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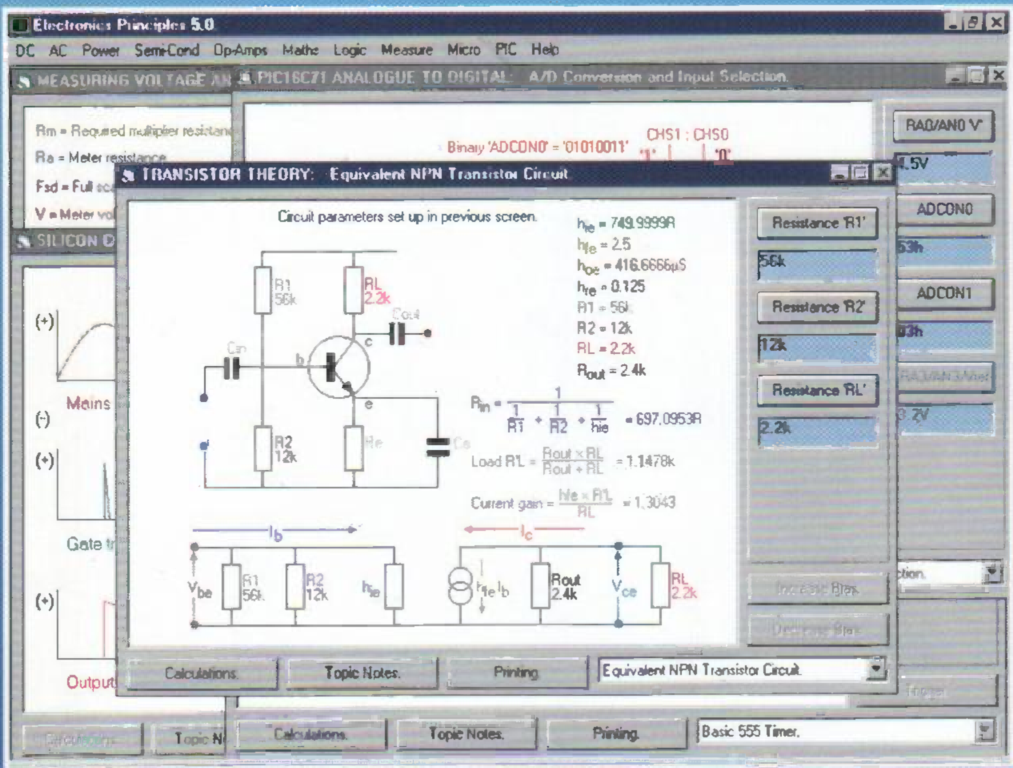
Electronics Principles 5.0

'A COMPLETE PC BASED ELECTRONICS COURSE'

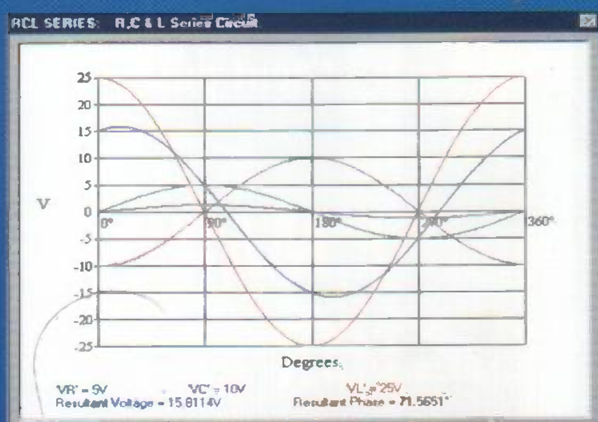
If you are looking for an easy and enjoyable way of studying or improving your knowledge of electronics then this is the software for you.

Now includes the PIC16C84 & PIC16C71 hardware and instruction set.



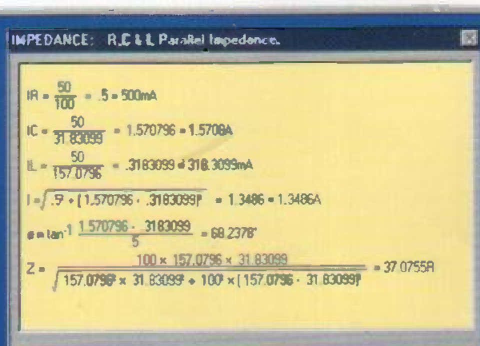
Electronics Principles 5.0 is a significant upgrade of our popular electronics educational software. Now containing even more analogue, digital and microcomputer theory, PLUS over a hundred new mathematics topics to further your understanding of formulae and calculations. Telephone for a comprehensive list or upgrade details.

This software has been developed to teach electronics and is suited to both the complete novice and the more advanced student or hobbyist wanting a quick revision and access to hundreds of electronics formulae. It is extremely easy to use. Just select a topic, which is always presented as a default diagram (no blank screens!) and input your own values. Alternatively, use those from any standard electronics text book to see the results as frequency response curves, calculations, logic states, voltages and currents etc.



Graphics presentation has been enhanced and speeded-up with new menus and indexing which enables a quicker access and more informative description of the extended range of five hundred and sixty electronics and mathematics topics.

The PIC16C84 microcontroller hardware and instruction set has been introduced and brought to life through colourful interactive graphics where you can study the architecture of this device by changing the data values to simulate all of the registers, direct/indirect addressing, program/data memory and input/output port configuration. Along with those analogue to digital functions of the PIC16C71. If you would like to learn more about the principles of these popular microcontrollers then it could not be made easier.



Electronics Principles software is currently used in hundreds of UK and overseas schools and colleges to support City & Guilds, GCSE, A-Level, BTEC and university foundation courses. Also NVQ's and GNVQ's where students are required to have an understanding of electronics principles.

Still only £99.95*

EPT Educational Software. Pump House, Lockram Lane, Witham, Essex. UK. CM8 2BJ.
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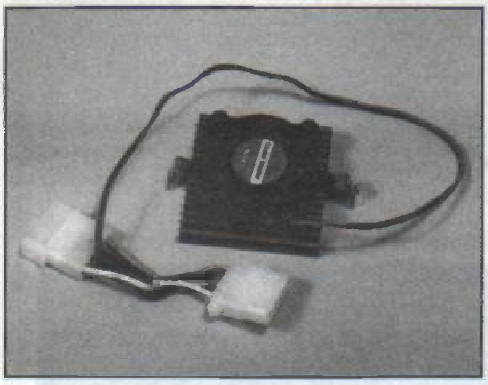
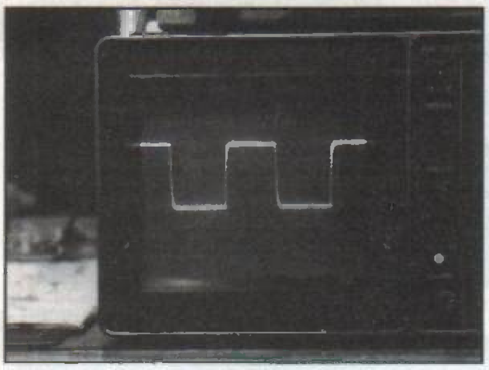
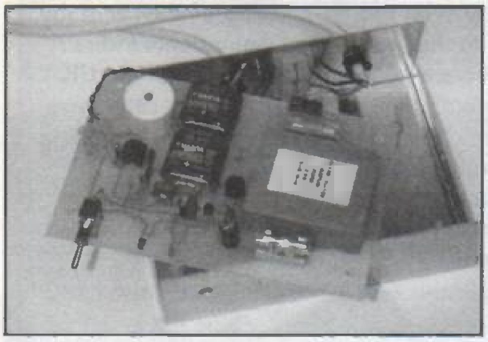






Regulars

ETI News...

World's fastest PC-based 16-bit A/D system runs at 10 msps

Strategic Test has brought out the CompuScope 1016 PC-compatible ISA bus card, the world's first and fastest 16-bit A/D system capable of sampling at speed of 10msps on one channel with a bandwidth of 5 MHz, while maintaining an 85-dB spurious-free dynamic range (SFDR). No other product on the market, say the makers, including stand-alone scopes, VXI or VME cards, can digitise analogue signals at 10MHz with a 16-bit resolution.

At the sampling rate of the 1016 is faster than the ISA bus can handle, the A/D data is stored in on-board memory, which can hold up to 8 million samples, to be read by a PC later. The multiple record mode allows "stacking" of data from successive triggers. This mode is ideal for high Pulse Repeat Frequency (PRF) systems in which data cannot be downloaded to the PC's memory in between triggers.

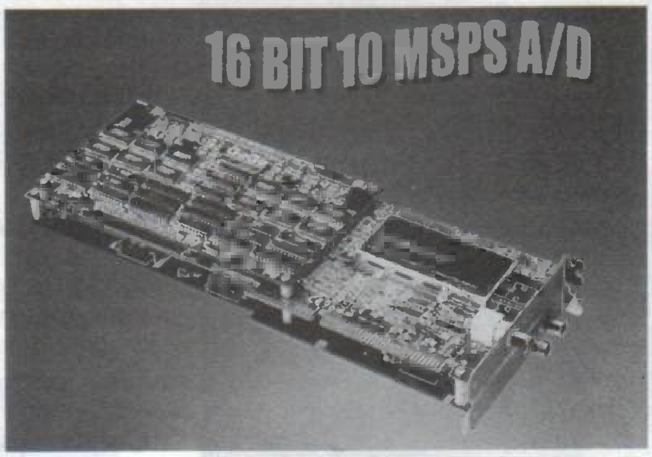
Compuscope comes a standard with the award-winning GageScope software which enables users to operate the card like an oscilloscope without writing a line of programming code. Users can store, analyse and print their data and convert is to an ascii format for export to spreadsheets and mathematical software packages.

Software drivers are available for all popular operating system and are supplied with sample programs demonstrating use. Sample programs are provided in source code. CompuScope does not need a GPIB or IEEE 488 interface to transfer data to the IBM PC environment. The on-board memory is mapped into the 80x86 processor's memory map. Data can be transferred from CompuScope 1016 to the PC extended memory at up to 500 ksps on a Pentium system using software drivers.

Listed key features of the device include, among others:
- True 16-bit analogue to digital conversion
- Up to 10 msps sampling
- Up to 8 Mega-samples on on-board memory
- Multiple record mode for optimising the on-board memory
- Free GageScope 'scope emulating software
- drivers in DOS, QNX, Windows 31, '95 and NT
- Support for LabView, HP VEE, LabWindows CVI and MATLAB

Numbered among the typical applications listed are infra-red imaging, radar, lightning testing, cellular communications, ultrasonic testing, vibration analysis, laser diode characterisation, etc.

For further information contact Bob Giblett, Strategic Test and measurement Systems Ltd., 11 Ashton Road, Wokingham, RG41 1HL. Tel 0118 979 5950 fax 0118 979 5951 email BobG@strattest.co.uk



Electronics technicians offered top prizes in Top Technician competition

Valuable prizes are being offered this year to the UK's top technicians in industrial electronics. The winner of the Top Technician in Industrial Electronics competition will win a top-of-the-range laptop PC and will represent the UK at the International Youth Skills Olympics in Canada in 1999.

With the help of sponsorship from the DTI Sector Challenge, and industrial sponsorship from British Aerospace, Racal, Oxford Instruments, Defence Evaluation Research Agency (DERA), Farnell and Vision Engineering was well as SME (small and medium sized enterprise) sponsors Chemotronics and Celab, all competitors will take prizes away from the contest.

Director of the Federation of the Electronics Industries and Chairman of the Top Technican Board Brian Arthur said: "All the technicians who enter the skills contest are winners because they represent the very best of the UK industry's skills and training. This year we shall be able to recognise that, by giving really good prizes to all of the competitors, not just the winners."

The 1998 Top Technician contest will hold five regional finals in Scotland, Northern Ireland, Wales and the North and South of England on the 1st and 2nd of July, with the winners going on to the Electronic Components Industry Fair '98 which will once again host and sponsor the UK final as a major event in the exhibition. Brian Arthur says that this year's stand will be a high-tech design reflecting the important status of the electronics industry.

The competition is co-organised by the Engineering Training Authority (EMTA), The Federation of the Electronics Industry (FEI), The Institution of Electrical Engineers (IEE), and the new Institution of Electronics and Electrical Incorporated Engineers (IIE), and is recognised by UK Skills as part of the national framework of skills competitions covering every industry sector.

Suitably qualified technicians seeking to enter the competition should contact The Competition Organiser, IEE, Michael Faraday House, Six Hills Way, Stevenage, Herts SG1 2AY. Tel 01438 767 283 fax 01438 742856 email sstewart@iee.org.uk

Companies wishing to support and benefit from the contest should contact Brian Arthur, Director - Components and Manufacturing, FEI, Russell Square House, 10-12 Russell Square, London WC1B 5EE. Tel 0171 331 2004 fax 0171 331 2056 email barthur@fei.org.uk

ETI ELECTRONICS TODAY INTERNATIONAL News...

Monitor specs are being looked into by Sony

Early news comes that Sony is working on "monitor glasses" that can display the image of a 30-inch monitor screen about four feet in front of the wearer.

No doubt it will be some time before these very useful devices appear on the market. Following that, we shall require glasses that display our favourite telly channels just to the left or right of any monitor screen we are supposed to be working with, preferably without anyone else noticing!

RD Research B2Spice Agents in UK

SPICE circuit simulation B2SPIce and B2Logic (mentioned by Owen Bishop in Spiced Circuits part 7, ETI 4/1998) is available in the UK directly from the UK agent, RD Research. For more information and prices, contact RD Research at Research House, Norwich Road, Eastgate, Norwich NR10 4HA. Telefax 01603 872331 email rd.research@paston.co.uk

RD Research also handle computer modelling, network and Internet products and Year 2000 date compliance.

Sub-credit-card sized RF smart card incorporates its own coupler and antenna

The Micro680 contactless smart card reader from Gemplus is smaller than a credit card. The reader is designed for use in small devices such as handheld card readers, card reloading terminals and vending machines, as well as larger devices such as bus validators and ticket machines. The Micro680 is based on the widely accepted MiFARE contactless standard.

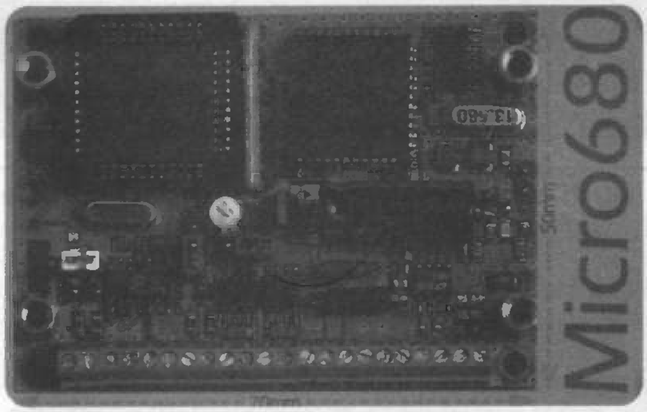
Contactless card technology is becoming more widespread and is not starting to appear in new card applications such as teleticketing, toll collection, access control and electronic purse systems.

As well as small size, the Micro680 is easier to install because it is in a single piece, combining the coupler and antenna, and occupies less space in the hardware.

Contactless smart cards do the same work as protected memory cards, but use RF technology to communicate with the card reader instead of being inserted into the reader.

The card transmits transaction data, and records data received when passed within 8 to 10 cm of the reader. Contactless cards can reduce transaction times by 20 or 30 times compared to insertion cards.

For more information contact Lisa Coley at Gemplus Ltd., New Lane, Havant, Hants PO9 2NR. Tel 01705 486444 fax 01705 472 081. Website www.gemplus.com



BT one-handset phone system for home and mobile to launch this autumn

British Telecommunications will launch this autumn the first telephone service which merges a GSM mobile handset with a domestic telephone line at a single number for members of the public. The business version of BT's OnePhone was introduced last year after on-site trials in June 1997.

Around the house, the OnePhone logs onto the fixed phone network like any digital cordless phone. Once outside its 300-metre home range, the phone switches to a GSM mobile network to act as a fully functional cellular phone. Users can have a new, single number that reaches the phone in either mode.

BT is pleased that the release gives it (and the UK) a lead over the rest of the world in integrated phone networks. Swedish company Ericsson has been working with BT's own research laboratories to develop the technology. The OnePhone service will gradually be developed to include further services such as access to email, fax and the Internet.

BT Mobility Solutions General Manager Eric Guilloteau said at the release: "Up to now, the emphasis has been on making products smaller. We are now moving to an exciting, practical new dimension - we're making them fewer."

BT's new style service follows closely in the wake of many mobile users who have given up using fixed-line telephone services altogether, preferring to rely on their mobiles. Around the house, it has long been known that the old Rabbit ex-cellular digital phones, used as home cordless systems, provide a much higher quality than most domestic cordless phones.

For more information about the BT OnePhone please contact Band & Brown Communications, tel 0171 419 7000 fax 0171 419 6969 email martin@bbpr.com

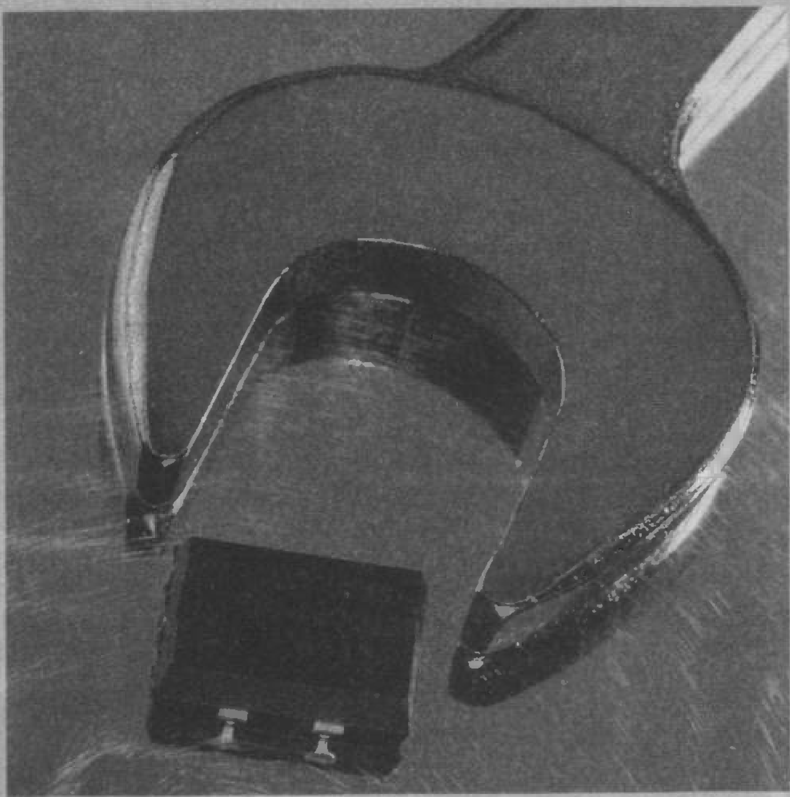
ETI News...

Smaller and lower cost from crystal suppliers

Advanced Crystal Technology are featuring "the first genuine surface mount voltage controlled crystal oscillator (VCXO)" (shown) as well the smallest real-time clock module (both by Epson) and the lowest-cost crystals for surface mount in their list of product on show in the first half of 1998.

ACT maintains one of Europe's largest stocks, and is currently extending its range of Epson products, including technical data and price information in its enquiry response information, to provide quick quotations, competitive pricing and technical support.

For more information contact Wayne Axten, Advanced Crystal Technology Ltd., 9 Kingfisher Court, Hembridge Rd., Newbury, Bertks RG14 5SJ. Tel. 01635 52820 fax 01635 528443. Email info@dryden.co.uk



Multi-channel graphics card can handle a mixture of monitor sizes

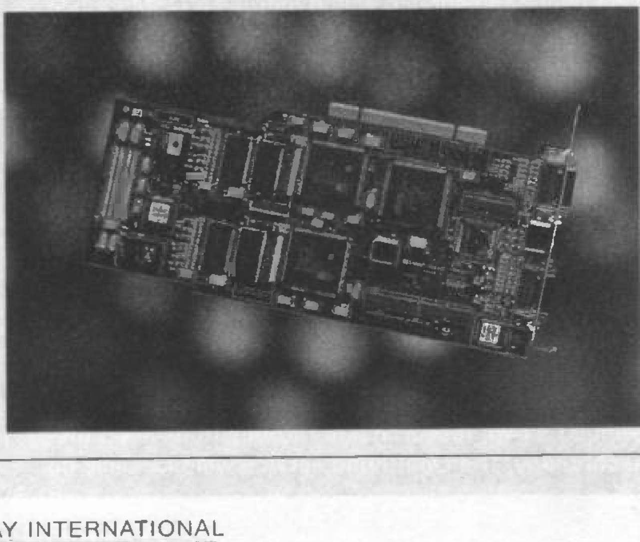
Specialist display technology and digital video company Imagine Graphics has announced the Jeronimo J3 series of multi-channel graphics cards for PCs. This release follows the 1997 introduction of the Jeronomo J2 series, which has been quickly superseded by the J3 series. The new series cards start at £470 plus VAT for a 2-channel, 2MB per-channel card to £925 plus VAT for a 4-channel, 4MB per-channel card.

The Jeronimo J3 cards use the high-performance 64-bit Laguna 2D and 3D graphics processors from Cirrus Logic. These address directly ultra-fast 2- or 4-MB rdram memory with a bandwidth of 450MHz. The card will display up to 1600 x 1200 resolution at 75Hz refresh with 4MB of memory per channel fitted. A bridge chip from Digital ensures that the Jeronimo cards are fully compatible with the latest Pentium II motherboards compliant with the PCI 2.1 standard.

Special driver and utility software HydraVision is supplied with the cards, enabling users with Windows '95 and NT4 to control precisely the positions and sizes of multiple windows on multiple screens. HydraVision also enables different resolutions and refresh rates to be set up for each monitor, so that a mix of monitor sizes and makes can be used on the system - a feature which Imagine Graphics announce as unique to the Jeronimo family. Up to 16 screens can be driven from four Jeronimo J3 cards In one PC. Drivers for Windows 98 and NT5 will be available on the formal release of these new operating systems.

Imagine Graphics has developed special 16 x 9 drivers for the Jeronimo cards to drive wide-screen CRT and flat panel plasma displays for use in public information and dealing-room applications.

For further information contact Norman Garland, Managing Director, Imagine Graphics, Lancaster House, 61 Lancaster Road, St. Albans AL1 4ER, UK. Tel 01727 844744 fax 01727 811660 email ngarland@imagine-g.com website www.Imagine-g.com



ETI News...

Incorporated Engineers get a new Institute from merged threesome

Three engineering institutions representing incorporated engineers and engineering technicians are to be merged into one engineering institution.

Minister for Science, Engergy and Industry John Battle launched the new Institution of Incorported Engineers in electronic, electrical and mechanical engineering (IIE) in April. The new institution is merged from the Institution of Electronics and Electrical Incorporated Engineers (IEEIE), the Institution of Mechanical Incorporated Engineers (IMechIE) and the Institution of Engineers and Technicians.

It is hoped that with the increasing demand for engineers at incorporated (IEng) level a new combined Institution will provide Incorporated Engineers and Engineering Technicians with a unified and enhanced voice in the engineering community.

Incorporated Engineers are seen as maintaining and managing the application of current and new technologies, and help to drive technology-led changes in Industry and business.

The President of the new Institution is Dr. A A Denton CBE FEng, and the Secretary and Chief Executive is P F Watson BSc(Eng) CEng, FIEE FIMechE FIMgt. Copies of the IIE's promotional literature can be obtained from the Membership Secretary, The Institution of Incorporated Engineers in electronic, electrical and mechanical engineering, Savoy Hill House, Savoy Hill, London WC2R 0BS. Tel 0171 836 3357 fax 0171 497 9006 Email iie@dial.pipex.com Not to be confused with the IEE (Institution of Electrical Engineers).

Higher memory-density flash memory cards from Hitachi

Two new units have been added to Hitachi Europe's range of flash memory cards. The 45-MB HB286045C3 CompactFlash card and the 150-MB ATA format HB286150A3 ATA format card provide very fast transfer rates of up to 8MB per second to and from the host, and exceptionally low power consumption of only 150mW.

This style of flash memory reflects demand for greater storage capacity in applications such as handheld PCs and digital cameras. Higher density is a particularly important factor for these applications. A picture taken with a "megapixel" digital camera, for example, can take up to 1MB of memory.

Hitachi now offers CompactFlash cards with 8, 15, 30 and 45-MB capacities and ATA cards with 8, 15, 30, 45, 60, 75, 90 and 150MB. All the cards are based on Hitachi's 64-Mbit AND-Flash device and single-chip microcontroller, which combines high programming speed of 400kbits per second, high capacity and very low power consumption.

Hitachi is the only company that designs and manufactures the flash memory chips, the controller and the component packaging in-house, allowing it to optimise speed, power and capacity.

The very low power consumption offered is important to extend battery life in portable applications. The third generation HB2860XXC3 and HB286XXXA3 series dissipate 150nW, 40 percent less than the previous generation of flash cards.

The company expect that reduced manufacturing costs and higher density will widen the applications field to including applications like network hubs and routers, Point of Sale systems, text and measurement equipment and LCD projectors. All the cards are available ex-stock in small quantities.

For more information contact Vince Pitt, Hitachi Europe Ltd., Whitebrook Park, Lower Cookham Road, Maidenhead, Berks Sl6 8YA. Tel 01628 585163 fax 01628 585160.

Year 2000 PC analysis software from Maplin

Maplin have brought in a software package, Prove It 2000, to help with the Year 2000 date problem that is likely to affect many computer systems at the turn of the Millenium or sooner.

A recent independent survey rated the 2000 test product best out of 16 tested. It is suitable for us on all IBM-compatible PC hardware and runs on a single floppy disk so that the operating system and hard drive applications are not interfered with. The user is guided through eight tests, including checking the real time clock, the BIOS and the operating system, as well as leap year and non leap year compliance. A hardware report gives a clear indication of pass or fail, will a full explanation of each test. In many cases, the BIOS problem will be automatically fixed.

The disk also has a help file with additional manufacturers' phone numbers and website URLs. Technical support and advice is supplied by Softbank Services Group.

Prove It 2000 costs £34.99 from Maplin stores and mail order catalogue. For further information call 01702 554155.

ETI News...

ELECTRONICS TODAY INTERNATIONAL

LCD controller takes a messages in many languages via Windows 95

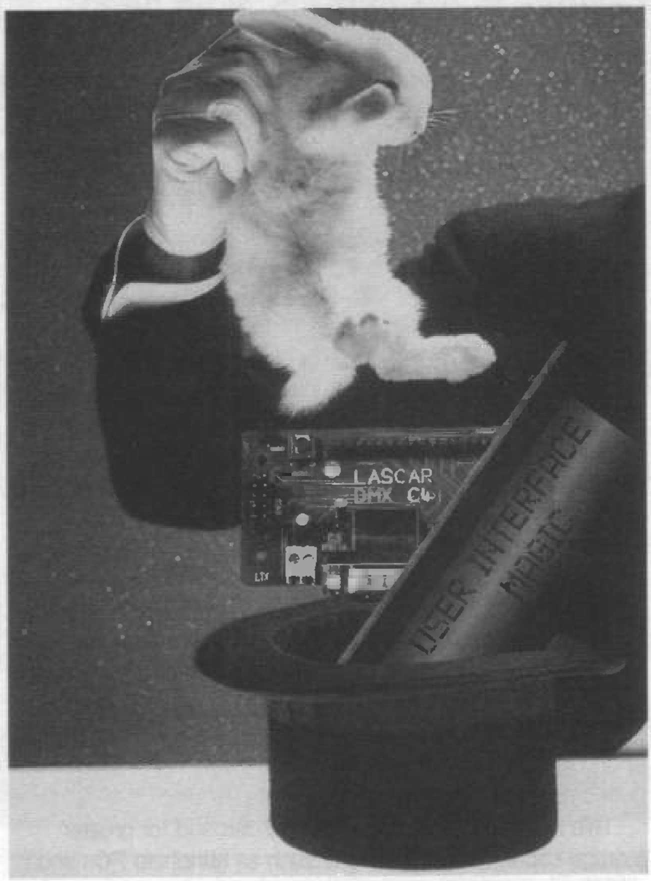
"User Interface Magic" - Lascar Electronics has launched the DMX C4 LCD character display controller to allow panel builders, even those with a modest level of electronics and programming skills, to integrate a message display into their products with a minimum of time and complexity.

The DMX C4 is deisgned to work with most industry-standard 1-, 2- and 4-line LCD character displays, and can safely store up to 100 messages, each up to 80 characters long, in permanent memory. The card combines a character display controller with a message storage area. The storage area can be divided into language pages, allowing the end-product to be easily reconfigured for a particular country or language region without the need for reprogramming.

Messages stored in the DMX C4 can be recalled on the character display via the card's serial or parallel port, or by connecting microswitches or sensor switch outputs to the card.

No specialist software is needed, as all text messages are written on-screen and downloaded into the card via the Windows 95 built-in HyperTerminal package. A separate programming cable is available to connect the card to a Windows 95 PC.

For more information contact the manufacturers, Lascar Electronics, Module House, Whiteparish, Salisbury, Wiltshire SP5 2SJ. Tel 01794 884567 fax 01794 884121.



New version of pro UK-developed SPICE simulator

Newbury Technology have released V2 of their analogue simulation package SIMetrix, The new version offers Monte Carlo analysis, components sweeping and a set of advanced post analysis features such as automatic rise and fall time calculation.

Based on Spice 3, SIMetrix is developed in the UK and features a full Integrated schematic editor with multi-level undo, comprehensive waveform analysis capabilities such as FFTs, schematic cross-probing and real time waveform display. It also supports transient, dc, dc sweep, ac, noise and transfer function analyses while device support includes lossy transmission lines, arbitrary sources and Gaasfets. Newbury Technology have carried out further development of the simulator core and claim much improved convergence performance allowing a wider range of circuits to be analysed than other PC-based packages.

Other features supported include a full-featured Basic-like scripting language allowing automation and customised post simulation analysis; user definable keys and menus; annotation of schematic with bias point voltages, and a new Mosfet model designed for vertical devices with non-linear gate-drain capacitance.

A model library containing around 1500 devices is supplied, comprising bipolar transistors, diodes, Mosfets and simple logic devices. In addition, a number of op-amp models from various semiconductor manufacturers are also provided.

Full support by phone, fax or email from the developers of the software is provided free of charge. Newbury Technology maintain a web page providing the latest information on the package including new version releases, FAQs (frequently asked questions) and Internet sites for manufacturers' device models.

The package was marketed at £295. A free demo version of the full working program with some more advanced features disabled and a simulation run-time limit is available on CD-rom

For more Information contact Newbury Technology Ltd. Tel 01635 866395 fax 01635 868322 email jrw@newburytech.co.uk

OVERSEAS READERS

To call UK telephone numbers, replace the initial 0 with your local overseas access code plus the digits 44.

Getting to Know Surface Mount Technology

DIY construction with surface mount components is a definite option these days. Robin Abbott describes the basic processes and offers a couple of useful examples for experimentation.

Surface Mount Technology (SMT) is a relatively recent development that is now almost universal in manufacturing industries. Traditionally surface mount has been ignored or avoided by the non-industrial press because surface mount technology has a reputation of being a "black art", too difficult to handle by manual techniques. In this article I shall look at various forms of surface mounting, and the techniques that can be used by the amateur constructor with surface mount components. I hope to show that it is quite possible to use surface mount technology for projects and not just in commercial production.

Traditionally, printed circuit board technology has been based on through-hole mounted components. This type of component has a limitation on its minimum size, because it is mounted on its wire connectors, and these must be strong enough to support the component body. Further restrictions on how close one hole can be to another also limits the minimum distance between component wires, and so also limits the minimum component size. With surface mount technology, the components, which may be made as small as possible, are mounted directly on to the copper side of the printed circuit board. As components do not necessarily require wire connections, but simply a termination built into the component body, they can be made much smaller than through-hole components.

Because the components are mounted on the surfaced of the pcb, and not through it, different sets of components can be mounted on each side of the board. Component densities can be more than doubled just by this method.

The primary reason for using surface mount technology is this reduction in board area. Smaller boards can be built, or greater functionality achieved in the same area. The smaller board size, together with the lower materials cost for surface mount components, reduces production costs. For some semiconductors the very high pin count required can only be achieved by using surface mount techniques.

Surface mount components

Most two-lead surface mount passive components fit into rectangular packages, where the termination of the components is formed around each end of the package. **Figure 1** shows a typical package.

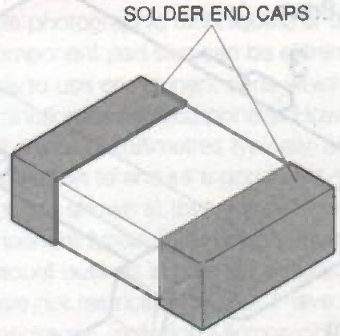


Figure 1: two-leaded surface mount package

These component package sizes are normally described in the form xxyy, where xx represents the length of the component in hundredths of an inch, and yy is the width of the component in hundredths of an inch. A popular surface-mount resistor size is 1206, giving a package 12 hundredths of an inch long, and six hundredths of an inch wide. In metric dimensions, this is approximately 3mm by 1.5mm. The height is usually so low that it is not normally quoted in the package type.

Resistors are supplied in a number of package types, with 1206 as the largest, and 0805 quite common. Smaller devices such as 0603 and 0402 are also available, with 0201 being used for very specialised applications, mainly in Japan. Components smaller than 0603 probably too small to handle manually reliably, even by the most dextrous constructor.

Resistors normally have their value printed directly on the package. The value is given as a three digit number, the first two numbers being the first significant digits of the value, and the last number being the power of 10 to which the first digits are multiplied. For example a 10k resistor will be printed with the value "103", and a 470R resistor with the value 471. The resistor value can be very hard to read without a magnifying glass, and on the very smallest components it is not printed at all. You know the value by reading the packet (usually a plastic strip supplied in a roll). Once the component is separated from its packet, it has no readable identity. Keeping a junk box of used surface mount components is pretty thankless.

Capacitors come in a similar package to resistors, but can be bigger for the higher values and the height may be greater than a resistor for the same length and width. Electrolytic capacitors are much bigger than resistors, reflecting the increased complexity of construction. Larger electrolytic capacitors are becoming more widely available, particularly in tantalum form, however, there are a number of circuits which still use through-hole techniques for large capacitors, with surface mount for the rest of the board. Surface mount capacitors can be much more sensitive to board flexing, and thermal effects, than the through hole versions. Capacitors are also rarely marked with their value, and it is important to keep track of capacitor values from the moment they are bought.

Transistors and semiconductors

The majority of small transistors are supplied in SOT23 packages. This package type has three leads (**Figure 2**). The leads of a SOT23 package are formed already bent over, and are soldered flat to the board.

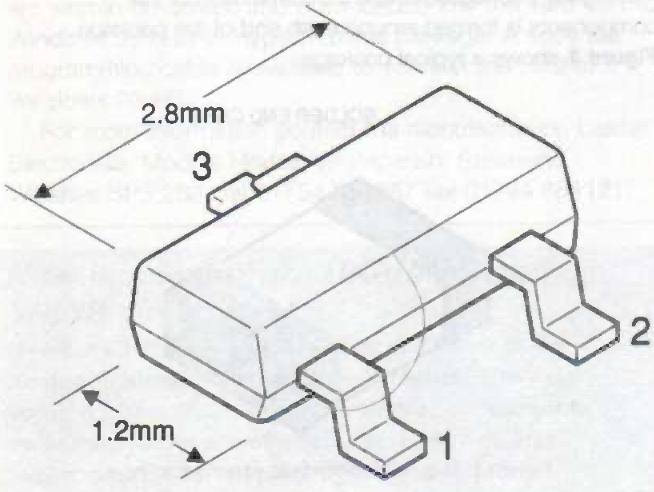


Figure 2: SOT-23 transistor/diode package

The larger packages used for surface mounted semiconductors have a lead spacing half the width used for through-hole components. The leads are usually on a pitch of 1.7 millimetres, or one-twentieth of an inch. The width of the package is half the width of the normal through-hole package, so is 3.8 millimetres, or 0.15 of an inch. These packages are also soldered to the board using the gull wing leads (**figure 3**).

Some larger semiconductors are supplied in square packages which have leads on each side of the package. The connections can be gull wing, J lead, or simply small copper-plated connection points on the side of the package (**figure 4**). These packages types are Quad Flat Pack (QFP), or PLCC (Plastic Leaded Chip Carrier). The PLCC package may be fitted into a socket which mounts on to a PCB using conventional through hole technology, or may be fixed using solder paste.

The largest semiconductors are now supplied in ball grid arrays (BGA), which have small solder connection points on the

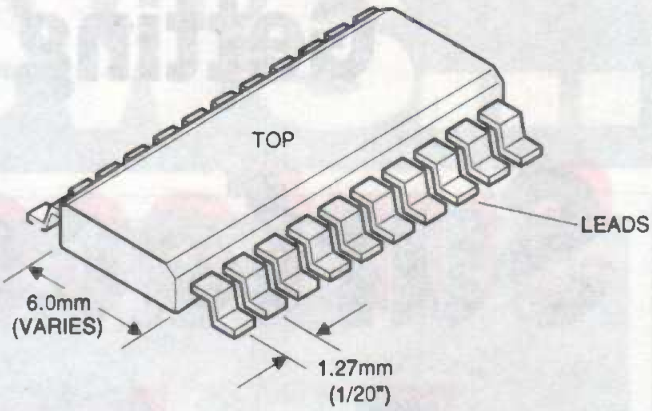


Figure 3: SOnnn ic packages

underside of the ic package, and it is the heating of the board which melts the solder connections of the ic directly to the board. The connections are not visible once the package has been soldered. These package types are PBGA, CBGA, and TBGA, standing for Plastic, Ceramic, and Tape Ball Grid Arrays respectively. The different types of package have different melting temperatures and therefore can require different handling techniques.

There are becoming available even smaller packages for smaller semiconductors, described as VSO (very small outline) packages. These packages have lead spacings of less than one millimetre.

Companies such as Maplin normally only supply the smaller components in quantities of 25 or more. Components come in tape carriers with a peel-off plastic seal. The seal prevents the components from being affected by atmospheric contamination, and components should only be removed from the tapes immediately before for use (this also helps to prevent them getting lost). Not only are many surface mount components not marked, but a number of SOT23 tape carriers are labelled not with the component type, but with the manufacturer's code, or a date. For this reason it is worth labelling all tapes as soon as they are purchased.

SM for small production projects

Currently the majority of components are still available in through-hole as well as surface mount packages. This situation seems likely to continue for some time to come, due to the large number of existing equipments which still use through-hole technology, as well as the equipment currently in use which still requires maintenance. In addition it is still far easier to build and maintain prototype circuits built using through-hole technology than it is to use surface-mount. The largest semiconductor packages in the square packages are the only components generally available in surface mount form only, because there are no through-hole technologies suitable for the very large number of connections required by these devices. Even here there are sockets and adapters available to allow the devices to be mounted on a through-hole board.

It is possible that in future some devices will only be available in surface mount form, and when this time comes then it will be necessary for amateur and educational constructors to become more familiar with surface mount techniques.

The other time when it is essential to use surface mount components for non-production projects, is when the advantages of gained in the small physical circuit size are the only way in which components may be fitted into a certain space. In this article we shall look at two simple projects which fall into this category. At present it is almost certainly not worth using surface mount components for any other use than in commercial production.

Even with this constraint it is still the case that for circuit development where designs are to be tested, or where functionality is not certain then prototypes must still be built using through hole techniques, and once operating successfully can be transferred to surface mount.

Obtaining SM components

Maplin now stock a variety of surface-mount components, and are a good source. Surface-mount components are usually available more cheaply than their through-hole versions, because they are simpler to make and contain less material. For hand assembly it is usually worth getting the larger packages. For example 1206 resistors are reasonably easy to solder by hand, but smaller devices can be very difficult. Surface-mount components with a lead pitch of one 20th of an inch are probably the smallest that it is a feasible to fit reliably by hand.

Please note that surface-mount resistors and capacitors are not usually available in the same tolerances and voltages as their through-hole equivalents. Care must be taken to make sure that the surface mount components are sufficiently highly rated for the task.

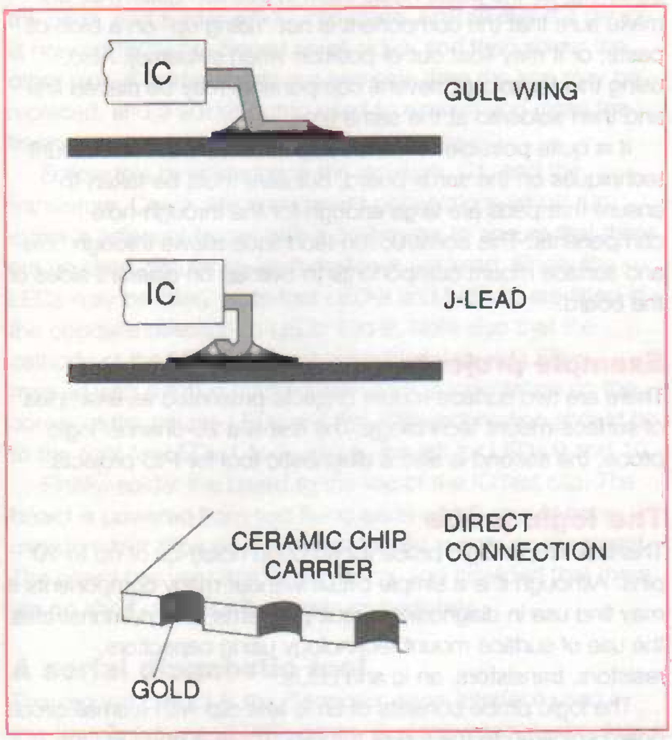


Figure 4: chip connections

Designing SM boards

Although surface-mount prototyping boards are available, the most sensible method of construction for surface-mount is a printed circuit board. The prototype board loses the advantages of small component sizes when the components have to be wired together with leads which require larger pads to connect them to the board.

PCB design for surface mount is different from designing for a through-hole board. The lead spacing of components is much smaller than for through-hole, and it is usually not possible to run the pcb tracks between the leads of components with the same ease as on a through-hole design. However surface-mount designs have the advantage that there is no drilling required except for through connections between the sides of a board.

The ability to place some circuit areas on one side of a board, and others on the opposite side, allows for circuit designs not previously possible. For amateur construction of through-hole pcbs it has normally been very difficult to get registration between the images on both sides of the board. With a double-sided surface-mount board this may not be so important. For example a radio receiver may be constructed with the RF/IF sections on one board side, and the audio amplifier sections on the other side of the board. Connections between the two sides of the board are limited to power and the audio connection.

I have constructed surface-mount boards using both photographic techniques, and the Press'n'Peel system. For those who are unfamiliar with the Press'n'Peel system, this is a proprietary method of producing printed circuit boards without having to go through a photographic process. The pcb track is printed in mirror image on to a special sheet using a laser printer or photocopier. The image is then transferred directly on to blank pcb material by carefully ironing the reverse side of the sheet. It may then be etched in the normal way.

The photographic technique is considerably harder, but results in a cleaner board construction. The Press'n'Peel technique requires less equipment, is considerably faster, but I have found that it results in slightly more ragged tracks.

PCB design is possible by hand, but for surface-mount it is almost essential to use a computer due to the small size of the component pads and tracks. I have found that tracks as narrow as one point, or 0.35mm, are the smallest that can be used with simple photographic techniques, or the Press'n'Peel system. The component pad size can be extremely small, in fact it is possible to use component pads which are the same size as the termination on the component. However, it is better to allow a small area, 0.5 millimetres typically, around the component termination to ensure a good joint. Figure 5 shows pad sizes, which are shown at the very minimum size, for a number of component types. PCB design packages normally have surface-mount outlines in libraries supplied with the package. You are not restricted to CAD. I have successfully used drawing packages, including Micrographx Designer and CorelDraw, for designing surface-mount boards.

Constructing SM by hand

Probably the most important tool for the construction of a surface-mounted board is a good soldering iron with a fine tip. It is a very hard to remove a component once two or more leads have been soldered to the board, and it is only too easy to destroy a component by attempting to remove or replace it. A small hand-operated vacuum holder is very useful for placing the component, and a component is lot easier to manoeuvre using a vacuum holder than a pair of tweezers (which will also take heat away from the component leads).

I recommend the following technique for hand assembly of a surface-mount circuit board:

if the board is not tinned, tin the connections on the board for your component using a very small amount of solder. If the solder forms a small bump above the board surface, use a solder pump to remove the excess solder. Now the component may be positioned using a vacuum holder or pair of tweezers. It is very difficult, if not impossible, to manipulate a component using your fingers.

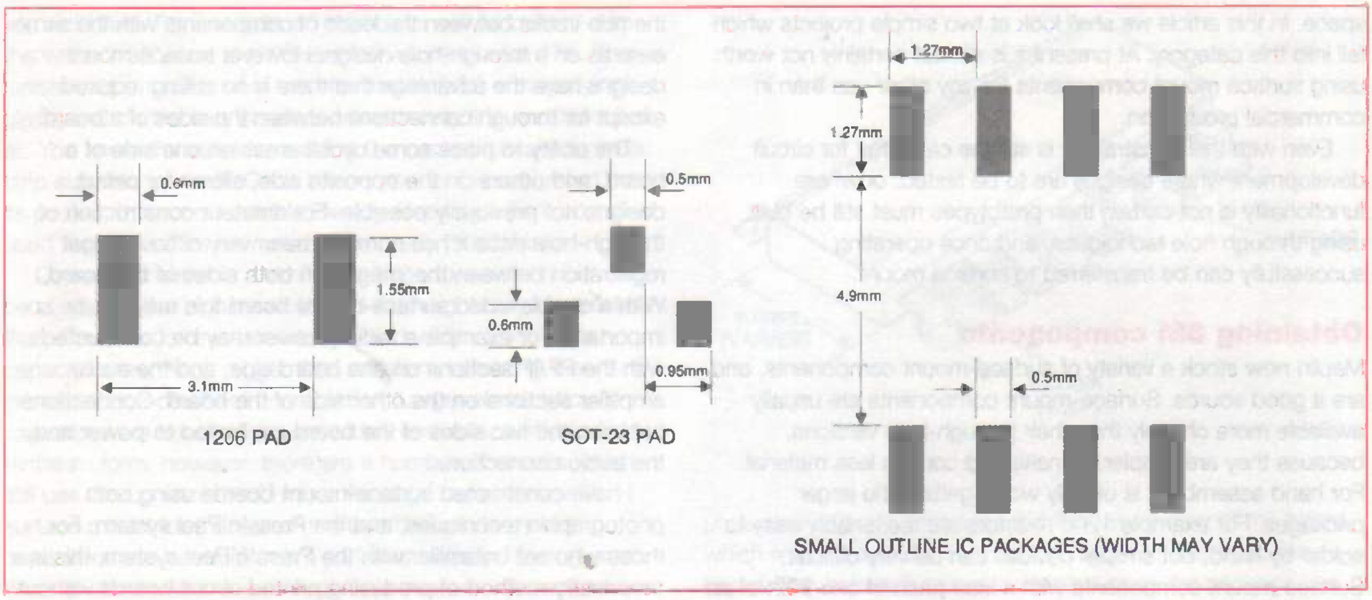


Figure 5: outlines for use in laying out pcbs. Minimum sizes are shown: in practice, real outlines for hand soldering are best made somewhat larger than the dimensions shown

Now use the soldering iron to solder the component's first lead to the tinned board. Usually there is sufficient solder to ensure that the component is firmly fixed to the board. If the component is not correctly positioned, then reheat the joint with the soldering iron, while carefully and precisely re-positioning the component using the tweezers. Once the component is correctly soldered to the board by one of its leads, then the other leads may be soldered to the board using fine solder, and the briefest application of the iron. Once this has been completed successfully, then the first lead may also be re-soldered to ensure that it is properly fixed.

Let me warn you again that it is almost impossible to reposition a component reliably once two or more connections have been soldered. Position the component correctly while soldering only one connection, then do the other connections.

If you are using solder paste, this is normally supplied in a syringe. The paste may be applied to each of the component pads, using a small amount - sufficient just to stick down the component and squeeze a small amount of paste around the connection. The soldering iron may then be used to melt the paste on each pin. This technique has the advantage that components may be positioned more accurately before soldering, as the paste holds them in position quite well, but make sure that the component is not "riding up" on a blob of paste, or it may float out of position when soldered). Also, using this technique, several components may be placed first and then soldered at the same time.

It is quite possible to mix through-hole and surface-mount techniques on the same board, but care must be taken to ensure that pads are large enough for the through-hole components. This construction technique allows through hole and surface mount components to overlap on different sides of the board.

Example projects

There are two surface-mount projects presented as examples of surface-mount technology. The first is a 20-channel logic probe, the second is also a diagnostic tool for PIC projects.

The logic probe

This is a simple logic probe for (through hole!) ics of up to 20 pins. Although it is a simple circuit without many components it may find use in diagnosing circuit problems, and demonstrates the use of surface mount technology using capacitors, resistors, transistors, an ic and LEDs.

The logic probe consists of an ic test clip with a small circuit board soldered to the top of the clip. There is one LED for each pin of the clip. The middle 8 pins of each side of the ic are latched, and normally the level-triggered latch is enabled, so the LEDs show the state of the pin, however, a latch input may be used to hold the state of the LEDs when it is taken low.

In practice the clip is attached to the top of a chip, and the power leads connected to a suitable 5V supply on the board. The LEDs will light to show those pins which are high. To hold the state of the pins the button may be pressed. Alternatively there are two hold inputs (one hold low, one hold high). The hold inputs may be connected to any pin on the circuit so that the LEDs will show the state of the pins when the hold pin is in a specific state. This is

PARTS LIST for the Logic Probe

Semiconductors

IC1	74HCT573M1R Maplin AE95
LED1-10	SMD Red LEDs Maplin CJ72
Q1-Q3	BC846A NPN SMD Maplin VR79

Resistors

R1-8,R10,R12	330R 1206 Maplin DJ09
R9,R11,R13,R14	10k 1206 Maplin DJ17

Capacitor

C1	100nF 1206 ceramic Maplin DJ00

Miscellaneous

20-pin IC test clip	Maplin JB70
Surface mount switch	Maplin DC71
4 x Veropins	
PCB	

useful to check the output pins of a device when the clock is triggered for example. One board may be connected to each side of the clip if it is required to examine both sides of a chip simultaneously.

The circuit diagram is shown in figure 6. The heart of the circuit is a surface-mounted HCT573 device. This is an 8-bit level-triggered octal latch. It is used here because its pinout has the latch outputs on exactly the opposite side of the chip to the input, which allows the pcb design to be more straightforward. An HCT device is used instead of the HC device because it has TTL compatible inputs as well as accepting standard CMOS levels. The outputs of the chip are sufficient to drive LEDs at about 13mA through resistors R1 to R8. The two end pins (one of which will normally be a power pin) are not latched, and simply drive LEDs through transistors Q1 and Q2. The latch input of IC1 is pulled high by a 10k resistor so that it is normally enabled. It may be disabled by pushing button 1, by pulling the pin directly to ground, or by pulling R14 high which disables the latch input through transistor Q3.

The circuit board overlay is shown in **figure 7**. Note that IC1 is an SO16L package 10mm wide, which makes it easier to handle than smaller devices. The first component to be soldered is IC1. Carefully tin the pad for pin 1, and position the device on the board. Now solder pin 1. If it is not exactly placed, melt the solder again and carefully manoeuvre it into position. Now hold the device so that all pins are exactly over the pads, and solder pin 11 into place. Ensure that the device is now correctly positioned on all sides, and then solder the other pins. If solder shorts out two pins then the iron may be replaced, and a solder pump used to remove and clean the tracks.

Follow this by soldering in the resistors, C1, and the transistors. Check any component connections which run close to adjacent tracks with a multimeter to ensure that there are no short circuits as each device is soldered. Finally the LEDs may be fitted. Note that LED 9 and LED 10 are fitted in the opposite direction to LEDs 1 to 8. Note also that the cathode of the LED (which on a traditional round LED is marked with a flat) is marked with a small indentation on the corner of the square LED package. This indentation should be to the right for LEDs 1 to 8, and to the left for LEDs 9 and 10.

Finally, solder the board to the top of the IC test clip. The board is powered from two flying leads which should have miniature test clips on the end to the 5V supply on the board. The board has very little to go wrong, and provided that there are no short circuits will operate immediately.

A serial diagnostic tool

The second project is the diagnostic serial interface used in this issue's Advanced PICs series. Surface mount technology is used to fit a small circuit with eight components on to a board just 13 millimetres square. The circuit diagram is shown in **figure 8**. This is a straightforward circuit and is not described here. Its use is described in the PIC article in this issue. The board is intended to be fully fitted into a 9-pin D connector case with four leads which connect to the circuit under test using crocodile clips.

Figure 9 shows the board layout. This style of construction is used to achieve the minimum size for the project. All the components are surface-mount devices except for C1 which is a 100uF capacitor mounted externally. The board is mounted by pads which are directly soldered to three of the pins of the nine-way serial socket.

Note that this board is considerably tighter than that for the first project, and greater care must be taken in its construction. The pcb can be made by photographic or Press'n'Peel techniques. Ensure that the tracks are separated with a sharp knife after etching.

The gap between the rows of pins is narrower than the width of the pcb, so the end of the circuit board which is soldered to the serial connector must be carefully filed, or pared with a knife, to reduce its width so that the board can fit between the pins as shown in **figure 10**.

The surface-mount components may be placed and soldered first, the order of construction is not important. This board is quite hard to build, and it is worth checking all the connections for short circuits with a multimeter before continuing.

Pin number 1 of the 9-pin socket should be cut off with a wire cutter so that it does not touch any of the components of the board. The board may then be soldered to the serial socket. Note that the three pads on the board are soldered to pins 2, 3 and 5 of the socket. C1 may now be wired between the ground connection and the capacitor connection of the board. Note that the ground wire is soldered into the same hole as C1, and therefore it may be better to twist the lead of C1 and the ground wire together before inserting into the ground hole.

There are four wire connections to the board, two power connections, and two data connections. For the prototype tests leads with a crocodile clip at each end were used, cut in half before soldering them to the board. The board may be tested (as described in the Advanced PICs article in this Issue), and then fitted into the connector shell. The best way to fix the wires and board into the shell is to fill it with potting compound, or to glue the wires into the case using silicone rubber, or epoxy cement.

PARTS LIST for the Serial Diagnostic Interface

Resistors

R1,R2,R5	10k 1206 Maplin DJ17
R3	330R 1206 Maplin DJ09
R4	2k2 1206 Maplin DJ13P

Capacitors

C1	100uF 16V sub-miniature electro

Semiconductors

Q1 Maplin VR79	BC846A NPN SMD transistor
Q2 Maplin VR18	BC856B PNP SMD transistor
D1 VR84	BAW56 SMD diode Maplin code

Miscellaneous

PL1	9 pin D connector socket

9-way D-connector shell (metallised) Maplin JB68Y
4 x leads with Crocodile clips
PCB

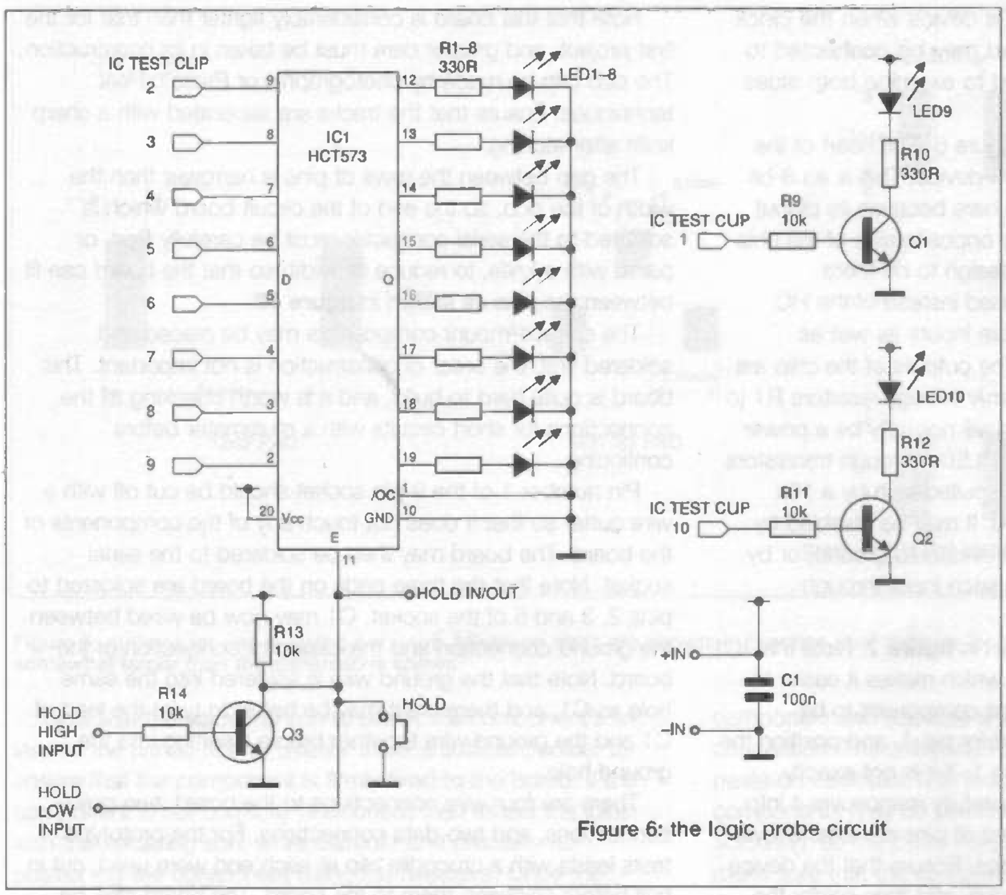


Figure 6: the logic probe circuit

Commercial SM techniques

Production lines make use of highly automated assembly tools to construct circuit boards very rapidly. PCBs for production equipment may be double sided, or for very high density applications may have a number of buried track layers to ensure connectivity without the need for wire links and jumpers. As for a normal through-hole board, the surface-mount pcb will be plated and printed with a solder mask.

However, the surface-mount board will then be screen printed with solder cream on the component terminations. The components may be placed on to the board and held in place by the solder cream, which is slightly sticky. For bigger components, glue may be used as well. Once all of the components have been placed on the board, it is passed through a hot oven which melts the solder cream and simultaneously solders all the components on the board at once. As the components have a low mass, and a lower density than solder, they tend to float into position on the solder pads pulled into place by surface tension. This is known as the self-centering effect, or "swim-in". It actually pulls larger components such as Ball Grid Arrays into place as well.

At the heart of an automated surface mount production line is the pick and place machine. These machines can automatically place thousands of components per hour onto boards. Component placement rates of 8 to 10,000 pieces per hour are not uncommon. The pick and place machine has at its heart one or more vacuum placement heads which pick up components from a cassette tape, move the board as necessary, and place the components to an accuracy which can exceed 0.5 micrometers in the more advanced machines. Typically there may be up to 150 tapes for a pick and place machine. Where there are more component varieties than this, pre-sorting of more than one component type per tape is required.

Some pick and place machines include optical recognition systems which are capable of determining the exact orientation and position of a component as it is lifted from a cassette. This allows a wider variety of components to be recognised and used. For example, **figure 11** shows the wide variety of component types which can be placed by the Panasonic NM2544,2545 pick and place machine. Most of these components are too specialised to be available to the small scale constructor. **Figure 12**, on the other hand, shows some SM components that are available to the home constructor life size.

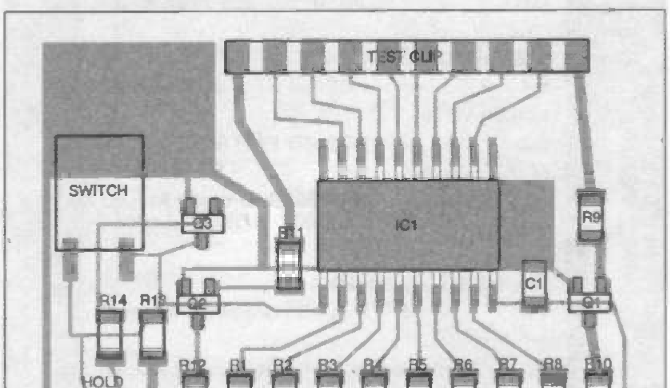


Figure 7: the logic probe component layout

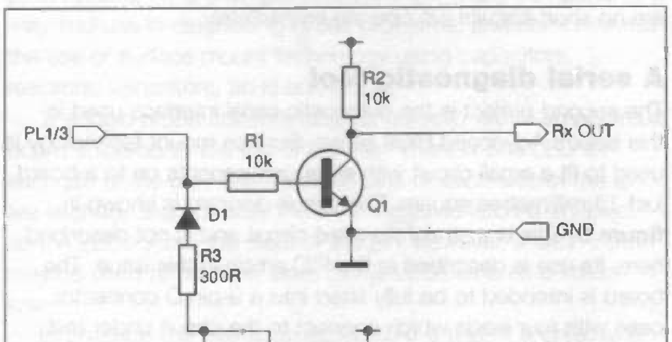


Figure 8: the diagnostic serial interface circuit

Reworking and maintaining SM boards

Clearly with the smaller component sizes used in surface-mount, specialist tools are required when reworking boards to replace failed components, or to make modifications. The two-leaded components are relatively easy to remove provided that both ends of the component can be heated at the same time. It is virtually impossible to remove surface mount components by using a desoldering pump, as there is nearly always residual solder under the component which holds it in place.

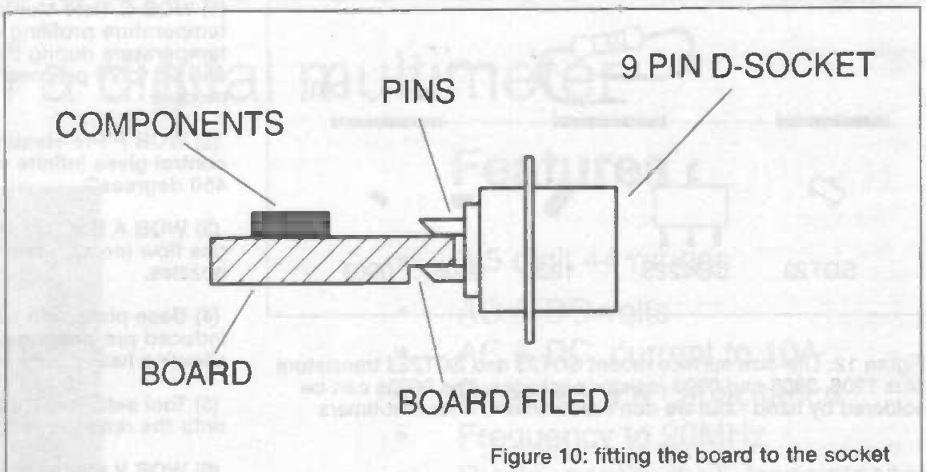


Figure 10: fitting the board to the socket

Semiconductors and other components with a large number of legs are much more difficult to remove. Components with gull wing legs can usually be removed by heating each leg in turn and bending it up from the board with a sharp knife. However, this is much easier if it is permissible to destroy the component in the process. A hot air gun may be used to melt the solder on all the legs of a component at once, at which point it may be removed. However, a hot air gun can be indiscriminate. One of the snags with surface mount assembly (and this is true for industrial machinery as well as small scale construction) is that it is only too easy to disturb surrounding components when treating a small area.

PLCC or QFP devices can be removed with a special soldering tool incorporating a frame which fits around the entire device heating all the terminations simultaneously. The complete device may then be lifted complete from the board.

Ball Grid Array devices are much harder to remove as the solder connections are hidden under the device. **Figure 13** shows a rework station for BGA components, in this case the Weller WQB 2000. At the heart of the device is a vacuum head with a hot air soldering tool. There is also an infra-red heater in the base plate of the unit. A board containing a BGA for repair is placed on the base unit and heated through the board. The BGA is also heated from above by the soldering tool. After a predetermined time the vacuum pump is activated and the BGA is automatically lifted from the board. Both the BGA and the board are then thoroughly cleaned, and a stencil is used to apply solder paste to both the BGA and the board in exactly the right positions. The BGA may be heated with a hot air gun to reform the solder balls, and then all the processes are reversed to resolder the device.

Ball Grid Arrays are a relatively new development, and are only used on the most expensive eqipment. For these reasons, the manual rework process is still cost effective.

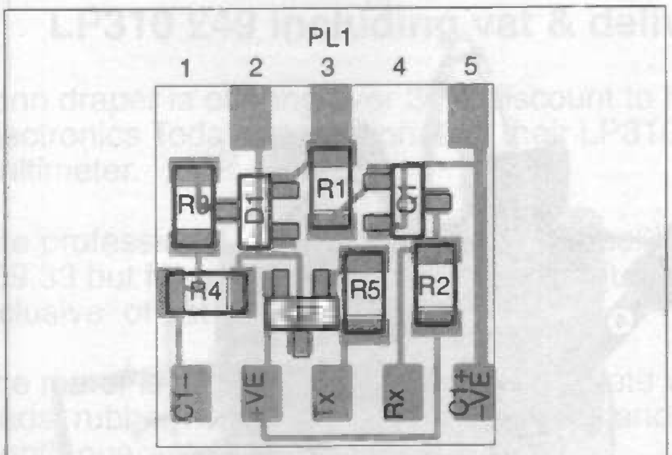


Figure 9: the diagnostic serial interface component layout

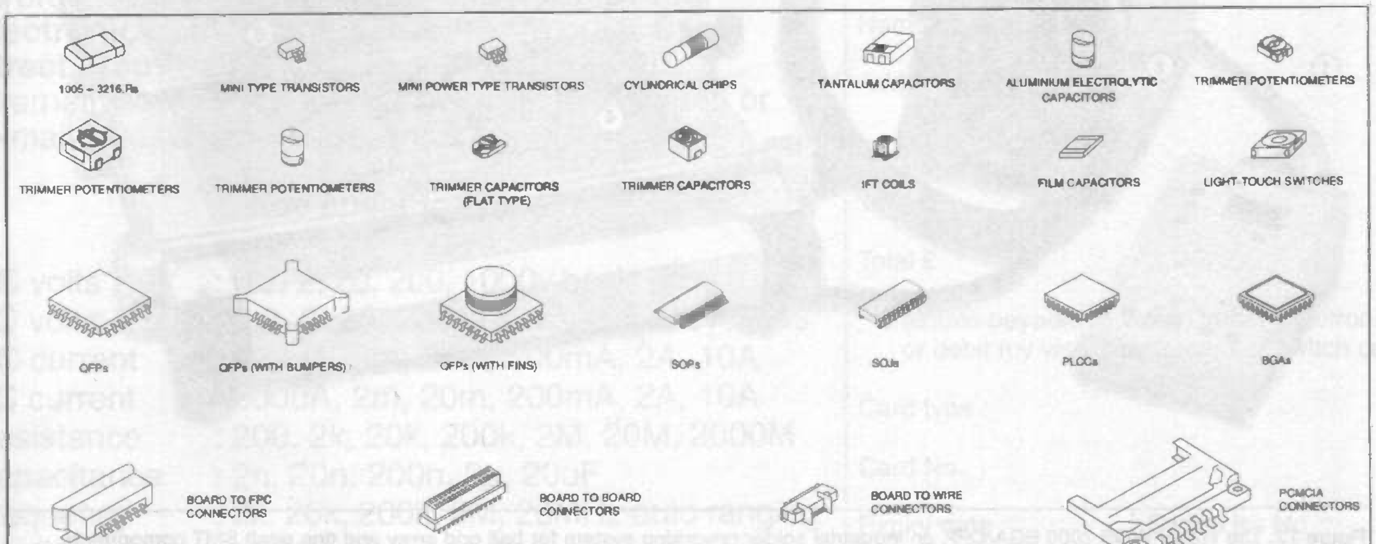


Figure 11: component types used with the Panasonic Panasert NM2544/2545 component placement machine

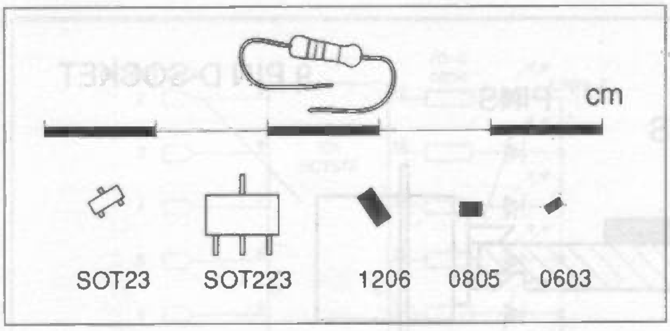


Figure 12: Life-size surface mount SOT23 and SOT223 transistors plus 1206, 0805 and 0603 resistor packages. The 0603s can be soldered by hand - but we don't recommend it for first timers

Further information

The purpose of this article has been to demystify surface mount technology, and to show that in the right place surface mount is straightforward to design and use. I recommend that interested constructors build one of the example projects just to assist in familiarisation with the technology.

The surface mount components for the projects described in this article are all available from Maplin: PO Box 3, Rayleigh, Essex SS6 8L. Tel 01702 554161. Press'n'Peel etching supplies can also be obtained from Maplin.

(1) WQB C Time Control Module: Time data taken from temperature profiling of a component is stored to control the temperature during the reworking process. 6 parameter steps and up to 20 process programmes can be stored in this module

(2) WQB P Pre-Heating Plate supply. Analogue temeprature control gives infinite variable temperature settings betweel 50-450 degreesC.

(3) WQB A Hot Gas Unit powers the hot gas temperature and gas flow (compressed air or inert nitrogen) to the rework nozzles.

(4) Base plate with substrate pre-heating plate. The infra-red induced pre-heating plate has an output of up to 280W, allowing heavy duty boards to be reworked.

(5) Tool selector. Three vertical slides adjust the soldering tool onto the requried reflow zone

(6) WQB V soldering head with rapid-change tool holder and vacuum lift. After the required reflow time, the component is raised automatically from the PCB inside the nozzle housing

(7) Enclosed Hot Air Nozzle casing design ensures that the required heat is guided precisely to the area to be reflowed. Nozzles are interchangeable for component size

(8) Alignment templates, vacuum nozzle and printing templates. A BGA alignment template is fixed to the board in the gap left by the removal of the defective component. The new component is dropped into the template; a vacuum nozzle then lifts and retains it while the solder paste is printed within the alignment template area. The vacuum nozzle then lowers the component into the exact position for reflow soldering.

Figure 13: The Weller WQB 2000 BGA/QFP, an industrial solder reworking system for ball grid array and fine pitch SMT components. Difficult repair processes: desoldering, printing a new solder paste layer, component placement and resoldering are carried out on a pre-heated base table. Exact repositioning of the component is achieved with a vacuum pick-up nozzle that lifts and lowers the new component before and after the solder paste printing process.

In-Line Mains Monitor

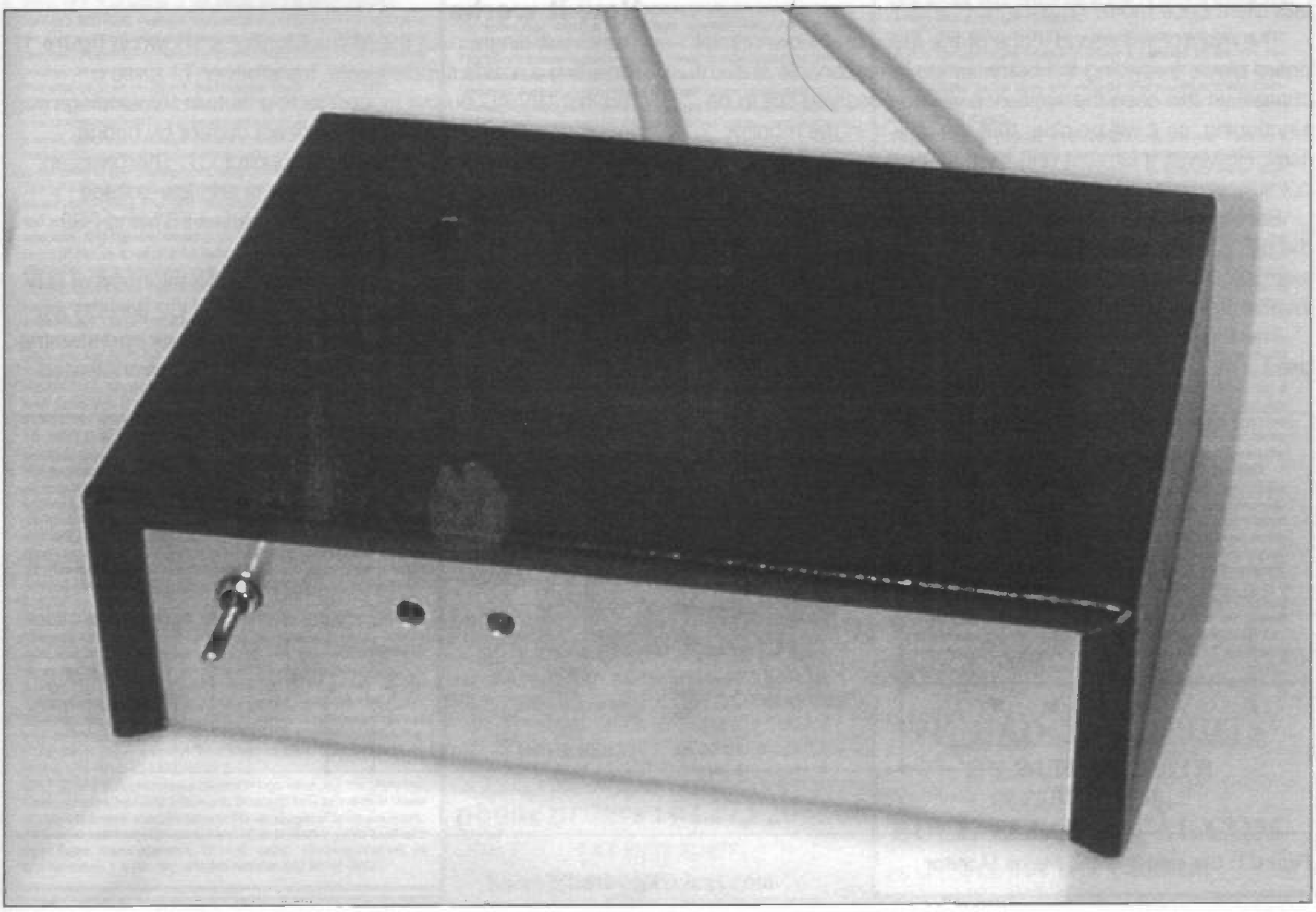
Are you unplugged? Have you blown a fuse? Find out first with Terry Balbirnie's warning circuit.

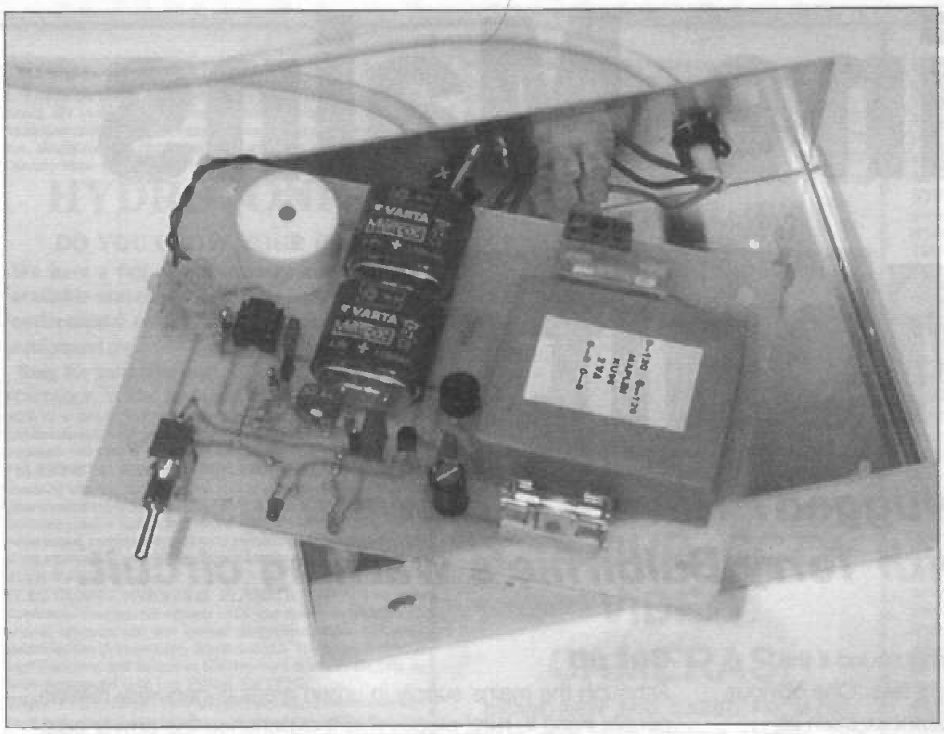
This monitor emits a loud pulsing sound if the supply to a piece of equipment fails. One obvious use would be for kitchen appliances such as fridges or freezers. However, you will no doubt find other applications such as for video recorders and possibly for computer and security items. It could also be handy for office equipment such as fax machines and answerphones.

This is a mains control project. If you do not have much mains construction experience, seek advice from a more experienced constructor before building this project.

Cut off

Although the mains supply in urban areas is generally reliable, people living in rural places might experience the power cuts due to overhead power lines coming down during storms. Having said that, the most usual reason for failure is that someone has unplugged the appliance - for instance, to plug in a vacuum cleaner - and forgotten to replace the correct plug afterwards. The fuse also occasionally fails inside the UK-type plug simply due to old age. Readers with an RCD (residual current device) in their household mains feed may experience the odd "trip" for no apparent reason and not notice it during the day when no lights are on.





appliance are connected to a piece of screw terminal block inside the unit. The system is suitable for use with items up to 6A rating (about 1400W on a 230V supply). In practice, this means that most pieces of equipment which could benefit from being monitored may be connected.

Pulsed operation

The piezo buzzer used in the prototype unit has a very low current requirement (10mA maximum) and the red LED requires a similar small current. Since their operation is pulsed, it effectively reduces the total average current to around 10mA, and the specified nickel-cadmium batteries will provide a full-power warning for at least 10 hours. They will then give a signal at reduced power for much longer. The prototype unit maintained a weak signal for more than 24 hours and for some time after the battery voltage had fallen to the point where the LED went out. Obviously, the full-power operating time depends on exactly which sounder is used and the state of charge of the battery when the failure occurs. Readers wishing to double the operating time could omit the red LED. There is also a way of extending the period even further but at some expense of loudness. More will be said about this later. When the mains supply is restored, the warning is cancelled and the batteries charge ready for the next time.

Loud warning

Whatever the reason for an interruption to the supply, this monitor will make a loud noise, and a red LED will flash when it happens. This should attract attention before any damage has been done. The warning will continue for several hours until power is restored. If there is no prospect of an early restoration, the audible warning can be swtiched off. The fault condition is then indicated by the flashing LED. When power is restored, the buzzer sounds continuously to remind you to switch to "normal" again. Then (you will be relieved to hear!) it falls silent once more.

The monitor will sound if one of the fuses on its own circuit board blows (providing the batteries are in reasonable state of charge). In this case the appliance will be observed still to be functioning, so it will be clear that the fault is in the monitor itself. However, it is most unlikely that the fuses in a well constructed monitor will fail.

Remember that it is the mains that it being monitored, so the monitor will not give a warning if a fault develops after it, for example, if the appliance itself is switched off or if one of its internal fuses fails.

The Mains Monitor is wired in line with the equipment being used. The incoming mains feed and wire leading to the

How it works

The circuit diagram for the Mains Monitor is shown in **figure 1**. Providing a mains supply exists, transformer T1 gives a nominal 18V AC output by connecting its twin 9V windings in series. The result is converted to direct current by bridge rectifier REC1 and smoothed by capacitor C1. This gives an on-load supply of some 20V. The mains and low-voltage sections of the circuit are protected by fuses FS1 and FS2 respectively.

The input of regulator IC1 is connected to the nominal 20V supply. The output then provides a fixed 12V. C2 and C3 are necessary to ensure stable operation. The output operates the monitor's green on/off indicator LED1, with its current limited

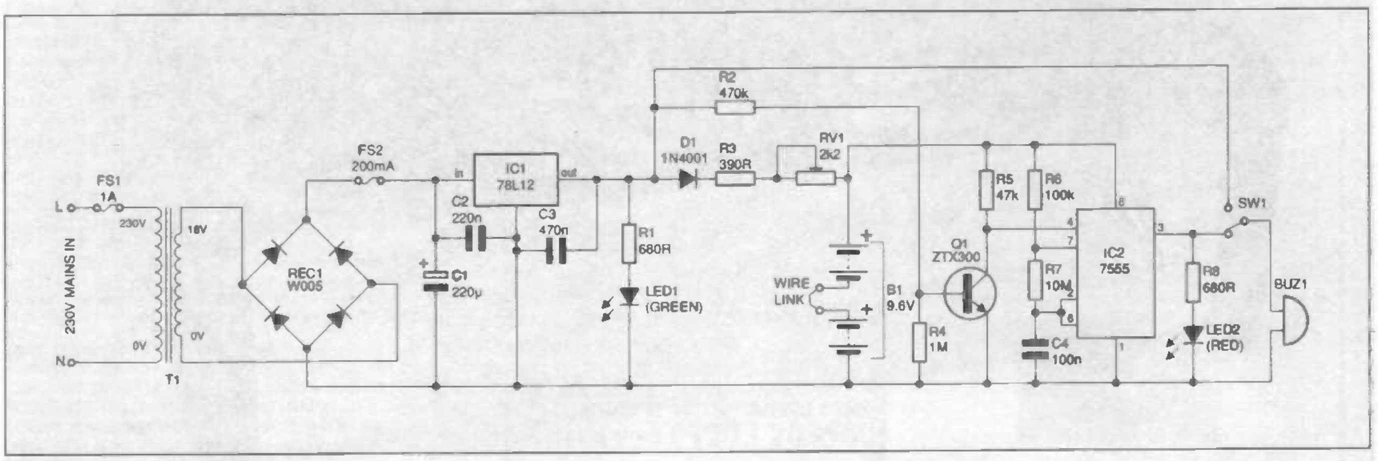


Figure 1: the circuit of the Mains Monitor

PINHOLE CAMERA MODULE WITH AUDIO! Superb board camera with on board sound! extra small just 28mm square (including microphone) ideal for covert surveillance. Can be hidden inside anything, even a matchbox! Complete with 15 metre cable, psu and tv/vcr connnectors. £73.95 ref CC6

BBC SELECTORS WITH SMART CARD SLOT AND VIDEO CRYPT Interesting new item in this week is this Selector. Originally made for the BBC to send encrypted video films to your VCR at night time. The project seems to have failed. Very complex units consisting of a smart card slot in the front plus several switches and an IR receiver. Fully cased and measuring 230 x 430 x 90mm, new and boxed. On the back of the unit is a scart socket plus a UHF input and output. A channel tuning control numbered 28 to 40 and an IR socket. Inside is a comprehensive tuner section, smart card reader mechanism and control electronics plus a power supply section. These units are sold as strippers but we imagine you could use one to convert a monitor into a TV or maybe use the videocrypt side of things for something else. Supplied complete with manual and mains lead. Clearance price just £9.95 ref BBC1X

INLINE RCB UNITS This in line minature earth leakage unit instantly shut off the mains supply in the event of any current flowing between live and earth thus preventing a potentially lethal shock. IEC plug one end, socket the other, fitted in seconds, reset button. The ultimate safety aid when working on electronic equipment, computers etc. As these units are fitted with an in-line IEC plug on one end and socket on the other than could even be used to extend standard IEC computer leads. **Pack of 3 £9.99 ref LOT5A**

THE ULTIMATE ENCLOSURE for your projects must be one of these! Well made ABS screw together beige case measuring 120 x 150 x 50mm. Already fitted with rubber feet and front mounted LED. Inside is a pcb fitted with other bits and pieces you may find useful. Sold either as a pack of five for £10 ref MD1, pack of 20 for £19.95 ref MD2

17 WATT 12V SOLAR PANEL A solar panel designed to give a nominal 12v. The solar cells are laminated within a high quality resin material! which offers excellent protection against UV and moisture. Mounted on tempered glass in an alauminium frame. The panel is ideal for charging sealed lead acid batteries and a protection diode in the circuit prevents reversed current flow. Mounting is by four adjustable hooks and connection is by screw terminals. Max power 17 wattts, 35 cells, 17vdc peak, 433x402x15mm, 1000mA max, 1.9kg. **Solar panel £115 ref SOL4**

SOLAR POWERED AM/FM RADIO A compact, AM/FM mono radio complete with earphone and a solar panel that recharges the built-in battery when placed in direct sunlight or under a strong lamp. It features a rotary Volume/On/Off control (which must be set to 'Off' for recharging), AM/FM selector switch, rotary tuning control, metal belt clip and socket for external 3V DC supply. **Solar Radio £7.95 ref SR23**

MOTOR CYCLISTS RADAR DETECTOR New in is the Whistler 1560 Laser/Radar detector complete with a speaker for motorcycle helmets. Super wid band covering X,K and Ka plus lasers at 950nm+/-10nm. 360 deg total perimeter protection, detects laser, radar and VG-2 wherever they come from. **£159.95 ref RD4**

MAGIC EAR Unlike previous 'sound-magnifiers' we have offered, Magic Ear fits unobtrusively behind the ear itself. Magic Ear's micro technology is very advanced, its built-in microphone is extremely sensitive and there's also a volume control to help you adjust to all conditions in use. Magic Ear is startlingly effective. It'll help you to follow every word of conversation even at a distance, and enjoy theatre, cinema or live music with stunning new sound. Comes fitted with 3 long life batteries, a free travel pouch, plus a choice of 3 different ear pieces designed to fit all shapes of ear. **Magic ear £16.99 ref MAGE3**

RADIO METER Perhaps the best of the scientific knick-knacks of the past and well overdue for revival! Fascinating, soothing and educational. In the vacuum inside the inverted bulb like container the vanes revolve, driven round by light particles alone! (each vane is black on one side white on the other). **Radiometer £9.99 ref SC120B**

SATELLITE NAVIGATION £119 The GARMIN- GPS 38- is the one navigational tool for the great outdoors that offers big features in a small, lightweight package - all at a truly affordable price. Mark your favorite fishing spot, tree stand or camp site. Or retrace your steps back to the safety of your starting point using our all - new TracBack feature. The GPS 38 shows you exactly where you are, where you've been and where you're going. The GPS 38 features easy, one-thumb operation and weighs only 255g. There's a resettable trip odometer, graphic compass' and highway steering guidance. And it provides up to 20 hours of use on a set of 4 AA batteries. The GARMIN GPS 38. The affordable way to bring you back. £119 ref GPS1

DIFFERENTIAL THERMOSTAT KIT An electronic self assembly kit designed for use in solar heating systems, heat recovery systems etc. The principle of the kit is that it has two thermistors that are placed on the items to be measured (typically a solar panel and a water storage tank) the controller then operates a relay all the time one temperature is higher than the other. The temperature difference is adjustable. A typical use would be to operate a pump all the time a solar panel was at a higher temperature than the water storage tank. **Differential thermostat kit £29 ref LOT93**

10 WATT SOLAR PANEL Amorphous silicon panel fitted in a anodized aluminium frame. Panel measures 3' by 1' with screw terminals for easy connection. One of these panels will run our solar water pump in full sunlight although we would recommend that for optimum performance two panels would be prefereable. **3' x 1' solar panel £55 ref MAG45**

12V SOLAR POWERED WATER PUMP Perfect for many 12v DC uses, ranging from solar fountains to hydroponics! Small and compact yet powerful. Will work direct from our 10 watt solar panel in bright sunlight. Max head I7 ft Max flow rate : 8 1pm Current :1 .5A (Ref AC8) £18.99

BOOST CELL PHONE RECEPTION ON THE MOVE! Compared to high-powered carphones, hand-portable mobile phones don't always work too well in moving vehicles. Sometimes the signal 'drops out' during a call, other times there's too much interference to get through at all. However, the affordable Cell Patch provides a major improvement, dramatically boosting signal reception without wires or batteries. The 9.5 x 9.5cm (3.3" X 3.3") microthin antenna adheres to your car window sunvisor, ideally within 61-122cm (2-4') of the handset, or can be carried in a pocket. Works with all types of portable cellular phone. Cell Patch £11.99 ref CEL1

CAT SCARER produces a blanket of high sonic and low ultrasonic sound, which is inaudible to humans, birds and fish - so it is ideal where you want to protect your bird table or fish pond against feline predators. It will deter cats from your garden and other protected areas. It will also deter foxes. mains operated, 10 m of cable. Running cost will be approximately 1 p per day. Garden watcher £42.45 ref GW2

VIDEO PROCESSOR UNITS?/6v 10AH BATTS/24V 8A TX Not too sure what the function of these units is but they certainly make good strippers! Measures 390X320X120mm, on the front are controls for scan speed, scan delay, scan mode, loads of connections on the rear. Inside 2x 6v 10AH sealed lead acid batts, pcb's and a 8A? 24v torroidial transformer (mains in). sold as seen, may have one or two broken knobs etc due to poor storage. £9.95 ref VP2X

SOLAR MOTORS Another new line for us are these tiny motors which run quite happily on voltages from3-12vdc. We have tried one on our 6v amorphous 6" panels and you can run them from the sun! 32mm dia 20mm thick. £1.50 each

TELEPHONES Just in this week is a huge delivery of telephones, all brand new and boxed. Two piece construction with the following features- Illuminated keypad, nice clear easy to use keypad, tone or pulse (switchable), reacall, redial and pause, high/low and off ringer switch and quality construction. Each telephone is finished in a smart off white colour and is supplied with a standard international lead (same as US or modem card sockets) If you wish to have a BT lead supplied to convert the phones these are also available at £1.55 each ref BTLX. **Phones £4.99 each ref PH2**

INFRARED CAR PHONE KIT £7.99 Interesting box of goodies! this kit was designed to convert car phones to enable hands free dialling, the kit contains the following items. 1) A keypad designed to mount in the centre of the steering wheel. It requires a 9v PP3 battery and transmits the numbers using three on board high power infra red LEDs. 140 x 120mm. 2) An infra red receiver module containing a IR photo diode, IR filter and control electronics 60 x 30 x 15mm (cased). 3) Control box (nice case) 100 x 170 x 35mm which we understand is the interface between the infra red and the car phone, it is also supposed to adjust the volume of your car stereo at the same time! made for Phillips car phones (but we don't know the model) Complete kit is £7.99 ref CP1

Hi power 12v xenon strobe variable rate flasher modules and tubes £6 Useful 12v PCB fitted with control electronics and a powerful Xenon tube! just apply 12v DC to the input and the tube will flash. On the board is a small potentiometer which can be used to vary the flash rat! PCB measures just 70x 55mm and could be incorporated into many interesting projects! £6 ref FLS1 Pack of 10 is £49 ref FLS2

WANT TO MAKE SOME MONEY? Stuck for an idea? We have collated 140 business manuals that give you information on setting up different businesses, you peruse these at your leisure using the text editor on your PC. Also included is a certificate enabling you to reproduce the manuals as much as you like! £14 ref EP74

TALKING WATCH Yes, it actually tells you the time at the push of a button. Also features a voice alarm that wakes you up and tells you what the time is! Lithium cell included. £8.99 ref EP26A

POWERBEAM INFRA RED Lamp. All this lamp gives out is infra red light, and loads of it! perfect for supplimenting night sight and surveillance equipment. Most mono CCTV video cameras are infra red sensitive so used in conjunction with this lamp would greatly enhance their operating performance. Water resistant case and rubber covered switch make this unit perfect for all weathers. Krypton bulb. 4 D cells required. **Powerbeam lamp £29 ref PB1**

GIANT SCREEN VIEWER Turn your TV picture into a supersize screen! This high precision Fresnel lens converts even the smallest screen up to a massive 26", giving a crystal clear picture at a fraction of the cost of a big TV. Easily fitted in minutes. Also ideal for PC monitors etc £26.95 ref SVGA2

NOGALIGHT NIGHT VISION £129 Open up a new world of adventures and experiences. Wildlife enthusiasts and adventurers in the wilderness, amateur astronomers, hunters, wargamers, private eyes on surveillance, all find Nightspy indispensable for their use. Nightspy's unique features include a special tube protection device, to eliminate over exposure, and infrared illuminator used in total darkness, such as in cave exploration and operations in dark rooms. The Nightspy is light and hand held, or can be mounted on a standard tripod. It uses two standard AA batteries and can be operated by left or right hand users, with or without optical glasses. Optical Magnification: X 1.7 Field of View: 10Degrees Focusing Range: 25cm to infinity objective Focal Length: 50 mm F/N: 1.6 Diopter Range: +/- 3 Mechanical Length: 182 mm Width: 65mm Height 100 mm Weight 700 gr. Electrical: Power Source: 3 VDC, 2AA batteries Battery Life: 40 hours Infra-red Illuminator: built-in Imaging Device: Night Vision Image Intensifier Tube. **£129 ref NOGA**

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12VDC 40MM FANS MADE BY PANAFLO, NEW, £4, REF FAN12

ELECTRONIC SPEED CONTROLLER KIT For the above motor is £19 ref MAG17. Save £5 if you buy them both together, 1 motor plus speed controller rrp is £41, offer price £36 ref MOT5A

RUSSIAN 900X MAGNIFICATION ZOOM MICROSCOPE metal construction, built in light, mirror etc. Russian shrimp farm!, group viewing screen, lots of accessories. £29 ref ANAYLT.

AA NICAD PACK Pack of 4 tagged AA nicads £2.99 ref BAR34

RUSSIAN NIGHTSIGHTS Model TZS4 with infra red illuminator, views up to 75 metres in full darkness in infrared mode, 150m range, 45mm lens, 13 deg angle of view, focussing range 1.5m to infinity. 2 AA batteries required. 950g weight. £199 ref BAR61. 1 years warranty

LIQUID CRYSTAL DISPLAYS Bargain prices,
20 character 2 line, 83x19mm £3.99 ref SMC2024A
16 character 4 line, 62x25mm £5.99 ref SMC1640A

TAL-1, 110MM NEWTONIAN REFLECTOR TELESCOPE Russian. Superb astronomical 'scope, everything you need for some serious star gazing! up to 169x magnification. Send or fax for further information. 20kg, 885x800x1650mm ref TAL-1, £249

YOUR HOME COULD BE SELF SUFFICENT IN ELECTRICITY Comprehensive plans with loads of info on designing systems, panels, control electronics etc **£7 ref PV1**

PHOTOMULTIPLIER TUBES Boxed and unused straight from the ministry of defence. Made by EMI with a MOD part no of 10/CV/5114 and packed almost 30 years ago ! Do you have a use? do you want to count light particles? They would look nice on the mantle piece! Offered to you at £15 each (we think the MOD paid more than this is 1958! £15 each ref PM3

CLOCK CAMERA WITH AUDIO Discretely monitor living rooms, reception, office, tills or any other area. Fully working clock houses an invisible spy camera complete with audio. Complete setup includes clock, camera, microphone, clock battery, 15 metres of cable, power supply, adapter for either scart or phono. Everything you need, no soldering required. Full instructions included. Easily installed in just a few minutes. Plugs straight into VCR or TV (scart or phono) Clock camera with audio £89.95 ref CC5

AUTO RECORD KIT This automatic system will instruct your VCR to start recording when movement is detected via the PIR. Recording will stop 30 seconds after your visitor has left which saves hours of tapes as the video only records what you want to see. Complete system with PIR, will work with all remote control video recorders. £89 ref CVC2

TELEPHONE VOICE CHANGER Changes your voice to a new or unfamiliar one. Simply place over the telephone mouth piece and speak into the changer. Fully adjustable for different voices. Supplied complete with batteries, ready to go. Unit measures 90 x 60 x20mm Telephone voice changer £14.95 ref CC3

EXTERNAL CAMERA Introducing the Bulldog model 4 vandal resistant camera in heavy steel case for interior or exterior use. Top quality case housing a 420 line camera module. Each camera is supplied with a 15m cable terminating in Scart and phono plugs. Multi angle bracket for easy installation in any situation. A 12vdc psu is also included. Easily installed in a few minutes, plugs straight into VCR or TV (phono or scart). **Bargain price £89.95 ref CC1**

GIANT INSULATORS Just in this week are some giant ceramic insulators, each one measures 130mm high and about 170mm diameter, Finished in a high gloss brown and black glaze. In the base of each insulator is a threaded hole approx 1" diameter, rather like a mop/broom head thread. If you are into shortwave radio, crystal sets or high voltage experiments then these are for you. (We've got one as a door stop) Not too sure what their original purpose was, all we know is they were made for export about 25 years ago, never exported and been in store since then. **Price is £8 each ref INSX**

NATO RADIATION MONITORS Interesting new line! These are small modules that strap on your wrist (strap supplied) and monitor radiation. We have stripped one apart and they contain a small piece of "crystal" this could be something like Naphthalene or any other rare radiation sensitive crystal. When radiation strikes the crystal, it scintillates and a small amount of light is produced in the crystal in reaction to the radiation exposure. That light is then picked up by a micro pv cell measuring about 2mm square! Also in the unit is a sheet of foil, a circular metal plate (insulation between the two) and a small pair of additional parallel metal plates. NATO part no is 6665-99-225-2314 any information gratefully received!! Alternatively if you wish to buy one they are just £3 each ref NATOX

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by R1. Current also flows through D1, fixed resistor R3 and preset VR1. This allows a small current to "trickle charge" battery pack B1. B1 consists of two 4.8V nickel-cadmium units connected in series giving a nominal terminal voltage of 9.6V. When fully charged, this will rise to some 11.2V. D1 reduces the voltage available for charging to 11.3V. When the batteries are fully charged, their terminal voltage will therefore almost match that of the supply. The current will then drop to a very low value which may safely flow continuously.

When the batteries are poorly charged, their terminal voltage will be less than 9.6V and there will be a considerable difference between this and the supply voltage. This will result in a relatively large charging current. RV1 will be adjusted at the end to limit it to a suitable value. D1 also prevents current flowing back from the battery into IC1 and LED1 when the supply fails, as the voltage at IC1 output would then be zero.

Astable pulses

If the buzzer is off, a small current flows from the supply to power CMOS timer IC2. This current may be regarded as negligible and will have virtually no effect on the battery charging aspect of the circuit. IC2 is configured as an astable - that is, it provides a string of pulses from its output, pin 3, providing there is a supply to pin 8 and its reset input (pin 4) is high (that is, close to positive supply voltage). However, while a mains supply exists, no pulses will be given, because R2 allows current to flow direct from the regulator output to the base of transistor Q1, turning it on. The collector therefore goes low and keeps IC2 reset input low also. This inhibits the operation of the astable.

When the mains fails, a supply is established by the battery pack. No current enters Q1 base because the path to R2 is blocked by D1, and R4 keeps it low. The collector, hence IC2 reset input, is maintained high by resistor R5. This enables operation, the output delivers pulses and red LED2 connected to it flashes. R8 limits its operating current to a safe working value. If SW1 is in the position shown, the buzzer will also sound.

Time period

The astable time period depends on the values of C4, R6 and R7. With the specified components this will be about 0.7Hz - that is, rather more than once per second. No adjustment is provided as the exact rate is not important. There is space on the pcb to add a diode in parallel with R7. This would reduce the mark/space ratio of the pulses so that the "on" period would be much shorter than the "off" one, reducing the current requirement markedly. This also give a quieter signal, so such a diode is best used only if it is essential to extend the operating time.

To cancel the buzzer, switch SW1 to its other position. When the mains supply is restored, the buzzer is connected direct to the regulator output, and sounds continuously. This is the prompt to return the switch to "normal".

Construction

The Mains Monitor board is a single-sided PCB on which all components are mounted except for two pieces of screw terminal block, TB2 and TB3. More will be said about these later. The full component layout is shown in **figure 2**.

Begin by drilling the four mounting holes. Then solder the transformer, fuseholders, switch, terminal block TB1 and the ic socket in position. If the switch is not of the specified type, solder short pieces of wire to its three pads so that it can be mounted off-board instead. Note the two unconnected pads near the edge of the pcb. These simply provide anchorage when using the specified switch.

Solder the other components, but do not solder the batteries or LEDs in yet and do not insert IC2 into its socket. Check the orientation of bridge rectifier REC1, capacitor C1, regulator IC1, diode D1, transistor Q1 and the buzzer. The flat face of the specified regulator will be the one closest to the top edge of the PCB. Then solder the LEDs in position taking care over the polarity. Bend their end leads so that the tops are level and aligned with the centre of the switch bush. This will give a neat layout on the front panel. Adjust RV1 to approximately one-third of its total clockwise rotation (as viewed from the top edge of the PCB). If you wish to minimise the current requirement as mentioned above, connect a 1N4148 diode in parallel with R7 using the pads on the PCB. The cathode (striped) end should be connected to the lower pads, leading to IC2 pin 6.

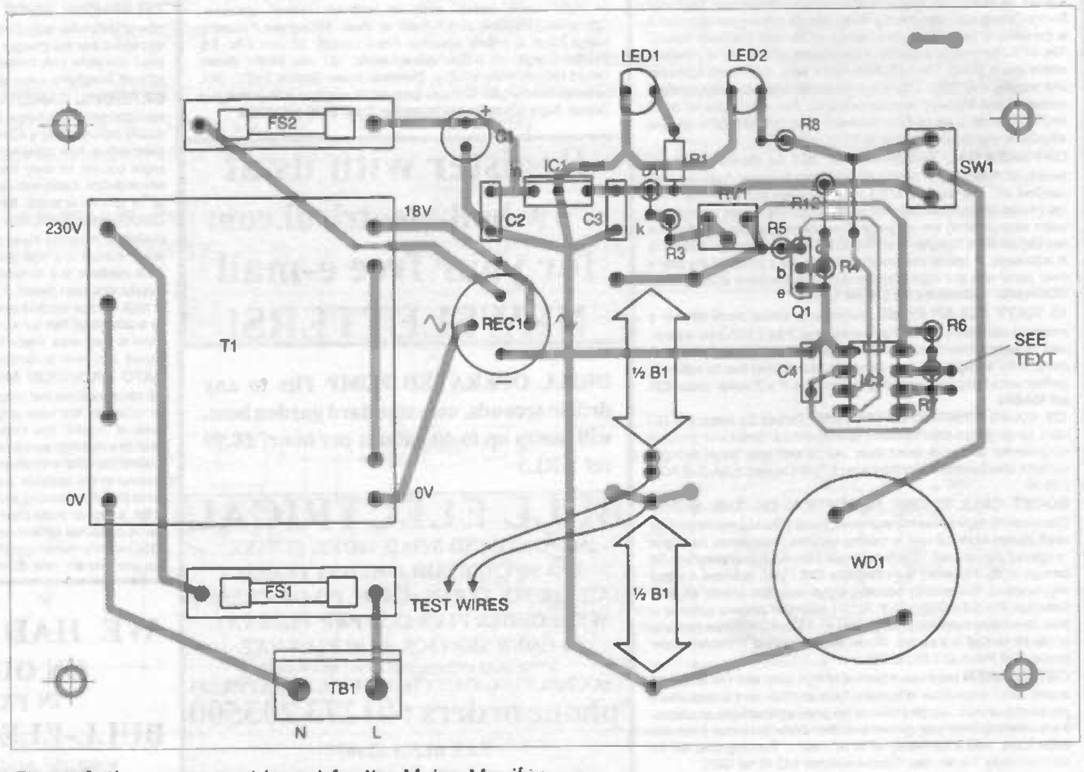
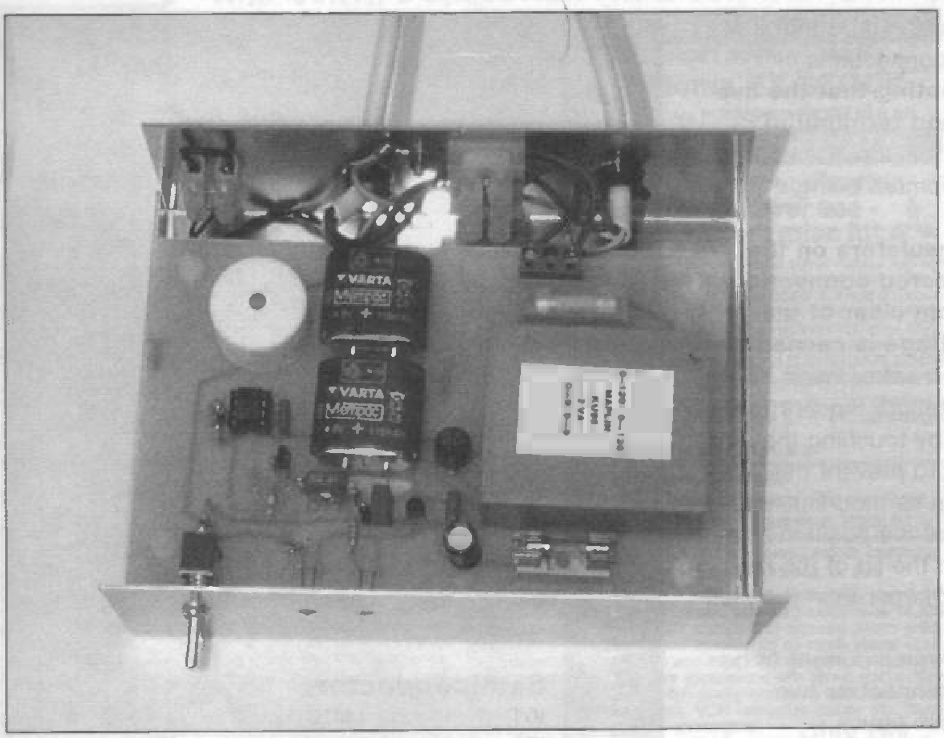


Figure 2: the component layout for the Mains Monitor



Fuse arrangements

Insert the fuses in their holders. **Note that the high-rupture ceramic type must be used in the mains fuseholder, FS1, and a plastic cover fitted to it.** This will make it impossible to touch any mains connections on the topside of the circuit panel.

Solder the batteries in place (each one is labelled "1/2 B1") taking care over the orientation. Be careful to avoid short-circuiting them, because they are likely to contain some charge and a large current could flow. A short circuit could cause a piece of wire or pcb track to overheat and burn your fingers, as well as damaging the batteries. Solder pieces of wire to the pads marked "test wires" - the battery circuit will not be complete until these have been connected together later. For the moment, do not allow this to happen by using the 2-section piece of 2A screw terminal block, TB3, without the link wire.

Making holes

Note: **This project must be housed in an earthed metal case.**

Drill holes for the strain relief bushes in the rear of the box as shown in the photograph. Drill a hole for the solder tag and attach it. Make holes for mounting terminal blocks TB2 and TB3 and attach them. TB2 consists three sections of 15A rating. TB3 has two sections of 2A rating and should be already connected to the test wires. Make sure TB3 is at least 20 mm clear of any mains connections. **It is essential to use TB3 (and not simply tape over the test wires) because it makes certain that they cannot find their way under the pcb and possibly touch mains connections.**

Place the pcb on the base of the box and support it on pieces of scrap wood of suitable thickness. It will be best if the face of the buzzer ends up near the lid of the box when this is in position, as this will give the loudest sound. Mark the positions of the holes needed in the front panel for the switch and LEDs. Remove the pcb again and drill these holes through. Hold the PCB in place and check that the switch and LEDs locate correctly in their holes. Make any adjustments as necessary so that the layout looks neat. Mark the pcb mounting holes, remove the pcb again and drill them through. This will be easier if the pcb is not actually mounted in position yet.

Finishing off

Refer to **figure 3**. Make up the input and output leads and fit them through their holes using strain relief bushes to prevent them breaking free in use - pull on the wires to check that they are secure. Wire up terminal block TB2 using 3-core wire appropriate to the load. Using a piece of mains-type earth wire, connect

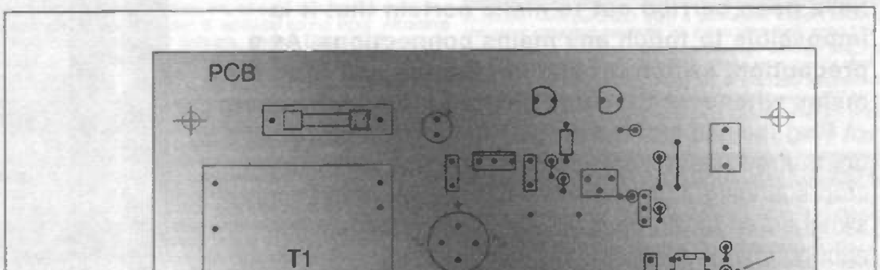


Figure 3: wiring connections to the mains

the mains earth to the solder tag making sure that it is securely attached. Make the mains connections between TB1 on the pcb and TB2 **noting that the live wire is connected to the right-hand terminal of TB1.** Fit a mains plug on the end of the input lead and insert a fuse appropriate to the equipment being connected.

Mount the PCB using plastic insulators on the bolt shanks. Make certain all soldered connections on the underside are at least 10mm clear of the metalwork - remember, mains voltage is carried on the transformer primary and FS1 tracks. Insert IC2 in its socket taking care over the orientation. Since this is a CMOS device, it could be damaged by touching the pins if static charge existed on the body. To prevent this happening, touch something which is earthed (such as a water tap) before handling it. Measure the position of the buzzer on the PCB and drill a hole in the lid of the box to correspond. This should be rather larger than the hole in the buzzer itself.

Terminal block TB3 allows the charging current to be measured. For the moment, simply connect its two sections together using a link wire (see figure 3). Providing the batteries are sufficiently well charged, the LED will begin to flash and, if the switch is on (upper position), the buzzer will sound. The warning operates because the circuit interprets the lack of a mains supply as a fault.

Testing

Do not connect the circuit to the mains unless the PCB is mounted securely in position and all checks have been carried out to make certain that it is impossible to touch any mains connections. As a precaution, switch off and unplug the unit from the mains whenever touching anything inside the case.

Plug the unit into the mains - the green LED will light up, the red one will stop flashing and the buzzer will stop sounding. If the batteries are flat, leave the supply switched on for an hour or two so that they receive enough charge to work.

You may now check the charging current by connecting a multi-tester, set to a suitable current range, to TB3. If you do not have a multi-tester, leave things as they are. To measure the current, remove the link wire and connect the multi-tester probes instead. Plug the unit into the mains and switch on. When the batteries are discharged, the current should not exceed 11mA. However, it may be as high as 20mA or so as long as it drops to 11mA or less for most of the charging cycle and remains cool. When the batteries are fully charged, the current should not exceed 1.1mA. Adjust RV1 if necessary and re-test - clockwise rotation reduces the current. When satisfied that the charging aspect of the circuit is satisfactory, replace the link wire again.

The batteries should last for several years. It will do them good, and prevent any "memory effect", to allow them to discharge completely, say, twice a year. This would also allow a check to be made on the operating time to see if there has been any deterioration. After a long period of use they will need to be replaced.

If the circuit is not to be used for a long time or the supply is going to be off for a few days, disconnect it and remove the link wire at TB3.

PARTS LIST for the Mains Monitor

Resistors

R1, R8	680R
R2	470k
R3	390R
R4	1M
R5	47k
R6	100k
R7	10M
RV1	2k2 vertical preset

Capacitors

C1	220u 25V electrolytic
C2	220n metallised polyester, 5mm pin spacing
C3	470n metallised polyester, 5mm pin spacing
C4	100n metallised polyester, 5mm pin spacing

Semiconductors

IC1	LM78L12ACZ
IC2	ICM7555IPA
Q1	ZTX300
D1	1N4001
D2	1N4148 (only if required - see text)
REC1	W005 bridge rectifier
LED1	3mm green LED
LED2	3mm red LED

Miscellaneous

T1	PCB-mounting mains transformer 2VA rating, 230V primary and twin 9V secondaries. Maplin KU95D
FS1	20mm chassis fuseholder, plastic cover and 1A ceramic mains-type fuse.
FS2	20mm chassis fuseholder, plus 200mA fuse to fit.
B1	2 x 4.8V 110mAh PCB-mounting nickel cadmium batteries Maplin BN19V
SW1	PCB-mounting SPDT toggle switch, vertical action. Maplin FA70M
BUZ1	PCB-mounting dc piezo sounder, 10mA maximum, 90bB output at 12V.
TB1	2 sections of PCB-mounting screw terminal block, 10mm spacing.
TB2	3 sections of 15A screw terminal block.
TB3	2 sections of 2A screw terminal block.

Metal box. PCB materials. 8-pin dil socket. Strain relief bushes. Solder tag.

Components for the prototype were ordered from Maplin, but most are widely available.

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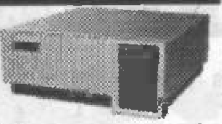

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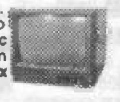

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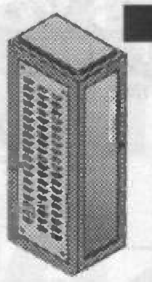

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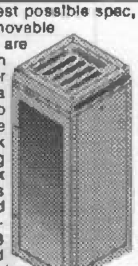

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Getting MORE out of PICs

Part 2

This month Robin Abbott looks at Diagnostics, Interrupts, and Background communications - some PIC functions that give programmers difficulty.

This month we shall take a look at a method of determining what is happening within a program while it is running on a real circuit. I shall also take a look at interrupts, and finally look at the use of interrupts on PICs which have USART support built in to perform serial communications while the main program is still running.

This month also includes a development board for the 16C74 and other 40-pin PICs on which the interrupt driven serial routines will work. All the programs given in last month's article will run directly on one of the two development boards given in this series.

Diagnostics

The PIC series (like most other microcontrollers) has comprehensive simulation support for the PC in the MPSIM and MPLAB programs. Simulators are also available from a number of third party suppliers. These are normally useful for checking program functionality, and for spotting common PIC programming errors such as stack errors, paging errors, or timing mismatches. However, simulators can never replicate the operation of real hardware such as IIC devices, or devices which operate using the SPI bus. When attempting to debug programs which use these devices, it is necessary to simulate the operation of the external devices using specific simulator mechanisms such as injection files, which operate to place bytes in to PIC memory at specific points during the simulation. However this technique cannot assist in debugging a program which does not write correctly to the external device.

In this circumstance is necessary to use alternative methods of debugging. For most amateur developers the cost of a true in-circuit emulator is impractical, and pseudo-emulators do not often replicate all chip functions exactly. In this case the developer is left to debug the program by trial and error, or by using a development system such as the Basic Stamp, or the Forest Electronics BASIC system to develop programs in an environment which offers greater debugging capabilities before translating to assembler.

Last month we looked at a serial interface capability for the PIC. We can make use of a serial interface to assist in debugging PIC programs. We shall develop three macros which may be inserted anywhere in the PIC program, and which will transmit information over a serial port to the PC while the program is running. This can be a great help in debugging. The serial port does not have to be included on the application circuit - by use of surface mount techniques, it is possible to put the complete serial interface circuit which was presented last month into a 9-way D-Connector shell. The power supply, and the transmit and receive connections to the serial circuit are then made through four wires which connect to the application circuit using test clips. In practice it is only necessary for the PIC to connect to the serial interface circuit using the transmit line as communication can be one way. This debugging technique can be undertaken on any circuit where the PIC has at least one spare input/output connector for the serial interface.

The three macros are called _DUMP, _EXECUTION, and _SENDNUMBER. They are used as described below:

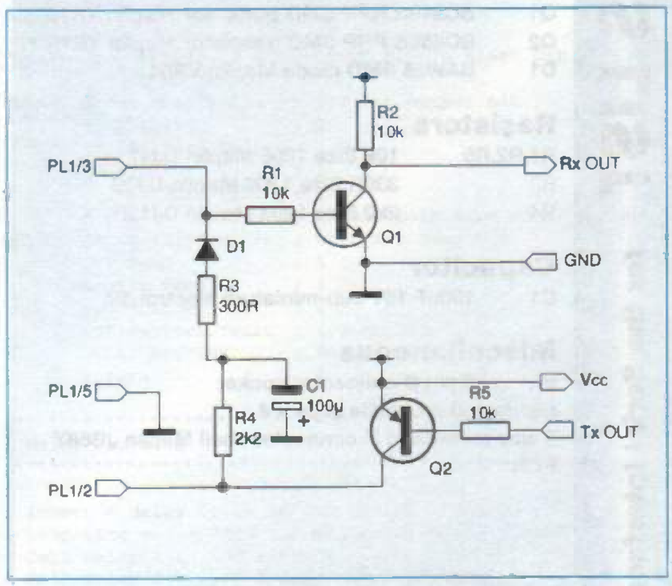

Figure 1: the circuit of the diagnostic serial interface

DUMP

This macro sends a number of bytes from PIC memory to the PC. It is used in the program with a start address and a length. For example:

_DUMP 0,0x30

This macro will send the 48 bytes from PIC memory starting at address 0. Therefore it can be used to determine the values of internal registers, and program variables during execution. In practice it is best to use this macros sparingly, as the complete program will stop for a period of 500 microseconds for each byte transmitted. I have used this macro in two ways: the first is to send variable information at specific trigger points during a program, such as when a measurement has been made. The second method is to use the macro at the start of the program before any other actions are undertaken. This is very useful for determining the values of variables at any time during a program's execution by resetting the processor (achieved by taking the reset pin to ground). Although all of the internal PIC registers will have been reset, the programs variables will hold the values they had when the processor was reset, and these values are the ones sent to the PC.

EXECUTION

This macro has no parameters. It is called as follows:

_EXECUTION

It simply sends the program address from where the macro has been executed. It is most useful to determine where a program fails. By placing a number of _EXECUTION macro calls at various points in the program, it is possible to show which points have been executed, and which have not. Therefore it is possible to find out where a program may have crashed or failed.

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SENDNUMBER

This macros has one parameter. It is called as follows:

_EXECUTION Number

When the macro is hit, the number defined is sent to the PC.

Setting up the diagnostic program

There are three component parts for serial diagnostics. The first is the serial interface, which is the only hardware necessary. The second is the diagnostic macros, which must be included within the test program. These macros use approximately 50 words of program memory, plus up to seven words of memory for each call of the macros. If the program already requires a serial interface, then some of the program memory may be reused in the main program. The last component of the diagnostics is the PC program, which takes information sent from the PIC and displays it on of the PC.

The serial interface

The serial interface is the same as that shown in last month's article. The circuit diagram is shown in **figure 1**. The circuit may be constructed on Veroboard, or the Development Board from last month's article may be used. The left hand area of the board is the serial interface. In both cases the board should be constructed with four flying leads, each of which should terminate in a small test clip. The board is connected to the application circuit by attaching the power supply leads, and the transmit (Tx Out) lead to one of the pins of the PIC.

Alternatively, the circuit may be built using surface mount techniques, and in this case may be fitted in to a 9-way connector shell. This technique is a very neat. The circuit board and its construction are described in the article on Surface Mount Technology to be found elsewhere within this magazine. The components used within the circuit are not critical, and any general purpose transistors may be used.

Incorporating the macros

To use the macros within a program, it is necessary to include an additional header file at the start of the program, and one additional code file at the end of the program.

The information transmitted by the PIC is preceded by two header bytes, and one indicator byte which shows which macro has been executed. This information is used by the PC program to a show the type of information sent by the PIC. The two header bytes are 0x19 and 0xB6. This format ensures that diagnostic information can be separated from normal program information sent by the PIC if a common serial interface is in use. Table 1 shows the information sent by the PIC for each macro type.

Figure 2 shows the header file (SERDIAG.INC), which should be included at the start of the program, and which defines the macros. There is nothing special in this file. The processor frequencies and the bit rates to be used on the serial interface are defined in this file. The DELAY macro is that shown in last month's article. The spare pin to be used for serial transmission is also defined in this file using the serport and txbit values. There are 9 bytes of program memory required by the macros, and so these are defined by the code block at the end of the header file. Please note that the code clock has no address shown, and therefore the memory variables follow those used by the application program. The application program must therefore use a code block itself, as is illustrated in the test program.

Figure 2: serial diagnostic header - SERDIAG.INC

```
;*****************************************************
; Header file for remote debugging of the application
;*****************************************************
;
; Set up the processor information
;
#define PROCFREQ .4000    ; Processor Frequency in kHz
#define BITRATE .19200    ; Baud rate in bps
BITTIME EQU    (PROCFREQ*.1000/4)/BITRATE  ; Time for a
                                            bit in cycles

RxBit       equ 2          ; Receive bit
TxBit       equ 3          ; Transmit bit
SerPort     equ PORTA      ; Serial port

_PREFIX1    equ   0x19     ; 1st header byte sent to
                           show a debugging frame
_PREFIX2    equ   0xB6     ; 2nd header byte sent to
                           show a debugging frame
;
; This macro dumps a number of bytes from memory to the
serial output pin
;
_DUMP          macro Address,Length
               movwf _SaveW
               movlw Length
               movwf _Length
               movlw Address
               movwf _Address
               call _SendBytes
               endm
;
; This macro returns the current execution address
;
_EXECUTION     macro
               movwf _SaveW
               movlw ($-1)>>8
               movwf _Length
               movlw $-3
               call _SendExec
               endm
;
; This macro sends a number
;
_SENDNUMBER    macro Number
               movwf _SaveW
               movlw Number
               call _SendW
               endm
;
; This macro delays an exact
; number of clock cycles between
; 8 at minimum or 186420 at max
;
DELAY macro Cyc
               if (Cyc<.8 || Cyc>.186420)
               error "DELAY out of range"
               exitm
               endif
               SmallCyc=Cyc
               if Cyc>.775
                BigCyc=(Cyc-.730)
                LoopDelay=BigCyc/.728
                movlw LoopDelay+1
                call BigDel
                SmallCyc=Cyc-(.730+LoopDelay*.728+3)
               endif
               LoopDelay=(SmallCyc-3)-5    ; Delay<=775 Cyc
               movlw LoopDelay/3+1
               call Delay0-LoopDelay%3
endm
;*****************************************************
; RAM variables
;*****************************************************

               cblock          ; Variables in RAM
                DelayIndex
                DelayIndexH    ; Delay variables
                RxByte         ; Serial byte received
                _Length        ; Length of memory dump
                _Address       ; Address of memory dump
                _SaveW
                Temp           ; Temporary variable
                Temp1          ; Temporary variable
                Temp2          ; Temporary variable
               endc
```

The additional code file (SERDIAG.ASM) is shown in **figure 3**. This includes the routines to transmit single bytes, and the routines to action the macros. Please note that the macros preserve all of the registers (including W), but leave memory addresses in page 0, and leaves the transmit pin in a low impedance driving state.

Figure 3: serial diagnostic code - SERDIAG.ASM

```
;*****************************************************
; Transmit and receive routines
;
; At 4MHz one cycle is 1uS. For these routines we
; will use a serial rate of 19200bps. So the time
; per bit is 52 cycle
;*****************************************************
; Wait for a byte to be received
;
; These routines are commented out because they are
; not needed for the Serial Diagnostic, uncomment if
; you want your own Serial Recieve routines
;*****************************************************

;Receive  btfsc SerPort,RxBit  ; 1/2 Wait for start bit
;          goto Receive        ; 2   Avg 1.5 cycles here

;          movlw 8             ; 1   pick up 8 bits
;          movwf Temp          ; 1
;          DELAY BITTIME*3/2-(BITTIME-7+2+4) ; Wait, middle
                                              of stop
;RxLoop   DELAY BITTIME-7      ;
;          bcf STATUS,C        ; 1   sample incoming bit
;          btfsc SerPort,RxBit ; 1
;          bsf STATUS,C        ; 1
;          rrf RxByte          ; 1   rotate data, LSB
                                     arrives first

;          decfsz Temp         ; 1
;          goto RxLoop         ; 2
;WaitEnd  btfss SerPort,RxBit  ; Wait for end of last bit
                                 if it was 0.
;          goto WaitEnd
;          movfw RxByte
;          return

;*****************************************************
; Transmit routine
;
; At 4MHz one cycle is 1uS. For these routines we
; will use a serial rate of 19200bps. So the time
; per bit is 52 cycle
;
;*****************************************************
; Transmit single character in W
;*****************************************************

TxW      movwf Temp
         movlw 9
         movwf Temp1
         bcf STATUS,C           ; first bit is start bit

TxLoop btfss STATUS,C           ; 1/2 Set output bit
         goto ZBit              ; 2
         bsf SerPort,TxBit      ; 1
         goto NBit              ; 2
ZBit     bcf SerPort,TxBit      ; 1
         nop                    ; 1 Make both arms of loop equal
NBit     DELAY (BITTIME-9)      ; Wait for next bit
         rrf Temp               ; 1
         decfsz Temp1           ; 1
         goto TxLoop            ; 2
         bsf SerPort,TxBit      ; 1 stop bit
         DELAY BITTIME          ; 50 Stay idle after Transmit
         return                 ; 2

;*****************************************************
; Delay routines
;*****************************************************
;
; Insert a delay of up to 772 Cycles
; Loop time = 5 + 3*(W-1), minimum 5
; Call Delay 1 to add 1 cycle
; Call Delay 2 to add 2 Cyc
;
; Remember it takes 2 Cycles to call this routine,
; and 1 cycle to load W before calling it
```

```
;
Delay2      nop                          ; 1
Delay1      nop                          ; 1
Delay0      movwf DelayIndex             ; 1
DelayLop decfsz DelayIndex               ; 1/2
            goto DelayLop                ; 2
            return                       ; 2
;
; Big delays need an outer loop
; This delays 730 + (W-1)*728 Cycles
;
BigDel      movwf DelayIndexH            ; 1
BDLop       movlw 0xf0                   ; 1
            call Delay0                  ; 724
            decfsz DelayIndexH           ; 1/2
            goto BDLop                   ; 2
            return                       ; 2
;***********************************************
; Serial Diagnostic routines
;***********************************************
;
; Send Header bytes - E0, E1, E2
;
; Send bytes from memory, called from macro _DUMP
;
_SendBytes  movfw FSR          ; Save FSR register
            movwf Temp2
            call init          ; Initialise Serial o/p
            movlw 0xE0
            call TxW
            movfw _Length
            call TxW           ; Send the length
            movfw _Address
            movwf FSR
            call TxW           ; Send the address
_SendLop1   movfw 0
            call TxW
            incf FSR
            decfsz _Length     ; And loop Length times
            goto _SendLop1
            movfw Temp2
            movwf FSR
_RestW      movfw _SaveW
            return
;
; Send Execution address, called from macro _EXECUTION
;
_SendExec   movwf _Address
            call init
            movlw 0xE1
            call TxW
            movfw _Address
            call TxW
            movfw _Length
_SendLast   call TxW
            goto _RestW
;
; Send Number
;
_SendW      movwf _Length
            call init
            movlw 0xE2
            call TxW
            movfw _Length
            goto _SendLast

;
; Set Serial port bit as output
;
init        bsf SerPort,TxBit
            bsf STATUS,RP0
            movlw ~(1<<TxBit)    ; set transmit output
            andwf SerPort
            bcf STATUS,RP0
            movlw _PREFIX1
            call TxW
            movlw _PREFIX2
            goto TxW
```

Figure 4 shows a test program which executes all three macros when the processor is reset. This program uses bit 3 of port A for transmission. This program may be run directly on a PIC16C84 or PIC16F84 on last month's development board.

Figure 4: test program for diagnostic macros

```
#ifndef __PICDE
Processor 16F84
#include "P16f84.inc"
#endif

            cblock 0x0c        ; Must set up cblock address
            endc

#include "SerDiag.inc"         ; Include this file last in the
                               include series

            org 0
            goto start

            org 4              ; Interrupts

start       clrf TMR0
            clrw
            option             ; OPTION_REG
            goto ExecTest

ExecTest    _EXECUTION         ; Return execution address

DumpTest    _DUMP 0,0x30       ; Send bottom 30 bytes from RAM

NumTest     _SENDNUMBER 0x9b ; Send a number

lop         goto lop           ; Simple Loop

            org 0x200          ; Put diagnostic routines here

#ifndef __PICDE
#include "SerDiag.asm"         ; Include at end of all
                               assembler files
end
#endif
```

Interpreting information at the PC

The information sent by the diagnostic program is useless if it cannot be interpreted by the PC. Version 3 of the PICDESIM simulator program from Forest Electronics interprets this information automatically. _DUMP macros update watch variables automatically. _EXECUTION macros cause the program to display the execution point in the correct source window.

For those who do not have PICDESIM, an alternative is presented here using BASIC. **Figure 5** shows the BASIC program which interprets the information sent by the diagnostic macros. Enter this program using a text editor, save it to the filename "DIAGNOSE.BAS", load it using the command line QBASIC DIAGNOSE and press Shift and F5 to execute it.

Figure 5: the Basic diagnostic program

```
DECLARE SUB Number ()
DECLARE SUB Execution ()
DECLARE SUB DUMP ()
DECLARE FUNCTION GetSer! ()
OPEN "COM1:19200,N,8,1,RS,DS,BIN" FOR RANDOM AS #1
CLS
PRINT "Press a key to terminate the program"

WHILE 1
 in = GetSer
 IF (last = 25 AND in = 182) THEN
  BEEP
  dtype = GetSer
  IF (dtype = 224) THEN DUMP
  IF (dtype = 225) THEN Execution
  IF (dtype = 226) THEN Number
 END IF

 last = in
WEND
```

```
SUB DUMP
 PerLine = 4
 Length = GetSer - 1: Address = GetSer
 PRINT
 PRINT "Received Memory Dump from : $"; HEX$(Address);
 " to $"; HEX$(Address + Length)
 PRINT
 FOR i = Address TO Address + Length
  IF (PerLine = 4) THEN PRINT : PerLine = 0
  x = GetSer
  PRINT "$"; HEX$(i); ": $"; HEX$(x), ;
  PerLine = PerLine + 1
 NEXT
 PRINT
END SUB

SUB Execution
 Address = GetSer: Address = Address + GetSer * 256
 PRINT
 PRINT "Execution Address hit - $"; HEX$(Address)
END SUB

FUNCTION GetSer

 WHILE LOC(1) < 1
  IF INKEY$ <> "" THEN CLOSE : END
 WEND
 a$ = INPUT$(1, #1)
 GetSer = ASC(a$)

END FUNCTION

SUB Number
 PRINT
 PRINT "Number received - $"; HEX$(GetSer)
END SUB
```

Figure 6 shows the screen dump output from this program when working with the test file of **figure 4** on the PIC16F84.

Figure 6: a screen dump from the Basic diagnostic program

```
Press a key to terminate the program

Execution Address hit - $8

Received Memory Dump from : $0 to $2F


$0: $0       $1: $72      $2: $2A      $3: $1A
$4: $4       $5: $1F      $6: $FF      $7: $0
$8: $FD      $9: $0       $A: $0       $B: $5
$C: $0       $D: $BF      $E: $FF      $F: $21
$10: $0      $11: $0      $12: $0      $13: $0
$14: $7F     $15: $0      $16: $0      $17: $0
$18: $FF     $19: $FF     $1A: $FF     $1B: $FF
$1C: $0      $1D: $F8     $1E: $99     $1F: $D9
$20: $D9     $21: $19     $22: $B6     $23: $E1
$24: $8      $25: $0      $26: $19     $27: $B6
$28: $E0     $29: $30     $2A: $0      $2B: $0
$2C: $72     $2D: $2A     $2E: $1A     $2F: $4

Number received - $9B
```

Interrupts

As this series is reviewing some techniques for the advanced use of PIC microcontrollers, the basic use of interrupts will not be considered here, however, in this brief section we shall look at some of the issues which arise with the use of interrupts in more complex programs.

The first issue is that of saving registers during an interrupt. **Figure 7** shows the standard method of saving the W register for the 16C73/74. Although Microchip identify the need for the variable W_TEMP to be defined both in bank 0 and bank 1 (and banks 2 and 3 for the 76/77 devices), this is not shown in their sample code.

Figure 7: context-saving during an interrupt

```
org 4

MOVWF W_TEMP            ;Copy W to TEMP register, could be
                        bank one or zero
SWAPF STATUS,W          ;Swap status to be saved into W
BCF STATUS,RP0          ;Change to bank zero, regardless of
                        current bank
MOVWF STATUS_TEMP       ;Save status to bank zero
                        STATUS_TEMP register
:
:(ISR)
:
SWAPF STATUS_TEMP,W     ;Swap STATUS_TEMP register into W
                        ;(sets bank to original state)
MOVWF STATUS            ;Move W into STATUS register
SWAPF W_TEMP,F          ;Swap W_TEMP
SWAPF W_TEMP,W          ;Swap W_TEMP into W
RETFIE
```

A bigger omission is that Microchip have not pointed out that the state of the PCLATH register on the occurrence of an interrupt is critical. PIC programs for the larger devices use the PCLATH register to define the top bits of the address used in goto and call instructions. For small programs this is not an issue - the PCLATH register will always point to the bottom program memory page. For larger programs the PCLATH register will be changed by the program to point to the program memory page being currently used. On interrupt the program will jump to location 4. Any jump or call made within an interrupt will cause a crash if the PCLATH register points to the wrong program memory page.

Figure 8: complete context-saving during an interrupt

```
cblock 0x20             ; Lower page
 W_TEMP
 STATUS_TEMP
 PCLATH_TEMP
 :
 : Program variables here
 :
endc

cblock 0xa0             ; Upper page
 W_TEMP                 ; Copy of lwr page
 : Program variables here
endc

org 4

MOVWF W_TEMP            ; Copy W to TEMP register, could be
                        bank one or zero
SWAPF STATUS,W          ; Swap status to be saved into W
BCF STATUS,RP0          ; Change to bank zero, regardless of
                        current bank
MOVWF STATUS_TEMP       ; Save status to bank zero
                        STATUS_TEMP register
MOVFW PCLATH            ; Save PCLATH
MOVWF PCLATH_TEMP
CLRF  PCLATH            ; Clear upper address bits
:
:(ISR) Can use any goto/call to lower memory page
routines here
:
MOVFW PCLATH_TEMP
MOVWF PCLATH
SWAPF STATUS_TEMP,W     ; Swap STATUS_TEMP register into W
                        ; (sets bank to original state)
MOVWF STATUS            ; Move W into STATUS register
SWAPF W_TEMP,F          ; Swap W_TEMP
SWAPF W_TEMP,W          ; Swap W_TEMP into W
RETFIE
```

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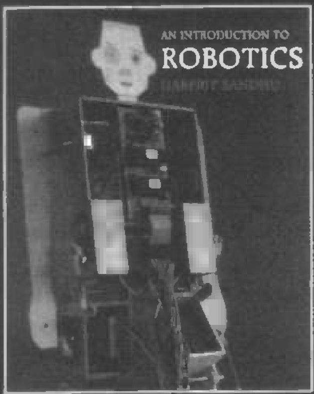

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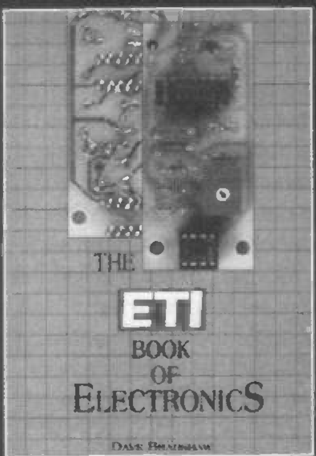

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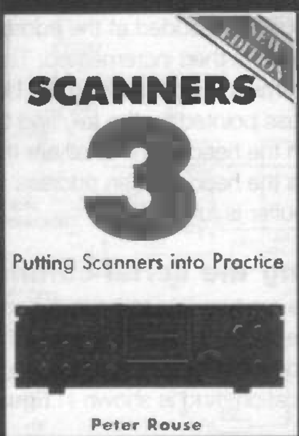

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Figure 8 shows a more complete interrupt routine which includes PCLATH saving and which should be used for all large programs including goto/call within the interrupt routines.

Another issue which should be examined carefully is the depth of the call stack. The 16Cxx PIC processors have a call stack which is only eight levels deep. In view the limited stack depth, coupled with lack of any capability to push and pop data to and from the stack is a major limitation with the PIC - it makes compiler writing considerably harder and limits the flexibility of assembler programs. In practice the limited call stack implies that calls should be restricted as far as possible within an interrupt routine, and preferably only nested to one level. When calculating stack call depths, always assume that an interrupt may occur within the lowest level of call nesting in the main program, the interrupt will use one further stack level, and any calls within the interrupt routine will use further stack locations.

Never enable interrupts within an interrupt - on any processor recursive interrupts can be difficult to handle, but on the PIC they are virtually impossible. Every interrupt call uses up all the temporary registers used to store status and W registers, and so a recursive call will overwrite previously stored values.

Finally, it probably goes without saying that an interrupt routine must not modify variables or registers modified by the main program (for example FSR), and if it does these values must be stored in temporary registers during the interrupt routine. More subtly, the main program may well read variable values which are being changed by the interrupt routine. For example, consider two variables set by the interrupt which are interdependent (for example a flag showing a new measurement has taken place and a counter of the number of values recorded). If the main program reads one value and then dependant on its value reads the second then consider what would happen if an interrupt occurred between the two reads - often program operation will be unpredictable. In this type of situation disable interrupts whilst both values are read.

Interrupt-driven serial communications

So far all of the applications that we have examined have been based on those PICs which have no built-in serial communications support. Our final look at serial communications will examine a full interrupt driven serial communications program which will run on any of the devices which have a built in USART.

The code for this program is too big to be included in this magazine article, but is available either from the ETI web site, or on the disk available from the author at the end of this series. See the note at the end of the article for details.

Within this article we shall look at the routines available, the set-up of the serial communications program, and its use in a very simple demonstration program.

Operation

While the interrupt-driven serial communications program operates in the background, the main program can run and perform normal operations, while bytes are transmitted and received from buffers automatically. There are two buffers, one for information which has been received, and one for information which is to be transmitted. As each byte is received it causes an interrupt, the interrupt routine reads the received byte from the hardware and write it to a circular buffer. Similarly as the main program requests a byte to be transmitted, it is added to the end of the transmit buffer, and is sent in turn with any other bytes due for transmission.

There are only four routines (apart from the interrupt handler) to be used within the main program. They are documented in the source code.

The first two routines return the size of the receive and transmit buffers, so that it is possible to tell if one or more bytes have been received, and if there is room to add one or more bytes to the transmit buffer. The other two routines return the next byte from the received buffer, and add a byte to the transmit power. If there is no byte waiting in the receive buffer then the routine waits until one is received, and similarly if there is no room in the transmit buffer then the transmit routine waits until a byte has been transmitted before returning.

The routines operate using Xon/Xoff signalling. This type of flow control operates using two special characters, the Xon and Xoff characters (code 0x11 and 0x13), to stop and start transmission from the other end of the serial link. The Xoff character is sent when the receive buffer is three quarters full, and the Xon character is sent when the buffer becomes three quarters empty.

To enable the Xon and Xoff characters to be sent and received in the data stream, these characters are sent using a simple protocol. If an attempt is made by the program to send Xon, Xoff, or Escape (code 0x1b) characters, then an Escape character is sent followed by the correct character with the top bit set. The receiving routine decodes the correct character whenever an Escape character is received.

The buffers used for transmission and reception are circular buffers. This type of buffer has two pointers to address it. The pointers rotate seamlessly around the buffer so that there is no end or beginning - for example, if a buffer was 4 bytes in length the address would run in sequence 0,1,2,3 and then 0 again. The first pointer is called the head, items to be added to the buffer are added at the address pointed by the head and the head is then incremented. The second pointer is called the tail, items to be taken from the buffer are read from the address pointed by the tail, and the tail is then incremented. When the head and the tail are the same, the buffer is empty. When the head is at an address which is one less that the tail, the buffer is full.

Using the serial communications program

There are two files to be included within the main program. The first is "serial.equ", which should be included after all other include files. This file will need to be modified for the application, and is shown in **figure 9**.

Figure 9: Serial.equ - include file for interrupt-driven serial routines

```
;
; Various defines
;

PROCFREQ    equ   .4000     ; Processor frequency in kHz
BITRATE     equ   .19200    ; Baud rate
XON         equ   .17       ; XON and XOFF bytes
XOFF        equ   .19
ESC         equ   .27
RXBUFSZ     equ   .32       ; Maximum number of bytes in
                            rx buf - Power of 2
TXBUFSZ     equ   .32       ; Maximum number of bytes in
                            tx buf - Power of 2
rxtab       equ   0b0h      ; Received character buffer -
                            RXBUFSZ in length
txtab       equ   0d0h      ; Transmit character buffer -
                            TXBUFSZ in length

;
; Calculate the values of BRGH bit, and SPBRG
;
SPLOW       equ  (PROCFREQ*.1000)/(BITRATE*.64)-1
```

```
SPHIGH      equ (PROCFREQ*.1000)/(BITRATE*.16)-1
#if SPLOW>.25
 DEFSPBRG   equ   SPLOW    ; Serial port bit rate generator
 BRGHVALUE  equ   0
#else
 DEFSPBRG   equ   SPHIGH   ; Serial port bit rate generator
 BRGHVALUE  equ   1
#endif

;
; Variables used in serial routines
;
cblock 20h
 sertemp          ; Temporary variable, may be used elsewhere
 rxhead           ; Pointer to head of receive buffer
 rxtail           ; Pointer to tail of receive buffer
 txhead           ; Pointer to head of transmit buffer
 txtail           ; Pointer to head of transmit buffer
 serflags         ; Serial flags register
 intw             ; stores W in interrupt -
                  DO NOT USE ELSEWHERE
 intflags         ; stores flags in interrupt -
                  DO NOT USE ELSEWHERE
 tempint          ; Temporary store used in interrupt routine
 - DO NOT USE ELSEWHERE
 intfsr           ; Stores fsr in interrupt register -
                  DO NOT USE ELSEWHERE
endc
;
; Flag bit definitions within the serflags byte
;
XOFFSENT    equ  0   ; An XOFF has been sent
XOFFRX      equ  1   ; An XOFF has been received
SENDXON     equ  2   ; Command tx routine to send XON now
SENDXOFF    equ  3   ; Command tx routine to send XOFF now
ESCRX       equ  4   ; An escape character has just been
                     received
;
; Serial transmit and receive bits on PORT C
;
txv         equ  40h
rxv         equ  80h
```

The processor frequency in kHz, and the bit rate in bits per second are entered in the lines which start PROCFREQ and BITRATE. In the example these are set to 4MHz and 19200bps respectively.

The receive and transmit buffer sizes are set up by using RXBUFSZ and TXBUFSZ. These buffers must be a power of 2 in size. Typically the transmit buffer may be 8 bytes and the receive buffer 32 bytes (note that if a PC is used with a receive buffer of less than 128 bytes, the buffer size at which the XOFF character is sent may need to be changed to one-third of the buffer size as the PC serial card has a built-in buffer of 16 bytes which may be sent even after the PC receives an XOFF character).

The start addresses of the receive and transmit buffers must also be defined using the rxtab and txtab lines. These may be in the upper memory page.

The demonstration program is included with the sample files and is called demo.asm. The main loop of the program is only three words long and simply receives bytes and transmits them straight back to the PC. The main loop is:

```
infloop:  call waitrx    ; Wait for a byte to be received
          call addtx     ; Transmit it
          goto infloop   ; and loop
```

Development board for the 16C74

The demonstration serial interrupt program operates on the 16C74 device. Last month we presented a development board for the 16C84, this month we shall show a board for the 16C74, which includes a serial interface for communications

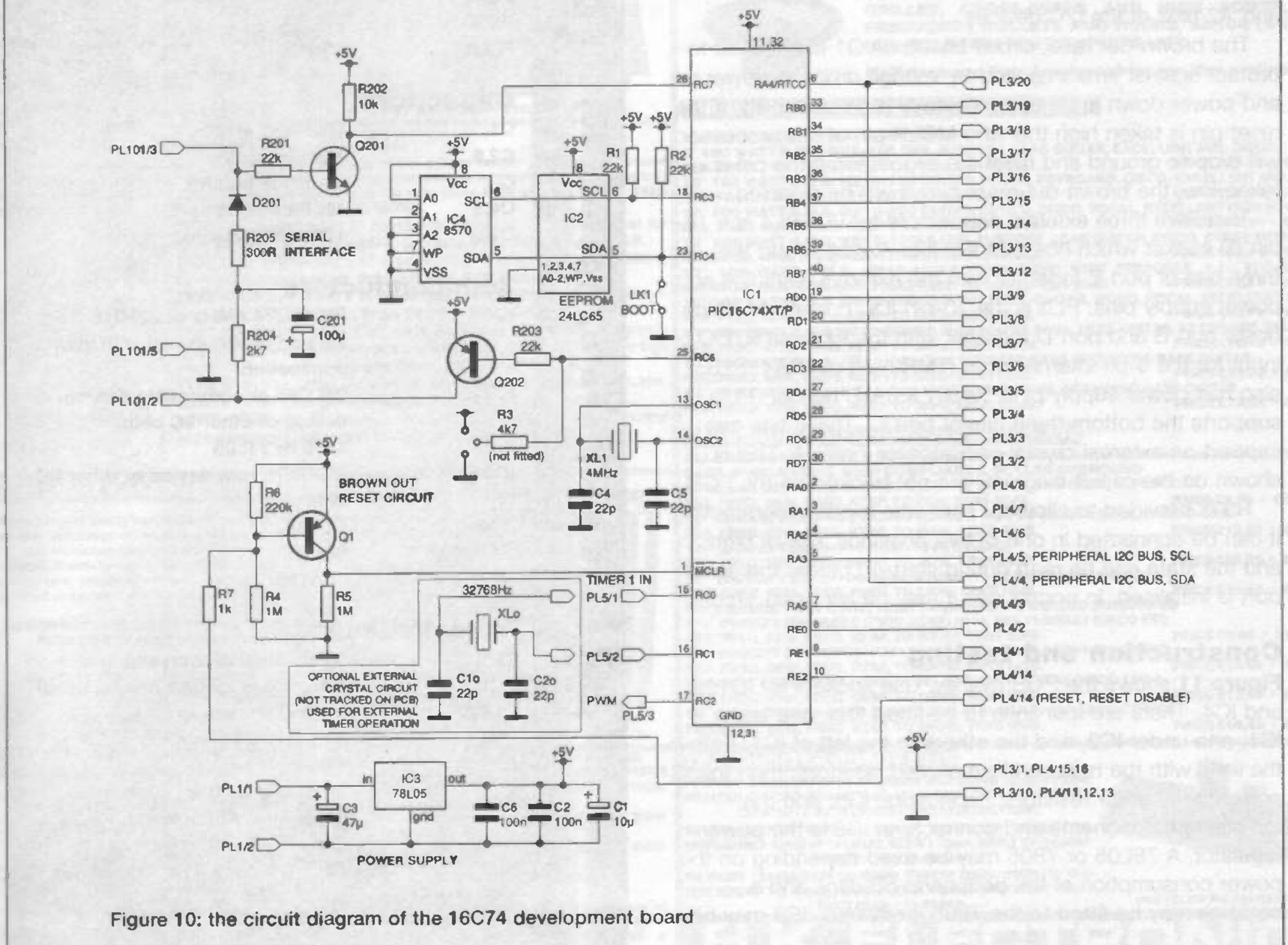


Figure 10: the circuit diagram of the 16C74 development board

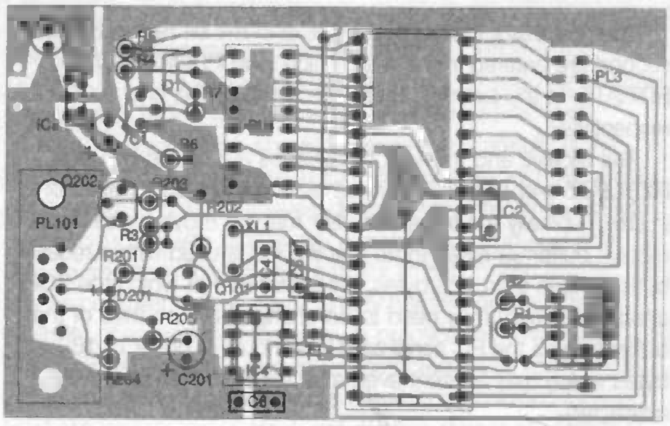


Figure 11: the pcb layout of the 16C74 development board

using the built in USART, and two sockets for IIC devices. This board was originally presented as part of the ETI Basic Controller series in 1995.

Figure 10 shows the circuit diagram of the 16C74 development board. Port C is used on the processor for the support circuitry, as this is the port used by most of the peripherals on the 16C74. The 16C74 uses the upper bits of port C for the serial interface to connect to the internal USART.

The IIC devices (IC2 and IC4) are an eeprom and a static ram supported on port C pins RC3 and RC4, however any IIC devices with the same pin-out could be supported on this port. A later article in this series will show the use of the IIC port in PIC controllers. The static ram is an 8 pin device, the Philips 8570, 256 x 8 static rams. The eeprom IC2 is connected to be at address 0 on the I2C bus, and the static ram is at address 1. This is achieved by using the A0, A1 and A2 pins of the I2C devices.

The brown-out reset circuit based on Q1 is provided to protect against errors caused by voltage drops in power up and power down and has an external reset capability. If the reset pin is taken high then the MCLR pin of the processor will drop to ground and reset the processor. If the pin is taken low, the brown-out reset circuit will be disabled.

There are three external connectors for I/O. PL4 is a 16-pin dil socket which hosts all five bits of port A and the three bits of port E together with the external reset line and power supply pins. PL3 is the 20-pin IDC connector which hosts port B and port D together with the external RTCC input for the 8-bit internal timer (TMR0) on pin RA4. PL3 also has power supply pins. Finally a 3-pin header (PL5) supports the bottom three bits of port C. These bits can support an external crystal oscillator for Timer 1. This is shown on the circuit diagram, but not tracked on the PCB.

R3 is provided to allow for hardware mode programming. It can be connected in one of two positions, low or high, and the state can be read during start-up before the serial port is initialised. In normal use it may be left open circuit.

Construction and testing

Figure 11 shows the PCB overlay. Use sockets for IC1, IC2 and IC4. There are four links to be fitted first, one under IC1, one under IC2, and the others to the left of IC1. Follow the links with the horizontally mounted resistors, then the IC sockets, the other resistors, capacitors, IC3, and the remaining components and connectors. IC3 is the power regulator. A 78L05 or 7805 may be used depending on the power consumption of the peripheral circuitry, and a heatsink may be fitted to the 7805 if required. IC3 may be removed altogether if an external regulated supply is available.

Before inserting any ICs, connect the power supply and check the voltages on the power supply pins of IC1, IC2 and IC3. Power down and insert those ICs which are to be used (note that the orientation of IC2 is opposite to that of IC4), power up, connect to the PC as shown in previous articles and use the serial interrupt software to confirm the operation of the module.

Next Month

In next month's article we shall look at driving LED displays - both multiplexed and non-multiplexed - directly from the PIC, and using specialist driver devices to ease the task.

Obtaining software

The Software listings for this month's and last month's articles are available from the ETI web site at www.aaelectron.co.uk, and will be available on a disk from the author at the end of the series.

PARTS LIST for the 16C74 development board

Resistors

All 5 percent unless otherwise stated

R1,2	22k
R3 (not fitted)	4k7
R4,R5	1M
R6	220k
R7	1k
R201	22k
R202	10k
R203	22k
R204	2k7
R205	300R

Capacitors

C1	10uF 16V electro
C2,6	100n ceramic
C3	47uF 10V electro
C4,5	15pF ceramic
C201	100uF 10V electro

Semiconductors

IC1	PIC16C74 4MHz or 20MHz version programmed with your application!
IC2	24LC65 or compatible eeprom device or other IIC chip
IC3	7805 or 78L05
IC4 (optional)	PCF8570 ram device or other IIC chip
Q201	BC548
Q1, Q202	BC557
D201	1N4148

Miscellaneous

XL1	4MHz or 20MHz crystal
PCB	(ceramic resonator can be used)
PL101	9-pin D socket
PL3	20-pin IDC connector
PL4	16-pin dil socket
PL5	3-pin header link
LK1	0.1-in link with jumper
IC sockets	2 x 8-pin, 1 x 40-pin
Veropins	x2
Heatsink	optional for IC3

POWER AMPLIFIER MODULES-TURNTABLES-DIMMERS-LOUDSPEAKERS-19 INCH STEREO RACK AMPLIFIERS

★ PRICES INCLUDE V.A.T. ★ PROMPT DELIVERIES ★ FRIENDLY SERVICE ★ LARGE (A4) S.A.E. 60p STAMPED FOR CATALOGUE ★

OMP MOS-FET POWER AMPLIFIERS
HIGH POWER, TWO CHANNEL 19 INCH RACK

THOUSANDS PURCHASED BY PROFESSIONAL USERS

THE RENOWNED MXF SERIES OF POWER AMPLIFIERS

FOUR MODELS:- MXF200 (100W + 100W) MXF400 (200W + 200W) MXF600 (300W + 300W) MXF900 (450W + 450W)

ALL POWER RATINGS R.M.S. INTO 4 OHMS, BOTH CHANNELS DRIVEN

FEATURES: ★Independent power supplies with two toroidal transformers ★ Twin L.E.D. Vu meters ★ Level controls ★ Illuminated on/off switch ★ XLR connectors ★ Standard 775mV inputs ★ Open and short circuit proof ★ Latest Mos-Fets for stress free power delivery into virtually any load ★ High slew rate ★ Very low distortion ★ Aluminium cases ★ MXF600 & MXF900 fan cooled with D.C. loudspeaker and thermal protection.

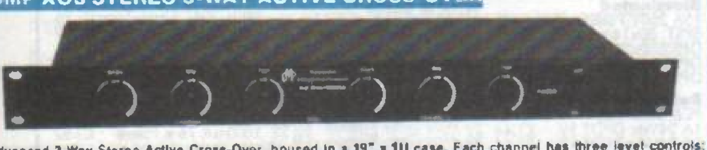
USED THE WORLD OVER IN CLUBS, PUBS, CINEMAS, DISCOS ETC.

SIZES:- MXF200 W19"xH3½" (2U)xD11"
MXF400 W19"xH5¼" (3U)xD12"
MXF600 W19"xH5¼" (3U)xD13"
MXF900 W19"xH5¼" (3U)xD14½"

PRICES:- MXF200 £175.00 MXF400 £233.85 MXF600 £329.00 MXF900 £449.15

SPECIALIST CARRIER DEL. £12.50 EACH

OMP XO3 STEREO 3-WAY ACTIVE CROSS-OVER



Advanced 3-Way Stereo Active Cross-Over, housed in a 19" x 1U case. Each channel has three level controls: bass, mid & top. The removable front fascia allows access to the programmable DIL switches to adjust the cross-over frequency: Bass-Mid 250/500/800Hz. Mid-Top 1.8/3/5KHz. all at 24dB per octave. Bass invert switches on each bass channel. Nominal 775mV input/output. Fully compatible with OMP rack amplifier and modules.

Price £117.44 + £5.00 P&P

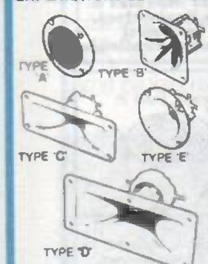
STEREO DISCO MIXER SDJ3400S
★ ECHO & SOUND EFFECTS★

STEREO DISCO MIXER with 2 x 7 band L & R graphic equalisers with bar graph LED Vu meters. MANY OUTSTANDING FEATURES:- including Echo with repeat & speed control, DJ Mic with talk-over switch, 6 Channels with individual faders plus cross fade, Cue Headphone Monitor. 8 Sound Effects. Useful combination of the following inputs:- 3 turntables (mag), 3 mics, 5 Line for CD, Tape, Video etc.

Price £144.99 + £5.00 P&P SIZE: 482 x 240 x 120mm

PIEZO ELECTRIC TWEETERS - MOTOROLA

Join the Piezo revolution! The low dynamic mass (no voice coil) of a Piezo tweeter produces an improved transient response with a lower distortion level than ordinary dynamic tweeters. As a crossover is not required these units can be added to existing speaker systems of up to 100 watts (more if two are put in series. FREE EXPLANATORY LEAFLETS ARE SUPPLIED WITH EACH TWEETER.



TYPE 'A' (KSN1036A) 3" round with protective wire mesh. Ideal for bookshelf and medium sized Hi-Fi speakers. Price £4.90 + 50p P&P.

TYPE 'B' (KSN1005A) 3½" super horn for general purpose speakers, disco and P.A. systems etc. Price £5.99 + 50p P&P.

TYPE 'C' (KSN1016A) 2"x5" wide dispersion horn for quality Hi-Fi systems and quality discos etc. Price £6.99 + 50p P&P.

TYPE 'D' (KSN1025A) 2"x6" wide dispersion horn. Upper frequency response retained extending down to mid-range (2KHz). Suitable for high quality Hi-Fi systems and quality discos. Price £9.99 + 50p P&P.

TYPE 'E' (KSN1038A) 3¾" horn tweeter with attractive silver finish trim. Suitable for Hi-Fi monitor systems etc. Price £5.99 + 50p P&P.

LEVEL CONTROL Combines, on a recessed mounting plate, level control and cabinet input jack socket. 85x85mm. Price £4.10 + 50p P&P.

ibl FLIGHT CASED LOUDSPEAKERS

A new range of quality loudspeakers, designed to take advantage of the latest speaker technology and enclosure designs. Both models utilize studio quality 12" cast aluminium loudspeakers with factory fitted grilles, wide dispersion constant directivity horns, extruded aluminium corner protection and steel ball corners, complimented with heavy duty black covering. The enclosures are fitted as standard with top hats for optional loudspeaker stands.

POWER RATINGS QUOTED IN WATTS RMS FOR EACH CABINET
FREQUENCY RESPONSE FULL RANGE 45Hz - 20KHz

ibl FC 12-100WATTS (100dB) PRICE £159.00 PER PAIR
ibl FC 12-200WATTS (100dB) PRICE £175.00 PER PAIR

SPECIALIST CARRIER DEL. £12.50 PER PAIR

OPTIONAL STANDS PRICE PER PAIR £49.00
Delivery £6.00 per pair

IN-CAR STEREO BOOSTER AMPS

THREE SUPERB HIGH POWER CAR STEREO BOOSTER AMPLIFIERS

150 WATTS (75 + 75) Stereo, 150W Bridged Mono
250 WATTS (125 + 125) Stereo, 250W Bridged Mono
400 WATTS (200 + 200) Stereo, 400W Bridged Mono
ALL POWERS INTO 4 OHMS

Features:
★ Stereo, bridgable mono ★ Choice of high & low level inputs ★ L & R level controls ★ Remote on-off ★ Speaker & thermal protection.

PRICES: 150W £49.99 250W £99.99 400W £109.95 P&P £2.00 EACH

OMP MOS-FET POWER AMPLIFIER MODULES
SUPPLIED READY BUILT AND TESTED.

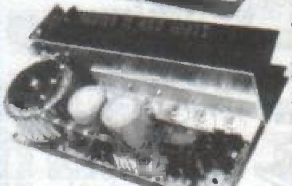
These modules now enjoy a world-wide reputation for quality, reliability and performance at a realistic price. Four models are available to suit the needs of the professional and hobby market i.e. Industry, Leisure, Instrumental and Hi-Fi etc. When comparing prices, NOTE that all models include toroidal power supply, integral heat sink, glass fibre P.C.B. and drive circuits to power a compatible Vu meter. All models are open and short circuit proof.

THOUSANDS OF MODULES PURCHASED BY PROFESSIONAL USERS

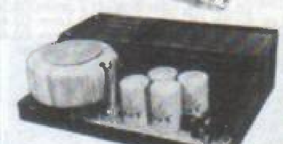
OMP/MF 100 Mos-Fet Output power 110 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 45V/uS, T.H.D. typical 0.002%, Input Sensitivity 500mV, S.N.R. -110 dB. Size 300 x 123 x 60mm.
PRICE £40.85 + £3.50 P&P

OMP/MF 200 Mos-Fet Output power 200 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 50V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB. Size 300 x 155 x 100mm.
PRICE £64.35 + £4.00 P&P

OMP/MF 300 Mos-Fet Output power 300 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 60V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB. Size 330 x 175 x 100mm.
PRICE £81.75 + £5.00 P&P



OMP/MF 450 Mos-Fet Output power 450 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 75V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay. Size 385 x 210 x 105mm.
PRICE £132.85 + £5.00 P&P



OMP/MF 1000 Mos-Fet Output power 1000 watts R.M.S. into 2 ohms, 725 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 75V/uS, T.H.D. typical 0.002%, Input Sensitivity 500mV, S.N.R. -110 dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay. Size 422 x 300 x 125mm.
PRICE £259.00 + £12.00 P&P

NOTE: MOS-FET MODULES ARE AVAILABLE IN TWO VERSIONS: STANDARD - INPUT SENS 500mV, BAND WIDTH 100KHz. PEC (PROFESSIONAL EQUIPMENT COMPATIBLE) - INPUT SENS 775mV, BAND WIDTH 50KHz. ORDER STANDARD OR PEC.

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LARGE SELECTION OF SPECIALIST LOUDSPEAKERS AVAILABLE, INCLUDING CABINET FITTINGS, SPEAKER GRILLES, CROSS-OVERS AND HIGH POWER, HIGH FREQUENCY BULLETS AND HORNS, LARGE (A4) S.A.E. (60p STAMPED) FOR COMPLETE LIST.

McKenzie and Fane Loudspeakers are also available.

EMINENCE:- INSTRUMENTS, P.A., DISCO, ETC

ALL EMINENCE UNITS 8 OHMS IMPEDANCE

8" 100 WATT R.M.S. ME8-100 GEN. PURPOSE, LEAD GUITAR, EXCELLENT MID, DISCO.
RES. FREQ. 72Hz, FREQ. RESP. TO 4KHz, SENS 97dB. PRICE £32.71 + £2.00 P&P

10" 100 WATT R.M.S. ME10-100 GUITAR, VOCAL, KEYBOARD, DISCO, EXCELLENT MID.
RES. FREQ. 71Hz, FREQ. RESP. TO 7KHz, SENS97dB. PRICE £33.74 + £2.50 P&P

10" 200 WATT R.M.S. ME10-200 GUITAR, KEYB'D, DISCO, VOCAL, EXCELLENT HIGH POWER MID.
RES. FREQ. 65Hz, FREQ. RESP. TO 3.5KHz, SENS 99dB. PRICE £43.47 + £2.50 P&P

12" 100 WATT R.M.S. ME12-100LE GEN. PURPOSE, LEAD GUITAR, DISCO, STAGE MONITOR.
RES.FREQ. 49Hz, FREQ. RESP. TO 6KHz, SENS 100dB. PRICE £35.64 + £3.50 P&P

12" 100 WATT R.M.S. ME12-100LT (TWIN CONE) WIDE RESPONSE, P.A., VOCAL, STAGE MONITOR. RES. FREQ 42Hz, FREQ. RESP. TO 10KHz, SENS 98dB. PRICE £36.67 + £3.50 P&P

12" 200 WATT R.M.S. ME12-200 GEN. PURPOSE, GUITAR, DISCO, VOCAL, EXCELLENT MID.
RES. FREQ. 58Hz, FREQ. RESP. TO 6KHz, SENS 98dB. PRICE £46.71 + £3.50 P&P

12" 300 WATT R.M.S ME12-300GP HIGH POWER BASS, LEAD GUITAR, KEYBOARD, DISCO ETC.
RES. FREQ. 47Hz, FREQ. RESP. TO 5KHz, SENS 103dB. PRICE £70.19 + £3.50 P&P

15" 200 WATT R.M.S. ME15-200 GEN. PURPOSE BASS, INCLUDING BASS GUITAR.
RES. FREQ. 46Hz, FREQ. RESP. TO 5KHz, SENS 99dB. PRICE £50.72 + £4.00 P&P

15" 300 WATT R.M.S. ME15-300 HIGH POWER BASS, INCLUDING BASS GUITAR.
RES. FREQ. 39Hz, FREQ. RESP. TO 3KHz, SENS 103dB. PRICE £73.34 + £4.00 P&P

EARBENDERS:- HI-FI, STUDIO, IN-CAR, ETC

ALL EARBENDER UNITS 8 OHMS (Except EB8-50 & EB10-50 which are dual impedance tapped @ 4 & 8 ohm)

BASS, SINGLE CONE, HIGH COMPLIANCE, ROLLED SURROUND

8" 50watt EB8-50 DUAL IMPEDENCE, TAPPED 4/8 OHM BASS, HI-FI, IN-CAR.
RES. FREQ. 40Hz, FREQ. RESP. TO 7KHz SENS 97dB. PRICE £8.90 + £2.00 P&P

10" 50WATT EB10-50 DUAL IMPEDENCE, TAPPED 4/8 OHM BASS, HI-FI, IN-CAR.
RES. FREQ. 40Hz, FREQ. RESP. TO 5KHz, SENS. 99dB. PRICE £13.65 + £2.50 P&P

10" 100WATT EB10-100 BASS, HI-FI, STUDIO.
RES. FREQ. 35Hz, FREQ. RESP. TO 3KHz, SENS 96dB. PRICE £30.39 + £3.50 P&P

12" 100WATT EB12-100 BASS, STUDIO, HI-FI, EXCELLENT DISCO.
RES. FREQ. 26Hz, FREQ. RESP. TO 3 KHz, SENS 93dB. PRICE £42.12 + £3.50 P&P

FULL RANGE TWIN CONE, HIGH COMPLIANCE, ROLLED SURROUND

5¼" 60WATT EB5-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC.
RES. FREQ. 63Hz, FREQ. RESP. TO 20KHz, SENS 92dB. PRICE £9.99 + £1.50 P&P

6½" 60WATT EB6-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC.
RES. FREQ. 38Hz, FREQ. RESP. TO 20KHz, SENS 94dB. PRICE £10.99 + 1.50 P&P

8" 60WATT EB8-60TC (TWIN CONE) HI-FI, MILTI-ARRAY DISCO ETC.
RES. FREQ. 40Hz, FREQ. RESP. TO 18KHz, SENS 89dB. PRICE £12.99 + £1.50 P&P

10" 60WATT EB10-60TC (TWIN CONE) HI-FI, MULTI ARRAY DISCO ETC.
RES. FREQ. 35Hz, FREQ. RESP. TO 12KHz, SENS 98dB. PRICE £16.49 + £2.00 P&P

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3W TRANSMITTER 80-108MHz, VARICAP CONTROLLED PROFESSIONAL PERFORMANCE, RANGE UP TO 3 MILES, SIZE 38 x 123mm, SUPPLY 12V @ 0.5AMP.
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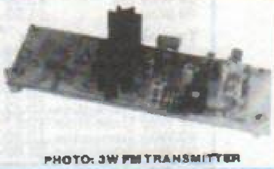

PHOTO: 3W FM TRANSMITTER

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DIY PCs

Homebuilding a PC today could be described as "easy - but with boobytraps". Robert Penfold starts this month with the basics of buying compatible parts and fitting them together.

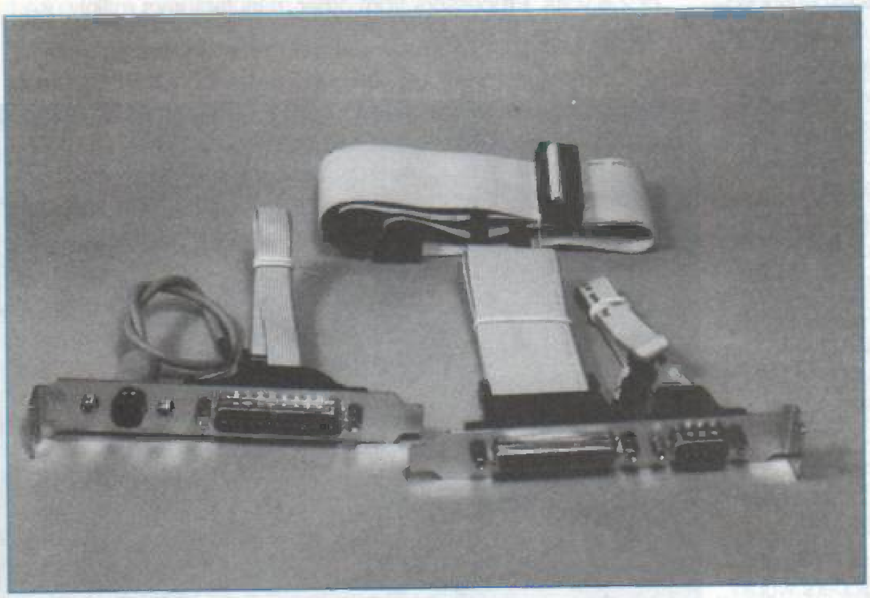
At one time custom, do-it-yourself PCs were very much the domain of the computer enthusiast, and not at all for the average PC user. Things have changed in recent years, and a fair percentage of PCs today are either home-built or upgraded by their owners to the point where they have what is virtually a home-assembled PC. Some PC market surveys seem to put home builders as a whole roughly on a par with some of the major PC manufacturers for numbers of PCs produced in the last year or two! Building up your own PC is simpler than it used to be, and the general level of computer competence has increased over the years. There are now many more people with the basic competence to undertake this type of thing.

This is not to say that anyone can successfully build and set-up their own PC. The bad news is that PC systems are not quite so "plug and go" as they are sometimes described. Actually building the computer is not very difficult at all. PCs have progressed well beyond the stage where you could seriously set about building your own circuit boards. Building a PC now is truly a matter of bolting ready-made circuit boards into a ready-made case. It is a simple assembly job that often requires nothing more than a screwdriver, and is probably easier than putting together some screw-it-yourself furniture. The skill required lies in selecting suitable components, and in getting the finished computer correctly set up and running your applications. DIY PCs are not really a practical proposition for those who are new to PCs, or even for those of limited experience. Someone who has been using PCs for a few years can sort out the minor difficulties that will inevitably arise. The same problems would probably baffle a new user.

It is only fair to point out the realities at the start. Some people undertake this task in the hope that they will save money. With careful buying from discount mail order suppliers, a DIY PC might be somewhat cheaper than a ready assembled equivalent. It should certainly cost no more. Some of the saving is because you are not paying someone to spend a few hours putting the thing together. Not paying for helplines and other customer support accounts for much of the saving but, bearing in mind that the first rule of buying PCs for the uninitiated is "buy from somewhere that provides support", you will be largely on your own if things go wrong.

Note: DIY computer building is not a suitable project for a complete novice, and also involves mains handling and static handling of expensive parts. Seek help from a more experienced colleague before undertaking any processes you are not sure about.

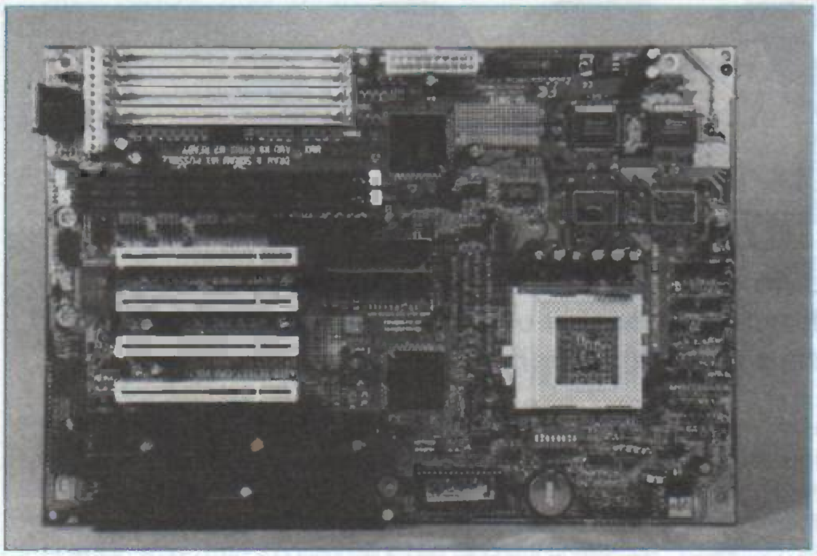
You might think that, if you choose reputable components, nothing much could go wrong, but this would be putting trust in optimism over experience! PCs are complex system and, despite increasing standardisation, they are still notorious for obscure hardware incompatibility problems. Putting together a set of perfectly functional components will not necessarily produce a totally functional PC. If you should run into this kind of problem, the supplier of the component that is giving you difficulty will almost certainly deduct a testing and restocking fee from any refund offered. If the offending part works when tried in their test computers, they will be unlikely to accept it as faulty. It is helpful if the DIY PC builder already has at least one reasonably modern PC. I recently ran into problems with memory modules that seemed to be faulty, but worked fine when tested by the supplier. When I swapped the memory from the new computer with the memory from an existing PC, they both worked fine! Juggling the components of two PCs will often banish obscure incompatibility problems.



Modern motherboards have integrtaed parts of various types. Make sure th board is supplied complete with a basic set of matching cables

The right stuff

I reckon that most PC builders fall into two basic categories: those who put a PC together from whatever they can get cheaply at the time, and those who select the components carefully for their ideal PC. Either way, but particularly with the cheap approach, you must plough quite a bit of effort into buying components that will work properly together. This is a list of the components needed to produce a fully operational multimedia PC:



This gigabyte motherboard uses the standard AT layout. The large ZIF socket is for the CPU.

A case with power supply and accessories
A motherboard with leads
A microprocessor with heatsink and fan
Memory or memories
A monitor
A video card
A 3.5-inch HD disk drive (optional but still very useful)
A hard disk drive
A CD-ROM drive
An operating system
A keyboard and mouse
A sound card and speakers

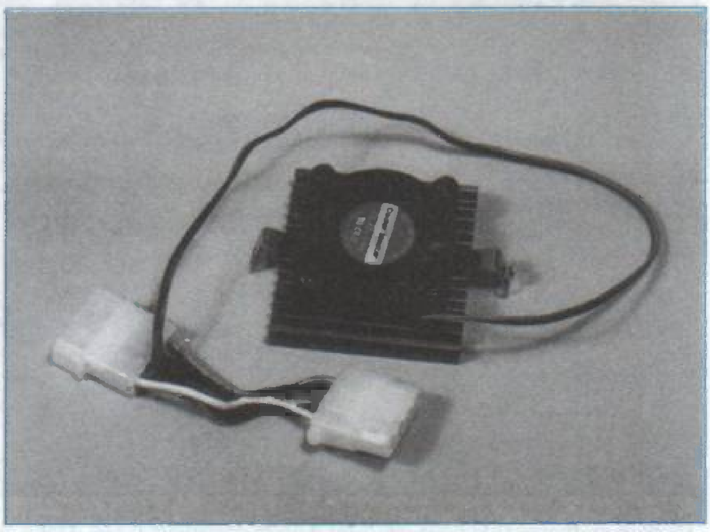
Obviously do not need the sound card and speakers if you are not into multimedia applications (or if you have a family and want a quiet life), but these days you will need the CD-ROM drive because virtually all software is supplied on CD-ROMs. Your applications will probably require further components, such as a printer or a modem, but at the moment we are only concerned with the basic PC and not with extras of this type. Obviously a lot of these components, such as the mouse and monitor, are standard items that should not give experienced computer users any trouble. Video cards are a rich source of compatibility problems. You often have the choice of ordinary PCI or AGP (advanced graphics port) versions. The AGP version is likely to give better 3D performance, but you then have to be careful with your choice of motherboard. An AGP port is not yet a standard motherboard feature.

Choosing the motherboard and processor present the main challenge. With so many different microprocessors currently available for PCs, and new ones coming along all the time, this is a confusing area. There seem to be dozens of different motherboards on offer. The safest option is to use an Intel processor and a motherboard from one of the larger manufacturers such as Gigabyte, QDI, Asus, Supermicro, and Chaintech. On the other hand, compatible processors from IBM/Cyrix and AMD have proved themselves to be very viable alternatives to the Intels. I have personally never experienced any major difficulties with inexpensive no-name motherboards, but many of these are supplied with rather limited documentation. Beginners would probably be in safer hands with well-documented products, such as those from Chaintech and Gigabyte.

There are two distinct types of Intel Pentium processor. These are the standard MMX processors, which fit into a square holder on the motherboard known as "Socket 7", and the Pentium II processors which fit into a connector that looks rather like a large memory module socket, and is known as "Slot 1". The two types of processor are not hardware-compatible, and motherboards take only one or the other. The normal Pentium II processors operate at speeds of 233, 266, 300, and 333 MHz. Two higher speed versions operating at 350 and 400 MHz have just been announced, but these chips require special motherboards that operate at 100 MHz (and a correspondingly fast memory), as opposed to the 66 MHz of the earlier Pentium II processors. The new processors and motherboards are not in the shops as I write, but the latest "turbo" technology is best left to the experts and is not really a suitable starting point.

Intel is expected to kill off its "socket 7" processors by the end of this year, and replace them with low-cost Pentium II processors (the "Celeron" processors) that lack the added 512K of memory cache of the normal Pentium IIs. At the moment it is unclear how much this will affect their performance, but full Pentium II processors look like a better bet if you need any kind of high performance. Socket 7 MMX processors are an attractive proposition at present if you can get by with less than the ultimate performance. The processors and motherboards are available at very low prices, and they will run virtually all current software properly (but check when buying). Also, they use well-tried and tested technology that is less likely to produce any unpleasant surprises for the DIY PC builder.

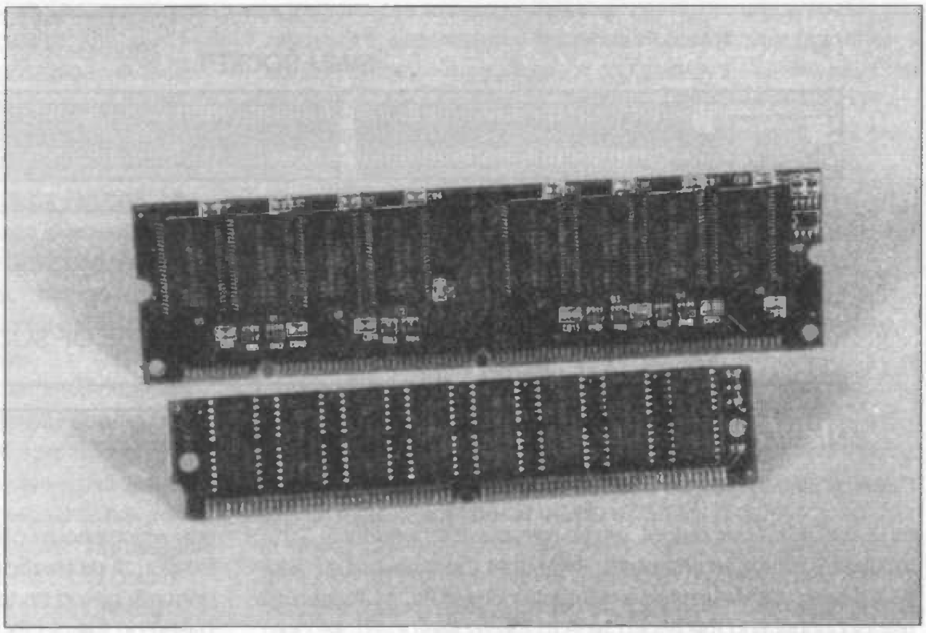
Any modern Pentium motherboard should work with Intel 166MHz, 200MHz, and 233MHz MMX processors, but if you opt for a compatible processor make sure that you do buy a motherboard that can operate with it. MMX processors operate with twin supply voltages, and the genuine Intel chips need a potential of 3.3 volts for the circuits that connect to the outside world. The main circuit of the processor requires a core voltage of 2.8 volts. Processors from other manufacturers mainly use different core voltages.



Most CPU fans tap power from a disk drive

Over-clocking

There are also differences in the clock speeds used for non-Intel processors. The subject of clock speeds often confuses newcomers to PC assembly, and one reason for this is that there are actually two clock rates within the PC. The processor operates at a clock frequency that is several times higher than the clock frequency used for the motherboard. For example, an Intel 200 MHz MMX processor operates with a motherboard clock rate of 66 MHz and so-called x3 operation. In other words, the processor is clocked at a rate that is three times higher than the motherboard clock frequency. Note that the clock speeds quoted for the IBM/Cyrix processors are not the actual clock frequencies used, but are given as a guide to the effective speed when running typical applications. For instance, the IBM/Cyrix 200 MHz MMX chip is actually clock at 150 MHz, but runs applications at a speed which is comparable to an Intel 200 MHz MMX processor. Rather unhelpfully, some of these chips exist in two versions operating with different clock speeds and (or) core voltages. Where appropriate, the chips themselves or normally marked with details of the required clock rates and operating voltages.



SDRAM in the form of 168-pin DIMMS (top) are now replacing 72-pin EDO SIMMs (bottom)

The choice of processor depends on the processing power you require and how much you are prepared to pay, but you clearly need to be careful that the motherboard you obtain is fully compatible with your processor. This is especially important with the IBM/Cyrix chips, because some of them require high motherboard clock rates that are not supported by all recent motherboards. There is a slight problem with processors that require board frequencies of more than 66MHz, which is simply that Intel VX, HX and TX support chipsets do not support these higher frequencies. There are alternative support chipsets, but many boards use the Intel chips together with so-called over-clocking. In other words, the chips are used beyond their designed maximum operating frequency. The manuals for these boards explain how to set the higher board frequencies, but usually include a disclaimer advising against doing so. In other words, you can use these boards at high clock rates if you like, but the manufacturers accept no responsibility if things go wrong. If you are going to use a processor that requires a high motherboard clock frequency, and especially if you are using one of the new Socket 7 chips that operate at more than 233MHz, the safe option is to buy the processor and motherboard as a package. Get a guarantee that they will operate properly together.

There are three normal methods of setting up the board to operate with the appropriate processor. The two old-fashioned ways are to use either jumper connectors or DIP switches. The manual for the motherboard should show how to set up the available clock frequencies and core voltage options. In most cases the settings required for each supported processor would be provided, making it easy to set up the board correctly for your chosen processor. The modern alternative is for the motherboard to automatically detect the type of processor fitted and to provide the correct settings for you. Manual control is still possible via the BIOS set-up program. I think there is no doubt that the automatic detection method is the most convenient, and I would guess that before too long practically all motherboards will use it. Incidentally, the same three methods of control are used with Slot 1 motherboards to set the clock frequencies.

All Pentium class processors consume a fair amount of power and require a heatsink and fan to prevent overheating. In general, the higher the clock frequency the larger the heatsink required. The IBM/Cyrix chips, despite their lower actual clock frequencies, require larger heatsinks than equivalent chips from other manufacturers. It is advisable to buy the heatsink and fan together with the microprocessor and an assurance from the supplier that the heatsink is adequate for the particular processor you are using. Modern motherboards have a 12-volt output for the fan, but most heatsink fans take the alternative route of taking power from one of the supply's power connectors for a 5.25-inch drive. A pass-through lead is normally included, so that the connector can supply power to both the fan and a drive.

Where it's AT

These days PC cases are normally supplied complete with a power supply unit of a fairly generous power rating of around 230 watts. Various styles of case are available, and the best type is largely a matter of personal preference. However, I would not recommend using the smallest types because these are often difficult to work on, and they can also be rather limiting due to their small number of drive bays. In the catalogues you will find AT and ATX cases listed, and it is important to understand the differences between them. AT cases are what I suppose could be regarded as the traditional PC cases, and they are equipped with standard PC power supply units. Most modern cases of this type will only accept "baby" AT motherboards, but the full-size variety is either not manufactured any more, or has become extremely hard to find; a situation which should make buyers cautious. AT cases will not normally accept ATX format motherboards.

ATX cases are primarily intended for use with ATX style motherboards, but in most cases they will also accept standard AT boards. With an AT motherboard the voltages required by the processor are provided from the +5 volt supply by an on-board voltage regulator. The power supply of an ATX

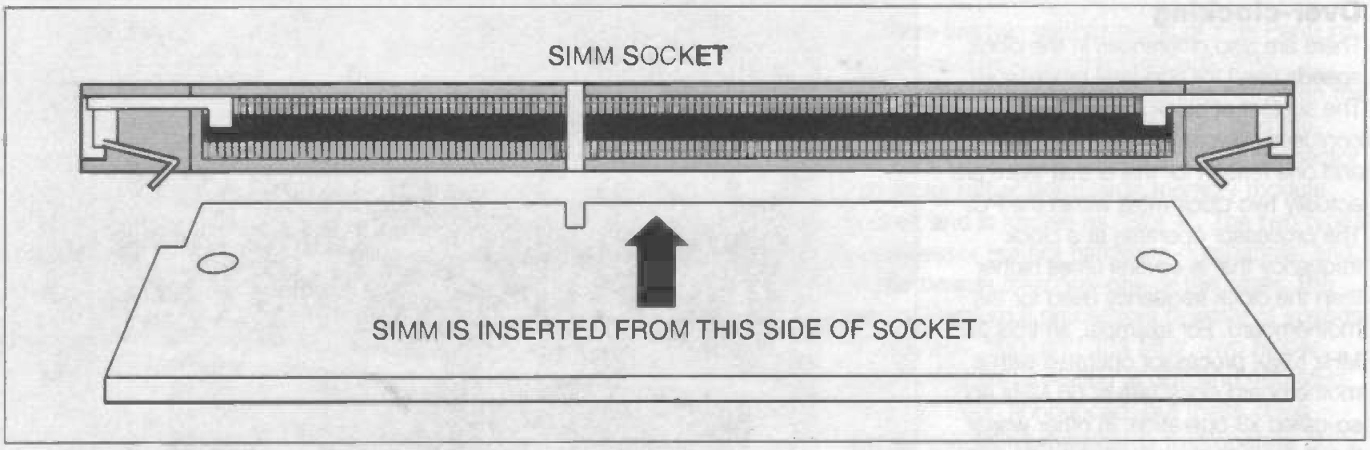


Figure 1: SIMMS must be inserted from the correct side of the socket

case has a 3.3-volt output, which reduces the need for regulators on the motherboard. Note that the standard AT and ATX power supply units use different connectors, so there is no risk of connecting the wrong type to the motherboard. Modem AT motherboards mostly have both types of connector so that they can be used with either type of supply.

Apart from differences in the power supply requirements, ATX boards differ from standard AT types in other respects. Modern motherboards have one parallel and two serial ports as standard. With AT boards, leads connect the board to the port connectors fitted on the rear of the case. Most cases have ready-made cut-outs for these connectors, but it is often more convenient to mount then in special blanking plates which can be fitted in place behind any unused or "dummy" expansion slots. In fact most motherboards are supplied complete with a basic set of leads, which includes serial and parallel port leads with connectors ready fitted into blanking plates. In most cases there is no difficulty in removing the connectors from the plates and fitting them on the rear of the case instead. This is all academic with ATX boards, since they have the serial and parallel port connectors on the rear of the motherboard, and these match up with cut-outs in the rear of the case, much like an ordinary PC keyboard connector. The interior of a PC tends to be a mass of cables, and the ATX approach eases this problem somewhat.

Another major difference between AT and ATX motherboards is that ATX boards have a totally redesigned layout. There is a slight problem when the traditional layout is applied to modern PCs with heatsinks and fans fitted to the processors. These appendages effectively increase the height of the processor, and can make it impossible to fit some of the longer expansion cards into certain of the expansion sockets. The situation is worse with Pentium II computers due to the large size of the processor, which looks more like a videocassette than an integrated circuit. The ATX layout places the microprocessor to the side of the expansion slots where it will not get in the way. The ATX layout is also supposed to make it easier to get at the memory sockets, but in practice things do not always seem to work out this way.

So far, ATX boards and cases have not been very popular, which is probably due to their relatively high cost. The price differential between AT and ATX components is now quite small, and an ATX case and motherboard probably represents the most practical choice, particularly if you are building a Pentium II computer. If you are building a PC based on a Socket 7 processor it is still probably worth using an ATX motherboard. Unless you are working on a really tight budget, it is worthwhile buying a board based on the TX support chip set, which should offer USB support and so on. Incidentally, Pentium II motherboards operating at up to 333MHz are normally based on the LX chipset, but some early designs are based on the old FX chips. It is definitely advisable to buy one of the latest LX boards, which should have "all mod cons".

Assembly

Assembling all the components should be reasonably straightforward but will be fiddly. Having nimble fingers is an asset! Bear in mind that the motherboards, processors and many of the expansion cards are static-sensitive, and that they require the same handling precautions that you would use when dealing with MOS integrated circuits in a normal project. Due to the relatively high cost of PC components it is only prudent to take more care than normal. It is probably not worthwhile paying out for expensive anti-static mats, wristbands, and so on, but it is essential to have an earthed metal worktop so that you can work safely on the motherboard. Something as basic as a large piece of metal cooking foil on the worktop is all that is needed. You can use a crocodile clip lead to earth the foil to the earth output of a bench power supply, to the metal case of a mains powered project, or any gadget that has an earthed case. It is a good idea to touch the foil occasionally, and before handling any PC components, so that any static build-up in your body is discharged to earth before it has a chance to do any harm.

It is a good idea to do as much work on the motherboard as possible before it is fixed inside the case, because the board will be much less accessible once it is in the case. Don't find out the difference the hard way if you can help it! Each situation must be taken on its own merits, but the preliminary work on the motherboard will normally include fitting the processor and memory modules, and where appropriate setting up any jumpers or DIP switches.

If you are building a Pentium II computer the motherboard will only accept DIMMs (dual in-line memory modules), but it will probably work with both EDO and SDRAM versions of these modules. There is no point in using EDO DIMMs, as they are more difficult to obtain, are likely to be more expensive, and will give inferior performance. Sockets 7 motherboards mostly have provision for four SIMMs (single in-line memory modules) or two DIMMs. The SIMM sockets will usually accept fast page memory or EDO memory, but as EDO memory is cheaper and faster there is no point in considering the fast page variety. In fact there is probably no point in using any form of SIMM memory, because SDRAM DIMMs are likely to cost no more but will give slightly better performance. Note that unbuffered, not buffered, SDRAM DIMMs are required, but this is the only type offered by most suppliers.

Fitting DIMMs is very easy, and it is impossible to fit them the wrong way round because a polarising key is cut in the circuit board. From this, and the matching bar in the DIMM socket, it is easy to determine which way around the module should go. The module simply drops into place vertically and as it is pressed down into position the plastic levers at each end of the socket should start to close up. Pressing them both into the vertical position should securely lock the module in place. Virtually all Pentium motherboards require SIMMs to be used in pairs, but DIMMs can be used singly.

SIMMs are slightly more awkward to fit and, although in theory it is impossible to fit them the wrong way around, in practice it does happen. There is the usual polarising notch in the module and key in the socket, but they are small and only slightly off-centre. Note that Pentium motherboards are only compatible with 72-pin SIMMs and that they will only take the old 30-pin variety via adapters. With the current low cost of memory there would seem to be little point in using these adapters, which have a reputation for problems. When fitting SIMMs orient the motherboard so that the sides of the sockets, which have the metal clips, are facing towards you and the plain sides are facing away from you **(figure 1)**. Take a SIMM and fit it into the first socket (the one that is furthest away from you), and note that it must be leaning toward you slightly and not fully vertical. Once it is right down into the socket it should lock into place when it is raised to the vertical position. If it will not fit into position properly it is probably the wrong way round. Turn it through 180 degrees and try again.

Unlike some previous Intel processors, the Socket 7 chips can only be fitted the right way round. If you look at the socket you will notice that one corner does not have a hole for a pin whereas the other three do. Similarly, the processor itself has a "missing" pin in one corner, and this corner of the chip is usually marked on the top surface by a dot. But be very careful when handling the processor, as getting even one pin slightly bent will prevent it from fitting into the holder. There is a large lever at one side of the socket and this must be raised to the vertical position before the processor can be fitted into place. Once aligned with the socket, the processor should drop easily into place. Once the processor is properly seated in the socket, return the lever to the horizontal position to lock it in place. The heatsink and fan have spring-clips that fit onto plastic lugs on the socket. The heatsink will sometimes be a rather lose fitting, but you will probably find that the clip can be adjusted to an alternative height setting that gives more reliable results. It is essential that the heatsink fits securely onto the socket, because the processor could easily be destroyed if the heatsink comes lose in use. Some motherboards have built-in processor temperature monitoring and safety circuits, but this is by no means a universal feature. Pentium II processors simply plug into a polarised socket that is rather like an ordinary expansion slot.

Stand-off

It is generally easier if the motherboard is fitted into the case first, and then the drives are fitted. The case should be supplied complete with fixings and stand-offs for the motherboard. In most cases there will be one or two holes in the motherboard which do not match up with fixings in the case, but provided the board is supported at about five or six points there should be no problems. Every case seems to use a slightly different mounting arrangement, so you have to use a little ingenuity (or guesswork) here. With modern cases there is no need for any mounting rails on the drives. They simply slide straight into the bays and are bolted in place using the screws supplied with the case.

Connect the power supply cables, drive cables, and so on before fitting the expansion cards, because the cards tend to severely restrict access to the interior of the case. The 3.5- and 5.25-inch drive power connectors are polarised and can not be fitted the wrong way round. The same is true of ATX motherboard power connectors. AT motherboards have two polarised power connectors, but be careful not to get them swapped over. The convention is for the four ground (black) leads to be in the middle of the line of 12 leads. The floppy drive controller is integrated with the motherboard, and the board should be supplied with a "twisted" lead for two drives. This is connected in the manner shown in **figure 2**. The two drives have the same set-up, and it is the twist in the cable that determines which is drive A and which is drive B. If only one floppy drive is fitted, simply leave the drive B connector unused. Computer data leads are made from grey ribbon cable that has a red lead at one end. The convention is for this lead to carry the pin 1 connection. The instruction manuals will indicate which pin on each connector is pin 1, but this information is usually marked on the motherboard and drives as well.

Modem motherboards have two IDE connectors that will each take two IDE devices such as hard drives and CD-ROM drives. There will probably be just one IDE data lead provided with the motherboard, but this will have connectors for two

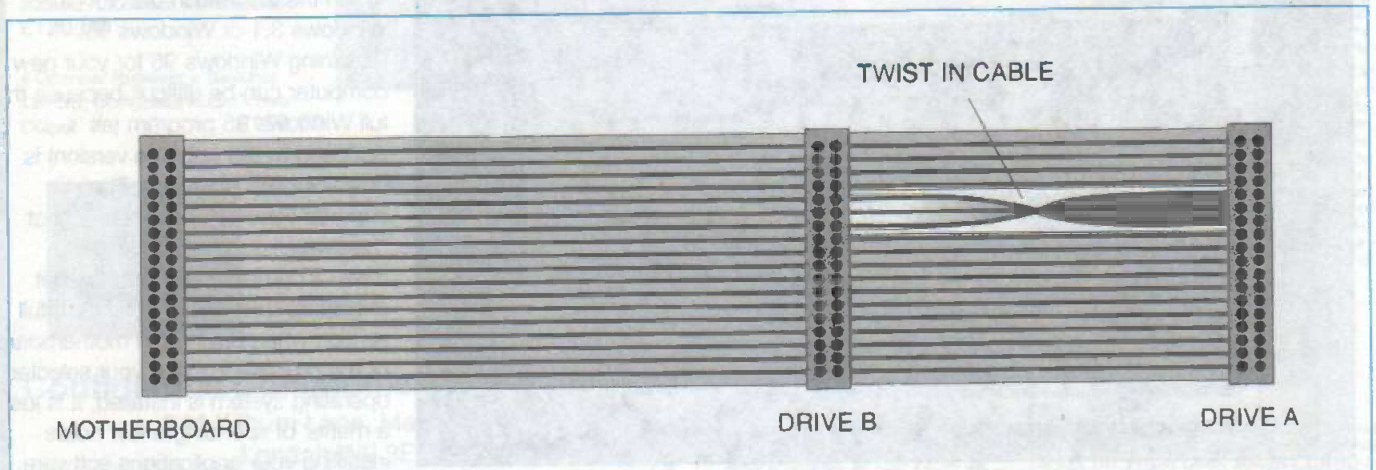


Figure 2: a twist in the data cables determines which floppy disk drive is A, and which is drive B.

drives. It does not matter which drive connects to which connector, as it is the drive settings that determine which one is the master and which is the slave. The hard drive would normally be set as the master with the CD-ROM drive its slave device. The drives' instruction manuals will give details of the jumper settings required. In theory there could be a slight advantage in buying a second data cable and installing the CD-ROM drive as the master device on the second IDE port. In practice this does not make any obvious difference in performance.

Where appropriate, the serial, parallel port and (possibly) mouse port connectors should be fitted to the case, and connected to the motherboard. The ribbon cables attached to these connectors follow the normal rule of having the red lead carry the pin 1 connection. If not marked on the motherboard itself, pin 1 of each connector should be indicated in a diagram in the manual. There are various switched and LEDs fitted to the case that must also be connected to the motherboard. These include such things as power and hard drive LEDs, and the reset switch. It is unlikely that the miscellaneous facilities of the motherboard will precisely match those of the case. The case may have a "turbo" switch and LED, but these are not usually implemented on motherboards (or do not actually do anything it they are). Some leads may therefore have to be left unconnected. Provided the computer has the power and drive LEDs, the reset switch and the loudspeaker connected, it should be perfectly usable. There may be "+" marks on the leads and motherboard connectors to indicate the LED polarities, but it is sometimes necessary to use the "suck it and see method" to get them connected the right way round. No damage will occur if you get it wrong at the first attempt.

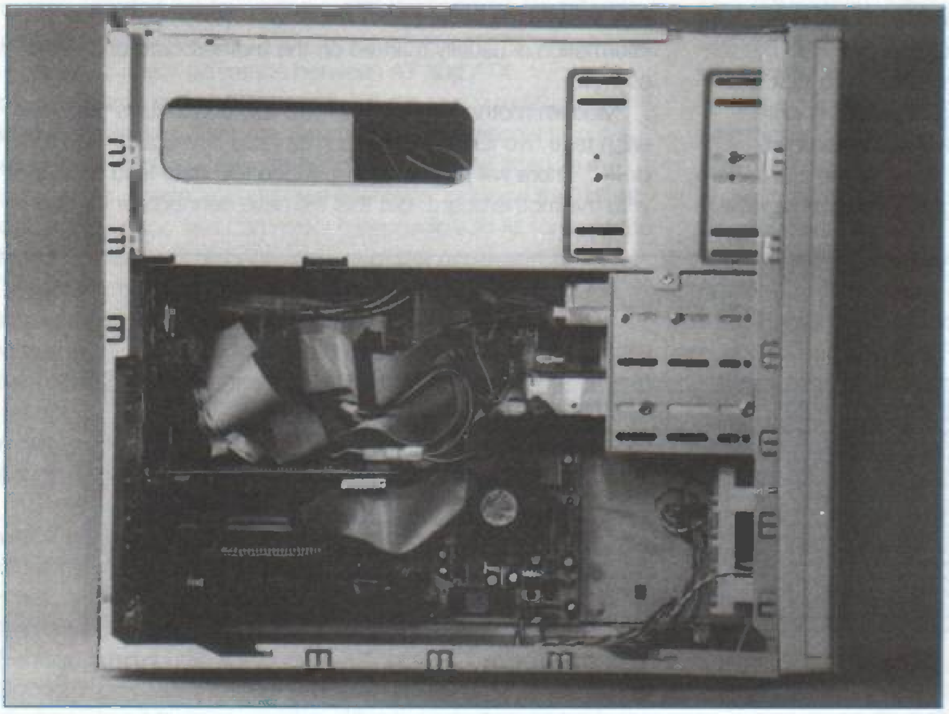
Finally, add in the expansion cards, and if you have one, fit the audio lead that connects the CD-ROM drive to the audio board. With the mouse, keyboard, monitor, and power leads connected, the computer is ready for testing. However, before switching on it would be a good idea to give everything a final check. Also, you may wish to use cable-ties or double-sided adhesive pads to stop loose cables from flapping around inside the case. **Make quite sure that there is no risk of any cables jamming in the CPU's cooling fan**. Due to the large number of leads going here, there, and everywhere, it is difficult to make the interior of the unit look really neat. Anyway, it is best not to overdo it when fixing cables to the case as this can make life difficult if you wish to make changes to the computer later on.

The BIOS

When you switch on the computer it should produce the usual start-up messages, but you should exit the start-up sequence and go into the BIOS Setup program by following the appropriate on-screen instruction (which usually tells you to press the "Del" key). A modem BIOS provides control over all manners of things, but to a large extent it is just a matter of setting the time and date, and specifying the floppy drive or drives present. The BIOS can auto-detect things like the hard drive type and the amount of memory fitted. You might have to indicate the type of memory fitted, and it might be possible to make a few improvements to the settings later on, but initially it is a good idea to let the BIOS use what it considers to be the optimum settings.

The hard disk will be supplied with the low level formatting completed, but it will need high level formatting and the operating system added. We will look at hard disk drives in detail in a subsequent article dealing with PC upgrading, but the process is quite easy. Some hard disks are supplied with software that simplifies the process, and it clearly makes sense to use this software if it is available. If not, you will need an MS/DOS or Windows 95 boot disk, which also contains the Format and Fdisk programs. Use the disk to boot-up from dive A, and then run Fdisk. This is used to partition the disk, and to set the active partition (the one that the system will boot from). Note that you must still run Fdisk even if the disk will only have a single partition, because the operating system will not accept the presence of the hard disk until Fdisk has done its stuff. When using Fdisk you simply choose the required option and follow the on-screen instructions.

Once Fdisk has processed the disk it can be high level formatted using the Format program, using the /s option to transfer the system files to the disk. It should then be possible to boot from the hard disk. Once the drivers for the mouse and CD-ROM drive have been installed it is possible to run the installation disk for Windows 3.1 or Windows 95. Obtaining Windows 95 for your new computer can be difficult because the full Windows 95 program (as opposed to the upgrade version) is only sold with hardware. The important point to note here is that "hardware" does not necessarily mean a complete computer and it should be possible to obtain the full version when buying the motherboard or the processor. Once your selected operating system is installed, it is just a matter of spending a few hours installing your applications software, and the new PC is then ready for use.



The interior of the finished PC tends to be cluttered with leads. Take particular care to secure any leads that might get into the fan

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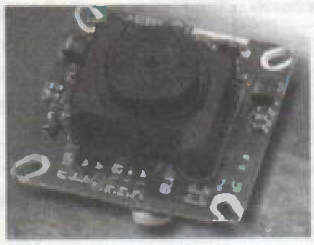

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High Quality 100W Mosfet Power Amplifier

Mosfets used in power amplifiers give rise to fewer and less severe distortion products for the designer to eliminate. As a result, a moderately complex design like this one by David N J White can perform superbly.

The original motivation for this project came from my decision to upgrade my 20-year-old hi-fi. I am still perfectly happy with my source players and loudspeakers. The rest of the system consists of a preamplifier of my own design and construction and a pair of Blomley 30W power amps. The amplifier and loudspeakers still sound fine, but the relentless improvements in semiconductors and other devices over the years prompted me to think that I could probably improve on these components in my system. An additional goad was the fact that I didn't design the power amplifiers and loudspeakers myself. I get a lot of satisfaction from the use of things that I design and build. As designing and building loudspeakers is much more difficult and expensive than doing the same for power amplifiers, I decided to tackle the amps.

My plan was to build a reasonably simple power amplifier to give excellent sonic and measured results. Using large numbers of semiconductors in pursuit of high performance is all very well, but multiple components, and complex, double-sided pcbs push up costs. I wanted another solution.

Mosfets or bjts?

My next decision was whether to use bipolar junction transistors (bjts) or mosfets as the output devices. The arguments either way are finely balanced. Power mosfets have a much better high frequency response, are easy to drive from simple voltage sources, and are not prone to thermal runaway. Power bjts suitable for high quality audio are cheaper, and give a higher power output in the emitter-follower mode than an audio mosfet in the source-follower configuration, unless recourse is made to expensive multi-rail power supplies. This is because the power mosfet gate would need to rise to around 8-10 volts above the mosfet power supply voltage in order to turn the mosfet fully on. Power bjts saturate when Vbe is around 2-3 volts at high collector currents. The output of emitter follower bjts can therefore swing closer to the power supply rails than the output of source follower mosfets, and so deliver more power into the load.

The measured performances of power amplifiers with mosfet and bjt output stages do not seem to differ greatly, so the only remaining consideration is: do they sound different? I made up a pair of the Maplin 150 W/4-ohm power amplifiers (these are very creditable performers considering their simplicity and low price) and compared them in listening tests to my bjt output-stage Blomleys. To my non-golden, but still pretty effective, ears the differences were small. The Maplins sounded a little brighter than the restrained smoothness of the Blomleys. I think this has more to do with the Maplins' wide-open bandwidth compared to the sensibly limited Blomleys than with any inherent differences in bjt and mosfet sound.

Power mosfets seem to produce power amplifier output stages that give good measured results, sound good, and have other advantages mentioned previously. I therefore decided to go with the power mosfets despite the lower cost of the roughly equivalent bjts.

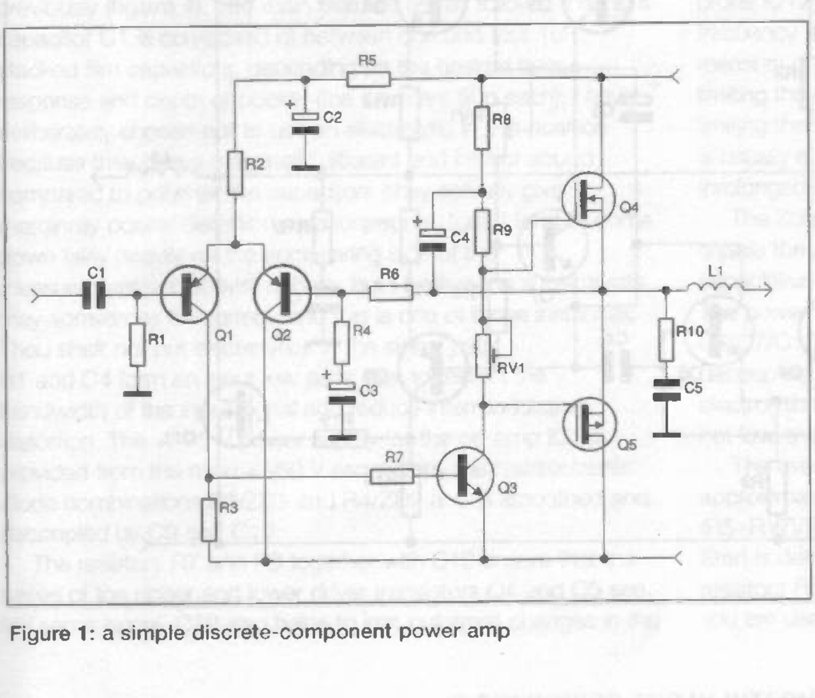


Figure 1: a simple discrete-component power amp

What's gone before

Having decided to use power mosfets, my next step was to choose a circuit topology. It is always profitable to look at semiconductor manufacturers' application notes and other published designs before embarking on a new one. Mosfet power amplifier designs frequently use an arrangement similar to that in **figure 1**. The input long-tailed pair, Q1 and Q2, is followed by a voltage amplifier stage, Q3, with a bootstrapped collector load, R8/R9 (bootstrapping increases the effective impedance of the collector load, which leads to better linearity). As the power mosfets are voltage-operated devices with a high-input impedance, they need almost no input current and can be driven directly from the low-current voltage amplifier stage (but this is not quite true, as we shall see later). The variable resistor RV1 between the gates of the mosfets is adjusted to give a current drain of around 100 mA through the mosfets, which biases them for class AB operation.

Although the circuit in **figure 1** gives reasonable performance and probably sounds OK, there is room for a number of improvements. The current through the input long-tailed pair is better set with a constant current source (Q1 in **figure 2**) than the simple resistor R2 shown in figure 1. The open loop gain can be increased, and the linearity improved, by using a pair of modern high voltage "super" transistors, Q4 and Q5 (hfe of 300-500 as a long-tailed pair voltage amplifier stage) in **figure 2**, rather than the single standard high-voltage transistor Q3 (hFE in the 50-200 range) in figure 1. This increase in open loop gain leads to a reduction in the closed loop distortion of the power amplifier. Loading the voltage amplifier pair with a constant current source/current mirror, D1/Q6, gives a higher collector load impedance than the bootstrapping of figure 1 and leads to a further improvement in linearity.

The biasing of the power mosfets can be improved by replacing the RV1 in figure 1 with the "amplified diode", Q, in figure 2. Driving power mosfets directly from the voltage amplifier transistor is not a good idea because of the relatively high input capacitance of power mosfets (of the order of 400-1000 pF). These capacitances will take a relatively long time to charge and discharge in the power amplifier of figure 1 because of the limited current drive available from the voltage amplifier transistor. These long charge/discharge times lead to an increase in distortion at higher frequencies. Its much better to use individual driver transistors, Q8 and Q9, interposed between the collector of the voltage amplifier transistor and the gate of each power mosfet, as shown in figure 2. The driver transistors should have high gain, so as not to load the voltage amplifier transistor; good high frequency response; low input capacitance, and a reasonable current drive capability (around 100 mA). This circuit arrangement also has the incidental advantage that the power mosfets are no longer operating as source followers, and so the power output will be greater than for the figure 1 circuit with the same power supply voltage.

If all these improvements are implemented, we end up with the circuit shown in **figure 2**. A number of designs similar to figure 2 have been published and are capable of very good performance if properly constructed. The question remains: can we improve on the circuit of figure 2? Yes, we can, but here things start to get complicated, with refinements such as complementary pairs of long-tailed pairs on the input, complementary cascode voltage amplifier stages, and so on, until the circuit begins to look like a commercial high-performance op-amp. So why not use an op-amp for the input and voltage amplifier stages of the power amplifier?

Integrated or discrete?

Why not indeed? The op-amp analogue of the power amplifier in figure 1 is shown in **figure 3**. How good is the figure 3 power amplifier? Once again, with the right op-amp, it is capable of very good performance at very low cost, but it has a number of shortcomings and limitations. One reason you don't see many high-quality audio power amps with op-amp voltage amplifier stages is that, until relatively recently, common op-amps were not up to the job. Most of the currently available op-amps were not designed for audio, and are deficient in one or more of the following areas: gain bandwidth product, slew rate, harmonic distortion, noise and output swing. However, the op-amp manufacturers have noticed the market and given us modestly priced (around £1.00 each) op-amps such as the TL071, NE5534, LF351 and LF411, which all have gain bandwidth products (gbwp) of around 10 MHz, slew rates of around 10 V/us, distortion of around 0.01 percent, reasonably low noise, and an output swing of around +/-13V. The best of all the low cost "audio" op-amps, however, is the OPA604 with 20 MHz gbwp, 25 V/us slew rate, 0.0003 percent distortion, 10

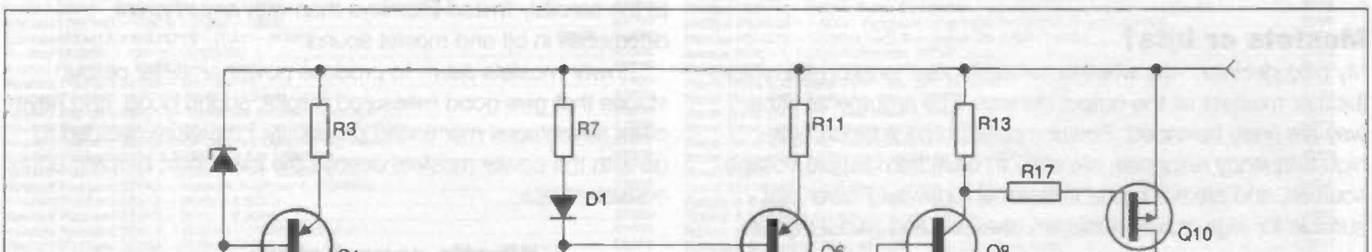


Figure 2: an improved discrete-component power amp

nV/[square root]Hz of noise and an output swing of +/-13 V.

Using one of these op-amps in the circuit of figure 3 will give you a good power amplifier, with some easily remedied drawbacks. Driving the power mosfets directly from the op-amp is not a good idea, for the same reason that driving the power mosfets directly from the voltage amplifier transistor, as in figure 1, is not a good idea in a high quality power amplifier. The op-amps generally do not provide enough output current to charge and discharge the power mosfet input capacitances quickly enough at high frequencies, leading to the previously mentioned increase in hf distortion. The remedy is the same: use driver transistors. The resistors R6 and R7 (figure 3) which connect the output of the op-amp to the +ve and -ve power rails will load the output of the op-amp and give rise to slightly increased distortion. Replacing the resistors with high dynamic impedance, constant current sources reduces the load on the op-amp, and consequently reduces the distortion.

The one remaining problem with the circuit of **figure 3** concerns power output. If the op-amp has an output swing of +/-13 V, corresponding to approximately 9 V rms with a sinewave input, then the theoretical maximum output power into an 8-ohm load is 9[squared]/8 or about 10 W! Obviously we would prefer a higher power output, which could be achieved by using an op-amp with a higher output swing, such as the +/-35 V obtainable from the OPA445. But this would still only give us about 75 W/8-ohm output at the price of increased distortion, because the OPA445 is not optimised for low distortion. Also, the OPA445 costs around £8 and is not commonly available. Maplin have now stopped selling them, and most other distributors favoured by hobbyists never did. The solution is to use one of the high-performance restricted output-swing op-amps mentioned earlier, together with an output stage which has a voltage gain of around five. This will give us a theoretical maximum output power of about 250 W/8R, which is much more satisfactory. However, we won't actually get that much out, because we are only using a power supply of +/-50 V, rather than the +/-65 V necessary to get 250 W/8R. In any case, the power mosfets we're going to use would not handle that much power without using pairs of devices.

The final circuit

The final circuit incorporates all the refinements discussed previously (**figure 4**). The main features are as follows: the input capacitor C1 is composed of between one and four 1uF stacked film capacitors, depending on the desired bass response and depth of pocket (the caps are 50p each). I have deliberately chosen not to use an electrolytic in this position because they give a marginally different and inferior sound compared to polymer film capacitors (they actually give marginally poorer distortion measurements, too). I tend to come down fairly heavily on the engineering side of the measurement/subjectivist debate, but I believe the subjectivists may sometimes be correct, and this is one of those instances. Thou shalt not put electrolytics in the signal path!
R1 and C4 form an input low pass filter to restrict the bandwidth of the input signal and reduce intermodulation distortion. The +/-15 V power supply for the op-amp IC1 is provided from the main +/-50 V supplies by the resistor/zener diode combinations R3/ZD1 and R4/ZD2 and is smoothed and decoupled by C9 and C10.

The resistors R7 and R8 together with C12 ensure that the bases of the upper and lower driver transistors Q4 and Q5 see the same signal. C12 also helps to iron out small changes in the

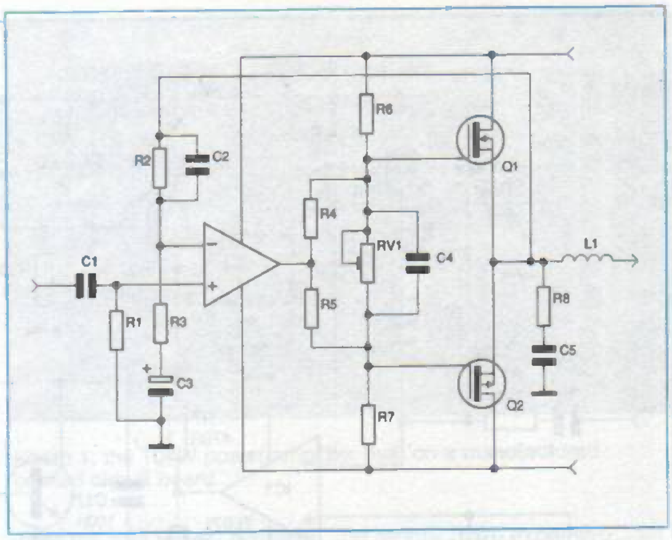


Figure 3: a simple op-amp power amp

bias voltage developed between the emitter and collector of the "amplified diode" bias transistor Q2. Notice the way that the preset, used to set the power amplifier quiescent current, is connected into the circuit. If the slider of RV1 doesn't make contact with its cermet track for any reason, the bias voltage and quiescent current will fail-safe to zero. If the open end of the cermet track is connected to the slider, as is often seen, failure of the preset's slider will result in a quiescent current of several amps. Not desirable!

The high impedance load for the op-amp is provided by the complementary constant current sources R6/R10/C11/LD1/Q1 and R9/R12/C13/LD2/Q3. Note the use of LEDs as voltage references. These give better temperature compensation than a pair of silicon diodes, and generate less noise than zener diodes. The configuration of the driver transistors Q4 and Q5 is fairly standard and the voltage developed across their collector load resistors R13 and R16 provides the gate drive for the output mosfets Q6 and Q7. The gain of the output stage is set to approximately five (R19+R20)/R20) by negative feedback via the resistors R19 and R20. C15 serves to roll off the high frequency response of the output stage before the MHz region (this is not, after all, a radio transmitter).

R18 and R21 are "stopper" resistors which help to prevent high frequency oscillation in the output mosfets. All mosfets are prone to high frequency oscillation because of their extended frequency response. The zener diodes ZD3 and ZD4 provide a measure of short circuit protection for the power mosfets by limiting the gate/source potential difference to 7.5 V, and so limiting the maximum drain current to a little under 8 amps. This is usually enough to prevent destruction of the output devices (prolonged shorts are handled by a fuse).

The Zobel network R22/C18 and the small inductor L1 enable the power amplifier to deal with awkward (that is, heavily capacititive) loads while maintaining stability and low distortion. The power supply lines are heavily decoupled by C2/C7/C16/C19 and C3/C8/C17/C20. The polyester film decouplers are necessary because the impedance of large electrolytic capacitors, while close to zero at low frequencies, is not low enough at high frequencies.

The overall gain of the power amplifier is set to approximately 20 by negative feedback via R5 and R17 (gain = (R5+R17)/R5) while the overall bandwidth (excluding the input filter) is determined by C14. The values of the various feedback resistors R5, R17, R19, R20 may be lower in value than those you are used to seeing (a gain of approximately 20 is often set

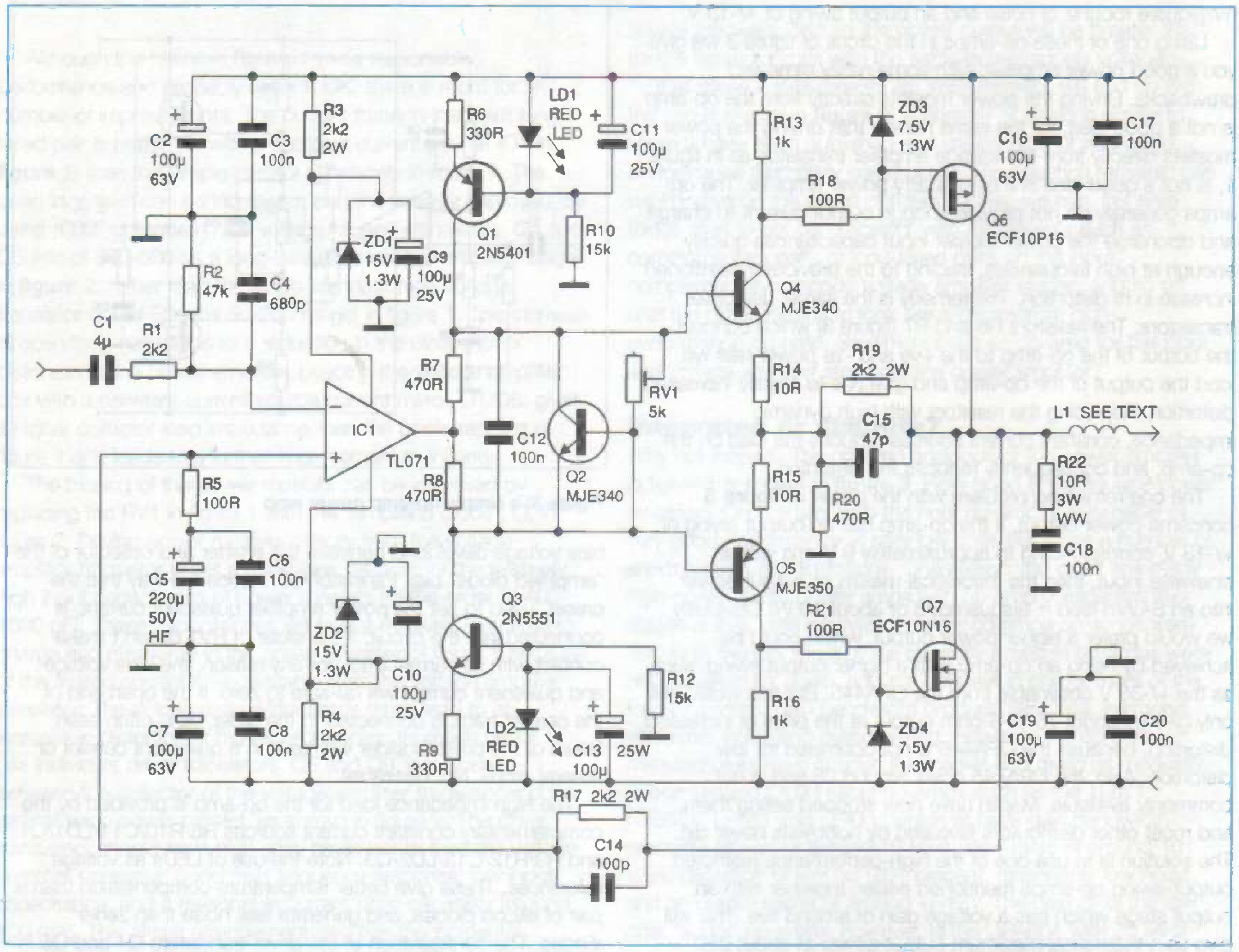


Figure 4: the final op-amp power amp circuit

by a 22k/1k resistor combination), but this is deliberately done to reduce high frequency distortion. The only penalty for using low value feedback resistors is the requirement to use high power devices for the larger resistor in each feedback pair, because of the magnitude of the ac current that flows around the feedback loops at high power outputs. In fact the amplifier would not fry R17 and R19 at full output even if they were the standard 0.6 W devices, rather than the specified 2 W, although they would get hot at full power. However, the constantly changing temperature of the smaller resistors with real programme material played at high volume would continually alter the value of the resistor and so modulate the gain of the power amplifier. Not desirable! Using a higher power resistor than is strictly necessary is equivalent to fitting a heatsink on a lower power device, reducing the gain modulation to insignificant proportions.

Construction

The prototype for this design was originally made on stripboard, but I would strongly recommend the use of a glass fibre pcb, and that is the design given here. If you do use stripboard it is essential either to solder thick copper wire, or to run solid solder, along the tracks which carry heavy currents, such as the power rails, between the drains of the power mosfets, to the Zobel network, to the output inductor, and so on. If you make your own pcbs you will need to use the component layout shown in **figure 5** to place your parts. If you use the boards that I have had commercially manufactured, you will have a component overlay silk screened onto the pcb. Take care to orient the transistors, zeners, leds, and particularly the electrolytic capacitors, the correct way round. Electrolytics will pop open and spread their messy contents all over the place if they are inserted with the wrong polarity (tantulum capacitors explode like small firecrackers if you mistreat them in this way, with all the risks entailed).

Construction is fairly straightforward and follows the usual customs: solder in the small discrete components first, then small actives, followed by larger discretes, and finally large actives. Be careful not to let polystyrene capacitors and active components get too hot when soldering. I find that the best kind of soldering iron for delicate (such as small surface mount parts) and general electronic assembly is a high wattage (50 W) type with a fine tip. This can get plenty of heat to the soldering site very quickly and complete a joint in under a second. With a low wattage iron it takes much longer to get enough heat into the pcb and component to melt the solder properly, and all the time the heat is damaging your components.

If you intend to experiment with various types of op-amp then it is best to solder an 8-pin IC socket in the IC1 position. I have tried a number of moderately priced op-amps (and some expensive ones) for IC1 and recommend the TL071 as the best cost/performance compromise, or the slightly more expensive OPA604 for the highest performance. IC1 is probably the most important single component as far as good measured and audible performance is concerned.

The constant current loads for the op-amp will track changes in temperature much better if Q1 is in close thermal contact with LD1, and Q3 is in close thermal contact with LD2. Q1/LD1 and Q3/LD2 are adjacent to each other on the pcb, and each transistor/diode pair should be clipped together either with a cable tie or a short length of copper strip. (Cut a 5-10 mm wide hoop from a length of 15 mm copper water pipe, cut the hoop to make a narrow strip, cut the strip to the correct length, and wrap the strip around the devices). Alternatively stick them together with a blob of quick setting epoxy adhesive. Only fix the devices together with adhesive when you know the power amplifier works and that you are not going to tinker or experiment with the constant current loads, as getting the devices apart without damage once the epoxy has set is almost impossible. Best performance is obtained if Q1, Q3 and LD1, LD2 are matched for Vbe/hfe and Vf respectively, but this is more expensive than using randomly picked parts. You would need to buy 5 or 10 of each component to be reasonably sure of getting a match (and even that is not guaranteed). The performance degradation as a consequence of using randomly chosen parts is very small, and matching is really only for perfectionists (like me!).

The quiescent current is most stable with temperature if Q2, Q4, and Q5 are in thermal contact. This is easily arranged by putting a suitably drilled aluminium strip (use the pcb as a template) on the pcb, putting greaseless semiconductor insulators on top of the aluminium strip, and putting the horizontally mounted transistors on top of the insulators. The transistors, aluminium strip, and pcb are then fixed together with 3-mm nuts and bolts. Finally the transistors are soldered to the pcb. The aluminium strip is not a heatsink, as the driver transistors barely get warm even at high power outputs.

There are various possibilities for Q4 and Q5. The cheapest and most readily available are the MJE340/MJE350 complementary pair which have reasonable hfe, but fairly low ft,

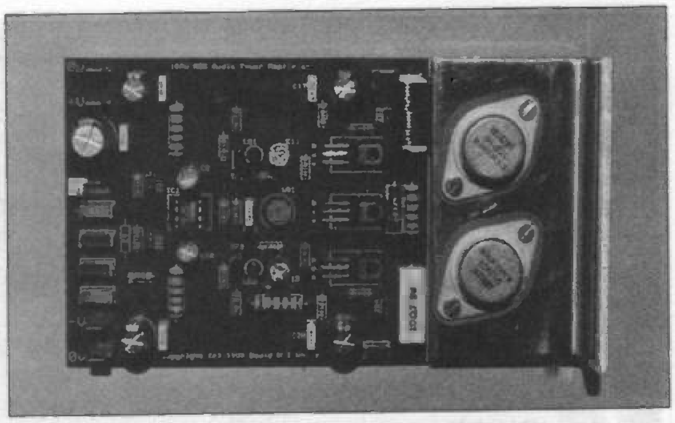


Photo 1: the 100W power amplifier built on a manufactured printed circuit board

while the less readily available, and slightly more expensive, 2SA968/2SC2238 pair (available from Viewcom or Grandata) have similar hfe but much higher ft, which leads to better high-frequency performance. Using a matched pair of driver transistors will give the best performance, but once again there is only a very small penalty for using randomly chosen pairs. If you use the MJE340/MJE350 pair (TO126), they must be mounted on the pcb with their metal faces up, followed by the insulating pads and the aluminium strip on top of the pads. If you use the 2SA968/2SC2238 pair (TO220), the aluminium strip goes on the pcb first, followed by the insulating pads, and then the transistors, with their metal sides down. These different arrangements are necessary to accommodate the different pinouts of the TO126 (ecb) and TO220 (bce) transistors.

Q2 need not be a power transistor. I used one as the easiest way to ensure good thermal contact between Q2, Q4 and Q5. You can use just about any small signal npn plastic transistor (such as the BC184L, flat face down) with epoxy adhesive to

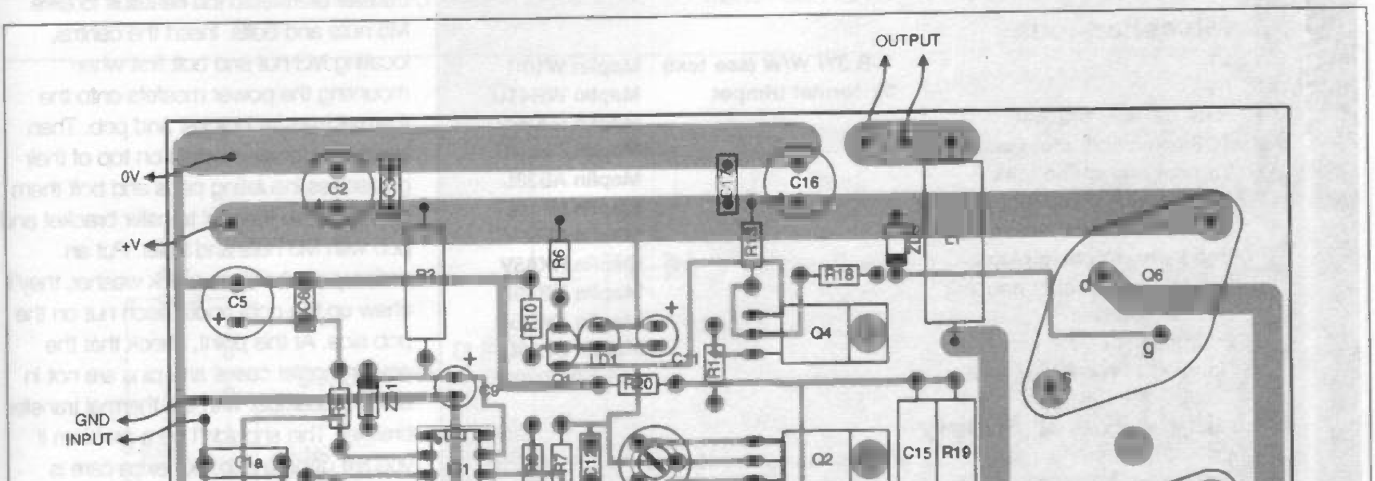


Figure 5: the component layout for the 100W power amplifier

PARTS LIST for the 100W Mosfet Power Amplifier

Maplin order codes are given, but equivalent parts from other suppliers are equally acceptable.

Resistors

R1, R11	2.2k	Maplin M2K2
R2	47k	Maplin M47K
R3, R4, R17, R19	2.2k 2W	Maplin D2K2
R5, R18, R21	100R	Maplin M100R
R6, R9	330R	Maplin M330R
R7, R8, R20	470R	Maplin M470R
R10, R12	15k	Maplin M15K
R13, R16	1k	Maplin M1K0
R14, R15	10R	Maplin M10R
R22	10R 3W	Maplin W10R

Capacitors

C1a,b,c,d	4 x 1uF polyester layer	Maplin WW53H
C2,C7,C9,C10,C11,C13,C16,C19	100uF 63V electro	Maplin AT81C
C3,C6,C8,C12,C17,C18,C20	100nF polyester film	Maplin DT98G
C4	680 pF polystyrene	Maplin BX34M
C5	220uF 50V HF electro	Maplin JL51F
C14	47pF polystyrene	Maplin BX26D
C15	22pF polystyrene	Maplin BX24B

Semiconductors

IC1	TL071CN	Maplin RA67X
Q1	2N5401	Maplin UL37S
Q2, C4	MJE340	Maplin QH54J
Q3	2N5551	Maplin UL36P
Q5	MJE350	Maplin WQ51F
Q6	ECF10P16	Maplin AY54J
Q7	ECF10N16	Maplin AY56L
LED1, LED2	3 mm red led	Maplin WL32K
ZD1, ZD2	15V 1.3 W	Maplin QF57M
ZD3, ZD4	7.5V 1.3 W	Maplin QF50E

Miscellaneous

L1	10R 3W W/W (see text)	Maplin W10R
RV1	5k cermet trimpot	Maplin WR41U
Heat transfer bracket		Maplin GA29G
TO3 semiconductor insulators		Maplin CH04E
Vertical pcb spade tabs		Maplin AS33L
Lucar push-on receptacle		Maplin HF10L
Push-on recptacle covers		Maplin FE65V
Pcb 2-way latching plug		Maplin RK65V
Pcb latching socket housing		Maplin HB59P
Pcb terminals		Maplin YW25C
Enamelled copper wire		Maplin BL26D
Heatsinks type MK		Cirkit 21-08035

Single Power Supply

T1	2 x 35V 160VA toroidal mains transformer	Maplin YK21X
BR1	200 piv 10A bridge rectifier	Maplin AR83E
C1,C2,C3,C4,C5,C6	4700uF 63V snap-in radial electro	Maplin AU31J
FS1	20 mm 3.15 A time delay glass fuse	Maplin GL64U
FS2	20 mm 3.15 A time delay glass fuse	Maplin GL64U
FS3,FS4	20 mm 3.15 A fast acting glass fuse	Maplin GJ94C
Chassis mounting 20 mm fuseholders x 2		Maplin KC01B
Double pole switched and fused mains inlet filter		Maplin CT82D

Dual Power Supply

T2	2 x 35V 300 VA toroidal mains transformer	Maplin YK22Y
FS1	20 mm 5A time delay glass fuse	Maplin GL65V
FS2	20-mm 5A time-delay glass fuse	Maplin GL65V

All other parts as per single power supply

glue it to the aluminium strip between Q4 and Q5.

L1 is made by wrapping 10 turns of 0.9 mm enamelled copper wire around the body of a 3W wirewound resistor (the square cross-section, white ceramic body variety) and soldering each end of the wire to the corresponding resistor lead.

If you intend to drive low impedance loads such as 4-ohm loudspeakers at high levels with this power amplifier, you might prefer to use Exicon ECF20N16/ECF20P16 power mosfets with 250W of dissipation capacity rather than the 125W ECF10N16/ECF10P16 pair specified. The voltage rating of ZD3 and ZD4 should then be increased to 8.2 V. There are undoubtedly other power mosfets which would work reasonably well in this design (such as BUZ900/BUZ905). I have not tried them myself, because none have specifications as good as the Exicon parts, and all are more expensive. Exicon mosfets are designed and manufactured in the UK specifically for hi-fi audio power amplifiers.

The power mosfets are bolted onto a pcb-mounting, thermal transfer bracket which is then bolted onto the heatsink proper (usually with the case back panel in between). I would recommend that you enlarge the holes fixing the thermal transfer bracket to the heatsink to take M5 nuts and bolts. Insert the central, locating M3 nut and bolt first when mounting the power mosfets onto the thermal transfer bracket and pcb. Then insert the power mosfets on top of their greaseless insulating pads and bolt them loosely to the thermal transfer bracket and pcb with M3 nuts and bolts. Put an ordinary washer (not a lock washer, they'll chew up the pcb) under each nut on the pcb side. At this point, check that the power mosfet cases and pins are not in electrical contact with the thermal transfer bracket. This shouldn't be a problem if you are using a pcb, but extra care is required if you are using a stripboard layout. In the latter case, use the thermal transfer bracket as a drilling template. When the power mosfets are properly seated, all the nuts and bolts can be tightened up. I usually then solder the nuts in place on the bolts; they often need a bit of scraping before they will take solder. Soldering ensures that the nuts and bolts don't work loose due to the inevitable thermal cycling of the power mosfets and thermal transfer bracket. If you ever need to remove the power mosfets, the solder on the nuts and bolts can be removed

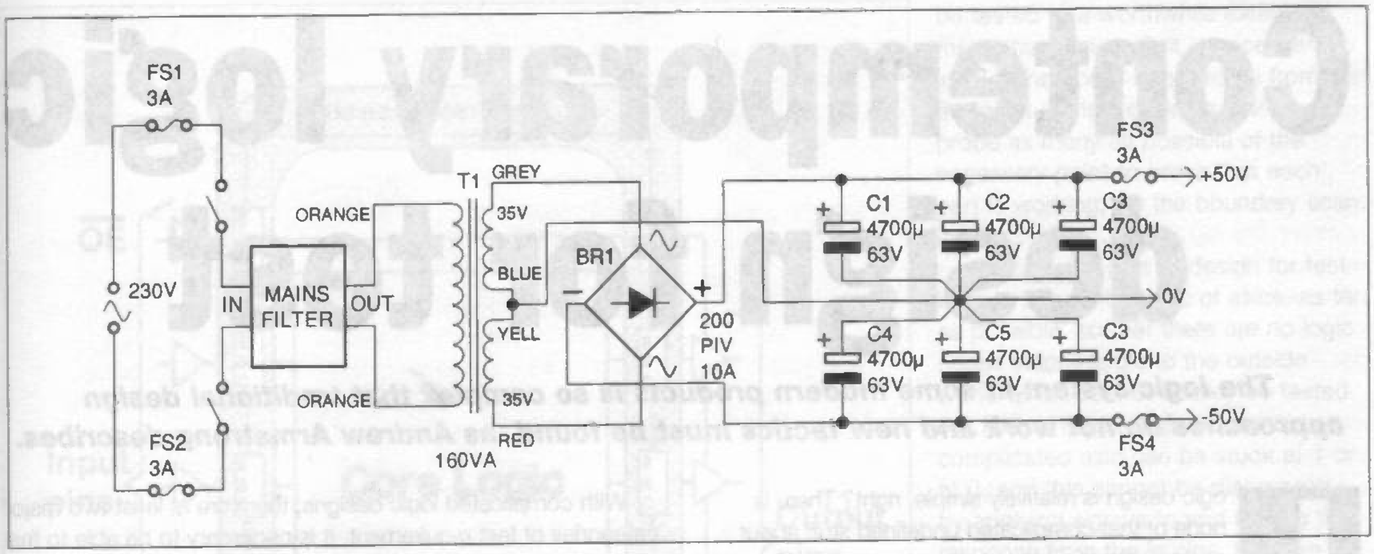


Figure 6a: a suitable power supply circuit for a single power amplifier

with a solder sucker or solder wicking braid. When finally bolting the power amplifier to the heatsink or case back panel/heatsink, use heat transfer grease between the thermal transfer bracket and heatsink, or between the thermal transfer bracket and case back panel, as well as between the case back panel and heatsink. **Photograph 1** shows a completed power amplifier built on a manufactured pcb.

The power mosfets can be mounted directly onto a heatsink and connected to the pcb by wires if desired. Keep the wires as short as possible. Although not quite as elegant as using the thermal transfer bracket, direct mounting probably provides better heatsinking. The heatsinks are usually chosen to fit in with the power amplifier casing, which is a matter of individual taste, but should be rated at no more than 2.0 degreesC/W for domestic use or no more than 1.3 degreesC/W for continuous sinewave use.

I used a 2U 19-inch rackmount case from Maplin (order code XM68Y) to house a stereo pair of power amplifiers together with their associated power supplies and protection circuitry (of which more later) in conjunction with 1.8 degreeC/W heatsinks from Cirkit (Stock Number 21-08035) for domestic use. I used white dry-transfer paint lettering (available from most good art supply shops), followed by three coats of water-based spray varnish, to annotate the power switch and indicator lights on the front panel.

One final point concerns the gain of the amplifier, which was set to 23 to work with my relatively high-output preamplifier. This may be a little low for some users and may be increased to 30 by reducing R5 from 100 to 75 ohms, at the expense of a very slight increase in distortion.

Figures 6a and b show two suitable power supply circuits The power supply, loudspeaker protection and testing will be discussed in the next issue, and the source and price of the professionally made PCBs will be given. See you next month.

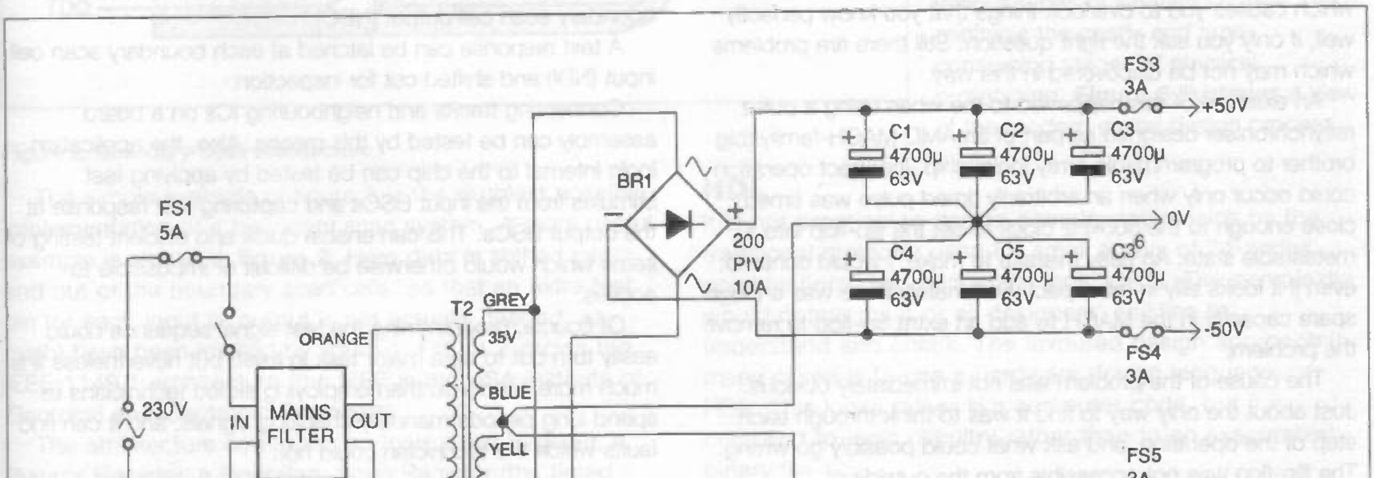


Figure 6b: a suitable power supply circuit for dual power amplifiers

Contemporary logic design for test

The logic system in some modern products is so complex that traditional design approaches do not work and new tactics must be found, as Andrew Armstrong describes.

Logic design is relatively simple, right? There is none of that complicated undefined stuff about analogue levels, biasing, frequency response, and so on. You can revel in the simplicity of ones and zeros, where the exact voltage does not matter.

Even so, sometimes logic designs don't work first time. At least occasionally, you will find that a small logic design with only a dozen 74HC series chips in it will not work, because somebody overlooked the result of what would happen if a clock pulse occurs too close to the clear line going inactive.

Still, it is normally fairly simple to discover what is going wrong by, for example, finding a short negative glitch in the signal between IC4 and IC5. In a commercial environment you might use a logic analyser with glitch capture turned on to examine a number of signals at once and track down the problem in one step.

A question of scale

What would happen if you could not attach probes to the logic signals? Clearly you would use a simulator before building anything. This would help you to avoid the kind of mental glitch which causes you to overlook things that you know perfectly well, if only you ask the right question. Still there are problems which may not be discovered in this way.

An example of this happened to me when using a pulse resynchroniser designed as part of an AMD MACH-family (big brother to programmable array logic) chip. Incorrect operation could occur only when an arbitrarily timed pulse was timed close enough to the 500kHz clock to set the flip-flop into a metastable state. An easy mistake to make, I would contend, even if it looks silly in retrospect. Fortunately there was enough spare capacity in the MACH to add an extra flip-flop to remove the problem.

The cause of the problem was not immediately obvious. Just about the only way to find it was to think through each step of the operation, and ask what could possibly go wrong. The flip-flop was not accessible from the outside of the MACH, though it might have been possible to design it so that it was. The only reason to do that would have been as an aid to test - had it been clear that access to that point would provide a useful test signal.

The above problem occurred in a fairly simple piece of logic, at least by comparison with some of the asics (application specific integrated circuits) designed into fancy bits of mass produced consumer hardware. There, a more advanced test technology is needed, both for development and production testing.

With complicated logic designs, there are at least two major categories of test requirement. It is necessary to be able to test large logic devices, both for design verification and for production test; and it is necessary to be able to test the pcb on which the chips reside, particularly for production test.

Boundary Scan

One important test technology is called Boundary Scan, a technology strongly supported by JTAG (the Joint Test Action Group - look at http://www.jtag.com). This is the application of a scan path at the boundary (that is, the I/O) of ics so that test signals can be applied and measured through scan operations. **Figure 1** illustrates this idea. Here an IC is shown with an application-logic section and its input and output, with a boundary scan cell interposed between the application logic and the data input and output pins. Extra connections for test data input (TDI) and test data output (TDO) are also added.

In normal operation, the BSCs are transparent, and signals flow through freely. However, during boundary test the following operations are possible:

A test word can be shifted in and fed out from each boundary scan cell output (NDO).

A test response can be latched at each boundary scan cell input (NDI) and shifted out for inspection.

Connecting tracks and neighbouring ICs on a board assembly can be tested by this means. Also, the application logic internal to the chip can be tested by applying test stimulus from the input BSCs and capturing test response at the output BSCs. This can enable quick and efficient testing of items which would otherwise be difficult or impossible to access.

Of course, programming the test signal sequence could easily turn out to be a major task in itself, but nevertheless it is much more economic than employing skilled technicians to spend long periods manually checking signals, and it can find faults which the technician could not.

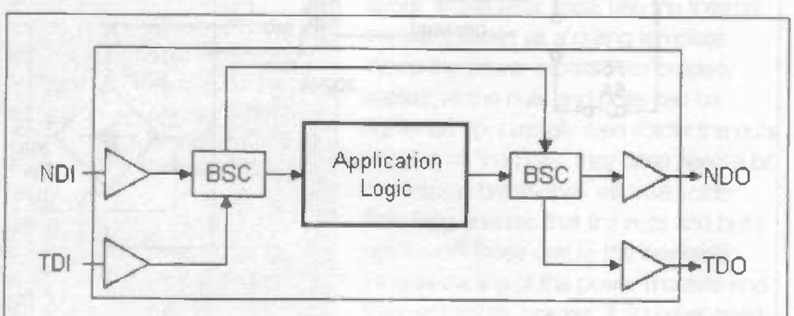


Figure 1: the principle of Boundary Scan

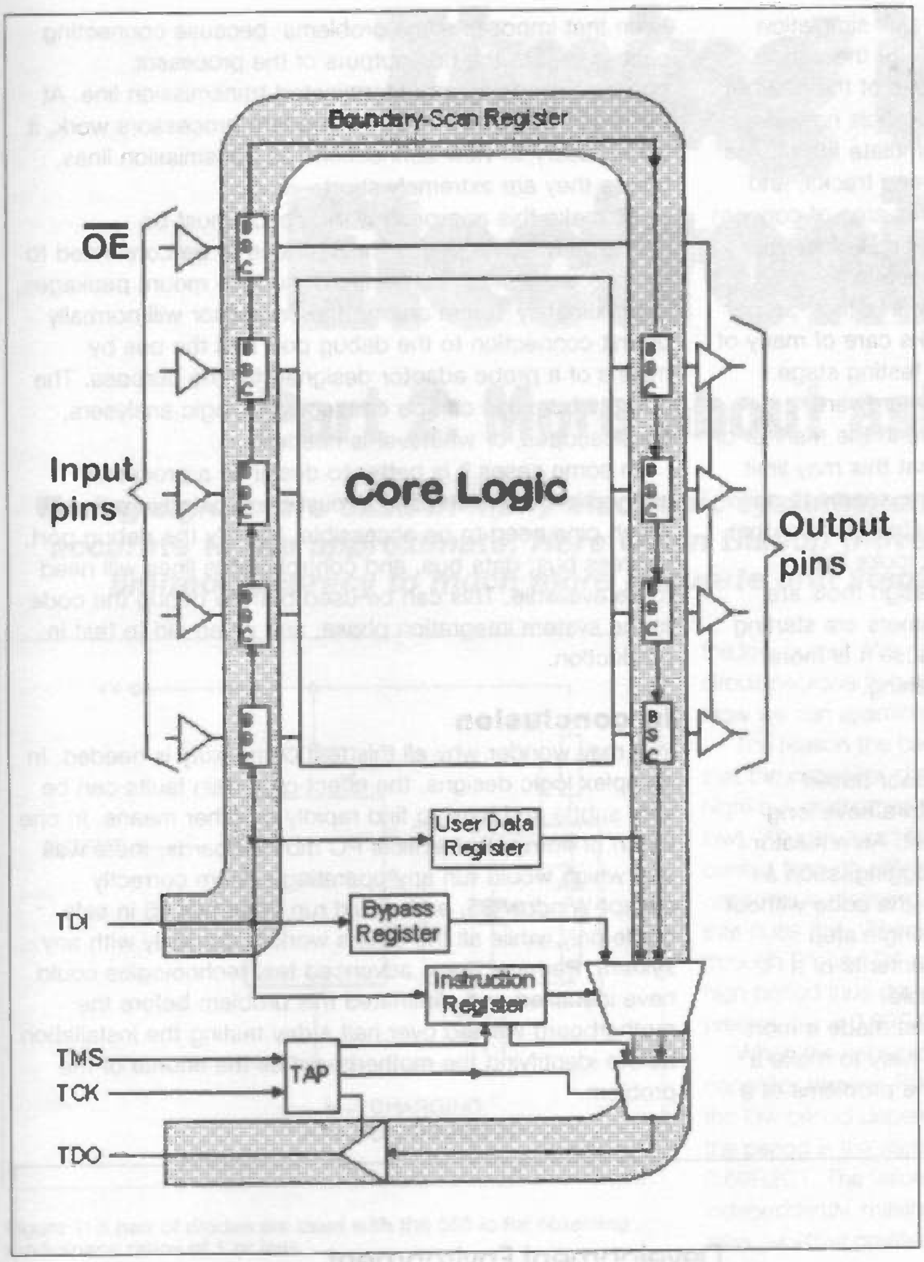


Figure 2: Boundary Scan architecture

The simple example of figure 1 is the simplest possible implementation of a boundary scan system. A more useful example is shown in **figure 2**. Here data is shifted into and out of the boundary scan cells, so that an extra test pin for each input or output is not actually needed, as might have been implied by figure 1. Figure 2 shows the IEEE 1149.1 architecture (the IEEE is the USA Institute of Electrical and Electronic Engineers).

The architecture comprises an Instruction Register, a Bypass Register, a Boundary-Scan Register (the tinted area in figure 2), an optional User Data Register, and the Test Access Port (TAP). The boundary scan register is a set of serially accessed test cells at the input and output boundaries of the application part of the ic.

The instruction register and data registers are separately accessible, so that the test access port can load instructions and data independently.

Design for test

Another advantage of boundary scan is that, if a reasonable proportion of the chips on a pcb incorporate boundary scan, other non-boundary scan chips can also be tested to a worthwhile extent. To make this work well, it is necessary to look at the board level design from the point of view of being able to probe as many as possible of the necessary point to prove that each part is working, via the boundary scan system.

A more vital part of design for test is to structure the logic of asics, as far as possible, so that there are no logic nodes inaccessible to the outside world which cannot quickly be tested. So, if a particular logic node inside a complicated asic can be stuck at 1 or at 0, and this cannot be discovered by applying signals to and testing the response from the ic pins, then we need either a test connection which can determine the fault, or a redesign of the internal logic to minimise the node-checking test sequence. This is a very complicated subject, and, in order to do this in a practical way, EDA (electronics design automation) tools incorporate tools to simulate the logic, and even to generate sequences of test signals (often called "test vectors").

In order to bring very complex-logic controlled products, often containing one or more processors embedded somewhere in the logic, to market while there is still a demand, a carefully structured design process is needed. There is a heavy reliance on various types of simulation, to minimise the costly and time-consuming stages of physical prototyping. **Figure 3** illustrates a view of the modern digital design process.

HDL

It is not practical to design complex logic asics by the traditional methods used for small arrays of 74-series combinational and sequential logic chips. The complexity would defeat most or all designers' abilities to understand and check. The favoured design approach in many cases is to use a hardware design language, or HDL. This looks rather like computer code, but it is compiled to logic circuitry rather than to an executable binary file.

The HDL code can be run on a simulator, to see what it will do as written. A chip design can be produced, and that can be simulated to find out what real hardware will do. Although the HDL code specifies the operation of the logic, it is possible that timing constraints on the actual chip will prevent it from functioning as first designed. The procedure then is the rewrite the relevant part of the HDL code into something which will compile to a different logic structure - one which will avoid the particular timing problem identified by the asic simulation. The HDL and asic simulation processes continue in parallel until all works correctly in simulation.

Timing requirements identified during this simulation phase will very likely impact on the layout of the pcb, which will be carried on in parallel because of the need to bring products to the market swiftly. EDA tools now in use in this sort of design environment can simulate the effects of delays in tracks, signal coupling between tracks, and suchlike electromagnetic phenomena. This area of concern is often referred to as signal integrity, and it is closely related to the requirements of electromagnetic compatibility mandated by European law. In effect, proper attention to signal integrity issues will take care of many of the requirements for a pass at the EMC testing stage.

As an aside, it is strange to note that hardware designers are being obliged to work more in the manner of programmers. I would hazard a guess that this may limit the design flair which, for many engineers, seems to arise from visualisation of the problem. It is a strange irony that, as hardware designers start to use what looks like computer code (perhaps because the design tools are written by programmers), some programmers are starting to use diagrammatic programming, because it is more intuitive, and easier to see what is happening.

Processor testing

Development and test of complex processor based designs adds extra requirements. Emulators have long been used as an aid to code development. An emulator generally offers many useful aids to debugging, such as real time trace, and breakpoints set in to the code without interfering with execution. The ability to single step through a program, and to change the contents of a register then continue, can also be valuable.

The increasing speed of processors has made it more difficult to build emulators. It is relatively easy to make a dil-pluggable module which can run all the problems of a simple 8-bit 4MHz processor in real time, while allowing break points to be set and sending information up the cable to the main body of the emulator. To do that for a processor running at well over 100MHz is much more difficult, not least because the shortest connection available between the emulator module and the pcb is likely to add too much delay for it to work at full speed.

Many fast modern processors now have a debug port, by means of which some of the functions of an emulator can be carried out by the chip itself. It is still necessary to have a module which connects to the processor connections on the pcb, but now the processor is connected, and the module communicates with the debug port and monitors bus activity etc.

Even that imposes some problems, because connecting such a load to the bus outputs of the processor constitutes adding an unterminated transmission line. At the high frequencies at which modern processors work, it is necessary to view connections as transmission lines, unless they are extremely short.

To make this approach work, space must be deliberately left to permit the interface to be connected to the processor. With conventional surface mount packages, approximately 10mm around the processor will normally permit connection to the debug port and the bus by means of a probe adaptor designed for the purpose. The outputs from this can be connected to logic analysers, oscilloscopes, or whatever is needed.

In some cases it is better to design in a processor connection, in which case it must be decided in advance which pins need to be accessible. Usually the debug port, address bus, data bus, and control/status lines will need to be available. This can be used both to debug the code at the system integration phase, and as an aid to test in production.

In conclusion

You may wonder why all this test complexity is needed. In complex logic designs, the effect of certain faults can be very subtle and hard to find rapidly by other means. In one batch of nominally identical PC motherboards, there was one which would run any operating system correctly except Window 95, and would run Windows 95 in safe mode only, while all the others worked correctly with any system. Perhaps these advanced test technologies could have identified and eliminated this problem before the motherboard wasted over half a day testing the installation before identifying the motherboard as the source of the problem.

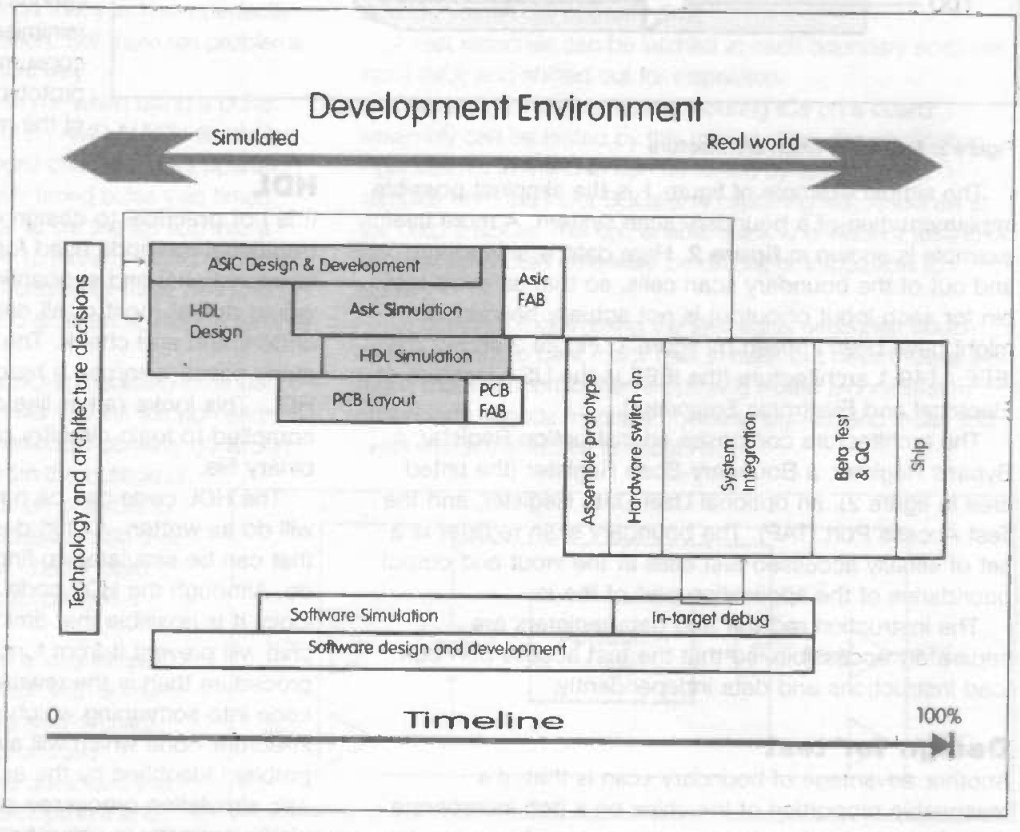


Figure 3: an ASIC development timeline

Timing in Electronics

Part 2: More about astables

Timing signals are used in many electronic systems, and can vary from the very accurate to the approximate. Here Owen Bishop moves from RC oscillators of limited accuracy to much more accurate and stable crystal oscillators.

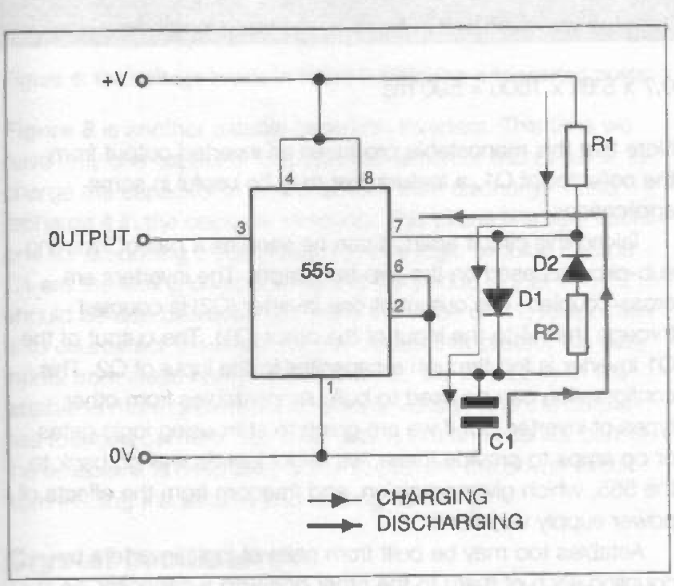


Figure 1: a pair of diodes are used with the 555 ic for obtaining mark:space ratios of 1 or less

If you remember, our old and dear friend the 555 was used in the first episode of this series last month to illustrate the two basic types of timing circuit:

Monostables for producing a single output pulse of precise length.

Astables for producing a pulse train of precise frequency.

The monostable circuit is limited for many purposes because it is difficult to produce a pulse several seconds or minutes long with reasonable precision. For timing long periods, it is usually easier to use an astable to produce a train of pulses, and then count the number of pulses. We will look into circuits of this type in the next episode. For now, we will examine variations of the astable circuit, look at another monostable, and build an astable which operates on a different principle.

Duty cycle

The 'duty cycle' of an astable describes the relative lengths of the periods during which its output is high and low. This is also known as the *mark:space ratio*, where the 'mark' is the duration of the high output, and the 'space' is the duration of the low output. We saw last month that the basic 555 astable circuit necessarily has a mark-to-space ratio greater than 1. Now we can examine ways of obtaining different ratios.

The reason the basic astable has a ratio greater than 1 is that the capacitor charges through two resistors (with output high) but discharges through only one of them (with output low). We can avoid this situation by using diodes to direct the current through different resistors, depending on whether the capacitor is charging or discharging. Figure 1 shows a circuit that does this. When the capacitor is charging, current flows through R1 and D1 to the capacitor C1. The duration of the high period thus depends only on R1 and C1. To be more precise, $t_{high} = 0.69R_1C_1$.

When the capacitor is discharging, current flows from the capacitor through R2 and D2 to pin 7 of the ic. The duration of the low period depends only on R2 and C1. The duration of the period is the same as for the simple astable, that is, $t_{low} = 0.69R2C1$. The values of R1 and R2 can be chosen independently, making it possible to obtain any mark:space ratio, whether greater or less than 1.

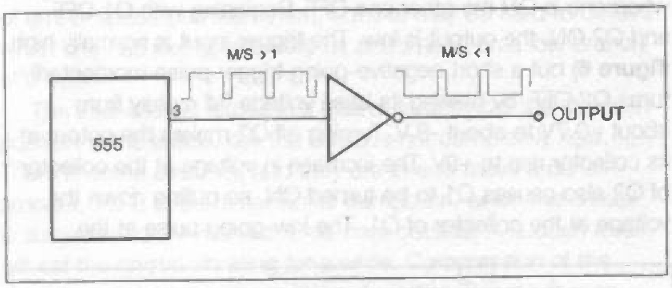


Figure 2: another way to obtain mark:space ratios of less than 1 is to use an inverter

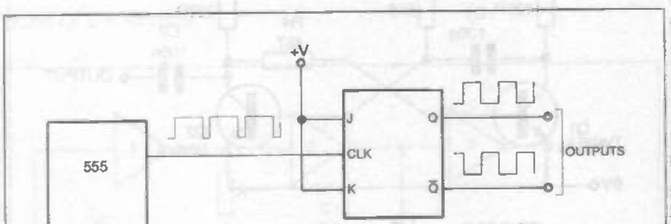


Figure 3: a flip flop converts a signal with any mark:space ratio to a signal at half the frequency and a ratio of exactly 1

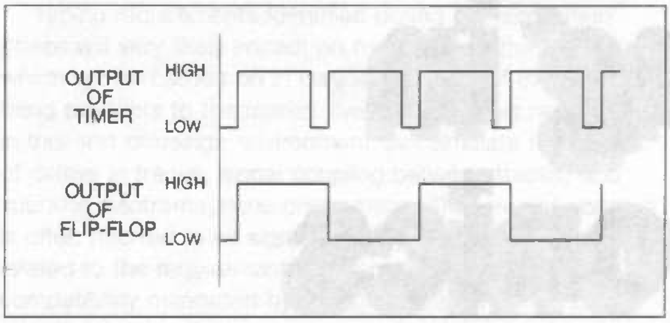


Figure 4: the waveforms of the circuit in figure 3

Another approach to obtaining a mark:space ratio of less than 1 is to invert a signal that has a ratio that is greater than 1. This is particularly convenient when working with digital circuits, as there is often a spare INVERT, NAND or NOR gate that can be used for the inversion (**figure 2**). The main snag of this is that a logic gate sources or sinks much less current than the 555 timer. For example, a standard TTL gate can source 16mA and sink only 0.4mA . Gates of other logic families sink or source less than this. This compares very unfavourably with the 555, which can sink or source 200mA (100mA for the cmos versions). However, this is not a problem if the inverter is being used to provide input only to subsequent logic circuits.

Often we need a mark:space ratio of 1 exactly. This can be done using the circuit in figure 1, with resistors of equal values, but a simpler way is to use a toggle flip-flop (**figure 3**). Toggle flip-flops, as such, are not manufactured, but can be made from a D or J-K flip-flop, as shown in the figure. **Figure 4** shows the waveforms; the flip-flop changes state (toggles) on every rising edge of the astable, and therefore has a mark:space ratio of 1. The frequency of its output is half that of the astable, so the astable is set up to run at twice the frequency required.

Other timing circuits

The 555 is purpose-designed for precision timing but there are other ways generating reasonably good single pulses or chains of pulses. **Figure 5** shows a monostable built from two cross-connected transistor switches. The transistors operate so that when one is ON the other one OFF. Beginning with Q1 OFF and Q2 ON, the output is low. The trigger input is normally high (**figure 6**) but a short negative-going trigger pulse momentarily turns Q2 OFF, by making its base voltage fall rapidly from about +0.7V to about -8 V. Turning off Q2 makes the output at its collector rise to +9V. The increase in voltage at the collector of Q2 also causes Q1 to be turned ON, so pulling down the voltage at the collector of Q1. The low-going pulse at the

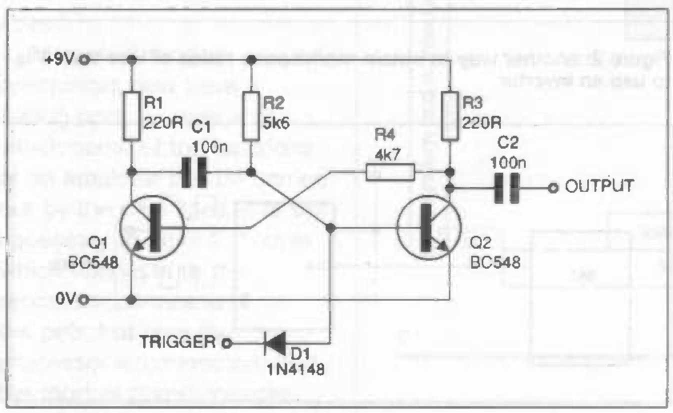


Figure 5: cross-connected transistor switches are used to build a monostable

collector of Q1 is passed through the capacitor, holding Q2 OFF even though the trigger pulse has ended.

The next stage is that current flows through R3, gradually charging C1 and raising the voltage at the base of Q2. **Figure 6** clearly shows the exponential rise of voltage across the capacitor. As soon as this reaches about 0.7V, Q2 begins to turn ON again, pulling down the voltage at its collector, which turns Q1 OFF, which raises the voltage at its collector, and turns Q2 more fully on. The effect is cumulative and results in the circuit rapidly returning to its original state. The output falls to zero.

Summing up, a low level on the trigger causes a high output pulse, the length of which is the time taken for the current through R3 to charge C1 from -8.3V to 0.7V. The length of the pulse depends on the values of R3 and C1, approximately:

$t = 0.7R_3C_1$

With the values shown in figure 5, the pulse length is:

0.7 x 5.6k x 100u = 590 ms

Note that this monostable produces an inverted output from the collector of Q1, a feature that may be useful in some applications.

Taking this circuit apart, it can be seen as a pair of inverting sub-circuits based on the two transistors. The inverters are cross-coupled. The output of one inverter (Q2) is coupled through the R4 to the input of the other (Q1). The output of the Q1 inverter is fed through a capacitor to the input of Q2. This configuration can be used to build monostables from other types of inverter. But if we are going to start using logic gates or op amps to provide these, we might just as well go back to the 555, which gives precision, and freedom from the effects of power supply variations.

Astables too may be built from pairs of logic inverters by coupling each of them to the other one with a capacitor, as in **figure 7**, which uses transistor switches as inverters. The circuit now has two capacitors. A trigger input is not needed because, owing to slight asymmetries in the circuit caused by slightly differing values of nominally identical components, the circuit will always go straight into one of its two states at switch-on, with one transistor fully ON and the other fully OFF. From then on it continues indefinitely, alternately charging and discharging the capacitors.

The charging time for each capacitor depends on the value of the capacitor and the resistor through which it is charged. The two capacitors and resistors may be made equal in value to obtain a mark:space ratio of 1, or may be unequal if a mark:space ratio greater or less than 1 is required.

Output is high while Q2 is OFF and C1 is charging through R2, so that:

$t_{high} = 0.7R_2C_1$

Conversely output is low when Q2 is ON and C2 is charging through R3, so that:

$t_{low} = 0.7R_3C_2$

Combining these two equations we obtain:

$f = 1.4/(R_2C_1 + R_3C_2)$.

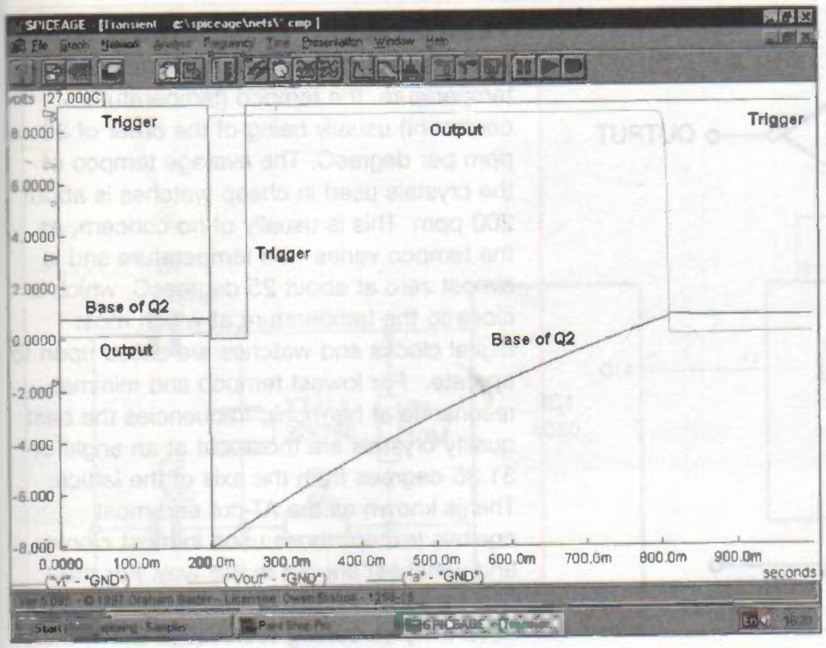


Figure 6: the voltage levels in figure 5 following a triggering pulse

Figure 8 is another astable based on inverters. This time we have only one capacitor because the action of this circuit is to charge the capacitor in one direction, then discharge it and recharge it in the opposite direction. This circuit is a very useful one for producing clock pulses to drive logic circuits. R1 and C1 are the timing components and the period is $2.2R_1C_1$. R2 should be approximately ten times the value of R1. Its function is to counteract the effects of the diodes that protect the gate inputs from static charges. Without R2, the frequency of the astable is more dependent on supply voltage and the output has rounded corners. The third gate is not an essential part of the astable. It is used as a buffer to prevent the driven circuit from loading the astable and altering its timing.

Crystal oscillators

All the timing circuits we have described so far rely on the timing of one particular physical process, the charging and discharging of capacitance. This is a convenient process to use because it can be directly coupled to electronic counting and display circuits. The period of swing of a pendulum is physical process that has been used by clockmakers for centuries because a long pendulum can be made with sufficient precision for accurate timing. Thermal contraction and expansion can be compensated for in various ways. It only remains to couple the pendulum to some kind of mechanism which (1) provides a regular input of energy to keep the pendulum swinging, (2) counts the number of swings, and (3) displays the result on a dial, in terms of the elapsed time. In a purely mechanical clock there is an escapement to release the energy stored in the hanging weights or in a coiled spring, swing by swing. The energy is also used to drive a system of gear wheels. The gears have hands attached and move them over a circular dial. A mechanical watch has much the same mechanism, but with a balance wheel rotating to and fro instead of a pendulum. The energy to keep this in motion comes from the mainspring. Another spring, the hairspring, attached to the balance wheel, alternately stores and releases the rotational energy of the balance wheel as it continually rotates in one direction and then reverses. Such mechanisms can be coupled to electronic circuits, usually by electromagnetic means.

Another mechanical device for timing is the tuning fork. A tuning fork is used by musicians as a convenient and portable way to produce of note of precisely known frequency. A tuning fork may be used as the basis for timing in a clock or watch. The fork is made to vibrate continuously by supplying it with energy, usually by an oscillating electromagnetic field. The fork vibrates at its own natural frequency (not necessarily in the audio range) which is detected electromagnetically and used to drive a counting circuit and hence a display.

For present-day clocks, except for those of the highest precision, pendulums, balance wheels and tuning forks have been replaced by another more compact and more convenient mechanical device, the crystal. This is usually a crystal of that very common and durable material, quartz. A quartz crystal consists of atoms of silicon and oxygen arranged in a regular three-dimensional lattice. Forces exist between the atoms, and some of these are electrical forces of attraction and repulsion. The total effect of these forces is very strong. They hold the atoms of the crystal into a firm and solid shape. All matter is known to consist of relatively small atoms with large amounts of empty space between them, but this may be hard to believe when one has just accidentally hit one's head on a low branch of a tree.

The inter-atomic forces in a quartz crystal hold the atoms in position in the lattice, but the lattice is not completely rigid. There is some elasticity, and they are free to move a certain amount, like a three-dimensional trampoline, when the crystal is subjected to mechanical force from outside. A sudden force will set the crystal vibrating for a while. Compression of the crystal squashes the atoms closer together. The result is an imbalance of the electrical fields within the crystal which causes a potential difference to develop between opposite faces of the crystal.

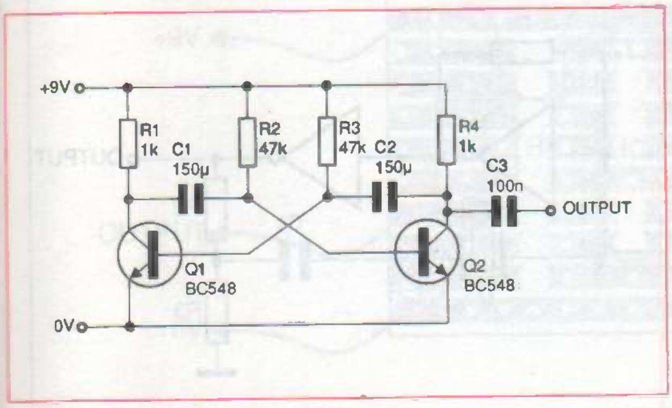


Figure 7: two cross-connected transistor switches form an astable. Compare this with figure 5

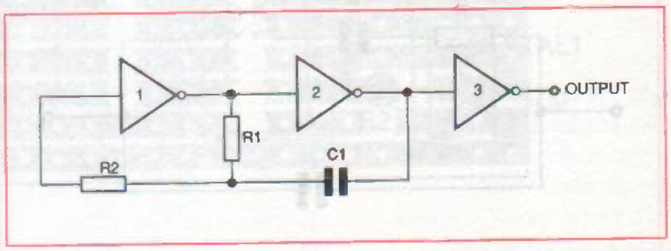


Figure 8: an astable may be built from two logic inverters, with a third inverter as an output buffer

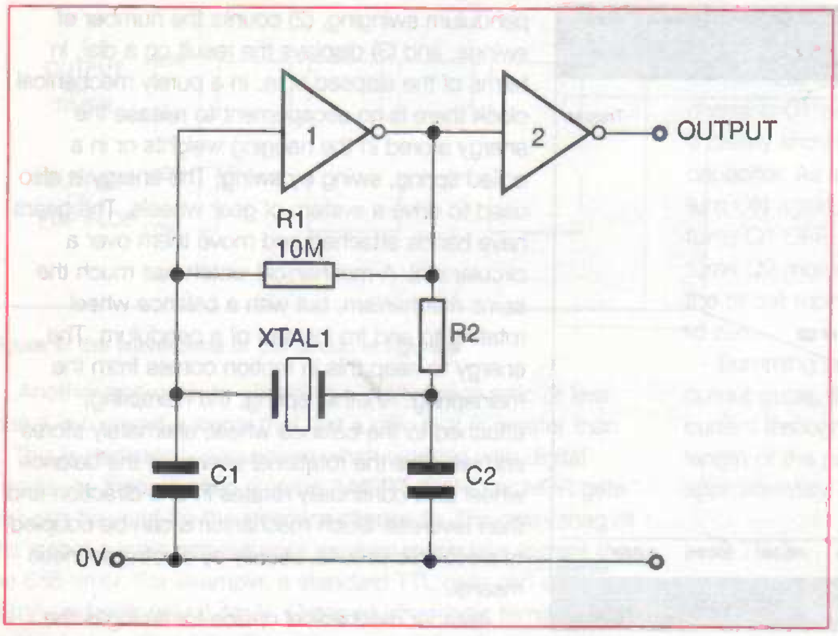


Figure 9: the astable of figure 8 is used here with a crystal to control its frequency. This is the parallel circuit

This is known as the piezo-electric effect, and it the basis of the action of crystal microphones and similar transducers. It is detected by evaporating a thin metal film on opposite faces of the crystal and measuring the changes in the potential difference between them. Mechanical energy is converted to electrical energy by this means. Perhaps the simplest example is the piezo-electric gas-lighter, which produces a spark when we press the trigger lever.

The piezo-electric effect operates in the reverse direction too. If we apply a voltage between opposite sides of the crystal, we reinforce some of the intermolecular forces and weaken others, causing the crystal to change shape. Electrical energy is thus converted to mechanical energy. This effect is used in piezo-electric sounders, including some used in security sounders capable of emitting ear-piercing shrieks.

The piezo-electric effect is widely used in electronic timing devices. The heart of these is a small quartz crystal, cut from a larger synthetic crystal of pure quartz to such a size and shape that it will vibrate most strongly at one particular frequency. This is equivalent to adjusting the period of a pendulum by carefully adjusting its length. Fortunately, it is easy to machine a crystal with a very high degree of precision. Inexpensive crystals are readily available with tolerances as small as 15 parts per million. In a cheap digital watch or clock, this is equivalent to about 40 seconds a month, far surpassing the performance of a mechanical watch or clock of comparable price.

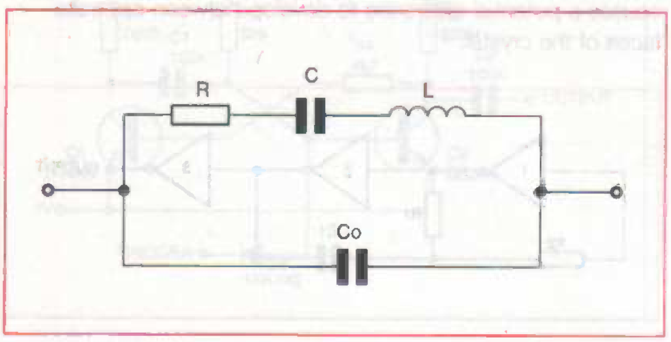


Figure 10: this network is the electrical equivalent of a piezo-electric crystal

Temperature coefficient

The frequency of a crystal is dependent on temperature, the tempco (temperature coefficent) usually being of the order of 30 ppm per degreeC. The average tempco of the crystals used in cheap watches is about 200 ppm. This is usually of no concern, as the tempco varies with temperature and is almost zero at about 25 degreesC, which is close to the temperature at which most digital clocks and watches are called upon to operate. For lowest tempco and minimal resonance at harmonic frequencies the best quality crystals are those cut at an angle of 31.35 degrees from the axis of the lattice. This is known as the AT-cut and most crystals (except those used in most clocks and watches) are cut in this way. For the highest precision the crystal is cut as accurately as cutting techniques allow, then put thorugh a sealing process in a thermostatically-warmed container or 'oven'. This eliminates the effects of tempco, and the best of such clocks have an accuracy of 0.0003 seconds a year.

Reference to clocks and watches raises the matter of finding a suitable frequency of vibration. All crystals vibrate at high frequencies, usually several megahertz, so a timer requires a digital frequency divider to produce a signal capable of driving a display. For the majority of timekeepers we use a crystal cut to vibrate at 32.768 kHz. The significance of this figure becomes apparent when we realise that 32768 is equal to 2^{15}. The signal from the oscillating crystal is passed through a 15-stage binary divider and emerges as a 1 Hz signal, all ready for timing in seconds. Below we describe a practical project which uses this system. Two further stages of division, both by 60, give us minutes and hours. An alternative time source is a 4.194304 MHz crystal followed by a 22-stage divider. Many other crystal frequencies are available off the shelf, including 6.5522 MHz for driving TV video circuits and a range of crystals with high frequencies used for driving microprocessors and timing the operations of their peripherals, and other crystals generating accurate carrier frequencies for radio transmitters.

Crystals are cut for operation in one of two different

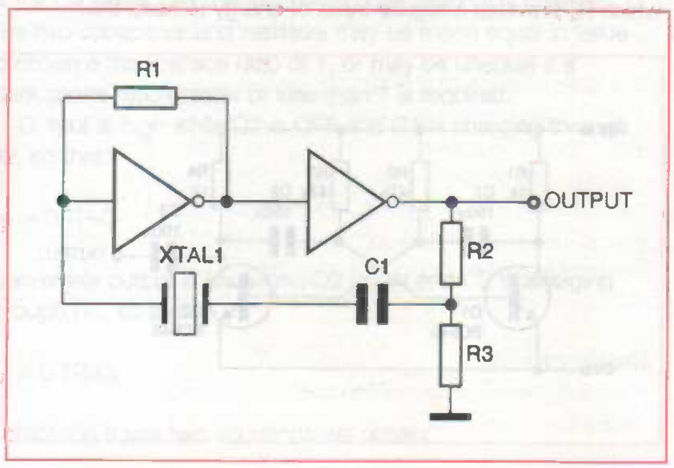


Figure 11: the series circuit for a crystal oscillator

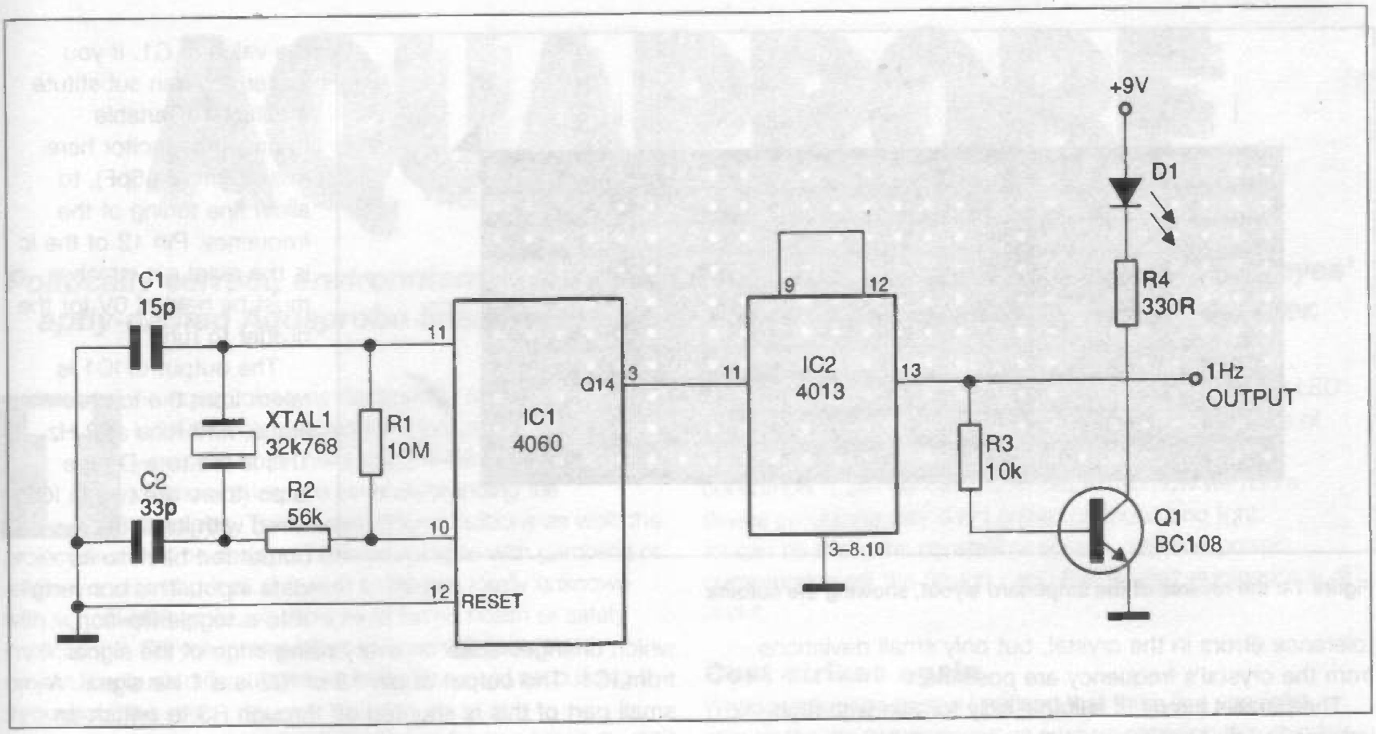


Figure 12: a 1Hz clock module deriving its frequency from a digital watch crystal

modes. Crystals for parallel operation are used in circuits such as **figure 9**. This circuit makes use of two logic inverters and is very similar to the oscillator in **figure 8**. The values of R2, C1 and C2 are chosen so that the circuit resonates at the specified crystal frequency. The essential point is that the output of the resistor-capacitor network being fed back to the input of inverter 1 is exactly 180 degrees out of phase with the input to the network taken from the output of the inverter. The output of the inverter is always 180 degrees out of phase with its input so there is resonance. Without the crystal it is an oscillator in its own right, but at a frequency dependent on the rather imprecise values of the resistor and capacitors. The addition of the crystal forces the circuit to resonate at the crystal's own natural frequency. It is rather the same as jumping on a trampoline. You can leap higher if you time your actions to its natural frequency. The oscillations of the circuit cause the crystal to vibrate but it will only vibrate strongly at a frequency very close to its natural frequency.

We say that the crystal has a very high Q.

To explain the matter of Q, **figure 10** shows the electronic equivalent of the crystal. There is a capacitance C_o between its leads and between the electrodes on opposite faces of the crystal. Then there is the equivalent of a series RCL resonant circuit due to the response of the crystal lattice to mechanical deformation. In this, C is low but L is high and, since:

$$Q = \omega_o L/R$$

where ω_o is the resonant frequency of the crystal (high too), we obtain quality factors up to 100000. High Q results in high selectivity, that is, strong resonance at a given frequency and a sharp fall-off at frequencies on either side. The result is that the crystal dominates the circuit, forcing it to resonate at the crystal's own frequency. If C2 is a variable capacitor, it is possible to use it to tune the circuit more finely and compensate for

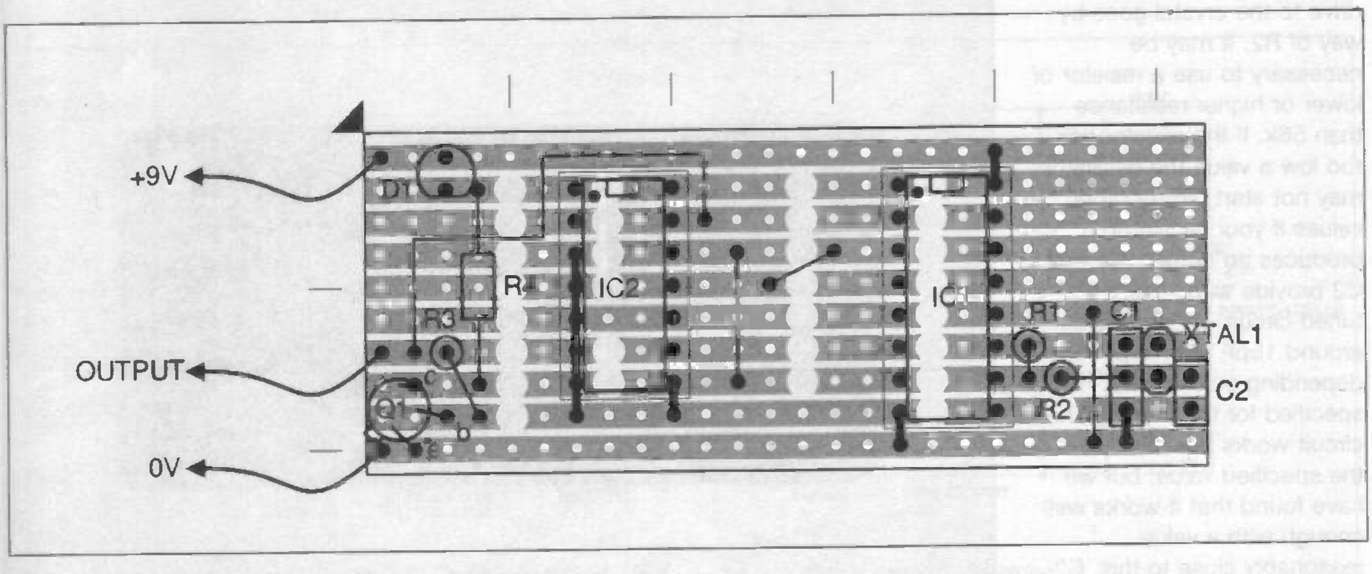


Figure 13: the stripboard layout of the clock module

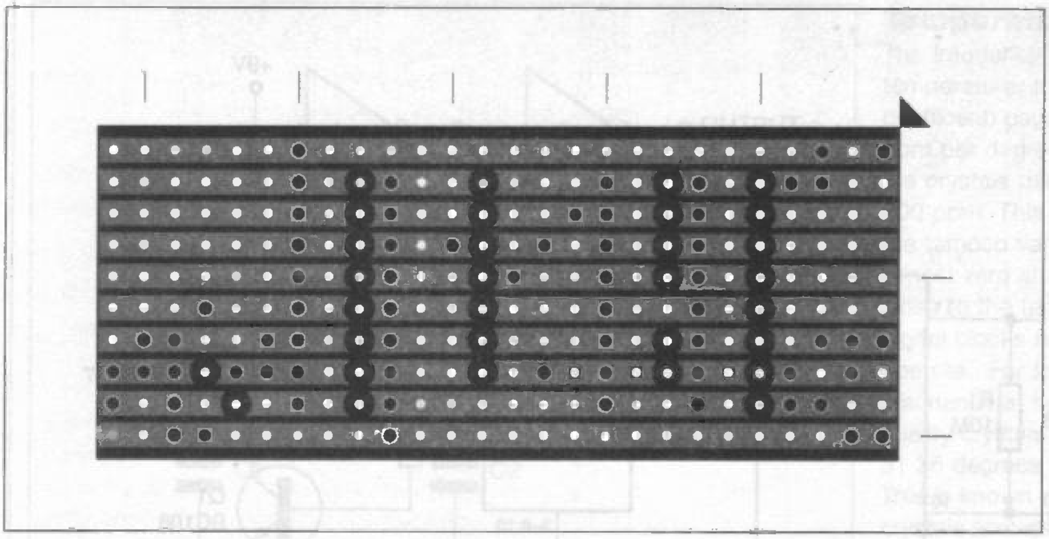


Figure 14: the reverse of the stripboard layout, showing the cutouts

the value of C1. If you prefer you can substitute a miniature variable trimming capacitor here (maximum of 65pF), to allow fine tuning of the frequency. Pin 12 of the ic is the reset pin which must be held at 0V for the divider to run.

The output of IC1 is taken from the fourteenth stage, and runs at 2 Hz. This is fed to a D-type latch (there are two in IC2) wired with its Q-bar output fed back to its data input. This converts it to a toggle flip-flop, which changes state on every rising edge of the signal from IC1. The output at pin 13 of IC2 is a 1 Hz signal. A small part of this is shunted off through R3 to switch an LED. This is optional but it is often helpful to have an indication that the timer is working properly.

Figure 13 shows a suggested stripboard layout. The components of the oscillator are soldered close together and with short leads to minimize lead capacitance. The capacitors used in this circuit were both sub-miniature ceramic types with NPO dielectric. This has a tempco of zero, so the effect of temperature is limited to the tempco of the crystal which is about -0.04 ppm/degreesC when ambient temperature is 25 degreesC. This is small enough to be ignored. Note that the strips beneath the board are cut at various places, but NOT at F8. There are important cuts at H23 and J22. Solder blobs are used to make connections beneath the board, particularly where pins 2 to 8 of IC2 are all grounded by solder to inactivate the unused flip-flop. The parts are all straightforward to get hold of.

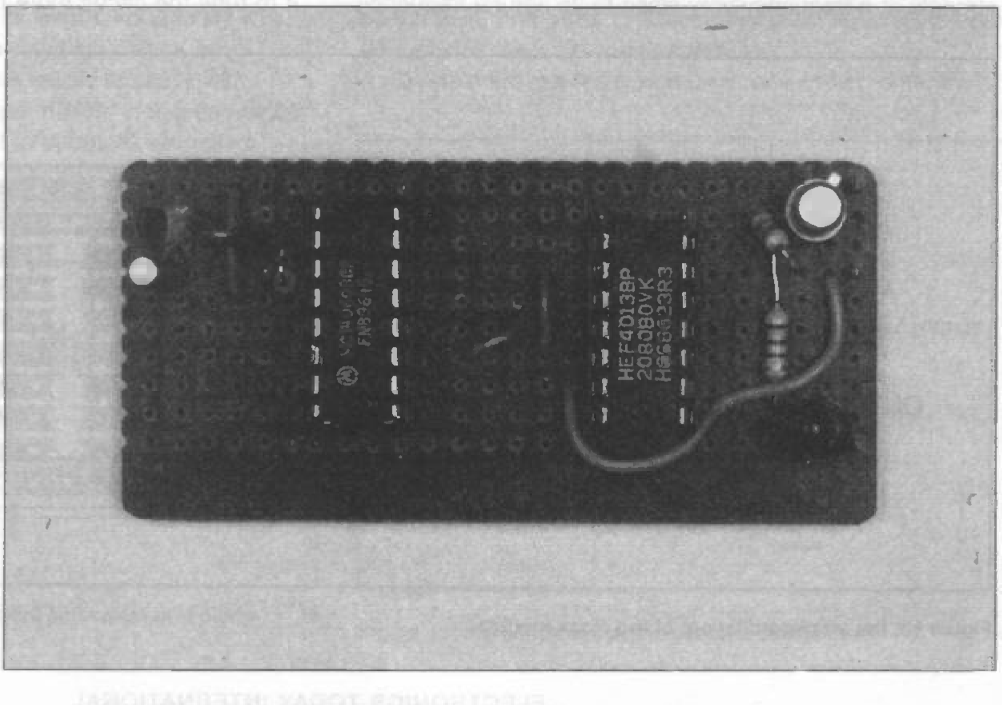
In this and the previous parts we built two astable modules. In the next and subsequent parts we will build them something to drive.

tolerance errors in the crystal, but only small deviations from the crystal's frequency are possible.

The parallel circuit is suitable only for use with high-impedance devices such as the cmos gates we use in our project below. Its main disadvantage is that it takes an appreciable time (a second or more) after power-up for oscillations to build up to maximum amplitude. This does not matter in a digital watch or clock which runs for years once powered, but there are applications in which almost instant oscillation is essential, for example, a microprocessor clock should be active at switch-on. For this purpose we use the series circuit (**figure 11**). This takes more current than the parallel circuit.

A Practical Crystal Clock

This is a 1 Hz clock (**figure 12**) based on dividing the output of a 32.768 kHz crystal by a 15-stage binary counter. A convenient way of doing this is to use the CMOS 4060 which has a built-in oscillator circuit and 14 stages of division. A 4013 flip-flop is added to this as the fifteenth dividing stage (**figure 12**). The clock circuit is uses an inverter which is inside the ic and has its terminals at pins 10 and 11. R1 provides feedback so that the inverter snaps sharply from one state to the other. The drive to the crystal goes by way of R2. It may be necessary to use a resistor of lower or higher resistance than 56k. If the resistor has too low a value the oscillator may not start, so try other values if your oscillator produces no output. C1 and C2 provide with XTAL1 a tuned circuit. C1 should be around 15pF normally, depending on the load specified for the crystal. The circuit works best if C1 has the specified value, but we have found that it works well enough with a value reasonably close to this. C2 should be two or three times



AQUAPROBE

Politically correct, environmentally sound and kind to green growing things: Bob Noyes' aptly-named Aquaprobe lets you know when your potted plant is gasping for water.

The Aquaprobe was designed in response to a local school's request for a low cost project that would be both useful and the focus of some electronics lessons on understanding the principles. There were other conditions as well: the project must not be sexist or have anything to with gambling or religion; and to cap it all, if it were to fail (not totally unknown with school-built projects!) there must be no health or safety implications. Oh yes ... and it had to be an all-year-round project, because different groups of pupils would be building it throughout the year.

After a few days of head scratching and furrowed brows Aquaprobe was born. It is a device that detects when a potted plant needs watering. Aquaprobe sits in the soil, minding its own business, until it detects that the plant requires water, which Aquaprobe indicates by a pulsing sound and a flashing LED.

Because of the financial limitations, the good old PP3 power source was ruled out. This had me thinking: one of the reasons that projects become expensive is the box; the bigger the box the bigger the bill just to house the battery; so ... we can make the battery small, but this will mean changing it too often. To keep battery life to an acceptable level the residual current consumption had to be minimal; this meant CMOS in order to work at low voltages well below 9V and have a long battery life.

It also meant that for most of the time nothing in the way of sound or light could be produced - no ON LED. When anything happened, it had to be low power in terms of watts but high in terms of volume. This meant PIEZO. A piezo sounder can be loud but it consumes minimal power. Because the sound would have to be given out in very short bursts with a long break in between, to keep power consumption low the problem of having several of these things going off and wondering which plant is in distress lead me to include a LED (sorry!). Although LEDs can consume significant amounts of power, if they pulse with an extremely low duty cycle, consumption can be made acceptable. So now we had a device producing very short pulses of sound and light. As can be seen, the constraints of cost, size and power consumption set the design - and that is what electronics is all about.

Cost strikes again

When starting the design I noticed that there is a specialist chip on the market designed as a water detector; this chip has two disadvantages: the cost, which is well out of our price range and the need for a stable supply of above 10V. So, back to the drawing board.

In the end a standard CMOS nand Schmitt was chosen, the 4093, which has an extremely low current consumption as well as the capacity to be configured into the design blocks required to function as a dampness detector. And all it was cheap.

The supply then had to be finalised. To keep the size down hearing aid batteries were chosen. These are reasonably priced and at about 500 mAh each, will give an acceptable battery life as well as being quite small.

The next thing to sort out was the box. On many occasions cheaper boxes could have been used if the dimensions of the PCB had been slightly different, so in this project the PCB has been designed to fit the box, rather than the other way round. The box chosen was 75 x 56 x 25mm, costing around £1 (cheaper if bought in bulk).

Now we had the box, the supply and method of sound and light output, and all we needed was the circuit. **Figure 1** gives the full circuit, comprising basically three stages:

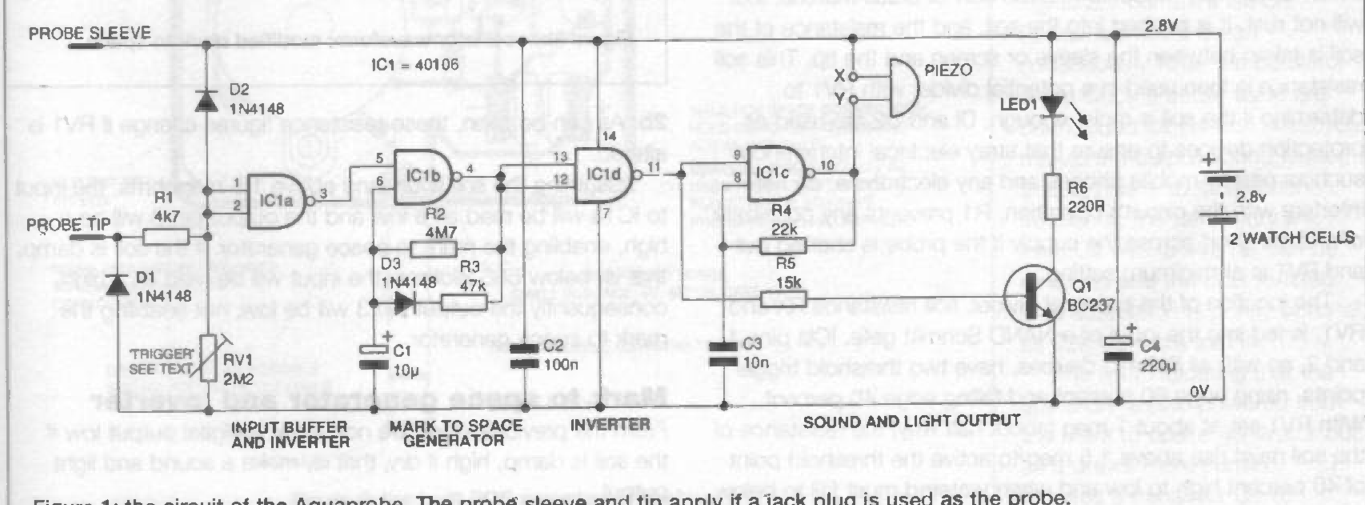


Figure 1: the circuit of the Aquaprobe. The probe sleeve and tip apply if a jack plug is used as the probe.

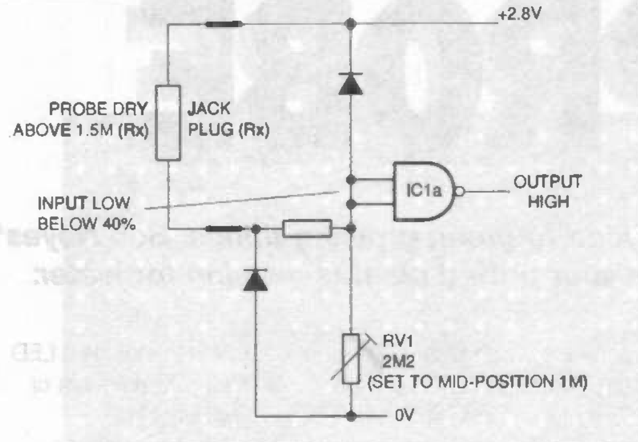


Figure 2a: the Probe in high resistance mode. In dry soil IC1a pins 1-2 see junction as a low, giving a high out on pin 3.

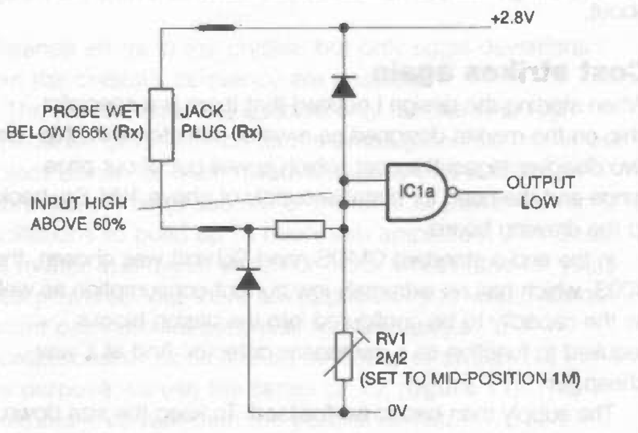


Figure 2b: the Probe in low resistance mode. In damp soil IC1a pins 1-2 see junction as a high, giving a low out on pin 3.

1. Input buffer and inverter.

2. Mark to space generator and inverter.

3. Output stages sound and light.

InDut Buffer and Inverter

The principle used in this project is that damp soil conducts electricity more readily than dry. To sample the soil a probe is required; the easiest and cheapest is the humble jack plug which is normally made from some sort of brass material that will not rust. It is pushed into the soil, and the resistance of the soil is taken between the sleeve or screen and the tip. This soil resistance is then used in a potential divider with RV1 to determine if the soil is moist enough. DI and D2 are used as protection devices to ensure that stray electrical interference, such as nearby mobile phones and any electrolysis, do not interfere with the circuit's operation. R1 prevents any possibility of a direct short across the supply if the probe is shorted out and RV1 is at minimum setting.

The junction of the potential divider, soil resistance RX and RV1, is fed into the input of a NAND Schmitt gate. ICla pins 1 and 2, as with all Schmitt devices, have two threshold trigger points, rising edge 60 percent and falling edge 40 percent. With RV1 set at about 1 meg (about half way) the resistance of the soil must rise above 1.5 meg to active the threshold point of 40 percent high to low and when watered must fall to below 666K or 60 percent low to high threshold. See **figures 2a and 2b**. As can be seen, these resistance figures change if RV1 is altered.

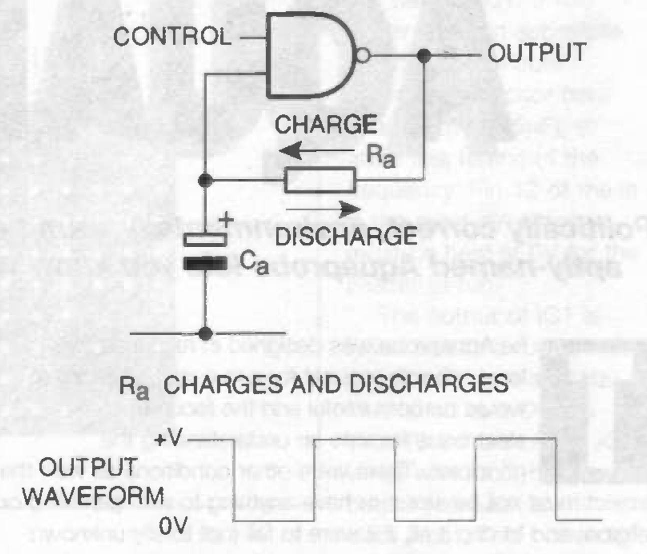


Figure 3a: oscillator waveform: normal 1:1 mark to space

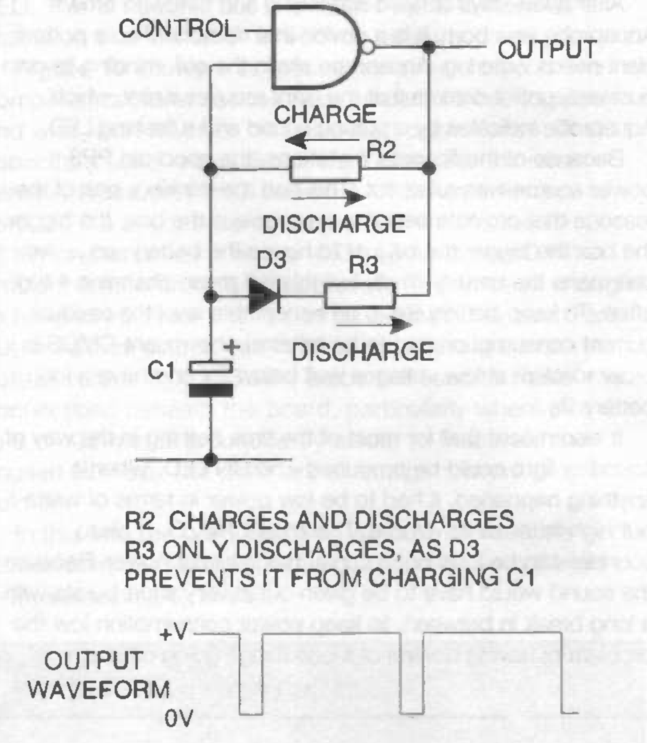


Figure 3b: oscillator waveform: modified mark to space

Assuming the soil is dry and above 1.5 megohms, the input to IC1a will be read as a low and the output pin 3 will be a high, enabling the mark to space generator. If the soil is damp, that is, below 666 kilohms, the input will be read as a high, consequently the output pin 3 will be low, not enabling the mark to space generator.

Mark to space generator and inverter

From the previous stage we now have a digital output low if the soil is damp, high if dry, that is, make a sound and light output.

The problem is that both sound and light (LED) outputs

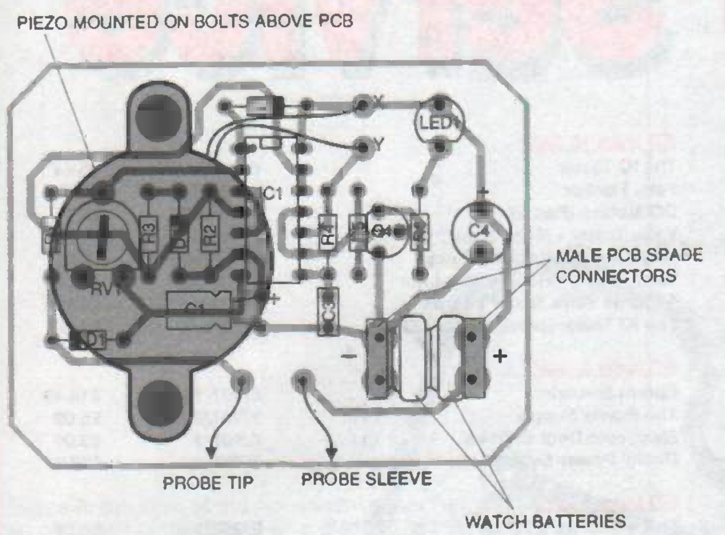


Figure 4: the component layout

consume power and with two small hearing aid batteries we have a limit on the length of time this can be maintained. The solution is to pulsate the outputs; if a 1:1 mark to space output was used the outputs would be off for as long as they were on (in dry conditions only), effectively doubling the active output life. The trouble is that even this would not be enough, so a duty cycle of around 40:1 is used. This increases the output life approximately 40-fold.

The heart of this mark to space generator is ICl b, see figures **3a and 3b**. **Figure 3a** shows the basic oscillator circuit, which gives a 1:1 mark to space ratio as RA is used to charge CA as well as discharge it. This charging and discharging is only between the two trigger points of 40 percent and 60 percent of rail. If two resistors could be used, one to charge CA and one to discharge it and they were of different values then the mark to space would alter accordingly.

This is basically what is happening in **figure 3b**. C1 is charged only by R2, 4M7. R3 cannot pass charge current because D3 is reversed biased, but when C1 is charged both R2 and R3 help discharge it. R3 is much smaller than R2, so it is discharged much more quickly. This is how the output waveform is generated and, in this case, has a duty cycle of around 40:1. Because of the PCB layout of the circuit this waveform is inverted to the one required by the output devices. This inverted waveform is brought back to the correct orientation by IC1d, an inverter (both input pins 12 and 13 connected together). The waveform, when triggered by dry soil, is normally low pulsing high with a duty cycle of around 40:1.

Output sound and light

The sound output consists of an oscillator built around IC1c. This time the mark to space ratio required is 1:1, so only one resistor, R4, is used to charge and discharge C3. The sound output device is a passive piezo sounder which comes in a range of sizes and styles. In this project, because it is going to be mounted above the PCB, a piezo with wire leads is used. It can be connected directly to the output of IC1 pin 10 which most of the time is high (while the soil is damp). Sound is only produced when this point goes low at a frequency set by R4, C3. The value of R4 can be changed either up or down; down increases the frequency and increasing R4 decreases it. This is a little hard to judge, because it is on for such a short period of time. If the +ve of C1 is temporarily shorted to the +ve rail with a link and the probe connections are open, the oscillator will operate continuously, making it easier to select an alternative value for R4.

While this is being done, it is a good idea to remove LED1 from the circuit as this draws significant current if left on. Remember it will be on continuously while the oscillator is on. Once a better value has been found for R4 that effectively makes the output sound louder, that is, nearer to its resonant frequency, the temporary link from C1 +ve to +ve rail can be removed and the LED re-fitted. This adaptation is purely optional, as 22k will work for R4.

The light indicating that the soil is dry is also powered from the mark to space generator but, as it draws more current, requires a transistor Q1 to provide this boost. The best type

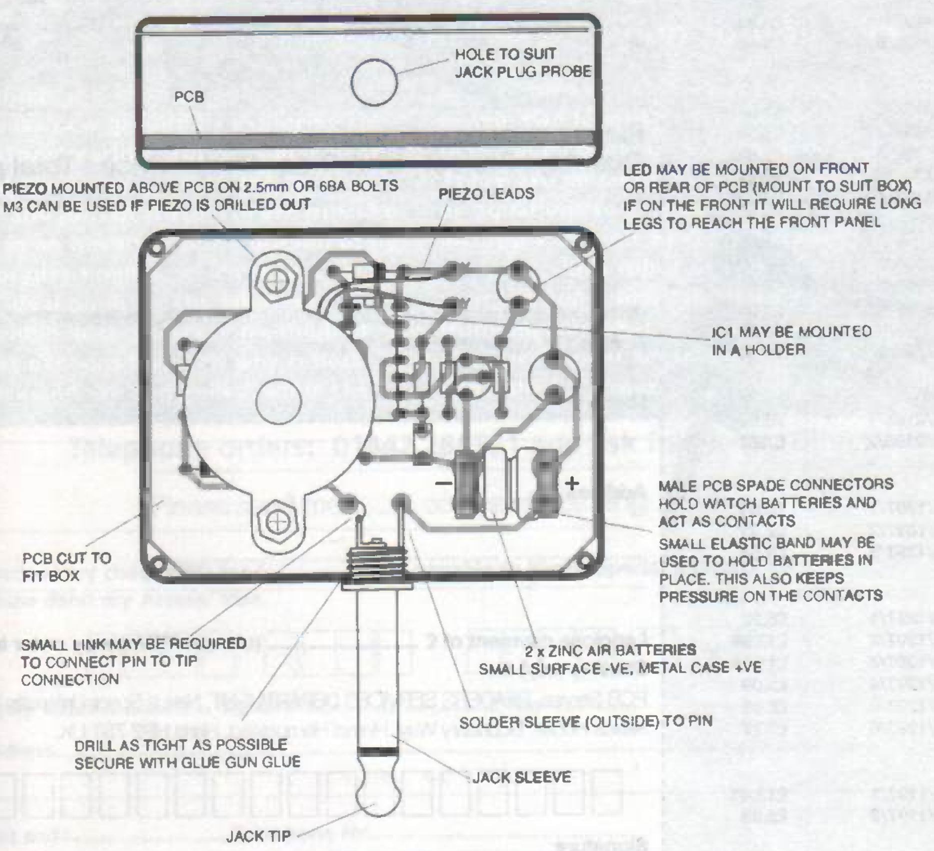


Figure 5: the built PCB mounted in the box

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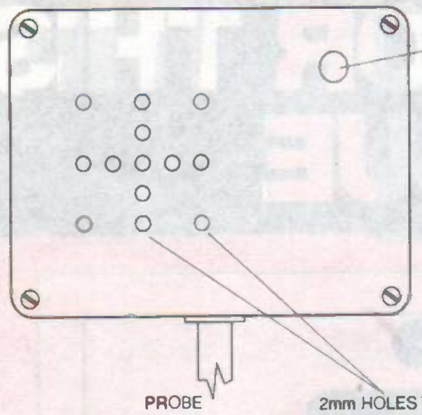


Figure 6: the front of the Aquaprobe case. Tip: you can use an old piece of Veroboard as a guide to get the holes lined up

of LED is the clear plastic type. These come in red or green, and normally can be found in bulk buy offers. The normal red or green ones only brighten up when on and always retain their colour when not on, but the type I suggest change from clear to red or green when they light up, making it easier to see when they are ON under low current conditions.

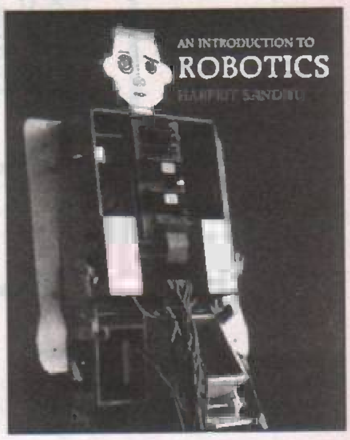
Construction

When the PCB has been built **(figure 4)** and tested and the piezo mounted on 2.5mm bolts above the PCB it can be installed in the box **(figure 5)**; it may need to be filed down to size, care being taken not to damage any of the tracks. When the PCB fits, the position of the hole for the probe can be found, directly below the holes in the PCB for the probe connections. Remember to allow enough room for the PCB when marking the hole position; a little too near the lid is better than pushing into the PCB. Remove the PCB before drilling. Ideally the hole should provide a snug fit for the jack plug probe; it if is a little loose a couple of blobs of glue gun glue will hold it in place. The lid of the box is drilled to expose the top of the LED and a few holes drilled over the piezo to allow the sound out. One tip is to use a scrap piece of Veroboard to position the holes in a pattern **(figure 6)**. Keep these holes small, 2mm, as they look neater and do not let in leaf debris and so on.

This project has proved very popular, with some students making more than one Aquaprobe for other members of the family.

When it is built and the batteries are fitted it will bleep and the LED will flash. A jack socket can be used with the tip and sleeve connections shorted, which will stop the output until required. When required the jack socket is removed and the Aquaprobe should bleep and flash because the probe is only in contact with the air, which has a very high resistance. Once you have confirmed that it is working the probe can be pushed into the soil in such a way that the body of the device is just above it. If the soil is damp Aquaprobe will stop bleeping and the LED stop flashing.

We noticed that with very sandy soil Aquaprobe worked better with RV1 set to higher than mid way (more anti-clockwise), and with peaty soil the setting should be a little lower, that is, further clockwise. Some soils "hang onto" damp better than others; this is found by trial and error.



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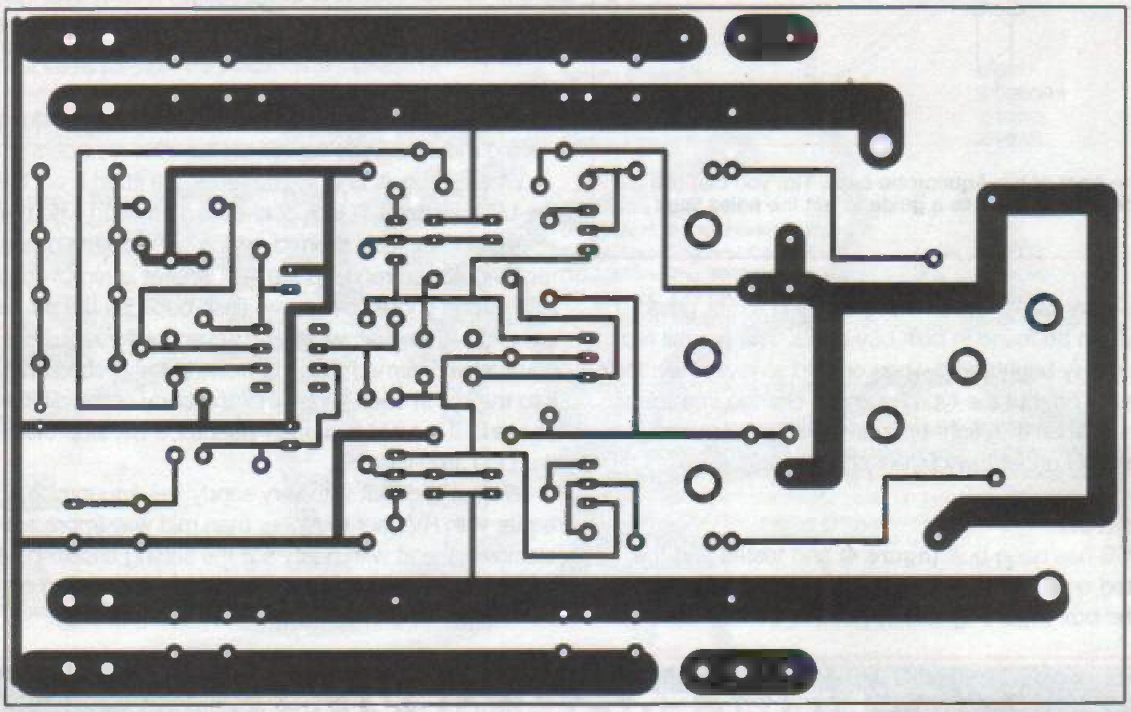

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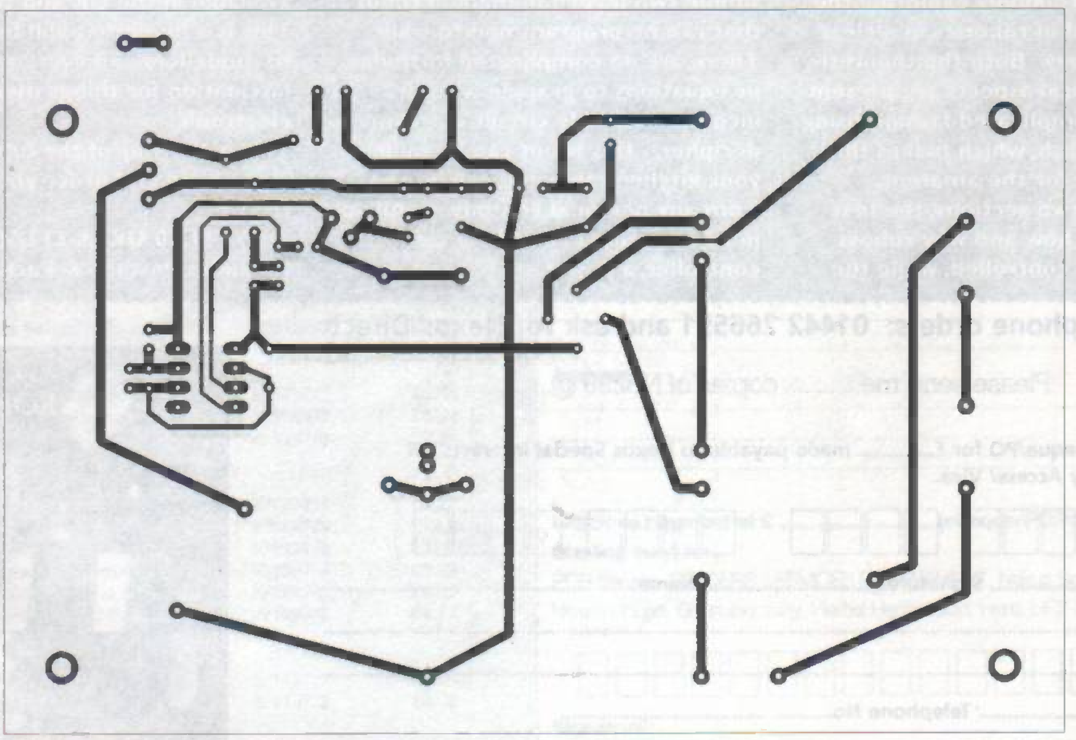

Mains Monitor

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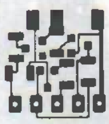

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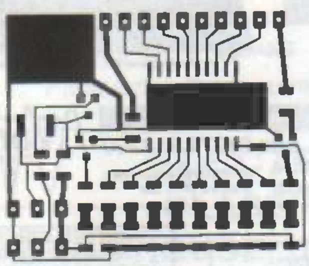
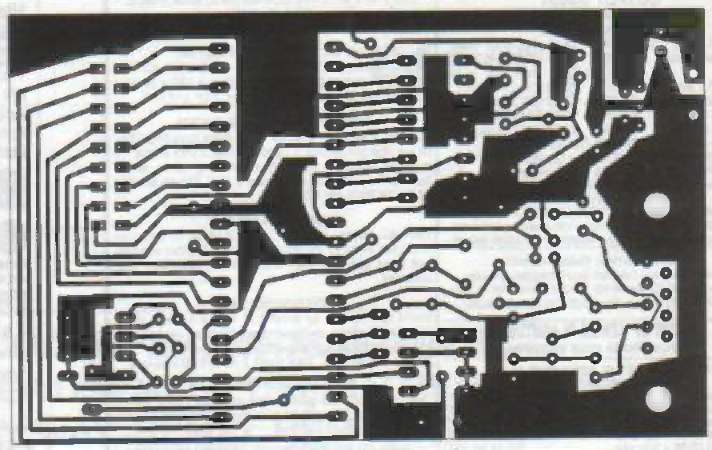
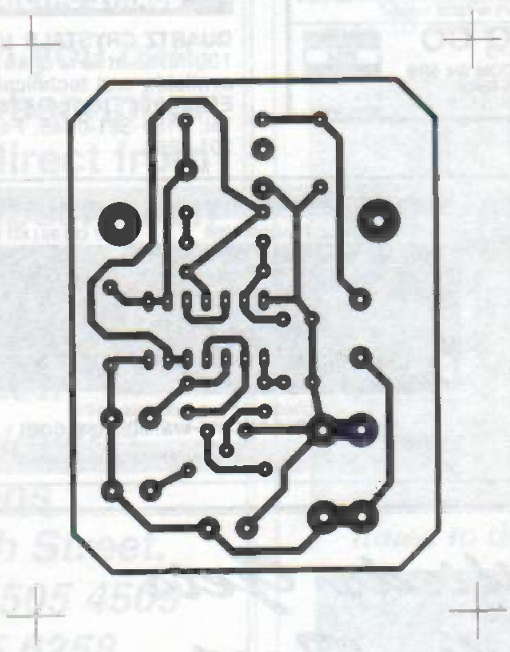


Surface Mount Logic Probe



PIC 16C74 Development Board



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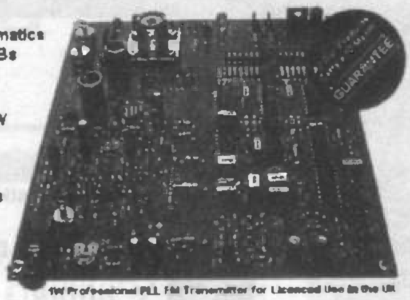

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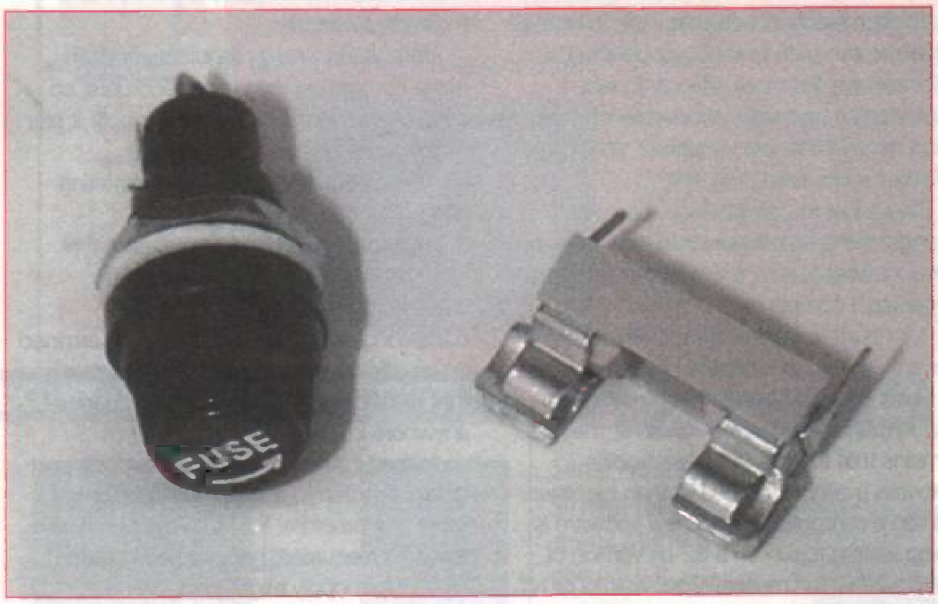
PRACTICALLY SPEAKING

TERRY BALBIRNIE

Last month we were looking at the topic of fuses, and I shall continue with it here. It is very important to choose the right fuse for the application.



On the left is a panel fuseholder, mounted through a hole in the case and changeable without opening the case up. On the right is a pcb-mounted fuseholder.

Choose your fuse

If you are selecting a fuse for a new circuit, you must first determine the maximum current which will flow through it. This can often be found by calculation, but otherwise it will need to be measured. A suitable fuse is then chosen to have a value slightly greater than this figure. If there are components which introduce a significant current surge when the circuit is switched on, such as transformers, large value capacitors, motors and filament lamps, it may be necessary to use a time delay (slow-blow) fuse rather than the ordinary quick-blow type.

You will also need to decide the physical size of fuse and whether it is to be of the glass or ceramic tube type. The high-rupture ceramic type **must** be used where it is to be wired directly into the mains. This is because, under short-circuit conditions, a current of several hundreds of amps could flow for a short time. This would result in the fuse blowing very violently, and a glass tube would shatter. The most convenient fuse length for amateur circuits is 20mm. Such fuses are used throughout Europe and are available in a wide range of values from about 50mA to 10A. They are also manufactured in standard and quick-blow variants and with glass or ceramic tube construction. In some pieces of equipment you will find 1.25-in (31mm) fuses with a diameter of 0.25in (6.35mm). These are popular in the USA and Canada.

Fuseholders

You will also need to choose a fuseholder. There are three main types - chassis, pcb-mounting (which looks very like a chassis fuseholder, but has downward-facing pins) and panel-mounting. These are available to suit 20-mm and 31-mm fuses. A chassis type is used when the fuses are mounted on the circuit board or fixed inside the case. However, the lid of the enclosure must be removed to replace it, and this will be inconvenient if the fuse blows more than occasionally. Some chassis and pcb fuseholders are of the self-contained (fuse block) type. Others consist of a pair of clips, which are soldered on to the PCB the correct distance apart. Clips save money and some space but are less convenient than fuse blocks. Fuse blocks can accept an insulating cover, which is **absolutely essential** when the fuse is used in the mains supply.

Some fuses do not require holders at all - they are simply "wired in" directly like a resistor. These are useful where space is at a premium and, of course, where it is not expected that they will blow very often. These are available in values from around 100mA to 10A and may be purchased in standard and slow-blow variants. A panel fuseholder is mounted through a hole drilled in the case, allowing the fuse to be removed from the outside. The end can be removed either by turning with the fingers or by using a coin or small screwdriver to allow the fuse to be replaced easily.

Inherently safer

When a fuse is used in the mains supply, it is always connected in the live wire. This is to ensure that, when the fuse blows, it is the live that will be disconnected, and this is inherently safer than if the neutral was the disconnected one. A further point is that when wiring up the mains supply to a panel fuseholder, the **bottom** connection is soldered to the incoming wire and the side connection is taken on to the circuit. Of course it would work if it the connections were interchanged, however, this method is safer because if someone was foolish enough to probe a metallic object such as a screwdriver into the fuseholder while the mains was connected it would be more likely to touch the side contact first. Also, if the object was pushed right in, it would probably cause a short-circuit and a fuse further down the line would blow. However, the rule is this: before replacing a mains fuse **always unplug the circuit from the mains socket** (do not just switch off) **first**.

Round the Corner

As I write this, a lawsuit has just been announced against Microsoft, and there are many opinions as to what it will mean in the long run. My immediate reaction was that if the Windows development path is seriously derailed, it will make my life more difficult. In fact, I shall start to be mildly inconvenienced as soon as my beta test version of Windows 98 reaches its valid time limit.

This is not to comment on the rights or wrongs of the situation, simply the knock-on effect of what is now a widespread standard in personal computing.

No doubt there are alternative and better ways to design an operating system. Users of Macs and other Apple machines think that Apple have just that. However, the fact remains that there is more electronics software available for the PC than for other personal computers. Most new software is being written to run on a 32-bit version of Windows, which means Windows '95 or NT. From the user's point of view, a prime significance of Windows is that it is a standard. If one program can use your monitor at full resolution, so can all others, without the need for a custom video driver for each program to run on each available graphics card. Been there, done it. Not in a hurry to do it again.

Even the user interface is similar, which speeds up the learning process on a new program.

The case against Microsoft has been compared to the break-up of AT&T, the aim of which was presumably to open up a monopoly to competition. Competition is known to drive improvements in service and cost reductions.

However, to get people using new technology in meaningful numbers, standards are needed. The ownership of VCRs rose after it became clear that VHS was likely to stay the dominant system. I personally thought that V2000 and Betamax showed more technical promise at the time, but I believe that it is more useful to most people to have one video system which works pretty well, than to have a multiplicity, some of which are superb, but with recorded and blank tapes expensive and limited in availability.

With VCRs, many manufacturers can make compatible tapes and recorders, so this is a standard without a monopoly. It has simply been selected from several competing standards by quick marketing and public preference.

Digital cellular phones are another example of a situation where a good standard is more useful than many competing ones. The standard is determined by an official body, and the result to date is that most cellular telephones can operate anywhere in Europe.

In the United States there are more different systems, and compatibility poses more of a problem. If AT&T, with its massive research resources, had not been broken up, the monopoly might plausibly have introduced standard cell 'phones across the United States. The benefits of improved competition probably outweigh a few compatibility problems, but a high grade of technical standards body might have been able to work round this downside to the company being broken up. A melee of competing standards is certainly better than a poor technical standard designed by bureaucrats proud of their lack of technical knowledge, but we do have examples of sensible standards which are largely beneficial. (I am hoping that the final digital television broadcasting system turns out well.)

Meanwhile, back on the question of Microsoft, I do not know what the right answer is, but I hope that the principle of standardising on a system which people find easier to learn is retained. Perhaps it will all be resolved by the time this reaches the newsagents, but equally it could take years. Will it affect most of us significantly? Yes! How? I doubt that anyone knows.

Next Month

Volume 27 no. 8 of *Electronics Today International* will be in your newsagents on 17th July 1998 ... Stephen Fleetwood has a practical Programmable Logic Control application to describe, along with the basics of Ladder Logic and programming ... Bart Trepak's digital electronic security lock keeps unauthorised users out of your equipment ... A sine-wave generator by Mark Roberts that plugs into your PC printer port gives you an on-screen display ... Terry Balbirnie's micro-trafficlights circuit can be fitted nearly anywhere ... plus all the regulars and more surprises.

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