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PROJECTS . . . THEORY . . . NEWS . . .
COMMENTS . . . POPULAR FEATURES . . .

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Cover illustration by Jonathan Robertson

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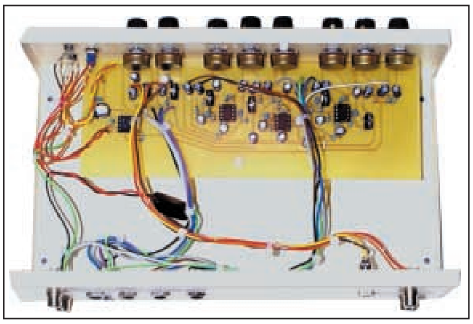

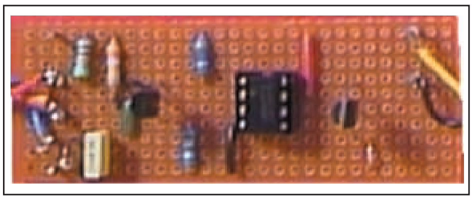

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Our June 2001 issue will be published on Thursday, 10 May 2001. See page 311 for details

NEXT MONTH

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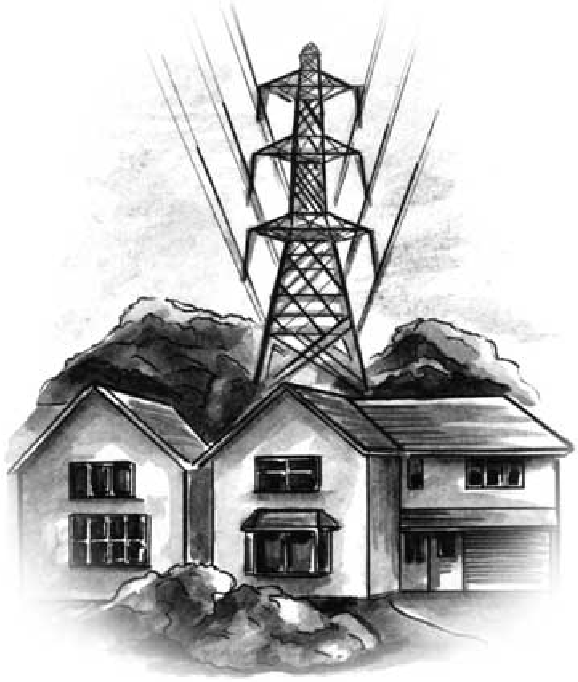

PIC16F87x EXTENDED MEMORY USE

Quite likely it may have escaped the attention of many PIC-microcontroller users that the PIC16F87x devices have considerably more data memory available than is apparent at first glance. Under normal programming circumstances the available memory would seem to be 96 bytes, between hexadecimal 20 to 7F ($20 to $7F).
In fact, the PIC16F873 and PIC16F874 each have 192 bytes available, while the PIC16F876 and PIC16F877 each have 368 bytes. Making use of this additional memory is moderately straightforward, once you know how – but it took the author a while to understand how to use it successfully in a design that required it.
The aim of this article is to describe how the extra memory can be used.

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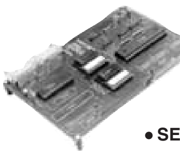

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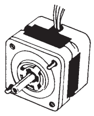

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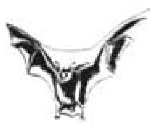

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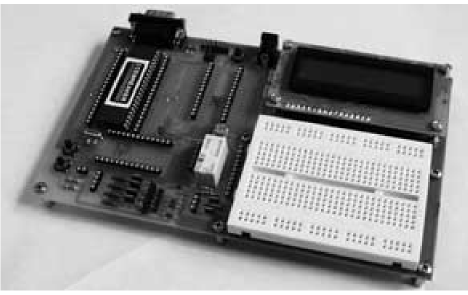

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MORE SCOPE

Oh no! Not another 'scope. Well yes actually, yet another 'scope, but even I must admit that this one probably rounds up the 'scope projects for some time to come. No apologies for having published six different designs – each is totally different and each has its own niche in the test equipment range. There was the full blown PC-based *Virtual Scope* in the Jan and Feb '98 issues, costing over £100 to build, then the mid-range *PIC Dual-Channel Virtual Scope* (also using a PC for the display) in Oct '00, costing about £33 to build, and the no frills *Micro PICScope* using a two-line alphanumeric display to depict the waveform, frequency etc. in the April '00 issue, costing about £20 to build. There was even the very simple analogue input waveform display PC interface in *Teach-In 2000* (March 2000 issue) which would only cost a few pounds to build.

So now we have another l.c.d. 'scope but this time with a graphic display and costing around £55 to build. "You pays your money and takes your choice". They each will appeal to a different type of user and no doubt some readers will find uses for more than one of the varieties.

Test gear projects have always been popular in *EPE* and the various 'scopes have not disappointed as far as reader response is concerned. The latest one again uses a PIC (along with two of the earlier designs) and, mainly because of this, it is easy to build.

STORE

I'm pleased to say our new shop on the UK web site has been up and running for over a month now (see *Network* April '01). So far everything is going smoothly thanks to our UK web guru Alan Winstanley. You have shown your approval by ordering in droves. It's an easy and quick way of buying all the books, p.c.b.s, CD-ROMs, back issues, binders, videos etc. we sell. If you have not yet taken a look please do so. By the time you read this we will also be able to take Amex and Diners Club cards as well as Visa, Mastercard and Switch. This makes buying, particularly from overseas, very easy. The site is at **www.epemag.wimborne.co.uk/shopdoor.htm**.

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Mike Kenward

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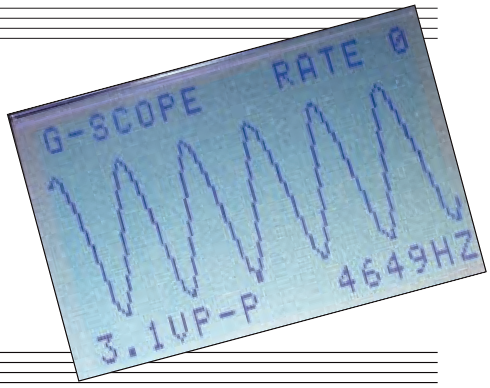
Constructional Project

PIC GRAPHICS L.C.D. SCOPE

JOHN BECKER



Long awaited, a PIC and graphics l.c.d. design for monitoring audio frequency signals has arrived!

OUR February '01 issue of *EPE* contained a supplement in which the author's researches into *Using Graphics L.C.D.s* were published. In this demonstration (nay, *semi-tutorial*) article, various programming routines were illustrated in conjunction with a specially designed printed circuit board.

Demos 11 and 12, many of you will recall, showed the results of experiments with creating waveform displays on the screen. As the text said, these were created preparatory to designing the *PIC Graphics L.C.D. Scope* (*G-Scope*) described here.

No doubt *EPE* will publish other graphics l.c.d. designs in the future, the "dam having been broken", so to speak. That is, the mysteries of using such devices have been revealed (and well hidden they were previously!). The *G-Scope*, though, is such an obvious application for them, that its design is inevitably the first to appear.

MULTI-SCOPING

G-Scope is, in fact, another addition to the widening family of oscilloscope-type constructional projects published in *EPE* over the last few years.

The *EPE Virtual Scope* (*V-Scope*) of Jan-Feb '98 was the most sophisticated of this family, interfacing a complex dual-channel hardware unit to a PC-compatible computer, with a frequency maximum in excess of 10MHz.

Micro-PICscope (M-Scope) followed in April '00, in which a stand-alone unit used an ordinary alphanumerics l.c.d. to display single waveforms on eight of its character cells. It was intended principally as a visual signal tracer, catering for frequencies in the audio range, up to around 15kHz or so.

October '00 saw the publishing of the *PIC Dual-Chan Virtual Scope* (*PIC V-Scope*) which used a PIC-controlled hardware unit to interface to a PC. It was a considerably easier unit to build than the original *V-Scope* and used a cut-down version of the same PC software. The frequency range was nominally audio, although this extended well above and below the human hearing range.

G-SCOPE

The *G-Scope* described here is a self-contained single channel unit, also catering nominally for the audio range. Like *M-Scope*, it is a stand-alone design intended for visually monitoring signals, but having a greater resolution of the signal amplitude display. Whereas *M-Scope* used a display area of 8 × 40 pixels, *G-Scope*'s graphics screen has a pixel density of 64 × 128 (vertical × horizontal).

Like *M-Scope*, it also displays frequency and signal amplitude factors as alphanumeric text lines.

G-Scope also provides sync (waveform synchronisation stability) on/off selection, frequency/voltage monitoring on/off and a choice of three sampling rates. The lowest sampling rate allows sub-Hertz signals to be slowly traced on screen while they occur.

The signal source can be a.c. or d.c. and waveforms up to 5V peak-to-peak can be input without external attenuation. A simple pre-amp stage can be switched to provide ×1 or ×10 amplification. The circuit does not permit negative d.c. voltages to be input.

CIRCUIT DETAILS

The *G-Scope* circuit diagram in Fig.1 is closely similar to that for *M-Scope*. One principal difference is the l.c.d. type used, in this case a Powertip PG12684 graphics display (X2) – i.e. the same device discussed when examining the use of graphics displays in the Feb '01 Special Supplement.

The second significant difference is that the display requires a negative voltage to control the screen contrast. This is provided by the voltage inverter IC4. It is powered at +5V, as set by the positive voltage regulator IC3, and outputs –5V from pin 5. Capacitor C8 sets the frequency at which the inverter operates and C9 smooths the output voltage.

Preset potentiometer VR1 is then used as a variable resistor to set the current flowing through the l.c.d.'s pin 4, so controlling the screen contrast.

A further difference is that the display is controlled by PORTD of the PIC16F877 microcontroller (IC2), instead of the previous PORTB. This now allows PORTB to be used for the mode switches (S4 to S6), taking advantage of this port's internal pull-up resistors in order to use two pushbutton switches instead of three s.p.d.t. toggles.

The signal to be monitored is input via socket SK1 to the gain-selecting switch S2. At this point, the signal routing is switchable via resistors R1 or R2. The gain is determined by the value of the selected input resistor in relation to that of the feedback resistor (R3) in the inverting op.amp circuit around IC1a.

Following R1/R2, switch S3 selects for d.c. or a.c. coupling, the latter routing being through capacitor C4. Resistors R4 and R5 provide mid-rail bias (+2·5V) to the op.amp's non-inverting input (pin 3).

From IC1a, the signal is fed to IC2 pin RA0, which is configured as an analogue-to-digital converter (ADC) input.

The PIC is operated at 5MHz, the maximum in keeping with the highest sampling rate that the PIC's ADC can handle.

As usual with this author's designs, the PIC can be programmed on-board, using a programmer such as *PIC Toolkit Mk2* (May-June '99). The programming connections are via terminal pin block TB2. Diode D1 and resistor R6 prevent the programming voltages from disturbing the rest of the circuit.

Resistor R7 holds l.c.d. pin $\overline{CE}$ (chip enable) high to prevent random display detail being created on screen while the PIC is being programmed.

Pre-programmed PICs are available should you not have a PIC programmer. This month's *Shoptalk* page gives details of this, and of obtaining the software (free) via the *EPE* web site, or from the *EPE* Editorial office on 3·5-inch disk (for which a nominal handling charge applies).

The unit may be powered by a 9V battery, or from an existing 7V to 12V d.c. mains operated power supply (e.g. mains adaptor). Current consumption is only a few milliamps. Note that 9V PP3 batteries are typically rated at between 100mA/hr (NiCad) and 500mA/hr (alkaline) and are not suited to long term powering of the unit.

CONSTRUCTION

Component positioning and track layout details for the *G-Scope* printed circuit board are shown in Fig.2. This board is available from the *EPE PCB Service*, code 300.

COMPONENTS

See SHOP TALK page

Resistors

R1, R4, R5, R7	10k (4 off)
R2, R3	100k (2 off)
R6	1k

All 0·25W 5% or better.

Potentiometer

VR1	22k (or 25k) min. round preset, horiz.

Capacitors

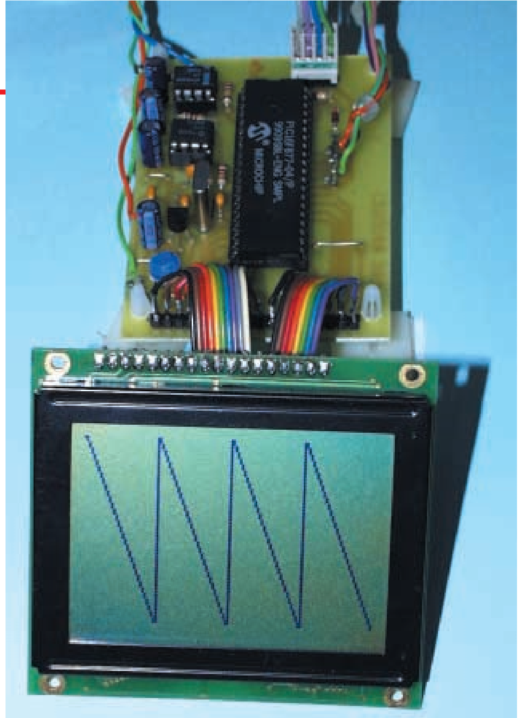
C1, C4, C5, C8, C9	22µ radial elect. 10V (5 off)
C2, C3	100n ceramic disc, 5mm pitch (2 off)
C6, C7	10p ceramic disc, 5mm pitch (2 off)

Semiconductors

D1	1N4148 signal diode
IC1	MAX492 dual op.amp (see text)
IC2	PIC16F877-20P (20MHz version), pre-programmed (see text)
IC3	78L05 +5V 100mA voltage regulator
IC4	7660 negative voltage converter

Miscellaneous

X1	5MHz crystal
X2	PG12864 graphics l.c.d. module (see text)
S1 to S3, S5	s.p.d.t. min. toggle switch (4 off)
S4, S6	min. s.p. push-to-make switch(2 off)



Printed circuit board, available from the *EPE PCB Service*, code 300; plastic case 190mm x 110mm x 60mm (see text); p.c.b. supports, self-adhesive (4 off); 1mm pin-header terminal strips; 80pin d.i.l. socket (2 off); 40-pin d.i.l. socket; mounting nuts and bolts to suit l.c.d.; connecting wire; solder, etc.

Approx. Cost Guidance Only £55 excluding case.

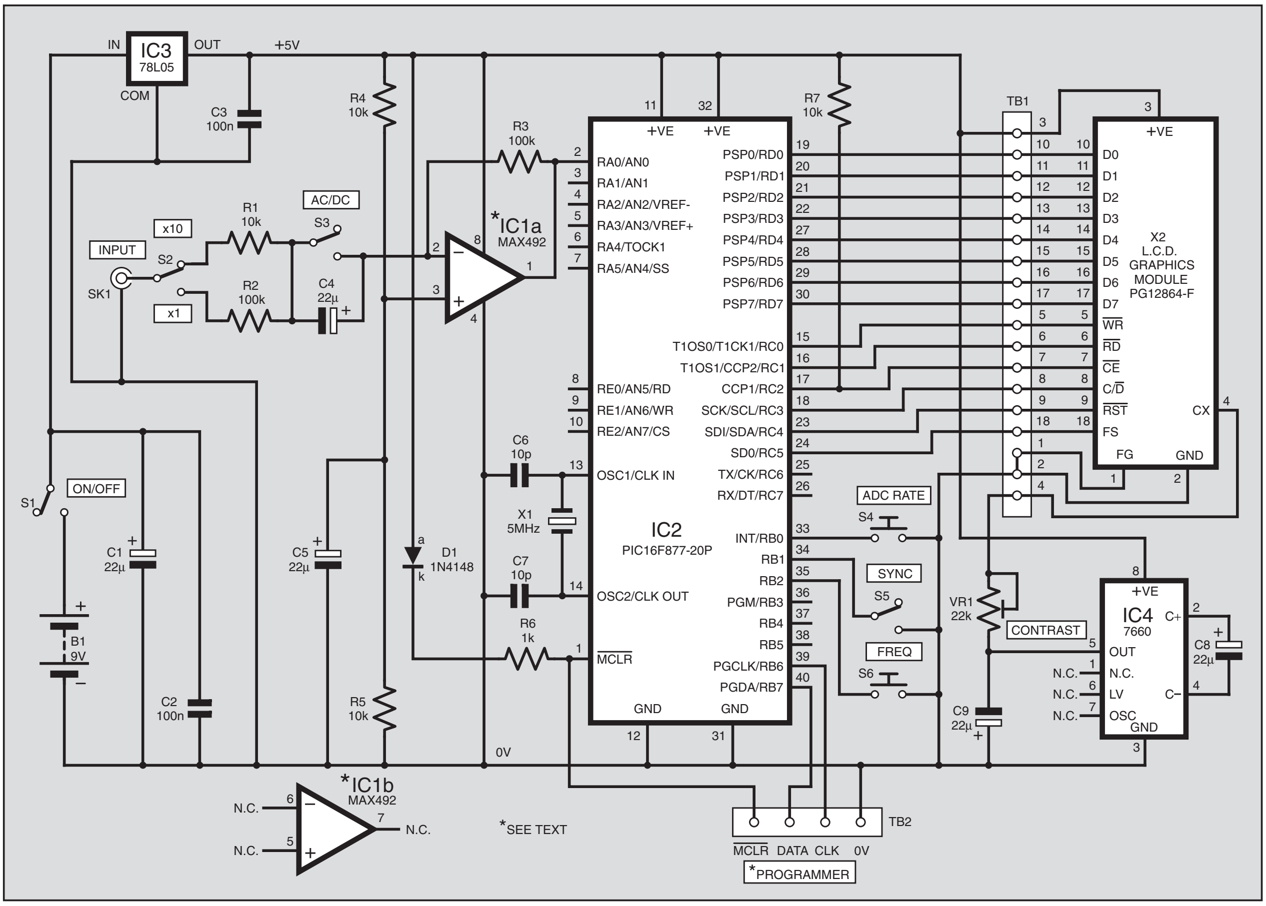


Fig.1. Complete circuit diagram for the PIC Graphics L.C.D. Scope.

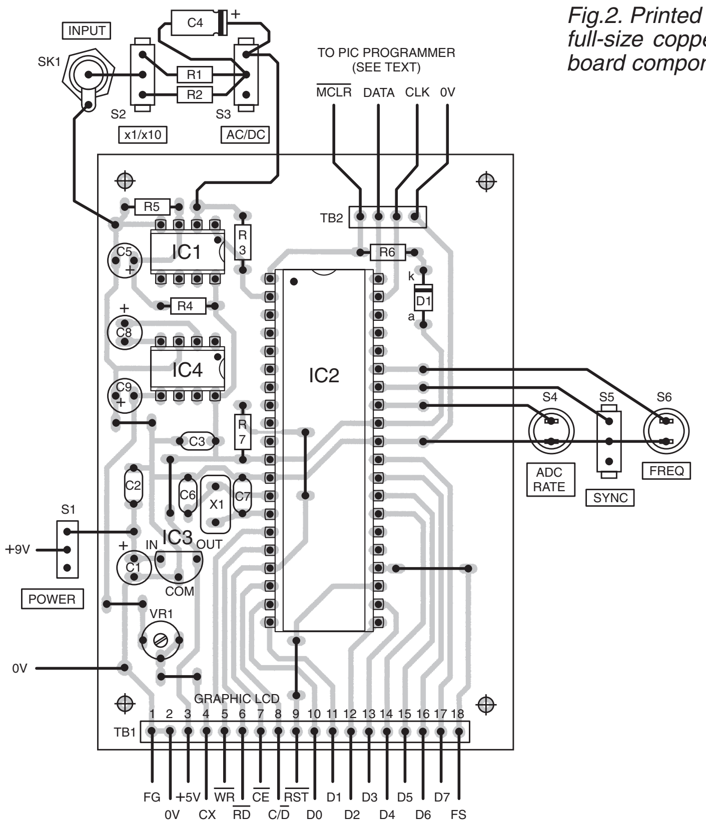
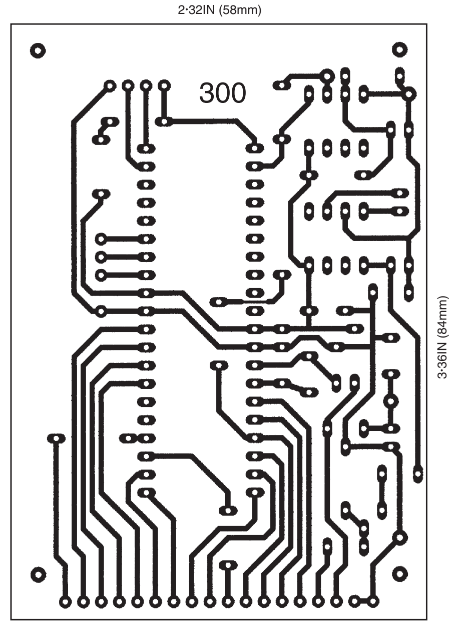


Fig.2. Printed circuit board topside component layout, full-size copper foil master pattern and wiring to off-board components.



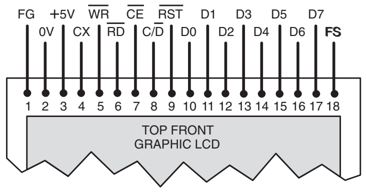


Fig.3. Pinout details from the l.c.d. to the circuit board.

Assemble in order of component size, starting with link wires, d.i.l. sockets (IC1, IC2 and IC4), and then upwards in ascending order. The d.i.l. i.c.s should not be inserted until after the board assembly and voltage output from IC3 have been fully checked.

Note that resistors R1, R2 and capacitor C4 are hard-wired between switches S2 and S3, which are mounted on the front panel, along with S4 to S6.

The p.c.b. pinout connections for the l.c.d. are in the same order as those on the l.c.d. module itself (see Fig.3).

Those of you who purchased a graphics l.c.d. in connection with the "Using them" article will be able to interchange it between the two units if you used a connector then.

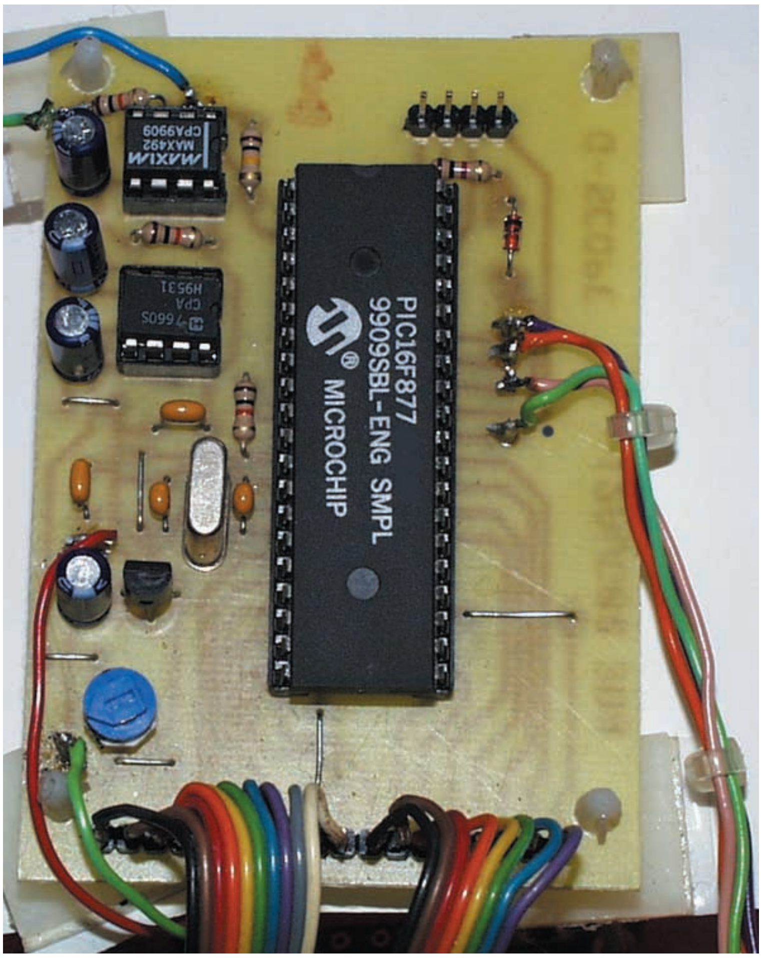
Do not connect the l.c.d. until you know that +5V and –5V are being correctly delivered by IC3 and IC4, respectively.

ENCLOSURE

The author used a suitable graphics l.c.d. viewing aperture in a case. He had, however, come very close to rebelling against this and almost used a case having a see-through lid, mounting the display immediately below it!

For ease of screen viewing the l.c.d. should face upwards in the case. This will allow the maximum amount of light to fall on its transreflective face. Viewing from the side could cause difficulties in a poorly lit workshop. It would be feasible, though, for a back-lit version (somewhat more expensive) to be used sideways in a different style of case.

The author cannot advise on back-lit types, other than to comment that many use internal l.e.d.s as the illumination source and thus probably require a fairly robust power source. Their data sheets should be consulted on this point.



Component layout on the completed prototype circuit board.

GREAT EXPECTATIONS

Having cracked the code structure for graphics l.c.d.s, the author had great expectations of not having to do much further programming work in respect of this *G-Scope*. He had, after all, already written the software for the seemingly similar *M-Scope*. It was, then, just a matter of a few changes in order to suit the needs of *G-Scope*.

But, *the best laid progs o' mice an' men gang aft a-gley*, almost said a certain Scot a wee two and half centuries ago!

Well, er, yes. While some routines *were* almost transported to *G-Scope* as library items, from both *M-Scope* and the L.C.D. Demo progs, the integration was considerably more complex than had first been anticipated.

The principle area of complexity was with the considerably greater quantity of data to be processed by *G-Scope* in comparison to *M-Scope*. The latter only needs 64 samples to be acquired and stored for intermediate processing. *G-Scope* needs 128.

In addition, *M-Scope* has only eight vertical screen positions to be filled or cleared. *G-Scope*, though, has 64 – a significant difference that required an investigative interruption of program development.

DATA BANKS

In normal use, the PIC16F877 has 96 bytes available for data storage. Not enough in which to store and process the sampled 128 data bytes for output to the l.c.d., let alone allow for the many other bytes needed for a variety of essential processes.

It was necessary, therefore, to bring the PIC16F877's additional banks of memory into play. Doing so required research into this aspect of the said PIC (and its other family members of the PIC16F87x series). This resulted in the *PIC16F87x Extended Memory Use* article which will be published next month, and to which you are referred for more information on this useful feature. Such research created quite a detour in the process of *G-Scope* completion.

Basically, members of the PIC16F87x family have four banks (pages) of data memory available, with a total capacity of between 192 and 368 bytes, depending on the device type. Any of this memory can be used in any program, but you have to keep a few wits about you in order to keep the banks correctly allocated, especially as some bytes have intentional joint-access between the banks.

To sum up the memory allocation for *G-Scope*:

- generally accessed variables are held in Bank 0
- the 128-byte ADC "recording memory" is split as 64 bytes in each of Bank 0 and Bank 1
- Bank 2 is used for the data compilation sent to the l.c.d. as graphics (waveform) drawing information
- Bank 3 is allocated for the variables used in decimalisation (from binary) of frequency and amplitude values prior to their screen display as text characters.

This leaves some data memory unused, but insufficient for two-channel's worth of signals to be processed, consequently *G-Scope* has had to be designed as a single-channel unit.

The software source code listing is "commented" with brief notes on the memory and bank use. For a fuller understanding of multiple bank use, though, see next month's article on the subject.

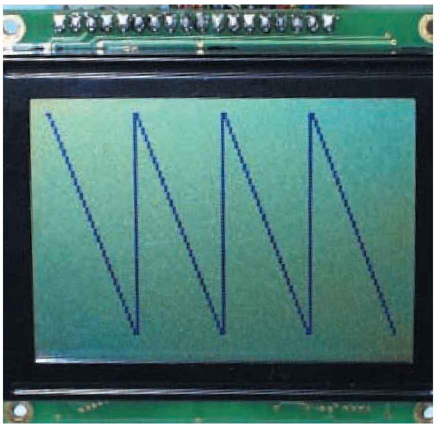
PROGRAM BASICS

In common with the *Using Graphics L.C.D.s* demo software, *G-Scope* uses PIC PORTD for l.c.d. data input/output, and PORTC for its command control.

Following the usual basic initialisation of program variables, an l.c.d. setup routine is called. In this, eight subroutines are called which, to all intents and purposes, are direct copies of those discussed in the L.C.D.s article. A ninth routine (also of the same origin) outputs tabled text data to the screen.

The body of the program starts at label MAIN. Here the choice of whether to monitor with or without synchronisation is checked, according to the status of switch S5.

If sync is needed, three subroutines (commencing with WAITS1) examine the input signal and wait for it to doubly cross a "trigger window" before progressing.



Graphics display module.

SAMPLES

On acquisition of the sync-trigger flag, or switched command to bypass sync, at label SAMPLE1, 128 bytes of input signal data are sampled, converted from analogue to digital, and stored in the memory bytes allocated, 64 in Bank 0 and 64 in Bank 1. This process is completed as rapidly as the PIC's internal ADC allows (also see later).

Although the PIC's ADC offers 10-bit sampling, only the upper eight sample bits are used, the lower two being ignored.

The 8-bit stored data is subsequently divided by four to limit the maximum value to 64, this figure being the same number of vertical pixels on the l.c.d. screen.

Each resulting data byte value now represents the actual line on which the data is to be shown as part of the overall signal trace. Its horizontal position is determined by which sample number it is in the 128-sample batch.

COORDINATES

Drawing the screen line at the correct horizontal/vertical address, though, is complicated by having to clear any previous data from that same region. Failing to do so would cause the screen to become rapidly filled with a congestion of lines.

The clearing process is aided by keeping track of each sample's value in relation that of the previous one. Suppose, for instance, that the first sample at the start of the screen trace has a value of 32. The time axis (Y) for that sample is at screen column zero (Y = 0). A sample value of 32 requires that pixel 32, counting upwards from the bottom of the screen, should be seen as active, i.e. at location X32/Y0.

However, data from the previous batch of samples is displayed somewhere in the Y0 column. The software cannot be told where it is since there is insufficient memory available in order to record the coordinates for 128 previous samples.

Because of this, all pixels of column Y0 have to be cleared in order to ensure that the previous data is removed. Only then can the pixel for the new value be activated at X32/Y0.

Sample two, now let's suppose, has a value of 40. Its coordinates are thus X40/Y1 (next step along the time axis).

We know that a "real" oscilloscope draws a constant trace between each position up and along its cathode ray tube screen. It is hence necessary to try to simulate a similar situation on the l.c.d. screen. Consequently a series of pixels between X32/Y0 and X40/Y1 has to be activated, and again the previous data cleared from that column.

It is wasteful of processing time to clear a full column on each step along the time axis. It is better to clear only those pixels above and below those that need to be active.

The software thus clears the lowest value pixels in the column, sets those required, and then clears those above. Before this happens, though, the software has to compare the preceding and current values and ascertain which is the lowest.

Then the software uses the following three sub-routines:

1. Clear pixels X0/Y1 to XL/Y1
2. Set pixels (XL + 1)/Y1 to XH/Y1
3. Clear pixels (XH + 1)/Y1 to X63/Y1

where XL is the lowest value, XH is the highest, and X63 is the top of the l.c.d. screen.

Obviously, various programming intercepts have to be included to cater for such situations as XL = XH, XL = 0, XH = 63, etc.

In order to use the same routines for each of the 128 time axis columns, prior to entering the controlling loop the program sets XL = XH = the value of the first sample, which is destined for column Y0.

Whilst it is easy to write to individual pixels on the l.c.d. graphics screen, it is far quicker to compile the data for eight columns as a series of 64 8-bit bytes, and then write the 64 bytes to the screen. After which the next 8-column batch can be assembled similarly. The process is so fast that the eye does not notice that it is a stepped assembly and display taking place.

As said earlier, the raw sampled data is held in data memory Bank 0 and Bank 1, while the screen data is assembled in Bank 2.

AMPLITUDE ASSESSMENT

Having displayed a full 128-byte batch of data on screen, frequency and minimum-maximum amplitude values are assessed.

Amplitude min-max values are easily ascertained. First, two temporary variables, MIN and MAX are set so that MIN is greater than or equal to the *highest* value expected, and MAX is set to be less than or equal to the *minimum* value expected. In this instance they are set for MIN = 255 and MAX = 0.

It is then a matter of repeatedly checking each data value against both MIN and MAX. If the sample is less than MIN then MIN is set to now equal the sample. If the sample is greater than MAX, then MAX is set to equal the sample. This checking occurs for all 128 data byte values.

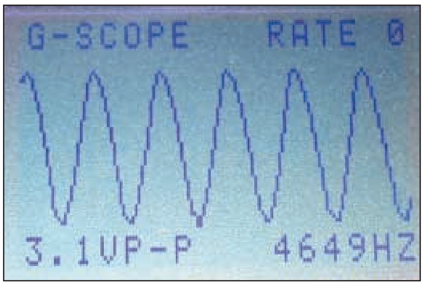
At the end of the process, MIN is subtracted from MAX and the result converted from its binary value to a 3-byte BCD (binary coded decimal) format. This is then output to the l.c.d.'s text screen as a 3-digit number with a decimal point inserted between the lefthand and middle digits, referencing the reading to the scale of the PIC's ADC.

An ADC value of 255 actually represents the supply line voltage at which the PIC's ADC is referenced, i.e. nominally 5V. The routines prior to decimalisation double the ADC values so that a MAX - MIN result of 5V (255) is represented as 510, and displayed as 5·10V. No attempt has been made to exactly "tune" the displayed value to the "real" value. The displayed value, therefore, should only be treated as a guide to actual min-max voltages.

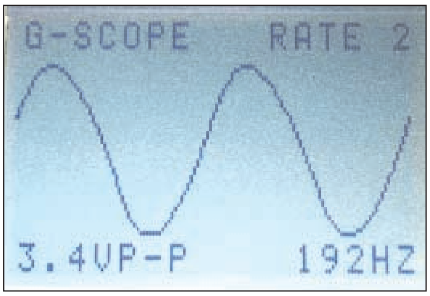
It should also be noted that the PIC does not monitor which gain setting has been selected via switch S2. The voltage reading simply represents that arriving at the PIC's RA0 pin.

FREQUENCY CALCULATION

Frequency calculation uses the same technique as in *M-Scope*. During development of the latter, the author fine-trimmed some counter reference values set into the program. In operation, the number of times that a signal value crosses a trigger level is counted during the period that a counter holding the preset value counts down to zero. The trigger-crossing count represents the frequency of the input signal in Hertz.



Examples of waveforms sampled at different rates, showing the peak-to-peak voltage and the frequency. An example of a display without the text captions is shown earlier.



The technique is remarkably accurate, but is subject to slight deviation from correct values for systems not operating at *exactly* the same rate as the author's.

Should readers wish to correct for their controlling crystal's actual oscillation rate, the preset values can be corrected within the software. It is necessary, though, to have a signal generator and frequency counter so that the signal frequencies can be compared with those shown on the *G-Scope* screen. It is also necessary to have a suitable PIC programmer (such as *Toolkit*) to allow the source code to be recompiled and downloaded to the PIC.

The routines to be amended start at label GETFREQ0, with sufficient notations in the source code to clarify the appropriate ones. There are three involved, catering for each of the ADC sampling rates (more on which in a moment).

The author was interested to find, however, that the factors originally ascertained with *M-Scope* still applied to *G-Scope*, even though the 5MHz crystal was physically another component, bought at a different time.

The *M-Scope* and *G-Scope* test models achieved the following maximum frequency input values while still maintaining good accuracy:

Rate	Sig-Gen	Display
0	17007Hz	16984Hz
1	17007Hz	16998Hz
2	5827Hz	5812Hz

MONITORING ON/OFF

Using the frequency and voltage monitoring routines adds to the time taken to process each sampled signal batch. Even though the process is still quite fast, it was felt worthwhile to allow it to be bypassed. Switch S6 controls this function, toggling between the on and off states.

When the functions are turned off, the screen is cleared of the related text "messages".

When monitoring is in use, decimalisation of the voltage and frequency binary values is performed by a routine which is based in Bank 3. After conversion, leading zeros are blanked for the frequency reading, but not for the voltage reading.

ADC RATES

In common with *M-Scope*, three ADC sampling rates can be selected by switch S4. The rates are stepped through cyclically at each switch press. The screen displays the rate selected by its allocated number, between 0 and 2, but not in terms of specific time values.

The rates are set according to the value by which the PIC's master clock oscillator is divided within the ADCON0 prescaler. Bits 7 and 6 of ADCON0 control the division rate and the displayed numerical value represents the value set into those bits (see the PIC16F87x data sheet, Table 11-1).

Rate 0 (bits 7 and 6 = binary 00 = 0) is the fastest sampling rate for a conversion time of 400ns when using a 5MHz crystal oscillator. The data sheet refers to this rate as 2Tosc. Theoretically, the rate is faster than the data sheet recommends, but the author has frequently run the PIC's ADC at this rate in other designs without experiencing problems.

Rate 1 (bits 7 and 6 = binary 01 = 1) sets the 8Tosc rate, in which the conversion time is 1.6μs at 5MHz. Rate 2 (bits 7 and 6 = binary 10 = 2) sets the rate at 32Tosc with a conversion time of 6·4μs at 5MHz.

The data sheet shows a fourth rate selected with bits 7 and 6 = binary 11 = 3, but this rate (conversion period 2μs to 6μs) is reserved for when the PIC is run under RC (resistor-capacitor oscillator) mode. It is not suitable for implementing with *G-Scope*.

Rate 0 is the one required for sampling signals having higher frequency rates. Rate 2 is well suited to sampling sub-Hertz frequencies.

PROBES

It is not essential that a proper oscilloscope probe is used with G-Scope, although using one will help to keep the monitored signal free of external interference, and provide a convenient probed or clipped connection to the monitored circuit.

In many situations, though, using your multimeter's leads will provide an adequate coupling solution, and more cheaply. If you choose this option, socket SK1 can be replaced by two sockets to suit your meter leads. One should be the signal input socket, and the other for the 0V (GND) connection that is required between the unit and the circuit being monitored.

SOFTWARE

If programming your own PIC, it must be initialised with the settings stated at the head of the source code.

The source code (.ASM) is written in TASM, for which the assembled file is in .OBJ format, such as required by *Toolkit Mk2*. For those who work in MPASM, the .ASM file can be translated to that dialect using *Toolkit*'s software, even if you do not have the *Toolkit* hardware. □

News . . .

A roundup of the latest Everyday News from the world of electronics

SURROUND SOUND HEADPHONES

Dolby has been involved in the design of hi-fi headphones that give you surround sound without annoying the neighbours! Barry Fox reports

AROUND 50 million homes now have a large screen TV set and thumping surround sound loudspeakers round the room, but cannot use them because the neighbours or family complain. Or perhaps you live next door to someone who is pumping sound. Either way, there is good news from Dolby Laboratories, the company which created the problem in the first place, with its surround sound music and movie systems. Dolby has been working with Australian company Lake Technology on a system which can now make ordinary stereo headphones sound like speakers all round the room.

The Dolby surround systems use at least five speakers, often with a woofer adding heavy bass. Both the listener's ears hear sound from all the speakers, and reflected from the walls. If the sound is fed direct to headphones, the left ear hears only the sound intended for the left speakers, and the right ear hears only the right speaker sound. The effect is tame stereo, coming unnaturally from inside the head.

In the 1990s Lake Technology patented (USP 5 502 747) a digital processor which works like an analogue filter to modify the frequency content of an audio signal as it passes through.

Dolby bought a licence to use the patent, measured the way the left and right ears hear sound waves from speakers around a room, and programmed the Lake filter to add a matching effect to signals fed direct to each ear.

Dolby has licensed Motorola, Texas Instruments, Zoran, Analog Devices, Sharp and Sanyo to make home processor chips which filter recordings intended for speaker listening, and make them sound natural on headphones. A black box will connect between an amplifier and stereo headphones, continually adding open-room effect to each of the five channels, and feeding the processed sound to the left and right ears. The listener hears sound apparently coming from outside the head and round the room (and can choose between small, medium and large room effect).

The first Dolby Headphone home processors were scheduled to go on sale early this year.

WIRELESS WEB

THE allocation of the broadband 28GHz licences is well underway. The services provided at this frequency will enable the delivery of Internet and multimedia devices over the airways. For more information browse the Radiocommunications Agency web site at **www.radio.gov.uk** and **www.spectrumauctions.gov.uk**

PYLONS ARE A HEALTH RISK

The National Radiological Protection Board (NRPB) has issued a statement that "some epidemiological studies do indicate a possible small risk of childhood leukaemia associated with exposure to unusually high levels of power frequency magnetic fields".

Elsewhere, a reliable source quotes Doctor Colin Blakemore, a member of the Advisory Group on Non-ionising Radiation (Agnir), as having said that it was acknowledged that evidence exists indicating an association between power lines and cancer, but that the mechanism was uncertain although it could be due to the high voltage lines emitting ions (charged particles) which may then be inhaled.

This is the first occasion on which it has been officially accepted that a link exists between cancer and power lines.

For more information, contact the NRPB, Chilton, Didcot, Oxon OX11 0RQ.

Tel: 01235 822744. Fax: 01235 822746.

Web: ***www.nrpb.org.uk****.*

STAND AND DELIVER

SOLID State Electronics have sent us not only a colourful selection of product leaflets, but also two examples of some very useful adjustable multimeter stands. These are illustrated in the photograph, with one of them holding the multimeter that we present monthly to the author of the best *Readout* letter.

The stands are solidly made and are in little danger of being knocked over on a busy workbench. Having your meter supported at a convenient angle can certainly be recommended. The angle can be adjusted using knurled finger knobs. So too can the position of the fore-stop support, and of the width clamps. Sensibly, there is a 4mm earthed connection socket via which the stand can be grounded, helping to maintain good anti-static precautions in the work area. We too shall find good use for the stands!

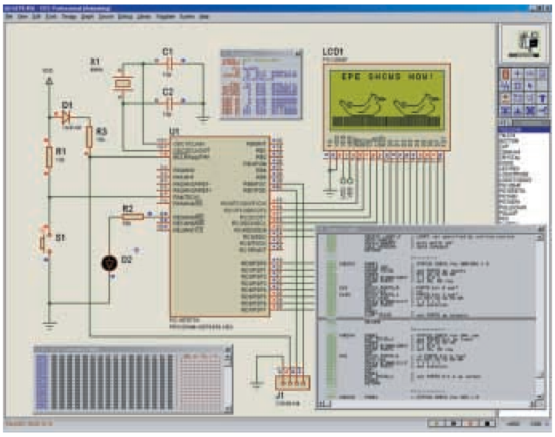
Amongst SSE's products is a variety of stands for other purposes too, including those for securely holding radio handsets, such as CB, amateur, marine, cellular etc.

Other products relate generally to radio in various ways, and include notch filters for interference suppression, antennas, fully regulated power supplies (complete with another adjustable support bracket), S-meters, etc.

Additionally, SSE sent information about the PMR 446 licence-free FM 2-way voice-only radio system, introduced in the UK in March 1999. A *Which & Why* series of leaflets was included as well, in which SSE director James Finch highlights and provides answers to various PMR 446 topics. He also provides information about the SRRG, the Short Range Radio Group.

For more information on all these subjects, contact Solid State Electronics (UK), Dept. EPE, 6 The Orchard, Bassett Green Village, Southampton SO16 3NA. Tel: 01703 769598. Fax: 01703 768315.

PROTEUS AND GRAPHICS LCDS



LABCENTER tell us that as an example of what their Proteus VSM simulator can do, they have put together the hardware and software for programming graphics l.c.d.s as featured in the *Free* supplement in our Feb '01 issue.

As you can see from the picture, Proteus VSM simulates the PIC16F877 and the EPE Graphics LCD display together with the pushbutton used to step between the various sections of the example program. Labcenter say, "There is no cheating here – VSM really does simulate the PIC processor as it executes John Becker's code". When the program writes to the PIC's ports, the logic state transitions are picked up by the Graphics LCD display model which draws the appropriate images onto the screen.

And if that wasn't enough, you get a full set of source level debugging tools including single stepping, register display, breakpoints and a user configurable watch window.

Labcenter suggest you download a copy of Proteus Lite from their web site and try a few experiments for yourself. The Graphics LCD sample is included along with a number of other microprocessor designs, all of which can be fired up and experimented with before you decide whether to register your copy of the software or not. You can change the microprocessor programs as much as you like, as long as you don't change any of the wiring on the schematics.

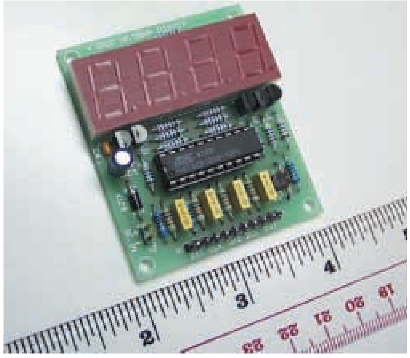
If you like what you see, you can register whichever modules of Proteus Lite that take your interest. To simulate designs like this one, you'll need ISIS Lite (schematics), ProSPICE Lite (simulator), the PIC16F87x processor model and the Graphics LCD model. Add the virtual oscilloscope, signal generator and logic analyser and you are all set to develop complete PIC-based microprocessor designs without soldering a single component.

The total cost of these modules would normally be £80 but Labcenter are making them available to *EPE* readers for just £69 inclusive, or £79 if you would like the ARES Lite PCB layout tool as well. Don't forget that Proteus Lite is not just a PIC simulator – it's also a fully featured schematic capture tool and general purpose SPICE simulator.

Comments John Becker: "It is obviously a most powerful tool if it can handle the full parameters of my software for PIC-controlling Graphics LCDs".

Labcenter Electronics, Dept. EPE, 53-55 Main Street, Grassington BD23 5AA. Tel: 01756 753440. Fax: 01756 752857. E-mail: info@labcenter.co.uk.
Web: www.labcenter.co.uk.

Counter Revolution



Quasar's Kit 3129 4-digit l.e.d. up/down counter module.

QUASAR Electronics has introduced two new low-cost microcontroller based counter kits.

Kit 3129 is a 4-digit l.e.d. up/down counter that can be used in the range 0000 to 9999. It accepts input pulses from any "make" contact, such as those from switches, relays, open-collector outputs and simple pushbutton switches. Quasar quote as examples the monitoring of a turnstile microswitch or the relay output from an infrared security beam (such as from their Kit 3130), counting cars, or people, or even items on a conveyor belt. An overflow output signal, which can be connected to a second counter, is triggered when the counter wraps around to zero, The maximum counting rate is 100 per second, and there are inputs for Reset, Up, Down, Disable and Overflow.

The other design is Kit 3154, which is a 4-digit presettable l.e.d. down-counter that can be used for both low (30cps) and high (4100cps) speed applications. Like Kit 3129 it accepts inputs from any "make" contact. It has four user-selectable output modes for use when the count reaches zero, and there are inputs for Rate, Count and Reset, plus an output to an *npn* transistor, rated at 100mA, 30V.

For more information contact Quasar Electronics Ltd., Dept EPE, Unit 14 Sunningdale, Bishops Stortford, Herts CM23 2PA. Tel: 01279 306504. Fax: 07092 203496.
E-mail: sales@quasarelectronics.com.
Web: quasarelectronics.com/counters/htm.

SMARTPHONE BATTLELINES

By Barry Fox

MOST desks now have a PC on the top and most people have a 2G (second generation digital) cellphone. The industry's sights are now set on a new generation of mobiles which combine a cellphone, a pocket computer, a games machine and an audio-video player. These new "smartphones" will use the faster wireless connections promised from 2·5G (GPRS) or 3G, third generation, technology. They will also need a new operating system, comparable to the Windows or Mac desktop systems. Battle lines are now being drawn for the fight to create a *de facto* standard.

Microsoft has developed a new mobile operating system, code-named Stinger, which is based on the Microsoft Pocket PC operating system for handheld computers (like HP's Journada) which itself was based on the Windows CE system for portables, which was based on Windows 95/98.

Windows CE was a flop. Pocket PC has had nothing like the success enjoyed by Windows in the desktop world where the only competition has been the Mac which was handicapped by years of Apple inertia. The mobile market has so far been dominated by the Palm Pilot/Handspring and Psion/Symbian. Now there is a new contender, the i-Mode platform from Japan's NTT, as used in the DoCoMo phones which are hugely popular in Japan.

Although Texas Instruments is offering a Stinger chipset and new cellphone manufacturer, Sendo has backed the system along with Samsung and Mitsubishi (with network trials by Vodafone), major players Nokia, Motorola, Panasonic and Ericsson are still deciding which way to jump.

So the real battle has not yet started.

Windfarms Encouraged

ENERGY Minister Peter Hain has published a consultation paper spelling out the Government's proposals to help companies set up new offshore windfarms. In a statement from the DTI, he said that:

"Wind power is a vital part of our commitment to clean and renewable energy. The Government has announced a total of £89 million available in the form of capital grants for demonstration projects including offshore wind.

"The Government is doing everything it can to help industry meets its target of supplying 10 per cent of our electricity from renewable resources by 2010, including encouraging a significant capacity for offshore windfarms . . . emphasising our commitment to boosting this source of green energy while at the same time ensuring that the effect on the environment is properly assessed and that local views are fully considered."

New Technology Update

Audio quality is being further improved by the introduction of digital amplification, reports Ian Poole.

THERE have been many electronic developments that have affected the audio and hi-fidelity business. In particular there has been a general trend to adopt digital techniques.

However, the one main area where the digital revolution has not had any significant impact is in the field of audio amplification. Here analogue amplifiers are still the only approach that is widely used. This means that after the digital sections of the system, the signals have to be passed into a digital-to-analogue converter (DAC) and transformed into an analogue waveform to be amplified. This destroys many of the advantages of the digital system.

Direct Digital Amplification

This might be about to change with new developments from a company named Apogee Technology Inc. They have developed a system called Direct Digital Amplification (DDX) that provides an all digital amplifier architecture. It has been developed to meet the needs of a wide range of applications where audio amplifiers are used, ranging from PC multimedia systems to home audio systems.

It will also be particularly applicable to portable units such as MP3, MiniDisc and CD players. Here the much greater efficiency of the new system is of particular benefit, reducing current consumption and increasing battery life.

The new DDX technology eliminates the requirement for a DAC to convert a digital signal to an analogue format to be amplified. Instead it uses patented digital signal processing techniques to control a high efficiency tri-state output device using pulse width modulation (PWM).

In this way audio signals can remain in a digital format right from the source medium on which they have been recorded through to the output device before being reproduced in an analogue format by the loudspeaker or headphones.

The system uses an all digital approach that consists of the DDX controller and a digitally controlled power device. This eliminates the analogue components as shown in Fig.1. The new digital approach improves the efficiency by up to a factor of three when compared to standard class-A or class-B designs that are widely used today. Even when compared to class-D amplifiers it still provides a useful improvement in efficiency.

To achieve this improvement the chip converts the incoming signal into a pulse width modulated waveform using Apogee's patented damped ternary system. The PWM signals generated within the i.c. are used to control the output section consisting of power transistors in a full-bridge configuration. As the devices are either completely on or off, little power is dissipated and as a result the system provides a very high level of efficiency.

A further advantage is that the system does not handle low level analogue signals, only digital and high level analogue signals are used. This means that the system is able to provide exceedingly high signal-to-noise ratios.

Apart from providing an exceedingly quiet system when no signal is present it has other advantages in terms of simplifying circuit board design because there are no problems with stray pick-up, hum loops and the like. Additionally, this means these systems can be used in environments where electrical noise levels are very high.

Reducing Interference

Any switching amplifier design will produce unwanted energy at and above the switching frequency. Minimising this to an acceptable level is a key element in the design. If this is to be achieved then it must be part of the initial design concept of the system, and DDX is no exception.

The required performance is achieved by adopting two techniques. The first and most obvious is to incorporate a low-pass filter close to the switching transistors used in the DDX output. In this way most of the unwanted high frequency components contained in the PWM signal are removed.

Additionally, the output of the DDX chip contains a unique three-state configuration, and this produces considerably less energy at the switching frequency and above than the more conventional two-state devices. Fig.2 shows how this operates.

Using a binary system switching must involve switching from one voltage state to the other. This means that to produce a low level or zero signal the output must switch equally from one rail to the next. This is akin to two large signals cancelling one another out. As most music contains many periods of low level sounds, this means that binary modulated signals are always providing energy into the filter.

The same is not true for the three-state output. Here switching only occurs from the zero state to the required rail. When no signal is present the load is connected to ground, providing damping to the loudspeaker.

In tests that have been performed this new concept reduces the levels of switching frequency energy by as much as 16dB and reducing electromagnetic interference (EMI). Not only does this concept improve the EMI performance, but it also gives better audio performance because earthing the speaker for part of the cycle effectively reduces the source impedance.

Applications

The DDX chips are available as a two-chip set. The DDX-2000 acts as a controller whilst the DDX-2060 contains the power devices, providing two channels up to 30W into an 8Ω load. Other features include digital volume control, anti-clipping, short circuit and thermal protection.

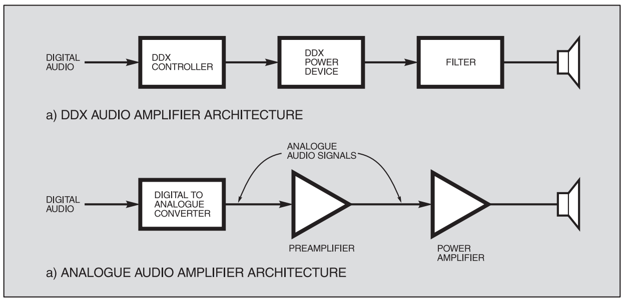


Fig.1. The architecture required for analogue and DDX solutions.

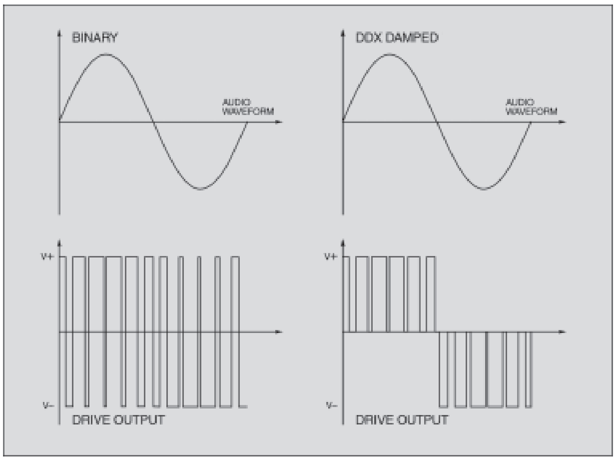
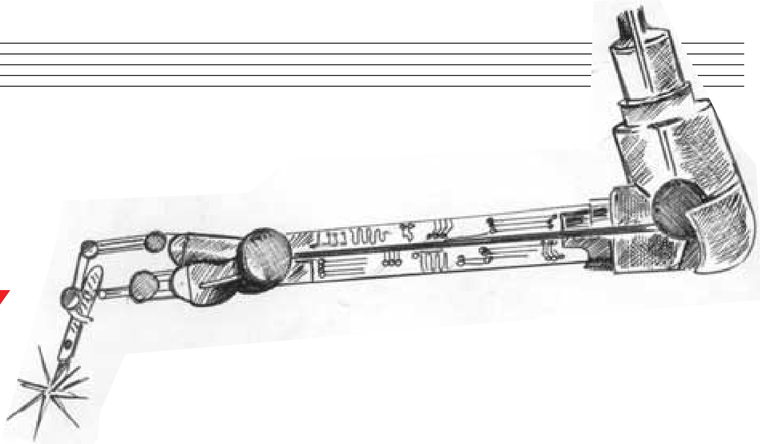


Fig.2. Comparison between binary and DDX damped three-state switching

Regular Clinic



CIRCUIT SURGERY

ALAN WINSTANLEY
and IAN BELL

The thorny aspects of impedance are investigated this month by our team of "surgeons"

Impedance Matching

THE term "impedance matching" is used quite frequently but is not always fully understood. We encounter the idea of impedance matching when we want to connect circuits, systems, and devices together – that is, we may ask, "is the source correctly matched to the load?"

In some cases the question should really be "is this source suitable for this load?", with the term *matching* being reserved for particular circumstances. But before looking at "matching" in various guises we should make sure that we understand what impedance is.

Impedance (symbol Z) is measured in ohms, but relates to a.c. rather than d.c. signals, so therefore it may be frequency-dependent. The *impedance* of an ideal resistor is simply equal to its *resistance* and is independent of frequency, but with capacitors and inductors often being involved things are not so simple.

Thinking Angles

For capacitors (C) and inductors (L) the magnitude of the impedances are $1/(\omega C)$ and ωL respectively, where ω is the "angular" frequency of the applied signal, measured in radians per second. To convert to a frequency in cycles per second (Hertz) use $\omega = 2\pi f$, where f is the frequency in Hertz. From the impedance formulae it is obvious that the "resistance" of inductors and capacitors is frequency dependent. This is one of the reasons we use impedance instead of resistance for the generalised analysis of "resistance" to signal flow.

If you have not met angular frequency before, don't worry too much – you probably have in fact been thinking in this way if you have ever used the idea of *phase shift.* The complete cycle of a waveform is 360 degrees, which is 2π radians (degrees and radians are two ways of measuring angle: we use whichever is most convenient). To convert between degrees and radians use $360° = 2\pi$ radians. A phase shift of 90° is a quarter of a cycle, or $\pi/2$ radians. We are interested in phase shift angles when dealing with capacitors and inductors for the very good reason that currents and voltages are not in phase.

If we apply a sinewave voltage to a pure (ideal) capacitor, the current waveform will be 90° "ahead of" (earlier than) the voltage waveform, i.e., the current will peak a quarter of a cycle before the voltage peaks. This means that we cannot treat it in the same way as we would a resistor; for example, we cannot simply multiply current and voltage together to give average power. In fact, the average power for a pure capacitor driven by a sinewave is zero!

Reactive Circuits

The fact that current and voltage are out of phase in circuits containing capacitance or inductance is the key reason for using the idea of impedance rather than just resistance. The reason that angular frequency (ω) is used in impedance formulae is because this makes it easier to manipulate equations in which we are dealing with both frequency and phase shift. Circuits containing capacitance, inductance, or both are called *reactive* circuits.

The phase difference between current and voltage in circuits with capacitance and inductance gives them a sort of "two dimensional" quality, whereas circuits consisting purely of resistors are "one dimensional" with current and voltage always in phase. This makes mathematical analysis of even simple reactive circuits more difficult than that of purely resistive ones. We have to use two-dimensional numbers to deal with the fact that the current and voltage respond differently to different impedances.

These two-dimensional numbers are known as *complex numbers* (which, having two parts, are more complex than normal numbers!); the two parts are known as the *real* and *imaginary* parts. The term "imaginary" is employed because the square root of –1 is used in this type of mathematics.

There is no "normal" number which when multiplied by itself gives –1, but it is a very useful mathematical concept for describing things that really happen. So impedances are measured using complex numbers, ones in which the purely resistive elements of the circuit contribute to the "real" part and the purely reactive elements form the "imaginary" part of the impedance.

Thus impedance (symbol Z) can be seen to consist of resistance (symbol R, real part) plus reactance (symbol X, imaginary part). Ideal resistors only have resistance and ideal capacitors and inductors only have reactance. Real components, however, will have some of each, but with resistance dominating for resistors and reactance dominating for inductors and capacitors. Circuit impedances (e.g. input and output impedances) may have any combination of resistance and reactance.

We can write Ohm's Law for impedances as $V = IZ$ in which V, I and Z are all complex numbers. When we are dealing with individual capacitors and inductors, though, and we're not concerned about current and voltage phase shifts, we can use the formulas for impedance magnitude given above to get the "resistance" of a capacitor or inductor, for example, in order to work out the magnitude of the current likely to be flowing through it.

As capacitors and inductors are purely reactive their "resistance" is equal to the magnitude of the reactance, which is why we use the well-known reactance formulae given below and the symbols X_C and X_L for capacitive and inductive reactance:

$$X_C = \frac{1}{2\pi fC} \qquad X_L = 2\pi fL$$

In these fomulae, the capacitance (C) is in Farads, the inductance (L) is in Henries, and the frequency (f) is in Hertz. Strictly speaking these are imaginary numbers, or should be described as "magnitude of reactance" but this is often overlooked when complex number mathematics is not needed.

A Good Match

So far we haven't said much about impedance matching itself, but we have seen that to really understand impedance requires the mathematics of complex numbers (and you need calculus and trigonometry functions too!), so maybe it is not surprising that anyone who never studied these topics (or has now forgotten them) occasionally has problems with "impedance".

When discussing matching we are concerned with the *source* and *load* impedances. This is illustrated in Fig.1 in which the source is represented as a voltage source V_s in series with a source impedance Z_L. Actually, any electronic or electrical device, circuit, or system that generates, produces or outputs a signal can represented in this way.

One example of a kind of "matching" which arises immediately from the preceding discussion concerns power and reactive loads. If the current and voltage are out of phase, then what power is consumed and how do we measure it?

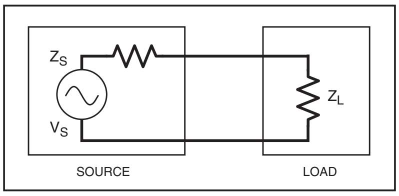


Fig.1. A simple source and its load, interconnected. Ultimately, any circuit can be represented this way.

This is a big problem for power companies supplying mains electricity because highly reactive loads, such as a factory full of industrial motors, would skew the measurement of (average) power delivered to the customer. The degree to which a load is resistive or reactive is measured by its *power factor* which varies from 0 for purely reactive to 1 for a purely resistive one. Power factor can be corrected by actually *adding* more capacitance or inductance to the circuit as appropriate, in order to make the phase relationship between the current and voltage closer to that for a resistive load.

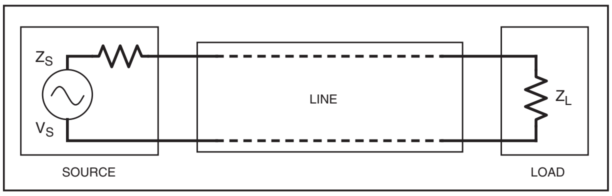


Fig.2. In real life, we may need to consider not only the source and load impedances but the interconnecting "line" as well.

Reactive loads can occur in circuit design as well, and again we can ask "is this load suitable for this source?" (continuing our theme of the idea of "impedance matching"). For example, a capacitive load may result in a large initial surge current as the capacitor charges up, whilst an inductive load (e.g. a relay or solenoid) may produce a large back e.m.f. Both of these situations could result in damage to circuits that were designed with only resistive loads in mind.

So far we have not really touched on the situation to which the term matching is most properly applied. In fact we have to go beyond the idea in Fig. 1 and consider not only the source and load but also the way in which they are connected together.

This leads to the scenario of a source, a "line" and a load, as shown in Fig.2. For proper matching, all three have to be right. We will look at the situations when – and why – we have to deal with this problem, in next month's column. *I.M.B.*

Phase-Locked Loops Revisited

Regular reader ***Malcolm Wiles*** enjoyed our articles on Phase-Locked Loops (PLLs) in the previous two months and E-mailed us with the following comments and a question.

Thanks for the two articles on PLLs. I am indeed inspired to have a go at experimenting with a 4046. I've used them in the past as a poor man's A/D converter with the smaller PICs that don't have on-board A/D. Put the analogue voltage into pin 9, and count the number of pulses output by the VCO in unit time using the PIC – ideas pinched from Robert Penfold and John Becker. I've found the 4046 to be stable, accurate, and sensitive in this application, but I've always tiptoed round the PLL section.

I don't have a signal generator, but I can knock up a square wave oscillator based on NAND gates and an RC circuit easily enough, or even use a 555. So my question is, are input square waves OK, or would a sinewave generator (harder) be better?

The answer is straightforward – a square wave source is fine for experimenting with the 4046, so even a 555 should be fine. If you use phase comparator 1 (pin 2) on the 4046 remember that the input should have 50% duty cycle for optimum operation.

If you need to generate a 50% square wave from a pulse train having some other duty cycle, you can do so easily using a toggle flipflop (see Fig.3): however, the resulting waveform will of course be at half the input frequency. This would not matter if the source was simply an oscillator rigged up for experimental purposes, as the divider could be considered as an integral part of the waveform generator. *I.M.B.*

Problem (dis)solved

I am about to do my first soldering project. I read that the p.c.b. should be cleaned using a stiff brush to apply solvent. What exactly is a solvent – can I use regular alcohol to clean the printed circuit board? What do you recommend to clean the p.c.b.? ***I.A.**, by E-mail.*

A solvent is simply a chemical which can be used to dissolve other compounds. Examples include car auto body cleaners that remove tarmac from the paintwork, gel hand cleaners or products that dissolve fluxes from printed circuit boards. However, the impurities being dissolved (tar, grease or flux) have to go somewhere – so they combine with the solvent to form a waste by-product, which can be absorbed by a cloth, washed away or perhaps evaporate into the atmosphere.

This is technically different from using, say, detergent and hot water to remove grease or oil, as the fatty oil globules don't dissolve but instead form a "suspension" within the water. Drainage experts know all about waste pipes being blocked by cooking oil which has been washed down the kitchen sink using hot water and detergent, only to "fall out" of suspension later and re-combine into a fatty mass further down the pipe.

Selecting the correct solvent for the job is very important, because you need one which dissolves a particular compound (e.g. solder flux or grease) whilst not affecting other products or compounds nearby (e.g. the plastics used in some components). A solvent which cleans and degreases an instrument panel is not much use if it also dissolves the silk-screen print of the panel's lettering!

Some solvents will say "safe on most plastics" whilst others can be very "aggressive" on many plastics, especially styrenes. Many types of popular adhesive (e.g. the rubber solution used to mend punctures) are actually solids of rubber or plastic dissolved in a solvent before being filled into tubes.

After soldering a circuit board it is useful to remove any excess flux, often to enable you to inspect the joints in more detail. I tend to use Isopropanol liquid because it evaporates ("flashes off") reasonably well, it's safe on most plastics, and it leaves little residue. Alternatively, you might want to try a specialty flux cleaner. Afterwards, to protect against oxidation I apply a spray-on coating of p.c.b. lacquer; some lacquers can be sprayed straight on after etching because they can be soldered-through.

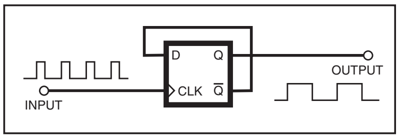


Fig.3. Generating a 50 per cent duty cycle pulse train using a flip-flop.

If you check under "Electrochemicals" or "Service Aids" in the mail order catalogues or on-line sources you'll soon find p.c.b. and solvent cleaners. Probably the best known UK brand is Electrolube. You can download data sheets from their web site at **www.electrolube.com**.

Going Green

The trouble with many modern chemicals is that we've become accustomed to using highly efficient and easy to use products that are often based on hydrocarbons. There is now a bit of a trend away from man-made solvents towards "greener" products instead of those manufactured by the chemical industry. Greener alternatives are sometimes better for the environment but can be less effective, needing more "elbow grease".

An idea that is rapidly catching on is the use of natural solvents, especially those based on by-products from the citrus fruit industry. Several companies manufacture orange or lemon-oil based cleaners which could be classed as "natural" solvents that form excellent degreasers, hand cleansers and solvent cleaners.

Co-incidentally, nearby to me is the UK depot of the Florida-based company Vin-Dotco Inc., (**www.vindotco.com**) who make a very interesting range of speciality industrial cleaners and solvents all derived from oranges. *ARW*.

Constructional Project

CAMCORDER MIXER

TERRY de VAUX-BALBIRNIE

Enhance the sound of your video productions – handy for other purposes too!

MODERN camcorders, especially the digital variety, produce pictures of a very high quality. However, the amateur often spoils the finished result with inferior sound. It could be said that most camcorder operators concentrate more on the visual aspect than the sound, yet only if both are treated with equal care will the video have a "professional" feel.

This begs the question as to whether a professional effect is wanted in the first place and for many purposes it probably is not. For the occasional holiday or family video, most people are happy to make do with a simple record of events and a rather amateurish result may not matter. In fact, it may even be thought to add to the fun of the occasion.

MIKED UP

Because it produces good results most of the time, many people are content to use the microphone already attached to the camcorder. Unfortunately, when the source of sound is distant from the camera the spoken word can sound "hollow" and weak.

Also, the existing microphone will pick up any unwanted sounds closer to it. These end up sounding louder than the intended subject. Most camcorder users have produced videos in which his or her own comments and mutterings come through "loud and clear" while the subject sounds like someone speaking into a bucket half a mile away!

Camcorders generally have the facility to plug in a separate microphone and this is usually done via a small jack socket. The attached microphone is then cut off.

Using a separate microphone allows more freedom of use because it may be placed closer to the source of sound. It may be hidden "in shot" or held on an improvised boom. Some people like to use a "tie clip" microphone which is a miniature device clipped to the clothing. This may appear in the picture without looking obtrusive.

A BIT MORE

Although the use of a single remote microphone can be very useful, there are times when several microphones would be more appropriate. An example would be an amateur stage production. The microphones could be placed strategically to cover the event more effectively than a single unit.

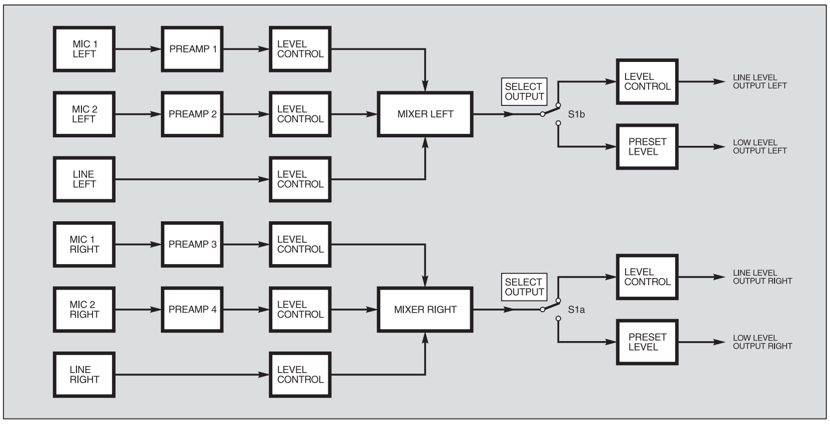


Fig.1. Block schematic diagram for the Camcorder Mixer.

The circuit presented here is a mixer which will combine the outputs of up to two stereo microphones (or four mono ones) plus a stereo line source and feed them into the camcorder. It may also be used in conjunction with a domestic hi-fi system or power amplifier for other purposes, such as Karaoke.

Depending on the camcorder, it may not be possible to use the line input to add music to a live performance. More will be said about this later.

However, assuming that you can, it would be handy when making a video involving singing and dancing to pre-recorded music on tape or CD. The music source (assuming it has a line output) could then be connected to the mixer *direct* and combined with the microphone outputs.

Simply picking up the music using a microphone placed near the loudspeaker reproducing it is generally unsatisfactory. The loudspeaker may not even be reasonably close to it. Even if it is, the quality is likely to be poor. A further point is that you would have no control over the balance – that is, how other sounds blend with the music without one swamping the other.

ON THE LEVEL

The block diagram for the Camcorder Mixer is shown in Fig.1. Each of the six input channels (four microphone and two for the stereo line source) have their own level control. Although the circuit has been designed with dynamic microphones in mind, the "tie clip" type of electret microphone is also suitable.

During the rehearsal (or, at a pinch, the actual production) the user sets up the levels by listening to headphones plugged into the monitor output on the camcorder. The controls are then adjusted to arrive at a balance where the sound seems "right".

The mixer has two outputs. One appears at a 3·5mm stereo jack socket and this may be connected through a piece of *screened* cable to the microphone socket on the camcorder. This is referred to as the *low-level output*. There is also a line output terminating in a pair of phono sockets. These may be connected to an external amplifier to allow the mixer to be used for other purposes.

It is thought useful to be able to use a device made with one application in mind for another. In fact, some readers will wish to construct the mixer for non-camcorder purposes.

ALL POWERED UP

The Camcorder Mixer is designed to operate using a 9V battery pack inside the unit. This is convenient and safe. *Do not use a mains-operated power adaptor*.

The current requirement of the prototype unit is only 40mA or thereabouts and six alkaline AA-size cells should provide about 50 hours of service. To double the operating time, it would be possible to use two 4·5V alkaline "3LR12" batteries connected in series. Note that a PP3 battery would give a poor life and would *not* be suitable.

While switched on, a green l.e.d. (light-emitting diode) operates and this acts as a reminder to switch the unit off after use. The circuit also has a red "early warning" l.e.d. indicator which glows when the supply voltage falls below 7V. This informs the user that the batteries are nearing the end of their useful life. The circuit will work correctly with a 6V supply but this gives an opportunity to change the batteries at the first available opportunity.

ON THE PANEL

The completed Camcorder Mixer is shown in the photograph. On the front panel, there are the six Input Level controls, two Line Output Level controls, an On-Off switch, green *on* and red *low battery* indicators.

On the back of the unit there are four 3·5mm mono jack Input sockets (for the microphones) and a pair of phono-type sockets (for the Line Input). There is also a 3·5mm stereo jack socket for the Low-Level output and a further pair of phono sockets for the Line output. A slide switch allows the user to select the type of output required (low-level or line).

Using separate input jack sockets allows either mono or stereo microphones to be used. Many stereo microphones terminate in a pair of 3·5mm mono jack plugs – one for the Left and one for the Right channel.

If the plug is of the stereo jack type, a splitter can be bought – or made – to give the required pair of mono plugs. If the microphones are fitted with 6·35mm jack plugs, converters are readily available to enable them to be plugged into 3·5mm sockets.

The prototype unit was built in an instrument case but, of course, this is optional and other types of enclosure could be used, providing everything fits. Note that the case should be made of ***metal*** – not plastic. This will ensure that the circuit is adequately screened to prevent hum pick-up. It also simplifies the internal wiring.

INITIAL CHECKS

Before constructing the Mixer, check that the camcorder has a socket into which a remote microphone may be plugged. This is because the output from the mixer simulates a single microphone. It would be best if the camcorder recorded *stereo* sound.

The circuit is designed for stereo operation even though the final result may only be heard in mono (that is, if a mono TV receiver is used to view the result). Making a stereo recording is best because many people will be able to listen to both channels with the correct equipment either now or in the future.

If the camcorder records in *mono*, it is still possible to use the mixer. However, some of the circuitry is wasted because the Left and Right output channels are simply combined at the end.

Make sure the camcorder has a headphone monitor socket. It would be difficult using the mixer effectively if the output could not be monitored using headphones during the performance.

LINE INPUT

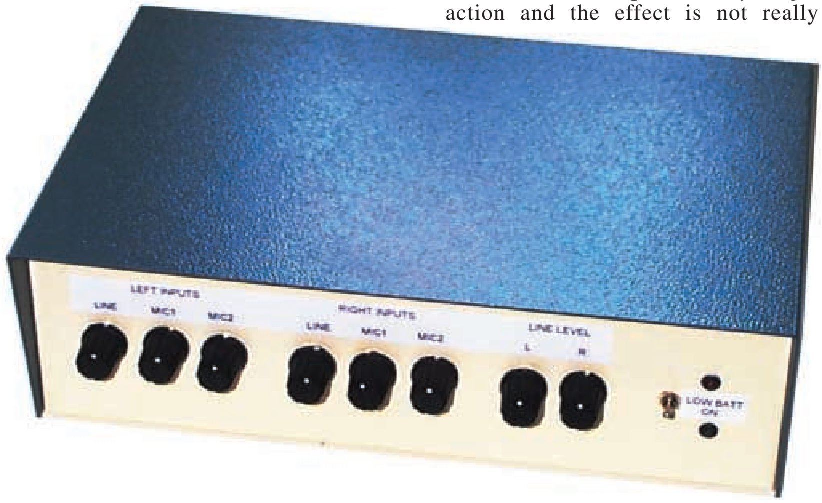
If you wish to use the line input to add music to a live video, check to see whether the automatic gain control (a.g.c.) for the camcorder microphone can be switched off. You may find an item in the menu which allows you to switch the input between "auto" and "manual".

The automatic gain control provides compression by giving a large boost when the sound is weak and less when it is loud. In other words, it attempts to smooth out large scale variations in input signal level and this is desirable most of the time.

Unfortunately, some camcorders apply a fairly "heavy" effect. With these, when music is added via the line input, the camcorder will change its gain quite drastically as the music rises and falls in volume. This gives an annoying "pumping" effect to the sound.

It was found that a high-quality digital camcorder did not work well with the input on "auto" (compressed) – presumably due to the sophisticated signal processing used. However, it was a simple matter to switch it to manual.

Some camcorders provide only a light action and the effect is not really



COMPONENTS

Approx. Cost Guidance Only £30 excluding batts.

Resistors

R1 to R8, R20, R21, R26, R27	47k (12 off)
R9 to R12	680Ω (4 off)
R13 to R16	180k (4 off)
R29, R30	100k (2 off)
R17 to R19, R23 to R25	10k (6 off)
R22, R28	22k (2 off)
R31	56k
R32	11k
R33	1M
R34	470Ω

All 0·25W 5% carbon film

See SHOP TALK page

Potentiometers

VR1 to VR4	470k min. preset vert. (4 off)
VR5 to VR10, VR13, VR14	10k min rotary carbon, panel mounting, log. (8 off)
VR11, VR12	1k min. preset vert. (2 off)

Capacitors

C1 to C4	4µ7 radial elect. 63V (4 off)
C5 to C8, C20, C26	47µ radial elect.16V (6 off)
C9 to C12, C21, C27	22p ceramic (6 off)
C13 to C19, C22 to C25, C28 to C32	10µ radial elect. 63V (16 off)
C33	100n metallised polyester
C34	220µ radial elect. 16V

Semiconductors

D1	3mm red low-current l.e.d.
D2	3mm green l.e.d.
D3	1N4001 1A 50V rect. diode
IC1 to IC3	NE5532 dual low-noise op.amp (3 off)
IC4	ICL8211 voltage detector

Miscellaneous

SK1 to SK4	3·5mm mono jack socket, switched (4 off)
SK5 to SK7, SK9	phono socket, single-hole fixing (4 off)
SK8	3·5mm stereo jack socket
S1	d.p.d.t. slide switch
S2	s.p.s.t. miniature toggle switch

Printed circuit board available from the *EPE PCB Service,* code 299; aluminium, vinyl-effect, box, size 250mm x 150mm x 75mm approx.; 8-pin d.i.l. socket (3 off); control knobs (8 off); alkaline AA cells – 6 off (or alternative 9V battery – see text); holder and connector for cells; coloured multistrand connecting wire; cable ties; solder tag; l.e.d. clips; nylon nut and bolt; plastic spacer; solder etc.

noticeable especially when the music is fairly quiet. Two mono analogue machines gave very good results even though it was not possible to switch off the a.g.c.

It is impossible to predict what the effect will be for a given camcorder. The only way forward is to "try it and see" and switch the microphone to manual if possible.

One final point. Do ***NOT*** operate the camcorder using a mains adaptor. This often introduces unacceptable hum into the mixer and hence on to the recording. Make sure you have a battery, or batteries, of sufficient capacity to cover the work you are doing.

CIRCUIT DESCRIPTION

The full circuit diagram for the Camcorder Mixer is shown in Fig.2. The supply is obtained from a 9V battery pack, B1, via on-off switch S2 and diode D3. Diode D3 provides reverse-polarity protection since, if the supply were to be connected incorrectly, the diode would not conduct and nothing would happen.

Capacitors C33 and C34 promote stability. The green On l.e.d. is D2 and this operates in conjunction with series resistor R34 which limits its operating current to a safe value.

The main part of the circuit uses three dual low-noise op.amps (operational amplifiers). Each one contains two identical circuits – that is, six op.amps in total. These are labelled IC1a and IC1b, IC2a and IC2b and IC3a and IC3b. IC1 and IC2 are associated with the Right and Left channel microphone inputs respectively.

The two sections of IC3 are used as mixers for the microphone sources and line input – IC3a for the Right and IC3b for the Left. IC4, together with associated components, form the Low Battery warning section and will be discussed later.

The signal provided by a dynamic microphone is extremely low and is likely to be in the region of 1mV (one millivolt) peak-to-peak. The exact value, of course, depends on the sound level. However, the line output from a CD or tape player is at a much higher level. This is likely to be some 500mV to 1V peak-to-peak. We are, therefore, using input signals having a factor of 500 or more between their average voltage levels.

BIG BOOST

The first step is to boost the microphone signals to that of the line inputs. All mixing is then carried out at the higher level. The result may then be used to feed the high-level (line) input of an external amplifier (for non-camcorder purposes). It may also be reduced to a low level to provide a suitable input for the camcorder.

Look first at the section of circuit (Fig.2) centred on IC1a. This is associated with Microphone 2 (MIC2) Right channel. The other three microphone channels are identical so need not be considered in detail. Here IC1a is configured as an a.c. inverting amplifier designed to operate from single supply rails.

The signal from MIC2 is passed via blocking capacitor C1, and input resistor R9 to the inverting input (pin 2) of IC1a. Ignoring capacitor C9 for the moment, feedback is provided between the output (pin 1) and inverting input by fixed resistor R13 and preset potentiometer VR1 connected in series. The latter provides an adjustment to the gain (amplifying factor).

NOTHING TO GAIN

The ratio of feedback resistance to input resistance determines the gain. With preset VR1 adjusted to minimum this will be some 260 and at maximum about 960. Note that because this is an *inverting* amplifier, the gain is actually *negative* within the range *minus* 260 to *minus* 960 but, in practice, this is unimportant here. It just means that the output signal will be inverted (180 degrees out of phase with the input).

The gain will be adjusted, along with that of the other microphone channels, to provide best results with the particular microphones being used. The level controls on the front panel will then all have a similar range of effect.

Capacitor C9, connected between the output and inverting input, reduces the gain at high frequencies by increasing the amount of negative feedback. This is because under such conditions the capacitor will have a low impedance. In the normal audio range it has a very high impedance and therefore a negligible effect. Reducing the high frequency gain avoids possible instability which could otherwise occur.

POTENTIAL DIVIDER

The non-inverting input of IC1a (pin 3) is connected to a potential divider consisting of equal-value resistors, R7 and R8. The d.c. voltage here will therefore be one-half that of the supply – nominally 4·5V.

However, capacitor C8, having a very low impedance at audio frequencies, makes the non-inverting input 0V as far as a.c. signals are concerned. To cut out detail, this allows the input signal to swing above and below a 4·5V "zero". It could not swing below true zero (0V) because the op.amp is powered from single battery rails (rather than a "split") supply.

The amplified output of IC1a appears at pin 1 and this is applied, via capacitor C13, to the top end of potentiometer VR5. The other end of this is connected to 0V. Capacitor C13 blocks the d.c. standing voltage while allowing the a.c. signal to pass.

Potentiometer VR5 is the Level control for MIC2 Right channel and is mounted on the front panel of the case along with the others. By adjusting this during use, the sliding contact will draw off a fraction of the output voltage and change the signal level as required.

This is similarly the case with the other three microphone channels. The signals from these are applied via blocking capacitors C2 to C4 and input resistors R10 to R12 respectively to the inverting inputs of IC1b, IC2a and IC2b.

They then appear at their respective outputs through capacitors C14 to C16 and at the top ends of Level control potentiometers VR6 to VR8. The Line level input signals are applied direct to the top end of level potentiometers VR9 (Right) and VR10 (Left).

MIXING IT

Operational amplifiers IC3a and IC3b are configured as summing amplifiers and it is here that the job of mixing the various sources takes place. IC3a is associated with the Right channels and IC3b the Left ones. Since the processing of the Left channel is the same as the Right, it is only necessary to look in detail at IC3a.

The signals derived from the Right microphone channels are applied via blocking capacitors C17 and C18 and input resistors R17 and R18 to the inverting input of IC3a, at pin 2. The Right Line input is applied from the sliding contact of Level control VR9 through capacitor C19 and input resistor R19.

Feedback resistor R22 has approximately twice the value of the input resistors. The gain of the mixer section is therefore approximately two (actually *minus* two). A boost is needed because, if we regard the mid-track positions of each line level control to be "normal", only one-half of the signal will be available to the mixer.

TWO ROUTES

The combined outputs appear at IC3a output, pin 1, (Right channel) and IC3b output, pin 7, (Left channel) via capacitors C25 and C28 respectively. From here each signal can follow either one of two routes depending on the position of Select Output switch, S1. This is a double-pole unit – S1a being responsible for the Right channel and S1b the Left.

With the switch set as shown (Lo position), the signals are applied to the networks consisting of fixed resistor R29 and preset potentiometer VR11 (Right channel) and R30/VR12 (Left). The fixed resistors and presets form potential dividers.

Since the top "arm" has a much higher value than the bottom one, even with VR11 and VR12 at the top end of their travel, the signal will be considerably reduced – by a factor of 100 times approximately. When at the bottom, no signal appears at the output.

With VR11/VR12 suitably adjusted, the Lo output will be at microphone level and provide a suitable input for the camcorder. The "low" output signal is passed, via capacitors C30/C32, to stereo jack output socket SK8.

With switch S1 in the alternative (Hi) position, the signals are applied to the top end of Line output level controls, VR13 and VR14 respectively (labelled Line Level on the front panel). The "high" outputs then appear at phono sockets SK7 (Right) and SK9 (Left), through capacitors C29 and C31.

VOLTAGE DETECTION

It was considered useful to include an "early warning" of when battery replacement is due. There could be a problem if the circuit began to fail during a performance – this would manifest itself by weak sound and distortion. Since the circuit will work with a supply voltage of some 6V, the warning has been designed to "kick in" at 7V approximately.

The low battery warning is centred on IC4 which is a voltage detector i.c. When a voltage less than 1·15V (an internally-set reference voltage) is applied to IC4 pin 3, the output (pin 4) will go low. A 7mA current sink to pin 4 is then "turned on".

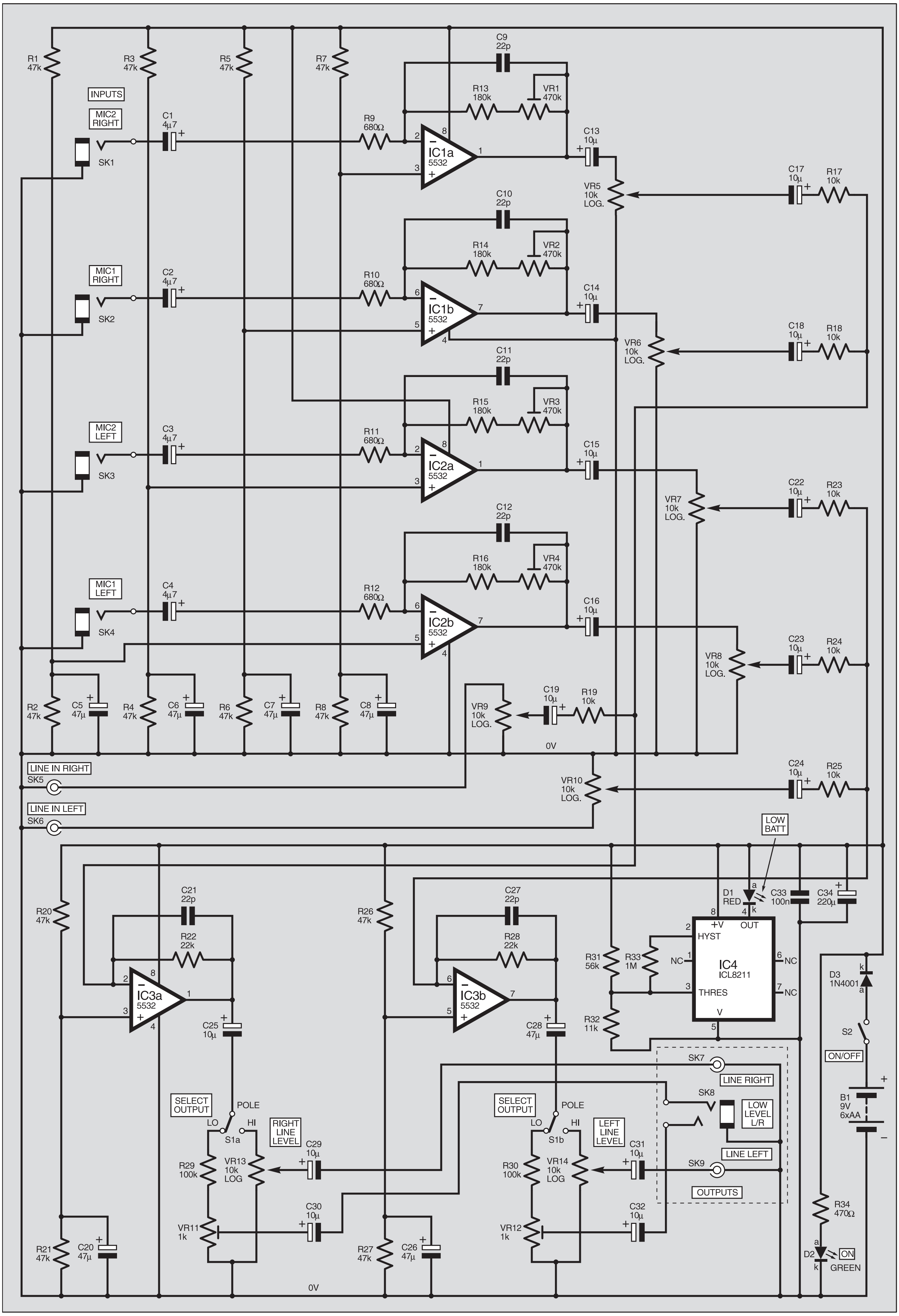


Fig.2. Complete circuit diagram for the Camcorder Mixer.

Current will then flow from the supply, through the Low Battery l.e.d. (D1) and into pin 4.

Since the l.e.d. operating current is regulated by the chip, there is no need for a series resistor. Also, the l.e.d. will glow with constant brightness throughout its working range. Note that, due to the small operating current, for best results D1 should be of the *low-current* type.

The potential divider consisting of fixed resistors R31 and R32 provides 1·15V at pin 3 when the supply is 7V approximately. At this point, the l.e.d. will operate. Resistor R33 applies a little feedback to the system and sharpens the switching action.

CONSTRUCTION

Construction of the Camcorder Mixer is based on a single-sided printed circuit board (p.c.b.). The topside component layout and full size underside copper track foil master are shown in Fig. 3. This board is available from the *EPE PCB Service*, code 299.

Begin construction by drilling the board single fixing hole and then solder the four d.i.l. sockets for the integrated circuits (but do not insert the i.c.s themselves yet). Follow with all fixed resistors, preset potentiometers and capacitors.

Note that there are 27 electrolytic capacitors in this circuit and it is important to solder all of these with the correct polarity. The negative (–) end is clearly marked on the body and the corresponding lead is slightly shorter than the positive (+) one.

Solder approximately 30cm lengths of light-duty stranded connecting wire to the take off points on the printed circuit board. Use different colours (pieces of "rainbow" ribbon cable are ideal) to avoid mistakes when interwiring later. Adjust all preset potentiometers to approximately mid-track position.

Front panel control layout on the completed mixer.

POTENTIAL PROBLEM

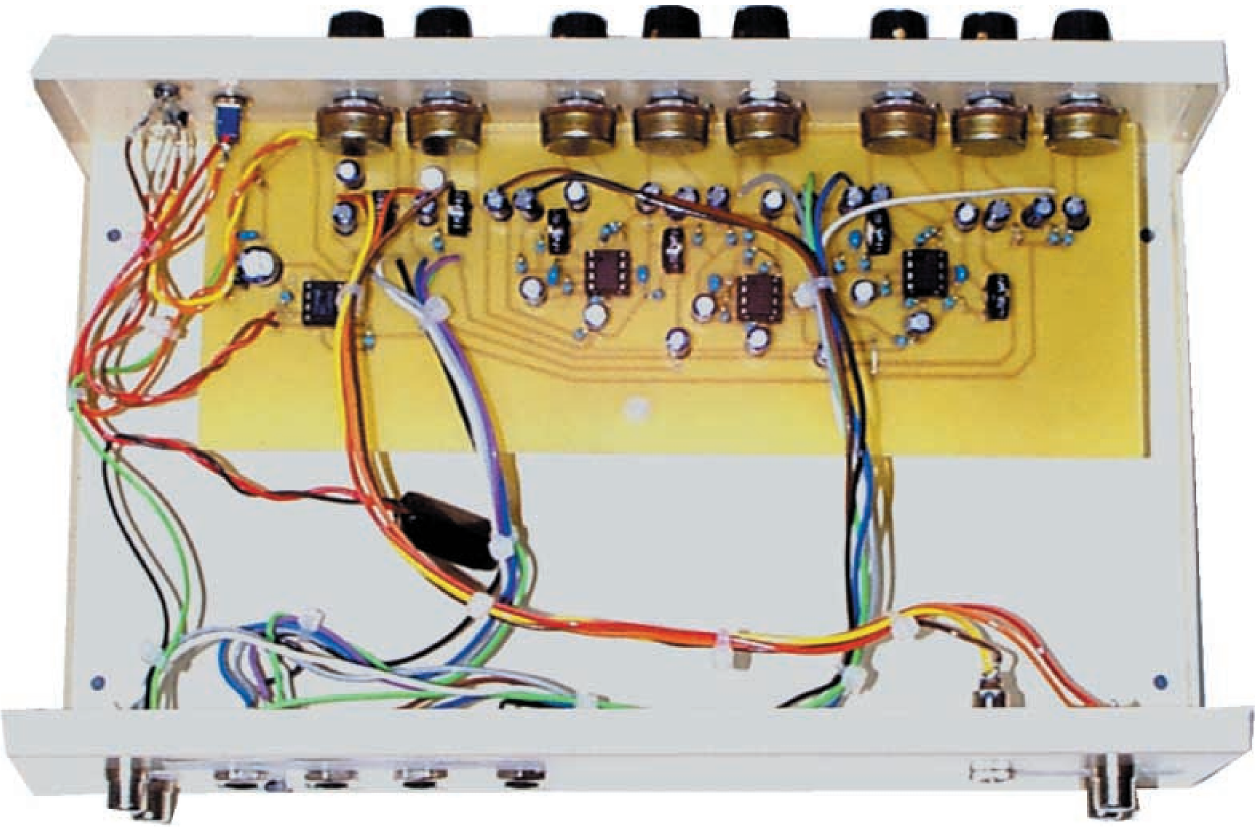
Fit a control knob to one of the panel potentiometers. Measure how much of the spindle needs to be cut off (allowing extra space for the front panel thickness and distance from the p.c.b.) then remove the knob. Hold the end of the spindle (not the potentiometer body or it is likely to be distorted and become useless) in a small vice and cut off the excess using a hacksaw. Cut the same length from the other potentiometer spindles. File the cut edges smooth and check that the knobs now fit correctly.

Cut or break off the panel location tabs on the body of the potentiometers. If these were left in place, the bodies might not be able to take up their correct positions when the p.c.b. was mounted in the case. With that done, solder the potentiometers in position on the p.c.b. (see photographs).

DRILLING OUT

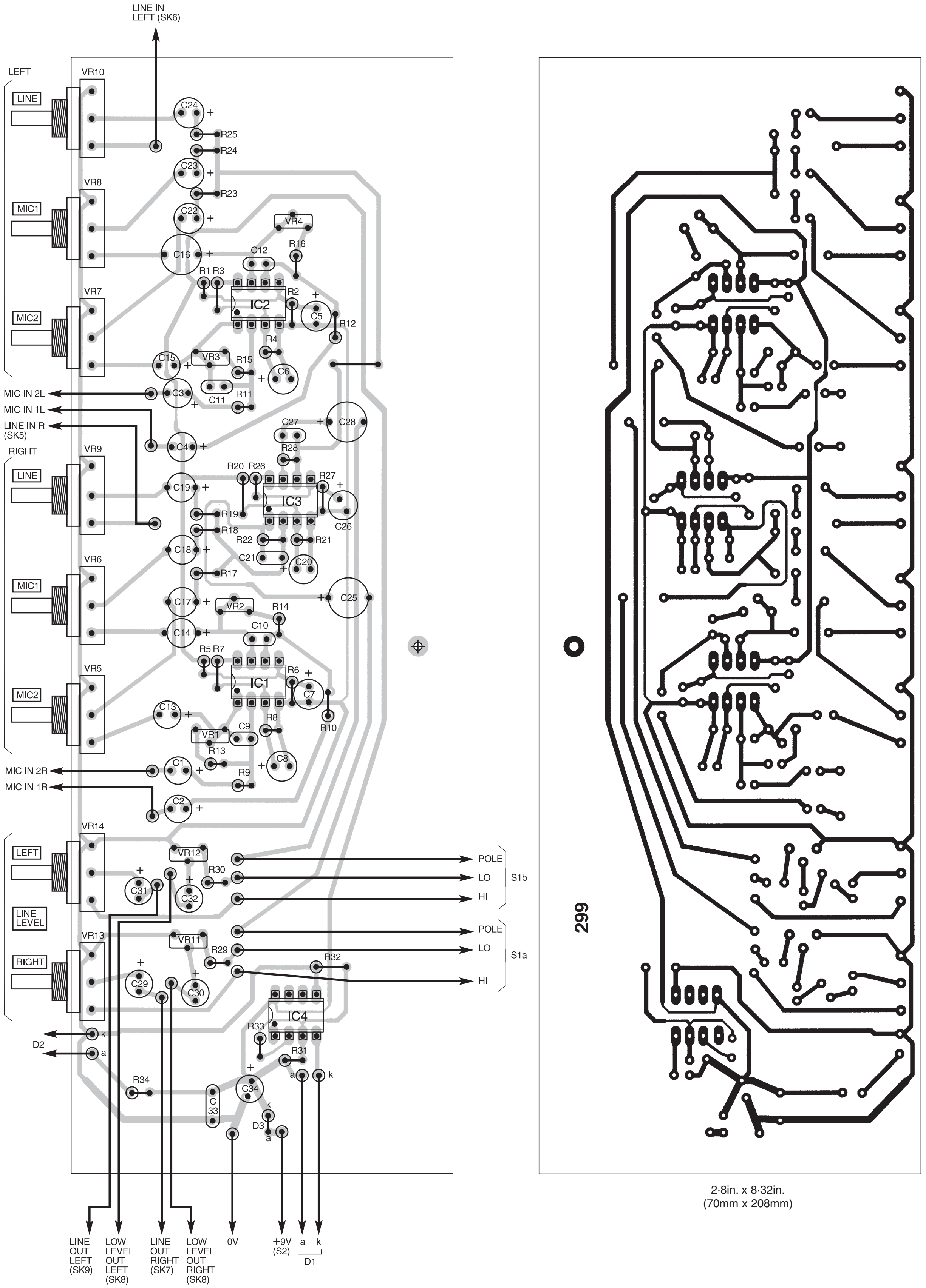
Measure the position of the holes needed in the front panel for the potentiometer bushes. Mark these out but, before drilling them, check that when the p.c.b. is mounted in position there will be several millimetres clearance between the copper track side and the base of the box. This is necessary to prevent any possible short circuits.

When satisfied on this point, drill the holes. *Note that these must be made large enough to allow all eight bushes to be passed through easily and without binding.* Keeping the p.c.b. supported by hand, try it in position *taking great care not to bend the potentiometers out of alignment. This could break tracks and/or soldered joints*



General component positioning and wiring inside the prototype.

CAMCORDER MIXER – CIRCUIT BOARD



2·8in. x 8·32in.
(70mm x 208mm)

Fig.3. Printed circuit board component layout and full-size copper foil master for the Camcorder Mixer.

on the p.c.b. Remove the p.c.b. again. Mark suitable positions and drill holes for the on-off switch (S2) and l.e.d. indicators (D1 and D2).

Next, mark positions on the rear panel for the input and output sockets also for the output selector slide switch (S1). Drill holes and mount all these components. Where the sleeve connection makes direct metal-to-metal contact with the case, scrape off any paint as necessary to make sure a good connection is formed.

The selector switch should be attached using spacers on its mounting bolt shanks so that the operating lever is almost level with the face of the panel. This will make it difficult for the switch to be accidentally moved between positions.

Taking the same care as before, hold the p.c.b. in position against the front panel. Measure what thickness of spacing washers (or spare fixing nuts) are needed on the potentiometer bushes so that the edge of the p.c.b. does not press against the panel and only sufficient of each bush protrudes to accept the fixing nut. Fit the spacers and check for the correct fit.

Rear view of completed unit showing positioning of the jack and phono sockets. Also shown is the output select switch.

With the p.c.b. in position, mark through its fixing hole on the floor of the case. Remove the p.c.b. again and drill this through. Now, attach the circuit board securely using the potentiometer fixing nuts.

Cut a plastic spacer to fit between the board and base of the box. Place this in position under the fixing hole and secure the rear of the p.c.b. using a thin nylon nut and bolt. *Make certain the panel is not placed under any strain.*

Fit the control knobs again setting the cursor line on each one vertically upwards when the control is at mid-track position. Check that all controls turn smoothly and make any adjustments as required.

Attach self-adhesive plastic feet to the bottom of the box to prevent it scratching the work surface.

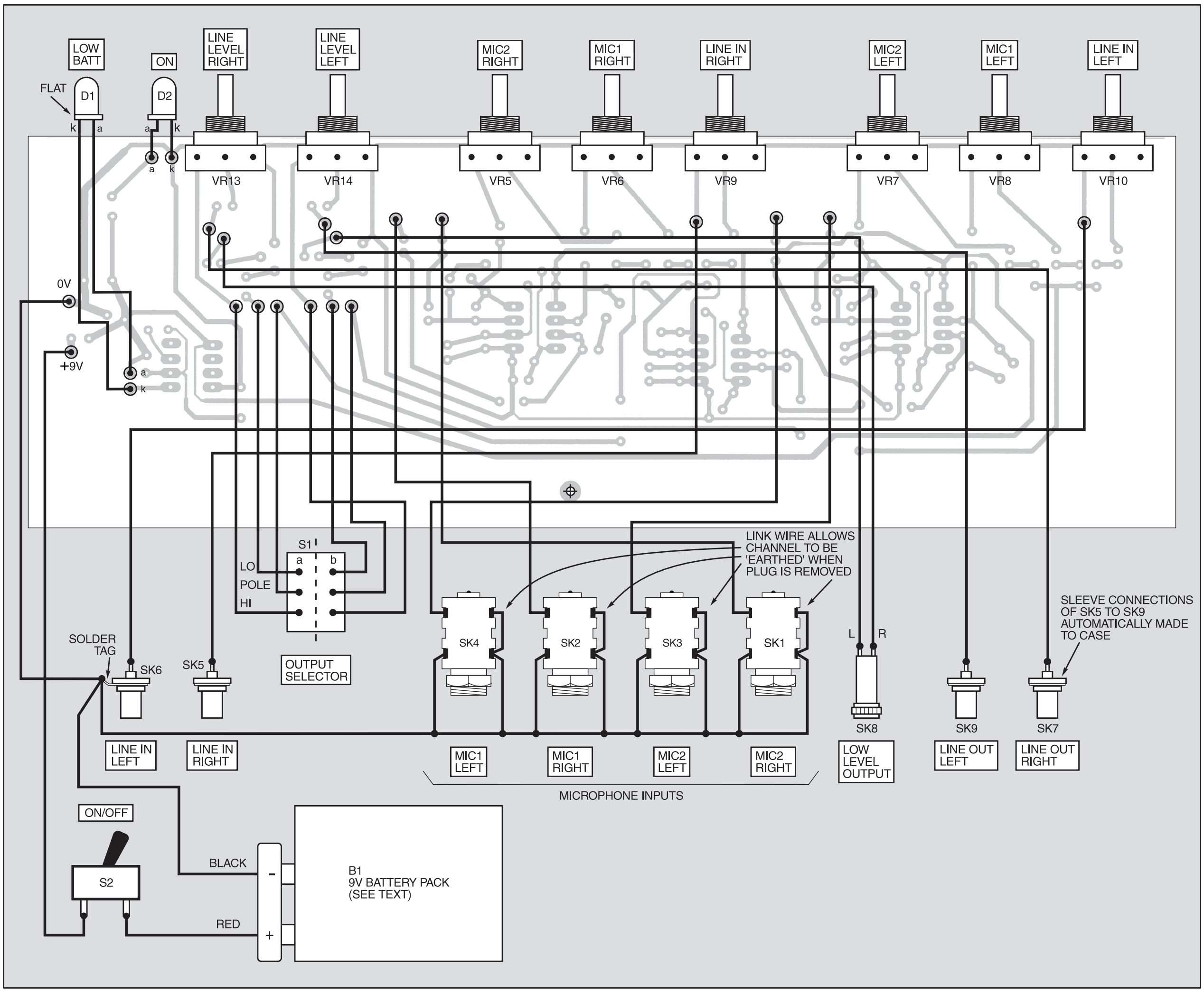


Fig.4. Interwiring from the circuit board to the front and rear panel mounted components. The general positioning of components within the metal case can be seen in the photographs.

WIRED FOR SOUND

Carry out the internal interwiring using multi-coloured, light-duty, stranded connecting wire as shown in Fig.4. Check that all inter-connecting wires to off-board components are long enough to enable the p.c.b. to be removed without placing them under strain.

The wires connected to the p.c.b. should be routed neatly and grouped together using small cable ties. Note particularly how the 0V point on the p.c.b. and the negative wire of the battery connector are connected to the metal case at a solder tag at one of the phono sockets (or at a separate small solder tag).

All the sleeve connections of the input and output sockets *must* be connected to the metal case to complete the respective circuit back to the 0V line. The phono sockets (SK5 to SK7 and SK9) and low-level stereo output socket (SK8) used in the prototype unit had metal bodies and made this connection automatically (note, however, the previous comment about scraping off paint if necessary). However, the 3·5mm mono microphone sockets (SK1 to SK4) had plastic bodies and the sleeve connections had to be hard-wired to the solder tag carrying the other "earth" (0V) connections, see Fig.4.

If the microphone sockets are of a type having a pair of normally-closed contacts, it is good practice to use these to "earth" the inputs (connect them to 0V) when no microphone is plugged in. The wiring in Fig.4 shows how this was done in the prototype unit. Whether it is possible and the exact method will, of course, depend on the design of the particular socket.

Attach the battery holder using a small bracket or self-adhesive fixing pads but do not insert the cells yet. Insert the i.c.s in their sockets taking care over their orientation.

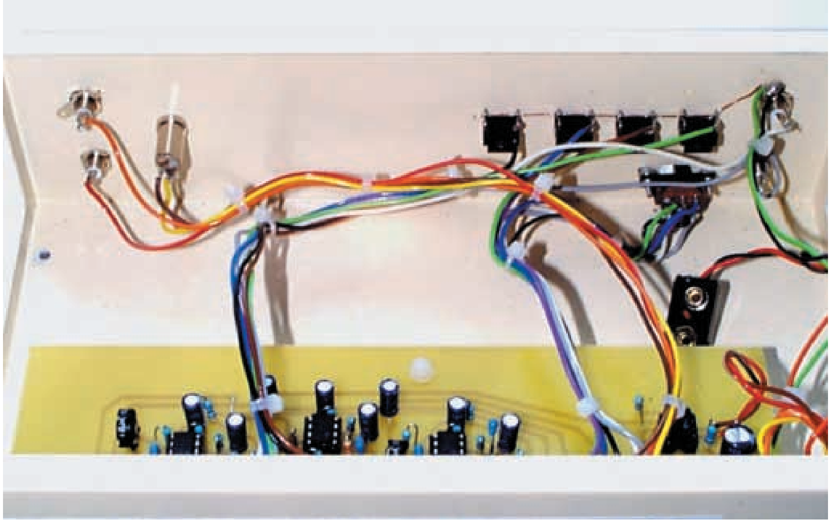
TESTING

Place the cells in their holder, connect it up and switch on S2. The green l.e.d. should light up. As the switch is operated, the low battery l.e.d. (D1) will flash momentarily. This is because it takes a short time for the supply voltage to rise to its full value (as capacitor C34 charges up) and below 7V it will be on. It will do similarly as S2 is switched off.

Begin testing the circuit using the Line output. To do this you will need access to an amplifier having line input sockets and a headphone output. You will also need a cassette or CD player having a line output. Many domestic systems have a line input in the form of a pair of phono sockets labelled "aux" or "auxiliary".

Make up two leads (or use ready-made leads) using twin screened cable with phono connectors (or as appropriate) at each end. Use these to connect the mixer unit to the amplifier and the line source to the mixer. Set output switch S1 to Line ("Hi" position).

Adjust the two Line Level controls (VR13/VR14) to maximum (fully clockwise) and the other rotary controls to minimum (fully anti-clockwise). Plug microphones into the input sockets using converters if necessary. Switch on the amplifier and turn its volume control to about one-third of its total clockwise travel.



Wiring to the rear panel mounted jack sockets, phono sockets and output selector slider switch. Note that the 3·5mm, chassis-mounting, stereo jack socket SK8 (above left) is a tubular metal screen type.

Use headphones to monitor the results rather than loudspeakers. These allow the result to be judged more accurately. Also, they largely avoid problems with acoustic feedback (a loud squealing noise due to sound from the loudspeaker entering the microphone and building up in a loop).

Gradually increase each microphone control in turn while someone speaks into that microphone. You should hear the voice clearly from the appropriate Left or Right channel. If this does not work, perhaps the output switch has been set to "low" instead of "high".

Switch on the line source and turn up all the panel input controls half way. You should now hear a mixture of sounds from all sources. Adjust the volume control on the amplifier for a comfortable listening level.

Note that the Line Level controls give an adjustment to the line output. Most of the time they will be left at maximum unless the amplifier being used is particularly sensitive. Their main purpose is to act as local Volume and Balance controls. Using these, the output may be adjusted at the unit. Note that these controls have no effect on the low level output so when using a camcorder, they should be left at minimum (turned fully anti-clockwise).

MAKING ADJUSTMENTS

Remove the line source. The preset potentiometer (VR1 to VR4) associated with each microphone should now be adjusted to make it suitable for the type of microphone being used and also to adjust for differences between the various microphones. For this, use an insulated trimming tool. Do not use a screwdriver unless it is insulated – *a metal shank is likely to cause short-circuits*.

Too little gain will give weak results; too much may result in instability. Rather more than half of the maximum gain will be best for most microphones. You will find that the exact setting is not particularly critical.

If you are using different makes and types of microphone you may need to dedicate the various channels to the individual microphones. It would then be necessary to label the sockets so that the microphones are plugged into the correct inputs.

LOW-LEVEL OUTPUT

Test the low-level output (SK8) using an amplifier having a microphone input. Again, use headphones to monitor the result. If you use a cassette recorder, use one which has manual adjustment to the input level.

Get a "feel" for the amplifier by plugging one of the microphones into it (that is, without using the mixer) and making some trials. Decide on a suitable setting for the amplifier Volume control and leave it like that.

Now connect the Camcorder Mixer. You will need a lead having a 3·5mm stereo jack plug on one end and the appropriate connectors (often two 6·35mm jack plugs) on the other. This should be made using twin screened microphone cable. Set output switch S1 to "low level".

Regarding the mixer output as if it was a single microphone, make some tests. Adjust the low-level output preset controls (VR11 and VR12 equally) to provide the same output level as the single microphone used previously. Too high a setting and distortion will become apparent. Too low and you will get no signal at all. These controls may need to be set again when the unit is connected to the camcorder.

Having satisfied yourself that the circuit is working correctly, connect the output to the camcorder microphone input. For this, you will need a piece of twin microphone screened cable with a 3·5mm stereo jack plug on each end. For a mono camcorder input, use a mono jack plug with both channels connected together.

If you are monitoring using stereo headphones, you may buy a converter which terminates in a 3·5mm mono plug. This can be used to prevent the sound being heard in one headphone only.

Turn the camcorder input selector from "auto" to "manual" if this is possible (see previous notes about this). Make some further test recordings and, if necessary, make further equal adjustments to VR11 and VR12 – You are now ready to make your first "recording". □

SHOP TALK
with David Barrington

PIC Graphics L.C.D. Scope

Most of the components used in the *PIC Graphics L.C.D. Scope* project appear to be RS Components types. Readers can order these from any local *bona-fide* RS stockist or directly through **Electromail**, their mail order outlet.

Some of our component advertisers may be able to supply the Powertip PG12864-F graphics l.c.d. module or may offer an alternative from a different manufacturer; but you should check its pinout arrangement and that it uses an integral Toshiba T6963C controller device before purchasing if they do. The author ordered his from RS and readers can purchase one through **Electromail** (☎ ***01536 204555*** or ***http://rswww.com***), code 329-0329. It is currently listed at £27.92 (excl. VAT/p&p).

The Maxim MAX492 low voltage, rail-to-rail, dual op.amp (code 182-22738) and the voltage converter type 7660 (code 651-490) both came from the above source.

A 20MHz version of the PIC16F877 should be used in this project. For those readers unable to program their own PICs, a ready-programmed PIC16F877-20P can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £10 (overseas readers add £1 for postage). Alternatively, the software is available on a 3·5in. PC-compatible disk (EPE Disk 4) from the *EPE* Editorial Office for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 384). It is also available *Free* from the *EPE* web site: **ftp://ftp.epemag.wimborne.co.uk/pubs/PICS/Gscope**.

The G-scope printed circuit board is available from the *EPE PCB Service*, code 300 (see page 384).

Camcorder Mixer

One or two components may cause local buying problems when shopping for parts for the *Camcorder Mixer* project. However, most of our component mail order advertisers should be able to help.

For the semiconductors you could try **ESR Components** (☎ ***0191 2514363***) and **Cricklewood** (☎ ***020 8452 0161***). The NE5532 dual low-noise op.amp used in the model was purchased from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code UH35Q. They also supplied the 3·5mm mono, plastic bodied, switched jack sockets (code CX93B) and the screened, metal barrel, chassis mounting stereo jack socket, code FK03D.

The micropower ICL8211 voltage detector was originally purchased from Maplin (code YH43W) but we understand that this device has been discontinued. However, **Farnell** (☎ ***0113 263 6311***) have offered the MAX8211CPA-2, code 205-230, as a replacement. This device is also listed by **Electromail** (☎ ***01536 204555***), code 427-506.

The printed circuit board is available from the *EPE PCB Service*, code 299 (see page 384).

D.C. Motor Controller

It would appear from recent readers' letters, and our own investigations, that the VN10KM *n*-channel MOSFET, called for in the *D.C. Motor Controller*, this month's Top Tenner project, has been discontinued. However, we understand that most low power *n*-channel MOSFETs should work just as well for low power (about 300mA) d.c. motors. Suggested alternatives are the VN0300L, ZVN3306A and ZVN1306A.

For higher power, low voltage, motors, say 1·5A to 2A max., the VN46AF, VN88AF and the VN66AF are offered as alternatives. These devices have not been tried "in-circuit" and a small heatsink is recommended with these transistors for a higher power, low voltage, motor. The VN66AF device is currently listed by Maplin, code WQ97F.

Small low-voltage d.c. motors are stocked by **Magenta** (☎ ***01283 565435***). You could also try contacting **Bull Electrical** (☎ ***0871 871 1300***), **J&N Factors** (☎ ***01444 881965***) and **Greenweld** (☎ ***01277 811042***), who occasionally have small low-voltage d.c. motors on "offer of the month" listings.

Intruder Alarm Control Panel (Part 2)

Since publication of the first part of the *Intruder Alarm Control Panel* project, stocks of Maplin's 93C06 non-volatile memory chip have run out and, we have been informed, discontinued. It is still available from **Farnell** (☎ ***0113 263 6311***), code 395-250 and **Electromail** (☎ ***01536 204555***), code 658-750.

On another point, the designation for the 8-way multiplexer (IC2) should be 74**HC**151 and *not HS.* This is currently available from Electromail, code 301-331.

As mentioned last month, the EP520M security chip has been specially masked for **Design Consultants** and is only available from them. It is available for the sum of only £3.50 and the keypad, together with lead, metal plate and label, is priced at £2.50. They will also supply the anti-tamper, p.c.b. mounting "click" switch and activating spring (60p), the 8 ohm 12W loudspeaker (£2.75) and alarm panel case (£5.50). They can also supply the p.c.b.-mounting relay for the Bell Unit, which is quoted at £1.65. They will also quote a price for the 8-way multiplexer (IC2) and the non-volatile memory (IC3) chips.

All the above prices include UK postage and packing. All cheques/money orders should be made out to *H. Data* and sent (Mail Order only) to: **Delta Consultants, Dept EPE, 21 Rachel Drive, Rhyl, Denbighshire, LL18 4UH**. Tel/Fax 07050 055041. E-mail: HData97476@aol.com.uk.

The two printed circuit boards for this security alarm project are available from the *EPE PCB Service*, codes 297 (main board) and 298 (ext. bell), see page 384.

VIDEOS ON ELECTRONICS

A range of videos selected by *EPE* and designed to provide instruction on electronics theory. Each video gives a sound introduction and grounding in a specialised area of the subject. The tapes make learning both easier and more enjoyable than pure textbook or magazine study. They have proved particularly useful in schools, colleges, training departments and electronics clubs as well as to general hobbyists and those following distance learning courses etc

BASICS

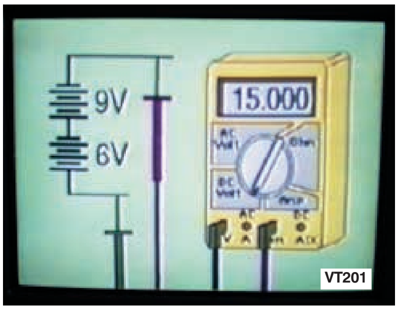
VT201 to VT206 is a basic electronics course and is designed to be used as a complete series, if required.

VT201 54 minutes. Part One; **D.C. Circuits.** This video is an absolute must for the beginner. Series circuits, parallel circuits, Ohms law, how to use the digital multimeter and much more. **Order Code VT201**

VT202 62 minutes. Part Two; **A.C. Circuits.** This is your next step in understanding the basics of electronics. You will learn about how coils, transformers, capacitors, etc are used in common circuits. **Order Code VT202**

VT203 57 minutes. Part Three; **Semiconductors.** Gives you an exciting look into the world of semiconductors. With basic semiconductor theory. Plus 15 different semiconductor devices explained.

Order Code VT203



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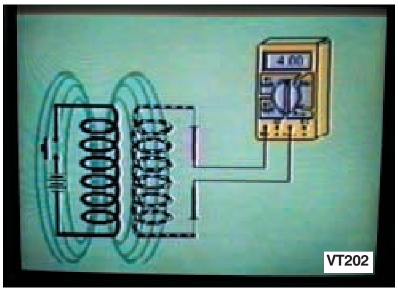

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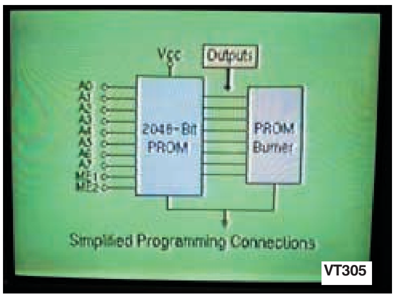

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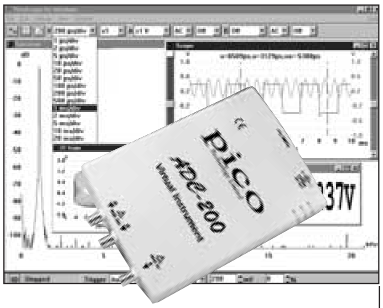

WIN A PICO PC BASED OSCILLOSCOPE

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Body Charge Detector – All Charged Up

IT IS well known that the human body accumulates a static charge through such ordinary everyday activities as moving in a chair, or walking on a nylon carpet. This charge may be as high as tens of thousands of volts in relation to the ground. However, it carries very little current, and will at worst give a nasty prick when the body discharges.

From the point of view of electronics, this is usually seen as a serious problem, since electrostatic charges can easily destroy sensitive components. But why not collect this charge, and use it for positive purposes?

In the circuit diagram of Fig.1, one terminal of a 1pF capacitor (C1) is connected to ground (e.g. a metal water tap, or a metal stake driven into the earth). The other terminal is a "sensor" which is taken to a metal object that has no connection (or a very poor one) to ground, such as a door handle. Without the well-grounded terminal, this circuit is unlikely to work.

In its "quiescent" state, the capacitor C1 holds a charge of perhaps less than 10mV. But as soon as a hand touches the metal sensor, the charge on the capacitor can easily jump one-hundred-fold, even if no bare metal is present – for instance, if the metal sensor is covered with paint. The body, however, must carry a static charge which will accumulate through physical activity.

The charge on C1 is detected by voltage comparator IC1 which causes l.e.d. D1 to glow. A high impedance input op.amp is essential here, since very little current is present. A high value resistor, R1, is used to protect the input at pin 3. Sensitivity is adjusted by means of potentiometer VR1. It would be prudent to use a capacitor having a suitably high voltage rating.

The bare-bones circuit offers scope for further experimentation. It may be used as the basis for an alarm, or for electronics enthusiasts, as an indicator of static charge in the body when handling sensitive components. It could even serve as a party-piece.

Rev. Thos. Scarborough,
Fresnaye, Cape Town, South Africa

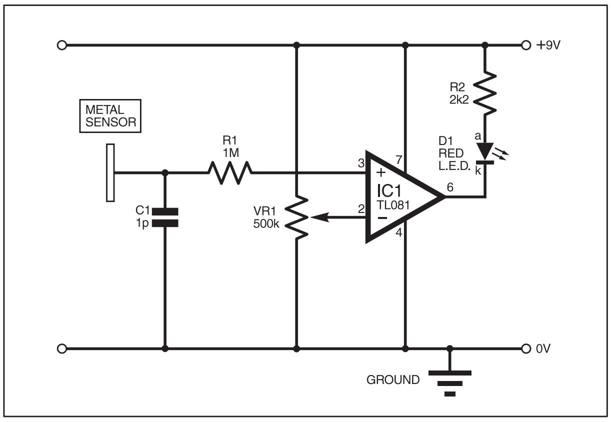

Fig.1. Circuit diagram for a Body Charge Detector.

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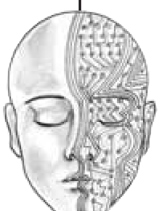


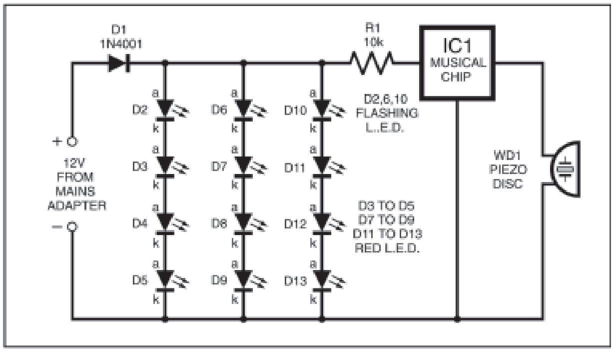
Flashing Christmas Tree – A Quick Flash

USING a single flashing light-emitting diode, several ordinary cheap l.e.d.s placed in series can also be made to flash. You can produce simple Christmas decorations or brighten up any other holiday event this way.

The circuit diagram of Fig.2 has been tried and tested, and uses three flashing l.e.d.s to control a further nine l.e.d.s. By alternating the l.e.d. colours, a simple light chaser display can be created.

The circuit can be powered by a 12V d.c. mains adaptor and the rectifier diode D1 protects against reverse polarity. A three-terminal musical chip was also added as shown to operate a piezo disc sounder.

Mrs Rose Morell,
Winchester, Hants.



L.E.D. lights flasher circuit, with sound.

Solid State Switch – No More Brownouts

THE circuit diagram shown in Fig.3 was intended to control the supply to a waterproof receiver which is used in harsh environments. Tactile switches were used, positioned behind a plastic membrane. *(Magnetically-operated reed switches could perhaps also be used behind a plastic panel, for a completely weatherproof design activated using a magnet – ARW.)*

Since the unit is battery powered and is switched off for long periods, the control circuit had to have negligible quiescent current. The versatile circuit also incorporates a "brown out" circuit, to protect the receiver against voltage supply dips. It automatically switches off the unit when the battery supply drops to below 5V; also it prevents the battery from being completely flattened and it functions as a form of overcurrent trip.

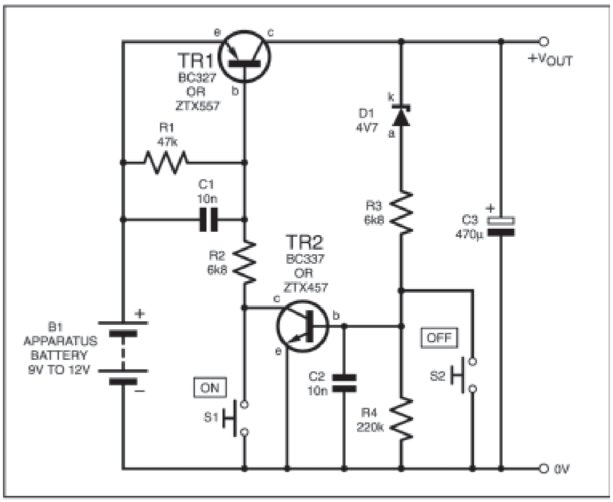


Fig.3. Circuit diagram for a Solid-State Switch.

Brown Out

As soon as the On button-switch S1 is pressed, the *pnp* transistor TR1 turns on as its base (b) is biased to 0V. This supplies base current to the *npn* transistor TR2 via the "brown out" Zener diode D1.

Both transistors will now stay on unless either the Off switch S2 is pressed (which shunts base current for TR2 away to 0V), or if the output voltage drops to approximately +5·3V. This is the point at which the Zener stops supplying the 0·6V needed by TR2 to maintain its conduction.

This feature also switches off the circuit in the event of an accidental short circuit on the output, or for any other reason that causes the output to dip below +5·3V. If these features are not required, the Zener diode can be omitted (shorted out).

When powered, the circuit consumes less than 2mA, which can be reduced by increasing the value of resistors R2 and R3. It draws no measurable current when off, unless the transistors are "leaky", but this is minimised by the base emitter resistors. The 10nF capacitors (C1, C2) avoid switching interference, and a large reservoir capacitor C3 is recommended to prevent nuisance tripping.

John A. Smith,
L'Agulhas, South Africa.

Electronic Tuning Fork – No Strings Attached

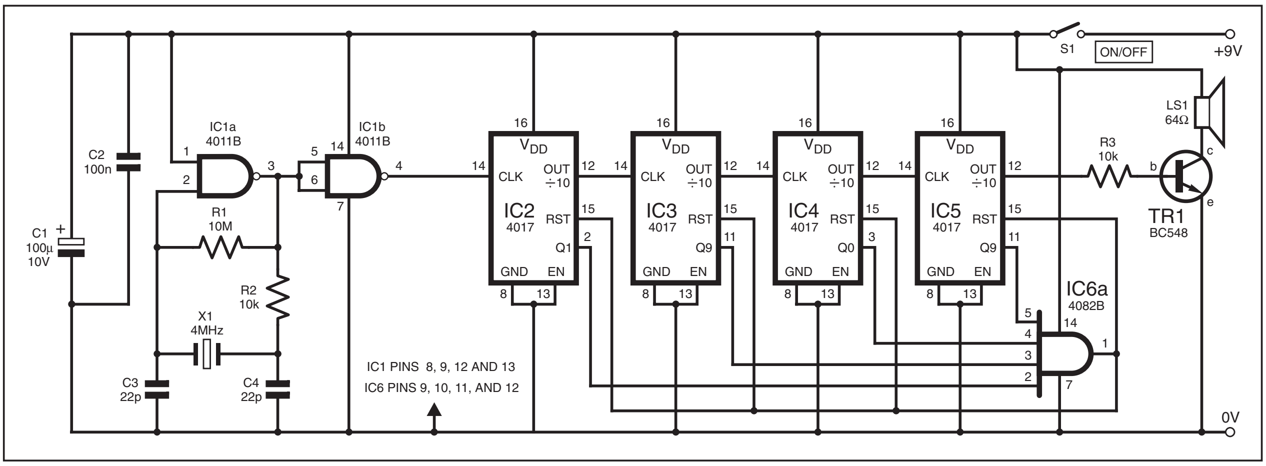


Fig.4. Complete circuit diagram for the Electronic Tuning Fork.

THE circuit diagram shown in Fig.4 was designed as an accurate alternative to an ordinary metal tuning fork. It has the advantage of continuous operation, as it does not require "striking" like an ordinary tuning fork. It is also louder and it generates its own sound through a loudspeaker rather than using a table-top, or even the musical instrument itself, as a resonating board.

The Electronic Tuning Fork is designed to produce the musical note "A" at 440Hz., as this is probably the most useful note for the purpose of tuning musical instruments. It can be adapted to produce other notes if desired.

In order to obtain good accuracy, a crystal oscillator is used at 4MHz. When this is divided by 9,091 a frequency of 439·996 Hz. is produced, which to the human ear is imperceptibly close to 440Hz (note *A*). If a round number is to be used for division purposes, the lowest frequency crystal which is commonly available is 11MHz. This is rather high for most logic chips, hence the use of the method described here.

Crystal Oscillator

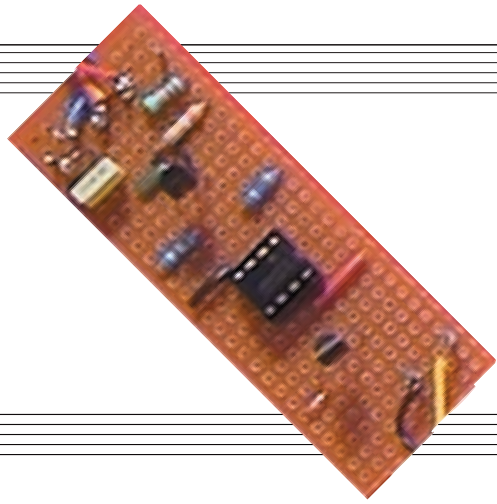
A crystal oscillator is based upon IC1a, with IC1b wired as an inverter which clocks the first of four 4017 decade counters. The "carry out" of each chip clocks a subsequent counter, and the total count on the outputs of the chips rises until 9,091 is reached. At this point the output of a four-input AND gate, IC6a, goes high, which resets the decade counters to zero so the count sequence restarts. The "carry out" pin 12 of IC5 drives a BC548 transistor which causes the loudspeaker LS1 to sound the tone.

The circuit can be powered from a 9V battery, the supply being decoupled by capacitors C1 and C2.

Simon Guest,
Balerno, Midlothian

Top Tenners

D.C. MOTOR CONTROLLER



OWEN BISHOP

Project 9

This short collection of projects, some useful, some instructive and some amusing, can be made for around the ten pounds mark. The estimated cost does not include an enclosure. All of the projects are built on stripboard, and most have been designed to fit on to boards of standard dimensions. All of the projects are battery-powered, so are safe to build. In a few cases in which, by its nature, the project is to be run for long periods, power may be provided by an inexpensive mains adaptor. Again, the cost of such a unit is not included.

INEXPENSIVE d.c. motors are often used by model-makers, not only for model locomotives and racing cars but in robots of all kinds. They may also be used for driving non-mobile models made from anything from cardboard to Meccano.

This project controls a small 6V d.c. motor, but can be used for 12V or higher-voltage d.c. motors as well. The circuit controls both the speed and the direction of the motor.

There is a wide range of cheap low-voltage motors available, running at maximum no-load speeds ranging from 3600 r.p.m. to 18,000 r.p.m. or more. Torque may be anything between 3g-cm for the cheaper versions and over 60g-cm for the slightly more expensive motors. Many applications require slower speeds with correspondingly greater torque, and there are several different plastic gearboxes available for the model maker to use.

There are also motor-driven devices such as cooling fans and water pumps that can be controlled by this project. If controlling motors is of no interest to you, perhaps you might like to use the circuit for controlling the brightness of a filament lamp.

HOW IT WORKS

It is possible to control the speed of a motor by simply wiring a resistor in series with it. Apart from the inefficiency of such a system, there is the need for a heavy-duty variable resistor (potentiometer).

A typical d.c. motor requires several hundred milliamps to drive it. If the motor is taking, say, 300mA and the variable resistor is dropping, say, 3V, the power dissipated in the resistor is 0·9W. The typical variable potentiometer is rated at only 0·25W, so something much more robust is required, costing three or more times as much.

Another factor is that motors do not run well on less than their full rated voltage. They fail to start turning when current is switched on and have a tendency to stall when extra load is applied.

This D.C. Motor Controller project avoids these problems by using *pulse width modulation* (PWM). Instead of running the motor on a lowered voltage, we apply its full voltage but for only a fraction of the time. Power is supplied as a series of *pulses* and the faster we want the motor to turn, the wider the pulses.

UNIJUNCTION OSCILLATOR

The full circuit diagram for the low voltage D.C. Motor Controller is shown in Fig.1. The pulses originate from an oscillator that is based on unijunction transistor TR1.

This is a rather unusual type of transistor in that it consists of a bar of *n*-type semiconductor with a region of *p*-type semiconductor formed within it near one end. The ends of the bar are termed base-1 (b1) and base-2 (b2) and the *p*-type region is called the emitter (e).

In Fig.1, this transistor, TR1, is wired in series with two fixed resistors (R2 and R3) and there is a drop in potential along the bar from b1 to b2. Also, capacitor C1 is being charged by current flowing through a resistor R1. The voltage across the capacitor rises slowly, and the voltage at the emitter rises equally.

At a certain voltage, known as the *peak point*, the voltage of the emitter is about 0·6V greater than the voltage in the bar at the level of the emitter. In other words, the emitter and the bar are at a level which constitutes a forward-biased diode.

Current begins to flow from the emitter into the bar and away though b1. The effect of this is to reduce the voltage in the bar so that a larger current flows through the emitter.

The charge on the capacitor falls very rapidly until it reaches the *valley point* of the transistor. Then it stops and the capacitor begins to charge again. Thus, the voltage across the capacitor ramps up relatively slowly (depending on the values of R1 and C1), but falls very rapidly. The result is a sawtooth waveform.

The sawtooth output from TR1 is sent to the inverting (–) input (pin 2) of operational amplifier IC1, where it is compared with a steady but variable voltage from the

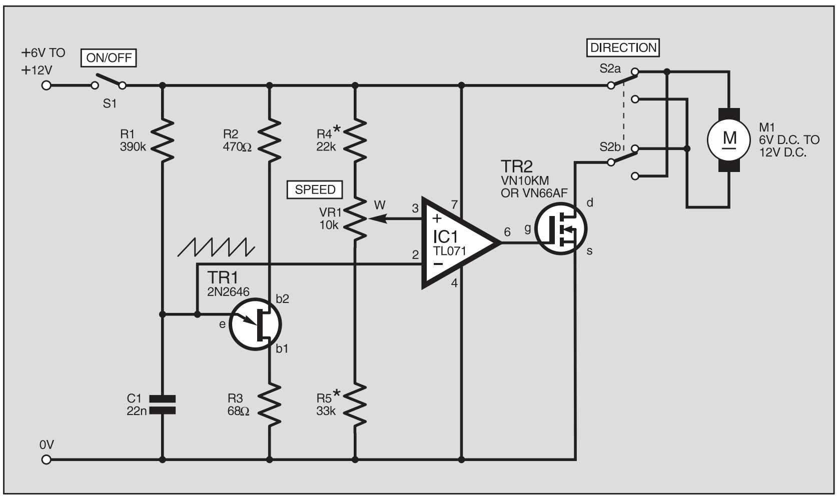


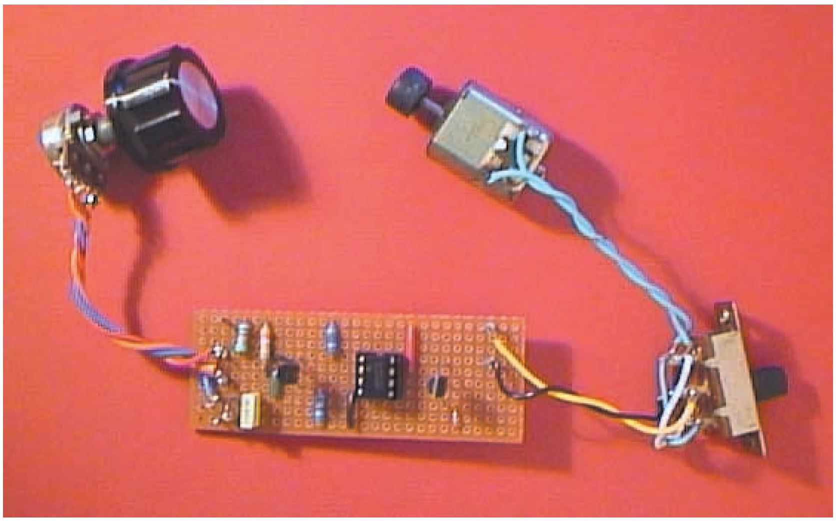
Fig.1. Circuit diagram for the low-voltage D.C. Motor Controller.

wiper of Speed potentiometer VR1. The result of the comparison of the sawtooth with the variable control voltage is illustrated in Fig.2.

If the control voltage is less than both the peak point and the valley point, the output of IC1 at pin 6 is continuously high. If we gradually increase the control voltage, we find that the output drops sharply whenever the sawtooth drops below the control voltage. This occurs when the sawtooth approaches the valley point or, in terms of inputs, when the voltage at the inverting input (–) of IC1 is less than the voltage at the non-inverting (+) input.

As the control voltage is increased, the sawtooth spends more of the time at values less than the control voltage. The output pulses have longer gaps between them. At the other extreme, the control voltage is higher than the peak point and the output is continuously low.

The result is that the op.amp produces a series of pulses of equal amplitude and at constant frequency, but with variable width. This is known as *pulse width modulation* (PWM).



Completed circuit board and wiring to the motor reversing switch and motor.

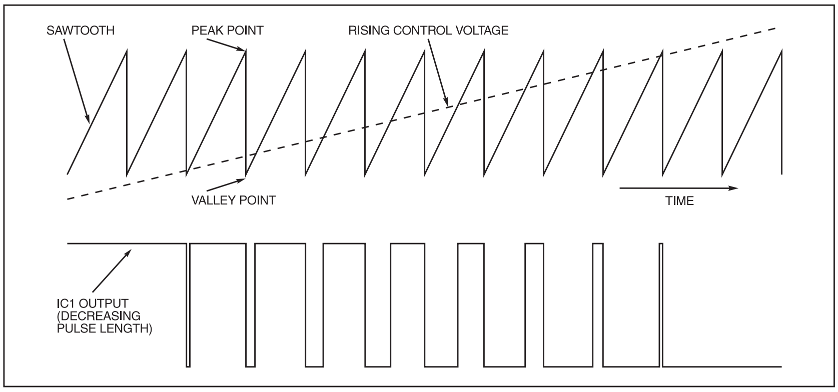


Fig.2. Waveforms comparing the input and output voltages of op.amp IC1.

SPEED CONTROL

The effect of the PWM output from IC1 (pin 6) is to turn the *n*-channel MOSFET TR2 *on*, and hence the motor, for a varying proportion of the time. The motor always receives the full voltage across its coils, but a variable amount of power is supplied to it by turning the voltage on and off in quick succession.

Its speed varies according to the rate at which power is supplied, that is, according to the pulse width. There is no jerkiness in the action of the motor if the frequency of the sawtooth is high enough. The frequency of this circuit is about 120Hz.

For the finest control of speed, we should arrange that the control voltage varies from just below the valley point to just above the peak point as Speed control VR1 is turned the full length of its travel. This is the purpose of resistors R4 and R5. It may be necessary to alter these, depending on the exact values of the peak and valley points.

The value of the peak point depends on a parameter known as the *intrinsic standoff ratio*. For the 2N2646, TR1, the data sheets state that the ratio may be between 0·56 to 0·75. This means that the peak point lies between 0·56 and 0·75 of the voltage applied across the transistor. There is an appreciable difference between individual transistors.

The valley point is rarely quoted but is usually a volt or so lower than the peak point. It may be necessary to alter the values of resistors R4 and R5 so that potentiometer VR1 covers the range more accurately.

BRIGHTNESS CONTROL

The action of the circuit is similar if we are controlling a lamp. The filament is turned fully on and off but, since the filament does not have time to warm completely during a pulse or to cool completely between pulses, the filament heats to an intermediate temperature. Instead of a flickering light, we obtain illumination of variable brightness.

REVERSING SWITCH

If the circuit is used for controlling a motor that does not need to be reversed, the switch S2 can be omitted. It is also omitted for controlling a lamp. In theses cases, the motor or lamp is connected directly between the positive supply rail and the drain (d) terminal of TR2.

The reversing switch is based on a standard two-pole two-way switch, which can be a slide switch, a toggle switch or a rotary switch. The connections shown in Fig.1 explain how this works.

CONSTRUCTION

The D.C. Motor Controller is built up on a piece of 0·1in. matrix stripboard having 10 copper tracks by 29 holes. The topside component layout, wiring to the optional reversing switch S2 and details of breaks required in the underside copper tracking are shown in Fig.3. (Note there is no row *I*.)

For the power supply, use the source that would normally be used for the motor or lamp concerned. The op.amp IC1 operates at voltages between (±3V and (±18V, so a d.c. supply between 6V and 36V can be employed. A heavy-duty battery or mains PSU (unregulated) is most suitable.

COMPONENTS

See **SHOP TALK** page

Resistors

R1	390k	
R2	470Ω	
R3	68Ω	
R4	22k (see text)	
R5	33k (see text)	

All 0·25W 5% carbon film or better

Potentiometer

VR1	10k rotary carbon, lin

Capacitor

C1	22n polyester film

Semiconductors

TR1	2N2646 unijunction transistor
TR2	VN10KM or VN66AF *n*-channel MOSFET (see text)
IC1	TL071 bifet op.amp

Miscellaneous

M1	small low voltage d.c. motor (see text)
S1	single-pole on/off toggle switch
S2	2-pole, 2-way slider or toggle switch (optional)

Stripboard, 0·1in. matrix 10 strips × 29 holes; 8-pin i.c. socket; knob for VR1; 1mm terminal pins (7 off); connecting wire, solder etc.

Approx. Cost Guidance Only **£8.50** *excluding motor, batts.*

MOSFET

It is important that MOSFET TR2 is rated to carry the fairly large current that the motor requires. Small d.c. motors require about 300mA and larger motors may require more. The VN10KM carries a maximum current of 500mA. A transistor of higher power rating is recommended for a larger motor or for one operating on a higher voltage.

Suitable substitutes are the VN46AF, VN66AF or VN88AF, which carry up to 2A. A small heatsink is recommended with these transistors. Although we have not tested this, calculations show that unijunction TR1 should operate correctly at supply voltages up to 36V.

Begin construction by building the unijunction oscillator stage (TR1) and use an oscilloscope or a frequency meter to check that its output is about 120Hz. If possible, measure the peak and valley points. These were about 4V and 3V, in the prototype.

Next, assemble the potential divider, VR1, R4, R5, and check the highest and lowest voltages obtained at the wiper (moving contact) of VR1. Their range should just cover the range of the peak and valley points. If it does not, you may need to substitute slightly different values for resistor R4 and/or R5, but it is best to leave this until later, after you have checked the operation of the whole circuit.

Add the op.amp IC1 and MOSFET TR2 to the circuit board next and connect the motor between the positive supply and the drain (d) terminal of TR2 (solder pin at D27). Test the circuit by switching on S1 and slowly adjusting the knob of Speed control VR1 over its full range.

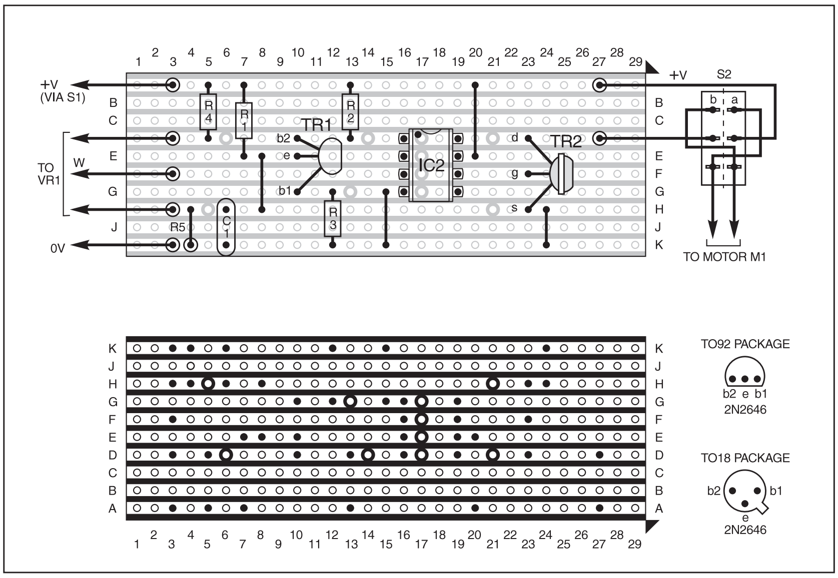


Fig.3. Stripboard component layout, wiring to off-board components, copper break details and underside pinouts for two packages of TR1.

The motor speed should vary from stationary to full speed. If the speed cannot be varied over the whole required range, substitute different values for resistors R4 and R5.

The simplest procedure is to disconnect the wiper of VR1 from the solder pin at *F3* and supply the variable voltage from a "breadboarded" 10kΩ potentiometer in series with various fixed resistors. Try different values until you obtain the speed control that you require. Then re-connect VR1 and replace R4 and R5 with resistors of the new values.

If a reversing action is required, add the reversing switch S2. The wiring connections for a slide-type switch are also shown in Fig.3. Corresponding connections are used with other types of switch. □

READOUT

E-mail: editorial@epemag.wimborne.co.uk

John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

WIN A DIGITAL MULTIMETER

A 3½ digit pocket-sized l.c.d. multimeter which measures a.c. and d.c. voltage, d.c. current and resistance. It can also test diodes and bipolar transistors.

Every month we will give a Digital Multimeter to the author of the best *Readout* letter.

★ LETTER OF THE MONTH ★

SERIAL MATTERS

Dear EPE,

I think the reason why Mike Von Der Heyden (*Readout* Feb '01) thought things were upside down is that the standard drivers and receiver chips for RS232 levels (such as the 1488/1489 and the MAX232 series) provide electrical inversion but not logical inversion. That is, they translate the 1 of a TTL High (3·5V to 5V) on their TTL side to a negative Mark voltage (–5V to –15V), which is the RS232 way of saying 1; and correspondingly the 0 of the TTL Low (0V to 0·7V) on the TTL side to a positive Space voltage (5V to 15V) which is RS232's 0. So 1 is High is negative . . .

To get away from this confusion, I like to keep my 1s and 0s inside software only, and think of these RS232 voltages using their ancient names Mark (negative) and Space (positive). They deserve this as these voltages are damagingly different from the TTL High and Low, and feeding them straight into a TTL (or CMOS) input without any protective components will "let the smoke out" of that unfortunate chip or at least make it seriously unhappy.

Going the other way, feeding 5V CMOS signals into an RS232 receiver, to me looks like a big "maybe". It seems that most modern PCs have RS232 receivers with a threshold near 2·5V, so anything above this becomes understood as Space (positive, remember) and anything below, though still positive, becomes Mark. But this is not according to the standard specs for RS232 voltages as I know them, and I would not depend on this to work over a long cable or with unknown hardware.

As for the interfacing software, I have been using various versions of C, because it allows me to make the programs easy to port between various machines running DOS, Windows and UNIX. On DOS, the favourite is still the old Borland Turbo C 2·0, I have used it for years, and it works great for I/O port interfacing. This version of Turbo C allows me to make interrupt service routines without using any assembler. Even in a DOS box on Windows NT4, the system allows me to manipulate the UART within the PC and even use the six handshaking lines as independent single-bit I/O lines, two outputs and four inputs.

I also followed Alan Bradley's pointer to the Borland site, and I will be checking out the free ANSI C compiler he mentions there. If this one does the same things as the old Turbo C 2·0 does, I think this will really be a good candidate for interfacing projects.

Fortunately, MS-Windows and UNIX (HP-UX, Linux, etc.) all have their sets of system calls that can be used in programs talking with devices sitting on the other side of a serial port. At least as long as C is being used. On Windows, I guess someone could make a Visual Basic component similar to the INPOUT32.DLL. Now, on Linux it appears that you can get compilers or interpreters for almost any language you like, and it is likely that these are interoperable, so one part could be in C and another could be in Basic.

Knut Reidar Leer,
Ashtead, Surrey, via the Net

Thank you Knut for your useful clarification.

On the subject of I/O, what does anyone know about USB (Universal Serial Bus) interfacing in relation to hobbyist projects? Do any readers have USB on their PCs? Is USB something that EPE *should begin to take notice of?*

ROCK SOLID LINUX

Dear EPE,

In response to Mr Elliot's letter in *Readout* Feb '01, I have often wondered why there has not been more mention of Linux in *EPE*, especially as Linux embodies just about everything that I can imagine an *EPE* reader would want. It is free, rock solid and you can pull it apart to see how it works!

More importantly, Linux is rapidly becoming the embodied language of choice. As embodied PCs continue to fall in price, more and more devices are going to be shipped with Linux driving them.

You can use C, Python and many other languages to control parallel ports and many of *EPE*'s projects can easily be driven by Linux. Windows and Linux can be dual booted on the same hard disk so get a copy off the front cover of a Linux magazine and give it a try...

Simon Faulkner, via the Net

I have to acknowledge that Microsoft seem to have most of us "brainwashed" into regarding their products as "The Standard". I have never even seen a Linux-based machine, let alone used one.

PIC TRICKS

Dear EPE,

I once went to a Microchip PIC course and they gave everyone a folder full of programming tricks. The following two might interest readers:

```
; Exchange contents of register REG and W
MOVWF TEMP1      ; save W
MOVF REG,W       ; save REG
MOVWF TEMP2
MOVF TEMP1,W     ; old <W> –>REG
MOVWF REG
MOVF TEMP2,W     ; old <REG> ->W

; Swap contents of W and REG without using
a second register
XORWF REG,F
XORWF REG,W
XORWF REG,F
```

Alan Bradley, via the Net

Interesting! Thanks Alan.

MORE PIC TRICKS
If you have any *short* snippets of interest to share, let us know!

ACTIVE PORT FINDING

Dear EPE,

Help regarding "Active Port Finding" may be closer to hand than Peter Hemsley (*Readout* Jan '01) remembers!

I believe that *EPE* once published an article by Robert Penfold, which explained that parallel port addresses are assigned sequentially. The most common cause of a change to the normal numbering sequence is; the use of a Mono or CGA video card which incorporates a built in LPT port, this, if present, always locates at a specific address and takes the lowest LPT number assignment (I think!).

COMM ports are usually more predictable in respect of which address they occupy, the main difficulty usually arises from IRQ3/4 assignment, this is usually dead easy to set up/view the current config by entering BIOS setup. Problems rarely arise unless the built in I/O is disabled, and a Multi I/O card installed with hardware config jumpers.

If a PC has peculiar port address assignments, it's probably as well to throw it in the skip! Problems will arise with any proprietary software that does not give total freedom to enter port addresses "anywhere you like"!

Anyone interested in using "programmers methods" might be interested to know that executing Interrupt H11 deposits the "Equipment List" in register AX:

Bit(s) 15/14	Number of printers installed
Bit(s) 13	Reserved
Bit(s) 12	Game adaptor
Bit(s) 11/10/9	Number of serial ports
Bit(s) 8	Not used
Bit(s) 7/6	Number of diskette drives
Bit(s) 5/4	Initial video mode (11 = Mono, 10 = 80-column colour, 01 = 40 column colour)
Bit(s) 3/2	Obsolete (PC/XT memory, PC/AT unused, PS/2 bit 2 = pointing device)
Bit(s) 1	Numeric coprocessor
Bit(s) 0	Set if any diskette drives are present

This is derived from the equipment list, stored in the BIOS data area of RAM during BOOT and can be altered by software at any time (but usually isn't!)

Ian Field, via the Net

Thanks Ian – useful information. I've checked with Robert who says that he has covered parallel ports many times through Interface*, and thinks that of May '98 might be appropriate. Scanning through it, I'm not sure it's what you refer to, although it does provide a lot of useful info.*

PICS AND KEYPADS

Dear EPE,

A few weeks ago I purchased your *PICtutor Deluxe* and cannot believe that I can now write PIC programs. Can a keypad to be connected to the board?

A.R. Vasseghi, via the Net

Nice to know that you too have found success through PICtutor*. Keypads can be used as discussed in* Using PICs and Keypads *in* EPE *Jan '01.*

EINSTEINIAN UNIVERSE

Dear EPE,

I cannot help but note your apparent frustration when readers suggest the magazine switch its emphasis from PICS and QBasic to such things as Visual Basic, Delphi, Power Basic, 8051 microcontroller series etc. I sense you want to say, "I have enough mastering the first two; who do you think I am, Einstein?!"

I have to say, though, I would love to learn about these other subjects and can only suggest to these readers that if they are sufficiently knowledgeable to suggest their advantages then they must be conversant enough to write an article on them.

Meanwhile, if there is an Einstein out there who does have a catholic understanding of several languages plus the hardware, with the ability to set out and discuss in general terms their various attributes, then it would be the first such article I for one would have ever read.

Such an article may give those of us who lack the knowledge and experience to appreciate the "big picture", a nudge in the right direction.

Also, given the mass of electronic hardware in computers, monitors, modems, scanners, CD drives to mention a few, there must be lots of otherwise expensive components one could strip out from obsolete and junked units which would prove useful for other projects.

Stepping motors would be a good starting point. Again the most important aspect here are authors with the know-how of the various models and "variations on the theme" which some manufacturers employ. For those readers who have limited time, *Ingenuity Unlimited* seems like an ideal repository for such articles.

Pat Alley, via the Net

The only thing Einstein and I have (had) in common was an interest in Marilyn Monroe (allegedly)! But, yes, I wish I had the time to explore all these other languages on your behalf. However, having just climbed some very steep slopes to get to good grips with VB (I doubt anyone can ever truthfully say they know ALL about it!), my batteries need recharging.

You do raise an interesting point though, about software discussion. Basically, EPE *is an electronics magazine and it is to that end that we believe readers wish us to remain true. It is certainly extremely obvious, though, that many readers have an intense interest in computing and programming as well. The nature of the letters published here in* Readout *confirms this.*

However, to get heavily into feature articles on software would seem to breach our primary objective, to the distress of those for whom it is "traditional" electronics that they want to know about through us.

Whilst I, for example, would be interested to do an "early learning" tutorial on Visual Basic, it seems that this cannot be categorised in the same way as my tutorial on PICs, or the software discussion for the recent Graphics L.C.D., which were both specific to electronics applications. VB, Delphi, C and the like do not fall into this category, and so seem outside our remit. (Reader feedback on this would be welcome.)

"Reclaimed" components, too, are not items to which we could lend our support. There are too many varieties and too many inconsistencies of source. Generally speaking, we only support those components which are readily available through suppliers content to supply small quantities inexpensively to the hobbyist market.

Whilst it would be nice to publish DIY projects using the very latest in technology, much of this is only available at reasonable prices in bulk quantity to the "trade", with one-off prices severely inflated by suppliers' handling and carriage overheads.

And to anticipate a possible next question – no, EPE *cannot bulk buy components and sell them to readers, we are publishers, not component retailers!*

Thank you Pat, it's appreciated that you should have raised the points. We do like to know what readers think, and if enough want the same thing, we try to oblige. Keep comments coming, on any electronics-related subject.

MISSED CALL INDICATOR

Dear EPE,

I thought David Corder's *Missed Call Indicator* was neat (*IU* Dec '00), so I knocked one up. I used a 4093 instead of the suggested 74HC132 because (a) I had one spare in the components box, and (b) I have a 5V power supply near the target phone which I could tap into, so running the circuit from a 3V battery was not a requirement for me. It works well and it's useful – I often forget to switch the answering machine on when I go out.

I found that initially the circuit as per the diagram wouldn't sustain oscillation (latch) once triggered, unless the bleed resistor R4 was removed. This could be due to my 4093 taking a higher gate current, but I'm a bit doubtful about that making much difference. More likely my capacitor C1 is a rather leakier specimen than the one David used – the fact that my circuit ran quite well without R4 at all tends to suggest this too. However, I did get the occasional false trigger, and I've now settled on using a 10M component for R4 rather than the 1M value suggested.

I also found that triggering sensitivity was quite dependent on the number of turns of the pickup wire wrapped round the phone wire. There are no comments in the text about this, whereas there are remarks about how the values of C1 and R3 relate to the sensitivity. I'm using about 12 turns round my (nominally REN 1) phone wire, and this usually triggers on the second "burr-burr". I guess most constructors can easily experiment with this, and probably different phones will be different anyway but maybe these comments will help as a starter for some.

Malcolm Wiles, via the Net

Thanks for the useful comments Malcolm (and the other comms we've shared via our Chat Zone *and e-mail).*

PIC UP C!

Dear EPE,

I echo Alan Bradley's request for a "C" tutorial (*Readout* Feb '01).

Having learned PIC assembly language through your *EPE PIC Tutorial* which was, well what can I say, it was idiot proof, which was just as well with me as the student. The individual exercises went exactly at the right pace, were understandable, and most importantly were easily adapted so I was encouraged with the knowledge that what I wanted to do wasn't so different from the example. A marked contrast to the book I had spent £20 on and had not been able to understand because of the level of expertise it assumed, despite being described as for beginners.

I think you are wrong when you suggest there would be little interest in "C". A "C" tutorial presented in a similar manner to that of the PIC would be much welcomed by myself and would soon lead to a heavy demand for *EPE*.

Derek Johnson, via the Net

Thank you Derek for your compliments about my PIC Tutorial *and comments on "C". My reply to Pat Alley (on this page) sums up my feelings, but we still like to learn readers' views on such matters.*

TOOLKIT DECODE FILES

Dear EPE,

I have just obtained some 16F877s and have been using my PIC Toolkit V2.4. Everything seems to work fine, but I have noticed that when disassembling even a small program, the Decode file produced is too large for the DOS editor to load (403Kbytes). I wonder if you have noticed this. When examined with Wordpad, it seems that there is a "garbage line" repeated to the end of memory and then the "END" command.

W. Scanes, via the Net

The thing to remember is that Toolkit *disassembles the entire contents of the PIC in question, and very large files can indeed be created. The PIC16F877 has 8192 command locations, and even if disassembled when its contents have been "erased" could generate about 122 kilobytes of data. It is the "erased" section of your PIC that you refer to as "garbage", on top of that you have got the translations of the codes extracted from the PIC.*

The way round it if only part of your PIC16F877 is used, is to disassemble as though it were a PIC of lesser capacity. Toolkit TK3 *that I'm working on will also allow memory capacities to be selected in steps of 250, from 250 to 8000 bytes, in addition to the fixed PIC sizes.*

I was unaware that DOS Edit had a limit to what it can pull in, indeed I have just asked it to pull in a 1388KB file having 54396 lines, which it did without objection.

At the time you wrote, however, I had just found that Notepad (a Windows editor facility) does have a limit. If you access Notepad with too large a file it will offer to open Wordpad instead, which I have just done with the same 1388KB file without trouble. There will be a user's choice of text editors with TK3.

LIBERTY BASIC

Dear EPE,

I have been following the correspondence in *Readout* regarding the unsuitability of QBasic and other DOS Basic languages and have to agree, that in the Windows environment which most of us now use, something more suitable is required. Delphi, Visual Basic, Visual C, etc., are all fine alternatives, but for electronics enthusiasts who, like myself, do not have enough time to devote to the intricacies of such languages, I recently did a web search for a substitute.

There is a little known (to my knowledge!) Basic language called Liberty Basic which is very easy to get to grips with, able to interface with Windows API's and gives access to both PC serial and printer ports and timers. It is a compiled language and with the registered version, produces stand-alone applications, i.e. the user does not need Liberty Basic to run them.

Having downloaded a trial version of Liberty Basic 1.42, I was able to produce a working application within a few hours. The trial version is fully functional but does not permit production of a stand-alone program. QBasic programs are easily converted to Liberty Basic for use in the Windows 3·1/95/98 environment.

My success was so appealing that further searches located version 2 of Liberty Basic which appears to be the Basic programmer's dream. Both versions have a GUI interface for easy layout of graphics, standard Windows buttons, bitmap buttons, drop-down menus etc. Version 2 also has enhanced functions and a millisecond timer function.

For the "infrequent" programmer, who would have to relearn Visual Basic each time, then I can find nothing more suitable than Liberty Basic.

LB trial version can be downloaded from **http://libertybasic.swiki.net/10** and the registration cost is 40 dollars if it answers your prayer!

M. Bradbury, Staffs, via the Net

So, yet another program tool for readers to think about playing with!

COIL WINDING PROGRAMS

Dear EPE,

Many thanks for the excellent article on Inductors in the March '01 issue. Congratulations to Raymond Haigh on a well-written article.

Your readers may be interested in two programs I have written for calculating inductor windings. They can be downloaded free from: **www.g7fic.freeserve.co.uk/electronics.html**. The programs run under Windows 95 or later.

Paul Fellingham,
Brighton, East Sussex

Thank you Paul for your kind comments and the software offer.

PIC CONFIG DATA

Regarding your reply in March '01 *Readout* to my original comments about the RC5 program for the *Remote Control IR Decoder* (Sep '00), you say that you don't understand the hex (0x) 400E address. I've now read the Microchip programming specs in order to write my own programmer, it's become apparent that the following is the case:

The PIC configuration word is located at program memory address 0x2007. The Intel hex file format used by Microchip contains 8-bit bytes. Because it takes two 8-bytes to represent a 14-bit PIC program memory word, all addresses in the hex file are double their actual location in PIC memory. Hence address 0x2007 is actually represented in the hex file as 0x400E.

There's a further twist. In their programming specs Microchip make it clear that production quality programmers must be able to program the PIC configuration and Data Eeprom from data embedded in the assembler output files, as well as program memory. In MPASM, "__config" is the implementation of the former, and the "de" directive the way of specifying embedded Data Eeprom values. Data Eeprom values appear in the hex file as being logically located at PIC address 0x2100 onwards, i.e. with address >=0x4200 in the hex file.

For *EPE*/hobby purposes we may not be too concerned about production quality. But the issue here is that the programmer supplied with the *Icebreaker* project software (March '00) supports this embedded Data Eeprom programming. More specifically still, it will actually *clear* a PIC's Data Eeprom when programming Program Memory if no embedded Eeprom data are found in the same hex file. Thus folks using *Icebreaker* and requiring certain data in the Eeprom at power on *must* embed that data in their hex files.

So in your forthcoming new *Toolkit TK3 For Windows* programmer, you should at least ignore these data as well, otherwise folk with *Icebreaker* files won't be able to use them with your programmer. Your fix of ignoring all addresses >8192 will do that, but I'd suggest something a bit better. Ideally, program the Eeprom too, if embedded data are found, as a user selectable option (it's not hard to do), but at least output a warning message that embedded Eeprom data were detected but ignored.

One other tip – I've found that if you build hex files from several ASM files using the MPLAB linker, then the first record in the hex file is of type 0x04. The MPASM documentation states that hex files will only contain records of type 0x00 and Ox01! From looking at it I've no idea what this type 0x04 record contains but it's nothing useful so far as I can see. So I'd advise for safety also check the record type in the hex file and ignore record types which are not 0x00 (0x01 is the end of file record). Though I suspect not many other *EPE* readers will come down this path!

Malcolm Wiles, via the Net

Hi again Malc. Following your very welcome comments, I have simply added intercepts into the forthcoming TK3 programmer which look for the higher Config and Data Eeprom address values, generating advisory messages if found.

TK3, incidentally, is scheduled for an Autumn '01 issue – evaluation copies are currently being "field-tested" (the first time I've ever done this, but seems worth it as I feel that Toolkit has a valuable long-term role to play for those readers who love PICs).

Thank you, too, to Peter Hemsley who also advised me about the Microchip Config address.

Incidentally, readers, Malc and Peter have been giving me extremely helpful "field-testing" advice with TK3. Malc has helped resolve a thorny problem with reading/writing PIC config data, and Peter has provided invaluable advice about MPASM. Thank you both!

ALFAC TAPES

Dear EPE,

I read with interest Mr Horton's plea for a source of Alfac p.c.b. tapes (*Readout* April '01). Alfac tapes are currently still available from Rapid Electronics in Essex (01206 751166). I gave Rapid a call to check availability and they say that there is no shortage of this product and that they do not know of any plan to stop production by Alfac.

I am the production manager for an electronics company in Nottingham and so spend relatively high sums of money with all of the major component suppliers. I can honestly say that the service from Rapid is second to none. Prompt delivery and superb packaging being two excellent virtues and although not so important to a medium sized company their prices are amazing. Components that I require for personal projects (i.e. pay for myself) are sourced from them whenever possible. Every hobbyist should have their catalogue.

Finally, have you any idea how much grief and midnight oil you have cost me over the last few months? Not long ago I had not a clue about PICs – and I had good long sleeps at night. Now if I am not still up debugging, then I am in bed thinking what I can do next! I've even introduced them into some of our latest products at work.

Kevin, via the Net

Thank you for the Alfac info, and to all readers who contacted us in this respect. We passed it all to John Horton immediately on receipt. Electrovalue was another name that was mentioned by several people.

Yes, PICs and midnight oil go hand-in-hand. My local supplier of the latter has trouble keeping pace with me! (I wonder if Rapid have any?)

GRAPHICS L.C.D.S

Dear EPE,

I am located in South Africa and have recently read your *Using Graphics LCD Displays With PICs*.

Initially I thought I would have to import the l.c.d., since I have a project in mind for one, but I managed to locate a supplier in South Africa. Although they are not the same brand, they have the same controller and are compatible. The only difference is there is no FS (font select) pin.

They can be obtained from Avnet Kopp (PTY) Ltd., 31 Commerce Crescent, Eastgate Ext 3, Sandton, Johannesburg, South Africa. Tel: +27 11 444-2333.

These l.c.d.s are made by Optrex. The company endeavour to provide data sheets as best they can, but Mr Becker's article is excellent and I would advise that all constructors use that instead. Also, Avnet have quite a variety of l.c.d.s and have a 640 × 480 dot version too, using the same controller T6963C.

Keep up the excellent work. You have a good magazine!

Jason Mitchell, South Africa, via the Net

Thanks for the info Jason, and for your kind comments.

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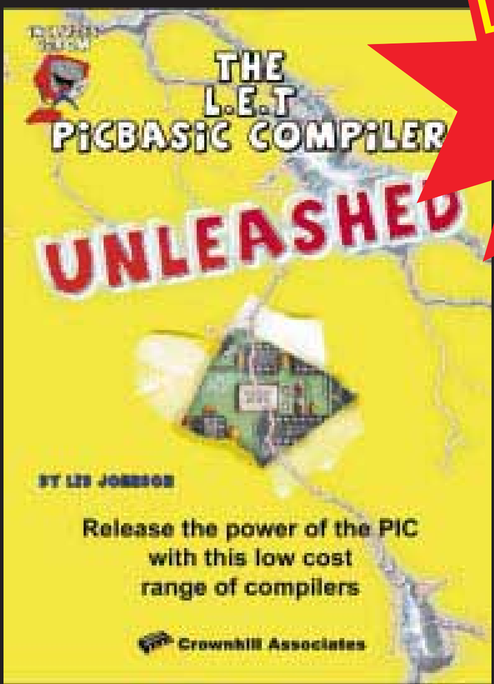

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Constructional Project

INTRUDER ALARM CONTROL PANEL

JOHN GRIFFITHS

Part Two

Microcontrolled security designed to meet British Standards specification BS4737.

LAST month we described the circuit for this sophisticated yet simple to construct alarm controller. We conclude by describing its construction and testing.

CONSTRUCTION

This unit is mains powered and its construction and testing should only be undertaken by those who fully understand what they are doing.

Complete assembly and tracking details for the main printed circuit board are shown in Fig.5, and those for the bell unit in Fig.6.

Carry out assembly in any order with which you feel comfortable. Use sockets for IC1, IC2 and IC3. Ensure that you insert the diodes and electrolytic capacitors the correct way round.

The voltage regulators IC4 and IC5 are mounted flat on the p.c.b. It is recommended that IC5 is also fitted with a small metal plate behind it to act as a heatsink (see photo).

Connections to the keypad are made via a pin-header and socket strip, using miniature diameter cable. Connection details are shown in Fig.7. Use connector position KP1 on the main p.c.b.

Note from the photo of the main unit how the anti-tamper switch has a spring fitting. This causes the switch contacts to close when the case lid is closed. They re-open if unauthorised entry to the case is attempted, causing the alarm to be triggered. The bell-unit is also protected by a microswitch.

All connections to the outside world, and to the speaker, are via p.c.b. mounted screw-terminal strips. If any zone circuit is not required, a shorting link wire must be connected across its appropriate terminals of the connector strip.

The schematics in Fig.8 and Fig.9 assist you in making the appropriate connections. Fig.8 also show the connections for

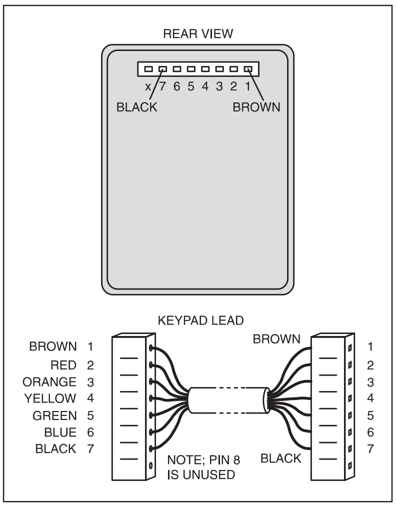
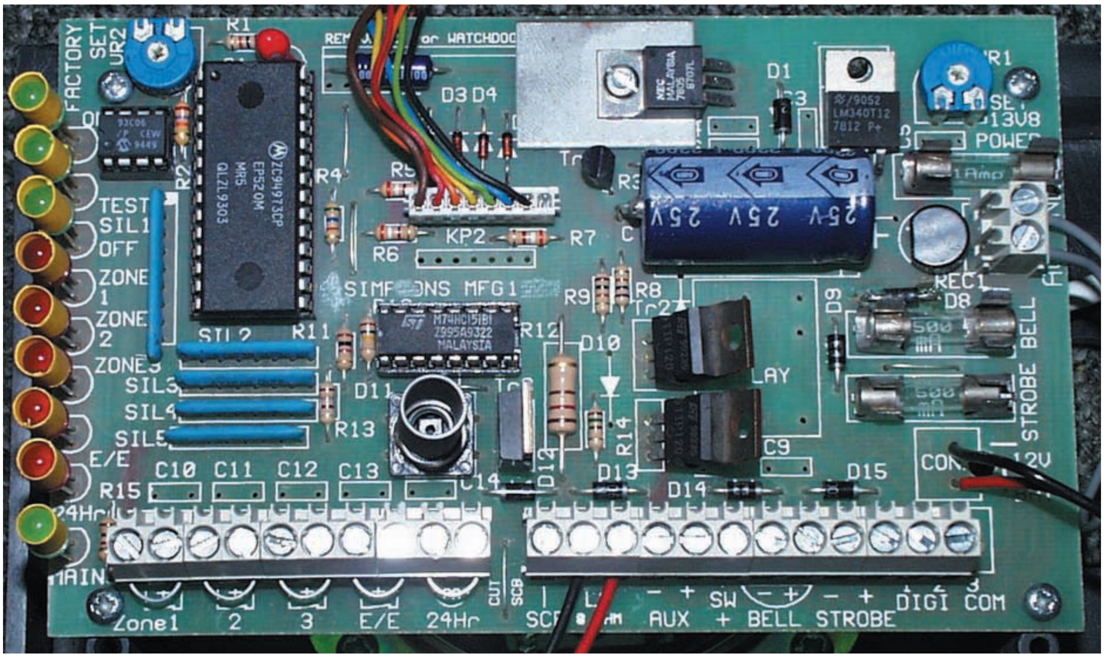
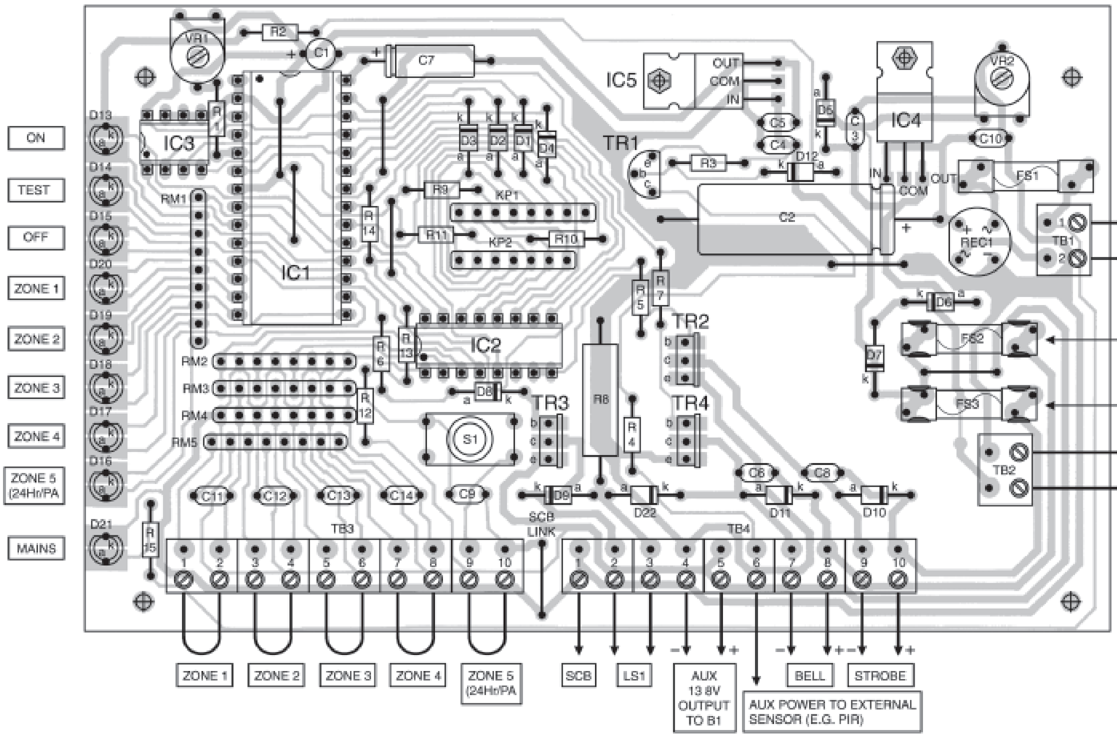
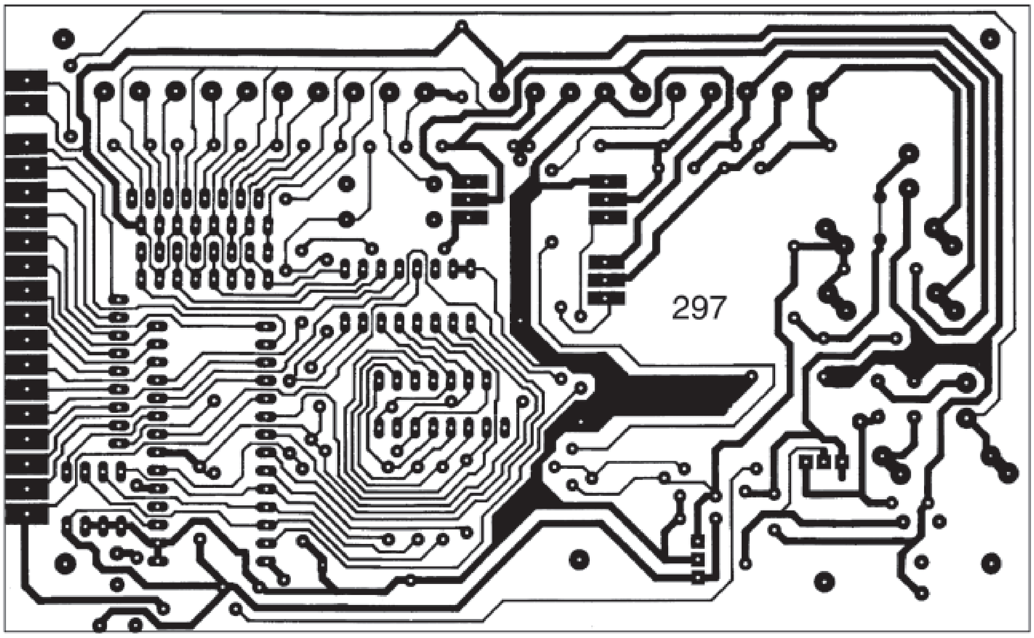


Fig.7. Keypad connections.

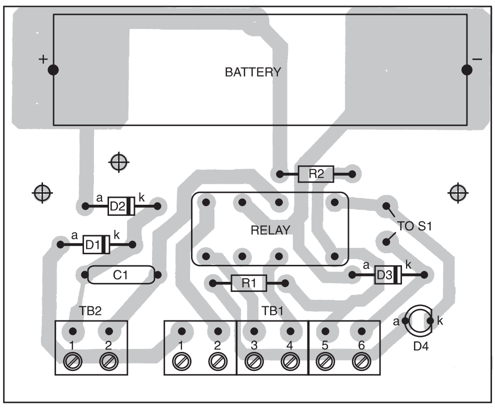


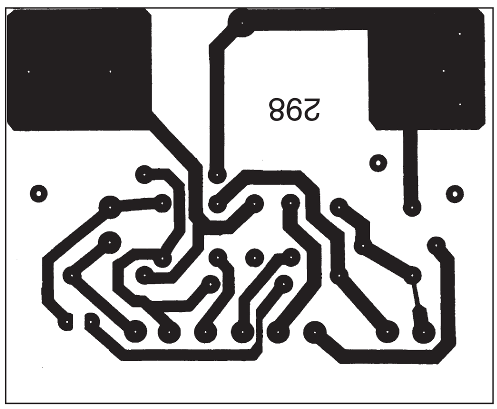
Component layout on the prototype main alarm printed circuit board. Note that the component numbering is different to the published design and that some components are not shown.





5·8in. x 3·6in. (145mm x 90mm)





2·8in. x 2·2in. (70mm x 55mm)

Fig.5 and Fig.6. Printed circuit board component layouts and full-size foil master track patterns.

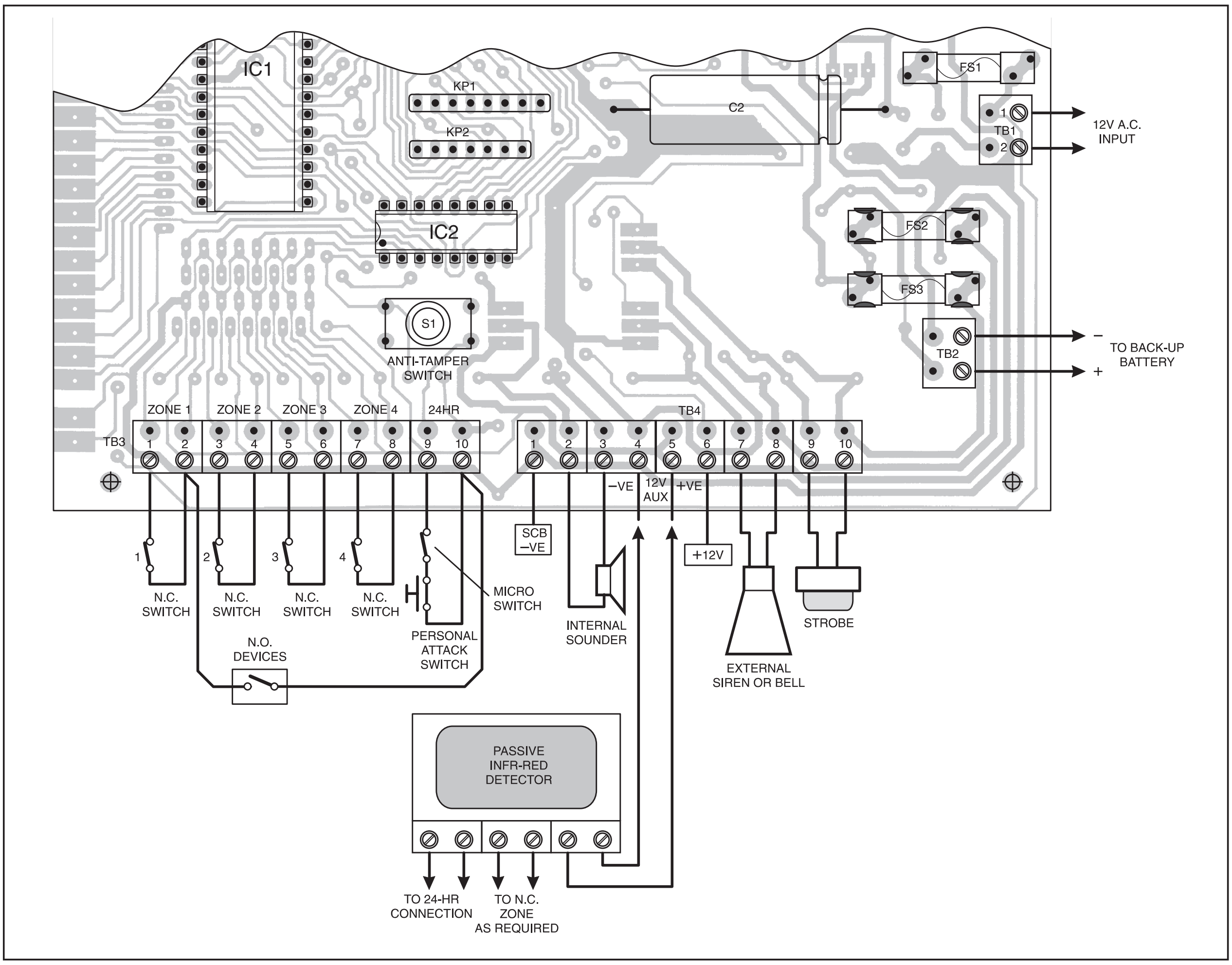
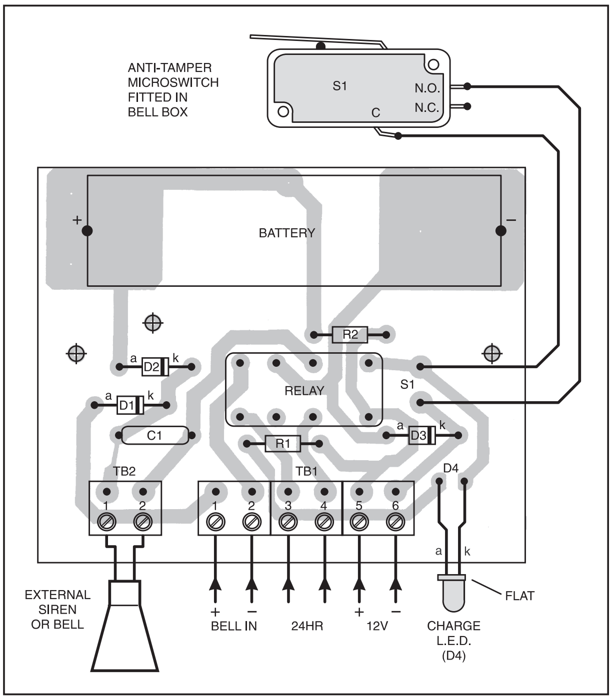
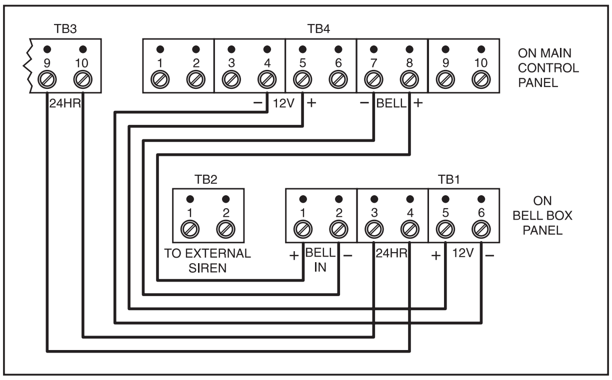


Fig.8. Controller connections to off-board components. Note that it is preferable for the siren/bell connection to be made via the external bell unit, as in Fig.10.





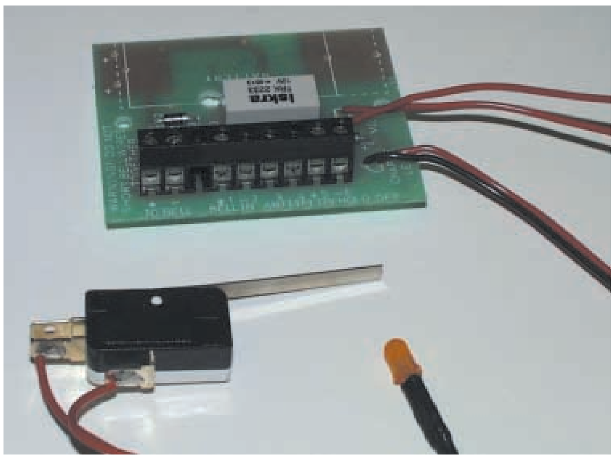
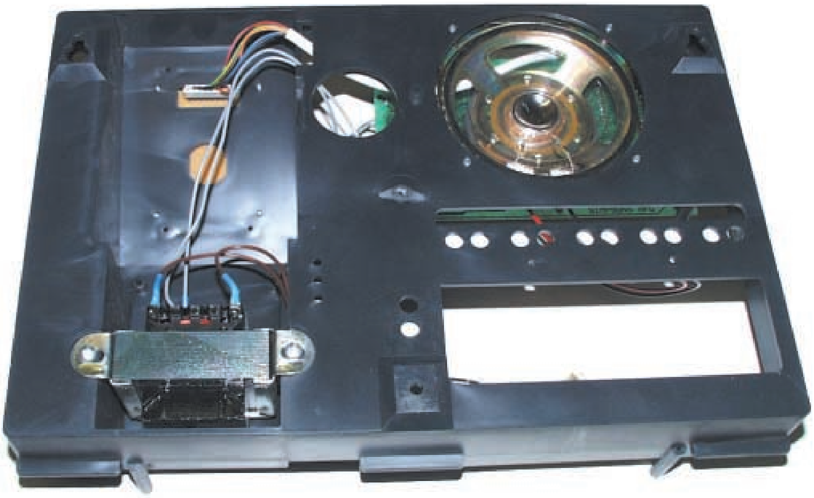


Fig.9. Bell unit connections to off-board components.

Fig.10. (Above right). Connections between the Controller and Bell unit.



a typical PIR detector, which can be wired to any of zones 1 to 4 as required. The normally-closed detectors on these zones are represented as though magnetically-closed switches. More than one can be used in the same zone if connected in series.

It is also possible to connect a normally-open detector between any of these zones and the personal attack zone as illustrated with Zone 1.

TESTING

Initially concentrate on testing the main unit without the bell unit connected. It is recommended that the mains power supply is tested with IC1, IC2 and IC3 omitted.

Set preset VR1 midway. Should you need to adjust the microprocessor's clock rate to a more precise frequency, this can be done via VR1 at a later date.

If all the components are placed correctly, the board should work first time on power up. It is recommended that wire links are inserted in the Zone and Anti-Tamper terminals to simulate the detection circuits and that initially the on-board 24-hour anti-tamper switch is shorted out. This will make it much easier to test the system and operate the keypad.

Before proceeding to test the p.c.b., set presets VR1 and VR2 to mid-position. Ensure that you have an 8Ω to 16Ω 5W speaker connected to the speaker terminals.

When connecting a back-up battery ensure that the resulting supply voltage is set to 13·8V, using VR2 with the battery connected.

It is important to check that you have connected the keypad leads in accordance with the detail in Fig.7. Reversal of the header connector at either end will result in non-operation of the system, even though you may hear a *beep* when keys are pressed.

FIRST POWER-UP

When applying power to the p.c.b. for the first time, hold the number 7 key down whilst applying the power and a short bleep should be heard from the speaker. This confirms that the NVM has been cleared and is not in any indeterminate state. The alarm is now powered up in the Set mode and you can proceed to test the system.

Note that the On mode l.e.d. D13 lights. This also indicates that the microcontroller program is running. The only other l.e.d. that should be on is the Mains indicator, D21. At this point there should be no sound from the speaker.

Enter "1234" at the keypad and check that D13 extinguishes and D15 (Off) lights. Enter "1234" again, at which D15 should extinguish and D14 (Test) light. You have now entered the Test mode and can make some preliminary tests of the zone circuits.

Start off by removing the shorting link from Zone 1 and noting that its indicator, D20, lights and that at the same time a *low amplitude* audible tone is heard from the speaker. Replace the shorting link and D20 should extinguish and the tone cease. Repeat the procedure for all the zones, including the 24-hour PA circuit.

If all the tests are satisfactory, restore all the shorting links. From the Test mode press the Set (#) key and note that the speaker sounds the Exit tone, D14 (Test) is off and D13 (On) is on.

After 20 seconds the Exit tone should cease, indicating that the alarm is now Set.

Connect a 12V sounder (not exceeding 1A) to the Bell terminals of the p.c.b., correctly observing the polarity. If available, also connect a Xenon 12V strobe (300mA) to the Strobe terminals.

Remove the shorting link from Zone 1, which should cause a full alarm condition, with both the internal and external sounders operating (very noisy!) and the strobe flashing.

Ok, now you are fully awake (!), simply enter the code "1234" and note the complete relief at the silence of the alarm sounders. Also check that the Zone 1 l.e.d. (D20) is on. This indicates the zone that caused the alarm condition was indeed Zone 1.

Pressing the "0" key should clear the "last to alarm" memory l.e.d. (D20 in this instance). Alternatively, if you enter your customer code "1234" again, this will also clear the memory and take you to the Test mode. Pressing the "*" from the Test mode switches the alarm to the Off mode or, if you have pressed the "#" Set key, the alarm switches to the Set mode.

SYSTEM PROGRAMMING

To alter any of the default conditions you must enter the programming mode as follows:

First put the alarm in the Test mode, i.e. from the Off mode enter the Customer Access Code "1234". This takes you to the Test mode, indicated by l.e.d. D14 being turned on. Now enter the engineer's code "54321". Test l.e.d. D14 should start to flash, confirming that the alarm is ready for programming.

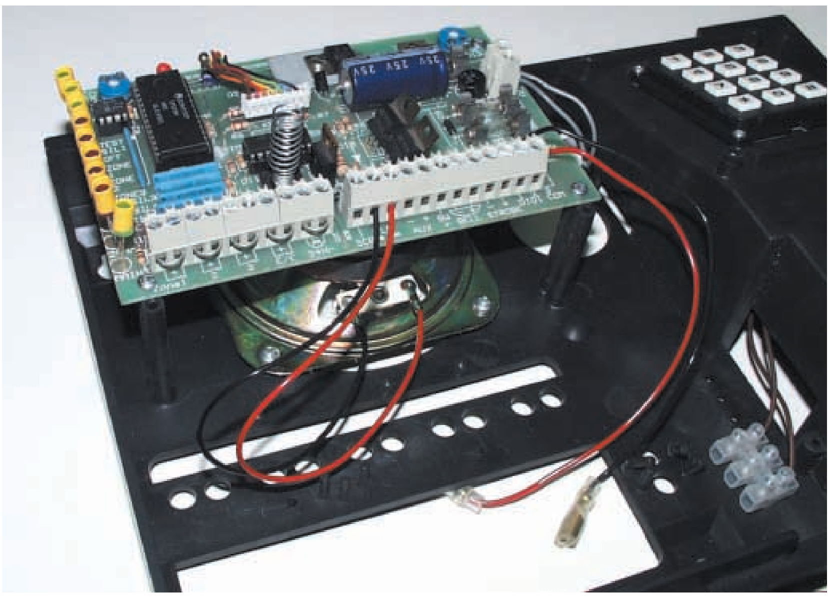
From the Program Menu you can choose which defaults you wish to modify. To change the Customer Access code, first press "4" and note that Zone 4 l.e.d. D17 lights. Next enter your new Customer Access code e.g. "9999". When the fourth digit has been pressed the Zone 4 l.e.d. will extinguish, confirming that the new code has been accepted.

You can now chose another function from the Program Menu and modify it in a similar manner. When you have finished, return to the normal alarm operation by first pressing the "0" and then the "*" keys, this takes you to the Off mode.

Remember the alarm has a non-volatile memory (NVM) and everything you have programmed will be retained by it even in the event of complete power loss.

Should you enter an access or engineer's code and then suffer a bout of amnesia the alarm can be reset back to the default conditions as follows:

1. Remove ALL power from the p.c.b.



2. Hold down the “7” key

3. Restore the power and note a short beep from the speaker confirming that the NVM has now been reset to the original default values.

BELL AND STROBE

From the Program Menu, you can test the bell and strobe outputs. For example, pressing the “6” key causes the Bell output to switch on. Entering “0” switches it off. Pressing “7” causes the Strobe output to switch on, entering “0” switches it off.

This facility is useful when carrying out routine maintenance of the alarm installation, as the output devices can be tested momentarily without having to cause full alarm activation and annoyance to neighbours.

SET

From the Test mode, pressing the Set (“#”) key causes the system to arm and a tone is sounded for 20 seconds (default timing) indicating that Zone 4 is deactivated for this period only. At the end of 20 seconds the tone stops and the alarm is set with Zone 4 now active.

Should you attempt to press the Set key whilst there is a Zone open (Fault), the system will not set but will beep twice and remain in the Test mode until either the fault is removed or the offending zone is omitted.

NIGHT SET

From the Test mode, pressing the “9” key causes the alarm to Set without any Entry/Exit delay on Zone 4. You may use this facility at night when retiring to bed, assuming that only the main Entry/Exit door is wired to Zone 4, causing an immediate alarm if the entry violated.

Note that this facility is deselected every time the alarm is re-armed.

OMIT

To omit any Zone (except 24-hour PA), from the Test mode press the “0” key and note that *all* Zone l.e.d.s turn on. Now press the number of the Zone that you wish to Omit. This causes the associated l.e.d. to extinguish. Then press the “0” key again to return to the Test mode. You can now press the Set key and arm the system without the omitted zone.

OFF

Pressing the Off key in the Test mode causes the alarm to switch off. Pressing the Off key in any other mode has no effect.

SETTING

Before Setting the alarm, ensure all doors and windows fitted with detectors are firmly closed.

On entering the User Access code the alarm will go to the Test mode. If there are any open detectors on the zone loops both an audible and visual indication will warn you to clear the faults.

If you ignore the warnings and attempt to Set the alarm, the speaker will beep twice and the alarm will remain in the Test mode.

Finally, keep an occasional watchful eye on the Power On l.e.d., to prevent power disconnection from running down your batteries.

PROGRAMMING MENU

FUNCTION	*KEY*		*RESPONSE*	*INSTRUCTION*
SET EXIT TIME	1	●○○○	Zone 1 L.E.D. On	Enter Exit time in seconds, eg ‘010’ = 10 seconds All 3 digits must be entered plus leading zeros. Do not enter numbers greater than 255.
SET ENTRY TIME	2	○●○○	Zone 2 L.E.D. On	Enter Exit time in seconds, eg ‘010’ = 10 seconds All 3 digits must be entered plus leading zeros. Do not enter numbers greater than 255
SET AUTO RESET TIME	3	○○●○	Zone 3 L.E.D. On	Enter ‘0’ followed by new time in minutes, e.g. 20 mins = 020. L.E.D. will extinguish indicating the new time has been accepted
SET BELL SHUT OFF TIME	3	○○●○	Zone 3 L.E.D. On	Enter 1 followed by new shut off time e.g. 20 mins = 020. L.E.D. will extinguish indicating the new time has been accepted
SET CUSTOMER ACCESS CODE	4	○○○●	Zone 4 L.E.D. On	Enter new 4 digit code, eg 0000 to 9999. When the 4th digit is entered new code is accepted and the l.e.d. will extinguish
SET ENGINEER CODE	4	○○○●	Zone 4 L.E.D. On	Enter # then 4 digit Engineer’s code. When the 4th digit is entered the new code is accepted and the l.e.d. will extinguish
ENTER UTILITIES MENU	5	●●●●●	Zone 1, 2, 3, 4 & 24hr lights	Turn l.e.d. On or Off by selecting the required function listed below, e.g. l.e.d. Off = function Off
			UTILITIES MENU	
EXIT TONE ON	1	○●●●	Zone 1 L.E.D. Off	Exit tone is now disabled.
ENTRY TONE ON	2	●○●●	Zone 2 L.E.D. Off	Entry tone is now disabled.
TEST TONE ON	3	●●○●	Zone 3 L.E.D. Off	Test tone is now disabled.
NO WALK THROUGH	4	●●●○	Zone 4 L.E.D. Off	Walk through is now selected on Zone 1
NORMAL TIMED ENTRY	5	●●●●●	24hr L.E.D. Lights	Final door cancel now selected

NOTE: When actually entering the Engineer’s code in normal use prefix the 4-digit code with the number 5 before the number, e.g. an Engineer’s code of 2310 entered in the program mode would be used as 52310 in normal use.

INTERFACE

Robert Penfold

GOING ACTIVE WITH VISUAL BASIC 5 CONTROL CREATION EDITION

OVER recent months there has been a substantial amount of correspondence in the readers' letters pages regarding various aspects of programming languages for use with PC-based projects.

It is fair to point out that many of the topics discussed have actually been covered in *Interface* articles over the last few years. Using Visual BASIC and various versions of Delphi have been covered, as has finding QBasic on the Windows CD-ROMs.

A Visual Gem

One gem of information that emerged from the correspondence was that a version of Visual BASIC is available as a free download from the Microsoft web site. This is the address to visit:

http://msdn.microsoft.com/vbasic/downloads/cce/

Here you can download the program itself (just over seven megabytes of it) plus some documentation and examples. As mentioned previously a demonstration version of Visual BASIC 6 is very occasionally to be found on the cover disk of a computer magazine, and that it is also supplied with some books on programming in Visual BASIC.

Unfortunately, this program does not seem to be available from the Microsoft site. The version available from the web address given above is the Visual BASIC 5 Control Creation Edition, and it is primarily intended as a means of producing ActiveX controls. Fortunately, it can also be used for ordinary programs, and the Save function is not disabled.

In common with the demonstration version of Visual BASIC 6, it does not have the ability to compile programs into a standalone program file or a program group. Programs can be run from inside Visual BASIC though, so it is possible to write and use your own programs, or load, modify and run existing Visual BASIC programs. In this respect it is like using GW BASIC or QBasic, neither of which have the ability to compile programs.

Getting Started

The file that is downloaded is an executable program that will install the program in standard Windows fashion. Each time the program is run you are provided with the window depicted in Fig.1, where you select the type of program to be produced. Compared with the "real thing" only a limited choice is available, but the all-important "Standard.EXE" option is present and should be selected. This launches the main program and a screen like the one in Fig.2 should be obtained.

One problem in using any version of Visual BASIC with electronic projects is that it does not have any means of accessing the ports. There are various commercial, shareware, and freeware add-ons available that solve this problem, but if nothing more than QBasic style Inp and Out instructions are needed, **Inpout32** is probably the best solution. This is available as a download from **www.lvr.com**, and this site has a great deal of information about using PC serial and parallel ports.

Several files are produced when the downloaded file is "unzipped". One of these is **inpout32.dll**, and this is the file that adds the Inp and Out commands. It must be placed where it will be accessible to Visual BASIC, and one option is to place it in the \Windows\System folder. It should also work properly if it is placed in the same folder used to store the Visual BASIC programs.

The second file is **inpout32.bas**, and this must be loaded into Visual BASIC in order to make the DLL file operational. In order to do this select the Add File option from the Project menu, and then use the file browser to locate and open **inpout32.bas**. The Inp and Out instructions will then work just like and other Visual BASIC commands.

Reading

Visual BASIC will look rather confusing if you have only used a conventional programming language such as QBasic. The form, which is the window that has the grid of dots, is where you start designing the program.

This represents the window that will open when the program is run. It can be dragged to a smaller or larger size, and this is the size that will be used for the program window. Various components that can be added to the form are provided in the window down the left-hand side of the screen.

Suppose that the program is required to provide a digital readout of values from a port. A component to provide the readout is required, and the obvious candidate is a label component (the one marked with an "A"). To add a label to the form, left-click on the label icon and then drag a rectangle onto the form. This rectangle then becomes the label.

Various parameters for the label will be shown in the Properties window on the right-hand side of the screen. By default the label will be called "Label1", and this will be its caption as well. Initially we require no caption, so the caption is deleted in the Properties window. Values read from the port will be used as the caption.

Virtually all the parameters that appear in the Properties window are variables

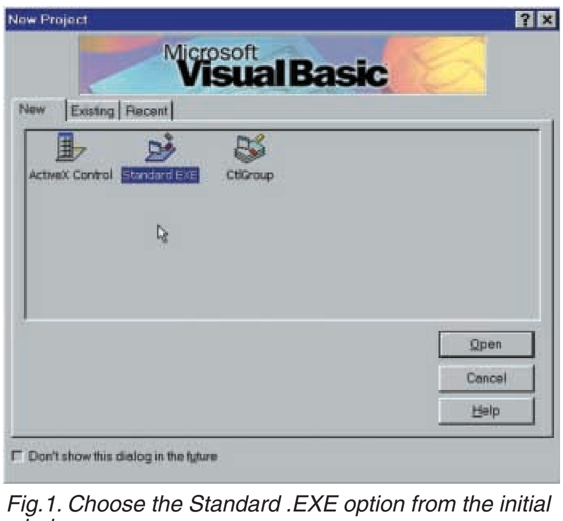


Fig.1. Choose the Standard .EXE option from the initial window.

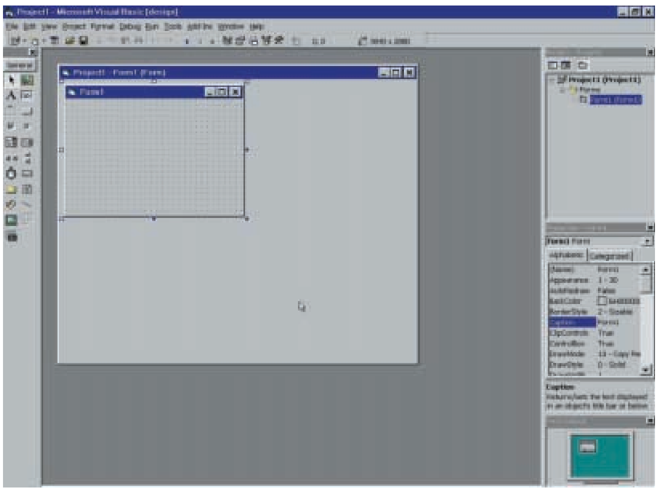


Fig.2. A number of windows are opened when the program is run.

and are easily changed by programs. The variable name is obtained by adding the name of the parameter to the name of the control, with a full stop added between them. In this case the component is "Label1", the parameter is "Caption", and the variable is "Label1.Caption".

The default text size is quite small, so you may like to change the font settings. Left-click on the font entry to produce a button, and then operate the button to bring up a dialogue box. Any font on your PC should then be available in a full range of styles and sizes. For a digital readout a large size (about 36 to 48 points) in a fairly plain font gives good results.

The ForeColor and BackColor settings in the Properties window respectively set the text and background colours for the label. Either make sure that the label is set large enough to take readings, or set the AutoSize option to True so that the label automatically stretches to take the text applied to it.

Eventing

Visual BASIC is event driven, which basically just means that program code will only be run if it is triggered by a suitable event. The timer component is more than a little useful for applications such as reading ports or writing to them at regular intervals.

The timer component is the one that has the stopwatch icon, and it is placed on the form in the same way as a label component. There are a couple of differences though. The size of the rectangle dragged on the form is irrelevant since the timer will always be the same size. Its position on the form is not important because it will not be visible when the program is run.

Also, the timer must be given suitable settings using the Properties window. The interval value determines the time between events generated by the timer, and it is in milliseconds. A value of 200 for example, will give five readings per second. The Enabled setting switches the timer on (True) and off (False), so make sure this is set to True.

All the basic elements of the program are now in place, and it is time to actually add the code that will make it work. In this example the data lines of printer port 2 are read on each occasion the timer generates an event. The program code is therefore applied to the timer.

Double clicking on the timer will bring the Code window to the fore, with the first and last lines of the timer's subroutine already present. The code for the timer is added in the gap between these two lines. This simple, two-line, program is all that is needed:

```
Out &H27A,32

Label1.Caption = Inp(&H278)
```

The first line sets bit 5 of the handshake output port high using an Out instruction. This bit is used as the direction register for the data lines, and writing 1 to it sets the data lines as inputs. Of course, this will only work if the PC has a standard bidirectional printer port.

The second line uses an Inp instruction to read the data lines and it assigns the result to the caption of Label1. The value read from the port is therefore displayed on the label component and it is updated five times per second.

In order to test the program go to the Run menu and select either Start or Start With Full Compile. The second option might give better results with complex programs, but with a simple routine such as this it does not matter which one is used.

The data lines are usually taken high by internal pull-up resistors, giving a returned value of 255 when the program is run. Connecting one or more of the inputs to ground should alter the reading accordingly. Fig.4 shows the program in operation with line D6 grounded.

Output

To try outputting data start with a fresh form and add a label plus two timer components. Set the interval of both timers at 1000 (one second). The Enabled setting of Timer1 should be set at True and that of Timer2 should be set as False. Use these two subroutines for the timers:

```
Private Sub Timer1_Timer()
Out &H27A, 0
Out &H278, 255
Label1.Caption = "High"
Timer2.Enabled = True
Timer1.Enabled = False
End Sub

Private Sub Timer2_Timer()
Out &H278, 0
Label1.Caption = "Low"
Timer1.Enabled = True
Timer2.Enabled = False
End Sub
```

Initially Timer1 is operational and Timer2 is switched off. After a one-second delay the first routine therefore starts running, and it first sets the data lines of printer port 2 as outputs. A second Out instruction then sets all of these lines high, and the caption of Label1 is set to read "High".

Finally, Timer2 is switched on and Timer1 is turned off. After a further one second delay, on this occasion provided by Timer2, the outputs are all set low again and the caption of the label is changed to "Low". Timer1 is then switched on and Timer2 is turned off.

After a one second delay the first routine is performed again, and the whole process repeats itself indefinitely. In the process a 0·5 hertz squarewave signal is generated on all the outputs.

In Conclusion

This simple program demonstrates the point that a timer does not have to run continuously. It can be switched on by a certain event, and having performed its routine after the preset delay it can switch itself off again.

It also shows the versatility provided by having practically every parameter of each component under program control. The Interval settings of the timers for example, could be altered via a scrollbar, or values read from a port.

For those who are used to conventional programming languages it is necessary to adjust to a new approach to programming. The event driven nature of programs means that the programmer is less responsible for program flow, although it is still necessary to take care to ensure that everything happens at the right time and in the right order.

The Control Creation Edition of Visual BASIC 5 provides a "free" way of experimenting with this language, and it is certainly worth downloading if you have not already tried Visual BASIC with PC projects. With the Inp and Out instructions added, Visual BASIC is just about ideal for producing the software for PC add-ons.

The only real drawback of the "free" version is that it does not have the help files or any documentation that can be printed out. However, there is no shortage of information on the Internet.

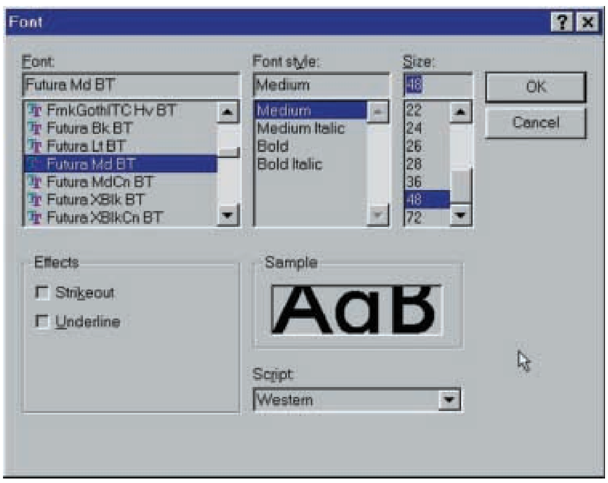


Fig.3. A full range of font and text sizes is available.

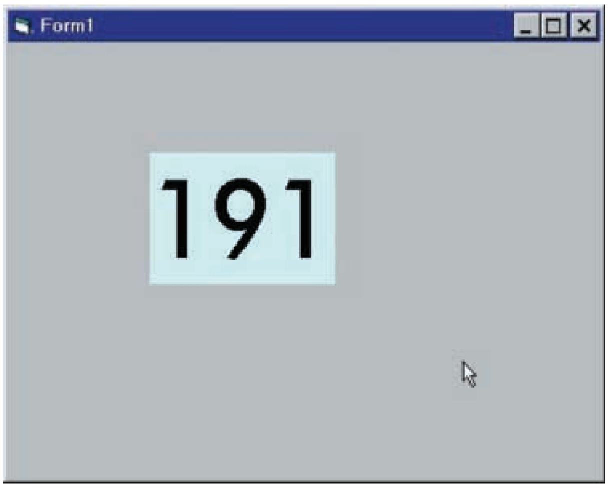


Fig.4. The port reading program in action.

BACK ISSUES

We can supply back issues of *EPE* by post, most issues from the past five years are available. An *EPE* index for the last five years is also available – see order form. Alternatively, indexes are published in the December issue for that year. Where we are unable to provide a back issue a photostat of any *one article* (or *one part* of a series) can be purchased for the same price. Issues from July 2000 onwards are also available to download from **www.epemag.com**.

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AUG '00
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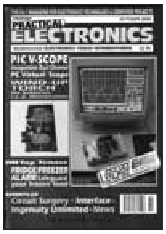
PROJECTS ● PIC-Monitored Dual PSU-Part1 ● Static Field Detector ● Motorists' Buzz-Box ● Twinkling Star ● Christmas Bubble ● Festive Fader ● PICtogram.
FEATURES ● The Schmitt Trigger–Part 2 ● Ingenuity Unlimited ● Interface ● Circuit Surgery ● New Technology Update ● Quasar Kits Review ● Net Work – The Internet ● 2000 Annual Index.

JAN '01
PROJECTS ● Versatile Optical Trigger ● UFO Detector and Event Recorder ● Two-Way Intercom ● PIC-Monitored Dual PSU–Part 2.
FEATURES ● Using PICs and Keypads ● The Schmitt Trigger–Part 3 ● New Technology Update ● Circuit Surgery ● Practically Speaking ● Ingenuity Unlimited ● CIRSIM Shareware Review ● Net Work – The Internet.



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APRIL '01
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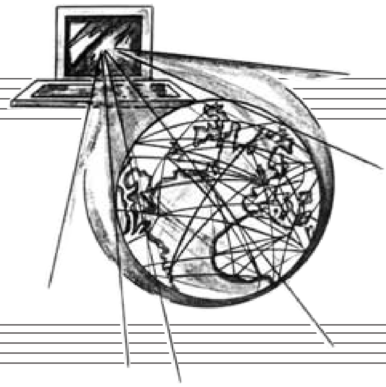
SURFING THE INTERNET

NET WORK



ALAN WINSTANLEY

Get Updated

SAD but true is the fact that software, as sold, can perform somewhat worse than intended, which is why it's often necessary to fetch patches, upgrades and fixes from the Internet: recently the author spent a fun hour or two downloading an 11MB upgrade for JASC *Paint Shop Pro 7* and a similar patch for Adobe *Live Motion*; also the software for the author's Onstream digital tape drive needed upgrading several times before it settled down properly.

If you have any problems running new hardware or software, then the manufacturer's web site should be your first port of call. Before calling them at a premium rate, check the on-line Frequently Asked Questions or search their "Knowledge Base" (often shortened just to "KB"). Keep any downloaded patch on a Zip disk or CD-R in case you need to re-install the software in the future.

In the case of new software, often you will be assigned a password or registration code needed to unlock anything purchased over the Internet. The loss of passwords is a common "gotcha" so keep a secure note of them in case you need to re-install the software at a later date.

Hide and Seek

Some downloads can contain unpleasant surprises, and to avoid viral or Trojan Horse infections you should only download legitimate software from *bona fide* sources. For some users, one of the darker sides of accessing the Internet is the number of hidden files which find their way mysteriously onto your system. *Cookies* are generally harmless text files which some web sites load onto your hard disk: a cookie is how some web sites "recognise" you when you visit next time. It is less clear whether cookie data is traded amongst certain types of web site owner with a view to targeting more customers though.

However, it *is* common practice for online advertisers to collect a certain amount of information about you, such as your domain or IP address, and sometimes a cookie may be essential to allow the correct operation of an E-commerce site anyway. See the Privacy Policy at **www.doubleclick.com** for an explanation of the nature of the data they gather when you visit one of the many web sites containing Doubleclick banner advertising code.

Apart from simple cookies, other forms of unwanted "spyware" can be installed onto your system without you ever realising it. A quick scan of my own system using the free Ad-Aware program from **www.lavasoft.de** revealed several examples of advertising-related files that had been sneaked onto my hard disk.

These included some hidden files related to an installation of a trial version of Cute FTP. Earlier versions of this popular FTP program installed an advertising module in a hidden folder called "Timesink" (see **www.conducent.com**), but this has been abandoned in later releases. Only by reading a licence file installed in the folder, did this become apparent.

For the lowdown on "spyware", one site worth checking is Steve Gibson's **http://grc.com**. Although his Opt-Out program has now expired, the web pages still currently contain interesting information written in his own characteristic style. Meantime, we are told to await a replacement program called *GRC Netfilter*.

Defend yourselves

In the March 2001 issue I recommended BlackICE Defender firewall software (**www.networkice.com**), which alerts you to possible intrusions on your system including attempted port scans or Trojan Horse probes. This excellent software installs easily and generally looks after itself. The online help files are also quite extensive, the main point being that most "intrusions" are harmless so there is no need to complain to the "attacker's" ISP, but when something more serious happens, you will then be able to handle it.

One optional extra I sometimes use is a reporting utility called *ClearICE Report Utility* which unscrambles the BlackICE log file to generate a report of attacks. It can be mailed to the hacker's ISP if desired, but the use of these reports is becoming almost as controversial as the "attacks" themselves. In fact, in March this year a spat broke out between Steve Gibson (see above) and Ben Brady, supplier of the ClearICE Report Utility used with my BlackICE Defender firewall.

The problem is this: BlackICE Defender does a very good job of monitoring "attacks" as it calls them, and it grades them according to severity. Brady's third-party bolt-on Report utility does a good job of gathering the data together from the log file and, if desired, wrapping it all up into an E-mail which the user can send to the hacker's ISP if he feels the need. That's what it was designed for.

This needs to be used with some common sense, and both the BlackICE and Brady web pages give plenty of advice to help interpret BlackICE results and prevent over-zealous use of the reporting feature: too much crying wolf will reduce the effectiveness of the reporting system, because ISPs will just ignore it.

False Alarms

Soon Gibson's own ISP (Verio Inc.) started to receive these very same reports. Apparently the root cause was Gibson's own Shields Up firewall testing service; some BlackICE users tried Shields Up but were interpreting the consequent BlackICE alarm signals as "attacks", and using the ClearICE utility they were generating what Gibson calls "specious intrusion reports" which were E-mailed by the truckload to his ISP.

He also takes exception to the use of the terms "Victim IP" and "Intruder IP" used in the ClearICE report, implying that this "inflammatory" language is likely to frighten its users into sending off that E-mail at the earliest opportunity anyway.

However, it is not surprising that these worrisome "victim" and "Intruder" terms are used, as they appear to originate within BlackICE Defender's comma-separated log files (just open a log in Excel to see). ClearICE is an irresponsible piece of software, Gibson repeats, and it is "socially irresponsible" for any such software not to take responsibility for the veracity of the reports it helps to generate, he adds.

It seems to me that the Gibson v. Brady dispute is a storm in a teacup. Anyone who knows the Gibson web site **grc.com** will recognise the excitable and frequently importunate style, and in the past GRC has offered several valuable utilities (including Trouble in Paradise – TIP – a freeware Zip disk analyser) which have won him many grateful admirers. This time though, over ClearICE Report, he seems to have blown a fuse.

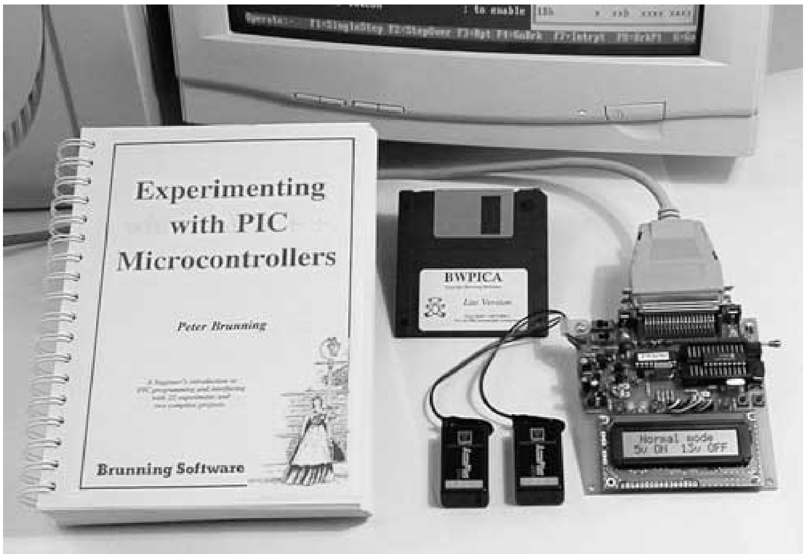
In my own view, any reporting utility whose job it is to merely unscramble a comma-separated value log file into a human-readable format, to help you paste it into an E-mail, is simply doing what it says on the wrapper. Where does the problem lie? Is it with the reporting system for churning out the data, or is it the worried end user for pushing the "Complain to ISP" button prematurely? Gibson lays the blame with ClearICE Report, but in my view the problem is with the latter for failing to interpret the data sensibly.

An alternative (freeware) log file analyser worth looking into is the BlackICE Attack List Viewer from **http://philholder.co.uk**. Not surprisingly, it too states "Victim" and "Intruder" details. The entire story is unfolding and is online at **http://grc.com/su/benbrady.htm** and the relevant newsgroup is **comp.security.firewalls**.

More advanced log reporting/interpretation software is soon to be released which will hopefully analyse BlackICE logs more realistically, which is worth looking out for.

You can E-mail me at **alan@epemag.co.uk**.

Learn The Easy Way!



Experimenting with PIC Microcontrollers

This third release in our *"Experimenting with....."* series concentrates on the PIC16F84 and PIC16C711 microcontrollers, and consists of the book, a programmer/experimental module, and an integrated suite of programmes to run on a PC.

The book with its abundance of flow diagrams and circuit diagrams is the heart of the system, and the software is the brains. A text editor with word processing power is the key stone supporting the assembler, disassembler, simulator, and programming software. The author begins with a detailed explanation of why PICs are the ideal place to start learning about microcontrollers, and why he has selected the PIC16F84 and PIC16C711. Then after a brief examination of the PICs memory structure and instruction set we begin the first experiment. In the space of 24 experiments, two projects and 56 exercises the system works through from absolute beginner to experienced engineer level. The importance of the information being in a real book cannot be over emphasised. The book lies open on the desk while we use the computer to work through the experiments.

The Basic System

We start with the simplest possible experiment and as we type in the text the assembler works in the background testing each line so that errors are immediately highlighted. If the line can be assembled correctly the equivalent PIC code is displayed at the top right of the screen. When the typing is done, without leaving the programme, we assemble the whole text into PIC code and use the simulator to single step the programme. Watching the data in the registers change and seeing this in decimal, binary and hexadecimal numbers at the same time solves the problems at a stroke. We see it happen and understand what we have done, and when our programmes use the alphanumeric liquid crystal display the simulator shows what will be displayed. If it works correctly we plug the programmer module onto the end of our printer lead, write the code into the test PIC and run the programme in the real world. All operations work directly from the assembler text in the editor and the experiments require no soldering.

The Experiments

The 24 experiments assume no prior programming or electronic experience. These are all performed using the programmer/experimental module which is already wired with LEDs, push buttons, and an alphanumeric liquid crystal display. When we have completed the first four simple experiments and gained some practical experience we go right back to the beginning and study PIC programming techniques. Then we examine the built in timer, write simple text to the display, multiplex writing text and running an LED sequence at the same time, create a real time clock, a period timer, and experiment with beeps and music, including a rendition of Beethoven's *Für Elise*. Each of the experimental chapters ends with a sequence of exercises which are designed to ensure that the main points covered have been properly absorbed.

First Project

In the first project we start by considering how a digital device can be used to create a sinewave. Then we put the ideas into practice by building our own digital to analogue converter and driving this with data derived from a table of sinewave values stored in the PICs memory. The final sinewave generator covers 0.2Hz to 20kHz in five ranges, and has an adjustable output level which is precisely maintained over the entire range of frequencies.

Second Project

For the second project we need the use of an analogue to digital converter so we swap over to using the PIC16C711. Strictly we use a PIC which can only be programmed once but by carefully organising our experiments we are able to reprogramme the PIC several times with modified code. We begin with a simple programme to measure DC voltages. Then we expand this to measure DC current and DC voltage, and calculate the power of the circuit from these measurements.

Measuring AC power is much more involved so all the implications are considered before we begin the real work. It is decided to feed the analogue to digital converter with the raw AC waveform so that the software has the possibility of being upgraded to include consideration of the phase angle between the voltage and the current. We then update the software to perform simple AC power measurement assuming that the current and voltage are in phase.

The Programmer

The programmer module itself is a fine example of what can be achieved with PIC microcontrollers. It uses it own PIC to control the timing and voltages required to programme the test PIC. The programming is performed and verified at normal 5 volts, then verified again with ±10% volts applied to ensure that the device is programmed with a good margin and not poised on the edge of failure. The system is optimised for the PIC16F84 and PIC16C711 and will programme similar PICs (83, 710, 71, 620, 621 etc).

The module is supplied with a test PIC fitted, and requires two PP3 batteries which are not supplied.

Hardware required

You will need a PC computer (386 or better) to run the software and a standard parallel port printer lead to connect the programmer. It is not necessary to open up your PC.

Ordering Information

Book Exp with PIC Micros. . £23.99
Programmer with software. . £62.51

Telephone with Visa, Mastercard or Switch, or send cheque/PO for immediate despatch. All prices include VAT if applicable. Postage must be added to all orders. UK postage £2.50 per book, £1.00 per module, maximum £7.50. Europe postage £3.50 per book, £1.50 per module. Rest of world £6.50 per book, £2.50 per module.

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Experimenting with PC Computers with its kit is the easiest way ever to learn PC assembly language programming. *Experimenting with C & C++ Programmes* uses a similar approach to teach C programming for the PC. *Experimenting with the PIC16F877* when used with our universal mid range PIC programmer is the ideal way to continue learning about PICs. Ask for information sheets or see last month's advert.

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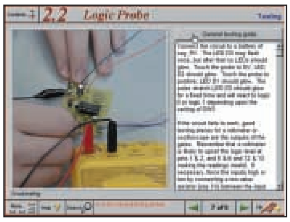
ELECTRONICS PROJECTS



Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture**, **circuit simulation** and **p.c.b. design** software is included.
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

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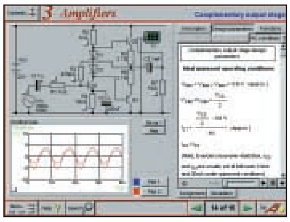
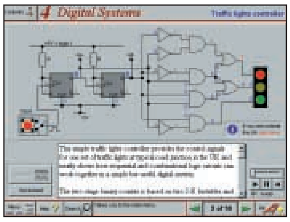


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

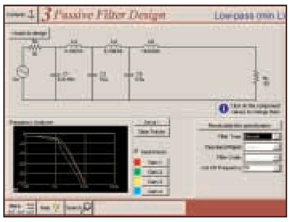
DIGITAL ELECTRONICS



Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units.

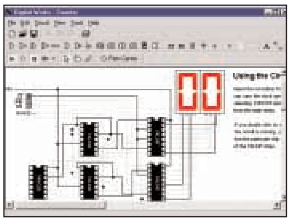
FILTERS



Filter synthesis

Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

DIGITAL WORKS 3.0



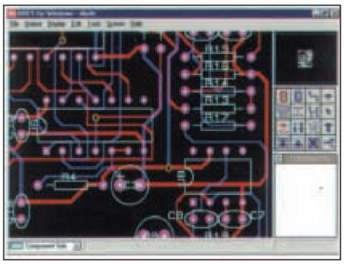
Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability.

- Software for simulating digital logic circuits
- Create your own macros – highly scalable
- Create your own circuits, components, and i.c.s
- Easy-to-use digital interface
- Animation brings circuits to life
- Vast library of logic macros and 74 series i.c.s with data sheets
- Powerful tool for designing and learning

ELECTRONICS CAD PACK

NEW



PCB Layout

Electronics CADPACK allows users to design complex circuit schematics, to view circuit animations using a unique SPICE-based simulation tool, and to design printed circuit boards. CADPACK is made up of three separate software modules: **ISIS Lite** which provides full schematic drawing features including full control of drawing appearance, automatic wire routing, and over 6,000 parts. **PROSPICE Lite** (integrated into ISIS Lite) which uses unique animation to show the operation of any circuit with mouse-operated switches, pots. etc. The animation is compiled using a full mixed mode SPICE simulator. **ARES Lite** PCB layout software allows professional quality PCBs to be designed and includes advanced features such as 16-layer boards, SMT components, and even a **fully functional autorouter**.

"C" FOR PICMICRO MICROCONTROLLERS

NEW

C for PICmicro Microcontrollers is designed for students and professionals who need to learn how to use C to program embedded microcontrollers. This product contains a complete course in C that makes use of a virtual C PICmicro which allows students to see code execution step-by-step. Tutorials, exercises and practical projects are included to allow students to test their C programming capabilities. Also includes a complete Integrated Development Environment, a full C compiler, Arizona Microchip's MPLAB assembler, and software that will program a PIC16F84 via the parallel printer port on your PC. (Can be used with the *PICtutor* hardware – see opposite.)
Although the course focuses on the use of the PICmicro series of microcontrollers, this product will provide a relevant background in C programming for any microcontroller.

PRICES

Prices for each of the CD-ROMs above are:

Hobbyist/Student ....£45 inc VAT
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Institutional 10 user (Network Licence)..........£199 *plus* VAT

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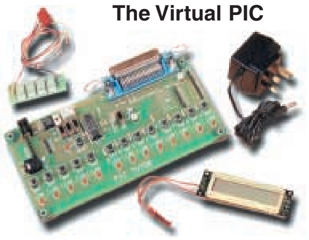
Interested in programming PIC microcontrollers? Learn with ***PICtutor*** *by John Becker*

The Virtual PIC



Deluxe PICtutor Hardware

This highly acclaimed CD-ROM, together with the PICtutor experimental and development board, will teach you how to use PIC microcontrollers with special emphasis on the PIC16x84 devices. The board will also act as a development test bed and programmer for future projects as your programming skills develop. This interactive presentation uses the specially developed **Virtual PIC Simulator** to show exactly what is happening as you run, or step through, a program. In this way the CD provides the easiest and best ever introduction to the subject.
Nearly 40 Tutorials cover virtually every aspect of PIC programming in an easy to follow logical sequence.

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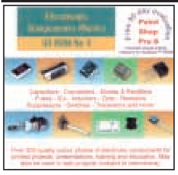

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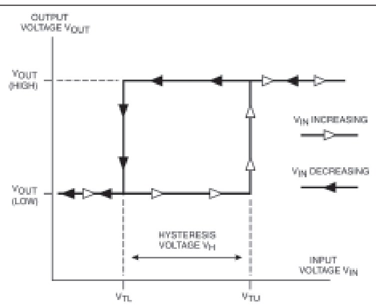

ANTHONY H. SMITH

Part 7

In this short series, we have investigated the Schmitt trigger's operation, explored the various ways of implementing its special characteristics and also looked at how we can use it to create oscillators and pulse width modulators.

Hysteresis in Specialised Devices

THROUGHOUT this series, we've seen how Schmitt triggers can be formed by introducing hysteresis into a switching circuit. For example, positive feedback around an op.amp can transform a simple voltage comparator into a Schmitt trigger. In parts Five and Six, we looked at "digital" Schmitt triggers – logic devices with intrinsic hysteresis in the form of pre-defined threshold levels.

However, there are many other devices on the market in which hysteresis is an in-built feature. In this, the last part of the series, we'll examine some of these "specialised" devices, and we'll see how their inherent hysteresis can be used to good effect in a range of simple circuits.

TACHOMETERS AND OPTOCOUPLERS

The popular LM2907/LM2917 frequency-to-voltage converters use a charge-pump technique to convert frequency to voltage, and the differential inputs typically provide 30mV of hysteresis to minimise the effects of noise. This is particularly useful in *tachometer* circuits, such as those using magnetic variable reluctance sensors; without hysteresis, the presence of noise and interference could produce gross errors in the output voltage.

Many optoelectronic devices also feature in-built hysteresis; two *optocoupler* examples are shown in Fig.7.1. The Hewlett-Packard HCPL-3700 shown in Fig.7.1a is an AC/DC to Logic Interface Optocoupler, which allows either a.c. or d.c. voltages or currents to be converted to an isolated logic level output. The hysteresis block controlling the l.e.d. provides typically 1·2V or 1·2mA of hysteresis at the inputs, depending on whether voltage or current excitation is used. The hysteresis provides essential noise-rejection, allowing the optocoupler to convert noisy signals (such as those found in industrial environments) into a "clean" logic level change.

Another HP optocoupler, the Dual Logic Gate HCPL-2231, is shown in Fig.7.1b. Like the HCPL-3700, this optocoupler is also intended for converting noisy input signals into clean logic levels, but makes use of hysteresis in the Schmitt trigger output stages to provide noise rejection. This corresponds to current thresholds at the l.e.d. inputs.

Typically, an l.e.d. current of 800µA will force the output high; the output will remain high until the input current has been reduced to around 750µA, at which point it goes low again, corresponding to around 50µA of hysteresis. With an appropriate choice of current limiting resistor at the l.e.d. input, the 750µA and 800µA current thresholds can be translated into suitable input voltage thresholds.

LIGHT COMMUNICATIONS

Hysteresis is found not just in optocouplers, but also in light detectors. Devices like the Infineon SFH5840 and the Honeywell SD5620 are "opto-Schmitt" detectors, in which a photodiode, amplifier, voltage regulator, Schmitt trigger and output stage are integrated onto the same chip, and mounted in a three-lead TO-18 or TO-46 "windowed" metal can package. By providing as much as 40 per cent hysteresis, these devices allow light sensing in noisy environments, without the need for external Schmitt trigger signal conditioning.

Try listening to someone in a noisy room and you'll soon discover how difficult it can be to "filter out" the unwanted chatter and concentrate on what's being said. Electronic communication systems are no different: without suitable means of rejecting the noise and interference, the signal will be polluted and corrupted.

Again, hysteresis is often an essential means of minimising or eliminating the noise present on data communication lines. Communication techniques like those used in the RS-232-C and RS-485 standards can suffer noise in the form of crosstalk and electromagnetic interference; consequently, special receiver devices like the venerable MAX232 and SN75176 were developed to minimise these problems using hysteresis.

The MAX232 is a Dual RS-232 Transmitter/Receiver having typically 500mV hysteresis at the receiver input terminals, whereas the SN75176 Bus Transceiver is intended for *differential* applications and features only 50mV receiver hysteresis but with a sensitivity of just ±200mV.

COMPARATORS

When looking at comparator applications in Part Two of this series, we saw how a small amount of hysteresis, usually just a few millivolts, can be sufficient to prevent the "chatter" caused by slowly changing signals. Since hysteresis is so powerful in eliminating chatter and other noise problems, several manufacturers now

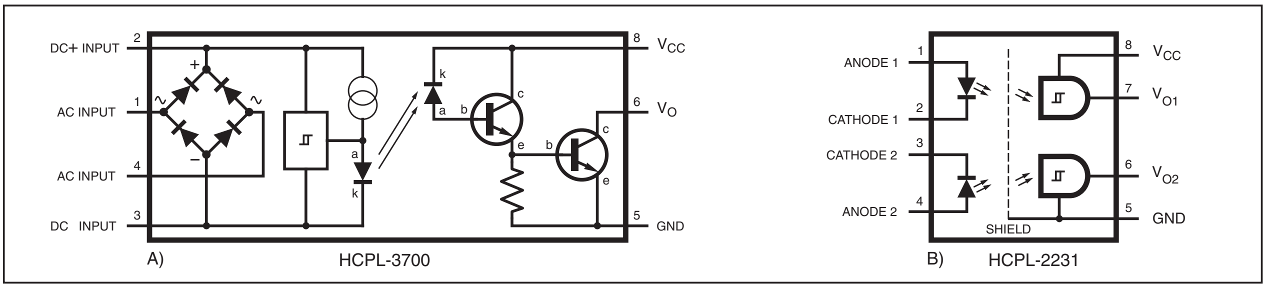

Fig.7.1. Hewlett-Packard optocouplers with hysteresis.

provide comparators with fixed, in-built hysteresis: a small selection of these devices is given in Table 7.1.

As well as having comparators, some of the devices offer flexibility by adding extra functions. The LTC1541, for example, features a comparator with 3mV in-built hysteresis, an op.amp, and a 1·20V voltage reference. The MAX951 provides the same functions in a pin-compatible package.

As with most "standard" comparators, there is a direct relationship between speed and power consumption. The LT1720, for instance, has very fast response (the typical propagation delay is just 4·5ns), but devours as much as 7mA supply current for each comparator. The MAX917, on the other hand, consumes a miserly 1·3µA but, with a typical propagation delay of 100µs, is around 22 thousand times slower!

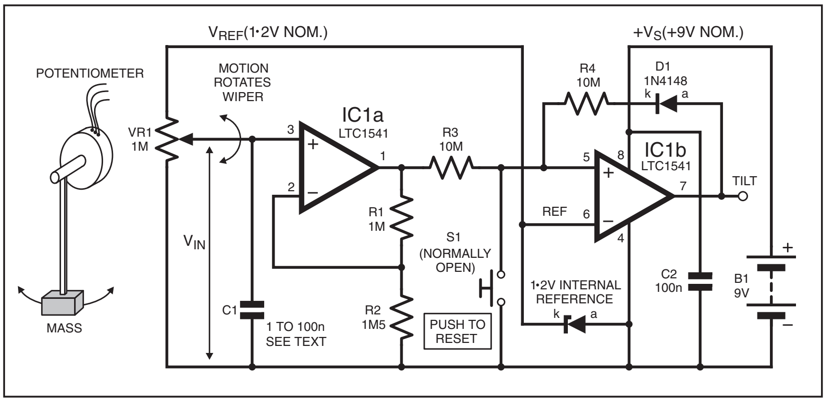

Fig.7.2. Circuit diagram for a Micropower Tilt Sensor.

Unfortunately, there isn't space to provide pin connection diagrams for each of the devices mentioned in this article; however, full details can be found in manufacturers' data books or at their web sites.

TILT!

Despite their lack of speed, the micropower devices can be especially useful in battery-powered applications, particularly where the additional functions (op.amp, reference) are required. An example of this is shown in the circuit diagram of Fig.7.2, where a Micropower Tilt Sensor is formed using just a potentiometer, an LTC1541 comparator, and a handful of other parts.

A pendulum with a small mass is attached to the shaft of single-turn potentiometer VR1 as shown. The potentiometer (pot.) is oriented so that the wiper (moving contact) is at mid-rotation in the rest position, such that the wiper voltage, V_{IN} , at the op.amp input is roughly half the reference voltage, i.e., $V_{IN} = V_{REF}/2 = 1{\cdot}2V/2 = 0{\cdot}6V$.

Op.amp IC1a and resistors R1 and R2 form a non-inverting amplifier having a gain of (1 + R1/R2) = (1 + 1/1·5) = 1·67. Consequently, in the rest state, the voltage at the amplifier output is: $V_{IN} \times 1{\cdot}67 = 0{\cdot}6 \times 1{\cdot}67 = 1{\cdot}00V$. This voltage is fed, via resistor R3, to the non-inverting (+) input of the comparator, IC1b. Since this voltage is less than V_{REF} (the voltage tied internally to the comparator's inverting input), the comparator output is low: this is the normal, rest condition. Under these conditions, diode D1 is reverse biased and has no effect on the comparator.

If the fixture is now tilted such that the pendulum swings, the voltage at VR1 wiper will "oscillate" about the quiescent value (0·6V): if the angle of tilt is sufficient to take the wiper voltage momentarily above 0·72V, the amplifier output will exceed 1·20V and the comparator output will go high. The comparator's internal 3mV hysteresis ensures that the output changes cleanly from low to high level, and provides some immunity to small-amplitude noise at the non-inverting input.

LATCHING INDICATION

Diode D1 now becomes forward biased, such that the comparator's non-inverting input voltage is pulled to a level greater than 1·20V via the R3/R4 potential divider, and *remains* greater than 1·20V even when the wiper returns to its rest position. The circuit is now "latched", with the high level at the comparator output (pin 7) indicating that a "tilt" has occurred. The circuit can be reset (IC1b output low) by pressing the normally-open pushswitch S1.

The circuit's sensitivity can be maximised by increasing the amplifier's gain, but a practical limit is around 1·9. Sensitivity can also be increased by lengthening the pendulum and/or by increasing the attached mass. These measures may also be needed if the pot. is fairly "stiff'.

Capacitor C1 is not essential, but can be helpful in removing any electrical noise or pick-up at VR1's wiper. C1 can also act as an "acceleration filter" by lowering the circuit's sensitivity to short-duration, transient motion of the pendulum. The value of capacitor C1 will depend on the application: values in the region 1nF to 100nF may be suitable.

Large resistance values are used throughout the circuit diagram of Fig.7.2 to keep current levels very low. Most parts of the circuit, particularly pin 5 of IC1b, are sensitive to noise, especially mains pick-up, so the layout should be neat and compact with no trailing wires other than the connections to potentiometer VR1.

Table 7.1: Comparators with Fixed Internal Hysteresis

Manufacturer	*Part Number*	*Description*	*Typical Hysteresis Voltage, V_H (mV)*	*Internal Voltage Reference (V)*	*Typical Propagation Delay, t_p*	*Max. Quiescent Supply Current per Comparator*	*Comments*
Linear Technology	LT1720/ LT1721	Dual/quad comparators	3·5	none	4·5ns	7mA	Very fast. Single supply operation (2·7V – 6V)
Linear Technoloogy	LTC1541/ LTC1542	Micropower op.amp, comparator and reference	3·0	1·20 (LTC1541 only)	20µs	7·5µA (total)	Very low power. Single or dual supply operation (±6·3V max)
Maxim	MAX907/ MAX908/ MAX909	Single/dual/quad comparators	4·0	none	40ns	1mA	Fast. Low power. Single supply MAX909 has differential outputs and latch facility
Maxim	MAX917- MAX920	Nanopower comparator with reference	4·0	1·245 (MAX917/ MAX918 only)	100µs	1·3µA	Very low power. Single supply operation down to 1·8V. SOT23-5 package
Maxim	MAX941/ MAX942/ MAX944	Single/dual/quad comparators	2·0	none	80ns	700µA	Fast. Low power. Single supply. MAX941 has latch and shutdown facility
Maxim	MAX951- MAX954	Micropower op.amp, comparator and reference	4·0	1·20 (MAX951/ MAX952 only)	4µs	10µA (total)	Very low power. Single supply operation (2·8V – 7V)
Micrel	MIC834	Micropower comparator and reference	23	1·24	12µs	3µA	Very low power. Single supply operation (1·5V – 5·5V) SOT23-5 package·

Notes: Values are quoted for ambient temperature = 25°C.
LTC1541 pinout same as MAX951/MAX952; LTC1542 pinout same as MAX953/MAX954.

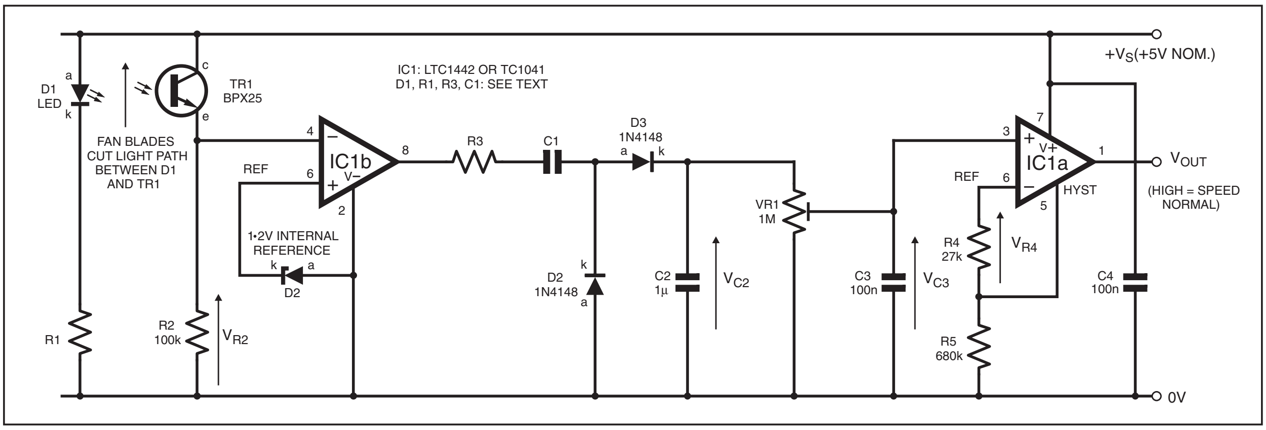

Fig.3. Circuit diagram for a dual comparator Fan Speed Monitor. The l.e.d. D1 should be a low-current high brightness type.

LONG SERVICE

Tests on a prototype set-up revealed that rotating the pot. about 30 degrees was sufficient to take V_{IN} above 0·72V and latch the comparator. With the supply voltage set to 9V, the total current taken by the circuit was just 3·8µA in the reset state, rising to 10µA in the latched state.

The low current drain and the fact that the circuit will operate down to about 3V means that it is ideally suited to battery operation. Theoretically, the circuit will continue to operate in the latched state for over five years when powered by a PP3 9V battery!

Apart from the obvious security applications (you could use the circuit to determine if someone has been moving or tampering with your belongings), it can also be used in commercial applications to detect whether a shipping container has been subjected to excessive tipping or vibration.

ADJUSTABLE HYSTERESIS

The fixed-hysteresis comparators of Table 7.1 make it easy to get the benefits of hysteresis without the need to use feedback components. However, there are many applications which require more than a few millivolts of hysteresis. Although it is possible to increase the hysteresis of the Table 7.1 comparators using conventional means (i.e., by applying suitable feedback to the non-inverting input), there is a range of alternative devices which feature *adjustable* hysteresis.

Table 7.2 lists some of the more common comparators whose hysteresis levels can be adjusted by means of an external control voltage. Also, all of the devices listed provide an on-chip voltage reference.

The hysteresis of all the devices listed may be varied by adjusting the voltage between the voltage reference pin (usually denoted REF) and the hysteresis pin (usually labeled HYS or HYST). To see how these devices can be used, we'll now look at some simple applications.

FAN SPEED MONITOR

A circuit diagram for monitoring the speed of a cooling fan is shown in Fig.7.3. The fan's blades are situated to cut the path of light between the light emitting diode, D1, and the phototransistor detector, TR1. As the fan rotates, the blades "chop" the light beam, resulting in a series of pulses at the emitter (e) of TR1. These pulses are "squared up" by IC1a, one half of a dual comparator package such as the LTC1442 or TC1041.

When lightly loaded, the output of the LTC1442 or TC1041 comparators swings rail-to-rail. Therefore, the output of IC1a consists of a series of sharp pulses, whose amplitude equals $+V_S$. The frequency of these pulses is given by:

$$\text{Frequency, } f = \frac{N \times S}{60} \text{ (Hz)}$$

where *N* is the number of blades on the fan, and *S* is the fan's speed in revolutions per minute (r.p.m.).

The pulses are fed to a *charge pump* comprising components R3, C1, C2, D2 and D3. A thorough analysis of the charge pump is beyond the scope of this article, but in simple terms, each pulse delivers a packet of charge into integrating capacitor C2. The amount of charge depends on C1, R3 and on the amplitude of the pulses. The voltage on C2, denoted V_{C2}, is proportional to the frequency of the pulses: if the fan speed falls, so, too, does the pulse frequency and hence V_{C2}.

Trimmer preset VR1 is used to adjust the voltage V_{C3} appearing across decoupling capacitor C3, which forms the input to the second comparator, IC1b. Note that both comparators have the *internal* reference voltage, V_{REF} (available at the REF terminal, pin 6) internally connected to one of their inputs. Therefore, provided the fan speed is high enough to make V_{C3} *greater* than V_{REF}, the output of

Table 7.2: Comparators with Adjustable Hysteresis

Manufacturer	*Part Number*	*Description*	*Hysteresis Voltage Range, V_H*	*Internal Voltage Reference (V)*	*Typical Propagation Delay, t_p*	*Max. Quiescent Supply Current*	*Comments*
Linear Technolgy	LTC1440/ LTC1442	Micropower single/dual comparators with reference	0 – 100mV	1·182	8µs	3·7µA (LTC1440) 5·7µA (LTC1442)	Very low power. Single supply operation (2V – 11V)
Linear Technology	LTC1444/ LTC1445	Micropower comparators with reference	0 – 100mV	1·221	4µs	8·5µA	Very low power. Single supply operation (2V – 11V)
Linear Technology	LTC1540	Nanopower comparator with reference	0 – 100mV	1·182	50µs	0·68µA	Fairly slow, but extremely low power Single supply operation (2V – 11V)
Linear Technology	LTC1842/ LTC1843	Micropower dual comparators with reference	0 – 100mV	1·182	4µs	5·7µA	Very low power. Single supply operation (2V – 11V)
Maxim	MAX921/ MAX923	Micropower single/dual comparators with reference	0 – 100mV	1·182	4µs	3·2µA (MAX921) 4·5µA (MAX923)	Very low power. Single supply operation (2·5V – 11V)
Maxim	MAX965/ MAX967/ MAX969	Micropower single/dual/quad comparators with reference	0 – 100mV	1·235	10µs	12µA (MAX965) 16µA (MAX967) 22µA (MAX969)	Low power. Single or dual supply operation
Telcom	TC1031/ TC1041	Micropower single/dual comparator with reference	0 – 160mV	1·200	4µs	10µA (TC1031) 16µA (TC1041)	Low power. Low voltage, single supply operation (1·8V – 5·5V)·

Notes: Values are quoted for ambient temperature = 25°C·
LTC1440 has pinout same as MAX921; LTC1442 has pinout same as MAX923; TC1041 is similar to LTC1442.

comparator IC1b will be high. However, if the speed falls below the normal level, V_{C3} will fall below V_{REF}, and the comparator output will go low, indicating a problem with the fan.

HIGH BRIGHTNESS

The circuit diagram of Fig.7.3 was tested using an HLMP-D155 l.e.d. for D1, although any other l.e.d. which provides high brightness at moderate current levels would suffice. The phototransistor, TR1, was located about 20mm from D1, and was positioned directly opposite the l.e.d. where the light intensity is greatest.

Resistor R1 sets the l.e.d.'s brightness, and should be selected to generate sufficient photo-current in TR1 to develop at least 2V across resistor R2. A value of 330 ohms for R1 (equivalent to an l.e.d. current of approximately 10mA) was found to generate 4·8V across R2 with the circuit in a dimly lit room.

Capacitor C1 and resistor R3 should be selected such that their time constant (C1 × R3) is less than $1/f_{MAX}$, where f_{MAX} is the maximum frequency of the pulses at IC1b's output. For fans running up to 6,000 r.p.m. with around ten blades, it was found that values of 10nF to 100nF for C1 and 10kΩ (kilohms) for R3 should be suitable.

With a small fan having ten blades operating at 5V positioned between l.e.d. D1 and phototransistor TR1, the pulse frequency was found to be 572Hz (equivalent to 3,432 r.p.m.), and V_{C2} was measured as 2·47V. Under these "normal" conditions, preset VR1 was adjusted until the output of IC1b just went high.

The fan's speed was then reduced by lowering its operating voltage. IC1b's output was found to go low when the pulse frequency had fallen to 507Hz (equivalent to 3,042 r.p.m.), a reduction in speed of 11 per cent.

DOUBLE HYSTERESIS

Hysteresis is used twice in this circuit. It helps to minimise the effects of noise and jitter at the input to IC1b, and is essential at IC1a to eliminate the effects of "ripple" voltage on capacitor C2 (typically around 20mV) which would otherwise cause the output to oscillate around the threshold.

For devices like the LTC1442 and TC1041, the hysteresis voltage, V_{HYS}, is roughly double the voltage appearing between the REF and HYST pins. A suitable voltage is easily established using the R4/R5 resistor potential divider, such that $V_{HYS} = 2 \times V_{R4}$, where V_{R4} is the voltage dropped across R4.

The actual value of V_{R4} depends on the reference voltage, V_{REF}, which is nominally 1·182V for the LTC1442, and 1·20V for the TC1041. With a value of 27kΩ for R4 and 680kΩ for R5, V_{R4} will be 45mV for the LTC1442, and 45·8mV for the TC1041, such that V_{HYS} will be roughly 90mV for each device.

Note that V_{R4} is limited to 50mV max. for the LTC1442, and 80mV max. for the TC1041. Also, remember that the value of V_{HYS} set by resistors R4 and R5 applies to *both* comparators.

THE HEAT IS ON . . .

The circuit diagram of Fig.7.3 is basically a *tachometer* which converts the speed-proportional frequency into a corresponding voltage, and could be adapted to monitor the speed of other rotating devices.

Monitoring the speed of a cooling fan is just one way of ensuring that the temperature of the object being cooled is not getting too high. Another method, shown in Fig.7.4, is to monitor the object's temperature directly.

In this circuit, the LM50B temperature sensor (IC1) is mounted directly on, or near to, the object being monitored (a computer's microprocessor, for example). The LM50B generates a temperature-proportional output voltage, V_O, having a nominal tempco (temperature coefficient) of +10mV/ºC. A portion of V_O is selected by trimmer pot. VR1 and fed to comparator IC2, which compares it to the internal reference voltage available at pin 6.

Values for resistors R1, R2 and preset VR1 are selected depending on the required temperature threshold. To understand how the circuit works, assume that we require the comparator to trip when the temperature exceeds +85ºC.

TEMPERATURE COEFFICIENT

The LM50B has a nominal output voltage, V_O, of +500mV at 0ºC. To determine the voltage at +85ºC, we multiply the temperature rise (85°C) by the nominal tempco (+10mV/ºC) and add this to the 0ºC value. Therefore, V_O at +85ºC = (85°C × 10mV/ºC) +500mV = 1·35V.

With values of 27kΩ for R1, 20kΩ for VR1 and 240kΩ for R2 (see Fig.7.4), the voltage at VR1's wiper will range from 1·129V to 1·223V when V_O = 1·35V. Therefore, preset VR1 can be adjusted to make the comparator's inverting input voltage just greater than 1·182V (the nominal voltage at IC2's non-inverting input (pin 3)) such that the comparator's output, V_{OUT}, goes low when the temperature exceeds +85ºC.

Preset potentiometer VR1 provides for fine adjustment of the trip point, and is necessary to counter the effects of tolerances in the sensor's output voltage and tempco, tolerances in resistors R1, R2 and VR1 itself, and tolerances in IC2's reference voltage together with offset voltages at the comparator's inputs.

THERMAL HYSTERESIS

Like the LTC1442 and TC1041 described earlier, the MAX921's hysteresis voltage, V_{HYS}, is roughly twice the voltage appearing between its REF and HYST pins. Although hysteresis can help to minimise the effects of noise in the circuit, its primary function is to provide "thermal" hysteresis which prevents the comparator oscillating around the trip point when the temperature hovers very close to +85ºC.

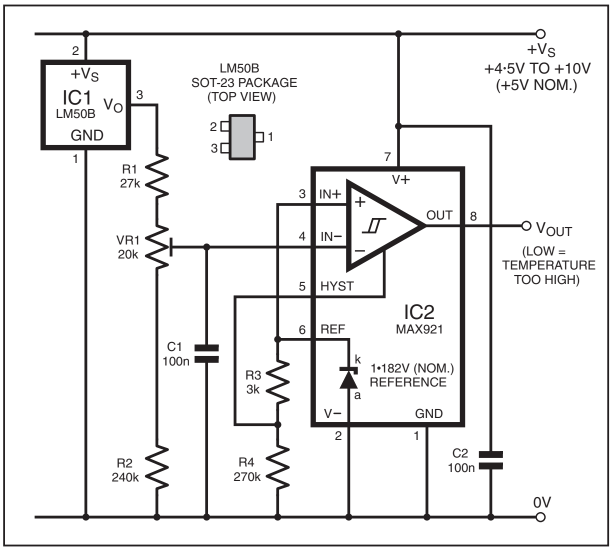

Fig.7.4. Circuit diagram for a Low-Power Temperature Monitor using the LM50B temperature sensor.

The MAX921's REF pin can only source around 15µA, so large resistance values must be used for R3 and R4. (Also, the REF pin must not be decoupled by a capacitor). With the values shown in Fig.7.4 of 3kΩ for R3 and 270kΩ for R4, the voltage between the REF and HYST terminals is nominally 13mV, such that V_{HYS} = 26mV. Taking into account the attenuation introduced by the R1-VR1-R2 divider network, 26mV is roughly equivalent to 3ºC hysteresis in the monitored temperature.

As it stands, with the reference voltage (pin 6) connected *directly* to the comparator's non-inverting input (pin 3), the circuit cannot monitor temperatures below about 68ºC. However, by connecting the non-inverting input to a reference voltage less than 1·182V (e.g.: by using a potential divider at the REF pin), the circuit can be used to monitor temperatures as low as –40ºC.

Although other temperature sensors could be used, the LM50B (IC1) is inexpensive and provides adequate accuracy for undemanding applications. It also has fairly low power requirements (supply current is 180µA max.), so the entire circuit consumes no more than 200µA quiescent supply current – important for battery-powered applications.

TEMPERATURE MONITORS

To simplify the task of measuring and controlling an object's temperature, a wide range of devices with integrated temperature sensors is available, many of which feature threshold detectors with integral hysteresis. A small sample of these devices is listed in Table 7.3.

Pinout details and the internal structure of one of the simplest devices listed, the AD22105, is shown in Fig.7.5. Consisting mainly of a temperature sensor, a comparator and an open-collector transistor, the device operates as a thermostatic switch, with the threshold temperature set anywhere in the range –40ºC to +150ºC by means of an external resistor at the R_{SET} input (pin 6).

When the ambient temperature exceeds the programmed setpoint temperature, the comparator trips and turns on the transistor. As the temperature falls, the comparator switches at a slightly lower temperature. The difference between the upper and lower switching points is the thermal hysteresis, nominally 4ºC.

When connected to the transistor's collector, the internal 200kΩ pull-up resistor can be used to drive light loads such as CMOS inputs. Alternatively, as it can sink up to 10mA, the transistor could be used to drive a low-power load such as an l.e.d..

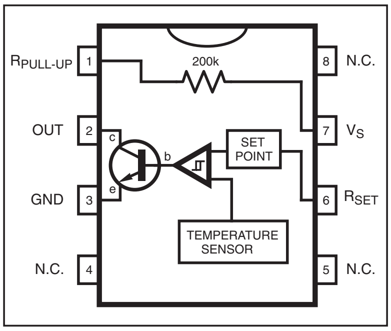

Fig.7.5. Internal structure of the AD22105 thermostatic switch i.c.

HEATING AND COOLING

Other devices in Table 7.3, like the TMP01, MC623 and TC620, are more versatile in that they provide *dual* trip points. An example of a circuit using the LM56 is the Dual Threshold Temperature Controller shown in Fig.7.6.

The LM56 (IC1) contains a temperature sensor, a voltage reference, and two comparators, each of which drives an open-collector transistor. The upper and lower temperature thresholds are set by programming the comparators' threshold voltages, V_{T2} and V_{T1}, respectively. This is conveniently achieved using the R1-R2-R3 resistor potential divider connected to the 1·25V voltage reference output, V_{REF}, at pin 1.

In this example, the LM56 is used to maintain the temperature of an object within the upper and lower levels set by V_{T2} and V_{T1}. The heating element, the fan and the LM56 itself would all be located on, or near, the object in question.

As the temperature monitored by IC1 rises above the upper threshold, the temperature-proportional voltage, V_{TEMP}, rises above V_{T2} and the upper comparator switches high and turns on the internal transistor at OUT 2 (pin 6). This provides gate bias for the *p*-channel MOSFET TR2, which turns on the fan, thereby cooling the object. The fan remains on until the temperature has fallen about 5ºC below the upper threshold: the 5ºC of thermal hysteresis ensures that the fan remains on long enough to cool the object sufficiently. During this time, the internal transistor of IC1 at OUT 1 (pin 7) is on, clamping TR1's gate (g) to 0V and holding it off.

With the fan now off, the object's temperature will depend on ambient conditions. If the temperature gets too low, V_{TEMP} falls below V_{T1} and the lower comparator trips, turning *off* the transistor at OUT 1. The *n*-channel MOSFET TR1 now receives gate bias via resistor R4, and turns on, providing power to the heating element. The object now begins to warm up. The heater remains on until the temperature has risen about 5ºC above the lower threshold. Again, the fixed 5ºC of thermal hysteresis is essential to ensure that the heater remains on long enough to heat the object sufficiently.

BATTERY BACKUP

Devices like the AD22105 and LM56 consume relatively little power, and are thus well suited to battery-powered applications. The devices listed in Table 7.2 are even more frugal with power consumption, and the combination of comparator and voltage reference makes these devices ideal for implementing a battery backup function: an example circuit is shown in the Battery Back-up schematic of Fig.7.7.

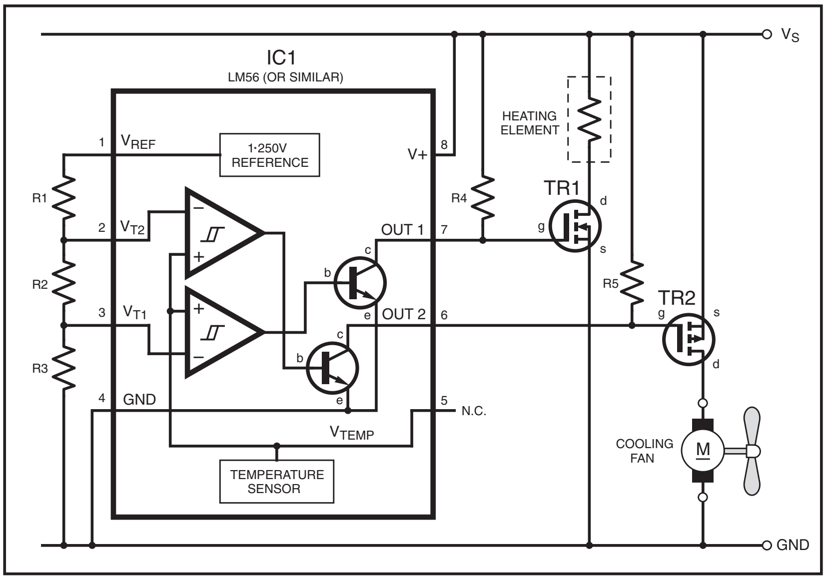

Fig.7.6. Circuit diagram for a Dual Threshold Temperature Controller.

In this circuit, the supply, V_S, is a d.c. voltage derived from the mains supply; its nominal value is 12V, but it can fall to a minimum of 11V. If the mains supply fails, the circuit automatically switches in the 9V back-up battery B1.

Rather than use a diode, the battery is switched in via the *p*-channel MOSFET TR2. Provided TR2 has a low "on'' resistance, there

Table 7.3: Temperature Detectors and Thermal Controllers

Manufacturer	*Part Number*	*Description*	*Operating Voltage Range (V)*	*Temperature Sensing Range (°C)*	*User-accessible Reference Voltage?*	*Max. Quiescent Supply Current (µA)*	*Comments*
Analog Devices	AD22105	Resistor Programmable Thermostatic Switch	2·7 to 7·0	–40 to +150	No	120	Temperature trip point set by external resistor. Open collector output
Analog Devices	TMP01	Low Power, Programmable Temperature Controller	4·5 to 13·2	–55 to +125	Yes 2·50V (typical)	500 (at 5V)	Temperature sensor, window comparator, hysteresis generator. Two open collector outputs indicate under- and over temperature
National Semiconductor	LM56	Dual Output Low Power Thermostat	2·7 to 10	–40 to +125	Yes 1·25V (typical)	230	Temperature sensor, window comparator, voltage reference. Two open collector outputs indicate under- and over temperature
Motorola/On Semiconductor	MC623	Dual Trip Point Temperature Sensor	2·7 to 4·5	–40 to +125	No	250	Dual outputs indicate high and low temperature limits as programmed by external resistors
Motorola/On Semiconductor	NCT22	Single Trip Point Temperature Sensor	4·5 to 18	–40 to +125	No	600	Temperature trip point set by external resistor.·Complementary push-pull outputs
Telcom	TC620	Dual Trip Point Temperature Sensor	4·5 to 18	–40 to +125 (type dependent)	No	400	Dual outputs indicate high and low temperature limits as programmed by external resistors

will be minimal voltage drop across it, such that V_{IN}, the switching regulator's input voltage, will be roughly equal to the battery voltage, V_{BATT}. By making all of the battery power available to the switching regulator, the efficiency of the circuit is maximised: this is particularly important where a heavy load draws lots of current from the battery.

Potential divider resistors R1-R2 are used to "sample" the supply (V_S): the values are chosen such that the voltage across resistor R2 is just greater than the reference voltage, V_{REF}, when V_S is just greater than 11V. Under these conditions, the output of comparator B, OUT B, will be low, and *npn* transistor TR1 will be "off'. With TR1 off, TR2 receives no gate drive (its gate-source voltage is zero due to resistor R8), so it, too, is off.

enough below the minimum possible value of V_S (11V) to prevent false tripping.

Comparator A is used to monitor the health of the battery. A fraction of the battery voltage appears across resistor R4 and is compared to V_{REF} by the comparator. If this voltage falls below V_{REF}, the comparator output goes low, signaling low battery voltage, $V_{BATT(LOW)}$, given by:

$$V_{BATT(LOW)} = \frac{(R3 + R4)}{R4} \times V_{REF} \text{ (volts)}$$

With R3 = 1·5MΩ and R4 = 300kΩ, the comparator output at OUT A will go low when V_{BATT} falls below 7·1V.

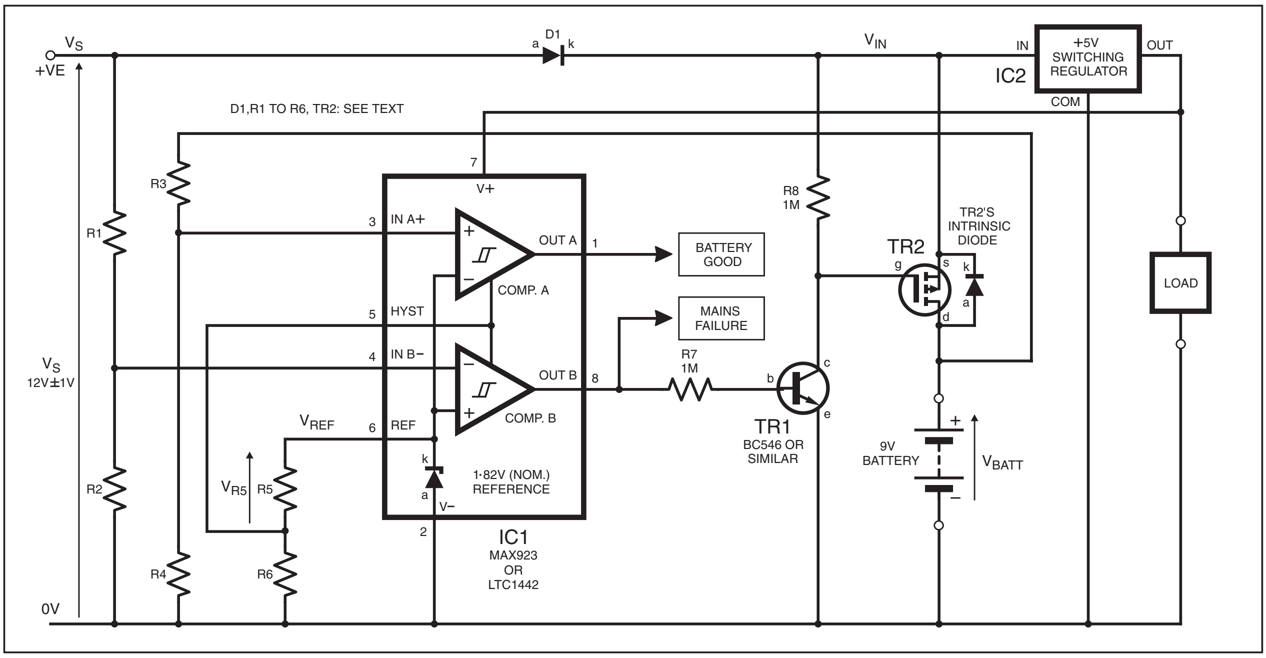

Fig.7.7. Circuit diagram for a Battery Backup using a dual comparator, with voltage reference.

SCHOTTKY DIODE

Voltage V_{IN} is now equal to $V_S - V_D$, where V_D is the drop across diode D1. For high power applications, a Schottky diode could be used for D1 to minimise V_D; however, if the current taken by the regulator IC2 is fairly low, a 1N4001 or even a 1N4148 diode could be used.

When the mains supply fails and V_S collapses, the voltage across resisitor R2 falls below V_{REF} and OUT B (IC1 pin 8) goes high, turning TR1 "on''. (Note that OUT B can also be used as a "mains failure'' flag). Voltage V_{IN} does not immediately fall to zero, but is "held up'' by capacitors (not shown) at the switching regulator's input. Consequently, TR2's gate voltage is now negative with respect to its source, turning it "on', and connecting the battery to the regulator input, such that $V_{IN} = V_{BATT}$. The regulator and the load are now powered entirely by the battery; blocking diode D1 ensures that no current can flow from the battery into the low impedance of the V_S power source.

The device used for transistor TR2 depends largely on the current drawn from the battery: ideally, the MOSFET should be turned fully "on'' with a gate-source voltage of around –5V or so, and the corresponding drain-source on-resistance, $R_{DS(ON)}$, should be as low as possible to minimise the voltage drop across the device. A device such as the VP0808L having $R_{DS(ON)} = 5\Omega$ (typ.) at $V_{GS} = -5V$ may be suitable for low current (<50mA) applications, but a device with much lower $R_{DS(ON)}$ would be needed for heavier loads.

TRIP VOLTAGE

The value of V_S at which comparator B "trips'' and turns on TR1 and TR2 is given by:

$$V_{S(TRIP)} = \frac{(R1 + R2)}{R2} \times V_{REF} \text{ (volts)}$$

The MAX923 and LTC1442 both have a nominal reference voltage of V_{REF} = 1·182V. Therefore, with R1 = 1MΩ and R2 = 130kΩ, the nominal trip voltage would be $V_{S(TRIP)}$ = 10·27V. This is far

Other values of $V_{S(TRIP)}$ and $V_{BATT(LOW)}$ could be arranged simply by changing the values of resistors R1 to R4. Remember, however, that the voltages across R2 and R4 must always remain within the comparators' common-mode input voltage range. For both the MAX923 and LTC1442, the input voltage may range from V– (0V) to 1·3V below the positive supply. Therefore, with a 5V supply, the input may lie anywhere between 0V and 3·7V.

The MAX923 and LTC1442 are limited to a maximum supply voltage of around 11V. In this application, since V_{IN} could rise as high as 12·5V, it is necessary to power IC1 from the regulator's 5V output, rather than directly from V_{IN}. However, what happens when mains power is off and we install a new battery? Before the battery is connected, there is no power to IC1, so how do we get TR1 and TR2 to turn on?

INTRINSIC DIODE

Most MOSFETs, both *n*-channel and *p*-channel, feature an *intrinsic* diode (sometimes called a "body'' diode) which appears between the drain and source terminals. This diode arises from the way the devices are fabricated, and its polarity for a *p*-channel MOSFET is shown for TR2 in Fig.7.7.

Therefore, when the battery is first connected and TR2 is "off'', its intrinsic diode becomes forward biased, allowing current to flow into the switching regulator, such that $V_{IN} = V_{BATT} - V_D$, where V_D is the drop across the intrinsic diode.

Provided V_{BATT} is high enough for the regulator to work properly and generate a 5V output, IC1 will start to function and will switch on TR1 and TR2. The intrinsic diode is now effectively shorted out by TR2's low "on'' resistance, such that $V_{IN} \approx V_{BATT}$.

Note that when mains power is present and V_S is powering the regulator, TR2 is "off'' and its intrinsic diode is reverse biased, such that current cannot flow from V_{IN} into the battery.

Hysteresis in this circuit is used to ensure a "clean'' switchover from mains to battery power. This is important if $V_{S(TRIP)}$ is set close to the minimum value of V_S, especially if V_S has significant ripple content. Hysteresis prevents comparator A oscillating about the $V_{BATT(LOW)}$ trip point, and can also be essential if a low level at the

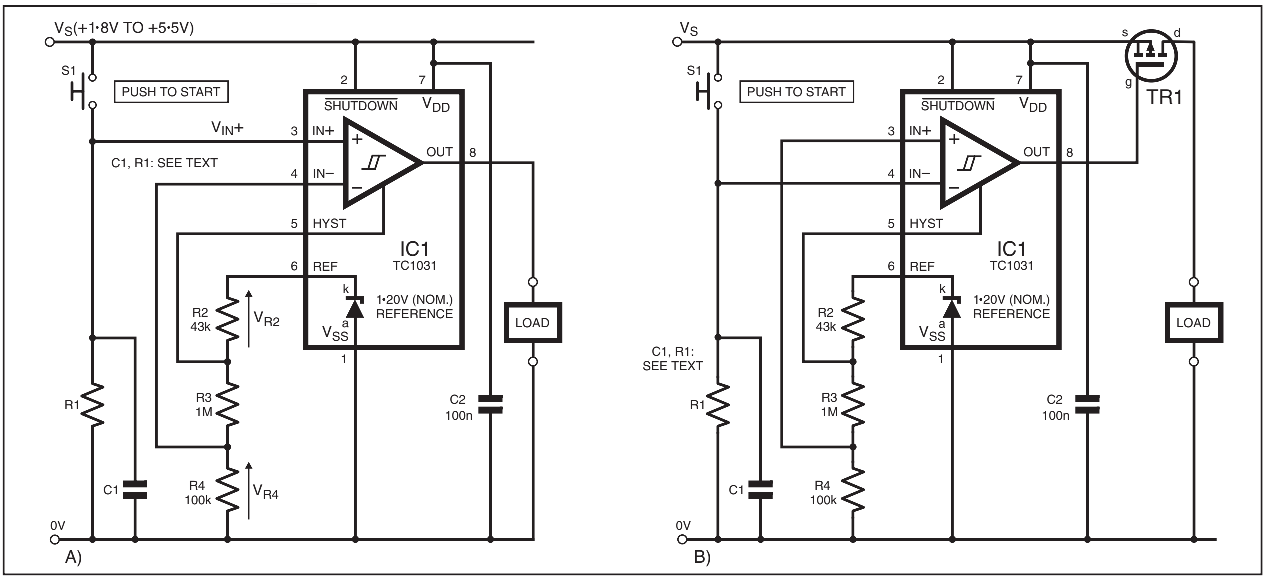

Fig.7.8. Two example circuits for providing Automatic Power Cut-off.

Battery Good output is used by an "intelligent" load to power down certain circuits which would cause the battery voltage to recover slightly.

The amount of hysteresis *relative to the comparator inputs* again depends on the voltage between the REF and HYST pins:

$$V_{HYS} = 2 \times V_{R5} = 2 \times \frac{R5}{(R5 + R6)} \times V_{REF} \qquad \text{(volts)}$$

For example, with R5 = 33kΩ and R6 = 2MΩ, V_{HYS} is typically 38mV. However, the hysteresis *relative to V_S* is: $V_{HYS} \times (R1 + R2)/R2$; similarly, the hysteresis *relative to V_{BATT}* is: $V_{HYS} \times (R3 + R4)/R4$. Note how V_{HYS} is effectively "scaled up" by the potential dividers.

AUTO POWER OFF

It is often desirable to switch off power to a load *automatically* after it has been on for a few seconds or minutes. Examples are l.c.d. backlights and audible alarms. Two simple circuits that provide this "auto power off" function are shown in Fig.7.8.

In Fig.7.8a, a low-power load is driven directly by the output of IC1's comparator. When switch S1 is closed, the comparator's non-inverting (+) input voltage, V_{IN+}, is taken higher than its inverting (–) input voltage, V_{R4}, and its output goes high, turning on the load.

When switch S1 is released, V_{IN+} does not immediately fall to zero, but decays exponentially at a rate determined by the C1/R1 time constant. When V_{IN+} falls below V_{R4}, the comparator output goes low and turns off the power. Therefore, after a momentary press of switch S1, the load will remain powered for a time T_{ON}, given by:

$$T_{ON} = \tau \ln \left\{ \frac{V_S}{V_{R4}} \right\} \qquad \text{(seconds)}$$

where τ = C1 × R1, V_S is the supply voltage, and ln denotes the natural logarithm.

Clearly, T_{ON} can be maximised by making V_{R4} very small. With the values for R2, R3 and R4 shown in Fig.7.8, V_{R4} is nominally 105mV, such that $T_{ON} = 3{\cdot}86 \times \tau$ when V_S = 5V.

TIME CONSTANT

The circuit of Fig.7.8 was tested with C1 = 1µF ±5% and R1 = 10MΩ ±5%, giving a time constant τ = 10s ±5%. Therefore, T_{ON} would nominally be about 38·6s. With V_S = 5·0V, the actual value was measured at just over forty seconds.

The TC1031, and similar devices like the MAX921 and LTC1440, have very low comparator input currents (±100pA max. for the TC1031) allowing large values to be used for resistor R1. However, capacitor C1's internal leakage current may have an effect on T_{ON}, particularly if an electrolytic or tantalum type is used.

The comparator in the TC1031, MAX921 and LTC1440 can only source a few milliamps to the load, so for heavier loads the circuit shown in Fig.7.8b should be used. By swapping over the comparator inputs, the output goes *low* when S1 is closed, thereby turning "on" *p*-channel MOSFET TR1 which can source much more current to the load.

In Fig.7.8a, the supply voltage, V_S, will be limited by the operating voltage range of the device used for IC1. The TC1031, for example, can work with supplies from 1·8V to 5·5V, whereas the MAX921 and LTC1440 can work up to 11V. In Fig.7.8b, the *minimum* supply voltage will be limited by the gate-source voltage needed to turn on TR1.

Hysteresis set by the voltage across resistor R2 ($V_{HYS} = 2 \times V_{R2}$) ensures that the comparator switches "cleanly" and is not affected by noise at the inputs. With R2 = 43kΩ, R3 = 1MΩ and R4 = 100kΩ, V_{R2} is nominally 45mV, such that V_{HYS} = 90mV, i.e., ±45mV either side of the threshold.

VOLTAGE DETECTORS

Many manufacturers produce a range of low power voltage detectors intended primarily for monitoring supply rails and generating a microprocessor reset if the voltage goes outside preset limits. A small selection of these devices is given in Table 7.4.

The internal structure of a typical three-terminal Voltage Detector is shown in Fig.7.9a. With slight variations from part to part, this configuration is representative of devices like the MC34164P, Rx5VT series, S-807 series, and TC54 series.

The voltage to be monitored, usually denoted V_{DD} or V_{IN}, also provides the detector's power. As this voltage varies, the current source helps to hold the reference voltage, V_{REF}, constant. The values of resistors R1 and R2 determine the value of V_{DD} at which the comparator trips. Usually, a range of devices is available offering trip voltages from as low as 0·8V to over 6·0V, usually in 0·1V steps.

The comparator's hysteresis, usually about 5 per cent of the detection voltage, ensures the output switches cleanly at the preset threshold. As shown in Table 7.4, most of the simple three-pin detectors require very little supply current.

FLEXIBILITY

Four-pin detectors like the MAX837 shown in Fig.7.9b are more versatile in that the threshold can be set by means of external resistors. As well as providing freedom in selecting the trip voltage, it also allows other functions to be built, like the simple Freezer Alarm shown in Fig.7.9b.

In this circuit, NTC (Negative Temperature Coefficient) thermistor R1 has a relatively large resistance at the normally low (sub zero) temperatures found in a freezer. With appropriate values for VR1 and R2, the trimmer pot. is adjusted to make the comparator's input voltage, V_{IN}, less than the reference voltage, V_{REF}, for normal freezer temperatures. Therefore, the comparator output is low, and *n*-channel MOSFET TR1 is "off".

If the freezer develops a fault and its temperature rises, the thermistor resistance falls, causing V_{IN} to rise; eventually, when V_{IN} just exceeds V_{REF}, the comparator trips and the output goes high, turning on TR1, which in turn illuminates the l.e.d. The comparator's inherent hysteresis (typically 6mV for the MAX837) provides a clean transition from "normal" to "fault" conditions.

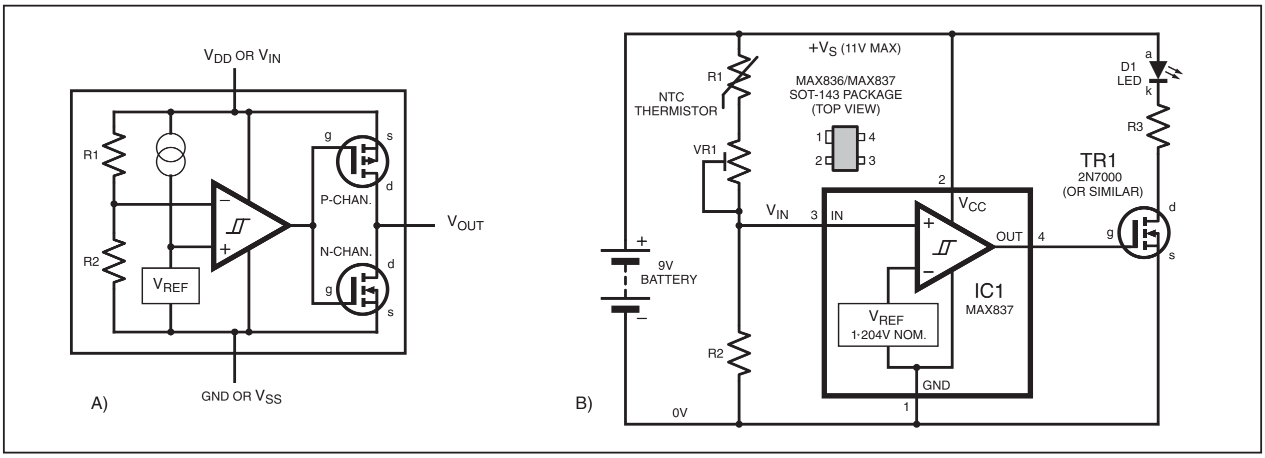

Fig.7.9. Simple circuit diagram for a three-terminal Voltage Detector (a) and (b) a Freezer Alarm.

Under normal conditions, when the l.e.d. D1 is "off'', the only current drawn from the battery consists of IC1's supply current (15µA max.) plus the current through the R1-VR1-R2 divider network. Provided a *high resistance* device is chosen for the thermistor, this current will also be small (a few tens of microamps) allowing the circuit to run for months or years on a 9V PP3 battery.

Although an l.e.d. has been incorporated to indicate the fault condition, other devices, such as an audible alarm, could also be used.

VERSATILE SUPERVISION

Several manufacturers produce a range of devices which expand on the simple voltage detectors described above; a few examples are listed in Table 7.5. As well as the basic voltage monitoring function, these devices provide additional features, such as programmable hysteresis and watchdog timers. For comprehensive supply monitoring, the TL7770 contains two independent supply monitors which detect both overvoltage and undervoltage conditions, generate power-up reset signals, and also provide an SCR (Silicon-Controlled Rectifier – or thyristor as it is called) gate drive for crowbar protection.

The SCR crowbar implements overvoltage protection by clamping the supply voltage when it gets too high. Another method, shown in Fig.7.10, uses the MAX8211 voltage monitor to *disconnect* the load when an overvoltage condition is detected. In addition to a voltage reference, comparator and *n*-channel open-drain output, the 8211 provides a "HYST'' output which allows for resistor-programmable hysteresis.

To understand how the Overvoltage Protection circuit of Fig.7.10 works, assume that supply voltage V_S is at its normal level, such that the voltage across R2, denoted V_{R2}, is less than the internal 1·15V reference voltage. Under these conditions, the 8211's comparator output is high, such that the internal *p*-channel MOSFET is off, and the *n*-channel MOSFET is on, providing gate bias for *p*-channel MOSFET TR1. Provided TR1's gate-source voltage is large enough, it will turn on "hard'' and connect the supply voltage, V_S, to the load, such that load voltage $V_L = V_S$.

OVERVOLTAGE PROTECTION

If V_S starts to rise, V_{R2} will increase proportionally. Should V_S get too high, V_{R2} will exceed the 1·15V reference level, causing the comparator to trip. Its output now goes low, turning off the internal *n*-channel MOSFET, which in turn removes gate bias from TR1, thus disconnecting the excessive supply voltage from the load. The load voltage, V_L, now falls to zero.

Since the comparator output is now low, the internal *p*-channel MOSFET is on, pulling the HYST pin up to the positive supply line. This has the effect of connecting resistor R3 in parallel with resistor R1, causing V_{R2} to rise even higher, thereby introducing hysteresis to the switching threshold. Hysteresis is important to provide "clean'' switching, and to ensure TR1 remains off until V_S has fallen back to a safe level.

Values for R1, R2 and R3 are determined using the following equations:

$$R1 = R2 \times \frac{(V_{TU} - V_{TH})}{V_{TH}} \quad \text{(ohms)}$$

$$\text{and:} \quad R3 = R1 \times \frac{(V_{TL} - V_{TH})}{(V_{TU} - V_{TL})} \quad \text{(ohms)}$$

where V_{TU} is the upper threshold voltage (the maximum value of V_S), V_{TL} is the lower threshold (the value of V_S at which power must be switched back to the load), and V_{TH} is the 8211's threshold voltage (equal to the internal 1·15V reference).

As an example, let's assume we require the load to be disconnected when V_S = 6·0V (i.e., V_{TU} = 6·0V) and must be reconnected when V_S has fallen back to 5·5V (i.e., V_{TL} = 5·5V). Using the above equations, we find that R1 = 4·22 × R2, and R3 = 8·7 × R1. Suitable, preferred values are R1 = 200kΩ, R2 = 47kΩ, and R3 = 1·8MΩ.

TRANSIENTS

A test circuit was built using these values. A VP0808L was used for TR1, and a 470Ω resistor was used as a simple load. The load voltage, V_L, tracked the increasing supply voltage until V_S reached 5·91V, at which point TR1 turned off and V_L fell to zero. Transistor TR1 remained off until V_S had been reduced to 5·48V. The hysteresis, in this case 0·43V, ensures there is no oscillation as TR1 turns off.

Although the MAX8211 and ICL8211 are low power devices, their response times tend to be slow, so a Zener diode, D1, should

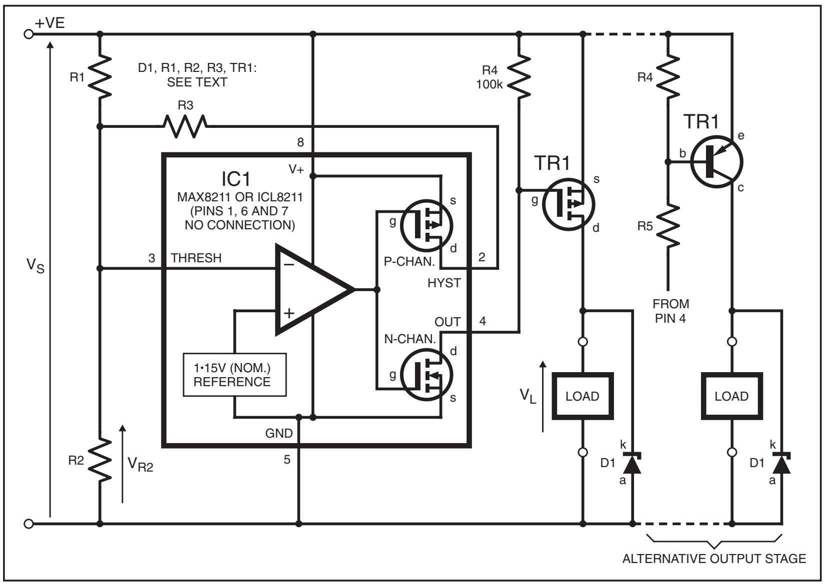

Fig.7.10. Overvoltage protection circuit diagram.

Table 7.4: Three- and Four-terminal Voltage Detectors

Manufacturer	Part Number	Description	Operating Voltage Range (V)	Typical Threshold Voltage, V_{TH} (V)	Typical Hysteresis Voltage (mV)	Max. Quiescent Supply Current (μA)	Comments
Motorola/On Semiconductor	MC33164P/ MC34164P	3-pin Micropower Undervoltage Sensor	1·0 to 10	2·68 (–3 series) 4·30 (–5 series)	60 (–3 series) 90 (–5 series)	50	MC33164P is same as MC34164P, but with wider temp· range (–40ºC to +125ºC)
Maxim	MAX6806-MAX6808	3- or 4-pin Voltage Detector	1·0 to 5·5	2·30 (23 series) 2·60 (26 seriees) 4·60 (46 series)	46 (23 series) 52 (26 series) 92 (46 series)	80	MAX6806 has active-low, push-pull output. MAX6807 has active-high, push-pull output. MAX6808 has active-low, open-drain output
Maxim	MAX836/ MAX837	4-pin Micropower Voltage Monitor	2·5 to 11	1·204	6	15	Trip point adjustable using external resistors. MAX836 has open-drain output. MAX837 has push-pull output
Ricoh	Rx5VT series	3-pin Micropower Voltage Detector	0·7 to 10	0·9 to 5·9 (type dependent)	45 to 295 (type dependent)	4·2	50 models available, each with different V_{TH}. Open-drain or push-pull outputs available
Seiko	S-807 series	3- pin Micropower Voltage Detector	1·0 to 15	1·5 to 7·7 (type dependent)	75 to 385 (type dependent)	4·0	44 models available, each with different V_{TH}. Open-drain or push-pull outputs available
Telcom	TC54 series	3- pin Micropower Voltage Detector	0·7 to 10	0·8 to 6·0 (type dependent)	40 to 300 (type dependent)	4·2	53 models available, each with different V_{TH}. Open-drain or push-pull outputs available
Zetex	ZM33164-3	3-pin Voltage Detector	1·0 to 10	2·68	60	190	Similar to MC33164P

Notes: Values are quoted for ambient temperature = 25°C.

be connected in parallel with the load to provide protection against fast, transient overvoltages appearing on V_S. In the example above, a 6·8V Zener would probably be suitable.

The maximum permissible supply voltage depends on the device used for IC1. The MAX8211 can operate safely up to 16·5V, whereas the ICL8211 may be used with supplies as high as 30V (albeit at higher supply current).

The minimum operating voltage is around 2V for each device. However, at such a low supply voltage, there may be insufficient gate drive for TR1 to turn on properly, so it may be necessary to replace the MOSFET stage with the alternative *pnp* bipolar transistor stage as shown.

UNDERVOLTAGE PROTECTION

As strange as it may seem, there are situations where it is necessary to protect against *undervoltage* conditions. For example, most circuits will malfunction when their supply voltage falls below a certain level, so it is appropriate to switch them off completely before this happens.

Batteries can also be adversely affected if their terminal voltage gets too low as a result of excessive discharge (some lead acid batteries can be damaged if subjected to "deep discharge").

A simple Undervoltage Protection circuit diagram, which disconnects the power to the load when the supply voltage gets too low, is shown in Fig.7.11. In this example, the supply is derived from a 12V battery, and a MAX8212 voltage detector is used to monitor the battery voltage, V_{BATT}.

The 8212 is exactly the same as the 8211 described above, but with an inverter before the internal *n*-channel MOSFET. Consequently, when the voltage at the THRESH pin (3) exceeds the internal reference voltage, both MOSFETs turn on together. The HYST pin functions in exactly the same manner as for the 8211, and the same equations may be used to determine values for resistors R1, R2 and R3.

Provided the battery voltage is high enough, the voltage across resistor R2, V_{R2}, will be greater than the 1·15V reference voltage, and the voltage at the OUT terminal (4) will be low, biasing MOSFET TR1 on and connecting the battery to the load ($V_L = V_{BATT}$).

Table 7.5: Miscellaneous Voltage Monitors and Supervisors

Manufacturer	Part Number	Description	Operating Voltage Range (V)	Typical Threshold/ Reference Voltage, V_{TH} (V)	Typica Hysteresis Voltage (mV)	Max. Quiescent Supply Current (μA)	Comments
Harris/Intersil	ICL7665A	Micropower Under/Over Voltage Detector	1·6 to 16	1·3	Resistor programmable	15	Features voltage reference and two comparators for under- and overvoltage detection; hysteresis set by resistor chain
Harris/Intersil	ICL8211 ICL8212	Programmable Voltage Monitors	1·8 to 30	1·15	Resistor programmable	250	Features voltage reference, comparator and open-collector output stage
Motorola/On Semiconductor	MC33161P MC34161P	Universal Voltage Monitors	2·0 to 40	1·27	25	900	Features 2·54V reference and two comparators each with hysteresis
Maxim	MAX8211C MAX8212C	Micropower Voltage Monitors	2·0 to 16·5	1·19 (max.)	Resistor programmable	15	Features voltage reference, comparator and open-drain output stage
Micrel	MIC833	Micropower Comparator & Reference	1·5 to 5·5	1·240	Resistor programmable	2	Very low power. Low voltage, single supply operation
Micrel	MIC2778	Micropower Voltage Monitors	1·5 to 5·5	1·240	Resistor programmable	2	Very low power; features voltage reference, two comparators and delay line
Telcom	TC32M	3-pin System Supervisor	4·5 to 5·5	4·50 (max.)	-	200	Features voltage monitor, watchdog timer and external reset override
Texas Instruments	TL7770-5	Dual Power Supply Supervisor	3·5 to 18	4·64 (max.)	15	5mA	Features two independent supply supervisors that monitor under- and overvoltage conditions

Notes: Values are quoted for ambient temperature = 25°C.

However, as the load drains the battery, V_{BATT} decreases, and eventually V_{R2} falls below the reference voltage. At this point, the internal *n*-channel MOSFET turns off, removing gate bias from TR1, which also turns off and disconnects the load from the battery. At the same instant, the internal *p*-channel MOSFET also turns off, disconnecting resistor R3 from its parallel connection with R1, causing V_{R2} to fall even lower, thus providing the required hysteresis.

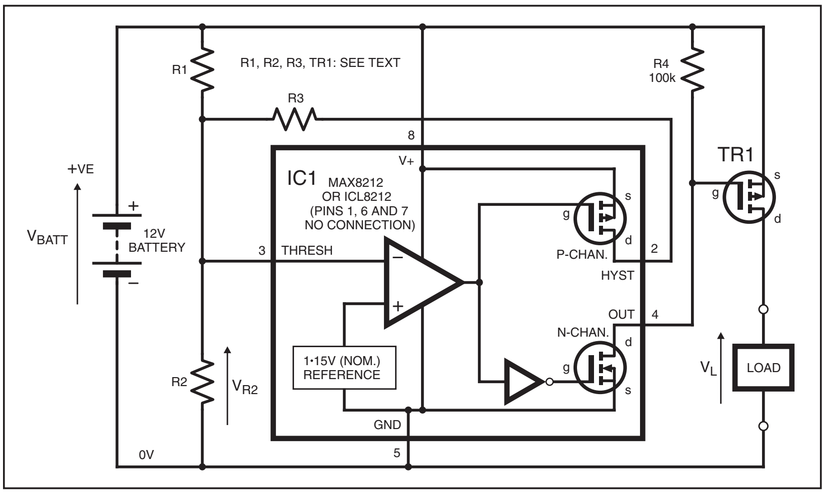

Fig.7.11. Circuit diagram for Undervoltage protection.

BATTERY RECOVERY

When the load is disconnected from the battery, its voltage will "recover" slightly, so adequate hysteresis is essential to prevent the battery being switched back in when this happens. For example, let's assume we wish to disconnect the 12V battery when its voltage falls to 10V, and tests have shown that V_{BATT} recovers to 11·5V when the load is removed.

If we set V_{TL} = 10V, we must have at least 1·5V hysteresis, but 2V would provide adequate safety margin. Therefore, V_{TU} = 12V. Using the equations given previously, we find that R1 = 9·43 × R2, and R3 = 4·43 × R1. Preferred values are not available to satisfy these equations exactly, but values of R1 = 150kΩ, R2 = 16kΩ, and R3 = 680kΩ provide a fairly close approximation.

A test circuit of Fig.7.11 built using these values was found to switch out the battery when its voltage fell to 9·91V. Transistor TR1 remained off until the battery had been charged sufficiently to raise V_{BATT} to 11·68V, equivalent to 1·77V of hysteresis. For applications where a heavy load draws a lot of current from the battery, TR1 must have very low "on" resistance to minimise power loss.

LATCHING OVERVOLTAGE INDICATOR

We conclude our selection of simple applications with a Latching Overvoltage Indicator built using the MIC833 – see Fig.7.12 circuit diagram.

The MIC833 shown in Fig.7.12a is a micropower voltage detector featuring two comparators, a reference voltage and an output latch. The MIC2778 is similar, but provides an additional delay section intended to generate a power-up reset lasting about 140ms for microprocessor systems.

The MIC833 functions in the same way as the "complementary precision" Schmitt trigger described in Part Three of this series (see Fig.3.5 on page 53 of *EPE* January 2001 issue). The supply voltage, V_S, is monitored by means of the R1-R2-R3 divider network.

When V_S is low and the voltage at the L_{TH} input falls below the internal reference, the upper comparator trips and resets the latch, causing the internal *n*-channel MOSFET to turn on. This pulls down the output voltage at the OUT pin (4), thereby providing an active-low reset signal for a microprocessor.

When V_S increases sufficiently for the voltage at the H_{TH} pin (1) to rise above the reference, the lower comparator switches and *sets* the latch, turning off the *n*-channel MOSFET. Proper selection of R1, R2 and R3 values allows adequate hysteresis to be established between the lower and upper threshold levels of V_S as determined by the following equations:

$$V_{TL} = V_{REF} \times \frac{(R1 + R2 + R3)}{(R2 + R3)} \quad \text{(volts)}$$

and: $$V_{TU} = V_{REF} \times \frac{(R1 + R2 + R3)}{R3} \quad \text{(volts)}$$

where V_{REF} = 1·24V.

SURGE CATCHER

The Latching Overvoltage Detector circuit shown in Fig.7.12b uses the MIC833 to detect and "store" an overvoltage condition, thereby functioning as a voltage "surge catcher". Resistors R1 and R2 are used to set the overvoltage threshold. To understand how the circuit works, assume switch S1 has just been pressed, putting the circuit in its "reset" state, such that the OUT pin is low, and transistors TR1 and TR2 are both off.

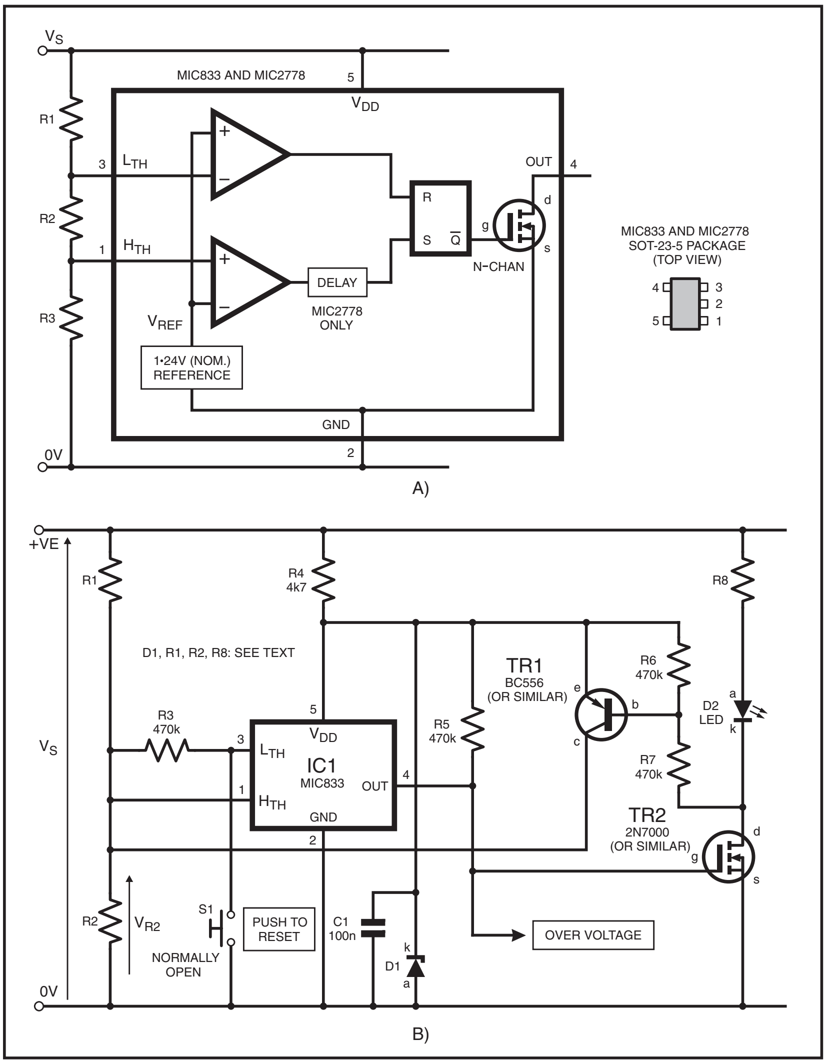

Fig.7.12. Latching Overvoltage indicator circuits.

When the supply voltage, V_S, exceeds the threshold, V_T, set by resistors R1 and R2, the voltage V_{R2} at the H_{TH} input exceeds IC1's reference voltage and causes its internal latch to be set: the OUT pin is now pulled up to V_{DD} via resistor R5, turning on TR2 which, in turn, illuminates l.e.d. D2 and turns on TR1.

Since TR1 is on, it pulls up the voltage on R2 to V_{DD} and holds it there, even if V_S falls back to a level below the threshold, V_T. The circuit is now latched, and the l.e.d. stays on to indicate that an over-voltage condition has occurred. The circuit can be reset either by removing power completely, or by pressing switch S1.

The threshold voltage, V_T, at which the circuit trips is given by:

$$V_T = V_{REF} \times \frac{(R1 + R2)}{R2} \quad \text{(volts)}$$

and so: $$R1 = R2 \times \frac{(V_T - V_{REF})}{V_{REF}} \quad \text{(ohms)}$$

For example, if we require a trip voltage, V_T, to be 6·0V, we find that R1 = 3·84 × R2. Suitable values are R1 = 1·5MΩ and R2 = 390kΩ. A test circuit built using these values was found to trip when V_S reached 6·02V.

ZENER CLAMPING

Note that the MIC833's maximum operating voltage is around 6V, so it is necessary to clamp V_{DD} using Zener diode D1 for applications where V_S could exceed 6V. A 6·2V Zener such as the BZY88C6V2 would probably be suitable.

With the circuit (Fig.7.12b) in its reset condition, and with V_S lower than the Zener voltage, the total current drawn from V_S consists mainly of the current through resistors R1 and R2, plus IC1's supply current (a meagre 2µA). Provided the values of R1 and R2 are large as in the above example, the total current drain will be less than 10µA, or so. This makes the circuit ideal for monitoring battery voltages where current drain must be kept to a minimum.

For supply voltages exceeding 6V, R4 and D1 could be replaced by a micropower, low dropout linear regulator to maintain low current drain in the reset state even at high voltages. Resistor R8 should be selected to provide adequate l.e.d. brightness at the minimum value of V_S.

SUMMARY

Throughout this series, we've looked at a wide variety of Schmitt trigger circuits, and we've seen how hysteresis is important not just to ensure "clean" switching, but also to provide the distinct thresholds needed in circuits like multivibrators and voltage-controlled oscillators. In fact, hysteresis, whether in the form of a voltage, current, or some other quantity like heat, is an essential factor in a vast range of electronic devices and systems.

It's interesting to ponder whether O. H. Schmitt, when he first proposed his new trigger circuit back in 1938, could have had any idea just how important the basic concepts of his idea would become, and how invaluable they would be to so many different functions. □

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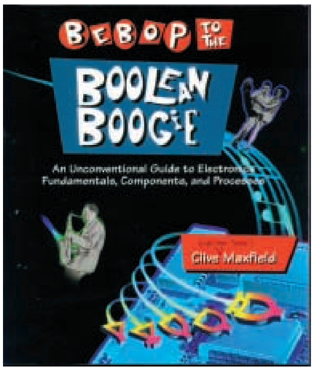

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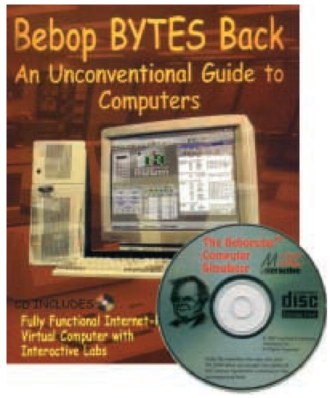

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