ETI

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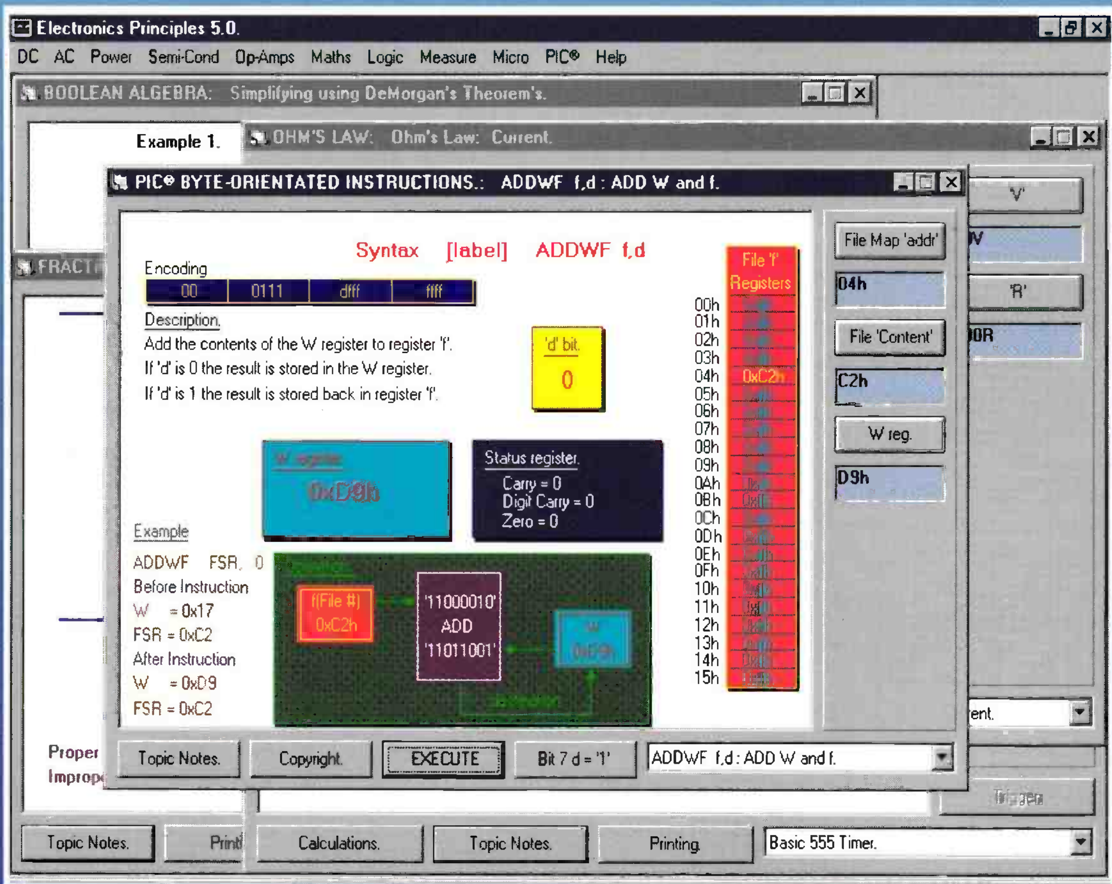

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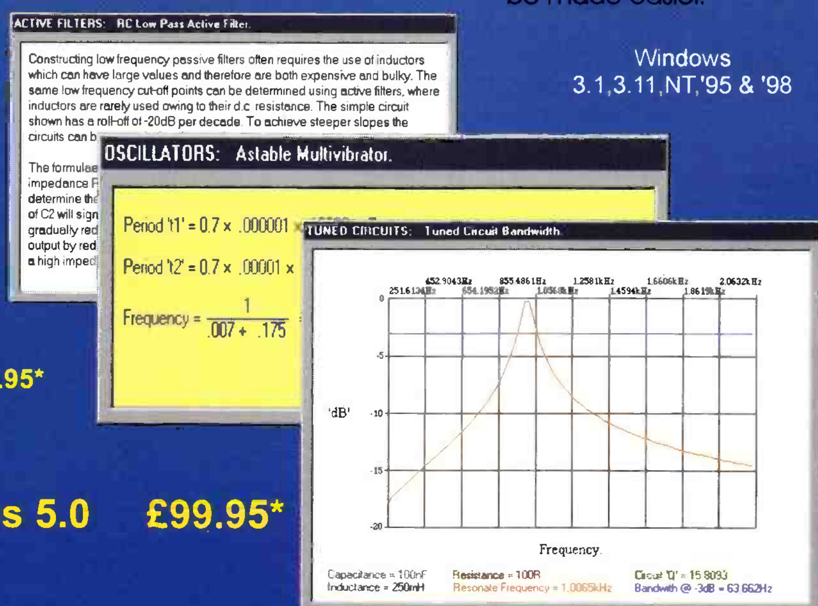

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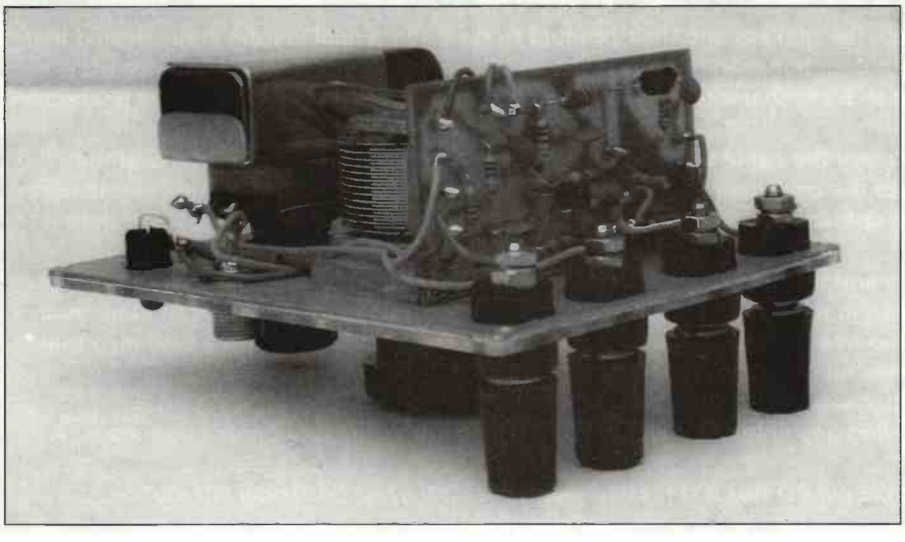


ETI ELECTRONICS TODAY INTERNATIONAL News...

New TTi dual and triple bench power supplies

Feedback Instruments of Crowborough, Sussex are distributing a pair of new dual- and triple- output bench power supplies from UK manufacturer TTi. The dual EX345D and triple EX345T deliver up to 280 and 305 watts respectively.

The power supplies are designed to provide accurate high resolution controls and readouts for exact setting of voltage and current levels, with separate, simultaneous voltage and current metering on each output. Line and load regulation are designed to be consistent and precise, and to provide high grade transient response with low noise.

The EX354D dual power supply has two independent isolated outputs with 0-35V and 0-4A capability. The outputs operate in constant voltage or constant current mode with automatic crossover and mode indication. Where higher voltages or currents are required, the outputs can be wired either in serious or in parallel to provide voltages up to 70V or currents up to 8A.

The EX354T has an additional "logic voltage" output with a 5A current capability. This output can be selected to 5V or 3.3V via a front panel switch and delivers an accuracy of +/- 2 percent.

The EX354D retails at around £354 and the EX354T at around £399 list price.

For more information contact Feedback Instruments, Park Road, Crowborough, E. Sussex TN6 2QR, UK. Tel 01892 653322 Fax 01892 663719.

BAEC Offers to Members

The British Amateur Electronics Club is offering its members help with PCB manufacture and components.

The long-standing BAEC always welcomes new members.

For information contact the Secretary, Mr. J F Davies, 70 Ash Road, Cuddington, Northwich, Cheshire SW8 2PB. Email john@fdavies.u-net.com

Micro-Monitor sits quietly in your keyboard cable

Micro-Spy is the name adopted by both the makers and their product to describe a mini cryptic cable device that plugs into Pentium or PC/AT X86 computers between the keyboard and the computer and records keyboard strokes. The Micro-Spy can record up to 2500 characters keyed in and then loops, leaving the last 2500 characters in place when it is read.

To retrieve the information, simply carry the cable with its built-in data collector away to your PC, load the accompanying Windows 95 software to the computer and connect up the Upload unit via one of the comms ports. The data collection unit plugs into the upload unit. Selecting Upload Data will display the contents of the data collector.

Between devices like the Micro Spy and the increasing monitoring of email and Internet use by company employees, this may be the time to bear in mind that the office computer is definitely not the place to store your personal secrets or indulge in frank and free discussions about your colleagues on company time (and also that removing data without authorisation has much the same legal standing as removing any other kind of documentary information without authorisation.

And talk to your data-doctor if you find any unfamiliar-looking lumps and bumps in your connecting leads. A complete kit is available at £195.

For more information, contact Micro-Spy, PO Box 3111, Milton Keynes, MK6 3ZH. Tel. 01908 607-007.

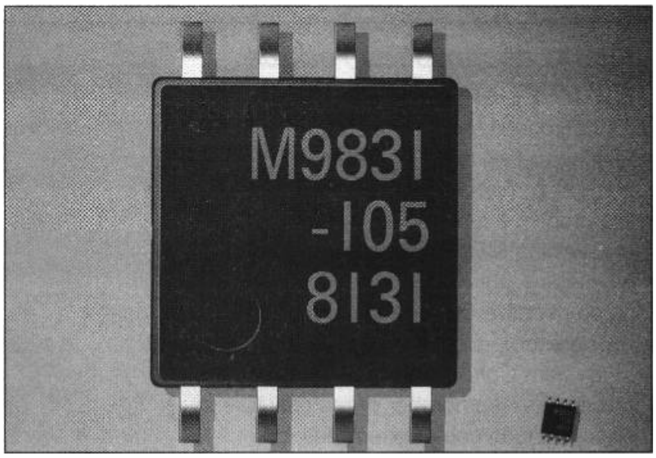
ETI ELECTRONICS TODAY INTERNATIONAL News...

Smallest speech synthesis LSI chip aims to put the sound back in appliances

OKI Semiconductor have developed the MSM9831, one of the industry's smallest single-chip speech synth LSIs, for applications including voice guidance systems, vehicle navigation systems and mechanical sound effects for digital appliances. With the increasing move from mainly mechanical to mainly digital equipment in everyday life, some "response sounds" expected by users are now being replaced by synthesised sounds.

A non-linear 8-bit PCM algorithm allows the MSM9831 to produce equivalent sound quality to a 10-bit straight PCM. The available sampling frequencies range from 4kHz to 16kHz, and voice quality and playback time to suit the application can be chosen by manufacturers. The MSM9831 provides up to 11 seconds playback time at 4kHz with up to 31 playback channels.

By using a special serial interface configuration, the normal number of pins has been halved, so that the device is small enough to fit into many portable appliances such as digital cameras, PDAs and portable CD players. The 8-pin SOP



(small outline package) is 6.8 x 5mm and holds a 10-bit DAC, a low-pass filter and 384 kbits of Mask rom. The power supply ranges from 2 to 5.5 volts, offering different voltage availability for different applications.

For further information contact Roger Bailey, Oki Europe, Shaftsbury Court, 18 Chalvey Park, Slough, Berks SK1 2HT. Tel 01753 516577 Fax 02735 517195.

The three best suggestions for a helpful (or not ?) "response sound" that might to be built into an everyday piece of household or workshop equipment each get a freebie from our Book Box. Suggestions must be printable. Computers don't count - they say quite enough already.

1998 Radio Spectrum Strategy Document released

The Radiocommunications Agency released the 1998 edition of the document Strategy for the future use of the Radio Spectrum in the UK in July.

The document provides the latest update to the consideration of how the radio spectrum between 9kHz and 105GHz will be managed into the 21st century. It currently takes account of the passing of the new Wireless Telegraphy Act 1998, the establishment of the UK Spectrum Strategy Committee and the 1997 World Radio Conference. The document also discussed the outcome from a series of demand studies. Minister for Small Firms Barbara Roche was quoted as saying in the foreword that "Radio contributes 1.8 percent of GDP and is creating 1000 new jobs a week; therefore a coherent and dynamic strategy towards managing the radio spectrum is virtually important." Given time, it could become vitally important. The forth edition of the document follows on from recent issues facing users such as the introduction of UMTS, digital broadcasting and spectrum pricing. The document is intended to continue a dialogue with users, so it is vital that radio spectrum users make their needs known to the DTI.

Agency publications including the Strategy document are available from The Information and Library Service, Radiocommunications Agency, New Kings Beam House, 22 Upper Ground, London SE1 9SA, UK. Tel. The Agency's Telephone Enquiry Point Service 0171 211 0211 8.30am to 5.30pm Monday to Friday. Fax 0171 211 0507 Web www.open.gov.uk/radiocom

ETI ELECTRONICS TODAY INTERNATIONAL News...

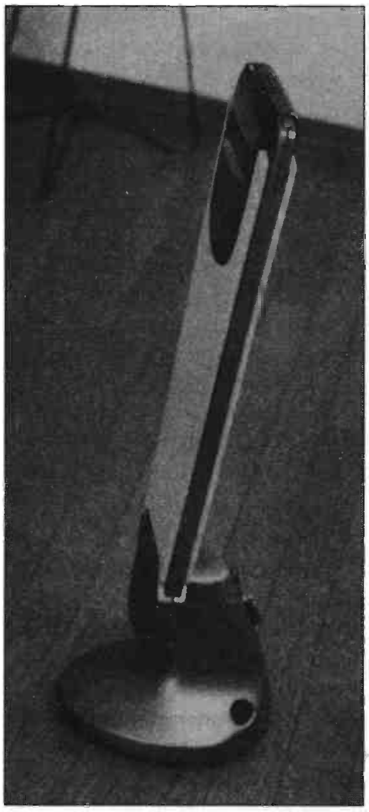
Cable assemblies reduce EMI/RFI emissions

As CE regulations introduced in 1996 relating to EMI and RFI emissions are becoming more strictly enforced, one of the problems facing designers is maintaining MEI/RFI suppression when cables are attached, as the cable acts as an effective aerial to radiate interference.

System Connections (Cambridge) Ltd. is one of a number of manufacturers specialising in cable assemblies for telecoms and data communications who are combating this problem with fully shielded cable sets.

Their Telco range uses specialised shielded cables, metal or metallised connector hoods and specific assembly techniques to exceed current emission regulations.

For further information contact Stephen Smith at System Connectors (Cambridge) Ltd. Tel 01223 860041 Fax 01223 863625.



NEC announces the world's first application of NXT flat panel technology

The world's first NXT flat panel technology loudspeakers have been launched by NEC Home Electronics in Japan in July.

The Euromint IS-101 'CD audio system' is based on the flat panel speak technology developed by New Transducers (NXT), Cambridge, UK, which allows the entire panel to vibrate and emit sound through 360 degrees around the panel with high clarity and without the need for a conventional speaker enclosure.

The NEC loudspeaker also provides "unprecedented wide 3-D sound" using SRS/Focus technology in combination - another first on the market - to give high specification horizontal and vertical sound reproduction characteristics.

The Euromint configuration is made up of a conventional 8-cm woofer installed in the pedastal combined with an NXT flat-panel mid-range unit and two NXT flat panel tweeters.

The whole unit includes a CD player and FM tuner in the top of the casing, and being a slimline 47 mm at the top and only weighing 4.2kg is easily movable (within the limits of its cable) for personal listening. Listeners who require stereo from the woofers would have to use two units on the line-in function from an outside, but the NXT flat panels in the upper and mid range give "surround" sound and the Euromint is designed to be used alone. Each speaker has an independent amplifier to maximise its performance.

The unit can be operated via a remote control unit and includes a nightlight and sleep/alarm timer function.

The Euromint is currently only available in Japan at a price of 59k Yen (about £300) but NEC hope that it will be available in Europe at the beginning of 1999 at a roughly comparable price.

For more information contact Monica Conway, NEC Europe Ltd. Tel 0171 353 4383 Fax 0171 353 4384 email monica.conway@uk.neceur.com

OVERSEAS READERS

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

ETI ELECTRONICS TODAY INTERNATIONAL News...

High functionality system-on-a-chip from Atmel MegaAVR

Atmel has announced its MegaAVRTM family of 8-bit system-on-a-chip microcontroller family for complex embedded control applications. The Atmega103 is the world's first 8-bit microcontroller to offer 1 Mbit (128KB) of in-system programmable Flash memory, 4 KB of in-system programmable eeprom data memory, 4 Kbytes of SRAM, a true 10-bit, 8-channel A/D converter, a full duplex uart, a watchdog timer, a real time clock with separate oscillator and three timer/counter4s with separate prescaler, packaged in a 64-pin TQFP package. The package allows 48 user programmable inputs/outputs.

The MegaAVR is a two-address machine with a two-stage pipeline and 32 8-bit working registers that provides single clock instruction execution for most instructions, which equates to 1 MIPS per megahertz. The MegaAVR's 120 instructions are optimised for every efficient assembly and C-language code density, exceeding that of most other 8-bit and 16-bit microcontrollers.

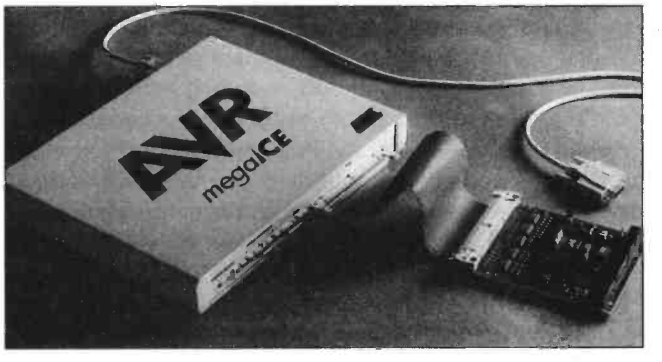
Devices such as analogue cellular phones, paper currency validators and electronic cameras are making dramatic demands in terms of instruction throughput, low power and a small footprint. These applications used to required a 16-bit microcontroller. With the MegaAVR family they can use an 8-bit processor at lower cost. Another significant advantage for updating in the field is the ability of update the application code simply and easily due to the Flash program memory.

Also out now, the MegaICE is a full featured real-time in-circuit emulator for the MegaAVR family of Flash-based microcontrollers.

MegaICE is optimised to offer real time emulation, supporting Flash memory densities up to 128KB, plus 4K of eeprom and up to 64KB of SRAM. Providing access to all the I/O pins, it emulates any MegaAVR peripheral set including full duplex uarts, timer/counters, real time clocks and the MegaAVR's 10-bit, 9-channel A/D converter. It allows an unlimited number of break points, including breaks triggered by external events such as an oscilloscope or logic analyser. It can also trigger external devices so that events can be captured and analysed. Single-step execution and an extensive trace buffer allow designers to identify the exact instruction or C statement that triggers a particular event.

The emulator is available from any Atmel distributor. AVR Studio is included with MegaICE and is available as freeware from the Atmel website www.atmel.com

For more information please contact Bob Henderson, Atmel UK, Riverside Way, Camberley, Surrey GU15 3YL. Tel 01276 686677 Fax 01276 686697.



Keep track of your Internet travels with a monitor-top timer

An established product with a useful look about it here: if you have ever wondered how much time you (or members of your family) are spending web-browsing each month, Oregon Scientific have produced a neat clock/timer to help keep track.
Home use of the Internet is the fastest-expanding area of web use and now accounts for over 25% of all access, most of it, you might think, by your teenage son or daughter.

The Internet Timer is a neat package that fits on top of the PC and uses a flexible set of time memories to allow you to follow either the count-up or count-down running time, and the total elapsed time simultaneously. You can therefore run an accumulating memory for elapsed timer intervals, add time to the memory for particular sessions, and so on.

The Timer has a large 69 x 19-mm LCD for easy reading and can stand freely on the desk or seated on top of any standard monitor using a "hook and loop" tape supplied.

The Oregon Scientific Internet Timer costs typically from £9.99 to £12.99 from leading electrical stores. It comes with a 1.5V battery, and the readout shows up to 99 hours and 59 minutes. "After which," say the makers tactfully, "even the most dedicated Internet surfer should perhaps consider taking a break." If you use more than that, you can either afford a whole team of timers, or you are likely to be receiving a stiff letter from your Bank manager sooner or later.

For more information, contact Andrew Dickson, Oregon Scientific tel 01628 826688 fax 01628 8236469 email admin@lha-pr.demon.co.uk

PRACTICALLY SPEAKING

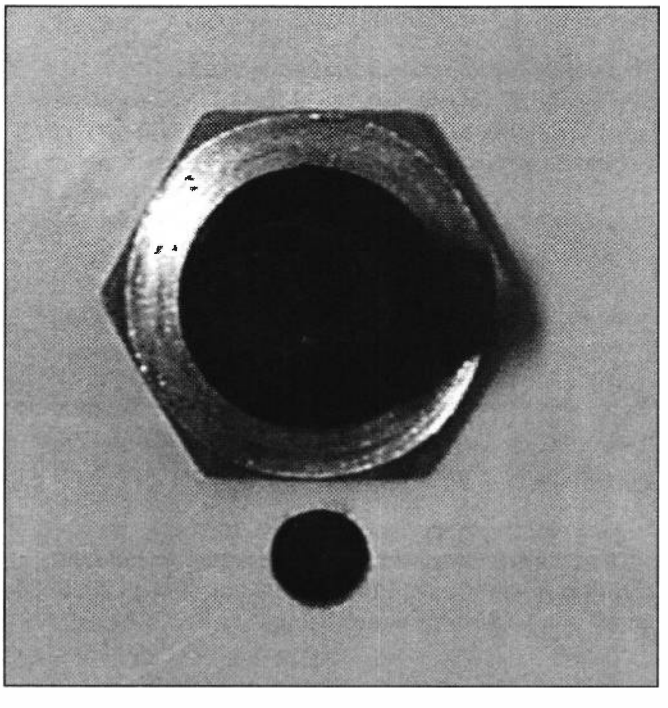
TERRY BALBIRNIE

This month we shall look at a few practical points about the use of panel-mounted potentiometers and rotary switches. For these purposes, any of my comments about a potentiometer applies equally well to a switch.

On the panel

When you are mounting a potentiometer, you must first cut the spindle to the right length for your control knob. The bottom of the knob should end up close to the panel. Spindles are always supplied much longer than you need in practice (rather like those jeans you used to get in the 1980s). Take care, however, not to cut off too much, or the grub screw in the knob will have nothing to tighten against and will not be secure. To cut the spindle, grip the end (the spindle, that is, not the potentiometer itself) in a small vice and support the body with one hand. Cut the spindle to the required length using a sharp hacksaw.

When you have drilled the hole in the panel, you may find that the potentiometer body does not locate correctly because there is a small plastic protrusion or metal tag (the "locating lug") on it. Many people simply cut this off, not knowing why it was there in the first place. However, it is much better to drill a small hole for it to pass through (see the photograph). The locating lug will then prevent the potentiometer from rotating in use if the fixing nut worked loose and the control knob was turned hard to its limit (as happens al too easily). The whole body would then turn, and this could even result in the connecting wires breaking off. Unsecured pots work loose quite easily, and it really spoils the look and feel of a construction to have a "free floating" pot on the front panel.



Anti-rotation

Potentiometers soldered directly to a PCB and then panel mounted do not need a locating lug because the construction prevents them from rotating. However, PCB-type potentiometers are often used for free panel mounting, and it is then essential to tighten the fixing nut securely and use the serrated washer supplied with it as a precaution against loosening.

Potentiometers are made in a range of spindle diameters. Most types available to the amateur have a 6mm diameter. This is suitable for the vast majority of control knobs. Although most knobs are secured with a grub screw, some up-market ones are held in place with collets. The best type of control knob has a recess on the underside to conceal the fixing nut. However, many of the types used in miniature circuits are too small to have this recess.

Fewer positions

Sometimes a project design specifies a single-pole rotary switch requiring, say, eight positions. When you look in the suppliers' catalogues, you find the switch is shown as having twelve positions. Some people just use it like that so that four of the positions do nothing. However, usually switches of this type can be adjusted to give any number of positions up to the specified maximum and it is obviously better to do this properly.

First, remove the fixing nut to reveal the metal washer. If the spindle end of the body is tapped on the table, the washer will probably fall out. If it is too tight, you will need to lever it out gently with a small blade. The washer has a small tab on the underside. Also, if you look at the place where the washer used to be, you will see a ring of holes. The tab may be placed in any one of them. The holes are usually numbered (although you may need a magnifying glass to see it). By using the appropriate hole, the switch will provide the required number of positions. You must turn the spindle fully anticlockwise before engaging the tab.

The Fingers That No-One Forgets

Fingerprints have long been part of police investigations, but demand for personal and commercial security has spurred a rush of development on fingerprint readers for everyday use in buildings, computers and even portable phones.

Of all "biometric identifiers", fingerprints are still the most famous. Tracing fingerprints has been synonymous with police work since Sir Edward Henry implemented them for criminal identification in India in the late 19th century, and later in the United Kingdom. Every fingerprint is different (the only exception is the fingerprints of identical twins). Fingerprints are fairly difficult to forge, and very rarely forgotten or left behind. They also have legal status as reliable evidence of identity, unlike some personal markers such as digital signatures.

In the last few years fingerprints could be stored as computer data by scanning an existing fingerprint (or the finger itself, known as live scanning) with an optical reader coupled to a digitiser to provide a digital file that pattern-recognition software could analyse and store.

Glass optics limited the extent to which readers could be miniaturised (and installed), but recent advances in semiconductor fabrication and pattern recognition software mean that fingerprints can be read by solid-state imaging ics other than the CCDs already in use. Some of these sensors can be made small enough to build into computer keyboards and other personal possessions such as mobile phones. They are likely to become a widespread means of secure ID in the very near future, particularly in fighting mobile phone fraud.

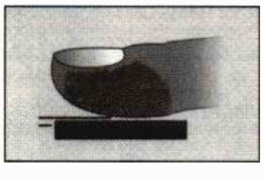
Capacitance

Since 1995, a team of scientists at the Bell Laboratories, part of US telecommunications giant Lucent Technologies, have been developing the FPS100 and FPS100A imaging chips with reading surfaces made up of a dense matrix of tiny capacitive plates. The array of sensors measures the capacitance generated between the surface of the chip and the surface of a finger. The ridges of the fingerprint contact the surface directly, but the "valleys" of the pattern remain clear of it. The software monitors the discharge times of the capacitance readings and converts these to a signal. The signal is processed into a greyscale image. This image is then analysed to provide the data which is stored for pattern recognition.

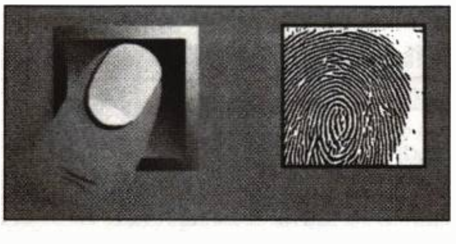
A significant security aspect of the method of analysis normally used is that the fingerprint pattern itself cannot be reconstructed from the data file. The data file holds only certain information, based on a selection of fingerprint features, to be compared with the original enrolment file and verify that the same finger is involved.

The Lucent system marketed by Veridicom of Santa Clara, California, has four main components:

* a silicon sensor to measure the ridges and valleys of the finger pressed against the chip
* analysis software that reconstructs the fingerprint in digital form and searches for the unique features (minutiae) that identify an individual fingerprint
* matching software that uses special algorithms to match the input fingerprint to the "enrolment" sample previously stored for the user
* data protection software that protects the fingerprint files from unauthorised copying or tampering

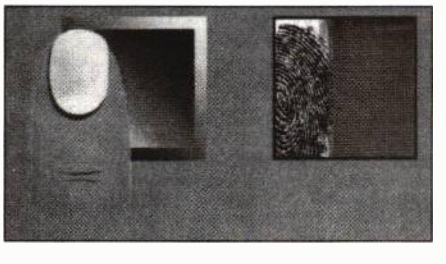


When a finger is placed on the chip's surface, the sensor array creates an 8-bit raster-scanned image of the ridges and valleys of the fingerprint.



The image presented to the sensor is captured. An on-board 8-bit ADC digitises the array output which is converted to a grayscale image

During image capture, automatic on-chip adjustments to sensitivity and gain control are made to obtain the best image. Integrated temperature and resistance sensors make it very difficult to fool the sensor



The quality of the image is analysed. Error codes flag problems like incorrect image position, no finger present or fingers that are too wet or too dry

The captured greyscale image is enhance to reduce noise and enhance ridges. Then it is converted to binary form

The minutia (ridge endings and bifurcations) of the fingerprint are identified. A set of minutia unique to that fingerprint is extracted and stored as a minutia template of that individual

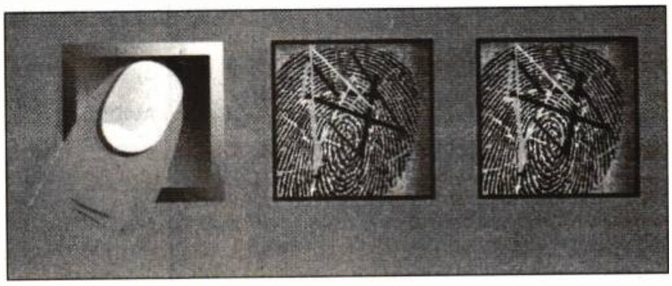
Finger plate

Lucent's capacitive imaging chip has around 90,000 (300 x 300) sensor pixels printed as the top metal layer of a CMOS chip with a surface roughly the size of a postage stamp, and covered with a thin layer of dielectric. When a finger touches the top of the chip, each sensor acts as the bottom plate of a capacitor, with the finger as the top plate. The chip has its own earth wires to discharge static carried by users (who are unlikely to remember to ground themselves each time they want to use the ID reader).

The company has also developed a coating for the reading surface combining titanium nitride and silicon nitride. The silicon acts as the dielectric, and the titanium gives the surface its hardness. This coating is many times harder than glass, and protects the chip from the wear and tear of daily use, moisture and airborne chemicals, and contact with acidic skin oils. The surface is highly resistant to scratching and abrasion, and is tough enough for industrial and commercial applications like ATMs.

When touched, the sensor array creates an 8-bit raster-scanned image (500 dpi) of the ridges and valleys of the fingerprint, and in the FPS100 ic an on-board ADC digitises the output. There is an 8-bit interface bus compatible with most microprocessors. There are also resistance and temperature sensors integrated that make it difficult to fool the system with, for instance, artificial fingerprints (see below). The stored file is a 300-byte data file of the fingerprint.

The matching software is designed to amplify the signal differences between the ridges and valleys of the print.



A live reading from a finger placed on the sensor is compared to the minutia data template stored for that person. If the data match, the individual's identity is verified. If the data do not match, the attempt is rejected.

Minutiae

Fingerprint features are divided into two types: the patterns, such whorls, arches and loops, that are formed by the collective paths of the ridges, and the minutiae, which are the ridge bifurcations, endpoints and other localised features. These are the "corners" seen on fingerprint patterns under a magnifying glass among the repetitive ridge patterns. It is the exact positions of these minutiae that provide the most easily analysable and distinctive differences. The pattern analysis software homes in on them.

Using silicon technology also allows extra functions to be added to the chips, such as A/D converters and on-board microprocessors, with little extra cost and no extra size. These chips are not yet crowded: there is a lot more to go on them.

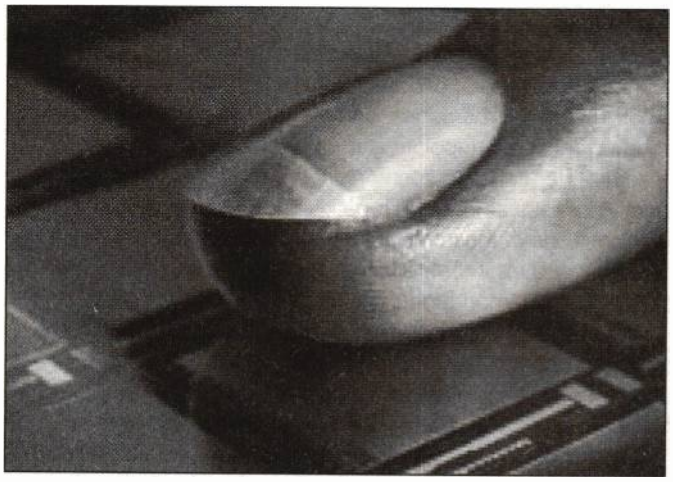
The image processing and analysis software developed at Veridicom must extract the minutiae from the inherently noisy fingerprint image, which can be contaminated by dirt, uneven pressure, cuts and scars, individual skin texture and even the stretching effect of skin plasticity. It enhances the ridge features and reduces the noise to produce a binary image of ridges on a white background. The software examines the ridges to locate the minutiae, and passes that information on the comparison software. An adaptive filter matches the pattern of ridges all over the print to give a more complete picture. This filter adjusts its passband to take account of the bandwidth of the actual signal, rejecting noise outside that range. It adapts to different signal frequencies - in this case spatial frequencies of minutiae. Many adaptive filters are, in effect, 2-D digital signal processing algorithms with a built in capability to adjust some of parameters according to the input data.

Veridicom's senior scientist Tony Russo worked on the matching code for several years. The software takes the list of minutiae information and plots the geometric relationships between their positions. Each detail, or minutia, is related to the others by distance, angle type and other features. These complex geometric relationships are compared between the input fingerprint and the database fingerprint. A match is accepted if a number of these relationships meet a specified threshold.

The matching is less exhaustive than for forensic work, as the input fingerprint is matched against a known sample - a bank customer or employee - and only the validity of that match needs to be established.

Using the sensor interface is just a matter of "press here", and the fingerprint is read. Printing the capacitive plates during silicon fabrication means that each sensor's pixel element positioning is precise, and each sensor gives identical resolution, without the risk of distortion that can arise from optical light paths. A success rate in accurate matching of greater than 99 percent has been reported.

- Fingerprints have been in use since the 19th Century
- The fingerprint data file does not normally store a whole image, and the fingerprint image cannot be reconstructed from it. As well as reducing file size, this is a useful security feature.
- Lucent's capacitive imaging chip has around 90,000 sensor pixels printed on a CMOS chip roughly the size of a postage stamp
- Each fingerprint detail, or minutia, is related to the others by distance, angle type and other features.



Touching a Seimens capacitive sensor

On the phone

German company Seimens Nixdorf have developed capacative fingerprint sensor which can be manufactured for les than US$50 (laser scanners now used in optical scanning cost around $1000. A small, low cost sensor like this could be integrated in mobile phones or car ignition locks, and a sensor fitted in a mobile phone has already been exhibited.

The 1.7 cm2 chip's surface contains over 65,000 capacitive sensor elements with the resolution of 500 dpi.The chip sends the image of the fingertip to the computer, where the minutiae are extracted, and compores 12 - 24 characteristic points with the stored original data.

Currently the software applications for the sensor are running on a Pentium, but in two years' time the company want to implement the image processing in a digital signal processor directly on the chipcard. Today the data already being digitised on the chip itself, making it possibly "the most advanced in the world as far as integration is concerned", according to Seimens.

Another advantage of fitting sensors in mobile phones - apart from user security - is itemised billing among authorised users. Used in a car ignition lock it could feasibly replace ignition keys altogether.

Following hardware applications, the plan is to mount the sensor on a smartcard to replace PIN numbers. Getting the price down "by three to five times what it is now" is one necessary goal for such a mass application.

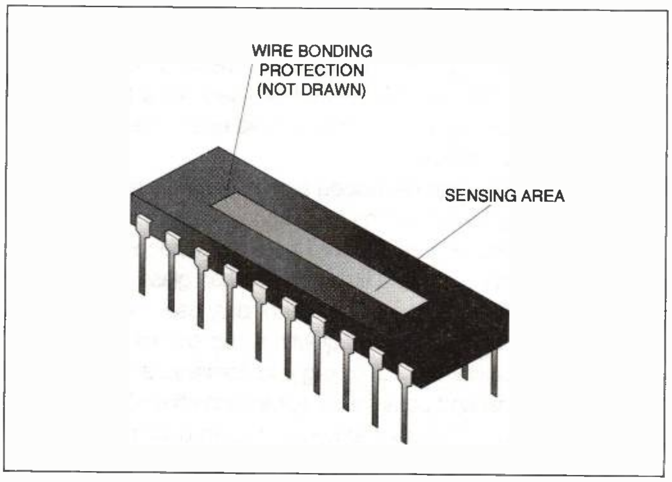
Seimens' researchers hope to achieve this by means of a membrane sensor in which the sensor surface consists of passive sensor elements.

Thermal imaging

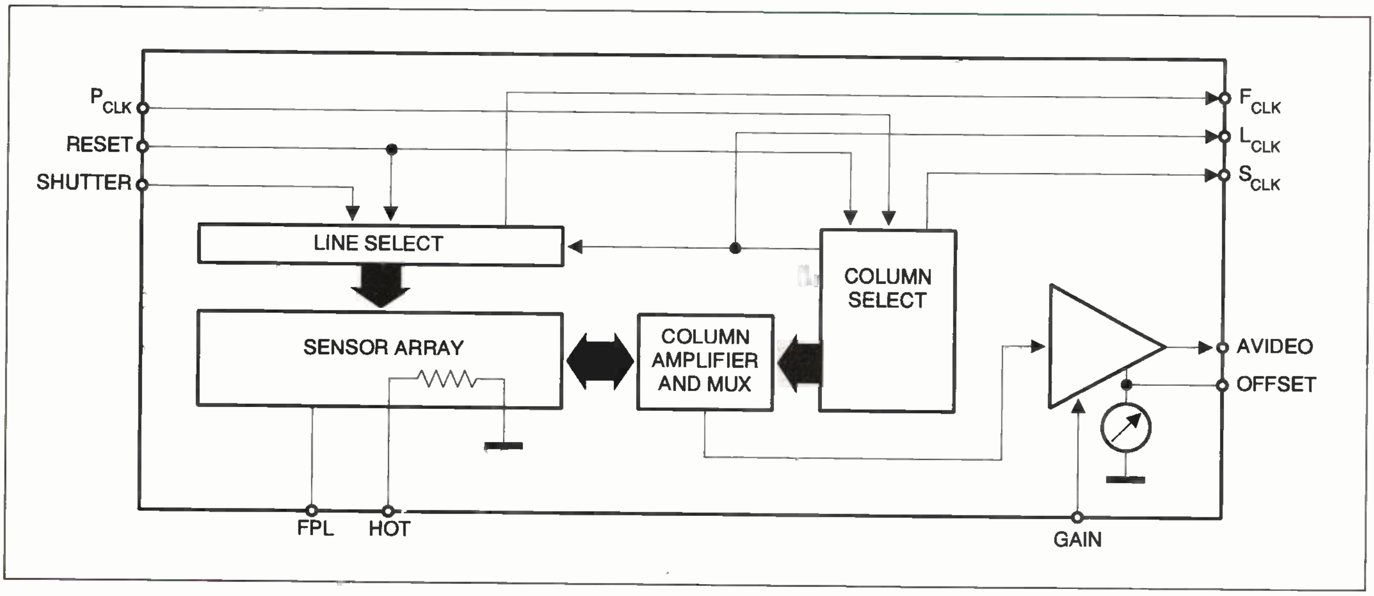
Thomson CSF Semiconductors Specifiques (TCS) have developed another new technique that uses an array of thermal sensors in their FingerChip(tm). The FC15A140 chip is a two dimensional array of 50um-square pyro-electric sensors with multiplex electronics and video output buffering. The array is long and narrow. To build up a complete fingerprint scan the user must draw the finger across the sensor chip while the reader takes a number of separate thermal readings. As it works fast, one pass of the finger can produce about 50 separate images, which are collated by the software into an accurate facsimile of the print.

Again, the thermal sensing is based on the fact that the skin contacts the sensor at the ridges, but not at the valleys, where it is the air (or water, etc.) in the valleys that makes contact. A damp finger couples better with a sensor surface than a dry one, giving a clearer image. At pixel level, it is the difference between the thermal conductivity of skin and air that makes the difference. The valleys do not need to be deep to create a signal.

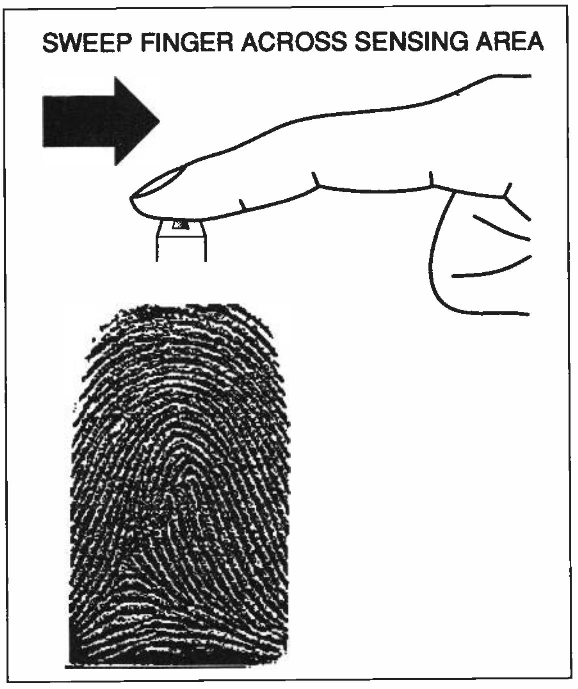
The sensing system can only work if the finger and the chip are at significantly different temperatures, but it does not matter whether the chip or the finger is warmer. If the finger is warmer than the chip,



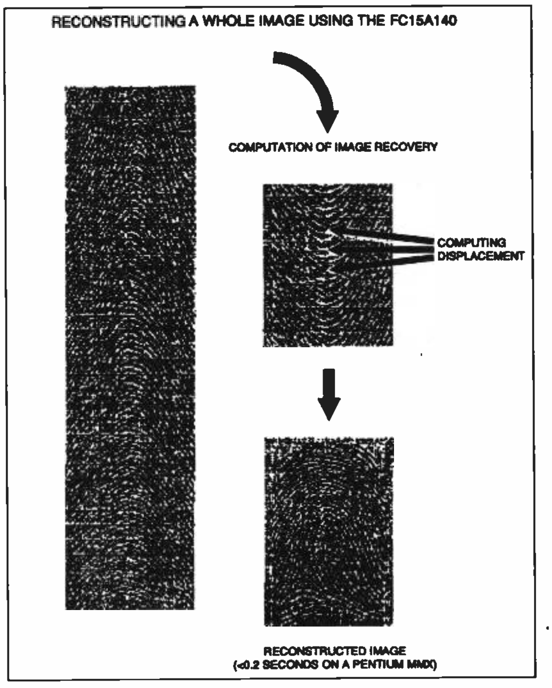
The FC15A140 FingperchipTM dil chip showing the sensing area



The block diagram of the FC15A140



Movement of the finger across the sensing area, and the area of fingerprint imaged



Reconstructing a whole image from samples using the FC15A140

then as the finger is moved over the array, the pyroelectric sensors receive extra heat in proportion to the shape of the fingerprint section over the array. They warm up, and after an integration period, dependent on the clock rate, the temperature difference between the start and end of the period is sampled. Then the current temperature is used as the new reference, and the next change in temperature is read.

Clearly, if the finger and the sensor are at the same temperature there will be no change in temperature, and therefore nothing to measure. To avoid this becoming a problem in practice, a heating element is included in the array. In a cold area this would not be used (unless it is so cold that build up of ice would otherwise occur). In a hot area, extra heat may be needed to warm the pyroelectric sensor array above the temperature of the finger. Then the finger moving across the array cools rather than warms it, so that the image is inverted. This can automatically be corrected by the verification software. The ideal is a good signal to noise ratio, and this depends on the implementation of the chip.

Data is clocked out of the array serially, with 280 rows of 30 pixels. The output signal must be converted to digital form using an analogue to digital converter, and then reconstructed using software.

There is a good reason for the array being of this apparently strange shape. If it were made large enough to cover the entire area of the fingerprint in one scan, then it would use five times as much silicon as the chosen shape uses. This would approximately multiply the cost by five. By using a moving finger, the size and cost of the sensor is kept down, while the repeat image scanning is able to provide a much larger image file than most systems if required, which makes it more suitable for 1-to-many comparisons, which require more detail than 1-to-1. As a heat difference of as little as 0.1 degree C can work under normal conditions, the moving finger also avoids the retention of heat and a build up of thermal equilibrium between the ridges and valleys and the sensor that could occur if the finger was pressed against the surface.

Another advantage of sweeping is that it tends to clear dirt off the sensor face, instead of accumulating it. Bearing in mind the tendency to "noise" in fingerprints, this is significant.

On the other hand, using only a single line of pixels would not permit the image to be reconstructed in the normal case where the speed of the finger moving over the sensor is neither constant nor repeatable. However, rather than capturing a single line of information, a narrow strip is captured. As long as there is some overlap between scans, a complete image can be built up without errors caused by variations in speed. If there is no overlap, then more than one pass may be required to build a complete image. A system can return a reconstructed image from about 50 partial images in under a second on a 133-MHz Pentium.

This image can then be processed by a suitable fingerprint identification algorithm.

One major advantage of a heat-based sensor is that it should be protection against the use of forged fingerprints (moulded in latex, for example) or any kind of substitute print that was not firmly attached to the owner's body.

Bureau work

Bureau work is different in some ways from individual identification for security purposes. Most fingerprint readers are taking an instant reading from the owner to compare with a single, known data file already stored. Cambridge Neurodynamics participates in fingerprint bureau work (such as that required by police forces) more than many fingerprint security businesses. @B:Neurodynamics' system is designed to provide both image and data files originating with latent prints (prints read from surfaces at the scene of a crime); tenprints (full sets taken on paper by the police or the military for their records and scanned in from the paper source), and damaged and partial prints retrieved in lieu of anything better, as well as single prints from security readers.

Fingerprints are familiar, so it is not always recognised how difficult it is to distinguish one print from another automatically. Pattern recognition is an extremely complex science. The difference between obtaining a graphics file and obtaining a matchable data file resembles the difference between scanning a letter as a graphics image, and subjecting it to optical character recognition so that it can be "read" by a word processor. The graphics file will return an image of a letter A, but cannot recognise it as a letter A, or use it as text in a database, wordprocessor or spellchecker. It is only a pattern of pixels. To utilise it, the pattern must be OCRd and recognised as an orthographic component, a letter.

To extract the pattern data from a fingerprint so that it can be automatically compared with other fingerprints is much more difficult. First, the image is analysed for one of the five major fingerprint classifications, according to the broad pattern type on the print. This homes in on the central part of the print, where the ridges usually form a "key feature" of a major whorl or loop. A neural network algorithm determines its location on the print, so that it will afterwards only be compared with prints of the same class, greatly reducing the number of comparisons needed.

Following this, the minutiae, as described earlier in this article, are analysed. Once all these characteristics are mapped and stored, making a comparison even through a very large database becomes more straightforward.

Programming each analysis stage is a very major task in artificial intelligence, with two main goals: accuracy is very important, as lives may depend on it; and the database searches involved are far larger than the one-to-one matches needed for security applications. For instance, matching any given suspect against a single print required manipulation of a "tenprint" file, as burglars - unlike employees or banking customers - do not select a particular finger when leaving prints behind. Prints are very often partial or extremely "noisy", and the size of a database search increases exponentially as the size of the database increases.

Unlike security access software, which does not normally store graphics files of fingerprints (for security reasons as well as saving space), security record systems do store "images for humans to look at", as human input is still required in the difficult environment of investigative matching.

Neurodynamics produce a low-cost fingerprint reader using a conventional optical system of a small solid state camera and prism, but their approach, designed to work with a variety of image readers, is a prime example of the ingenuity of software.

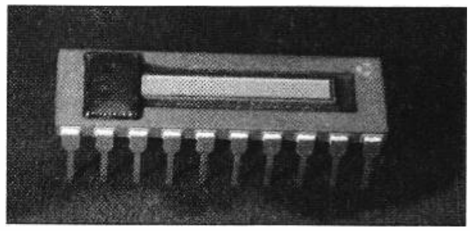
The company also produces N.VISAGE facial identification software. Security by facial recognition normally has not always enjoyed high confidence as many systems cannot tell the difference between the owner's face and a photograph of the same face. Systems that use advanced software to build up three-dimensional images and compensate for variables like a new beard or a change of head rotation give more secure matching

The N.VISAGE system uses infra-red to capture multiple frames from a face approaching the camera, scanning with a single beam, or with two beams set up opposite each other so that the subject walks through a "sheet" of sensing light to build up contours into a 3D image which is then used for pattern matching. As IR is invisible, the scans can be made in darkness or daylight without the subject knowing, and stored for later matching with scans taken from suspects.

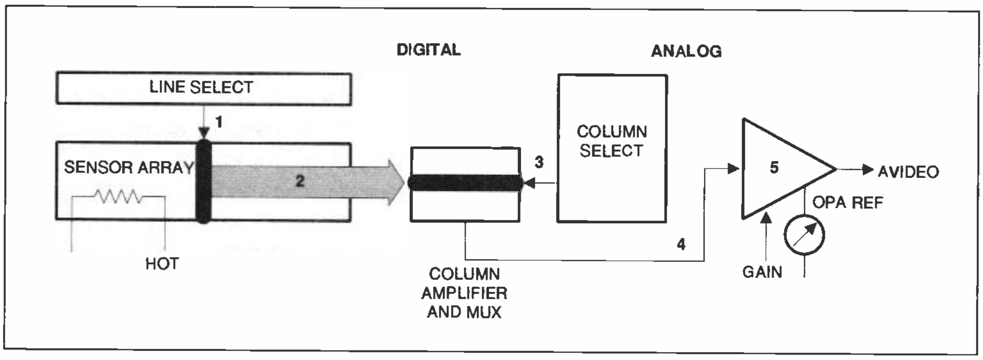
Ultrasound

Another method of reading fingerprints developed in recent years uses ultrasound. The system was developed by Ultra-Scan in the USA as a response to pass-rate problems with optical scanners.

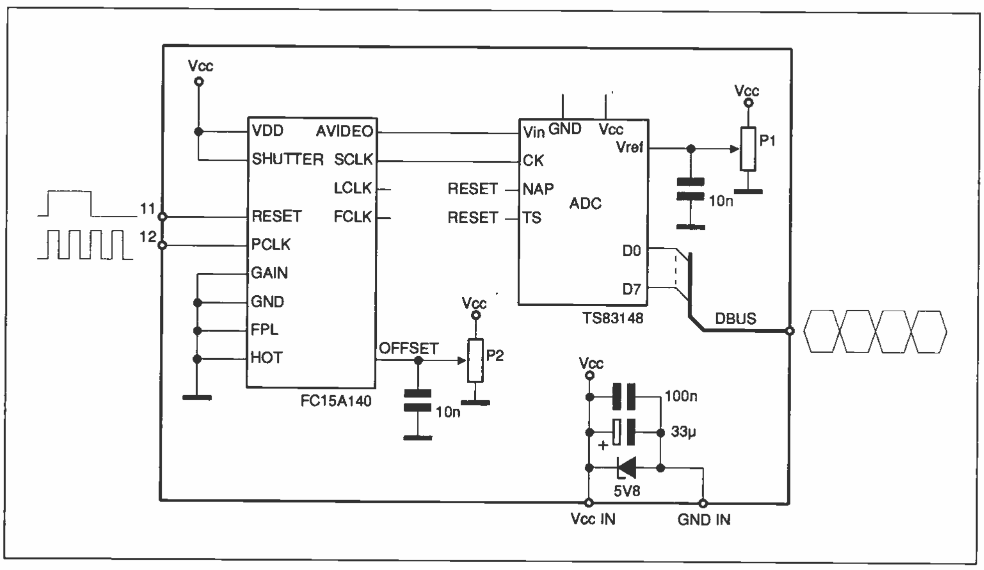
Ultrasound has the advantage over purely optical readers that the reading area does not need a frequently-replaced platen surface, and is not affected by the dirt and natural oil that tends to



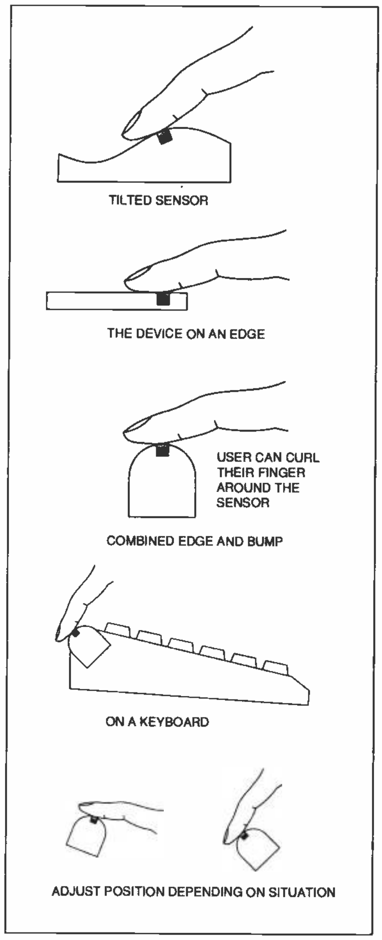
The FC15A140 FingperchipTM with the sensor in the middle and the connections covered at the left hand end.



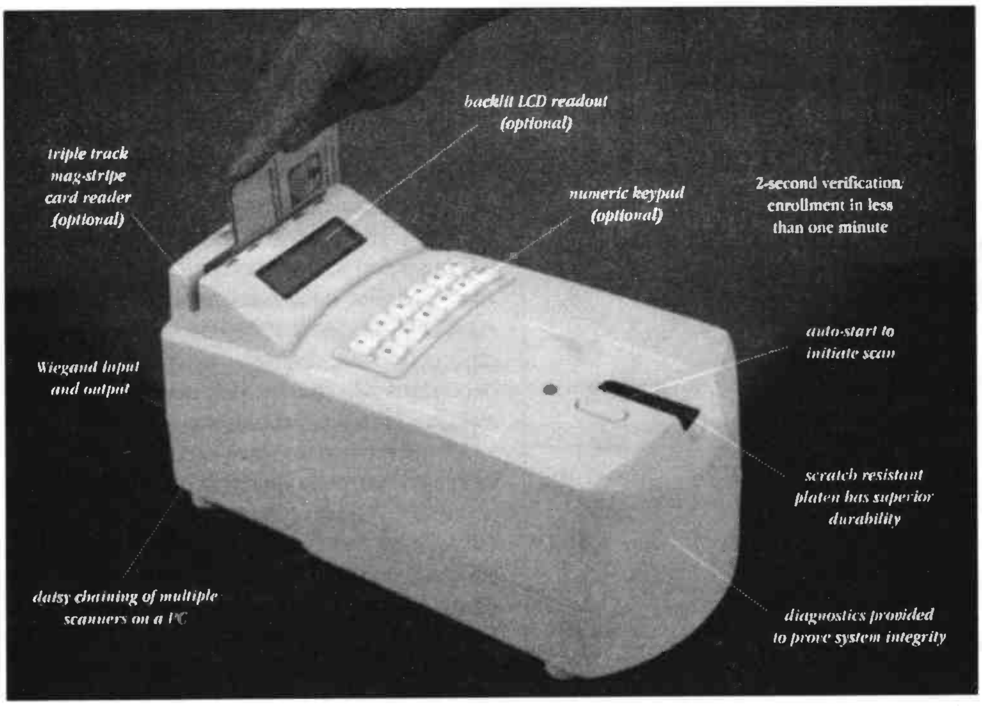
A functional diagram of the FC15A140



A final system implementation of the FC15A140 directly connected with the ADC, and using the rule "one clock stroke, one data". Future versions will integrate to ADC on the chip



Various configurations for mounting the sensor in equipment. The sensor has a very small footprint, but is not ideal for a completely flat surface



Ultra-Scan Series 700 ID StationTM with integrated finger scan, cardswipe and keypad options

accumulate even on fairly clean fingers. As the system does not rely on direct contact with the fingerprint pattern, it can also read an image through the latex gloves that must be worn by many people in Health professions. Many optical scanners use a soft surface on the reader to improve finger contact, whereas ultrasound, like capacitive and heat-sensitive readers, uses a hard-surfaced reader much less susceptible to wear.

Optical scanning also faces problems with, for example, very dry or very oily fingers, low humidity conditions and fingers with an uneven skin surface, along with the usual problems of dirt on the digit or the platen. Acoustic waves can travel through solid objects (like particles of everyday dirt) that are opaque to light.

Poor performance by optical scanners in some large-scale tests demonstrate that imperfect readings cannot simply be "fixed in software". The software may be (as programmers often tell us) the "clever bit" but it cannot entirely compensate for what is not captured accurately in an application where accuracy actually matters.

Ultrasonic acoustic energy passes through or is reflected from materials in its path, so that an image can be formed by reading the relative acoustic impedance between materials, including the solid ridges and hollow valleys of a fingerprint. When an acoustic wave meets an interface between materials of different acoustic impedance, part of the incident energy is reflected, and the rest passes through the interface. The reflections are picked up and read at a predetermined point to provide a signal which is then digitised to give the image data files. The plane surface of the platen would provide a convenient field from which to read reflections.

The fingerprint data is digitised inside the scanner and processed using a digital signal processor built into the scanner module. This means that the fingerprint image can be encrypted at the scanner before it is sent to the host computer, removing the likelihood of the fingerprint data being siphoned off or altered before it is encoded as a data file.

Ultra-Scan's hardware development and choice of software was based on experience gained working with the Identification Division of the FBI, and experiencing the shortfall in live-scanning technology available at the time (and as recently as 1996). Until the recent development of security biometrics, the matching of archived prints has been the main requirement for fingerprint matching.

Types of scanner

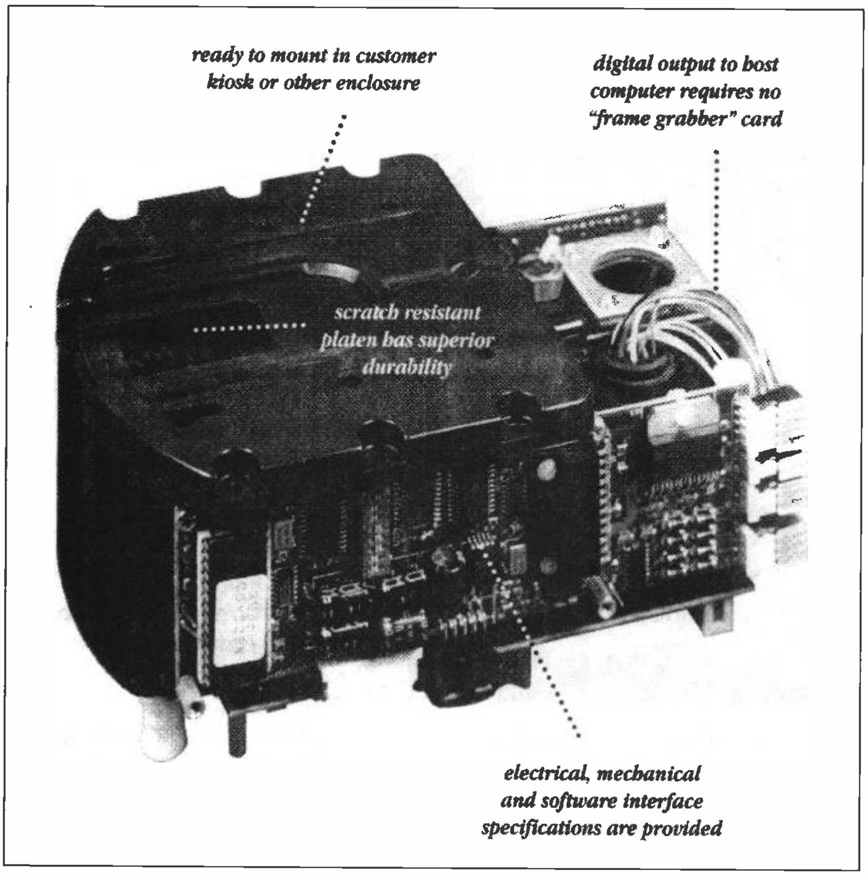
The range of reader modules produced gives some idea of the basic applications in fingerprint reading: the Series 500 is a forensic scanner, providing high resolution images to meet forensic requirement for law enforcement agencies: no distortion, wide greyscale range, high contrast and 500 dpi resolution. The series 600 is a fast, ruggedised scanner for large-scale applications, able to perform identity verification in 1.7 seconds. The Series 700 'Integrated ID ScannerTM' includes a card reader, keypad and LCD readout, with Wiegand input/output and RS-232 ports. The Series 700 are recommended for access control and time-and-attendance (clocking in and out). The Series 400 provides two OEM models, the 401 with the same functions as the Series 500, and the 411 corresponding to the Series 600. An OEM version of the Series 700 is planned for later in 1998.

Two image sizes are used for scanning: the Full Scan (1.2 x 0.8 in) and the Express Scan (0.5 x 0.5 in). The scan sizes are stored in firmware and can be altered in the field for different applications. Full Scans are used chiefly for enrolment, usually with a single scan.

Series 400 scan times with default image sizes

Series 400 500 dpi	Express	Full
Scan	1.7 sec	4.6 sec
Verify or enrol	3 sec	8.1 sec
Series 400 250 dpi	**Express**	**Full**
Scan	0.8 sec	2.3 sec
Verify or Enrol	1.7 sec	4 sec

- Live print matching is less exhaustive than for forensic work, as the input fingerprint is matched against a known sample, instead of an entire database.
- Fingerprints are so familiar that it is not always recognised how difficult it is to distinguish one from another automatically.
- Dirt on the finger or the reader is one of the biggest problems for fingerprint readers, particularly optical ones.
- Without a dual images from separate cameras, or separate readings from a single camera, face recognition cameras can be triggered with a photograph.



Images are stored (normally) as templates, containing the information about the minutiae extracted from the image, which gives a binary data TIF file of between 25 and 451 bytes. The recommended size for most analysis is 100 bytes (giving a file size of 1KB with the template). The larger the file, the more minutiae are extracted and the more rigorous the comparison possible. If the fingerprint image is to be stored, the file will be much larger, in the region of 236 KB for one finger or 470 KB for two. The minimum processor size recommended is still a 486, although faster results will be obtained with a faster processor.

Processing times using a Pentium 200 with 64MB ram

Enrollment	Scan size	Processing	Match time
Series 500/Model 401	Full	3.52 sec	0.9 sec
Series 600/700/Model 411	Full	1.77 sec	0.9 sec
Verification			
Series 500/Model 401	Express	1.29 sec	0.25 sec
Series 600/700/Model 411	Express	0.67 sec	0.25 sec

Three types of "start" settings can be used to initiate a scan: pushbutton (typically, a quick push initiates an Express scan and holding the button down initiates a Full scan); an autostart, which senses a finger placed on the platen and sends an ascii response to the host computer via the RS-232 port, and an ascii command issued via the RS-232 port by the host computer to the scanner. The OEM 400 models can also be operated from an external switch or an Ultra-Scan autostart request switch.

Diagnostics that run each time the scanner is powered up verify that all parts of the scanner are running at specification and that the quality of images does not deteriorate over time. A grey-scale calibration is performed on the scanner, and a code is sent via the serial port if the scanner fails any part of the diagnostics. Coupled with the fact that the reading surface needs no maintenance, no regular replacement (unlike soft coated platens) and virtually no cleaning, the reader is designed for low maintenance and a working life of more than 5 years in heavy use - good for a public interface.

Ultra-Scan do not release construction details of their ultrasound hardware, but extensive literature and support is provided to OEMs and other users on software applications and interfacing. The readers are packaged into a number of ways so that they can be built into other equipment, operate as simple plug-in units or combine with other security devices such as swipecard readers and keypads.

UltraScan have also promoted an industry-wide standard for fingerprint readers in their 1996 document Fingerprint Reader Specifications for Single Finger Live-Scan Devices (Proposed). The company points out that a great many test figures on optical scanners in particular have been produced under ideal conditions - moisturised fingers and assistance with accurate placing of the finger - that do not occur in real-life scanning.

Optical tests

Tests carried out by Network Computing in the USA on six optical fingerprint readers showed that there was more difficulty getting an accurate identification from people with less marked ridge definition - including many women and Asian people. Generally, men's fingerprints, with thicker skin surface, are easier to read than women's. Out of 20 people tested per system, nearly all the scanners rejected one valid user even after five attempts to read.

More entertainingly (but only for computer criminals), the tests found that latent fingerprints on a tabletop, carefully dusted with toner and lifted with adhesive tape, copied onto acetate on a photocopier, damping the ink side of the image and presenting it to contact readers, two of the readers were fooled into validating the print. In the case of silicone rubber copies of the fingertip skin moulded from wax finger imprints, four of the six scanners tested were fooled. Fingerprints may be distinctive, but they are by no means unforgeable.

Compatibility

A large number of companies are working on fingerprint biometrics using several different techniques.Studies have found that fingerprint minutiae may have up to seven distinct characteristics, and the average finger has about 70 minutiae, which would give 490 pieces of data for comparison. However, as many of the minutiae are similar, this is not enough to ensure a completely accurate match; hence the use of geometrical information relating to minutia positions in some algorithms, or comparison of the whole or part of the image in others, or a combination.

There is no general standard either for the template data (the stored information about a single print) or for the data extraction algorithms used, and these are kept confidential by the companies that develop them, for both commercial and security reasons. This can increase security and commercial competitiveness, but it also reduces compatibility between systems.

Faces forward

Earlier in this article we touched on the developing technology of facial recognition. TrueFace is a patented face recognition

technology belonging to Miros Inc. of Wellesley, USA. Trueface is designed as the "core technology" for a number of security software packages, including TrueFace PC (secure log-on to desktop PCs), and TrueFace Access, which is used for controlling entries such as doorways, or for clocking workers' time and attendance.

Preventing the system from being fooled with a photograph, as we said above, is essential for serious security. TrueFace can either be used with two camera modules, which effectively provide "stereo vision" that can distinguish between a 3D face and a 2D photograph, or it can be set to input two facial orientations (that is, a small move of the head) to make sure that the image comes from a 3D source.

Combined with a keypad or magnetic card reader, this gives a very flexible means of entrance security.

The TrueFace software uses neural networking to recognise faces, so that the software can learn from a variety of images that may be, for instance, affected by a change of angle or variations in lighting. It also samples features from all over the face, whereas some systems home in on distances and angles only in the eye/nose/mouth area.

The advantage of neural networks over fixed algorithms in pattern recognition, and particularly in facial recognition where the variation in faces is so great within the standard pattern, is that it is very difficult to write algorithms which cover all the relationships between possible inputs and possible actions. Neural networking is adaptable and can give a closer "fit" to the images it actually has to work with as it "learns" the best relationship between inputs and outputs (actions towards a known goal taken by the software on the basis of the inputs).

The TrueFace software can continuously monitor a video signal for new faces appearing in its field of view, or it can be accessed on demand by a key click, for example where the user may need to be matched to one area of a very large database ("Electronics Laboratory", for example!). The software engine in this case is a PC Dynamic Linked Library (DLL) or a Unix library, independent of particular computer peripherals. It can therefore work with virtually any database, smart card reader, video camera, scanner, frame grabber or image capture card, including the low-cost PC video cameras popular with Internet users in the States.

The main criterion is that the minimum height of the face within the image is 80 pixels of 8-bit grey-scale (like all biometric systems, the image is converted to greyscale before processing). Some face recognition systems need higher-specification cameras to deliver a sufficient frame rate to function properly.

Fast enough

The main requirement for a scanner or image capture card is that it should be fast enough to match the software in processing a pair of images to verification in about 1 second. Another new application, TrueFace Isolator, allows an unmanned camera to recognise, isolate, crop and scale a face from any background area. This is being used for "live" automatic recognition of faces, and for producing images for ID cards quickly and without manual setup.

As it is mainly used for access, speed is a real factor. TrueFace can verify a live image in about 1 second on a Pentium PC and produce a best match on a database at 500 faces per second on a Pentium 200 PC. Faster processors can process the faces roughly in proportion to the increase in processing speed.

Having compared a captured face image with a stored file, the software returns a "confidence level" on how good the match is in about a second, and then refers to a user-definable threshold to decide whether the confidence level indicates that the two faces are the same.

Because face recognition requires little or no special action on the part of the subject, it is convenient for the person seeking entry or loggin on, and has the added advantage to the user (if so desired) that faces can be read and analysed for surveillance purposes without the knowledge of the person being scanned. No other automatic biometric can yet do this. Even voice recognition, which is well established, is easier to thwart through changing a normal timbre, or signal distortion, than a visual image.

Identical twin faces can still fool facial systems, but, as Miros says, "What percentage of all fraud is cause by a twin perpetrator?"

The Miros software - in the form of TrueFace CyberWatch Logon95 - is available for individual PCs armed only with a small video camera mounted on the monitor, and can be downloaded from their website for around US$100. Another application combines it with a Mobile Phone Kit from US company ChatVideo!, which includes a mobile camera, microphone and loudspeaker headset and software that allows the user to talk, hear and see, using the Internet as the phone provider. And we thought that personal stereos were the last word in ignoring other pavement (or sidewalk) users.

The future

In biometrics, the ingenuity of the hardware is necessary to capture image data that can be analysed by the software, often under somewhat difficult conditions. The ingenuity of the software is important, because the better the software is, the more reliable are the comparison results from the signal delivered from the hardware, and the more flexible is the processing that can be obtained from it.

BUT the hardware must be capable of measuring something which is different for different people, substantially constant for the same individual, and only works with a actual living individual, not with a photo or replica. (There speaks a hardware engineer!)

Security will probably come to depend on multiple biometric readings. As we have seen, there already exist security systems that depend on at least two readings, such as finger and face, or finger and swipecard. It may be a while yet before we give up plastic cards in favour of our built-in barcodes.

A monitor-top camera sends the image to Trueface recognition software

Getting MORE out of PICs

Part 4

Robin Abbott

The first of two parts on using the I^2C bus. [part 1 of 2]

There are two main serial buses widely used for integrated circuit control: the I^2C bus and the SPI bus. Both buses are designed for relatively low-speed communications for those integrated circuits which rarely require configuration.

The SPI bus is based on a three-wire interface: one wire for the clock, one wire for transmitted data, and one for received data. It is easy to drive, and therefore is not the subject of this series. It has the disadvantage that it is not easy to hang multiple devices on the bus, or to have multiple bus masters.

The I^2C bus is a two-wire bus which is more difficult to drive. There are approximately 1,000 types of integrated circuit, mainly in the consumer markets, which use this type of bus.The bus is a proprietary standard designed by Phillips/Signetics. It has a great advantage with devices which have traditionally been multi-pin, and which can now be fitted into much smaller packages. Also, a number of devices can be driven on the single two-wire bus, which reduces the I/O count on the processor circuitry and makes pcb layout easier. This flexibility comes at the expense of increased interface complexity, and of relatively slow transfers.

Among PIC applications, the devices I have used most often which run on the I^2C bus are the small 8-pin serial eeproms. These suffer from slow access, but are mainly intended for storing configuration information or for data logging where speed is not significent. This article will describe how to drive the I2C bus from a PIC, and the following article (in next month's issue) will describe a complete serial eeprom programmer/reader application.

Slave devices

Devices on the I^2C interface can be master devices, slave devices or both. There must be at least one master, and there can be any number of slaves (limited by the addressing range of devices). **Figure 1** shows a configuration for two master devices and three slave devices. The wires on the interface are the clock line SCL and the data line SDA. The master device controls the clock line SCL. Normally devices use open-collector drivers on the I^2C bus, so the bus usually has a pullup resistor on SCL and SDA. This allows multiple devices to drive the bus simultaneously, so that if two masters attempt to access the bus at the same time there is no excessive current drain. For the purposes of this article, we shall assume only one master device as it is very rare that an I^2C bus has dual masters.

In any transfer of data there is always one device which acts as the master and one which acts as the slave. The master supplies the clock for the transfer, and defines which device is to be addressed and whether the transfer is a read or a write

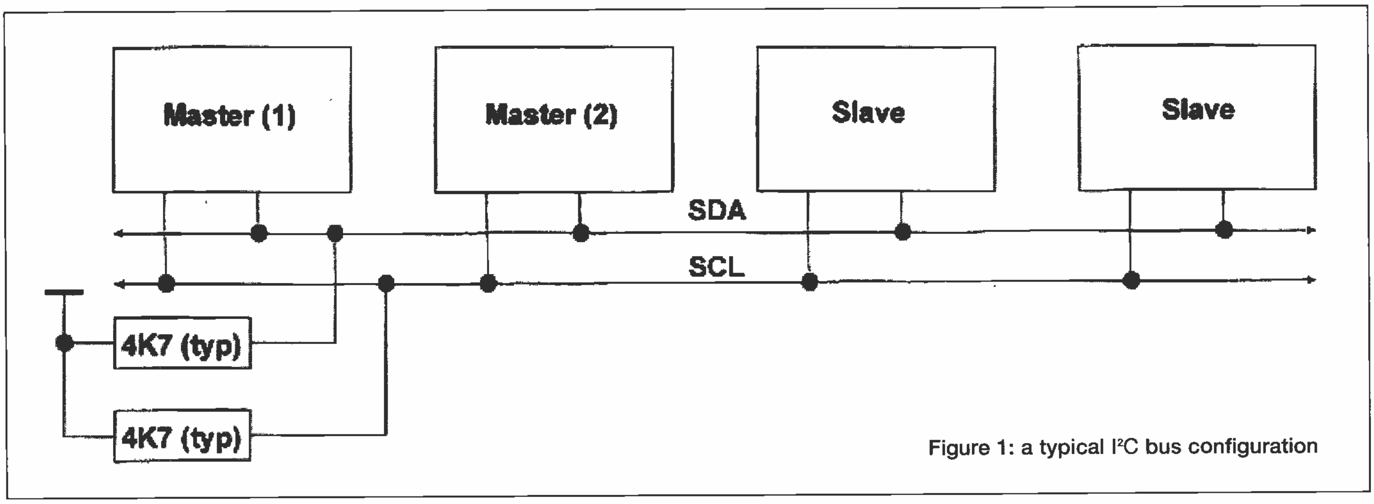


Figure 1: a typical I^2C bus configuration

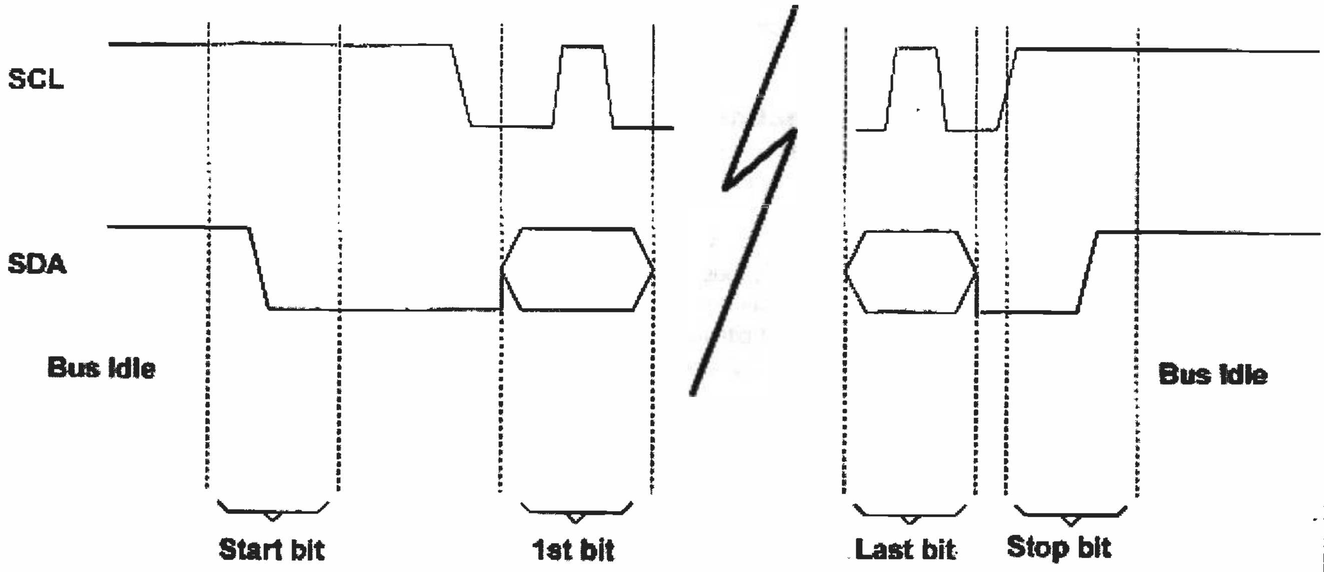


Figure 2: start and stop conditions

access. The slave checks the address, and if it is correct responds as defined by the master. In any transfer there will be eight bits and one acknowledgement bit sent. The acknowledgement bit is always sent by the device which is reading from the bus: if the master is transferring to the slave, the slave device acknowledges; if the slave is transferring to the master, the master acknowledges.

Bus states and data transfer

The idle state of the bus is defined by both the data and clock lines staying high. When the clock line is low, the data line can change without affecting the state of the bus. When the clock is high, the data line can only change to alter the state of the bus. The master bus must issue a start condition to gain control of the bus, and a stop condition when it has finished with the bus. A start condition is defined as the data line falling from high to low when the clock line is high, and a stop condition is defined as the data line rising from low to high when the clock line is high. These state changes are illustrated in **figure 2**.

Once a start condition has been issued, the master device can initiate transfer of one or more bytes to or from the slave device. Data is transferred using the clock. Each clock pulse (defined as a high period of the clock) transfers a single bit. The data can change when the clock is low, but must stay stable while the clock is high. Data is transferred in eight bits with the most significant bit transferred first. Following the eight data bits, the master must issue one final pulse for the acknowledgement. The transfer of a single byte with an acknowledgement is illustrated in **figure 3**.

It is important to note that several bytes may be transferred between the start and stop states: for example, many bytes may be read sequentially from a serial eeprom without issuing start and stop states between bytes. This increases the transfer speed.

Addressing and controlling slave devices

Most I²C slave devices have an address which is sent by the master device immediately after the start bit. The address forms the first seven bits of the first byte. The final bit of the first byte transferred is normally the read/write bit which defines whether a read or write transfer is to be initiated. This bit is low to write, and high to read.

The address of slave devices usually has a fixed part and a variable part. The fixed part occupies the upper bits of the address, and the variable part allows several devices of the same type to share the same bus. The fixed part is the same for a group. For instance, I²C memory devices such as serial eeproms and serial ram devices have a fixed address part of 1010 (binary).

The lower bits of the address (the variable part) can be selected using pins of the device. Some I²C devices have address pins, normally named A0, A1 and so on. These pins can be connected to Vss or Vdd. Thus, to define the address as 001 on a device with three address pins, A0 would be connected to Vdd, and pins A1 and A2 would be connected to Vss.

Some devices use the variable part of the address for internal decoding. For example, the 24LC16 eeprom device uses the three variable address bits to provide the top three address bits of the eeprom memory. There can only be one 24LC16 device on an I²C bus, and no other devices with the same fixed address part can share that bus or the devices will clash.

For example, a 24LC65 has a fixed address of 1010, and a variable part of 001, giving the overall address 1010001. The sequence to read a byte from a LC65 is as follows:

Start State
Send the byte 10100011 (Read from address 1010001)
Receive single bit acknowledgement from the LC65
Receive byte from LC65
Send single bit acknowledgement to the LC65
Send stop bit

The acknowledgement bit sent by the slave is low if the slave device recognises the address and has acted on the command, and high otherwise. The acknowledgement bit sent by the master is low if further bytes are to be received, and high if this is the last byte read.

Once a master device has control of the bus (having sent a start state and an address), then that master, and the addressed slave, can send or receive further bytes until a stop state is sent and the bus returns to the idle state. The further bytes sent depend on the specific device. For example an address and a write bit sent to the 8570 serial ram is followed by a single eight-bit internal address which is the ram address to be written, followed by one or more bytes to be written to that address and the following addresses sequentially.

Driving the I²C bus from a PIC in practice

The routines shown below provide a completely general-purpose I²C interface. A full serial eeprom programmer/reader using these routines will be in next month's article.

There is one main routine which has two entry points. This main routine provides a complete 8-bit interface to the I²C bus. It may be configured to send a start state before the transfer, to send a stop state after the transfer, to read or write eight bits to the bus, and finally to read or write an acknowledgement bit after the transfer.

Variables

The variables and definitions necessary for the I²C routines are shown in listing 1. This Include file is set up to use the 18-pin PIC general-purpose module shown in the first part of this series. The general-purpose module includes a DIL socket suitable for 8-pin eeprom devices.
Not all variables are used in this month's article; some are intended for the eeprom routines. The variables are as follows:

PROCFREQ	This is the processor frequency in kHz. This frequency must be set correctly for the correct operation of the eeprom, particularly at higher processor frequencies.
picio	This is the port used for the I²C bus. For the demonstration this is set to PORTA.
scl	This is the bit on the I²C port which is use for the serial clock, the SCL line to the I²C bus. On the demonstration this is bit 0 of port A.
sda	This is the bit on the I2C port which is use for the serial data, the SDA line to the I2C bus. On the demonstration this is bit 1 of port A.
sclv,sdav	These represent the values of the port bit when set. Sclv is 1, and sdav is 2.
writeval	This is the value to be written to the eeprom. It may be used for other purposes when the eeprom is not being accessed.
temp-temp4	These are five temporary variables used in the I²C and eeprom routines. They may be freely reused when the eeprom and I²C buses are not being accessed.

Listing 1

```
;
; This is the IIC bus header file
;
#ifndef __PICDE
 TRUE EQU 1
 FALSE EQU 0
#endif

PROCFREQ EQU .4000            ; Processor frequency in
                              KHz

EESETUP        EQU .100       ; Set up time for IIC in
                              nS
EEHOLD         EQU .0         ; Hold time for IIC in
                              nS
EECLOCKWID     EQU .600       ; Minimum High clock
                              width for IIC
EECLOCKWIDLO   EQU .1400      ; Minimum low clock width
                              for IIC
OPDELAY        EQU .1000      ; Output delay from clock
                              for IIC
STOPSETUP      EQU .600       ; Stop bit set up time
                              for IIC
FREQNS         EQU (.1000000/PROCFREQ)*4      ;
                                   Clock Cycle (nS)

picio          EQU      PORTA  ; Port to be used
                                      for IIC bus
scl            EQU      0     ; Serial clock bit on
                                      IIC bus port
sda            EQU      1     ; Serial data bit on
                                      IIC bus port
sclv           EQU      1     ; Value of clock bit
                                      if set
sdav           EQU      2     ; Value of data bit
                                      if set

#define RAMPAGE0 BCF STATUS,RP0        ; RAM page 0
#define RAMPAGE1 BSF STATUS,RP0        ; RAM page 1
#define ROMPAGE0 BCF PCLATH,3          ; ROM page 0
#define ROMPAGE1 BSF PCLATH,3          ; ROM page 1
;
; System variables
;
cblock 20h
   writeval      ; Holds value to write to IIC bus
   temp          ; 5 temp registers
   temp1         ;
   temp2         ; IIC routines
   temp3
   temp4
endc
```

Write/Read eight bits to the I²C Bus

Listing 2 shows the routines which are used to read and write the I²C bus. The routines are optimised for time not space. The first half of the listing shows the macros which are used to ensure that bus timing is met. Each macro is called with a parameter which is the number of machine cycles between two bus changes, the macro then inserts the necessary number of NOPs to ensure the time is met. A machine cycle is four clocks of the processor's main oscillator.

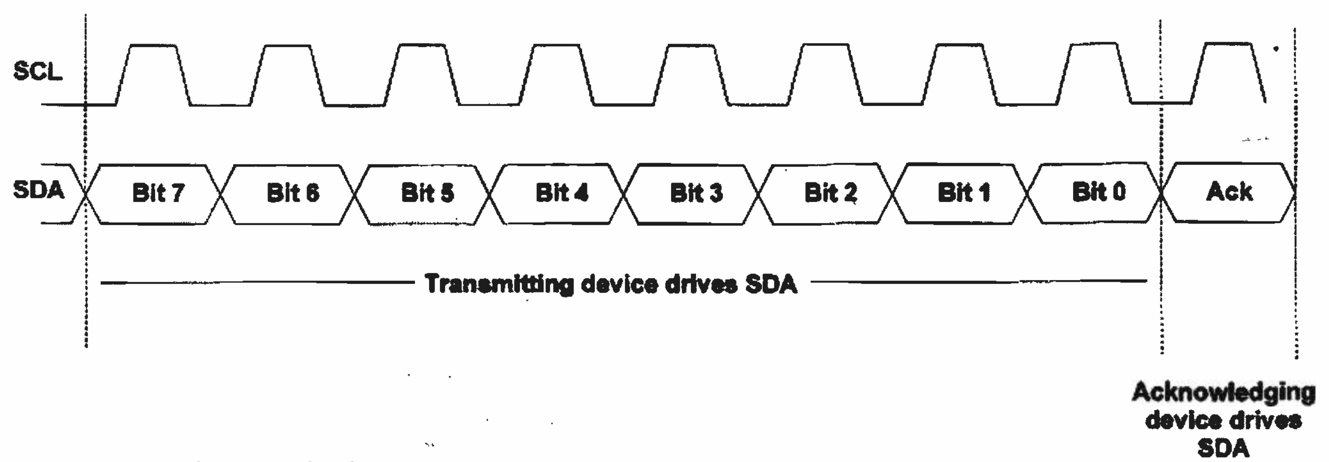
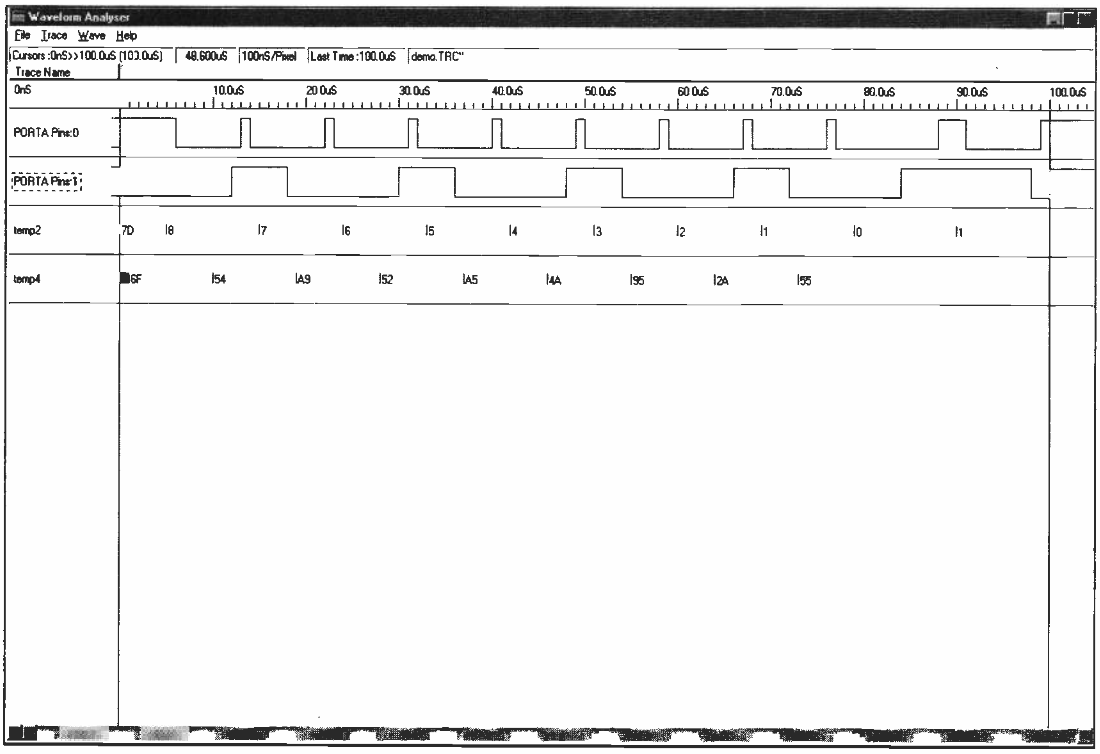


Figure 3: transferring a complete byte

Listing 2 - IIC Routines

```
;xxxxxxxxxxxxx
;
; IIC read/write
; Uses : temp, temp1,2,3,4
;
;xxxxxxxxxxxxx
;
; delay macros
;
; These are the number of delay cycles needed between
actions, these vary
; according to processor frequency and are essential at
20MHz clock to meet
; the IIC characteristics
;

SETUPCYC EQU  (EESETUP/FREQNS)+(((EESETUP/FREQNS)*FRE
QNS)!=EESETUP)
HOLDCYC  EQU  (EEHOLD/FREQNS)+(((EEHOLD/FREQNS)*FREQ
NS)!=EEHOLD)
CWCYC    EQU  (EECLOCKWID/FREQNS)+(((EECLOCKWID/FREQNS)*FR
EQNS)!=EECLOCKWID)
CWCYCLO  EQU  (EECLOCKWIDLO/FREQNS)+(((EECLOCKWIDLO/FRE
QNS)*FREQNS)!=EECLOCKWIDLO)
WAITOP   EQU  (OPDELAY/FREQNS)+(((OPDELAY/FREQNS)*FRE
QNS)!=OPDELAY)
STOPCYC  EQU  (STOPSETUP/FREQNS)+(((STOPSETUP/FREQNS)*FR
EQNS)!=STOPSETUP)

STOP macro exdelay
 x=STOPCYC-exdelay
 while x>0
  NOP
  x-=1
 endw
endm

WAITCLOCK macro exdelay
 x=WAITOP-exdelay
 while x>0
  NOP
  x-=1
 endw
endm

SETUP macro exdelay
 x=SETUPCYC-exdelay
 while x>0
  NOP
  x-=1
 endw
endm

HOLD macro exdelay
 x=HOLDCYC-exdelay
 while x>0
  NOP
  x-=1
 endw
endm

CLOCKWID macro exdelay
 x=CWCYC-exdelay
 while x>0
  NOP
  x-=1
 endw
endm

CLOCKWIDLO macro exdelay
 x=CWCYCLO-exdelay
 while x>0
  NOP
  x-=1
 endw
endm

; Write/read 8 bits to IIC, check ack
; Call WriteIICStart for start bit to the local IIC bus
; Call WriteIICNoStart for no start bit to the local IIC
; Call with scl bit driving
; Call with sda bit set to read for a Read operation, and
                driving for Write op.
; temp2 is index, and returns the state of the ACK bit
                from the device
; temp3 bit 0 is not used
; temp3 bit 1 indicates to generate a stop after the
                transfer
; temp3 bit 2 indicates to generate ack if set (Read ack
                if reset)
; temp3 bit 3 indicates to read from device if set
; temp4 reads input byte, or writes output byte
; Ends driving sda & scl

WriteIICStart   bcf picio,sda        ; Call here for
                                     Start bit - drops
                                     data
WriteIICNoStart movwf temp4          ; Call here for no
                                     start bit
                movlw picio          ; Move default bus
                                     to FSR
doiic           movwf FSR
                movlw 8
                movwf temp2
                bcf 0,scl            ; drop clock
                btfsc temp3,3        ; leap forward if
                                     read
                goto rdeelop
;
wrteelop        bcf 0,sda            ; This writes 8 bits
                                     to the IIC
                rlf temp4            ; now get correct
                                     port bit
                skpnc                ;
                bsf 0,sda            ;
                SETUP 1
                bsf 0,scl            ; clock now high
                CLOCKWID 1
                bcf 0,scl            ; clock low again
                CLOCKWIDLO 7
                decfsz temp2         ; and loop
                goto wrteelop        ;
                goto endthis
;
rdeelop         clrf temp4           ; This reads 8 bits
                                     from the IIC
                clrc
rdee2           bsf 0,scl            ; clock now high
                CLOCKWID 4
                btfsc 0,sda          ; now read input
                setc                 ;
                rlf temp4            ; Read in bit
                bcf 0,scl            ; clock low again
                CLOCKWIDLO 4
                decfsz temp2         ; and loop
                goto rdee2           ;
;
; This section handles the last bit (acknowledge or read
ack), and handles stop
;
endthis         bcf 0,sda            ; Acknowledgement is
                                     low

etstop          bsf FSR,7            ; either read or
                                     drive SDA
                bsf 0,sda;            Read from data line
                btfsc temp3,2
                bcf 0,sda            ; Now drive data
                                     line if ack
                bcf FSR,7
                SETUP 2
                bsf 0,scl            ; Send the last
                                     clock
                WAITCLOCK 1
                btfsc 0,sda          ; Test state of
                                     acknowledgement bit
                incf temp2           ; and if 1, then
                                     leave in temp 5
                CLOCKWID 3
                bcf 0,scl

                bsf 0,sda            ; Data line high
                bsf FSR,7            ; End by driving the
                                     data line
                bcf 0,sda
                bcf FSR,7

                btfss temp3,1        ; 1/2
                return                  ; 1 If no stop
bit return with scl low

dostop          bcf 0,sda            ; Call here to do a
                                     stop bit
                SETUP 1
                bsf 0,scl            ; otherwise clock
                                     high
                STOP 1
                bsf 0,sda            ; If stop return
                                     driving high on
                                     scl/sda
                return
;
; Generate a quick stop bit on the local IIC bus
; rapidly clock 8 bits and then do no_ack and STOP bit
;
quikstop        movlw picio
                movwf FSR
                movlw 8
                movwf temp2
quikclk         bsf 0,scl
                CLOCKWID 1
                bcf 0,scl
                CLOCKWIDLO 4
                decfsz temp2
                goto quikclk
                movlw 2
                movwf temp3          ; Set for stop bit and
read ack
                goto etstop
```

For example, the value CWCYC is set to the minimum number of machine cycles that the PIC must wait between raising the clock line and dropping it (the clock width). Now when the routine raises the clock it calls the macro CLOCKWID with a parameter of 1 (the number of machine cycles between the instruction to raise the clock, and the instruction to drop it). The macro now inserts NOPs to make up the total required number of clock cycles.



There are two bus read/write call points to be used by user routines:

WriteIICStart This is the call point which should be used when a start bit is to be generated. Before calling this routine the caller should ensure that the scl bit is high. In a write operation W should hold the value to be written to the bus.

WriteIICNoStart This is the call point which should be used when no start bit is to be generated. In a write operation W should hold the value to be written to the bus.

The following variables are used by these routines:

temp2	This variable returns the state of the acknowledgement bit, 0 or 1 after the transfer is complete.
temp3	This defines the actions to be undertaken on the bus.
bit 0	Not used
bit 1	If set, a stop bit is generated after the transfer
bit 2	If set, an ack is generated by the PIC after the transfer.
bit 3	If set, a read from the bus is performed, and the read byte is returned in temp4, otherwise the value in W is written
bit 4	Not used
bit 5	Not used
bit 6	Not used
bit 7	Not used
W	The W register holds the value to be written to the bus when the routine is called.
temp4	This is the byte which is read from the I²C bus when a read operation is to be performed.

It is the responsibility of the calling routine to ensure that the SDA line is set to read or write depending on the operation to be undertaken. The routine returns with SCL and SDA both set to drive the I²C bus.

quikstop this routine sends a number of clocks and terminates the bus operation with a stop bit. It is used to terminate the bus in the middle of an operation.

Figure 4 shows the waveform generated by the routines when sending the value AA hex to the I2C bus with a start bit and stop bit. This is printed from the PICDESIM logic analyser, and so is an accurate simulation report. The value of the pins of port A, and the variables temp2 and temp4, are also shown as the routine runs. Note that temp2 returns with the value 1, which is read as an acknowledgement bit from the bus.

Note that this routine is running with a PIC clock of 4MHz, and that the total time (measured by the cursors) is approximately 100 microseconds, it can be seen that the I2C bus is not very fast when driven by software! When reading from eeprom, this is as fast as a byte can be read sequentially. Random address reads take up to about 500us.

Initialisation

To initialise the I²C bus the SCL bit must be set to drive, it must also be set to the value 1. As the processor could be reset when the I²C bus is in any state the initialisation routine also writes clocks and a stop bit to the I²C bus. This has no effect normally, but terminates any current I²C operation when the device is reset.

Next Month - Using the routines

Next month we shall look at using these routines to drive 24LC65 devices, to make an EEPROM reader/writer. The LCD module driving article will be held over until the article after that.

Obtaining software

The software listings for this month's articles will be available from the ETI web site after the next article, and will be available on a disk from the author at the end of the series.

DIY PCs

Part 3: The BIOS and the Hard Disks

Robert Penfold

No doubt most readers will have heard the about the NASA service manual which listed several things to try in the event of a fault, concluding with "kick with space boot". This was later admitted to be an error - "kick with space boot" should of course have been at the top of the list!

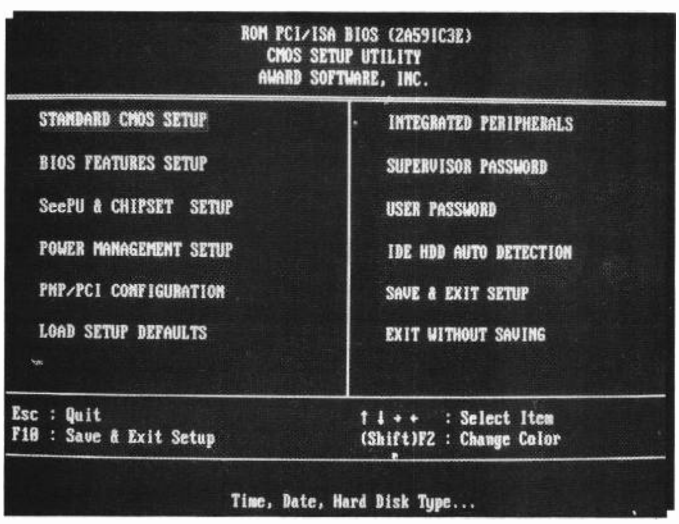
Perhaps kicking troublesome equipment is taking things a little too far, but problems with computer hardware often are genuinely caused by nothing more technical than a loose connector. Vibrating faulty equipment will often produce a cure, but such a cure is likely to be short-lived. Usually the main cause of problems with a newly constructed or upgraded computer is in getting everything set up correctly and the operating system installed. In this concluding part of this series we will look at some common teething problems, and how to overcome them.

Touch and go

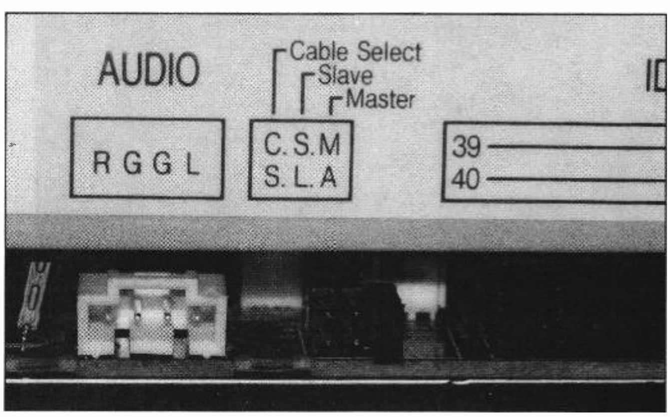
If the computer fails to boot up properly, or hardware error messages are produced during boot-up, it is always possible that there is a faulty component in the system, but it is far more likely that something is not connected properly. When investigating this type of problem it is quite normal to find that one of the connecting cables has come adrift at one end. Because of the mass of cabling in PCs, getting everything connected properly can be awkward. Fitting the last one or two cables can result in one of the cables fitted earlier being dislodged. Also, if you are tidying the cables with cable-ties, it is very easy to dislodge a connector in the process, so watch out for this. Often the connector will not pull completely free, giving no indication that all is not well. Or it may become fully disconnected, but in the mass of cables it may be less than obvious.

Correcting this type of fault is just a matter of checking every cable thoroughly to make sure that it is connected firmly at both ends. It is also worth double-checking that all the connectors are the right way round. In theory, most PC connectors are polarised, but in practice many of the connectors are slightly simplified versions that can be fitted either way round. Carefully check the connection diagrams for the motherboard and peripheral components to make sure that everything is as it should be. Fortunately, if you should accidentally connect a data cable incorrectly, it is unlikely that anything will be damaged. Faulty PC components are rare these days, and if you get everything connected properly it is virtually certain that the computer will work.

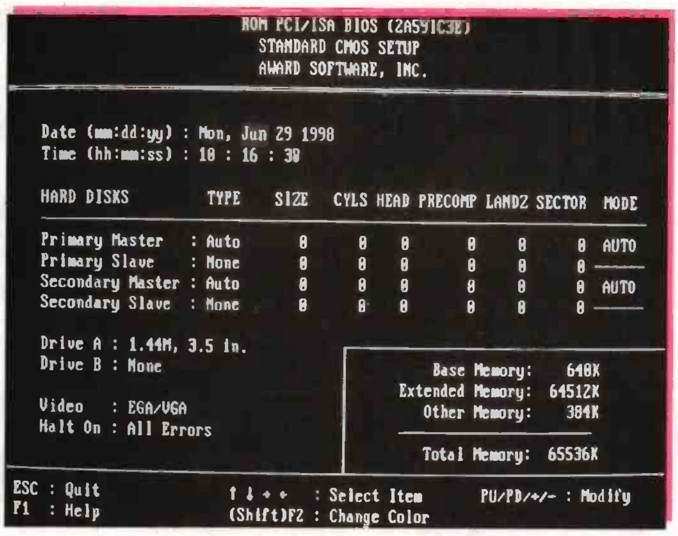
When I have been asked to help solve problems with newly constructed or upgraded computers the problem has often turned out to be an incorrect jumper setting on one of the IDE drives. When installing hard disk drives it is very easy to overlook these jumpers and end up with two slaves or two master devices on the same IDE channel. If the BIOS start-up routine seems to last an eternity, and operation of the computer is erratic, one of the IDE drives configured incorrectly is the most likely cause.



The Award BIOS Setup progam is controlled via the keyboard



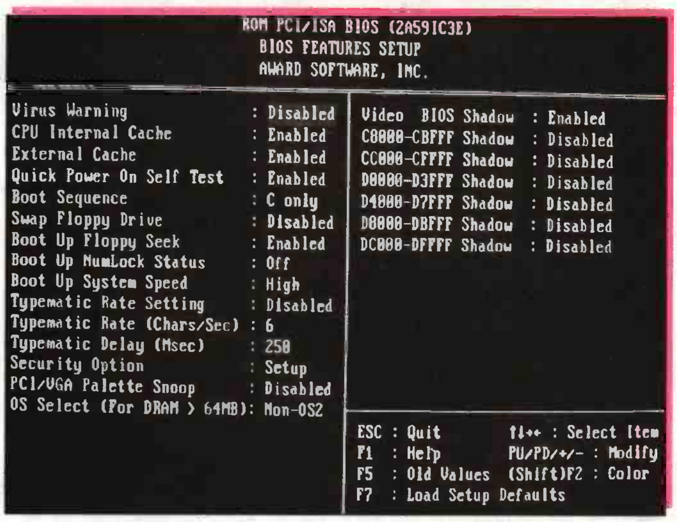
Do not forget to set IDE devices for master or slave operaiton, as appropriate. Ignore any "cable select" or similar option



The "Standard CMOS Setup" page of the Award BIOS. This will auto-detect IDE drivers, but you have to set the correct floppy drive type/s.

The microprocessor (under all normal circumstances!) will only fit onto the motherboard the right way round, and the ZIF sockets used on PC motherboards are of a very high quality. If there appears to be a problem with the processor, it is more likely that the motherboard is not configured right. Where appropriate, check that the jumpers or DIP switches have the correct settings for the exact microprocessor you are using. If the computer fails to enter the normal BIOS preliminary routines and just beeps at you, some form of memory failure is the likely culprit. Study the section of the motherboard manual that deals with memory to make sure that you are not trying to use a memory arrangement that the motherboard can not handle. Remember that SIMMs, unlike DIMMs, must normally be used in pairs. If you are using a single one pair of SIMMs they might work properly only if they are fitted in the appropriate pair of sockets (usually the bank 0 sockets). If the motherboard has provision for both SIMMs and DIMMs it will probably not be possible to use both types together, or one bank of SIMMs may have to be left unused.

The most likely cause of memory problems is that one or more of the modules is not fitted into its holder correctly. Even some of the more up-market motherboards have quite crude memory sockets that make it difficult to fit or remove the modules. Make quite sure that the memory modules are all fitted right down into their holders at both ends. In theory it is not possible to fit any memory modules around the wrong way, but in practice some SIMMs seem to fit either way round into their holders, however, on close inspection a module the wrong way round will be clearly off-centre. Whenever memory problems are suspected, it is probably worthwhile removing all the memory modules and re-fitting them. This often clears the problem.

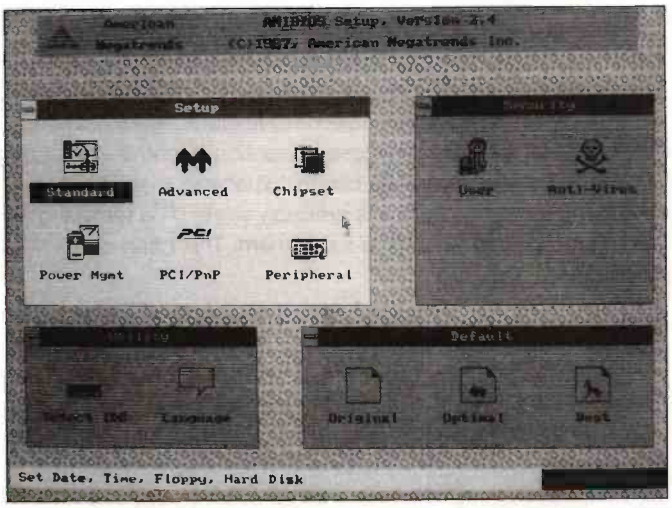


The BIOS Features Setup enables you to select the boot drives and search sequence. As with other sections of the BIOS, the default settings should give good results.

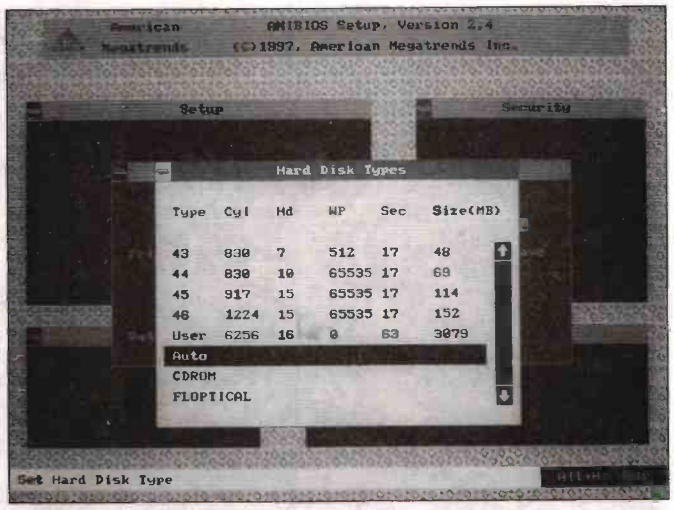
The BIOS

Many would-be upgraders and PC builders are put off by worries about dealing with the BIOS (basic input/output system). In early PCs the BIOS Setup program was run from a floppy disk, and stored only a few items of information in the battery-powered CMOS ram, such as the time, date, types of disk drive fitted, and the amount of memory. These are still stored in the battery-backed memory of the computer, but so are dozens of other parameters. It is this multitude of settings that is so daunting for first-time users. However, the BIOS defaults should ensure that the PC works reliably and reasonably quickly, and you do not have to deal with things like the memory timing. Nowadays the BIOS often detects the drive types, etc., leaving you nothing to do except enter the correct time and date.

- ***Cables can easily become disconnected as you connect up the other cables. Often the connector will not pull completely free, giving no indication that all is not well.***
- ***In theory it is not possible to fit any memory modules around the wrong way, but some SIMMs will "fit" incorrectly either way round into their holders***
- ***Nowadays the BIOS often detects the drive types, leaving you nothing to do except enter the correct time and date***
- ***If you like trying to tweak things for optimum performance you can experiment with the ram and I/O timing settings.***
- ***Although the new hard disk will be low-level formatted, it needs high-level formatting and the operating system added before it will boot***
- ***Life will be much easier if you set up the disk correctly at the start***
- ***Microsoft does not allow Windows 98 to be sold on its own, and it can only be obtained with some kind of hardware***
- ***In Windows 98 there is now a conversion utility to make the change from FAT16 to FAT32.***



The modern AMI Setup programs can be controlled using a mouse. The "Standard" sectionis the one used to set the time, date, and so on



Selecting the drive type with the AMI Setup program. Forget the 40 or so predefined drive types. Select Auto, or user if you want to enter the correct figures yourself

Now that virtually every motherboard has its own custom BIOS, a custom Setup program is needed to handle it correctly. The Setup is normally in an eprom on the motherboard, and is activated by pressing the delete key while the BIOS is going through its start-up routine. An on-screen message normally tells you which key to press when this stage of the start-up routine has been reached. BIOS Setup programs vary somewhat depending on the age of the motherboard and the BIOS manufacturer. Most can only be controlled via the keyboard, and some basic on-screen instructions provide details of the key functions. Some recent AMI BIOS Setup programs will detect a mouse. The number of parameters controlled by the BIOS is now so great that the Setup program invariably divides then into several categories.

The most important category is the standard CMOS set-up. This deals with traditional BIOS parameters such as the drive types, time and date. Most of this is perfectly straightforward, and only the IDE devices are likely to give any problems. Various parameters must be entered for the hard disk drive/s, and the manual for each drive should give the appropriate BIOS settings. Any modern BIOS should be able to automatically detect the drive types.

There are two ways of handling this. If you select "auto" as the drive type, the drive will be automatically detected and the appropriate parameters entered into the BIOS each time computer is booted up. The only problem with this method is that it can extend the boot-up time quite significantly with some drives. The alternative is to go into the auto-detection routine, which tests each of the IDE devices and places suitable parameters into the BIOS. This is probably the better option, as it should ensure that there is no boot-up delay.

There may be a BIOS setting specifically for CD-rom drives, but it is often absent. Selecting "auto" is the easy solution to the problem, but with some drives it produces a long boot-up delay, and is not always reliable. Again, the better option is to use the auto-detection routine so that suitable parameters are entered into the BIOS. These settings have no real significance for a CD-rom drive, and the auto-detect facility will probably just enter zero for each parameter.

Other BIOS settings

The only other section of the BIOS that may need your intervention to get satisfactory results is the one that deals with memory. This will be called something like "Chipset Features", and by default it will probably have an automatic configuration enabled. On most recent motherboards this will detect the type of memory and set the BIOS parameters accordingly. The BIOS is not able to detect the ram speed, and has to be rather conservative. It will probably set a ram speed of 70 nanoseconds, which is suitable for fast page ram. If you are using the EDO or SDRAM varieties this should be changed to 60ns. It may be necessary to tell the BIOS which type of ram is in use, but with most modern types this is unnecessary. If you like trying to tweak things for optimum performance you can experiment with the ram and I/O timing settings. The usual way of doing this is to try various settings, using a speed test program to check the system performance each time a change is made. Some settings that give fast operation may also give poor reliability. It's a matter of finding settings that give both speed and reliability.

It is worth looking through the various options available via the BIOS Setup program, as some of these allow some customisation. For example, you can normally select whether "Num lock" is on or off after boot-up, as well as which drive/s are used during the boot-up sequence. Many modern motherboards have a sensor that monitors the CPU temperature and sounds an alarm or shuts down the computer if a certain threshold temperature is exceeded. The BIOS Setup program may offer a range of threshold temperatures, and may even tell you the current CPU temperature. Perhaps more usefully, the section dealing with the on-board serial and parallel ports enables you to select the port addresses and interrupt numbers. This can sometimes help avoid conflicts with expansion cards such as an internal modem. In the case of the parallel printer port you can also select its operating mode. This may default to the standard (output only) mode, and will probably have to be changed to EPP or ECP operation in order to work properly with a modern printer or a scanner.

There is usually a BIOS setting that enables or disables support for Plug and Play operating systems. On the face of it, this feature should be enabled if you are using Windows 95 or 98. In practice, there can be the odd problem if this support is enabled, and it is safer to leave it at the default "off" setting.

There will almost certainly be a facility for low-level formatting a hard disk drive. Modern hard disks are supplied with the low-level formatting already completed, and you should not attempt to format them with this program. There will also be an option that enables the BIOS to be returned to its default settings. This is useful if you should tinker a little too much and completely scramble the settings.

Speed reading

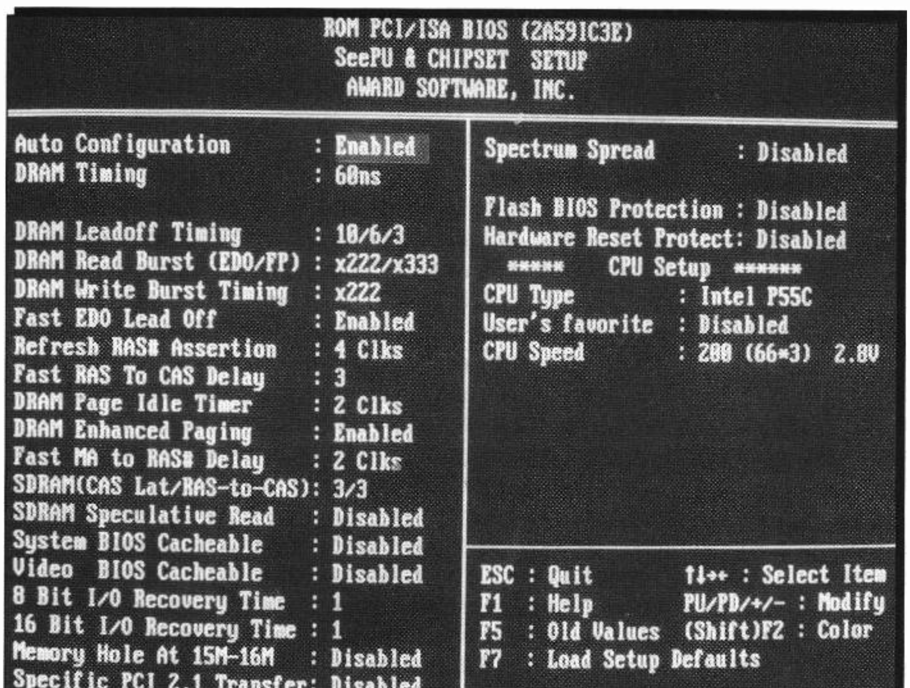
There can be problems when dealing with the UDMA33 hard disk interface. This is an improved version of the EIDE interface, which is itself an upgraded version of the original IDE interface. EIDE and IDE drives are fully compatible with the UDMA33 interface, and UDMA33 drives are fully compatible with the earlier interfaces. If you upgrade the motherboard to one that has a UDMA33 interface, but you continue to use your old drive, there will be no improvement in drive performance. Similarly, upgrading to a UDMA33 drive will not bring any major improvement in performance if the motherboard has only one of the earlier hard disk interfaces. To get the higher speed of a UDMA33 drive you require a motherboard and hard drive that both support this interface. Additionally, the BIOS must also support the UDMA33 interface, but if the motherboard supports this feature it would seem reasonable to assume that the BIOS will as well. The only other requirement is that the operating system you are using supports this interface and that it is equipped with a suitable driver. If you do not already have a suitable driver, a Windows 95 driver is apparently available from the Intel website http://developer.Intel.com/design
(look for the file called SETUPEX.EXE). However, a suitable driver should be supplied with the hard drive, or (more probably) with the motherboard.

UDMA33 hard disk drives are normally trouble-free when installed in a new computer, but not always when installed as an upgrade along with a new motherboard. The problem seems to be that Windows 95/98 does not automatically remove old drivers when installing new ones. This can lead to conflicts between the new and old drivers. At boot-up the operating system is likely to play safe, and revert to a basic 16-bit MS-DOS driver that will provide relatively poor performance. In theory, correct operation can be obtained by going into the Control Panel, then System and Device Manager. Select the offending drivers, delete them, and reboot the system. In practice this will not always work, because the new drivers may not have installed properly. If there are still some of the dreaded exclamation marks against the drivers in Device Manager, then all is certainly not well. Deleting the damaged drivers, rebooting, and then doing any necessary re-installation may put things right. In practice, you may have to delete and reboot repeatedly until everything sorts itself out. (This is known as the "try everything until it works" method, and seems to occur in computer troubleshooting up to very high levels.)

There can sometimes be problems with IDE devices for no apparent reason. This is probably due to obscure compatibility problems between certain makes of hard drive and CD-rom drive. It is most likely to occur when trying to use old and new hard drives together, but it can also occur when using a UDMA33 hard drive and a CD-rom drive on the same IDE interface. The CD-rom may fail to work at all, or can work in an erratic fashion. In either case, simply operating the incompatible drives on separate IDE interfaces will usually clear the problem.

Beating the system

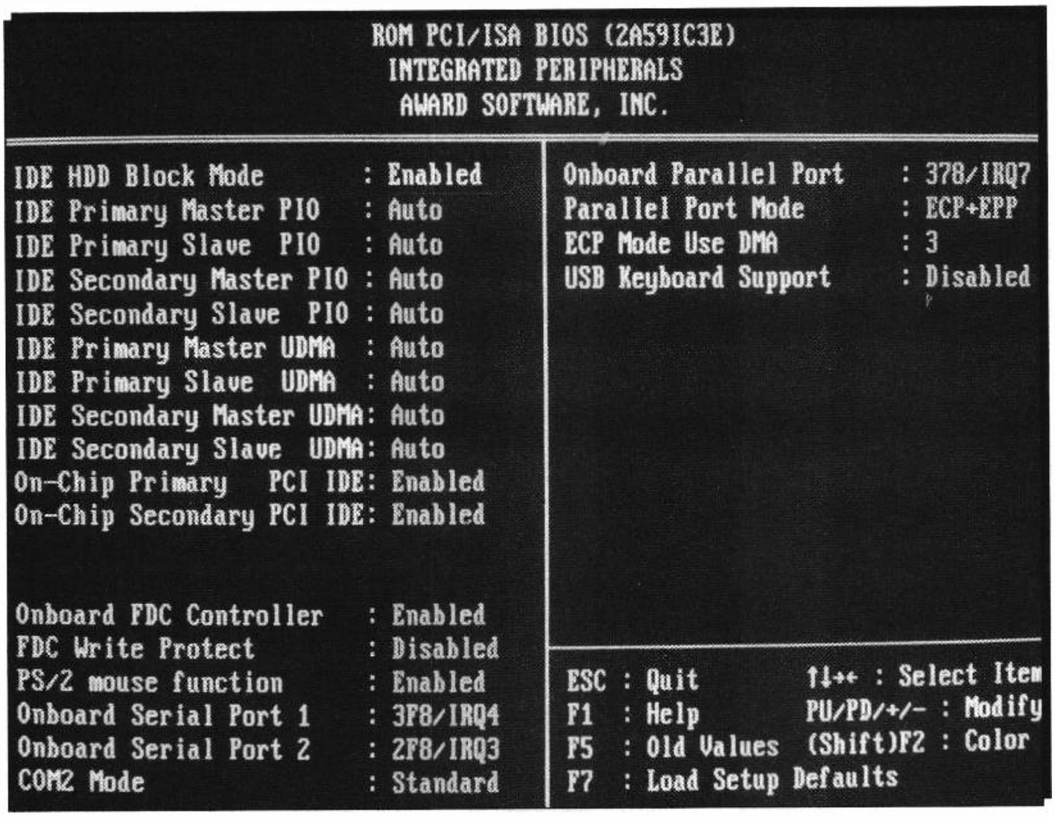
One problem with building a new PC from scratch or undertaking a major upgrade that includes a new hard disk is that the completed PC usually needs some further work before it is fully operational. Although the new hard disk will be low-level formatted, it still requires high-level formatting and the operating system to be added before you can boot from it successfully. Having the disk supplied with the low-level formatting completed saves a fair amount of time, and it also solves that old problem of the computer tending to hang-up at switch-on with a totally blank hard disk connected. The default BIOS settings will cause the computer to attempt to boot from floppy drive A before trying the hard disk, so there should be no problem in booting from a system disk in drive A. If the hard disk drive is supplied with partitioning and formatting software, it is probably best to use that rather than the DOS programs. Follow the instructions supplied with the software and you should soon be able to boot from the hard drive successfully. Otherwise, the MS-DOS/Windows 95/98 FORMAT and FDISK programs should be copied to the boot disk.



By default the DRAM timing will probably be 70ns. Modern ram can use the 60ns setting.

Things are unlikely to be much more difficult using the DOS programs. FDISK is run first, and this is used to partition the disk. The menu system makes it easy to create or remove partitions. Newcomers to PC construction sometimes make the mistake of not using FDISK because they only require a single partition. This will not work because the disk cannot be formatted at all until it has been partitioned with FDISK. There must be an active partition for the format program to work on, and you must use FDISK to set the whole disk as a single partition before it can be formatted. Depending on the vintage of the DOS version you are using, the maximum size for a single partition may be 2.1 GB.

Even if it is possible to set a large hard drive as a single partition, this may not be the best way of using your disk drive, and it is worth giving some thought to the way in which the computer will be used before partitioning the disk. There are programs that enable the partitioning to be altered



The default "Integrated Peripherals" settings should give good results, but you may need to change the printer port mode.

without wiping the disk and starting from scratch, but they are not cheap and do not generally guarantee that there will be no loss of data. Life will be much easier if you set up the disk correctly at the start.

Once the required partitions have been set up on the disk you should format them. The active partition is the one that the computer will boot from, and is normally drive C. This is formatted using the FORMAT C: /s command so that the system files are copied to drive C and it is made bootable. Alternatively, do a straightforward format of drive C and use SYS.COM to transfer the system files to drive C. If there are any other partitions they will be drives D, E, etc., and they must be individually formatted. Of course, you do not need to boot from these partitions and the system files are not copied to them. It should be possible to boot from the hard drive once the formatting has been completed.

These days most PC users run Windows 95 or 98, and putting MS-DOS onto the disk is really just a first step in getting Windows installed. In the unlikely event that you have the floppy disk version of Windows 95/98, you should first install the mouse driver, and then run the Windows Setup program to install Windows onto the hard disk. With the CD-rom version you must first install the mouse driver and the CD-rom driver. Some new CD- rom drives do not make any mention of MS-DOS compatibility on the box, but in most cases suitable drivers are actually included. If the CD-rom drive does not include MS-DOS drivers it is necessary to resort to a generic driver. No doubt such drivers can be purchased somewhere, but at present I am only aware of one solution to this problem: use another computer to make a Windows 98 recovery disk. This offers the option of CD-rom support during the boot-up process.

With the mouse and CD-rom drive operational, you can then run the Setup program on the Windows 95/98CD-romand install the operating system. This is largely automatic, and the user has to do nothing more than answer a few simple questions and follow a few basic instructions. If you have an upgrade version of Windows 95 or 98, note that you do not have to install the old version first and then upgrade it. The full version of Windows is included on the upgrade CD-rom or disks, and this can be installed onto a "clean" hard disk. During the installation process you will almost certainly be asked to prove that you have something to upgrade by inserting the disk containing the old Windows Setup program into the appropriate drive. Do not throw away, give away or recycle your old Windows Setup disk!

Buying problems

There is no need to buy an operating system if you are upgrading an old computer, or scrapping an old machine and building a replacement. It is quite legitimate to use the old operating system on a new or upgraded computer, because you will still be running just a single copy of it. The situation is different if you are building a computer from scratch, and to be legitimate you should buy an operating system for the new PC. Microsoft does not allow Windows 98 to be sold on its own, and it can only be obtained with hardware. There is a "get out clause" here, because "hardware" does not necessarily mean a complete computer system. Therefore, when buying a motherboard and processor, or perhaps just a hard disk drive, you may also be able to obtain the full version of Windows 98. The alternative is to buy Windows 3.11/MS-DOS 6 and an upgrade to Windows 98. In theory this should give a total cost that is about the same as buying the full version of Windows 98, but in practice it could well cost more.

FAT chance

FAT16 is the 16-bit disk filing (File Allocation Table) system used by MS-DOS and Windows up to the original version of Windows 95. This was still the default disk filing system in the later versions of Windows 95, but from OSR2 onwards there was some support for the improved 32-bit FAT32 filing system. This support has been improved in Windows 98, and there is now a conversion utility that makes the change from FAT16 to FAT32. For most users it is well worthwhile doing this. FAT16 can only handle large disk partitions by using a large sector size. Unless a large hard disk is split into lots of small partitions this results in a sector size of 32k. The important factor here is that the filing system only allows one file to be assigned to each sector. This means that something like a 100-byte batch file will occupy some 32k of disk space! In theory an average of about 16k per file will be wasted, but due to the large number of small files used by most Windows programs the real figure seems to be about 20k or so. FAT32 permits a sector size as small as 4k to be used, which greatly reduces the amount of wasted hard disk space. In fact it seems to give an effective increase in capacity approaching 20 percent. Programs should also load slightly faster.

The conversion utility is accessed via Start, Programs, Accessories, System Tools, and then selecting Drive Converter (FAT32). The conversion process is largely automated and requires little user input. Read the warnings in the Windows 98 manual before going ahead with the conversion. The drawbacks are mainly minor, but users of dual-boot systems that can boot either Windows 98 or their old version of MS-DOS will find that the MS-DOS boot option is no longer available. The "real" versions of MS-DOS are not compatible with FAT32. The Windows 98 version will still be available though, either via the MS-DOS prompt option in the Programs menu, or Start, Shutdown, and Restart Computer in MS-DOS Mode.

Spitting image

You may wish to copy the image of an old disk drive to a new drive so that all your old programs run exactly as they did before, complete with any customisation. Unless you are unlucky it should be easy enough to run the old drive alongside the new one, and copying files from one drive to the other is then quick and easy.

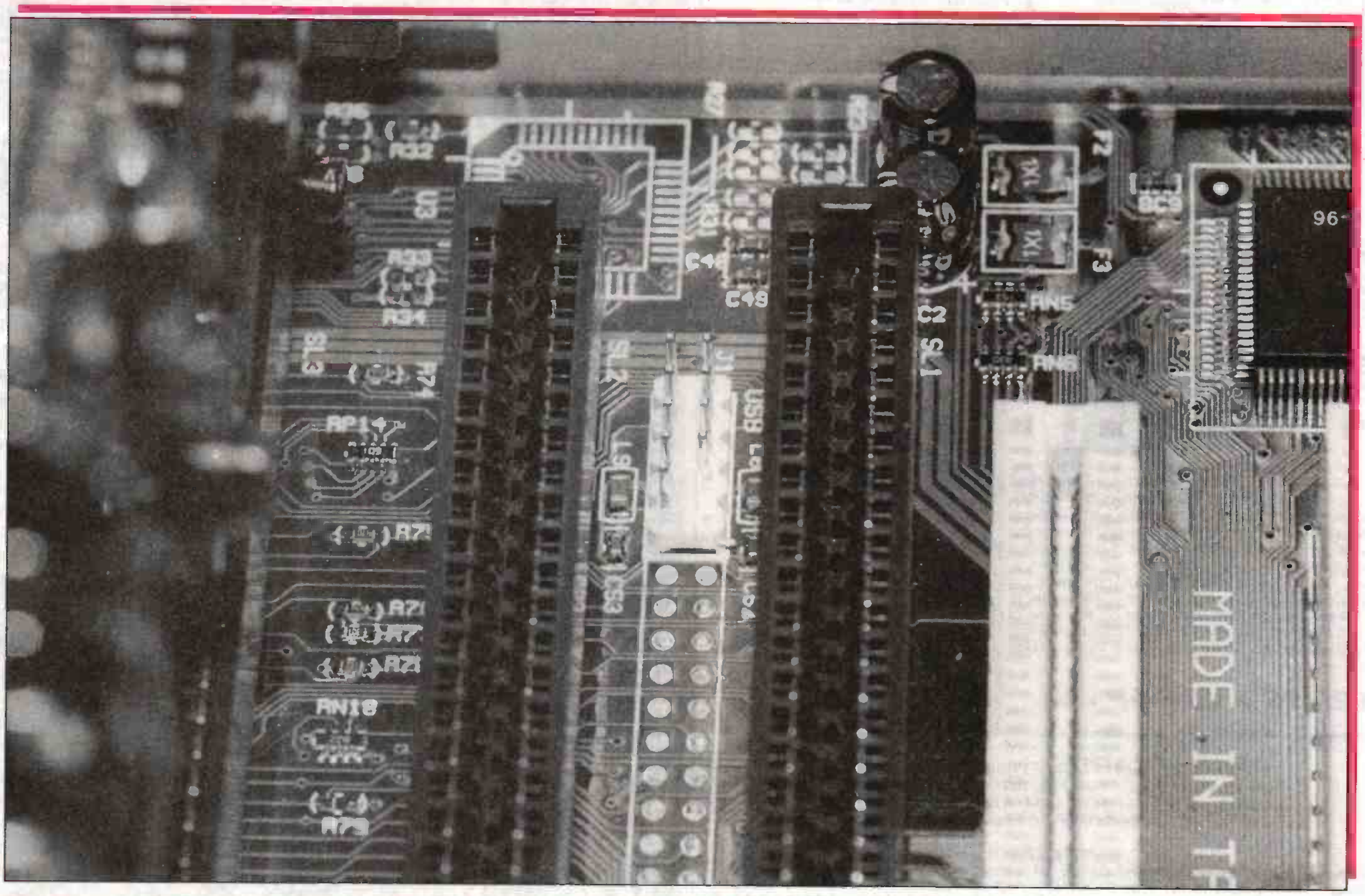
However, simply copying programs and their support files across to the new drive will not give the desired result with Windows. Unless the programs are properly installed, Windows will not know they are there and they will probably not run properly. It is possible to copy an image of the old disk across to the new disk, complete with all the system files. It should then perform just like the old drive, booting-up and running all the programs properly. There are utilities available that give varying degrees of help with this process. This may seem like the ideal way of getting your new PC up and running, but I would certainly recommend taking the longer route of reinstalling everything "from scratch", and then copying across your data and customisation files.

This will take longer, but it is likely to provide a better installation. One major drawback of Windows is that it tends to get clogged up with obsolete files over a period of time. Making an exact copy of an old hard drive retains all this clutter. Reinstalling everything from the beginning will be time consuming, but it is a good opportunity to get the computer "cleared out" and working efficiently.

USB

Although USB (universal serial bus) ports have had little impact yet, it seems likely that this interface will be central to computing soon. Most modern motherboards have a USB port, but a connector and lead is usually an optional extra. One reason for the lack of use so far is that USB ports tend to give problems with Windows 95. If you go into the System Manager there will probably be an entry for the USB port, but it will almost certainly be accompanied by an exclamation mark and warning notices to the effect that it is not installed properly and is not working. Even when using the last version of Windows 95, getting the USB port to work reliably seems to be problematic. Probably the only practical solution is an upgrade to Windows 98. This operating system will install proper support for the USB port, and the exclamation mark in Device Manager should miraculously disappear (!)

Some more details on upgrading a modern PC system will appear in the next issue of ETI.



Most modern motherboards have a USB port, but you may have to delve between expansion slots to find it. You may also need Windows 98 to make it work

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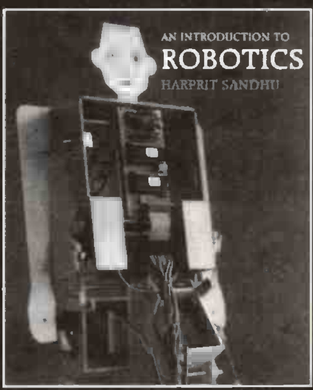

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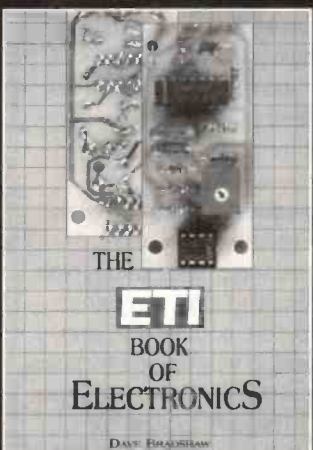

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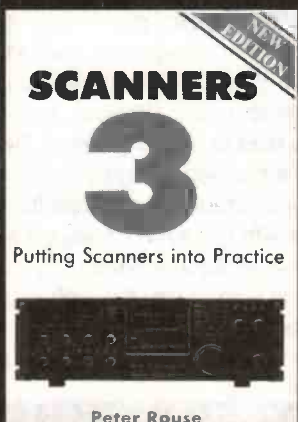

SCANNERS 3 - PUTTING SCANNERS INTO PRACTICE

This is the fourth revised and completely updated edition of Scanners, the complete VHF/UHF radio listeners guide, containing everything you need to know to put your scanner to better use. There is a great deal more information than ever before on frequency listing: in particular, actual frequencies used by coastal stations, airfields and the emergency services. Also included for the first time is a section on the HF (short wave) band as many scanners now cover this range.

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SCANNERS 2 INTERNATIONAL

The companion book to 'Scanners' provides even more information on the use of VHF and UHF communication bands, and gives details on how to construct accessories to improve the performance of scanning equipment. The book is international in its scope and contains frequency allocations for all three ITU regions, including country-by-country variations.

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Recruitment Today, Or Which Engineer?

Technical staff shortages there may be, but employers are still looking for a sound skills base when interviewing

"Qualified to degree or PhD level in engineering or science..." "significant product development experience ..." "a wide range of technological skills ..." "graduate engineer with 3.5 years' experience ..." "RF engineering" "embedded real-time software ..." "If you are degree qualified OR have relevant experience ..."

Extracts from recruitment adverts in a well-known trade journal around the end of the academic year show that there are any number of large companies falling over themsleves to catch the engineering talent now pouring off the educational production lines.

"talented senior development engineer to lead a team ..." "take our design capability into the next generation ..." "pioneering multi-disciplined engineer ..." "test, commissioning, support and board layout ..." "leading new developments..." "Engineers drive our business ..."

The more elusive creature that employers want to net is the engineer with 3 to 5 years' experience in the specific job slot they need to fill, or a closely related one. That particular trophy is a harder one to find, because engineers with practical qualifications tend to be snapped up the minute they stick their heads out into daylight. For that reason, engineers and technicians with good skills and experience and a flexible attitude may well find adjacent fields open to them - provided the interviewer is convinced that they have what it takes to do the job.

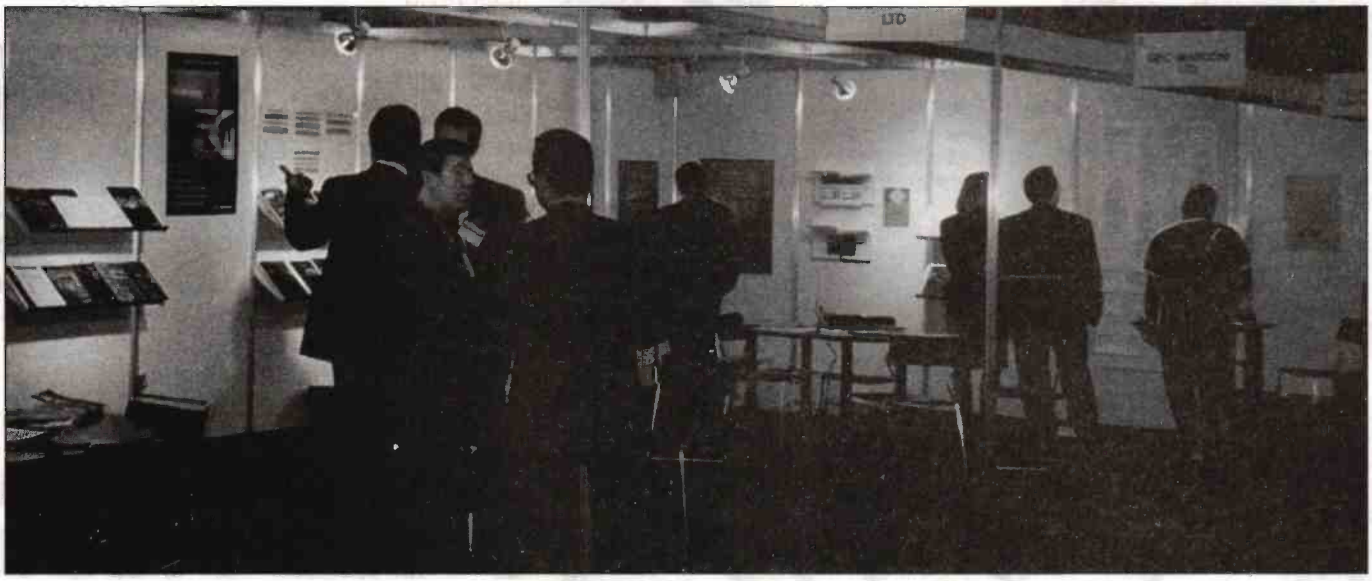
The travelling IEE Engineering Recruitment Show concentrates on experienced engineers and recent graduates. When the show came to Hammersmith, London, we asked a number of the exhibitors what they were looking for, and whether they were finding it.

Up to 10 years

Established in Berkshire in 1998 to manufacture cellular phones under the prestigious **Panasonic** brand name, **Matsushita Communication Industrial UK** is now a thriving part of the Matsushita empire turning over more than £200 million annually, and a major employer in the Berkshire/Oxfordshire area. Their original GSM handheld cellular phone was the first to gain Type Approval in the UK. Having built up their cellular phone line, the company is expanding again and moving into other digital mobile technologies.

Panasonic are looking both for graduates, and engineers with up to 10 years' experience, particularly in RF and software. The company is in an expanding phase, with a high demand for technical people and attracting staff from other large organisations. Salaries, they say, are competitive, and people tend to stay with them. (Retaining well-trained technical staff is a problem faced by nearly all engineering firms in these days of shortages and competition.) They are looking for people with telecommunications expertise - and finding them. Awareness that telecomms is going to be the growth industry for some time to come is high at the moment.

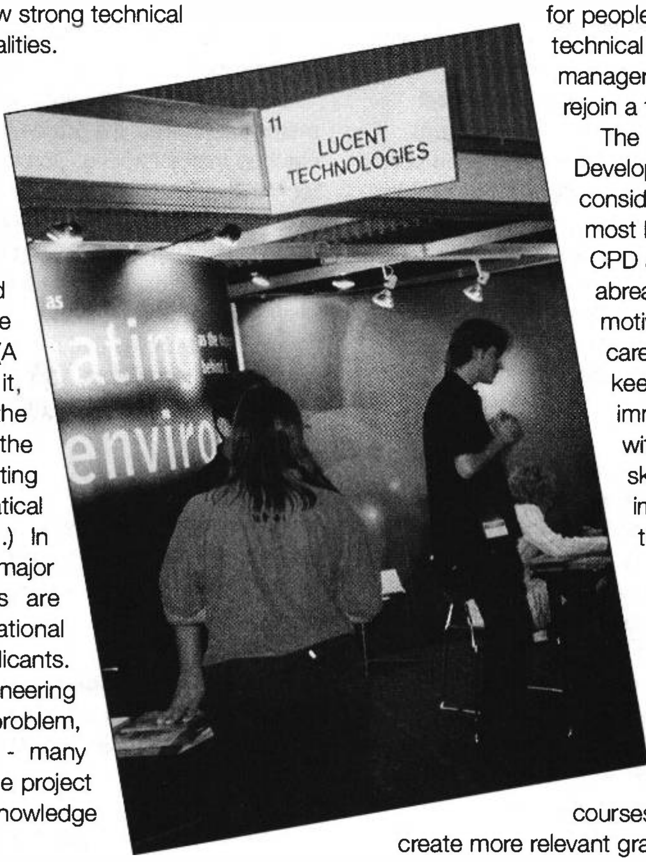
How is the company finding the basic skills among recent graduates? The news is good and bad: there is no skills



problem "if you can get the right people". In general, the standards among new graduates is good - but a previous fair produced some very poor applicants, believed to be the unfortunate leftovers from the previous year who had failed to establish themselves in a career in the intervening time. It's a salutary warning that a degree qualification is not an instant passport to success even in these days.

One problem faced by companies recruiting technical staff is that many graduates expect to move quickly into management. Career offices are tending to advise engineers that the management path is likely to be more prestigious and profitable than working at the cutting face. Unfortunately, in the UK this is still true in many cases, but graduates need to know that if they want to work for leading companies, they will progress to management mainly through work on project teams, and then only if they show strong technical competence as well as other qualities.

The Panasonic recruiters always carry out basic tests "because the applicants can't always do them, even though their degree should have covered it." The days when employers could assume that successful students had mastered all the elements of the course passed a long time ago. (A colleague of ours dates it, somewhat bitterly, to the introduction of "new maths" into the school syllabuses and the resulting sidelining of tougher mathematical disciplines in too many cases.) In general, maths is not seen as a major problem, but the weak areas are effectively in the whole educational system, not just in a few applicants. Weakness in essential hard engineering skills like transistor biasing is a problem, "even in First Class Honours" - many students get too focussed on one project and fail to develop a breadth of knowledge and flexibility.



Applicants with very specific experience at top levels are still hard to obtain, and specialised skills tend to be developed in-house.

This is the case in many companies, and there is a problem here for engineers of some years' standing in one project area: they can become overspecialised. It may be better to look for a sideways move every few years to avoid being left behind when demand changes. Panasonic find that the best age range for experienced engineers is between 26 and 35, widely seen as the best compromise between up to date study and experience in the field.

Many companies offer training, but keeping up with changes independently is now an important part engineering at all levels, particularly in the higher salary bands.

Good skills, poor maths

Roke Manor Research were finding a good supply of graduates to interview, but having more difficulty obtaining experienced people in RF and digital signal processing, currently among the most competitive fields. Skills relevant to mobile communications and mobile phones are also much in demand.

Roke have found that graduate applicants are weak in essential maths. A shortage of technical candidates means that candidates are getting onto good courses with two Es at A level, and are failing to deliver in some areas. The recruiters have found that the younger universities and former Polytechnics provide some very good specialised courses at MSc level, but are less reliable at Degree and HNC. Roke tend to concentrate on "traditional good quality universities" which attract higher A level passes and generally provide a good level of skills, but this this is by no means infallible.

The Roke recruiters have no problem with older applicants, and will undertake a certain amount of retraining to get good experienced applicants up to speed in specific skills. They stress that they tend to attract people "in work rather than out of work" - an indication that they are looking for people who are currently active in technical fields, rather than displaced managers and others hoping to join or rejoin a technical career.

The goal of Continuing Professional Development is encouraged but is considered to be a personal matter. Like most large employers, Roke look upon CPD as just one approach to keeping abreast of developments and a useful motivator for the individual, but not as a career qualification. Engineers need to keep up with changes outside their immediate field if they are to compete with more recent trainees, but the skills they can demonstrate are more important to employers than how they acquired them.

The advice at all levels is to "keep flexible" - but not to opt for a broad-based engineering degree. Mixed engineering qualifications spread skills too thinly to produce good results on one of the major engineering fields. Roke would like to see colleges design more courses in consultation with industry to create more relevant graduates. There is demand for software skills with direct commercial application, such as embedded systems software. The computer science course at York University was well regarded, as was Manchester UMIST for commercial software.

Biasing matters ...

GEC Marconi were experiencing finding experienced people, particularly in software. The "big shortage area" is in people with 3-5 years' experience. Too many years in one field can be a positive disadvantage: they find that people with more than 10 years' specific experience risk falling behind in other fields and losing their flexibility, so unless their skills are the exact fit to the job requirement they may be less useful than someone with fewer years on the job but more recent training.

Once again, the demand is for "doers, not managers". Embedded software, ADA software, C++, structured design methodologies and digital signal processing are particularly in demand.

GEC says that there is an element of truth about weakness in basic skills. The message is: "biasing a transistor does matter". The engineer must be able to follow calculations even when using a simulator, and understand the basis of the data generated. The trend towards wide-ranging, mixed media degrees is again judged to be counter-productive. Put bluntly: "We are very rarely interested in them, because they cannot design printed circuit boards." The general degree "dilutes the time spent learning about electronics." People with MBAs and other business qualifications are not required. A good level of management training is available to staff who can do the tech job productively for a number of years.

GEC admits that engineering in the UK still pays less well across the board than some careers because many of the best people are dedicated, but that skills shortages (the Best People are hard to find) are gradually pushing salaries up, particularly in the telecomms field. It is a seller's market for people with good skills.

The **Central Laboratory of the Research Councils (CLRC)** develops very high level instrumentation for test facilities and universities, among others. They are IEE certified for graduate training, and anyone working for them can expect technical training in line with their involvement with high-level research. Unfortunately, one side effect of this enlightened policy is difficulty retaining trained engineers - nearly always a problem for companies that train, even where salaries are good, as younger and more restless employees move on looking for a change of experience and a chance of promotion elsewhere.

However, trainees or no trainees, CLRC still find that technical staff are at their most useful at around 30 - 35 years of age - that desirable time when a combination of training and experience comes into its own.

Software shortage

Lucent Technologies at Swindon are part of one of the largest technology companies in the world and start graduates off at around £18k, with teamwork and product training, and management development for people with aptitude.
@B:Unsurprisingly, with the advantages of a very large, very modern company with a wide spread of interests, they have no trouble attracting good graduates in most disciplines. They are currently looking for electronics, RF and software engineers with telecomms backgrounds. Finding software engineers, "real time and applications", is the biggest problem because the field is expanding faster than the supply of good engineers.

Lucent employ contractors as well as permanent staff, and are keen to convert contractors to permanent if they get on well in the company. They describe their success in persuading good contractors to settle down in one spot as "gradual". The '90s is a buoyant time for contract engineers, especially in software. It remains to be seen how long this remains the case in the 2000s. Lucent uses a recruitment agency, Venus, which determines the company's selection process.

Japanese entertainment electronics giant **Sony** describes its company culture as "easy-going, laid back, but very productive" - rather like the company's legendary Walkman in the '80s. Sony has a very high technical standard, and is looking for graduates in computer science, electronics and micro-electronics. Success in getting the right people is "reasonable - we are not saying it's easy". Finding good experienced people is harder. The company is expanding and there are plenty of vacancies.

Sony's experience with basic skills is "no real problem", but they would like to see people with better grounding in specific technologies. They are definitely looking for graduate skills, particularly C++ and systems engineering at present.

Experienced engineers changing jobs are welcome but the company looks carefully at relevant experience versus salary expectations. People who have retrained or are moving into a new area should not expect to achieve their previous salary level until they have practical experience in their new field. This advice is almost universal now, but some older engineers still go forth unprepared for the fact that they will have to drop down the salary tree again until they build up a track record in their new field.

In the end ...

A career move more often adopted in the USA than the UK is for engineers to take a year or three out of work in their late thirties or early forties and study for a second degree to update their skills. Americans are used to financing their own education on a shoestring, so this is perhaps not such a shock to them as it is to a Brit suddenly compelled (unless they have an understanding and well-salaried partner) to go back to living on beans and bananas. Nonetheless, the signs are that midlife study will become increasingly important in all professions.

For prospective students who are concerned about their maths capabilities, the advice is: find a college that offers catchup maths tutoring. Don't trade off a college with a good technical reputation for a lesser one with remedial maths, but take the trouble to find out if there is a thorough program of engineering maths at your first choice. It is difficult to top up maths without the help of a tutor, and essential if you hope for even a reasonably high-level career. Nobody who works with figures now believes that it is sufficient to relay on calculating machines or simulators.

Good luck.

Contacts:

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Roke Manor Research: CV to Roke Manor Research Ltd., Roke Manor, Romsey, Hants SO51 0ZN Email chris.prince@roke.co.uk Web www.roke.co.uk

Panasonic: CV to Mark Robinson, Matusuhite Communications Industrial UK Ltd., Daytona Drive, Colthrop, Thatcham, Bers RG19 4ZD. Tel. 01635 871466.

GEC: Many different establishments: check recruitment advertising in trade journals or your college library.

18-Channel Infra-red Remote Controller

By Pei An

This article describes a general purpose infra-red remote receiver which could be implemented in equipment where remote control would be desirable. Its partner is a handset transmitter using the BL9148/BL9150 chipset.

The remote controller consists of a *receiver board* with 18 remotely controlled digital outputs (**figure 1**), which responds to a transmitter handset with an 18-key keypad. The handset requires two 1.5-V AA size batteries. The maximum control distance is up to 10 meters. The handset unit or the chips are available from the author.

Today's televisions sets, VCRs, satellite decoders, hifi, CD players etc. are expected to have remote control facilities. There are also emerging applications such as domestic lights, garage doors, curtains, air conditioners, heating appliances and computers, and so on. It won't be long before we can choose whether or not to walk across the room at all.

With a multi-channel controller like the one described here there are many more complex control opportunities than with a simple one.

Output waveforms

As has been mentioned, there are 18 controlled outputs on the receiver board. They have three output waveforms (**figure 2**).

Among the 18 outputs, ten of them have a single pulse output form (SP, key 7 to key 16). When one of these buttons on the remote handset is pressed, one infra-red emission cycle is produced by the handset. On the receiver side, a single low-to-high-then-low pulse is produced at the corresponding output.

Two channels have a *latched pulse* output waveform (LP, key 17 and key 18). When a button is pressed, the handset produces one infra-red emission cycle. On the receiver side, the corresponding output changes the logic status from one to the other.

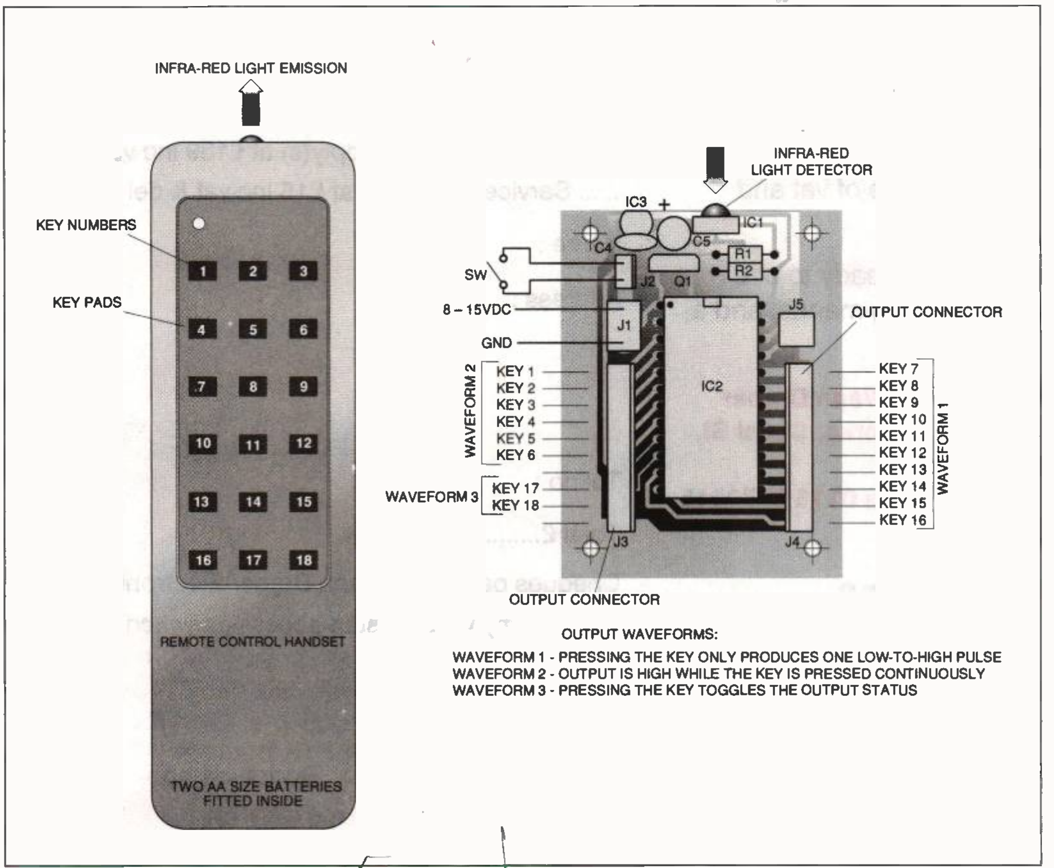


Figure 1: the 18-channel intra-red remote control system

Six channels among have a *continuous high pulse* output waveform (CP, key 1 to key 6). When a button on the handset is pressed continuously, the handset repeatedly produces the infra-red emission cycle. On the receiver side, the corresponding output goes from logic low to logic high state and stays high as long as the button is pressed.

These output forms can be used for different applications. Some suggestions are given lower down this article.

How it works

Figure 3 illustrates the principle of the remote control system. The handset consists of an 18-key keypad, a key encoder IC (BL9148), an infra-red light emitter and its driver (**figure 3a**). The key encoder detects which key is pressed, then outputs a stream of digital

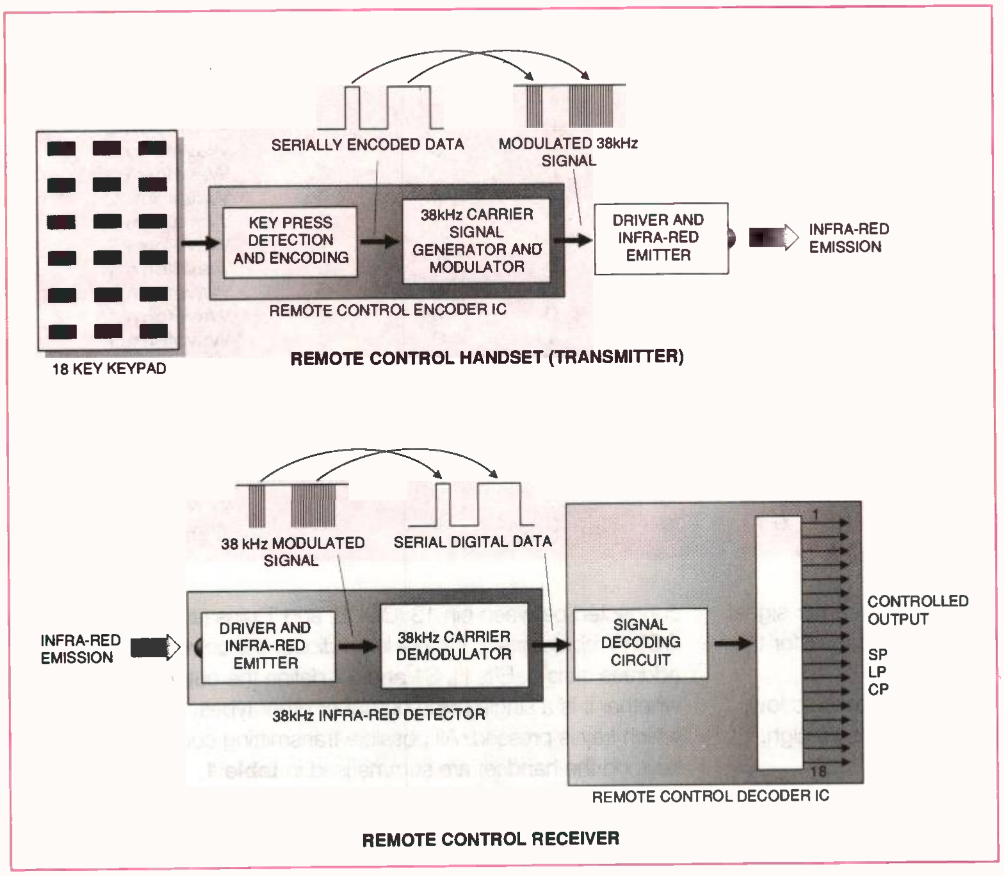


Figure 3: the principle of a typical remote control system

data (a stream of "0" and "1") which is unique to the pressed key. This data modulates a 38-kHz carrier signal. When the data is 0, no carrier signal is produced. When it is 1, the 38k-Hz carrier signal is produced. The signal is amplified by the infra-red LED driver and is transmitted by the LED emitter.

The receiver board consists of an infra-red detector which is tuned to receive only the 38-kHz signal (**figure 3b**). When it detects a 38-kHz carrier, the output goes high; when it does not receive the carrier signal, it goes low. The output from the detector is fed into a decoder ic (BL9150) which is in pair with the encoder. The received data is decoded first, and then causes the corresponding output change status.

The reason why the 38-kHz carrier signal is used to transmit the code is because that there is always interference in the environment. This however interferes in a random manner. Using a specific frequency signal for the data to be transferred could eliminate this interference to some extent.

The second reason is that using an oscillating carrier signal reduces electrical power consumption required for transmitting the data, as the transmitted signal consists only of pulses. To reduce power consumption even further, the carrier signal has a duty cycle of 1/3. This means that the switch-on period of the infra-red emitter is shortened still further.

- Ten channels with single pulse operation
- Two channels with latched pulse operation
- Six channels with continuous high pulse operation
- No adjustment needed on the receiver board.

The format of the codes generated by the encoder is unique to a certain encoder/decoder pair. This means that different remote control systems can be operated in the same area. The code for the present encoder/decoder will be explained later.

The handset

The circuit of the remote control handset is given in **figure 4**. It consists of a BL9148 encoder, a 3 x 6 key matrix, a 455-kHz ceramic resonator, one infra-red emitting LED and two transistors which drive the LED.

The encoder ic, BL9148, is a CMOS device and requires a voltage supply 2.2V to 5.5V. The ic automatically detects which is key pressed. When no key is pressed, the ic is in the standby mode. Once a key press is detected, the ic is activated and outputs an encoded data stream. In the standby mode the quiescent current is less than 10 uA and in the active mode, the current consumption is around 1 mA. This chip is ideal for battery-powered applications.

From figure 4 we see that pin 16 and pin 1 of the ic are connected to the positive and negative rails of a power supply. Pin 4 to pin 9 (K1 to K6) and pin 10 to pin 12 (T1 to T3) form a 6 x 3 scanning key matrix. Pin 13 (CODE) is used to set a user address of the handset. Pin 15 (TX) is the data output which is a stream of burst of the 38-kHz carrier signal. When no key is pressed, the TX line is always at logic high state. The 455-kHz

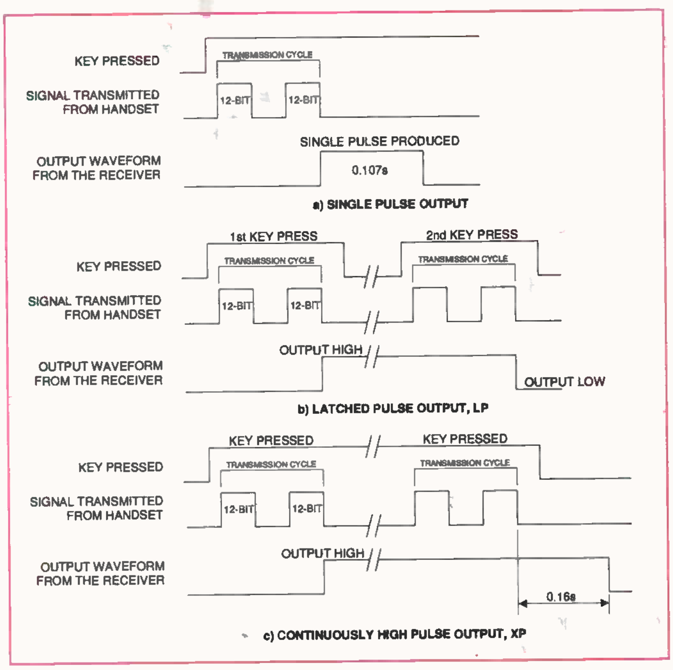


Figure 2: waveforms of the controlled outputs on the receiver board

Table 1: encoded data format for keys

Key	H	S1	S2	D1	D2	D3	D4	D5	D6	Output waveform
1	1	0	0	1	0	0	0	0	0	Waveform 2
2	1	0	0	0	1	0	0	0	0	Waveform 2
3	1	0	0	0	0	1	0	0	0	Waveform 2
4	1	0	0	0	0	0	1	0	0	Waveform 2
5	1	0	0	0	0	0	0	1	0	Waveform 2
6	1	0	0	0	0	0	0	0	1	Waveform 2
7	0	1	0	1	0	0	0	0	0	Waveform 1
8	0	1	0	0	1	0	0	0	0	Waveform 1
9	0	1	0	0	0	1	0	0	0	Waveform 1
10	0	1	0	0	0	0	1	0	0	Waveform 1
11	0	1	0	0	0	0	0	1	0	Waveform 1
12	0	1	0	0	0	0	0	0	1	Waveform 1
13	0	0	1	1	0	0	0	0	0	Waveform 1
14	0	0	1	0	1	0	0	0	0	Waveform 1
15	0	0	1	0	0	1	0	0	0	Waveform 1
16	0	0	1	0	0	0	1	0	0	Waveform 1
17	0	0	1	0	0	0	0	1	0	Waveform 3
18	0	0	1	0	0	0	0	0	1	Waveform 3

ceramic resonator is used to produce the 38-kHz carrier signal. It is connected between pins 2 and 3. The driver circuit for the LED consists of two transistors (T1 and T2, BC557 and ZTX300) and has an inverting action. When TX is at logic low, the LED is turned on, and goes off when TX is at logic high.

Encoded signals

Once a key press is detected, at least two identical 12-bit serial digital data are generated inside the encoder ic (the two transmissions are termed as a *transmission cycle*, see **figure 5a**). The signal is not the one output from pin 15 (TX). Pin 15 is the 38-kHz carrier signal which is modulated by the signal. The actual signal at pin 15 has a waveform which is shown in **figure 5c**. It can be seen that pin 15 (TX) is always at logic high state if no key is pressed. The 38-kHz carrier signal has a 1/3 duty cycle. The logic low period is 8.8 us and the period is 26.3 us (see **figure 5c**).

The bit functions of the 12 serial data bits from bit 0 to bit 11 in sequence are:

C1, C2, C3, H, S1, S2, D1, D2, D3, D4, D5, D6

C1, C2, C3 are user defined address bits. Possible combinations are 011, 101 and 111 (001 is not used). The address must be the same as that on the decoder ic. This allows up to three remote control systems to work in the same vicinity without interfering each other. Bits C1, C2 and C3 are determined by the connection of T1, T2 and T3 pins. A diode connected between pin 13 (CODE) and T pins (anode connected CODE) represents 1. If there is no diode, the corresponding address bit is 0. Bits H, S1 and S2 define the output waveform-whether it is a single pulse output or other types. D1-D6 specify which key is pressed. All possible transmitting codes for the 18 keys on the handset are summarised in **table 1**.

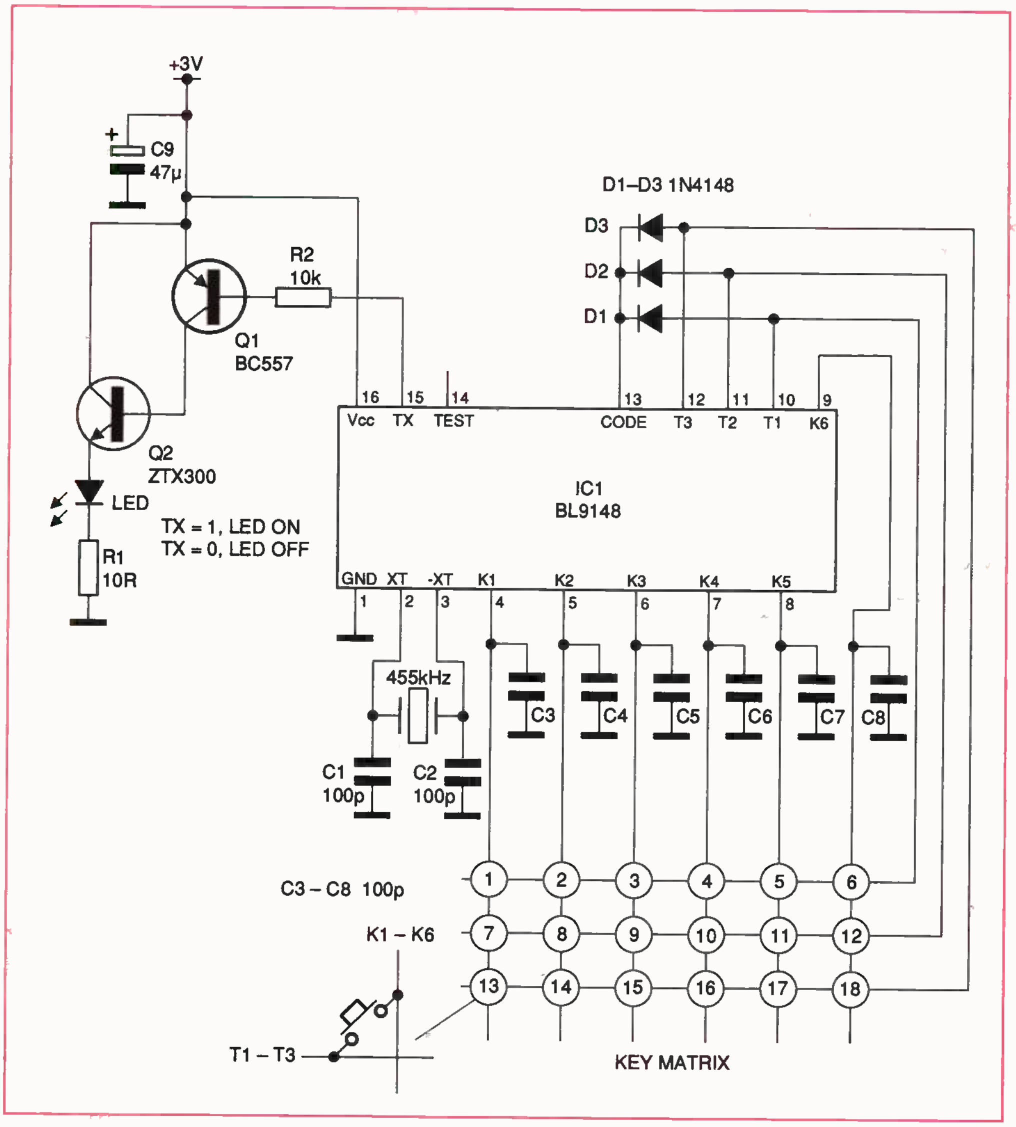


Figure 4: the circuit diagram of the remote control transmitter

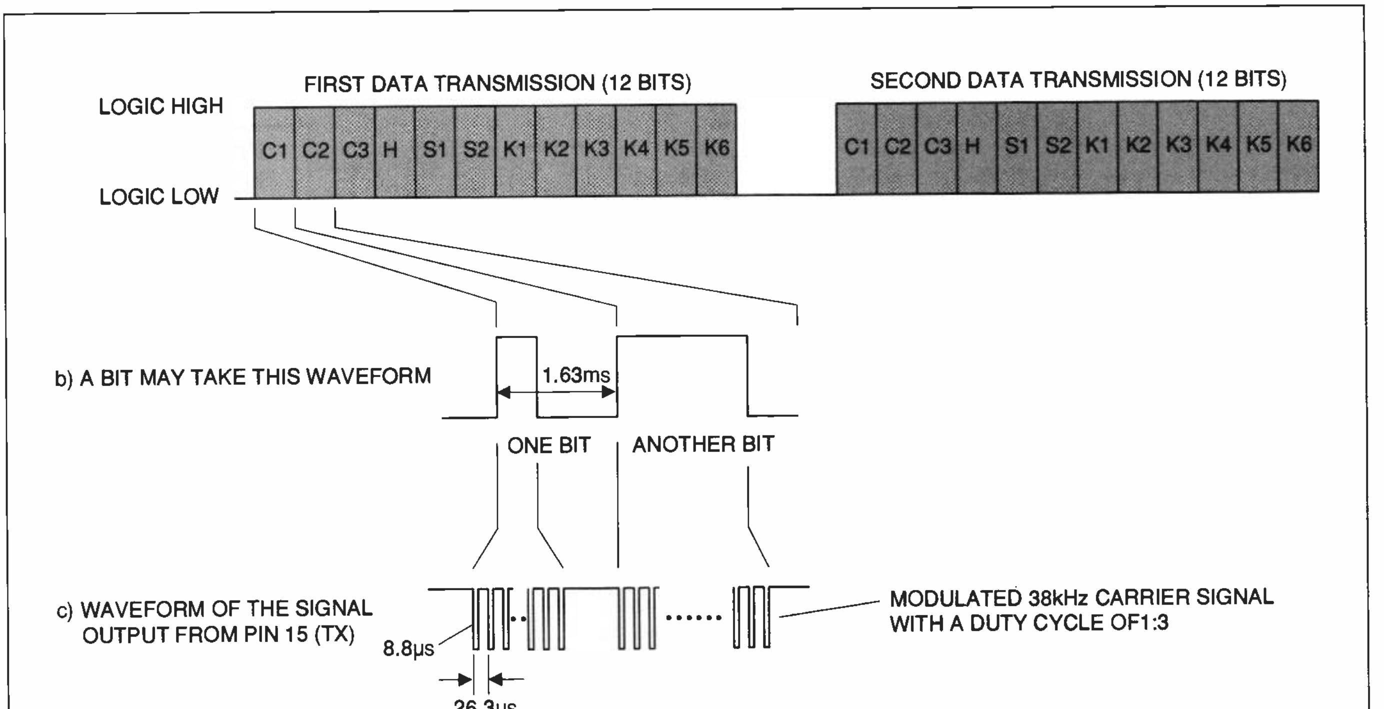


Figure 5: transmission cycle and the modulated signal output

If the external resonator is 455 kHz, the period for one bit is 1.62 millisecond (a = 405 micro second). A serial data 0 and 1 are represented by different duty cycles. 0 has a 1/4 duty cycle and 1 has a 3 /4 duty cycle (**figure 6a**). As an example, if an encoded data 010100100100 is to be transmitted, the serial data has the waveform as shown **figure 6b**. If a single pulse key is pressed (keys 7 to 18), only one transmission cycle is generated (**figure 6c**). If a continuous high pulse key is pressed (keys 1 to 6), The cycle is transmitted repeatedly (see **figure 6d**).

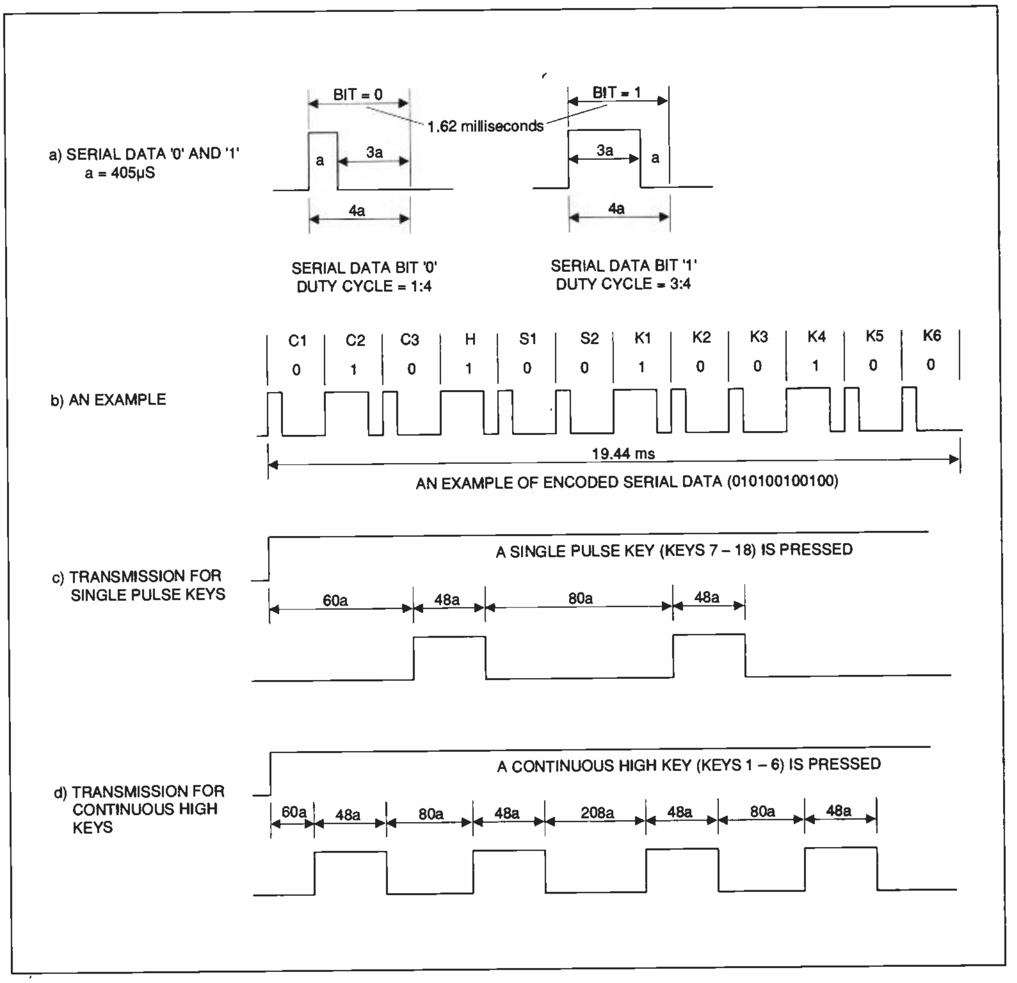


Figure 6: the format of the encoded serial data

The receiver board

The circuit of the receiver board is given in **figure 7**. It consists of a 38-kHz infra-red detector (IS1U60), a decoder (BL9150, which is in pair with the encoder) and a 7805 voltage regulator.

The infra-red detector is the IS1U60. It is housed in a 3-pin plastic package and incorporates a circuit capable of receiving a modulated 38-kHz infra-red signal and converting it to a digital pulse train at the output. The pin-out and the internal block diagram of the IC are shown in figure 8. The voltage supply is +5V and the current consumption is typically 3 mA. It will receive infra-red emission coming in a 30-degree angle (see **figure 7**). When it receives a 38-kHz infra-red light, the output goes high. The signal output from the IS1U60 is inverted by T1 before it is fed into the decoder.

The decoder, BL9150, only requires a 5 percent tolerance capacitor and a 5 percent

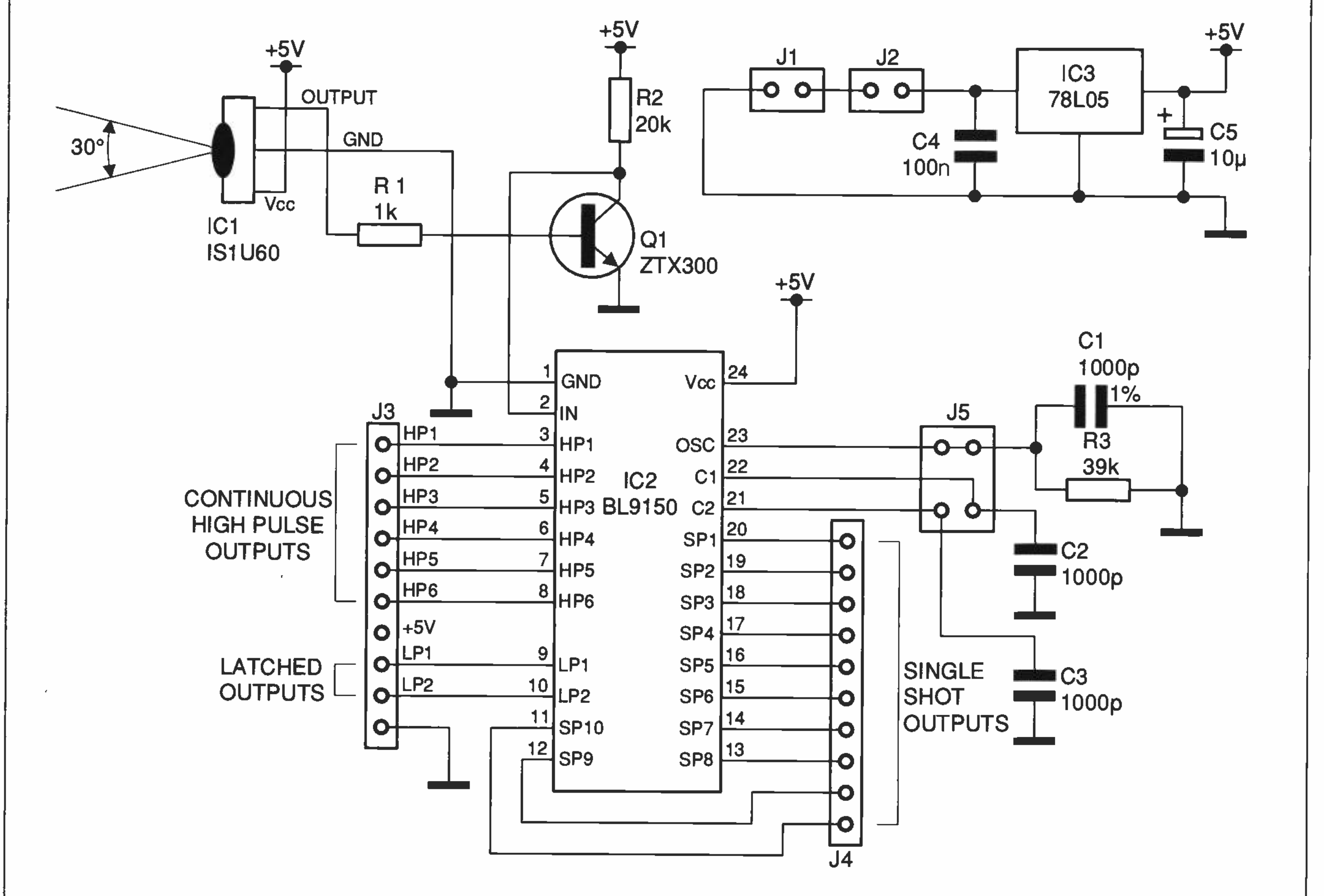
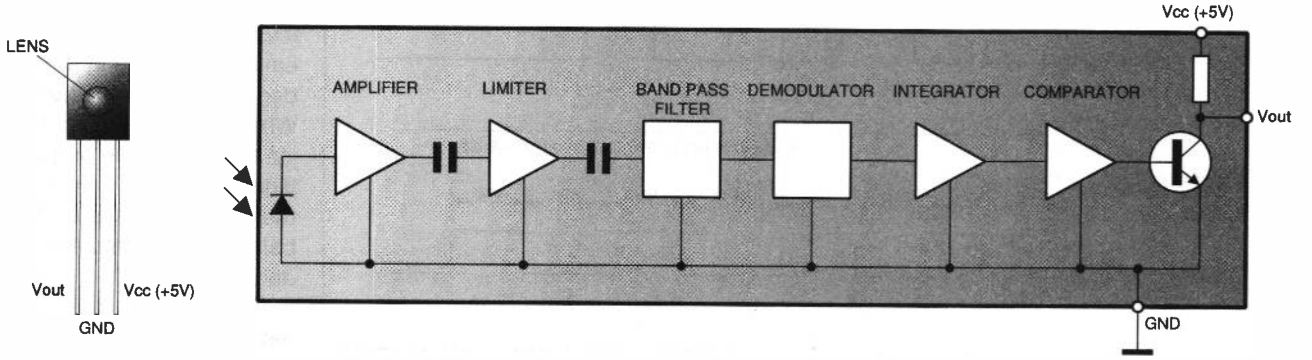


Figure 7: the circuit of the remote control receiver

tolerance resistor to make it to work. The 18 controlled outputs are from pins 3 to 20. As was explained earlier (see figure 2), the waveforms of the outputs are different. HP1 to HP6 (pins 3 to 8) are continuous high pulse output. LP1 and LP2 (pins 10 and 9) are latched outputs. SP1 to SP10 (pins 20 down to 11) are single pulse outputs. They are available from connectors J3 and J4. C1 (pin 22) and C2 (pin 21) set the address of the decoder. Pins 21 and 22 are pulled to Vcc internally. Capacitors C1 and C2 are used to generate a reset signal when the decoder is firstly power on. The BL9150 is a CMOS device. The quiescent current is typically 1 mA.

The decoder operates by receiving the first serial data of the transmission cycle and storing it in a register. The decoder then receives the second data. If the second data is identical to the first, the transmission is valid. Next, the decoder checks if the address of the serial data received is the same as the address selected by C1 and C2 pins. If it is, the received data will be latched to the output and the output goes high. If the addresses are different, the received data will not be latched to the output. If the two received data are different, the decoder resets itself and is ready to receive the next data.

Figure 8: the pin-out and internal diagram of the IS1U60



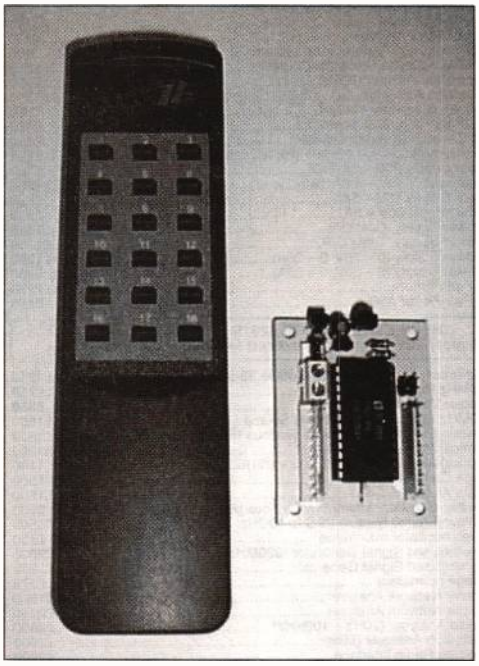


Figure 9: the handset unit with the Receiver PCB

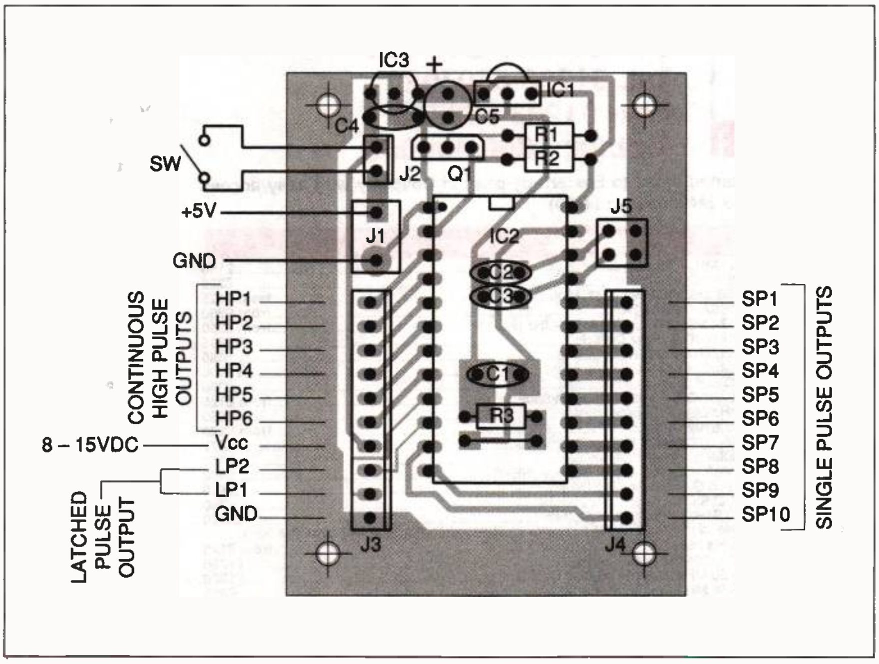


Figure 10: the component layout of the remote control receiver board

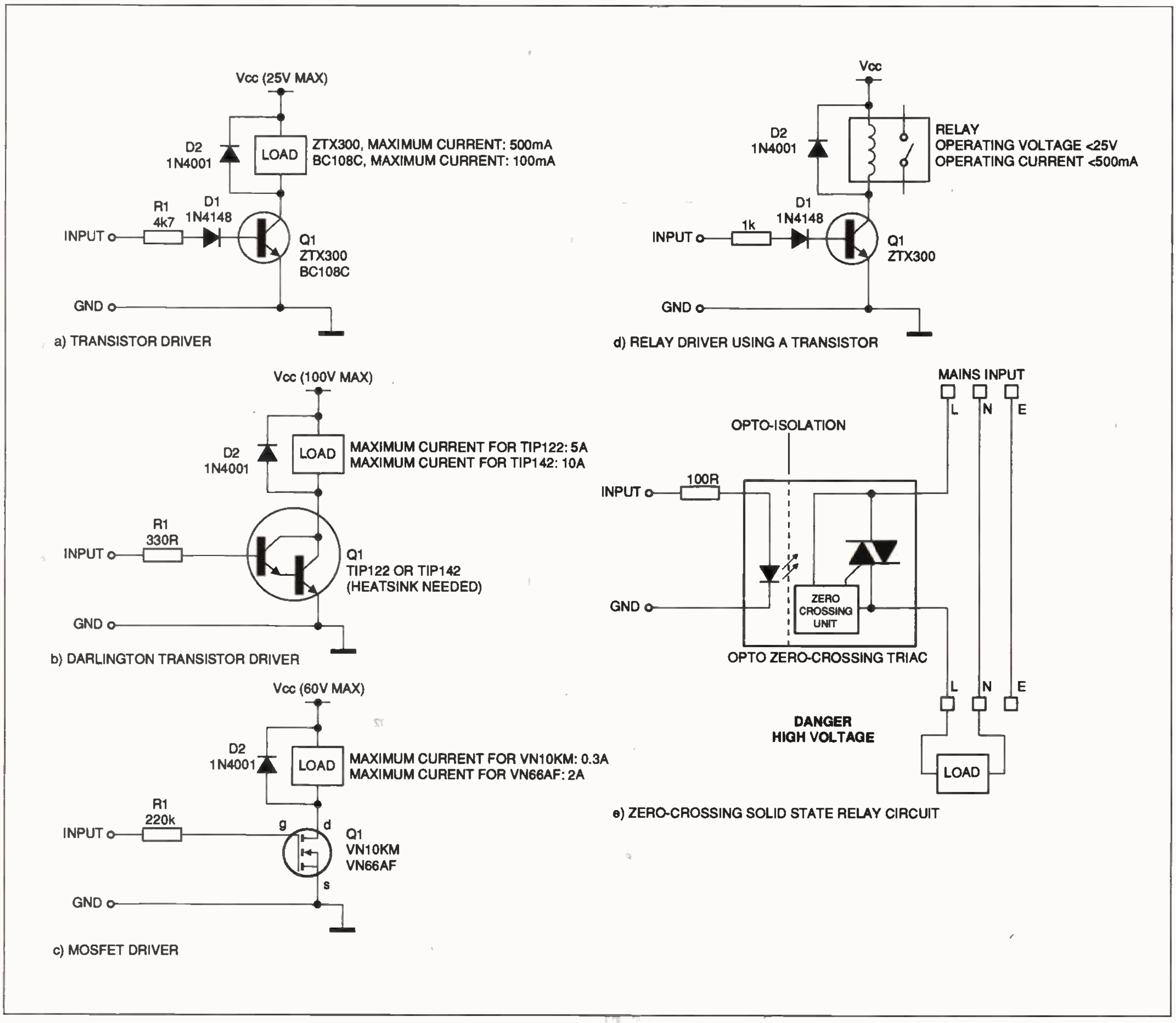


Figure 12: various power drivers

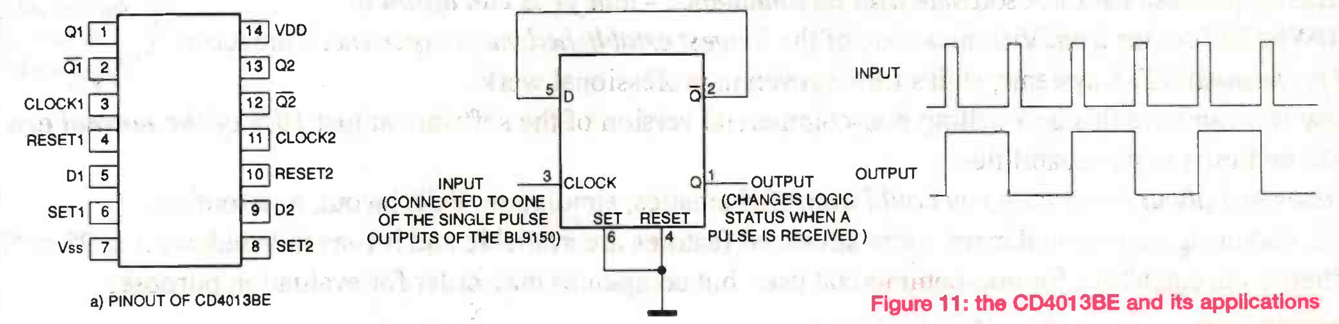


Figure 11: the CD4013BE and its applications

Construction and testing

The receiver is constructed on a single-sided PCB. The component layout is given in **figure 10**. The board is easy to put together. Use an ic socket for the decoder ic. There is no adjustment required on the board. Once the components are mounted correctly, the system should work straight away. During testing, you could connect some LEDs to the outputs and point the handset at the receiver board.

The transmitter is available as a single unit, but the circuit is given and the transmitter can be built on a piece of stripboard for experiments. A keypad (Maplin JM09K) can be used to operate it.

Application notes

Latched outputs (2 outputs) can be used for controlling lights. If a key is pressed, the corresponding light is switched on and stays switched on. If the key is pressed again, the light goes off. This can also be used for controlling other electrical appliances.

The single shot (10 outputs) outputs are useful in light dimmer applications. A single pulse will cause the lighting control circuit to increase the power output light bulb by one step. The outputs can also have a latch action using an external CD4013 (see the circuit in **figure 11**).

The continuous high outputs (6 outputs) can be used for controlling curtains. When a key is pressed, the curtains open (or close). If the key is released, the curtains stop! So the actual position can be controlled.

To control electrical devices operating at a higher voltage and current, transistor, mosfet transistor and relay drivers can be used. For mains controls, optically-isolated solid state relays can be used. Some of the driver circuit types are shown in **figure 12**.

Parts and kit

The project is available as a whole kit, which includes an assembled handset and an unassembled receiver board with decoder ics and other components. The price is £39.00 sterling including P&P. The handset unit alone is priced £21.00. Handset parts are not available separately. The receiver IC BL9150 and PCB are £8.00 and £6.00 respectively. Please add £3.00 post and packing to each order. If you require information or other receiver components, please make your enquiry to **Dr. Pei An, 11 Sandpiper Drive, Stockport, Cheshire, SK3 8UL UK. Tel/Fax 0161 477 9583. Email: pan@fs1.eng.man.ac.uk.**

PARTS LIST *for the 18-channel Remote Controller*

Receiver board

Resistors

(1 percent metal film 0.25W)

R1	1k
R2	20k
R3	39k

Capacitors

C1-C3	1000 pF ceramic disc 5 percent
C4	100 nF ceramic disc
C5	10 uF electrolytic

Semiconductors

IC1	IS1U60 infra-red detector
IC2	BL9150 18 key decoder ic
IC3	78L05 +5V voltage regulator
T1	ZTX300 npn transistor

Others

J1	2-way screw terminals
J2	2-way PCB connector
J3,J4	10-way PCB connector
J5	2 x 2 PCB pins

PCB and PCB pillars

Components used in the handset

Resistors

(1 percent metal film 0.25W)

R1	10R
R2	10k

Capacitors

C1-C8	100 pF ceramic disc capacitors
C9	47 uF electrolytic capacitors
TX	455 kHz

Semiconductors

D1-D3	1N4148
IC1	BL9148 18 key encoder ic
T1	BC557 pnp transistor
T2	ZTX300 npn transistor
LED	Infra-red emitting diode, maximum forward current: 100 mA

Others

PCB, key board, handset housing

Most components are available from Maplin. The encoder and decoder ics (BL9148 and BL9150), the receiver PCB and the handset unit are only available from the author (see text).

A 'Q' METER ADAPTER

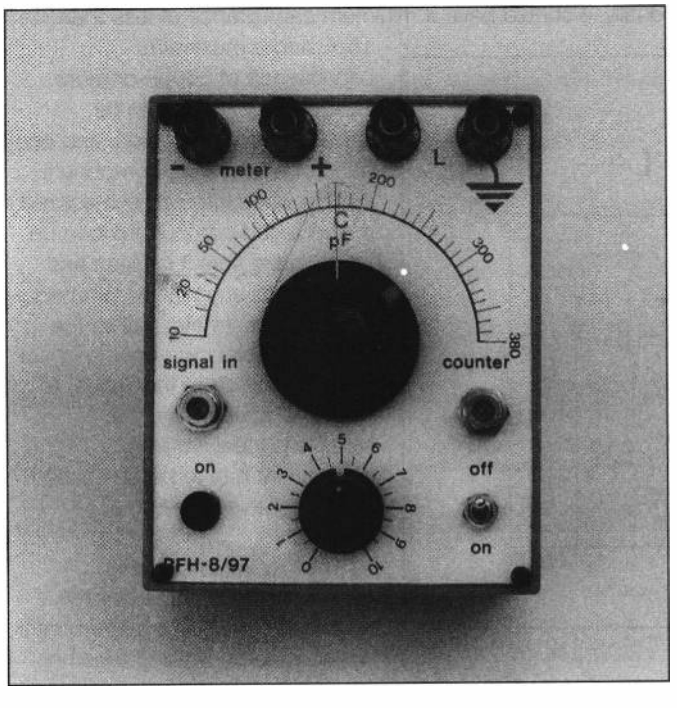
This simple adapter by Raymond Haigh enables the Q factor and inductance of RF coils to be measured with a signal generator and multimeter.

Anyone involved in radio construction will, from time to time, wish to measure the inductance of RF coils and transformers, and to compare their performance by determining the Q factor. Most serious experimenters will have a multimeter and signal generator in their workshops, and the unit described here enables these items to be used for Q metering purposes.

The Q factor

The Q factor of a tuned circuit defines its ability to magnify a signal at its resonant frequency, and to reject signals at frequencies off resonance; that is, its selectivity. An inductor with a Q of 100 arranged in an L/C tuned circuit will magnify a 1mV signal to 100mV. If the Q factor is reduced to 20, the voltage developed across the inductor will then be only 20mV. This is an important aspect of signal amplification; one without recourse to valves or transistors and the added noise these devices introduce.

Turning to the question of selectivity: for a a medium-wave coil tuned by a capacitor to resonate at 1MHz with a Q factor of 100 the bandwidth at the 3dB down (half power) points is 10kHz. If its Q is reduced to 20, the bandwidth widens to 50kHz and selectivity is seriously impaired.



The benefits of a high Q factor, under most circumstances, are very clear. Indeed, the standards of performance achieved by early valve receivers can be attributed, in no small measure, to the quality of their RF and IF coils and transformers. The quest for miniaturisation and the ability to maintain sensitivity by means of high-gain, low-cost semiconductor devices, has sometimes led to the Q factor being traded off for reductions in size. Home constructors are not always preoccupied with extreme miniaturisation, and space can often be found, especially with simple or single band receivers, for larger, and possibly more lightly coupled, inductors, in order to secure the advantages of their higher Q factors. Even when small size is important, it is still desirable to select inductors with the highest possible Q.

Methods of measurement

Q factor can be measured by determining either the magnification or the selectivity of a resonant circuit formed by an inductor and a capacitor. The Q of a good quality air-spaced variable capacitor can, for all normal purposes, be regarded as infinite, and any resistive or dielectric losses which reduce the Q of the tuned circuit can be attributed solely to the inductor. Q measuring instruments which rely on the phenomenon of signal magnification place the coil under test in series with a variable capacitor. The capacitor tunes the coil to resonate with a signal injected into the circuit, and the magnified voltage developed across either the inductor or the capacitor (the voltages across the two components are identical) is compared with the applied signal voltage.

A diagram showing the basic arrangement is given in **figure 1**.

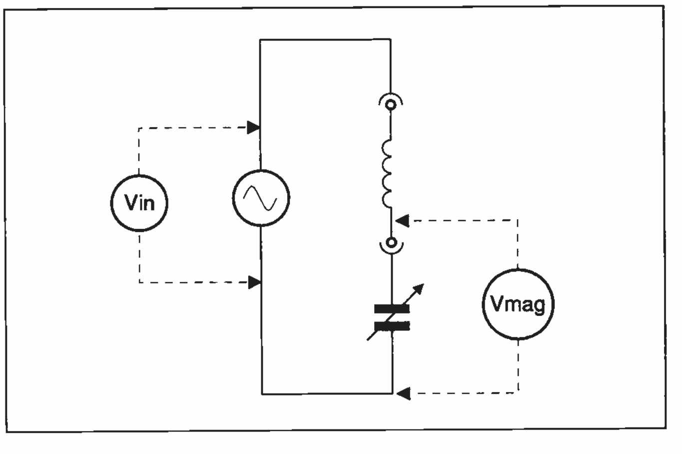


Figure 1: method of deviing the Q factor from the selectivity of a tune circuit: Q = resonant frequency/bandwidth at 0.707 of V at resonance

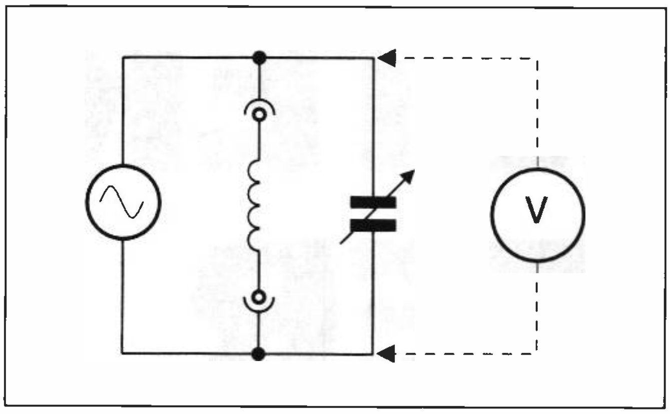


Figure 2: method of deriving the Q factor from the magnification effect of a tune circuit: Q = Vmag/Vin

The meter used for the measurements must be a high-impedance electronic instrument, and the signal generator must have a very low output impedance, or the accuracy of the measurements will suffer. Such a circuit cannot normally be used to measure the Q of coils wired into equipment.

Measuring instruments which exploit the relationship between selectivity and Q test the inductor in a parallel tuned circuit. A simplified diagram is given in **figure 2**. Signal source and voltmeter must both have a high impedance in order to avoid damping the tuned circuit.

The adapter unit described here provides the necessary low-to-high impedance buffers between the signal generator, the voltmeter, and the inductor under test, so that selectivity can be measured, and the Q factor determined, with reasonable accuracy. With this arrangement, the Q factors of coils wired into equipment can usually be checked and, if the variable capacitor is calibrated, inductor values can be measured also.

The circuit of the adapter unit

The circuit of the adapter is given in **figure 3**, where Q1 acts as a low-to-high impedance buffer for the signal generator, and Q2 as a high-to-low impedance buffer for the testmeter. Blocking capacitor C1 avoids the possibility of the output circuitry of the signal generator disturbing the operation of Q1. This transistor is configured in the grounded gate mode, and input impedance at the source is accordingly low and output impedance at the drain high. The signal from the generator is applied across the source bias resistor R1, and the output voltage is developed across L1, an RF choke which acts as the drain load. Coupling to the inductor under test is by means of the low-value capacitor C2.

The inductor to be checked is connected in a parallel resonant circuit with variable capacitor C4. The Q of RF coils is best measured at the mid-point of their tuning range, and C4 can be set to simulate this.

The high impedance at the gate of Q2 minimises damping on the tuned circuit. The gate is grounded by R3 to avoid the possibility of damage to the device when there is no coil connected, and this resistor has been given a high value in order to maintain the input impedance of the stage.

Output to the moving coil meter is developed across source resistor R5. As there is a DC potential at the source, a blocking capacitor C6 has to be provided, and a signal rectifier, D1, shunt connected. R6 and R7, wired in series with the meter, set the sensitivity of the voltage measuring circuit, and R7 is adjustable so that the pointer can be set to a convenient scale reading.

R2 eliminates a tendency for Q2 to become unstable when very high Q coils are being tested. Bypass capacitor C3, connected across the supply rails, also ensures the stability of the circuit.

A frequency counter makes the unit much easier to use and improves the accuracy of the measurements, especially when the signal generator is not finely calibrated. An output for a counter is taken from the drain of Q2 via blocking capacitor C5. Further guidance on connecting a counter is given later.

An instrument of this kind can be inadvertently left switched on when it is not in use. Low current LED D2, with its dropping resistor R8, acts as a visual reminder that current is being drawn from the battery.

Components

All the components are widely available and constructors should experience no difficulty in obtaining them. No doubt many spares boxes will already contain the necessary parts.

A good quality air-spaced variable capacitor must be used for C4. (Polythene dielectric variables reduce Q measurements by around 10 percent). Its precise value is not critical but, ideally, it should have a minimum capacitance of less than 15pF and a maximum capacitance of 350pF or more. Suitable units can often be salvaged from old radios, and one gang of a two gang component can be wired into circuit if desired. If a salvaged component is to be fitted, make sure it is clean and dry, remove any built-in trimmers, and use a testmeter, set to the highest resistance range, to check for any shorting of the vanes. A single-gang Jackson type 0 variable is ideal if a new component has to be purchased. Maplin list this item in their catalogue.

The low-value coupling capacitor C2 can be a ceramic type. In the prototype instrument it was formed by twisting together,

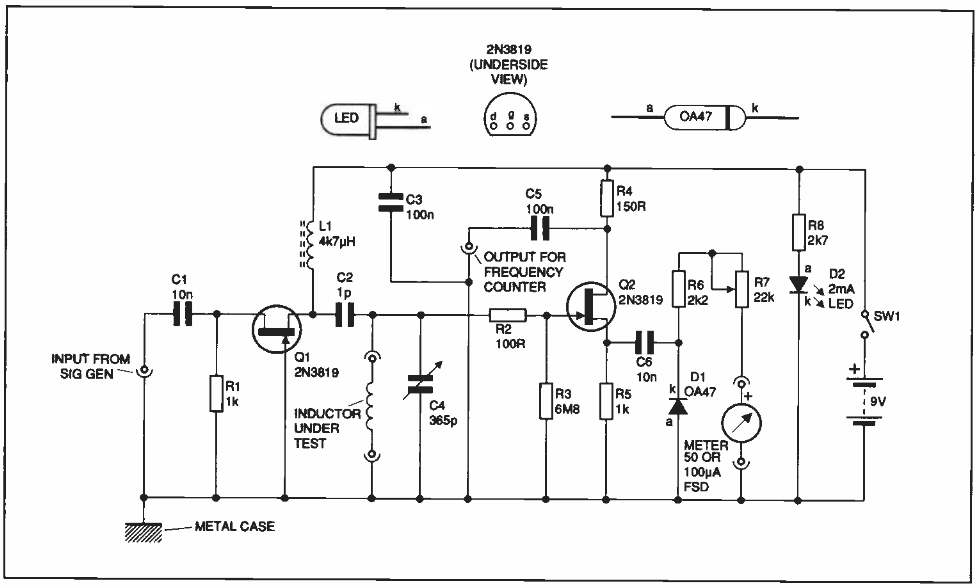


Figure 3: the circuit of the Q meter adapter

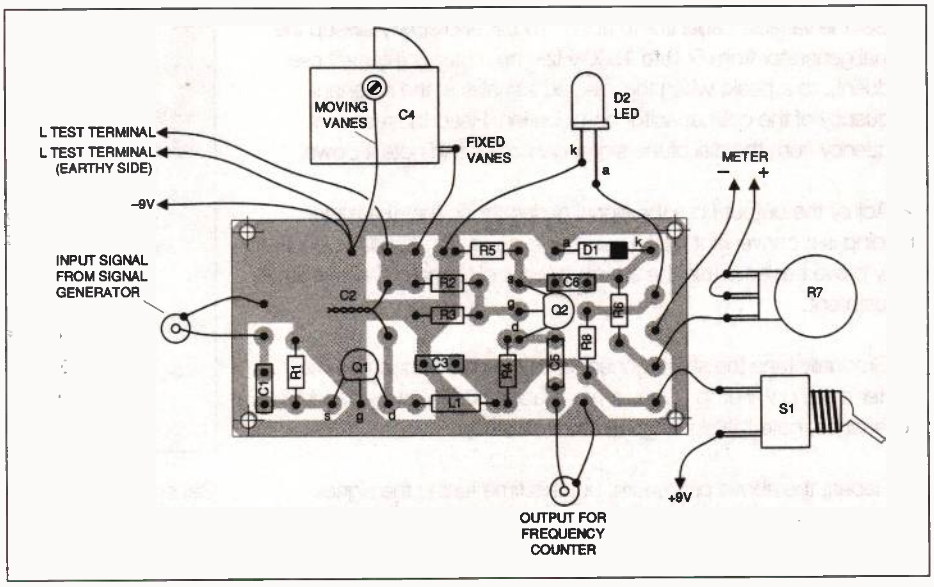


Figure 5: the front panel layout used in the prototype, approximately real size

fairly tightly, lengths of plastic insulated, solid core, hook-up wire. The length of the twisted section should be about 6mm.

An 0A47 is listed as the meter rectifier D1, but most germanium signal diodes should work well. Do not substitute a silicon diode. A slight improvement in accuracy was perceived when a Schottky diode was used in this position, and constructors may wish to try this. An inexpensive general purpose device should prove satisfactory.

Any test meter or moving coil meter with a full-scale deflection of 50 or 100uA will be suitable. It should have a 0-100 graduation, and a meter with a large scale will, of course, be easier to read accurately.

Provided lead lengths are not excessive, there is no need to screen the connections between the adapter, signal generator, multimeter and, if used, the frequency counter. If preferred, therefore, terminals can be fitted instead of the coaxial connectors quoted in the parts list. The output from some simple signal generators can be low, especially as they are tuned into the upper HF region. If low readings are encountered even when R7 is set for maximum sensitivity, fitting a J310 FET in the Q1 position will give more gain and boost the output. The use of this 'hotter' device will not affect the stability of the adapter unit, but its lead-out arrangement is different from that of the 2N3819, and **a length of insulated sleeving should be placed on its centre (source) lead to prevent shorting**.

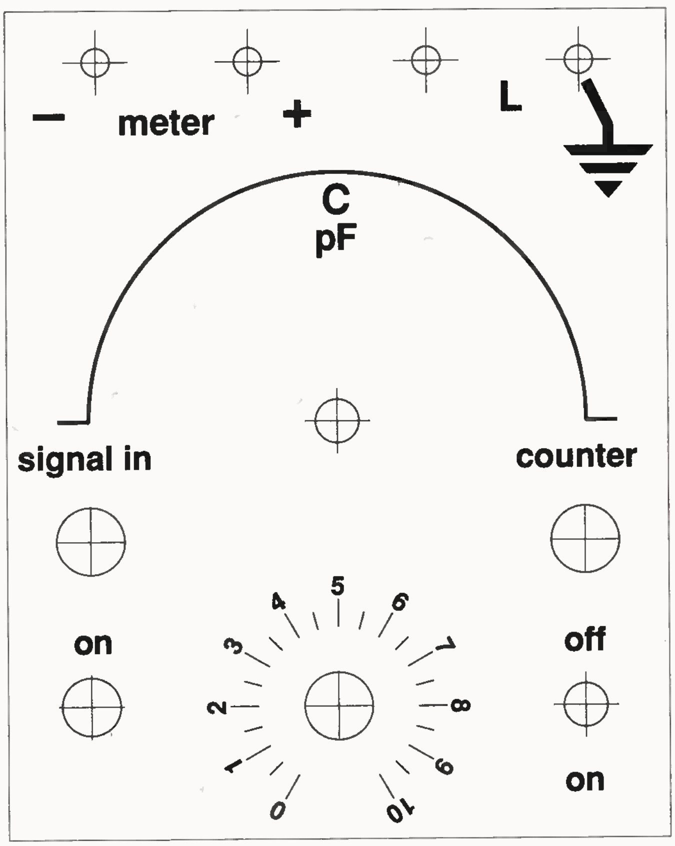


Figure 4: the component layout

Construction

Most of the small parts are mounted on a printed circuit board. The component layout is given in **figure 4**. Vero pins, inserted at the lead-out points, make the task of off-board wiring easier.

The PCB, together with the remaining components, is mounted on the lid of a small box, and the arrangement adopted for the prototype is shown in the photographs. The PCB is secured by means of small Perspex brackets Supaglued to the underside of the lid. The retaining clip for the PP3 battery is likewise Supaglued to the potentiometer case. It is a good idea to check the PCB for poorly soldered joints, bridged tracks or wrongly placed components before mounting it. The moving vanes of the variable capacitor are connected to the negative supply rail. If a metal case is used (this is recommended), it should be connected to the negative supply rail also.

The front panel layout is shown in **figure 5**. The panel was marked out on thin card and annotated with rub-down letters and numerals. A piece of 2mm acetate sheet, drilled jointly with the box lid, protects the card panel. Capacitor calibrations have been omitted so that constructors who wish to adopt this arrangement can mark up a copy of the panel layout to suit their own component. The 'earthy' inductor terminal is indicated on the panel so that an appropriate connection can be made when testing coils wired into equipment.

When the off-board wiring has been completed and checked, connect a fresh 9V battery. Current consumption, including that of the LED indicator, should be in the region of 7mA.

Measuring Q values

The input from the signal generator should be kept as low as possible consistent with meter readings of around 75 percent of full-scale. Too high an input may cause clipping of the signal and the accuracy of the measurements will be impaired (the results will err on the low side).

If a 100uA meter, or a test meter switched to this range, is used, the sensitivity control, R7, will have to be set towards maximum, that is, to a low resistance. If a 50uA meter is connected, R7 can be turned closer to the half-way position.

A medium wave coil is useful for getting the feel of the unit. Connect an inductor of this kind across the test terminals and proceed as follows:

1: Set the variable capacitor to about 150pF and slowly sweep the signal generator from 500 to 1500kHz. The meter pointer will rise, suddenly, to a peak, when the injected signal is at the resonant frequency of the coil/capacitor combination. Read the resonant frequency from the dial of the signal generator and note it down.

2: Adjust the output from the signal generator so that the meter reading is a convenient round number such as 60, 70, 80 or 90. It may prove easier to use the sensitivity control to make the final small adjustment.

3: Gradually tune the signal generator to a higher frequency. The meter reading will drop. When it has reached 0.707 of the reading at resonance, note the signal generator frequency.

4: Repeat the above procedure, but this time tuning the signal generator below the resonant frequency. Again, note the frequency when the meter pointer has dropped to the 0.707 position.

5: The Q of the coil can now be calculated from the following formula:

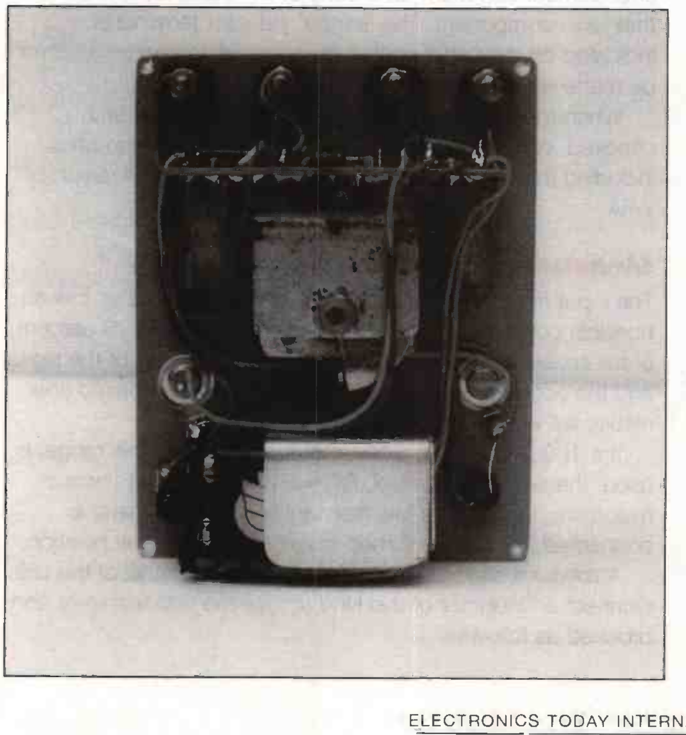
$$Q = \frac{\text{frequency at resonance}}{\text{higher 0.707 frequency - lower 0.707 frequency}}$$

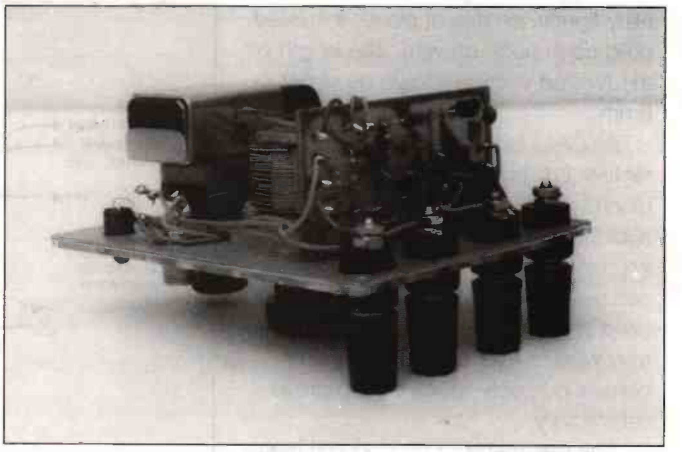
The use of a round number for the meter reading at resonance just makes the arithmetic easier. 70 is a good scale marker to choose for the peak. The 0.707 point is then, near enough, 49.5, and the readings are being taken over a segment of the pointer swing where the meter is likely to be at its most linear.

An actual example should help to make the process clear. The inductor is a Toko medium wave RF coil with a quoted Q value of 70 and a nominal inductance of 330uH. The variable capacitor in the adapter is set to 150pF and a meter with a FSD of 100uA is connected.

Generator frequency for peak response (meter pointer set to read 70) = 720.48 kHz

Generator frequency above resonance to give meter reading of 49.5 = 726.50 kHz





Generator frequency below resonance to give meter reading of 49.5 = 716.15 kHz

$$Q = \frac{720.48}{726.50 - 716.15} = 69.61$$

The procedure takes longer to describe than it does to execute. In this instance the correlation between the manufacturer's quoted figure and the Q measurement is close. However, core setting has a significant effect on Q, especially with modem miniature coils, and the measurements can produce results which differ by up to 20 percent from the figures quoted by manufacturers.

When measuring the Q of commercial or home-made coils, it is a good idea to set any cores at roughly the mid-way position, and to set the variable capacitor to simulate the mid-point of the proposed tuning range. Intermediate frequency transformers already have the necessary tuning capacitors wired inside the screening can, and the variable capacitor in the unit should be set to its minimum value. When measuring the Q of IFTs, always adjust the cores to give a peak reading at the intended operating frequency, for example, 455 or 470 kHz.

Measuring the inductance value of coils

The variable capacitor in the unit will have to be calibrated if inductance values are to be measured. Connecting a capacitance meter and marking off the dial at appropriate round-number settings is the easiest and quickest method of doing this. Constructors who do not have access to meter of this kind can, however, use inexpensive, close-tolerance ceramic capacitors as a means of calibration. Obtain ten 10pF and three 100pF capacitors, and proceed as follows:

1: Disconnect the variable capacitor, connect up the signal generator and meter, and wire a suitable coil to the test terminals (a medium wave coil is ideal).

2: Connect one of the 100pF capacitors across the coil and adjust the signal generator to peak the meter reading.

3: Remove the 100pF fixed capacitor, reconnect the unit's variable capacitor, and adjust it to restore the peak. Mark the scale accordingly.

4: Repeat this procedure with different series and parallel combinations of the fixed capacitors until the scale is marked out. The 10pF components will, of course, facilitate the sub-division of the scale.

When the capacitor has been calibrated, the relationship between inductance, capacitance and frequency, in a tuned circuit at resonance, can be used to determine the unknown value of the inductor. For radio frequency work, the following variant of the standard formula is a convenient one:

$$f = \sqrt{\frac{25330.3}{L \times C}}$$

where f is in MHz; L is in uH and C is in pF.

Transposing the formula to give the value of the inductor:

$$L = \frac{25330.3}{f^2 \times C}$$

Using the same Toko medium wave coil as an example, set the variable capacitor to 100pF (a convenient round number) and slowly sweep the signal generator up from 500kHz. With this particular inductor, the meter peaked at 871kHz, (or 0.871MHz). Inserting this value in the formula:

$$L = \frac{25330.3}{0.871 \times 0.871 \times 100} = 333.89\text{uH}$$

The manufacturers quote a nominal value of 330uH, but this will vary over fairly wide limits depending on the setting of the cup core.

Harmonics

Resonant circuits are responsive to harmonics of their fundamental frequency, and the swing of the variable capacitor will usually cover at least the second, even on the lower frequency ranges. Fortunately, the instrument is far less sensitive to harmonics, and provided the input from the signal generator is kept reasonably low, it will be very obvious when the fundamental is being injected. This is, of course, more of a problem when coils of unknown inductance are being checked and it is not possible to estimate the appropriate capacitor setting and the likely resonant frequency. In these cases, the generator must be slowly swept over its ranges until the dramatic peaking of the meter occurs at the fundamental frequency.

In-situ measurements

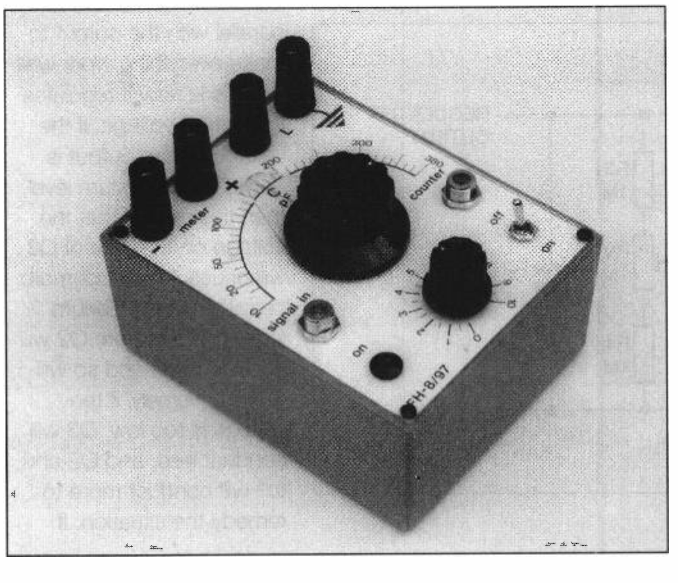
The adapter can be used to check coils wired into equipment. Disconnect the equipment from its power supply before making any tests, and keep the leads to the coil as short as possible.

If the inductor is at 'earth' potential as far as DC is concerned, and if there are no signals present (other than the test signal from the generator), its Q can be measured while it is operating. The adapter imposes a minimal loading on the coil under test, and it is possible to observe the rise in Q with increasing amounts of positive feedback in regenerative circuits.

Unloaded Q factors, whether measured or quoted by manufacturers, can seldom be realised in practice. The damping effects of transistor input and output impedances, and other circuit elements, inevitably reduce the operating Q level. This is particularly evident with miniature coils which usually have tightly coupled impedance matching windings.

Using a frequency counter

Unless the signal generator is of a very high quality, a frequency counter will considerably improve the accuracy of the readings, particularly in the case of HF coils with a high Q factor. (With inductors of this kind, comparatively narrow 0.707 bandwidths have to be measured on signal generator ranges where the calibration is often in fairly broad increments.) Accordingly, provision is made for connecting a unit of this kind to the adapter. @B:Do not attempt to overcome any lack of sensitivity in the frequency counter by increasing the input from the signal generator beyond that suggested earlier. If counter-triggering becomes erratic, perhaps when the generator is tuned to the '0.707 position', connect the counter directly to the unattenuated output of the signal generator.



PARTS LIST for the Q Meter Adapter

Resistors

All 0.25W, 5 percent tolerance

R1, R5	1k
R2	100R
R3	6M8
R4	150R
R6	2K2
R7	22k linear potentiometer
R8	2k7

Capacitors

C1,C6	10nF ceramic
C2	1p5 ceramic, or twist insulated wires together (See text)
C3, C5	100nF ceramic
C4	365pF air-spaced variable capacitor (See text)

If the variable capacitor is to be calibrated by the substitution method, ten 10pF and three 100pF close-tolerance ceramic capacitors will also be required.

Inductors

L1	4700uH miniature RF choke.

Semiconductors.

Q1	2N3819 (See text)
Q2	2N3819
D1	0A47 (See text)
D2	low current (2mA) LED

Miscellaneous

PCB making materials, Vero pins and hook-up wire. Four terminals and two co-axial sockets. Miniature toggle switch, LED holder, PP3 battery and connector. Metal or plastic case, front panel making materials and two control knobs.

TECH TIPS

Different ways of doing things

Andrew Armstrong

Many people who work in the field of electronics develop their own collection of design fragments which can add up to a useful part of a larger design. This is the first of an occasional series of circuit techniques and design hints.

The origins of most of these circuits stretch back into the depths of time, to past design projects and problems that needed solving - not necessarily by the circuits here, but on a path that passed through them along the way. Other people will have independently encountered and solved the same problem, or similar ones. If, as this series progresses, I find the odd useful one which does not fit well into the magazine, I will try to find time to put it on to the website.

If you are looking for something specific, email me at eti@aaelectron.co.uk or drop me a line c/o Nexus House (see page 76) and I will include anything I can find which is relevant in a subsequent part.

Microamp voltage regulation

The range of single-chip voltage regulators is excellent, and for most applications there is a suitable one available at a reasonable price. The use of discrete regulator circuitry has rightly declined almost to zero. Occasionally, however, there is a requirement which cannot be met by an available chip, and then discrete circuitry is necessary.

One such requirement involved a battery operated device, which had to operate for a minimum of one year from a PP3 battery. The circuit needed between 4.5V and 5V, so regulation was definitely needed. The specification required a very low drop-out voltage, so that the equipment would continue to function until the PP3 battery was down almost to the regulator output voltage, and that it should consume as little current as possible to operate itself.

These two characteristics were not, at the time, included in any easily available regulator. One or two came near, but in addition to having a slightly higher power consumption than was desirable, available re-entrant regulators also increase their power consumption dramatically as the input voltage gets very close to the output voltage. This is because they employ a pnp transistor with its emitter to the input positive supply, and its collector supplying the positive regulated output. When the transistor has to be switched on to the point of saturation, the base current must rise considerably. In addition, when the transistor is fully saturated, it is difficult to limit the base current to only that which is actually required.

At the time I could find no re-entrant regulator chips using mosfets and possessing the required characteristics. I did see one fairly recently - it was only available in surface mount and cost too much, but otherwise it was a possible candidate.

The circuit shown in **figure 1** does what is required, although it has its limitations. It uses a p-channel mosfet as the series pass element, so that the voltage drop across the regulator can be arbitrarily small if a device with a suitably low on resistance is chosen, and if the input voltage is sufficient to bias it fully into conduction. Because the gate requires no actual current for it to remain switched on, the only requirement for drive current is that the mosfet must be capable of switching off, so there must be a resistor which discharges the gate bias voltage. The current through this resistor may be very small, but the smaller it is, the slower will be the switch-off, and therefore the less will the regulator will be able to respond to rapid reductions of load current.

In extreme cases the delay could be sufficient to cause oscillation, in less severe cases there may be an unacceptable level of overshoot if the load current suddenly reduces. Therefore, it may be necessary to add a large value capacitor, 100uF or even more, in parallel with the output to make everything work well.

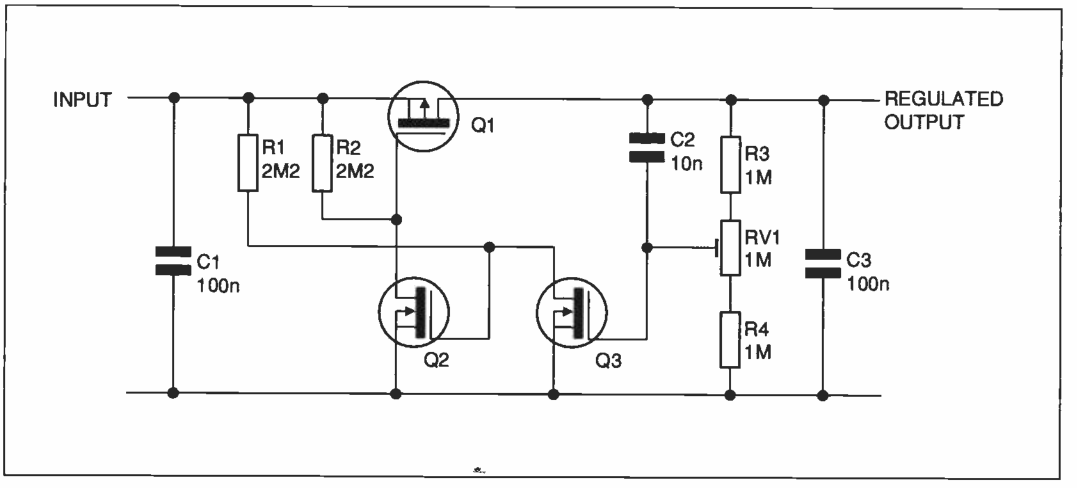


Figure 1: a very low power mosfet voltage regulator

This is how it regulates the output voltage: if the voltage on the output is above its equilibrium level, then this means that the voltage on the gate of Q3 will cause it conduct more heavily than equilibrium level, and therefore Q2 will conduct less, and so will Q1. Conversely, if the voltage is too low, Q3 will conduct less, and Q2 and Q1 will conduct more to remedy the situation. If

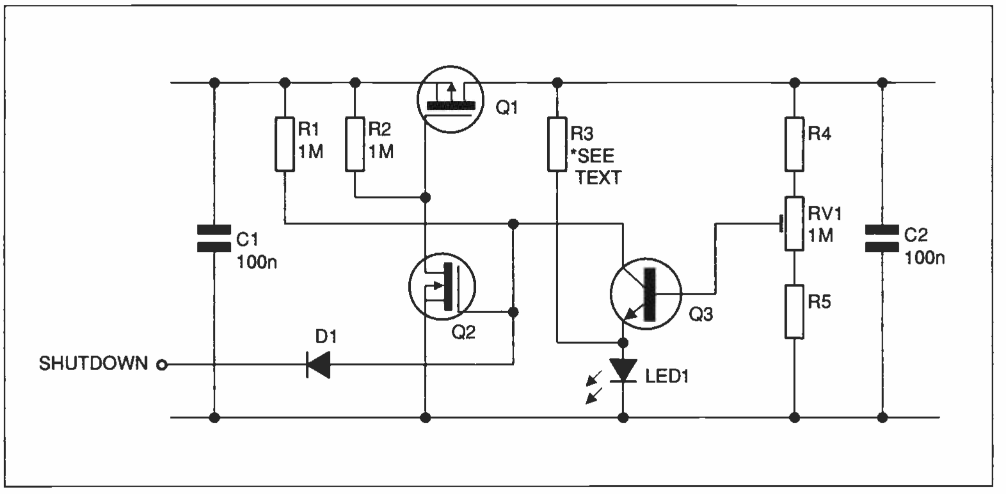


Figure 2: a low power voltage regulator with improved stability

employs the little-known property of a light-emitting diode that it can act as a reasonable low current voltage reference. If approximately 50 uA is fed through a red LED, the voltage across it will be about 1.8V, and this will not be nearly so temperature dependent as the turn-on voltage of a mosfet.

The current to drive the LED is drawn from the regulated output of the circuit, so that the current will remain constant and hence voltage variations will be minimised. Variation of regulated voltage with temperature is not eliminated because of the variation is base/emitter voltage of Q3. If necessary, an approximate compensation could be made by adding a diode in series with R5, or a carefully chosen thermistor in parallel with it. However, if a very precise regulated output is required, then it may be better to use a low-current voltage reference and a low-current op-amp to control the output. This circuit is better used when low-cost and a reasonable degree of regulation are the main criteria.

The circuit in **figure 2** also illustrated the possibility of shutting the circuit down by the use of an external logic signal. If the cathode of D1 is taken to logic 0, then the circuit will switch off, making it suitable for use in cases where the load need only be energised occasionally.

The value of R3 should be chosen to pass approximately 50uA through the light emitting diode. This figure may be chosen differently, according to the size of LED used, but 50uA is a reasonable average.

The shut-down capability illustrated in figure 2 could also be used with the circuit in figure 1 but has not been shown there, in the interests of simplicity.

there is insufficient input voltage to meet the set output voltage, then Q3 will be switched off, Q2 and Q1 will be switched fully on, and the output voltage will be very close to the input voltage. Inspection of the circuit reveals that the current drawn to operate the regulator does not rise particularly in this mode.

Tempco

There is no actual voltage reference in the circuit. For its voltage reference it relies on the turn-on voltage of Q3. This has four main consequences. First of all, the cost is minimised, because a voltage reference is not needed. Secondly, the current consumption is minimised for the same reason. Then, it is unavoidable to have an adjustment in the circuit because of the tolerance of mosfet turn-on voltage, even for fets from the same batch. Finally, and perhaps most seriously, the turn-on voltage of a mosfet is temperature sensitive, so that if a precise regulated output is needed then it will not be good enough.

This last problem is addressed in the circuit of **figure 2**, which is not much more expensive in terms of parts cost. This

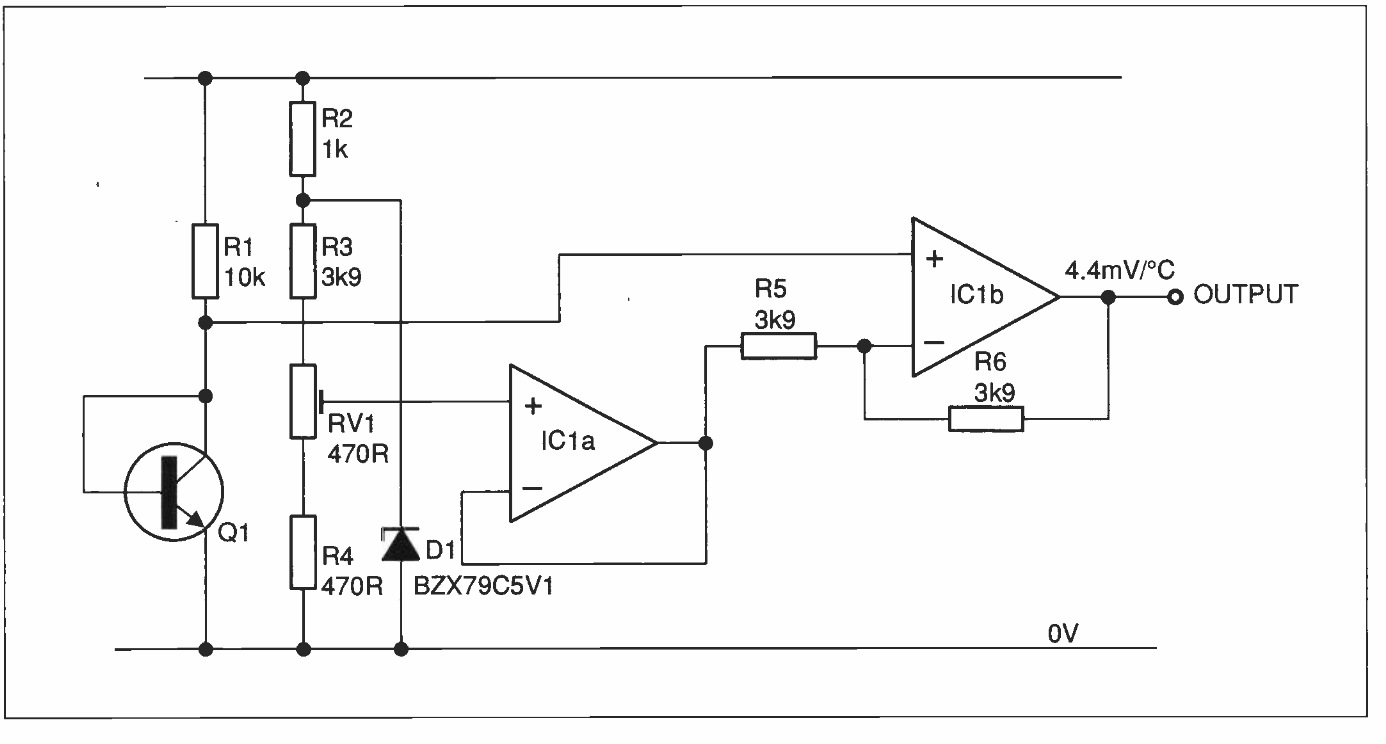


Figure 3: using a transistor as a good, low-cost temperature sensor

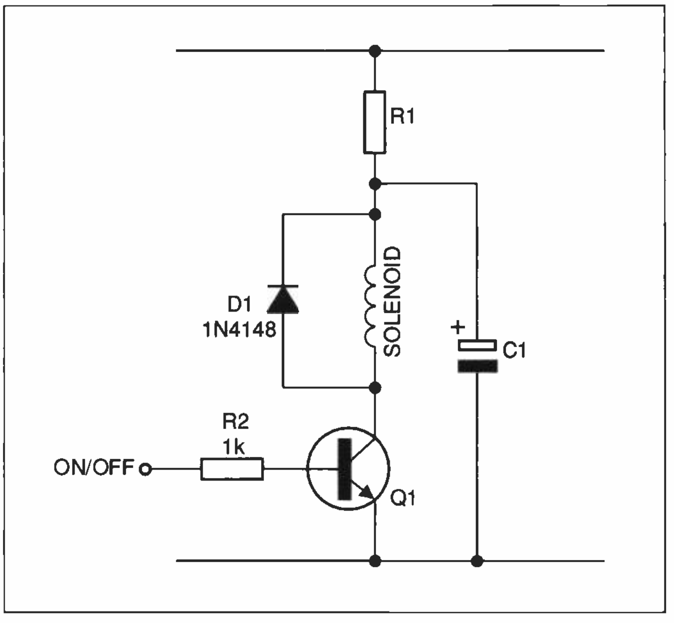


Figure 4: a simple way to reduce the power dissipated in a solenoid

Temperature measurement

There are occasions when the variations of base/emitted voltage in a transistor with temperature can be a benefit rather than a nuisance. It might be considered a benefit when a transistor is used as an amplified diode to temperature-compensate the output stage of a class A/B amplifier. Closer consideration reveals that if the output stage were not temperature sensitive, then the temperature sensitivity of the amplified diode would no longer be necessary.

However, it is possible to use this temperature variation to measure the actual temperature. If a constant current is fed through a silicon P-N junction, then the voltage across it changes the rate of 2.2 mV per degree Centigrade. One snag associated with this is that the voltage drop at a given temperature is not necessarily the same for different samples of the same type of diode or transistor run at the same current. It is only the change which is predictable, so that if a diode or transistor is to be used for accurate temperature measurement, then a calibration adjustment is required.

There is a way to avoid the need for a calibration adjustment, by using the fact that, whatever the precise voltage drop of the device at a given temperature, the amount by which it changes when the current is varied does remain constant. Therefore, if the current through a diode is varied over a range of 10 to 1, and the voltage at the lower current subtracted from the voltage at the higher current, the result will be a voltage relating to the actual temperature with no calibration required. However, this approach required significant circuit complexity, and would only be suitable for use if a large number of temperature measurement channels were used. In this case, the cost and delay associated with calibrating them would be considerable, while the extra circuit complexity would not grow linearly with the number of channels.

For most projects likely to be encountered in ETI, only one or two measurement channels are likely to be needed, so that the use of a calibration control will result in the simplest solution. The circuit of **figure 3** illustrates a way in which this property may be used to provide a temperature measurement. It uses more components than would be used with a precision temperature measuring device such as the AD590, but the temperature sensing device is very much cheaper that the overall cost of the circuit is very competitive.

Further, if IC1B were wired as a comparator, then with no extra complexity this circuit would form a thermostat. This type of thermostat would be good enough to control the temperature of a room, or for example of a PCB etching tank, although it may not be suitable for precise laboratory applications. It could certainly be used to provide a cheap substitute for the now-obsolete **LM3911**. The temperature setting would use a potentiometer

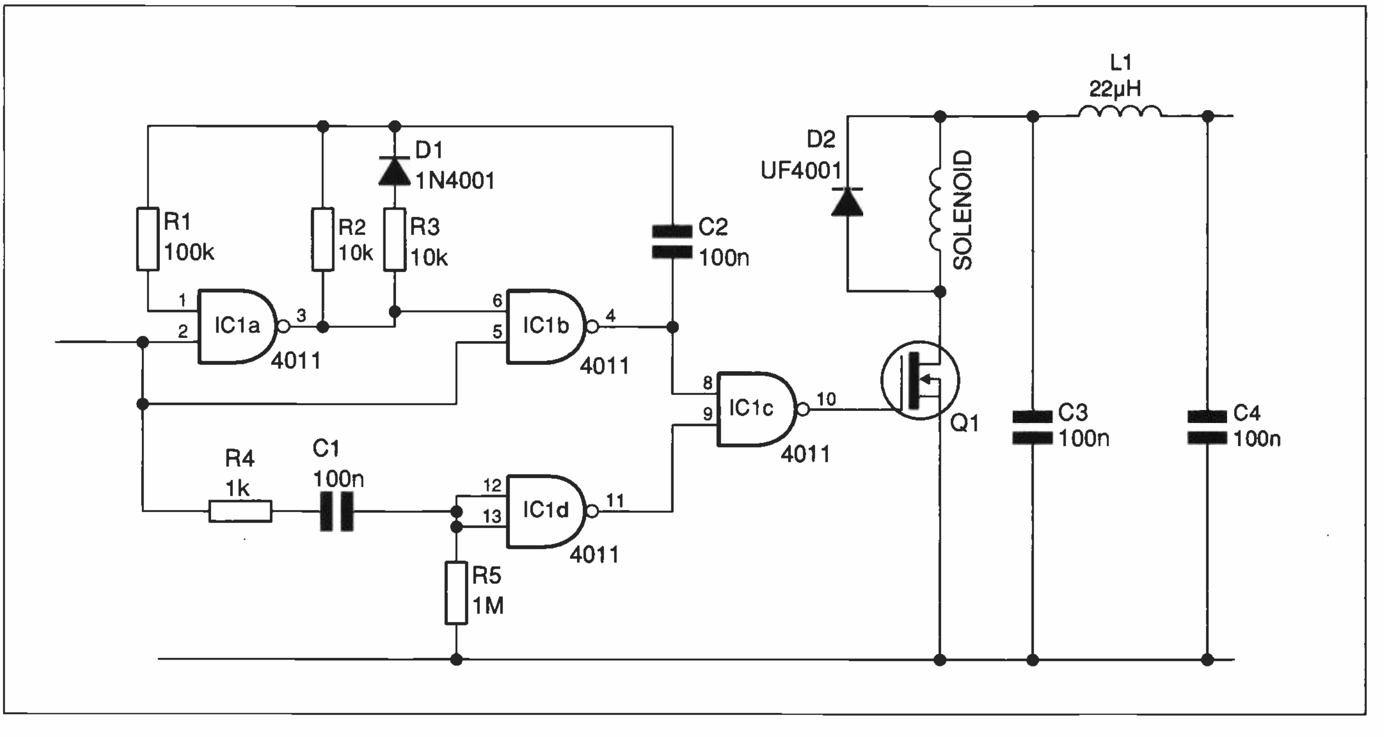


Figure 5: a way to minimise the power drawn by a solenoid where power consumption is critical

instead of a preset in the calibration position, and actual calibration would be carried out by positioning the knob to match the actual temperature to the scale.

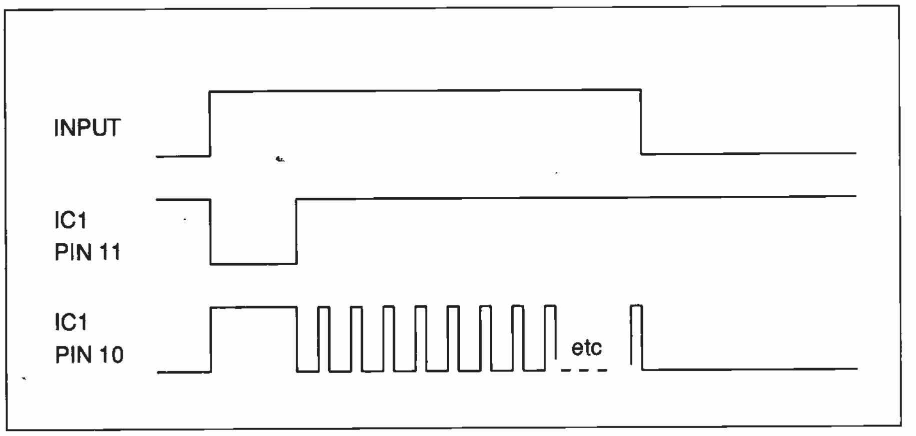


Figure 6: timing diagram given by the circuit of figure 5

Temperature reduction

If used in the ON position for a long time, solenoids get hot. The first time I encountered this problem was when I build a comprehensive charging and control system for the secondary battery supply in a large camper van. What I wanted to do was to connect the subsidiary battery to the main battery with the lowest possible resistance path when the following two conditions were satisfied: the vehicle was running and charging its main battery, and the voltage difference between the two batteries was not so great that a dangerous current would flow. The purpose of this was to permit the subsidiary battery to be charged as fully as possible as rapidly as possible while the vehicle was actually running, without any risk of compromising the capability of the vehicle to start even if use of the interior lights etc. had completely flattened the secondary supply.

To this end the secondary battery was charged via two separate paths. The first was via a diode with a series current-limiting resistor from the switched side of the ignition, and via a starter solenoid directly from the main battery. The solenoid was only switched on in the above specified conditions.

This worked very well, with the secondary battery rapidly being recharged to a high-enough voltage for it to be safe to switch on the starter solenoid, and the charging thereafter proceeding rapidly.

The problem which became apparent was that the starter solenoid draws a lot of current to operate its coil, and becomes dangerously hot if left switched on for a protracted period. The solution I employed at the time was to use a spare cmos gate as a delay timer to switch a large wire-wound resistor in series with the coil after it had time to pull in properly. The circuit shown in **figure 4** achieved this end more simply. The value of C1 is chosen so that it has enough charge to guarantee to energise the solenoid fully, while the value of R1 is chosen so that the required holding current, but not much more, will flow.

Two interesting points about this circuit are that, although the overall dissipation is much reduced, unnecessary heat is still generated by R1. The second point to note is that, although the current flowing in the solenoid may be substantial, a 1N4148 diode would normally be sufficient to pass the current flowing in the coil when Q1 is switched off, thus protecting Q1 from destruction by voltage spike. Normally, diodes can pass a brief peak current of 10 or more times their continuous rating without any damage, so long as the duration is within the limits specified for that type of diode, and the device is allowed to reach thermal equilibrium before another such pulse is applied.

It is not only vehicle starter solenoids which can become excessively hot if energised continuously. Even if the heat is within reasonable limits, a lot of power is wasted if a solenoid is energised at full power continuously, because the holding current is normally much less than the pull-in current.

Another way to reduce the power consumption, by as much as possible if this is the main requirement, is shown in **figure 5**. What this does is to switch the solenoid on continuously for a short period, then subsequently to mark:space ratio modulate the current to provide an adequate holding current. This is like a switched mode power supply, with the solenoid acting as both load and magnetic energy storage element.

If the input is at logic 0, then IC1 pin 4 is forced to logic 1, and IC1 pin 11 remains at logic 1 in its normal state, so that the output remains off. When there is a 0 to 1 transition on the input, IC1 pin 11 switches from 1 to 0 for a time period determined by the values of R5 and C1. This period is chosen to be sufficient to pull in the solenoid. The function of R4 is to limit the current which will flow when the input returns to logic 0, when the right hand pin of C1 has discharged to 0V via R5. The current to restore this point close to 0V instead of the -5V it would have been, flows in the input protection diodes of IC1d - and limiting this current is good for long term reliability.

After this period, which is about 150ms with the values shown, the output of IC1 pin 11 reverts to its normal logic 1 state, and the output is now controlled by the oscillator. This is illustrated by the timing diagram in **figure 6**.

The oscillator is of a conventional type, but has its mark:space ratio modified by the addition of R3 and D1. The values chosen should make the on time of the output about half the off time. The resistor value may be altered to set the current to the level actually required to hold the solenoid in reliably.

The oscillation frequency has been chosen to be a reasonable compromise between the need to minimise the ripple on the current flowing in the solenoid, and the need to minimise losses due to circulating currents in the core, which is not laminated or arranged in any way to reduce circulating currents in a dc solenoid. The frequency may be altered to suit specific solenoids being driven.

When the input returns to logic 0, the oscillator is immediately disabled, and the output switches off.

The catch diode for this circuit is of a higher rating than that for **figure 4** because it has to conduct for two thirds of the time that the solenoid is ON, rather than one pulse occasionally.

Finally, L1 and C4 prevent switching noise from leaving the confines of the circuit and radiating from the power supply connections.

Bart's BATH DUCK

Bart Trepak's scalded foot gave him the idea for a bathwater warning device mounted in the most appropriate fashion, and using a blue LED for instant temperature identification.

I guess that I have always been a sucker when it comes to electronic gadgets - show me a corkscrew with a built-in digital wine thermometer or a can opener with a built-in calculator and I am hooked. Of course, some gadgets are more useful than others, so my fascination is usually limited to "I wonder how they managed to fit that in there?" I stop short of actually buying unless I can see a clear need for it or can adapt it for some purpose useful to me. Naturally, my fascination extends to electronic components but there I am far more easygoing because of the relatively low cost. The very fact that a new component has become available is usually enough to persuade me to send off for one first and think up a use for it later.

LEDs are a particularly good example. I suppose it is the magic of seeing a piece of plastic glow red or green when a current is fed into it. Seeing a new, blue one listed in a catalogue was something I could not resist. Having obtained a few, the question then became "what I could do with them?" that I could not do with a cheaper red or green one. I was idly pondering this question the day I stepped into a scalding hot bath . . .

"Eureka" I shouted (it was actually "You ******er", but it sounded enough like the exclamation reserved for great discoveries to pass unnoticed by other members of the household) as the solution dawned on me - faster, incidentally, than it did on Archimedes. Luckily, I retained enough presence of mind not to run down the street in my birthday suit, but then my discovery was not quite as earth shattering (or as profitable) as that of the great man. I realised that what I needed to do, apart from put my foot under the cold water tap, was to build a device that would display the temperature of the water before I got in and my toe found out the hard way.

A full blown thermometer was obviously an overkill, but a simple device which would show if the water was too hot for comfort would be most welcome. Since a freezing cold bath is only marginally less unpleasant than a scalding hot one, a three-LED display would be ideal. What better than a "cold" colour like blue to show TOO COLD, a "hot" red to show TOO HOT and a green LED to show when the temperature was just right.

Sensor

The first requirement is a sensor. We are spoilt for choice nowadays, with temperature sensing devices from the humble silicon diode to fancy integrated circuits with matching prices which provide an output voltage or current proportional to temperature.

The best sensor to use for this project, however, is a thermistor. Not only does this produce a relatively large output change for a given temperature, so that the signal does not need further amplification, but it is also relatively cheap. The only disadvantage is that it is non-linear but, since we are not displaying the actual temperature but merely determining if it is too high or too low, this is not important.

A thermistor is basically a device whose resistance varies with temperature. Devices with positive or negative temperature coefficients (PTC or NTC) are produced, although the latter seem to be more generally available, so I have used this type for this circuit. With these, the resistance changes inversely with temperature, so that, as

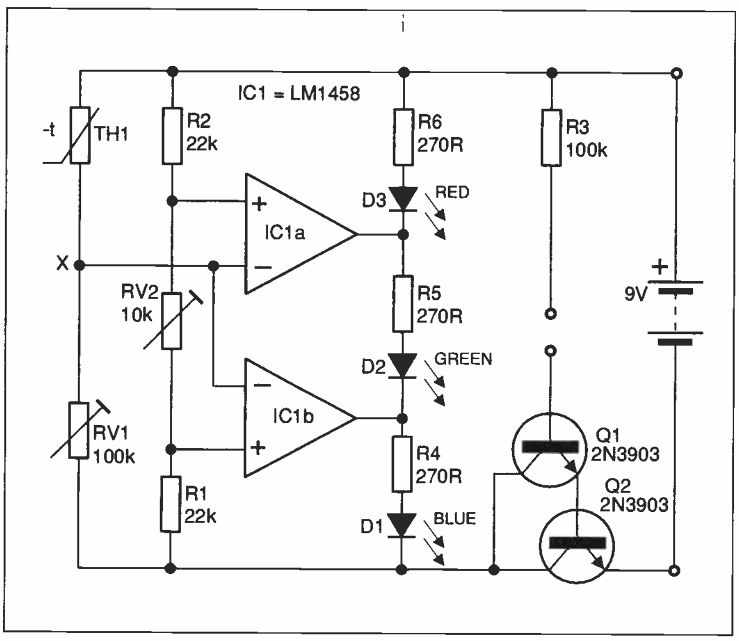


Figure 1: the Duck circuit

the temperature increases, the resistance falls. The value is normally specified at 25 degrees C, and devices are available with resistance values of a few hundred to tens of thousands of ohms which fall to a few ohms (or a few hundred ohms) at a high temperature. The precise value at any particular temperature is not too important in this application as virtually any NTC thermistor could be accommodated simply by changing the value of resistor RV1. Since the unit must be battery operated (mains electricity and bathrooms should, famously, be kept well apart) the current consumption of the circuit should be kept low. Therefore, a higher value of thermistor resistance is preferable.

The complete circuit of the bath temperature indicator is shown in **figure 1** and it can be seen that the thermistor is connected in series with a resistor RV1 across the 9V battery supply, assuming that Q2 is switched on. The voltage at the junction of the two resistors (marked X) will therefore depend on the relative values of the resistors so that, if they both have the same value, the voltage will be one half of the supply, or 4.5 volts. If the temperature rises, the thermistor resistance will fall and the voltage at point X will rise above 4.5 volts. If the temperature falls, this voltage will fall. Incidentally, if a PTC thermistor were to be used, the relative positions of RV1 and TH1 would need to be altered, with the thermistor placed in the lower arm (connected to the negative rail).

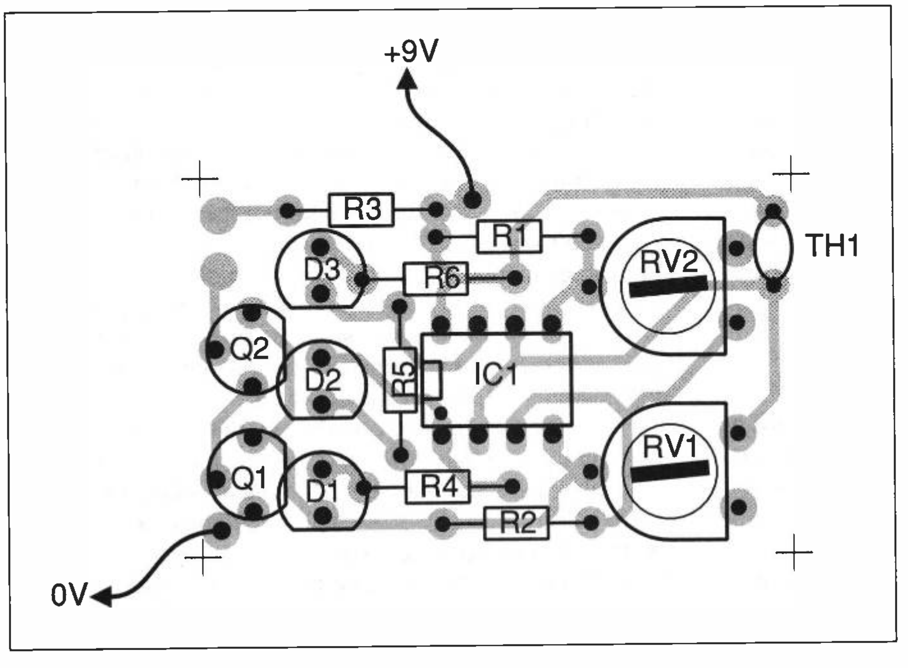


Figure 2: the component layout

Comparators

To determine the category into which the water temperature falls and which LED should be lit, the voltage at point X needs to be compared with a voltage which represents the "TOO HOT" state and another which represents the "TOO COLD" state. This is done by means of two comparators. These are basically op-amps with no feedback, so that the gain is very high and any small imbalance in the voltage at the two inputs will result in the output limiting at the positive or negative supply rail, depending on which input has the higher voltage. Sometimes a little positive feedback is added by connecting a high-value resistor from the output to the non-inverting input to cause the output to switch "cleanly" between the two states, especially if the input voltage changes slowly. But this is not necessary in this circuit.

Because everybody's idea of what is too hot or too cold varies, the two voltages representing these conditions must be made variable and since the voltage representing TOO HOT will always be higher than that representing TOO COLD, these can be obtained by a single potential divider chain consisting of R1, RV2 and R2. If RV2 is adjusted to minimum (zero) resistance, then the voltage at the non-inverting inputs of both comparators will be the same and since R1 and R2 have equal values this will be the mid-supply voltage. As RV2 is increased in value, the voltage across it will increase so that the voltage at the non-inverting inputs of both comparators will vary symmetrically about the mid-supply voltage. R1 and RV2 therefore sets the lower trip level and R2 and RV2 the upper one with RV2 effectively defining the range of temperatures which is considered to be not too hot or not too cold.

To see how this circuit works, suppose that the temperature is very low so that the voltage at point X is below the value set at the junction of R1 and RV2. The inverting inputs of both comparators will therefore be below their non-inverting inputs so both comparator outputs will be high at + 9 volts. In this condition, only LED D1 (the blue LED) will have a voltage across it and will therefore light with R4 limiting the current to a safe value.

As the temperature increases, the voltage at point X will rise until it becomes higher than that set by R1/RV2 but lower than that due to R2/RV2 and the output of the lower comparator IC1b will therefore switch to 0 volts causing LED1 to go out. The output of IC1a will however remain high so that LED D2, the green LED, will now light to signal that the temperature is alright. Should the temperature continue to rise, the voltage at X will eventually also exceed that set by R2/RV2 so that the output of comparator IC1a will also go low, causing LED D2 to extinguish and LED D3 to light, indicating that the temperature is too hot.

In a real circuit, things would not normally work so smoothly, because the outputs of most op-amps do not switch between the full supply rails and it would not be unusual for the output to swing only to within 2 volts of the negative line. This would normally mean that when the temperature was at the safe value and output of IC1a was high, the ouptput of IC1b would be low but would only fall to around 2 volts. This could still be enough to light an LED which has a forward volt drop of 1.5 - 2 volts. In this situation, both the lower LEDs D1 and D2 would come on - which is not what is required. The answer is either to use a more expensive CMOS op-amp for IC1, so that the outputs swing much closer to the supply rails, or to insert a low voltage zener diode (2.7V or 3.3V) or a few forward biased silicon diodes between R4 and D1 to increase the effective forward voltage drop of the LED. Luckily, blue LEDs, which are manufactured from silicon carbide and not gallium arsenide as is the case with red, green and yellow ones, exhibit a higher forward voltage drop of around 2.5 - 3 volts. In this case, the LED will either not light or it will glow only very faintly and no other components should be required. This is a point to bear in mind should you want to build the circuit using a cheaper yellow or amber LED for D1.

Switch

It was envisaged that the circuit together with the battery would be fitted into a waterproof box of some kind and simply allowed to float in the water with the thermistor either on the outside or in contact with the wall of the container where it would monitor the temperature of the bath water. However, a battery-powered circuit of this sort which draws a current of 10 mA or so has to be fitted with an on/off switch if the battery is to last any reasonable length of time, but most small switches such as sliders or toggles are not waterproof, so a different method of on and off switching had to be found.

Water is a pretty good conductor of electricity so the solution adopted here is to use a simple touch switch circuit consisting of two transistors connected in Darlington configuration, which produces a transistor with a very high gain, together with two contacts mounted on the surface of the "box", plus a series resistor. The contacts should be arranged so that when the box is placed in the water, they are bridged, causing a small base current to flow into the first transistor Q1 resulting in the second transistor Q2 conducting heavily and effectively switching on the supply for the rest of the circuit. When the box is removed from the water, the contacts will no longer be bridged, so the transistors will switch off, saving the battery. The contacts can easily be sealed to prevent water from entering the box and should be positioned sufficiently far apart to prevent them being bridged accidentally by drops of water and surface tension remaining on the box when it is removed from the water.

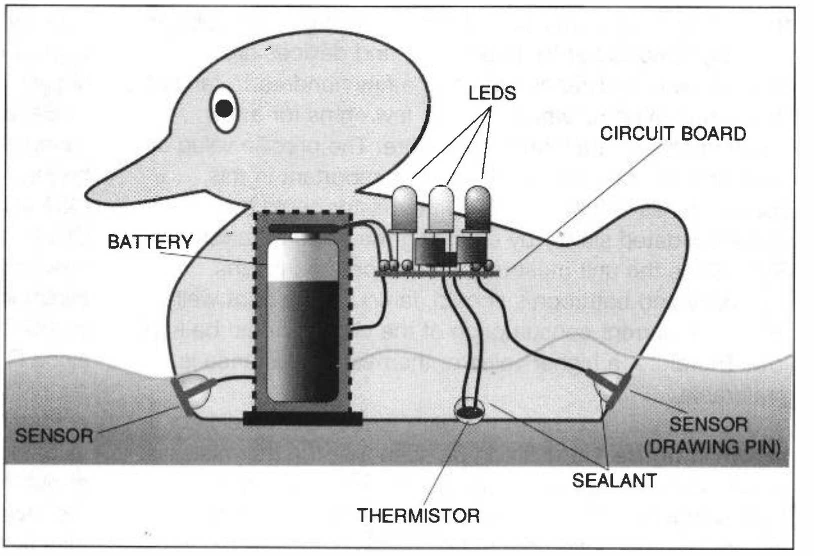


Figure 3: a suitable internal arrangement in a duck

Construction

A suitable printed circuit board layout is given in **figure 2** which is small enough to allow the device to be fitted into almost any sized box which will accommodate the PP3 battery and construction should not present any problems even to a beginner. The thermistor will probably need to be connected to the circuit board with flying leads to allow more flexibility in positioning, as will the sensor pads, so that a few centimetres of insulated wire should be soldered to the appropriate points on the circuit board to connect these components.

Once construction of the board is complete, the two preset resistors should be adjusted with RV2 initially set to minimum resistance and RV1 to maximum. With a 9-volt PP3 battery connected and the thermistor placed in water which you consider to be at the correct temperature for a bath, RV1 should be adjusted to give a voltage of around half the supply across it. Next, place the circuit in water that is just about bearable and adjust RV2 until the RED LED goes out and the GREEN LED lights. Placing the thermistor in cold water will automatically ensure that the BLUE LED lights. To ensure that the circuit remains switched on while these adjustments are made, the sensor pads may be bridged by touching them with wet fingers or by temporarily soldering the two leads together. The conductivity of the water may also upset the adjustment, especially if a high resistance unencapsulated thermistor is used so that it is important that water is not allowed to bridge the thermistor leads. The thermistor may be placed in a thin polythene bag when it is dipped in the water while the circuit is set up.

Once the circuit is working satisfactorily, it should be fitted into its "box". The thermistor should be mounted adjacent to the wall of the box which will be in contact with the water and in good thermal contact with it which may be difficult to achieve. Better still, a small hole may be drilled in the box to allow the thermistor to protrude into the water. If this is done, the circuit will respond better to changes in the water temperature but the hole for the leads will need to be sealed with Araldite or a silicone sealer (available in most DIY shops for sealing gaps around sinks and baths) to prevent water from entering the box. A thin smear of adhesive should also coat the component itself to prevent it being "short circuited" by the water if the thermistor is an unencapsulated type.

The sensor pads may be made by drilling two small holes in the box and pushing drawing pins into them. If possible, use ones that have been plated which will prevent them from rusting and arrange them on the box so that the water will drain from them when it is removed from the bath. If possible, do not place them on one face as this could result in the circuit being switched on if left on a wet surface or one which became wet of which there are many in a bathroom. The distance between them is immaterial, but should be at least a centimetre or two and they should be connected to the appropriate points on the printed circuit board by flying leads.

It is important that the circuit is housed in a waterproof box which can of course be any shape as long as it floats in an upright position with the thermistor and sensor contacts submerged and the LEDs showing. For this, perhaps, the most appropriate shape is a duck or a toy boat (which can always double as a toy if you are into playing with such things in the bath!). The most important requirement is that it has a tightly fitting cap which covers an opening large enough to enable the PP3 battery to be inserted and changed. A look along the shelves in a supermarket will reveal many suitable plastic containers

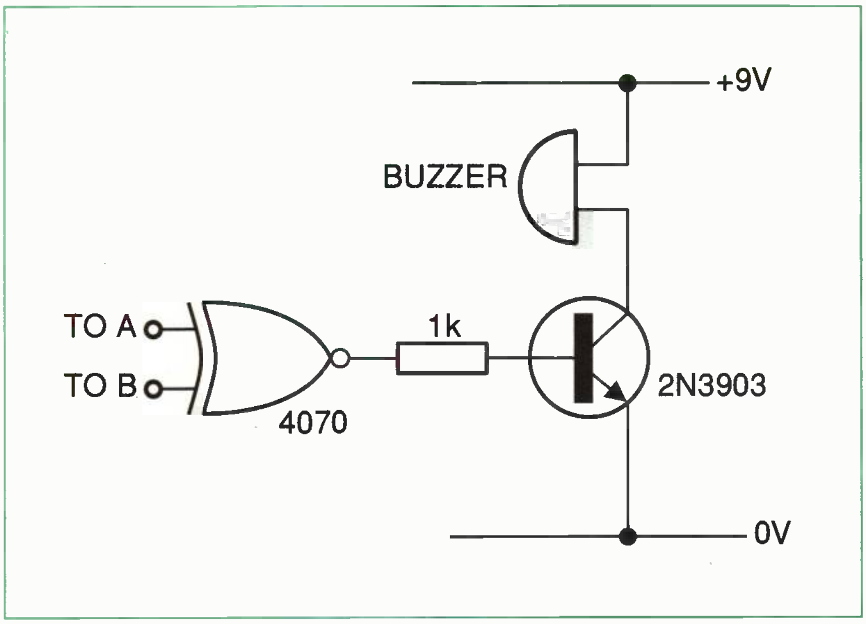


Figure 4: adding an over/under temperature alarm

such as shampoo bottles, etc. If the chosen one is round and could therefore float in any position, it can be suitably weighted down to ensure that it floats in the correct position with the thermistor and the contacts always submerged. The battery itself will probably act as a suitable weight especially if it is secured so that it cannot move about inside the box. The exact details will depend on the size and shape of the box and are therefore left to the ingenuity of the constructor, but **figure 3** shows the general idea.

The prototype was built into a hollow polythene duck into which the circuit was fitted. The "battery compartment" was made from a film container which is just large enough to fit a PP3 battery and connector and has a tight fitting cap. This was inserted into the base of the duck by cutting a suitable diameter hole and sealing any gaps around the container with sealant. Note that the circuit had to be calibrated **before** it was fitted into the duck to avoid the necessity of making further holes in it to gain access to the pre-sets.

Other applications

The circuit is not limited to showing the temperature of a bath and may also be used for displaying the temperature of the water in a hot water tank or the air in a room or freezer but for this application RV1 may need to be re-adjusted. It may also be possible to mount it on a mixer bath (or kitchen) tap instead and in these cases, it is not too important to have a waterproof case. Because the sensor pads will not now be immersed in water, a more conventional on/off switch such as a push button will need to be fitted in place of the two transistors.

Providing the circuit is not used in damp or wet conditions, a mains adapter could be used enabling the unit to be powered continuously. The circuit could then be used as the basis of a dry-condition over/under temperature alarm by the addition of a buzzer. Since the outputs of the comparators are both high or both low when the temperature is outside the set limits, and only assume different levels when the temperature is correct, an exclusive or gate connected to these points will give an output high only at this time. Connecting a buzzer so that it switches off in this condition as shown in **figure 4** will therefore sound the alarm when the temperature drifts outside the set limits. It should be remembered that the output of most op-amps does not drop to zero when the output is low so that a further potential divider may be required between points A and B and the logic gate to provide recognisable low logic levels to the gate.

As well as providing over/under temperature monitoring or warning, it is also possible to replace the thermistor with, say, a light dependant resistor (LDR), in which case the circuit would indicate if the light level at a particular location was suitable for (for example) photography or environmental monitoring. In general the value of any parameter such as temperature, light level, pressure, weight etc. could be displayed provided a suitable sensor which converts the parameter in question to resistance can be devised.

Editor's note: an LED-scale sensor circuit built into a tobacco tin and detecting hot water level in the domestic tank has been the means of avoiding bathtime conflicts around the editorial household for many years. It beats us why they don't come fitted as standard. Now: who is going to send us a design for an indicator that warns you when the shower is about to run freezing cold - before it does it?

PARTS LIST for the Bath Duck

Resistors

R1	22k
R2	22k
R3	100k
R4	270R
R5	270R
R6	270R
RV1	100k
RV2	10k

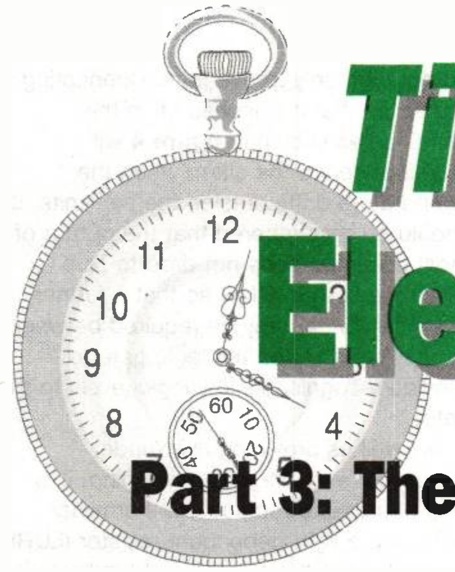
Semiconductors

IC1	LM1458
Q1, Q22	N3903 npn
D1	Blue LED
D2	Green LED
D3	Red LED

Miscellaneous

TH1	Thermistor (see text)

Printed circuit board, 8-pin dil ic socket, battery connector, etc.



Timing in Electronics

Part 3: The long and the short of it

Owen Bishop

Divider chains can be used to prolong timing periods. Two demonstration boards - a divide-by-60 chain and a 15-minute timer are included, with programming examples for the 4018, 4541 and Basic Stamp.

In the previous part of this series in issue 7, I described a practical crystal clock running at 1Hz. The crystal naturally vibrates at high frequency, and we use a binary dividing chain to slow down the oscillations to more useful frequencies. With a 32.768 kHz crystal we use a 15-stage binary dividing chain to produce the 1-Hz output. You can also use 4.194304 MHz crystals and a 22-stage binary chain to produce 1Hz. In both examples, the crystal frequencies are predetermined to produce a convenient 1-Hz signal after repeated binary division.

The 555 timer described in the first article in issue 6 also runs at 1Hz and needs no dividing chain. This is a reasonably stable timer because we can use a polycarbonate capacitor for frequencies around 1Hz. Polycarbonate capacitors are stable, have low tempco and are made with 1 percent precision. In any case we can include a trimmer resistor in the circuit for final adjustment to exactly 1Hz or whatever other frequency is required.

Unfortunately those ancients of Babylon who pioneered our units of time were not 'binary-minded'. They worked in sixties, so when we move from seconds to minutes and hours, we have to leave binary behind. It would be possible to cut a crystal that, divided by a suitable number of binary stages, would give a 1-minute frequency, but this does not seem to have been done. We need a divide-by-sixty chain.

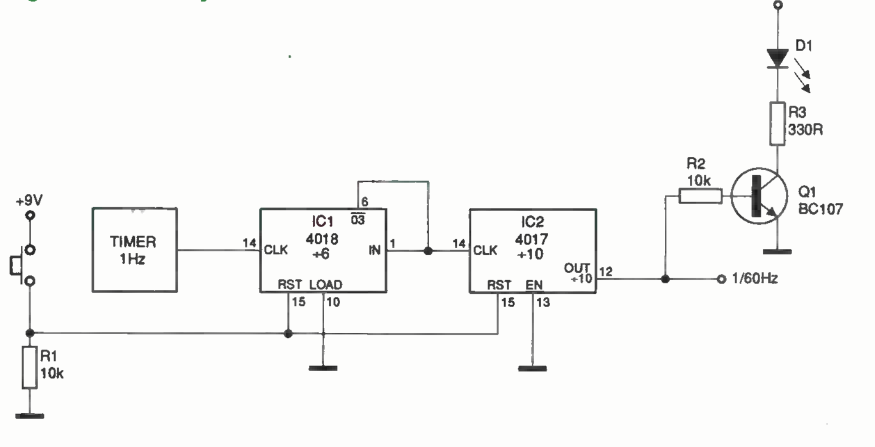
The 555 timer is an excellent and precise device with many applications. The difficulty with using it for long-period timing is that it depends on the precision of the capacitor, and large-value capacitors such as electrolytic and tantalum capacitors are not precise. They are also unstable. The best way to obtain long period timing is to build a short-period timer (such as the 1-Hz 555 timer) and feed its output to a divide-by-sixty chain.

Divide-by-sixty chain

Figure 1 shows a practical divide-by-sixty chain. Given a 1-Hz input from the crystal clock or 555 timer, as shown in the figure, the output has a frequency of 0.1667 Hz, or 1 cycle per minute. No single divide-by-60 ic is available, so we are tackling the division in two stages. First we use a 4018 to divide by 6, and then we take the output from this and feed it to a 4017 for division by 10. The two dividers (or we can also think of them as counters) are rather different in their action, so we shall look more closely at each one in turn.

The 4018 is usually known as a divide-by-n counter because it can be set to divide by any number from 2 to 10. This is a useful feature because we can use this ic to build dividing chains for other values. To divide by 6 we take the 03-bar output from pin 6, and use this as the output of the ic but at the same time feed it back to the IN input at pin 1 (see table 1). There are also five inputs that allow the counter to be pre-loaded with a starting value. We do not use this facility here so these inputs (pins 2, 3, 7, 9 and 12 must be connected to the 0V rail, as must the LOAD input at pin 10. The RESET input at pin 15 is held low by a resistor R1. A push-button wired as in **figure 1** allows the counter to be reset. Instead, the reset input could be connected to a logical output to reset the counter digitally.

Figure 1: a divide-by-60 chain



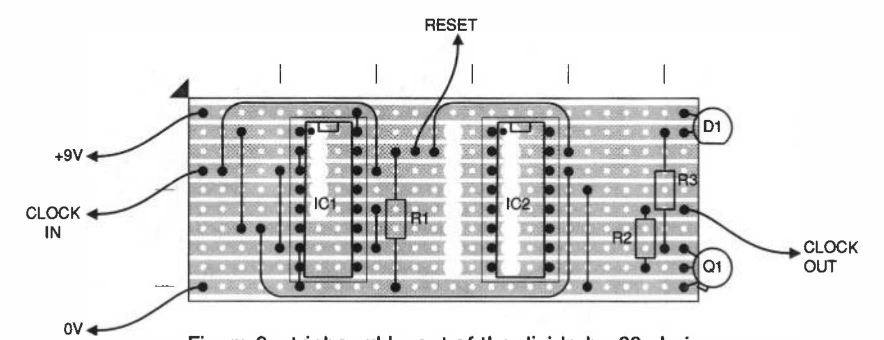


Figure 2: stripboard layout of the divide-by-60 chain

Table 1: Programming the 4018

Take the output listed, or AND the two listed outputs together, to obtain the division required, then feed back the output to IN (pin 1).

Divide by	Output from pin no.
2	5
3	4 AND 5
4	4
5	4 AND 6
6	6
7	6 AND 11
8	11
9	11 AND 13
10	13

The 4017 is unusual in that its 10 outputs are normally at logic low but on each count one of these goes high. This feature has some interesting applications but we use the special divide-by-10 output at pin 12, which goes high on counts 0 to 4 and low on counts 5 to 9. In other words, it has a frequency one-tenth that of the input.

This practical project (**figure 2**) includes a transistor-switched LED to indicate the state of the output. It is best to build and test the circuit in two stages. First assemble IC1, complete with the pull-down resistor R1. Note that a solder blob connects pins 2 and 3. Pins 7 and 8 are also connected in this way and to the 0V strip. Strips H and J are not cut beneath IC1. Connect either one of the 1Hz timers to pin 14 and use a testmeter to monitor the output of IC1 at pin 1. The output is low for three 1Hz flashes on the timer's LED, then high for three flashes, repeating. If this does not operate correctly, check that all the relevant pins are connected to 0V and that the reset pin (pin 15) is also at 0V.

Next assemble IC2 and the LED circuit (R2, R3, Q1 and D1). The only connections to 0V are the ENABLE (pin 13) and the 0V-supply terminal (pin 8). The RESET (pin 15) shares resistor R1 with IC1, so that both counters may be reset at the same instant. Switch on and count the flashes on the 1-Hz clock. The LED is on for counts 1 to 30 and off for counts 31 to 60, repeating. The circuit is a precise minute-timer.

Longer periods

The chain may be extended to increase the time period. Just adding another 4018 to the output of figure 1 allows you to increase the time to any whole number of minutes between 2 and 10 minutes (see **table 1**). It is possible to design a switching system so that the circuit can be switched to provide several different output frequencies. However, if you want to divide by 10 only, use a 4017 instead of a 4017 as the wiring is easier. You could use other divide-by-ten (decade) dividers such as the 4029 (decade/binary, up/down), 4518 (dual decade, up/down) and the 74HC390. The latter contains two dividers, to divide by 2 and by 5, which can be used individually. If you need division by 10, divide by 5 first, and then divide by 2. If you connect the counters the other way round, you get an asymmetrical output.

Adding another complete divide-by-sixty chain to figure 1 increases the period to 1 hour. This can be increased to 2 to 10 hours by following with a 4018. A period of 24 hours could be obtained from 1 hour by using two 4018s to divide by 6 and then divide by 4. The use of dividing chains gives very precise periods, with the same precision as the initial timing circuit. A crystal clock with an inexpensive crystal has a precision of 15 ppm and a zero or very low tempco. This is equivalent to 1.3 seconds in 24 hours.

The circuits we have described so far are intended to provide a timed period, at the end of which something happens (or something stops happening). So far we have been content merely to switch an LED off at the end of the period. But we can design circuits to produce all kinds of actions and these will be the subjects of a future installment. Another way in which these circuits can be used is to measure the time elapsed since the circuit was set to run. This is another topic that will appear in future issues. For the moment we will look at a few more methods for generating the fundamental timed periods.

Ready-made chains

The technique of coupling a fast clock to a long dividing chain works so well that a number of integrated circuits are available which have the circuitry for the clock and the chain on a single chip. Of course, building up a chain to your own specification allows you to plan it to produce a number of different timing periods at various points along a single chain. But if you want a single long period with the minimum of wiring and using the minimum of board-space, then the dedicated timing ic is the answer.

One well-established example of this is the 4541 timer ic (**figure 3**) which, in spite of what we said just now about single long periods, does have the facility for producing four periods of different lengths. The clock is

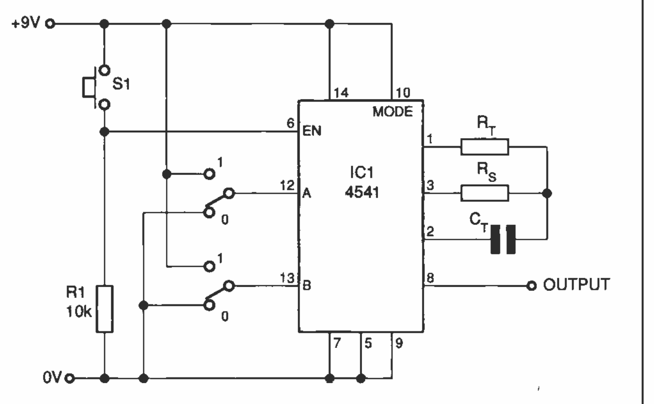


Figure 3: a long-period astable, based on the 4541 timer ic

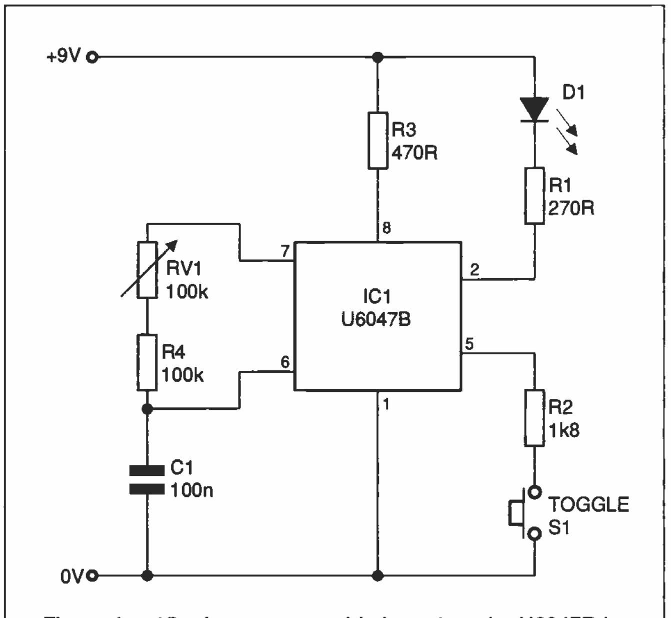


Figure 4: a 15-minute monostable based on the U6047B ic

based on charging a capacitor. The timing capacitor CT can have a value between 100pF and 100nF, so we can use polycarbonate or multilayer ceramic capacitors for maximum precision. The timing resistor RT can be between 5k and 1M. The basic frequency is f = 1/(2.3RTCT). This gives a wide range of possible basic frequencies, from 4.35Hz to 870kHz. But the basic frequency is divided by one of four amounts, depending on the division control inputs, as in **table 2**.

Table 2: Programming the 4541

Input A	Input B	Divides by
0	0	8192
0	1	1024
1	0	256
1	1	65536

This provides output ranging from 66.4uHz (period about 4.2 hours) to 3.4kHz (period 300 us). Division amounts can be switched by the use of two single-pole double-throw switches as shown in **figure 3** or under logical control. Pressing S1 resets the counter, after which the ic counts continuously as a low-frequency astable. If pin 10 (MODE) is wired to the 0V rail instead of to the positive rail, counting stops after 1 period.

A more recent ic operating on similar principles (though without the facility for switching ranges) is the U647B. This is intended for automotive use. With filtering on the power line provided by R1 and C1, it is relatively immune to the spikes and surges commonly encountered in car power supplies. The ic has many applications outside the automotive field as our second practical project for this month shows (**figure 4**). Basic timing is provided by RT and CT. RT may have any value between 59 k and 650 k, and CT may range from 1nF to 4.7uF. These values give a timing period from 3.7s to 1229 min (just over 20 hours).

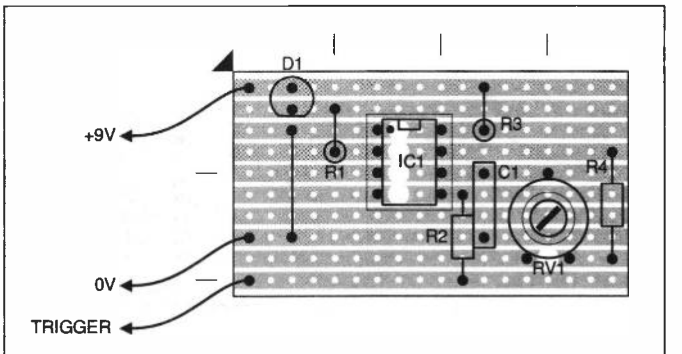


Figure 5: stripboard layout of the 15 -minute timer

One-hour timer

This design (**figure 5**) may be adapted for any period within the range of the U647B. It is just a matter of changing the values of RT and CT within the limits specified in the previous section. This design does not include the decoupling capacitor which is necessary to filter out spikes, but, if you are intending to use the device in a car or other 'noisy' environment, wire a 47 nF capacitor between the supply rails. Once again we are using only an LED to indicate the state of the timer, but it should be mentioned that the output of this ic is capable of driving much heavier loads. The output stage at pin 2 consists of an open-collector Darlington transistor able to switch up to 300 mA. So this ic can be used for switching on various devices for precisely timed periods. The output can switch a relay and is protected by a diode to prevent damage due to induction.

Starting and stopping errors

The usual way to use a counting chain is to have the clock running continuously and to reset the counter(s) when timing has to start. Counting starts on the next rising or falling edge of the clock's output. The 4060 used as the first counter in the crystal clock advances one count on the falling edge. The 4018 used in the divide-by-60 chain counts on the rising edge. Whichever kind of edge is used, there is an indeterminate delay of up to one clock cycle before the first active edge arrives and counting begins. Thus the timing period may be up to one clock period late in starting. In the case of the crystal clock, the period of oscillation of the 32.768 kHz crystal is about 30us, so the average delay is only 15us. This is insignificant when measuring periods of a second or more.

If we are using the output to indicate when the timing period ends, there is no further error. If we are using the clock to measure the time interval between, say, a 'start' pulse and a 'stop' pulse, we do this by counting the number of clock pulses between 'start' and 'stop'. There is a similar error at the end. Again, with high clock frequency and a relatively long

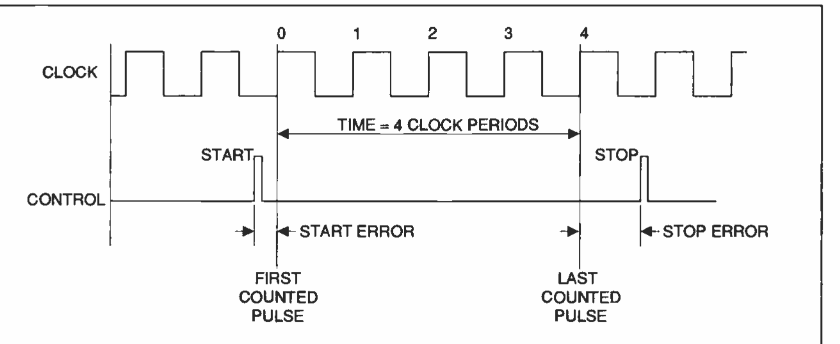


Figure 6: timing by counting pulses. The clock is incremented on the rising edge

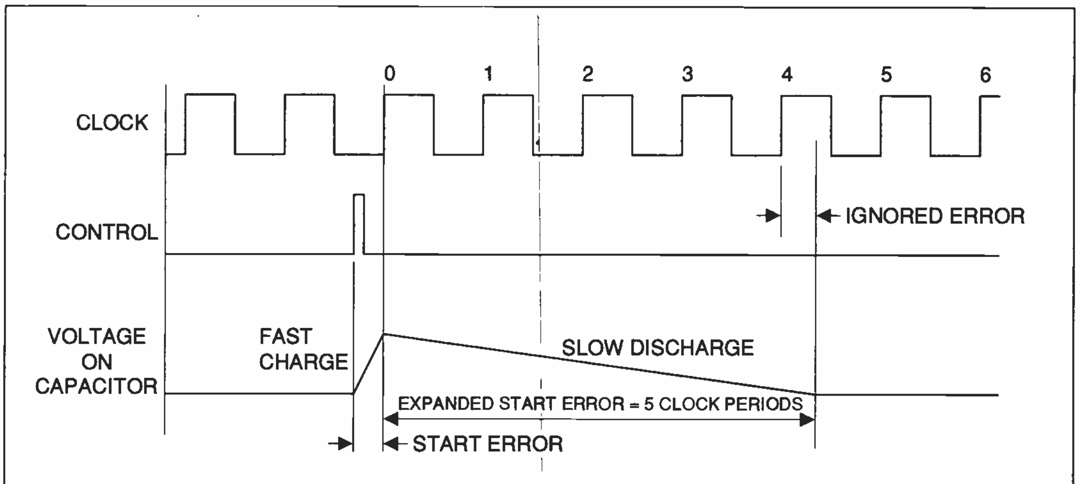


Figure 7: using the dual slope techique to measure the starting error

timing period the error can be ignored. The general aim for high precision timing is to make the clock period as short as possible and use a long counting chain.

A problem arises when we are timing periods than are only a few clock periods long. We might want to time the length of the flash of a camera flash-gun using a photo-sensor to detect the flash with logic to produce the 'stop' and 'start' pulses. There is a limit on how fast the clock can go. As well as a circuit to count the clock pulses we need to measure the time interval between the 'start' pulse and the first clock edge, and between the last clock edge and the 'stop' pulse (**figure 5**). The circuitry to do this is fairly complicated and we have to take into account the various delays inherent in the system, but the principle of one such technique is easily understood.

The idea of a dual slope integrator is known from its application in analogue-to-digital conversion. In measuring the short time interval between the 'start' pulse and the first clock pulse, we start charging the capacitor at the 'start' pulse and continue charging until the first clock edge occurs (**figure 6**). We charge it from a constant-current circuit, so that the voltage built up on the capacitor is proportional to the length of the start-up period. The capacitor is then discharged through another constant current circuit which restricts the current to, say, 1/1000 of the charging current. The capacitor takes 1000 times longer to discharge than it took to charge. We can not show this to scale in the figure. There the start error has been expanded by only about 25 times. The time taken to discharge the capacitor can be measured against the clock. In effect we have expanded this short period by 1000. There is still a 'stop' error in measuring the length of this period but this is on 1/1000 the scale and can be ignored. A similar charge-discharge technique is used to measure the period between the last clock edge and the 'stop' pulse.

Time stamp

In these days when we come across a microprocessor inside even a humdrum appliance such as a cheap fan heater, it is not surprising to find that it is simpler and less expensive to tackle complex measuring tasks by using software in place of hardware. The dual slope integration technique described above is certainly one in which the pulse counting, and the calculation of errors and the final result is better done by a computer. This is not to say that we need a whole PC to perform the task. A humble micro-controller will do the job adequately.

One such device is the Basic Stamp, and we shall use this to illustrate how a microcontrollers can be used in time measurement or in the production of timed output pulses. The Basic Stamp is so called because it can be programmed in its own version of Basic. This includes commands specially designed to make it easy to do things that the Stamp is likely to be used for. This includes timekeeping.

The command of special interest for time-keeping is PULSIN, which measures the length of a input pulse and returns the pulse length in units of 10us. The maximum length measurable is 65535 units of 10us. This comes to 0.65535 seconds, so the Stamp is obviously a candidate for measuring short time periods. The units are based on the period of the Stamps clock, which is a ceramic resonator, accurate to +/-1 percent.

Figure 7 shows a circuit suitable for measuring the length of a photoflash, or some other short-lived phenomenon involving light. Photodiodes have a rapid response time, often only 250ns. Some have even shorter times, such as the BPX65 with a response time of 0.5ns. VR1 is set so that the voltage at the (() terminal of IC1 is higher than that at the (+) terminal and the output of IC1 is 0V. IC1 is wired as a comparator. It has a reasonably high slew rate, which suits it for this application, and can operate on a supply of +/-2.5 V. During the flash there is an increase in the leakage current through the photodiode. This causes an increase in the voltage across R1. The voltage at the (+) terminal of IC1 rises above that at the (() terminal. The output of the circuit rises close to 5 V, the equivalent of a logical high input. In summary, we get a positive pulse lasting as long as the flash.

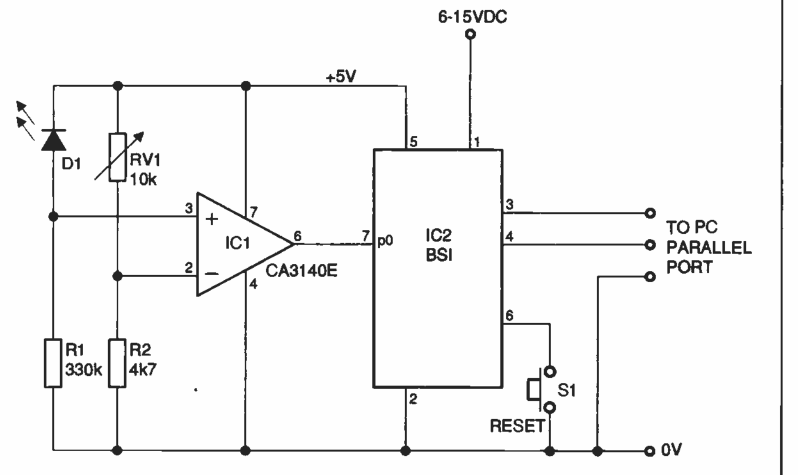


Figure 8: using a Basic Stamp to measure the length of a photoflash

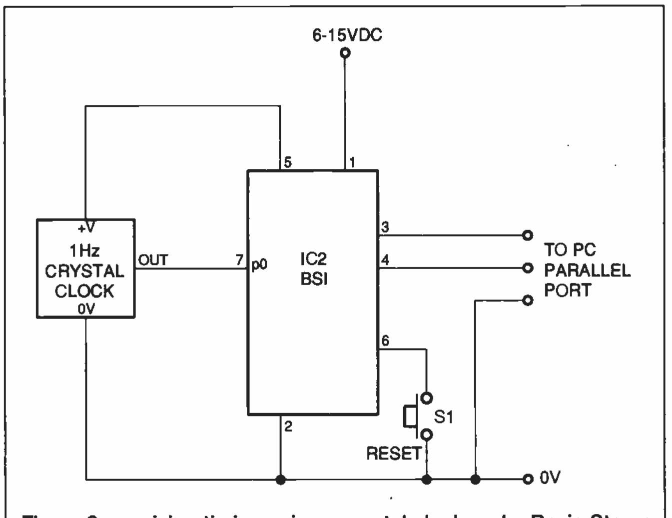


Figure 9: precision timing using a crystal clock and a Basic Stamp

We use PULSIN to measure the length of the flash by measuring the length of the pulse received at pin p0 (**table 3**). This is a very basic Basic program with plenty of scope for expansion. To use this program the Stamp must be connected to a PC, using the special lead provided in the Stamp kit. The syntax of PULSIN is:

pulsin pin, condition, byte or word

The condition is 0 for a low pulse, or 1 for a high pulse. In the program we are waiting for a high pulse at pin p0, and the time is to be stored in word 1. The easiest way to read the result is to use DEBUG to send the contents of w1 to the PC. Eventually the Stamp might be programmed to send the result to a LCD numeric display.

Table 3: Programming the STAMP

```
' Program to measure a flash
pulsin 0, 1, w1
debug w1
```

Run the program by pressing the reset button. Then operate the flash. If the flash is operated within 0.65 seconds, its duration in units of 10us then appears on the computer screen.

Another application of the circuit is to measure the length of time for which the photodiode detects a shadow. A light source and a photodiode are set up to that an object (for example, a model racing car) comes between them. There is a low output each time the car passes by. Knowing the length of the car, we could then calculate its velocity. The program has '0' as the second parameter of PULSIN. It could include a routine to calculate and display the velocity. There are numerous other ways in which physical events can be made to generate pulses and Stamp or similar microcontrollers (such as the PIC family) can be programmed to measure them.

Measuring long periods

The Stamp's built-in ceramic resonator is a convenient way of timing short periods but its precision is insufficient for timing long periods. For longer periods we employ a precise pulse-generator, such as the crystal clock unit, and use the Stamp to count the pulses and then flash an LED, sound an alarm, or take other appropriate action when a particular count is reached.

Figure 8 shows how the crystal clock is interfaced to a Stamp. The clock needs only 300 uA, plus about 15 mA for the LED. This can easily be powered from the Stamp's 5V regulated output. If you want to power other things from the same source, omit the transistor and LED from the clock. The figure shows the Stamp connected to the PC for programming and for reading results by using DEBUG during the development stages. Later it could be freestanding with outputs controlling LEDs, relays and anything else that needs time control. We plan to include a working project of this kind in a future part of this series.

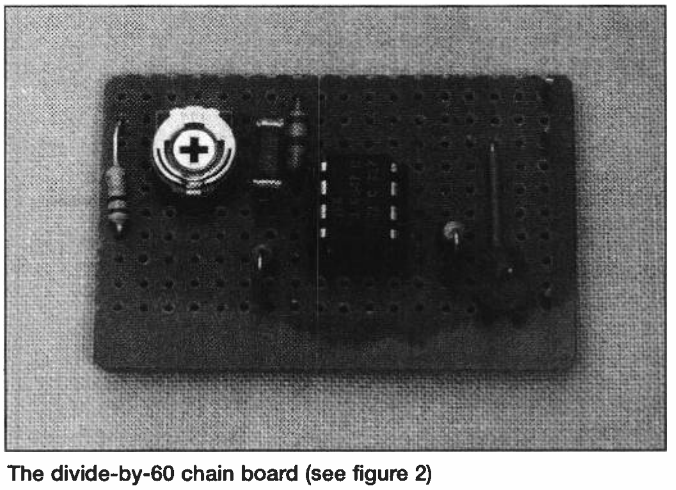
A program for using the Stamp with an external clock appears in the Application Notes in the Programming Manual, so we shall not repeat it here. Our version is using a 1-Hz clock instead of their 2-Hz clock, so the second line of subroutine 'tick' must read:

if b0<2 then MAin

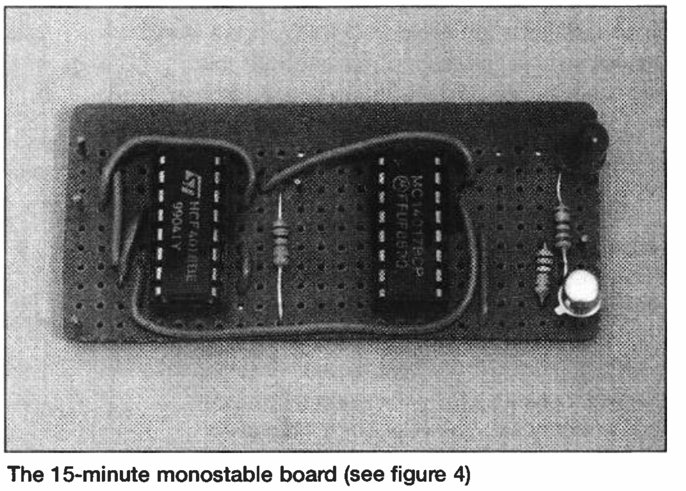
As it says in the Manual, this timer can measure periods up to 18 hours or, if modified to count minutes instead of seconds, up to 45 days. Quite a lot of counter ics would be needed to do the same thing in software.

Supplier

The Basic Stamp is available from Milford Instruments, 120 High Street, South Milford, Leeds, LS25 5AQ, UK. Tel 01977 683 665 Fax 01977 681465.



The divide-by-60 chain board (see figure 2)



The 15-minute monostable board (see figure 4)

REVIEW

oszilFOX universal storage oscilloscope

A handheld 'scope with promise in the field

NoNuts Ltd.
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Essex CO6 3QT
Tel/fax 01206 213322

When I first saw this I didn't believe it. It's about the same size as any normal self contained pen-type digital multimeter, but it is a 20-MHz oscilloscope as well as a meter. It does need an external power source, which is hardly surprising. It is still impressive to fit all so much functionality into so small a package.

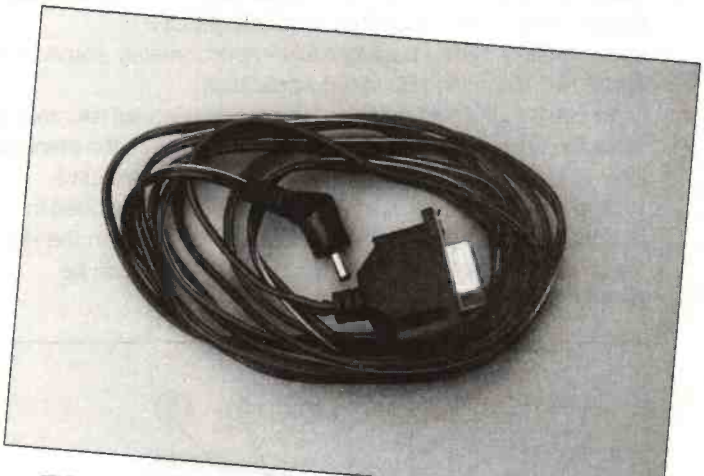
With this pocket scope, a gas-powered soldering iron, and perhaps half a dozen small hand tools, you have the basic equipment to fault find and repair a wide range of equipment. You can also use it with a PC to capture waveforms via the serial port.

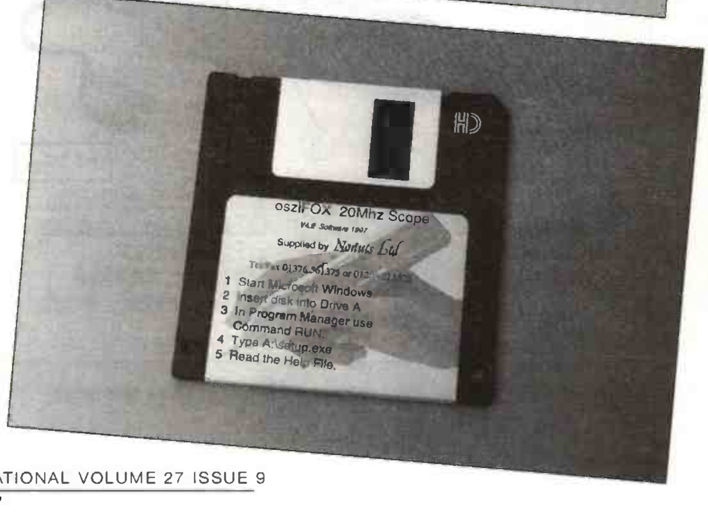
Essential

information

As a standalone instrument it is minimalist in operation. Menu and select buttons are used to select the different functions, while input range selection (1V, 10V, 100V and AC, DC, GND input coupling) is carried out by two three-way slide switches. Compared with a desktop instrument, the setting of timebase and trigger levels is fiddly, but if you are debugging audio or logic it is likely that one setting will do for most measurements, while the instrument is not suitable for use in the kind of development laboratory environment where very accurate waveform measurements are needed.

The printout of the hardware Help (figure 1) gives a fair view of the controls and their functions. The scope comes into its own in situations where you would not otherwise have an oscilloscope available, and it can help you to trace at which stage in an amplifier distortion is introduced, or which half of a waveform is being clipped. This sort of information is usually all you need to identify the necessary repair.





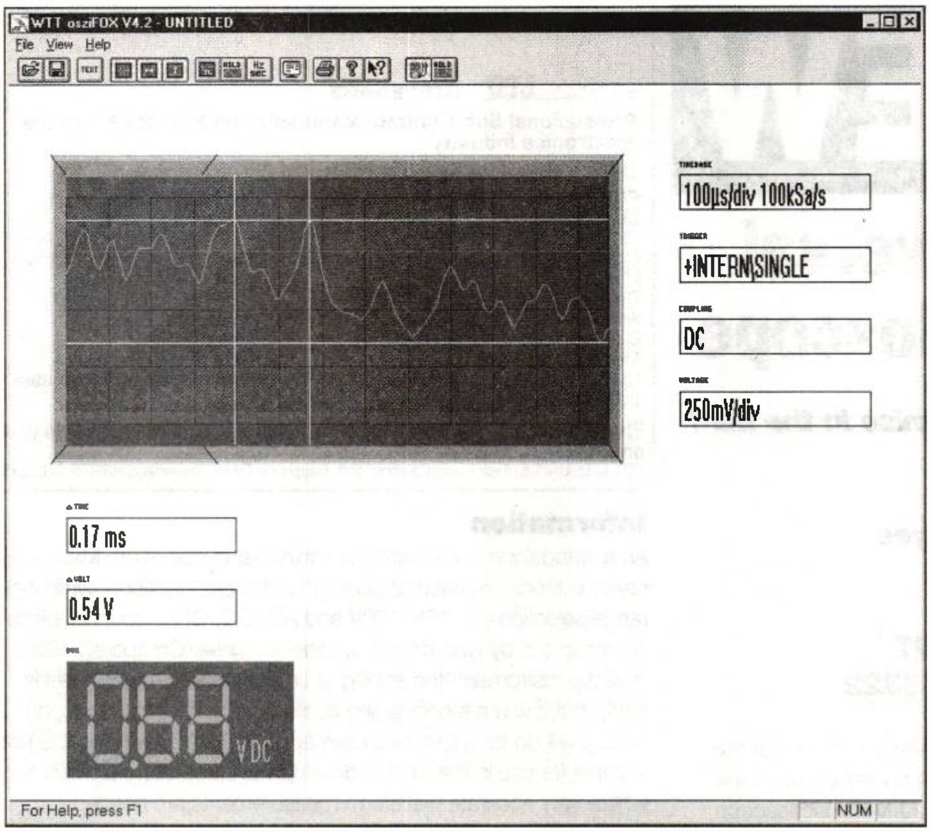


Figure 1: the hardware Help screen

The bandwidth is specified as 5MHz, with sample periods of 50ns, 100ns, 0.5us, 1us, 5us, 10us, 50us, 0.1ms, 0.5ms, and 1ms. The resolution is 6 bits, and there is 128 bytes of ram. The display on the side of the instrument is a 16 x 32-dot liquid crystal, green-backlit.

Power is from a 9V to 13V source. In practice I found a small 12V sealed lead acid battery convenient for the function. Power consumption is quoted as: backlight OFF - approximately 12mA; backlight ON - approximately 85mA. A 1-Ah battery has a long life in this application.

In use, I found that the auto trigger function was reluctant to allow the applied signal to trigger the scope, while the standard internal trigger and single shot modes were very effective.

The croc-clip power lead and a data lead are included in the pack. Instructions and other documentation are in the Help file on the software disk that is included, and this can be printed out or read on-screen.

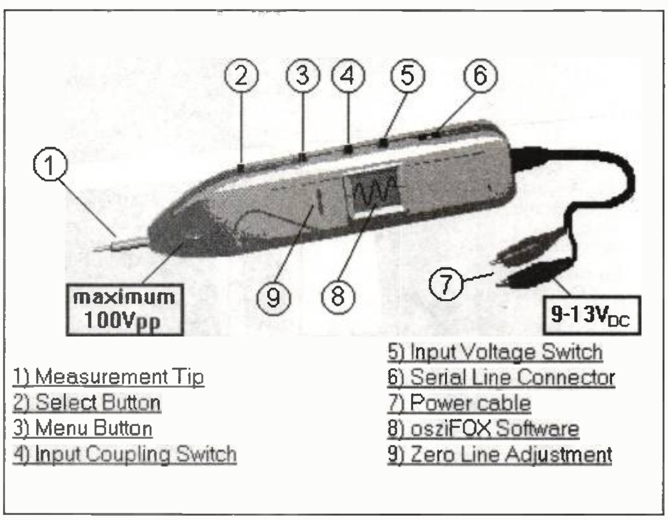


Figure 2: a PC screen showing waveform and DVM readings

Software

You may be wondering why the oscilloscope has more memory than is reflected by the LCD screen fitted. This is to provide for its other function, which is to display captured waveforms on the screen of a PC. Interface software to run under Windows is provided, and this captures waveforms and DVM readings as shown on the screen printout (figure 2). The resolution and length of trace on the PC screen is much better than that on the LCD screen, so the usefulness of the instrument for more complex measurements is enhanced.

The screen captured also shows the use of cursors to measure voltage and time. On the toolbar is a button to switch from time display to frequency, and it is possible to hold one waveform to compare with a current one.

The PC is not used to control the oscilloscope, but functions merely to indicate the current settings. The timebase, trigger level and so on must be set using the menu and select buttons.

Software to run under DOS is also provided, but it did not prove possible to verify the complete operation of this. It would load, and it displayed the last waveform which had been shown when the Windows software was running. However, it claimed that the oscilloscope was connected to Com 1, to which in my case the modem is actually connected. When I manually configured it to Com 3 it would still not display current waveforms under DOS.

No doubt this is due to some sort of clash with the Win95 drivers, and it may reasonably be expected to work correctly on a basic DOS machine which does not have Windows installed. This does raise the possibility of using an otherwise obsolete PC with the osziFOX 'scope. Still, if you have Windows installed, the Windows interface is more convenient for the purpose, and works well.

On the other hand, if you have a laptop PC for other reasons, this can form a useful adjunct to the portable oscilloscope. We could be seeing this kind of thing in the armoury of PC or network support staff in some contexts.

In conclusion

At a price of around £75 this handheld oscilloscope is remarkably good value for anyone who can make good use of its functionality, and a nice present for anyone who likes to keep their pocket-collection up to date.

For more information contact NoNuts Ltd. (see head of this article).

All the documentation is in a Help file on the software disk

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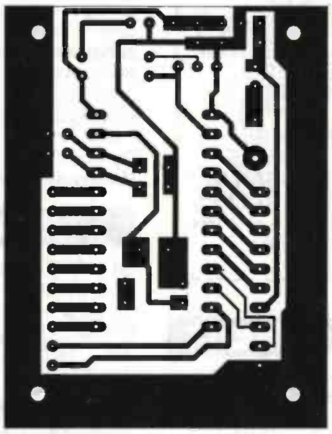

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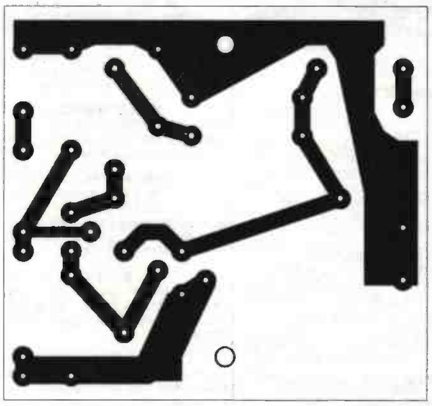

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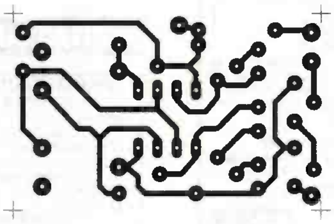

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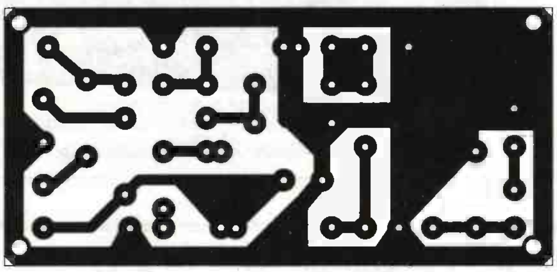

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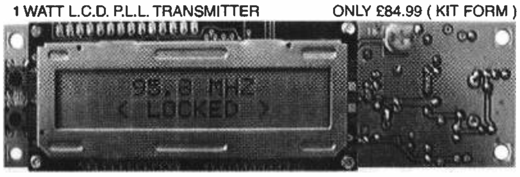

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Round the Corner

Limits to growth In the light of the increasing complexity of semiconductors, it is exciting to hear from Ball Semiconductor that they have successfully transferred the metalisation pattern of an integrated circuit on to the surface of a sphere. The surface area of a sphere is proportional to the cube of its radius, so increasing the radius by 26 percent approximately doubles the area on which circuitry can be fabricated.

Ball's long term plan is to build a semiconductor fab in a sealed tube, and to make larger designs by joining ball integrated circuits using contact bumps on their surface. That's another way to increase the number of semiconductors in a small space. Early in the next century something more powerful than today's most powerful PCs will be small enough to lose in your pocket (always assuming you can get the heat out).

This could be useful, if plans to shut down analogue radio broadcasting early in the next century come to pass. Current DAB receivers are more expensive than many people want to pay, and a reduction in the cost of processing would be welcome.

First, manufacturers will aim to sell the biggest systems they can for the real buffs. Later the tiny systems will appear. For constructors and designers the big systems are likely to hold more possbilities for add-ons and ideas than the small ones to begin with, but the size of construction is coming down too. Invest in a good bench magnifier rather than assuming that miniature construction is not practical.

The face of electronics is changing. Among other steps forward, we would like to hear from readers what projects and features they would like to see in future issues of the magazine, even if they seem impractical to start with. There are many new components appearing, and advanced versions of older ones. If you are interested and have internet access, email us on eti@aaelectron.co.uk, and don't forget the website on ttp://www.aaelectron.co.uk/eti/ But ordinary pieces of paper in non-virtual envelopes are very welcome, as always.

Next Month

Volume 27 No 9 of Electronics Today International will be in your newsagents on 14th August 1998. Mike Bedford will be reporting on the progress with Digital Audio Broadcasting. Robert Coward starts a construction project on a pro-standard large-scale moving display which can be built into a flight case. John Howden describes how to exploit plain spreadsheet programs to do circuit simulation. We are working on a major software review. See you in August.

Contents are in preparation but are subject to space and availability.

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Sorry, we cannot answer queries about projects or other technical queries on the phone. Our administration assistant Jenny can often help with other queries about this issue

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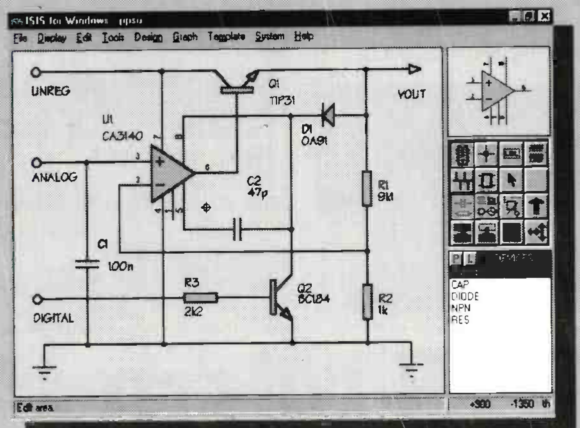

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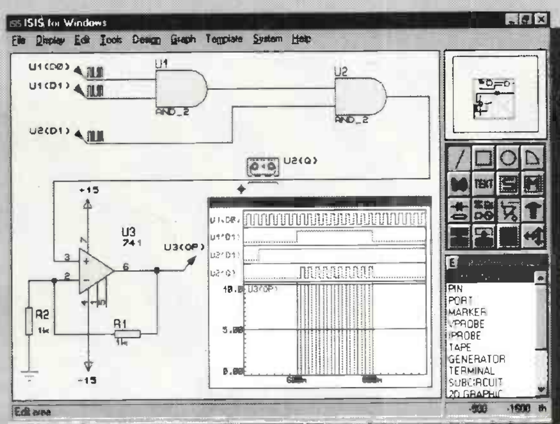

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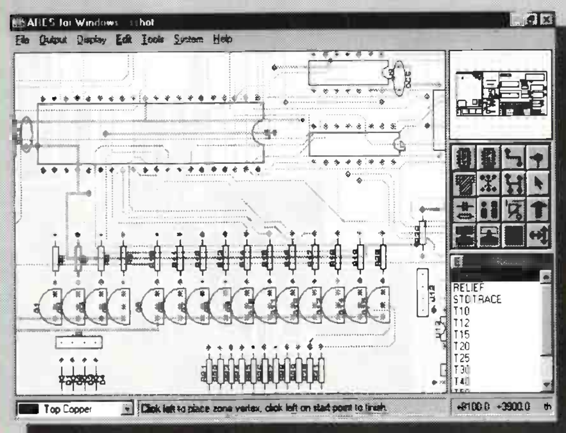

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