THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EVERYDAY PRACTICAL ELECTRONICS

FEBRUARY 2004

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PIC LCF METER

Measures inductance, capacitance & frequency

JAZZY NECKLACE

Futuristic jewellery

TUG-OF-WAR

A two-player game

PLUS

TEACH-IN 2004

Part 4 - LOGIC GATES

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ISSN 0262 3617
PROJECTS ... THEORY ... NEWS ...
COMMENTS ... POPULAR FEATURES ...

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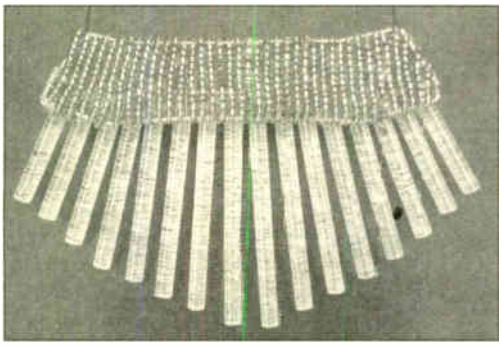

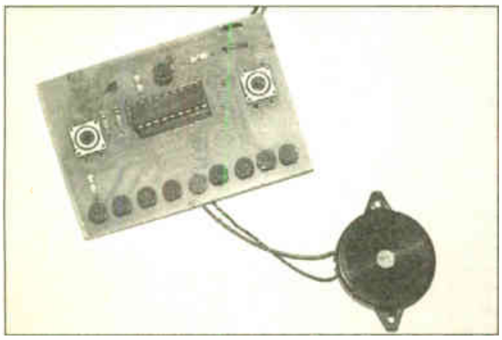

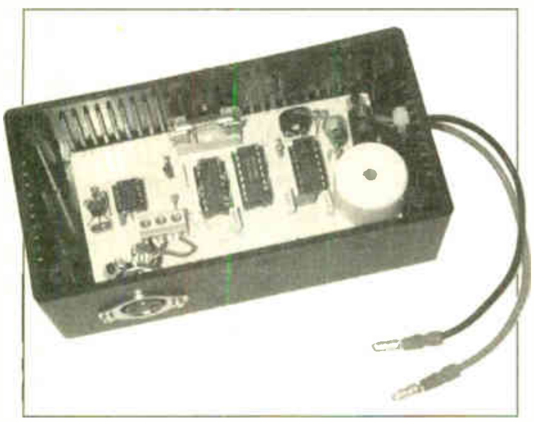

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NEXT MONTH

BAT-BAND CONVERTER

A Bat-Band Converter that not only detects bats but converts their sounds to frequencies that fall within the range of human hearing. It does this using just a single quad op.amp i.c. and a handful of components to deliver surprisingly good performance.

A bat will emit rapid bursts of ultrasound – typically 10 to 200 times a second – increasing rapidly as it nears its prey. These bursts are in the region of 12kHz to 150kHz depending on the species. This unit will "hear" the sounds over the range of 13·6kHz to 180kHz depending on the transducer used.

The converter has a number of other uses, such as a puncture finder, for checking other ultrasonic devices and, with slight modification, as a v.l.f. receiver or a digital voice transmitter.

MIDI HOME STUDIO HEALTH-CHECK

A MIDI code transmitter and receiver that will enable you to check out a range of MIDI (Musical Instrument Digital Interface) based instruments/modules/ computers. When originally using a new MIDI set-up, the system will often not function correctly the first time and it is usually difficult to decide if something is faulty, devices are connected wrongly or if particular settings are incorrect. This easy-to-build PIC-based system transmits and detects single MIDI messages in a way that clearly demonstrates the presence or absence of meaningful code signals using an l.c.d. readout.

Invaluable for those who need to set up a home recording studio etc.

RC MIXER FOR DELTA OR V-TAIL PLANES

This simple mixer cross-mixes two radio control channels for delta or V-tail model airplanes. In such a configuration one servo must respond to both aileron and elevator commands; this mixer takes the signals as they come from the receiver, does the maths, and generates the required servo signal to move the control surfaces correctly. It's all done with a score of components and a PIC, and provides resolution of one microsecond, giving one thousand steps over the servo's range.

PLUS **STANDBY LIGHT – BE PREPARED FOR POWER CUTS**
TEACH-IN 2004 – PART 5 LOGIC GATES AS SWITCHES

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Cool New Kits This Winter!

Here are a few of the most recent kits added to our range. See website or join our email Newsletter for all the latest news.

NEW! EPE Ultrasonic Wind Speed Meter

Solid-state design wind speed meter (anemometer) that uses ultrasonic techniques and has no moving parts and does not need calibrating. It is intended for sports-type activities, such as track events, sailing, hang-gliding, kites and model aircraft flying, to name but a few. It can even be used to monitor conditions in your garden. The probe is pointed in the direction from which the wind is blowing and the speed is displayed on an LCD display.

Specifications

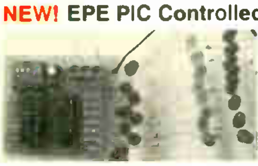
- Units of display: metres per second, feet per second, kilometres per hour and miles per hour
- Resolution: Nearest tenth of a metre
- Range: Zero to 50mph approx.

Based on the project published in Everyday Practical Electronics, Jan 2003. We have made a few minor design changes (see web site for full details). Power: 9VDC (PP3 battery or Order Code PSU203).
Main PCB: 50 x 83mm.
Kit Order Code: 3168KT – **£34.95**

NEW! Audio DTMF Decoder and Display

Detects DTMF tones via an on-board electret microphone or direct from the phone lines through an audio transformer. The numbers are displayed on a 16-character, single line display as they are received. Up to 32 numbers can be displayed by scrolling the display left and right. There is also a serial output for sending the detected tones to a PC via the serial port. The unit will not detect numbers dialled using pulse dialling. Circuit is microcontroller based.
Supply: 9-12V DC (Order Code PSU203).
Main PCB: 55 x 95mm.
Kit Order Code: 3153KT – **£17.95**
Assembled Order Code: AS3153 – **£29.95**

NEW! EPE PIC Controlled LED Flasher



This versatile PIC-based LED or filament bulb flasher can be used to flash from 1 to 160 LEDs. The user arranges the LEDs in any pattern they wish. The kit comes with 8 superbright red LEDs and 8 green LEDs. Based on the Versatile PIC Flasher by Steve Challinor, *EPE* Magazine Dec '02. See website for full details. Board Supply: 9-12V DC. LED supply: 9-45V DC (depending on number of LED used). PCB: 43 x 54mm.
Kit Order Code: 3169KT – **£10.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix)

FM Bugs & Transmitters

Our extensive range goes from discreet surveillance bugs to powerful FM broadcast transmitters. Here are a few examples. All can be received on a standard FM radio and have adjustable transmitting frequency.

MMTX' Micro-Miniature 9V FM Room Bug

Our best selling bug! Good performance. Just 25 x 15mm. Sold to detective agencies worldwide. Small enough to hide just about anywhere. Operates at the 'less busy' top end of the commercial FM waveband and also up into the more private Air band. Range: 500m. Supply: PP3 battery.
Kit Order Code: 3051KT – **£8.95**
Assembled Order Code: AS3051 – **£14.95**

HPTX' High Power FM Room Bug

Our most powerful room bug. Very Impressive performance. Clear and stable output signal thanks to the extra circuitry employed. Range: 1000m @ 9V. Supply: 6-12V DC (9V PP3 battery clip suppied). 70 x 15mm.
Kit Order Code: 3032KT – **£9.95**
Assembled Order Code: AS3032 – **£17.95**

MTTX' Miniature Telephone Transmitter

Attach anywhere along phone line. Tune a radio into the signal and hear exactly what both parties are saying. Transmits only when phone is used. Clear, stable signal. Powered from phone line so completely maintenance free once installed. Requires no aerial wire – uses phone line as antenna. Suitable for any phone system worldwide. Range: 300m. 20 x 45mm.
Kit Order Code: 3016KT – **£7.95**
Assembled Order Code: AS3016 – **£13.95**

4 Watt FM Transmitter

Small, powerful FM transmitter. Audio preamp stage and three RF stages deliver 4 watts of RF power. Can be used with the electret microphone supplied or any line level audio source (e.g. CD or tape OUT, mixer, sound card, etc). Aerial can be an open dipole or Ground Plane. Ideal project for the novice wishing to get started in the fascinating world of FM broadcasting. 45 x 145mm.
Kit Order Code: 1028KT – **£22.95**
Assembled Order Code: AS1028 – **£34.95**

25 Watt FM Transmitter

Four transistor based stages with a Philips BLY89 (or equivalent) in the final stage. Delivers a mighty 25 Watts of RF power. Accepts any line level audio source (input sensitivity is adjustable). Antenna can be an open dipole, ground plane, 5/8, J, or YAGI configuration. Supply 12-14V DC, 5A. Supplied fully assembled and aligned – just connect the aerial, power and audio input. 70 x 220mm.
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3143KT – 10W Stereo Amplifier £9.95
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1019KT – Car Alarm System £10.95
1048KT – Electronic Thermostat £9.95
1080KT – Liquid Level Sensor £5.95
3005KT – LED Dice with Box £7.95
3006KT – LED Roulette Wheel £8.95
3074KT – 8-Ch PC Relay Board £29.95
3082KT – 2-Ch UHF Relay £26.95
3126KT – Sound-Activated Relay £7.95
3063KT – One Chip AM Radio £10.95
3102KT – 4-Ch Servo Motor Driver £15.95
3160KT – PIC16F62x Experimenter £8.95
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3049KT – Ultrasonic Detector £13.95
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SG10 MKT – Animal Sounds £5.95
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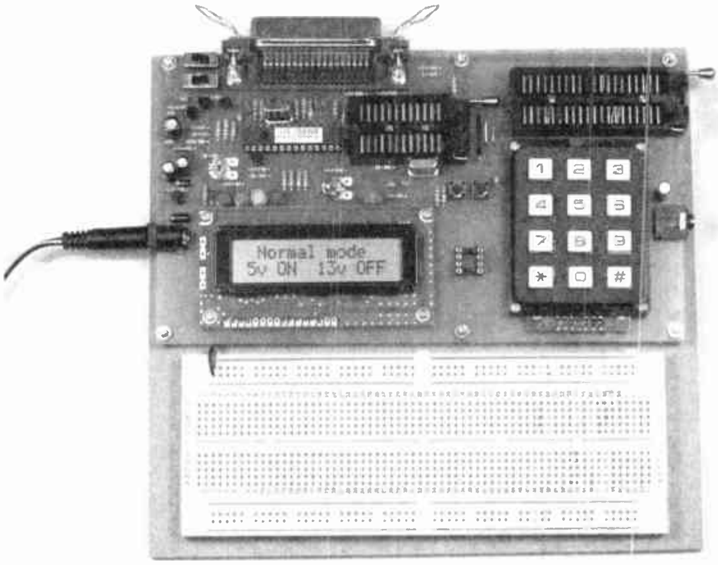

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The best place to start learning about microcontrollers is the PIC16F84. This is easy to understand and very popular with construction projects. Then continue on using the more sophisticated PIC16F877 family.

The heart of our system is two real books which lie open on your desk while you use your computer to type in the programme and control the hardware. Start with four very simple programmes. Run the simulator to see how they work. Test them with real hardware. Follow on with a little theory.....

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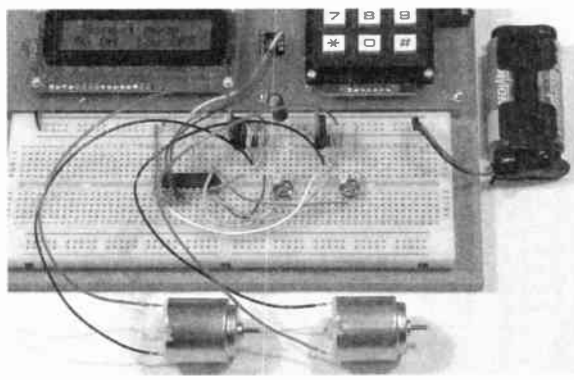

Experimenting with the PIC16F877

The second PIC book starts with the simplest of experiments to give us a basic understanding of the PIC16F877 family. Then we look at the 16 bit timer, efficient storage and display of text messages, simple frequency counter, use a keypad for numbers, letters and security codes, and examine the 10 bit A/D converter.

The PIC16F627 is then introduced as a low cost PIC16F84. We use the PIC16F627 as a step up switching regulator, and to control the speed of a DC motor with maximum torque still available. We study how to use a PIC to switch mains power using an optoisolated triac driving a high current triac. Finally we study how to use the PICs USART for serial communication to a PC.

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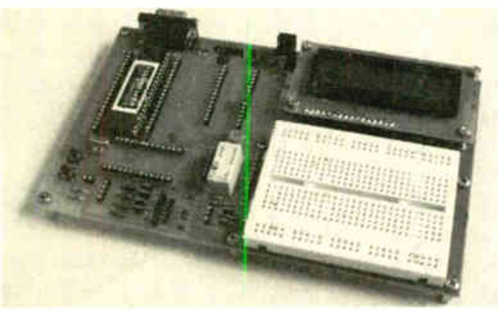
ICEBREAKER



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MARCH - APRIL - MAY '98 EPE SERIES 16F84

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COMMERCIAL

I often wonder if some of the projects we publish will make it as commercial products. Over the years we have seen a number of projects eventually emulated as commercial designs. One I remember well from many years past was a meter to monitor electricity use that was featured on *Tomorrow's World*. They demonstrated it by showing the cost of electricity used to cook a casserole in a conventional oven and in a microwave oven. The day I spent at the BBC was fascinating – they also had a motorised rollerskate on the same programme and watching the presenters try it out was quite fun, but that is another story – one thing that I remember well was how fast the crew devoured the two casseroles once the programme had finished! We have published other electricity monitors since, the last one being John Becker's *PIC Electric Meter* back in 1996, and, of course, these are now available as commercial products.

On a totally different subject, the *Jazzy Necklace* design by Thomas Scarborough in this issue surely deserves to be turned into a commercial product. The display is fascinating and, with some miniaturisation of the electronics and development of the style, it would make a truly beautiful piece of unusual and relatively inexpensive jewellery. It will be interesting to see if anything on similar lines becomes available. Or if indeed anything is already available – if you are aware of any jewellery of this type please let us know. In the meantime you can stand out from the crowd with your own "unique" necklace.

POINTLESS?

Of course, many of our projects are already widely available. Take, for instance, the *Sonic Ice Warning* in this issue. Plenty of cars now have outside temperature monitors that will tell you when it is freezing outside, but, of course, there are still large numbers of models that do not have this feature, hence our worthwhile design.

There are also a number of projects that we publish that, on the face of it, seem a little pointless because it is easier and cheaper to buy the commercial equivalent. The recent series of *Practical Radio Circuits* falls into this category, but what is more satisfying than building your own receiver and tuning in to programmes and amateur transmissions from around the world?

The whole point of a hobby is doing it because you enjoy doing it. No matter that you can buy a radio off the shelf, where is the satisfaction in that? We engage in electronics because we are fascinated by it, because we enjoy it and because of the satisfaction gained from designing or making something unusual that works. It works for us!

Mike Kenward

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PIC LCF METER

JOHN BECKER

Simple monitoring of inductance, capacitance and frequency values

THIS simple PIC-based unit was designed to measure and display the values of inductors and capacitors. As a by-product of the technique used, it can also display the frequency of an external 0V/+5V signal source.

The ranges are approximately:

Capacitance:	1pF to 6500µF
Inductance:	1µH to 10H
Frequency:	0·05Hz to 5MHz

OSCILLATOR CONCEPTS

The design is based upon the concept that oscillators can be constructed from CMOS NAND gates or inverters, and that their oscillation frequency depends on the values of inductance, capacitance and resistance in their feedback paths. The principles were discussed by George Hylton in his two-part series *Logic Gate Inverter Oscillators* of Sept/Oct '02.

Using a suitable microcontroller, such as one from the PIC16F62x or PIC16F87x families, software can read the frequency of an oscillator and calculate the value of an unknown component if the values of the other components are known. In this design, a PIC16F628 is used and the results are output to an alphanumeric liquid crystal display (l.c.d.).

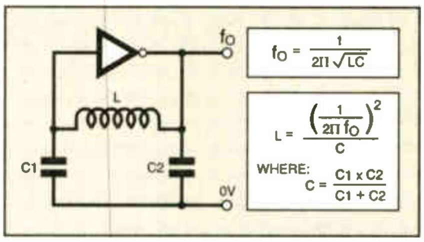

Fig.1. A basic inductance and capacitance (LC) oscillator.

One technique for using an inductor in a CMOS oscillator circuit is that shown in Fig.1. Here the oscillation frequency is determined by the formula:

$$F = \frac{1}{2 \times \pi \times \sqrt{(L \times C)}}$$

where:

F = frequency

$$C = \frac{C1 \times C2}{C1 + C2}$$

L = inductance
$\pi = 22/7$

Using this formula, if any two values are known, the third can be readily calculated. For instance, if C and F are known, then L can be calculated using the formula:

$$L = \frac{\left(\frac{1}{2 \times \pi \times F}\right)^2}{C}$$

Similarly, using the capacitance-resistance oscillator configuration shown in Fig.2, the output frequency can be calculated for known values of R and C. Several formulae exist for this calculation and the one used in this application is:

$$F = \frac{1}{\pi \times R \times C}$$

from which the value for C can be calculated if R and F are known:

$$C = \frac{1}{\pi \times R \times F}$$

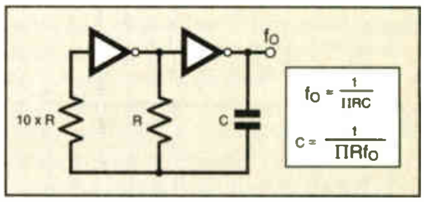

Fig.2. A basic capacitance and resistance (CR) oscillator.

FREQUENCY TO PIC

Referring to the full circuit diagram for the PIC LCF Meter in Fig.3, two independent oscillators are used, one based on inductance and capacitance (LC) values, the other on capacitance and resistance (CR) values.

The LC oscillator is formed around NAND gate IC3a. The inductance is provided by inductor L1, used in series with the external inductor whose value needs to be measured. The external inductor is connected across probe clips P1 and P2 and switched into circuit by rotary switch S2 in position 1. The capacitance is provided by capacitors C5a, C5b, C6a and C6b.

Two pairs of capacitors are used so that the value of C in the LC formula is simple for the software to process. The values for each of the four capacitors is set at 10nF.

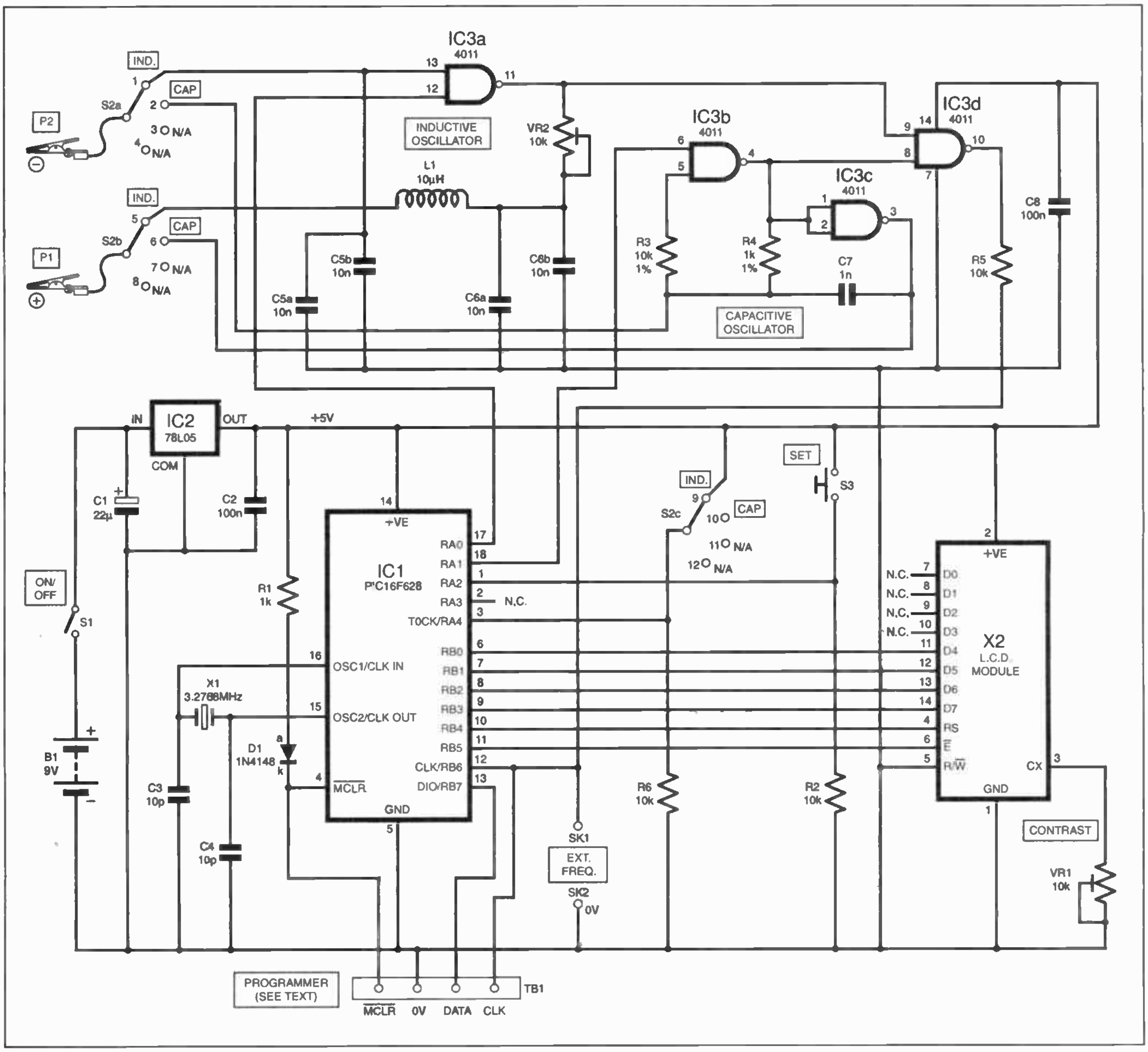

Fig.3. Complete circuit diagram for the PIC LCF Meter.

Therefore the parallel value of C5a/b = C6a/b = 20nF (a value not obtainable in standard capacitor ranges). In the formula as expanded above, the value for C is thus 10nF.

A preset potentiometer, VR2, is also included in the feedback path. Its principal purpose is to ensure that oscillation starts reliably and then continues in a stable manner. The effect is due to its relationship with capacitors C6a/b, which impose a more pronounced phase shift on the signal being fed back through the inductor than the output of the gate itself can allow.

Potentiometer VR2 also has the side effect of providing a degree of frequency control, although this is not important in this application.

In use, the inductor whose value is to be measured is placed in series with L1. The latter provides a minimum inductance value against which the circuit is "nulled" prior to taking measurements. Its use minimises the effect of stray fields within the physical circuit assembly.

The CR oscillator is formed around NAND gates IC3b and IC3c. The maximum frequency at which the oscillator runs is basically set by resistor R4 and capacitor C7. The external capacitor whose value is to be measured is connected between the probe clips and switched in parallel with C7 by switch S2 in position 2. As with L1, C7 provides a minimum reference against which the circuit is "nulled".

Because the reference value has been set to be high enough to effectively "swamp" stray capacitance into an unimportant role, the software is capable of discerning very small capacitance differences, typically from 1pF upwards.

It should be noted that the value of resistor R3 also has an effect on the oscillation frequency. In this circuit it has been chosen to be ten times the value of R4 and is ignored in the frequency calculation formula.

GATE CONTROL

The use of NAND gates in this circuit allows the oscillators to be selectively turned on and off by the PIC microcontroller, IC1.

The LC oscillator becomes active when IC3a input pin 12 is taken high by PIC pin RA0. When RA0 is low the oscillator is inhibited, with IC3a output pin 11 being held high.

The CR oscillator is similarly controlled. PIC pin RA1 when high allows the IC3b/c configuration to oscillate. When RA1 is low, the oscillator stops with IC3b output pin 4 held high.

The outputs from IC3a and IC3b are jointly fed to the inputs of NAND gate IC3d. When IC3a is oscillating, its frequency is passed through IC3d via pin 9 since its other input, pin 8, is held high by IC3b's output pin 4. Conversely, when IC3b/c is oscillating, its frequency is passed through IC3d via pin 8 since pin 9 is now held high by IC3a's output pin 11.

As only one oscillator can be selected at any time, there is no conflict of frequencies passing through IC3d. The output from IC3d pin 10 is fed via resistor R5 to PIC pin RB6. This pin is used as the input to the PIC's TMR1 16-bit counter/timer.

FREQUENCY CAPTURE

For high frequency monitoring, the PIC is set for non-synchronous input to TMR1 and input rates in excess of 5MHz can be registered correctly. It is this fact that also makes this circuit suitable as a frequency counter up to about 5MHz.

For external frequency counting the signal is input directly to PIC pin RB6 via socket SK1, with resistor R5 providing a buffer between the signal and the output of IC3d. The resistor also provides a buffer when the PIC is programmed in-circuit from a system such as *PIC Toolkit TK3* (Oct-Nov '01) – see later.

The frequency output from IC3d can be connected via R5 and socket SK1 to an external frequency counter suited to accepting normal logic-level signals.

MODE SELECTION

As stated earlier, the function of switch S2 is two-fold. The component to be measured, either inductor or capacitor, is connect via crocodile clipped leads (P1 and P2) to the poles of S2a and S2b. The switch is set so that the component is connected to its appropriate oscillator circuit. There is no danger of component or circuit damage if the wrong switch setting is selected. It will be obvious from the measured results if the wrong path has been chosen!

The second function of switch S2 is to inform the PIC which type of component it is to measure. This is controlled by S2c. When in position 1, S2c connects the +5V line to PIC pin RA4. In position 2, RA4 is held at 0V via resistor R6. Software monitors the logic on RA4 and reacts accordingly.

Switch S3 is a push-to-make type and is used to "null" the circuit prior to taking measurements. It is monitored by PIC pin RA2, which is biased low by resistor R2 when S3 is not pressed.

Switches S2 and S3 are also used to set "corrective" factors should any be found necessary, as discussed later.

OTHER COMPONENTS

The results of component value calculations are output to the 2-line by 16 characters per line l.c.d., X2. Preset VR1 sets the l.c.d.'s screen contrast.

The system is operated at 3·2768MHz, as set by crystal X1 in conjunction with capacitors C3 and C4. It can be powered at between +7V and +12V d.c., at about 9mA for a 9V supply.

Regulator IC2 reduces the input supply voltage to +5V, to suit the PIC and the l.c.d. Capacitors C1, C2 and C8 help to ensure additional power line stability.

Connector TB2 is in the author's standard configuration for programming PICs *in-situ* should readers wish to modify the software. Brand new PICs should *not* be programmed via this option due to the configuration settings installed during manufacture (adverse LVP setting). Such PICs should only be programmed on the board of a dedicated PIC programmer.

Diode D1 and resistor R1 prevent the programming and unit supply voltages from interacting. (They must be retained even if on-board programming is not required.)

CONSTRUCTION

Component position and track layout details for the PIC LCF Meter's printed circuit board are shown in Fig.4. This board is available from the *EPE PCB Service*, code 434.

In order to obtain the best potential accuracy from this unit, components C5a, C5b, C6a, C6b, R3 and R4 should have the best tolerance that you can obtain. Ideally all should be 1% devices, although capacitors having such close tolerance are not widely available and you may have to accept 2% or 5% for them. The software has an offset compensation facility should you need to correct displayed values upwards or downwards in the light of experience.

Assemble in your own preferred order – that preferred by the author is wire links, i.c. sockets, and then in ascending order of component size. Ensure that electrolytic capacitors and the semiconductors are inserted the correct way round, but do not insert IC1 and IC3, or connect the l.c.d. (whose p.c.b. connections are in the author's standard order, also see Fig.4), until the correctness of the power supply has been checked. The latter should only be done once you are sure that everything else is correctly positioned and soldered.

Note that inductor L1 is mounted vertically on the board, with its other lead trimmed to serve as a terminal pin. In the prototype it was originally mounted flat on the board but it was found that this caused instability in the oscillation frequency due to the proximity of a signal-carrying p.c.b. track running in parallel with the inductor.

The switches and socket SK1 need only be temporarily connected at this stage, wiring them permanently once the case has been prepared and assembled. Adjust S2's lugged washer so that only positions 1 and 2 can be selected.

In the test model, extra-flexible wire was used for the probe leads, about 15cms long, terminated in miniature crocodile clips with different coloured insulating covers indicating their polarised identities.

For the prototype, a plastic case (the author's "orange box" again!) measuring 150mm × 80mm × 50mm was used, having been suitably drilled for the panel-mounted components (see photograph). Note that the author did not use 0V socket SK2 (see later).

TESTING

When initial checks have been made, connect the l.c.d., insert IC3 and the preprogrammed PIC microcontroller.

Switch on power and recheck that the +5V supply voltage is still correct. Then adjust preset VR1 until the l.c.d. screen contrast is satisfactory. Switch off power and then go through the following main check routine:

Set switch S1 to position 2 (capacitance). Leave the probe clips unconnected (open circuit). Switch on the power. The screen will first briefly display an opening message on line 1, EPE LCF METER, followed by CAPACITOR, with WAITING TIMING on line 2.

The software then assesses the frequency generated by the CR oscillator in relation to capacitor C7 and any stray capacitance present around the assembled unit.

Sampling is done at approximately one-second intervals, so that the frequency monitoring is in Hertz (cycles per second). After each sampling period, the frequency is displayed on screen line 1. Below it is shown the interpretation of that frequency in terms of capacitance. It will be wrong at this time, until the circuit has been nulled. With the prototype, the frequency at this stage is typically about 247000Hz with a displayed capacitance value of 1227pF.

This is the value which results from the exact value of capacitor C7 and any stray capacitance in relation to the values of resistors R3 and R4. When taking active measurements of a capacitor connected

COMPONENTS

See SHOP TALK page

Resistors

R1	1k
R2, R5, R6	10k (3 off)
R3	10k 1%
R4	1k 1%

All 0·25W 5%, except where stated

Potentiometers

VR1, VR2	10k min. preset, round (2 off)

Capacitors

C1	22µ radial elect. 16V
C2, C8	100n ceramic disc, 5mm pitch (2 off)
C3, C4	10p ceramic disc, 5mm pitch (2 off)
C5a, C5b, C6a, C6b	10n ceramic disc, or plate, ideally 1% (see text), 5mm pitch (4 off)
C7	1000p (1n), ceramic disc, 5mm pitch

Semiconductors

D1	1N4148 signal diode
IC1	PIC16F628 microcontroller, pre-programmed (see text)
IC2	78L05 +5V voltage regulator
IC3	4011 CMOS quad NAND gate

Miscellaneous

L1	10µH axial inductor
S1	min. s.p.s.t. toggle switch
S2	3-pole 4-way rotary switch, panel mounting
S3	s.p. push-to-make switch
SK1, SK2	socket, size as preferred, one each red and green suggested
X1	3·2768MHz crystal
X2	2-line 16-character (per line) alphanumeric l.c.d. module

Printed circuit board, available from the *EPE PCB Service*, code 434; plastic case, 150mm x 80mm x 50mm; 14-pin d.i.l. socket; 18-pin d.i.l. socket; knob for S2; 1mm terminal pins; cable ties; p.c.b. mounting supports, self-adhesive (4 off); min. crocodile clips, with insulating covers, one each red and green suggested; extra-flexible wire; connecting wire; solder, etc.

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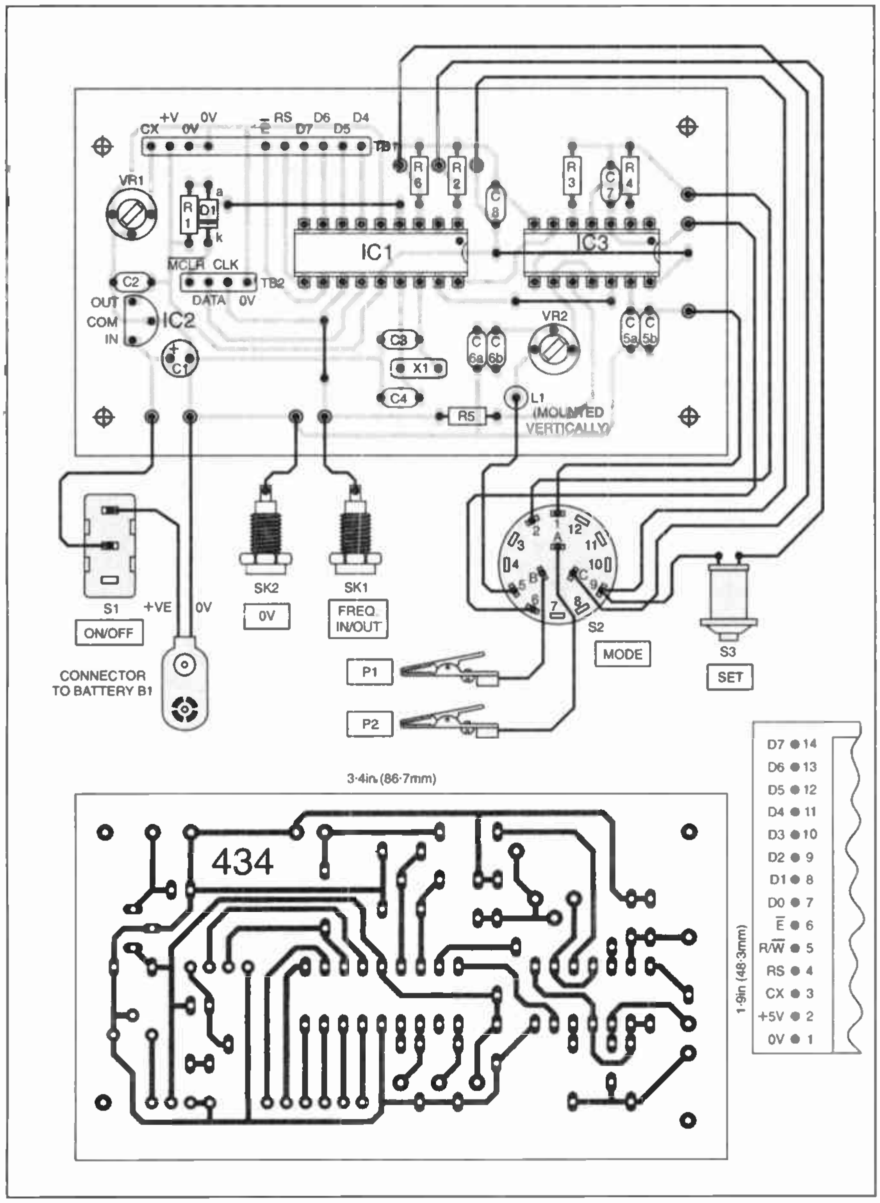
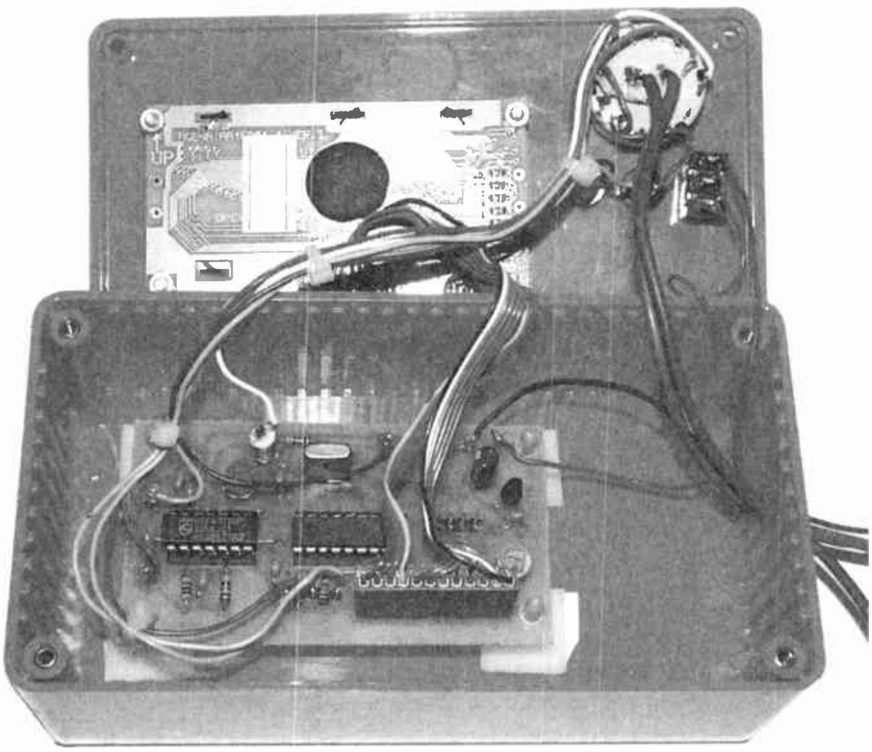


Fig.4. Component layout and master track pattern for the PIC LCF Meter. Typical l.c.d. pinouts are shown to the right.



between the probe clips, this "reference" value is subtracted from the result of the measurement. However, the PIC must be "told" that this is the value to use. At present it is subtracting zero from the value, as set when the power is switched on.

Pressing switch S3 sets the reference value into temporary memory within the PIC. This is confirmed by the word NULLED being shown on line 1, followed by the capacitance value being reset to zero on line 2.

Having released switch S3, the next sample value should also read zero until the capacitance across the probes is changed. Clip the probes to a capacitor nominally specified as, say, 1000pF and its actual value will be displayed on line 2. Note that the frequency value on line 1 is always the actual oscillation frequency and is not affected by the "nulling".

Be aware that the act of touching the probe leads with your hands will introduce additional capacitance across the probes, so do not hold them while taking value measurements.

A 470pF ceramic capacitor being monitored while this text is being written is producing a frequency of 177653Hz and, after the reference value has been subtracted by the software, is shown as having a real value of 492pF, well within its catalogue-stated tolerance of ±5%.

Now clip an electrolytic capacitor in place of the previous one, say a value of 1µF, correctly connecting the positive clip to the positive capacitor lead – an important point to note when measuring electrolytic capacitors, which are polarity sensitive, of course.

Observe the capacitor's displayed value on screen. Using a test capacitor while writing this, the screen shows a frequency of 311·138Hz and a value of 0·974µF (not a bad value for a 1µF capacitor whose tolerance is nominally ±20%!).

Two points are worth noting in relation to this displayed value. First, a different timing technique is used for frequencies that are below 1024Hz, in order to obtain better accuracy than with pulse counting for low frequencies.

In this mode, which is entered automatically if a frequency below 1024Hz (a binary "round" value) is detected, the PIC assesses the logic status of the signal on its RB6 pin. It then waits until this logic phase changes. It then starts a timing counter (TMR1) which runs until the pin status has changed twice more, representing a complete cycle of the waveform. At the end of this cycle the counter is stopped.

The count value, which is in relation to the 3·2768MHz crystal used, is converted into microseconds (T), and then converted into the equivalent frequency (F) for that timing (F = 1/T). In this mode the reference value is too low to be of interest and is ignored.

Secondly, this mode produces frequency results that have three places of decimals and a decimal point is displayed

accordingly. Additionally the value is now expressed in microfarads (μF – but shown as "uF").

Now, if you have a capacitor to hand of, say, 220nF (0·22μF), clip it to the probes and examine the result. Taking one at random, the prototype displayed a frequency of 1305Hz, representing a value of 231·210nF. Note the "nF" suffix – the software, when registering a calculated value of less than 10000 (but which has not been obtained by the "uF" route), gives an "nF" suffix, but otherwise shows "pF".

Note that with larger values of electrolytic capacitor, you need to be patient while the values are assessed, since up to three logic half cycles may need to be processed – the initial logic level change, followed by one complete cycle. For instance, a random test with an electrolytic monitored as 5055μF had a full cycle period of 0·060Hz.

INDUCTANCE TEST

To test the LC oscillator, switch S2 to position 1 (inductance) and clip the probes to each other (as a short circuit). In this configuration inductor L1 completes the feedback circuit for IC3a, which oscillates accordingly.

Adjust preset VR2 until the oscillation rate appears stable, as indicated by the frequency value shown on screen line 1. The setting will be obvious if an oscilloscope is used. If a scope is not available, try VR2 at various wiper settings and chose the best – it is not critical. In the prototype the author set the wiper for approximately three-quarters clockwise rotation (about 7k5).

Again the frequency and calculated results are shown on the upper and lower lines of the screen. In the prototype typical un-nulled values are 468608Hz and 11.492μH. Pressing "null" switch S3 the inductance value should read 0·000uH

Now clip an inductor of, say, 10μH between the probes. A typical display might then be 342348Hz, 9·969uH. In this case showing that the external inductor is pretty close to its marked value.

As with the capacitance mode, the pulse width assessment technique is used when the monitored frequency is below a certain value, 16384Hz for inductors. Again the frequency value is shown with three decimal places.

On the normal frequency counting range, values less than 100μH are displayed with a "uH" suffix, otherwise they are shown in millihenries (mH), i.e. 100.801μH would be displayed as 0·100801mH.

Values obtained using the pulse width technique are displayed in henries, with a suffix of "H", for example 7.305H.

Be patient when monitoring higher values of inductance, for the same reason as for larger values of capacitance.

FREQUENCY COUNTING

To monitor an external frequency, which must conform to normal logic levels (swinging between 0V and +5V), connect the signal source to socket SK1. Switch S2 may be in either position.

Resistor R5 prevents the signal from being adversely affected by the running of either internal oscillator.

Frequencies from about 0·05Hz to greater than 5MHz can be monitored.

Because switch S2 does not cause the internal oscillators to be inhibited during external frequency input, the displayed frequency will always be accompanied by an inductance or capacitance value on line 2.

Socket SK1 may also be used to feed the internal oscillator frequencies to an external frequency counter.

Note that if the LCF Meter is not powered by the same power supply source as the external signal source or frequency counter, then a common 0V (ground) connection between them must be provided via socket SK2.

In the prototype SK2 was omitted as the author always uses a common workshop power supply for all circuits.

ALIGNMENT

In the event that the component values used with the oscillators are not exactly those for which the software has been written, compensation is possible through a routine selectable when the LCF Meter is first switched on.

With power switched off, set switch S2 for the capacitance or inductance mode you want to modify. Press switch S3 and hold it pressed while the power is switched on. On recognising the pressed status of S3 during its initialisation routine, the PIC's software jumps to the appropriate correction routine selected by S2.

This will be confirmed by a screen message on line 1 stating which correction mode has been accessed, for example CAP CORRECTION. On line two the existing correction value will be displayed. The default is 100.

In normal running mode the calculated capacitance and inductance values are multiplied by the correction value and then divided by 100. For instance, if the correction value is 100, then there is no correction applied, since multiplying by 100 and then dividing by 100 is the same as multiplying by 1, so leaving the value unchanged.

If the correction value is 101, however, the effect is to multiply the value by 1·01 (a 1% increase). Conversely, if the correction is 99, then the effect is a multiplication by 0·99 (a 1% decrease). The range of correction values is 1 to 199, i.e. a multiplication range of 0·01 to 1·99.

When the screen shows that correction mode has been entered, release S3. Wait briefly for the software to exit a switch debounce routine (about 0·5 seconds). The correction value can now be changed using both S2 and S3.

If S2 is in position 2 (capacitor) then each press of S3 causes the correction value to be incremented. On the other hand, if S2 is in position 1 (inductance) then each press of S3 causes the correction value to be decremented.

Each press of S3 causes the new value to be stored to the PIC's internal non-volatile (EEPROM) memory, where it remains even after power has been switched off. (The "nulling" factors referred to earlier are not stored beyond switch-off.)

Each time the unit is switched on, the correction values for the two oscillator modes are recalled from memory and applied to each value calculation.

It would have required an extra switch to allow the software to be told to exit correction mode and the only way out of it is to switch off and then switch on again, leaving a suitable pause before doing so to allow the circuit's power line capacitors to discharge.

Correction for the other oscillator's routine is entered in the same way, first setting switch S1 to the opposite position prior to power-up.

STABILITY

A point to appreciate is that this simple unit has no temperature compensation circuitry. The oscillator frequencies can and will drift with temperature changes. For higher capacitance and inductance values, especially those in the "μF" and "H" ranges, the drift is insignificant. For lower component values (i.e. higher oscillation rates), though, you should always "null" the meter prior to taking a measurement.

For capacitance nulling the probes must be open; for inductance nulling they should be closed (shorted).

Finally, **never** try to measure the values of components that are "in-circuit". At best, the existence of other components within that circuit is likely to result in incorrect readings. At worst, if the other circuit is powered, it and the PIC LCF Meter could be damaged.

RESOURCES

The software for the PIC LCF Meter is available from the *EPE PCB Service* on 3.5in disk (for which a nominal handling charge applies). It is also available for *free* download from the *EPE* website, accessible via the Downloads click-link on our home page at **www.epemag.wimborne.co.uk** (path **PICs/LCFmeter**).

Read this month's *Shoptalk* page for information on component buying for the PIC LCF Meter.

ACKNOWLEDGEMENT

The author gratefully thanks Peter Hemsley for his excellent maths routines which have been used extensively in the PIC software, and without which this design would have been extremely difficult to achieve.

A selection of Peter's routines is in the PIC Tricks folder on our Downloads site. □

News . . .

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

MOBILISING PICTURE PHONE PATENTS

Sendo challenges Orange under Patents law, as Barry Fox reports.

ALTHOUGH less than four years old, British mobile phone maker Sendo is not afraid to tangle with the big boys. Last year Sendo pulled out of a deal with Microsoft to make Windows-powered picture phones for use on the Orange network. Sendo is still in dispute with Microsoft and is now trying to stop Orange selling Windows picture phones made in Taiwan. The Orange Smartphone, claims Sendo, infringes Sendo's patent on integrated circuits and printed circuit boards.

Last year Microsoft and Orange joined forces to launch a Smartphone service, offering SPV (Sound, Pictures and Video) on the move for 40 million Orange subscribers in 21 countries. The SPV phones use Microsoft Windows and Internet Explorer to access the Internet, and the GPRS (general packet radio service) system to squeeze higher transmission speeds from existing GSM networks.

At the London launch Orange and Microsoft announced support from Sendo, and Sendo called its Windows-powered Z100 "the world's smartest phone". A month later Sendo backed out, and adopted the rival Symbian system from Nokia.

Now Sendo has started legal proceedings in the British High Court, using recently granted British Patent 2 377 080 to try and stop Orange selling the Orange SPV phone. Sendo also wants damages for phones already sold.

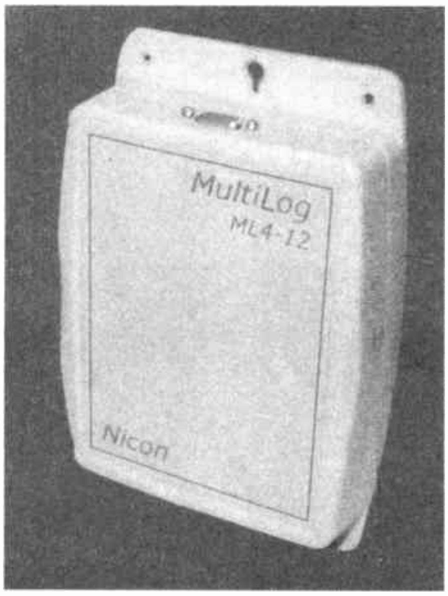
"We have tried to solve the matter in an amicable way", says Hugh Brogan, Sendo's CEO, "Now we have to take legal steps".

The patent tells how to keep the many connections to an integrated circuit short and separate from each other, by arranging them in rings like a square darts board. The power supply contacts are in the outer rings, the earth or ground contacts in the centre and data contacts in between.

So far Sendo only has a British patent. So the company cannot try to stop manufacture in Taiwan. But the UK patent has legal force as soon as the phones are imported into Britain for sale and use.

MULTILOGGING DATA

NICON Designs have introduced a low cost analogue data acquisition module that offers 4-channel 12-bit logging on demand, and with timed measurement capabilities. The Multilog ML4-12 module provides true differential and unipolar inputs with 12 programmable voltage/current ranges and independent sensor supplies for each channel.



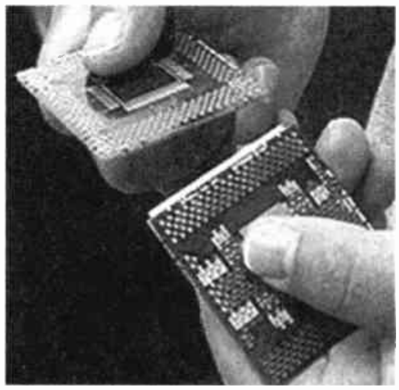
When fitted with the optional MMC memory card, the unit is capable of storing up to two million time-stamped data sets. Setup and data transfer is via a standard RS232 interface. The simple interface enables straightforward connection to off-the-shelf GPRS and LPRS modules.

Multilog is supplied with a weatherproof enclosure and Windows-based control and display software.

For more information contact Nicon Designs Ltd, Dept EPE, 13 The Buntings, Bradwell, Norfolk NR31 8PE. Tel: 01493 442350. Fax: 01493 667689.

Web: **www.nicon-designs.co.uk**.

Schmart Boards



A NEW product for developing electronic circuits and known as Schmartboard has been introduced. It is described as providing "electronic circuit blocks for engineers, students and hobbyists".

Schmartboard allows prototype electronic circuits to be assembled in a modular fashion, allowing subsequent modifications to be made with minimal changes to the overall assembly. The system uses pre-tracked printed circuit boards that are connectable like building blocks. They allow circuits to be assembled block by block, connecting the blocks together to form a functional board. Because the boards are pre-tracked, the need for wire jumpers is minimised. The boards are available in several style configurations.

For more information browse **www.schmart.com** and **www.engineeringlab.com**.

NCT on Course for 2004

SINCE joining forces with OakCAD Training, the National College of Technology has been focusing on the needs of the electronics sector. Its range of distance learning courses is suitable for beginners and those with more experience who need to update their skills.

The programme of courses offered through the college is being adjusted as part of the continuous development process and further new courses are currently being prepared for launch during 2004. These courses can lead to a BTEC qualification or taken as individual modules. Tutor support is available to help individuals through each part of a course.

Anyone interested to register can contact NCT on 08456 345 445 or view the courses on **www.oakcad.co.uk/nct.aspx**.

MINITOOL

THE new Minitool range of high quality precision tools from Shesto is designed and made in Germany to exacting standards. The manufacturers, Boehler, have over 30 years experience in producing 12V tools which answer the specific needs of anyone interested in miniature precision work. They enjoy a high reputation in Europe as well as in the USA and Canada.

The functions offered by the Minitool include sword saw, detail sander, 3D contour sander, high speed rotary tool, jigsaw/scrollsaw, planer, screwdriver/rotary tool, rotary cutting tool, engraving pen, 4-in-1 cutting tool.

For more details of the Minitool and its stockists, contact Shesto Ltd., Unit 2, Sapcote Trading Centre, Dept EPE, 374 High Road, Willesden, London NW10 2DH. Tel: 020 8451 6188. Fax: 020 8451 5450. Email: sales@shesto.co.uk. Also browse **www.minitool.co.uk**.

SQUIRES 2004 CAT

SQUIRES are renowned for their comprehensive range of miniature hand and power tools and their extensive range of electronic components. Their 2004 catalogue has recently been received at HQ. It seems even more massive than their previous one. It is impossible on this page to give full credit to the enormous variety of items that are listed and illustrated in 600-odd pages, but it seems fair to say that there can surely be nothing of the craft tools nature that has been omitted.

Squires have also purchased Gough Brothers fine art materials shop and The Nimble Needle needle craft shop, both in Bognor Regis, where Squires themselves are based. So whatever your art and craft requirements, Squires should be more than capable of helping you.

For more information contact Squires Model and Craft Tools, 100 London Road, Bognor Regis, W. Sussex PO21 1DD. Tel: 01243 842424. Fax: 01243 842525.

Email: sales@squirestools.cm.

Web: **www.squirestools.com**.

STRONG L.C.D.S

HAVE you ever had the misfortune to break the glass screen of an l.c.d., or damaged one by dropping it, or exposing it to adverse weather conditions? It seems that these are quite common occurrences, for Sharp have now introduced new "Strong L.C.D.s". These have been designed specifically for use under difficult conditions. You may not only touch and shake these new displays, but even expose them to temperatures as low as −10°C and as high as 65°C.

Enhanced integration and a more compact mechanical design make these l.c.d.s much less susceptible to vibration, surface pressure and shock. Sharp have also increased the brightness by a new long-life backlight, providing for excellent visibility even with bright sunlight or from greater distance.

Initially, the size available is 10·4 inches (26·4cm) with 640 × 480 pixels resolution, but Sharp say that 12·1in (53·3cm) with 800 × 600 pixel resolution will soon become available.

BOOSTED DVD+RW/+R

DVD recording capacity is increased again. Barry Fox reports

THE DVD+RW/+R recordable format, developed by Philips, has received three significant boosts. Pioneer, the driving force behind the rival DVD-RW/-R format has built DVD+ support into its new generation of PC burners. These are now on sale. Apple, previously committed to DVD-R, has now added DVD+RW/+R support to the latest version of its Mac operating system.

Hot on the heels of announcing 8× recording speeds for DVD+R blanks at the IFA show in Berlin, Philips and Mitsubishi/Verbatim have increased DVD+R capacity from 4·7GB per side to 8·5GB. This extends recording time to four hours of DVD-quality video or 16 hours of VHS-quality video, without the need to turn over the disc.

The new DVD+R blanks use a dual-layer coating. During recording the laser focuses first on one organic dye film, and then during a second pass on the other. Although the new blanks will only work on new recorders, the dual-layer recordings will play back on existing players – because DVD drives are already designed to play dual-layer pressed discs.

The trick is to use a highly reflective lower layer and sandwich a thin layer of semi-reflective silver-alloy in the upper layer. The upper layer passes 50% of the laser light through to the lower layer for recording and playback, while reflecting at least 18% for readout of the upper layer.

All eyes are now on Pioneer and the DVD-RW/-R camp to see if they can come up with a dual-layer DVD-R blank.

MICROMOUSE 2004

THE micro-robotics competition known as *Micromouse 2004* is to be hosted by the Technology Innovation Centre at Birmingham's Millennium Point on Saturday 19 June 2004. It is the latest event in the world's longest running robotics competition. Originated in the UK by the Institution of Electrical Engineers (IEE), it has run for more than 20 years.

The event consists of races against the clock between microprocessor controlled robotic "mice" programmed to search and solve complex mazes. There are several technical standards in the competition, with senior and junior categories. This enables individuals and organisations at different levels of technical skill to enter. Individuals, clubs, schools, colleges and universities have all competed in past competitions.

Anyone interested in learning more about *Micromouse 2004* should contact the Event Administrator, Rita Kerry, on 0121 331 5400 or rita.kerry@tic.ac.uk.

Also browse: **http://micromouse.cs.rhul.ac.uk/events**.

Handset Hazards

How safe is your mobile phone? Andy Emmerson explains how to avoid becoming the next victim.

THE pronouncement "Woman burned by exploding cellphone" was one of several similar headlines last year. It wasn't booby-trapped and it won't be the last to cause injury. So exactly what happened and why?

Figuratively, mobile phones can burn a hole in your pocket, but the last thing you expect them to do is to burn up in your hand. Yet over the past 12 months or so there has been a spate of occurrences of this kind.

According to news reports on the Web, the first victim was an Indonesian man, who suffered severe burns on his face when his cellphone ignited a fire at a gas station in 1999. Closer to home was 15-year-old Niklas Eivik in Norway, whose Nokia 3310 cellphone exploded during November 2002. A report states that the phone first vibrated, then started beeping while smoke erupted, and finally the phone exploded leaving marks on the floor, the ceiling and people in the room.

Ten months later in Amsterdam another phone, again reported to be a Nokia product, exploded in a woman's face while she was out shopping. The blast caused burns to her face and neck. Apparently the phone switched itself off when its 33-year-old owner dropped it. When she switched it back on again, the phone exploded.

LINKING FACTOR

Reading all this you might think that Nokia phones were at worst lethally dangerous or at best hopelessly unreliable. That's not the case, however, and other makers' kit has been struck as well. When an Ealing-based electrician's phone combusted spontaneously, it was a Sharp, not a Nokia.

Steve Wing said that after recharging his GX10 (in a proper Sharp charger) it started hissing, glowed red and then shot the back off the phone in a cloud of smoke. Reports on the Internet indicate that GPS receivers have also self-destructed and in all cases the linking factor is the use (or possibly misuse) of lithium batteries.

The actual mechanism causing the explosions is simple – overheating caused by a short-circuit.

BAD NAME

Investigation into the incidents shows that in most cases the explosions were caused by non-original (but perfectly legal) replacement batteries. Nokia, concerned that these explosions were giving its mobiles an undeserved bad name, held a press conference the day before this article was written at which the company took aim at unsafe, low-quality counterfeit batteries.

"I want to stress that consumer safety is our top concern," said Janne Jormalainen, Vice President, Mobile Enhancements, Nokia Mobile Phones. "We believe consumers are unknowingly being fooled into buying unsafe, low-quality batteries and we are actively taking measures to combat the illegal counterfeit operation at the root of this problem."

He revealed that tens of thousands of counterfeit products had been seized in recent raids in Belgium, the United Kingdom, and other countries in the EU, bringing the total global number of seized and destroyed products in 2003 to more than five million. As a result of these raids, authorities gained valuable leads on a counterfeit network, enabling them to begin immediate actions against those involved.

MISLEADING

Counterfeit batteries had also misled consumer groups, he said. Test-Aankoop, a Belgian consumer group, acknowledged their recent test results that had led them to announce Nokia batteries were unsafe were "most probably unreliable" due to the inclusion of counterfeit batteries in their test sample. Test-Aankoop has agreed to a new, independent test of batteries, using only Nokia original batteries.

If consumer protection groups can be fooled by sophisticated counterfeits, it's little wonder that users are taken in, although retailers should know full well when they buy through other than normal channels. For this reason Nokia will now adopt "aggressive, regional anti-counterfeit measures" to thwart the sale of products that to the average consumer appear to be Nokia original accessories.

Retailers sell counterfeit batteries for one reason only: because they are cheaper. And the reason why these replacements are cheaper is because they lack essential safety features. "Official" replacement lithium-ion battery packs cost more than generic equivalents because they include extra electronics to guarantee reliable (and safe) performance.

A small printed circuit board, shrink-wrapped inside the pack, performs a number of vital functions. While charging, the circuit balances the voltage of the cells, ensuring that both cells are properly charged as well as preventing the cells from being overcharged, which could lead to rupture.

During discharge, the circuit prevents the cells from being shorted by automatically shutting down the pack if too much current is drawn. This prevents the batteries from exploding if something shorts out the pack. To ensure long battery life the circuitry also shuts down the battery pack automatically before the individual cell voltages reach 3V.

HOBBY APPLICATIONS

Needless to say, the statistical risk of being injured by an exploding mobile device is minimal; you have more chance of winning the national lottery. But you need to be aware of the risks of misusing lithium-ion cells, regardless of their environment or application.

You may have spotted that lately some sellers have been offering surplus cellphone batteries on eBay for use in micro radio-controlled aircraft and other electronic projects. One typical battery pack contains two lithium-ion cells that can provide 8·4V at 830mAh. They are rated for discharge rates up to 1·66A. Weighing only 2oz (56g), they are seemingly perfect for most applications. In addition, with only a little bit of work, the single cells in the packs can provide 4·2V for smaller models.

So why are these cells not sold more widely? The main reason why lithium-ion batteries are not more widely sold for hobby use is the limitations in their safe use. It's a fact that lithium-ion batteries can explode if shorted out or (and this is crucial) if the cells are charged improperly. Unless you have a charger designed for charging lithium-ion cells and tailored to the specific type of cell you are using, you should not attempt to charge them at all. Fortunately, the more responsible vendors sell suitable chargers as well as the battery packs.

SAFETY TIPS

To avoid being scarred by your mobile:

- Buy only original batteries from your phone's manufacturer; products from third-party suppliers may have different characteristics even though dimensionally compatible.
- Even if the battery bears your cellphone maker's name, check that it looks "right". Crummy packaging is an obvious give-away.
- Buy from recognised dealers and keep the receipt; you'll have a job claiming against boot sale or street market traders.
- Avoid leaving batteries charging unattended in case they overheat and catch fire.

STOP PRESS

After this article was written, Nokia announced that a new study by the Belgian consumer organisation confirmed the safety of genuine Nokia batteries.

Constructional Project

SONIC ICE WARNING

TERRY de VAUX-BALBIRNIE

Don't let icy roads catch you out!

THERE is nothing new about car ice alarms. The first appeared many years ago and the author has produced one or two of these designs.

Usually, the "ice warning" is given by an l.e.d. (light-emitting diode) which operates at, say, 2°C. A small margin above the ice point (0°C) is desirable to provide an early warning.

RESISTANCE TO CHANGE

Many circuits have used a thermistor to sense the temperature of the air close to the road surface. These devices change their resistance according to the temperature (most types reduce this with rising temperature). A thermistor would therefore have a certain resistance at the chosen operating point and this could be used as a basis of operation.

This method is satisfactory but there are some potential problems. The first is that inexpensive thermistors do not have a precisely known resistance at a given temperature. The finished circuit would, therefore, need to be calibrated using a thermometer.

DRIFTING ALONG

A further problem is that the resistance of a thermistor tends to drift slightly with time. This has the effect of changing the operating point so the circuit would possibly need to be recalibrated after a period of use.

An l.e.d. is not altogether satisfactory to use as the warning device. During daylight hours, it might not even be seen. At night it tends to be distracting. It is also true that most people do not want a home-made panel to appear on their dashboard. No matter how well it might be made, it would almost certainly not blend in with the styling of a modern car.

The present design overcomes the above problems. It uses a temperature-sensing i.c. (integrated circuit) to determine the temperature. This requires no calibration because it provides an accurately known voltage output at a given temperature. The operating temperature should lie within 0·5°C of the theoretical value and it will remain like that in the long term.

HEARD BUT NOT SEEN

Instead of a visual warning, the signal given here is *audible*. This is not provided as a continuous tone but takes the form of intermittent bleeps that will not be found unduly distracting.

It was thought that *two* operating signals would provide a better warning than just one. The first occurs as the temperature falls below 4°C (single bleeps) and the other at 2°C (double bleeps). A spin-off to using an audible warning is that the device may be placed behind the dashboard out of sight.

CIRCUIT DETAILS

The complete circuit diagram for the Sonic Ice Warning is shown in Fig.1. A nominal 12V supply is obtained from the car battery via an existing fuse, the ignition switch, terminal block TB2, local fuse FS1 and diode D1. This diode provides reverse polarity protection. Thus, if the supply were to be mistakenly connected in the opposite sense it would be reverse biased and would not conduct. Capacitor C6 smoothes the noisy output from the car charging system and conditions it for the rest of the circuit.

The remote temperature sensing integrated circuit, IC1, provides an output voltage that is directly proportional to its Celsius temperature at the rate of 0·01V (10mV) per degree. It will therefore provide 20mV at 2°C and 40mV at 4°C (the chosen operating points).

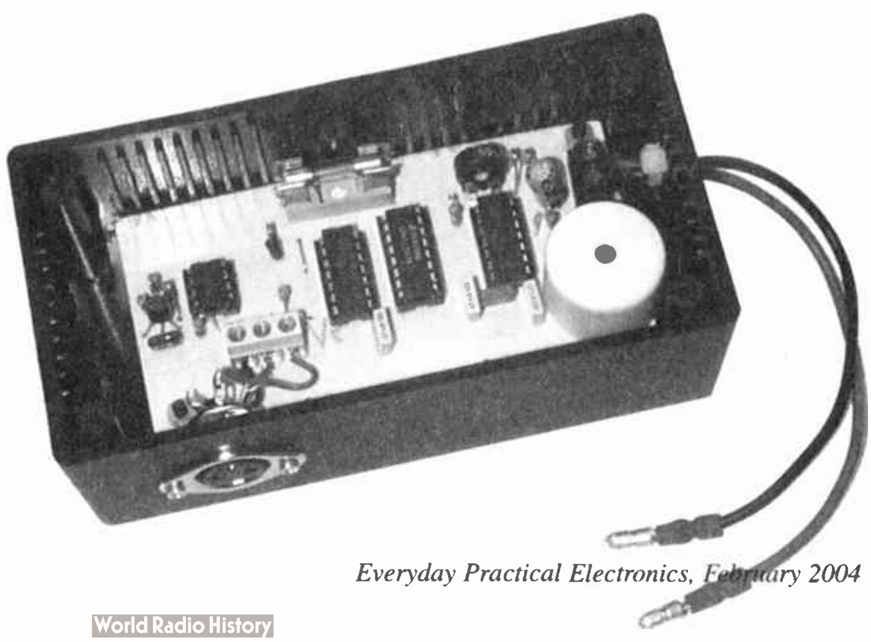
Sensor IC1's operating current is only 60μA so there is very little self-heating which would disturb the operating values. Connections are made to it using a piece of stereo screened wire via terminal block TB1 and plug and socket PL1/SK1 in the main unit.

Devices such as IC1 have a limited capability to drive capacitive loads. The cable along which the output signal passes will be moderately capacitive.

To overcome the inaccuracy which would ensue from excessive capacitance, resistor R1 is included in series with the output and wired close to IC1 itself. This has the effect of isolating the output from the load. It does not do it perfectly but this method is quite adequate for the present purpose.

The positive supply voltage feed to IC1 is made via resistor R2 on the circuit panel in the main unit. This has no effect on normal operation since, due to the low current flowing, the voltage drop across it will normally be very small.

However, in the event of a short circuit between the +V sensor wire and 0V, the current flowing from the supply will be limited to some 5mA. This is why it is satisfactory for the sensor's positive supply to be made using one of the cores of the connecting wire.



Voltage reference device IC2 has three pins: supply positive (pin 3), 0V (pin 1) and output (pin 2). The output is an accurate 2·5V over a wide range of input voltages. Capacitor C1, connected directly across the supply pins, is necessary for stable operation.

DUAL CONTROL

The output from sensor IC1 is applied to both inverting inputs (pin 2 and pin 6) of IC3, a dual low-power operational amplifier (op.amp). Resistor R6 prevents the inverting inputs from "floating" (being left unconnected) if the sensor were to be disconnected while a supply voltage was present.

The 2·5V reference voltage, from pin 2 of IC2, is connected to the "ladder network" comprising resistors R3, R4 and R5 connected in series. These provide a potential divider "chain" with connections made to two points along it. The upper point is connected to IC3a non-inverting input (pin 3) while the lower one is connected to IC3b non-inverting input (pin 5).

With the resistor values used, the voltage at IC3b pin 5 will be very close to 0·02V (20mV) and at IC3a pin 3, 0·04V (40mV). These voltages have been chosen because they are equal to those at the corresponding inverting inputs at sensor temperatures of 4°C and 2°C respectively. Any small discrepancy is not important since precise operating values are not required.

Imagine the temperature of IC1 is greater than 4°C. The voltage at *both* op.amp inverting (–) inputs will exceed those at the corresponding non-inverting (+) ones. Both outputs of IC3a

COMPONENTS

See SHOP TALK page

Resistors

R1	2k2
R2	2k2 1%
R3	27k 1%
R4	220Ω 1%
R5	220Ω
R6	2M2
R7	47k
R8, R9	2M2 (2 off)
R10	4M7

All resistors 0·25W 5% carbon film, except where stated

Potentiometer

VR1	2M2 min. enclosed carbon preset, vertical

Capacitors

C1, C4	100n ceramic (2 off)
C2, C3, C5	47n ceramic (3 off)
C6	100µ radial elect. 25V

Semiconductors

D1	1N4001 50V 1A rect. diode
IC1	LM35 temperature sensor
IC2	AD680 2·5V reference
IC3	TS932IN micropower dual op.amp
IC4	4017 decade counter
IC5	4011 quad 2-input NAND gate
IC6	7556 dual CMOS timer

Miscellaneous

WD1	solid-state buzzer, 3V to 24V d.c. operation, 10mA maximum
FS1	200mA 20mm fuse and p.c.b. mounting fuseholder
TB1	3-way p.c.b. terminal block, 5mm spacing
TB2	2-way p.c.b. terminal block, 5mm spacing
PL1/SK1	3-pin DIN line plug and chassis socket

Printed circuit board available from the *EPE PCB Service*, code 433; plastic case, size 130mm x 68mm x 46 mm (external); 8-pin d.i.l. socket; 14-pin d.i.l. socket (2 off); 16-pin d.i.l. socket; light-duty auto-type wire; bullet-type connectors; small nylon fixings; plastic stand off insulators (2 off); solder etc.; stereo screened cable; sleeving; plastic tube and silicone adhesive/sealant to make sensor (see text).

Approx. Cost Guidance Only **£16** *excl. case*

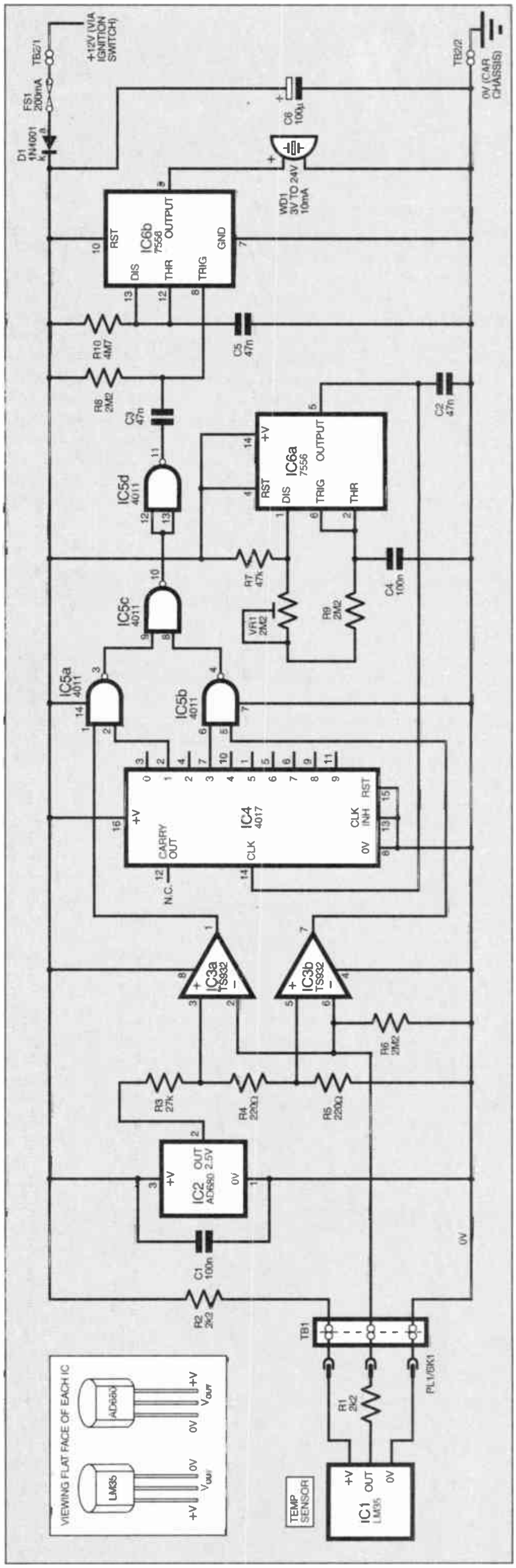


Fig.1. Complete circuit diagram for the Sonic Ice Warning.

and IC3b (pins 1 and 7) will therefore remain low.

With a temperature less than 4°C, the voltage at IC3a pin 2 will fall below that at pin 3 and IC3a output, pin 1, will go high (positive supply voltage). With a temperature less than 2°C, the voltage at IC3b pin 6 will be less than that at pin 5 and the output at pin 7 will go high as well as pin 1.

COUNTING THE COST

The next section of the circuit is centred on decade counter IC4. This device has ten individual outputs 0 to 9 (pins 1 to 7 and 9 to 11). The outputs go high in turn and the process repeats when positive pulses are applied to the clock input at pin 14. These pulses are obtained from the astable (pulse generator), which comprises IC6a (one section of dual timer IC6) and peripheral components.

Capacitor C2 bypasses any electrical noise on the printed circuit board track connecting IC6a output pin 5 to IC4 clock input at pin 14. Without this, the counter might tend to pick up false clock pulses.

Only IC4 outputs 1 and 3 are used (pins 2 and 7) in this circuit. The reset input and the clock inhibit are not required and are connected to 0V rail along with the 0V input, pin 8. Pin 12 is the carry out (which could be used to cascade more than one counter) and this is ignored.

The frequency of astable IC6a (pulse repetition frequency) is related to the values of resistor R7 and preset VR1 connected in series with fixed resistor R9 in conjunction with capacitor C4. Preset VR1 allows for an adjustment of the frequency to suit personal preference.

THROUGH THE GATE

The output from op.amp IC3a (pin 1) and output 1 (pin 2) of counter IC4 are fed to the input pins (1 and 2) of gate IC5a. Likewise, the output from IC3b (pin 7) and output 3 (pin 7) of counter IC4 are connected to the two inputs of gate IC5b. The outputs from IC5a (pin 3) and IC5b (pin 4) are fed to gate IC5c and its output (pin 10) passed to the combined inputs of IC5d.

The final output (IC5d pin 11) is normally high. Below 4°C (IC3a pin 1 high) *and* on each high pulse from IC4 pin 2, it will go low. Below 2°C it will go low on pulses received from both IC4 pin 2 and pin 7. The effect is that single low pulses are given below 4°C and double pulses below 2°C. The short interval between these double pulses is provided when IC4 output 2 (pin 4) goes high.

FINDING TIME

The final part of the circuit is based on the remaining section of dual timer IC6b. This is connected as a short-period monostable. The timing components are resistor R10 and capacitor C5 and with the values specified, the period will be some 0·2 seconds. This provides the actual buzzer "on" time.

Thus, the output (pin 9) will go high for this time when the device is triggered by a *low* pulse applied to the trigger input, pin 8. Trigger pulses are derived from IC5d output, pin 11, via capacitor C3. Resistor R8 keeps the trigger input normally high and this prevents false operation.

The purpose of the monostable is to provide short bleeps at the buzzer. Without it, the buzzer would pulse on for much longer periods due to relatively long "on" times of IC4 outputs.

CONSTRUCTION

Note that this device should never be relied on to provide a timely warning of icy roads. It does not absolve the driver from exercising normal vigilance. It is only intended to be an aid to safe driving.

Construction of the Sonic Ice Warning is based on a single-sided printed circuit board. This board is available from the *EPE PCB Service*, code 433. The component layout and actual size copper master pattern are shown in Fig.2.

Begin construction by drilling the mounting holes (the upper one should be kept well clear of the +12V track). Solder the pieces of terminal block TB1 and TB2, the i.c. sockets and the two link wires in position. Add all resistors (including preset VR1) and capacitors apart from C6.

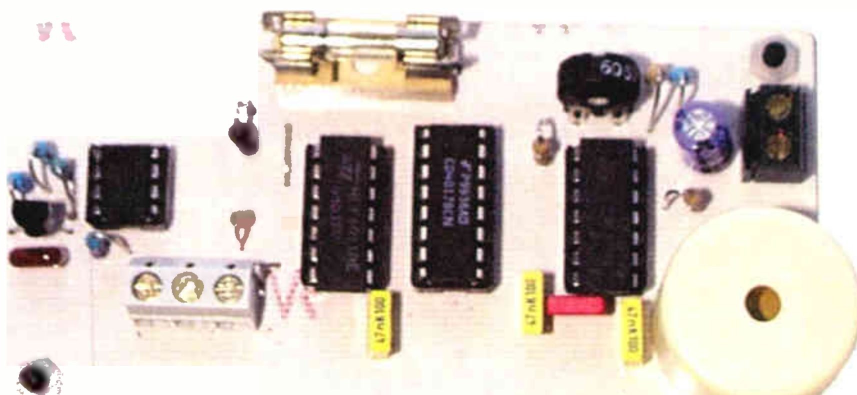
Follow with the polarity-sensitive components: electrolytic capacitor C6, buzzer WD1, diode D1 and the voltage reference device, IC2. Note that this latter component is placed so that its flat face is towards the upper edge of the p.c.b. Insert fuse FS1. Adjust preset VR1 to minimum resistance (fully clockwise as viewed from the bottom edge of the p.c.b.).

TESTING

Do not make any connections to terminal block TB1 for the moment. Commence preliminary testing by connecting a 9V battery to TB2 observing the correct polarity – usually the buzzer bleeps once on power-up. Since no sensor is present, the effect is the same as if it were present at 0°C (that is, the output would be 0V). Double bleeps should therefore be heard. Adjust preset VR1 as necessary for best effect – usually left at minimum.

Disconnect the battery and now connect the temperature sensor IC1 direct to TB1 observing the orientation. With the flat face uppermost the pins will connect correctly (the pinout is shown inset in Fig. 1). Reconnect the battery.

Providing the ambient temperature is greater than 4°C, the buzzer should remain



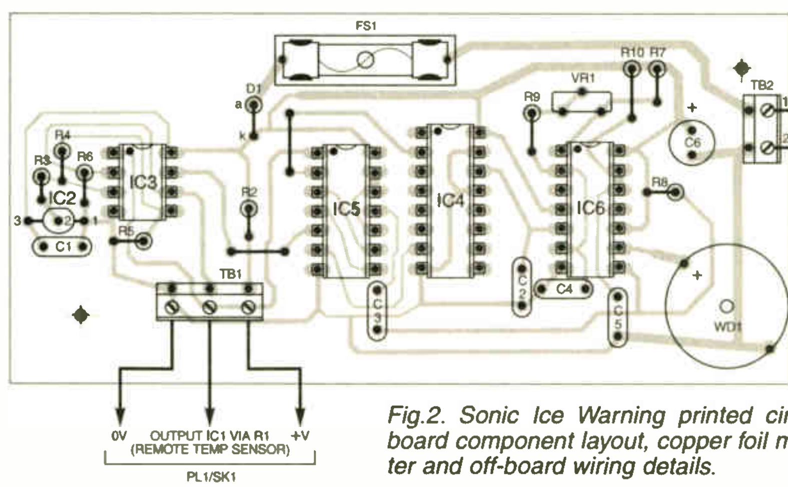
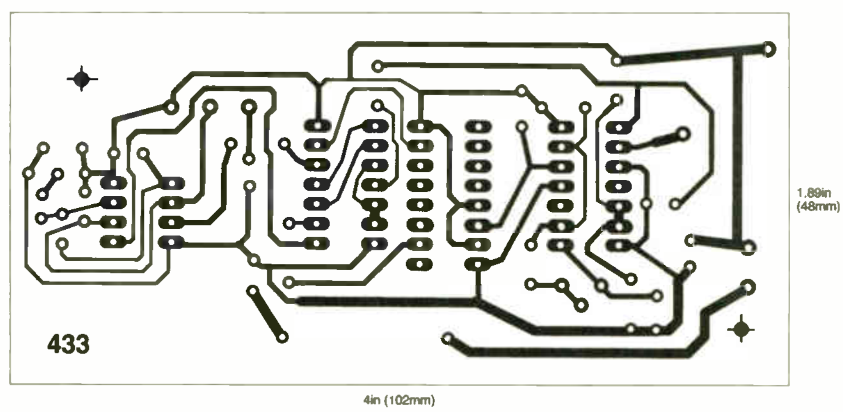


Fig.2. Sonic Ice Warning printed circuit board component layout, copper foil master and off-board wiring details.



silent. Hold digital voltmeter probes between TB1 terminals 2 and 3 (that is, IC1 output). The reading in millivolts divided by ten should correspond to the ambient temperature.

Wrap an ice cube in cling film and hold it on IC1 (this method ensures that no water can reach the connections). You should hear single bleeps when the temperature reaches 4°C and this should change to double bleeps when 2°C is reached (with approximately 40mV and 20mV respectively being indicted)

BOXING UP

If all is well, the p.c.b. may be mounted in its case and a permanent sensor constructed. Use a small *plastic* box that will accommodate the circuit panel and a 3-pin DIN socket that will be used to connect the sensor.

Mark through the p.c.b. fixing holes and drill these through. Make holes for the DIN socket fixing and a further small hole for the power supply wires to pass through. Attach the p.c.b. on short stand-off insulators and *nylon* fixings. This will prevent any possibility of a bolt head assuming battery positive potential and causing a short circuit with a metallic part of the car.

You may need to drill a hole in the lid of the box later to allow the sound from the buzzer to pass through. However, depending on the type of buzzer used, it might be loud enough without this.

WHAT A DIN

Referring to Fig.3. Attach the DIN socket and connect it to terminal block TB1 using short pieces of stranded connecting wire.

As a departure from normal practice, the metal part of the DIN socket should *not* make contact with 0V. The reason for this is because, if the supply were to be connected incorrectly (in the opposite sense), the socket body would assume battery positive voltage. It would then be possible for it to touch a metal part of the car body and cause a short circuit to the supply resulting in a remote fuse blowing.

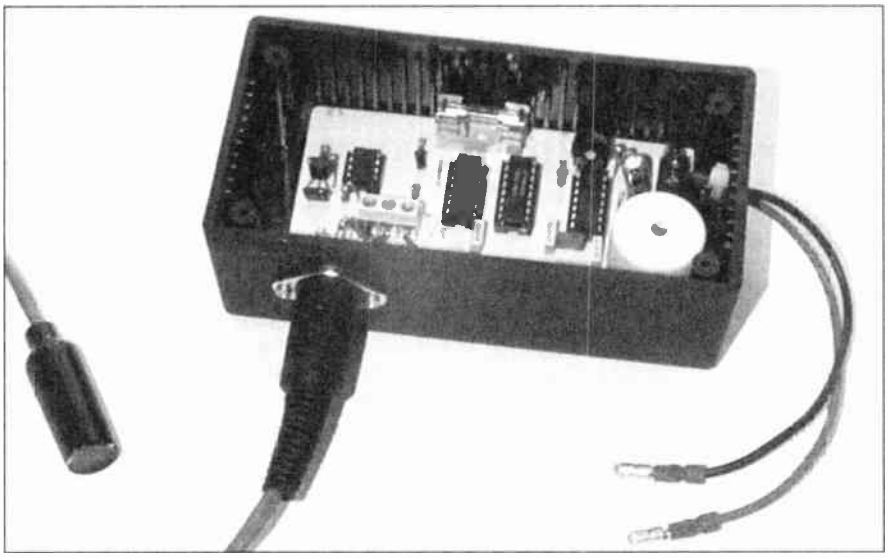
Connect short pieces of red and black *automotive type* stranded wire to terminal block TB2/1 (+V) and TB2/2 (0V) respectively. Pass the wires through the hole drilled in the case for them. Leave a little slack inside the case and apply a strain relief (a tight cable tie) so that they cannot be accidentally pulled out of the terminals. Connect the free ends of the wires to insulated "bullet" type plugs (*not sockets*).

SENSOR CONSTRUCTION

The sensor "head" unit should now be made. The method used in the prototype is shown in Fig.3. Remembering that the sensor will be sited outside the car, it is important this is completely waterproof.

Decide on suitable positions for the sensor and main unit. A good place for the sensor would be behind the front bumper where it would respond to the temperature of the air close to the road. Of course, it must not be placed near any source of heat such as the exhaust system.

Find the best way for the connecting wire to pass between the two units. Measure the length of stereo screened wire required and cut this off. The sensor provides a very low voltage output and ordinary (unscreened) wire would pick up electrical noise that could result in false operation.



Sensor head (left) plugged into the DIN socket on the side of the case.

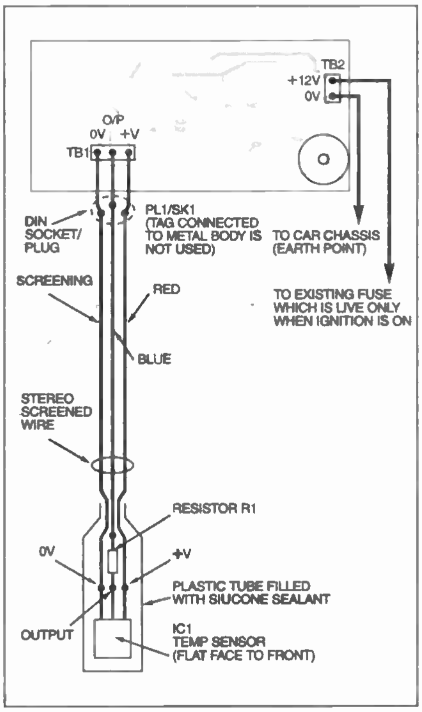


Fig.3. Sensor head details and wiring.

The prototype sensor was housed in a fuseholder boot. It is important that the screening of the interconnecting wire should be used for IC1's 0V connection and the inner conductors for its output and +V feed, *keep a note of which is which.* Use a piece of sleeving to insulate the end of the screening.

Solder resistor R1 in series with the sensor output pin inside the housing as shown. It is acceptable to solder the connections to IC1's end leads but this must be done quickly to avoid damage. Make certain all connections are properly insulated and cannot short circuit with one another.

Now fill the tube using *non-conducting* silicone adhesive/sealant. This should be forced into the open end of the tube until it is completely full and emerges from the other end. In this way, IC1, resistor R1 and the soldered joints will be totally waterproofed, insulated and held securely. Wait for the material to completely harden before proceeding.

GOOD CONNECTIONS

Secure the sensor in position on the vehicle. Apply some strain relief to the wires using, say, a small clip to prevent them pulling free. Route the wire to the main unit position remembering that wherever it must pass through a hole drilled in metal, a rubber grommet must be used. Sleeve the screening at the end and connect the wires to the DIN plug terminals that correspond to those made at the socket.

Disconnect the car battery positive terminal before proceeding. Make sure you have noted any code needed for audio equipment since this will need to be entered again when the supply is re-established.

POWER SUPPLY

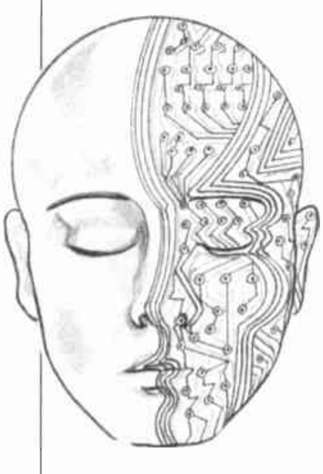
Using light-duty *auto-type* cable, make the +12V connection to a point that is "live" (via an existing fuse) *only* while the ignition is switched on. This ensures that the device does not drain the car battery and sound unnecessarily when the vehicle is left parked. Similarly, make the 0V connection to an "earth" (car chassis) point. It is often convenient to make these connections to the existing radio wiring using "snap-lock" connectors.

Note that car radios usually have *two* +12V feed wires – one is "live" all the time and the other "live" only when the ignition is switched to the "radio" position. Terminate both +12V and "earth" wires using bullet-type sockets (not *plugs*). Connect these to the unit making sure the polarity is correct and plug in the sensor.

Connect the car battery. Make a check that everything is working by switching on the ignition and applying ice to the sensor (or use freezer spray). If after using the circuit you decide to alter the operating points, change the value of resistor R3. Raising its value will lower the operating temperatures and vice versa.

FINAL POINT

Remember that the sensor has a fairly large thermal inertia. This means that it takes several minutes to respond to the temperature of its surroundings. It will not "see" sudden, local changes of temperature which can cause patches of ice to form in unexpected places! □



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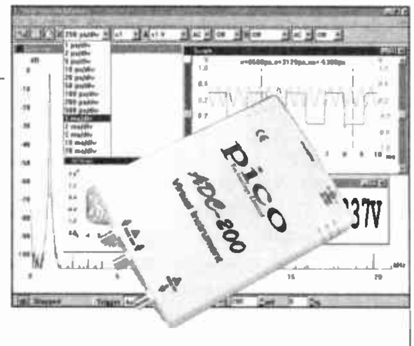

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MANTELPIECE ANEMOMETER – WINDY REPEATS

THE domestic variety of anemometer usually employs an external anemometer spinning in the wind, with a digital or linear display indoors to indicate wind speed. The anemometer itself, however, is seldom seen. This usually stands in the garden, or is attached to the roof.

The circuit of Fig.1 is a domestic anemometer with a difference. When the wind blows, a miniature anemometer spins on the mantelpiece indoors. All that is required to achieve this is a simple current amplifier, namely power transistor TR1. This amplifies the current generated by outside anemometer M1, so as to spin miniature anemometer M2 on the mantelpiece.

Both of these motors need to spin freely at various speeds, therefore "solar" motors (those designed to be powered by solar cells) are recommended. As shown, both motors will spin clockwise. Since we need to overcome the base-emitter voltage drop of TR1, a higher voltage solar motor (6V to 12V) is recommended for M1. A lower voltage motor here would require higher wind speeds to start to move M2. M2 on the other hand is any solar motor powered at between 3V and 12V, preferably geared.

If wind speed is moderate to high, an ungeared M2 will spin at great speed, therefore a geared motor will give a more realistic representation of the wind speed outside. Supply voltage should match the voltage of M2, alternatively use a suitable series resistor with M2. The motor outside is connected to the circuit inside through a length of narrow "twin-flex" wire. Resistor R1 serves to limit current through the base-emitter junction of TR1 (since this would not normally rise very high, the value of R1 may be low). Preset resistor VR1 adjusts the sensitivity of motor M2 – that is, its readiness to spin.

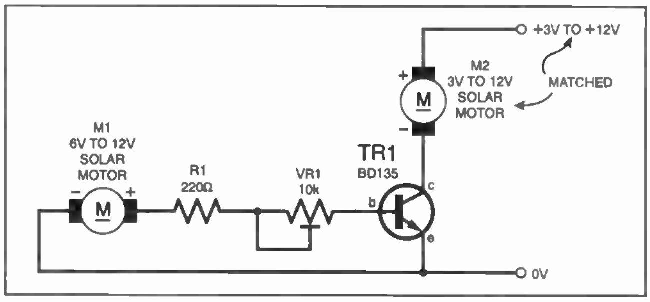


Fig.1. Circuit diagram for the Mantelpiece Anemometer.

A mains operated d.c. power supply is recommended for the circuit, since it may draw significant current over long periods. Since most small motors will not draw more than about 0·5A, and since TR1 is rated as 1·5A 12·5W, there should be no overheating of TR1, even if a 12V supply is used. However, if M2 at full speed draws more than about 1A, use a suitable series resistor to limit current.

If a more powerful external motor and larger anemometer cups were to be used for M1, this could in fact drive M2 directly.

Thomas Scarborough, South Africa

SHORT CIRCUIT ALARM – DESIGNER SHORTS?

BEING prone to accidentally shorting out my home-made 2V to 25V power supply, I decided to incorporate the alarm circuit shown in Fig.2 to warn me when it happens. Its operation is as follows:

As long as the power supply output voltage is above 1V or so, the current flowing through resistor R1 will be sufficient to keep transistor TR1 saturated, ensuring that transistor TR2 is held off. If the power supply output is short circuited, the current flowing through resistor R1 will fall to zero, and transistor TR1 will be cut off. This allows transistor TR2 to conduct due to the base current via R2, saturating the transistor. This turns on the piezo sounder WD1.

Resistor R3 reduces the unregulated voltage of the power supply to that required by the piezo sounder and should be selected to suit. The optional l.e.d. D1 can be included in series with the sounder to give a visual indication if required. The circuit should work well on any power supply with an output voltage greater than about 1V, so long as the unregulated voltage is sufficient to drive the sounder.

If the unregulated voltage is around 12V then R1 and R2 should be 47kΩ, and above 20V they should be 100kΩ – the general rule being that R2 should be low enough to saturate TR2 when TR1 is cut off, and R1 should be low enough to saturate TR1 at the lowest output voltage of the power supply.

The power supply cable feeding the unit should be substantial enough to prevent significant voltage drop across it, which would prevent the unit from working.

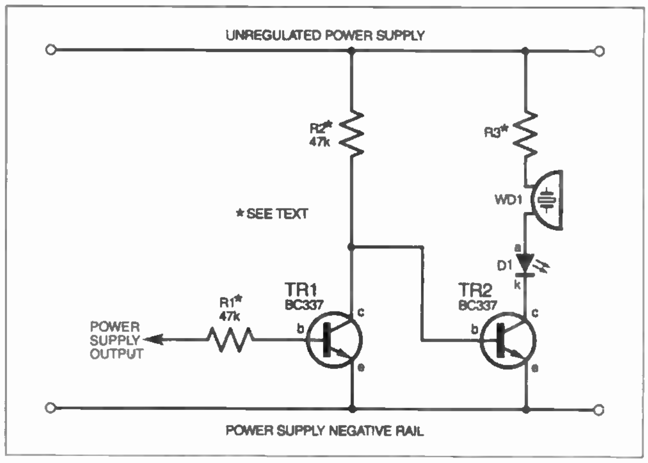


Fig.2. Circuit diagram for a Short Circuit Alarm.

This circuit, although useful, is no substitute for a current limiting circuit, and is intended to complement such a circuit rather than replace it.

P. A. Tomlinson, Hull

BLUE FLASH – A VOLT FROM THE BLUE

A SUPPLY of more than 3V is normally required to light a blue l.e.d. The circuit diagram shown in Fig.3a will repeatedly flash a blue l.e.d. from a 1·5V D-cell.

Transistors TR1 and TR2 are configured as a complementary astable with a cycle of approximately 1 to 2 seconds, adjustable by potentiometer VR1. In this type of oscillator both transistors are either on or off together.

While TR1 and TR2 are off, which is the case for most of the timing cycle, capacitor C3 charges close to the supply voltage through resistors R3 and R7 and similarly C4 charges through R6 and R5. When C2 charges sufficiently so that it can no longer divert the current through VR1, R1 and R2 from entering the base of TR1 the astable switches and both transistors are driven into saturation.

The collector of TR1 now falls close to 0V taking the negative side of C3 well below zero volts, similarly the positive side of C4 is forced above the voltage of the battery as the collector of TR2 rises. Capacitor C4, the battery and C3 are now effectively connected in series across the l.e.d. (see Fig.3b) and there is sufficient voltage to cause the l.e.d. D1 to light.

Transistors TR1 and TR2 only remain on for a short time while sufficient base current to TR1 can be supplied by C2. Once TR1 starts to come out of saturation the astable switches and the the next cycle begins.

If the cycle rate is too quick the flash brightness will dim because C3 and C4 do not get enough time to recharge between flashes. Capacitor C1 helps to maintain the flash brightness as the battery ages.

B. L. Page, Bracknell

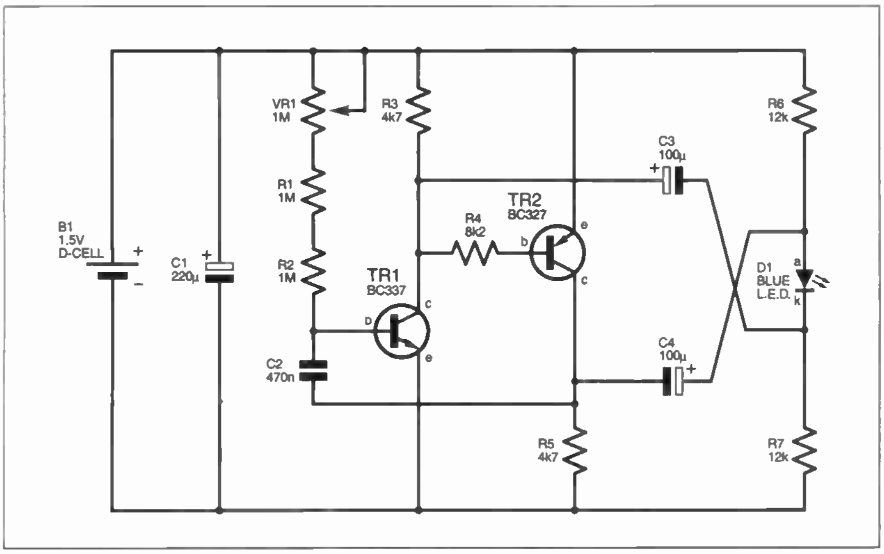


Fig.3a. Circuit diagram for a Blue L.E.D. Flasher.

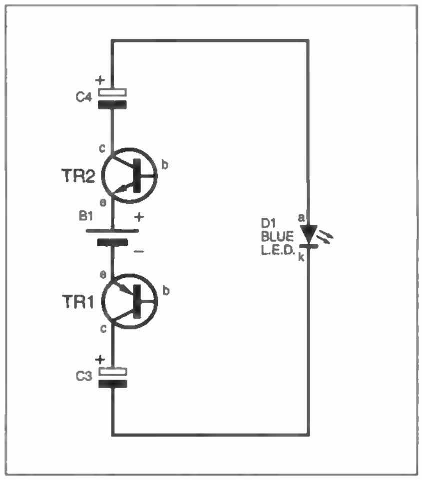


Fig.3b. When TR1 and TR2 conduct C4, B1 and C3 are connected in series across D1.

STEPPER MOTOR DRIVER – WAVY PACED

THE simple circuit shown in Fig.4 will operate a unipolar stepper motor (6V to 15V) in wave mode, using just a handful of common components. Such motors are now widely available from discarded floppy disk drives, printers and scanners in particular. As shown, the circuit is wired up for manual control, with switch S1 determining the motor's direction (clockwise/anticlockwise), and S2 advancing the motor one step at a time. If S1, S2, R1 and C1 are removed, then IC1 pins 10 and 15 may be controlled by digital inputs.

IC1 is wired as a 4-bit binary up-down counter. The state of the up-down input at pin 10 (through S1) causes the motor to reverse direction. Depending on the state of pin 10, the count is either increased or decreased as digital pulses are received at clock input pin 15, thus turning the motor either clockwise or anticlockwise.

IC1's outputs Q1 to Q4 produce a four-bit binary number, which is converted to decimal, one to four, to sequence the four phases of the unipolar stepper motor. The two centre digits of IC1's binary sequence repeat every four steps, therefore outputs Q2 and Q3 are selected to clock two-to-four line decoder IC2.

Four IRF510 power MOSFETs (or similar) are used to drive the stepper motor. These have the advantage of being able to carry a heavy current, while introducing a minimal voltage drop across the motor. Since stepper motors work up quite a heat (they are frequently rated at more than 100°C). a suitably rated resistor may be inserted in the motor's common line to avoid excessive heating if full power is not required. A suitably rated power supply is also required – typically 500mA.

Further possibilities would be to use the circuit (with suitable ballast resistors) to sequence lights or l.e.d.s, or to use switches S1 and S2 to carry out sequential tasks with button-presses or even a light beam. If eight signal diodes are added, as demonstrated with the *Manual Stepper Motor Controller* (see *EPE* May 2001), and if a 47kΩ pull-down resistor is employed at the gate of each MOSFET, the circuit will operate a unipolar stepper motor in full-step mode. thus greatly increasing torque.

Thomas Scarborough, South Africa

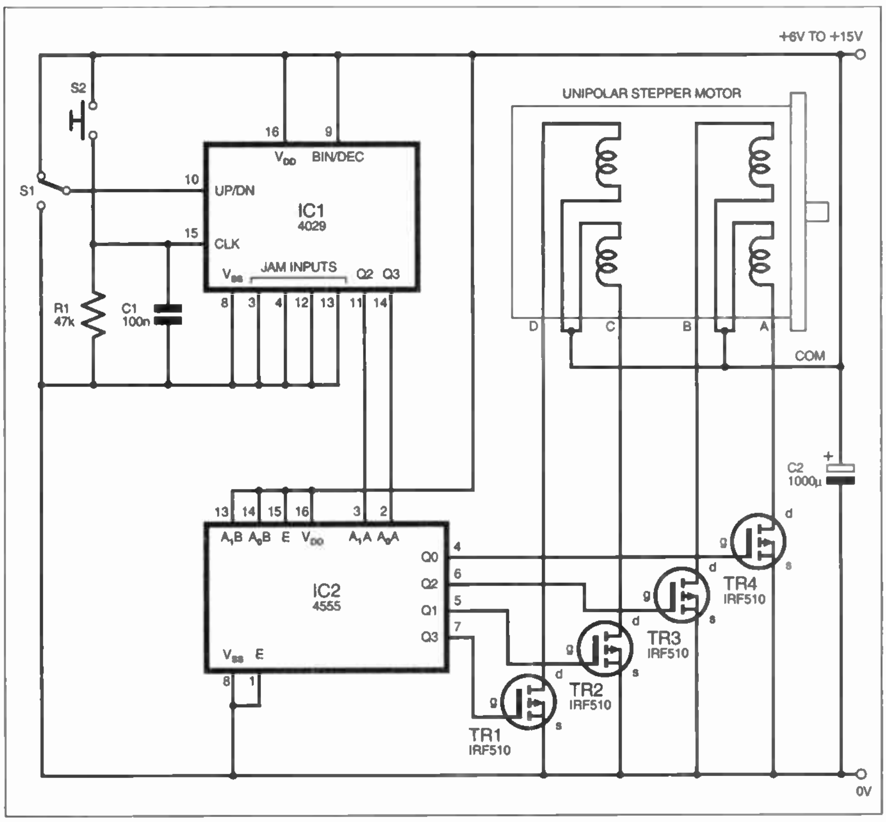


Fig.4. Circuit diagram for a simple Stepper Motor Driver.

AUDIO SIGNAL GENERATOR – A SOUND BRIDGE

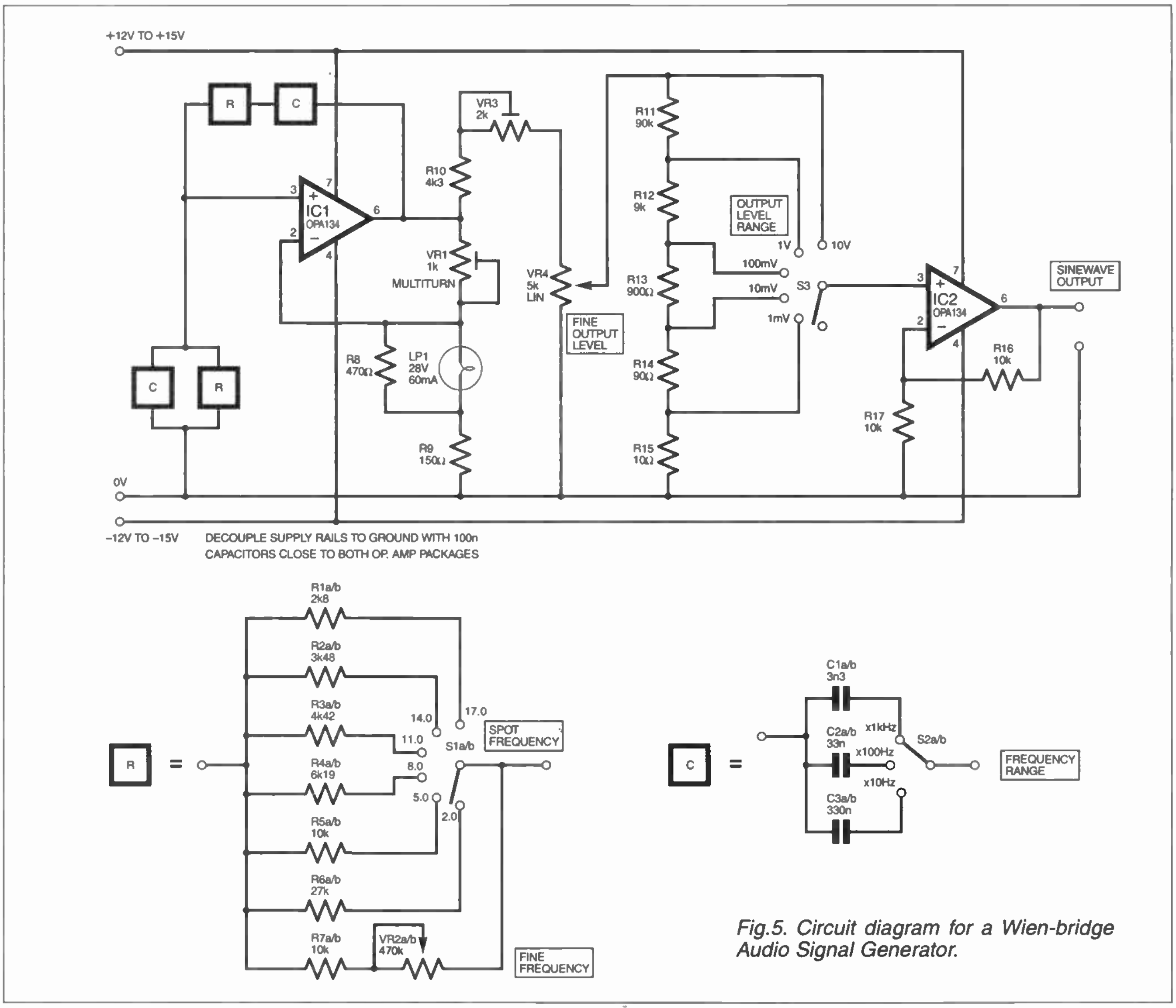


Fig.5. Circuit diagram for a Wien-bridge Audio Signal Generator.

THE Wien-bridge oscillator (WBO) is familiar from textbooks. However, a practical WBO-based signal generator covering the whole audio range of 20Hz to 20kHz benefits from some tweaks to the basic textbook circuit.

The oscillation frequency of the bridge is given by $1/(2\pi RC)$, where R and C are the resistance and capacitance in the branches of the Wien network (blocks "R" and "C" in the circuit diagram of Fig.5). Switch S2 selects the frequency decade.

However, frequency adjustment with a simple variable resistor (potentiometer) would give a horrendously non-linear (reciprocal) relationship between control rotation and frequency. The circuit shown in Fig.5 therefore uses switched resistors R1a to R6a and R1b to R6b to provide six evenly-spaced frequencies per decade (e.g. on lowest frequency range: 20, 50, 80, 110, 140, and 170Hz) with a dual-gang variable resistor VR2 wired in parallel to access intermediate frequencies. The unusual resistor values are from Rapid Electronics's 0·4W, 0·1% precision range (not much more expensive than 1% types).

In WBOs, the closed-loop gain of the active device must exactly balance the attenuation in the Wien network, if the oscillation is not either to die away, or run into clipping. Several methods are commonly applied, but a small incandescent lamp (28V, 60mA) appeared a simple and cheap solution.

When used on its own, preset VR1 could not be adjusted to a value which gave stable oscillation over the whole frequency range, with large periodic variations of amplitude ("squegging") often observed. Adding resistors R8 and R9 solved these problems by making the feedback factor less sensitive to the lamp resistance. Amplitude bounce on changing frequency died away in 5 to 6 seconds, and a good sinewave was available over the whole range.

The feedback network has a low resistance of around 500 ohms to 600 ohms, so IC1 must be able to provide over ±15mA output current. The OPA134 has an output current rating of ±35mA as well as low distortion.

The amplitude of the sinewave at the output of IC1 is not well-defined, so preset VR3 is used to adjust the amplitude at VR4 to ±5V peak, so that the maximum output from buffer IC2 is ±10V. Potentiometer VR4 and the stepped attenuator series resistor (R11 to R15) then allow output level to be adjusted. The attenuator resistors are made up from series combinations: 90k = 75k +15k, etc.

The prototype had a reasonably flat frequency response: 1dB down at 20kHz. To estimate the distortion, a notch filter was used to null out the fundamental at 1kHz by –66dB and the residual viewed on an oscilloscope. Only the fundamental could be seen above the noise. Thus thd (total harmonic distortion) is likely to be no worse than 0·05% at 1kHz – although it may be larger at lower frequencies as lamp LP1 heats and cools during an oscillation cycle.

M. Toohey, Manchester

Special Feature

SURFACE MOUNT DEVICES

LYN JONES

How to use SMDs – it's easier than you might think

Most commercial equipment is now made with at least some surface mount devices (SMDs) which means that automatic equipment can place components on a printed circuit board (p.c.b.), making production faster and reducing costs. Another advantage of SMD technologies is miniaturisation. Equipment that uses SMDs is usually smaller than if through-hole components are used, and there are major advantages in not having to drill holes to accept component leads.

For many hobbyist constructors, though, there may seem little appeal to SMDs since through-hole components work well. However, the major advantages of SM components enjoyed by manufacturers can be had with minimal equipment. It is worth noting also that many components are now only available as SMDs, which is a trend that is set to continue.

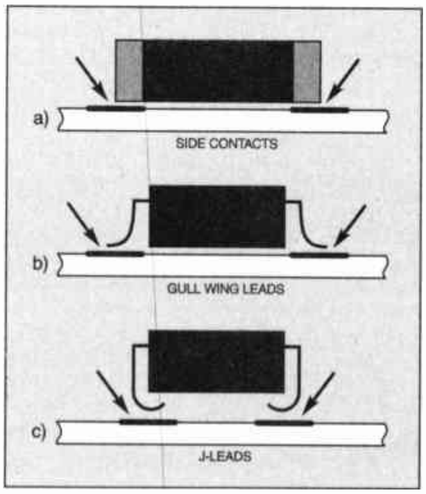


Fig. 1. SMD chip (a) and semiconductor (b and c) contact assemblies.

COMPONENTS

Most of the normal components that are used in electronic circuits are available as SMDs, including semiconductors, resistors, capacitors, inductors, switches and connectors. As with through-hole components, there is a large array of sizes and variations available.

One of these variations is in the lead-outs of the components. Most passive SMD components are usually called "chips" and have the contacts either side (Fig.1a), while semiconductors usually have bent legs (Fig.1b and Fig.1c). Solder is simply applied between the contacts and the p.c.b. pad, in the same way as with a through-hole component.

Table 1 lists the dimensions of some common SMD chip packages, which are indicated by number codes. The smallest sizes (0402 and 0603) are often used in modern commercial equipment, but the 0402 size is too small to solder accurately by hand. Larger sizes are easier to solder manually, with size 1206 chips being the recommended choice for hobbyist constructors.

Table 1. Typical chip dimensions

Size code	Width (mm)	Length (mm)
0402	1·0	0·5
0603	1·6	0·9
0805	2·0	1·3
1206	3·2	1·6

OFF THE MARK

One of the problems that results from the small size is that many components lack the usual markings. Chip capacitors are the worst offenders as they have no marking whatsoever. Some components, mainly resistors, have a three or four digit code that identifies the value. See Panel 1 for more information on resistor markings.

Electrically, the components have similar characteristics to through-hole equivalents. But note that the power dissipation and working voltages are typically lower because of the smaller size. Like all components, SMDs have a limited shelf life because the contacts oxidize. However, the packaging is designed to limit this problem and components should be stored in their protective packaging until they are needed.

One major concern for constructors is that the components are generally only available in large quantities from major mail order suppliers and can sometimes be difficult to obtain. It might be worthwhile buying some packs of assorted surplus components, especially resistors and capacitors, when they are advertised. Sometimes it is possible to salvage parts from scrap commercial equipment p.c.b.s.

P.C.B.S FOR SMDS

Readers who produce their own p.c.b.s should already have the equipment needed for SMDs, especially if an ultra-violet light box is available. Most p.c.b. CAD (computer-aided design) packages have SMD capabilities available.

Not everyone has access to a UV light box, though, and then the only way to create a p.c.b. is by hand. To show how simple this can be, the author's prototype for the demonstration circuit, shown in Photo 1, was hand-drawn on a small scrap of copper-clad board using etch resist transfers and a pen.

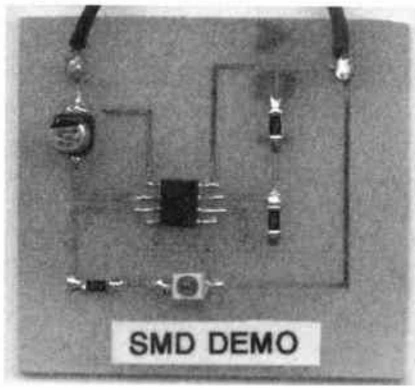


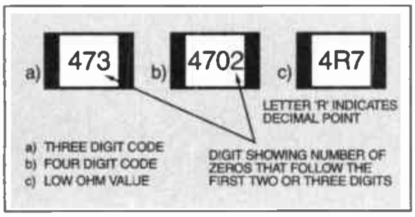
Photo 1. The demonstration circuit board was hand-drawn.

One of the biggest advantages, as already mentioned, is that no holes need to be drilled to take the components. Removing this additional stage means that constructors can immediately work on the p.c.b. after the etching process has finished. This rapid turnaround in prototyping is a definite advantage for those who like to see as quickly as possible if their new circuit actually works!

TOOLS

Many readers will already have the tools that are needed for working with SMDs. Panel 2 lists the few tools that are needed (although some readers might like to add to this list).

PANEL 1. Resistor Codes



The three main numbering systems used on SMD resistor chips. With types *a* and *b*, the codes are simply made from the first significant figures with the last digit indicating the number of zeros. In these two examples, both resistors are 47k ohms.

Another code is often found on low value resistors in which an R is used to show the value in ohms. If this appears with numbers either side it acts as the decimal point, so in example *c*, the value is 4·7 ohms.

The most important tool is the soldering iron, which should have a pointed tip so as to accurately supply heat to the components. Most low power soldering irons are adequate, but a soldering iron station is more useful because the temperature of the soldering iron can be altered depending on the component that is being soldered. Set the iron to the lowest setting that melts the solder and gives a good joint.

Some manufacturers produce soldering iron handles that resemble tweezers with two tips either side of a handle, as shown in Photo 2. These are used to heat both sides of an SMD chip simultaneously, which can be especially useful when removing a component. It is also possible to get special two-pin soldering iron tips that can be used on standard soldering irons, but these restrict the user to one component size at a time.

A source of hot air can be useful to melt the solder on more than one pin of a component. In industry, special hot air guns and soldering pencils are used, some needing compressed air. The unit shown in Photo 4 has adjustable airflow and temperature controls, and the nozzles can be changed depending on the component dimensions. For occasional use, a small butane powered blowtorch is useful, providing it has a suitable "hot air" adaptor which does not produce any flames that would damage the board.

A fine grade solder, for example 0·4mm or 0·7mm, is preferred because it is easier to dispense just the right amount of solder onto the joint. Both traditional solders and lead free equivalents can be used, but a

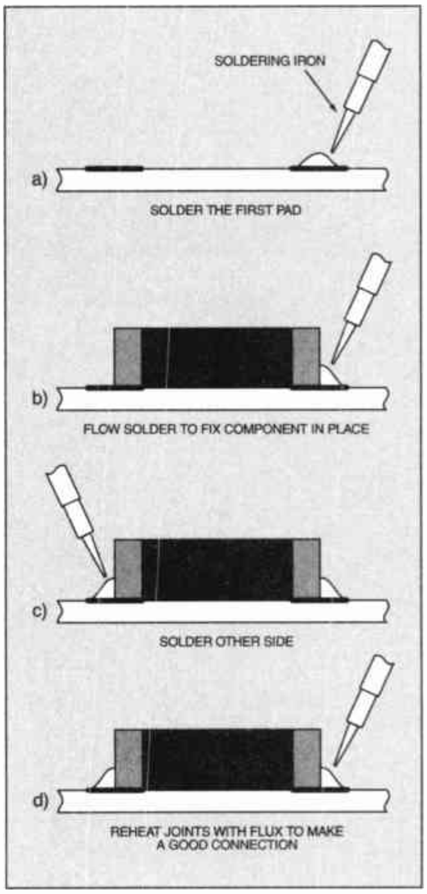


Fig.2. Recommended steps when soldering SMD components.

PANEL 2. Tools

For SMD soldering you will need:

- Soldering iron with small pointed bit and fine solder
- Flux pen and (optional) flux cleaner
- P.C.B. cleaner block and/or abrasive pen
- Tweezers with fine points (e.g. size AA)
- Magnifying lens

Additional tools for rework are:

- Hot air gun
- Desoldering braid and solder sucker

Recommended:

- Bench mounted lamp unit with magnifier

"no-clean" flux provides a cleaner and more satisfactory result than "rosin" flux.

Because of the small size of components, a well-lit workstation is necessary. Some readers will find a magnifying lens a necessary aid, in which case a bench mounted magnifier and lamp unit is ideal.

SOLDERING

Soldering SMDs onto a p.c.b. is straightforward. Following the steps outlined below, and with a little practice, readers who are competent in through-hole assembly will become proficient in soldering SMDs. Fig.2 shows the most important stages graphically:

1. Prepare the p.c.b. using a p.c.b. cleaner block or an abrasive pen to make sure that the copper is clean and will accept the solder.
2. Place a small quantity of solder onto one of the pads for the component, as shown in Fig.2a.
3. Offer the component onto the p.c.b. using tweezers and flow the solder to secure the component in place as shown in Fig.2b. Make sure that the component is flush and square with the p.c.b., checking for short circuits between pads.
4. Solder other pin(s) or pad(s) on the device. For chips, as shown in Fig.2c, simply solder the other side. For i.c.s, continue

*Photo 2. Soldering station with both standard and tweezer-type soldering irons. Courtesy **www.paceworldwide.com***

*Photo 3. The Antex 690SD temperature control solder station with a selection of surface mount bits. Courtesy **www.antex.co.uk**.*

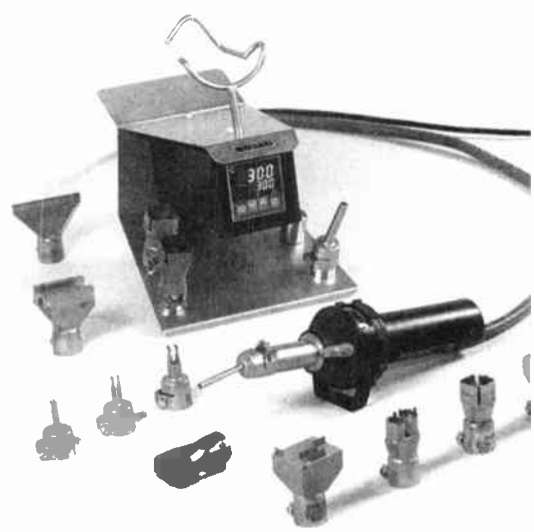


*Photo 4. Hot air station for SMD rework. Courtesy **www. leister.com**.*

with the lead that is diagonally opposite to the first pin then continue in any order.

5. If needed, reheat the joints with flux (from a flux pen) and melt the solder so that all connections are good and "wet" as in Fig.2d.

6. Inspect the whole component and check for dry joints etc. Should you need to remove excess solder shorting out i.c. pins, first apply some flux and re-flow the solder using the soldering iron.

7. Repeat for any other components.

8. Clean off any flux residue on the board as this could lead to reliability problems.

A solder resist layer is usually present on commercial boards to prevent solder shorts and to stop the solder flowing along the tracks. Home-made p.c.b.s usually do not have the benefit of this layer, so a little additional care is needed when the components are soldered onto the p.c.b. Sometimes a small piece of heat resistant Kapton tape can be used as a solder resist, or as protection for other parts on the board.

Care is also needed not to overheat the components because their small size makes them more susceptible to heat damage. As when soldering through-hole components, the soldering iron should be used for the shortest time possible for the solder to melt and flow to make a good joint.

COMPONENT REMOVAL

Although soldering components onto a p.c.b. is a relatively easy operation, sometimes components need to be removed to rework a p.c.b. The most important consideration when removing SMDs is to make sure that the pads do not lift off from the p.c.b. Extra care is needed because the heat required to melt the solder also loosens the adhesive that bonds the copper pads and tracks to the board.

For many components, the whole device must be heated so that all soldered joints melt simultaneously. However, care is needed because some components, like electrolytic capacitors and l.e.d.s, are made from plastic housings that melt with the heat.

On some commercial p.c.b.s a small spot of adhesive is used to hold the components in place so that they do not fall off in the soldering machinery. If boards using this technique are encountered, take extra care not to damage the pads because more force is needed to remove the components.

There are three methods that can be used to remove SMDs from a board, as shown in Fig.3.

Small chips can be removed simply by heating the whole component with the soldering iron tip, as shown in Fig.3a. Sometimes, a little solder might need to be added to cover the whole component to make it easier to remove. A solder sucker can be used to "vacuum up" the component.

Medium sized components, like larger chip resistors and i.c.s, can be removed by hot air, as shown in Fig.3b. Take extra care not to dislodge nearby parts when heating up the p.c.b. (the use of Kapton tape is advisable). Lift the component straight up using tweezers.

Large components (especially electrolytic capacitors) may be gently prised off one side at a time, which is shown in Fig.3c.

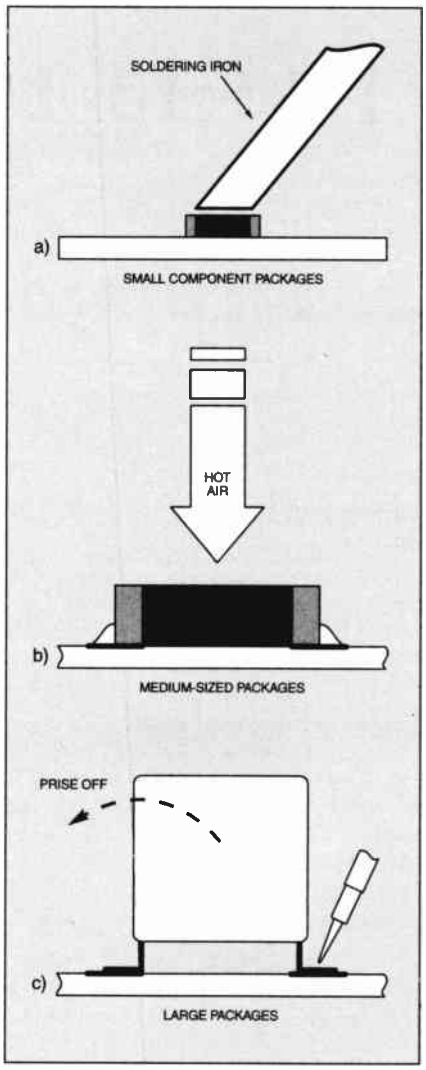


Fig.3. Removal of SMD components from a circuit board.

Gently lever the component when the solder is fully molten, taking extreme care not to lift off the pad. Some components might need tweezers to be used underneath to prise the part off the p.c.b.

The pads should then be cleaned off using desoldering braid before a new component is soldered onto the board.

EXAMPLE CIRCUIT

The example circuit presented in Fig.4 can be used to demonstrate the soldering techniques for a number of common and low cost SMD components. It is a simple 555 timer plus l.e.d. flasher circuit that can

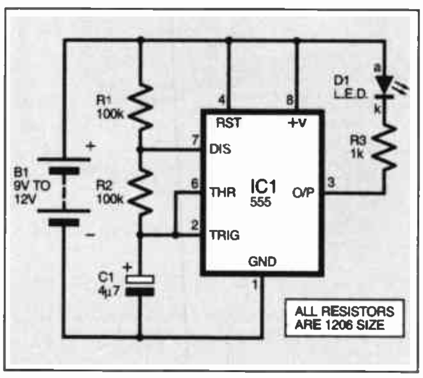


Fig.4. Circuit diagram for the SMD assembly demonstration board in Photo 1 and Fig.5.

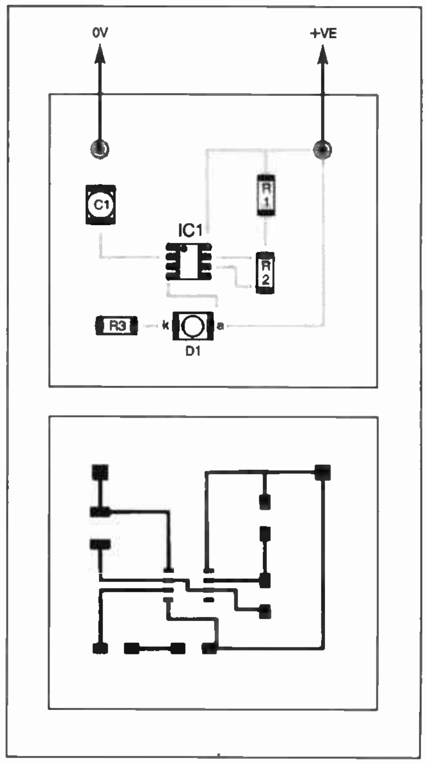


Fig.5. Component and track layout for the suggested demonstration p.c.b.

be constructed with minimal cost. This circuit should be familiar to most readers, which is why it has been chosen and no functional description is offered here.

The p.c.b. layout shown in Fig.5 has been designed with space to help readers who are new to SMDs to solder the components. This board is intended for creation as described earlier. It is *not* available for purchase. Throughout construction, refer to the soldering guide given earlier.

Start by soldering the resistors on the p.c.b. as these are the smallest components. The i.c. should then be fitted, checking the orientation, which is usually shown by a small dot, indent or the manufacturer's logo near pin 1. First solder pin 5 of the i.c., then solder all the remaining pins in any order.

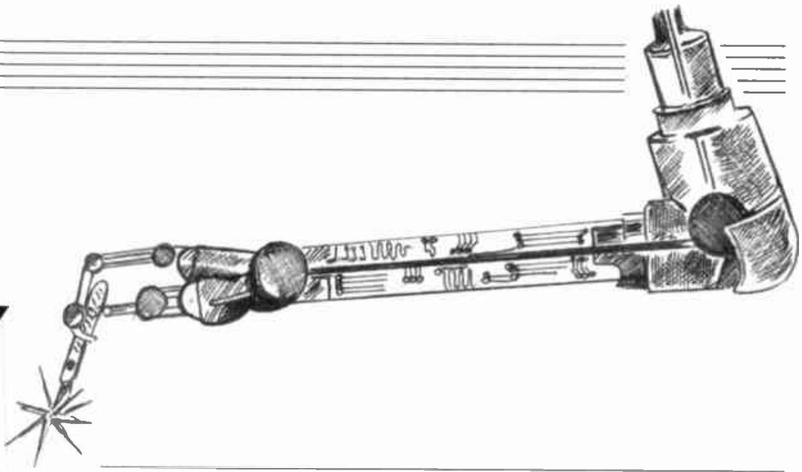
Finally, solder the capacitor and the l.e.d., making sure that they are both in the correct orientation. Electrolytic capacitors usually have a mark showing the negative side, but note that with tantalum capacitors the mark shows the positive side. L.E.D.s usually have a dot or mark on the cathode, but it is advisable to test this first using a multimeter.

The circuit can be powered from any 9V or 12V d.c. power supply, and can be incorporated into many different projects. The l.e.d. should flash for about half a second every one and a half seconds, but this can be altered by changing the resistor and capacitor values.

CONCLUSION

With SMDs being used increasingly in equipment, an appreciation of how to use them is important for constructors and students. It is clear that we will all encounter more of these components as the industry makes ever smaller products. Additionally, many readers will appreciate the speed with which designs can be made into working circuit boards when they use SMDs, with the space saving an additional benefit. □

CIRCUIT SURGERY



ALAN WINSTANLEY and IAN BELL

Following on from last month's column, the basic design of a single MOSFET amplifier stage is outlined, anti-static soldering precautions are described and we look at the differences between CMOS and bipolar timers.

MOSFET Amplifier Basics

LAST month we looked at the basic physics of how MOSFETs can conduct in a linear circuit. Many readers probably think of power switching when MOSFETs are mentioned, as this is a particularly popular application. Furthermore, a look at a catalogue such as Farnell will reveal a lot of switching MOSFETs and few or no devices obviously aimed at linear applications.

However, MOSFETs can be used in linear amplifier circuits, and are commonly used this way inside i.c.s. Discrete devices optimised for linear rather than switching use do exist, for example the ADL1101 matched *n*-channel MOSFET pair from Advanced Linear Devices Inc., which is targeted at precision analogue circuit designs.

Another area where linear discrete MOSFET circuits are used is in RF amplifiers, in particular dual-gate MOSFETs (semiconductor tetrodes) such as the BF996S from Philips. Dual-gate MOSFETs are used to build cascode amplifiers, which have better performance than single transistor amplifiers. MOSFETs are also used in the output stages of audio power amplifiers.

This month we will look at the design of a single transistor MOSFET voltage amplifier. Previously, after a request to discuss linear MOSFET circuits, we described the behaviour of a MOSFET and showed that in the saturation region the drain-source current was controlled by the gate-source voltage, more or less independently of the drain-source voltage. This region of operation is exploited in linear amplifiers.

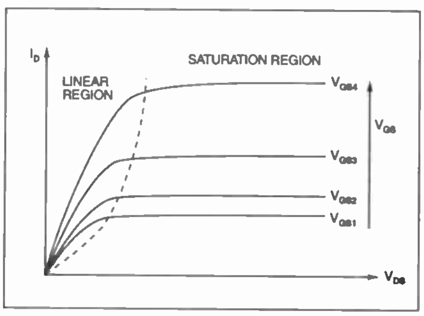


Fig.1. Idealised output characteristics for a MOSFET transistor.

The first step in designing such a circuit involves finding a suitable operating point at which to bias the transistor. Usually this will be well into the saturation region to allow the device to amplify a relatively wide range of signal levels without distortion (see Fig.1).

Amplifier Circuit

The amplifier circuit is shown in Fig.2. This circuit will look familiar to many readers as the same circuit arrangement can be used with BJTs (bipolar junction transistors) and JFETs (junction field-effect transistors). In this circuit resistors R1 and R2 set the bias voltage at the gate, the output voltage is developed across R3 and R4 provides negative feedback to stabilise the bias.

The voltage at the gate V_G is given by the standard potential divider equation $V_G = V_{DD} \times R_2/(R_1+R_2)$ and controls the gate-source voltage along with R4. This determines the quiescent drain current, I_{DS}, an important element in the bias conditions.

Resistors R1 and R2 can be large values to keep the input impedance high; values around 1M are practicable. Similar circuits using BJTs cannot usually employ such high values due to the need to supply base current without loading the potential divider.

The quiescent drain-source current is usually chosen by the designer rather than calculated. A value which gives best performance can be selected using the data sheet, but other considerations such as power consumption may come into play.

If we know the required value of I_{DS} we can find the corresponding value of V_{GS} using the equation $V_{GS}=V_T+\sqrt{(I_{DS}/K)}$ or using a suitable graph from the data sheet. To use the equation we also need to know the threshold voltage V_T and the transistor gain parameter K.

For example if we have a MOSFET for which $V_T= 0{\cdot}7V$ and $K=2{\cdot}5mA/V^2$ and we choose a quiescent drain-source current of 10mA we require a gate source voltage of $0{\cdot}7+\sqrt{(10/2{\cdot}5)} = 2{\cdot}7V$.

Unfortunately K is a fundamental MOSFET parameter that you may not find on the data sheet. It is related to the **transconductance** (g_m), which is often quoted, by $g_m=2\sqrt{(KI_{DS})}$, or $K=g_m^2/(4I_{DS})$. Note that transconductance varies with the drain-source bias current. The above example has a transconductance of about 3·2mA/V at I_{DS}=1mA.

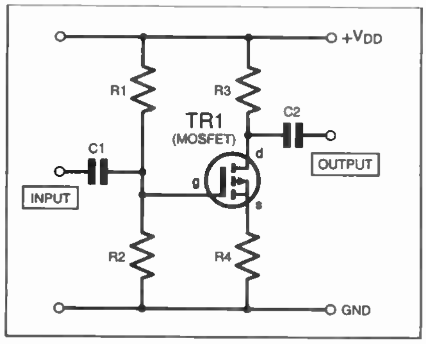


Fig.2. Single MOSFET amplifier circuit diagram.

Resistor R4 helps stabilise the bias point against variations between individual devices (in different copies of our circuit) or variations for an individual device with factors such as age and temperature. Each device will have slightly different values of K and V_T and hence different values of I_D will result from a fixed V_{GS}. Similarly I_D will vary with temperature for a fixed V_{GS}. If R4 was not present these variations would upset the bias conditions.

The negative feedback operates as follows. Imagine we have set up the circuit with a particular drain-source current, but due to (say) a change in temperature the drain-source current increases. This results in a larger voltage drop across R4, which decreases the gate-source voltage, which in turn reduces the drain-source current, and tends to cancel out the original increase.

If we choose 500 ohms for R4 we get 0·5V at the source from the 1mA bias current. This means the R1/R2 potential divider must give 0·5+2·7 = 3·2V, so we could use R1=900 kilohms and R2=330 kilohms.

The value of R3 influences the voltage gain and output swing. The drain voltage should not fall below the gate voltage by more than V_T (0·7V in our example), so the minimum drain voltage is 2·5V. The maximum drain voltage is the supply voltage (12V), so we have a maximum swing of 9·5V or ±4·75V centred on 7·25V. For a drain voltage of 7·25V with no signal we need R3=(12–7·25)/1mA=4·75 kilohms.

The voltage gain of the circuit is given by $-g_mR3 / (1+g_mR4)$.

In our example the gain is about 5·8. The stabilising resistor reduces the gain, but this can be overcome by bypassing it with a capacitor. *I.M.B.*

CMOS or Bipolar Timers

I am about to build the Super Motion Sensor *from the May 2003 edition* (Back Issues available by visiting our Online Shop **www.epemag.wimborne.co.uk** – ARW). *One component is listed as a 7556 CMOS dual timer. I have been offered an alternative NE556 dual timer instead. Is there a difference between the two types?* Thanks from ***Neil***, posted in the *EPE Chat Zone.*

We looked at some basic differences between the two families in last month's *Circuit Surgery.* The NE556 is the original dual 555 timer and is classed as a bipolar device, i.e. one that is made from *n-p* semiconductor material.

Ordinary silicon transistors such as the BC548 also belong to the same bipolar family. Then along came the CMOS (Complementary Metal-Oxide Semiconductor) timer which in theory is pin-for-pin compatible with the old bipolar chip whilst offering all the advantages of CMOS technology.

The main differences are that the output of the CMOS type is better able to switch from one rail to the other (nearer to +V and 0V), where a bipolar timer output tends to swing to say a volt or two below the maximum, or above the minimum. A CMOS timer operates typically down to +3V (bipolar: +5V).

Also, the CMOS device has a lower operating current than the bipolar timer, which can improve a circuit's current consumption, especially when twin timers are used. The inherently high impedance of the CMOS timer enables it to use higher value resistors and smaller capacitors compared with the bipolar 555/556.

In practice I have usually found no problems with swapping one timer for the other, but one area to check is the output characteristic: if output currents are important, then a bipolar type is higher (200mA) than a CMOS (100mA). The CMOS output falls noticeably when source current (see last month) increases. Using a voltmeter, some tests with both types driving a simple load (e.g. a 150 ohm resistor) will soon highlight any differences, or you can try to unravel the graphs in a data sheet downloaded from the web. *A.R.W*

Anti-Static Desoldering

*In an effort to find some information on soldering and desoldering techniques I found your web pages and photos (**www.epemag.wimborne.co.uk** then the **Resources** link on the home page). In my case I need to take care of ESD (electrostatic discharge), and wondered what is the best mode of soldering and desoldering, and where can I buy an ESD proof desoldering pump?* Thanks from ***Dr Sumi Dhar*** by email.

For the hobbyist, CMOS damage caused by static is far less of a worry than it used to be, and it isn't necessary for ESD-proof equipment to be needed to assemble typical projects. However, nylon carpets and PVC carpet protectors are notorious for creating enormous static voltages that can be dealt with using an anti-static wriststrap – and it is wise to do this when handling e.g. computer memory chips or expensive motherboards.

In manufacturing applications, where static sensitive components or boards are being soldered or repaired, then problems can arise due to static electricity discharging into semiconductors, possibly destroying them. For example, a search on the Internet soon unearthed (no pun intended) the web site of Assurance Technology Corporation who posted some interesting images of an ESD failure in an op.amp. See **http://www.assurtech.com/FA1.asp**.

ESD-safe tools are made from partially conductive materials that will not generate any damaging static nor allow static charges to be carried to components being soldered. The bit of an ESD soldering iron is usually grounded (possibly through a resistor) to prevent static accumulating on it, so that you can't transfer a charge to a semiconductor. They may be listed as "static dissipative" tools.

An ESD-safe desoldering pump is also static-conductive, this time so that it will be automatically discharged to earth when you take hold of it: wrist or ankle straps can be worn which are grounded through a resistor. ESD benchtop mats can be bought that also connect to ground through a special mains adaptor that has plastic live and neutral pins and a metal ground pin. These can also allow a wriststrap to be connected and earthed.

Manufacturers of ESD safe soldering irons include Antex (**www.antex.co.uk**) – see their advert in this issue, and pumps are made by Edsyn (Soldapult brand) or Abeco to name but two. Major suppliers include Farnell (**www. farnellinone.co.uk**) and RS Components (**www.rswww.com**).

If using a wriststrap, then the fact that you are grounded, and that the tools are ESD safe as well, means that there is nowhere for static charges to gather, so there is no possibility of "zapping" components being soldered or desoldered. It's rather like the way the equipment and buildings in a power station are completely grounded throughout, using heavy copper busbars, to make it easy for "escaping" high voltages to find their way to earth and blow a trip switch. *A.R.W.*

Constructional Project

JAZZY NECKLACE

THOMAS SCARBOROUGH

Be the light and soul of your party or disco

A CHIC appearance and a striking piece of jewellery can emphasise the beauty of the wearer, as well as adding a sense of lightness to life.

An item of jewellery that lends itself particularly well to electronic enhancement is a traditional African necklace which comprises an array of vertical rods, artistically arranged, suspended from a string around the neck. These rods may be made of various traditional materials, including wood, ivory, tortoiseshell, or stone.

This article unveils a 21st-Century version of this necklace which, instead of using rods of wood or other customary materials, employs sixteen sparkling clear cast acrylic rods. These are accompanied by a compact circuit which darts all colours of light down the length of the rods, at random.

Clear cast acrylic rods are superb transmitters of light. They are also good reflectors of light, when their surfaces are suitably abraded. If a 45-degree arc is roughened at the back of such a rod, 315 degrees remain for the transmission of light down the length of the rod.

Any light that is caught by the abrasions at the back is cast forward through the magnifying curve of the rods. Thus if an ultrabright l.e.d. is shone down the length of the rod, there is no apparent loss of brightness down tens of centimetres of rod.

CIRCUIT DETAILS

The Jazzy Necklace randomly flashes *sixteen* l.e.d.s using just two common CMOS i.c.s. The full circuit diagram for the "necklace" is shown in Fig.1.

This is not a pseudo-random display, as may be created (as an example) with shift registers, but comes close to a truly random display by using three oscillators, IC1a to IC1c, each of which oscillates independently of the other two. These create a constantly changing three-digit binary "select" number, which is decoded to eight switch positions of a CMOS 4051 eight-channel analogue multiplexer (IC2).

This multiplexer i.c. is similar to a single-pole, eight-position switch, with the important difference that it allows random access to each of the eight switch positions. This means that it does not need to sequence through each of the eight positions as a normal switch would do, but has the ability to jump randomly from one position to the next.

It has, of course, only eight switch positions, and in order to independently flash *sixteen* l.e.d.s, the number of switch positions is effectively multiplied by two by creating two alternating 0V rails. A

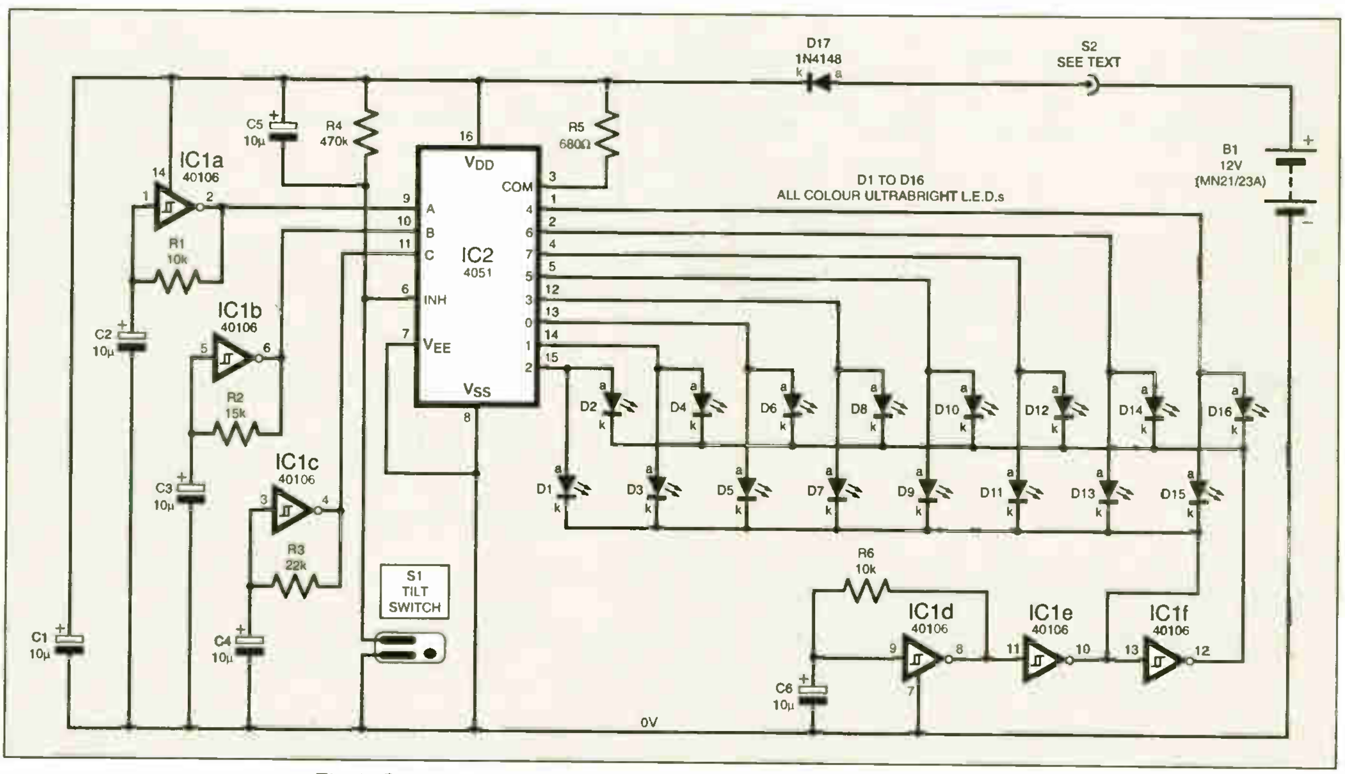
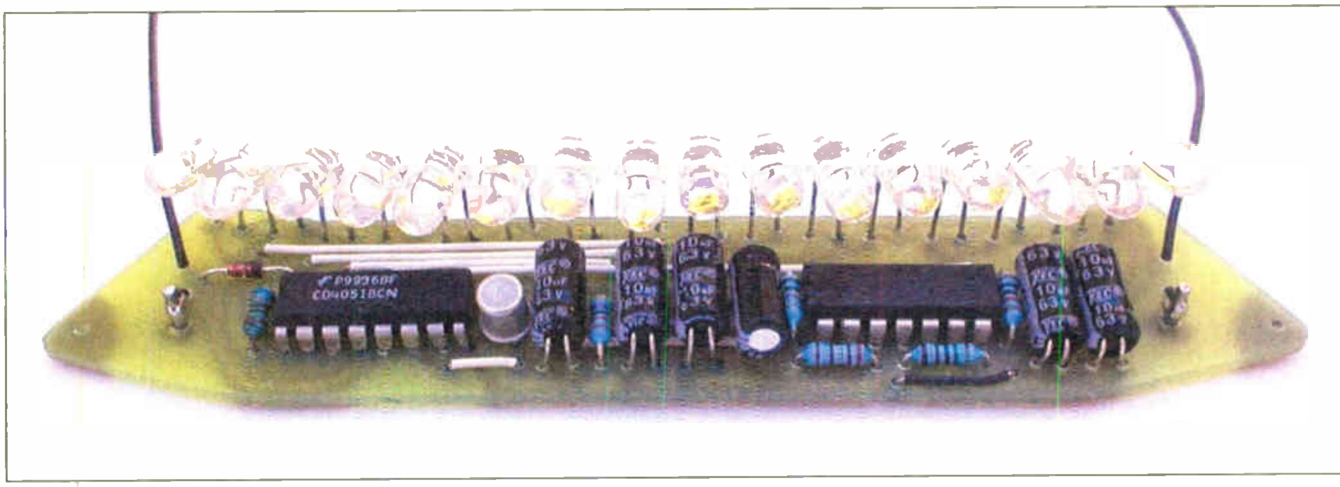


Fig.1. Complete circuit diagram for the sixteen l.e.d. Jazzy Necklace.



Front-on view of the "necklace" circuit board. Note the l.e.d.s bent at an angle just above the components.

fourth oscillator (IC1d) is employed for this purpose, again oscillating independently of the other three, to effect the multiplication. Two buffers (IC1e and IC1f) prevent excessive loading of the oscillator. This creates a random display of sixteen l.e.d.s., using less than one component per l.e.d.

Pin 3 of IC2 is the centre or common pole of the "switch", which is connected to any given output position (numbered 0 to 7). The three-bit binary value which is presented at the three "select" terminals *A*, *B* and *C* (pins 9 to 11) are decoded to the eight separate outputs.

Since only one three-digit value can be entered at a time, only one of the output terminals can go "high" at any time. Thus, a practically random three-digit binary value is generated, with fleeting patterns emerging.

Since the common pole (IC2 pin 3) in this circuit is connected to the positive supply rail, through ballast resistor R5, each of the switch positions goes "high" when connected, therefore the cathodes of the l.e.d.s are connected to the alternating 0V rail.

An important feature of this design is that when a switch position is disconnected from the common pole, the corresponding l.e.d. is disconnected from the power supply. This is in contrast with the 4028 CMOS i.c., which may serve a similar function in digital circuits.

However, the output terminals of the 4028 i.c. will only go "high" or "low" (it is thus a bi-state device). Therefore, if the 4028 had been used in this design, the reverse voltage across the l.e.d.s would have been close to 12V, which exceeds the rating of the typical l.e.d.

While the supply voltage could have been reduced to overcome this, the design could not then have accommodated *all colour l.e.d.s.* Therefore the 4051 8-channel analogue multiplexer i.c. is used.

FOUR-TO-ONE

The four oscillators (IC1a to IC1d) are each based on a single Schmitt inverter (or NOT) gate, and are thus very simple, requiring only one resistor and one capacitor each. For the purpose of preventing "frequency lock" (the tendency of oscillators to "lock on" to one another in close proximity), the values of capacitors C2 to C4 and C6 are, therefore, relatively large (10μF).

For a less jazzy (that is, more sedate) display, increase the values of the capacitors, and vice versa. A supply decoupling capacitor C1 is included for "good practice", although it is not strictly necessary.

Due to the relatively high supply voltage (12V), and since only one l.e.d. is ever flashed at a time, a single ballast resistor (R5 – connected to IC2 common pin 3) can be used for all sixteen l.e.d.s combined, thus simplifying and compressing the circuit. While it would be possible to use several ballast resistors, thus perfectly matching them to each colour l.e.d., in practice this is not necessary, and would considerably increase the component count. The result is a very compact circuit.

Do note, however, that when selecting l.e.d.s, their luminous intensity should be approximately the same – alternatively, test them first with 12V and a one kilohm (1k) ballast resistor.

SLEEP SUPPLEMENT

Besides the "circuit proper", three further components are employed, so as to disable the Jazzy Necklace when the wearer is no longer moving (for instance, when having moved off the dance floor to enjoy a refreshment).

To accomplish this, the inhibit pin (pin 6) of IC2 is wired to a non-mercury tilt switch, S1. As long as this switch is occasionally closed, pin 6 is held "low" through capacitor C5, and the circuit continues to flash jazzily. But when pin 6 is taken "high" through the gradual discharging of C5 through resistor R4, all switch positions are disabled, and the Necklace, after a few seconds, "goes to sleep".

Note, however, that it does not *switch off*, but continues to draw about 2mA current. If a tilt switch is not available this component may simply be omitted from the p.c.b.

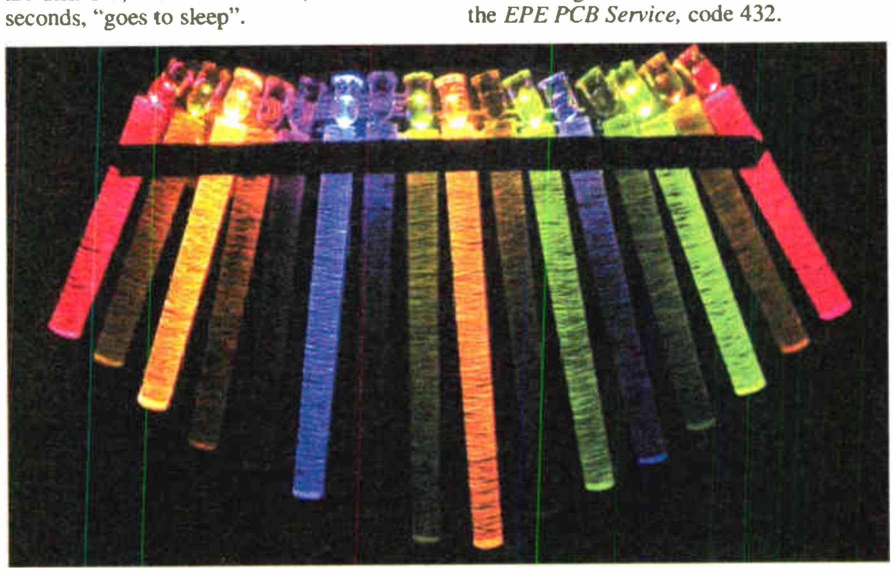
A miniature 12V battery is used (a 23A or MN21 or similar), and diode D17 is employed on the printed circuit board (p.c.b.) for supply reverse polarity protection. The circuit is switched off simply by removing the battery – or a suitable connector may be inserted in one lead. The circuit draws about 10mA, and should therefore run for about three hours continuous off the specified battery.

Finally, a question which is commonly asked about the 4051 i.c. is what purpose pin 7 (V_{EE}) serves. When this terminal is tied low, the i.c. will handle signals between 0V and +Ve, as it does in the present circuit.

When, on the other hand, analogue signals need to be routed through the i.c., this pin would normally be connected to the lowest voltage level in the circuit. For instance, pins 16 and 7 could be connected to +6V and –6V respectively, while pin 8 could be connected to ground (0V). In this way, analogue voltages of up to ±6V could be handled with 6V digital control signals.

CONSTRUCTION

Construction of the Jazzy Necklace is on a single-sided printed circuit board (p.c.b.) measuring 128mm × 28mm, which is further cut and filed to shape as shown in Fig.2. The topside component layout and full-size copper foil master pattern is illustrated in Fig.2. This board is available from the *EPE PCB Service,* code 432.



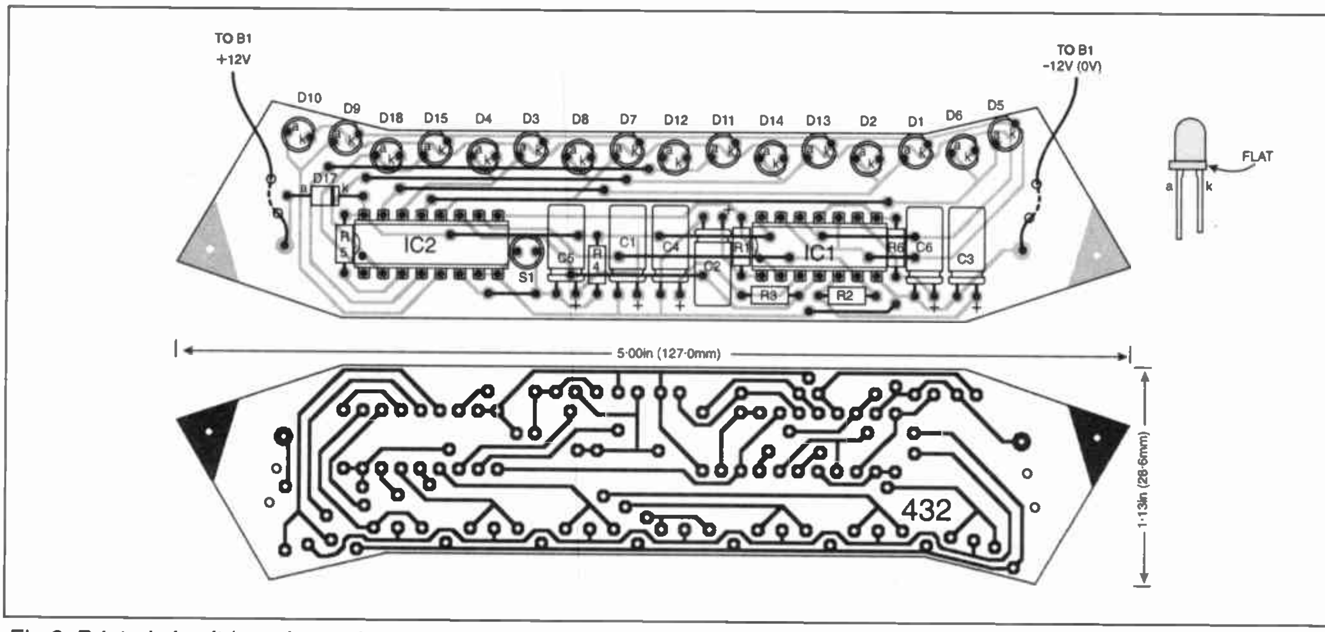


Fig.2. Printed circuit board topside component layout and full-size underside copper foil master for the Jazzy Necklace. Cover the back of the p.c.b. with some felt or other fabric to prevent it from scratching the skin.

CIRCUIT BOARD

Turning to the main printed circuit board, the two solder pins and twelve link wires are soldered to the p.c.b. – followed by the six resistors, diode D17, and the six electrolytic capacitors. Take special note of the polarity of diode D17 and the electrolytic capacitors.

Insert the miniature non-mercury tilt switch S1, keeping it raised a little on its legs, so that it may be tipped forward slightly. In this way it will switch "on" only when the circuit is jiggled. Note that as mercury is such a highly toxic substance, a mercury-filled switch **MUST NOT** be used here.

Now solder IC1 and IC2, observing anti-static precautions (most importantly, touch your body to earth immediately before handling), directly in position on the p.c.b. Be quick with the soldering iron, so as not to damage the i.c.s.

Alternatively, you should use low-profile dual-in-line (d.i.l.) sockets. The author omitted such sockets in the prototype to achieve a flatter profile, but these would be advised for less experienced constructors.

BATTERY HOLDER

A battery holder (see Fig.3) is constructed of two round 8mm crimp terminals which are soldered to a 40mm × 12mm piece of copper-clad board with a score down the centre to isolate the battery terminals from each other. In the prototype, a No.2 brass round-head paper fastener was inserted into one of the crimp terminals as shown, and soldered into place, to accommodate the negative terminal of the battery. This serves its purpose well, and also makes a neat impression. The battery holder is connected to the circuit via suitable lengths of flexible wire, and the battery is worn behind the neck.

BRIGHT LIGHT

Finally, solder the sixteen ultrabright l.e.d.s into place, noting their correct orientation (the flat on the encapsulation is the cathode (k)). These l.e.d.s are given fairly long legs, so that they may "peer over" the components beneath them and so illuminate the array of clear cast acrylic rods.

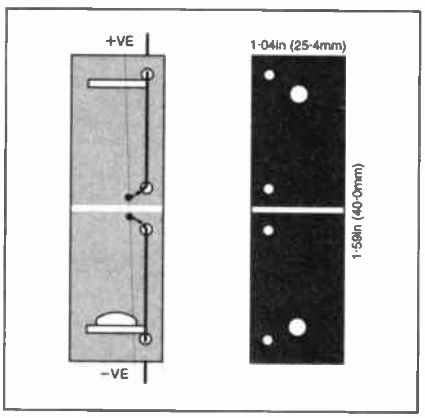
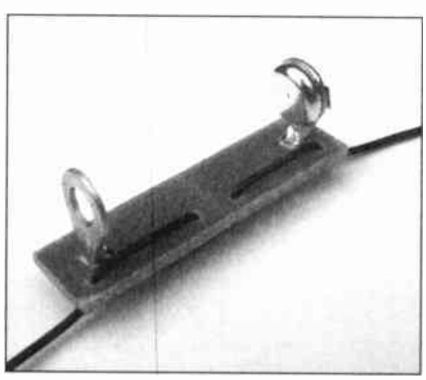


Fig.3. Using a piece of copper-clad board, two crimp terminals and a paper fastener to make a battery holder.



Battery contacts made from two crimp teminals and a paper fastener.

Author's improvised battery holder.

COMPONENTS

Resistors

R1, R6	10k (2 off)	
R2	15k	
R3	22k	
R4	470k	
R5	680Ω	

All 0·25W 5% carbon film

See SHOP TALK page

Capacitors

C1 to C6	10μ radial elect. 16V

Semiconductors

D1 to D16	5mm ultrabright l.e.d.s (16 off – 6 red, 5 green, 3 yellow, 2 blue)
D17	1N4148 signal diode
IC1	40106 hex Schmitt inverter (or equivalent)
IC2	4051 8-channel analogue multiplexer

Miscellaneous

S1	min. non-mercury tilt switch (see text)
B1	12V battery, MN21 or 23A or equivalent 12V keyfob type

Printed circuit board available from the *EPE PCB Service*, code 432; clear cast acrylic rods, 2 metres x 6mm dia.; piece of copper-clad board for battery terminals, 40mm x 12mm; 14-pin d.i.l. socket; 16-pin d.i.l. socket; plastic covered link wire; 8mm crimp terminal, for battery holder (2 off); No. 2 round-head paper fastener for battery negative terminal; 30cm x 5mm (3/16in.) dia. brass rod; 20cm x 6mm wide brass strip (2 off); suitable lengths of flexible "necklace" wire (2 off); epoxy glue; 1·2mm drill bits (several off – to allow for breakages!); solder pins (2 off); solder etc.

Approx. Cost Guidance Only **£15** *excl. clear cast acrylic rods*

Note that some ultrabright l.e.d.s are static sensitive, and anti-static precautions may need to be observed. Only ultrabright l.e.d.s should be used, since these typically offer many times the luminous intensity of ordinary l.e.d.s.

The author specially chose a sequence of colours which would offer a colourful display while also being cost effective. This is red-green-yellow, red-green-blue, and so on, ending with red (thus requiring six red l.e.d.s, five green, three yellow, and two blue).

Little remains now but to squeeze the battery into its holder, taking care to insert it the correct way round. If the circuit is laid on its back, the Jazzy Necklace should immediately "fire up", and all of its l.e.d.s should pulse, apparently at random. In the cover photograph a half-second exposure is shown – in reality only one acrylic rod lights up at a time.

If the circuit does not behave as described, immediately disconnect the battery, and carefully re-check the circuit board. Ensure that there are no solder bridges on the p.c.b., that all components are inserted correctly, and that all interwiring is correct.

SPARE THE ROD

The clear cast acrylic rods are a pleasure to work with, since they are relatively easy to cut and machine, and are fairly forgiving with regard to their positioning on the necklace.

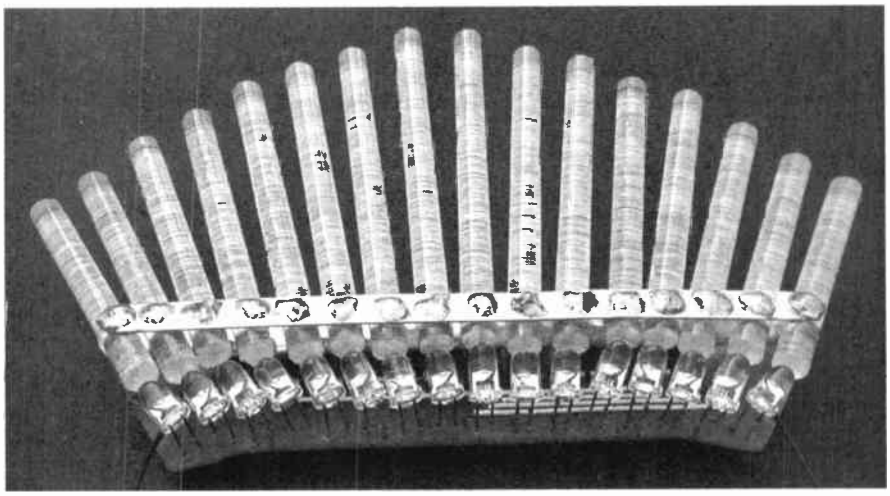
Each individual rod is cut to length as required, with a fine saw. A slightly rough finish at the ends was not found to diminish light output, therefore they need no polishing at the ends. The traditional African necklace frequently arranges its rods in a V-shape, so that those at the sides are shorter than those in the middle, and a similar arrangement was used for the prototype.

In order to reflect the light forward through the magnifying curve of the rods, the backs of the rods need to be abraded. For this purpose, about a 45-degree angle of the rods is abraded at the back, as shown in Fig.4. Abrasion with sandpaper or a file was found to be inadequate, therefore the author used a sharp knife to create a dense "cross-hatch" pattern of cuts (see photographs). This is a labour-intensive exercise, but it is well worth the effort.

The author's most important consideration was how to bind the acrylic rods to the circuit board so that the Necklace would represent a durable whole. Glue seemed inadequate to the task, therefore the rods were clamped between two 6mm wide brass strips.

These strips were drilled with sixteen 1·2mm dia. holes each, placed 8mm apart, and then cut to length with pliers. Sixteen short pieces of 5mm (3/16in.) dia. brass rod were then passed through the top strip, and soldered into place – with the two end rods being longer than the other fourteen (the end rods are eventually inserted into the holes provided at the corners of the p.c.b., and soldered into place).

The sixteen acrylic rods were each drilled with 1·2mm holes, and pressed onto the brass rods. The second brass strip was then pressed over the brass rods, and simultaneously glued and soldered into place – the rods being held temporarily in position in relation to each other with Blu-Tack (or Pres-stik).



Rear view of the necklace showing the l.e.d.s aligned with the ends of the rods.

While drilling the acrylic rods slightly reduces their light output, this seemed a worthwhile trade-off to produce a robust necklace. Note that drilling needs to be fairly swift if a hand-drill is used, otherwise the bit may stick and break. Remove the bit immediately the hole goes through, or it may be "glued" into place! Also, the angle of the through-holes needs to be reasonably accurate.

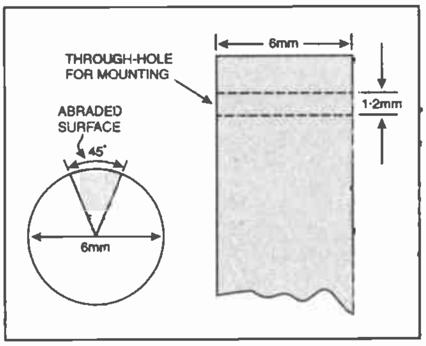
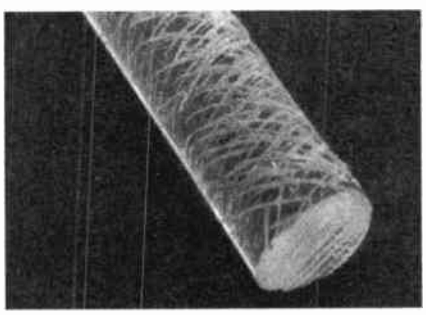


Fig.4. Preparation details of the clear cast acrylic rods.



Abraded surface of acrylic rod.

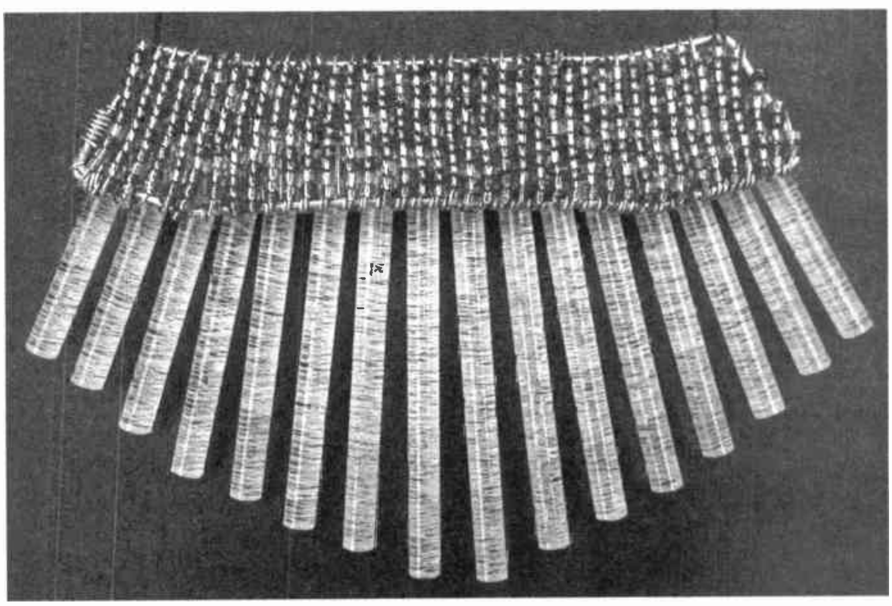
LIGHT TRANSFER

Fortunately, the rods do not need to be mounted particularly skilfully in relation to the l.e.d.s. An approximately correct position is all that is required. Try to avoid ultrabright l.e.d.s with a very narrow viewing angle (e.g. 10 degrees), mainly because their light is more easily obscured by the mounting holes.

The final assembly weighed a whole 99 grams – but then, needless to say, some of the most desirable pieces of jewellery weigh a little more than the rest!

Last of all, a decorative strip of artwork may be used to conceal the necklace's circuitry, and a piece of felt used to cover the scratchy rear of the p.c.b. The author commissioned street artist Fijo Jumira in Sea Point, Cape Town to create a suitable frontpiece for the necklace (see photographs), made of wire and beads.

The resulting necklace, particularly when viewed in subdued light, is a striking adornment. The first comment of the wife, on seeing a working prototype, was: "It is truly impressive!" □



Completed Jazzy Necklace with a decorative glass bead strip covering the circuit board.

READOUT

Email: john.becker@wimborne.co.uk

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

All letters quoted here have previously been replied to directly.

WIN AN ATLAS LCR ANALYSER WORTH £79

An Atlas LCR Passive Component Analyser, kindly donated by Peak Electronic Design Ltd., will be awarded to the author of the *Letter Of The Month* each month.

The Atlas LCR automatically measures inductance from 1μH to 10H, capacitance from 1pF to 10,000μF and resistance from 1Ω to 2MΩ with a basic accuracy of 1%.

★ LETTER OF THE MONTH ★

LIFE OF BRYON?

Dear EPE,

Just a thought about your mag! I've been a subscriber now for many years and really appreciate the trouble you guys must go to in finding new projects and articles each month. I am also a professional electronics engineer having worked in various fields, from my early days in domestic radio and TV, through main frame computers, then industrial computers, CNC machines and PLCs, with some interface module design and manufacture thrown in, an interesting life? Yes – well paid, no.

My other great love is aviation. I hold a private pilots' license and subscribe to *Pilot* magazine. One of their regular features, *I learnt about flying from that*, is a column written by readers about interesting or scary moments that have happened to them while flying. Couldn't you run a similar column for electronics related subjects? Nearly everyone interested in electronics must have a story of how they solved an unusual problem. Somewhere between *Ingenuity Unlimited*, *Readout* and *Circuit Surgery*. Just to give you a bare bones example:

The mystery of the blowing 12V fuse: after retrofitting a PC in place of a Tape Reader to a CNC system, the 12V fuse would blow at switch on, exhaustive tests found no shorts but the vital clue was that during the retrofit an interface module powered by 12V was removed as not required. The culprit was a transducer module with catching diodes (connected to the 12V line) on a level changer circuit that stopped the transducer input from going above 12V.

The power supply was fitted with a crowbar circuit and though capable of sourcing 10A had no sink capability, so the catching diodes were pulling the 12V above the crowbar voltage limit and thus blowing fuses. The removed interface module was acting as current sink. Loading the p.s.u. with a suitable resistor fixed the problem.

This story is a practical demonstration of the use of catching diodes, crowbar circuits and the often-overlooked fact that most p.s.u.s cannot sink current.

Some years ago I remember a series, sort of "week in the life of a radio and TV repair shop". This was a "fictional" story about an Old Bob figure in charge of the workshop and his keen-to-learn apprentice struggling with a problem. Old Bob explains, with the aid of circuits and drawings, how to fix it. Sorry but I can't remember which publication it was in, or know of anyone who could write it. Maybe it wouldn't work today anyway, just an idea.

Bryon Epps, via email

Yes, Bryon, I half remember a column of that nature, but I'm also not sure that it would work today. You may recall that we used to do a column Ohm Sweet Ohm *by Max Fidling. From his workshop, and helped by his cat Piddles, Max looked at life's electronic oddities and their possible solutions, but that was eventually dropped as it was hard to sustain.*

ZAPPER AND BLOWN BULBS

Dear EPE,

I've just been perusing Andy Flind's *PIC Virus Zapper MkII* (Dec '03). I can see that he's creating a square wave that sweeps between <2kHz to >22kHz. But what is the frequency of the sweep, and does it pause at each end, or come straight back?

Also, regarding Blown Bulbs (*Readout* Dec '03) – a company did a Bulb Failure Detection presentation to us at Jaguar in '86. They used exactly the system that David Palmer describes, i.e. reed switches. It was so simple and reliable. Unfortunately, Jaguar decided not to try this system (internal politics I think) on the XJ40 and stuck with another one using in-line resistors – just some crude coils of wire on formers.

Because they were doing high-side detection, the op.amps that were monitoring the voltage drop across the coils had to have a supply rail greater than that of the vehicle. To achieve this, they used a simple 555 oscillator driving a charge pump. Now – each corner of the car had a Bulb Control/Failure Detection module, so there were four of these units in all.

This seemed to be doing the business until my mate tried to do his radio reception sign-off test. He was getting all sorts of interference – which was ultimately traced to these 555s merrily oscillating away and bunging out r.f. harmonics into the car wiring harnesses! A few carefully placed capacitors managed to smooth off the edges.

The design for the Dim/Dip Headlamp controller was even more hilarious – as a dealer was launching the new model to some enthusiastic potential customers, smoke was pouring out the front corner of the car behind him as the MOSFET controlling the 60W bulb drifted uncontrollably into the linear region! And boy did it stink!

Sorry to digress – I've got pages of Automotive Electrical horror stories! Perhaps I ought to make it into a regular column?

Steve Dellow, via email

Thanks, Steve, for the interesting "bulb" comments! I regret we can't offer you an X-rated column but they do make interesting Readout *– also see above.*

Andy replies to your question:

In the article a few lines under the heading "Mk2 Circuit" it says, "a simple oscillator with a period of about sixteen seconds, or eight seconds in each phase direction, as set by capacitor C8 and resistor R9". There's not supposed to be any "dwell" at either end, though component tolerances may mean that it "bottoms" and gives a brief period. I seem to recall struggling a bit to minimise that during the design stage.

PICS FOR RADIO CONTROL

Dear EPE,

I was interested to see the discussions on servos etc., in recent *Readout* columns. PICs and servos do make a very good combination.

You asked for information, so please have a look at my website: **www.rdforrest.freeserve.co.uk**. This gives some of my ideas for radio control applications – many of them based on *EPE* articles. The links give some info on other applications, such as R/C aircraft etc.

Thanks for an excellent magazine.

David Forrest, via email

Thanks David, that's an interesting site you've got – and even covers model subs! Also see page 83 of this issue.

TEACH-IN DIODES

Dear EPE,

I am avidly reading your *Teach-In 2004* articles and although I have a little electronics experience and understanding, there are occasions where I cannot get my head around certain diagram configurations.

In your December issue on page 828 there is one such arrangement. In Fig.2.7 there is a diode and it is inserted to prevent back-e.m.f. from the motor damaging the transistor. Yes I can understand back-e.m.f. and I do know that current can pass one way through a diode but not the other. What I cannot understand is why it is in parallel. Surely it should be in series? In that drawing there is a clear path between the motor and the transistor and I just cannot see how the diode is likely to protect the motor. Can you explain?

Stephen Eyre, via email

Max Horsey, author of our Teach-In 2004 *series replies:*

Parallel diodes often provoke questions like this. The main thing to appreciate is that electricity always takes the easiest route. So a diode in parallel with the motor will provide an easy path for the current caused by back-e.m.f. In normal circumstances the maximum voltage across a silicon diode in the forward direction is around 0·7V. So the voltage at the collector of the transistor cannot rise much above P + 0·7, where P is the power supply voltage. Hence the back-e.m.f. which may otherwise rise to 100V or more, is held at P + 0·7V.

It's rather like a lavatory pan. If you pour a bucket of water (the back-e.m.f.) into the toilet, the water level rises a little, but quickly returns to normal, as the water flows though the U-pipe (the diode). The analogy isn't perfect, as the U-pipe would allow flow both ways, unlike the diode which allows the flow in only one direction.

A series diode wouldn't work. If the diode pointed downwards, the back-e.m.f. would damage the transistor. If the diode pointed upwards, it would prevent the normal flow of current via the motor.

Max Horsey

CAR COMPUTER

With our US friends always in his mind, our Online Editor Alan Winstanley asked whether Mike Hibbert's PIC Car Computer *(Jan '04) could display miles per US gallon (which is 0·83268 British gallons). Mike replied:*

The simple answer is yes. The reason for this is that the combinations ltr/km, ltr/mile, gallons/km, gallons/mile are nothing more than text labels. The calculation is simply **distance travelled/fuel used**. The program doesn't care what the units of measurement are expressed as. This is why you have to clear the memory when you change from one unit type to another.

Mike Hibbett, via email

EVERYDAY PRACTICAL ELECTRONICS

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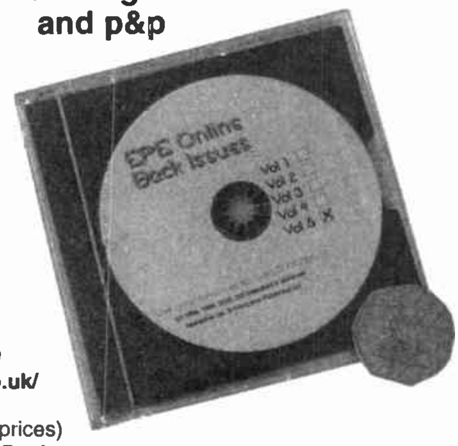

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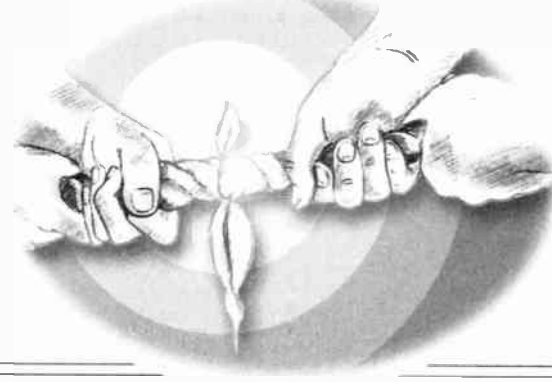
Constructional Project

PIC TUG-OF-WAR



BART TREPAK

PIC up the battle rope without the brute force!

MANY electronic handheld games are intended for only one player who pits his wits against the computer, thus giving the player little opportunity for social interaction and producing what many psychologists fear could become a generation of social misfits!

This simple Tug-of-War game, although it is built around a PIC microcontroller, must be played by two people (in their anoraks if they wish), providing, as they say, "fun for all the family".

SPEED OF LIGHT

Unlike the real game, however, it does not require a rope or a large space such as a field or village green, or large quantities of beer(?). Nor does it rely on brute strength so that a large number of rugby types are also superfluous and, as the winner is clearly indicated, there should be no need for any "physical" interaction either during or after the game!

Instead, speed of reaction is important and the two players are equipped with pushbuttons which they must press as quickly as possible after a light emitting diode (l.e.d.) is lit to "pull" their opponent over the line. The software program is written to ensure that the delay before the l.e.d. lights is random, so the players cannot accurately predict when it will light.

STATE OF PLAY

To make the game last longer (just like the real Tug-of-War game does not rely on one sharp tug to determine the winning team) the winner must beat his opponent five clear times before the game is decided.

The state of play is displayed on a row of nine l.e.d.s and the game begins with the centre one lit. Each time a player beats his opponent, the l.e.d. to the left or the right of the centre will light, depending on which player was successful. At the end of the game, the l.e.d. on one or other end of the row remains lit to indicate the winner. The microcontroller then plays a tune in the winner's honour!

To prevent any cheating, a player who anticipates the Pull l.e.d. lighting and presses his (or her – it's a non-sexist game) button *before* this l.e.d. has lit is penalised by the cancellation of one of his earlier successful attempts. Thus if he has beaten his opponent four times and requires only one more successful attempt to win the game but presses his button too early, he will have one of his earlier attempts cancelled. He will then require a further two successful turns to win, assuming his opponent continues to be slower.

CIRCUIT DESCRIPTION

The complete circuit diagram for the PIC Tug-of-War is shown in Fig.1.

Being based on a microcontroller, all of the logic is performed by software so that

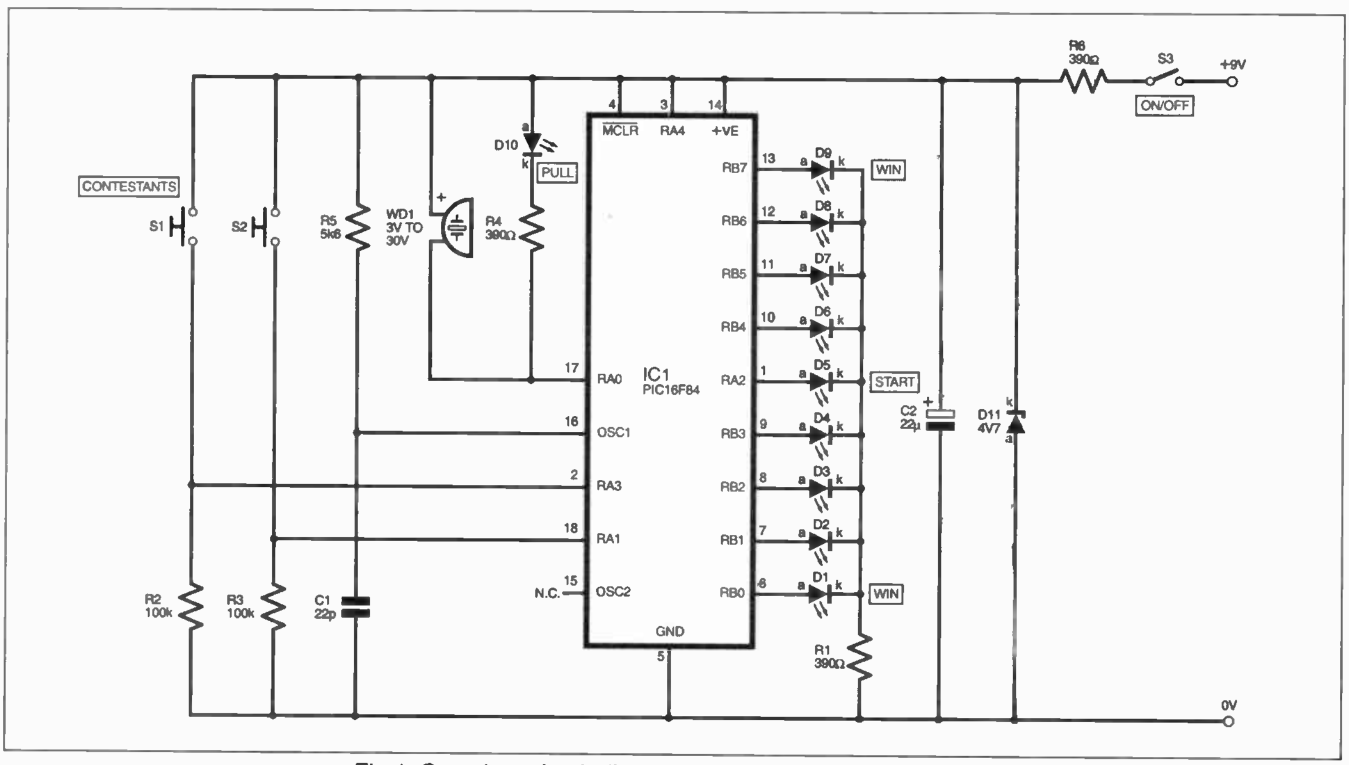


Fig.1. Complete circuit diagram for the PIC Tug-of-War game.

the circuit itself is quite simple. It consists of a PIC microcontroller, IC1, to which are connected two switches, S1 and S2, which set their respective inputs (RA3 and RA1) high when they are pressed. When the switches are released, the inputs are held low by resistors R2 and R3.

DISPLAY OF STRENGTH

The other port pins, except for RA4. are used to drive the ten l.e.d.s required. Since only one of the "contestant" l.e.d.s lights at any one time, only one current limiting resistor, R1, is required.

The "central" display l.e.d., D5, which is controlled by RA2, is lit at the beginning of the game and may be a different colour if desired. The Pull l.e.d., D10, is controlled by RA0. This lights to indicate that it is safe to press the button. Resistor R4 limits the current flow.

Pin RA0 is also used to drive a piezo sounder, WD1, to play the tune at the end of the game. Since this output is common to both the sounder and the l.e.d., both will be activated together. This means that each time the l.e.d. lights to indicate "Pull", the sounder will produce a short click.

As the timing in this application is not critical, the PIC is operated in RC oscillator mode, at a rate set by resistor R5 and capacitor C1.

POWER PLAY

The circuit is run from a 9V battery, such as a PP3. Since this voltage is higher than the maximum allowable for the PIC, it is reduced to a nominal 4·7V by the inclusion of Zener diode D1 and resistor R6. Current consumption is around 10mA, due mainly to the l.e.d.s.

Note that the author used a PIC16C84, but the use of a PIC16F84 (which is pin-compatible) is recommended, as the former is no longer manufactured.

SOFTWARE

In the software, the delay before the Pull l.e.d. is illuminated is made variable, and thus unpredictable. A routine counts the number of internal instructions which have been executed since the buttons were last pressed. Since the counter is never reset, and so is effectively always started from a different initial count, the delay generated will be different each time.

The program continuously reads the input ports to determine if either of the switches S1 or S2 has been pressed, and if not the random delay counter is decremented. When this counter reaches zero, the Pull l.e.d. is switched on.

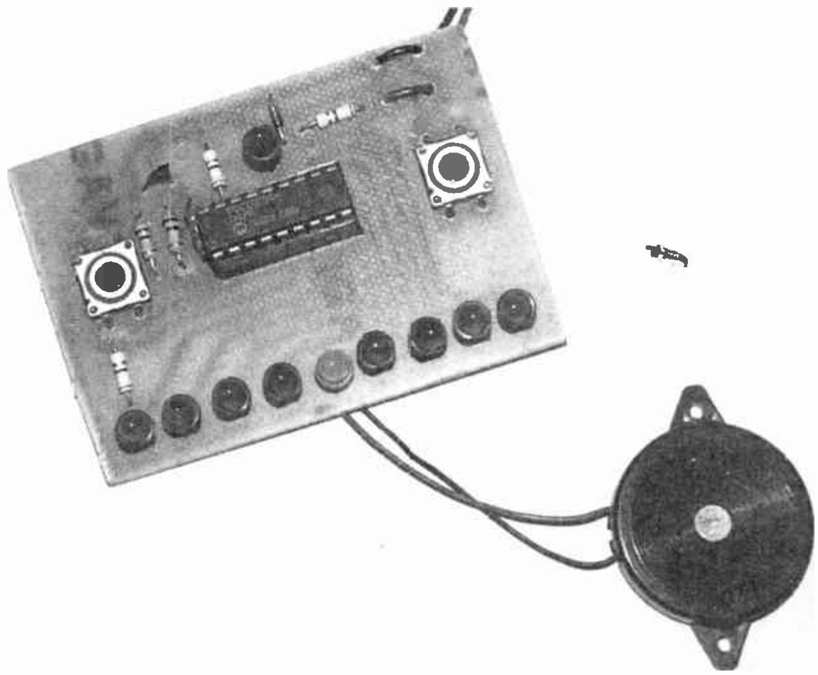
In the interests of strict fairness, both switches are read simultaneously, by reading the whole of Port A, and then extracting the status of RA1 and RA3 using an AND command. This is preferable to using the bit test instructions (BTFSS) on RA1 and RA3, which would have to be used sequentially.

WINNING LINE

Once a switch operation is detected, the program determines which instruction to execute, depending on which button was pressed and whether or not the Pull l.e.d. is on, and then checks if an overall winner has emerged. The l.e.d. display is updated accordingly, if appropriate. In the unlikely event that both switches have been pressed simultaneously the l.e.d. display remains unaltered.

Once l.e.d.s D1 or D9 are turned on, a further win by switches S1 or S2 respectively does not result in a further shift and the l.e.d. remains on indicating the winner.

Normally at this point in a real tug-of-war, the teams retire to the village pub where the winning team would enjoy a round of drinks at the expense of the losers. Here, with this PIC version, the winner must be content with the rendition of a tune, which in the author's opinion is appropriate, as it may remind you of *Queen's* "We are the champions . . .", even though it is only played via a simple piezo electric sounder!



Completed prototype Tug-of-War circuit board. The supply "smoothing" electrolytic capacitor (C2) is missing from the board and the Zener diode (D11) has been repositioned in the final model. You could use chassis mounting pushswitches and mount them in separate "contestant" boxes on long connecting leads if desired.

CONSTRUCTION

Printed circuit board assembly and layout details are shown in Fig.2. This board is available from the *EPE PCB Service*, code 435.

The board holds all of the components except for the sounder WD1, on/off switch S3 and, of course, the battery B1. Assemble the board in order of ascending component size. Ensure that capacitor C2, Zener D11 and the l.e.d.s are mounted the right way around.

If the finished board is to be mounted in a box, the switches could be changed to panel mounted types and connected to the board by short lengths of wire.

A socket *must* be used for the PIC, IC1, which must be pre-programmed – see later. Normal anti-static precautions should be observed when handling the PIC and it should be fitted only when all the other components are soldered in place and thorough checks made of the assembly.

Before fitting the PIC, connect a 9V battery to the circuit. With a voltmeter set to a suitable range, measure the voltage between pins 5 and 14 on the i.c. socket (pin 5 0V) and check to see that it does not exceed 5V.

If all is well, switch off and mount the chip in the socket taking care to ensure that

COMPONENTS

Resistors

R1, R4, R6	390Ω (3 off)	
R2, R3	100k (2 off)	
R5	5k6	

All 0·25W carbon film.

See SHOP TALK page

Capacitors

C1	22p ceramic disc
C2	22µ axial elect. 16V

Semiconductors

D1 to D10	red l.e.d., 5mm (10 off)
D11	4V7 500mW Zener diode
IC1	PIC16F84 microcontroller (preprogrammed, see text)

Miscellaneous

S1, S2	min. s.p. push-to-make switch, p.c.b. mounting (2 off) (see text)
S3	min. s.p.s.t. toggle switch
WD1	piezoelectric passive sounder
B1	9V battery (PP3 type), with clip

Printed circuit board, available from the *EPE PCB Service*, code 435; plastic case, size and type to choice; 18-pin d.i.l. socket; connecting wire; solder etc.

Approx. Cost Guidance Only £15 *excl case & batt.*

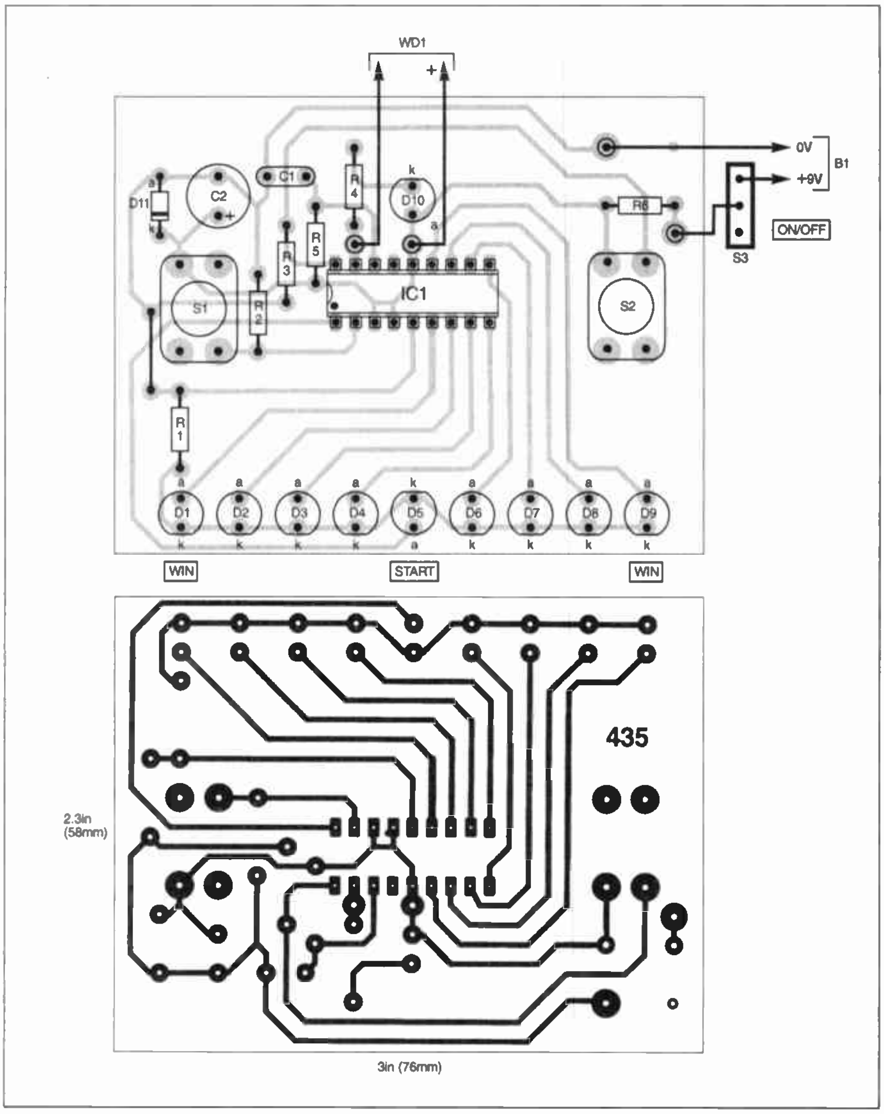


Fig.2. Printed circuit board component layout, full-size copper foil master and wiring details for the PIC Tug-of-War.

it is fitted the correct way around. Further testing or setting up is not required and provided no wiring mistakes have been made, the circuit should function correctly.

BRINKSMANSHIP

Having played the game a few times, the author realised that if the Pull l.e.d. was disabled, an even more interesting version of the game would result. Since there would now be no indication of whether or not it was "safe" for a player to press his button, the whole nature of the game would change from one based simply on the speed of reaction to one of brinkmanship.

It would obviously be in a player's interest to hang back for as long as possible to ensure that it was safe to press his button, but on the other hand delaying too long could result in his opponent pressing his button first and winning the round.

This change can be implemented at the time that the unit is first switched on prior to any gaming session.

If switch S2 is held pressed prior to power being applied, the circuit simply programs pin RA0 as an input and in this (high impedance) mode it is unable to light the Pull l.e.d. so that it remains off throughout the game. At the end of the game, when the unit plays its tune, port RA0 is redefined as an output so that the tune plays normally.

RESOURCES

The PIC programming software for this design is available from the *EPE PCB Service* on 3·5-inch disk, for which a nominal handling charge applies. It is also available for *free* download via our website at **www.epemag. wimborne.co.uk**. It is in folder *PICs/Tug of War*. Read this month's *Shoptalk* page for details about purchasing preprogrammed PICs and other components for this project. □

SHOP TALK

with David Barrington

Sonic Ice Warning

Some readers may have difficulties in tracking down a local source for two of the semiconductor devices used in the *Sonic Ice Warning* project. The rest of the components seem to be "off-the-shelf" items. Certainly, the LM35DZ temperature i.c. is stocked by most of our components advertisers.

The TS932IN dual, rail-to-rail, micropower op.amp is currently stocked by **Farnell** (☎ ***0870 1200 200*** or ***www.farnellinone.co.uk***), code 332-9392. They also supplied the Analog Devices AD680 2·5V reference voltage chip, code 411-218. Expect to pay a handling charge.

The author suggests that other low-power dual op.amps that are pin-for-pin compatible and suitable for a single supply could be used here. The same applies to the reference voltage i.c.

The printed circuit board is available from the *EPE PCB Service*, code 433 (see page 147).

Finally, note that it is most important that the metal body of the DIN socket ***must not*** make contact with the 0V line. The light-duty auto-wire and "bullet" connectors should be available from motor spares shops.

PIC LCF Meter

Just a few minor points came to light when checking out parts for the *PIC LCF Meter* project. As a 2-way 3-pole combination rotary switch appears to be non-existent, you will need to order a 4-way 3-pole type with an adjustable rotation end-stop and set it for 2-way operation. Quite a number of our advertisers now stock 2-line 16-characters per line alphanumeric l.c.d. modules and sourcing should not be a problem.

The 10μH axial inductor used in the prototype is the type that resembles a resistor and should be widely available. It can usually be found in catalogues listed as an r.f. choke.

Ideally, the LC oscillator capacitors, C5a/b and C6a/b, should be 1% types but these are not generally available and you may have to accept 5% tolerance types. We have only seen "close tolerance" polystyrene film and silvered mica types boasting a 1% tolerance – at a price, of course.

A pre-programmed PIC16F628 microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £4.90 each (overseas add £1 p&p). The software is available on a 3·5in. PC-compatible disk (Disk 7) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 147). It is also available *Free* via the Downloads click-link option on the *EPE* home page when you enter our main web site at **www.epemag.wimborne.co.uk**, then enter the PIC Microcontroller source codes folder and select **PIC LCF Meter**.

The printed circuit board is available from the *EPE PCB Service*, code 434 (see page 147).

Tug-of-War

No likely problems to report concerning components for the *Tug-of-War* game project.

For those readers unable to program their own PICs, a ready-programmed PIC microcontroller can be purchased directly from the author for the sum of £5.50 inclusive (add £1 for overseas). Although the author used a PIC16C84 in the model, which is no longer manufactured, and the PIC16F84 is its pin-compatible replacement, we understand the author will be supplying the PIC16C54.

Orders should be sent to **Bart Trepak, 20 The Avenue, London, W13 8PH**. Payments should be made out to *B. Trepak*, and *only* in £ sterling and drawn on a British bank, UK postal orders are also accepted.

The software is available on a 3·5in. PC-compatible disk (Disk 7) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 147). It is also available *Free* via the Downloads click-link option on the home page when you enter our main web site at **www.epemag.wimborne.co.uk**, then enter the PIC Microcontroller source codes folder and select **PIC Tug-of-War**.

The printed circuit board is available from the *EPE PCB Service*, code 435 (see page 147).

Jazzy Necklace

The only source we have located for the 6mm clear cast acrylic rods used in the *Jazzy Necklace* project has been **RS Components**, code 824-531 (five per lot). They can be ordered through any *bona-fide* RS stockist, including some of our advertisers. You can order direct (*credit card only*) from RS on ☎ ***01536 444079*** or ***rswww.com***). A post and packing charge will be made.

We most strongly recommend that readers only use a *non-mercury* tilt switch in this project. If any readers have problems finding one, it is currently listed in the new **Squires** (☎ ***01243 842424*** or ***www.squirestools.com***) catalogue, code TSW760.

The ultrabright l.e.d.s and other semiconductors are fairly common devices and should be easy to find locally. The "necklace" printed circuit board, together with the small battery p.c.b., are obtainable from the *EPE PCB Service*, code 432 (see page 147). For the glass beads we can only suggest you try needlecraft shops.

New Technology Update

Whilst the spotlight seems to be continually on semiconductor developments, equally important advances are being made in capacitor technology, reports Ian Poole.

MANY of the recent improvements in capacitor technology are being taken for granted. These days capacitors are far smaller, and offer far greater levels of performance and reliability than those produced a few years back.

As many of the improvements have taken place without all the fanfare of the semiconductor developments they are often overlooked. Nevertheless, there are many revolutionary ideas that are being worked upon even now.

Increasing the capacitance density is one major focus for activity. The possibility of having very large capacitances in a small volume is of particular interest. With much greater values of capacitance density very large figures for capacitance are available in manageable packages.

The developments are opening up new applications for these components. Many of these are in the higher current areas, including some electrical applications.

New Research

Researchers at Cambridge University are developing new electrode materials for very high performance super-capacitors. The focus of this research has been directed towards merging the properties of nano-tubes and conducting polymer films. Carbon nano-tubes provide a very high surface area and good electrical conductivity that enable them to achieve very fast response times, making them particularly good for many electronic applications.

The other element to the research has been into developing the conducting polymers. These polymers can be reversibly oxidised and reduced, and their conductivity approaches that of copper. This makes them ideal for use in capacitors where high levels of charge storage are required. However, they offer comparatively slow response times.

It was the aim of this research to be able to provide the best from both technologies to enable high value super-capacitors, with fast response times, to be produced. In this way super-capacitors will be able to be utilised in a number of new applications that were not previously possible. Using the new technology capacitance levels of up to $2F/cm^3$ have been attained – levels which only a few years ago would not have been thought possible.

The research has focussed upon merging the two technologies by utilising carbon films and conducting polymers in composite films of the two materials.

Growing Films

In order to be able to grow the composite films, very close control of the conditions is required. Only in this way is it possible to effectively combine the redox charge storage mechanism of the conducting polymers with high surface area of the carbon nano-tubes. It has been found that the alignment, concentration, production, dimensions and the chemical treatment of the nano-tubes all varied the overall performance of the resulting material. This has resulted in nano-tubes coated in a very thin layer of a conductive polymer known as polypyrrole.

It has also been found that introducing a negatively charged functional group improves the production process. The group is attached to the nano-tube surface during production using an acid treatment process.

This enables excellent interaction between the nano-tube surface and the conducting polymer film to be achieved. It also indicates that theories developed for the interaction of small molecules with conducting polymers is equally applicable in many respects for the interaction of much larger carbon nano-tubes with these polymers.

The technology works using an electrochemical reduction and oxidation process. Charge is stored on the polypyrrole molecules that are strictly known as pseudo-capacitors. It is then possible to optimise the capacitor using different levels of film thickness, different polymers and different production techniques. In this way the optimum performance can be provided for a given application.

Results

The research team managed to successfully produce composites of carbon nanotubes with conducting polymers and to gain some remarkable results. They were able to achieve capacitance levels in excess of 200F/g and $2{\cdot}6F/cm^2$. These levels are quite remarkable and are more than twice the figures seen when the technologies are used on their own.

These levels of capacitance open the way for the use of these capacitors in electric vehicles. Currently one of the major problems limiting the use of electric vehicles is that the batteries used are typically lead acid types that are exceedingly heavy. This weight significantly limits the use of these vehicles with most of the weight often being contributed by the batteries themselves. By using these new capacitors to store power electric vehicles could be given a new lease of life.

In addition to this the capacitors could find many uses within the much lower current electronics area. Here they could provide very high levels of capacitance for small circuits. They may even provide a hold-up-battery function, charging up when the power supply is available, and then supplying the circuit when the power is removed.

Now that the technology has been proved, the university is looking for investors to help in commercialising the technology.

Other Developments

There are many other capacitor developments that are being undertaken. AVX, a major manufacturer of capacitors has moved forward tantalum capacitor technology to provide capacitors with an extended temperature operating range, allowing operation at temperatures up to 170°C. Although these temperatures are unlikely to be experienced in normal domestic electronics, automotive and especially many "on-engine" applications as well as many applications in the industrial sector experience extreme temperatures. Here the ability to use components that are operating well within their limits ensures that reliability is kept to the highest levels.

To achieve this the maximum operating temperature of the materials was investigated to prove their long-term stability at elevated temperatures.

Further developments of other areas have also been made. The tantalum anode itself is particularly important. Applying similar rules to those used for the general material development, the tantalum powder used for the anode has been optimised. Even small changes in characteristics such as the granularity, porosity, and purity make significant differences.

Again the encapsulation of the finished capacitor is important. This needs to be able to reduce the stresses arising from thermal and mechanical shocks as well as preventing moisture ingress. To achieve this new moulding compounds have been developed.

This work has resulted in components that are able to run continuously in an environment at 150°C with reliability levels twice that of existing components at lower temperatures.

Further information about electronics technology can be seen at **www.radio-elecronics.com**.

INTERFACE

Robert Penfold

FURTHER PC SERIAL PORT USE OF INPOUT32.DLL

IN the previous *Interface* article the subject of directly controlling the PC serial ports was considered with special reference to the new version of **inpout32.dll**. By writing the appropriate values to the registers of a serial port it is possible to set the required baud rate and word format.

Writing bytes of data can be equally straightforward, and in its most basic it is just a matter of writing the data to the data register of the UART. Receiving is also fairly straightforward. The UARTs used in PCs, in common with most UART chips, do not provide individual control of the sending and receiving baud rate or word format. The methods of setting the baud rate and word format described in the previous *Interface* article therefore apply equally to receiving data.

Multiple Readings

When sending data it is necessary to ensure that bytes are not written to the transmission register at an excessive rate. There can be a similar problem when receiving data, in that it is possible to take readings at a higher rate than data is received. This is not necessarily of importance, and it depends on how the received data will be used. In a very simple application it would probably be of no importance.

Suppose that the serial port is receiving readings from a temperature interface and displaying the readings on the screen via a digital readout. Suppose also that the interface is monitoring the air temperature, which would change only quite slowly. The interface could be designed to provide (say) a new reading once per second. This would be more than adequate to accurately track slow temperature changes.

The software could be designed to update the display at a somewhat faster rate of perhaps ten times per second. This would ensure that any change in the data from the interface would quickly be read and the new reading would be displayed almost at once.

Sampling Rates

With this system each byte of data would be read from the UART about ten times. While this is admittedly a bit inefficient, it is unlikely to be of any practical importance. Although there are multiple readings of each byte of data, the values being displayed are the latest readings and are accurate. The situation would be different if readings were being taken at regular intervals and plotted on a graph. Readings would have to be taken at one second intervals in order to match the rate of the interface.

This could be done using separate timers in the interface and the software running on the PC, but this type of thing cannot be guaranteed to maintain proper synchronisation. With a low sampling rate it might actually work quite well, but at higher rates the two parts of the system would inevitably suffer from a lack of accurate synchronisation. Some bytes of data would be missed and others would be read twice.

On the face of it, with a serial interface it is possible to transfer bytes of data, which is of little use where it is necessary to transfer 16 or 32 bits of data. Also, a serial interface seems to be unsuitable where it is necessary to read several sensors with each one producing a byte of data.

In practice serial ports are often used with sophisticated pieces of hardware that require something more than an 8-bit interface. The trick is to send groups of bytes. With five sensors for example, groups of five bytes would be sent.

This is another example where it is essential for the PC receiving the data to be properly synchronised to the sending device. The receiving computer knows that the first, second, third, etc., bytes of data in each group correspond to the first, second, third, etc. sensors. This method clearly relies on the computer detecting each new byte of data so that its group, and position in the group, can be determined using a simple counting system. With random reading there is no way of knowing which sensor has produced each byte of data.

Polling

In both cases the way around this problem is to have the software detect and immediately read each fresh byte of data. With this system the rate at which readings are taken is controlled solely by the timer in the interface, and synchronisation will not be lost provided the program in the PC can keep up with the flow of data.

This should not be a problem because an ordinary serial interface is not particularly fast even when used at high baud rates. Some other form of interface is required if you need to transfer data at more than about 10 kilobytes per second.

Of course, things are effectively slowed down still further when sending data in the form of groups of bytes. With a single sensor producing single bytes of data it is possible to take readings at about 10,000 per second when using the highest normal baud rate of 115 kilobaud.

Using five sensors would still give an overall rate of 10,000 per second, but just 2,000 per sensor. Using a single sensor but with (say) four bytes per reading, the maximum number of readings per second would be reduced to 2,500. Clearly these rates are still high enough to accommodate many applications, but serial interfacing is not suitable for the more demanding tasks.

Basic Reading

In order to read data from a serial port it is just a matter of reading from the data register, which is at the base address of the port. This will usually be &H3F8 for port one (COM1) and &H2F8 for port two (COM2), but these port addresses can be checked using the Windows Device Manager program if you are in any doubt.

Reading from the ports using Visual BASIC is now very straightforward regardless of which version of Windows is in use. Using the new version of **inpout32.dll** it is possible to add the Inp and Out commands, even with a PC running under Windows NT, 2000, or XP. In the simple examples provided here it is assumed that Visual BASIC is equipped with the new **inpout32.dll**.

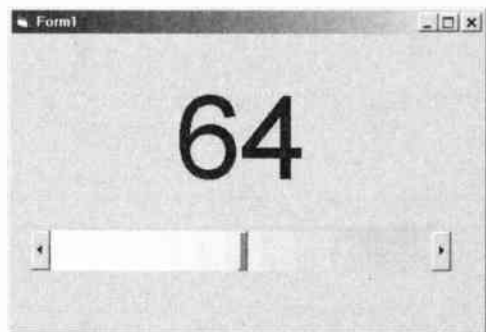


Fig.1. Incorrect value at the halfway slider setting when the slider's maximum value is set to 255.

In order to display readings from a serial port it is merely necessary to add a label and a timer to the form and add a line of code. Make the label quite large and give it a suitably large text size using the Font panel of the Properties Inspector.

Set the timer's Interval value at (say) 50 milliseconds using the Properties Inspector, which will give twenty readings per second. Use this routine for the timer component:

```
Private Sub Timer1_Timer()
Label1.Caption = Inp(&H3F8)
End Sub
```

The Inp function reads the data register of the serial port and writes that value to the caption property of the label so that it is displayed on the screen. The address used here is correct for serial port one, and should be changed to &H2F8 in order to read serial port two.

The easiest way to test the reception of serial data is to get the port to send data to itself. This requires a link between the transmit and receive pins on the serial port. A nine or 25-way female D connector is needed to make connections to a PC serial port, and with both types the required link is between pins 2 and 3. The pin numbers are marked on the connectors, but you might need a magnifier in order to read them. In this case a small crocodile clip can be used to bridge the relevant two pins on the male connector, but due care must be taken to avoid accidental connections to earth or other pins.

The setup described above needs a horizontal scrollbar added to the form. This should have its Min and Max values set at 0 and 255 respectively using the Properties Inspector. This routine is used for the timer:

```
Private Sub Timer1_Timer()
Out &H3F8, HScroll1.Value
Label1.Caption = Inp(&H3F8)
End Sub
```

The additional line of code outputs the value read from the scrollbar to the serial port's data register. As before, values from this register are read and applied to the caption. It is easy to show that the values read from this register are being sent via the serial link and are not simply being read from the transmitter's data latch. Remove the link and the readings on the display will be "frozen".

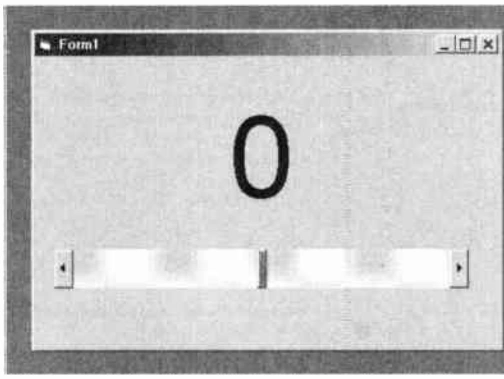


Fig.2. Setting the slider's maximum value to 127 produces the correct result for a halfway setting.

Limitation

If you try the program it will soon become obvious that it does not work properly! Values advance correctly as the scrollbar is adjusted to the left, but things go wrong at the halfway point (Fig.1).

What is happening is that bit 7 is stuck at zero, causing the count to go from 0 to 127 at the midpoint. It then counts up to 127 again as the scrollbar is advanced further to the left. The port seems to opt for seven-bit operation regardless of the word format set via the operating system or writing direct to the serial port's registers.

This is not a limitation of the hardware, and Microsoft's MSCOMM ActiveX add-on provides full eight-bit operation. It is presumably due to a peculiarity in the operating system or firmware. Anyway, limiting the system to seven-bit operation by setting the Max value of the scrollbar to 127 does get the system functioning correctly (Fig.2).

Looping

Data being received by the serial port generates an interrupt, so this represents one way of limiting the program to only taking a reading when fresh data is available. If you prefer to avoid the complications of interrupts it is possible to obtain a hold-off by using a flag bit in the UART's Line Status register.

This register is at &H3FD for serial port one and &H2FD for serial port two. The received data bit is at bit 0, and this is set to 1 when a new byte of data is received. It is automatically reset to zero when the serial port is read.

To receive groups of bytes the program would therefore have to provide a hold-off before reading each byte of data. The hold-off would be provided by monitoring the received data bit and only allowing data to be read once it had been set. A simple loop gives the required action, such as this Do ... Until type:

```
Do Until
(Inp(&H3FD) AND 1) = 1
Loop
```

The bitwise AND function is used to read only the required bit of the register and mask the others. Of course, some form of simple counter routine is needed in order to ensure that each byte of data is sent to the correct destination.

Ins and Outs

The UART gives individual access to the handshake lines of the serial ports, which makes it possible to use them as general purpose inputs and outputs. Remember though, that these lines operate at nominal levels of ±12V and not normal 5V logic levels.

The DTR and RTS outputs are respectively controlled by bits 0 and 1 of the Modem Control register which is at address &H3FC (port one) or &H2FC (port 2). Setting one of these bits at 0 places the relevant output at –12 volts, and setting it to 1 sends it to +12 volts.

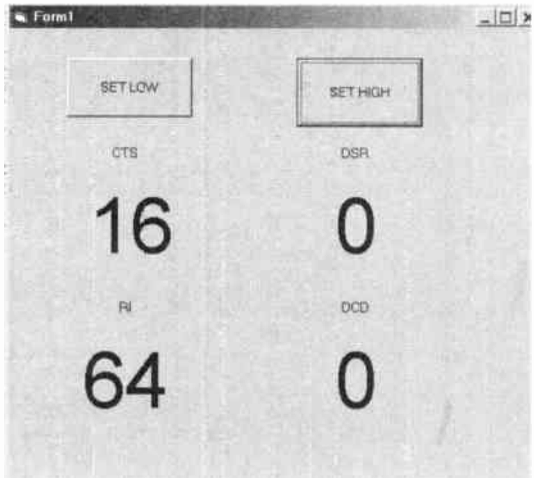


Fig.3. The program in operation.

Handshake

The handshake inputs can be read at the most significant nibble of the Modem status register, as detailed below:

Bit	Handshake Line
4	Clear to send (CTS)
5	Data set ready (DSR)
6	Ring indicator (RI)
7	Data carrier detect (DCD)

The following listing, together with eight labels, two command buttons, and a timer, enables the handshake outputs to be set high or low, and the values read from individual handshake bits to be displayed. You can check out the handshake lines by coupling the outputs to some of the inputs and operating the buttons.

The readings on the relevant labels should change when the output states are changed using the buttons. Fig.3 shows the program in operation.

```
Private Sub Command1_Click()
Out &H3FC, 0
End Sub

Private Sub Command2_Click()
Out &H3FC, 3
End Sub

Private Sub Timer1_Timer()
Label1.Caption = (Inp(&H3FE) And 16)
Label2.Caption = (Inp(&H3FE) And 32)
Label3.Caption = (Inp(&H3FE) And 64)
Label4.Caption = (Inp(&H3FE) And 128)
End Sub
```

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS

Logic Probe testing

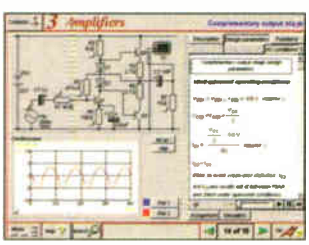
Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations 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.

ELECTRONIC CIRCUITS & COMPONENTS V2.0

Circuit simulation screen

Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits. Active Circuits.*** *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.
Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

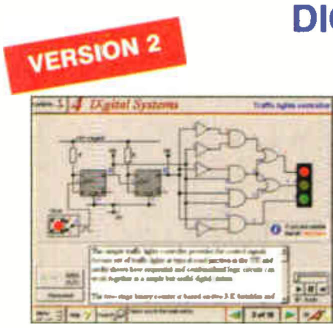
ANALOGUE ELECTRONICS



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.

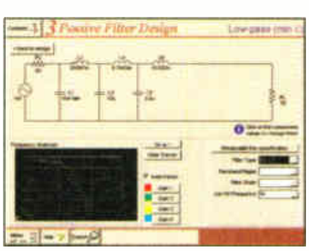
DIGITAL ELECTRONICS V2.0



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. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

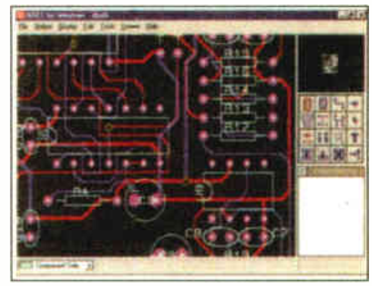
FILTERS



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.

ELECTRONICS CAD PACK



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. (These are restricted versions of the full Labcenter software.) **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 an autorouter operating on user generated Net Lists.

ROBOTICS & MECHATRONICS

Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student	**£45 inc VAT**
Institutional (Schools/HE/FE/Industry)	**£99 *plus* VAT**
Institutional 10 user (Network Licence)	**£199 *plus* VAT**
Site Licence	**£499 *plus* VAT**

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

PICmicro TUTORIALS AND PROGRAMMING

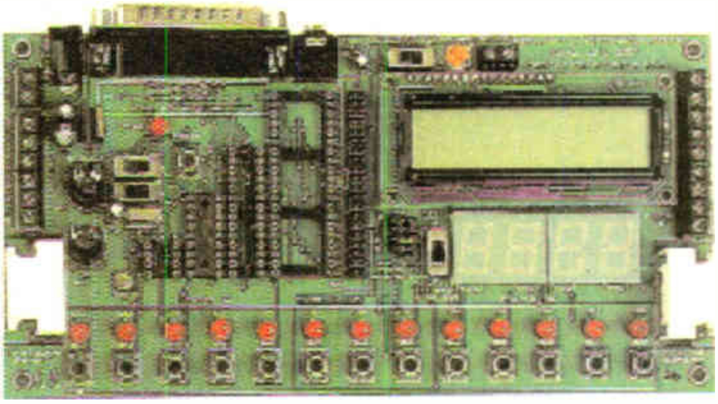
HARDWARE

VERSION 2 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 13 individual l.e.d.s, quad 7-segment display and alphanumeric l.c.d. display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- All inputs and outputs available on screw terminal connectors for easy connection



£145 including VAT and postage

12V 500mA plug-top PSU (UK plug) £7

25-way 'D' type connecting cable £5

SOFTWARE

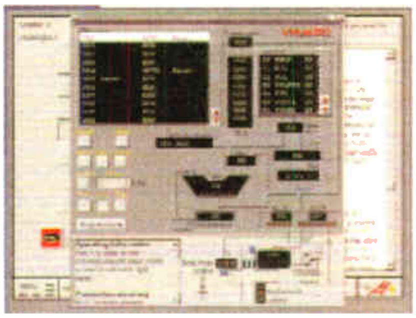
Suitable for use with the Development Board shown above.

ASSEMBLY FOR PICmicro V2

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V2.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes. The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro micro-controller. This is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

● Comprehensive instruction through 39 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.



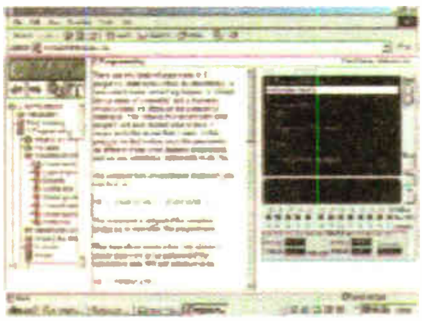
Virtual PICmicro

'C' FOR PICmicro VERSION 2

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

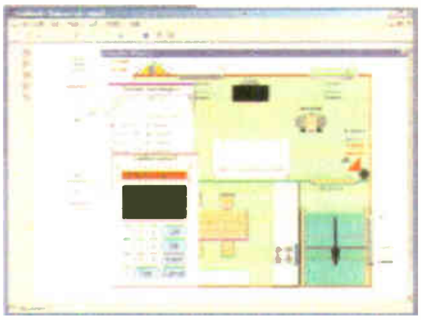
FLOWCODE FOR PICmicro

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex robotics and control systems in a matter of minutes.

Flowcode is a powerful language that uses macros to facilitate the control of complex devices like 7-segment displays, motor controllers and l.c.d. displays. The use of macros allows you to control these electronic devices without getting bogged down in understanding the programming involved.

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 2 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols (ISO5807) ● Full on-screen simulation allows debugging and speeds up the development process ● Facilitates learning via a full suite of demonstration tutorials ● Produces ASM code for a range of 8, 18, 28 and 40-pin devices ● Institutional versions include virtual systems (burglar alarms, car parks etc.).



Burglar Alarm Simulation

PRICES

Prices for each of the CD-ROMs above are:

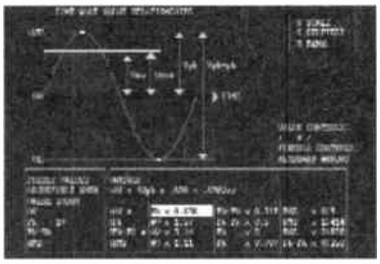
(Order form on next page)

Hobbyist/Student	£45 inc VAT
Institutional (Schools/HE/FE/Industry)	£99 *plus* VAT
Flowcode Institutional	£70 *plus* VAT
Institutional 10 user (Network Licence)	£249 *plus* VAT
Site Licence	£599 *plus* VAT

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

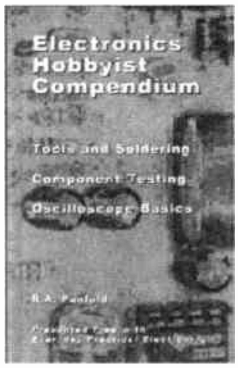
TEACH-IN 2000 – LEARN ELECTRONICS WITH EPE

EPE's own *Teach-In* CD-ROM, contains the full 12-part *Teach-In* series by John Becker in PDF form plus the *Teach-In* interactive software covering all aspects of the series. We have also added Alan Winstanley's highly acclaimed *Basic Soldering Guide* which is fully illustrated and which also includes *Desoldering*. The *Teach-In* series covers: Colour Codes and Resistors, Capacitors, Potentiometers, Sensor Resistors, Ohm's Law, Diodes and L.E.D.s, Waveforms, Frequency and Time, Logic Gates, Binary and Hex Logic, Op.amps, Comparators, Mixers, Audio and Sensor Amplifiers, Transistors, Transformers and Rectifiers, Voltage Regulation, Integration, Differentiation, 7-segment Displays, L.C.D.s, Digital-to-Analogue.



Sine wave relationship values

FREE BOOK WITH TEACH-IN 2000 CD-ROM



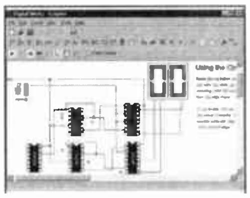
Each part has an associated practical section and the series includes a simple PC interface so you can use your PC as a basic oscilloscope with the various circuits.

A hands-on approach to electronics with numerous breadboard circuits to try out.

£12.45 including VAT and postage. Requires Adobe Acrobat (available free from the Internet – **www.adobe.com/acrobat**).

FREE WITH EACH TEACH-IN CD-ROM – *Electronics Hobbyist Compendium* 80-page book by Robert Penfold. Covers Tools For The Job; Component Testing; Oscilloscope Basics.

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.

Hobbyist/Student £45 inc. VAT.
Institutional £99 *plus* VAT.
Institutional 10 user £199 *plus* VAT.
Site Licence £499 *plus* VAT.

ELECTRONICS IN CONTROL

Two colourful animated courses for students on one CD-ROM. These cover Key Stage 3 and GCSE syllabuses. **Key Stage 3:** A pictorial look at the Electronics section featuring animations and video clips. Provides an ideal introduction or revision guide, including multi-choice questions with feedback. **GCSE:** Aimed at the Electronics in many Design & Technology courses, it covers many sections of GCSE Electronics. Provides an ideal revision guide with Homework Questions on each chapter. Worked answers with an access code are provided on a special website.

Single User £29 inc. VAT. Multiple User £39 plus VAT
Student copies (available only with a multiple user copy) £6 plus VAT
(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

MODULAR CIRCUIT DESIGN

VERSION 3

Contains a range of tried and tested analogue and digital circuit modules, together with the knowledge to use and interface them. Thus allowing anyone with a basic understanding of circuit symbols to design and build their own projects. Version 3 includes data and circuit modules for a range of popular PICs; includes PICAXE circuits, the system which enables a PIC to be programmed without a programmer, and without removing it from the circuit. Shows where to obtain free software downloads to enable BASIC programming.
Essential information for anyone undertaking GCSE or "A" level electronics or technology and for hobbyists who want to get to grips with project design. Over seventy different Input, Processor and Output modules are illustrated and fully described, together with detailed information on construction, fault finding and components, including circuit symbols, pinouts, power supplies, decoupling etc.

Single User £19.95 inc. VAT. Multiple User £34 *plus* VAT
(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

ELECTRONIC COMPONENTS PHOTOS

A high quality selection of over 200 JPG images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).

Also contains a **FREE** 30-day evaluation of Paint Shop Pro 6 – Paint Shop Pro image editing tips and on-line help included!

Price £19.95 inc. VAT

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 95/98/NT/2000/ME/XP, mouse, sound card, web browser.

CD-ROM ORDER FORM

Please send me:

- ☐ **Electronic Projects**
- ☐ **Electronic Circuits & Components V2.0**
- ☐ **Analogue Electronics**
- ☐ **Digital Electronics V2.0**
- ☐ **Filters**
- ☐ **Electronics CAD Pack**
- ☐ **Robotics & Mechatronics**
- ☐ **Assembler for PICmicro**
- ☐ **'C' for PICmicro**
- ☐ **Flowcode for PICmicro**
- ☐ **Digital Works 3.0**

Version required:

- ☐ **Hobbyist/Student**
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- ☐ **Institutional 10 user**
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Note: The software on each version is the same, only the licence for use varies.

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Student/Single User/Standard Version price includes postage to most countries in the world
EU residents outside the UK add £5 for airmail postage per order

Institutional, Multiple User and Deluxe Versions – overseas readers add £5 to the basic price of each order for airmail postage (**do not add VAT** unless you live in an EU (European Union) country, then add 17½% VAT or provide your official VAT registration number).

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Ferndown, Dorset BH22 9ND

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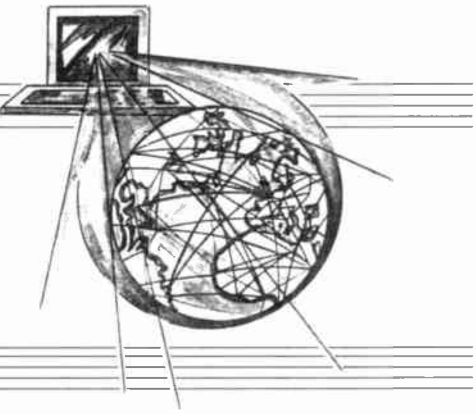
E-mail: orders@wimborne.co.uk
Online shop:
www.epemag.wimborne.co.uk/shopdoor.htm

SURFING THE INTERNET



NET WORK

ALAN WINSTANLEY

A Shedload Of Spam

THIS month we examine what effect the latest legislation will have on the deluge of spam that affects almost every Internet user.

Major Internet service providers intercept millions of spam emails every day, yet a vast number of uninvited spam mails still find their way through to unsuspecting recipients. Fraudulent and deceitful spammers are using increasingly desperate and dirty tricks to confuse spam filters, including stripping in random characters to avoid being trapped by filter systems.

Ironically, many spammers are becoming ever more self-defeating this way, because the mails are so full of random ASCII as to make them virtually unreadable anyway. Other tricks include using an enticing Subject in the message, such as "About our meeting tomorrow" or "I called you last night but you were out", or Subject lines may be left blank altogether. The unrecognised sender's name is usually the giveaway.

Spammers have an atrocious habit of forging senders' email addresses, by mixing usernames with legitimate domain names. For example, at the time of writing I am receiving numerous reject messages to e.g. *alberto_zutman@epemag.demon.co.uk* from irate people who think I am a big cheese in the latest "Weight Loss Patch 100% Guarantee" sales drive. It was my Usenet posts from the mid 1990's that yielded my email address to spammers, and I now receive many thousands of spams every year as a consequence. Email addresses are also vacuumed up from web sites for use by spammers, either to target mail or to forge them as senders' addresses.

A Case for Enterprise

There are some commercial solutions to help overcome the problems of spam. In the case of *EPE*'s mail, when the volumes of highly unsavoury spam reached industrial quantities, genuine incoming emails were in danger of being overlooked or buried as our mailboxes filled up with hundreds of unwanted messages every day. A two week trial with the Enterprise version of Email Filtering (**www.emailfiltering.co.uk**) revealed these statistics: out of 5,843 emails received, 89% of them (5,200 or 371 per day) were either spam or virus-laden. The few hundred pounds a year that is now being spent on EMF's commercial filtering seems like money well spent: for just five users the service starts at £137 per year plus VAT, for which the vast majority of spam, virus and porn emails are filtered out. But of course, this pushes the cost of dealing with spam onto the recipient whilst the senders can send spam for next to no cost.

The EMF commercial system requires alterations to the MX (mail exchange) records of the domain name, so that all incoming email actually arrives at EMF's servers where the junk is then sieved out. The remainder is forwarded to the ISP's mail server awaiting customer collection. It must be said that on a couple of occasions, delays in delivery have resulted in our mail backing up, but alarm bells do ring when the email suddenly dries up so we know something is wrong somewhere. A good tip is to use a POP3 mail client such as Popcorn (**www.ultrafunk.com** price $20) or the recommended JBMail (**http://jbmail.pc-tools.net** $35) to track the live contents of mailboxes, so you can see for yourself what's happening on the mail servers.

A cheaper filtering system operated by EMF is classed as the "home" service. Their server fetches all mail from your POP3 mailbox and filters out most of the spam and virus mail, leaving the client to fetch the remainder from an EMF mailbox or through webmail. This system is less configurable and has been problematic on a small number of occasions, but overall the cost is negligible and the ardent home email user will definitely consider it as money well spent (£3.75 per month). My **epemag.demon.co.uk** mail is filtered this way and EMF has intercepted at least 10,000 emails over the year. Home users face other restrictions, notably the 15MB mailbox size.

Looking at more robust and high-end options, MessageLabs (**www.messagelabs.co.uk**) is one of the best known filtering services around and is used by many large commercial and Governmental sectors, including, they claim, our military intelligence services. Their service requires customers to install a dedicated mail server at the ISP, so it's not possible to hook into your ISP's shared mail server. The cost is more substantial therefore, but they do still offer to cater for small to medium enterprises.

Look – No Teeth!

For readers in the UK, I have some fantastic news – spam email is now illegal! Yes, that's right: under the *Privacy & Electronic Communications Regulations*, UK marketers cannot transmit unsolicited marketing material by electronic mail to individual subscribers, unless they have previously advised that they consent (i.e. they opt-in) to receive it "for the time being".

The catch – sorry to dash your hopes so cruelly – is that there is an immediate exception to this rule that cow-tows to UK-based marketers, known as the "soft opt-in". It's still OK for them to spam individuals if they have previously obtained your contact details from previous sales or negotiations, provided that (i) the products or services now being spammed are similar to anything transacted previously, **and** (ii) the recipient had been given a means of refusing the use of his details for marketing purposes when his details were first collected, **and** (iii) where recipients did *not* refuse the use of his details, he is offered a chance to refuse their use at the time of each subsequent communication (from that marketer). Corporate users will enjoy none of the anti-spam protection afforded to individual subscribers (that's residential users, sole traders and partnerships) under these regulations.

These UK anti-spam rules became law on 11 December '03 but the realisation soon dawned that, actually, it will have little immediate impact on UK users' mailboxes, a view echoed by the highly respected UK anti-spam group Spamhaus (**www.spamhaus.org**). The main problem is of course that the majority of spam is of American origin. A new US law (*Controlling the Assault of Non-Solicited Pornography and Marketing Act of 2003*, or "CAN-SPAM") effective Jan 1st 2004 actually makes it entirely legal to spam recipients provided they get an opportunity to be removed from subsequent mailings.

However, misleading Subject lines, the harvesting of email addresses from web sites, the hijacking of open relays (i.e. using someone else's mail server to send it) and the forging of Return Addresses are all outlawed. Spammers must also provide a valid Remove-me link for at least 30 days (i.e. links of the sort that we've become conditioned to never using, because it often confirms your valid address to the spammer.)

This means that the UK/European Directive and the new US law will be at odds with each other, with UK marketers needing a (soft) opt-in from recipients before mails can be sent, whilst US spam will arrive in torrents, requiring only a subsequent Opt-Out from recipients. In fact, Spamhaus reckons that as a result of the new US anti-spam laws being implemented, the volume of spam seen by European users will more than double in 2004.

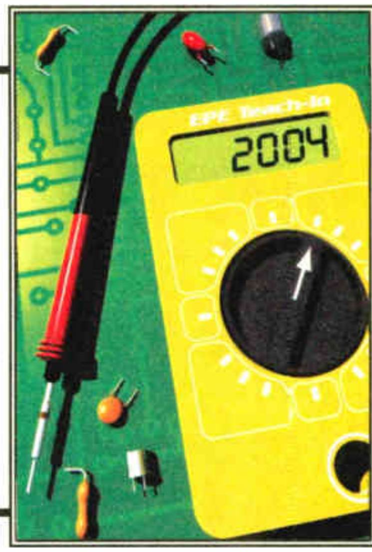
My own view is that although spam volumes may certainly rise as a result of the US CAN-SPAM law, the new rules do at least address a number of major aspects that will help users to identify spam more easily, avoid users being deceived by falsified Subjects and avoid having one's personal address forged as the sender. In two to three years time we should also be able to filter out spam ruthlessly because it will also be a requirement that US spam Subjects are labelled with "ADV" (advert) to permit ruthless filtering. It remains to be seen whether spammers will follow the rules!

You can email me at **alan@epemag.demon.co.uk**.

EPE Tutorial Series

TEACH-IN 2004

Part Four – Experimenting with Logic Gates



MAX HORSEY

How to apply electronics meaningfully – the aim of this 10-part series is to show, experimentally, how electronic components function as part of circuits and systems, demonstrating how each part of a circuit can be understood and tested, and offering advice about choosing components

OPERATIONAL amplifiers (op.amps), as discussed in Part 3, deal with analogue signals, i.e. voltages which can vary *continuously* between the upper and lower power supply voltages. A digital signal has only two voltage states, generally zero and positive.

ANALOGUE vs DIGITAL

Analogue systems have – unfairly – gained a reputation for being less accurate than digital systems. The word *digital* seems to have become synonymous with *excellent* and *perfect*. Advertisers frequently use the word *digital* even in systems which are inherently analogue, *digital headphones*, for example.

As another example, *digital television* is sold as the ultimate in picture quality, but the rather low bit-rate allowed in the digital signal for some programmes, sometimes produces a picture inferior to the analogue alternative.

In principle, an analogue system *can* be perfect. But it is rarely perfect in practice, and it is difficult to copy an analogue signal perfectly. Analogue systems can suffer from external interference, e.g. the wires and components can be affected by magnetic and electrostatic fields. Once interference is added to a signal, it is very difficult to remove.

A digital system can be virtually immune from interference, and a digital signal can be copied with great, even perfect, accuracy. We will return to the problems of digitising an analogue sound signal later in the series, but for now we will concentrate on digital signals – examining logic gates and logic systems.

LOGIC LEVELS

Logic systems, from the humble logic gate to the mightiest Pentium chip, work on two logic levels, logic 0 (generally 0V) and logic 1 (generally the power supply voltage). The power supply voltage used to be 5V for most systems, but some types of CMOS logic gates can operate at up to 16V, (making them very useful for hobbyist project work), and the latest computer chips operate on 3V or less. The lower the voltage, the closer you can pack the components in the chip, and the faster they operate.

If, for now, we assume a 5V power supply, then we can generalise by saying that any signal of less than 2·5V will be interpreted by the chip as logic 0, and any signal above 2·5V will be interpreted as logic 1, although there are exceptions to this rule. The point is, though, that within the voltage ranges called logic 0 and logic 1, our signals do not need accurate voltage levels.

A LOGICAL PROBLEM

To understand why logic gates are useful, consider the problem of a simple coffee vending machine. To obtain coffee, the customer must insert a coin, and press a button. The coffee will only be dispensed if a cup is in place, and the machine is not shaken. We can sum this up as follows:

Coffee dispensed if:

coin-sensor AND coffee-button AND cup-sensor AND NOT shake-sensor

You could probably devise a circuit using switches. For example, an AND circuit could simply be two switches connected in series as shown in Fig.4.1. When switches A or B are pressed separately, nothing happens, but if switch A AND switch B are pressed at the same time, lamp LP1 is turned on.

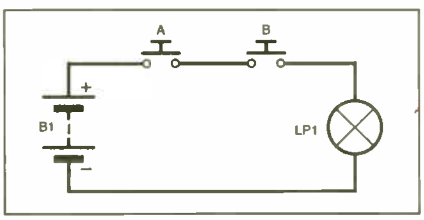


Fig.4.1. Example of an AND function using switches.

However, a hard-wired system is inflexible, and becomes very complicated if more options are added, e.g. milk and sugar! So we resort to electronic logic gates.

INVERTER (NOT) GATE

Our shake sensor switch produces a positive output (logic 1) whenever the machine is shaken. So we will need a NOT gate since shaking must prevent the coffee being dispensed.

A NOT gate is simply a circuit in which the output always has the opposite logic level to that at the input. It is also known as an *inverter* gate, a term we shall use here (and you are unlikely to find the term NOT gate used in catalogues).

An example using a transistor is shown in Fig.4.2. If you connect a voltmeter across the output points it will show a reading of the same voltage as the power suply, in this case the battery. This is because no current is flowing through the transistor, and so there will be no voltage drop across resistor R2 (as explained in Part 2). Since the top end of R2 is connected to positive, the lower end will therefore also be positive.

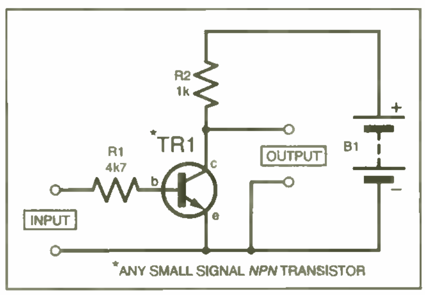


Fig.4.2. A transistor-based inverter circuit.

Now connect the input to R1 directly to the positive power line. The transistor will switch on, and the voltage at the output will fall to zero. Hence the output is always at the opposite logic level to the input. We have an inverter gate.

A transistorised inverter gate may be appropriate when only a single inverter

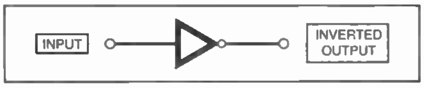


Fig.4.3. Symbol for an inverter gate.

is required, but in logic systems we often require large numbers of gates, and so symbols are used to represent them. The symbol for an inverter gate is shown in Fig.4.3. When the input is at logic 0, the output will be at logic 1, and vice-versa.

It is essential to realise that the gate has access to a power supply, even though power supply pins are often not shown.

The inversion principle is illustrated in Fig 4.4. Note that the switch within the inverter symbol is imaginary – the true story is more like that illustrated by the transistor gate in Fig.4.2.

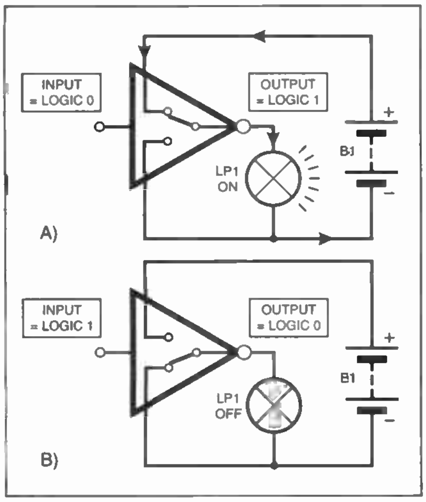


Fig.4.4. Schematic representation of the inversion function.

The circuit in Fig.4.4a shows an imaginary lamp, LP1, which is lit when the inverter input is at logic 0. When the input is at logic 1, the imaginary switch changes over, and the situation is as shown in Fig.4.4b.

(In practice the outputs of most logic gates cannot control a lamp directly, due to the limited current that is available, although some gates can manage to light an l.e.d.)

AND GATE

Our coffee machine also requires an AND gate function. The symbol for an AND gate is shown in Fig.4.5.

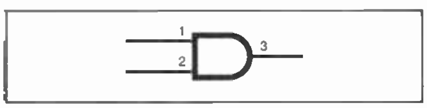


Fig.4.5. Symbol for an AND gate.

The function of the AND gate is summed up as follows:

both inputs logic 0 = output logic 0
either input logic 1 = output logic 0
both inputs logic 1 = output logic 1

We will see later how this information is expressed as a "truth table" and how logic gates are used in practice, but for now we will wire-up our coffee machine.

COFFEE MACHINE SYSTEM

As said, coffee is dispensed if:

coin-sensor AND coffee-button AND cup-sensor AND NOT shake-sensor

We will begin by reducing the word-count as follows:

coffee = coin AND button AND cup AND NOT shaken

When we devise an electronic circuit, the output (coffee) will be on the right, and the inputs on the left. The complete system is shown in Fig.4.6, comprising three AND gates and one inverter.

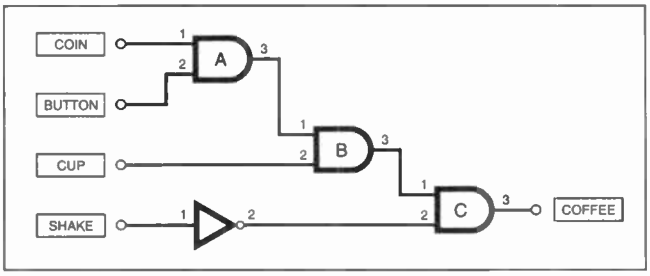


Fig.4.6. Symbolic logic for the coffee machine.

If the coin is inserted (logic 1) AND the button is pressed (logic 1), then gate A outputs a logic 1. If the cup is also in place (logic 1), then gate B outputs a logic 1. If the machine is NOT shaken (logic 0) then the inverter (NOT) gate outputs a logic 1, and so gate C outputs a logic 1 and the coffee is delivered.

So, only if all inputs to all three AND gates are at logic 1 will coffee be delivered. If *any* of the AND gate inputs is at logic 0, then coffee will not be delivered.

SELECTING THE GATES

There are a number of "families" of gates available, but for now we will consider the CMOS 4000 series. These are ideal for project work, since they can be powered from a supply of around 3V to 15V. In this Teach-In we shall use a 9V supply.

In the CMOS 4000 series, four 2-input AND gates are included in one package. This device has the type number of 4081. Because it has four gates it is known as a *quad* 2-input AND gate. Its outline and pinouts are shown in Fig.4.7.

Positive power is delivered to the gates via pin 14, which may be notated as V_{DD} or +VE. The 0V supply is fed to pin 7, which may be notated as 0V, or GND (ground) or V_{SS}.

Note the notch at the top of the i.c. outline. With the real i.c. package, pin 1 is always to the left of this notch, although some i.c.s have a dot indicating pin 1, and some have both the notch and a dot.

The CMOS 4000 series has a device, type 4069, with six inverter gates in it, hence its name of *hex inverter* gate. Its pinouts are also shown in Fig.4.7.

Since we require only one inverter for our coffee machine circuit, we might actually consider using a transistor inverter as shown in Fig.4.2, but many circuits will require several inverter gates, making the use of an i.c. worthwhile, so we will stay with the type 4069 hex inverter.

Having chosen the i.c.s we need, we can now amend the circuit in Fig.4.6 to a physical layout, such as that in Fig.4.8. This is not meant to be a fully finished layout, but shows how the two i.c.s could be combined. There are also refinements to this layout which we must make, as discussed later.

STATIC PRECAUTIONS

There are several things you need to understand in order to use CMOS logic i.c.s successfully. The first is that the input pins on each gate are static sensitive, and you must take "static precautions" in order to avoid damaging the chip.

When we move about, our bodies and clothes often become charged with static electricity. The amount of current involved

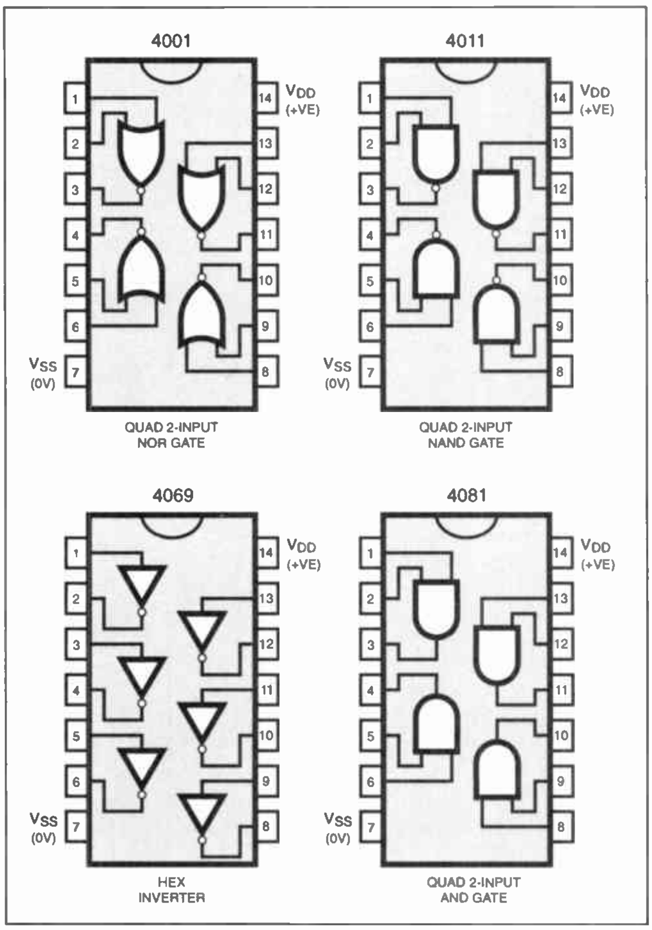


Fig.4.7. Pinout diagrams for four logic gate types.

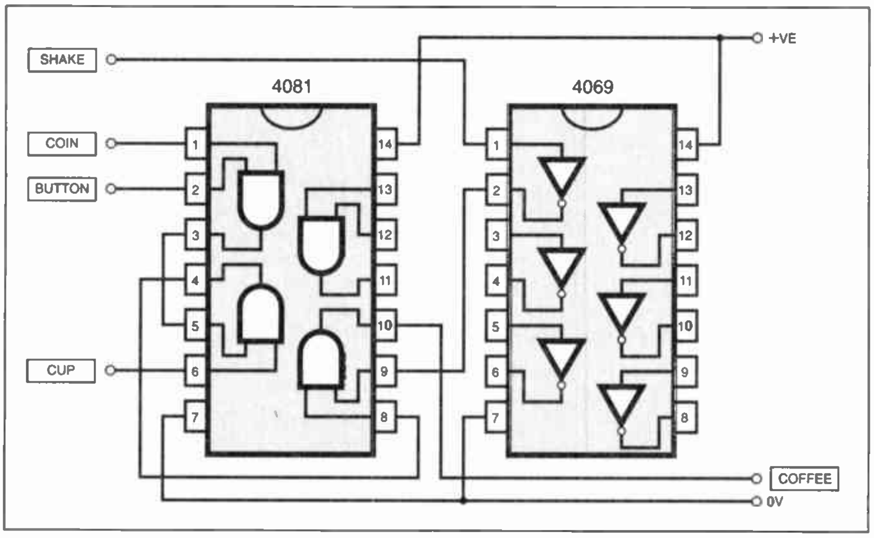


Fig.4.8. Physical interpretation of the logic in Fig.4.6.

is too small to cause us any harm, but the voltage can rise to several hundred volts or more.

When we handle "ordinary" components, such as resistors and bipolar transistors, this voltage is unlikely to harm them. However, an increasingly wide variety of modern electronic components *can* be damaged or destroyed if such voltages are appplied to them. Such devices include field effect transistors (f.e.t.s) and, in particular, those devices manufactured using what is known as the CMOS process, which includes the 4000 series of logic gates.

Therefore, when handling a CMOS device you must first touch an earthed metal object, such as the metal case of an appliance plugged into the mains. This discharges the static electricity from your body.

Once a CMOS device has been connected into a circuit, the presence of other components in the circuit will *usually* protect it from static damage. However, when experimenting, it is wise to frequently touch an earthed object, especially after walking around the room.

Wrist earthing straps are also available and should be used when handling expensive i.c.s. Such straps have a very high resistance which limits the current flow to a very small amount, and so allows high static voltages to flow harmlessly out of your body and to ground. Photo 4.1 shows an earthing strap plugged into the earth terminal on a power supply.

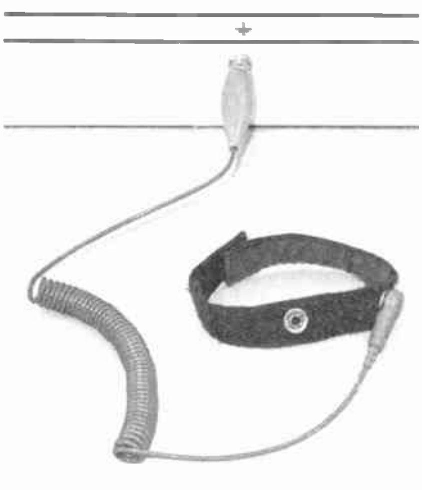


Photo 4.1. An earthed wrist strap which prevents the build-up of static electricity in the user.

INPUT PROTECTION

Any CMOS logic gate input which is *open-circuit* (also known as *floating*), i.e. not connected to anything, is liable to static damage at worst, and erratic behaviour at best. This applies to inputs that are controlled by switches, and those that are unused. In the case of unused inputs, they must be connected to either the 0V or +VE power line. It is preferable to use the 0V line wherever convenient.

Note that the *outputs* of unused gates *must* be left unconnected.

If unused gate inputs remain open-circuit, stray voltages may cause the gates to oscillate (switch rapidly between logic 1 and logic 0). This in turn may generate interference and will certainly increase the current consumed by the i.c.

An example of an input that can be switched from logic 0 to logic 1 is shown in Fig.4.9. When switch S1 is open (not pressed), resistor R1 pulls the input to logic 0. When the switch is closed, the input is forced to high (positive), i.e. logic 1.

The value of the resistor can be from 10kΩ to 1MΩ. A lower value will make the system less sensitive to stray voltages, a higher value will waste less current when the switch is closed. A value of 100kΩ is a good compromise.

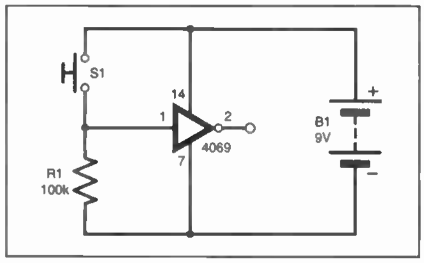


Fig.4.9. A switch-controlled inverter circuit.

When experimenting with the logic gate circuits described from hereon, it is advisable to always connect any unused inputs to the 0V line.

FINAL CIRCUIT

The output from a CMOS gate cannot source enough current to operate a solenoid or motor required to switch on the flow of coffee. So a Darlington transistor is employed (these were discussed in Part 2).

The final circuit is shown in Fig.4.10, minus the inverter gate, which has been designed out! This is achieved by using resistor R1 as a "pull-up". If switch S1 is *not* pressed (i.e. machine not shaken) then the input at IC1c pin 9 will be at logic 1, until S1 is pressed. Hence the inversion action is achieved without an inverter gate.

Note the pull-down resistors R2, R3 and R4. These ensure that the inputs are held at logic 0 unless switches S2, S3 or S4 are pressed.

There is one unused gate in the quad package of the 4081 AND gate, IC1d. Its two inputs are connected to 0V, and its output left unconnected, as discussed earlier.

The output of gate IC1c is fed to Darlington transistor TR1, with resistor R5 limiting the current flow into its base (b). The transistor is employed to power the output device, labelled as the "coil". This may be a relay coil, a solenoid or a motor. In all three cases, diode D1 is required to remove high voltage spikes (back e.m.f.) produced by the coil at the moment that it is switched off.

Capacitors C1 and C2 help to remove any power supply line voltage fluctuations, especially those caused by a solenoid or motor starting up.

Note that the supply has now been increased to 12V. This is because the majority of relays and solenoids require 12V. The breadboarded test circuit, complete with p.c.b. mounting relay but minus capacitor C2, is shown in Photo 4.2.

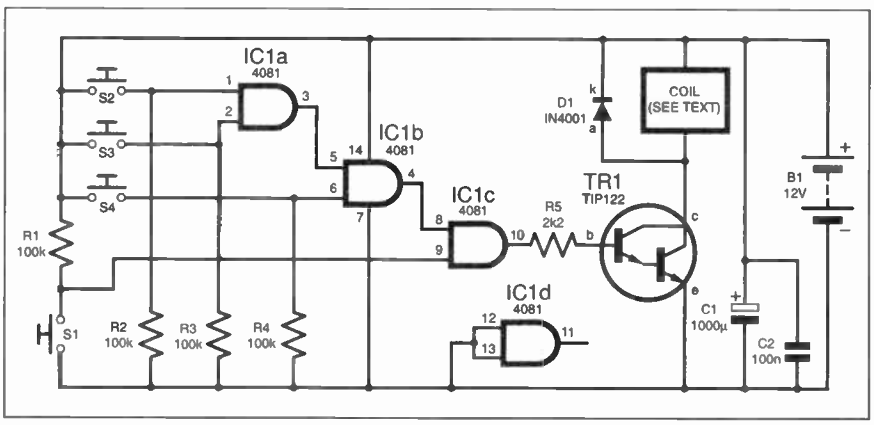


Fig.4.10. Final circuit diagram for the coffee machine controller.

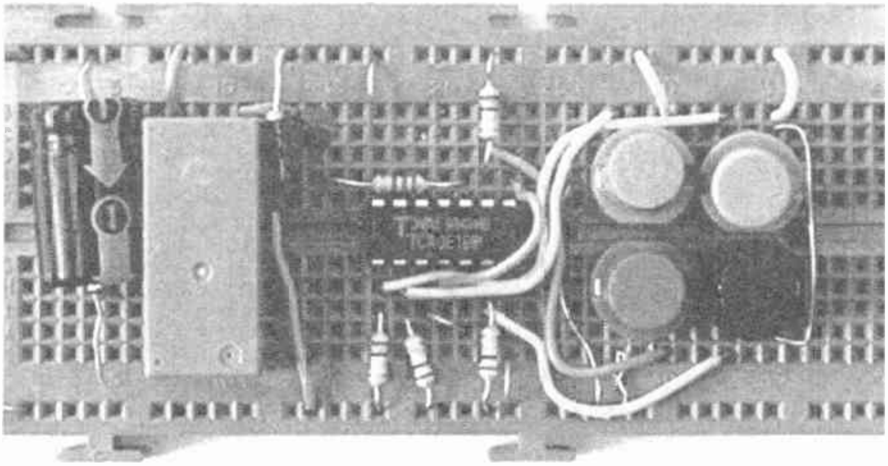


Photo 4.2. Breadboard layout for the circuit in Fig.4.10, but minus capacitor C2.

TRUTH TABLES

Having seen the practical use of an AND gate, we need to consider the full range of gates available. First, though, you need to be familiar with the concept of *truth tables*. These were mentioned earlier in relation to the behaviour of an AND gate in response to the logic levels on its inputs.

It is easier to view the effect of gates by means of a truth table (see Fig.4.11). To take the truth table for an AND gate, the inputs are labelled A and B, and the output Q. Notice how all the possible combinations of logic levels for A and B are shown. Output Q remains at logic 0 unless both A and B are at logic 1.

All the principle logic gate symbols, together with their truth tables, are shown in Fig.4.11.

We have already discussed the use of AND and inverter gates. Example uses of other gate types will be given as we progress, but in brief their functions are:

NAND GATE: a NAND gate combines an AND gate and an inverter. Its output is the opposite of an AND gate in response to the same input logic levels.

OR GATE: with an OR gate, if *either* input is at logic 1, so too is the output. Both inputs must be at logic 0 for the output to also be at logic 0.

NOR GATE: the output of a NOR gate is the opposite of that for an OR gate.

BUFFER GATE: this gate may appear pointless, but remember that the current required at the input is generally very low, under $1\mu A$ for a CMOS gate, yet the output current required can be several milliamps. A buffer can be used as a "current amplifier" between the input and output devices.

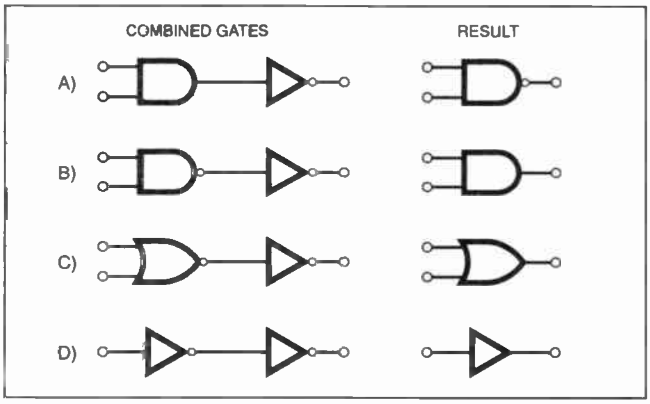


Fig.4.12. The results of following a logic gate by an inverter.

XOR GATE: the output of an exclusive-OR gate (written as XOR or occasionally EOR) is at logic 1 when input A is at logic 1, OR input B is at logic 1, but not both together – when the output is always logic 0.

XNOR GATE: the output of this gate is the opposite of that for an XOR gate.

COMBINING GATES

It is possible to combine some gates to achieve another function. For example, if you follow an AND gate with an inverter gate, as shown in Fig.4.12a, the result is a NAND gate.

If you combine a NAND gate with an inverter (Fig.4.12b), then like any double-negative the negatives cancel, and we are left with an AND gate.

The combination of a NOR gate with an inverter is shown in Fig.4.12c. Using two inverters together simply produces a buffer gate, as in Fig.4.12d.

We can also make an inverter gate by joining together the inputs of a NAND gate or a NOR gate, as shown in Fig.4.13. For example, if you need an AND gate, a NAND gate and an inverter gate in the same circuit, instead of buying three i.c.s, you can use a single quad 2-input NAND gate (e.g. CMOS 4011), as shown in Fig.4.14.

The NAND gate is simply IC1a. The inverter is formed by connecting the inputs of IC1b. The AND gate is made combining IC1c and IC1d.

In fact you can make any gate out of NAND gates or NOR gates. For instance, the making of an OR gate from three NAND gates is illustrated in Fig.4.15.

But how do you know the system in Fig.4.15 will work? Again, a truth table comes to the rescue. Begin by labelling the intermediate points, T and U in our case. Now list all the possible combinations of the inputs, R and S:

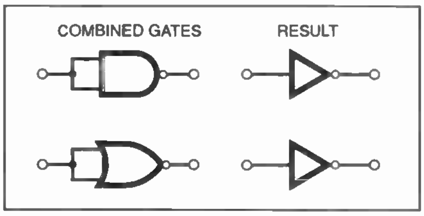


Fig.4.13. Connecting the two inputs of NAND or NOR gates results in an inverter gate.

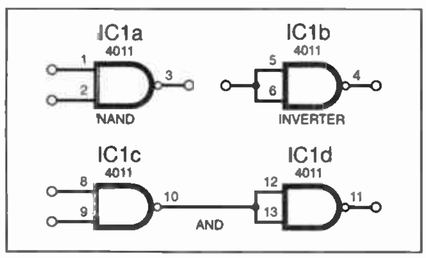


Fig.4.14. Using the four gates in a quad NAND package to achieve inverter, AND and NAND functions.

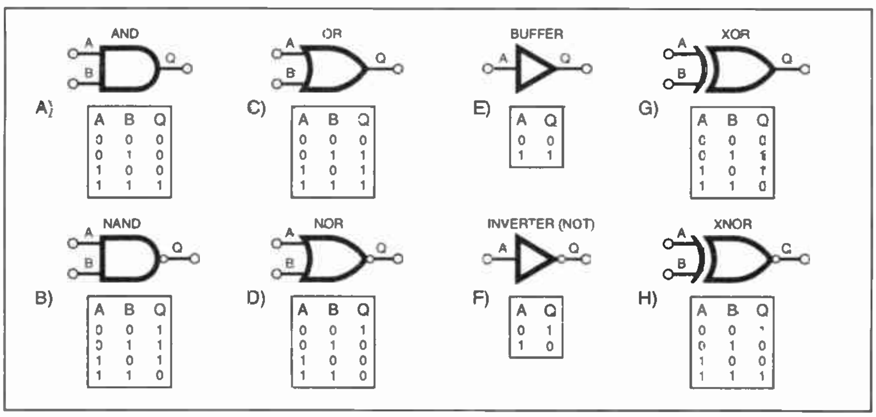


Fig.4.11. Truth tables for a variety of logic gates. other gate types with more inputs exist.

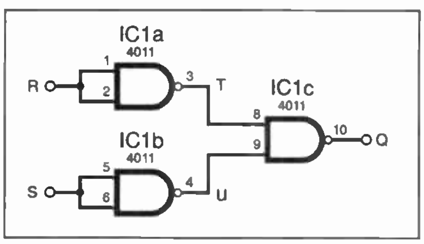


Fig.4.15. Using three NAND gates to achieve a NOR function.

R	S	T	U	Q
0	0	1	1	0
0	1	1	0	1
1	0	0	1	1
1	1	0	0	1

Notice that output Q is logic 1 when R or S are logic 1. Hence we have an OR gate. You could add another NAND gate with its two inputs joined to make an inverter and convert the system into a NOR gate. It can often be cheaper or more convenient to use several NAND gates and convert them into whatever gate is required.

LATCHING

From this point on, we will use the word *high* to indicate logic 1, and *low* to indicate logic 0.

An OR gate can be made to latch, i.e. the output changes to high and remains high even if the input is made to switch back to low. To do this we can employ *positive feedback* where the output is fed back to a spare input as shown in Fig.4.16.

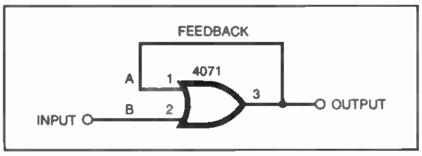


Fig.4.16. Using feedback to produce a latching OR gate.

If input B goes high, the output will copy, and will in turn feed to input B, so keeping the gate latched in the new state. The gate behaves rather like a "bit" of memory.

In practice, if input B is controlled by a switch, it must be held at logic 0 by means of a resistor (as discussed earlier), and we must make provision for unlatching (resetting) the gate, so a more intelligent approach would be the circuit shown in Fig.4.17.

Resistor R1 holds input pin 2 low unless switch S1 is pressed. When S1 is pressed, the output goes high and feeds back via resistor R2 to input pin 1, so latching the system. When switch S2 is pressed input pin 1 is pulled to 0V, so unlatching the system.

Resistor R2 is needed so that the output is not "shorted" when S2 is pressed.

An example of using two inverter gates in a latch configuration is illustrated in Fig.4.18. Note that the value of feedback resistor R2 has been reduced to 10kΩ. This is to ensure that when the output is high, the potential divider effect of resistors R1 and R2 provides a high enough voltage to ensure that the system remains latched.

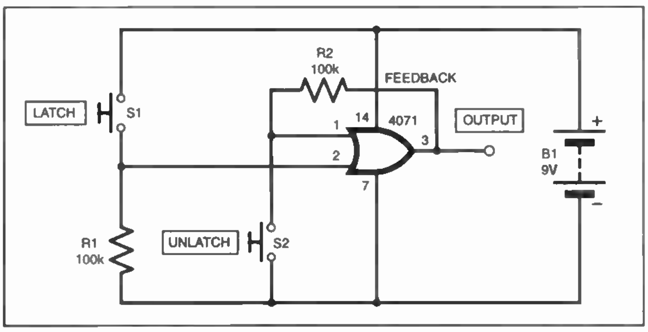


Fig.4.17. A practical latch/unlatch function using an OR gate.

Resistor R2 could be replaced with a diode (D1) if preferred, with its anode (a) connected to the output at pin 4.

QUIZ GAME CONTROLLER

And now for something fun! It is a "who's first?" monitor for two contestants, each with a pushbutton switch. The circuit is shown in Fig.4.19. If contestant A presses first (switch S1) then A's output will go high, and that prevents contestant B's switch from working.

The system requires four inverting gates; we will use NOR gates wired as inverters, based on the quad 2-input NOR gate type 4001, although four gates in a hex inverter type 4069 would do just as well. You could also use NAND gates, type 4011 for example.

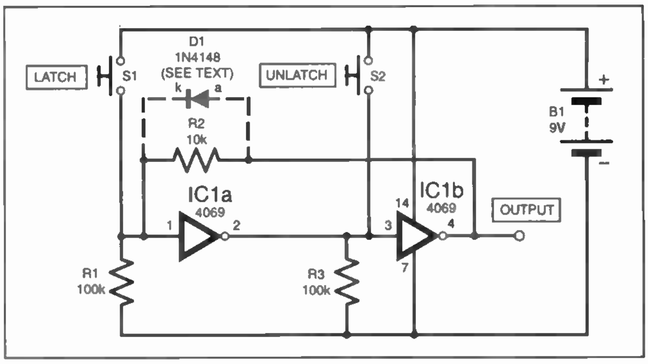


Fig.4.18. Using two inverters in a latching configuration.

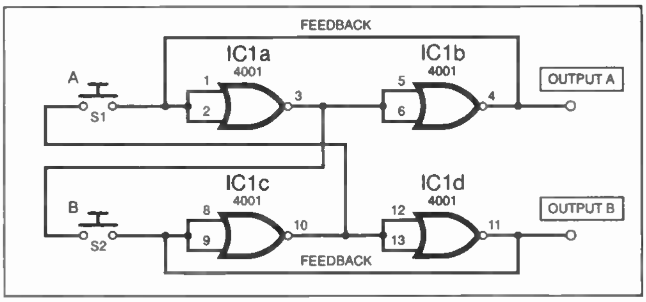


Fig.4.19. Circuit diagram for an elementary "who's first" monitor.

We will assume that at power-up the outputs from pins 4 and 11 are low. Hence the feedback will cause input pins 1, 2, 8 and 9 to be low. The inversion action will make pins 3 and 10 high, and these will force pins 5, 6, 12 and 13 high. The system is therefore stable, and the high from pin 3 is connected to switch S2, and likewise the high from pin 10 is connected to switch S1.

Suppose person B presses switch S2. Pins 8 and 9 will go high, and so pin 10 will go low. This makes pins 12 and 13 low, and the inversion action of IC1d forces pin 11 high. Hence output B switches high. Meanwhile, the feedback loop to pins 8 and 9 maintains gates IC1c and IC1d in this new state. Remember that pin 10 is now low. Hence if person A tries to press switch S1, nothing will happen. So person A has been beaten by person B.

Whoever presses their switch first will make their own output switch high, and this prevents the other output from working until the system is reset.

FINER DETAILS

There are several potential failings for the circuit in Fig.4.19. The first is that there is no way of telling whether A has beaten B. This can be resolved by using l.e.d.s activated appropriately in response to the winning output level.

However, CMOS 4000 series devices cannot provide sufficient current to adequately drive an ordinary l.e.d. The outputs can typically provide about 4mA maximum, and the output voltage falls if an attempt to take more than this is made.

To boost the output current a transistor can be used. The circuit in Fig.4.20 shows how this is done. Each output has its own transistor, TR1 and TR2, with its drive current buffered by resistors R3 and R4.

When an output is high, the respective transistor is turned on, so turning on the l.e.d. (D1 or D2) in its collector path. The current through the l.e.d.s is buffered by resistor R5. Only one resistor is needed here as only one l.e.d. can ever be active at any given time.

The second problem is that we assumed that at power-up the circuit would start in its reset state, with output pins 4 and 11 both low. This depends upon which gates switch on first – and this depends upon minute differences in manufacture. To the user, it is random. We need to ensure that inputs 1, 2, 8 and 9 are held low for a moment at power up, so forcing the system to start-up in its reset state.

This can be achieved by means of capacitors C1 and C2. Capacitor C1 holds pins 1 and 2 low at power-up, and capacitor C2 does the same for pins 8 and 9. When switch S2 is pressed, C2 quickly charges and so pins 8 and 9 go high.

Whilst there is virtually a short-circuit current into C2 at this moment, it is for a very short time, and CMOS 4000 series outputs can tolerate a brief short-circuit. A 10kΩ resistor could be placed in series with each pushswitch, but it really is not necessary.

A more risky short-circuit is prevented by resistors R1 and R2. These ensure that input B at pins 8 and 9, for example, can be made positive when switch S2 is pressed, even though output pin 11 is low. Resistor R2 ensures that the current flowing via S2 from output pin 3 is not "lost" into output pin 11, which is initially at 0V.

The power supply, 9V in this case, is decoupled by capacitor C3. The value required for C3 depends upon the amount of current required by the output devices but 470μF should be more than sufficient with l.e.d.s D1 and D2 as the output devices.

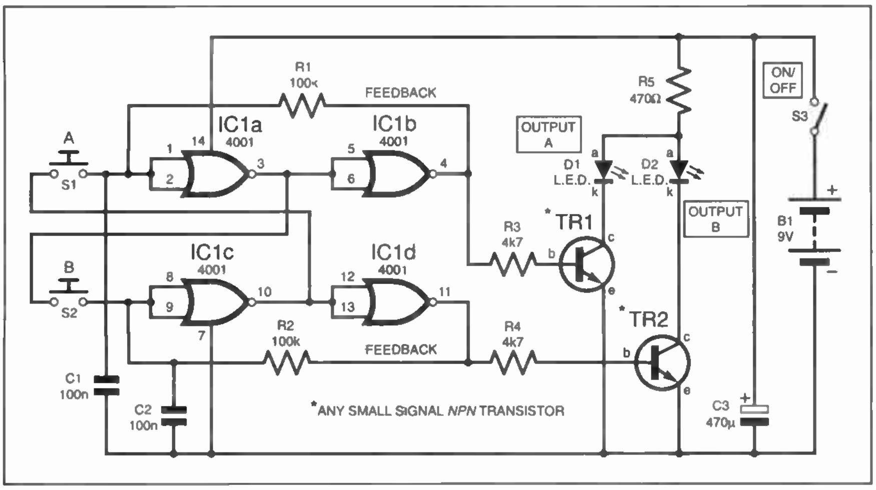


Fig.4.20. A fully working implementation of the circuit in Fig.4.19.

Every musical instrument has a different set of overtones, and so, for example, a trumpet sounds different to a piano, even when both are playing the same note.

A square wave (the bottom graph in Fig.4.21) contains an infinite number of overtones. Most amplifiers can handle sinewaves with ease, but a test of a good amplifier is to apply a square wave at its input and view the shape of the waveform at the output. You are likely to see rounded edges and other imperfections, especially at upper and lower frequencies.

We will examine three types of multivibrator, based on logic gates:

- **Bistable multivibrator** – often referred to as a flip-flop or latch
- **Monostable multivibrator** – also known as a one-shot multivibrator and is often used as a timer
- **Astable multivibrator** – which generates a continuous stream of waveforms, typically square waves but not necessarily so.

Remember that the purpose of C3 is to "smooth-out" any sudden dips in the power supply voltage, which could cause the system to fail to latch (i.e. fail to stay on after a switch is pressed). In other applications, if a greater load is used, the value of C3 may need increasing.

Toggle switch S3 is used to reset the system, by switching it off and then on again. You could use a normally-closed pushswitch in series with S3 if a pushbutton reset is preferred.

The prototype test circuit assembly is shown in Photo 4.3.

It is worth noting that the 74HC family of logic gates can provide an output current of up to about 25mA, and so could be used to drive an l.e.d. (via a buffer resistor of course) without transistors.

It must be noted, though, that the 74HC series can only be powered at a typical maximum of about 6V (7V for 74HC devices from some manufacturers). Secondly, devices in this 74HC family have different pinouts to devices of a similar function in the 4000 series.

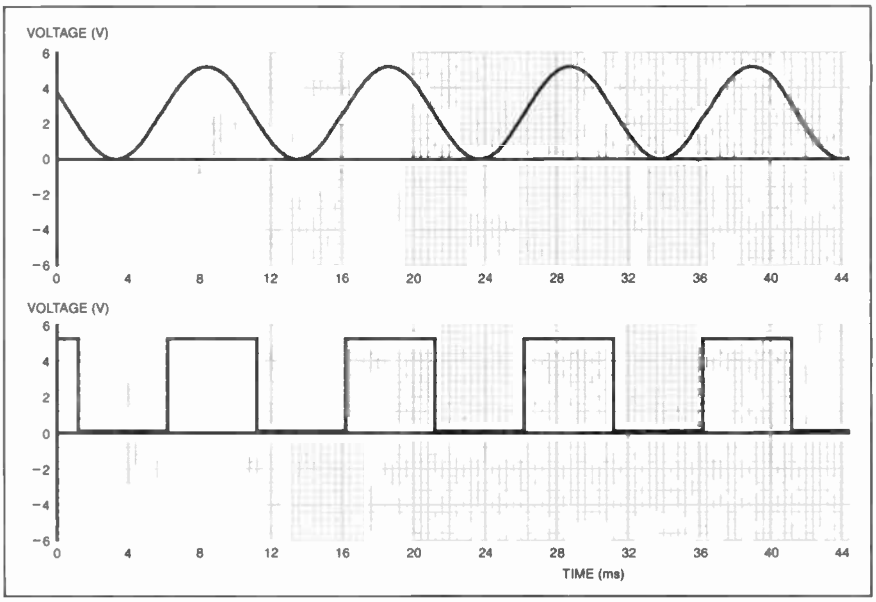


Fig.4.21. A sinewave (upper graph) contains no harmonics or overtones and is a "pure" waveform. A square wave (lower graph) contains an infinite number of overtones.

MULTIVIBRATORS

In the context of electronics, the term *multivibrator* simply means a circuit which generates a voltage that switches between high and low, either once, or many times.

Two graphs are illustrated in Fig.4.21, the upper one is a sinewave. This is a "pure" waveform and it consists of an exact frequency with no overtones or harmonics.

A mechanical tuning fork produces a sinewave and so is useful when tuning instruments. But most musical sounds contain overtones – additional frequencies which add "colour" to the sound.

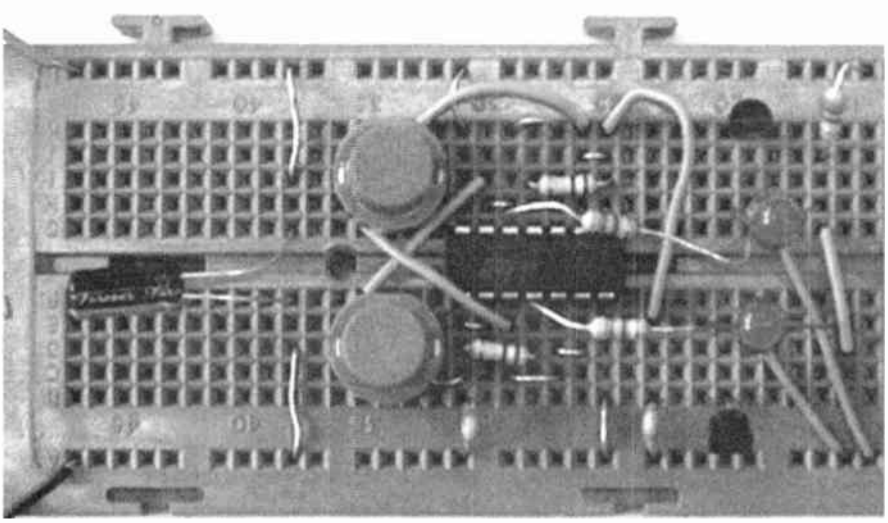


Photo 4.3. Breadboard assembly for the circuit in Fig.4.20.

BISTABLE MULTIVIBRATOR

A bistable circuit is stable in two states, but can be switched between those states. So our quiz circuit was a type of bistable since each half of the circuit could be latched with its output high or low. We have already seen how an OR gate can be made to latch by means of feedback, but we will now examine a more sophisticated bistable, using two NOR gates, as shown in Fig.4.22.

We will assume that at power-up IC1b output pin 4 (marked Q) is low, and that IC1a output pin 3 (marked $\overline{Q}$) is high. Hence IC1a input pin 2 is low and IC1b input pin 5 is high.

At this stage we need to check the truth table for a NOR gate since this will help understand the action of the circuit.

INPUTS		OUTPUT
0	0	1
0	1	0
1	0	0
1	1	0

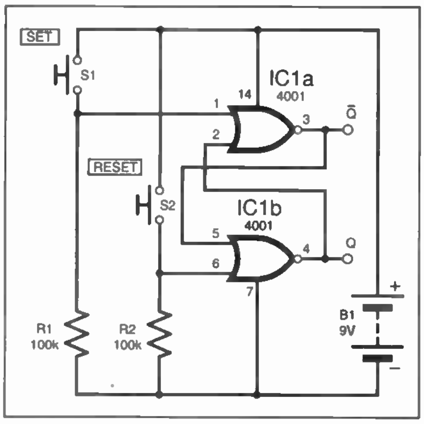


Fig.4.22. A NOR gate bistable.

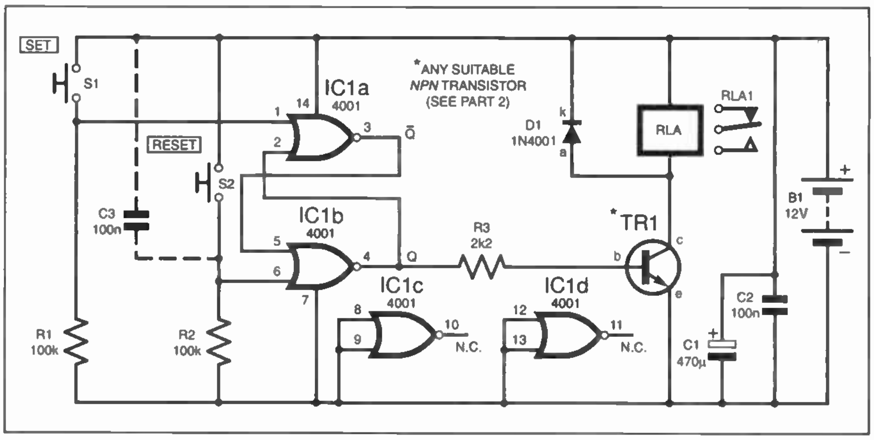


Fig.4.23. A practical implementation for a bistable controlled relay.

GATE A: At present, IC1a input pin 1 will be low since it is pulled down by resistor R1. Remember that IC1a input pin 2 is held low by IC1b pin 4. The truth table shows that if both inputs are low then the output will be high. Hence IC1a output pin 3 is high, which is what we agreed earlier – i.e. gate IC1a is stable.

GATE B: If IC1a pin 3 is high, then IC1b pin 5 will be high. IC1b pin 6 will be low, due to R2. The truth table shows that with one input high, and the other low, the output will be at logic 0. Hence gate IC1b is also stable.

PRESS S1: When S1 is pressed, IC1a pin 1 will go high. IC1a pin 2 will still be low, so our truth table shows that IC1a output pin 3 will now go low. This forces IC1b pin 5 low. Now with both input pins 5 and 6 low, IC1b output pin 4 will go high.

RELEASE S1: When S1 is released, IC1a pin 1 will return low. But IC1a pin 2 is now high since it is connected to IC1b output pin 4, and the truth table shows that IC1a output pin 3 will remain high. In other words, the system has now been latched into its alternative state.

You will have seen from this sequence that the two outputs always have the opposite logic state, one inverted in respect of the other. Conventionally, such outputs are labelled Q and $\overline{Q}$, the bar symbol indicating the inversion.

Triggering the Set input (S1) causes output Q to go high and output $\overline{Q}$ to go low. The Reset input (S2) causes output Q to go low and output $\overline{Q}$ to go high.

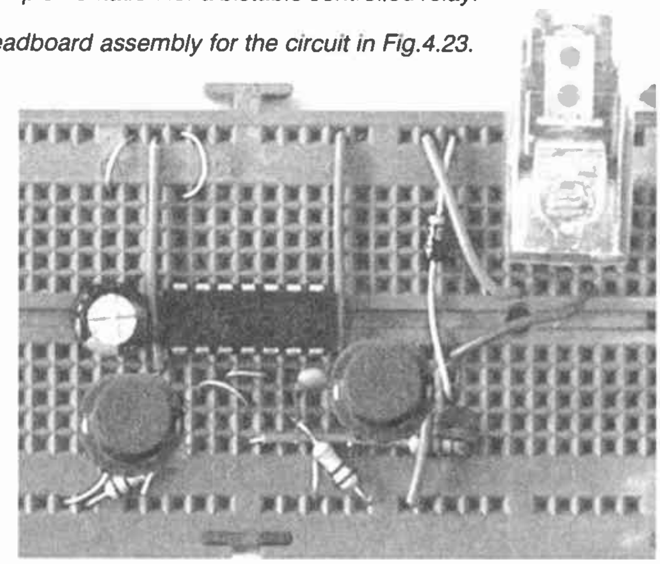
It is worth noting that with slight modification to the circuit, a NAND gate could be used to perform the same function. The modification is to interchange the positions of S1 and R1, and also the positions of S2 and R2. This means that the inputs are normally held high but go low when their switch is pressed.

PRACTICAL NOR BISTABLE

Staying with the NOR gate bistable, we will add the necessary components to make a practical circuit, plus a transistor and relay to control an appliance. You will then be able to press S1 to switch on the appliance, and press S2 to switch it off.

The full circuit is shown in Fig.4.23 (and Photo 4.4). We have added transistor TR1, which can be any high-gain *npn* type capable of driving a small relay, a BC549 for example (see Part 2). It is controlled by IC1b output pin 4 (Q) via base resistor R3.

Photo 4 (below). Breadboard assembly for the circuit in Fig.4.23.



The value of R3 has been chosen to ensure that enough current is available through TR1 to suit the relay coil (RLA). As the relay coil will generate back e.m.f. at the moment that it is switched off, diode D1 is used to protect the transistor.

The relay contacts (RLA1) are used like any change-over switch, to control the appliance. DO NOT use a mains appliance, unless you are suitably qualified, in which case ensure that the relay contacts can withstand the a.c. mains voltages applicable in your country. The contacts must also be suitably rated for the current (amps) used by the appliance.

The power supply for the circuit is shown as 12V, since this is a more useful supply when using relays. Note that at power-up the circuit may latch in either state, and may need to be reset by pressing switch S2. If you require the circuit to always latch into its "output low" state at power-up, then add capacitor C3. This will provide a short logic 1 pulse at power-up to force a reset.

MONOSTABLE

As the name suggests, a monostable multivibrator is stable in only one state. If it is forced into the alternative state it returns to its stable state after a set period of time. It is frequently used as the basis of timing circuits.

A basic monostable is shown in Fig.4.24. Again we have employed NOR gates, but note that you cannot use NAND gates in this design without redesigning it.

At power-up the system generally triggers. This should not be a problem, though, as the circuit is normally left permanently on and the initial triggering will time out after the preset period.

Assuming we have waited sufficiently for the circuit to enter its standby state, the output pin 4 will be low and l.e.d. D1 will be switched off. In this state, the current consumed by the circuit is negligible.

IC1a pins 1 and 2 will be low when the circuit is in its standby state, IC1a output pin 3 will be high. The positive side of capacitor C1 will also be high due to the presence of resistor R2. Hence IC1b pins 5 and 6 are high, so making its output pin 4 low. The system is stable in this condition.

Pressing switch S1 sets IC1a pin 1 high. The NOR gate truth table shows that output pin 3 will thus go low. This sudden change

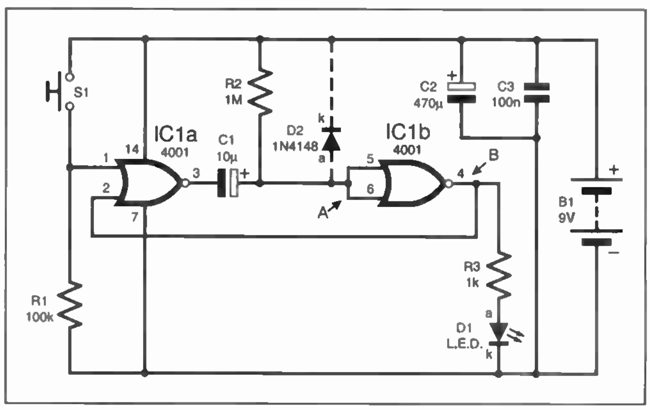


Fig.4.24. A basic monostable circuit.

of voltage on the negative side of C1 will be copied to its positive side (remember that capacitors conduct *changes* of voltage). Consequently IC1b pins 5 and 6 will go low, hence the output pin 4 will go high and l.e.d. D1 will light.

This high state is fed back to IC1a pin 2 so that even if the switch is released, the system will remain in this new state. In other words, pressing switch S1 just provides a trigger.

However, the system is now unstable. There is a voltage difference across resistor R2 and so current will flow through it, slowly charging up capacitor C1. The negative side of C1 will remain low, while the positive side rises in voltage. When this voltage reaches about one half of the supply voltage, the output of IC1b changes state, pin 4 going low. So l.e.d. D1 is turned off and IC1a pin 2 goes low again.

The truth table shows that IC1a output pin 3 will now go high, and this change of voltage is copied to the positive side of C1, trying to push it above the positive power supply voltage, as shown in Fig.4.25a.

All this happens very quickly, and the effect is to make IC1b output pin 4 change state very decisively – a good thing. However, trying to push IC1b input pins 5 and 6 above the positive supply voltage can be quite a bad thing!

CMOS gates are (within limits), designed to withstand such abuse, having protection diodes built into their input circuitry. These diodes limit the input voltage swings to about 0·6V above the power supply positive voltage, and to about 0·6V below the power supply 0V line.

Provided that the current flow through these diodes is not too great, input voltages are held within the set extremes. It is preferable, though, to place an external diode on the input pins in the type of situation just described for IC1b. The diode is shown as D2, and a type 1N4148 is suitable.

TRIGGER PERIOD

The time for which the output at IC1b pin 4 is high can be obtained from the formula:

T = R × C × 0.7

where:

T is in seconds
R is in ohms
C is in farads

The units in this formula are rather inconvenient in relation to the values for R2 and C1 in Fig.4.24, and a better arrangement is for R to be expressed in megohms and C in microfarads. So in Fig.4.24, with R2 at 1MΩ and C1 at 10µF the triggered time will be:

T = 1 × 10 × 0.7 = 7 seconds

The actual time will depend upon the tolerances of the components used. Note in particular that large value electrolytic capacitors are very inaccurate. Also, there is no provision in the circuit for completely discharging the capacitor, and so the actual time will be slightly shorter than predicted if the button is pressed soon after the end of the previous timing cycle.

It is also unwise to use a resistor value greater than 1MΩ as electrolytic capacitors can be "leaky" (see Part 1), which can cause considerable inaccuracy. So a maximum capacitor value of 1000µF is recommended if reasonable accuracy of repeatability is required. This provides a maximum calculated time of 11·7 minutes. If much longer times are required, it is better to use an astable and a counting circuit.

Note that holding the switch down does not affect the timing – you can even hold it for longer than the timing cycle and the circuit will still time-out correctly.

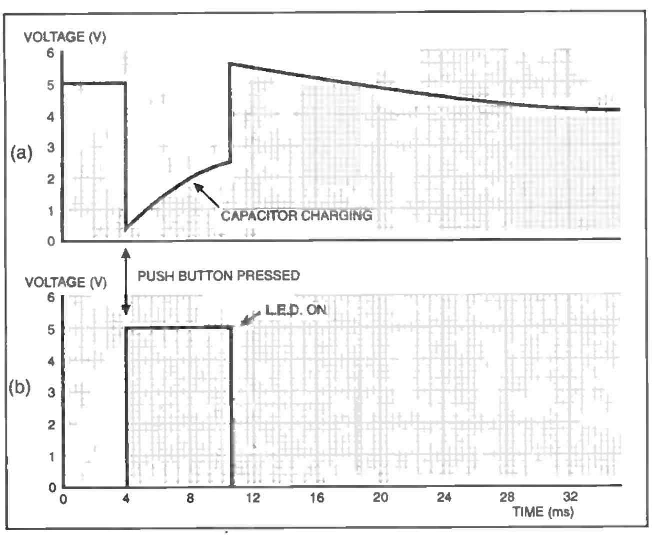


Fig.4.25. Graphs illustrating the behaviour of the circuit shown in Fig.4.24.

ASTABLE

An astable multivibrator is never happy! If its output is high, it soon changes to low, and then back to high, and so on. An example circuit and its waveforms are shown in Fig.4.26.

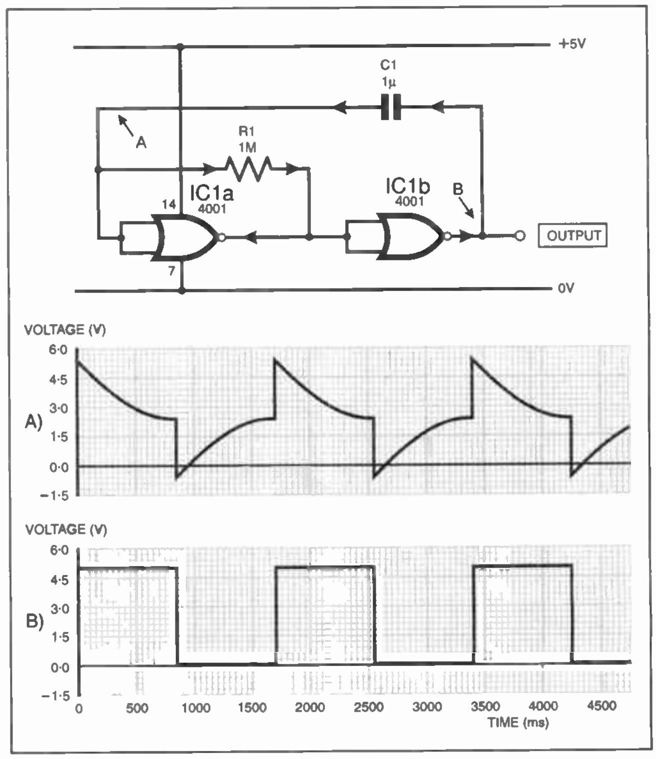


Fig.4.26. An example astable (oscillator) circuit and associated waveforms.

The circuit consists of two NOR gates used as inverter gates, IC1a and IC1b, plus resistor R1 and capacitor C1. NAND gates would work equally well in place of the NOR gates.

At power-up, one gate generally turns on faster than the other. Let's assume that gate IC1b's output goes high first. The change of voltage will be transferred via capacitor C1 into the inputs of gate IC1a and its output will go low.

However, a voltage difference now exists across the resistor, and so current flows from the left hand side of the capacitor, via the resistor and into the output of IC1a. Hence the voltage point A falls as shown by graph A.

At about half the supply voltage (i.e. 2·5V assuming a supply of 5V), gate IC1a changes state and its output goes high. This causes gate IC1b to change state, its output going low, as shown by graph B.

The change of voltage passes via the capacitor making the voltage at point A fall to just below 0V, causing the output from IC1a to go high. There is again a voltage difference across the resistor, but in the opposite direction. Current now flows into point A from the output of IC1a. When the voltage reaches 2·5V again the gates switch back to their original state and the cycle continues.

The approximate frequency of the astable is given by:

$$\text{Frequency (Hz)} = \frac{1}{2RC}$$

FLASHING LIGHT

The circuit shown in Fig.4.27 (and Photo 4.5) shows an astable designed to make two l.e.d.s flash alternately. It is important that the current flowing through the l.e.d.s is kept to a minimum otherwise the circuit will not perform correctly (see earlier regarding CMOS 4000 output currents). It may be wiser to use a transistor buffer for each l.e.d. as shown in previous circuits (although low current l.e.d.s. are available).

The circuit is likely to start correctly at power-up, but the addition of resistor Rx and capacitor Cx will ensure start-up by providing a "kick-start" to input 2 of gate IC1a. If the inputs are wired in this way it is essential that NOR gates are used. If you wish to do the

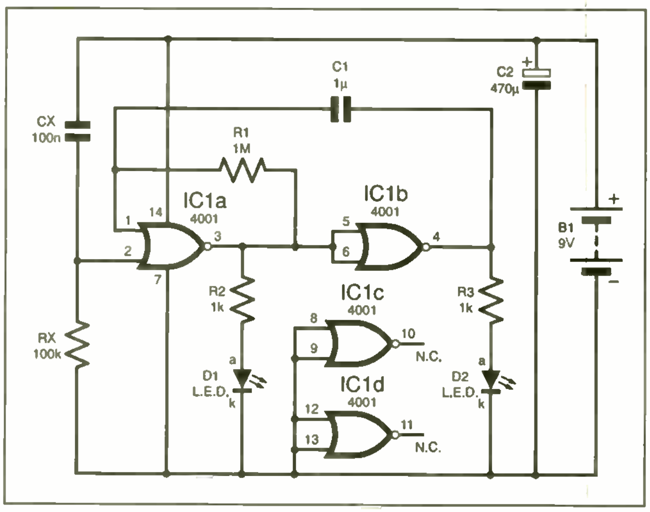


Fig.4.27. An astable circuit to alternately flash two l.e.d.s.

PANEL 4.1. LOGIC FAMILIES

There are two main families of logic i.c.s: TTL, based on ordinary bipolar transistor technology, and CMOS, more akin to field-effect transistor technology:

TTL (Transistor-Transistor-Logic)

The original range of TTL logic devices was known as the 7400 series. This has long since been superseded by other TTL logic families, such as the 74LS series, for instance. All are designed for operation on 5V. This inflexible supply voltage, and rather awkward operating characteristics, make them unsuitable for the *Teach-In 2004* series.

CMOS (Complementary Metal Oxide Semiconductor)

The oldest range of CMOS logic devices in common use is the 4000 series. These are ideal for use in this Teach-In as they can operate on a supply voltage of between about 3V and 15V.

Another range of CMOS logic i.c.s is the 74HC series. These have many advantages, including higher speed than the 4000 series, and their outputs can supply a generous amount of current, typically around 25mA, plenty to light a typical l.e.d. for example.

However, because 74HC devices can only operate on supply voltages within the range 2V to 6V, they are only suited for use in *Teach-In 2004* if the power supply voltage suggested in the circuit diagrams is reduced to within this lower range. It is essential to note that the 4000 and 74HC series have different pinouts.

Both CMOS families require static precautions, as explained earlier.

Note that CMOS 4000 series device numbers may have a suffix of "B", standing for *Buffered*, or "U" or "UB", which stands for "*Unbuffered*". Buffered outputs are generally better as they are electrically more robust, but will make little difference in the circuits in this series.

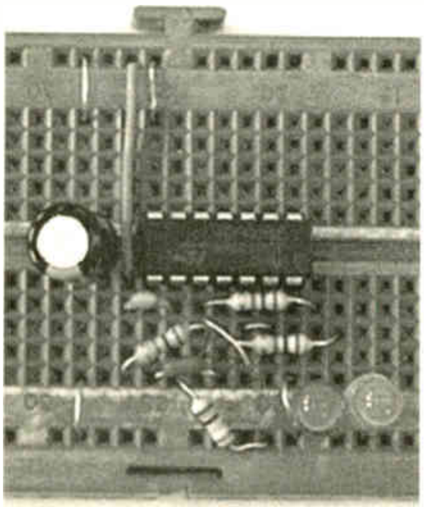


Photo 4.5. Breadboard assembly of the circuit in Fig.4.27.

same trick with NAND gates, then Rx and Cx should be interchanged.

TO INFINITY AND BEYOND

We have barely scratched the surface of digital electronics in this part of Teach-In 2004. Each of the elements discussed can lead to other systems. Logic gates, for instance, can be made into complex problem solving systems, and bistable latches can lead to counters and computers.

However, although logic gates and counters, etc., still form the basis of many electronics applications, the use of microcontrollers, such as PICs and other similar devices, have largely taken over as a way of squeezing a lot of processing power into a small, low-cost package.

But while the means of achieving digital processing may be forever changing, with more complex and faster processors, the electronic principles employed remain the same, and it is well worth understanding them.

NEXT MONTH

In Part 5 next month, we shall examine logic gates and their use as switches, with special reference to audio applications. We also introduce PIC microcontrollers to reduce the chip count. We shall look at more specific applications using digital circuits as and when appropriate in other parts of this series.

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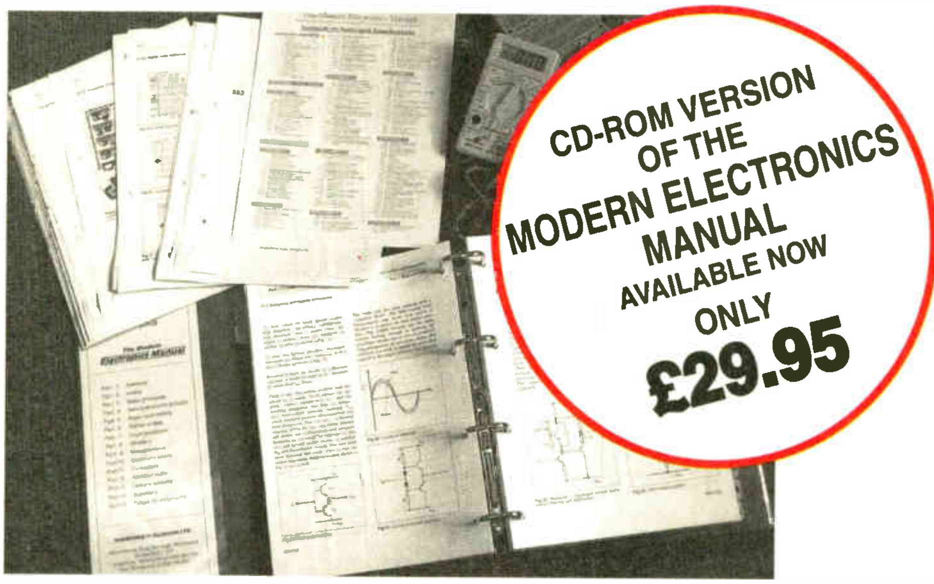

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