sensitive device but it is not particularly cheap either. 6-pin DIL holders can be a bit difficult to obtain but it is not too difficult to saw an 8-pin type down to size.

When fitting the integrated circuits, note that IC8 has the opposite orientation to the other DIL devices. FS1 is mounted on the board via a pair of fuse-clips. Use plenty of solder when fitting the clips into place so that they are given a very firm mounting. Note that FS1 should be an anti-surge type and not a quick-blow because of the initial surge current as C7 charges up at switch-on.

A number of link-wires are required and for most of these trimmings from resistor leadouts are perfectly adequate. Some 22 swg tinned copper wire will be needed for the longer wires though. The wire must be quite taut on these longer links, or else insulated with PVC sleeving so that there is no risk of them short circuiting together. Crystal XTAL1 must be a miniature wire-ended type (such as an HC-49/U cased crystal) if it is to fit into the layout easily. Printed circuit pins are fitted to the board at the points where connections to off-board components will be made later, so that these connections can easily be made once the board has been installed in the case.

I used an inexpensive 19-inch (one unit high) rackmount case. This is actually somewhat larger than is really necessary and it could easily accommodate two or three boards if necessary. Even if a single board is used, a 19 inch rackmount case is still a good choice as this should make it easy to fit the unit into an existing MIDI system with the minimum of fuss. A light-duty type is perfectly adequate for this application (heavy-duty types can be extremely expensive).

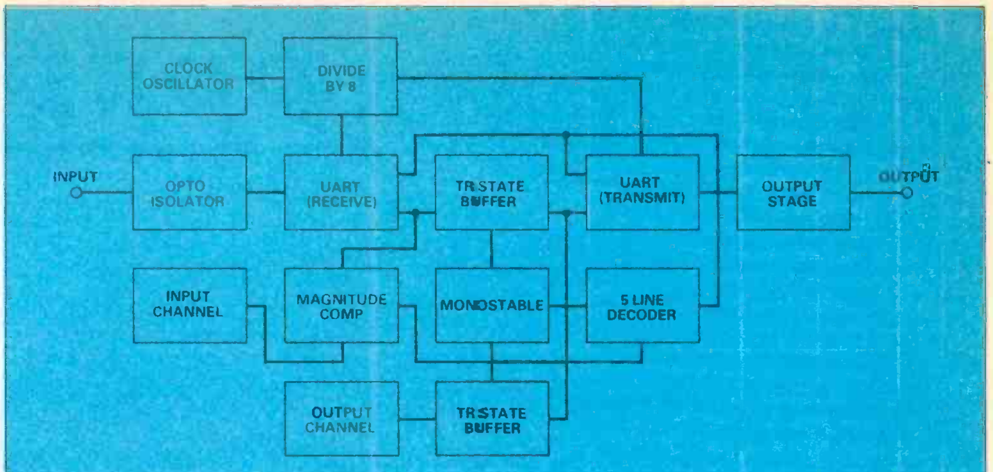


Fig. 1 Block diagram of the MIDI Mapper

HOW IT WORKS

The block diagram of Fig. 1 helps to explain the way in which the unit functions. It is based on a UART (Universal Asynchronous Receiver/Transmitter) which converts the incoming serial MIDI signal into parallel form and then retransmits it in serial form again. However, on appropriate bytes the signal is retransmitted in slightly altered form.

The MIDI standard calls for opto-isolators at all inputs. This is necessary in order to eliminate any problems with high voltages causing damage to equipment, to reduce the risk of hum loops and to prevent digital noise from being coupled into the audio stages of instruments. MIDI outputs are a form of current loop stage and must provide a nominal output current of 5mA.

The MIDI baud rate is 31250, set using a 4MHz crystal oscillator and a divide-by-eight circuit. This gives a clock signal at sixteen times the required baud rate which is what the UART requires. Only one word format is used for MIDI systems — one start bit, eight data bits, one stop bit and no parity. This word format is programmed into the UART by connecting certain of its inputs to the appropriate logic levels. Unlike many serial interface chips, UARTs are perfectly suitable for simple stand alone units and do not have to be programmed via the data bus and suitable software.

In order to understand how the unit provides channel switching you need to understand a few basics about the nature of MIDI signals. Each MIDI message consists of a header byte which contains the code for the type of message concerned (most significant nibble) and the channel number (least significant nibble). These channels messages include such things as note on/off instructions, pitch bend information, and so on. There is another form of MIDI instruction in the form of system messages. With these the most significant nibble has the system message code (1111 in binary) and the least significant nibble contains the code for the particular type of message involved (clock signals, system exclusive, and so on). Many of the header bytes are followed by one or more data bytes.

The unit only needs to process header bytes for channel messages that are on the appropriate channel. System messages must not be altered. Similarly, data bytes for channel messages must not be changed — their channel number is that of the header byte that precedes them and they do not carry any channel information themselves. As the channel number is contained in the least significant nibble, only this nibble is ever processed. The most significant nibble is always passed straight though to the transmitter section of the UART without undergoing any changes.

The least significant nibble is checked for the right channel number using a magnitude comparator which compares the received nibbles with the binary code set using the input channel selector switch. If a match is detected, the comparator sends the appropriate logic level to one input of a 5-line decoder. The other four lines of this circuit are fed with the most significant nibbles. The decoder only provides an output pulse if it detects that the correct logic level is being provided by the magnitude comparator and that the most significant bit is set to 1 (which means that the received byte is a header type and not a data byte) (it will not provide an output pulse if all four bits of the most significant nibble are set to 1, a system message header type).

If a channel message header byte is detected, the decoder produces an output pulse that triggers a monostable. This controls two tristate buffers, one from its Q output and one from its $\bar{Q}$ output. Normally the upper tristate buffer of Fig. 1 is active and the signal passed through to the output unprocessed. When the monostable is triggered, its outputs momentarily swop states and the other tristate buffer is activated. It then couples through to the transmitter UART the binary code set using the output channel selector switch. This code replaces the channel nibble of the received byte on the transmitted signal.

Figure 2 shows the main circuit diagram for the mapper the comparator, decoder, and monostable circuits are shown separately in Fig.3 and the mains power supply circuit appears in Fig. 4. Transistor Q2 generates the clock signal to be divided by eight in IC1 (where only three of its seven binary counters are used). Q1 is the output stage.

IC4 and Q3 provide a high speed opto-isolated input. The TIL111 specified for IC4 is not a particularly fast device but by using its output transistor in the emitter follower mode together with an external amplifier (Q3) it can handle the relatively high frequencies involved in a MIDI application. Q4 is used to reset the data received flag of UART IC2, and it also produces a pulse to initiate transmission of received bytes.

IC3 and IC5 are the two tristate buffers. These are 8-bit types but in this circuit only four buffers of each one are used. SW1-4 plus R12 to R15 form the output channel selector circuit.

IC6 is the magnitude comparator, a 74HC85 four bit type. SW5-8 plus R16 to R19 are the input channel selector circuit. IC8 is the 5-line decoder, actually a 74HC138 3-line type. The extra two input lines are provided by the positive enable terminal and one of the negative enable inputs. The latter is driven from IC6 via an inverter formed by one gate of IC7.

The positive enable input of IC8 is fed from the most significant data bit. The other three most significant bits of data drive the normal inputs of IC8. Seven of its outputs are ANDed by a simple diode gate circuit and any one of these (active low) outputs going low will trigger the monostable. The latter is based on IC9 which is a 4047BE astable/monostable connected in the negative edge triggered monostable mode. SW9 can be used to disconnect the gate circuit from the monostable so that the channel shifting is disabled.

Output 7 of IC8 is not connected. This is activated when a system message header byte is received. (these must not be altered). A form of MIDI filtering can be obtained by removing some of the diodes in the gate. Some classes of message would then be passed through unaltered while others would be shifted to an unused channel and effectively filtered out. Each output of IC8 represents a different class of message. For example. output 5 (pin 10) is the channel pressure output. By including a diode on this output but not the others, channel pressure messages could effectively be filtered out.

The power supply circuit is unspectacular, just a standard regulated 5V supply using push-pull rectification. As the current consumption of the circuit is only a few milliamps it is quite in order to use battery power if preferred. Omit T1, D8, D9, FS1 and C7, then connect the battery across C8, fitting one pole of the on/off switch in the positive battery lead.

PROJECT

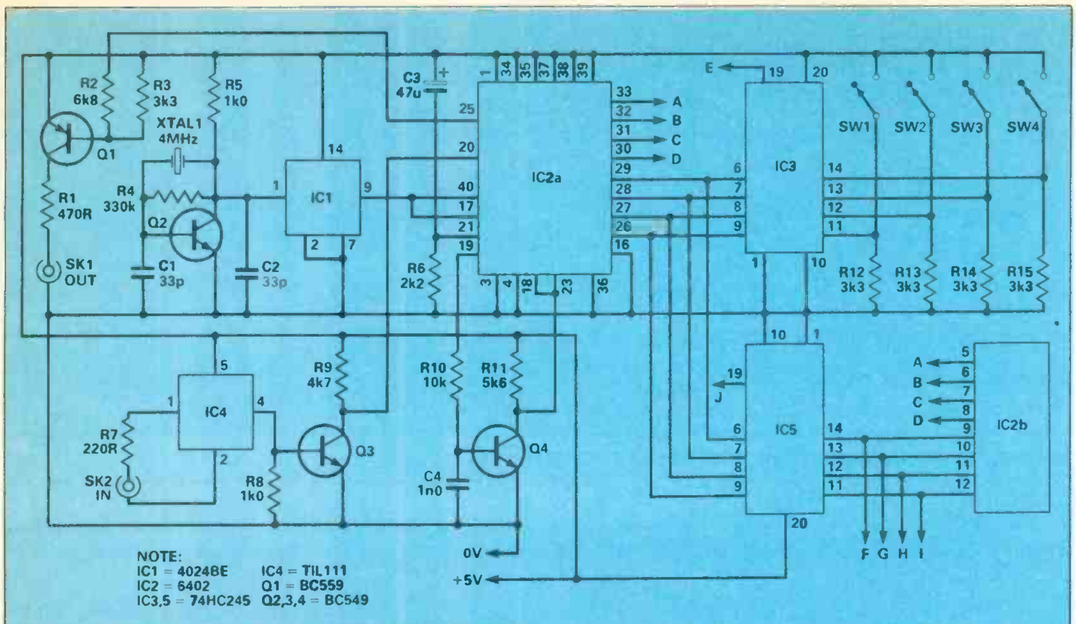


Fig. 2 The main circuit diagram of the MIDI Mapper

The general layout of the unit is not critical but position everything sensibly so that there are a minimum of crossed wires. SK1 and SK2 should be 5-way 180° DIN sockets, the standard type for MIDI equipment. Switches SW1-8 could be two sets of four miniature toggle or slider switches but you would then need to set up the right binary patterns in order to select the desired input and output channels. The extra expense of hexadecimal switches is probably worthwhile, and it is switches of this type that I used on the prototype. A lot of hex switches are printed circuit types which are only intended for preset use. Switches of this type can be wired in if the unit will always be used with the same input and output channels. A few wire links are much easier and cheaper if preset operation is all that is required.

If selection of the input and output channels via the front panel is required, thumb-wheel style hex switches are probably the best option. I used the miniature RS type. These require one pair of end cheeks if the two switches are to be clipped together to form a single unit, or two pairs of end cheeks if they are to be mounted separately.

The panel cutout can be made using a fretsaw or similar implement. A good way of getting it really accurate is to cut just inside the line marking the boundary of the cutout, and to then carefully file out the hole to precisely the required size. The correct size for the cutout is 31mm x 17mm for a single switch, or 31mm x 24.5mm for a twin switch assembly.

PARTS LIST

RESISTORS (all ¼W 5%)

R1	470R
R2	6k8
R3,R12-19	3k3
R4	330k
R5,8	1k0
R6,20	2k2
R7	220R
R9	4k7
R10,21	10k
R11	5k6

CAPACITORS

C1,2	33p ceramic plate
C3	47µ 16V radial elect
C4	1n0 polyester
C5	4n7 polyester
C6	100µ10V radial elect
C7	1000µ 16V radial elect
C8,9	100n ceramic

SEMICONDUCTORS

IC1	4024BE
IC2	6402
IC3,5	74HC245
IC4	TIL111 opto-isolator
IC6	74HC85
IC7	4001BE
IC8	74HC138
IC9	4047BE
IC10	µA78L05 (+5V 100mA reg.)
D1-7	1N4148
D8,9	1N4002
Q1	BC559
Q2-4	BC549

MISCELLANEOUS

FS1	20mm 100mA anti-surge fuse
NEON1	Mains panel neon
SK1,2	5-way 180° DIN chassis socket
SW18	Hex thumbwheel switch
SW9	SPST miniature toggle
SW10	rotary mains
T1	Mains primary, 9-0-9V 100mA secondary
XTAL1	4MHz (HC-49/U or similar case)

PCB. Case. Knob. IC sockets.
16 pin DIL holder (2 off)
20 pin DIL holder (2 off)
40 pin DIL holder
Pair of 20mm fuse-clips
Stand-offs, mains lead and plug, wire, solder, etc.

BUYLINES

The hex switches used on the prototype are RS components (available from Electromail tel (0536) 204555). The order code for the switches and end cheeks are 337-093 and 338-406 respectively.

The 19-inch rack mount case is a Rackz Products (tel (0275) 823983) type U1, which is an inexpensive light-duty type which is perfectly adequate for this project. Any other one unit high rack-mount case should be suitable but many of the alternatives are prohibitively expensive.

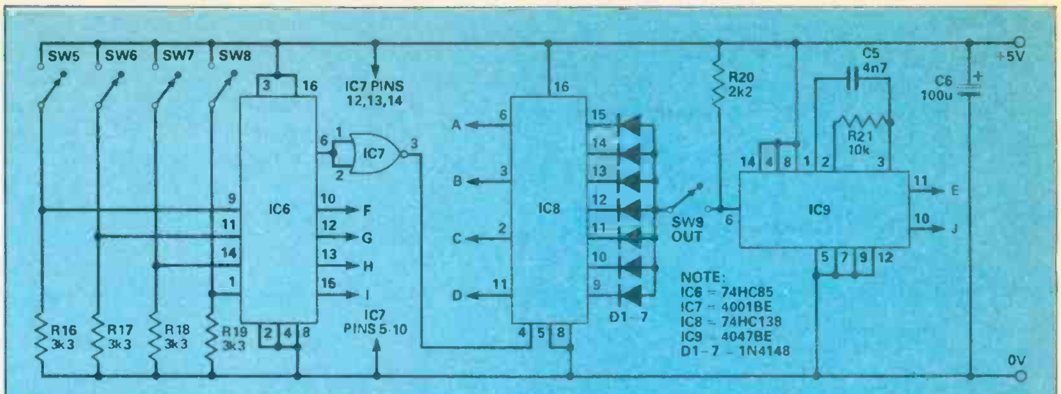


Fig. 3 The comparator, decoder and monostable circuitry

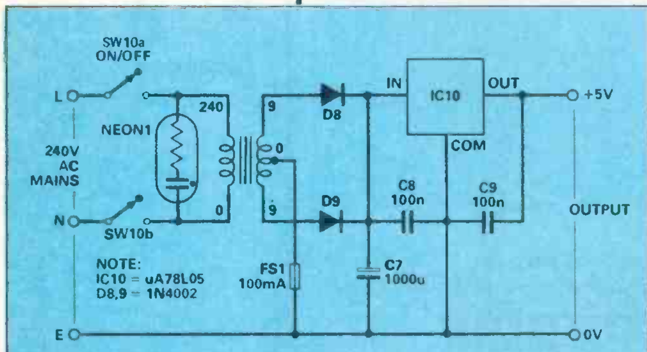
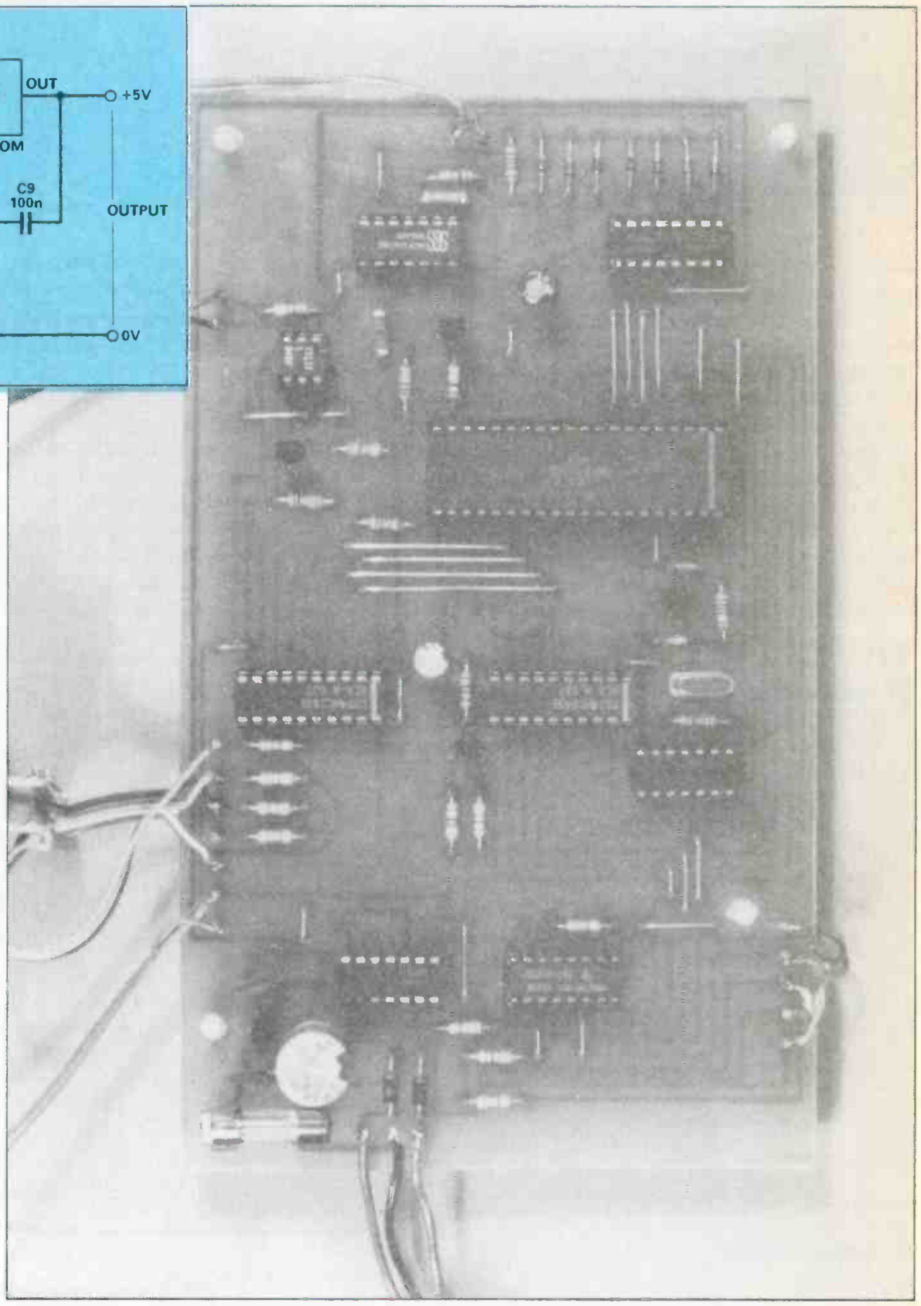


Fig. 4 The mains power supply circuit



Mount the PCB on the base panel of the case using stand-offs or use long spacers over 6BA mounting bolts. Most of the hard-wiring is straightforward but the wiring to the thumbwheel switches and IN/OUT sockets needs to be completed with care if everything is to work first time. 'Rainbow' ribbon cable is probably the best type to use for the point-to-point wiring.

Note that there is a link wire from pin 2 of SK1 to the chassis tag of this socket but this link must be omitted from SK2 (otherwise the opto-isolator at the input of the unit will be effectively bypassed). Take due care with the mains wiring. The case must be earthed to the mains earth lead and a soldering fitted on one of T1's mounting bolts is an easy way of providing a suitable connection point.

In Use

Assuming you use the specified type of socket connected in the manner shown in Fig. 5, standard MIDI leads can be used to connect the unit to the other items of equipment.

The main point to bear in mind when fitting the unit into a system is that it must not be connected ahead of any item of equipment which must receive the undoctored MIDI signal. For example, if you are using the MIDI THRU method of connection and only one piece of equipment must be fed with the doctored signal, then the processor should be the penultimate unit in the chain of connection, and the equipment to receive the doctored signal connected as the final unit. If the unit is used with a synthesiser that will only transmit on MIDI channel 1, simply connect the OUT socket of the synthesiser to the IN socket of the mapper. The OUT socket of the mapper is then used to drive the other items of equipment in the system, and the output channel selector of the mapper is used to effectively select the output channel of the synthesiser.

Unfortunately the hex switches are calibrated from 0 to F, whereas MIDI channels are conventionally numbered from 1 to 16. Obviously a little mental arithmetic is all is needed in order to convert switch settings to their corresponding MIDI channels. SW9 can be used to switch out the channel shifting if desired, (setting the same input and output channel provides the same effect). In either case the unit will only pass the MIDI signal if it is switched on.

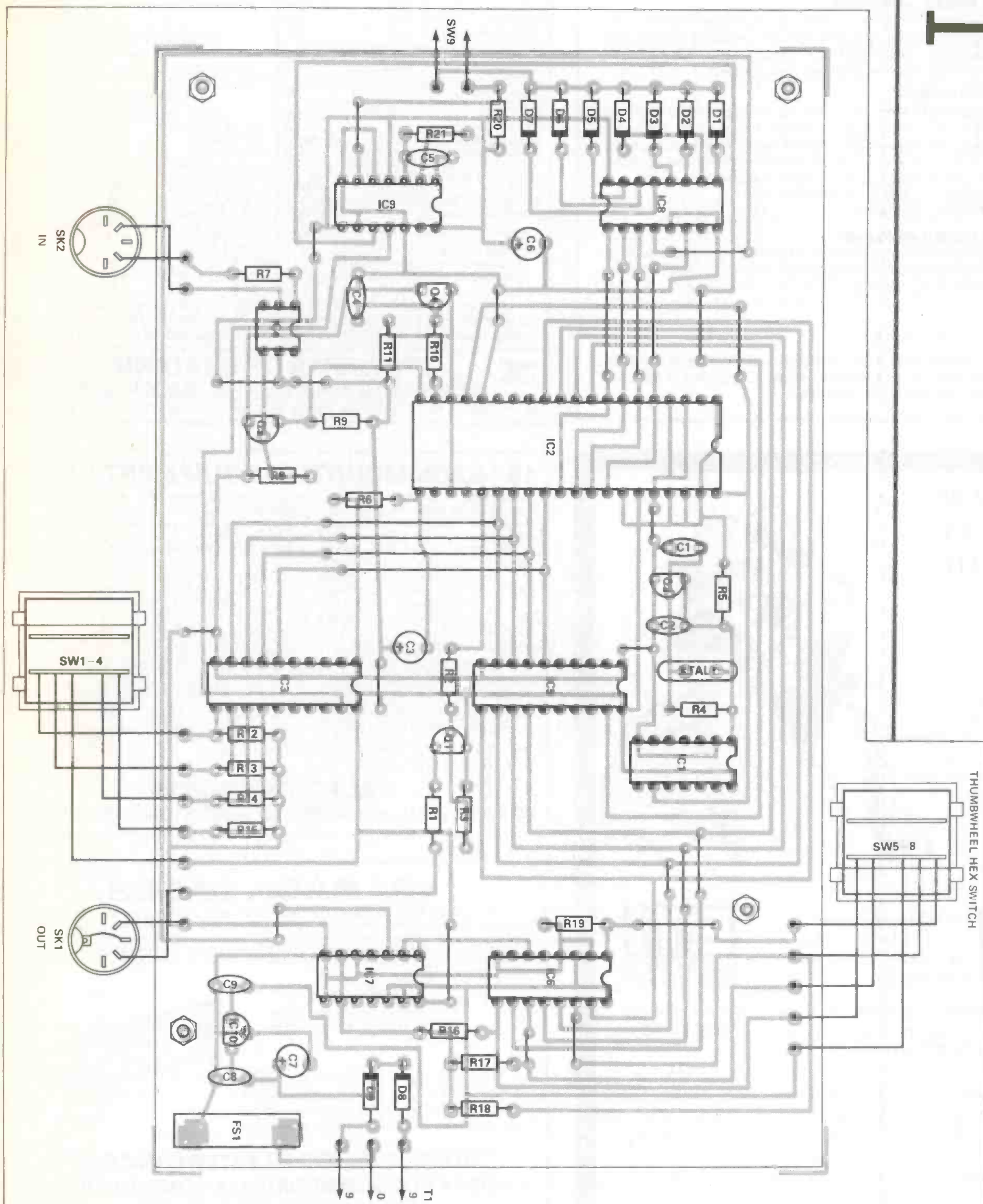
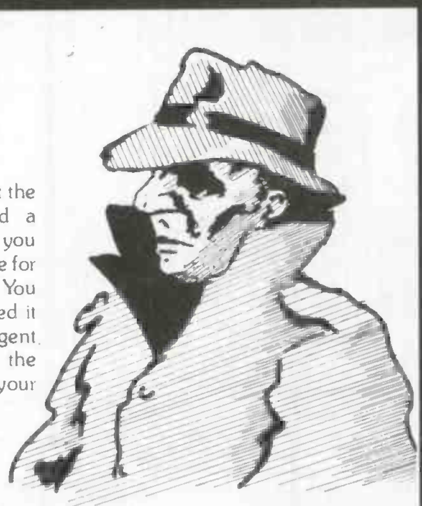


Fig. 5 Component overlay and off-board wiring for the MIDI Mapper

PUT YOUR AGENT ON THE TRAIL



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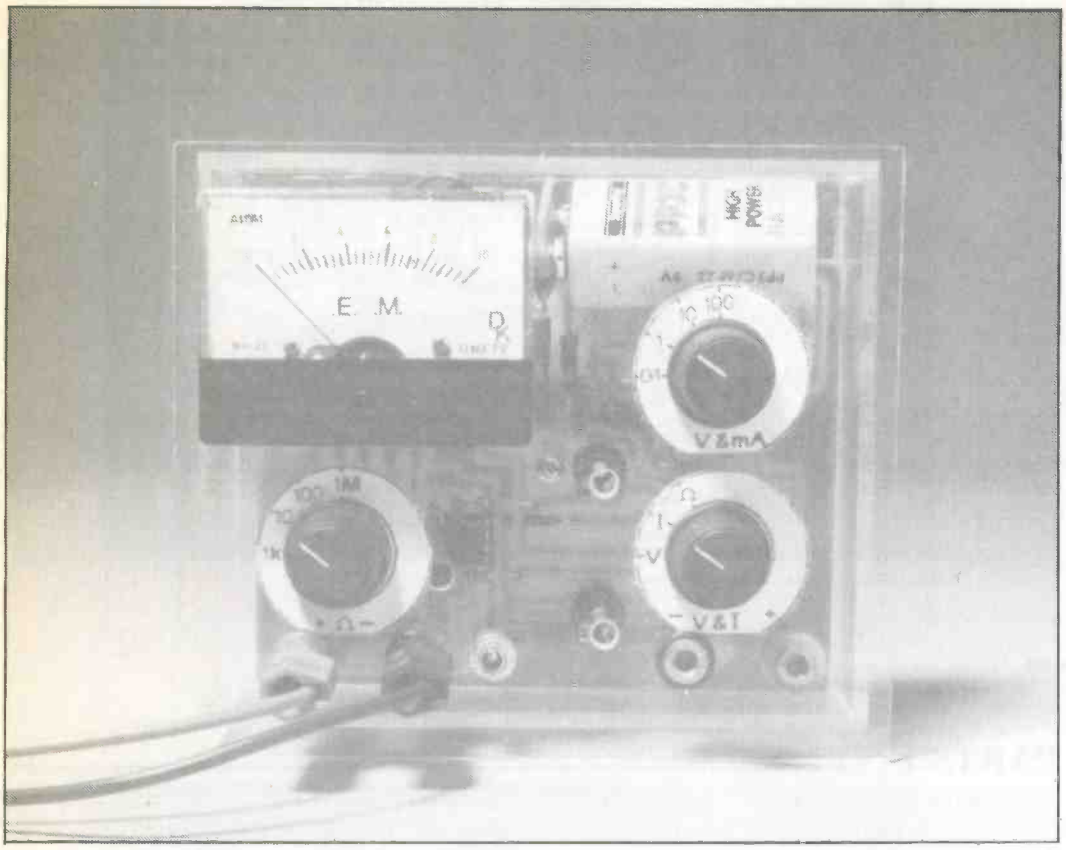
THE MULTIMETER

Douglas Kennedy presents some wide-ranging ideas with this simple budget piece of test gear



The humble multimeter is the fundamental piece of test gear in every workshop. Without it, most people would not dream of setting out to mend anything, let alone build something. This does present a problem when presenting a project to build such a meter. Dare one build the project without a multimeter to test it? And if you have one, why build one?

You can sort out such arguments for yourself. This simplest answer is to borrow a meter for the weekend. Happily this project is reasonably simple and there isn't too much to go wrong.

It was originally designed as an Industrial Skills class project for BTEC/C&G students. The design criteria were that it should measure a limited range of DC volts, current and resistance with a reasonable degree of accuracy, that it should use low-cost and readily available components. Plus it should be easily put together with a minimum of tools and equipment.

There are four DC voltage ranges with full-scale deflections of 100mV, 1V, 10V and 100V. Four DC current ranges have FSDs of 100mA, 1mA, 10mA and 100mA. There are also four resistance ranges with ranges up to 1k0, 10k, 100k and 1M0.

Multimeters manufactured with only passive components usually have a non-linear resistance scale. However, this project includes an active device. The friendly LM358 dual op-amp provides the measurement of voltage, current and resistance using a linear scale (ETI March and April 1986 contain more information on the LM358).

The multimeter with its high impedance input has negligible loading effect on the circuit being measured — this is essential when, for example, measuring transistor base voltages.

Zero resistance on most analogue multimeters is on the right-hand side of the meter scale. With this multimeter, voltage, current and resistance have their zero positions on the left-hand side of meter scale.

The multimeter should zero automatically on all ranges once adjusted and calibrated.

The accuracy of the multimeter relies on the close tolerance of resistor values.

Off the shelf 5% tolerance (gold band) are listed, these will give surprisingly good results. However 1% tolerance (brown band) resistors are easily obtainable, except perhaps the 10M value.

Construction

If you are using the PCB from the ETI PCB Service (see centre pages) then construction is very straightforward. Those wishing to etch their own board can find the foil pattern at the back of the magazine.

The component overlay is shown in Fig. 1. Integrated circuits are notoriously fickle things when it comes to soldering and you may prefer to solder in an 8-pin IC socket to take the LM358 rather than fixing it directly to the board.

Solder in the resistors and diodes first. Remember the diodes need to be orientated correctly. Leave enough distance between the red LED and the board so that you can mount it through the case later. The prototype made use of a transparent case made out of something similar to Perspex so that it didn't really matter if the LED protruded from the case or not!

To mount the preset resistors RV1,2 you may need to enlarge the PCB holes slightly — the legs are a bit thicker than those on resistors.

The meter and rotary switches are mounted directly on to the PCB. This improves mechanical and electrical terminal connection. You'll need to cut the eyes from the rotary switch tabs unless you want to make huge holes in your PCB.

The on/off switch and the sockets do not go direct onto the board. They are connected with lengths of 1mm tinned copper wire, although you may

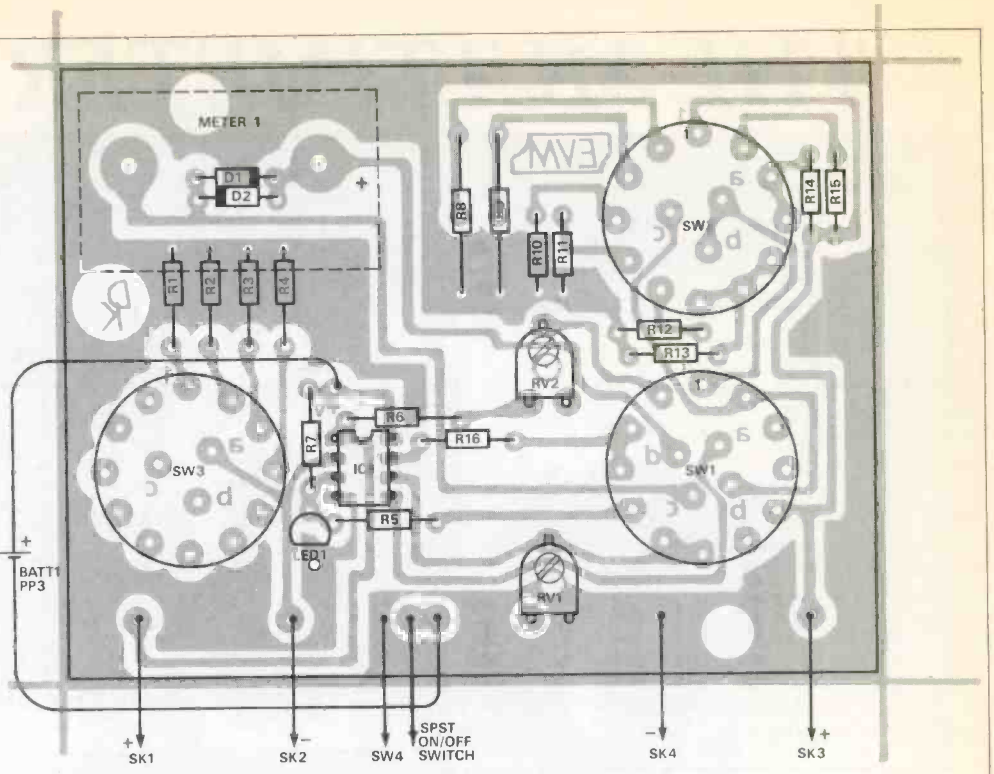


Fig. 1 The component overlay for the multimeter

PARTS LIST

RESISTORS (all ¼W 5% unless stated)		**SEMICONDUCTORS**	
R1	1M0	IC1	LM358
R2,13	100k	D1,2	1N4148
R3,12	10k	LED1	0.2in red LED
R4-7,11	1k0		
R8	1R0 ½W	**MISCELLANEOUS**	
R9	10R ½W	BATT1	9V PP3 battery
R10	100R	METER1	100µA meter
R14	10M	SK1-4	4mm sockets: 2 red, 2 black
R15	910k	SW1	4-pole 3-way rotary switch
R16	2k2	SW2,3	3-pole 4-way rotary switch
RV1	pre-set 10k	SW4	single pole single throw switch
RV2	pre-set 220k	PCB. Knobs (3). IC socket. Battery clip. Case. Test leads.	

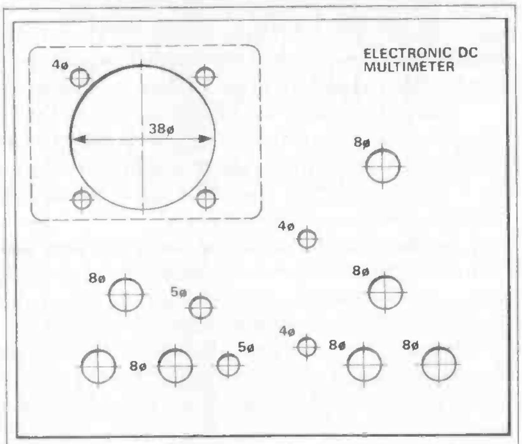


Fig. 2 The front panel template

prefer to wait until you've prepared the front panel and fixed the components on that before you connect them in. It will depend on the case you use and how conveniently things will fit together.

The Front Panel

So that you can get a neatly arranged front panel with the holes and switches in the right place for the PCB, there is a template for drilling shown in Fig. 2. Place this over your case firmly and scribe the hole positions with a knife or bodger. Then drill all the holes with a 2mm bit and enlarge them to the sizes shown on the template.

The hole for the meter is pretty big and the ideal tool for the job is a 38mm hole-saw. However, panic not if you haven't got one, you can make several small holes around the circumference and then blast your way through with a sharp knife (shortly to become a not so sharp knife). Happily the meter itself covers the edges of the hole so a disastrous botch job will be quite sufficient!

With everything wired in you can finally put the case together. Poke the stems of the switches through the holes you've made and trim them for the knobs. Mark up some dials on the case with the ranges shown in the photograph. Now connect up the PP3 battery (with the on/off switch off), fit that somewhere in the case with tape if necessary, and close the box. Now you're ready to test the meter.

Setting Up And Calibration

Calibrate the voltage and current ranges first. Switch on the multimeter and set the VmA switch (SW2) fully anticlockwise to the 0.1V position. Get a small

HOW IT WORKS

The complete circuit diagram is shown in Fig. 3. Depending on the function selected by the 4-pole selector SW1, the circuit operates as follows.

Voltage Measurement
Figure 4 shows the arrangement for voltage readings. The meter display is proportional to the input voltage which is sampled at the junction of the switched potential divider network and the non-inverting input terminal (pin 5) of IC1a. The op-amp is connected as a unity gain DC amplifier.

Current Measurement
Figure 5 shows the arrangement for current readings. Again IC1a is used in non-inverting mode. The input current is sampled through either R8,9,10 or 11.

Resistance Measurement
A potential difference of 1V6 is produced across the LED which performs a similar function to a zener diode. This reference is used to generate a stable voltage at the non-inverting input of IC1b.

The op-amp gain is set by resistor R1, 2, 3 or 4 switched into the circuit plus the resistor on test, connected to the output terminal and the inverting input terminal of the op-amp.

Therefore a full-scale meter reading on each switch position should equal the value of resistor switched in by SW3.

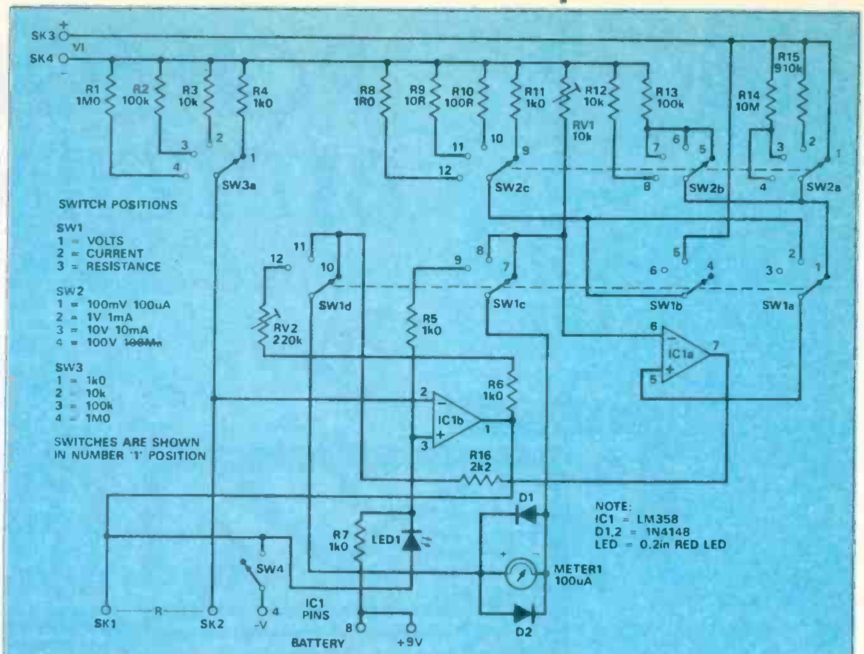


Fig. 3 The complete circuit diagram for the multimeter

screwdriver and tweak the slot adjustment on the meter until it reads exactly zero. Then click SW2 over to the 10V position. Connect a 10V DC supply across the voltage and current input sockets 3 and 4. Adjust RV1 to give a reading of exactly 10V FSD on the meter. And that's it. The multimeter should now give accurate measurements of up to 100V or 100mA in a linear manner.

Resistance Ranges

To calibrate for resistances, set the V&I switch SW1 over to the 'ohms' position. The meter needle should shoot off the scale as you are presenting it with an open circuit — more or less infinite resistance.

Set SW3 to the 10k position and get the closest tolerance 10k resistor you can find and connect across the resistance input sockets SK1,2. Adjust RV2 to give you the full 10k deflection.

No further adjustment should be necessary. Of course calibrating like this does depend on the quality of the supply or components you are using. If you don't have a DC supply (and there's little excuse since ETI published one not so long ago), you could check on the exact voltage of a spare PP3 at a friend's house or at work/school, then rush home and calibrate with that (making sure not to heat it, freeze it or use it in your stereo on the way!). Similarly it might be wise to get a second opinion on the 10k resistor you use to calibrate with, it would be a terrible shame to calibrate with a dud.

Other Things

The multimeter is also useful for basic testing of components. To test a silicon diode simply insert the test leads into the resistance test sockets and put the range on 1k. Connect the positive lead to the anode (no band) and the negative to the cathode (banded). If you get low resistance you're OK, if you get high resistance then the diode is open circuit (which it shouldn't be). Swap the leads over. You should now get a high resistance. If you get a low resistance then your diode is short circuit. Note that germanium diodes normally indicate a small resistance when reversed biased.

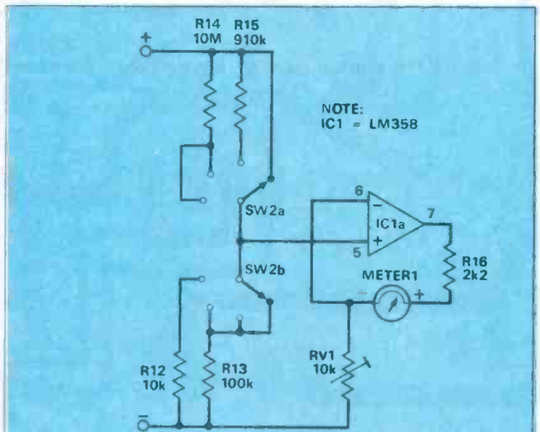


Fig. 4 Circuit operation for voltage measurement

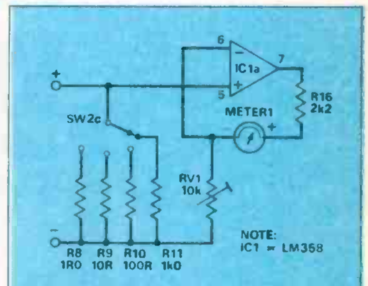


Fig. 5 Circuit operation for current measurement

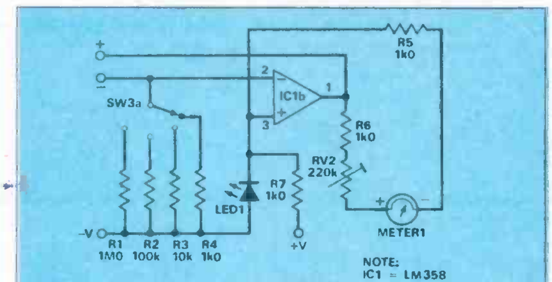


Fig. 6 Circuit operation for resistance measurement

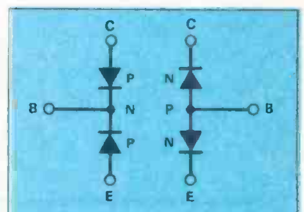


Fig. 7 Testing transistors as back-to-back diodes

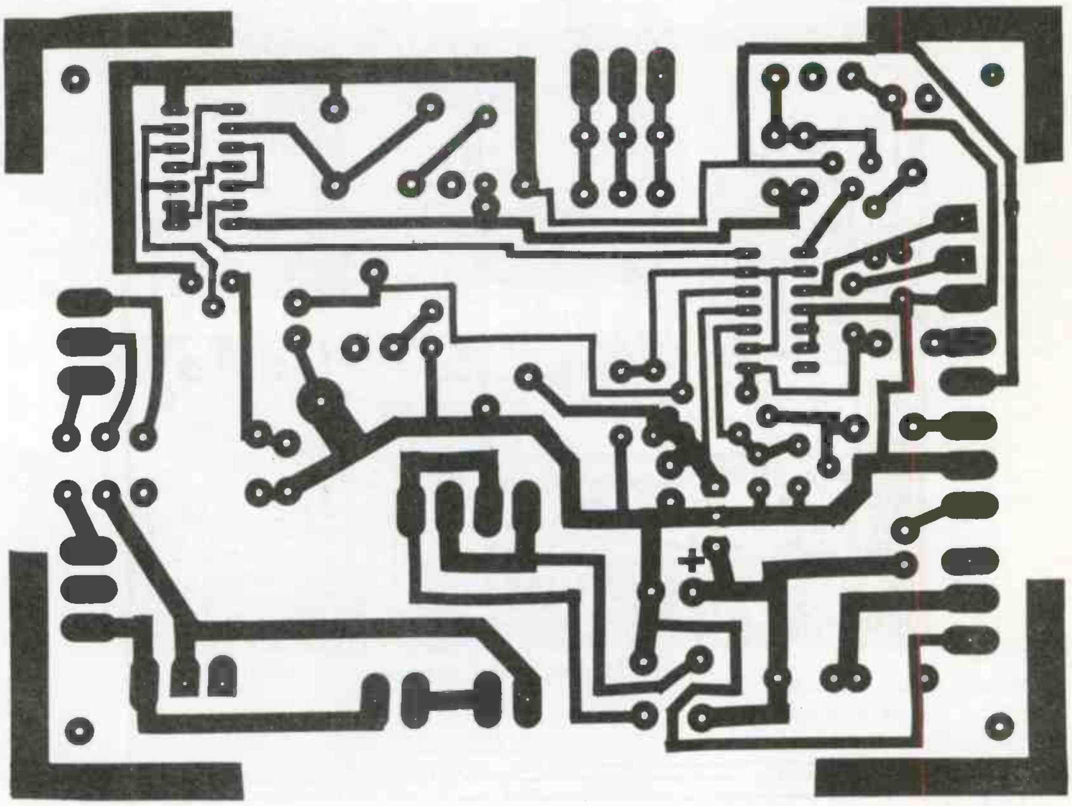
You can also check transistors by regarding the silicon sandwich as a pair of diodes and testing accordingly. Figure 7 shows which way the diode equivalents are orientated for NPN and PNP types.

To test a thyristor, connect the positive test lead to the anode and the negative to the cathode. The meter should read high resistance. Momentarily short the anode to the gate and the resistance should go low — even when the gate voltage has been removed.

BUYLINES

All components for the multimeter are easily obtainable from Maplin (tel: (0702) 554161), Rapid Electronics (tel: (0206) 751166), or Electromail (tel: (0536) 204555).
The PCB is available from the ETI PCB Service (see centre pages).

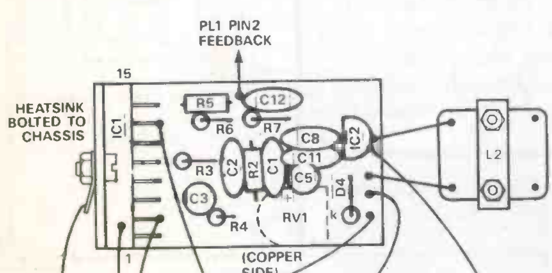
PCB FOIL PATTERNS



The Intruderbeam Control Unit foil pattern

Field Power Supply for the Spectrum 3 (September 1989)

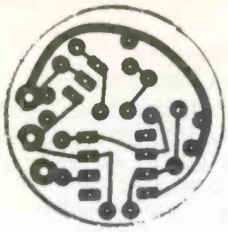
In last month's issue, a design error led to the component overlay being published with the printing densities reversed, rendering it rather difficult to interpret. The board is reproduced here with the error rectified.



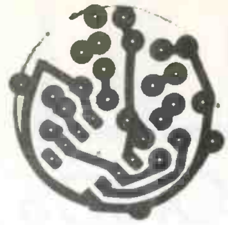
Coil Winding Data

Coil	Turns	SWG	Gap in inches	Inductance at I_{DC}
L1	30	18	0.013	200µH at 700mA
L2	100	22	0.013	2mH at 50mA
L3	15	18	0.013	40µH at 2.5A
$T1_{prim}$	30	18	0.013	200µH at 2.5A
$T2_{sec}$	096	22	—	—

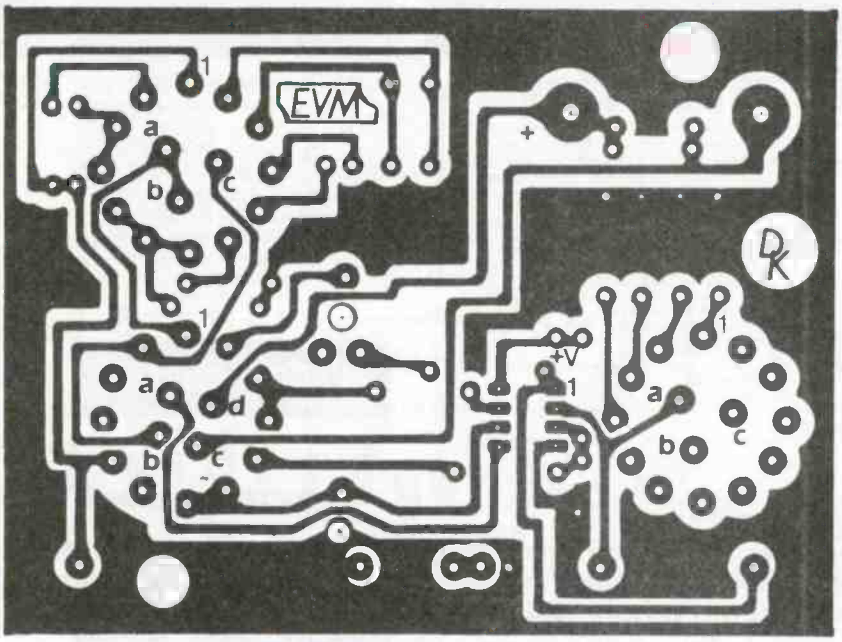
Another omission from the Field Power Supply was the coil winding data, which is shown here.



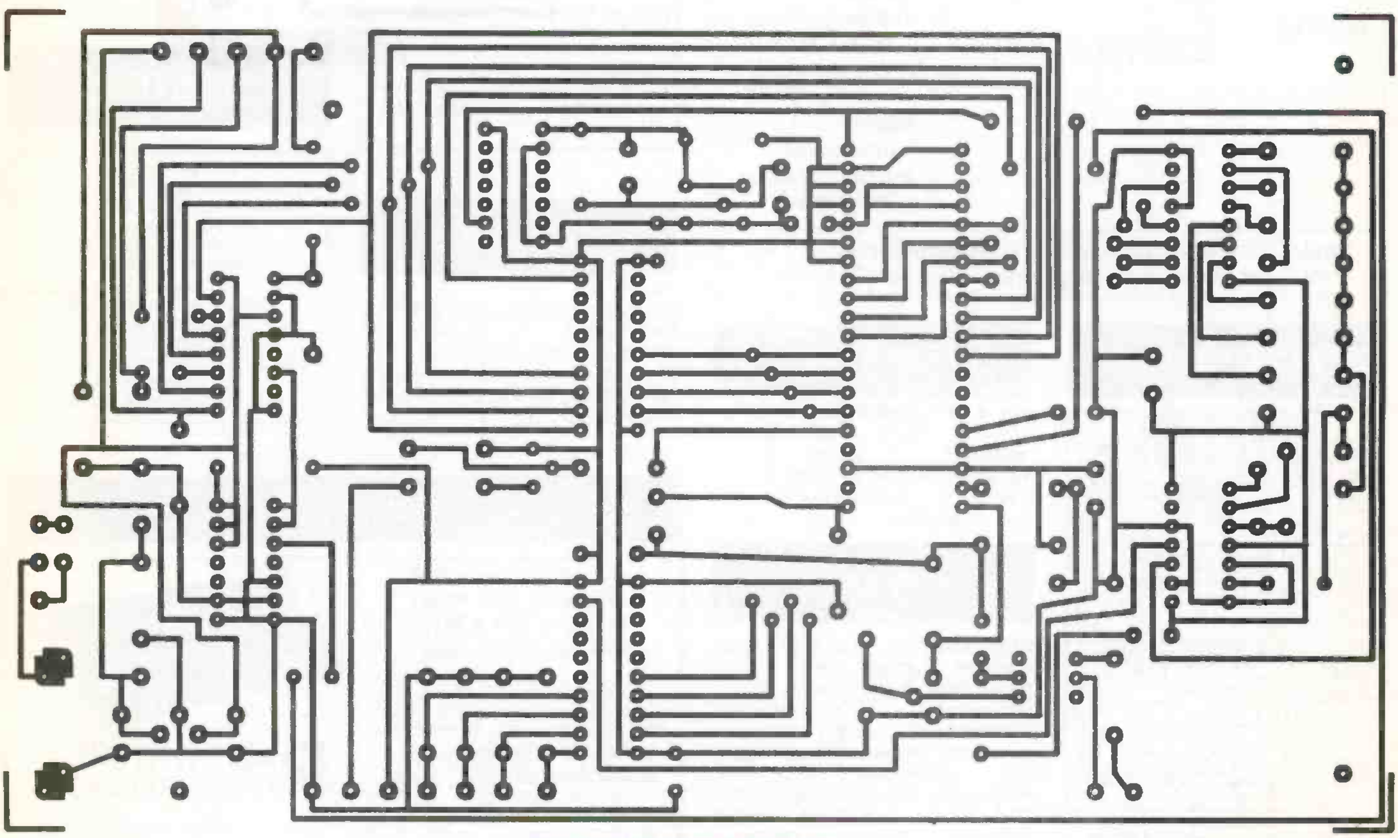
The Intruderbeam receiver foil



The Intruderbeam transmitter foil



The Multimeter foil pattern



The MIDI Mapper foil pattern

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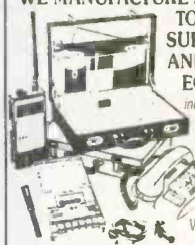

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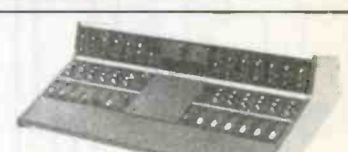

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NEXT MONTH

NOVEMBER ETI — OUT OCTOBER 6th

The superhero sat on the ventilation shaft and looked out over the city. He adjusted the elastic of his undies over his latex laggings. Things weren't the same anymore, he thought. Business was bad. Seems no-one wanted a superhero unless he was psychologically disturbed and sinister-looking, rubber bathood and all. Whatever happened to a friendly smile, a cheery quip and that all-important cute hair-curl? The fist-fights and the superpowers? Where were you when the good guys gave you worse wobblies than the bad ones? Standards were definitely slipping in the superhero business.

He sighed and adjusted the volume in his superhero listening device, adapted from one of the surveillance circuits in the October issue of ETI. Just because Batman was mega-rich, it didn't mean he had all the best equipment. For just £1.50, ETI provided all the technical innovation that this superhero required. Why, he had already successfully used October's Intruderbeam to capture the legendary arch-criminals the Pelican, the Jolly Green Giant and Bonnie Langford, as they worked together in a sinister plot to make a new series of The Hot Shoe Show. What a publicity coup that capture should have been — but strangely the city media baron Bruce Wayne had refused to run the story. People wanted more bats, he had said.

Dawn broke through the clouds, filtering down through the smog and lighting the packed skyline with an eerie orange glow. The superhero checked the date — October 6th! Publishing date for the November issue of ETI! He leapt from the parapet into his Superheromobile and headed to the newsagent.

Inside the November issue he found Paul Chappell's study of counter-surveillance, how to spot the bugs and have you watching them watching you. He found an in-depth explanation of neural networks and their development to the cutting edge of computing. A project to make a serial logic scope for stand-alone data stream monitoring. A smoke-alarm to protect the citizens from harm. The next installment of the *Testing Testing* series. Plus more projects and features than any superhero had a right to expect.

Together with the latest news, reviews and comment on the worlds of audio, computing, music and communications, the November issue of ETI is indeed a superhero among its fellow magazines.

ELECTRONICS TODAY INTERNATIONAL

The above articles are in preparation but circumstances (or the Pelican) may prevent publication

ADVERTISERS INDEX

KITS & COMPONENTS

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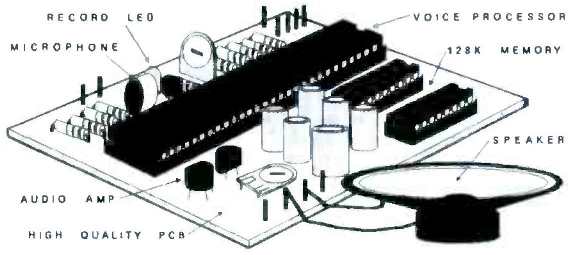

This simple to construct and even simpler to operate kit will record and playback short messages or tunes. It has many uses – seatbelt or lights reminder in the car, welcome messages to visitors at home or at work, warning messages in factories and public places, in fact anywhere where a spoken message is announced and which needs to be changed from time to time. Also suitable for toys – why not convert your daughter's £8 doll to an £80 talking doll!!

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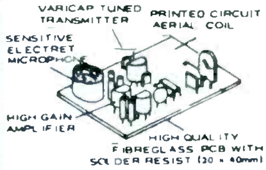

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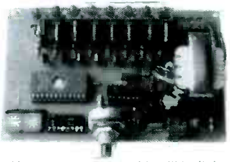

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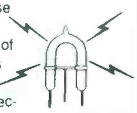

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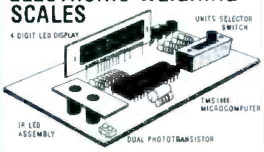

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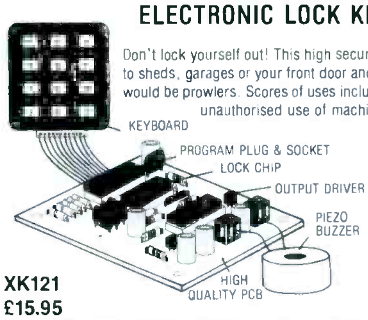

Don't lock yourself out! This high security lock kit will secure doors to sheds, garages or your front door and the built-in alarm will deter would be prowlers. Scores of uses including area access preventing unauthorised use of machinery or even disabling your car. One correct 4 digit code (out of 5000) will open the lock, incorrect entries sound the alarm and disable the keyboard for up to 3 mins. Kit includes 12-way keypad, and operates from 9 to 15V (50uA) supply. Will drive relay or 701 150 lock mechanism.

XK121
£15.95

MICROPROCESSOR TIME

Kit controls 4 outputs independently switching on /off at 18 preset times over a 7-day cycle. LED display of time/day easily programmed. Includes box.

CT6000K 49.50

XK114 Relay kit for CT6000 includes PCB, connectors and one relay. Will accept up to 4 relays. 3A/240V c/o contacts £4.75

701115 Additional relays £1.80

TK ELECTRONICS

TK ELECTRONICS
13 Boston Road
London W7 3SJ
Tel: 01-567 8910
Fax: 01-566 1916

ORDERING INFORMATION. All prices exclude VAT. Free p&p on orders over £50 (UK only), otherwise add £1+VAT. Overseas p&p: Europe £3.50, elsewhere £10.00. Send cheque/PO/Barclaycard/Access No. with order. Giro No. 529314002. Local authority and export orders welcome. Goods by return subject to availability.

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ORDERS: 01-5678910 24 HOURS

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★ High Temperature Flame Torch
★ Hot Air Blower

GREAT FOR

★ Electrical and Electric Work
★ Cutting Plastics and Fibres
★ Sealing, Bonding and Shrinking
★ Removing Paint and Putty

The Flame Master hot gas tool kit has many uses. It can be a soldering iron, a pencil flame torch, a hot air blower or a wide (flat) flame torch.
You can fit the soldering head with a selection of soldering tips and the hot knife, or you can fit the flame head, onto which you can attach the hot blower or the wide flame unit.
The choice is yours!

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Maplin ELECTRONICS

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ALL PRICES INCLUDE VAT.

All items subject to availability, both items will be on sale in our shops in Birmingham, Bristol, Leeds, Hammersmith, Edgware, Manchester, Nottingham, Southampton and Southend-on-Sea.