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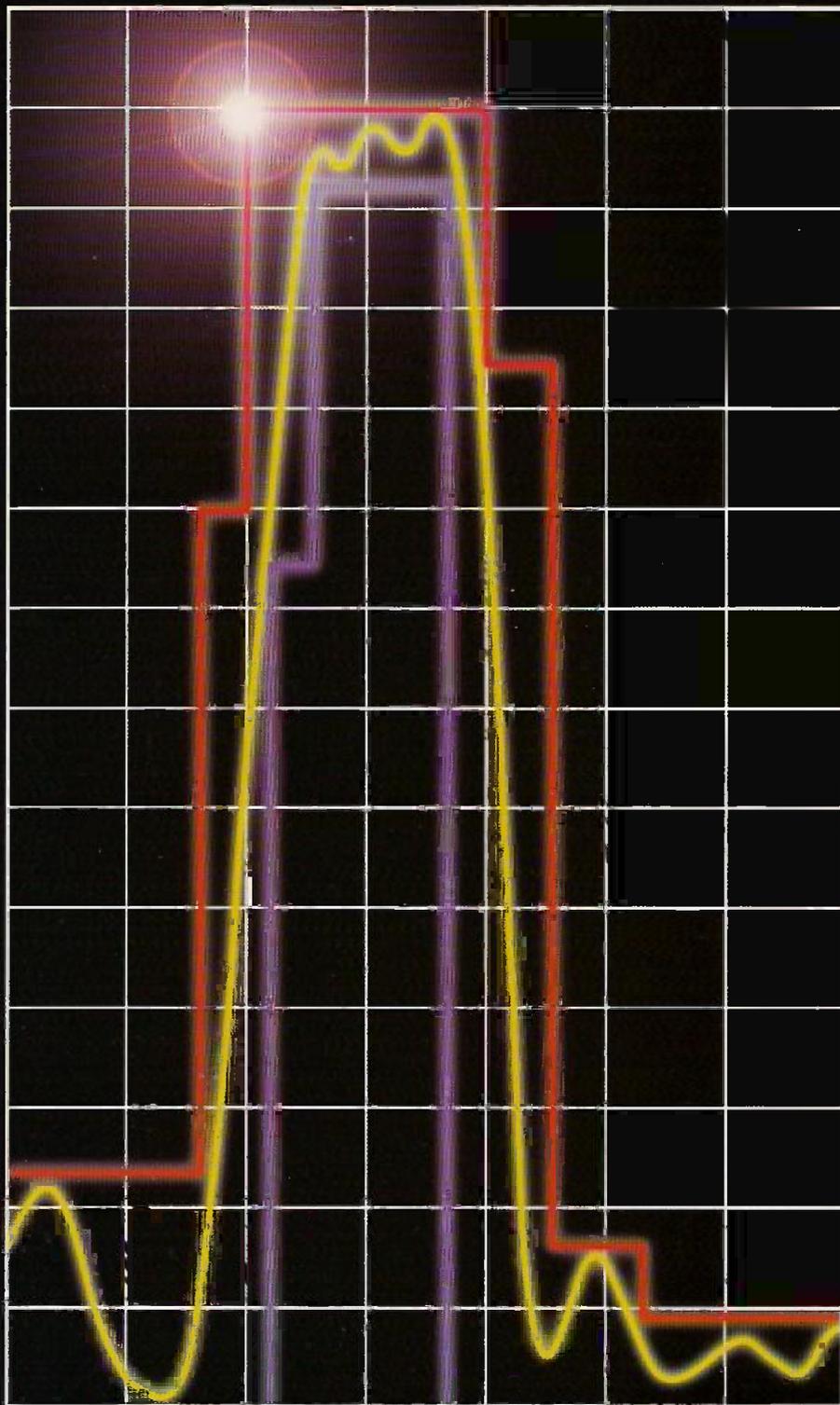
Is It The Wind? Or Is It A Fish? Ask Our Fishbite Alarm

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For The PC Centronics Port

PLUS

- S OR $\sqrt{\omega}$? MATHS FOR FILTER DESIGN
- REVIEW: EASY-PC FOR WINDOWS
- PC-CONTROLLED DOT MATRIX DISPLAY



Vol. 27 Issue: 12 Price £2.75
6th November - 3rd December 1998

Electronics Principles 5.0

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

By Clive W. Humphris.

The screenshot shows the 'OSCILLATORS: Wien Bridge Oscillator' window. It displays a circuit diagram with an operational amplifier, resistors R1, R2, R3, R4, and capacitors C1, C2. The natural resonance frequency is 636.6138Hz, and the frequency is forced to 1kHz. The output voltage is 939.8mV. The circuit is powered by a 3V source. The window also contains several calculation windows for binary arithmetic and R,C values.

"One rather good program that I've found is Electronics Principles. The range of electronics covered is very wide, from simple atomic structure to the workings of the latest microcontrollers."

I was very impressed ... it ran smoothly and without problems on several IBM PCs."

Tex Swann, Technical Projects Sub Editor, Practical Wireless magazine June 1998.

"Electronics Principles is a well thought out and comprehensive program that is also easy to install and stable in operation. It can be wholeheartedly recommended." Robert Penfold, Everyday Practical Electronics magazine, October 1998.

The screenshot shows the 'ACTIVE FILTERS: RC Low Pass Active Filter' window. It contains text explaining that constructing low frequency passive filters often requires the use of inductors which can have large values and therefore are both expensive and bulky. The same low frequency cut-off points can be determined using active filters, where inductors are rarely used owing to their d.c. resistance. The simple circuit shown has a roll-off of 20dB per decade. To achieve steeper slopes the circuits can be designed with multiple poles.

The formulae impedance F determine the of C2 will sign gradually red output by red a high imped

The screenshot shows the 'OSCILLATORS: Astable Multivibrator' window. It contains formulas for period and frequency:

$$\text{Period } t_1 = 0.7 \times 0.00001 \times \dots$$

$$\text{Period } t_2 = 0.7 \times 0.0001 \times \dots$$

$$\text{Frequency} = \frac{1}{0.007 + 0.175}$$

Below the formulas is a graph showing the frequency response of a tuned circuit. The x-axis is Frequency (Hz) and the y-axis is dB. The graph shows a resonance peak at 1.0069 kHz. The bandwidth is 63.662 Hz.

Capacitance = 100nF, Inductance = 250nH, Resonance = 1000, Resonate Frequency = 1.0069 kHz, Bandwidth @ -3dB = 63.662 Hz, Circuit Q = 15.8093

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4th December 1998

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Fun with Filters 10

Different design compromises must be made according to the intended function of a filter, and different configurations of a given filter design are required. Douglas Clarkeson explains how filters design can be aided using standard chips such as switched capacitor filters, for which design software is often available.

s or $j\omega$ - two aspects of the same problem 21

Martin Smith goes into some of the basic mathematics underlying filter design.

Beerstat 24

The use of semiconductor temperature measurement to control the temperature of a thermoelectric coldbox is a practical application of a technical tip from Issue 9. Keep your beer at the correct temperature for optimal enjoyment.



Circuits for Music Lovers (Part 2) 29

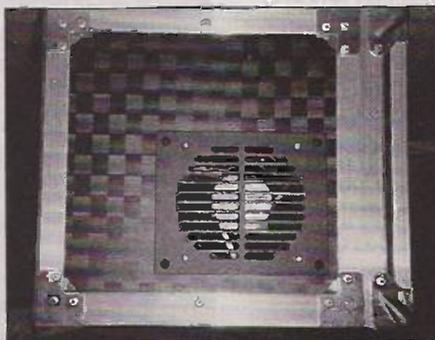
Some more music control circuit ideas including a combined Bass and Treble Boost, a Soft Limiter and a Smooth Fuzz.

Review: Easy-PC for Windows 34

Andrew Armstrong tests the Easy-PC CAD package and the autorouter designed to work with it.

Vulkan Gas Powered Soldering Iron 38

Portable soldering irons can be battery powered or gas powered. This gas powered iron proved to be reliable and versatile in use.

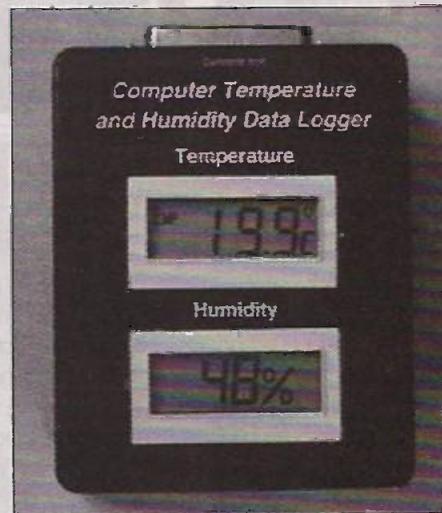


Professional PC-Controllable 4-Line Dot Matrix Display (Part 3) 40

The third and last part of Robert Coward's modular display system describes how to make up the casework and also gives advice on the in-circuit PIC programming facility, and interfacing external equipment.

Timing in Electronics (Part 6): counting the seconds 50

This month Owen Bishop describes the best way of timing periods of minutes and seconds, and adds a decoder circuit and an alarm circuit.



Temperature and Humidity Logger 54

Pei An describes a temperature and humidity measuring device using standalone modules and a choice of Turbo Pascal and VisualBasic drivers.

A Fishbite Alarm With a Difference 64

What is really going on under the water on a windy day? Bob Noyes uses tiny vibration in a fishing line under tension to detect if a fish is "trying it out" and trigger a discreet audible or visual alarm. For salt or freshwater fishing.

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Teach-Yourself C Package with Experimental Circuits

Brunning Software of Clacton-on-Sea have released a practical step-by-step C & C++ learning package by experienced programmer and author Peter Brunning. Brunning's software learning packages include experimental electronic circuits designed to be built up on a special soldering-free plugboard. The book teaches the user to program by using C to drive the simple hardware circuits built with materials supplied in the kit of parts. The circuits plug into a PC printer lead. The programming techniques for the experiments are kept simple enough for a

complete beginner to follow. The experimental circuits build up to the construction of a storage oscilloscope circuit, which combines the relatively simple C techniques to construct an overall program that is by no means simple.

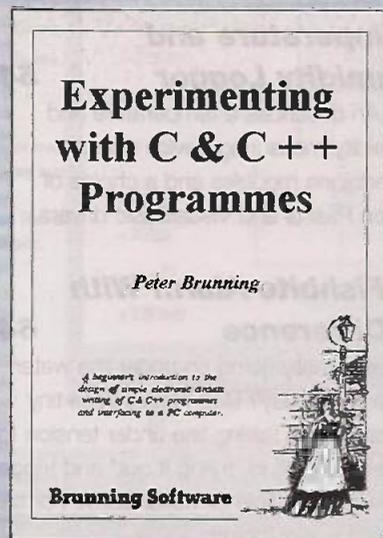
Peter Brunning believes that most beginners' packages for C are written by experienced C programmers who have long since

forgotten how complicated the subject can be to a complete beginner. No doubt some will remember this situation from the last teaching course undertaken. Peter Brunning instead brought his 20 years of programming experience to learning C and C++ from scratch at the outset of the project, and the first part of *Experimenting with C & C++ Programmes* as he went. A second section was then written, reviewing the early chapters with the benefit of the accumulated C programming experience. His experience has showed that typical C programs use complex procedures very difficult to follow by anyone other than an expert programmer, while Basic appears much easier to understand. In reality, at equivalent levels of complexity C is only marginally more difficult than Basic, and it is infinitely more powerful. There is also a ready demand for C programmers in industry, which is no longer the case with Basic.

The book of *Experimenting with C & C++ Programmes* costs £24.99, and the hardware kits are available pre-assembled and ready to use for £46 from Brunning Software (Tel. 01255 862308), or requiring some assembly and soldering for £39.99. For owners of Brunning Software's earlier package *Experimenting with PC Computers* there is a "top-up" kit for £22.99. (Hardware kits do not include the books.)

The kits include two C compilers. One will run on any IBM-compatible PC with a 3.5-in disc drive. Ideally, to work right through the book, you will need a minimum 386 PC with 14MB of free hard disk space. The programming learned will be in C, but the methods are selected to prepare the learner to program in C++.

For more information, see the latest Maplin catalogue on pages 760 and 764.



Universal Serial Bus digital-to-analogue audio chip

A new audio DAC from ET Electronics is designed to provide complete USB (Universal Serial Bus) Version 1.0 compliant digital audio playback for new multimedia systems. The USA standard will make it faster and easier to interface PCs to peripherals with an expected massive reduction in configuration conflicts and system resource limitations.

The Dallas Semiconductor DS4201 is a monolithic digital audio ic that integrates a full USB transceiver, stereo 16-bit sigma/delta D-to-A converter and digital signal processing. It also includes an on-chip analogue mixer to support existing analogue audio technology and hybrid speaker designs. This ensures that the user can connect a CD player, FM receiver or TV audio with analogue outputs and still use the USB digital technology. The converter ensures that the PC receives a digital signal to work with, reducing electric noise, and the analogue signal is directed to the speakers and multimedia monitors, giving a better sound quality.



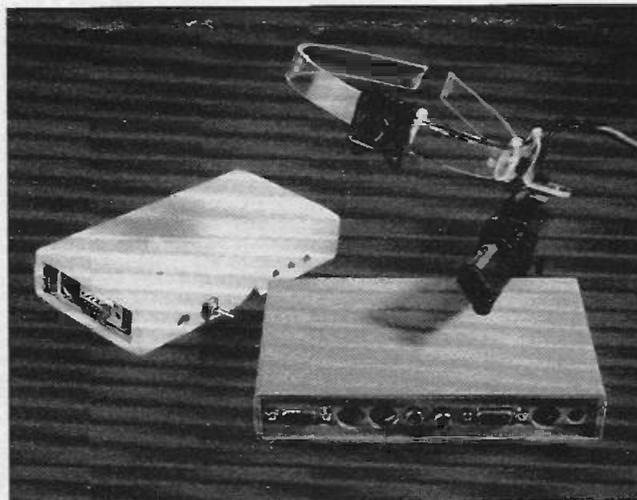
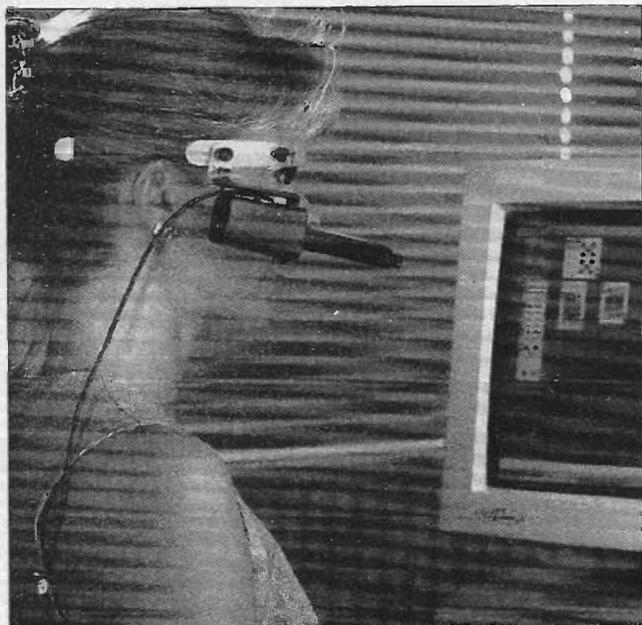
Power management on the chip allows the chip, as well as the external audio circuits such as amplifiers and power supplies, to be set on standby when not in use.

For more information contact DT Electronics, 11-12 Mercia Business Village, Westwood Business Park, Coventry, CV4 8HX UK. Tel 01203 466500 fax 01203 466501.

"Here's Looking At You, Kid" Now Fully Verifiable

Vision Control Systems' VCS technology is a further move towards replacing the computer mouse with "look and click" control. The headset-mounted control system will be likely to appeal to games players as well as disabled people and robot engineers. VCS was developed through a research programme to control computers and other machinery by monitoring the user's eye movements, originally for use by fighter pilots. Integrating a miniature camera with holographic optics operating in the infra-red part of the spectrum, VCS uses retinal reflection to track the eye's position. Linked to a computer, VCS moves the cursor to the user's exact point of observation.

An add-on the VCS is Testimony™, designed to follow the user's visual movements and record and analyse them to



provide information to enable the users "visual behaviour" to be analysed. The lightweight system is expected to be useful in applications ranging from market research to pilot/driver training, surgery and surveillance. The associated miniature field-of-view camera provides a conventional video image of the wearer's general visual field, which can be synchronised with cursor output from VCS to give an accurate indication of what the wearer is looking at within the field of view. Vision Control Systems (part of Ferranti) believe this is the first system of its kind.

The VCS eye tracker has been selected as a Millennium Product by the Design Council and will be displayed at Millennium exhibitions in Britain and abroad, including the Millennium Dome.

VCS systems currently operate through PC serial ports, but expect to be able to transmit data and video output via radio link in the future.

For more information contact Vision Control Systems, Oldham, OL4 3JA, UK. Tel 0161 624 0281 Fax 0161 652 0972 Email sdobinson@visioncs.com Web www.visioncs.com

Winter Maplin Catalogue Now Has 17,000 Semiconductors

The new Maplin Catalogue, on the shelves from September, has a number of new features to help users. The print version (order code CA18U) features a new semiconductor guide with an extra 17,000 items, making it the largest source of semiconductors from a single catalogue in the UK. There are price reduction on more than 2,000 products, and extended ranges of 1000 new items across the 42 product categories.

Also available is the double Cdrum catalogue (CQ02C) with everything described above plus a number of other features. The companion CD include a free copy of the

MacAfee anti-virus software, a free 30-day Internet trial with Demon including software, and over 1000 datasheets.

Component information can be searched either by Maplin order codes, by the product index or through a keyword search. Once located, the product is given as a picture, technical specification and pricing details. To order, you press an Order button to add the item to your shopping basket. When the ordering is complete, the prices are totalled and the information can be printed as a finished order form including personal details.

The CDs come in both PC and Mac formats. You can obtain the catalogues via mail order, or from any Maplin store. **For information, store locations, etc. call 01702 554 000 Web www.maplin.co.uk**

Technology Innovation Foundation Offers Development Cash and Sponsorship Prizes

Altran Technologies, the France-based technology consulting group, is currently launching its 1999 Foundation for Innovation awards in the UK.

The international Award offers £11,000 in cash to the global winner, plus one year's expert development support from Altran's 5,500 technology consultants and managers to develop the winning project into a commercially viable proposition.

The 1999 competition theme is "the access to and quality of water", a worldwide issue covering a host of problems affecting the developed world as well as the under-developed regions, from drinking water to irrigation.

The Altran Foundation was set up in 1996 by one of the European leaders in technological consulting, and aims to discover innovative technologies that will be of general benefit. The prize is awarded in a different category each year to company research and development teams, schools and universities, public or private research organisations and associations. A maximum number of three winners are chosen each year.

The judges of the 1999 theme of water will be looking for technology which will apply not only to Western countries but

also to the East and third world, where the key necessities are low cost and ease of use. The judges will be an international selection of leading academics and industry specialists.

For the 1998 award, entrants were asked to focus on innovation devoted to detecting, preventing, relieving and compensating for physical impairment, pain and handicap. The judging panel awarded two prizes and one special award. Of the 96 entrants who actually applied formally to last year's Foundation, 33 percent came from companies (mainly SMEs), 25 percent from schools and universities, 14 percent from hospitals, 10 percent from private research laboratories, 10 percent from associations and 8 percent from private initiatives.

Altran is also hoping to create 200 new jobs in the UK in the next 12 months through its group companies Altran Technologies UK, Praxis Critical Systems, High Integrity Systems (HIS) and DEC consultants.

Applications must be sent in before the end of February 1999. Final judging will take place in April 1999. Altran would like entries to be submitted through their website at www.altran.fr/indexe.htm. Further information can be obtained through the head office at **Altran, 251 Boulevard Pereire, 75017 Paris, France. Tel +33 1 44 09 64 00 Fax +33 1 44 09 54 10.**

Free Power Op Amp Software from Ashwell

Ashwell Electronics are offering free copies of a power op-amp design spreadsheet that automates the long calculations associated with stability analysis, internal power dissipation, PWM filter design and current limit control. Designed and developed by Apex Microtechnology, it is described as thoroughly documented and includes many dynamic examples to be used as practical tutorials on power op amp design.

Although power op amps follow the general rules for small signal op amps, the higher voltage and current values encountered demand extra attention. The program is intended to enable designers to enter their own application data and confirm the results of changing components without the need to do repetitive manual calculations.

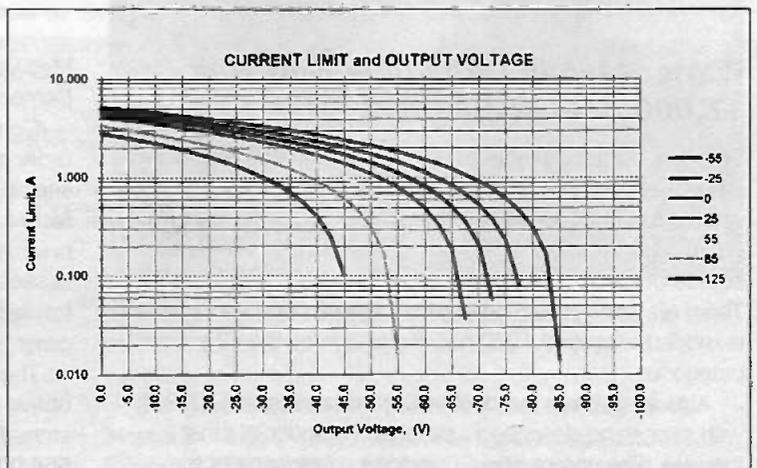
The key considerations such as capacitive load, Howland charge pump, current limit, inductive loads and power designs are all considered individually in detail, supported with guiding notes and practical advice.

Based on Excel (suitable for Excel 5 to Excel '97) it provides a structure with which to analyse and design a complete power op amp application where

all the static and dynamic parameters are addressed.

Free copies of the program are available to all qualifying engineers on request to **Apex agents Ashwell Electronics, Carlton House, Boulton Road, Stevenage, Herts SG1 4QY. Tel. 01438 364194. Fax 01438 313461 Email sales@ashwell-hq.com**

On a different but related subject, see our article by John Howden, Computer Aided Design on a Shoestring, in last month's ETI issue 11/1998, on how do basic circuit simulation on Excel and other spreadsheet programs.



Surplus always wanted for cash!

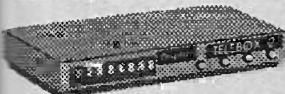
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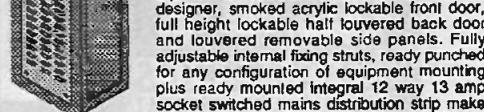
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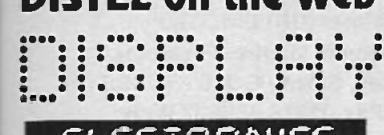
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Data-gathering pen handheld PC now has radio link

Fujitsu's Point 510 RF handheld pen PC now has radio communications capability built in. The Windows 95 computer was designed in consultation with users in health care, retail and transport to provide real-time computing with integrated radio comms for workers in the field.

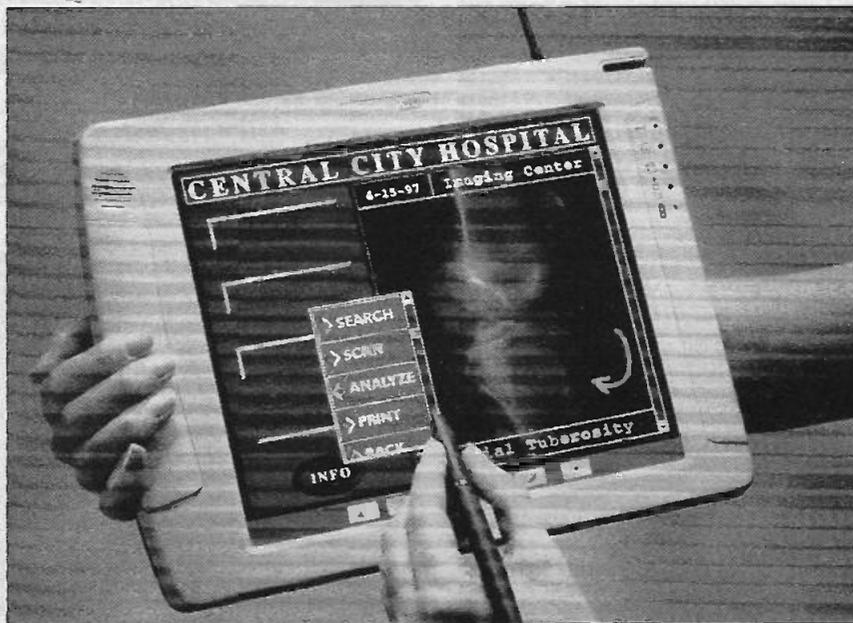
The Point 510 RF, with a 10.4-in SVGA colour screen, is designed to handle record gathering inside and outside hospitals, product control, retail store management and air transport checkin. The integrated radio links the remote handheld PC to the network server to give real-time computing on the move.

Fujitsu's Radio Ready system reduces interference between the radio and the computer, extending the mobile's range. Windows 95 compatibility allows mobile users to run the same applications used on desktops and laptops.

Industrial-standard docks can be located in the workplace to provide battery charging and keyboard or mouse facilities for the portables at various points.

The Point 510 RF has a 100-MHz 5 x 86 processor, shock-mounted 2.1GB hard drive, many ports including IrDA, RS-232serial, Tx/Rx second serial, keyboard, mouse, monitor, parallel, floppy, audio in/out and port replicator, one Type III PC card slot, a longlife lithium-ion battery and 8MB EDO ram expandable to 64MB. It weighs 1.8kilos (3.9 lb) with battery pack, radio and antenna, and 1.7k (3.74 lb) without the radio.

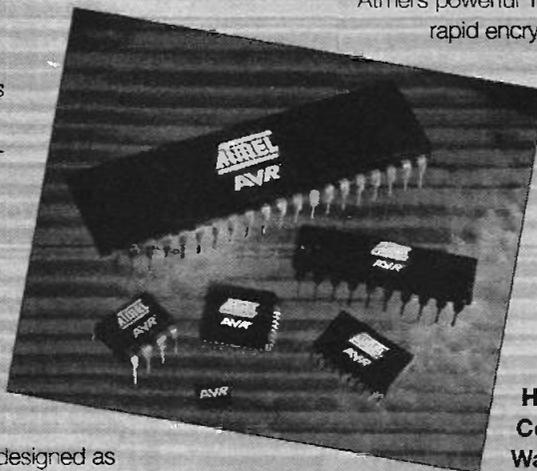
For more information, contact Nigel Owens, Fujitsu Personal Systems (UK) Ltd., 2 Longwalk Road, Stockley Park, Uxbridge, Middx UB11 1AB. Tel 0181 573 444 Fax 0181 561 3775.



Secure on-chip eeprom on AVR 8-pin microcontrollers

Atmel's AT90S2323 and AT90S2343 8-pin AVR microcontrollers are the world's first 8-pin, 8-bit microcontrollers with secure on-chip eeprom.

The AT90S2323 also has an on-chip crystal oscillator, making it useful for small remote control applications needing minimal I/O, such as remote keyless entry (RKE) systems. It amounts to an in-system programmable, single-chip solution for "even the smallest single- or two-button remote control or similar devices". The sister AT90S2324 is designed as a good security processor for applications with external clocks, such as analogue telephones.

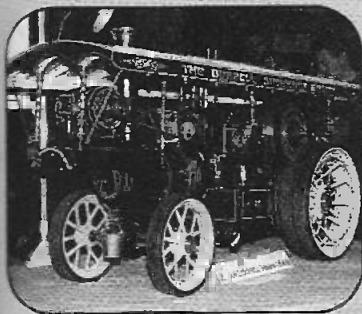


Both chips operate from 2.7 to 6V and have low power modes that bring the power consumption to below one microamp. Both come in 8-pin PDIP and SOIC packages.

Atmel's powerful 10-MIPS AVR core can be used for the rapid encryption and decryption of data stored in the eeprom, giving data security in circuits needing non-volatile storage of secure data, such as cellular phones and security systems.

Atmel has a comprehensive set of development tools for code development and debugging for the two chips, including the ICEPRO in-circuit emulator for all AT90S series microcontrollers.

For more information contact Bob Henderson, Atmel (UK) Ltd., The Coliseum Business Centre, Riverside Way, Camberley, Surrey GU15 3YL. Tel 01276 686677 Fax 01276 686697 Web: www.atmel.com



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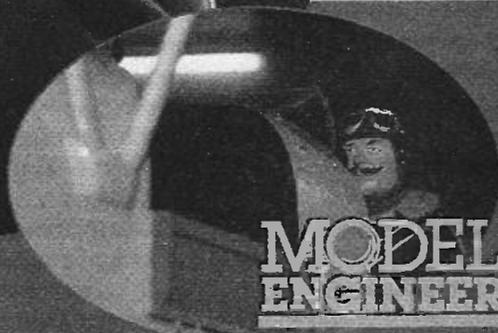
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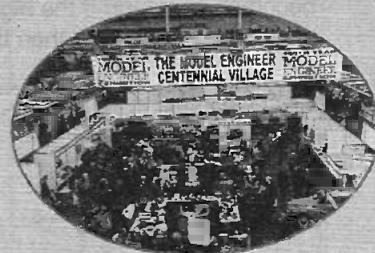
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Fun with Filters

Electronic filters are not necessarily formidable. For many purposes, filters can be designed using standard chips such as switched capacitor filters, for which design software is normally available.

Douglas Clarkeson

Electronic filters always assume an aura of difficulty. My earliest introduction to electronic filters was with passive filters utilising LCR components. Even then, they were introduced as an abstract entity - something perhaps to encounter in an examination question. Before PCs were widely used, for practical purposes filters could be designed by using books of standard, normalised filter tables. These are still used, and can still be useful. They consist of standard filter configurations, usually normalised for input and output impedances of 1 ohm, and for a frequency of 1 radian per second. The component values for different types of filter are chosen from the table for these conditions, then scaled for the actual frequency and impedance used.

The books of filter tables are generated either by doing the mathematics by hand, or by using a computer to speed the process. Without the aid of a computer the process is extremely laborious, but not impossible.

You may wonder why different configurations of, for example, a second order lowpass filter are required. The reason is that different design compromises must be made according to the intended function of the filter. A Chebyshev filter is designed to give the best attenuation in the stopband close to the passband - the fastest rolloff. The compromises here are ripple in the passband response, and a lack of phase linearity. This sort of filter may be very useful to control the audio passband of, for example, a direct conversion receiver.

It would not, however, be useful to limit the bandwidth of a series of pulses. A Chebyshev filter is not phase linear. What this means is that different frequencies are subjected to a different time delay. Remembering that a square wave contains an infinite series of frequencies, the problem becomes apparent. If the higher frequencies in the wave are simply attenuated, then the edges are no longer

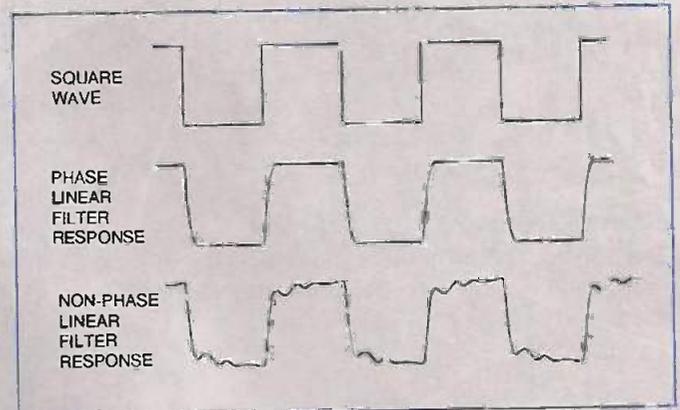


Figure 1: the effects of phase linear and non phase linear filters on a squarewave

vertical, and the corners are rounded. Slight ripple may be introduced, depending on the shape of the filter rolloff.

However, if different frequencies are delayed by a different time, then the shape of the waveform can change out of all recognition. This is illustrated in figure 1. If a non-phase-linear filter were used in the intermediate frequency stages of a radar system, then the resulting screen display would be misleading. For a radar system, the phase response of the intermediate frequency filter is more important than its exact frequency response.

In the early days relatively few organisations that had access to computer facilities able to design filters from scratch in a reasonable period of time. During the 1970s when operational amplifiers become more widely available, active filters became practical and widely used. In the 1980s, switched capacitance filters came into prominence and tended to replace active filters in many applications.

Today, with second- and third-generation of families of active and switched capacitance filters available in a competitive marketplace, designers can choose very powerful filter designs for demanding circuit performance. Moreover, devices are usually supplied with extensive data and software to allow solutions to be readily identified.

Just as it is still necessary to know something about maritime navigation while using GPS navigation systems, so in electronic filter design, an appreciation of the fundamentals is still helpful, even when using state of the art filter design packages. To get the best out of complex devices, however, software packages are the best course. With the drive towards miniaturisation, surface mount technology and lower component count, switched capacitance filters dominate the market in many applications.

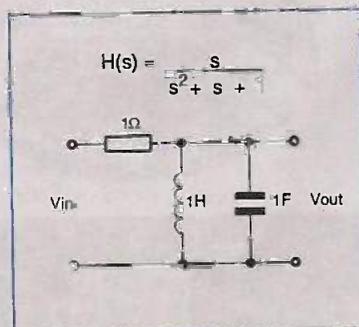


Figure 2: simple LCR bandpass passive filter

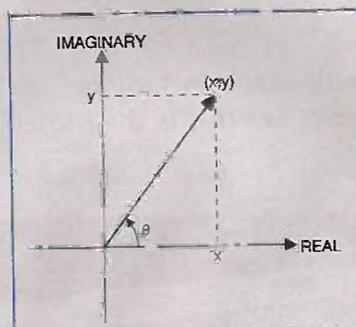


Figure 3: representation of filter using (real,imaginary) coordinate plane

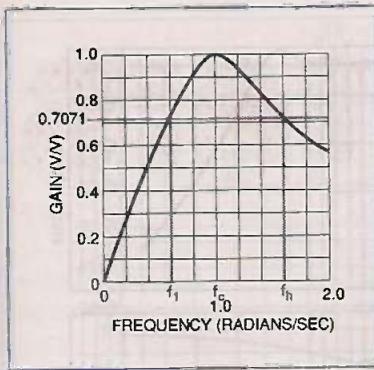


Figure 4: response of filter of figure

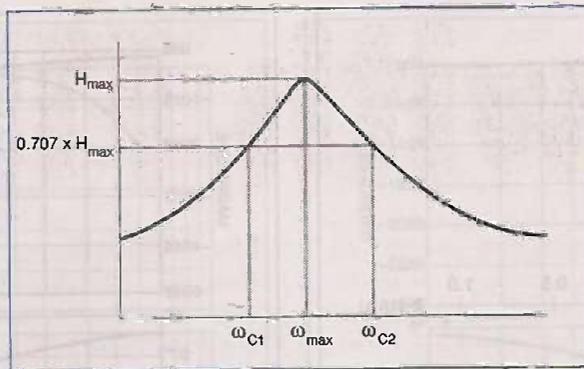


Figure 5: response curve of high Q tuned circuit

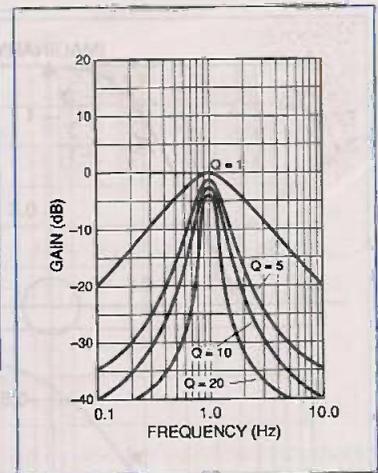


Figure 6: specific filter solution with different values of Q

It is always practical to relate filter functions to specific widely used filter devices. I will look at the LMF100 switched capacitance filter in some detail, and also the Burr-Brown UAF42 active filter - the latter more as a kind of marker of active filter design. I will refer to Maxim options for active filter design.

Some Elements of Theory

The transfer or network function of the filter designates the ratio of the voltage output to voltage input, and is expressed as a function of $j\omega$ where:

$$f^2 = -1$$

and ω is the radial frequency ($2\pi f$ where f is the frequency of the signal in Hz). In the very simple example of a passive filter in figure 2, the transfer function can be described as:

$$H(s) = s / (1 + s + s^2)$$

Where $s = \alpha + j\omega$, but for filter design purposes $\alpha = 0$. The transfer characteristic of this passive filter, of very simple design, can be expressed as a polynomial of order 2 - the highest power of variable s in the expression. For a passive filter, involving LCR components, the order of the filter is equivalent to the sum of contributing L and C components.

In this sort of design, parallel combinations of capacitors are sometimes used to produce the required total capacitance value.

Key parameters derived for the transfer function are the magnitude of the gain and phase values. This involves expressing the transfer function as the sum of a real component and an imaginary component ($x + jy$) and with the magnitude given by:

$$\sqrt{(x^2 + y^2)}$$

as indicated in figure 3, and the angle of phase given by $\arctan(y/x)$. This diagram shows the output amplitude and phase of the filter, given a unity real input, at a specific frequency. To show the performance over a range of frequencies, a plot would be made of point (x,y) against frequency. This sort of graph could be generated, for example, by a network analyser.

When the transfer function of the simple LCR circuit of figure 1 is solved in this way, the gain is given by:

$$\text{gain} = \omega / \sqrt{(\omega^2 + (1 - \omega^2)^2)}$$

The particular response of this filter is in fact a band pass filter as indicated in figure 4 and with the phase of the signal changing linearly with frequency.

Normally in this band pass filter, the passband limits are taken where the gain has dropped by 3dB relative to the maximum gain, a factor of 0.707 times the voltage.

The centre frequency of the filter is defined as the square root of the product of the product of the two cutoff frequencies:

$$\omega_{C1} \times \omega_{C2} = \omega_{max}^2$$

that is, the geometric mean of the upper and lower 3dB points.

If the filter consists of a single LC tuned circuit, there is a quality or Q factor defined for it. The basic definition of the Q factor is $1/(2 \times \text{percentage loss per radian})$. If very little energy is lost from the tuned circuit per radian, the Q is very high, and the bandwidth is small.

The Q can also be determined from other measures, all of which result from the basic definition related to the loss of the circuit. In the response curve shown in figure 5, the 3dB points and the centre frequency are shown. The Q is $\omega_{max} / (\omega_{c2} - \omega_{c1})$.

In other words, the Q is defined as a quality for relating to the percentage bandwidth of a filter. A filter with a 1Hz bandwidth at 10Hz has a Q of 10, as does a filter of 5kHz bandwidth at a centre frequency of 50 kHz.

Another calculation commonly used is related directly to the loss in the circuit. Assuming that the

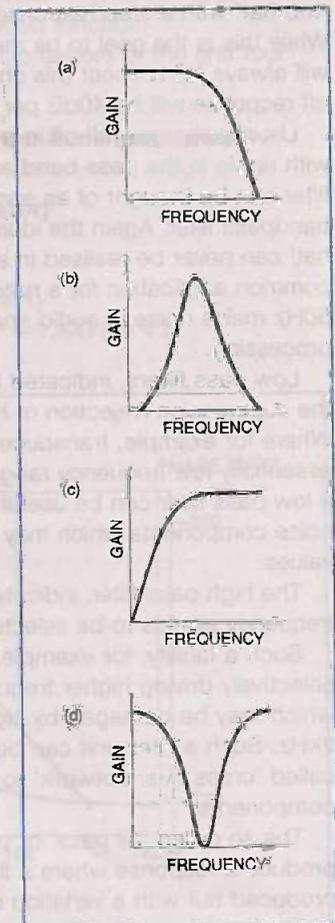


Figure 7: general types of filter: a) lowpass; b) bandpass; c) highpass; d) notch

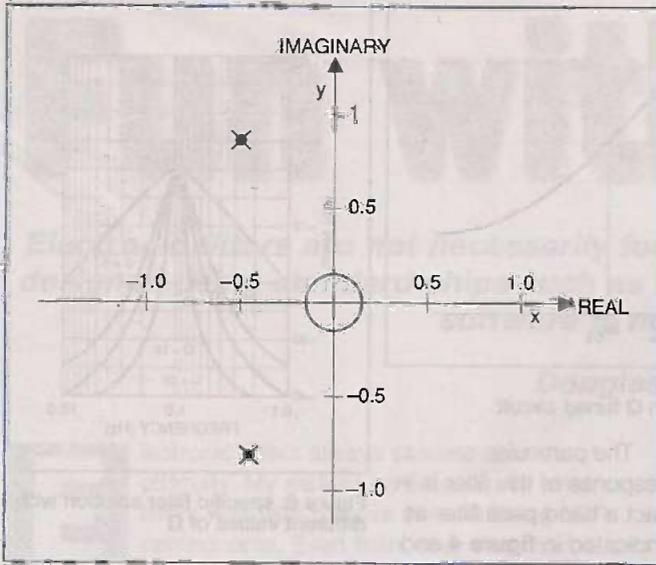


Figure 8: representation of solution which provides a pair of poles $s = -0.5 - 0.866j$ and $s = -0.5 + 0.866j$

loss is due to the series resistance of the circuit, the Q is $\omega \times L/R$, where ω is the resonant frequency of the circuit.

Figure 6 shows a specific filter solution with different values of Q .

Basic filter types

Moving into generalities of types of filter, however, figure 7 illustrates the typical lowpass, bandpass, highpass and notch characteristics.

For the bandpass, the best response would be that of a 'top hat' with a step response of gain in the passband. While this is the goal to be realised, actual performance will always fail to meet this characteristic. The typical roll off response will be 40dB per decade per second order.

Usually sharper roll off in a filter design is associated with ripple in the pass band and stop bands. The notch filter can be thought of as some kind of inverse to the bandpass filter. Again the idealisation of the 'inverted top hat' can never be realised in analogue circuit designs. A common application for a notch filter is for rejection of 50Hz mains noise in audio and transducer signal processing.

Low pass filters, indicated in figure 7, are utilised for the suppression /rejection of high frequency signals. Where for example, transducer systems are detecting essentially low frequency ranges say less than 100Hz, then a low pass filter can be useful to suppress high frequency noise components which may be significant at small signal values.

The high pass filter, indicated in figure 7 allows higher frequency signals to be selected.

Such a facility, for example, can be useful for selectively driving higher frequency tweeter systems, which may be damaged by signals in the range 100Hz to 2kHz. Such a filter unit can be incorporated into a so called 'cross over network' to drive a unit of loudspeaker components.

The so called 'all pass' or phase shift filter will seek to produce a response where a flat gain response is produced but with a variation of output phase relative to input phase for a given frequency. Such a filter is typically used to restore phase shifts introduced by previous circuit elements.

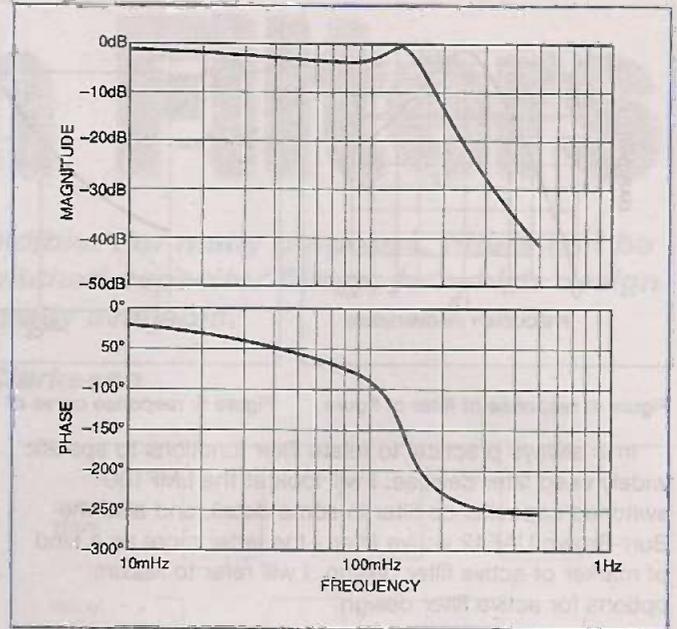


Figure 9-was-7 Amplitude and phase response for a 3dB Chebyshev filter of order 3. Higher order filters have more ripples in the passband

Generalised Filter Response Characteristics

The transfer function of a filter can be described as a ratio of polynomials. A fourth order filter can, for example, be described as:

$$H(s) = H_0 \frac{s^4 + b_3 s^3 + b_2 s^2 + b_1 s + b_0}{s^4 + a_3 s^3 + a_2 s^2 + a_1 s + a_0}$$

where $s = j\omega$

In theory, therefore, any complex filter function can be described in this format. The various formats of filter that have been defined represent mathematical functions that map well into a specific filter design characteristic, such as flat passband, steep rolloff, and so on. There can be tradeoffs of one factor against another. Most of the commercially available filters, however, cater for the broadly based needs of filter technology. The real differences between the functions are best modelled using computer software. The Maxim package which I will describe later provides an excellent way of calculating and displaying a wide range of filter responses.

The filter response can also be written as:

$$H(S) = H_0 \frac{(s-z_0)(s-z_1)(s-z_2)...(s-z_n)}{(s-p_0)(s-p_1)(s-p_2)...(s-p_n)}$$

where the roots of the bottom line are termed poles and the roots of the top line zeroes. These elements are in general complex numbers of the format $R + jI$ where R is the real component, j is the square root of -1 and I is the imaginary part.

The zeroes or poles are either real roots with no imaginary parts or complex conjugate pairs as in the expression below:

$$H(s) = s / (s + 0.5 + 0.866j)(s + 0.5 - 0.866j)$$

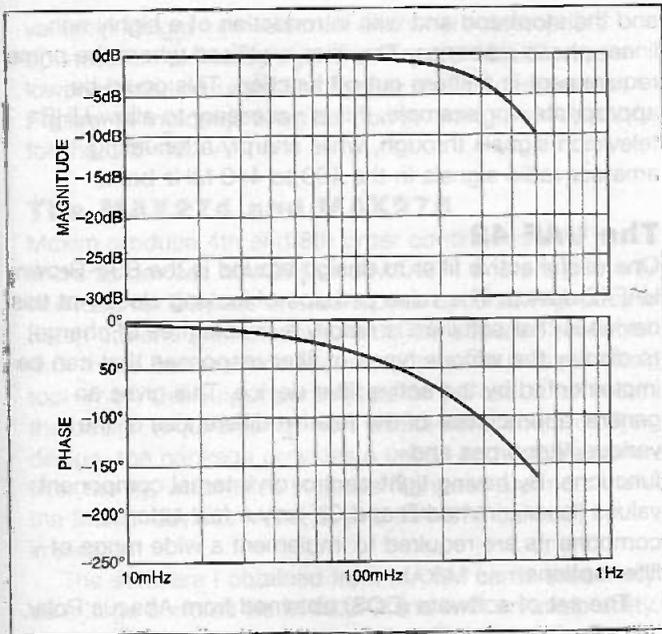


Figure 10: Amplitude and phase response of a Bessel filter

which gives a pair of poles, $s=0.5 - j0.866$ and $s = -0.5 + 0.866j$. Such a solution can be represented in figure 8.

Poles in the right hand plane should be avoided, with stable solutions on or to the left of the imaginary axis. This method of mapping the poles on the (x,y) co-ordinate system provides a basis for discrimination of stable or unstable designs.

Design of three and four order filters and higher orders can be simplified by expressing them as products of first and second order filters. This is in fact a common strategy for implementation of filter function with devices perhaps able to implement two order elements or a pair of such elements which can be cascaded.

It is common also, for either active or switched capacitance filters to be configured as general purpose devices of at least units of second order. Some devices will provide two independent second order devices or even four independent second order devices, giving functionality at fourth and eighth order respectively.

While filters are normally considered in relation to response at a specific frequency, the transient element of performance can be an important determination of suitability of performance. In general, circuits of higher Q will tend to demonstrate more ringing.

A filter can be described as monotonic when its gain slope never changes sign - a characteristic possible with low pass or high pass type filters. Often designs will demonstrate so called passband ripple. Usually specific filter characteristics will indicate limits (usually less than 1 dB in the passband) though the relevance of performance factor will depend on the application.

Stop band ripple may appear in filter responses but this is often of less importance since the key factor is the overall relative level of attenuation outside the passband.

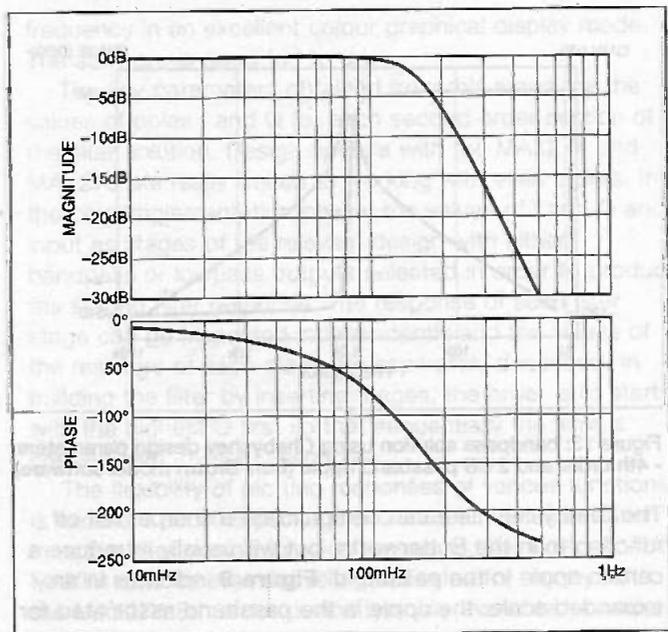


Figure 11: amplitude and phase response of a Butterworth filter

Specific filters

The transfer function of the Butterworth filter is given by:

$$H(\omega) = 1/1 + (\omega/\omega_0)^{2n}$$

where n is the order of the filter and ω_0 is the -3 dB frequency of the filter. This design gives approximately -20 dB reduction per decade per order. Thus a 5th order filter will have a -100 dB decade roll off function.

Table 1 outlines the quadratic factors of the first four Butterworth filters.

Table 1: Description of the first four Butterworth orders

Order n Function (denominator)

- | | |
|---|------------------------------------------|
| 1 | $(s + 1)$ |
| 2 | $(s^2 + 1.4142s + 1)$ |
| 3 | $(s + 1)(s^2 + 0.765s + 1)$ |
| 4 | $(s^2 + 0.7654s + 1)(s^2 + 1.8478s + 1)$ |

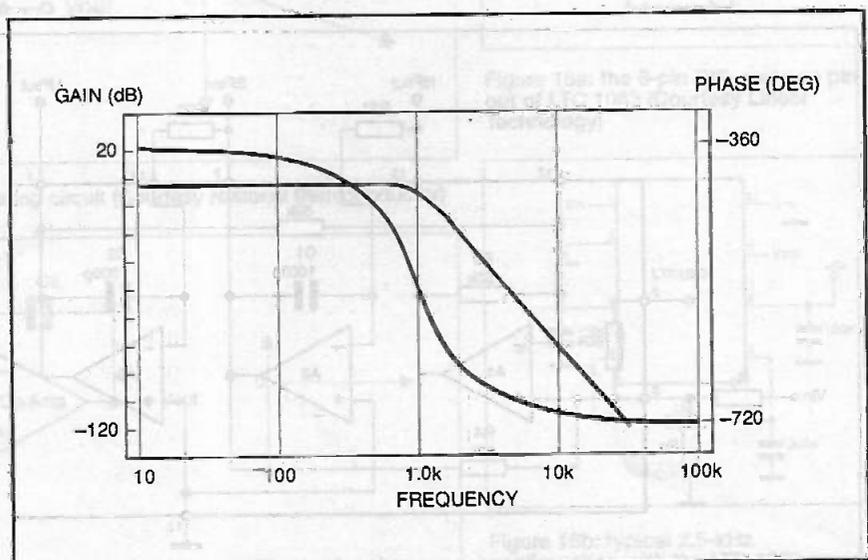


Figure 12: lowpass solution using 4th order Butterworth design parameters (Burr-Brown model software)

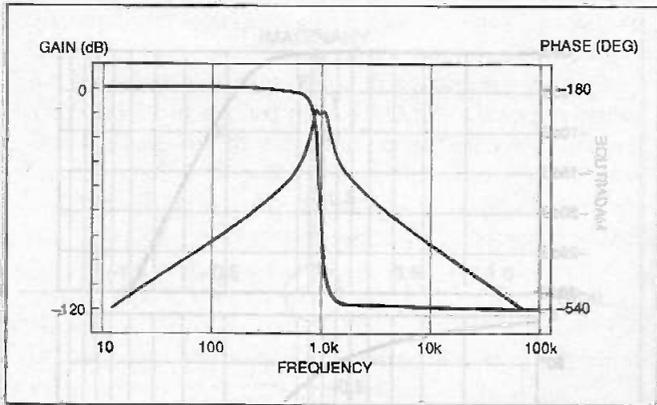


Figure 13: bandpass solution using Chebyshev design parameters - 4th order and 2 dB passband ripple (Burr-Brown model software)

The Chebyshev filter can demonstrate a sharper roll off function than the Butterworth, but will usually introduce a certain ripple in the passband. Figure 9 indicates in an expanded scale, the ripple in the passband associated for a range of orders.

For a Chebyshev of order n , there will be $n-1$ peaks or dips in the passband response. Where it is desired to operate an even order Chebyshev at DC frequencies, it is necessary to include a nominal gain equivalent to the ripple amplitude.

In 1952 W E Thompson described a filter specially linear phase response, using Bessel polynomials. Consequently, this type of filter is known as the Thompson filter or the Bessel filter. It is optimised for linear phase response, but has a much slower rolloff, as well as starting to roll off earlier, when compared with the widely used Butterworth (or maximally flat) filter. Figures 10 and 11 illustrate this comparison.

Successively higher order Bessel filters achieve improved linear phase function. Thus a fourth order Butterworth filters will produce more alteration if the shape of a square wave input than would a Bessel filter of the same order.

The elliptic filter can produce a shaper cut off than Butterworth, Chebyshev or Bessel but with the complication of introducing ripple in both the passband

and the stopband and with introduction of a highly non linear phase response. The filter is utilised where the prime requirement is a sharp cut off function. This could be appropriate, for example, if it is necessary to allow UHF television signals through, while sharply attenuating amateur radio signals in the 430 to 440 MHz band.

The UAF 42

One useful active filter to design around is the Burr-Brown UAF42 device. The value perhaps of looking closely at this device is that software is readily available (free of charge) to display the various types of filter responses that can be implemented by the active filter device. This gives an general appreciation of the relative differences of the various filter types and functions. By having tight control on internal component values (laser trimmed R and C), only a few external components are required to implement a wide range of filter options.

The set of software (DOS) obtained from Abacus Polar, 'FilterPro', is primarily configured for the Burr-Brown UAF42 device. It is also claimed possible to load the software from BurrBrown's Web page. In addition, the program can give the f_0 and Q values corresponding to universal filter implementations, such as the pair of f and Q values corresponding to a 4th order Butterworth low pass response. This information can also be applied to other filter solutions such as the LMF100 switched capacitance filter to implement solutions.

The program provides for a combination of filters as defined in table 2.

Table 2: Configuration of filter designs able to be modelled for the Burr-Brown UAF42.

	Lowpass	Bandpass	Highpass	Notch
Butterworth	yes	yes	yes	yes
Bessel	yes	yes	yes	yes
Chebyshev	yes	yes	yes	yes
Inv Chebyshev	yes	no	yes	no

For the Chebyshev, the ripple amplitude in the passband can be specified. For the inverse Chebyshev the frequency at the first notch of maximum attenuation can be separately specified. The frequency specification of this filter is essentially different from the other types listed. The -3 dB response frequency is reported by the program, allowing the frequency response to be adjusted as required.

For each solution, the values of resistors corresponding to each device are specified. Order 4 and order 6 filters would be implemented by using two and three UAF42 devices respectively. The UAF42, however, remains a relatively expensive device but no doubt with good performance characteristics.

Figure 12 indicates a bandpass solution using Butterworth design parameters. To experiment with such a package, therefore, provides an

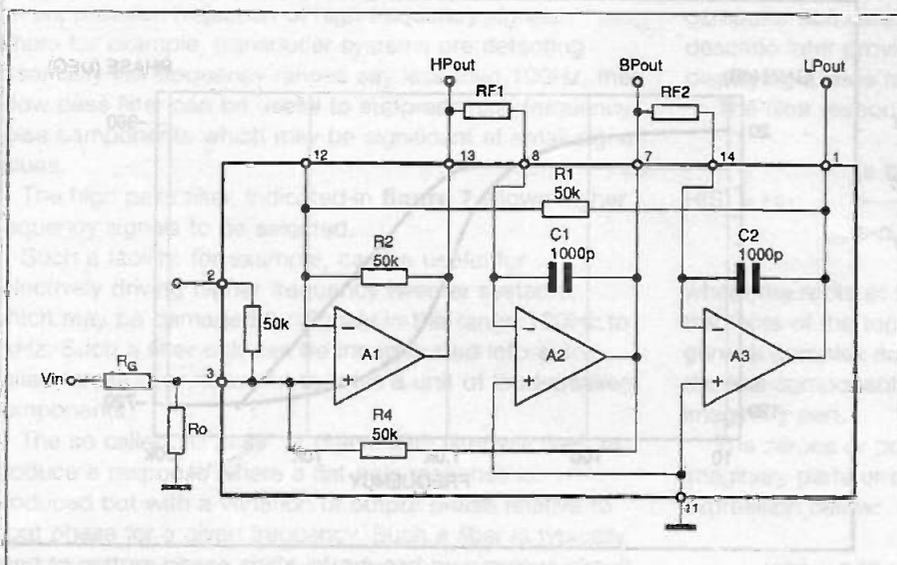


Figure 14: non inverting pole solution for the UAF 42 (Courtesy Burr-Brown)

valuable insight into selection and where appropriate optimisation of filters in general. **Figure 13** indicates a lowpass solution using Chebyshev design parameters. **Figure 14** indicates a typical non inverting pole solution for the UAF 42.

The MAX274 and MAX275

Maxim produce 4th and 8th order continuous time active filters as devices MAX275 and MAX274 and are primarily intended for lowpass and bandpass options. Highpass and notch options are not supported. The software available with these devices, however, does provide a useful design tool where the output parameters of the circuit fall within the design requirements. As a useful component of filter design, the package provides a useful and flexible general filter facility, which also includes highpass and notch which the Maxim devices MAX274 and MAX275 cannot implement.

The software I obtained from MAXIM came essentially as a large bundled file MAXIM-7 and with an unzip utility. The file required is that of FILTER.EXE and also with associated help file FILTER.HLP. The disk actually supplies two versions of the EXE file: one dating from 1988 and one more recent which is the one to be used. The software can also be provided as part of an evaluation kit with the MAX274 device.

The use of the filter design package is relatively straightforward once a few quirks of the DOS package are identified. A filter design screen allows selection of various parameters relating to standard filter characteristics. Standard functions implemented include Butterworth, Chebyshev and Bessel. This option is usefully interactive with options to alter A_{max} , A_{min} , f_s , f_c , and order of specific functions etc. Gain, phase and delay of each function can be identified separately as a function of

frequency in an excellent colour graphical display mode. The software is good fun to drive.

The key parameters obtained from this stage are the values of poles f and Q for each second order section of the filter solution. Design options with the MAX274 and MAX275 are really limited to working with even orders. In the chip implementation phase, the values of f and Q and input as stages of the relevant design with either bandpass or lowpass outputs selected in order to produce the staged filter response. The response of each filter stage can be inspected independently and the values of the resistors of each stage are separately described. In building the filter by inserting stages, the order is to start with the highest Q first so that sequentially the filter is created with lowest Q sections.

The flexibility of plotting responses of various functions is excellent and the package provides a good foundation in active filter design for wide ranges of filter devices. The MAXIM devices are relatively good value for money, with the MAX274 8th order device typically available for under £10.00.

Reviewing the Options

Many applications utilise passive filters which use discrete resistors, capacitors and inductors. One of the advantages of such an approach is the fact that they require no power supplies and are not restricted to the bandwidth limitation of operational amplifiers and can be used in situations involving large currents and high voltages. Also components of noise introduced by use of such components is generally negligible. Passive filters, however, provide no inherent gain and the use of inductors of high accuracy can prove expensive.

Active filters have been developed to provide for devices with excellent characteristics including principally

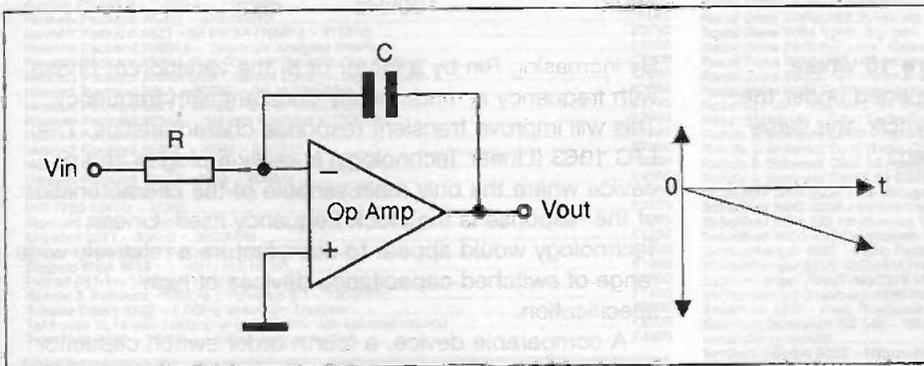


Figure 15a: standard implementation of an integrating circuit (Courtesy National Semiconductor)

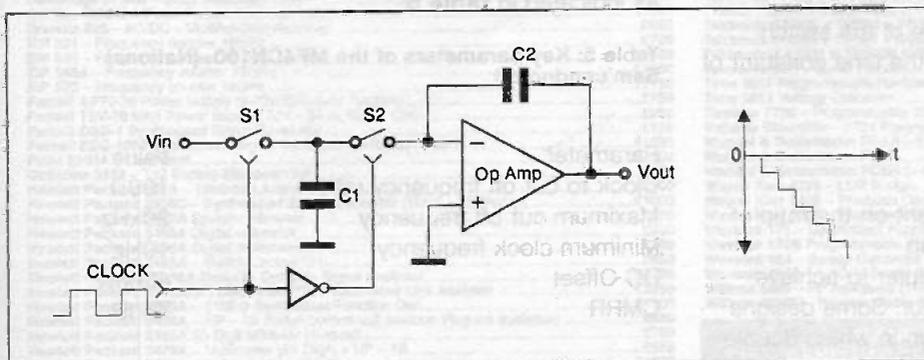


Figure 15b: equivalent implementation of switched capacitance filter (Courtesy National Semiconductor)

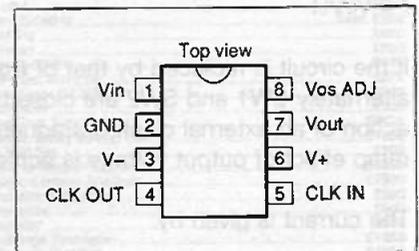


Figure 16a: the 8-pin DIP package pin out of LTC 1063 (Courtesy Linear Technology)

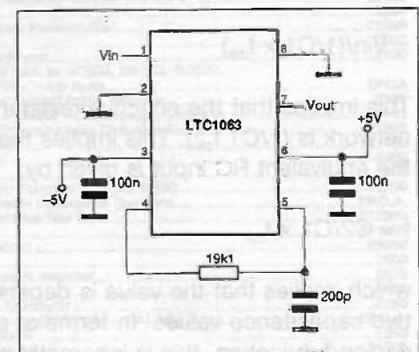


Figure 16b: typical 2.5-kHz configuration with the LTC 1063 device self clocking using the 19.1k resistor and a 200pF capacitor (Courtesy Linear Technology)

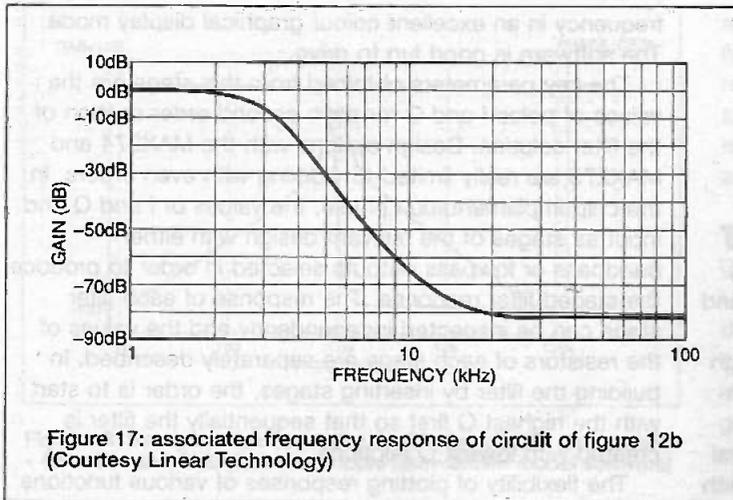


Figure 17: associated frequency response of circuit of figure 12b (Courtesy Linear Technology)

low noise. More recently, however, the switched capacitance filter has gained widespread acceptance in a broad range of applications, particularly in telecommunications. The essential feature of this device is that the frequency of operation of such devices is determined by an independent clock signal whose accuracy can be tightly controlled. Thus the frequency response is more easily controlled than establishing and maintaining correct circuit values within an active filter design.

How the switched capacitance filter works

Due to the increasing uptake of switched capacitance filters, it is appropriate to look at the function of these devices. A standard implementation of an integrating input is indicated in figure 15 where the current in the circuit is given by:

$$I = V_{in}/R$$

If the circuit is replaced by that of figure 15 where alternately SW1 and SW2 are closed/opened under the action of an external clock of frequency f_{clk} , the same ramp effect of output voltage is achieved.

The current is given by:

$$DQ/dt = V_{in} \times C1/dT$$

$$= V_{in} \times C1/(1/f_{clk})$$

$$= V_{in}/(1/C1 \times f_{clk})$$

This implies that the effective resistance of the switch network is $(1/C1 \times f_{clk})$. This implies that the time constant of the equivalent RC input is given by:

$$t = C2/C1 \times f_{clk}$$

which implies that the value is dependent on the ratio of two capacitance values. In terms of chip design/fabrication, this is inherently simpler to achieve than for a specific independent capacitor. Some designs also use non-inverting integration design in which double pole switching is utilised to ramp outputs in a positive sense with function.

Practical circuits: switched capacitance

The Linear Technology LTC 1063 is described as a fifth order Butterworth low pass switched capacitance filter with key parameters, indicated in table 3.

Table 3: key parameters of the LTC 1063

Parameter	Value
Clock to cut off frequency ratio	100:1
Maximum cut off frequency	50 kHz
Minimum clock frequency	30 Hz
DC Offset	1 mV
CMRR	80 dB

Figure 16 shows the 8-pin DIP package pin out and figure 16 a typical 2.5-kHz configuration with the device self clocking using the 19.1k resistor and a 200pF capacitor. The associated frequency response is indicated in figure 17. Such self clocking is advisable only below 500 kHz. The self clocking option is also subject to variability of internal component values. Exact frequencies would require to be set by using variable resistor components.

An input resistor R_{in} should be connected at V_{in} as indicated in table 4 for Supply = + 7.5V.

Table 4: Input values of R_{in} as a function of clock frequency.

R_{in} (kilohms)	f_{CLK}
2.2k	4MHz
3.4k	3MHz
5.5k	2MHz
11k	1MHz
24k	500kHz
120k	100kHz

By increasing R_{in} by a factor of 6, the variation of phase with frequency is made nearly constant with frequency. This will improve transient response characteristics. The LTC 1063 (Linear Technology) is really a plug in and go device where the only main variable of the characteristics of the response is the clock frequency itself. Linear Technology would appear to manufacture a relatively wide range of switched capacitance devices of high specification.

A comparable device, a fourth order switch capacitor Butterworth low pass device, the MF4CN-100 (National Semiconductor) provides a similar characteristic function as indicated in table 5.

Table 5: Key parameters of the MF4CN100. (National Semiconductor)

Parameter	Value
Clock to cut off frequency ratio	100:1
Maximum cut off frequency	20kHz
Minimum clock frequency	10Hz
DC Offset	400mV
CMRR	78dB

The MF4CN-100 has a much larger DC offset voltage. The roll off of the device is approximately 80 dB per octave.



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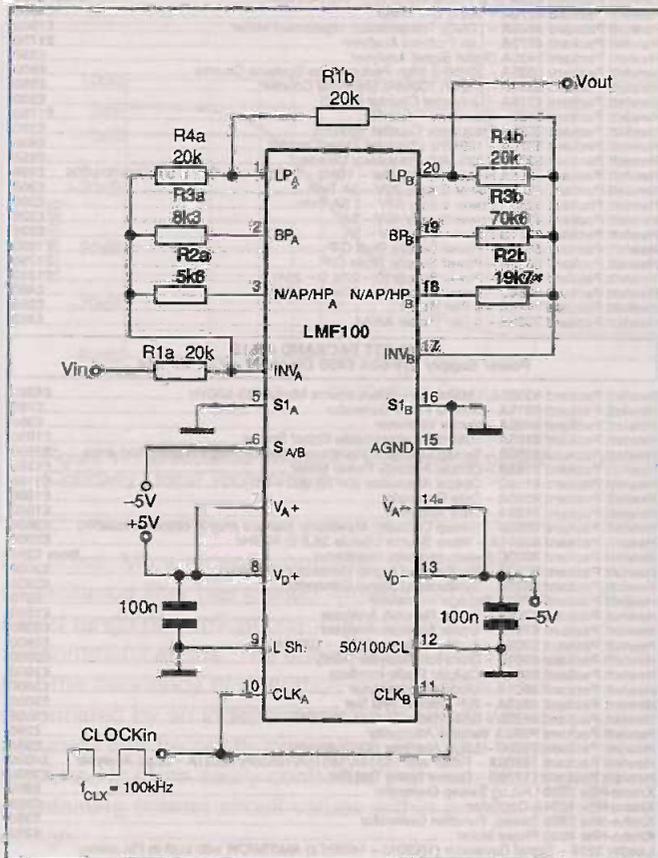


Figure 18: Fourth order Chebyshev low pass filter based on the mode 3 usage of the LMF100 - the general purpose mode. The basic requirements for the example were stipulated as 1dB ripple in the passband, unity gain at DC and with 1000Hz cut off (Courtesy National Semiconductor).

The National Semiconductor LMF100 Switched Capacitor

The LMF100 device produced by National Semiconductor provides a replacement for the industry standard MF10 device in terms of increase in maximum frequency of operation from 30kHz to 100kHz and with improvement in offset voltage and a tighter clock to frequency ratio error of typically only 0.2 percent.

The LMF100 is a general purpose dual second order state variable filter with a total of 12 modes of operation/connection which allows options/combinations which allow options/combinations of a basic types of filter, bandpass, low pass, high pass, notch and all pass. The device also allows all classical filters to be realised - Butterworth, Bessel, Elliptic and Chebyshev and so on.

The clock to centre frequency ratio for each filter can be programmed to either 100:1 or 50:1. In some modes, also, the centre frequency for a given section can be altered by inclusion of additional resistors. This is often necessary where a specific roll off function will require the selection of clock rates different from a single available input clock value.

The typical roll off slope for each mode of operation is approximately -40 dB per decade. The essential transfer function is provided with each response.

Figure 18 indicates a fourth order Chebyshev low pass filter based on the mode 3 use of the device, the general purpose mode. The basic requirements for the example were stipulated as 1- dB ripple in the passband, unity gain at DC and with 1000-Hz cutoff frequency using fourth order function (two sections cascaded together). Standard

filter design text such as National Switched Capacitor Filter Handbook, incorporates tables which list the characteristics of f_0 and Q for this combination. This data can also be extracted from the Burr-Brown FilterPro filter package and the Maxim package. The data sheet then describes how to work from f_0 and Q values to the desired circuit configuration. The two stages are described as stages 'a' and stage 'b'.

The first section value of F_{0a} and Q_a are identified from this look up process as 529 Hz and 0.785 and f_{0b} and Q_b as 993 Hz and 3.559. With unity gain at DC, $H_{0a} = 1$ and $H_{0b} = 1$. While the cut off frequency of the combined filter is 1000 Hz, the component cut off frequency of the separate second order sections are different - 529 Hz and 993 Hz. Normally the section with lower Q is implemented first.

Starting at $R_{1a} = 20k$, since we know that low pass gain (H_{0lp}) tends to $-(R_{4a}/R_{1a})$ and which is a value of -1, the R_{4a} is also 20k. With pin 12 connected to V^- to give a 100:1 clock ratio:

$$f_{0a}^2 = (f_{clk}^2/10000) \times (R_{2a}/R_{4a})^2$$

Solving for R_{2a} gives a value of 5.6 kilohms. Also:

$$R_{3a} = Q_a \sqrt{(R_{2a} \times R_{4a})} \times 0.5 = 8.3 \text{ kilohms.}$$

A similar exercise for the higher Q order gives $R_{1b} = R_{4b} = 20k$ and $R_{2b} = 19.7k$ and $R_{3b} = 70.6k$. For this particular device, therefore, the LMF100, there are three critical elements of design. One is to identify the order of the filter required, the filter type, the filter parameters such as the cut off frequency and gain at DC in the low pass example and any possible ripple in the bandpass and stop bands. Then the values of f and Q for the various second order elements are determined which when combined will produce the desired effect. This data can be found in a range of sources but is not generally included in the general specification of a device data sheet. Having determined f and Q and the mode of the LMF100, the required values of resistors are calculated, based on the formula presented in the data sheet for each mode. Perhaps it is indeed easy to see why such a process of filter design does ruffle some electronic feathers.

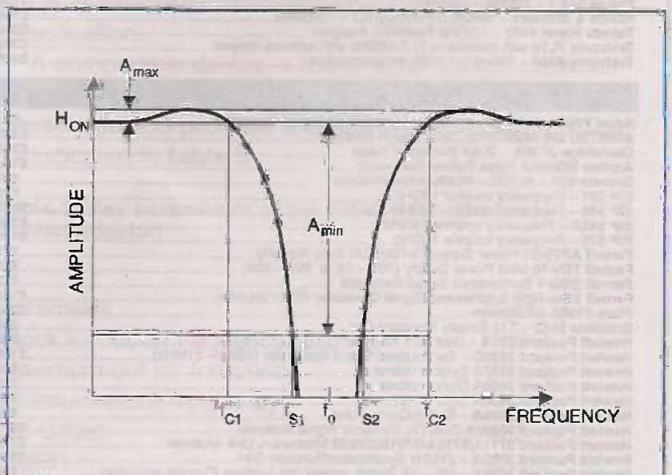


Figure 19: parameters relating to functional specification of the LMF 90 notch filter (Courtesy National Semiconductor)

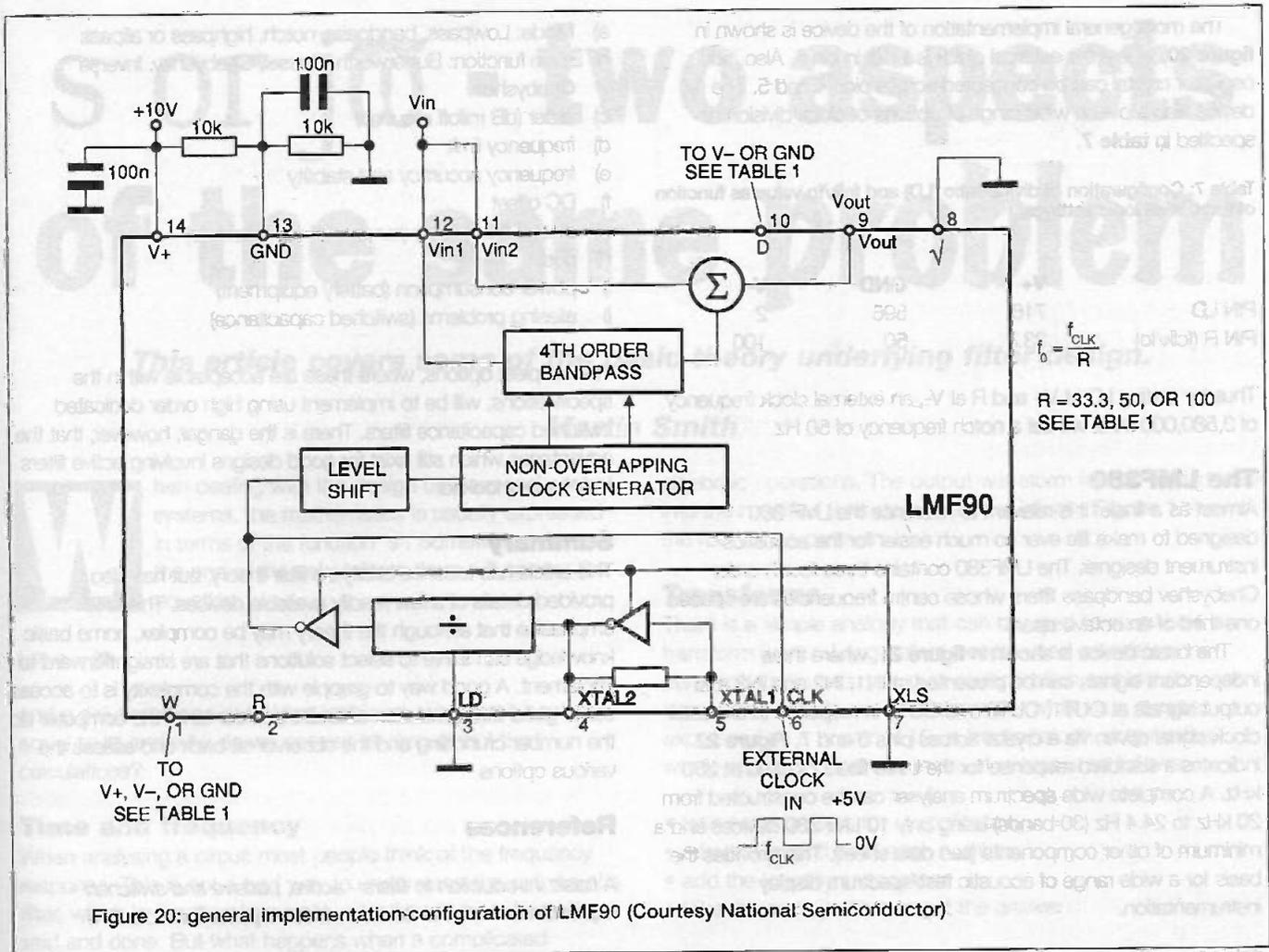


Figure 20: general implementation-configuration of LMF90 (Courtesy National Semiconductor)

There can be a distinct advantage, therefore, of using a dedicated implementation of switched capacitance filter such as the low pass Butterworth described earlier which involves very little in the way of design effort.

The LMF90

There are also available high order notch filters implemented using switched capacitance filters. Where the specification of the devices is satisfactory for the task in hand, these units offer a much simplified design approach compared with basic active filter design.

Where there is a specific request for a high specification elliptic notch filter, then there is probably an advantage in considering the LMF90 device from National Semiconductor. The parameters defined for this type of notch filter are outlined in figure 19.

The key function of the device is set by the clock frequency and clock ratio factor (100:1; 50:1 or 33.3 : 1) and by logic levels connected to two additional lines. Table 6 summarises the options available by setting logic levels on lines D and W when fclk/fo value is set at 100.

Table 6: Notch filter characterisation for setting logic levels at pins D and W for a fclk/fo setting of 100.

D	W	Amin (dB)	BW/fo	SBW/fo
V-	V-	-30	0.12	0.019
V-	GND	-30	0.26	0.040
V-	V+	-30	0.55	0.082
GND	V-	-35	0.12	0.010
GND	GND	-40	0.26	0.024
GND	V+	-40	0.55	0.050

In this definition, stopband width (SBW) is the difference in frequency between the two stopband edges fs2-fs1. These stop band edges are defined at level Amin(dB) between the DC response level.

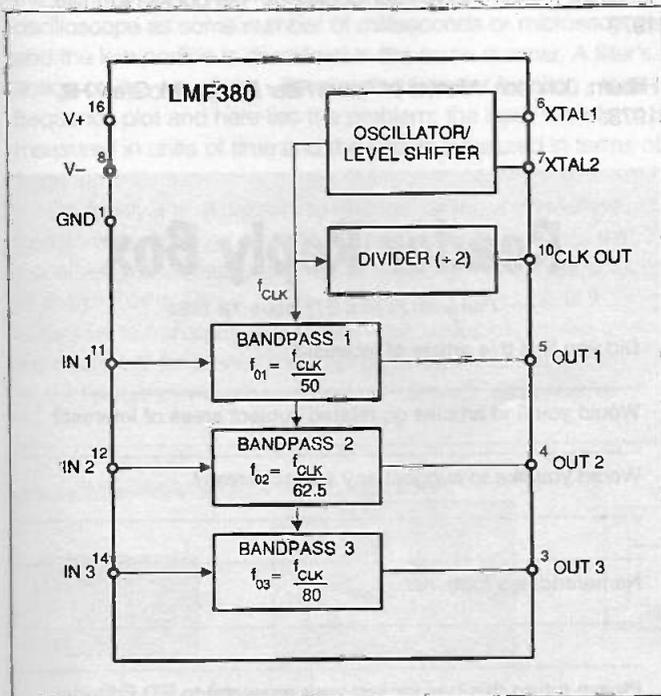


Figure 21: basic pinout of the LMF380 (Courtesy National Semiconductor)

The more general implementation of the device is shown in **figure 20**, where the external clock is input in pin 6. Also, an oscillator crystal can be connected across pins 4 and 5. The device also allows a wide range of options of clock division as specified in **table 7**.

Table 7: Configuration of divide ratio (LD) and fclk/fo value as function of three level logic settings.

	V+	GND	V-
PIN LD	716	596	2
PIN R (fclk/fo)	33.3	50	100

Thus by setting LD at V+ and R at V-, an external clock frequency of 3,580,000 MHz will set a notch frequency of 50 Hz.

The LMF380

Almost as a finale, it is relevant to reference the LMF 380 - designed to make life ever so much easier for the acoustics instrument designer. The LMF380 contains three fourth order Chebyshev bandpass filters whose centre frequencies are spaced one third of an octave apart.

The basic device is shown in **figure 21**, where three independent signals can be presented at IN1, IN2 and IN3 and output signals at OUT1, OUT2 and OUT3 in response to a master clock signal driven via a crystal across pins 6 and 7. **Figure 22** indicates a standard response for the three filters clocked at 250 kHz. A complete wide spectrum analyser can be constructed from 20 kHz to 24.4 Hz (30 bands) using only 10 LMF380 devices and a minimum of other components (see data sheet). This provides the basis for a wide range of acoustic test/spectrum display instrumentation.

Making Choices

At one time, before switched capacitance filters, it was necessary to have a firm grip of filter design before venturing to design and build circuits. The advent of switched capacitance filters and in particular 'self contained' fourth order and higher types, has allowed more devices to be used without an in depth understanding of their function. There has been, as it were, the introduction of a 'black box' approach, which is fine for those who wish to implement a clearly defined requirement without being drawn too much into the detail of filter design.

When switched capacitance filter types are being cascaded, usually in steps of two order such as with the LMF100, this does require more in the way of understanding of filter theory, in particular for the derivation of the relevant f and Q of each section of the filter. At this level of design it is important to have access to

tables/software that can provide such information.

There is also, however, an understanding required relating to what is the best filter for a given application. Moreover, the basic starting point is to define the essential requirements of the filter circuit. Key elements of selection would include:

- Mode: Lowpass, bandpass, notch, highpass or allpass
- main function: Butterworth, Bessel, Chebyshev, Inverse Chebyshev
- order (dB rolloff required)
- frequency limit
- frequency accuracy and stability
- DC offset
- design complexity (number of components)
- cost
- power consumption (battery equipment)
- aliasing problems (switched capacitance)

The simplest options, where these are acceptable within the specifications, will be to implement using high order dedicated switched capacitance filters. There is the danger, however, that the advantages which still exist for good designs involving active filters may be overlooked.

Summary

This article has touched briefly on filter theory, but has also provided details of a few readily available devices. This is to emphasise that although the theory may be complex, some basic knowledge can serve to select solutions that are straightforward to implement. A good way to grapple with the complexity is to access some good filter simulation software in order to let the computer do the number crunching and the observer sit back and assess the various options.

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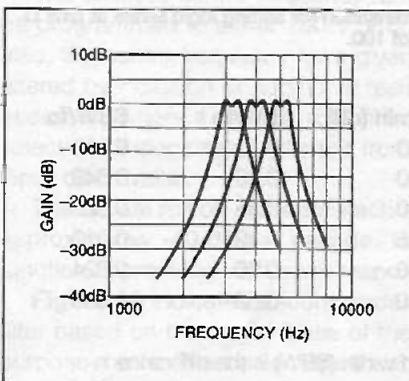


Figure 22: standard response of LMF380 clocked at 250 kHz (Courtesy National Semiconductor)

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s or $j\omega$ - two aspects of the same problem

This article covers some of the basic theory underlying filter design.

Martin Smith

When dealing with the design of filters and control systems, the mathematics is usually expressed in terms of the function 's'. Somewhere towards the end of the calculations there will appear the equation:

$$\text{Let } s = j\omega$$

and a solution drops out. What is this 's', why can it be made equal to $j\omega$ and why do we not use $j\omega$ throughout the calculations?

Time and frequency

When analysing a circuit most people think of the frequency response. This is not a bad way to understand the actions of a filter, which is simply a frequency selective device when all's said and done. But what happens when a complicated waveform such as a square wave is fed into such a circuit and how do we calculate what happens at the output? The square wave is a commonly occurring, so-called time dependent, waveform that can be easily displayed on an oscilloscope. The waveform is normally described in terms of time. For example, the high period of the wave can be measured on the oscilloscope as some number of milliseconds or microseconds and the low portion is described in the same manner. A filter's action on the waveform - its so-called transfer function - is a frequency plot and here lies the problem: the input waveform is measured in units of time and the filter is measured in terms of frequency.

Obviously it is necessary to change (or more correctly, to transform) one of the parts of the problem into the units that the other one is measured in. This would give a simple solution to the problem. This is where the term 's' comes in, as it allows us to transform a complex time waveform into an expression of frequency that can be easily matched to the filter's frequency response (also transformed) using normal

algebraic operations. The output waveform is then turned back into the modified time dependent waveform. **Figure 1** shows the root of the problem.

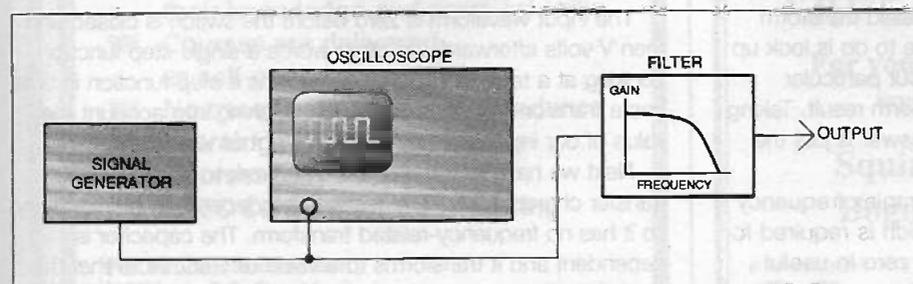
Transforms

There is a simple analogy that can be used to show how a transform works. Long before people used calculators or personal computers, complex multiplication and division was done using logarithms. The logarithm, which is a number expressed as a power of 10, is the transform stage in the whole operation. The sequence of events is as follows:

- take two numbers for multiplication
- take the logarithm of each number
- add the logarithms together
- take the antilogarithm to get the answer

Here's a simple example: supposing we want to calculate 100 multiplied by 1000 and have to use logarithms:

- Stage one. The two numbers are defined as 100 and 1000.
- Stage two. Find out what the two numbers are when expressed as logarithms. If a logarithm is a number expressed in terms of a power of 10 then we can write that $100 = 10^{(\text{some number})}$. Let us define this as $100 = 10 \times 10$ or 10 squared which we can write as 10^2 . Therefore the answer to what is the logarithm of 100 is 2. Therefore the equation becomes $100 = 10^2$ and the logarithm of 100 is 2. A similar train of reasoning will give the logarithm of 1000 as 3.
- Stage 3. Add the logarithms together. $2 + 3 = 5$.
- Stage 4. Take the antilogarithm. If as shown above the logarithm of a number is its value when expressed as a power of 10, then the antilogarithm is the result of taking 10 to the power of the logarithm. In this case we have 10^5 , or 100,000 which is the result you should get when multiplying 100 and 1000 together.



That was a very simple example, but it shows how a transform works: it takes the original problem, transform it to a point where it can be solved using simple mathematics, and then convert it back into the original units. If you don't believe me, try working out what $\pi \times e$ is when solved by long hand calculation, where π (π) is 3.1415927 and e (the unit of natural logarithms) is 2.7183. Now try using log tables.

Figure 1: a typical test setup showing a frequency stimulus to a circuit that is being investigated

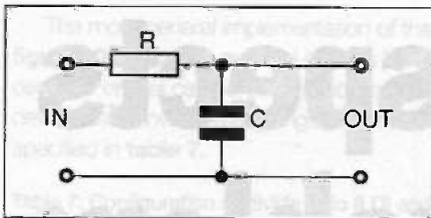


Figure 2: the RC low pass filter circuit

Because the two parts of the problem relating to filters are time and frequency it is necessary to understand the links between the two and why this particular transform works.

Time and frequency

If, for example, a 1kHz sine wave is displayed on an oscilloscope which has a timebase of 0.5ms/division the screen shows a number of waves, five for a typical scope, each with a duration of two divisions on the horizontal, or time, axis. Since we have 0.5ms/division each whole cycle of the wave lasts for $2 \times 0.5\text{ms} = 1\text{ms}$. 1ms is just another way of writing $1/1000$ so we can conclude that $1\text{kHz} = 1000\text{Hz}$ ($1/1000$ second). (The expression (means 'is equivalent to' in mathematics.) Or frequency = $1/\text{time}$ and this interrelation is the foundation of the transform method we are going to use. Taking this expression, it is possible to express a frequency as a function of time and vice versa.

The Laplace transform

The transformation to convert time waveforms into frequency information is named after the French mathematician and astronomer Pierre Simon, Marquis de Laplace (1749 - 1827). I will not go into the details of the mathematical proof here, but there are plenty of good text books available that will expand on the theory. The equation below is the definition of the Laplace transform of a time dependent waveform $f(t)$.

$$L[f(t)] = F(s) = \int_0^{\infty} f(t) \cdot e^{-st} \cdot dt$$

Equation 1: the Laplace transform equation

It is rather a complicated equation but what it boils down to is that $f(t)$ (the time waveform) can be expressed in terms of 's', by multiplying the component parts of the time information by e^{-st} and integrating the result over the period of the waveform. 's' is an expression of frequency that also contains the phase information, vital for calculating the correct response of a filter.

Luckily, very few people have to go through this process, as numerous tables of calculated results (called transform pairs) have been published and all you have to do is look up the time information that corresponds to your particular problem and then read across to the transform result. Taking the inverse Laplace transform to get the answer is just the reverse of this procedure.

The usual way of defining s is as a complex frequency variable equal to $\sigma + j\omega$. σ is a number which is required for the convergence of the integral, equal to zero in useful cases. This leaves the formula $s = j\omega$ which you may remember from above.

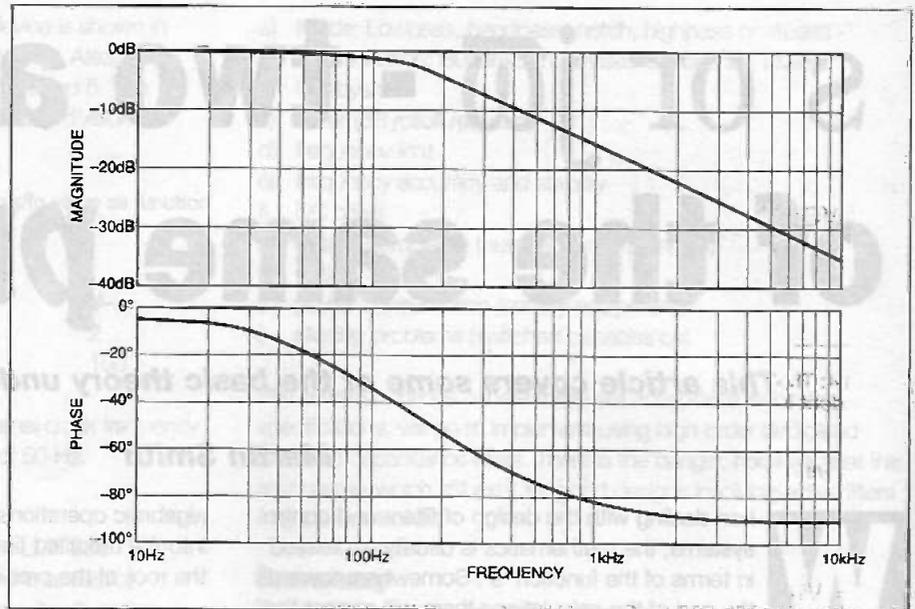


Figure 3: the frequency and phase transfer plots for the circuit of figure 2

Example

Having explained what Laplace transforms are, let's look at an example in real life. Figure 2 shows an RC filter that will be readily known to all of you. It is a low pass filter and the frequency dependent element is the capacitor. Solving this in the frequency domain in order to obtain a standard amplitude versus frequency plot we follow this procedure.

The circuit is a potential divider so the output voltage is

$$V_{out} = V_{in}(\text{reactance of capacitor } C) / (\text{reactance of capacitor } C + \text{resistor } R)$$

Capacitive reactance is $1/j\omega C$, so the formula simplifies to:

$$V_{out} = V_{in}(1/j\omega C) / (1/j\omega C + R)$$

Or more usually expressed in terms of the ratio of output to input and also multiplying the right hand side by $j(C)$:

$$V_{out} = (1/V_{in}) \times (1 + j\omega CR)$$

This can be solved for both amplitude and phase of output with respect to the input and the graphs in figure 3 are obtained. Note however that the analysis was done for single frequency inputs, so what happens when we apply a time dependent waveform such as a step?

Figure 4 shows the circuit configured to accept the input from a DC supply when the switch is closed. A single condition will be made in order to keep the analysis simple, the capacitor C has no charge on it so that before the switch is closed $V_{in} = V_{out} = 0$ volts.

The input waveform is zero before the switch is closed and then V volts afterwards, in other words a single step function. Looking at a table of Laplace transforms a step function in time has a transformed value of $1/s$. Thus taking into account the value of our input step we have an input of V/s .

Next we have to transform the network to obtain the transfer characteristic. The resistor is independent of frequency so it has no frequency-related transform. The capacitor is dependent and it transforms to a value of $1/sC$. Note that this is very similar to the $1/j(C)$ we used above. Now we can proceed with calculating the potential divider circuit as before.

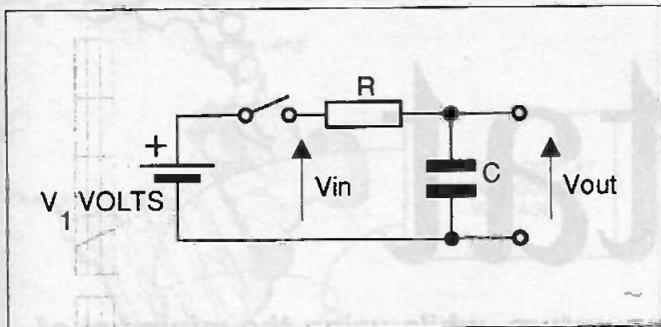


Figure 4: The RC filter network when subjected to a time dependent input

$$V_{out} = V_{in} \frac{1/sC}{1/sC + R}$$

Or:

$$V_{out} = V_{in} \times \frac{1}{(1 + sCR)}$$

Having already described the input step as being V/s we can substitute this into the above equation and simplify:

$$V_{out} = V_{in}/s \times \frac{1}{(1 + sCR)}$$

The term $1/s(1+sCR)$ is usually rewritten as:

$$\frac{1/CR}{s(s + 1/CR)}$$

Looking up the inverse transform for this expression we get:

$$(1 - e^{-t/CR})$$

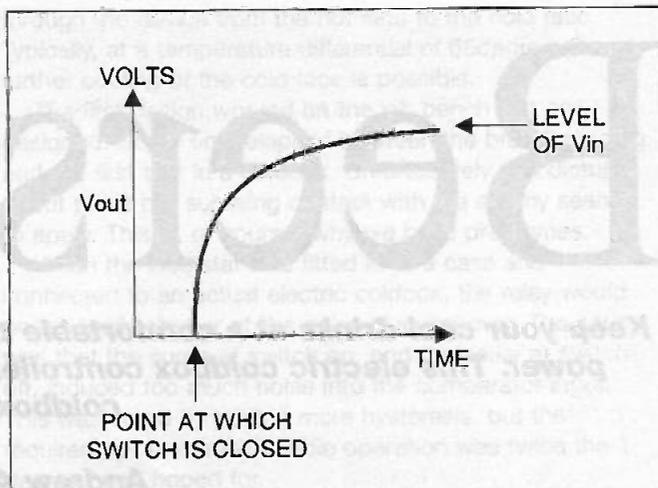


Figure 5: the output waveform (in the time domain) of the circuit of figure 4

and we can substitute this into the original equation:

$$V_{out} = V_{in}(1 - e^{-t/CR})$$

This equation describes the output time-related response and is shown in **figure 5**. This will be familiar to anyone who has observed a step input to an RC network on an oscilloscope.

For an inductor, the Laplace transform impedance is sL , and in circuits containing inductors, this can be used in the algebra just as $1/sC$ is used for the capacitor. In fact, even very complicated circuits can be resolved using the same algebra used for networks of resistors, but with $1/sC$ or sL used instead of a resistance as appropriate.



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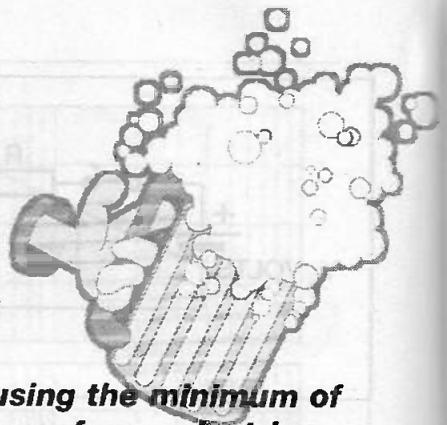
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Andrew Armstrong



difference in temperature between the two junctions. Of course, this is not very useful for measuring, say, room temperature, because both junctions will be at the same temperature. However, if one junction is at room temperature and one at the temperature of a furnace to be controlled, then variations in room temperature will only have a small percentage effect on the measured output.

To eliminate the unknown factor of the thermocouple temperature, what is known as "cold junction compensation" is normally used. This usually employs a semiconductor temperature sensor accurate over a limited range of temperatures to add or subtract a voltage equal to that generated by the reference junction.

However, any junction between dissimilar metals generates a voltage across itself which is a function of its absolute temperature. This can cause problems.

In a circuit which is at the same temperature throughout, the voltages across all the junctions will cancel out, regardless of the number of different metals involved. If, on the other hand, there is a difference in temperature between two different junctions, then there will be a net voltage developed. This effect can cause unintended small voltages in circuits, so that it can be difficult to measure very small dc signals accurately. So much of a problem is this, that in extreme cases printed circuit designs must explicitly take account of the problem. Slots can be cut out of boards to isolate a section thermally, leaving just enough material to provide physical support and to carry connections.

Warm cola is occasionally useful, in small doses, to help relieve a slightly uneasy stomach, but as an enjoyable drink, it leaves something to be desired. I'm not sure that warm beer is good for anything at all, apart from proving that you are in Olde England. In summer, on a picnic, a cool drink is good, so you can use an insulated coldbox.

The snag here is that, to keep the temperature down for a while, the contents start off cold enough to be like lightning on the teeth. Then, after a while, it warms up to a comfortable coolness, then eventually back to the old familiar warmth. The answer to this lack of cool is an electric coldbox.

Electric coldboxes normally use a Peltier effect device to pump heat out of the insulated space. The Peltier effect is the absorption or production of heat in junctions between dissimilar materials. Electrons passing across the junction absorb or release a quantity of energy equal to the transport energy and the energy difference between the conduction bands of the materials.

Figure 1 illustrates the construction of one stage of a thermoelectric cooler using the Peltier effect. The Peltier effect is the reciprocal effect of the familiar thermocouple. Thermocouples are used to measure temperature, and can be made to operate accurately and reliably at high temperatures.

Figure 2 is a schematic example of a thermocouple for measuring temperature. To a close approximation, the voltage across the two wires is proportional to the

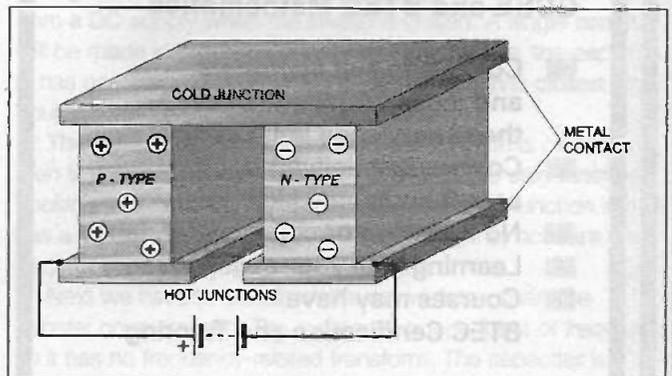


Figure 1: a Peltier effect device, very much like a series of thermocouples optimised for heat pumping instead of temperature measurement

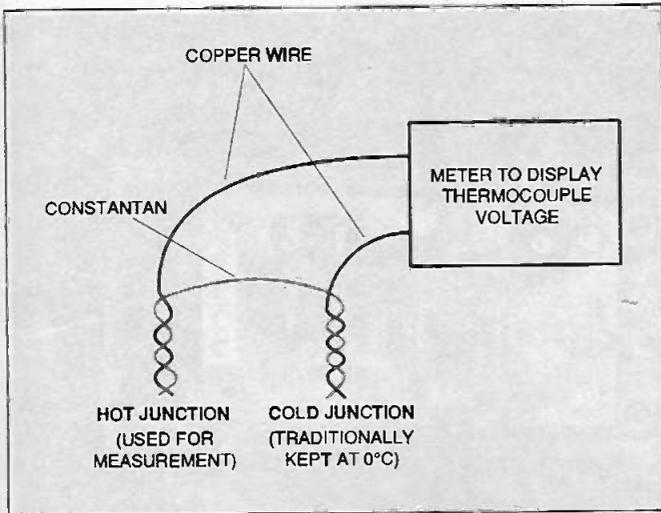


Figure 2: the "classical" thermocouple

Control freak

Running a coolbox consumes a lot of power from the point of view of a car electrical system, particularly if the engine is not running. It does not make sense to cool the drinks to the point where they are too cold for comfort, using extra charge from the battery.

The extra power consumption is more than it might at first seem. At a lower temperature inside the coldbox, the rate of heat flow into the box is increased proportionally to the difference in temperature between the inside and the outside, but also the efficiency of the thermoelectric cooler is reduced as the temperature difference across it increases. At higher temperature differentials, more of the energy is used to pump out heat which has conducted

through the device from the hot face to the cold face. Typically, at a temperature differential of 65degreesC no further cooling of the cold face is possible.

The first design worked on the lab bench just as designed. Some time elapsed between the breadboarding and the first test in a coldbox. Unfortunately, the dictum about plans not surviving contact with the enemy seems to apply. This is, of course, why we build prototypes.

When the Beerstat was fitted in to a case and connected to an actual electric coldbox, the relay would occasionally chatter at the point of switchover. The cause was that the surge at switch on, and the spike at switch off, induced too much noise into the comparator input. This was cured by adding more hysteresis, but the required hysteresis for reliable operation was twice the 1 degree I had hoped for.

The solution was to use two diodes in series to sense the temperature, rather than just one. The same number of millivolts of hysteresis now only corresponded to 1 degree, and all worked well.

Subsequently I used the controller with a mains power unit to run the coldbox. The fault seemed to reappear, and time was spent searching for a (non-existent) design error. Eventually I discovered that the connections to the reservoir electrolytic in the mains power supply had become high resistance (the capacitor is a unit the size of a baked-bean can, with bolt-down aluminum terminals coarse thread terminals). The bolts had loosened by a tiny fraction of a turn, and the contact resistance had risen. The result was a high level of 50Hz ripple on the output of the power unit, and a 50kHz oscillation in the regulator circuitry, which needs a low-input impedance to remain stable.

The circuit

The circuit is of a reliable and non-controversial design. It has been deliberately designed to use the temperature dependence of the forward voltage of a silicon diode to measure temperature, avoiding expensive temperature sensors, which would work no better for this application.

The change in forward voltage drop of a silicon diode is approximately $-2.1\text{mV}/\text{degreesC}$, a fact which is widely applied, but which is not obvious from the normal diode junction equation.

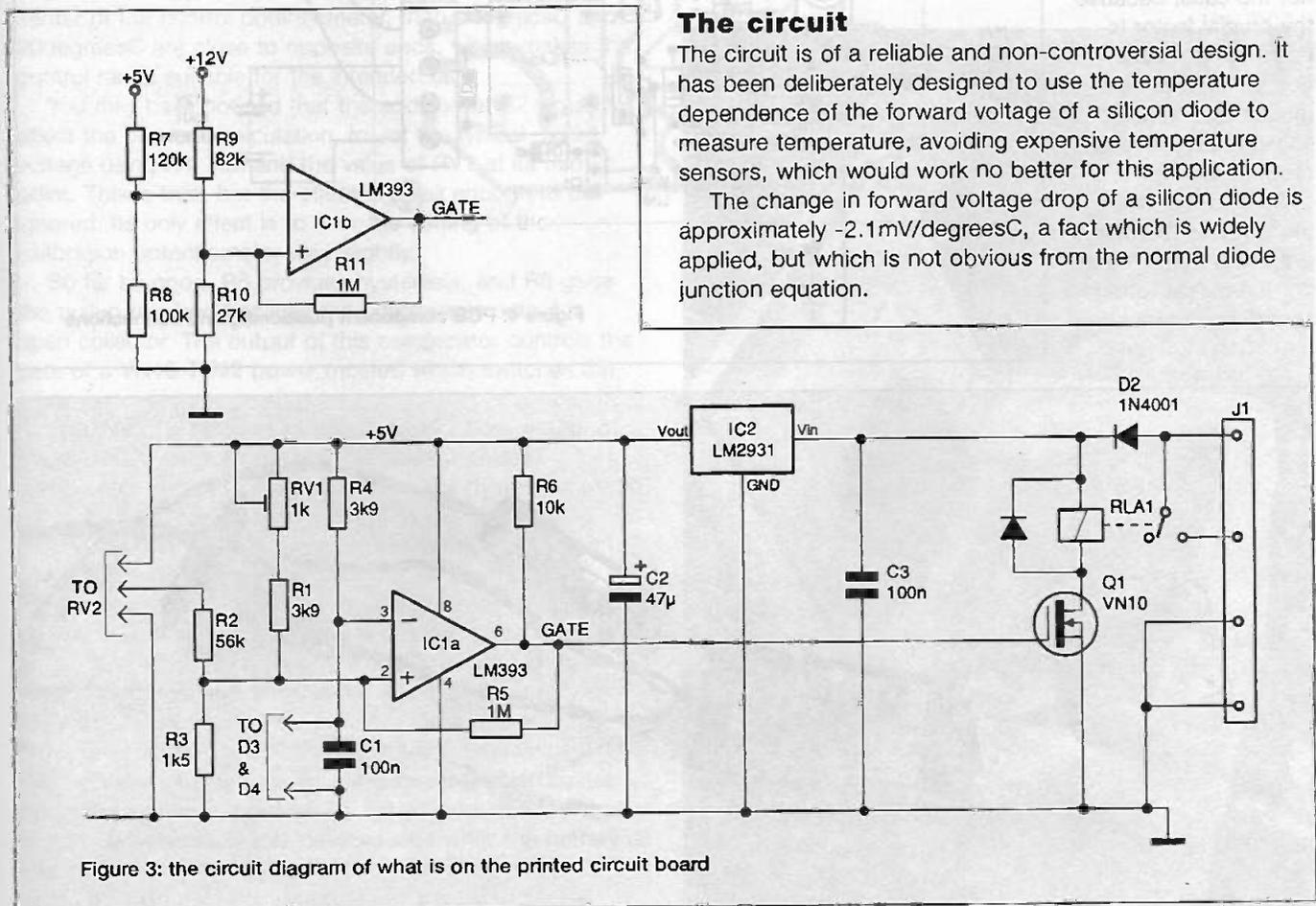
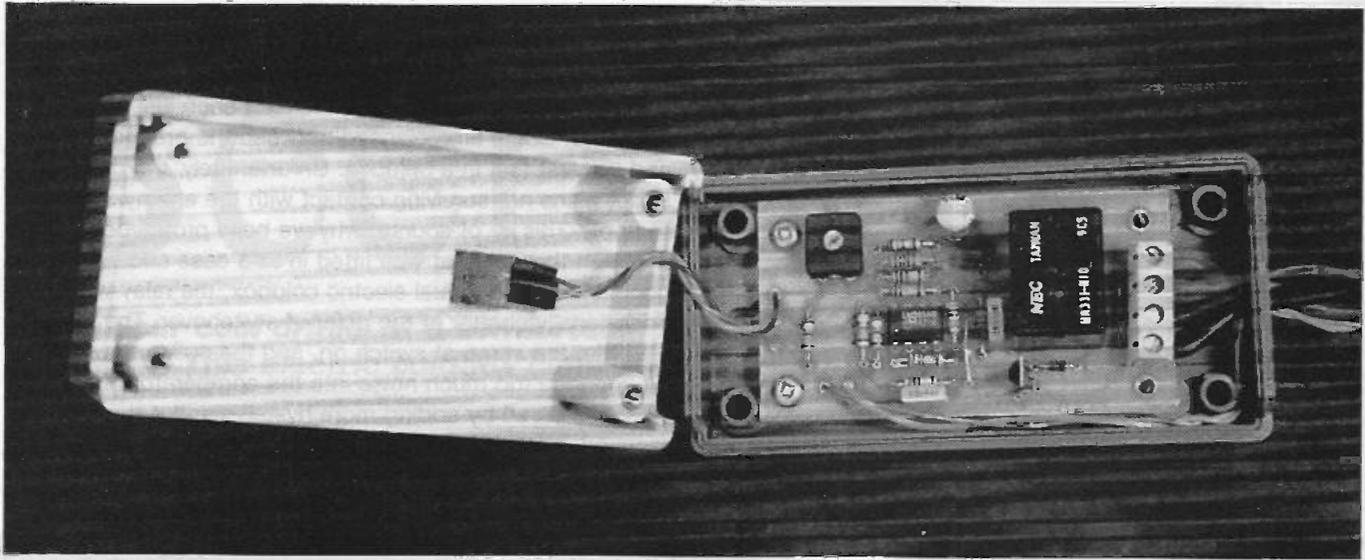


Figure 3: the circuit diagram of what is on the printed circuit board



$$I = I_s \left[e^{\frac{qV}{kT}} - 1 \right]$$

where v is the forward voltage across the diode, q is the charge on the electron (1.6×10^{-19} coulombs), k is Boltzmann's constant (1.38×10^{-23} J/K (joules per Kelvin)), and T is the absolute temperature in Kelvin. This equation, beloved of

semiconductor lecturers, implies that the junction voltage increases with temperature. This is not the case, because the crucial factor I_s has a temperature dependence which reduces the junction voltage approximately proportionally to $1/T$.

This accounts for the variation of voltage drop with temperature, but the actual voltage at a given temperature

is different for different diodes out of the box. This tolerance amounts to many degrees, so that a calibration system is needed to allow the temperature to be set with a reasonable range on the control potentiometer.

The first attempt to design the circuit used resistors and preset potentiometers each side of the temperature control potentiometer, so that the upper and lower voltages could be set to match the diode voltage at the

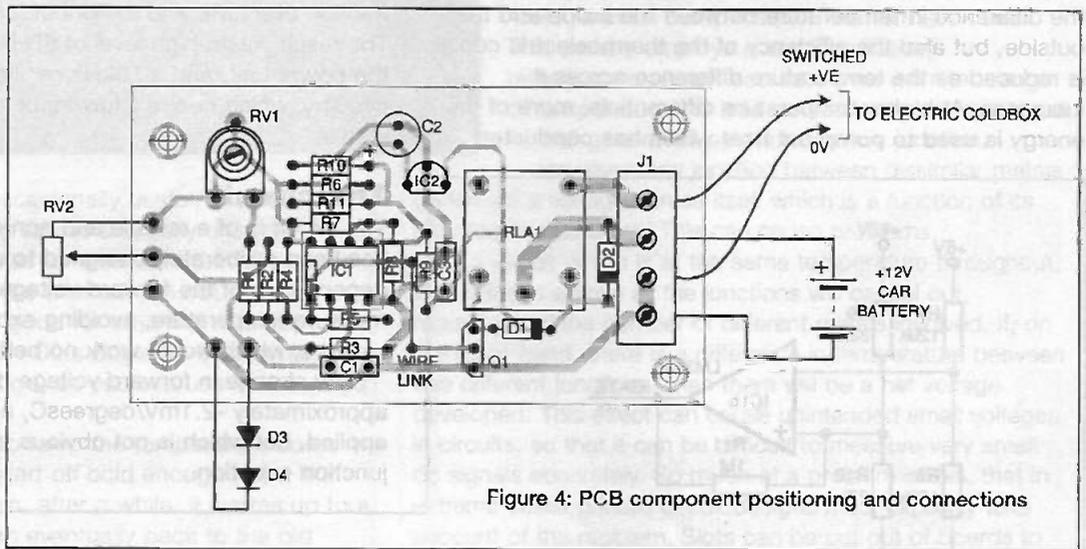
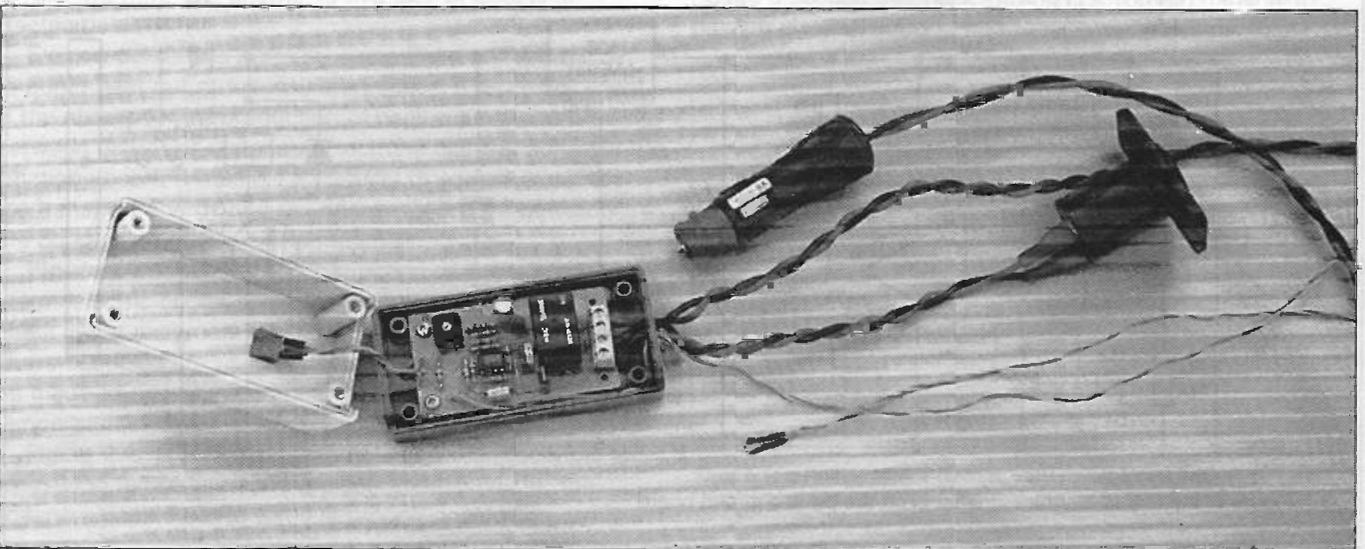


Figure 4: PCB component positioning and connections



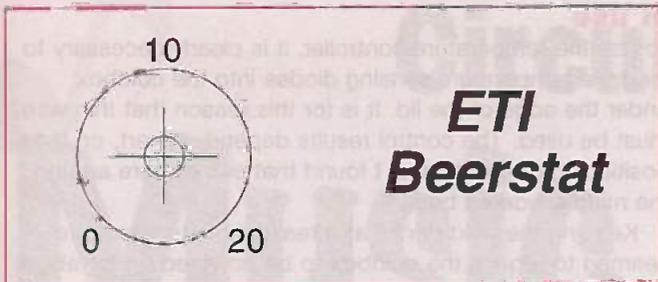


Figure 5: front panel label

high and low temperature points. Then I tried to figure out a calibration procedure, and abandoned it on the spot.

The next approach is shown in **figure 3**, the circuit used for this project. First of all, the value of R3 was chosen, then R1 and RV1 were calculated to provide a voltage equal to approximately the middle of the tolerance range for the two diodes in series at 0degreesC, with RV1 set at its mid position.

Then the value of R2 was calculated. The requirement here was to pot down the range of 0 to 5V, down to a range of 0 to 84mV. The "lower" resistor of the potential divider network is actually R3 in parallel with the series combination of R1 and RV1, which can change as RV1 is adjusted. However, the magnitude of this change is small, and its only effect is to alter the scale slightly. This means that if the calibration is set so that 10degreesC falls in the middle of the range of the control potentiometer, no setting that is likely to be used will be far from its expected point.

This provides an adjustment range of 0 to 20degreesC. In practice, the value chosen for R2 allows a range of 23 degrees, but if the unit is set so that 10degreesC is at the center of the control potentiometer, then 0degreesC and 20degreesC are close to opposite ends, which makes the control range suitable for the intended use.

You may have noticed that the addition of R2 would affect the previous calculation, to set the typical diode voltage using R1, R3, and the value of RV1 at its mid point. This is true, but the effect is small enough to be ignored. Its only effect is to alter the setting of the calibration potentiometer very slightly.

So far so good. R5 provides hysteresis, and R6 gives the pullup required because the comparator output is open collector. The output of this comparator controls the gate of a VN10 TO92 power mosfet, which switches the relay.

The use of a bipolar junction transistor here would, of course, have reduced the voltage change on the comparator output to the point where the hysteresis would not have been sufficient for correct functioning.

The LM393 contains two comparators, so I decided to use the other one to protect any battery used with this project from over-discharge. The operation of this part of the circuit is a compromise. I first designed it to work at about 10V, with a volt of hysteresis. I then altered the values using trial and error until it worked reasonably at the end of a length of wire, in which there was a voltage drop. It would obviously cause problems if the voltage drop in the wire when the cooler is running were greater than the hysteresis. Equally it is not a good idea for it to switch off because of too low a voltage while the battery is perfectly healthy at the other end of the wire.

In any case, this comparator uses the 5V regulated

supply as a reference to measure the 12V supply, and switches off the cooler if the battery runs flat. It should protect against damage to the battery caused by over-discharge, but is unlikely to leave any useful amount of energy in it. You might push start your car, but don't expect to operate the starter motor!

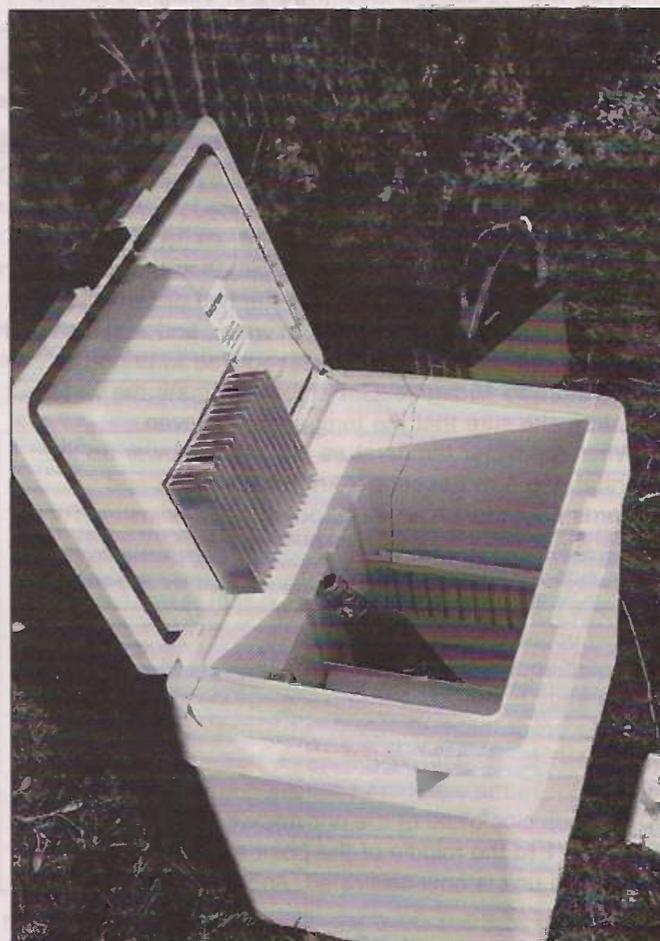
The voltage regulator used is an automotive rated one, so it should survive operation when the engine is running. It has done so in my car, but this should not be taken as proof that it will be reliable in all cases.

Reverse polarity protection is provided by D2, which is not in series with the load drawn by the cooler, so it does not dissipate much power. However, there is another reverse polarity situation to consider. The coldbox used to test this unit can heat as well as cool, while the thermostat in the unit can only control cooling. Cooling or heating is selected by reversing the power plug to the coldbox, so it is vitally important to plug it in the correct way round.

Construction

The printed circuit board is easy to assemble, and has only one static-sensitive component on it. The mosfet, Q1, can be damaged by static, so it is best to fit this last, touch a grounded object before picking it up, and don't shuffle your feet on the carpet until it is soldered in place. The component overlay, and the pcb connections, are shown in **figure 4**.

The unit is designed to fit into a case made by OKW, and available from RS/Electromail. The mounting holes match the offset bosses moulded into the case, so do not be confused by the apparent error in hole spacing on the pcb.





The connections are all taken via a hole drilled in the dark grey end of the case, the end with the wider mounting-hole spacing. The diodes are connected using thin twisted wire, soldered to the pads on the pcb. The connections to the diodes should be protected using insulated sleeving. The diodes themselves will easily fit through the hole for the connections after the pcb has been fitted to the case. The power connections, to the cigarette lighter plug, which plugs into the outlet in the car, and the cigarette lighter socket, into which the coldbox plugs, can be fitted after the board is mounted. A pair of narrow nosed pliers will be helpful to fit the wires into the screw terminals.

The prototype used a fused cigar lighter plug, with an 8A fuse fitted. If an unfused plug is used, it is recommended that an inline fuse is fitted in series with the positive connection.

If you wish to use the label (figure 5) designed for this project, it is suggested that you photocopy it onto transparent film, and stick it on to the lid of the case before drilling the hole for the potentiometer. Then drill the hole, file a small slot for the polarisation pip and fit the potentiometer. Then fit the knob so that the 10°C mark is in the middle of the rotational range.

Calibration

If an accurate thermometer is available, then the best means of calibration is to immerse the two diodes and the accurate thermometer in a glass of water, and add small quantities of warm water or ice as required to bring the temperature to 10degreesC. Remember to stir the water well, to make sure that the temperature is even.

When the water temperature is correct, power up the Beerstat and turn the control knob backwards and forwards past the 10degreesC point, while adjusting RV1 with a screwdriver until the relay clicks on and off just either side of the 10degreesC point. The unit is now calibrated, and the lid may be screwed in place.

If an accurate thermometer is not available, then the next best approach is to use melting ice as the temperature reference. Small pieces of ice in just enough water to cover them will remain at a temperature of 0degreesC for as long as the ice is melting. Immerse the two diodes in the water, and set the control knob to about 10 degrees clockwise of the anticlockwise end stop. Adjust RV1 to the middle of the point at which the relay clicks. The unit is now calibrated, and the lid may be screwed in place.

In use

To use the temperature controller, it is clearly necessary to feed the temperature sensing diodes into the coldbox under the edge of the lid. It is for this reason that thin wire must be used. The control results depend, in part, on the positioning of the diodes. I found that somewhere around the middle worked best.

Keeping the cold drinks at a reasonable temperature seemed to require the coldbox to be powered up for about one-third of the time. To maintain a reasonable temperature for storing milk (approximately 4 degrees) needed the unit to be running for most of the time. So, a practical size of solar panel could keep a small sealed lead acid battery charged when cooling drinks to 12degrees C, but a much larger panel would be needed to keep milk cool (max 4degreesC) on a camping weekend.

The unit now resides in my garage, when not in use on the move, keeping the beer, lemonade, and cola at a comfortable temperature to drink.

PARTS LIST for the Beerstat

Resistors

All 025W 1 percent unless stated

R1, R4	3.9k
R2	56k
R3	1.5k
R5, R11	1M (5 percent suffices)
R6	10k (5 percent suffices)
R7	120k
R8	100k
R9	82k
R10	27k
RV1	1k CP10H style eg Electromail 187-084
RV2	10k min conductive plastic potentiometer eg Electromail 240-2262

Capacitors

C1, C3	100n polyester, 0.2-in pitch
C2	47uF 16V radial electrolytic 0.1-in pin spacing

Semiconductors

D1, D2	1N4148
Q1	VN10
IC1	LM393
IC2	LM2931

Miscellaneous

J1	4 way 0.2-in pitch pcb mounting screw connector
RLA1	12V min 5A spco relay. Electromail 171-8780 or 369-444 or 369-472 or equivalent. Case: OKW type A9011065 (Electromail 583-088) Knob to fit specified potentiometer eg Electromail 259-6812

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Circuits for Music Lovers

James Scott

Part 2

The combined Bass and Treble Boost, the Soft Limiter and the Smooth Fuzz to build



Here are four more circuits to following last month's collection mainly for guitar and vocalists.

Working Together for Clarity

A combined bottom and top end booster

This combined effort is a switched filter network centred around transistor Q2 (figure 16). First, the guitar signal arrives via a decoupling capacitor C1 to the transistor Q1. Note that Q1 is biased in a common emitter configuration, which in fact buffers the signal before it is processed by Q2. To obtain a distinctive treble boost, you must close S1 and set RV1 to its minimum value. To get bass boost, do the contrary, open S1 but set RV1 to about 500 ohms, you'll soon hear if you have the correct value.

It is also possible to get the smiley U-shaped curve if you keep S1 closed and adjust RV1 to nearly its maximum value. This will enrich the sound, giving simultaneously bass and treble boost.

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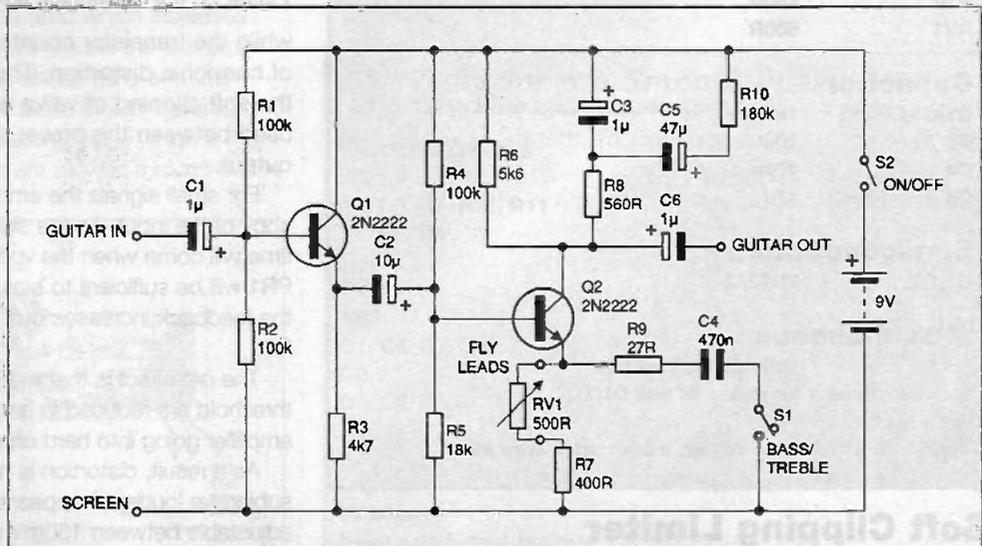


Figure 16: the combined Treble and Bass Booster circuit

How it works

Consider Q2 to be an amplifier with its gain determined very roughly by R6/R7. Now look at the circuit again, and you will notice that R6 has some other components in parallel with it, notably C3, R8, C5 and R10.

The same goes for R7, which has R9 and C4 in parallel with it for treble boost. As you know, the impedance or ac resistance of a capacitor is determined as $Z_c = 1/2\pi fC$. Thus, if gain of the amplifier is defined more precisely as the

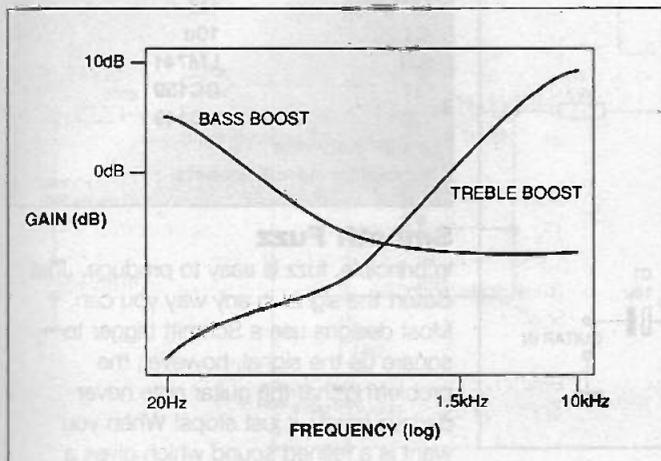


Figure 17: plot of a single-switch treble OR bass booster

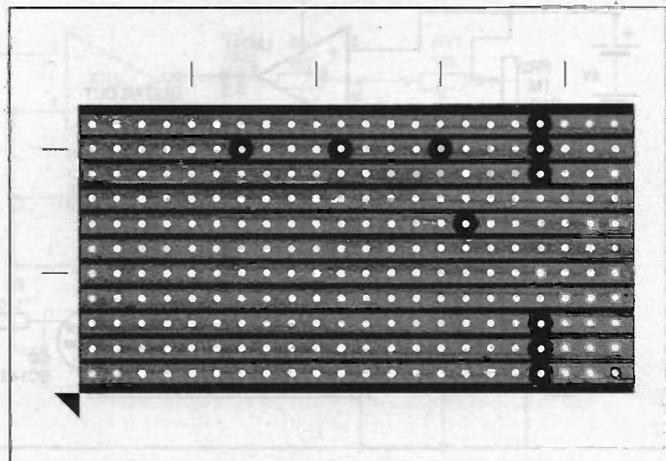


Figure 18: the stripboard plan for the Treble and Bass Booster

impedance in the collector divided by the impedance in the emitter of Q2 (that is, Z_c/Z_e), then for various frequencies and opening/closing of S1, we will have different amplification factors at all frequencies as shown in the Bode plot (figure 17).

This circuit can easily be put together as a prototype onto a copper stripboard as shown in figures 18 and 19. You can then select a suitable rigid box to mount the board and foot-switch.

Parts List for the Bass/Treble Booster

Resistors

R1,R2, R4	100k
R3	4.7k
R5	18k
R6	5.6k
R7	400R
R8	560R
R9	27R
R10	180R
RV1	500R

Capacitor

C1,C3,C6	1u
C2	10u
C4	470n
C5	47u

Semiconductors

Q1,Q2	2N2222
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Miscellaneous

- SW1 suitable foot switch
- 2 x Jack sockets for guitar IN and OUT
- Battery clip
- Rigid box, stripboard, solder, track cutter, wire etc.

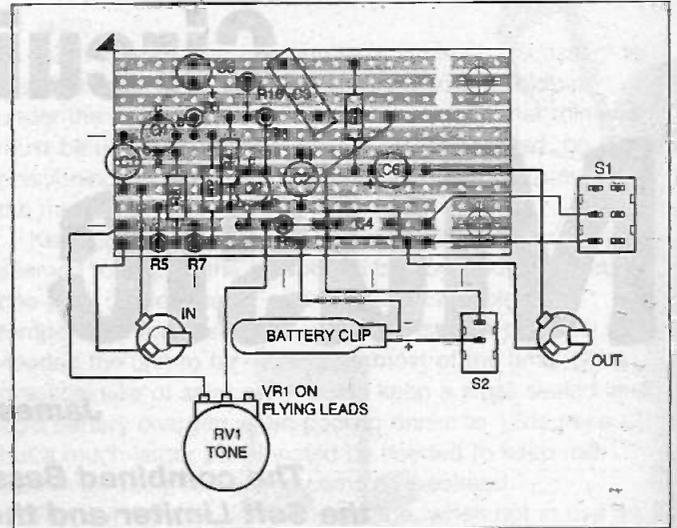


Figure 19: the component layout for the Treble and Bass Booster

while the transistor counterparts generate vast quantities of harmonic distortion. The circuit in figure 20 simulates the soft clipping of valve amplifiers and is intended to be used between the power amp input and the pre-amp output.

For small signals the amplifier's output is an exact unity gain copy of the input. As the signal level increases, however, the time will come when the voltage across the output and slider of PR1 will be sufficient to bias Q1 and Q2 on. When this occurs, the feedback increases due to the shunting effect of R2 and R3.

The net effect is that musical peaks above a certain threshold are reduced in amplitude to prevent the power amplifier going into hard clipping.

As a result, distortion is noticeably decreased, while the subjective loudness appears unaffected. The circuit is adjustable between 130mV and 10mV rms input sensitivity by means of PR1. To set up the circuit, simply set the pot so that it is shorted to the output of the amplifier. Play some music at high volume through the system, and adjust until the harshness just disappears. Adjust PR6 to fine-tune the correct gain. It's easier to do than it is to describe!

Soft Clipping Limiter

Soft Limiter

One of the fundamental differences between valve and transistor amps is their behaviour when driven into clipping. The valve amps go into so-called soft clipping

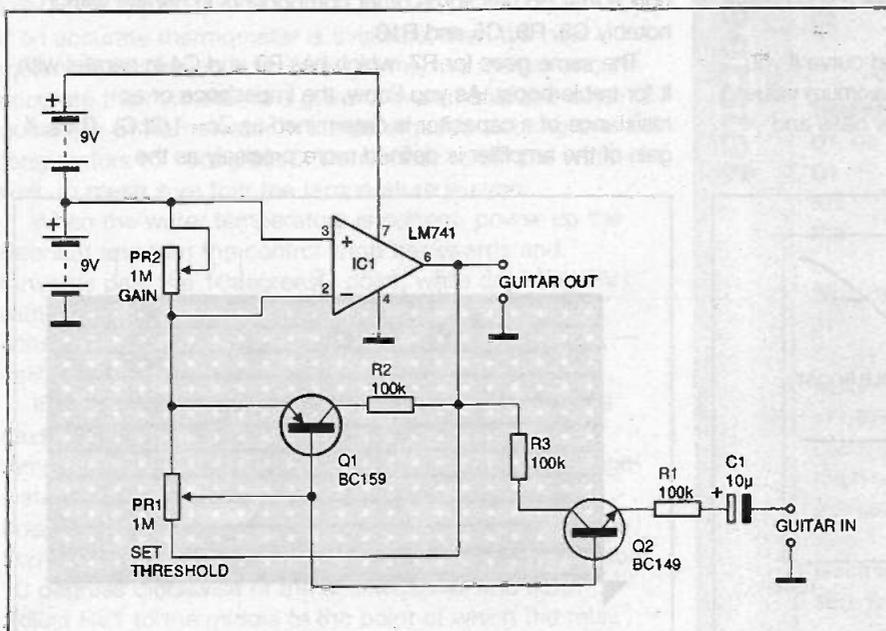


Figure 20: the circuit of the Soft Limiter

Parts List for the Soft Limiter

Components

R1,2,3	100k
PR1,PR2	1M
C1	10u
IC1	LM741
Q1	BC159
Q2	BC149
2 x 9V batteries	
Input and output sockets	

Smooth Fuzz

In principle, fuzz is easy to produce. Just distort the signal in any way you can. Most designs use a Schmitt trigger to square up the signal, however, the problem is that the guitar note never decays gently, it just stops! When you want is a refined sound which gives a limited sustain without destroying all the

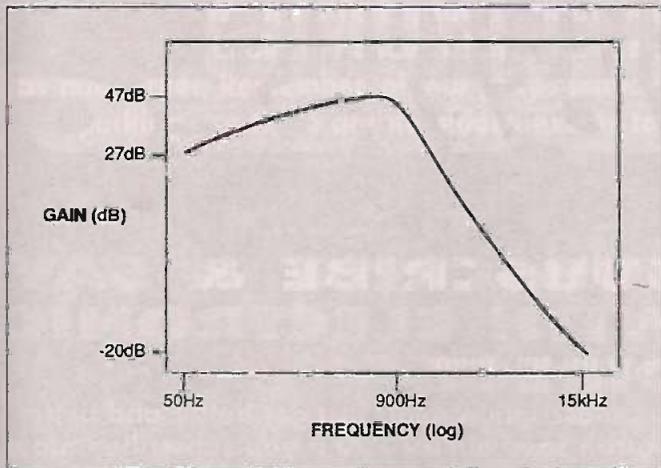


Figure 21: the Bode plot of the Smooth Fuzz

harmonics - and all at a reasonable price.

The guitar signal enters the first op-amp which increases the gain by about 60. The filter network around the first amp acts as a low pass filter, cutting off at about 1kHz and then dropping dramatically down as in the Bode plot in figure 21.

The filtered signal now enters the second stage which is the distortion generator. Very small signals are allowed through but as

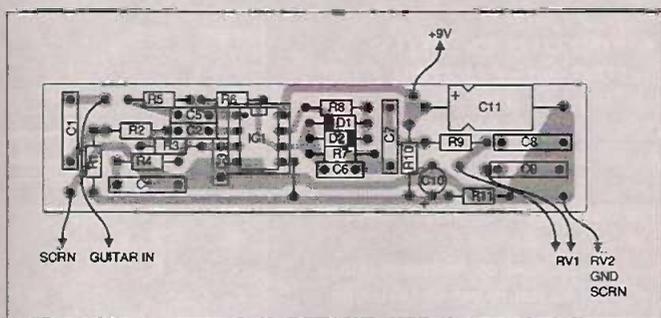


Figure 23: the component layout for the Smooth Fuzz

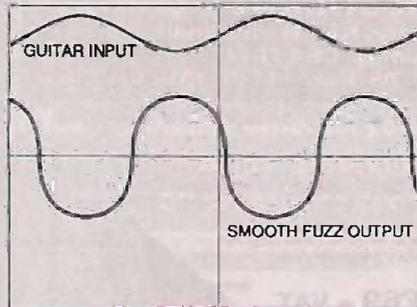


Figure 22: the waveform plot of the Smooth Fuzz

soon as the signal rises above 500mV, the two back diodes conduct, which in fact simulates a short circuit, thus putting in effect R8 and R7 in parallel with each other, which has the consequence of

decreasing the amplitude of the signal. The output of this stage is further processed by a passive filter RV1/C8/C9 and RV2, which controls the overall output amplitude. The oscilloscope simulation in figure 22 shows the classic distorted but rounded waveform.

A suggested component layout for the smooth fuzz is shown in figure 23, and a circuit for the smooth fuzz is shown in figure 24.

Parts List for the Smooth Fuzz

Components

R1, R5	330k
R2, R3, R7, R10, R11	100k
R4, R8, R9	4.7k
R6	10k
RV1	10k
RV2	100k
C1, C4, C7, C9	100n
C2	4.7n
C3, C5, C6	470p
C8	47n
C11	TL72
D1, D2	1N4148
9V battery	
Input and output sockets	

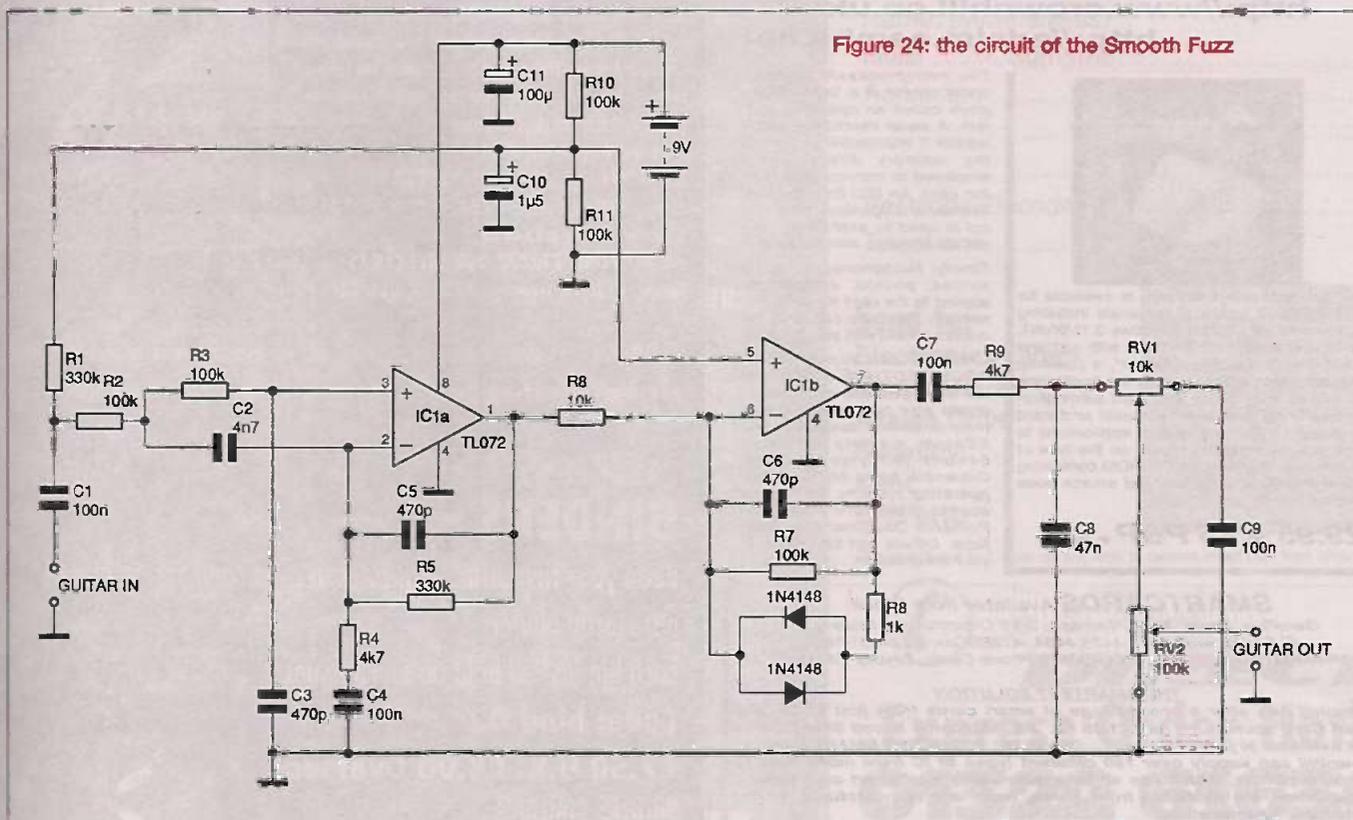


Figure 24: the circuit of the Smooth Fuzz

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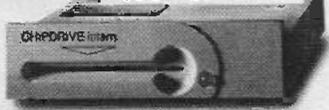


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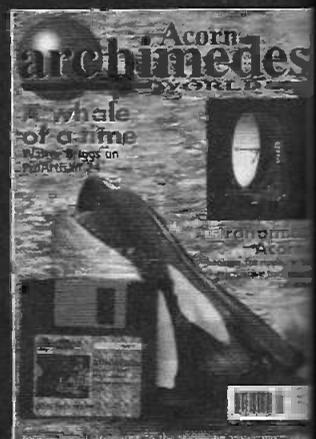
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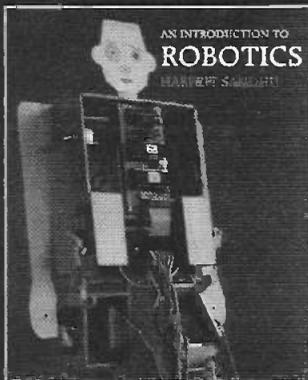
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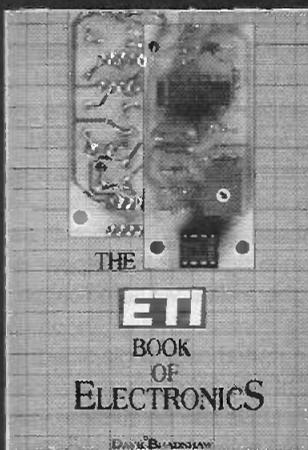
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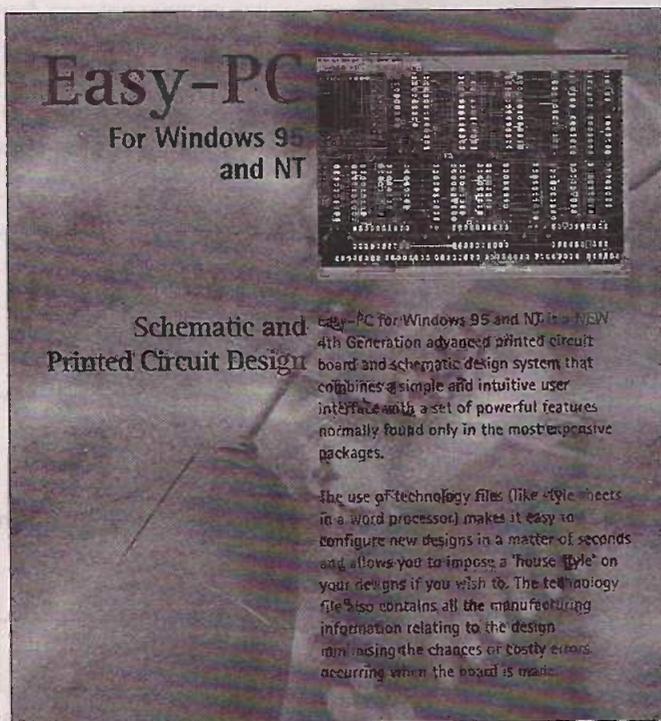
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REVIEW

Easy-PC for Windows and MultiRouter II for Windows 95

Easy-PC and the companion MultiRoute II is put through its paces.



Easy-PC and MultiRouter

Number One Systems, Harding Way, St Ives, Cambridgeshire, England, PE17 4WR. Tel 01480 461778.

Easy-PC £595.00
MultiRouter II £295.00
Pin limited versions:
Easy-PC 500 £245.00
MultiRouter II-500 £195.00

You can get the most up to date information on the Number One Systems website at <http://www.numberone.com/> (also linked from the ETI website on <http://www.aaelectron.co.uk/eti/links.html>).

Number One Systems have offered a 20% discount on list prices for ETI readers who quote this review when ordering.

I first encountered Easy-PC in 1984, when the program, like nearly all PC programs, ran under DOS. This was a low cost program with limited capabilities (for example, tracks connected to a component did not move when the component was moved). It was extremely easy to learn, and represented good value for money.

Easy-PC for Windows and MultiRouter II for Windows 95

The current version of Easy-PC bears about the same relationship to its forbear as a modern car does to a cart with an engine and a tiller for steering. It features separate schematic and layout editing tools, which can be integrated via a project file.

In brief, the program is still easy to learn relative to its capabilities, and is inexpensive compared to its industrial rivals.

Installation

The basic CAD system is installed from five floppy discs. A product key code is needed to allow the installation to proceed. It does seem to be aimed squarely at business users, as it refuses to install unless you give it a company name.

Easy-PC includes schematic and layout. Since the normal way to design a printed circuit board is to start with the circuit diagram, and use information derived from this to specify the component outlines and the routing for the pcb, I have carried out the process in this order to test the system in a realistic way.

In order to do a fair test I chose a circuit of just sufficient complexity to demonstrate the features. The chosen circuit, as it appeared on the screen, is shown in **figure 1**. Its purpose is to compare two frequencies, and give a clear visual indication of beats between them.

This circuit should be able to be routed as a single sided pcb, perhaps with a small number of wire links, a typical requirement for a small project. The LEDs can be surface mount on the component side, giving at least a first indication of how easy it is to use the system for surface mount designs.

Drawing the schematic

The chapter on "Getting Started" (page 23 of the manual) suggested that I start a new schematic, which I did. Placing components on the screen was intuitively obvious in its operation. Simply click on the "add component" tool, which displays a tool tip in the way standard for windows programs, and a dialogue box appears, as shown in **figure 2**. It was easy enough to select libraries which contained the relevant components and place them on the pcb. The option to view the component, added in version 2, was for me a valuable addition.

As it turned out, one of the components needed, the LM311, did not appear in either the expectable library names, nor in the library listing in the manual. The next task was to generate a new component. First it was necessary to find out if the necessary schematic and layout symbols already exist, which they did. Opamp5 and DIL8 seemed to be correct.

It is vitally important to select [file], [libraries], {component} on the menus and set the active symbol and component libraries. I needed the IC layout and schematic libraries, and created a new library for this and any other special components which may be needed. If you do not select the

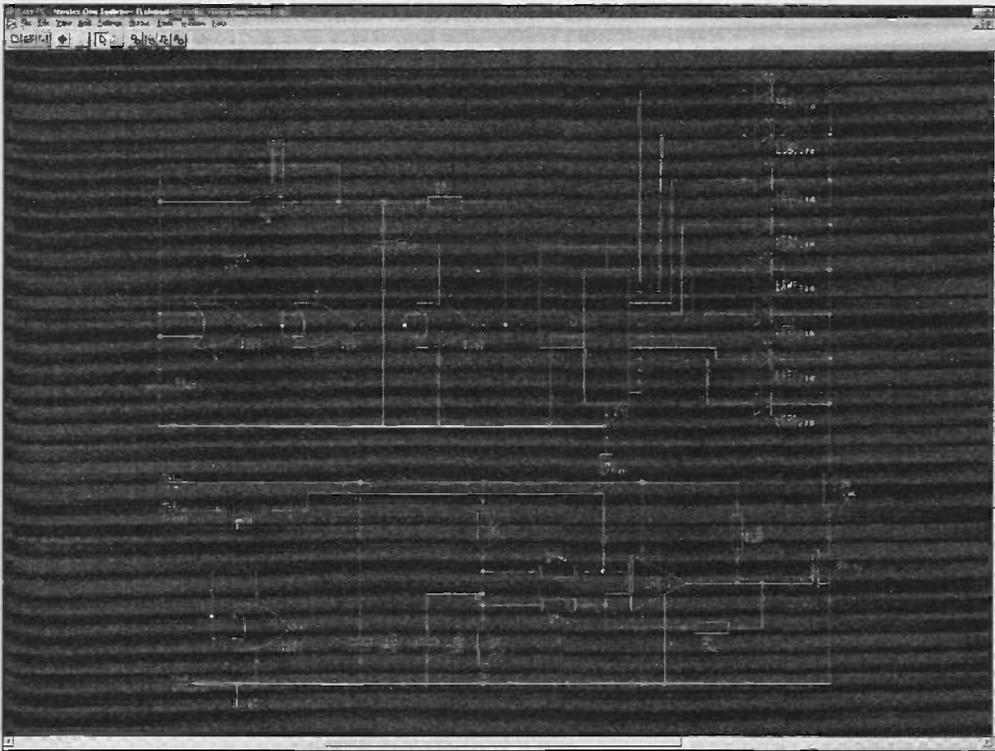


Figure 1: The schematic as it appears on screen. The light-on-dark is clearer on screen than in print

libraries at this stage, then the component edit dialogue box will only offer you the choice to select component libraries in the directory where the current design is saved.

The component creation process is straightforward and logical. You select [edit], [assign pins], then click on a pin on one symbol, and its corresponding pin on the other one. In this way schematic pins are mapped to layout pads. **Figure 3** shows the component creation window.

Once the components have been placed in a logical order on the schematic page, they need to be connected together. Connections can be added by clicking on the Add Connection button on the tool bar, double clicking on a component connection, or hitting F2. Right click and Finish on the pulldown menu completes the connection, as does double clicking on the end point.

Version 2 adds the option of double clicking to route, in so-called stitch mode. This may be selected by choosing the Settings menu then clicking on preferences. Other options added in version 2, include auto-pan on the pcb layout, and dynamic optimise.

It is also possible to alter the width of connection lines, as can be seen by the thicker ground tracks in **figure 1**.

I could not find a way to move the component value separately from the component number, but the dialogue box to display the other component parameters is self-explanatory. It is shown in **figure 4**.

Another component had to be generated: a surface mount LED. Editing the layout symbol to include a polarity indication, and storing it in a new library afterwards, presented no problems.

Finally, I needed some input and power connections. An ordinary pad with a wire soldered to it is suitable for a project of this nature, so I searched for one in the library. For some reason I failed to find it immediately, so I decided to leave it until later, in order to see the rest of the

software in action as soon as possible. This proved to have been an error of judgement, as will be clear later.

A useful function added in version 2 is the ability to copy a section of circuit diagram and duplicate it. A dialogue box offers the choice to merge named nets, so that power, ground and suchlike can be common, but the signals can be separate. Components are automatically renumbered appropriately. One minor example of where this would be useful is in the design of a stereo amplifier.

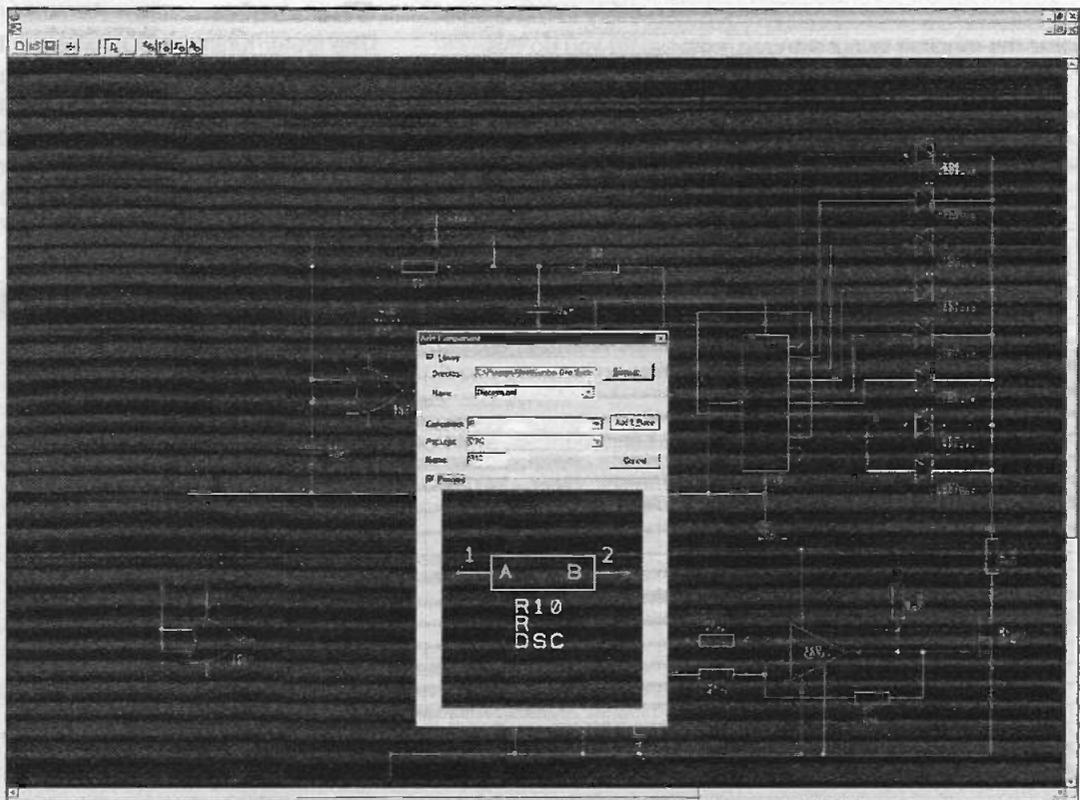


Figure 2: The "Add Component" dialogue box, showing the component preview

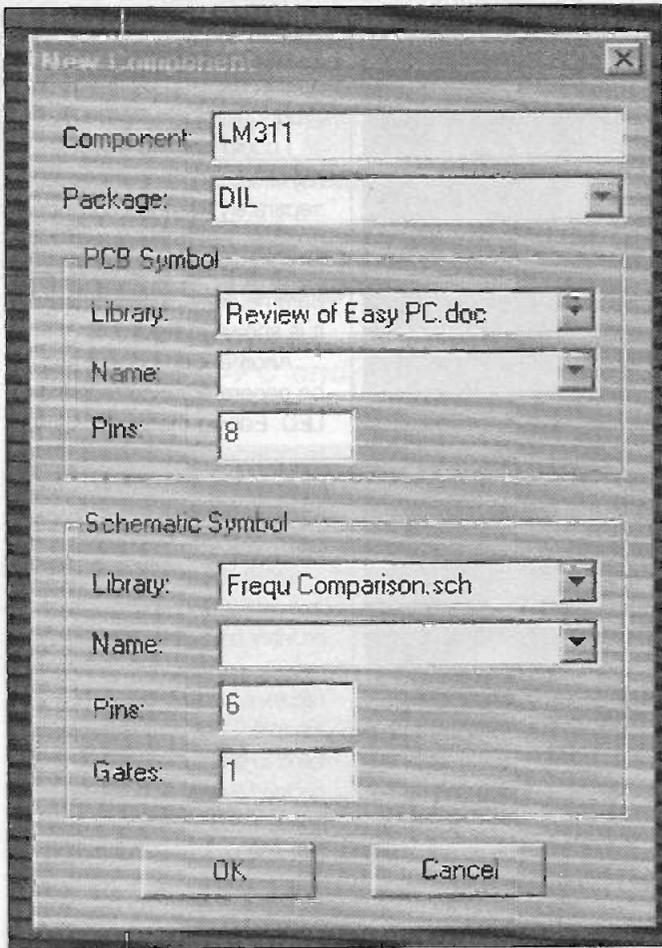


Figure 3: The new component creation dialog box

PCB generation

When the schematic was drawn, clicking on [tools] [convert to pcb] transferred the schematic information to a pcb outline shapes in a pcb layout window. It is necessary to make sure that the required layout symbols exist before you do this, otherwise the system will continually ask you for a library name for the given component. ESC does cancel the operation, but it is not intuitively obvious.

The components are initially placed as shown in figure 5.

I drew a board outline and proceeded to place the components. The LEDs were to be mounted on the copper side of the pcb, and they were transferred to that side all at once by selecting them and using the flip command.

At this stage there was a long pause. The ratsnest lines refused to admit to being attached to the LED pads, and the helpful people at Number One Systems explained that the sequence of operations which I had carried out had triggered a problem which only a few people had experienced, and which was being fixed. As things were, I could not route to the pads, and the autorouter would not even start.

I received update discs, but was unable to return to the layout immediately because of other scheduled work. These updates would also have been available to any purchaser for the first six months after purchase. In addition, if you register your software, Number One Systems will notify you of further updates, and offer you an upgrade price.

I used MultiRouter II to route the pcb, with good results as detailed below. When the autorouter was finished, I decided to add the power and input connections. I returned to the circuit diagram, and found the component for a single connection immediately. After adding it to the schematic I

tried to make the system update the pcb layout, but it would not do so. In order to proceed it was necessary to overwrite the existing pcb layout in the project, and lose the board outline, the component placement, and all the routed tracks.

I did discover a workaround. The existing layout was first saved under a new name, then the pcb was overwritten. The added components were simply copied from the new unrouted pcb to the existing routed one, and when they were pasted on to the layout a dialogue box popped up offering the option to merge nets of the same name. It might not be possible to cope with changed connections in this way, but the added components were netted to the correct points.

One other minor niggle (a problem I have encountered with other CAD packages in the past) is that, when moving a component name, there is no indication which component on the layout it refers to.

I noticed a couple of particularly useful features: When re-starting the program, it restores the screen to the state it was in before the program was closed, which few programs trouble to do. Also, in the pcb editing mode, simply hitting the "A" key will zoom the pcb to fit the window.

Technology

Manual routing of the board is carried out by double clicking on a net line, routing the track where it is needed, then double clicking again at the end. The corners may optionally be mitred while routing, or alternatively this can be done later by simple clicking and dragging the cursor on the corner to be mitred. The intelligent track segment drag makes it relatively simple to move a track aside to fit another on through a limited space.

The track width used is controlled by a technology file, which specifies a maximum and minimum track width for different net classes. Normally the only two net classes needed will be power and signal.

The router

The router runs in a DOS window. I am informed that the version currently available will not run under Windows NT, but that the version which will run under Windows NT will be available very soon, perhaps by the time this review appears.

While the router is running, the display of its progress is simply a list of success percentages. However, this may speed up the process.

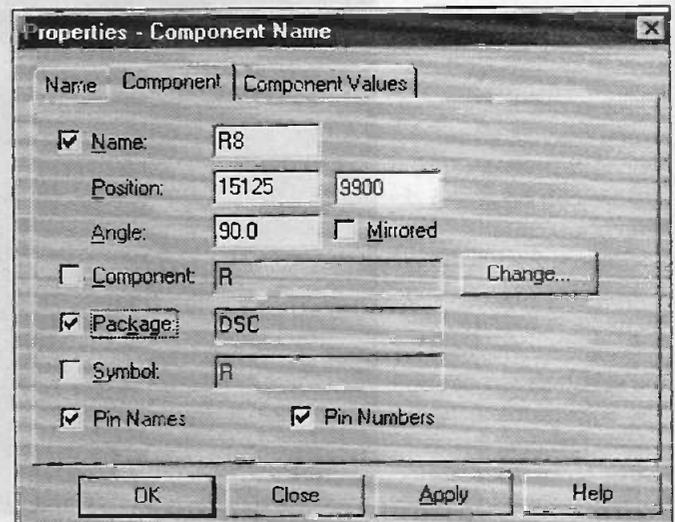


Figure 4: The comprehensive component properties dialog box

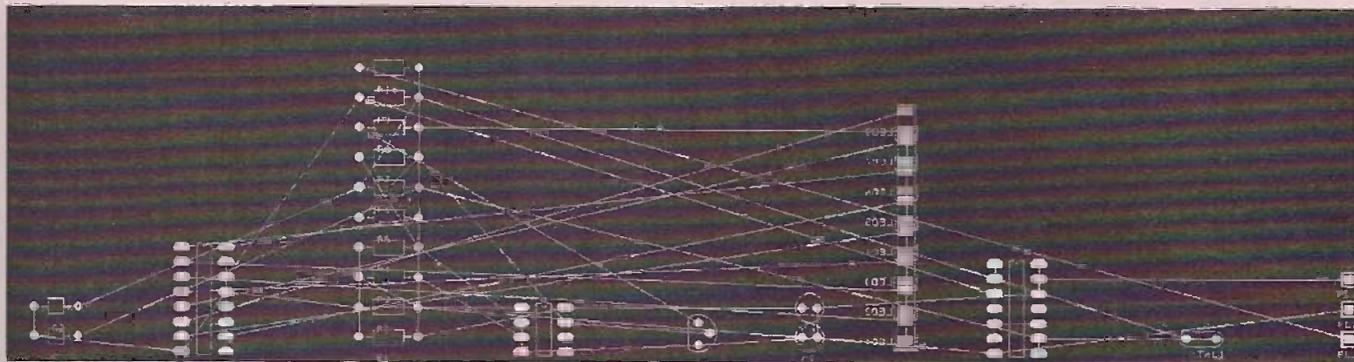


Figure 5: The components positioned after using "Translate to PCB" from the Tools menu in the schematic editing window

It is a rip up and retry router, and therefore it is useful to allow it to use multiple passes. It has its good and bad points - in common with other autorouters I have seen, it appears impossible to prevent it from connecting to pads in illogical directions occasionally. On the other hand, it demonstrated a surprisingly high completion rate on a number of tests, and did succeed in routing the pcb completely as a single sided board. I would judge this board to be exceptionally difficult to route completely as single sided, and would have expected typically two wire links to be needed.

The routed pcb does exhibit some tracks which leave the pad in an illogical direction, and some manual tidying would be needed for this design. Nevertheless, after the manual tidying has been done, the time taken to route the pcb will still have been much less than to route it all manually.

One function which I could not make work after a number of tests was that of fixing track segments so that they would not be re-routed by the autorouter. Although, when I started the routing, I had fixed several tracks, and made sure that only the bottom layer was present in the design, and that the single sided technology file was loaded, the process of autorouting always generated a new layer on which all the tracks were routed.

Layer 1, as it was always named, was a top layer, and always coloured light blue by default. Tracks which I had fixed on the bottom layer were transferred to this new layer and normally re-routed. Subsequent attempts to run the router to complete the board would result in 100% completion because the bottom layer was used as well.

All this must have been an effect of trying to route the pcb single sided, (not a simple thing to do) because routing it double sided gave 100% completion in two steps, without any fixed tracks being moved. Possibly the single-sided test was a little unfair, but it is worth knowing about because so many small projects are single sided.

One thing which you cannot do, as yet, is to exchange gates or connections on the layout, and automatically update the schematic to reflect this. This feature, called back annotation, is under development for future updates. At present, the function must be carried out manually. However, if an integrity check is carried out, differences will be listed, giving a checklist for schematic revisions to match the layout.

Plotting the output

Easy-PC can provide outputs in several formats, including the essential Gerber format for use with photoplotters.

Although there is no explicit means to step and repeat designs, or to tile different boards to make the best use of the available film area, if the different boards are plotted with appropriate offsets so that their positions do not overlap, then a tiled Gerber file can be produced by concatenating all the files, remembering to remove the M02 (which turns off the plotting machine) command from the end of all files except the last.

Conclusion

Easy-PC is a pcb design package which works well. Its second greatest virtue, from my point of view, is that it is relatively easy to learn, and seems to work in the way that a reasonable person would expect. In reviewing a program, it is sometimes difficult to learn sufficient about it, in the time available, to provide a fair assessment of its capabilities. In this case, although I know that there are capabilities which I have not covered here, I believe it has been possible to give a fair picture to enable comparison with competitive products.

The very strongest aspect of the system is MultiRouter II. It does a better job of routing than any other I have seen to date, excepting very expensive professional ones.

Please note, by the way, that the circuit used to test the program has not been prototyped. It has been designed to be workable, but constructors should not depend on its functioning as drawn. It may perhaps be developed into a project in a future issue.

Because of the timing of this review, it has not been possible to investigate some technical points in sufficient detail. By next month I expect to have investigated its handling of ground planes, how well it copes with more intensive surface mount work, symbol creation, and anything else which comes to light under further detailed testing.

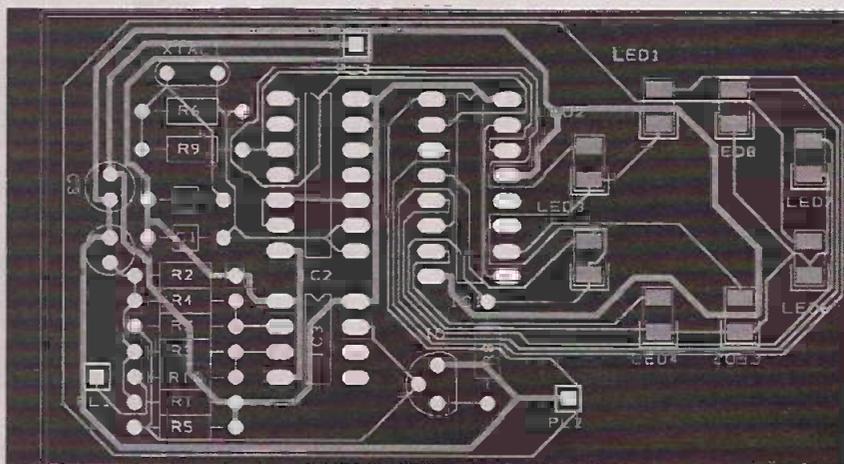


Figure 6: The pcb after completion by MultiRoute II

REVIEW

Vulkan Gas Powered Soldering Iron

A neat and handy portable soldering iron.

**BS Manufacturing Ltd., Strawhill Industrial Estate
Carlow, Ireland. Tel. +353 (0)503 41340**

Fax. +353 (0)503 40363.

Soldering iron: £35 + VAT

Soldering iron + accessory kits: £40 - £50.

It can sometimes be useful to have a portable soldering iron to hand. There are two approaches to portable power: battery power and gas power. Given a straight choice, I would normally pick gas-powered, so it was with some interest that I received this tool to review.

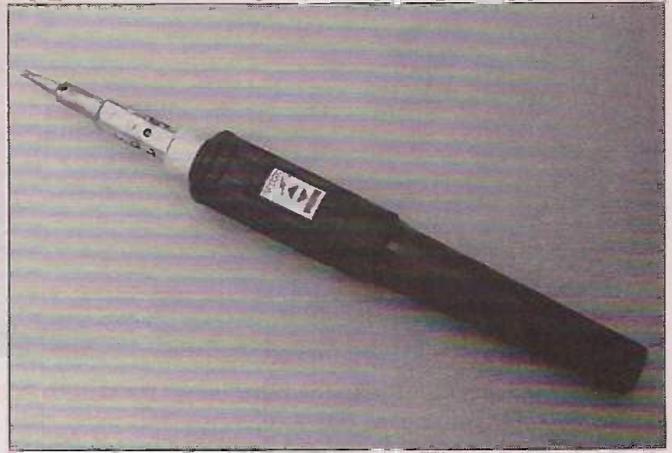
The iron has a tough plastic handle and cover, and is supplied with one soldering bit and one gas torch accessory. It also has a neat stand which clips together, and which contains a sponge for tip cleaning.

To try it out in a realistic situation, I threw it into my luggage when I went to stay with a friend for a couple of days. I also packed a standard cigarette lighter refill, some solder, and a Swiss army knife in my toolkit.

There is always something that needs repair just waiting for a visit from someone who can do the repair (you have no doubt noticed this). In this case it was the battery charger for an old analogue cellular telephone which had given up the ghost. It would sometimes work if you put a rubber band around the power connector, which indicated the problem. The low voltage power socket of the battery holder had broken from its printed circuit board and needed to be re-soldered.

Matchless

I unpacked the soldering iron and asked my friend to find a match to light it while I filled it with gas. Once the iron was fuelled I checked how to turn it on, and realised that I did not need the match. The ON valve also operates an igniter, so that as long as you wait for about half a second to let the gas reach the tip, it will ignite on the first try and start to react with the



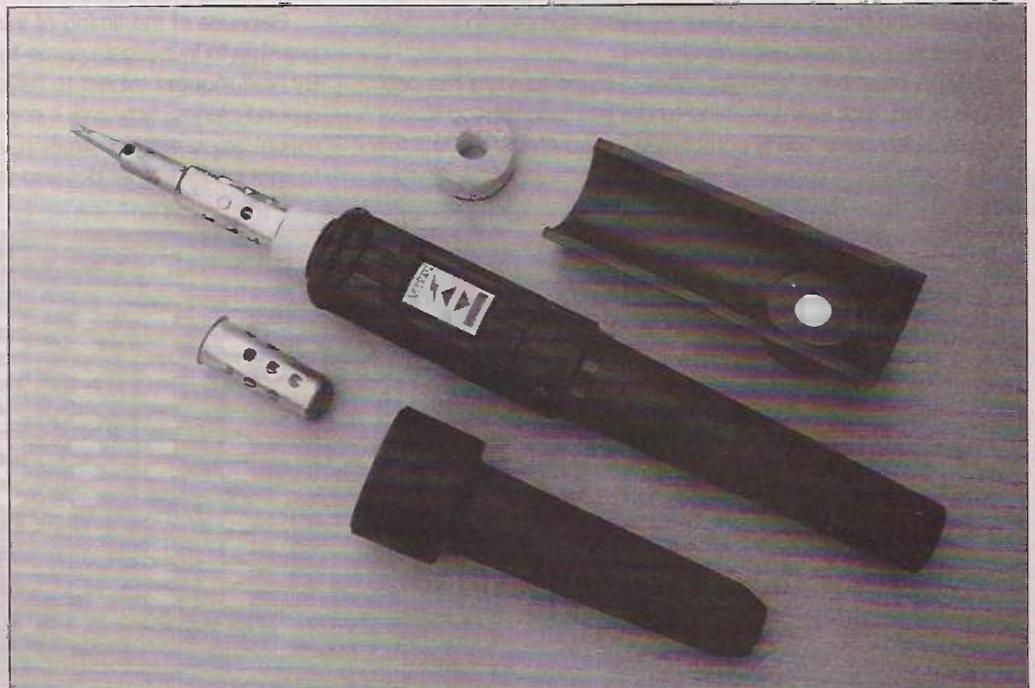
catalyst. There is no naked flame, the reaction is carried out at a lower temperature in a catalyst inside the hollow base of the soldering tip.

On the opposite side of the iron from the on-off valve is an adjuster to control gas flow rate, and hence the temperature. There was plenty of heat for the small soldering job on minimum setting.

Subsequently the iron has performed well in other tasks, including a television repair. Temperature cycling had crystallised the solder joint on one terminal of the line output transformer, and the pin was arcing to the pcb. A little extra heat was needed for this task, but I still used only 30 percent of the soldering iron's maximum available power.

The flame gun gives a fine flame, though I have not yet had a use for it. A number of extra accessories may be purchased, and I suspect that I shall be looking at the hot-blow accessory for heat-shrink sleeving.

The only criticisms I had of the unit we were given were that the stand could overbalance if you were clumsy with it, and that the parts of the iron could become separated because there was no proper carrying case or bag. There is in a set with a carrying case and additional accessories. All in all, this is a very useful tool.

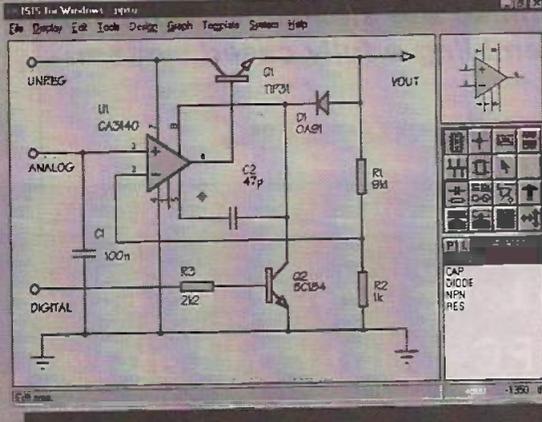


The soldering iron with flame nozzle, protective cover and stand cradle (which rests in a metal frame)

PROTEUS

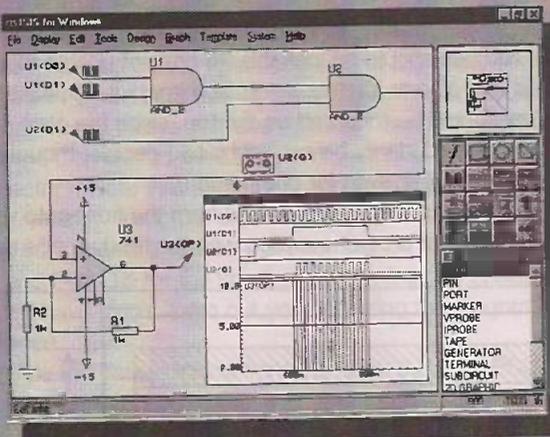
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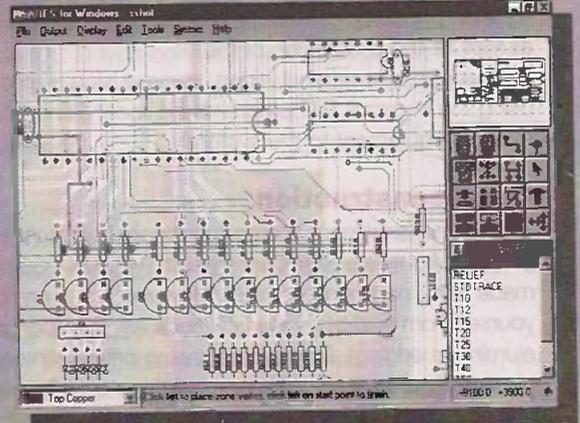
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PC Controllable 4-Line Dot Matrix Display

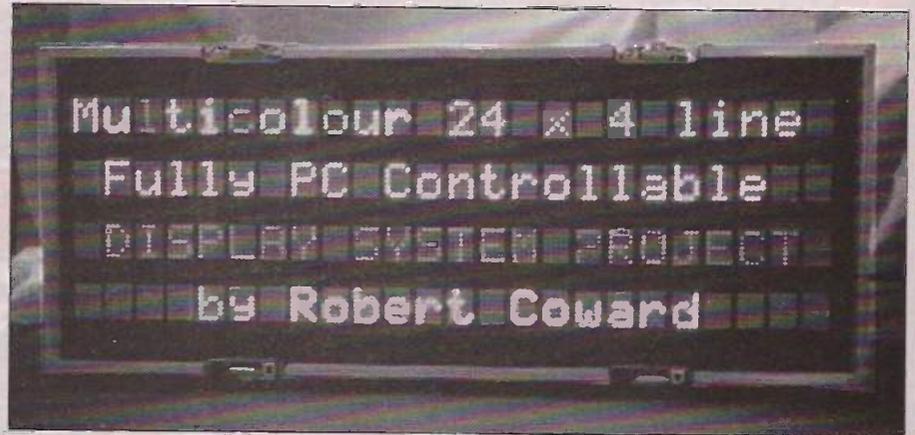
This third and final part describes how to make the enclosure and metalwork, wiring up the control panel and assembling a fully cased system.

Robert Coward

This is the third and final part of this three-part series describing how to build a professional quality 24-character by 4-line dot matrix LED display system. In part 1, the various system components were described, and detailed instructions were given on constructing the QUICC-IDM control board. In part 2, last month, advice was given on choosing suitable power supplies, constructing various cable assemblies and assembling a working prototype system. In this part, as well as the description of the enclosure hardware and wiring, some advice is also given on using the in-circuit PIC programming facility, and interfacing external equipment to the system.

Case construction

The original enclosure is a professionally built flight case, available from Five Star Cases (tel 01945 474 080) as a ready made item, part number 6637. However, you can make a case yourself from suitable materials (such as plywood and aluminium edging). Diagrams showing critical dimensions are given in figures 6-9. While the height and width are fairly critical in order to accommodate the panels, the depth is less



so, and was chosen to accommodate the power supplies and QUICC board comfortably, while also allowing plenty of room for future expansion. The case has a "rack" format, where the front and rear faces are removable; the former so you can see the displays, the latter so you can service the system. The rear panel catches should be lockable, to prevent unauthorised access and also to identify which face is which! At least two handles should be mounted on the top, since the case is quite heavy; it should ideally be carried by two people, though two handles are easier even for one person.

The display panels are mounted from the front onto vertical metal struts that are not supplied with the ready-made case.

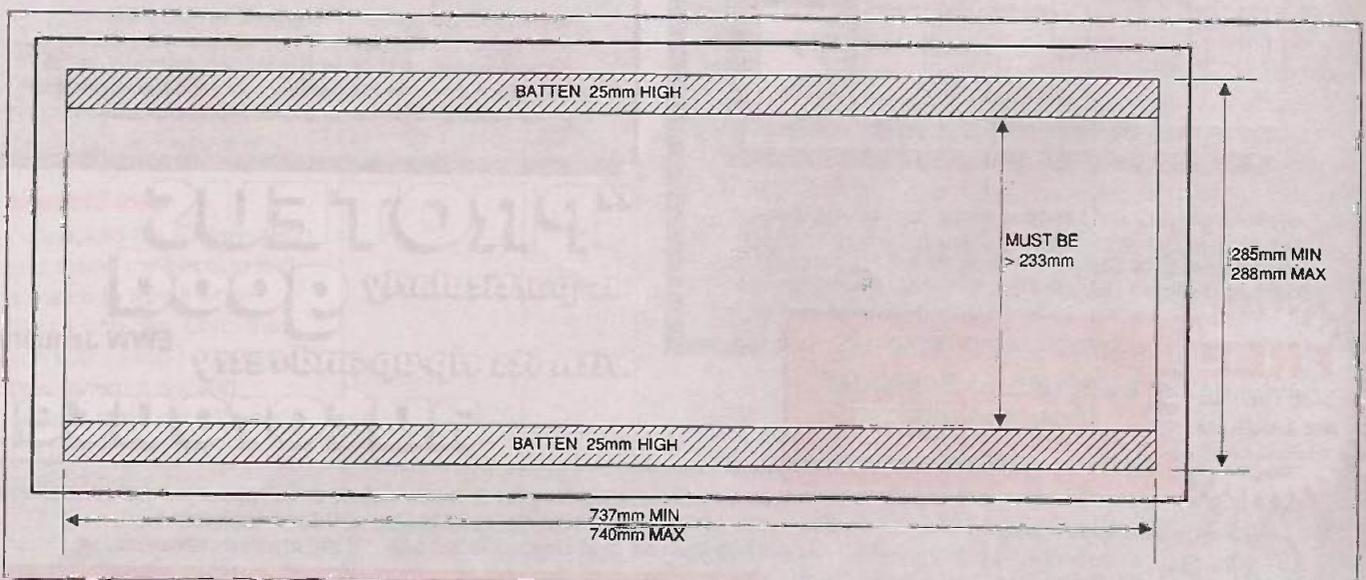


Figure 6: the front view of the case, showing the critical inner dimensions

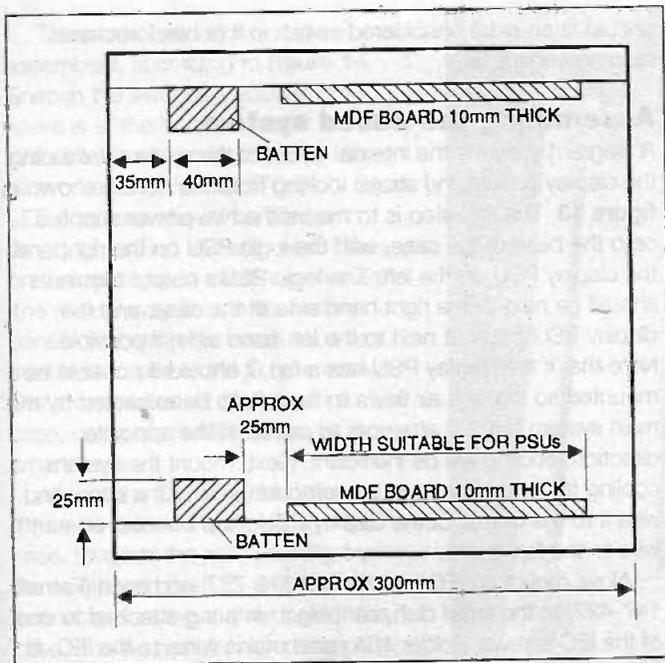


Figure 7: the cross sectional view of the case showing the battens and MDF boards

These screw into wooden battens fitted along the top and bottom edges of the case. Figure 10 gives accurate dimensions for constructing your own struts. You will need four in total, and they should ideally be made of steel, though 2mm thick aluminium will suffice. Ideally, the display panel mounting holes should be M3 threaded inserts, so that the panels can be screwed in from the front; otherwise, you can drill M3 holes and mount using nuts at the rear. Note that the extra holes between the display mounting holes (which can be used for mounting a filter) are not orthogonal, and are slightly closer to the top than the bottom.

All switches, LEDs and connectors are brought out to two recessed dishes on the right hand side of the case; see figures 11 and 12 for cutout dimensions. The small dish carries the IEC mains inlet and optional neon indicator while the large dish carries the LEDs, switches and D type connectors. Note that some LED and switch positions are spare, to allow for future expansion. The dishes are available blank from Five Star Cases (Part number D2101K for the large one and D0941K for the small one, both finished in black), so you will have to cut them out yourself using the diagrams for reference.

Inside the case, looking from the front, the logic PSU is mounted on the base to the right, and the display PSU on the base to the left. A piece of MDF fitted to the bottom of the case provides a stable mounting platform. The QUICC-IDM board is mounted on the underside of the top of the case, to the right hand side, also on a piece of MDF. You can either screw it in directly using woodscrews and spacers, or you could construct a suitable mounting plate (out of aluminium) with M3 spacers mounted on it to align with the mounting holes on the board.

A 12V 120mm cooling fan is mounted on the left face, extracting air out of the case. Air flows in through gaps between the display panels and battens along the top and bottom edges, providing cooling to the panels themselves and the power supplies inside the case. The fan is powered from the 8V supply, so it shuts down when the system is in standby. The system does not require a high airflow (around 50cfm), so a very low noise fan can be used. In the prototype system the

temperature rise was less than 10 degrees C, at maximum loading (all display LEDs on). Note that since the fan is powered from 8V, the airflow and noise will be significantly less than the manufacturers' rated figures. For safety, I recommend fitting fan guards to both outer and inner faces. On the ready made case an external grille is already fitted, which doubles as a mounting plate for the fan.

Provision is made for mounting a filter to cover the displays; this should have a non-reflective surface, and be very light, to prevent excessive attenuation of the display brightness. A gap of at least 1cm should be left along the top and bottom edges to ensure adequate airflow into the system. The filter can be mounted on spacers screwed into the extra mounting holes provided on the struts, which fit through the large holes in the front of the display panels. To minimise internal reflections, it should be mounted as close to the LED modules as possible.

Cable assemblies

The control panel needs extra cable assemblies that were not required to get the prototype system working. These are an RS232 serial lead (9-way D type), auxiliary power lead (15-way D type), and the reset button and standby switch assemblies. You should already have the LED leads (covered in part 1), and the 25-way Expansion Bus D type should already be attached to the display ribbon cable.

Serial cable assembly

The serial cable assembly consists of a 9-way ribbon cable, one end terminated in a 9-way male IDC D type connector which fits on the panel, and the other end terminated in a 9-way female IDC D type connector which plugs into the IDM board. The cable length should be approximately 30cm.

Parts required:

- 9-way IDC-male D type - RS 472-613 or Farnell 460-140
- 9-way IDC female D type - RS 472-641 or Farnell 460-187
- 9-way IDC ribbon cable - RS 360-093 (10 way) or Farnell 297-276

Auxiliary Power Cable assembly

The auxiliary power cable assembly is simply a 15-way female solder bucket D type connector (RS 473-919 or Farnell 315-321), soldered to wires which will be connected to the 5V, 24V

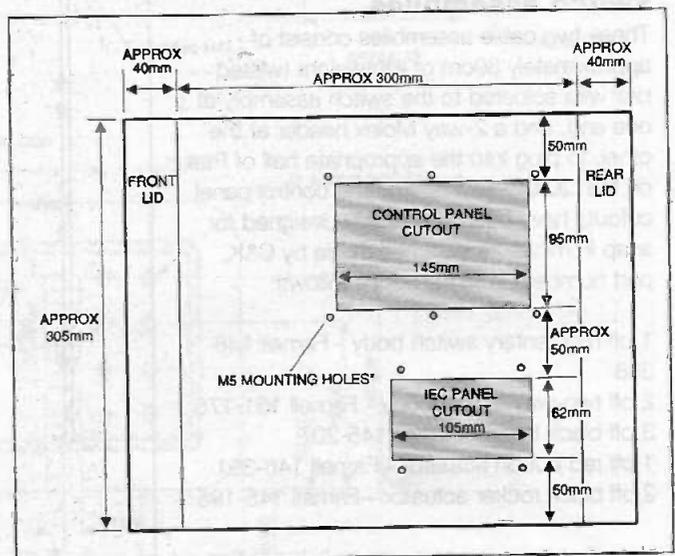


Figure 8: the right hand end of the case showing panel cutouts. Use the dishes as templates for positioning the mounting holes

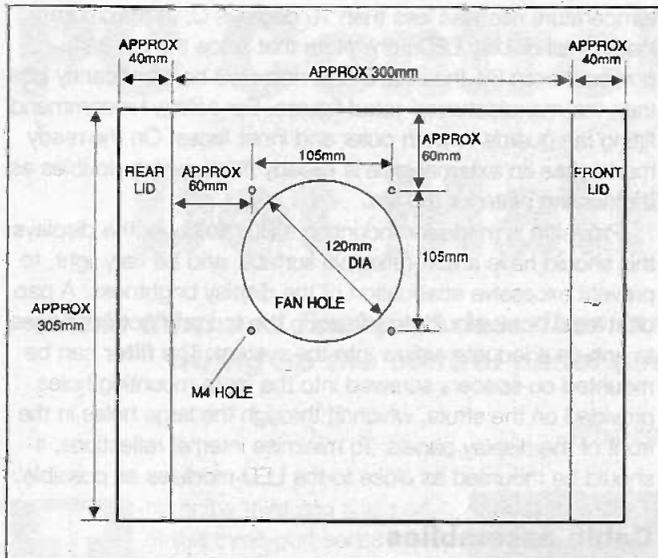


Figure 9: the left hand end of the case, showing the fan mount. Extra mounting holes may be required for some types of grilles

and 0V lines on the logic PSU. As several pins are connected to each wire, it is advisable to solder them as "bus bars", by laying each pre-tinned wire along the pins, and soldering each pin to it in turn. Note that, for this reason, insulating sleeving cannot be fitted over the wires. The pin connections are as follows:

24V - pins 1, 2 and 3

5V - 6, 7 and 8

0V - all other pins (lay along bottom row, and solder bridge to pins 4 and 5)

This arrangement ensures that it would be very difficult to short the 5V rail directly to 24V, without involving 0V as well. The logic PSU should be short circuit proof, but accidentally connecting 5V to 24V could damage it, and all the connected 5V circuitry. Note that reasonably thick wire should be used to avoid voltage drops, and that the wire length should be approximately 30cm.

Reset button and standby switch assemblies

These two cable assemblies consist of approximately 30cm of lightweight twisted pair wire soldered to the switch assembly at one end, and a 2-way Molex header at the other, to plug into the appropriate half of PL4 on the QUICC-IDM board. The control panel cutouts have been specifically designed for snap in miniature switches made by C&K, part numbers from Farnell as follows:

- 1 off momentary switch body - Farnell 146-388
- 2 off two-way switch body - Farnell 151-176
- 3 off black bezel - Farnell 145-207
- 1 off red button actuator - Farnell 146-391
- 2 off black rocker actuator - Farnell 145-195

Note that there is one spare switch position on the control panel, reserved for future expansion. To produce a neat finish, you

should fit an extra unsoldered switch in it (a black rocker is recommended).

Assembling the cased system

A diagram showing the internal layout of the system (excluding the display panels and struts) looking from the front is shown in figure 13. The first step is to mount the two power supplies onto the base of the case, with the logic PSU on the right and the display PSU on the left. The logic PSU's output terminals should be next to the right hand side of the case, and the display PSU's output next to the left-hand side, if possible. Note that if the display PSU has a fan, it should if possible be mounted so that the air flows to the left, to be extracted by the main system fan. If it attempts to pull air in the opposite direction, cooling will be inefficient. Next, mount the system cooling fan and guard(s) in the left-hand side of the case, and wire it to the output of the display PSU. Also connect an earth wire to the fan guard.

Now, mount an IEC inlet (Farnell 313-737) and neon (Farnell 147-422) to the small dish, earthing it via a tag attached to one of the IEC screws. Solder 10A rated mains wires to the IEC, fit an insulating boot, and run the wires to both power supplies, terminating them in suitable connectors. Note that an extra mains fuse must be fitted if both supplies are not individually fused internally (most switch mode supplies have internal fusing). All internal mains wiring should be rated at 10A minimum, so that it has the same rating as the highest rated IEC mains lead that can be plugged into the system, therefore being protected to the same degree as the lead. Mount the dish into the case via M5 screws, preferably black for a smart finish.

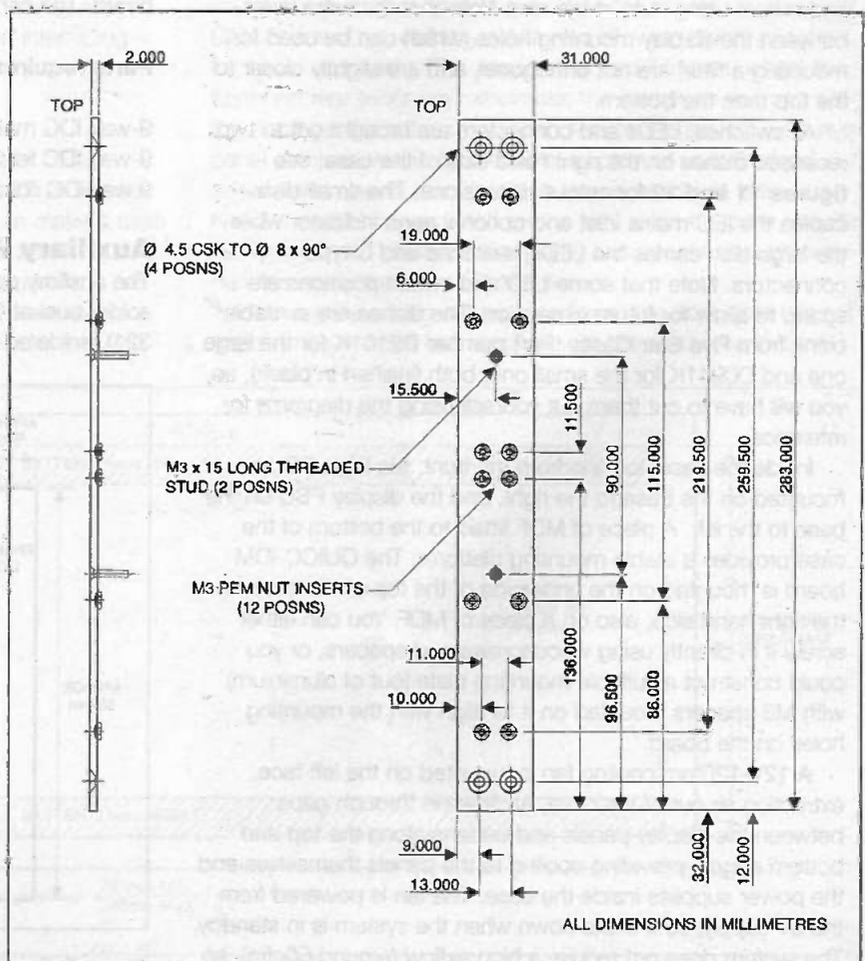
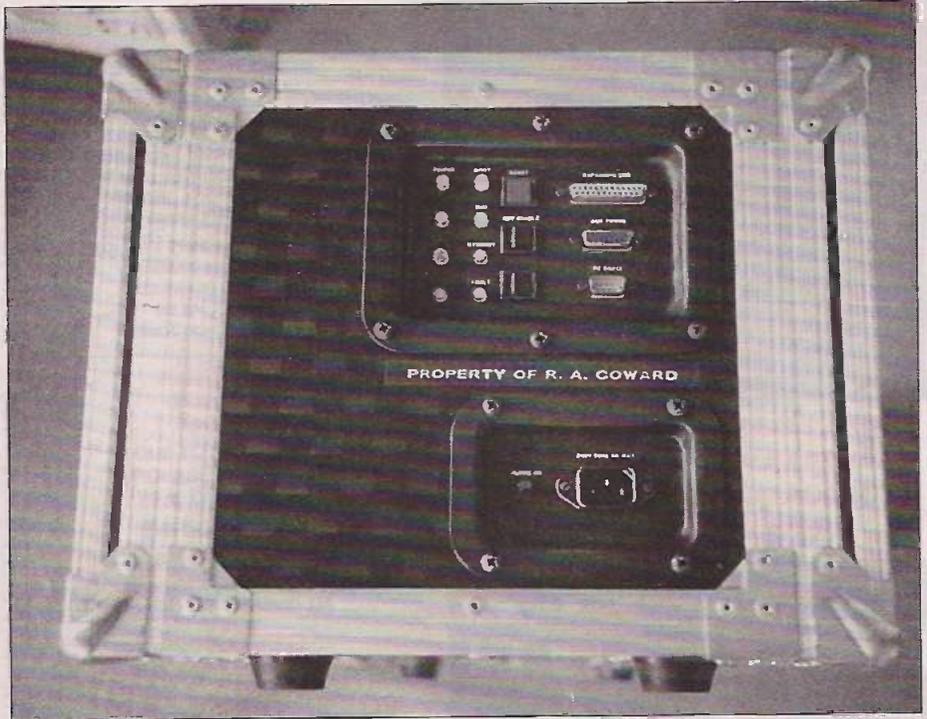


Figure 10: the display panel mounting strut dimensions

The control panel can now be assembled, according to **figure 14**. Snap in the switches, ensuring the spare is at the bottom, and fit the LEDs into suitable clips (clear Fresnel clips recommended, Farnell 170-812). Spare LED positions should be filled with empty clips. Bolt in the three D types on the appropriate cable assemblies (the male 9 way D type fits in the panel), and earth the panel via a tag attached to one of the D type screws. Once completed, fit the panel into the case, using black M5 screws for a smart finish.

Mount the QUICC-IDM board on to the underside of the top face of the case, towards the right (looking from the front), with the IDC and D type connectors facing to the back of the case. If using a metal mounting plate, earth it via a tag connected to one of the mounting screws. Plug all the LED and switch leads into the appropriate connectors on the board, and secure the cables with clips. Run the control cable from the display PSU to the appropriate connector on the QUICC-IDM board.

Now place the case on its back and place the mounting struts in their approximate positions, ensuring that they are the right way round (the display mounting holes are orthogonal, but the extra holes between the mounting holes are not, so they must align with the holes in the struts). Place the display panels into position and secure loosely using M3 screws. Looking



The control panel end of the prototype case

from the front, move the whole assembly to the left as far as possible (this ensures slightly more cool air from the right hand edge enters the system, though it is not critical). Drill pilot holes in the batten for all the mounting strut holes, and secure them into position using black japanned woodscrews.

Next, remove the display panels and attach earth wires to all the struts, linking them together. Connect all earth wires to the mains earth from the IEC inlet. Now position the three

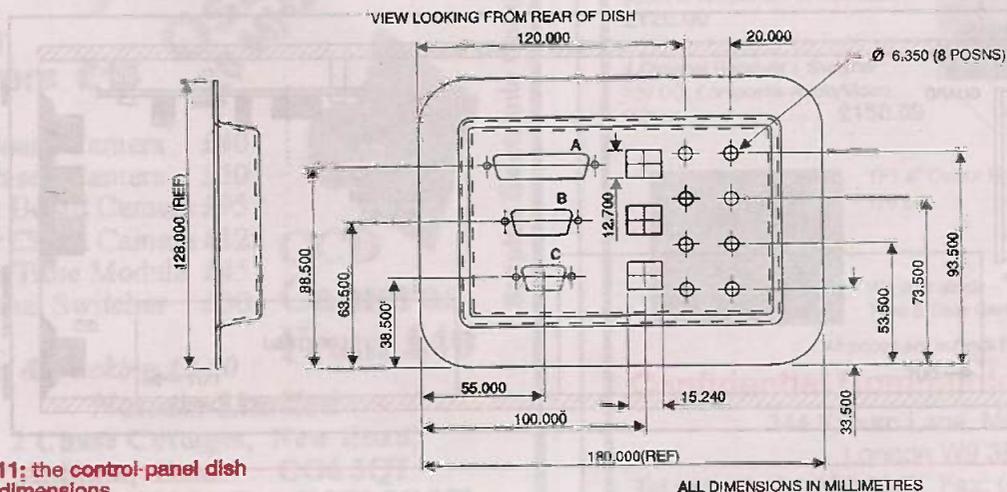
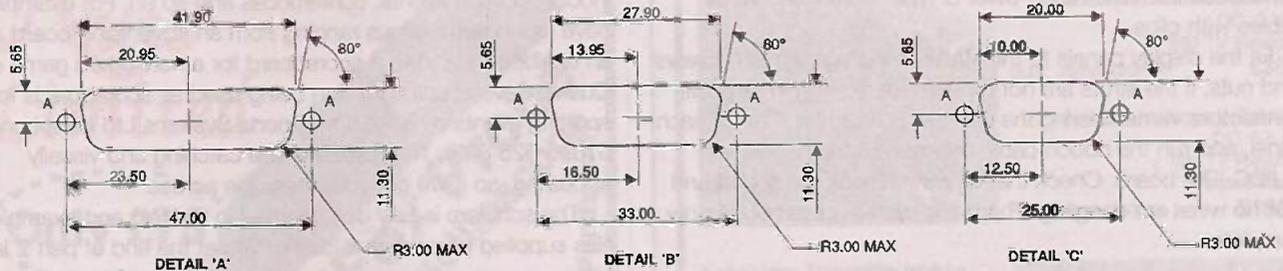


Figure 11: the control-panel dish cutout dimensions

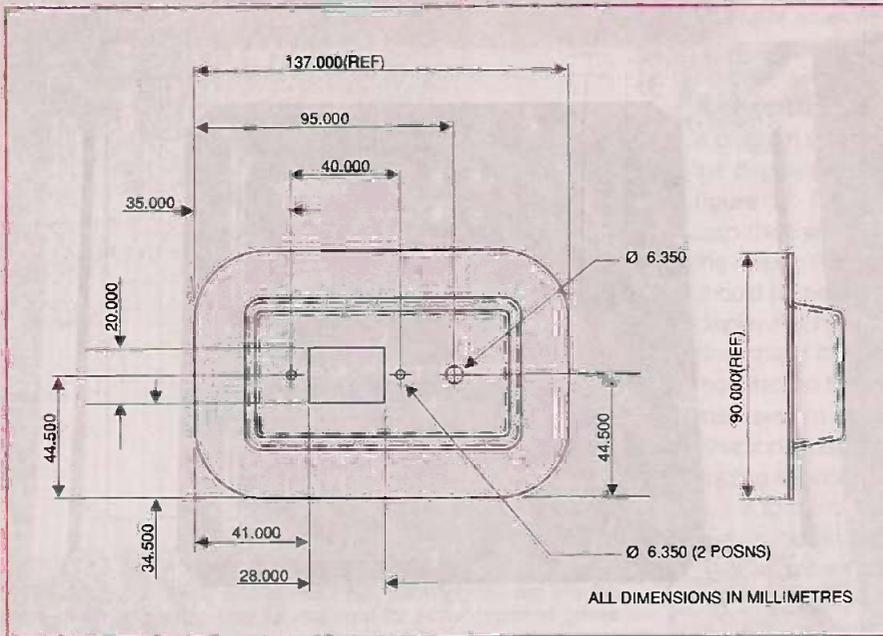


Figure 12: the mains inlet dish cutout dimensions

8V/24V cable assemblies so that each AMP connector will mate with the back of the appropriate panel (allow some slack), and run the 8V cables to the display PSU output terminals. Run the 24V cables to the 24V output on the logic PSU, along with the 24V connection from the Aux. Power D type on the control panel. Ensure that all cables are secured with cable clips.

Next, run the 5V logic supply cables to the display panels, using cable clips to secure them to the backs of the battens near to the positions of the P16 connectors on the back of the panels (allow some slack). Also connect a logic supply cable to PL3 on the QUICC-IDM board, and run the four cables to the 5V output on the logic PSU, along with the 5V connection from the Aux. Power D type. Again, secure all cables with clips.

Fit the display panels to the struts, securing with M3 screws (and nuts, if the struts are not pre-threaded). Plug in all power connectors, remembering the earth tags P13 and P14 on each panel, and run the ribbon cable between all the panels and QUICC-IDM board. Check that all connections are sound and that no wires are dangling. The basic system assembly is now complete.

As mentioned previously, the appearance of the system would be enhanced by attaching a suitable filter over the front, remembering to leave at least a 1cm gap along the top and bottom edges for cooling. Use spacers (ideally painted black) screwed into the holes between the panel mounting positions to allow the filter to be secured from the front. If the filter material is susceptible to cracking, the use of neoprene washers is recommended to reduce the stress placed upon it by the mounting screws.

Using the system

You now have a smart display unit that can be used for all kinds of purposes, such as exhibitions, quiz shows, small indoor sporting events, conferences and so on. For example, I have found applications ranging from an advertising board at an exhibition stand to a scoreboard for a networked game of Quake! Several units are also being used as scoreboards for sporting events by Mikrotime Sports Systems Ltd (telephone 01895 625 838). The display is eye catching and visually appealing, so it will get your message across.

The software is fully documented in the text and example files supplied come with it (see details at the end of part 2 last

Testing and finishing

The cased system should be tested as for the prototype system described in part 2. The only differences are regarding the Standby and Reset switches, which are now on the control panel. You should also leave the system running for a few hours at maximum loading, and check that nothing gets excessively hot internally. Unless you are using an extremely low airflow fan, the temperature rise at the outlet should be no more than 10 degrees C hotter than ambient.

The control panel should be labelled with the legends shown in figure 14, using a labelling machine (a white-on-clear or white-on-black tape would be ideal), or transfer lettering. The IEC inlet should be labelled with something like "240V 50Hz 5A MAX" and the neon with "MAINS ON". If using transfer lettering, lacquering the panels is recommended for durability.

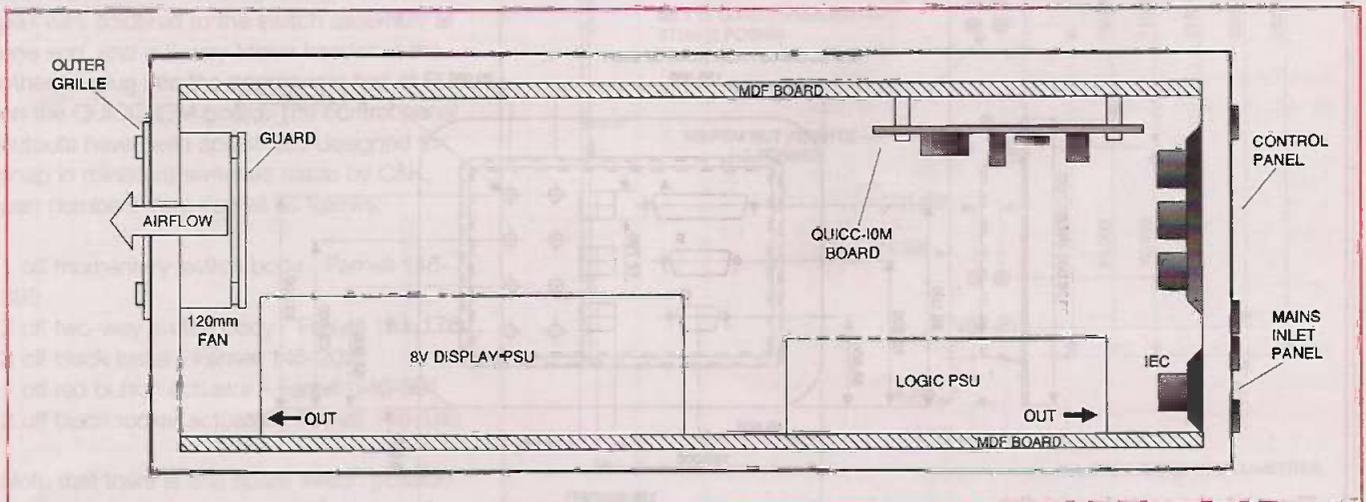


Figure 13: layout of the major components (excluding the display panels and struts), front view, with the panels, struts and battens removed.

AN 5150	= 299	STR 44115	= 475
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AN 5521	= 100	STRD 5441	= 400
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CNX 62A	= 080	STRM 6559	= 900
CNX 82A	= 060	STRS 5701	= 1700
CNX 83A	= 080	STRS 5717	= 550
CNY 70	= 350	STRS 5741	= 600
HA 11377	= 250	STRS 5941	= 700
HA 11744	= 650	STRS 6307	= 450
KA 2101	= 100	STRS 6309	= 550
KIA 6289H	= 200	STRS 6525	= 1350
LA 3180	= 120	STRS 6545	= 725
LA 4120	= 270	STRS 6707	= 800
LA 4270	= 300	STRS 6708	= 550
LA 4505	= 220	STRS 6709	= 850
LA 7225	= 250	STRZ 2152	= 1000
LA 7830	= 090	STV 5180D	= 400
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LM 1881N	= 375	STV 2110B	= 685
M 29381	= 1500	STV 2118A	= 1000
M 71081	= 610	STV 2118B	= 1085
M 523075P	= 900	STV 2145	= 400
MB 8719	= 360	STV 2151A	= 950
MDA 2050	= 350	STV 2160	= 500
MEA 2050	= 250	STV 8224A	= 450
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SAA 1250	= 250	TA 7280P	= 190
SAA 1293-3	= 515	TA 7318P	= 490
SAA 1293A-31TT	= 850	TA 7898AP	= 400
SAA 3004P	= 400	TA 8216	= 300
SAA 7000	= 550	TA 8218N	= 500
SAA 9057	= 475	TA 1170S	= 135
SAF 1039P	= 590	TDA 2579A	= 210
SMR 4000	= 825	TDA 3502	= 360
STK 441	= 980	TDA 3780	= 500
STK 463	= 850	TDA 4505M	= 450
STK 4046/v	= 1200	TDA 4944	= 175
STK 4151/2	= 850	TDA 7256	= 400
STK 4162/2	= 790	TDA 8218	= 300
STK 4843	= 2100	TDA 8740	= 500
STK 5481	= 470	TDA 8880	= 500
STK 7233	= 550	TEA 2114	= 250
STK 730-060	= 845	TEA 5114	= 200
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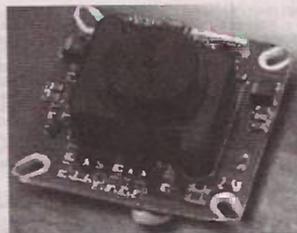
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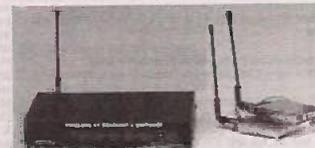
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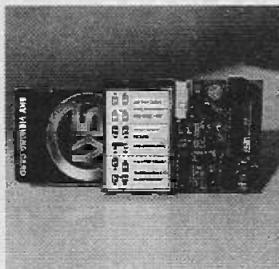
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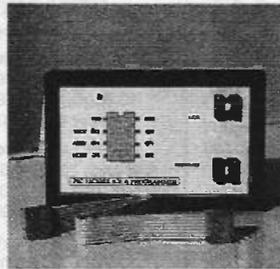
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month), so no further discussion is given here. If you are using a low performance PC, then QDSL is your best bet. To familiarise yourself with the language, have a look at the demonstration file DEMO1.DSL, which shows many useful techniques that you can apply to your own scripts. For power users, WinDSL is a more user-friendly choice, and it can output QDSL scripts if you want to subsequently run with QDSL. Note, however, that in some cases manual touching up may be necessary.

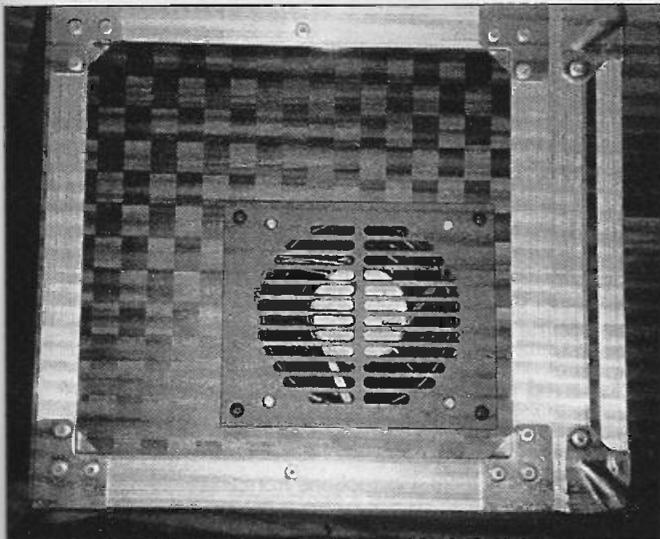
A standard computer IEC mains lead should be used to power the system, fused at 5A max. Lower rated fuses should not be used, as they may eventually blow due to the power supply inrush currents. The serial cable can be the same one that you used to test the prototype system (reversed or "null modem" for DTE and straight through for DCE).

If you plan to leave the system unattended, you can use the automatic standby feature to save power when the system is not needed. QDSL fully supports this and allows you to define a number of "start" and "stop" times, using the PC's real time clock. Note, however, that the system still consumes a small amount of power even in this mode, so it should be turned off fully at the mains if it is not going to be used for extended periods.

Note that you should not run the system while the front cover is attached, since there will be very little cooling airflow, and it could well overheat (you will not be able to see the displays, either!). Even in standby mode this is not recommended, since a small amount of convection cooling is desirable to prevent the logic PSU from running excessively hot. If you run the system with the back cover removed, the top edge of the case will get quite warm, as the panels will only be cooled by convection; again, this is not recommended, except for fault finding.

In-circuit PIC programming

Since the existing PIC firmware is not copy protected, you may wish to make modifications for your own use, or to write new code from scratch. To facilitate this, you can program the device in-situ, without having to remove power from the board. To do this, you connect a programming cable between PL5 and your programmer, taking care to remove the link from PL9 beforehand. The pinout of the cable, with the corresponding connection to the programmer's DIL socket (assuming an 18 pin device) is as follows:



The fan mounting end of the prototype case

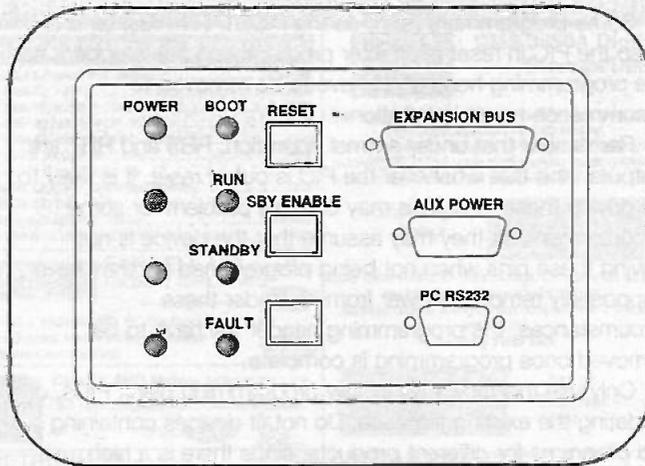


Figure 14: control panel assembly and labelling

PL5 pin 1 (+5V) - do not connect
 PL5 pin 2 (RB6) - programmer pin 12 (clock)
 PL5 pin 3 (RB7) - programmer pin 13 (data)
 PL5 pin 4 (MCLR) - programmer pin 4 (Vpp)
 PL5 pin 5 (0V) - programmer pin 5 (Vss)

You can connect both commercial programmers (such as the PICSTART Plus) and home-brew programmers to this header, providing they conform to the serial programming specification outlined in the Microchip data book. However, there are some important points to note:

During programming, a high (12.75V) voltage is applied to pin 4 of the header, and in turn to the reset (MCLR) pin of the PIC. This will cause approximately 18mA current to flow through diode D2, which will not cause any problem, unless the programmer cannot supply this much current. **However, if the reset button is accidentally pushed during programming, up to 60mA could flow, which will be far more likely to overload the programmer, and will cause programming to fail.** For this reason, you should not push the button while programming.

You must remove the link from PL9 during programming, otherwise programming will fail because D5 will drop the voltage to a lower level, and U7 could be damaged. To force yourself to do this, use a programming cable with an 8-way Molex header. Do not connect anything to pins 1, 2 or 3; the remaining pins are as described above, but offset by 3 (so pin 3 becomes pin 6). You will find that in order to fit the cable, any link from PL9 has to be removed beforehand.

The RB7 port is also connected to the "Boot" LED, which doubles as a handy programming indicator. However, if the programmer cannot provide the 10mA drive current and maintain reliable logic thresholds, you may have to disconnect the LED via link PL10.

The RB6 port is also connected to the PC's receive line, so during programming, garbage will be sent down the line. This should not be a problem unless QDSL or WinDSL is currently running, where they could report comms errors. For this reason, it is advisable to always exit these programs before starting programming.

To prevent possible latch-up in the QUICC-IDM circuitry or the programmer itself, ensure that both devices have power before connecting them together. To prevent ground loop currents, it's also advisable to keep at least one power supply isolated from mains earth.

Some programmers (such as the PICSTART Plus) tend to keep the PIC in reset even after programming has stopped, so the programming header will have to be removed to recommence normal operation.

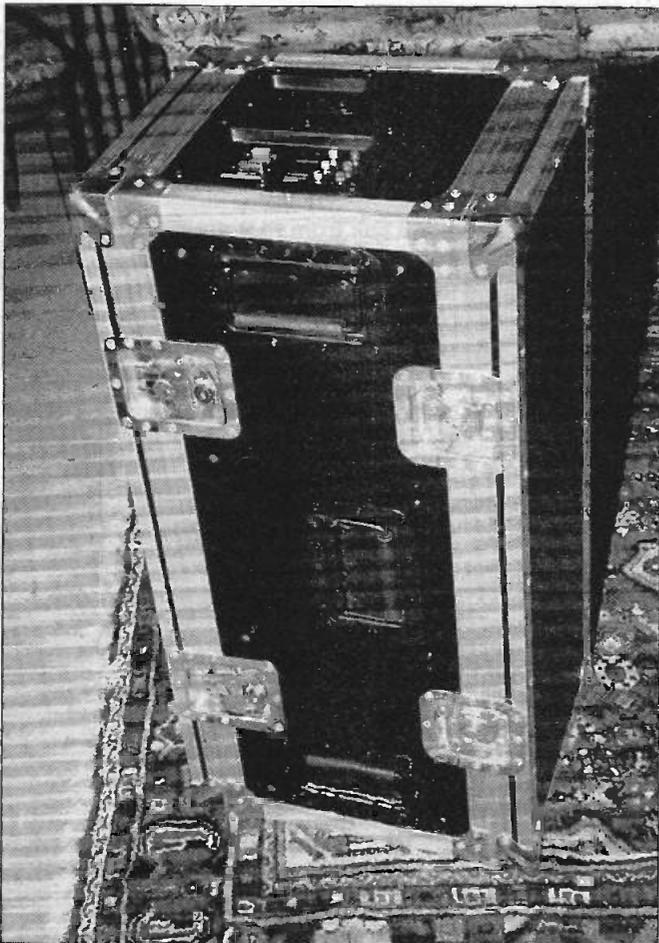
Remember that under normal operation, RB6 and RB7 are outputs, and that whenever the PIC is out of reset, it is likely to be driving these pins. This may cause a problem for some programmers, as they may assume that the device is not driving these pins when not being programmed (as they have supposedly removed power from it). Under these circumstances, the programming header will have to be removed once programming is complete.

Only use this facility for initially programming blank PICs, or updating the existing firmware. Do not fit devices containing old programs for different products, since there is a high possibility of I/O conflicts, that could damage the PIC and other circuitry before you have had a chance to program the device.

Interfacing external equipment to the system

This section gives a brief overview of the design requirements for any external equipment that will be connected to the Expansion Bus and Aux Power connectors. A typical example would be a thermometer module that would return the temperature to the controlling PC, which could then output it to the displays.

When supplying power from the Aux Power connector, remember that the amount of power available at 5V and 24V depends on the specification of the PSU, and how much is being consumed internally (allow 1A at 5V and 100mA at 24V for



The flight case on which the dimensions are based

the basic system). Attention should also be paid to the amount of heat dissipation from the internal supply, especially in standby mode where only convection cooling is available. To this end, it would be beneficial if any high current consuming equipment entered a low power state when the system is in standby.

The Expansion Bus connector brings out the entire RS422 display bus to the outside world, allowing the PC to communicate with any external equipment. A global reset signal is also provided, which will be asserted while the system is in standby, thus allowing the equipment to enter a low power state if desired. The display watchdog signals and flash clocks are also available on this connector; they can be received if required, but should never be driven by external equipment.

The pinout of the 25 way D connector is numerically different from the IDC connectors on the same cable, due to the way D types are numbered. The following list shows both pinouts, together with the signal description. Note that with the exception of the flash clocks, all RS422 signal pairs have the positive signal on the odd numbered IDC pin, or the numerically lowest D type pin.

IDC	D type	Description
1, 2	1, 14	Watchdog 1 output from panels
3, 4	2, 15	Data transmitted from PC to system
5, 6	3, 16	Data received by PC from system
7, 8	4, 17	Not connected anywhere
9, 10	5, 18	Not connected anywhere
11, 12	6, 19	Flash clock 1 from PC
13, 14	7, 20	External NMI to displays (unused)
15, 16	8, 21	Flash clock 2 from PC
17, 18	9, 22	Watchdog 2 output from panels
19, 20	10, 23	DMA end output signal from panels (unused)
21, 22	11, 24	Watchdog 3 output from panels
23, 24	12, 25	Reset/standby signal from QUICC-IDM board
25, 26	13, NC	Not connected anywhere

When designing external equipment, you can continually receive all data from the PC via D type pins 2 and 15; this will include messages transmitted to the display panels and QUICC-IDM board, which should be ignored. The equipment can transmit responses to the PC via D type pins 3 and 16, but since this is shared with the display panel transmitters, it is vital that the RS422 transmitter is only enabled when the equipment is actually transmitting, and that the embedded software is designed only to transmit in response to a direct PC request. Likewise, the PC software should be designed so that the PC waits for a response before transmitting messages to any other devices. If two devices attempt to transmit at the same time, contention will occur, that could possibly damage the RS422 drivers due to overheating.

Note that it is not possible for external equipment to drive the display panels directly, nor for it to receive responses from them. If it generates information to be displayed (such as the temperature), the PC software should read this data and output it to the panels in the desired format.

Parts and software

The Buyline details for this project are given at the end of Parts 1 and 2 in ETI issues 10 and 11/1998, and the full parts list in Part 1 in issue 10/1998. Corrections from Part 1 are given in Part 2. **This is a mains project. Please seek the assistance of an experienced mains constructor if you do not have mains construction experience.**

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Timing in Electronics

Part 6: counting the seconds... and audible alarms.

Owen Bishop

The timing systems described in previous parts have all depended for timing lengthy periods on dividing down the basic 1 Hz signal. This works well when we divide 1 Hz by 60 to get minutes and by 60 again to get hours, but getting a period of, say, 5 minutes and 15 seconds is not so easy. To do this it is best to count the seconds. Decide the length of the period in seconds, and then set up a counter to signal when that number of seconds has elapsed.

Figure 1 shows one way of doing this. The circuit is designed so that it is virtually the same for any period between 2 seconds and just over an hour. The ics stay the same and you just have to modify the wire connections according to the number of seconds required. With a rotary switch to change the connections, you can select timing periods of several different lengths. Time is taken from a 1 Hz clock, which may be either one of the two types previously described. This feeds its signal into a CMOS 4040 timer. This 12-stage timer is chosen because it is the only one that has outputs for all its stages. The outputs are wired to two logic gates, which function as decoders. In the figure they are

connected to decode the number 300 (the number of seconds in 5 minutes) in binary form. If you use the accurate crystal clock you can build a circuit to time 5 minutes to the nearest second.

When converted into binary, decimal 300 comes out as 100101100 (the sum of $256 + 32 + 8 + 4$). The binary version has nine digits, so we decode the outputs of the first 9 stages of the counter. At the count of 300, four of these digits are high and five are low. The circuit detects this number because we connect all the outputs that are supposed to be high to an 8-input NAND gate (IC2) and all low outputs to an 8-input NOR gate (IC3). Unused inputs on each gate are wired high or low. When '300' appears on the outputs, the NAND gate goes low and the NOR gate goes high. We invert the output of the NOR gate to give a low. The two lows are then sent to a 2-input NOR gate, and the output of this goes high.

Summing up, the counter is reset to all-zero output by pressing SW1. The output is low for 300 seconds while it counts to 100101100. Then a high pulse appears at the output. Before going on to discuss what we can do with this high output, let's see how to set up other timing periods.

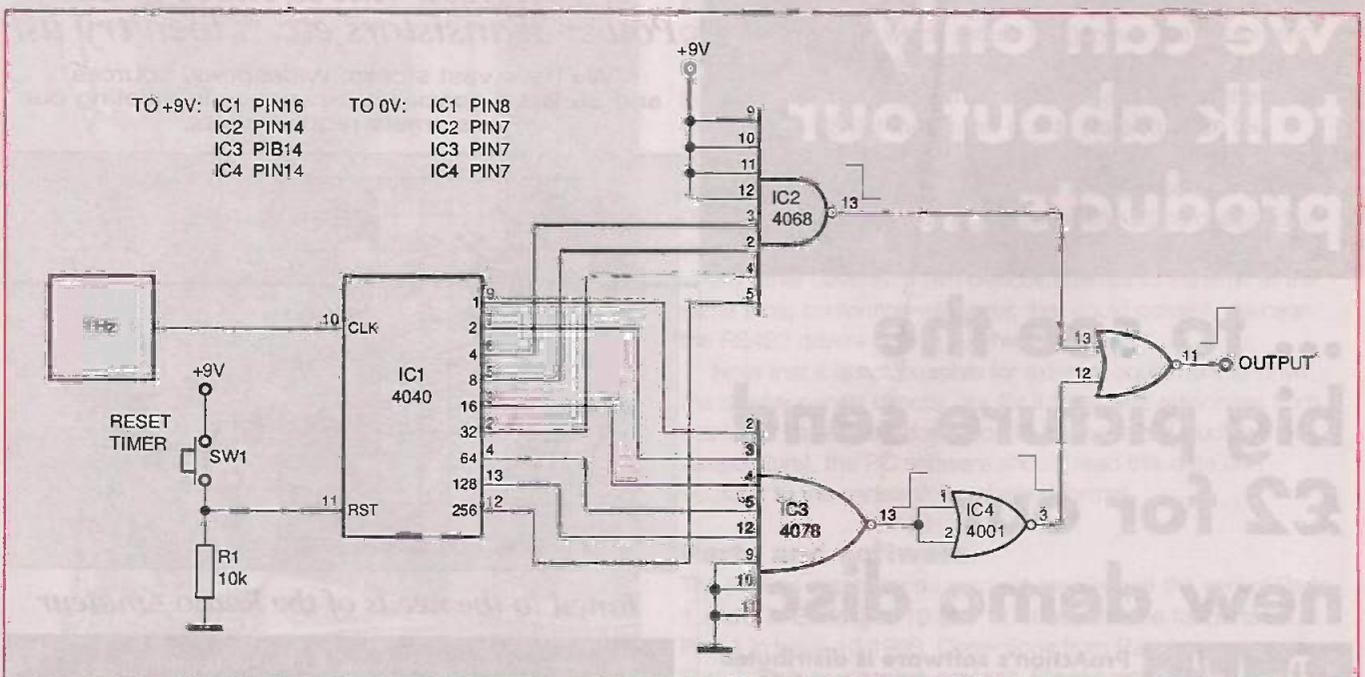


Figure 1: the NAND and NOR gates are connected to decode the counter output for a period of exactly 5 mins, but most other periods up to 4095 seconds can be timed with this circuit

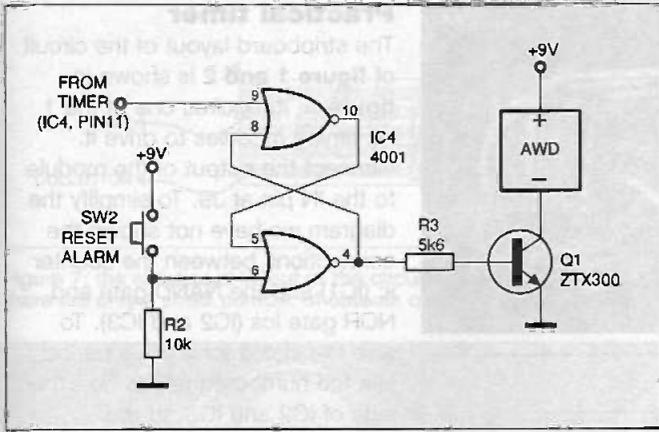


Figure 2: connecting an audible warning device to the decoder circuit of figure 1

Other times

The 4040 has 12 binary stages whose outputs first go high after the number of counts listed in the table:

Stage	1	2	3	4	5	6	7	8	9	10	11	12
Count	1	2	4	8	16	32	64	128	256	512	1024	2048
Pin	9	7	6	5	3	2	4	13	12	14	15	1

To find out how to wire the circuit for any given number of seconds (up to 4095), we work out which of the count numbers are needed to add up to that number of seconds. Each count can be used only once. Then all the outputs corresponding to these count numbers (the 1s) are connected to IC2 and the rest (the 0s) are connected to IC3.

The easiest way is to start with the biggest count number. Suppose we want a count of 12 minutes, or 720 seconds. The largest count under 720 is 512. Subtract 512 from 720, leaving 208 and start again. The largest count is 128, and taking this from 208 leaves 80. In the same way we find that the other counts needed are 64 and 16. Connect pins 14, 13, 4 and 3 to IC2 and the rest to IC3. Connect unused pins on IC2 and IC3 to +9 V and 0 V.

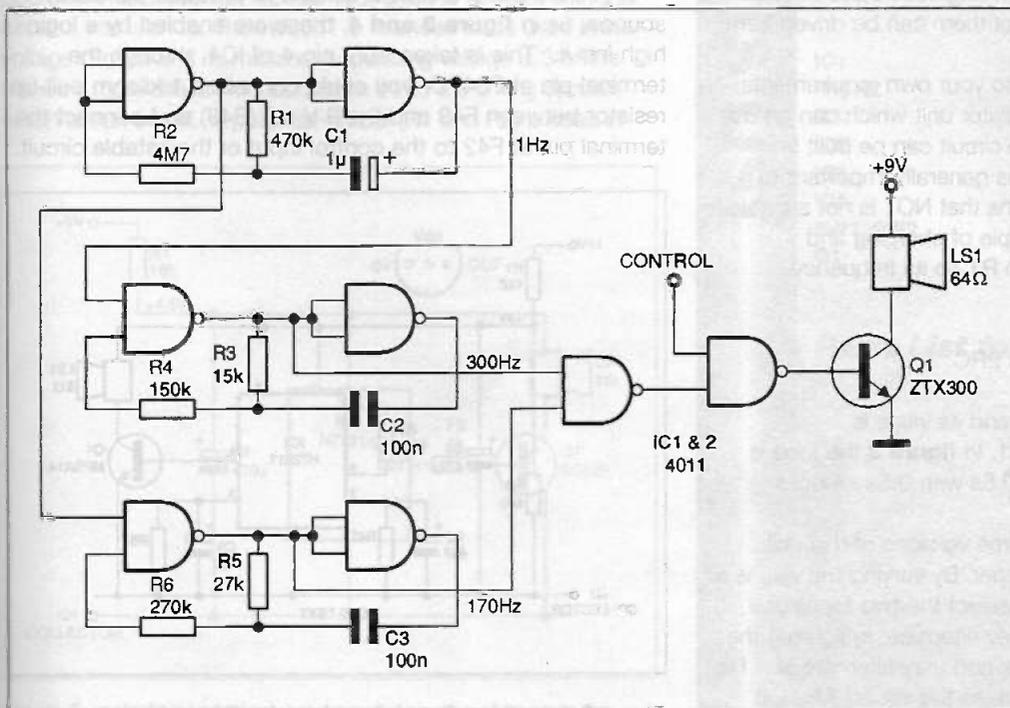


Figure 4: a two-tone alarm circuit based on two ics

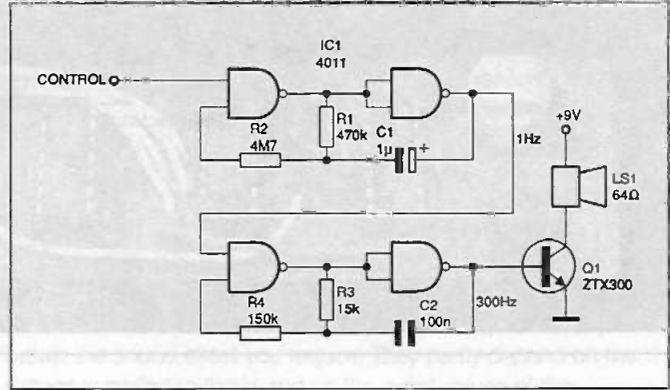


Figure 3: an intermittent alarm circuit uses only 1 low-cost ic

This table shows the counts used for some commonly used times:

Time in minutes	Time in seconds	Counts needed
5	300	256 32 8 4
10	600	512 64 16 8
20	1200	1024 128 32 16
30	1800	1024 512 256 8
60	3600	2048 1024 512 16

In each of these examples, there are four wires going to IC2 and between 5 and 8 going to IC3. There are numbers that require more than 8 wires to one of the ICs. For example, 1056 (10 000 100 000) has to have nine wires to IC3. Numbers such as these can not be used with this circuit (wait a second longer by using 1057, which needs only 8 wires to IC3). If you really must have more than eight 1s, use a 74LS30 13-input NAND gate for IC2. Unfortunately there is no 13-input NOR gate. The circuit of figure 1 therefore has its limitations but it is usually possible to get around these, if they are encountered at all, and the simplicity of the circuit is its big advantage.

Triggering

The output of figure 1 goes high for only one second. It can be used to trigger the counter to reset and start all over again. It also has to trigger some indication that the timed period has ended. In figure 2 we use it to trigger a set-reset flip-flop built from two cross-connected NOR gates. The output of this at pin 4 is normally low but goes high when a high pulse arrives at pin 9. Pressing SW2 resets it. The output at pin 4 can drive an LED or other visual indicator but this month we are going to look at audible indicators. Figure 2 shows an AWD (audible warning device) being switched by a transistor.

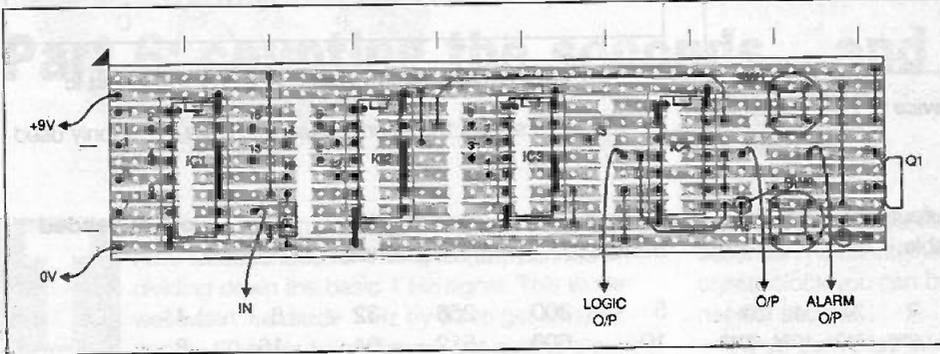
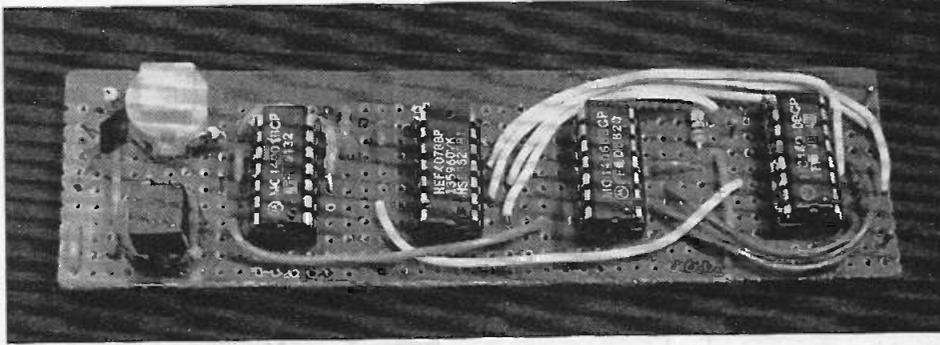


Figure 5: stripboard layout for the counter circuit of figure 1

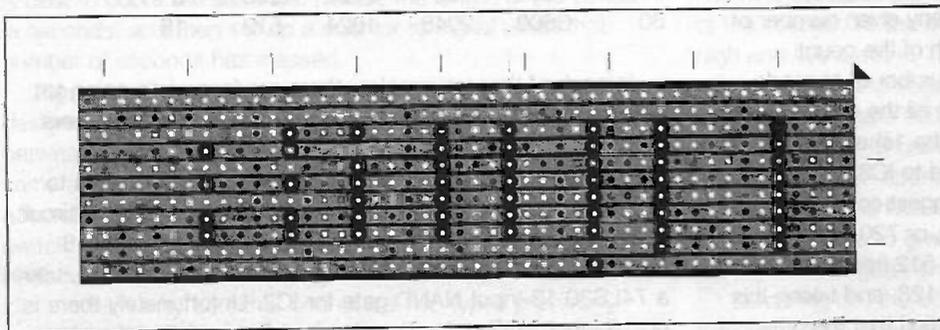


Figure 5F: the back of the stripboard layout for of figure 5 showing the cutouts

There is an enormous range of AWDs to choose from, from piping piezo-bleepers, to growling solid-state buzzers and blaring 115 dB sirens. Most of them can be driven from the circuit in figure 2.

If you want to tailor a bleeper to your own requirements, figure 3 shows an adaptable oscillator unit which can be used to provide a range of effects. The circuit can be built from NOT, NAND or NOR gates but it is generally important to have an enable input, which means that NOT is not suitable. The oscillator works on the principle of charging and discharging the capacitor through R1 so its frequency depends on their values:

$$f = 1/2 \times 2RC$$

R2 makes the waveform squarer and its value is approximately ten times that of R1. In figure 3 the tone is 300 Hz, alternately sounding for 0.5s with 0.5s silences between.

Figure 4 shows how to put three versions of this unit together to make a two-tone bleeper. By varying the values of resistors and capacitors you can select the two tones you prefer and fix the rate at which they alternate. In figure 4 the two tones are 170 Hz and 300 Hz and they alternate at 1 Hz. There is a control input which enables the sound when at logic high (in this case +9V).

Practical timer

The stripboard layout of the circuit of figure 1 and 2 is shown in figure 5. It requires one of the 1 Hz timing modules to drive it. Connect the output of the module to the IN pin at J9. To simplify the diagram we have not shown the connections between the counter ic (IC1) and the NAND gate and NOR gate ics (IC2 and IC3). To wire the circuit for a 300s period, join the numbered points on either side of IC2 and IC3, to the identically numbered points around IC1. Several of the outputs on IC1 are left unconnected. Any unconnected inputs on IC2 and IC3 are connected to 0V either directly or by means of blobs of solder joining adjacent pins. In IC4, two gates are used for the output logic of figure 1, and two more are used for the flip-flop of figure 2. Note that the strip beneath IC4 is NOT cut at E34 and G34.

The output from the timer appears at a terminal pin at F38. This gives the 1-second output pulse, which can be used to drive other circuits. More probably you will use the output of the flip-flop, which appears at the terminal pin at F42. This is an open-collector output. The load such as an audible warning device, a lamp or a relay is connected between F42 and the positive rail. This terminal can sink up to 500 mA.

If you are using a CMOS astable to produce the alarm sounds, as in figure 3 and 4, these are enabled by a logic high input. This is taken from pin 4 of IC4, through the terminal pin at F34. Or you could connect a 1 kilohm pull-up resistor between F43 and the 9 V rail (B43) and connect the terminal pin at F42 to the control input of the astable circuit.

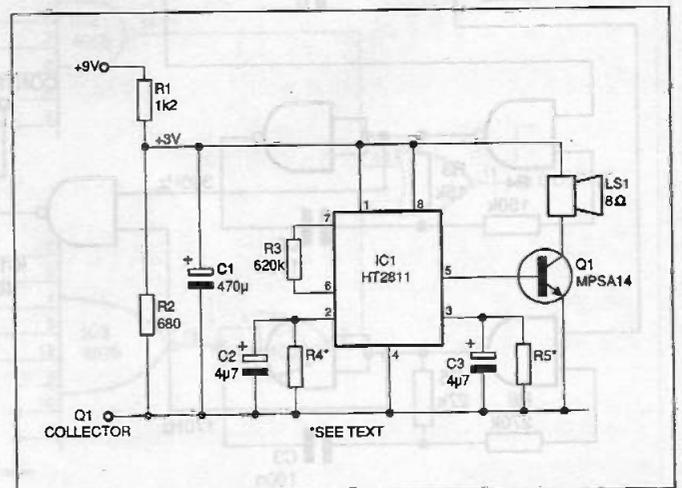


Figure 6: a soothing ding-dong chime circuit based on an inexpensive ic

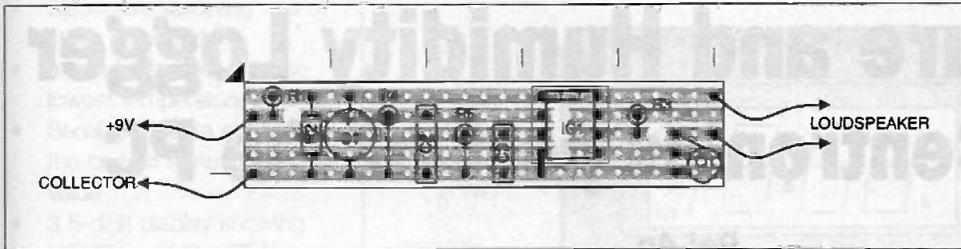
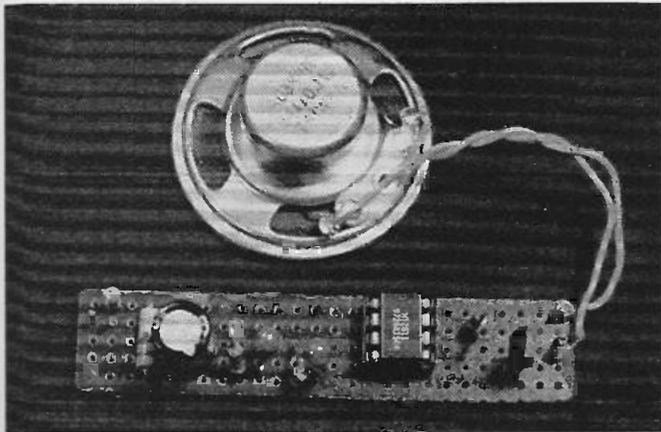


Figure 7: the stripboard layout of the circuit of figure 6. (The back is not shown separately as there are only a small number of cutouts on this board.)



In a lighter mode

Bleepers and sirens are all very well but their notes are intended to sound (and usually do sound) imperative. It seems to be a characteristic of almost all electronic warnings. The worst offenders in this respect are the screaming alarms in smoke detectors, proud to announce that they have detected some infinitesimally small measure of smoke in the air. Anyone would think the house was on fire! But actually its only that the toast is a bit overdone. So that no one can accuse us of the same failing, we finish with two audible warnings of a much less aggressive nature.

Figure 6 shows a circuit for using the HT2811 ic. This produces a ding-dong chime-like sound, similar to a two-tone doorbell. In fact you can replace your existing doorbell with this circuit if you wish to. The HT2811 is intended to be used in low-voltage circuits and its maximum operating voltage is 3V. This makes it more difficult to incorporate it into the timing circuits, which all run on 9V. A potential-divider (R1 and R2) is used in

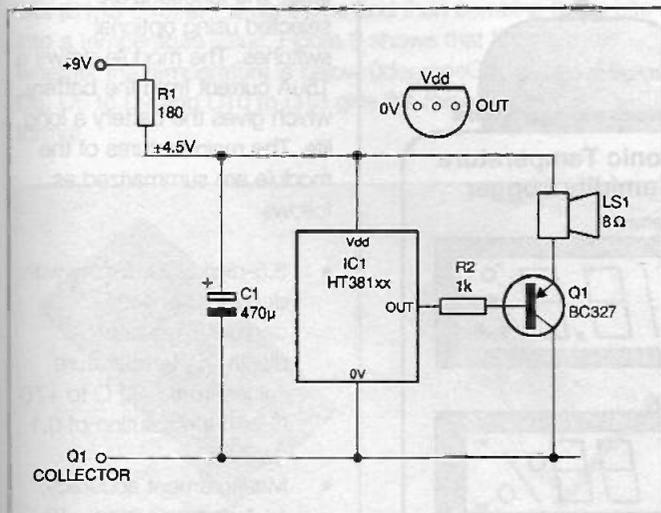


Figure 8: melody generators are a useful source of sounds for timed alerts

figure 6 to provide the 3V supply. A large capacitor is essential (C1) to keep the voltage reasonably steady while the ic is producing its sounds.

Figure 7 is the stripboard layout of this circuit. The envelope of the chime sounds is controlled by R4 and C2 and by R5 and C3. Q1 is a npn Darlington transistor with very high gain. The values of R4 and R5 need to be set fairly accurately to

obtain the sound effect you require. They partly depend on the voltage supplied to the ic and on the exact values of the capacitors. Since tantalum and electrolytic capacitors have a fairly wide tolerance it is best to establish suitable values by trial and error. The simplest technique is first to assemble the circuit except for R4 and R5. Then temporarily connect a 1 megohm potentiometer across each of C2 and C3. Connect the circuit to the output of the timer (figure 1). If the timer is not reset, its output stays high while you adjust the potentiometers. Find settings so that the 'ding' and the 'dong' are distinct from each other and each sound dies away gradually, rather than abruptly. When you have found the settings, remove the potentiometers (without readjusting them) measure their resistances and solder in fixed resistors which are as close as possible to these values.

Another option is to use one of the melody generating ics, which are available very cheaply. Figure 8 is a circuit for using one of the HT381XX series. These operate on a rather higher voltage than the previous ic but 9 V is still too high. A dropper resistor (R1) brings the voltage down to about 4.5 V. Note that Q1 is a pnp transistor. There are plenty of tunes to choose from. The prototype circuit plays HT3812A, a traditional and sprightly 'Greensleeves'. For a really no-obligation alert sound, try HT3814K, 'I just called to say I love you'.

PARTS LIST

Parts List for the decoder circuit

IC1	4040
R1, R2	10k
R3	5k6
IC2	4068
IC3	4078
IC4	4001
SW1, SW2	momentary switches
Q1	ZTX300

Parts List for the chime circuit

R1	1k2
R2	680R
R3	620k
R4	*see text
R5	*see text
IC1	HT2811
C1	470u
C2, C3	4u7
Q1	MPSA14
LS1	8 ohm loudspeaker

Temperature and Humidity Logger For the Centronics port of the PC

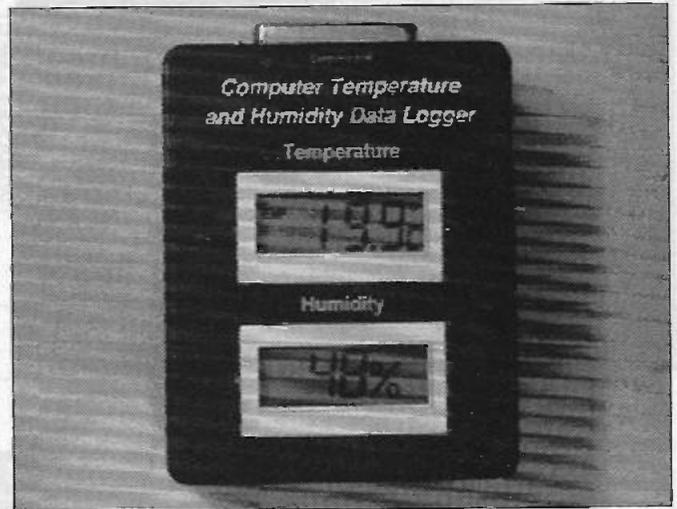
Pei An

This PC-based temperature and humidity measuring device uses standalone LCD temperature and humidity modules and a choice of Turbo Pascal or VisualBasic drivers.

The logger has two main features. Temperature and humidity are measured and displayed on liquid crystal displays. The logger can be plugged into the Centronics port of a PC via a printer lead. The PC reads temperature and humidity and records them onto a hard disk for future data analysis. The complete system is shown in **figure 1**.

Each module require a 1.5V AA size battery, and the battery should last more than a year. The circuitry which interfaces the modules to the PC does not require a power supply, as it 'steals' power from the Centronics port.

I developed two software drivers for the device, a DOS-based one in Turbo Pascal 6 and the other based in Windows and written in Visual Basic 4 (VB4). The DOS program is very simple, and sufficient to demonstrate how PCs read data from the two modules. The user interface, however, is not of the 'user friendly' kind that we expect now. The Windows program is more complicated and it gives a much nicer user interface. As VB4 does not provide commands to access to a hardware port, I have to use Turbo Pascal for Windows (TPW) to write dynamic link libraries (DLLs) which allow the VB4 program to access the port and read data from the temperature and humidity modules.



The LCD thermometer modules

The temperature module used in this project is a versatile digital thermometer module with an LCD display and circuitry on a small PCB with a 16-way solder edge connection. The PCB is fixed to a small plastic bracket that houses a 1.5V battery. The module has an on-board temperature sensor. An external temperature probe can be used instead if some appropriate connections are made. The module not only measures and displays temperature, but also displays time. The functions are selected using optional switches. The module draws a 15uA current from the battery, which gives the battery a long life. The main features of the module are summarized as follows:

- 3.5-digit LCD display with degreesC or with degreesF indicator displaying temperature values from -20 C to +70 C with a resolution of 0.1 degreeC
- Measurement accuracy: +/- 1 degreeC from -10 C to 40 C and +/- 2 C for other ranges

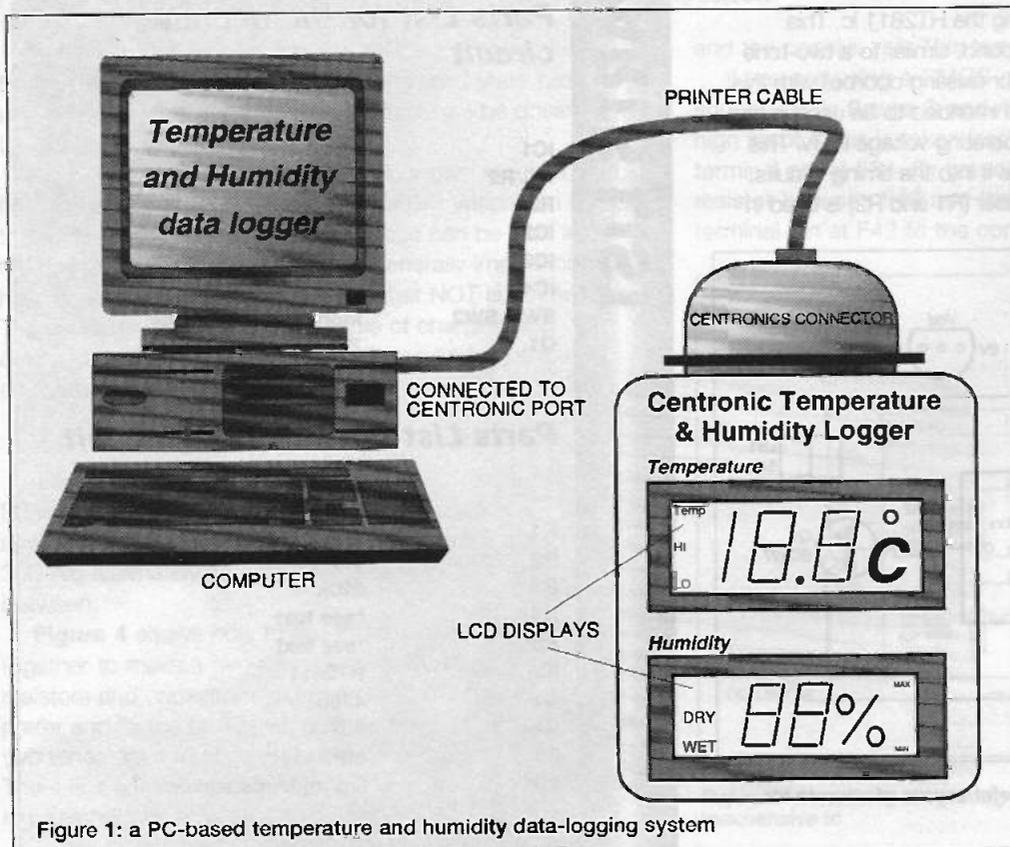
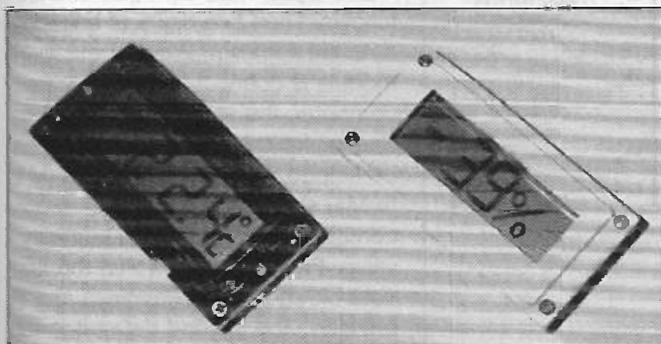


Figure 1: a PC-based temperature and humidity data-logging system

- Selectable sampling rate of 10 or 1 second
- Alarm for highest and the lowest temperature settings
- Serial BCD data output of the current temperature value
- 3.5-digit display showing HOUR and MINUTE for displaying time
- Timer accuracy of +/-0.5 seconds per day
- Powered by a 1.5-V AA cell with a life of more than a year and supply current of 15uA

The pin-out and a typical connection of the module are given in **figure 2**. Switches are used to select the operation modes of the module. For example, if pin 11 is left unconnected, the module measures temperature. If it is connected to pin 16, it displays time. When the module measures temperature, pin 5 determines the sampling rate: 10 seconds if it is left unconnected, and 1 second if it is connected to pin 16.

The module has two data outputs: the serial data output and the clock. This feature allows the module to be connected to external digital circuits. The serial data outputs send a 13-bit code at every sample point, containing the current temperature value in BCD format. The clock outputs the synchronising clock pulses. The timing sequence of these two outputs is shown in **figure 3**. The clock is used to synchronise external circuits to read temperature data bits at the right time. When the clock is at logic high, the data bit is valid. When the module is connected to a computer, the software running inside the PC must be able to read the data bits (D1 to D13) at the right time and then combine these bits into a temperature value. Figure 3 shows that D1 indicates whether the temperature is below 0degreesC or above. D2 to D5, D6 to D9 and D10 to D13 give the three digits in BCD format.



The temperature and humidity modules used in the logger

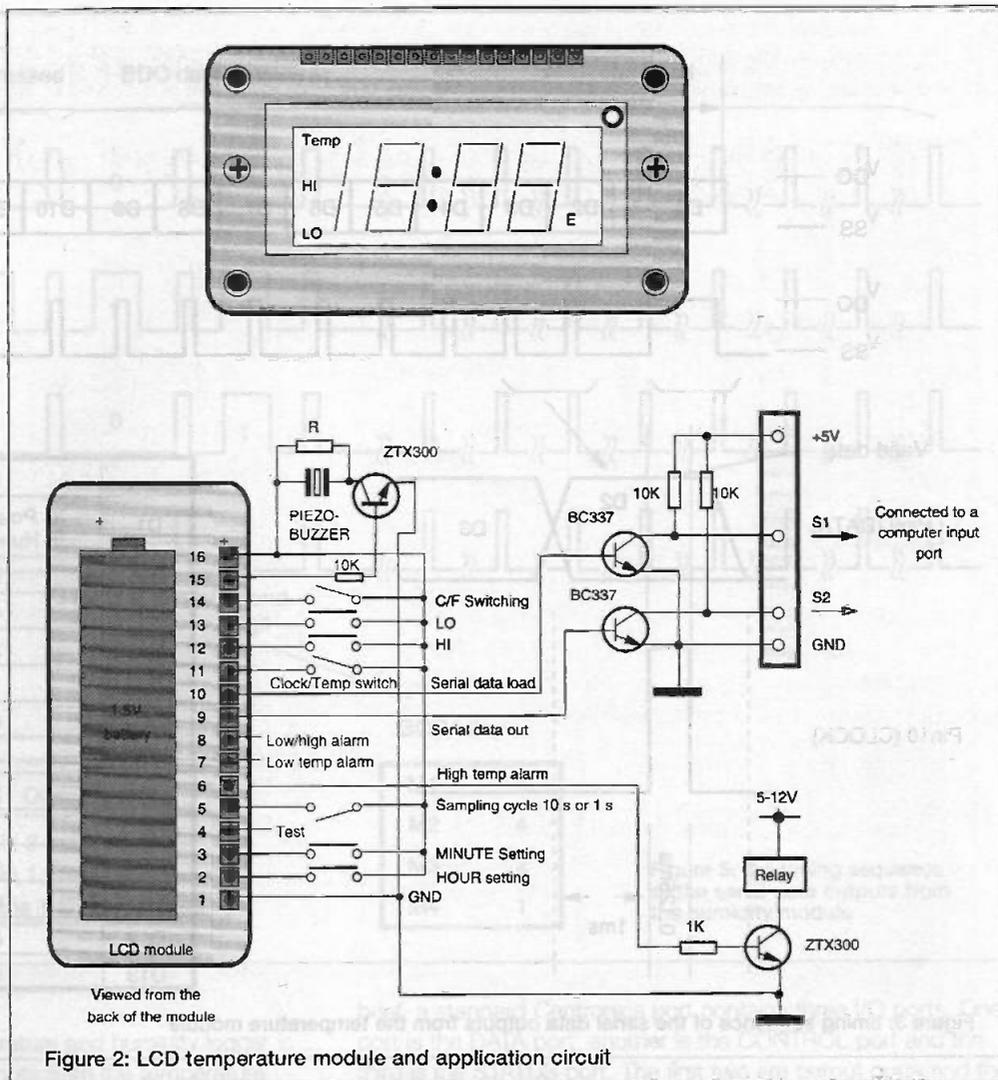


Figure 2: LCD temperature module and application circuit

The LCD humidity module

The LCD humidity module is of the same type as the temperature module. It is designed to measure the relative humidity (RH) of air and record the minimum and maximum level reached at any time since last reset. The humidity sensor is on board. The display normally shows the current humidity value continuously, but will show the stored minimum and maximum values via two momentary action push buttons, identified as MIN and MAX on the LCD. The display also shows DRY or WET depending on the humidity. DRY is approximately less than 53 percent and WET is more than 67 percent. Features of the modules are:

- 2-digit LCD readout
- Measurements from 25 percent RH to 95 percent RH with a resolution of 1 percent
- Accuracy of +/- 5 percent RH between 40 to 80 percent RH at 25 degrees C. +/- 7 percent RH for other ranges at 25 degreesC
- Sampling rate: 1 second
- Serial BCD data output for humidity measurement
- Power supply: one 1.5V AA cell with a life of over a year; supply current: 20uA

There are 12 connections to the module. The pin-out and a typical means of connecting the module are given in **figure 4**. Pins 1 and 2 are connected to two switches to select the maximum and minimum humidity value recorded. Both

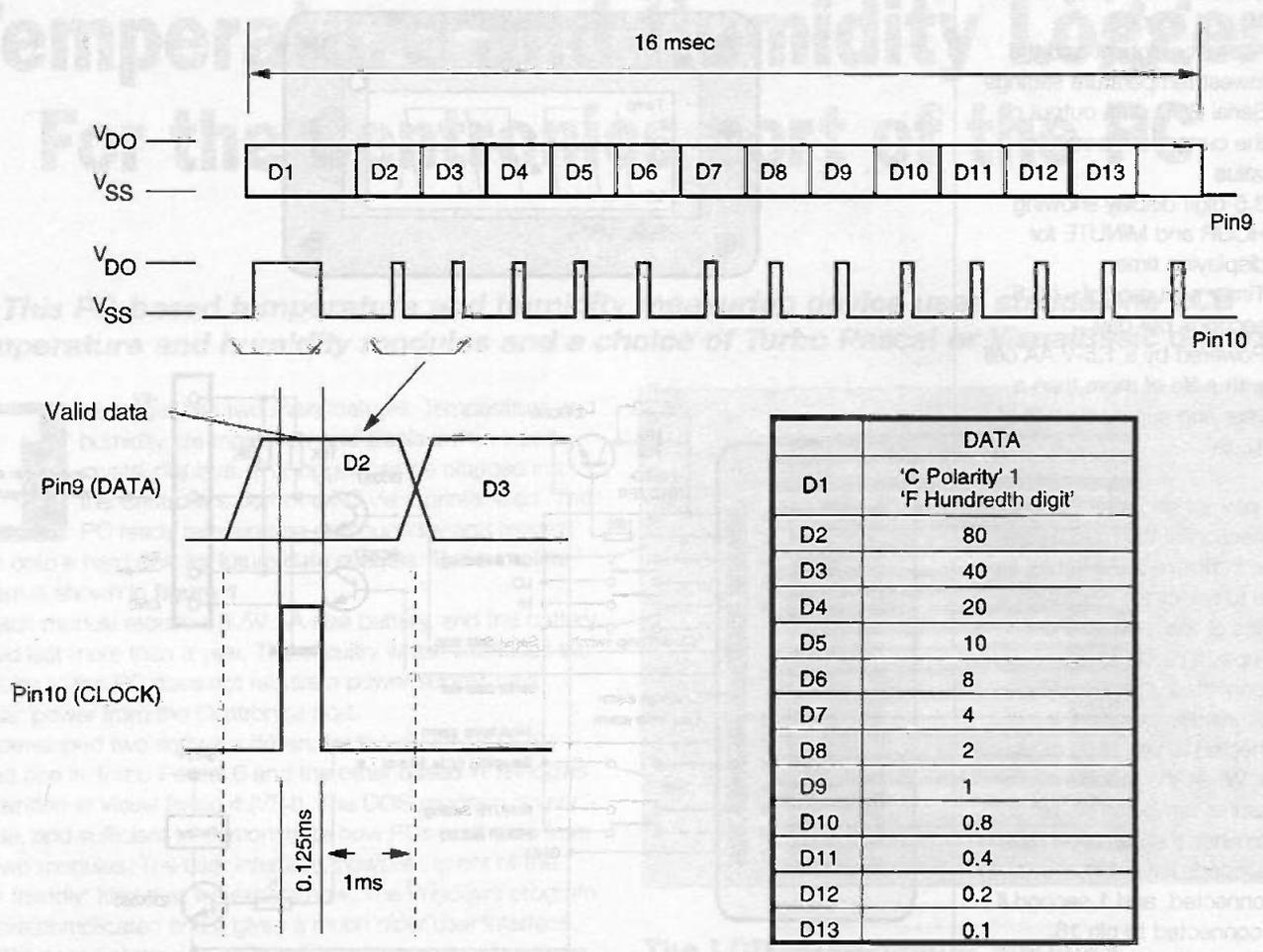


Figure 3: timing sequence of the serial data outputs from the temperature module

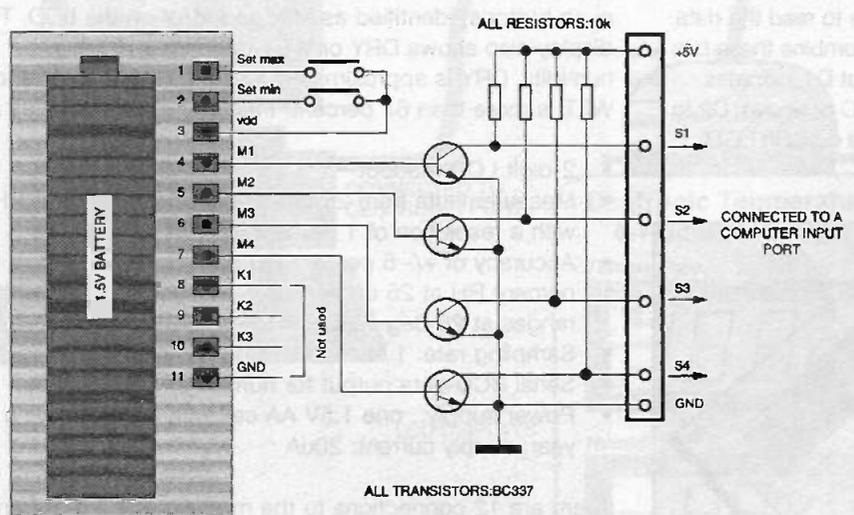
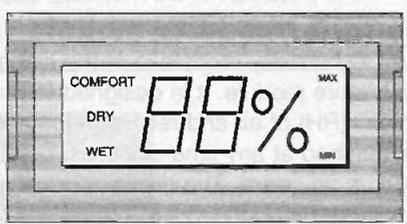


Figure 4: LCD humidity module and its application circuit

memories can be cleared by holding both buttons down.

Pins 4 to 7 output the currently measured value of humidity in a 4-bit BCD format. This feature makes the module possible to be connected to external digital circuits. The output timing sequence is shown in **figure 5**. When outputting the data, each data line begins with two synchronisation pulses, followed by a bit indicating if the data to be sent is the current, minimum or maximum humidity reading. A further synchronisation pulse follows. Then two digits of humidity data are sent out. When the module is connected to a computer, the software driver running inside the computer must be able to read the 4 data bits (M1 to M4) at the right time and combine these bits into a humidity value. **Figure 5** shows that the first data bit shows how the keys are pressed. The second data bit is the tenth digit of the humidity value in the BCD format.

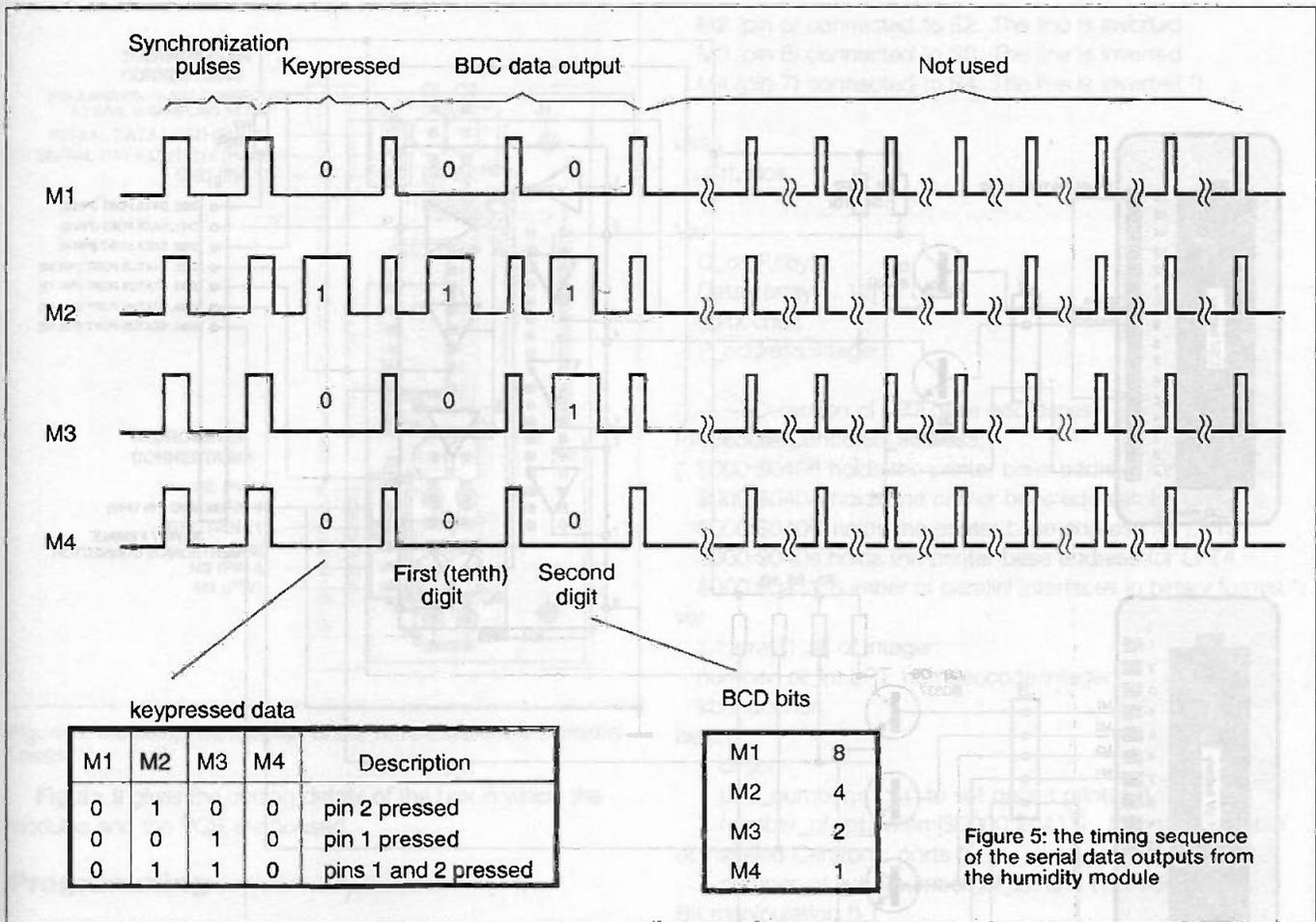


Figure 5: the timing sequence of the serial data outputs from the humidity module

The works

The circuit diagram of the temperature and humidity logger is shown in figure 6. The data outputs from the temperature module (two lines, DATA and CLOCK) and from the humidity module (four lines, M1, M2, M3 and M4) are input into a computer via the STATUS port of a Centronics port.

The voltage level of the serial data outputs from the modules is 0 to 1.5V. This is not the TTL voltage level used by the computer, so the signals from the modules are converted to the TTL voltage level using sic BC337 transistors, Q1 to Q6.

A standard Centronics port has only five digital lines on this STATUS port. In order to read data from the two modules, a data switch based on a 4503 tri-state buffer (IC1) is used. The DATA and CLOCK lines from the temperature module and M1 and M2 from the humidity module are connected to DB3 and DB4 of the Status port of the Centronics ports in turn under the control of DB1 and DB2 of the DATA port. If DB1=1 and DB2=0, the signal from the temperature module is fed into the Centronics port; if DB1=0 and DB2=1, the signal from the humidity module is fed into the port. M3 and M4 lines from the humidity module are connected to DB4 and DB5 of the Status port permanently.

The transistor circuits and the 4503 buffer consume a small current. A single data line of the DATA port is enough to supply the amount of current required. Consequently, no external power supply is required. DBO of the DATA port is used for such a purpose.

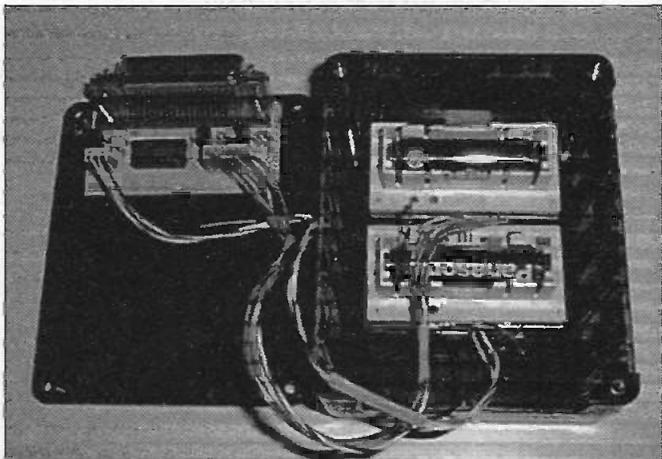
The Centronics port

The pin-layout and functions of a PC Centronics port is shown in figure 7. The Centronics port has been described in detail in an article *Centronics mini-Data Lab* in ETI Volume 26 No.2. In

brief, a standard Centronics port contains three I/O ports. One port is the DATA port, another is the CONTROL port and the third is the STATUS port. The first two are output ports and the third one is an input port. A computer uses the DATA and CONTROL ports to output data and the STATUS port to input data. In this application, the DATA port (3 lines) and STATUS port (4 lines) are used.

Construction

The component layout of the PCB is shown in figure 8. The two modules are connected to the PCB with wires. No adjustments are required. Once the components are properly soldered to the board and modules are connected to the PCB, the system will work straight away.



The assembly of the logger

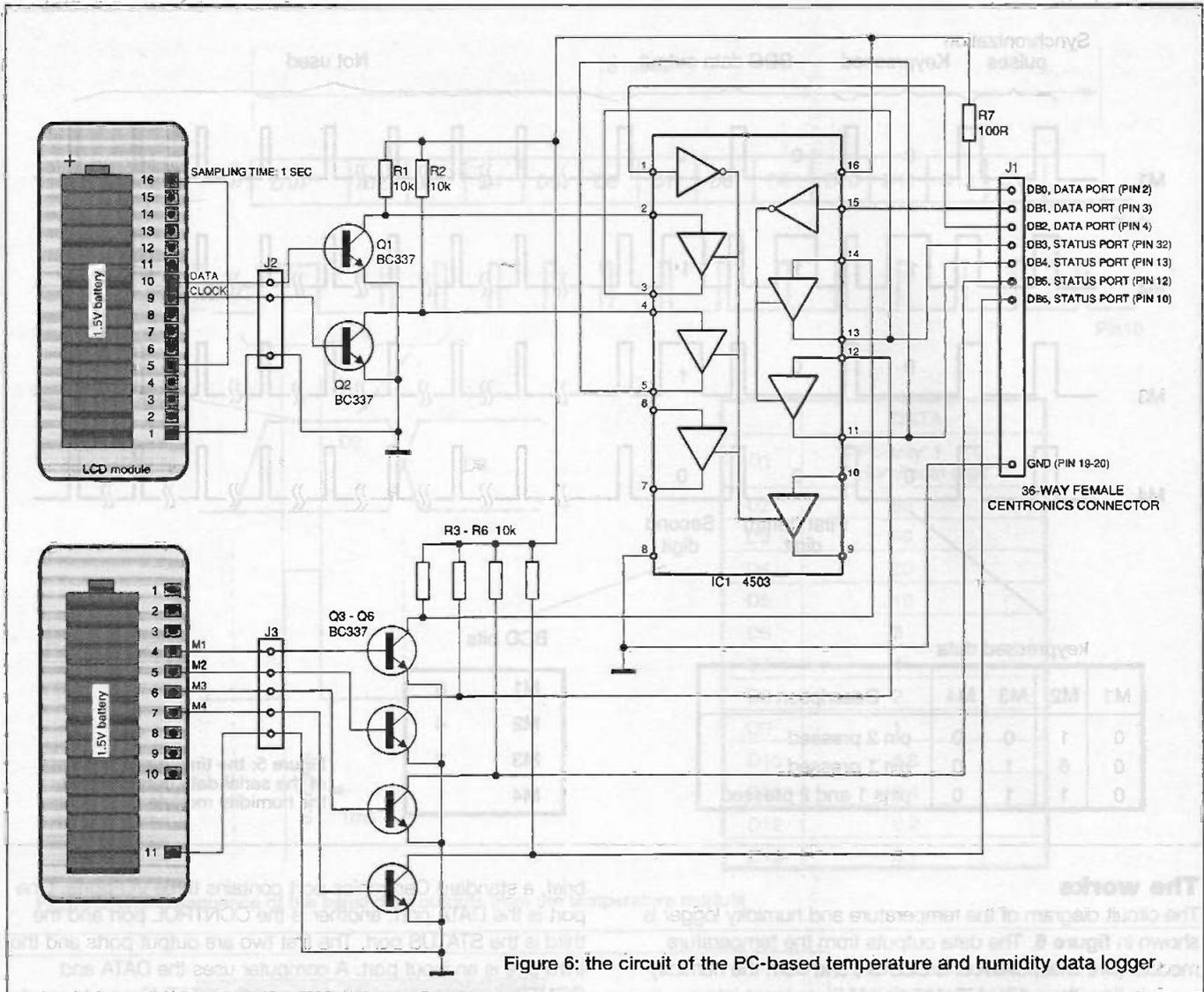
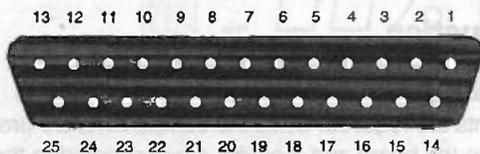
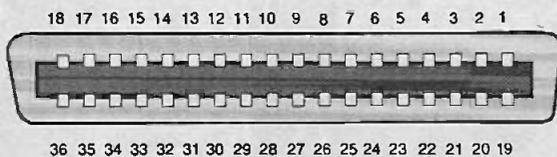


Figure 6: the circuit of the PC-based temperature and humidity data logger

(c) Pin functions of Centronics port connectors



(a) Pin-out of the Centronics connector on PC computers - Viewed from the back of the PC Connector type: 25-pin female D-type



(b) Pin-out of the Centronics connector on printers - Viewed from the back of the printer Connector type: 36-pin female Centronics-type

Connectors on		Direction	Name	Explanation
computer	printer			
1	1	C to P	STROBE	Strobe data
2	2	C to P	DB0	Data bit 0
3	3	C to P	DB1	Data bit 1
4	4	C to P	DB2	Data bit 2
5	5	C to P	DB3	Data bit 3
6	6	C to P	DB4	Data bit 4
7	7	C to P	DB5	Data bit 5
8	8	C to P	DB6	Data bit 6
9	9	C to P	DB7	Data bit 7
10	10	P to C	ACK	Indicating data received
11	11	P to C	BUSY	Indicating printer busy
12	12	P to C	PE	Indicating paper empty
13	13	P to C	SLCT	Indicating printer on line
14	14	C to P	LF/CR	Auto linefeed after carriage return
15	32	P to C	ERROR	Indicating printer error
16	31	C to P	INITIALIZE	Initialize printer
17	36	C to P	SLIN	Select/deselect printer
18-25	19-30 and 33		GND	Twisted-pair return Ground
	18,34		Unused	
	16		Logic GND	Logic ground
	17		Chassis GND	Chassis ground

'C' = Computer 'P' = Printer

Figure 7(a): pin-out of the 25-pin Centronics port connector on most PCs (b): pin-out of the 36-pin Centronics port connector on most printers (c): pin functions of Centronics port connectors

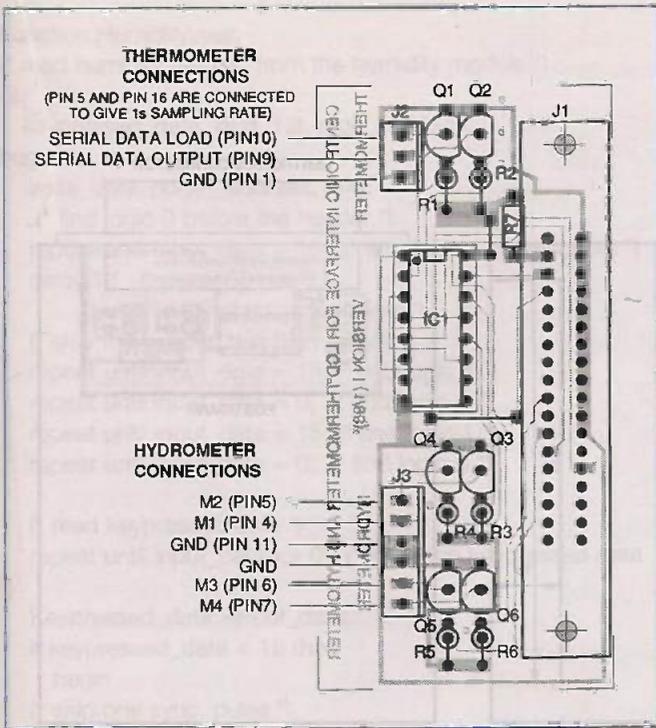


Figure 8: the component layout of the Temperature and Humidity Logger

Figure 9 gives the cutting details of the box in which the modules and the PCB are housed.

Programming

DOS TP6 programs

A software driver written in Turbo Pascal 6 is listed below. It contains several useful procedures and functions. *Procedure Centronic_address* selects a Centronics port to be used. It firstly detects the number of LPTs installed on your PC and then allows you to select an LPT port. *Function read_status_port* inputs a 4-bit data from the STATUS port of the Centronics port. Necessary bit manipulations are carried out in the function. *Procedure write_data_port* outputs a specified data to the DATA port of the Centronics port. *Function temperature* and *Function humidity* are two functions to read temperature and humidity value from the modules. They are able to read the serial data from the two modules, and extract the temperature and humidity data from the serial data. These functions or procedures can be implemented in your own TP6 programs.

Listing 1: TP6 software driver

Program Temperature_Humidity_Logger;

(* Temperature and Humidity Logger

Hardware and software developed by Dr. Pei An, 1/98 *)

(* Connection of the Temperature Module to the Centronic port

Serial data load (pin 10) connected to S1. The line is inverted

Serial data output (pin 9) connected to S2. The line is inverted *)

(* Connection of the Humidity Module to the Centronics port

M1 (pin 4) connected to S1. The line is inverted

M2 (pin 5) connected to S2. The line is inverted
M3 (pin 6) connected to S3. The line is inverted
M4 (pin 7) connected to S4. The line is inverted *)

uses

Crt, dos;

Var

C_or_F:byte;

Datax:array[1..12] of byte;

*unitx:char;

P_address:integer;

(* ---Detection of LPT base addresses--- *)

Procedure Centronic_address;

(* \$000:\$0408 holds the printer base address for LPT1

\$000:\$040A holds the printer base address for LPT2

\$000:\$040C holds the printer base address for LPT3

\$000:\$040E holds the printer base address for LPT4

\$000:\$0411 number of parallel interfaces in binary format *)

var

lpt:array[1..4] of integer;

number_of_lpt,LPT_number,code:integer;

kbchar:char;

begin

clrscr;

LPT_number:=1; (* to set default printer *)

number_of_lpt:=mem[\$0000:\$0411]; (* to read number of installed Centronic ports *)

number_of_lpt:=(number_of_lpt and (128+64)) shr 6; (* Bit manipulation *)

lpt[1]:=memw[\$0000:\$0408]; (* Memory read procedure *)

lpt[2]:=memw[\$0000:\$040A];

lpt[3]:=memw[\$0000:\$040C];

lpt[4]:=memw[\$0000:\$040E];

textbackground(blue); clrscr;

textcolor(yellow); textbackground(red);

window(10,22,70,24); clrscr;

writeln('Number of LPT installed : ',number_of_lpt:2);

writeln('Addresses for LPT1 to LPT 4: ',lpt[1]:3, ' ',

lpt[2]:3, ' ', lpt[3]:3, ' ', lpt[4]:3);

write('Select LPT to be used (1,2,3,4): ');

delay(1000);

if number_of_lpt>1 then begin {select LPT1 through LPT4 if more than 1 LPT installed}

repeat

kbchar:=readkey; (* read input key *)

val(kbchar, LPT_number, code); (* change character

to value *)

until (LPT_number>=1) and (LPT_number<=4) and

(lpt[LPT_number]<>0);

end;

clrscr;

P_address:=lpt[LPT_number];

writeln('Your selected printer interface:

LPT',LPT_number:1);

write('LPT Address : ',P_address:3);

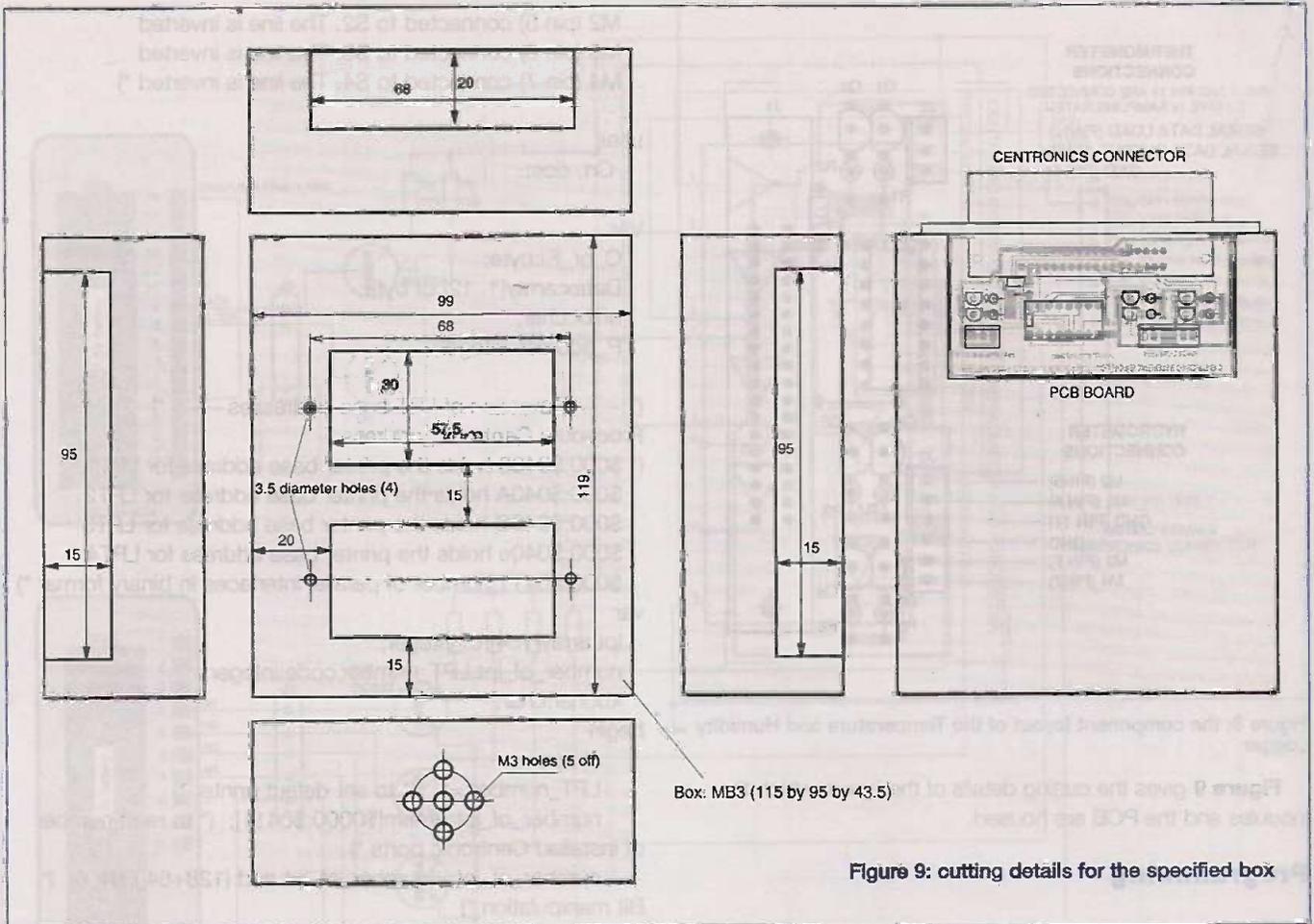
delay(1000);

textbackground(black); window(1,1,80,25); clrscr;

end;

(* ---read data from STATUS port of pc--- *)

Function Read_status_port(P_address:integer):byte;



```

var
  byte1:byte;
begin
  byte1:=port[P_address+1]; (* read a byte from the status port *)
  byte1:=byte1 and 120; (* 01111000 (MSB to LSB) and
  Odddd... = Odddd000 *)
  Read_status_port:=byte1 shr 3; (* shift 3 bit right,
  Read_status_port = 0000hhhh *)
end;

(* ---Write data to DATA port of pc--- *)
Procedure Write_data_port(P_address:integer;
port_data:byte);
(* no lines in the Data port are not inverted *)
begin
  port[P_address]:=port_data; (* output a byte to the data
  port *)
end;

Function Input_data:byte;
(* All inputs from the modules to the status port are inverted
  *)
begin
  input_data:=15 - read_status_port(P_address);
end;

Function Temperature:real;
(* read temperature reading from the LCD temperature
  module *)
begin
  write_data_port(P_address,1+2); (* power the two voltage
  translation transistors *)

```

```

(* find the header. the header is an 1ms high pulse *)
repeat
  repeat until read_status_port(P_address) and 1 = 1; (* find
  logic 0. the line inverted *)
  repeat until read_status_port(P_address) and 1 = 0; (* find
  logic 1. the line inverted *)
  delay(3); (* delay 0.8 ms *)
  C_or_F:=round(read_status_port(P_address) and 2/2); (*
  get deg C (=1) or deg F (=0) *)
  if C_or_F=1 then unitx:='C' else unitx:='F';
  until read_status_port(P_address) and 1 = 0;

  (* read BCD data. read sequence:
  80,40,20,10,8,4,2,1,08,04,02,01 *)
  for i:=1 to 12 do
    begin
      repeat until read_status_port(P_address) and 1 = 1; (*
      find logic 0 *)
      repeat until read_status_port(P_address) and 1 = 0; (*
      find logic 1 *)
      repeat until read_status_port(P_address) and 1 = 1; (*
      find logic 0 *)
      datax[i]:=1-round(read_status_port(P_address) and 2/2); (*
      read data bit. bit inverted *)
    end;
    (* generate temperature *)
    Temperature:=10*( 8*datax[1] + 4*datax[2] + 2*datax[3] +
    1*datax[4] ) +
    1*( 8*datax[5] + 4*datax[6] + 2*datax[7] + 1*datax[8] ) +
    0.1*( 8*datax[9] + 4*datax[10] + 2*datax[11] +
    1*datax[12] );
  end;

```

```

Function Humidity:real;
(* read humidity reading from the humidity module *)
var
  keypressed_data, digit_1st, digit_2nd:byte;
begin
  write_data_port(P_address,1+4);
  (* find logic 0 before the header *)
  repeat until input_data = 15; (* find logic 1 on all inputs *)
  delay(1); (* delay 50 ms *)
  (* after delay, it is the logic low *)
  (* skip the header, two high pulses *)
  repeat until input_data = 15; (* find logic 1 *)
  repeat until input_data = 0; (* find logic 0 *)
  repeat until input_data = 15; (* find logic 1 *)
  repeat until input_data = 0; (* find logic 0 *)

  (* read keypressed data *)
  repeat until input_data <> 0; (* input the keypressed data *)

  Keypressed_data:=input_data;
  if keypressed_data < 15 then
    begin
      (* skip one sync. pulse *)
      repeat until input_data = 15; (* find logic 1 *)
      repeat until input_data = 0; (* find logic 0 *)
      end
      else repeat until input_data = 0;

      (* read the 1st digit *)
      repeat until input_data <> 0; (* input the tenth digit *)
      digit_1st:=input_data;

      (* skip one sync. pulse *)
      repeat until input_data = 15; (* find logic 1 *)
      repeat until input_data = 0; (* find logic 0 *)

      (* read the 2nd digit *)
      repeat until input_data <> 0; (* input the 2nd digit *)
      digit_2nd:=input_data;
      if digit_2nd = 15 then digit_2nd := 0;

      (* generate humidity *)
      Humidity:=(digit_1st)*10 + (digit_2nd);
    end;

```

```

(****MAIN PROGRAM *****)
begin
  Centronic_address; (* select a Centronics interface *)
  clrscr;
  writeln(' Temperature and Humidity Logger ');
  gotoxy(1,24);
  write(' Press any key to stop the program. ');
  repeat
    gotoxy(24, 10); write('Temperature
,temperature:5:1,' o',unitx);
    gotoxy(24, 11); write('Relative Humidity ;',humidity:5:0,'
%');
  until keypressed
end.

```

Windows Visual Basic program

The Window program is written in Visual Basic 4. The screen dump of the driver is shown in figure 10. As Visual Basic is not able to access to a hardware port directly, dynamic link

libraries (DLLs) which are specialized in direct port access should be used. Whenever the Visual Basic is about to read or write data to a port, the dynamic link libraries are called. In the present case, the DLLs are written in Turbo Pascal for Windows. The program listing of the DLLs (**listing 2**) and VB3 programs (**listing 3**) are given below.

Listing-2: Windows DLLs (written in TPW)

```

Library thmeters;
{Window DLL for the Mobile Lab data logger/controller}
{Hardware and software designed by Dr. Pei An. All rights reserved}

(* Temperature and Humidity Logger
Hardware and software developed by Dr. Pei An, 1/98 *)

(* Connection of the Temperature Module to the Centronics port
Serial data load (pin 10) connected to S1. The line is inverted
Serial data output (pin 9) connected to S2. The line is inverted *)

(* Connection of the Humidity Module to the Centronics port
M1 (pin 4) connected to S1. The line is inverted
M2 (pin 5) connected to S2. The line is inverted
M3 (pin 6) connected to S3. The line is inverted
M4 (pin 7) connected to S4. The line is inverted *)

uses
  Windos;

Function Centronic(x:integer):integer; export;
{Universal detection of printer base address. x=0 for number of LPTs, x=1..4 for address of LPT1 to LPT4}
{ $000:$0408 holds the printer base address for LPT1
$000:$040A holds the printer base address for LPT2
$000:$040C holds the printer base address for LPT3
$000:$040e holds the printer base address for LPT4
$000:$0411 number of parallel interfaces in binary format}
var
  number_of_LPT, LPT1, LPT2, LPT3, LPT4 :integer;
begin
  number_of_LPT:=mem[$40:$11]; {read number of parallel ports}
  number_of_LPT:=(number_of_LPT and (128+64)) shr 6;
  lpt1:=0; lpt2:=0; lpt3:=0; lpt4:=0;
  LPT1:=memw[$40:$08]; {Memory read procedure}
  LPT2:=memw[$40:$0A];
  LPT3:=memw[$40:$0C];
  LPT4:=memw[$40:$0E];
  case x of
    0: centronic:=number_of_LPT;
    1: centronic:=lpt1;
    2: centronic:=lpt2;
    3: centronic:=lpt3;
    4: centronic:=lpt4
  end;
end;

(* ---read data from STATUS port of pc--- *)

```

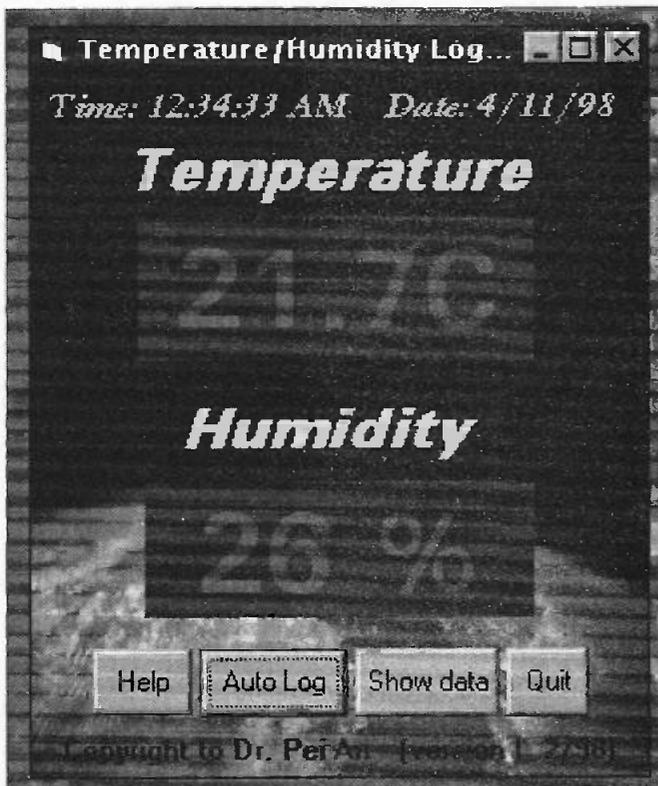


Figure 10: the screen display of the logger software

```
Function Read_status_port(P_address:integer):byte;
var
  byte1:byte;
begin
  byte1:=port[P_address+1]; (* read a byte from the
status port *)
  byte1:=byte1 and 120; (* 01111000 (MSB to LSB) and
00000000 = 00000000 *)
  Read_status_port:=byte1 shr 3; (* shift 3 bit right,
Read_status_port = 0000hhhh *)
end;

(* ---Write data to DATA port of pc--- *)
Procedure Write_data_port(P_address:integer;
port_data:byte);
(* no lines in the Data port are not inverted *)
begin
  port[P_address]:=port_data; (* output a byte to the data
port *)
end;

Function Input_data(P_address:integer):byte;
(* All inputs from the modules to the status port are inverted
*)
begin
  input_data:=15 - read_status_port(P_address);
end;

Function Temperature(P_address:integer):integer; export;
(* read temperature reading from the LCD temperature
module *)
var
  C_or_F:integer;
  datax:array[1..20] of byte;
  id,i:integer;
begin
```

```
write_data_port(P_address,1+2); (* power the two voltage
translation transistors *)
```

```
(* find the header. the header is an 1ms high pulse *)
repeat
  repeat until read_status_port(P_address) and 1 = 1; (*
find logic 0. the line inverted *)
  repeat until read_status_port(P_address) and 1 = 0; (*
find logic 1. the line inverted *)
  for id:=1 to 100 do id:=id;
(* delay 0.8 ms *)
  C_or_F:=round(read_status_port(P_address) and 2/2);
(* get deg C (=1) or deg F (=0) *)
  until read_status_port(P_address) and 1 = 0;

(* read BCD data. read sequence: 80,40,20,10,8,4,2,1,
08,04,02,01 *)
  for i:=1 to 12 do
  begin
    repeat until read_status_port(P_address) and 1 = 1; (*
find logic 0 *)
    repeat until read_status_port(P_address) and 1 = 0; (*
find logic 1 *)
    repeat until read_status_port(P_address) and 1 = 1; (*
find logic 0 *)
    datax[i]:=1-round(read_status_port(P_address) and
2/2); (* read data bit. bit inverted *)
  end;
  (* generate temperature *)
  Temperature:=round(10*(10*( 8*datax[1] + 4*datax[2] +
2*datax[3] + 1*datax[4] ) +
1*( 8*datax[5] + 4*datax[6] + 2*datax[7] + 1*datax[8] ) +
0.1*( 8*datax[9] + 4*datax[10] + 2*datax[11] + 1*datax[12
] )));
end;

Function Humidity(P_address:integer):integer; export;
(* read humidity reading from the humidity module *)
var
  keypressed_data, digit_1st, digit_2nd:byte;
  id,i:integer;
begin
  write_data_port(P_address,1+4);

(* find logic 0 before the header *)
  repeat until input_data (P_address) = 15; (* find logic 1
on all inputs *)

  (* after delay, it is the logic low *)
  for id:=1 to 100 do id:=id;
  (* skip the header, two high pulses *)
  repeat until input_data (P_address) = 15; (* find logic 1 *)
  repeat until input_data (P_address)= 0; (* find logic 0 *)
  repeat until input_data (P_address)= 15; (* find logic 1 *)
  repeat until input_data (P_address)= 0; (* find logic 0**)

  (* read keypressed data *)
  repeat until input_data (P_address)<> 0; (* input the
keypressed data *)
  Keypressed_data:=input_data(P_address);
  if keypressed_data < 15 then
  begin
  (* skip one sync. pulse *)
  repeat until input_data (P_address)= 15; (* find logic 1 *)
  repeat until input_data (P_address)= 0; (* find logic 0 *)
```

```

end
else repeat until input_data (P_address)= 0;

(* read the 1st digit *)
repeat until input_data (P_address)<> 0; (* input the
keypressed data *)
digit_1st:=input_data(P_address);

(* skip one sync. pulse *)
repeat until input_data(P_address) = 15; (* find logic 1 *)
repeat until input_data(P_address) = 0 ; (* find logic 0 *)

(* read the 2nd digit *)
repeat until input_data(P_address) <> 0; (* input the
keypressed data *)
digit_2nd:=input_data(P_address);
if digit_2nd = 15 then digit_2nd := 0;

(* generate humidity *)
Humidity:=round((digit_1st)*10 + (digit_2nd));
end;

```

Exports

```

Centronics      index 1,
Temperature     index 2,
Humidity        index 3;

```

```

begin
end.

```

Listing-3: Visual Basic 4 driver

```

Private Sub Form_Load()
    Label1.Caption = "Time: " & Time & " Date: " & Date
    dummy = MsgBox(Str(Centronic(0) - 1) & " Centronic ports
(LPTS) installed on your PC. Their base addresses are: " &
Format$(Centronic(1), "####") & " " & Format$(Centronic(2),
"####") & "Decimal", 48, "Centronic ports (LPT) on your PC")
    ipt_number = Val(InputBox$("Input 1,2,3,or 4 to select a
Centronic port for the data logger", "Select LPT ports"))
    P_address = Centronic(ipt_number)
End Sub

Private Sub Timer1_Timer()
    Label1.Caption = "Time: " & Time & " Date: " & Date
    Label4.Caption = Format$(temperature(P_address) / 10,
"00.0") & "C"
    Label5.Caption = humidity(P_address) & " %"
End Sub

Module1. Bas

Global P_address As Integer

Declare Function Centronic Lib "C:\THmeters\thmeters.dll"
(ByVal x As Integer) As Integer
Declare Function temperature Lib "C:\THmeters\thmeters.dll"
(ByVal P_address As Integer) As Integer
Declare Function humidity Lib "C:\THmeters\thmeters.dll"
(ByVal P_address As Integer) As Integer

Sub delay()
Dim i As Integer

```

```

For i = 1 To 1
Next i
End Sub

```

Applications ideas

Normally, the device is connected to a computer using a standard printer cable of one or two meters. If the device is to be operated remotely, you can use a longer cable up to 10 meters. A screened cable is preferred. Such a connection will be very useful if you want to monitor temperature and humidity in your greenhouse, while you sit in your study. You can make the cable yourself.

Another application is to build a standalone data logger for the device, based on a PIC or a microcontroller. The standalone data logger can be left in a designated place with the device. The logger measures temperature and humidity at regular intervals and stores the data in its own on-board memory. Subsequently the standalone data logger can be connected to a computer to download the data recorded.

Technical support

The TP6 driver and VB4 driver are available separately from the author for £17, and the PCB for £5, both inclusive of P&P.

A kit is available. It consists of all components to construct a Centronics temperature and humidity logger. DOS and Windows source code and EXE file are provided on a 3.5-in floppy disk. **Please send enquiries to Dr. Pei An, 11 Sandpiper Drive, Stockport, Manchester SK3 8UL, UK. Tel/Fax/Ansmac: 0161 477 9583 email: PAN@ FS1. ENG. MAN. AC. UK.**

PARTS LIST

for the Temperature and Humidity Logger

Resistors

All 1 percent metal film
R1-6 10k 0.25W
R7 100R 0.25 W

Semiconductors

IC1 CD4503 tri-state buffer
Q1-6 BC337 NPN transistors

Connectors

J1 36-way female Centronics connector
J2 3-way PCB connector
J3 6-way PCB connector

Modules

Temperature LCD module (Maplin FE33L)
Humidity LCD module (Maplin, ZA38R)

Miscellaneous

PCB (available from the author; see above)
MB3 box (Maplin LH22Y)
Wires

All components are available from Maplin apart from the PCB. Maplin MPS: PO Box 777, Rayleigh, Essex SS6 8LU. Tel. 01702 554000.

Fishbiter

or The One That Didn't Get Away

A Bite Alarm with a difference
Bob Noyes

This project was developed following a conversation I had with a fellow fisherman. We were chatting, as fishermen do, when suddenly he said he thought he had a bass playing with the bait because he could feel the line being tugged or butted as the fish was testing the bait for freshness (or whatever fish test for). Being a normal spring morning, ie freezing cold, the fisherman's hands were almost numb so trying to interpret these small line movements and differentiating between them and the normal action of the wind and tide was almost impossible. He said that he would give anything to know what was happening under the water and to know when to strike.

This conversation got me thinking: it must be possible to build something to help without costing the earth. A small television camera was ruled out owing to the expense and practicality so a

more modest piece of equipment was required. As bait can be cast out up to 100 yards it was not practical to have anything to go out with it because of the weight, size and connecting cables required, as well as the problem of keeping it watertight to a depth of several tens of feet.

The only practical solution was to monitor the line somehow. The normal way to do this is to keep some tension on the line and stare at the end of the rod. As the line is tugged the end of the rod bends, indicating a fish but, as every fisherman knows, it's more often the wind or the movement of the water. To overcome these problems some sort of sensor was required that could convert all this information into a medium that would give a more precise picture of what was actually going on down in the depths. The obvious sense to use was sight, but short of a camera down there (already rejected) nothing could provide the visual information. The

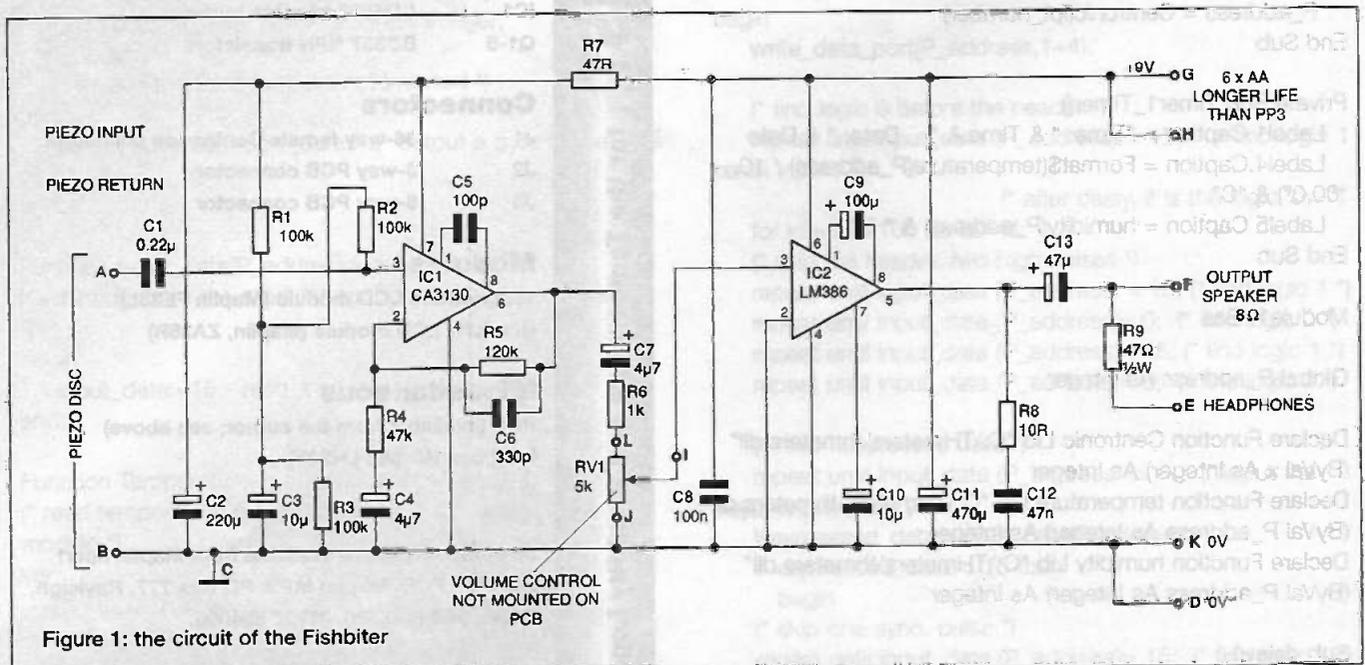


Figure 1: the circuit of the Fishbiter

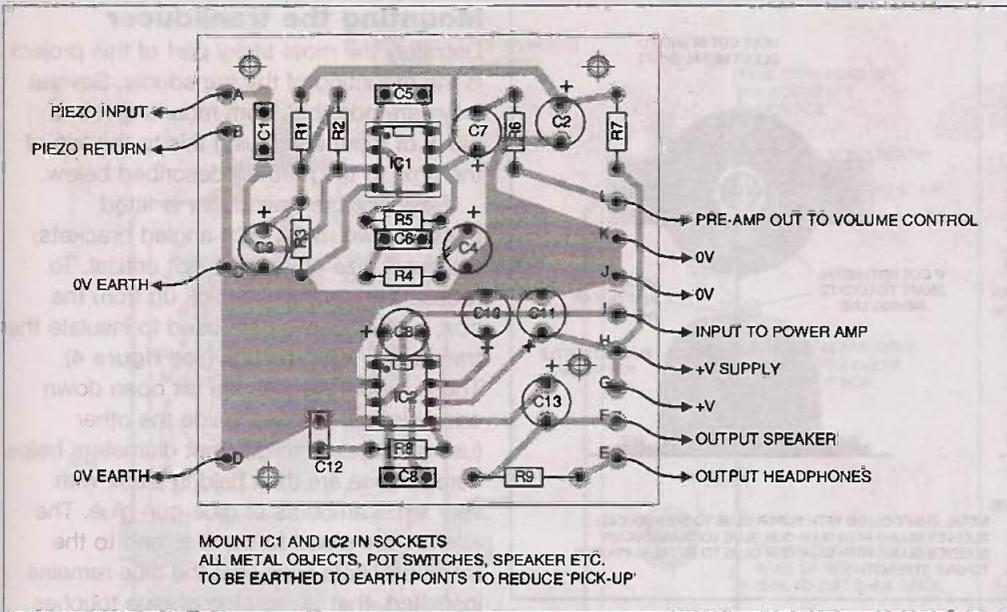


Figure 2: the component layout and connections of the Fishbiter

next most accurate sense is hearing, which proved to be far more practical. As the line is being butted or tugged it sends vibrations along its length, which can even be picked up by the rod. If these vibrations could be heard, we could have something really useful. This, then, is the principal I adopted behind the project: hearing tiny vibrations carried along the line to the rod.

How it works

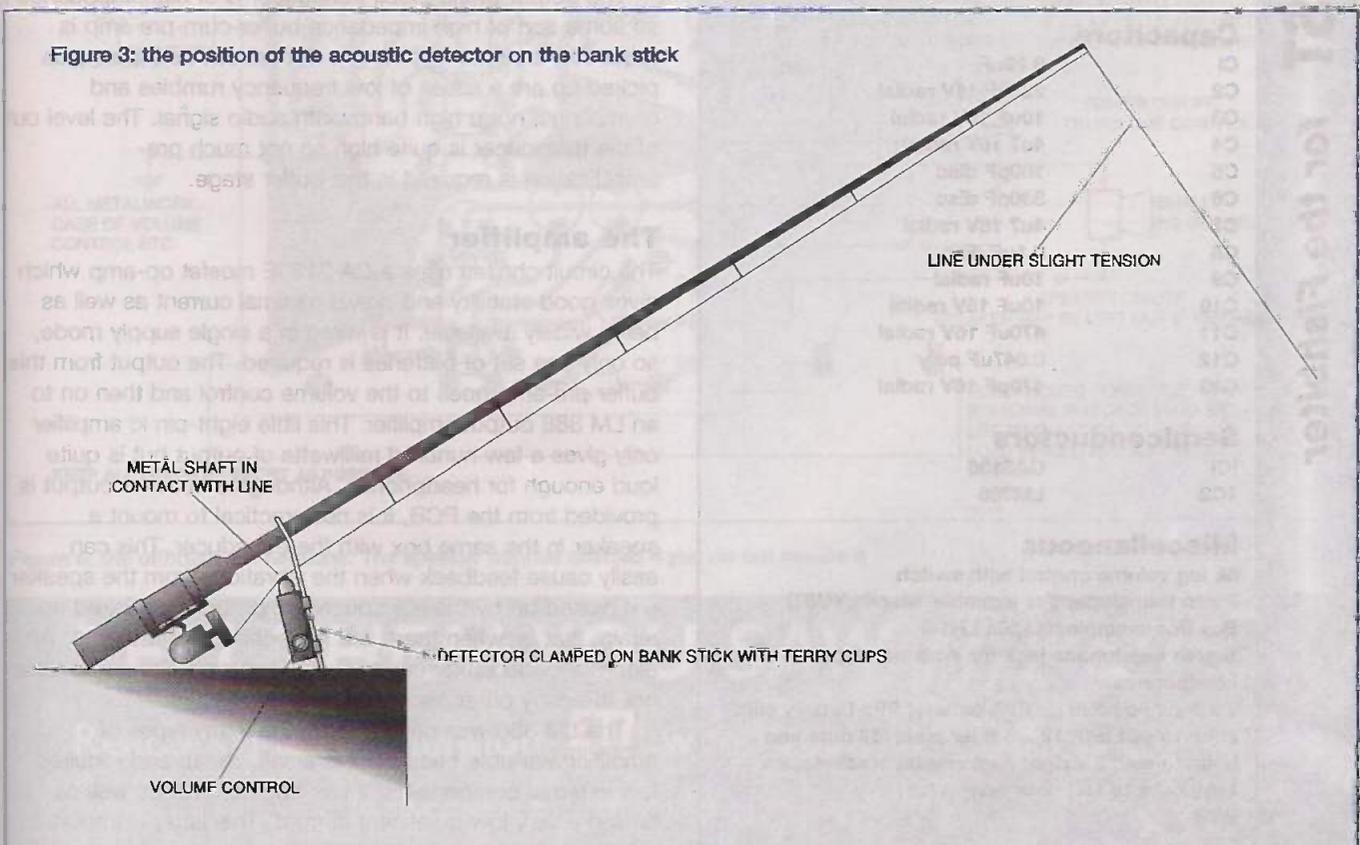
The circuit diagram and component layout for the Fishbiter are shown in figures 1 and 2. The basic system is similar the classic 'telephone' made of two tin cans and a bit of string. If the string is held taut, any sound vibrations generated by the tin can at one end of the string will be communicated to the tin can at the other. In our case, only one-way communication is required (unless

you want to ask your fish some questions) and fishing line is even more effective than string. A microphone could be used to pick up vibrations in the line, but it would also tend to pick up everything else, such as wind and surf noise. A transducer type of pick up is more practical as well as being a lot cheaper. Also, a conventional microphone could be prone to feedback at high gain levels.

The type of transducer used in this project is the piezo type which comes as a very thin disc with two wires; one side of the disc is the piezo material, a grey rough substance which should always be protected from any

damage. The other side of the disc looks like brass and is used as the pick up surface. The vibrations in the line have to be transferred to this surface. Although the transducer could be mounted on the rod, great care must be taken with any trailing leads from the rod as they could cause an accident. Another problem with mounting a sensor and connecting it to the electronics remotely is that the lead connecting it becomes sensitive and can pick up sounds in its own right, or, to be more accurate, become microphonic. To reduce these problems it is easier to mount the transducer in the same box as the electronics, which keeps the sensitive transducer lead down to an acceptable length. To this end the best solution is to mount the electronics and transducer on a rod rest such that the sensor is in contact with the line when the rod is on the rest. The transducer must be

Figure 3: the position of the acoustic detector on the bank stick



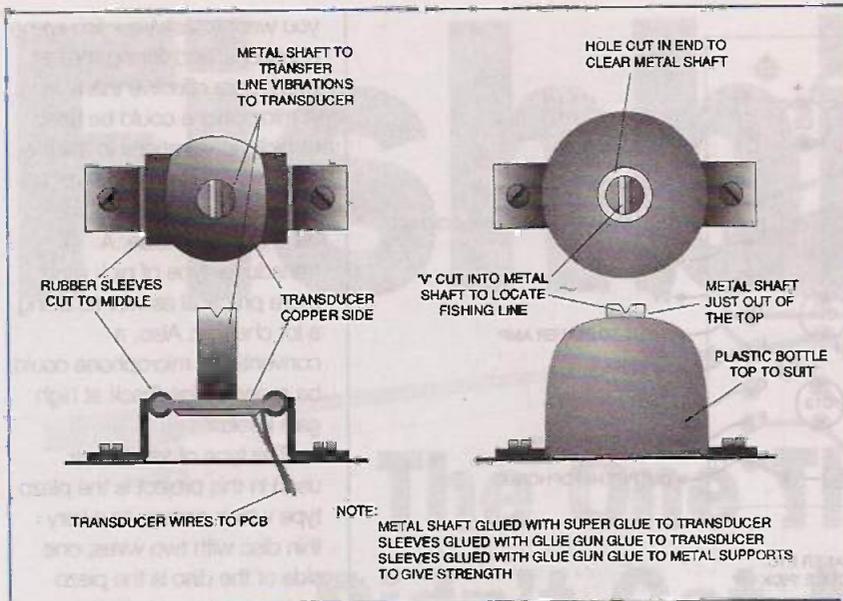


Figure 4: mounting the transducer. Note the 3 slit rubber sleeves fitted one inside the other

as mechanically isolated as possible from its mounting to minimise ground vibrations being picked up.

A little experimenting may be required for each individual rig, but a general idea is given in figure 3.

PARTS LIST for the Fishbiter

Resistors

R1	100k
R2	100k
R3	100k
R4	47k
R5	120k
R6	1k
R7	47R
R8	10R
R9	47R, 0.5 watt

Capacitors

C1	0.22uF
C2	220uF 16V radial
C3	10uF 16V radial
C4	4u7 16V radial
C5	100pF disc
C6	330pF disc
C7	4u7 16V radial
C8	0.1uF disc
C9	10uF radial
C10	10uF 16V radial
C11	470uF 16V radial
C12	0.047uF poly
C13	470pF 16V radial

Semiconductors

IC1	CA3130
IC2	LM386

Miscellaneous

5k log volume control with switch
Piezo transducer (for example, Maplin YU87)
Box (for example, Maplin LH14)
Stereo headphone jack for Walkman type headphones
2 x 8-pin ic holders; PP3 battery; PP3 battery clip; knob to suit pot; 12 x Solder pins; M3 nuts and bolts to suit; 2 x right angle metal brackets; 2 x terry clips to suit your bank stick.
PCB

Mounting the transducer

Definitely the most tricky part of this project is the mounting of the transducer. Several ways are possible, from mounting it in a block of foam and gluing this to the top of the box, to the method described below.

Basically, the transducer is fitted between two metal right angled brackets, the exact size of which is not critical. To reduce the mechanical pick up from the box, rubber sleeves are used to insulate the transducer from the box (see figure 4).

These rubber sleeves are slit open down one side and put one inside the other (using sleeves with different diameters helps here). These are then held in place with very small amounts of glue-gun glue. The sleeves are glued to the disc and to the metal brackets such that the glue remains insulated, that is, no blob of glue touches the transducer and the brackets as this would reduce the anti-vibration qualities of

the rubber sleeves. A small round piece of metal bar is used to transfer the vibrations in the line to the transducer as shown in figure 4. This can be the cut-down shaft of a potentiometer (metal type), about 6mm in diameter. If all else fails a 25mm/3mm spacer can be used. This piece of metal should be Supaglued to the copper side of the transducer, in the middle. Once this has been assembled (see figure 5) a plastic bottle top can be used to cover the transducer - this makes everything look a bit neater. A hole cut in the top of it allows the metal shaft to protrude about 5mm. This hole should clear the shaft completely to allow a couple of mm all round (see figure 4). Shampoo bottle tops seem to be the best as they are normally quite large and can be cut down to size.

The output of the piezo transducer is of high impedance so some sort of high impedance buffer-cum-pre amp is required. Absolute matching is not critical, as the sounds picked up are a series of low frequency rumbles and grumbings, not a high bandwidth audio signal. The level out of the transducer is quite high so not much pre-amplification is required in this buffer stage.

The amplifier

The circuit chosen uses a CA 3130E mosfet op-amp which gives good stability and draws minimal current as well as being widely available. It is wired in a single supply mode, so only one set of batteries is required. The output from this buffer pre-amp goes to the volume control and then on to an LM 386 output amplifier. This little eight-pin ic amplifier only gives a few hundred milliwatts of output but is quite loud enough for headphones. Although a speaker output is provided from the PCB, it is not practical to mount a speaker in the same box with the transducer. This can easily cause feedback when the vibrations from the speaker are picked up by the transducer, amplified and picked up again, that is, when there is a loop gain greater than 1. An external loudspeaker can be used, but care should be taken not to annoy other people nearby.

The LM 386 was chosen from the many types of amplifier available because it is small, cheap and requires few external components; it has bags of gain as well as having a very low quiescent current. This latter is important

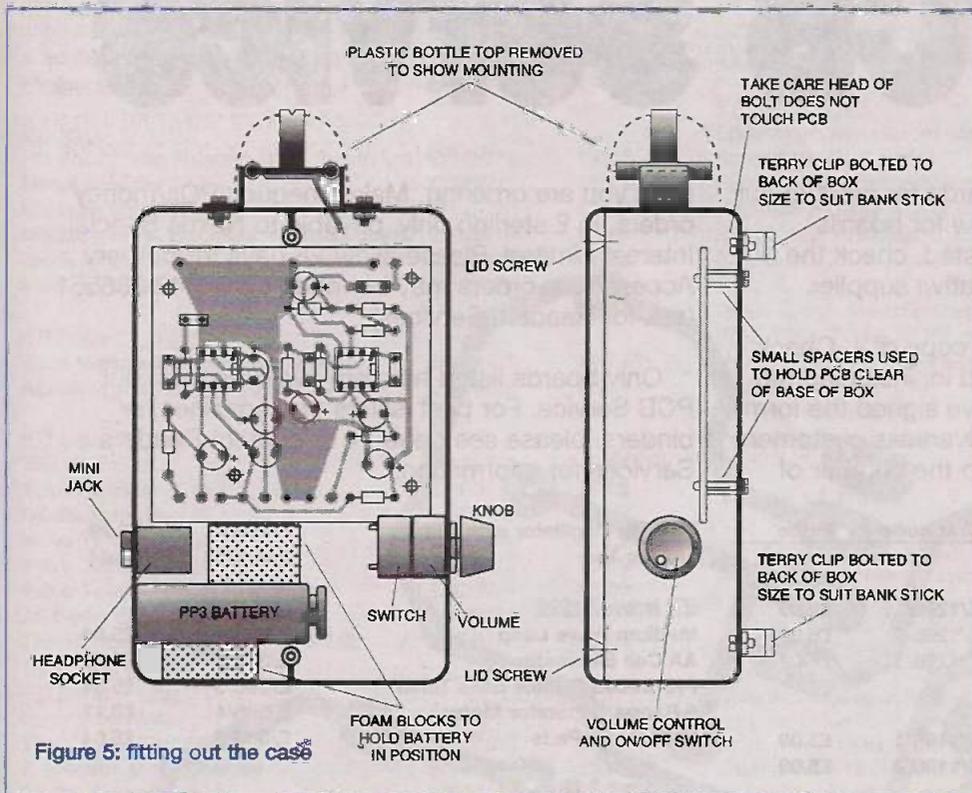


Figure 5: fitting out the case

increases the gain from 20 to around 200. In order to further reduce the effective output power from the amplifier, the headphones are wired in series rather than parallel; this increases the load from 15 ohms, two 30-ohm loads in parallel to 60 ohms, two 30-ohm loads in series, a fourfold saving in power. The easiest way to do this is to use the tip and ring connections of a standard lightweight pair of Walkman-type headphones. Great care must be taken that the headphone lead is not in a position to trip you or anyone else up, especially if you are fishing off a pier or cliff. An extension lead for the headphones may be required.

Although this project was originally designed for sea fishing the same principle works extremely well for river fishing. Although the line is a lot thinner,

(as we know only too well) as it may be used for several hours on end.

The power amplifier is wired in its high gain mode, that is, a 10uf capacitor is fitted between pins 1 and 8. This

enough information can be gathered to seriously increase your chances of catching fish.

Good luck!

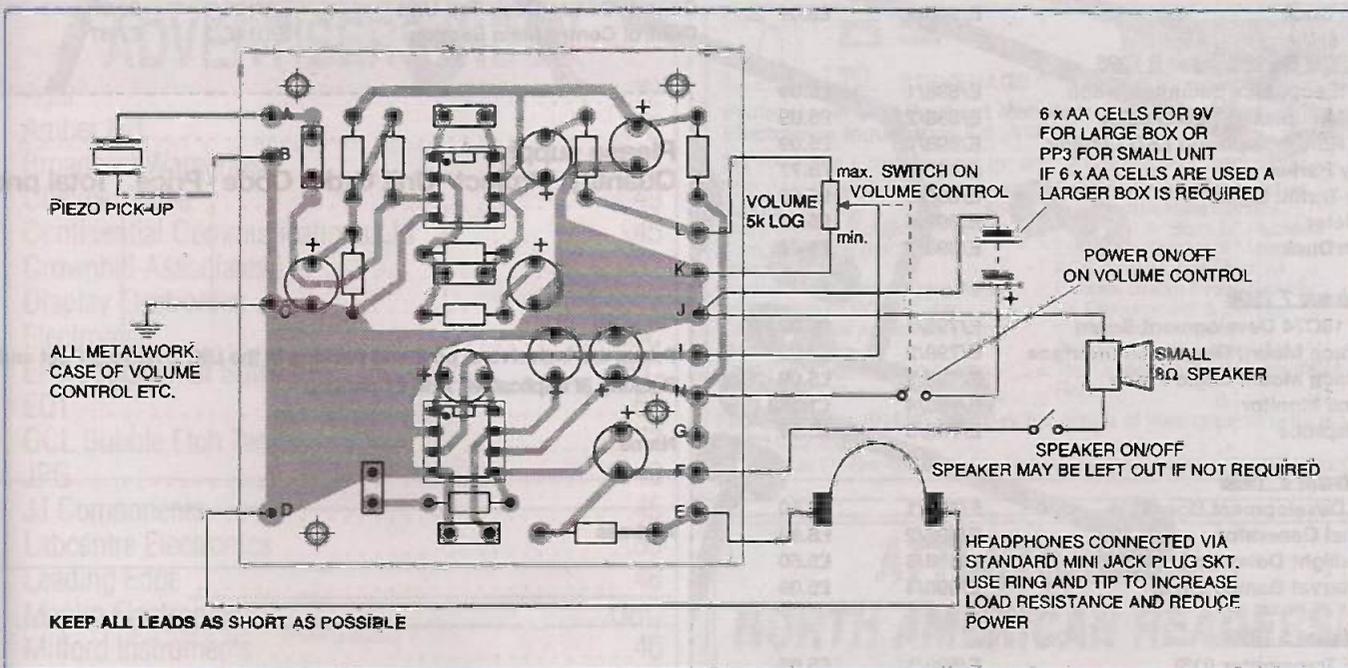


Figure 6: the offboard connections. The speaker may be omitted if you do not require it

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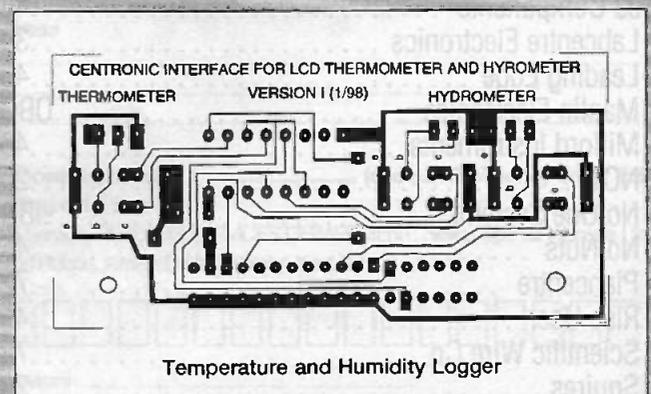
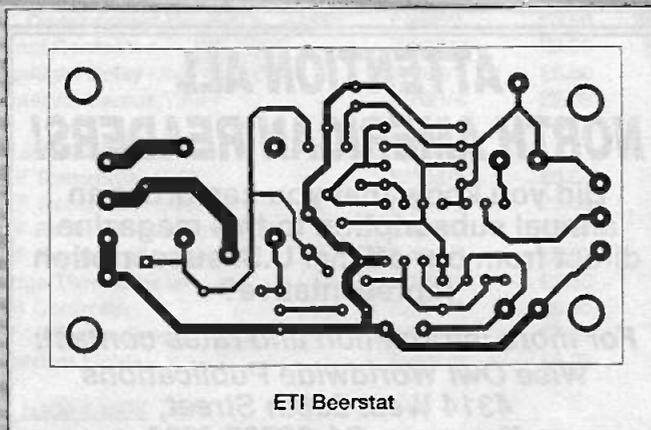
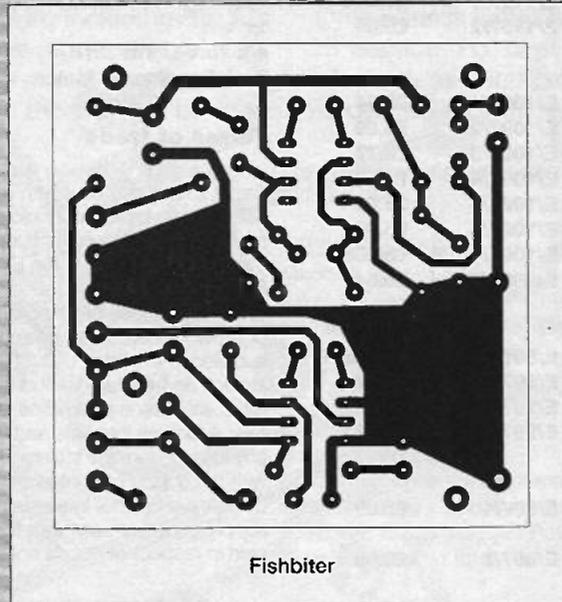
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PRACTICALLY SPEAKING

By Terry Balbirnie

Over the next few issues of *Practically Speaking* we shall be looking at the uses of the magnetic reed switch.

Reed switches are made up of a glass tube with two springy metal "fingers" (the reeds) inside. One end of each reed is sealed through the glass (figure 1). The inside ends overlap slightly and are usually maintained in a normally-open rather than a normally-closed state. Since the reeds are made from a magnetic alloy, they can be influenced by a magnetic field. Most will operate satisfactorily when a small magnet is brought within 5-10mm of the case. The flat face of the magnet should directly approach the flat section of one of the reeds for best results.

Getting close

Look at the arrangement in figure 2. The magnetic field causes both reeds to become magnetised. Each reed therefore develops a north and south pole. Since both reeds are affected in the same way, their left and right ends will develop matching poles and the overlapped ends will have opposite polarity. They will therefore attract each other, make contact and behave like an ordinary switch. When the magnet is removed, the reeds "break" again and the tips separate. Although this is the most common variety of reed switch, there are also types with "break" or changeover contacts.

The glass tube of a reed switch is filled with an inert gas, and the inner tips of the reeds are plated with a precious metal such as rhodium, so that there is no chance of corrosion occurring and the switches are extremely reliable. Reed switches have a typical mechanical life (that is, when the contacts carry only a negligible current) of 100 million operations. When carrying the maximum rated current, the life may be shorter. The maximum allowed current is generally quite small, about 500mA.

Reed switches operate more quickly than conventional ones. The typical "make" time is 2 milliseconds, and less for a "break" switch.

Totally enclosed

Reed switches are sometimes enclosed in a plastic casing with a matching one containing a small magnet. These can be used in a burglar alarm system to protect windows and doors, or to provide an entry/exit delay to prevent the owner setting off the alarm on entering or leaving the premises. The magnet section is generally attached to the moving part and the reed switch to the fixed one. When the door or window is closed, the two parts will be close enough to hold the contacts closed. When the door or window is opened, the magnet is moved away from the reeds, the contacts open and the action triggers the alarm. Several reed switches may be connected in series to protect more than one door or window, as opening any one will break the chain and trigger the alarm.

If you are designing an alarm of this type, you will need a circuit which allows the sounder to operate when the contacts break

rather than when they make. Look at the circuit shown in figure 3. A Darlington transistor, Q1, has its base connected to the reed switches in series and hence to 0V. Since the loop is normally closed, it grounds the base and no current will flow into it. When one of the switches opens, the loop is broken and current flows via R1 into Q1 base, turns on the transistor and directs collector current through the sounder. A small standby current flows via R1 and the loop. Making the value of R1 high renders this current negligible. Since this current also becomes the base current, it is necessary to use a Darlington transistor (which has an extremely high current gain) to ensure that sufficient collector current flows to operate the sounder.

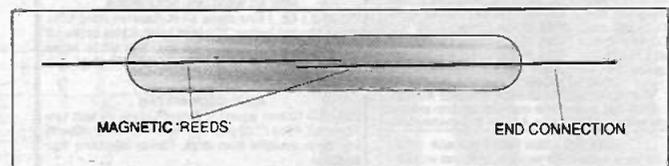


Figure 1: the structure of the reed switch inside its glass envelope

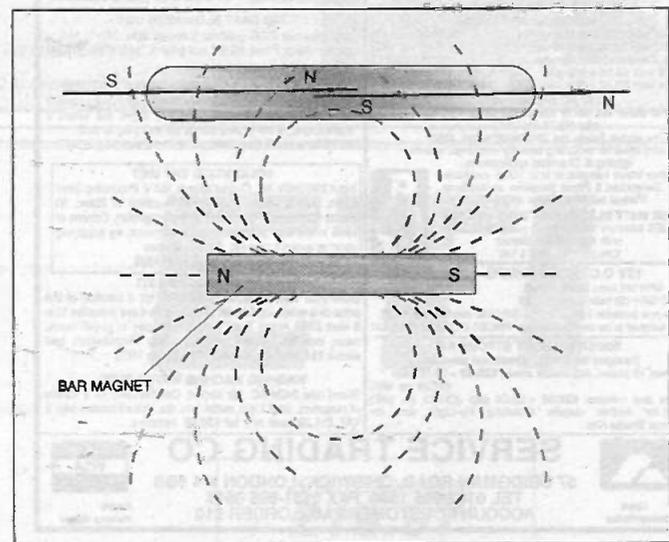


Figure 2: the proximity of a bar magnet induces magnetism in the metal reeds

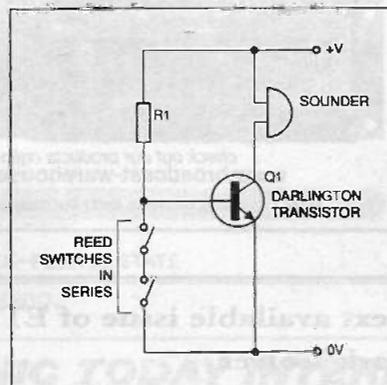
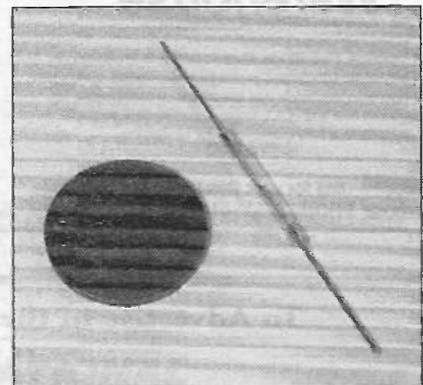
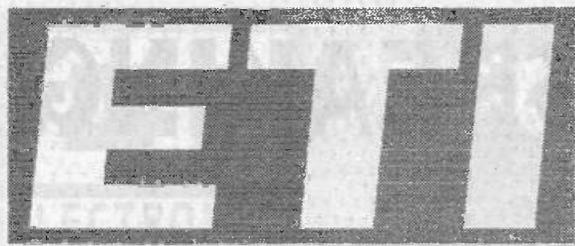


Figure 3: a basic "break" circuit for a security system



A typical reed switch, normally mounted by soldering to insulated wire



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Round the Corner

Electronics - It's Difficult

Electronics - It's Difficult. At the time of writing, Peter Mandelson has just delivered a blunt message about the number of start-up businesses he wants to see over the next three years. On the one hand, the electronics industry is suffering in the current manufacturing recession, with all the knock-on effects into the components business, and on the other hand the DTI never tires of telling us that leadership in the high technology industries is the way forward for Britain. Let's hope that some of these start-ups will be in electronics, which could be good news for technicians and engineers.

However, Peter Mandelson has not been heard to say anything about the load of regulatory problems faced by smaller businesses (including start-ups). The one that most people think of - VAT - need not be much of a problem for a small electronics company. A fish and chip shop may need to quadruple its turnover just to get back to the profit level it had before it hit the VAT threshold. By contrast, an electronics company's customers are probably VAT-registered, so any VAT charged is deducted from the customer's VAT returns. The money goes round in a circle, with some admin costs but no serious loss to the economy until it is charged to a consumer.

Employment legislation, which is meant to protect employees from unfair exploitation,

can however backfire seriously at times. To take an example from our locality from a few years back, a small company manufacturing printed circuit boards was taken to an industrial tribunal by a hopeful employee who believed that he was being discriminated against because he was disabled. The job involved lifting large racks of circuits, and he had only one arm. (I have one ricked shoulder muscle at present, and I'm having some problems lifting anything that requires a bit of reach.) The industrial tribunal eventually ruled in favour of the company. It's never any cause for celebration when a job is ruled out for somebody who needs one, but it was hardly a day of celebration for the PCB maker, either. His small company lost a day of his labour, he lost the income from work which could not be done adequately in his absence, and he lost his legal costs.

All that was some time ago. Nowadays there are more regulations, from how much waste the company can leave for the refuse collectors to the multiple records that must be kept for every employee.

Large companies bear these costs as well, but as a lower proportion of turnover. A really large company has compliance advisers, a choice of job opportunities and sufficient legal services to leave little room for misunderstandings. Small companies don't.

If Mr Mandelson wants more startups, he could help by making the regulatory environment less hostile.

Next Month

Volume 27 No 13 of *Electronics Today International* will be in your newsagents on 4th December 1998 ... Stephen Fleetham kicks off on the first rung of Ladder logic ... Bart Trepak brings light into our lives and peace to the Festive Season with his handy Christmas Tree Light Tester ... Terry Balbirnie has a switchable low-voltage project power supply ... and much more.

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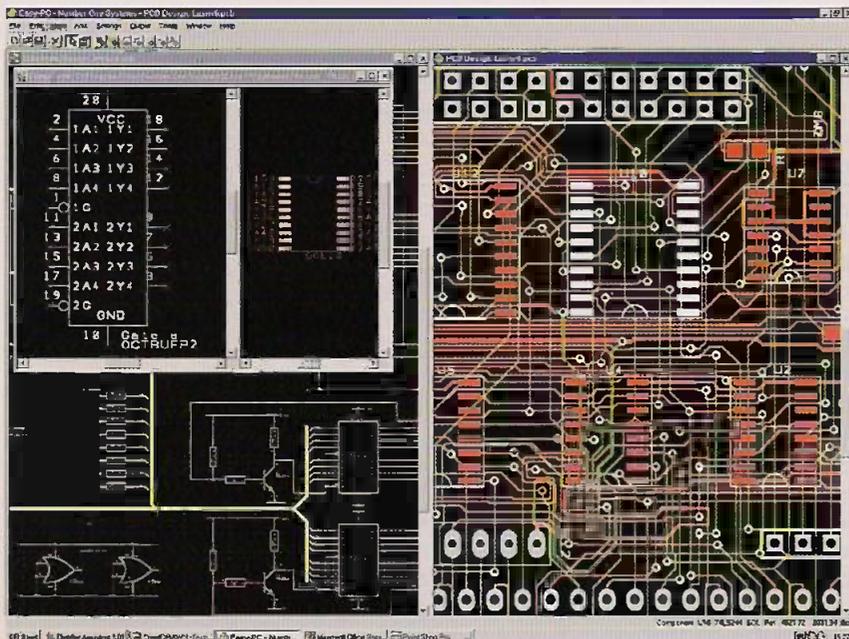
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