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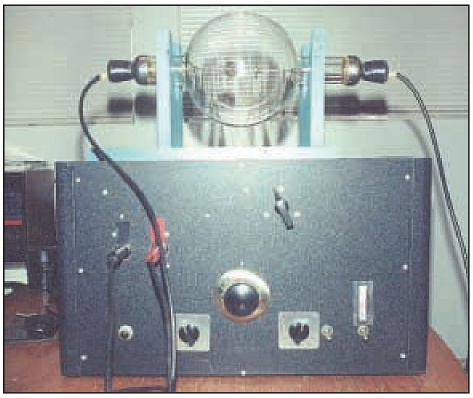

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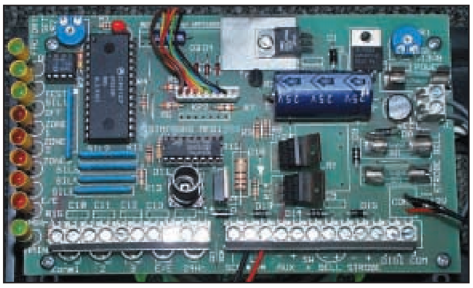

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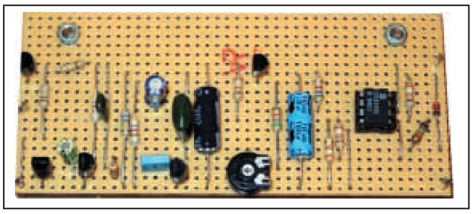


Free Supplement

Our May 2001 issue will be published on Thursday, 12 April 2001. See page 235 for details

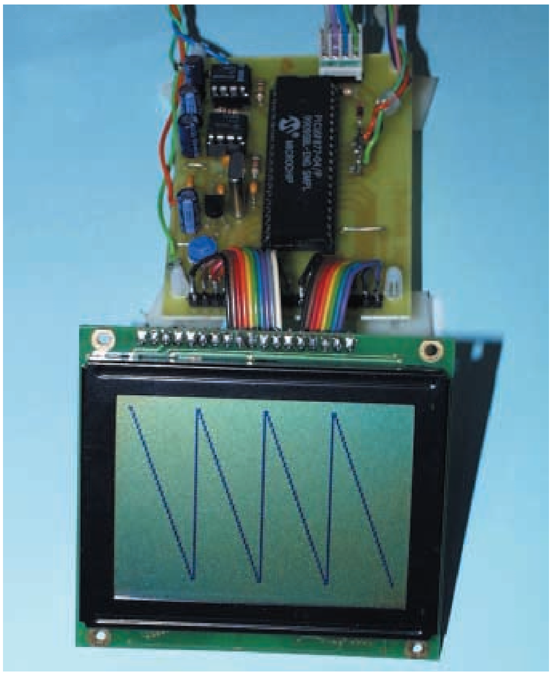
NEXT MONTH

PIC GRAPHICS L.C.D. SCOPE

EPE *Feb '01 contained a supplement in which the author's researches into* Using Graphics L.C.D.s *were published. The* PIC Graphics L.C.D. Scope (G-Scope) *is* EPE*'s first example of putting such displays to practical use. It is another addition to the widening family of simple oscilloscope-type constructional projects published in* EPE *over the last few years.*

G-Scope is a self-contained single-channel unit, catering nominally for waveforms in the audio range and uses a graphics l.c.d. screen having a pixel density of 64 x 128. It also displays frequency and signal amplitude factors as alphanumeric text lines. The signal source can be a.c. or d.c. and waveforms up to 5V peak-to-peak can be input without external attenuation. A simple pre-amp stage can be switched to provide x1 or x10 amplification.

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



CAMCORDER MIXER

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

This circuit is a mixer which will combine the outputs of up to two stereo microphones (or four mono ones) plus a stereo line source and feed them into the camcorder. It may also be used in conjunction with a domestic hi-fi system or power amplifier for other purposes, such as karaoke. By using a well placed microphone or microphones instead of the built-in camcorder mic the sound on videos can be greatly improved.

D.C. MOTOR CONTROLLER

Inexpensive d.c. motors are often used by model-makers, not only for model locomotives and racing cars but in robots of all kinds. They may also be used for driving non-mobile models made from anything from cardboard to Meccano. This project controls a small 6V d.c. motor, but can be used for 12V or high-voltage d.c. motors as well. The circuit controls both the speed and the direction of the motor. This Top Tenner project is simple, easy to build and inexpensive.

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Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS EDITORIAL
ALLEN HOUSE, EAST BOROUGH, WIMBORNE
DORSET BH21 1PF
Phone: Wimborne (01202) 881749. Fax: (01202) 841692.
E-mail: editorial@epemag.wimborne.co.uk
Web Site: http://www.epemag.wimborne.co.uk
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SUPPRESSION

It's not often that we carry an interesting story in *EPE* rather than a technical feature, project or review, but this month our *The End To All Disease?* supplement is just that. It's quite a departure for us, but when you read it you will realise why we feel it is important to publish the full story, rather than simply skim the surface and give an experimental circuit.

The level of interest in this material, following our brief announcement last month, has been amazing and once you are aware of the story some research on the web will throw up many sites with information. We hope that by giving exposure to the original work of Rife it will encourage a more open-minded approach by those in the medical profession and thus further research and development of this important area.

In some parts of the world TENS machines are still regarded as a form of "quackery", whilst in the UK they have been used in the National Health Service and by private individuals for a few years. At one time, these units were quite expensive and only available from specialist suppliers, we hope that we helped to change that by publishing various designs in *EPE* for easy-to-build, inexpensive TENS units (the last one was the *Simple Dual-Output TENS Unit* by Andy Flind in the March '97 issue). Now, of course, you can buy TENS machines on any UK high street without spending a small fortune and the fact that they work well for virtually all users is accepted throughout the medical profession.

Let us hope that the work of Rife will be resurrected and that substantial investment will be made in progressing this important area of medical research to the benefit of everyone. Unfortunately, for too long powerful organisations with vested interests have suppressed development and research in this area. It appears that with the availability of information via the web that is no longer so easy.

Mike Kenward

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Editorial/Admin: Wimborne (01202) 881749
Advertisement Manager:
PETER J. MEW, Frinton (01255) 861161
Advertisement Copy Controller:
PETER SHERIDAN, Wimborne (01202) 882299
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CLIVE (MAX) MAXFIELD and ALVIN BROWN

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E-mail: techdept@epemag.wimborne.co.uk
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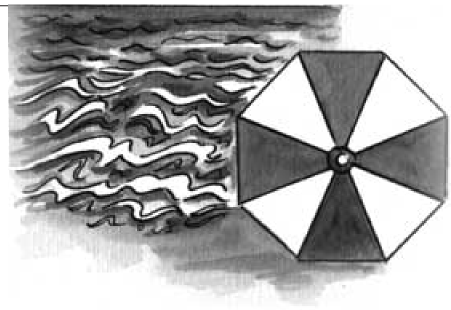
WAVE SOUND EFFECT



ROBERT PENFOLD

Bring the relaxing sounds of the sea into your living room.

In a world that seems to be ever noisier, using more noise to improve matters might seem like a strategy that is doomed to failure. However, it is a characteristic of human hearing that one sound tends to mask other sounds, and this can be used to good effect in counteracting otherwise obtrusive sounds.

How well or otherwise this masking works depends on a number of factors. If the sounds that you wish to shield yourself from are relatively quiet and some distance away, it is easy to mask them with sounds that are louder and closer.

Many of the annoying sounds we encounter at home originate outside the house and are some distance away. Although their irritation factor is often quite high and they are plainly audible, the actual sound level is often quite low. The masking technique can then be very effective.

COVER UP

Another factor governing how well or otherwise a sound is masked is the relative frequency contents. Masking works best if the sound used to counteract the unwanted noise is a good match for the noise itself.

The obvious problem with the matching approach is that the masking sound could be more irksome than the sound it masks! Another problem is that the annoyance will often be caused by a variety of sounds covering a wide frequency range.

The way around these problems is to use a blanket approach in the masking sound, by using a signal that covers a wide range of frequencies. This usually means a "hissing" noise signal such as pink or white noise.

A steady noise signal is very effective at masking sounds, but after a while this can itself become slightly irritating. The more refined method is to doctor the noise to give a simple sound effect, and waves sweeping onto a beach are the usual choice.

Most people find this sound very relaxing, which is clearly an advantage when trying to counteract irritating sounds. In fact many people simply use a wave effects unit primarily as an aid to relaxation rather than as a means of cutting themselves off from the outside world.

The wave effects unit described here is a simple battery powered device that can be used with headphones or used to feed a spare input of a hi-fi system. It does not provide results that are as convincing as units utilising digital recording techniques or sophisticated synthesiser circuits, but it is quite good for a device that uses just a handful of inexpensive components. It is simple to build and is well suited to beginners.

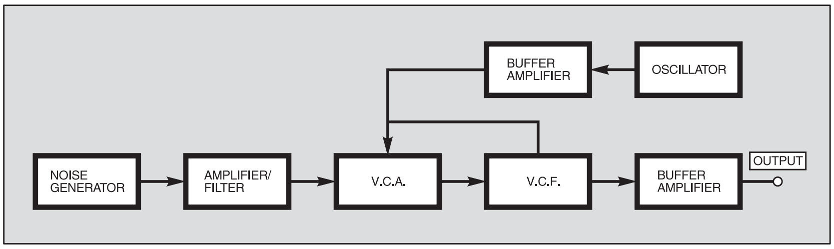


Fig.1. Block diagram for the Wave Sound Effect unit.

SYSTEM OPERATION

The block diagram of Fig.1 shows the general scheme of things used in the Wave Sound Effect unit. Wave sounds consist of noise rather than tones, and the raw signal is therefore produced by a noise generator and not by oscillators. The signal from the noise generator is (more or less) "white" noise, which is sound that has equal power at all frequencies.

Although one might expect this to sound "uncoloured", as suggested by its name, it is perceived by human listeners as having a very strong high frequency bias. The audio range extends from about 20 hertz to about 20 kilohertz, and the high frequency range is from about 2 kilohertz upwards. There are many more frequencies in this range than in the low and middle range combined, giving "white" noise its ferocious high pitched sound.

IN THE PINK

The next stage of the unit amplifies the output of the noise generator to give a more useful signal level, and it also provides some lowpass filtering. This reduces the high frequency content of the signal to give a more gentle "hissing" sound that is more suitable for wave synthesis. This gives something closer to "pink" noise, which is often likened to the sound of gentle rainfall.

Pink noise has equal power in each octave band (e.g. the same amplitude from 100Hz to 200Hz as from 100kHz to 200kHz). The simple filter used here does not give a true "pink" noise signal, but it is near enough for the present application.

IN CONTROL

In order to get a wave type sound the noise must be processed to vary its volume in an appropriate manner. Ideally, variable filtering should be applied at the same time.

The amplitude of the sound increases as the wave approaches, reaching a crescendo as the wave breaks onto the shore. Then the sound diminishes relatively quickly, as the water drains back into the sea. The pitch of the noise decreases as the wave approaches and crashes onto the shore, and increases again as the water flows back into the sea.

These changes in volume are provided by a voltage controlled attenuator (v.c.a.) that is controlled by a low frequency oscillator via a buffer amplifier. As the output voltage from the oscillator *falls*, the attenuation through the v.c.a. decreases, giving a rising output level. As the output voltage from the oscillator *rises*, the losses through the v.c.a. increase again, reducing the amplitude of the output signal. The output waveform from the oscillator is such that the volume rises slowly and decays much more quickly.

The voltage controlled filter (v.c.f.) provides highpass filtering, but its effect is minimal when the v.c.a. provides high volume levels. As the output level reduces, the highpass filtering gives less and less low and middle frequency content on the output signal. This produces the required drop in pitch as each "wave" crashes onto the

shore, and rising pitch as the water flows back into the sea.

The v.c.a. and v.c.f. are shown as separate stages in Fig.1, but they share a common control element. A buffer stage at the output of the unit provides sufficient output to drive medium impedance headphones, a crystal earphone, or virtually any power amplifier.

CIRCUIT OPERATION

The full circuit diagram for the Wave Sound Effect unit appears in Fig.2. The noise source is based on TR1, which is a silicon *npn* transistor having its base-emitter (b/e) junction reverse biased by resistor R1. There is no connection to the collector (c) terminal.

The base-emitter junction acts rather like a Zener diode having an operating voltage of about 7V or so. Like a Zener diode, transistor TR1 produces a stabilised output voltage that contains a substantial amount of noise.

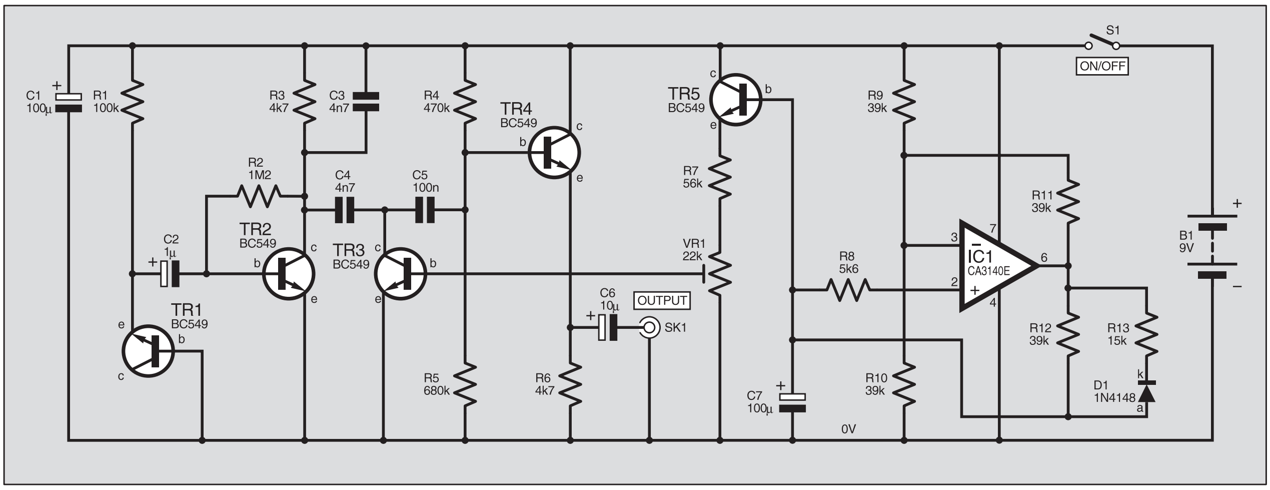


Fig.2. Complete circuit diagram for the Wave Sound Effect unit.

Using a transistor rather than a Zener diode gives noise over a narrower frequency range, but much greater noise output over the audio range. This is ideal for the present application where high frequencies are of no interest.

Capacitor C2 couples the output signal from TR1 to the input of a high-gain common emitter amplifier based on transistor TR2. Capacitor C3 provides the lowpass filtering, and gives a 6dB per octave attenuation rate.

To produce true "pink" noise an attenuation rate of 3dB per octave over the entire audio range is required, but this characteristic is difficult to achieve. The simple filtering used here avoids the excessive high frequency content of the "white" noise source and gives good results.

ACTIVE RESISTANCE

Transistor TR3 is used as the active element in the combined v.c.a. and v.c.f. Altering the current flowing into its base (b) terminal can vary its collector to emitter resistance. With no current flow an extremely high resistance is produced, but a large input current produces a resistance of a few hundred ohms or less.

An ordinary bipolar transistor is far from ideal for an application of this type because it does not produce pure resistance. The effective resistance varies considerably with changes in the signal voltage. In the present context this is of little consequence because the input signal is noise, and any distortion generated will just be more noise.

The variable highpass filtering is provided by capacitor C4 in conjunction with the resistance provided by transistor TR3. As this resistance decreases, the cut-off frequency of the filter is moved upwards. This increases the pitch of the sound, and in severely attenuating the lower and middle frequencies it also reduces the output level.

The increased loading on the output of TR2 also helps to give a reduction in the output level, and TR3 effectively forms the v.c.a. in conjunction with resistor R3. Transistor TR4 is used in a simple emitter follower buffer stage at the output of the unit. Its purpose is to ensure that loading on the output has no significant effect on the operation of the v.c.a. and v.c.f.

RELAXED OSCILLATOR

The oscillator is a form of relaxation oscillator that uses IC1 in what is almost a standard configuration. IC1 operates as a Schmitt trigger, and the oscillator operates by repeatedly charging and discharging timing capacitor C7.

Normally this type of circuit produces an output waveform of the type shown in Fig.3a. The charge and discharge rates are initially quite high, but gradually reduce as the voltage on timing resistor R12 reduces.

The rising edge of this waveform gives the desired effect, but the falling edge needs to be comparatively short. This is achieved by including steering diode D1 and an additional timing resistor (R13). Diode D1 shunts R13 across R12 when C7

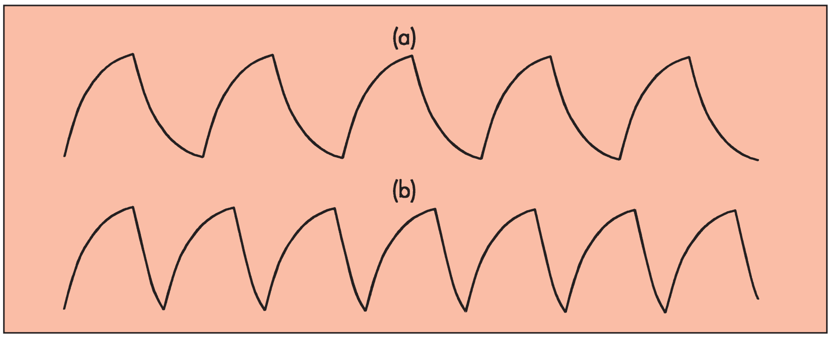
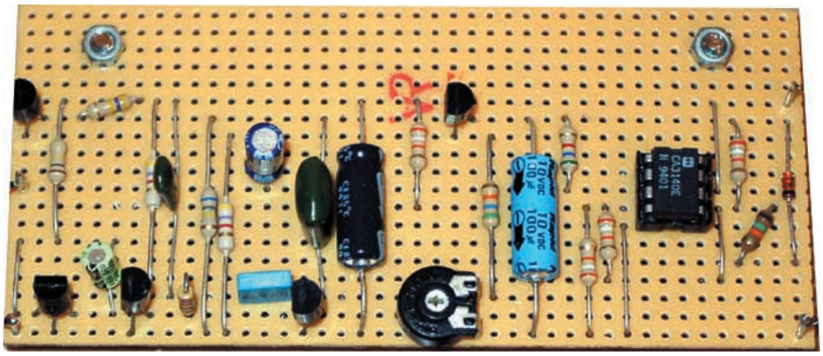


Fig.3. The normal waveform from the oscillator (a), and the waveform produced with steering diode D1 and resistor R13 included (b).

is discharging, but D1 prevents any current flow through R13 when C7 is charging. The rising edge of the waveform is left intact, but the falling edge is shortened, as in Fig.3b.

Transistor TR5 operates as an emitter follower buffer stage at the output of the oscillator. Preset potentiometer VR1 attenuates the output of the oscillator and brings it into a suitable voltage range to control transistor TR3. In practice preset VR1 is adjusted to obtain the most convincing wave effect.

The current consumption of the circuit is around 4mA to 5mA, and a PP3 size battery is therefore adequate as the power source.



General layout of components on the completed circuit board.

CONSTRUCTION

The Wave Sound Effect stripboard component layout is shown in Fig.4, which also shows the small amount of hard wiring and details of breaks required in the copper strips on the underside of the board. The board measures 42 holes by 19 strips and, as this is not one of the standard sizes in which stripboard is sold, it must, therefore, be cut from a larger piece using a hacksaw or a junior hacksaw. Cut along rows of holes and then file any rough edges to a neat finish.

The breaks in the copper strips can be made using the special tool, alternatively a handheld twist drill bit of about 5mm to 5·5mm in diameter does the job quite well. Either way, make sure that the strips are cut across their full width and that no hairline tracks of copper are left. The two mounting holes are three millimetres in diameter and will take either 6BA or metric M2·5 bolts.

Next, the components and link-wires should be added. The CA3140E specified for IC1 is a PMOS device, which is therefore vulnerable to damage from static charges. The normal handling precautions should be observed when dealing with this component, and the most important of these is to fit it onto the board via an i.c. holder.

Do not fit IC1 into its holder until the circuit board has been completed and double-checked for any errors. Try to touch the pins as little as possible, and keep the device away from any obvious sources of static electricity.

In all other respects construction of the board is perfectly straightforward. The

COMPONENTS

See SHOP TALK page

Resistors
R1 100k
R2 1M2
R3, R6 4k7 (2 off)
R4 470k
R5 680k
R7 56k
R8 5k6
R9, R10, R11, R12 39k (4 off)
R13 15k
All 0·25W 5% carbon film

Potentiometer
VR1 22k min. enclosed carbon preset, horizontal

Capacitors
C1, C7 100μ axial elect. 10V (2 off)
C2 1μ radial elect. 50V
C3, C4 4n7 mylar (2 off)
C5 100n mylar
C6 10μ 25V or 100μ 10V radial elect. (see text)

Semiconductors
D1 1N4148 signal diode
TR1 to TR5 BC549 *npn* transistor (5 off)
IC1 CA3140E PMOS op.amp

Miscellaneous
S1 s.p.s.t. min toggle switch
B1 9V battery (PP3 size), with connector clip
SK1 3·5mm stereo jack socket (see text)

Stripboard 0·1-inch matrix, size 42 holes by 19 strips; small or medium size metal or plastic case; 8-pin d.i.l. holder; multi-strand connecting wire; solder pins (4 off); solder; fixings, etc.

Approx. Cost Guidance Only £8.50 excluding batt. & case

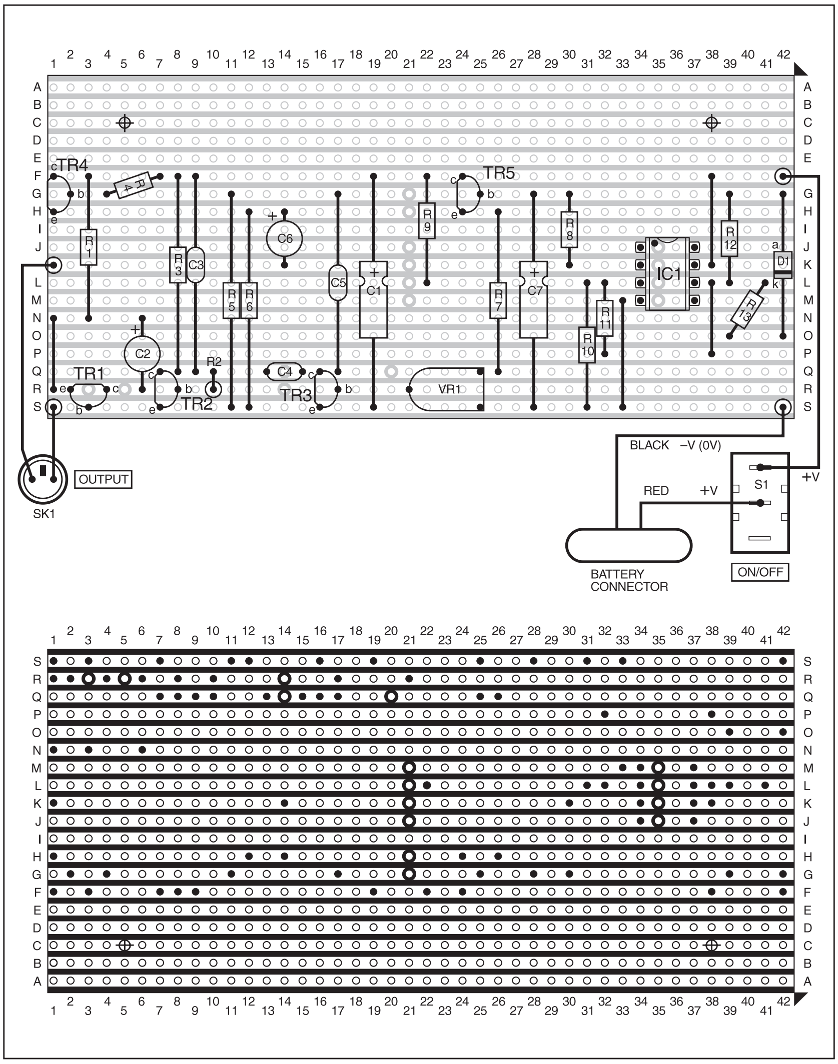


Fig.4. Wave Sound Effect stripboard component layout, wiring and details of breaks required in the underside copper tracks.

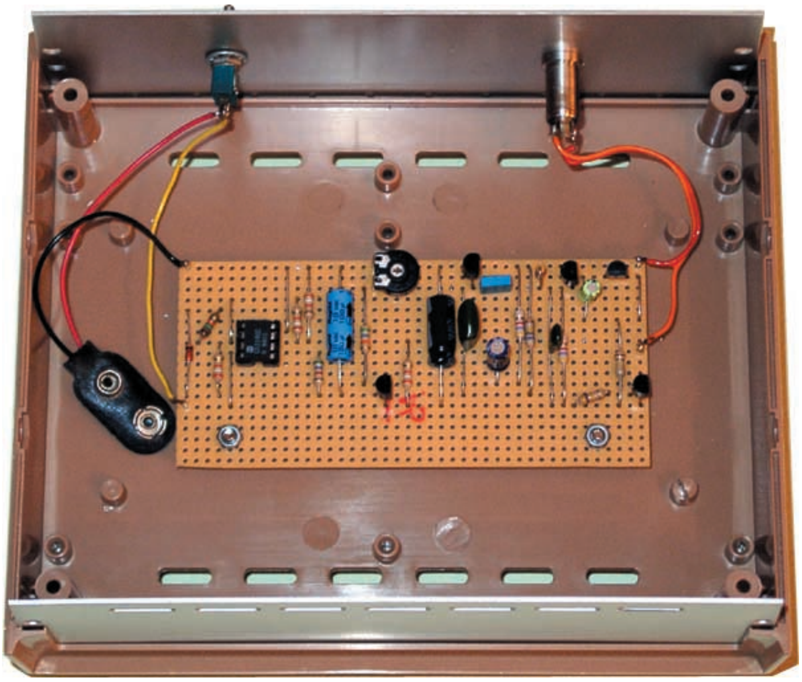
link-wires can be made from 24 s.w.g. tinned copper wire or the trimmings from the leads of the resistors. Fit single-sided solder pins to the board at the positions where connections will be made to output socket SK1, switch S1, and the battery connector.

Apart from C4, the non-electrolytic capacitors must have proper leads rather than pins, and Mylar capacitors are the best choice. The board was designed for use with axial lead electrolytic capacitors in the C1 and C7 positions, but radial lead components should fit quite well into the layout. A value of 10µF is suitable for C6 if the unit is to be used with an amplifier or a crystal earphone, but a value of 100µF is better if the output will be used to drive headphones.

CASING UP

Most small and medium size cases are suitable for this project. A small instrument case is used for the prototype, but a simple plastic or metal box is perfectly adequate.

The circuit board is mounted inside the case using 6BA or metric M2·5 bolts, including short spacers or some extra nuts between the case and the board. It is probably best not to use plastic stand-offs, since most types do not work well with stripboard. On/off switch S1 and output socket SK1 are mounted on the front panel.



These is plenty of room inside this small instrument case for the battery.

The best type of socket to use for SK1 depends on the way the unit will be used. For use with the "Aux" input of a hi-fi system a phono socket is the most appropriate. In fact, the easiest way of handling things is to connect the output of the board to two phono sockets. The output of the unit can then be coupled to both stereo channels of the hi-fi system using a standard twin phono lead.

A 3·5mm mono jack socket is needed for a crystal earphone, and a stereo type is required for use with medium impedance headphones, which are the type sold as replacements for personal stereo systems. The wiring shown in Fig.4 is correct for a popular form of 3·5mm stereo jack socket. As the two phones are wired in series the common earth tag is left unused, and the output of the unit is wired to the other two tags.

ADJUSTMENT AND USE

With the unit set up for use and preset VR1 set fully counter-clockwise, there should be a continuous noise sound at a fairly low pitch from the headphones or loudspeakers. If VR1 is tried at various settings in a clockwise direction some sweeping of the pitch and amplitude of the noise should be produced. You need to be patient here, because the sweep rate is quite low and it takes a while for each cycle to be completed.

Adjusting VR1 is really just a matter of using trial and error to obtain the best effect. This means finding a setting that provides the full sweep range without the sound holding for too long at either end of its range, but particularly at the low pitch end.

There is plenty of scope for experimenting with circuit values in an attempt to optimise the effect. Here are a few suggestions:

C3 – A higher value gives an overall reduction in the pitch of the sound, and a lower value has the opposite effect.
C4 – Use a lower value to give a higher maximum pitch, or a higher value for a lower maximum pitch.
C7 – A higher value reduces the frequency of waves, and a lower one gives an increased wave rate.
R11 – A lower value gives a wider sweep range, and a higher value produces a more restricted sweep range.
R13 – A lower value reduces the time taken for waves to recede, and a higher value has the opposite effect. Changing the value of this resistor will also produce some change in the wave rate.

If the signal tends to cut off when the battery voltage falls slightly due to ageing, it is probably worth replacing transistor TR1. Some BC549s have lower breakdown voltages than others, and one having a low breakdown potential gives better battery life.

Incidentally, virtually any small silicon *npn* transistor should work in the TR1 position of this circuit. The other transistors can be any high gain silicon *npn* devices such as a 2N3704, but note that alternative devices will mostly have different encapsulations or leadout configurations. □

New Technology Update

An innovative approach to using liquid crystal display technology has made it possible to create 3-D images, reports Ian Poole.

Lateral Thinking

NOWADAYS, it is likely that there are many dormant ideas waiting for a suitable application. There are possibly many other ideas that already have one area in which they are used, and by using some lateral thinking they could be used in another.

One example of this is liquid crystal technology. Currently l.c.d.s are widely used as displays, but CRL Opto based in Hayes UK, a leading supplier of custom shutters and specialist coatings, has devised a way of using fast switching ferro-electric liquid crystal devices to capture a 3-D image in combination with a *single* lens camera. Normally two cameras, or at least two lenses are required to capture the two images that are required for a 3-D image. This new technology, it is claimed, can be incorporated easily into a variety of applications where a 3-D image is required including ordinary camcorders, more sophisticated television cameras or endoscopes.

L.C.D. Operation

Unlike many other types of display a liquid crystal display (l.c.d.) operates by allowing or blocking the light passing through it. The principle of operation is based around the polarisation of the light.

The most common type of l.c.d. is known as the "twisted nematic" display. Light entering the display first passes through a polarising filter to ensure that all the light is of a given polarisation. A second polarising filter is placed at the back of the display, with a polarisation at 90 degrees to the first one. Under these circumstances no light will pass through the display because the two polarising filters have different polarisations, and the display will appear dark.

The two polarising filters are held a small distance apart, typically only 10 micrometers. This space is filled with a substance known as a liquid crystal. A transparent conducting element is placed on the inside of each of the filters to give the required display patterns.

The liquid crystal has the property that it rotates the polarisation of the light passing through it. About 40 micrometers is sufficient to give a full 360 degree rotation – 10 micrometers gives 90 degrees. With the liquid crystal in place the light passes through the first polarising filter, is rotated through 90 degrees by the liquid crystal and is then able to pass through the second filter which has its line of polarisation at 90 degrees to the first.

However, when a potential is applied across the liquid crystal it looses its ability to rotate the polarisation of the light. Accordingly, when the light reaches the second filter its polarisation is 90 degrees out of line with the second filter and cannot pass through. A dark area is seen. The area that is affected is dependent upon the area across which the potential is applied. Therefore by varying the patterns of the conductors on the inside of the filters and which ones have potentials applied across them, different areas can be made to be light and dark.

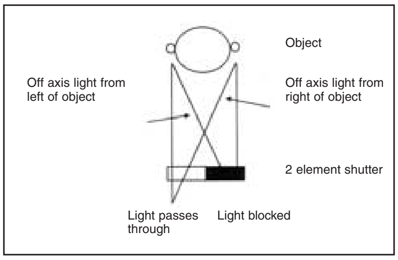


Fig.1. How a two element shutter in the iris plane selects right and left views of the same object through a single lens.

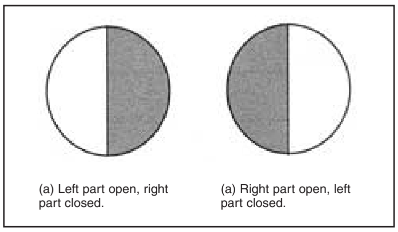


Fig.2. Simple 2-element stereo shutter. The shaded area indicates the non-transmitting region, and the open area indicates where the shutter is open.

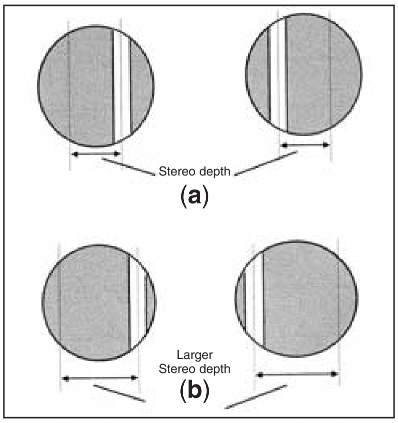


Fig.3. Using multiple vertical strips in the shutter enables the amount of stereo depth to be altered to the application in hand: (b) shows a greater stereo depth than (a).

Operation

The CRL system operates by having a two element shutter placed in the iris plane of the optics so that either a left or right hand view of an object can be seen. By blanking off half the liquid crystal screen or shutter, a left or right hand view of the image is obtained,see Fig.1.

The shutter can switch from one image to the other in less than 100 microseconds enabling switching rates greater than 25Hz to be achieved making it ideal for many camera scanning formats. When employed with an interlaced camera scanning system, the shutter has one half open for the even lines of the frame, and the other half open for the odd lines. This creates a simple basic 2-element "stereo" shutter, see Fig.2. The stored composite signal can then be replayed on a conventional system and viewed using a similar liquid crystal shutter system, or through a more conventional system using red/green glasses.

It is possible to alter the stereo separation (i.e. the stereo depth). This can be achieved by altering the separation between the two images. The shutter can employ strips as shown in Fig.3. By changing the separation between the two strips, the separation and hence the stereo depth can be altered. This is particularly useful when using a zoom lens to ensure that a realistic stereo depth is maintained during a zoom operation.

The problem with using small strips in the shutter is that the amount of light entering the camera is reduced. In cases where light is a problem it is possible for less than half the shutter to be blanked off.

This does reduce the amount of light but it gives a greater degree of flexibility to trade off stereo depth against the amount of light received. This is very analogous to the trade-off between aperture and depth of focus in more traditional cameras.

Summary

This new development shows a particularly innovative approach to using liquid crystal displays. CRL has taken a well-known piece of technology and used it in a totally new way, thereby extending its application. In doing this it provides a new method of producing stereo images using existing equipment technology, but with the addition of the new shutter, and possibly a small amount of additional electronics to synchronise the shutter.

As costs are relatively low it could be a particularly attractive proposition for anyone wanting to produce stereo images. Further information can be found at: **www.crlopto.com**.

News . . .

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

BT REPORTS REDUCTION IN PHONE KIOSK USE

It's all down to the mobile, reports Barry Fox

THE widespread use of cellphones is providing BT with the opportunity to cut back on the costly installation and maintenance of payphones – as required under BT's licence to operate.

BT had 77,000 payphones in 1984, when the company was privatised. Until recently BT was adding a hundred boxes a year. The current number is 141,000, but there has been no increase since 1999.

BT justifies this by saying that over the same two year period payphone use has declined by 37 per cent.

For most people with a cellphone, it is cheaper to use it than feed a payphone. The minimum payphone charge went up in October 2000 from 10p to 20p, with calls to anywhere in the UK costing a flat fee of 11p a minute. Payphones do not give change for unused payment.

Oftel wants BT to keep providing boxes in rural areas where a public service is needed, and cellphone cover is erratic. BT insists that it will do this.

BT also points to the fact that there are now 600 multi-media payphones, each with a 12-inch touch sensitive colour screen. Until June 14 these can be used to access the Internet or send E-mail for free. But after June 14 the calls will be chargeable, probably at around the same rate as a speech call, and possibly with a few minutes free in return for viewing adverts.

So far the 600 multi-phones are in "safe" locations, in shopping centres, railway and tube stations, airports and motorway services. Vandalism is less likely at these sites, than in remote rural areas.

The biggest risk may come from "scratchiti", the word coined in the USA to describe vandalism by the deliberate scratching of glass windows with diamonds and pumice stone.

BT says it sees the move into multi-media kiosks as helping the Government honour its pledge of offering everyone on-line access by 2005.

PROTEUS

LABCENTER, one of Britain's leading CAD developers, has released Proteus VSM. This latest addition to Labcenter's range is described as a revolutionary system level simulation product, and is the first in the industry.

VSM simulates microcontroller based designs, including the CPU, and all associated electronics at near real-time speeds. It includes animated component models. For example, l.e.d./l.c.d. displays, switches, keypads and virtual instruments, allowing the user to interact with the microprocessor software as if it were a physical prototype. It supports PICs, 8051 and 68HC11 processors.

The system includes an integrated debugger. It is also compatible with the Keil C51 development system.

For more information contact Labcenter Electronics, Dept EPE, 53-55 Main Street, Grassington, N.Yorks BD23 5AA. Tel: 01756 753440. Fax: 01756 752857.

E-mail: info@labcenter.co.uk.

Web: www.labcenter.co.uk.

CHILD'S PLAY

MAPLIN have launched a new range of kits aimed at helping children to understand the basic principles of electronics.

The Experilab kits are said to be ideal for children aged nine and above. No soldering or previous electronic knowledge is required and the inexpensive packs include all the necessary components and easy to follow instructions. The kits are available from Maplin's 59 nationwide stores and via Maplin's web site.

For more information contact Maplin Electronics, Dept EPE, Valley Road, Wombwell, Barnsley S73 0BS. Tel: 01226 751155. Fax: 01226 340167. Web: www.maplin.co.uk.

Greenweld Fires Enthusiasm

GREENWELD continue to rise, phoenix-fashion, from the crisis the company underwent nearly two years ago. Their latest bargains catalogue has increased to 48 pages and is crammed with items that any self-respecting electronics hobbyist loves browsing through in search of those that make our hobby even more interesting and worthwhile.

From modellers' tools and equipment, to electronic components and superb kits, Greenweld say that with their great value prices and mail order service, there's something in the catalogue for everyone. Check it out for yourself:

Greenweld Ltd, Dept EPE, PO Box 144, Hoddesdon EN11 0ZG. Tel: 01277 811042. Fax: 01277 812419. E-mail: service@greenweld.co.uk.

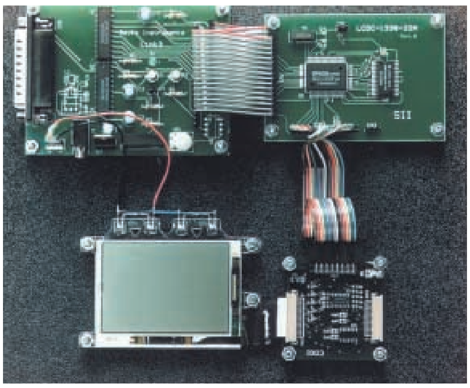
WCN Supplies Catalogue

ISSUE 7 of WCN Supplies' 24-page A4 catalogue includes a broad variety of items that electronics enthusiasts will find appealing. Principally, they are of the "workshop accessories" type, including meters, batteries, computer cables, connectors, power supplies, tools etc.

The catalogue appears to be a useful source of supply and can be obtained from WCN Supplies, The Old Grain Store, 62 Rumbridge Street, Totton, Southampton SO40 9DS. Tel/fax: 023 8066 0700.

CHIP-ON-GLASS L.C.D. MODULES

NOW that you've been inspired to investigate graphics l.c.d.s (Feb '01), why not have a browse of Glyn's web site for information about their new Chip-On-Glass L.C.D. Display modules, from Seiko's Vitrium series? COG modules are said to be ideal for portable applications, offering high density performance in the smallest possible package.



Glyn tell us that the modules "eliminate the need for printed circuit boards . . . are mounted directly on glass, achieving greatly improved optical performance and reliability".

Glyn's web site is at www.glyn.com.

SCIENCE CATALOGUE

COLE-PARMER have released their 2001-2002 catalogue, which they describe as "the best scientific and technical catalogue". It contains over 2000 full colour pages with more than 40,000 innovative products. The general headings highlighted include Manufacturing, Semiconductor, Chemical, Industrial, Environment, Education, Pharmaceutical, R&D, to mention just a few. It's the sort of catalogue which can be invaluable to any hobbyist with an enterprising mind and fertile imagination.

For more information contact Cole-Parmer Instrument Company Ltd., Dept EPE, Unit 3, River Brent Business Park, Trumper's Way, Hanwell, London W7 2QA. Tel: 0500 345300. Fax: 020 8574 7543. E-mail: sales@coleparmer.co.uk. Web: www.coleparmer.com.

Rabbit's Demise

Barry Fox

HONG Kong telecoms giant Hutchison ran the ill-fated Rabbit second generation cordless phone system, before replacing it with the Orange cellphone network. Hutchison also ran a paging system which took on the Orange name. This still has 30,000 customers, of which 5,000 are consumers. But most people now use cellphones and SMS, short messaging service, instead of pagers. So Orange is shutting down the paging service on 30 June.

Customers will be given sweeteners, such as free Orange phones. "Our paging business has been overtaken by developments in technology", says Orange.

In the USA paging is still popular because cellphone users must pay for incoming calls. Cost conscious consumers use a pager along with a cellphone, taking incoming messages free by pager and returning selected calls by cellphone.

Paging also remains the only safe way to communicate in hospitals, because the pager is just receiving, not transmitting. Paging signals, at lower frequencies and lower data rate than cell phones, also penetrate deeper into multi-level concrete buildings.

OOPS-OOPIC!

LAST month we misinterpreted Total Robots' press release about their OOPic object-orientated programmable integrated circuit. The design *is* based on PIC microcontrollers – it uses the PIC16C74. We apologise for this error. For more information browse web site **www.totalrobots.co.uk** or phone 01372 741954.

Atmel Acquires Siemens

ATMEL have reached an agreement to acquire Siemens' North Tyneside plant and will resume semiconductor fabrication. This should lead to the creation of between 1000 and 1500 high quality direct jobs within two to three years, with additional spin-off employment as well.

Siemens closed their plant two years ago when the world semiconductor market collapsed. You may recall that Fujitsu also closed their semiconductor plant in County Durham at about the same time.

American headquartered Atmel designs, manufactures and markets advanced logic, mixed signal, non-volatile memory and RF semiconductors. The company's arrival is excellent news for the North East region of the UK, and has been assisted by a £27.8m Government grant.

Educating Quasar

QUASAR Electronics in their latest newsletter remind tutors and teachers that generous discounts are available for bulk purchases of their electronics kits. Schools, colleges and universities are granted automatic 30-day account facilities and discounts of up to 35 per cent.

Of course Quasars kits and other electronics products are of interest to anyone, so get hold of their catalogue and onto the mailing list for regular updates!

Quasar Electronics Ltd., Dept EPE, Unit 14, Sunningdale, Bishops Stortford, Herts CM23 2PA. Tel: 01279 306504. Fa: 07092 203496. E-mail: epesales@quasarelectronics.com. Web: www.quasarelectronics.com.

CHINA'S DVD CHALLENGE

Barry Fox

CHINESE and Taiwanese electronics companies are under attack. They have been undercutting Western suppliers, by selling DVD players for under $100. Now, the 6C Group (Hitachi, JVC, Matsushita, Mitsubishi, Toshiba and Warner) are using their pooled patents to seek a four per cent royalty on hardware. Another group, Philips, Pioneer and Sony separately claim 3·5 per cent. Dolby claims another slice for digital surround, Macrovision for copy protection, the MPEG Licensing Authority for compression. Discovision and Thomson are still claiming royalties on old optical disc patents. The total claim is around 10 per cent of the manufacturing cost for a player.

During meetings in Beijing and Taipei China with Toshiba's Koji Hase, Chairman of the DVD Forum, the Chinese sprang a surprise. They claimed that the Chinese government will set its own modified DVD standard called Advanced Video Disc, and will claim its own royalties if foreign manufacturers try to import AVD players into China.

This is a re-run of the situation when China developed the Super Video CD system to rival the Video CD format developed and patented by JVC, Matsushita, Philips and Sony.

The AVD idea looks suspiciously like an attempt at trading one set of royalties off against another, but it overlooks the basic fact that AVD will still have to use the basic DVD technology patents.

The many companies in Europe and the USA which import DVD players from China, for branding with Western names, may now find themselves legally liable for royalties unpaid by their Far Eastern suppliers.

Mobile Phones Risk Report

THE National Radiological Protection Board (NRPB) has advised us that the results of a study in the USA in respect of brain tumours and the use of mobile phones have been released at **www.nejm.org/content/inskip/1.asp**.

The study does not show an association between them. NRPB state that further study is required.

The NRPB also tells us that it has published a broadsheet, *Medical Radiation*, as part of its *At-a-Glance* series. It is intended for readers with little or no knowledge of the subject and explains how radiation is used to diagnose and treat illnesses. It relies heavily on illustrations and captions as a means of communicating information.

Individual copies of *Medical Radiation* are free of charge and can be obtained direct from the NRPB Information Office.

For more information contact: NRPB, Chilton, Didcot, Oxon OX11 0RQ. Tel: 01235 822744. Fax: 01235 822746.

E-mail: information@nrpb.org.uk.

Web: www.nrpb.org.uk.

INTRUDER ALARM CONTROL PANEL

JOHN GRIFFITHS

Part One

Microcontrolled security designed to meet British Standards specification BS4737.

THIS Intruder Alarm Control Panel system is based on the Motorola EP520M security microcontroller.

The EP520M is a robust device having its origins at the heart of an automobile engine management system – a hostile environment for any microcontroller to work in. Now masked as an alarm controller, the device operates in high electrical noise and RFI environments, displaying a high degree of immunity to such hazards.

These devices are used in control panels throughout the UK and Europe, and are reputed to be completely reliable and free from false alarming.

The EP520M's extensive features include four detection zones, with one programmable as an Entry-Exit Delay zone, plus a 24-hour monitor for anti-tamper devices and Panic Attack (PA) use. Normally-closed (NC) and normally-open (NO) detectors can be used on all zones. The main features of the system are listed in the Specifications panel.

It can be seen from the block diagram in Fig.1 that the EP520M requires only the addition of a simple keypad and a minimum of readily available components. The circuit has been designed to comply with the installation requirements of British Standards BS4737 Part 1.

Despite the sophistication of the system, the alarm is extremely simple to construct and operate.

ZONES

Zones 1, 2 and 3 are all "immediate" and violation (opening) of the normally-closed (NC) circuit causes an alarm activation. Zones 1 to 4 are positive polarity and if the NC loop is shorted to the negative 24-hour PA anti-tamper circuit NC loop, then a full alarm activation results, and is indicated on the associated zone l.e.d. Consequently, normally-open devices can also be used to activate the zones.

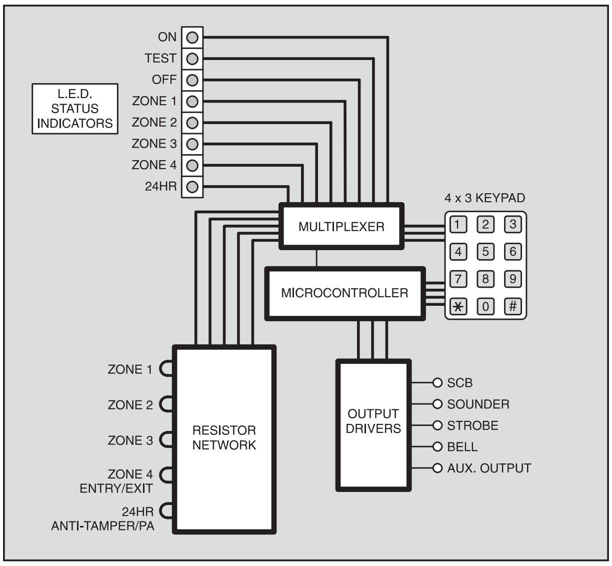


Fig.1. System block diagram.

Zone 4 is used for timed entry-exit control and is programmable to give a delay of between 0 and 255 seconds, in order to enter and leave the alarmed area.

Zones 1 to 4 are for use with any standard type of normally-closed intruder detector, such as magnetic contact switches, pressure pads, passive infra-red (PIR) sensors etc.

Zone 5 comprises a normally-closed 24-hour Anti-Tamper PA loop circuit which causes a full alarm activation if violated. Anti-tamper switches to protect the detection and external sounder devices are wired to this circuit. Panic Attack button switches can also be wired to it.

You can activate the alarm when it is switched off by pressing the PA button. This a very useful security feature when answering a door with a PA button sited nearby.

AUDIO-VISUAL ALARMS

The bell output is the main alarm driver and direct current (d.c.) sounders requiring up to about 1A can be connected to it.

SPECIFICATIONS

4 ZONES 4 × 12hr positive polarity detection circuits for NO and NC devices

24HR CIRCUIT 1 × 24hr anti-tamper circuit for NC devices

NVM Non-volatile memory to retain all programmable data during power failure

AUTO RESET Automatic resetting of the alarm after preset period

BELL SHUT OFF Automatic silencing of alarm after a preset period (selectable)

AUDIBLE WALK TEST Tests all detection zones prior to setting system

LAST TO ALARM MEMORY Shows zone that was violated

NIGHT SET Sets system without the Entry/Exit delay time

OMIT ZONE Allows any zone except 24hr to be omitted

LATCHING STROBE Strobe carries on after Auto Reset or bell switch off

SWITCHED +12V OUTPUT For latching PIRs and other control purposes

SCB INPUT Negative control for self-contained bell

STATUS DISPLAY System status shown on 8 l.e.d. indicators

INTERNAL/EXTERNAL SIREN High and low level siren output to 4Ω to 16Ω speaker

1·2A PSU For charging up to 7AH back-up battery

FINAL DOOR SET OPTION Sets alarm when the Exit door is closed

ENGINEER’S CODE Used to change factory defaults

USER CODE Used to Set and Unset Alarm

12 BUTTON KEYPAD To Set and Unset the alarm and program variables

WALK THROUGH Allows user to violate zone when exiting and entering

PROGRAMMABLE FEATURES

		Default
EXIT TIME	0 to 255 secs	20 secs
ENTRY TIME	0 to 255 secs	20 secs
AUTO RESET	1 to 99 mins	20 mins
BELL SHUT OFF	1 to 99 mins	Off
ACCESS CODE	0000 to 9999	1234
ENGINEER’S CODE	0000 to 9999	54321
WALK THROUGH	Zone 1	Off
TEST TONE	All zones	On
FINAL DOOR CANCEL	Zone 4	Off
EXIT TONE ON	Zone 4	On
ENTRY TONE OFF	Zone 4	On

NOTE: When actually entering the engineer’s code in normal use prefix the 4-digit code with the number 5 before the code, e.g. an engineer’s code of 4321 entered in the program mode would be entered as 54321 for engineer’s access.

An optional 12V d.c. 250mA Xenon strobe may be connected to the Strobe terminals. In the event of an alarm activation the strobe will operate. If the alarm carries on until the Auto Reset period is reached, the alarm sounder will silence but the strobe will carry on operating. This gives an indication to the user returning to the property that something may be amiss and to proceed with caution.

When the alarm is activated, a high and low level 1kHz tone output is generated via an internal loudspeaker. In normal operation, the output level is restricted and gives the test tones and keypad response. However, when a full alarm condition occurs, the full output power is delivered to the speaker.

CIRCUIT DESCRIPTION

The circuit diagram for the Intruder Alarm Control Panel is shown in Fig.2.

The EP520M microcontroller is designated as IC1. It has its own internal clock oscillator whose precise frequency can be set by resistor R1 and preset potentiometer VR1.

Zone 1 to Zone 4 connections are biased on one side to the 12V line via resistors in module RM5, and on the other side to the 0V line via resistors in module RM4. Series resistors in module RM3 feed from the zone loop to the 8-way multiplexer IC2. On the same inputs the resistors in RM2 act as potential dividers in conjunction with those in RM3.

This resistor combination holds the inputs to IC2 at around 4V when the zone loop is in circuit. When the circuit is broken, the inputs are held at 0V.

Zone 5 is biased from the 12V line in the same way, using discrete resistors R12, R13 and R14. However, the 0V connection is made via anti-tamper microswitch S1. In this path an optional link (SCB) can be broken and an external anti-tamper switch connected as well.

COMPONENTS

Approx. Cost Guidance Only **£25** *excluding case*

See SHOP TALK page

MAIN BOARD

Resistors

R1	27k
R2, R3, R5 to R7	10k (5 off)
R4	150Ω
R8	68Ω 1W
R9 to R11	3k9 (3 off)
R12	2k7
R13	100k
R14	56k
R15	1k

All 0·25W 5% metal film except R12.

Resistor modules

RM1	8 × 1k common 9-pin
RM2	4 × 47k individual 8-pin
RM3	4 × 100k individual 8-pin
RM4	4 × 10k individual 8-pin
RM5	4 × 1k individual 8-pin

All single-in-line resistor modules

Potentiometers

VR1	10k preset, min. horiz, 5mm
VR2	1k preset, min. horiz, 5mm

Capacitors

C1	10μ tantalum, 16V
C2	2200μ axial elect. 25V
C3 to C6, C8 to C14	100n ceramic disk (11 off)
C7	1μ axial elect. 25V

Semiconductors

D1 to D4, D8 to D10, D22	1N4148 signal diode (8 off)
D5, D6	8V2 Zener diode (2 off)
D7, D11, D12	1N4001 rectifier diode (3 off)
D13 to D21	red l.e.d. (9 off)
TR1	BC307 *npn* transistor
TR2, TR4	TIP120 *npn* Darlington transistor
TR3	TIP125 *pnp* Darlington transistor
IC1	EP520M alarm system microcontroller (Motorola)
IC2	74HS151 8-way multiplexer
IC3	93C06 non-volatile memory
IC4	7812 +12V 1A voltage regulator
IC5	7805 +5V 1A voltage regulator
REC1	W05 50V 1A bridge rectifier

Miscellaneous

TB1, TB2	2-way screw terminal block, 5mm pin spacing, p.c.b. mounting (2 off)
TB3, TB4	10-way screw terminal block, 5mm pin spacing, p.c.b. mounting (2 off)
FS1	1A fuse, 20mm slow blow
FS2, FS3	500mA fuse, 20mm, slow blow (2 off)
LS1	loudspeaker, 12W 8Ω mylar
S1	s.p. push-to-make switch, p.c.b. mounting, spring activated (Alps)
T1	mains transformer, 12V a.c. 1A secondary

Printed circuit board, available from the *EPE PCB Service*, code 297 (Main); 3 × 4 matrixed keypad, data entry type; fuse clip, 20mm, p.c.b. mounting (3 off); small metal heatsink for IC5 (see text); 8-way pin-header, 0·1in pitch, straight; 8-way pin-header connector, 0·1in pitch, straight (2-off); 7-way cable, thin guage, 30mm long approx; spade connectors for battery, 5/16in (2 off); 8-pin d.i.l. socket; 16-pin d.i.l. socket; 28-pin d.i.l. socket; 6BA nuts and bolts; plastic case (see *Shoptalk*); solder, etc.

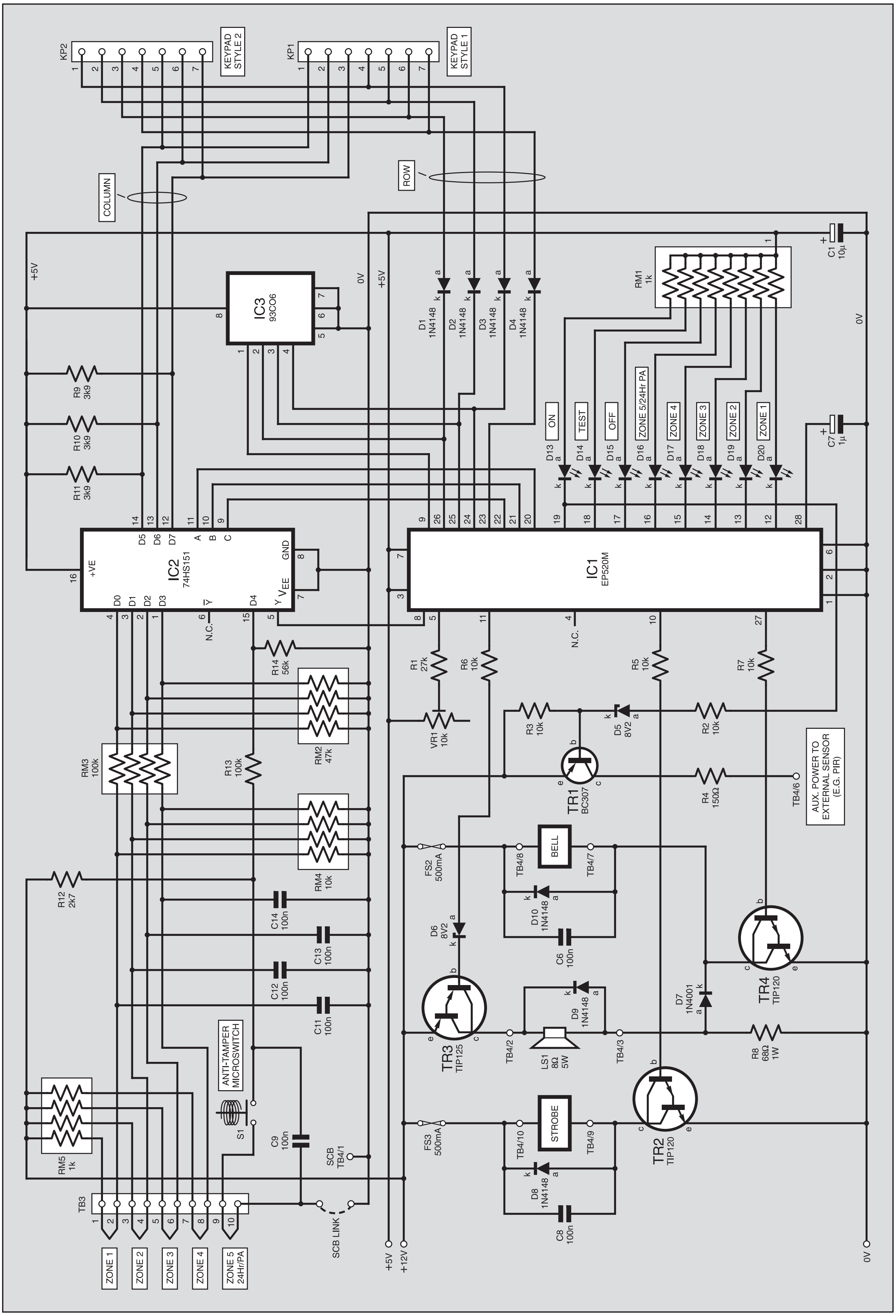


Fig.2. Circuit diagram for the main control unit.

This arrangement holds the Zone 5 input to the multiplexer normally at 0V, going high if the circuit is broken via the anti-tamper or PA switches.

The multiplexer's zone selection is controlled via its ABC inputs by microcontroller IC1, with the selected path routed back to IC1 via output Y.

FALSE TRIGGERING PROTECTION

Loop resistance of up to one kilohm (1kΩ) is permissible on the zone circuits. In practice, though, you would find this would represent several kilometres of wiring. In reality, in a normal domestic alarm installation, the loop resistance would rarely exceed several ohms, representing a loop current flow in the order of 1mA, giving good protection against induced transients.

Additional protection from false triggering on the detection loops is provided by the resident software, which polls the zones and looks for a period of intrusion detection of not less than 200ms. It then times the period during which the circuit is detecting. If after one second the input is still positive, an alarm condition is validated.

KEYPAD MONITORING

A standard 12-switch data-entry keypad is also monitored by IC1 via multiplexer IC2. The keypad has one set of its matrixed lines (Column) connected to the multiplexer. These are biased high by resistors R9 to R11. The other set of matrixed lines from the keypad (Row) are routed to IC1 via diodes D1 to D4.

The keyboard is strobed and key debouncing software routines ensure reliable operation.

Originally the author intended for a choice of two keypad pinout styles to be available, with connections via the pin-header terminals marked as KP1 and KP2. However, only the data-entry keypad style (see later) suiting connector KP1 is recommended.

ALARM INDICATORS

A further eight outputs from IC1 control the status-indicating l.e.d.s D13 to D20, via current limiting 1kΩ resistors in module RM1. The l.e.d.s show the violated zone(s) and also the On, Off and Test mode conditions.

Other IC1 outputs control the internal loudspeaker (LS1), plus the external strobe and bell lines, buffered by *npn* Darlington transistors TR2, TR3 and TR4.

The microcontroller output that turns on l.e.d. D13 (Power On) also turns on transistor TR1 via resistor R2 and voltage limiting Zener diode D5. The transistor routes 12V d.c. to external devices such as passive infra-red detectors. The current supplied is limited by resistor R4.

The circuit is arranged so that in Entry, Exit and Test modes, the loudspeaker only emits a low level audio tone. An audio frequency generated by IC1 controls TR3 via R6, and so activating the speaker but limiting its current flow by the inclusion of resistor R8.

In a full alarm condition, transistor TR4 is also turned on, not only activating the bell but also sinking current from LS1 via diode D7. The speaker thus emits a high level tone, which serves in place of an internal siren.

NO MEMORY LOSS

The third integrated circuit, IC3, is a non-volatile memory (NVM) which is used by the microcontroller to store the keypad and zone status settings, plus the Access and Engineer's pass-codes.

In the event of a complete power failure, the variables are not lost and when the power is restored the original codes are still available, so the system cannot be compromised under such conditions.

EXTERNAL BELL UNIT

Whilst the main circuit can directly control an external bell, the security of the bell itself would be compromised – an intruder could cut the power to it.

To ensure that your alarm installation is really secure and complies with the installation requirements of BS4737, it is recommended that a Self Actuating Bell module (SAB) is fitted. This is intended to thwart the alarm being silenced in the event that an intruder removes the power from the system. It is a bit like an alarm on the alarm, so to speak.

Bear in mind that any intruder system that can be disarmed by removing the power source is as good as useless.

A secondary control unit is thus provided for inclusion with the external bell housing. It allows the bell to be switched on by the main system but it also includes its own battery and anti-tamper circuit, causing the bell to operate if the bell enclosure is interfered with. The circuit diagram is given in Fig.3.

COMPONENTS

EXTERNAL BELL UNIT

See SHOP TALK page

Resistors

R1, R2 — 1k, 0·25W 5% carbon film (2 off)

Capacitor

C1 — 100n ceramic disk

Semiconductors

D1 to D3 — 1N4148 signal diode (3 off)

D4 — red l.e.d.

Miscellaneous

RLA — 2-pole changeover relay, 12V coil, 24V 1A contacts, p.c.b. mounting

TB1 — 6-way screw terminal block, 5mm pin spacing, p.c.b. mounting

TB2 — 2-way screw terminal block, 5mm pin spacing, p.c.b. mounting

Printed circuit board, available from the *EPE PCB Service*, code 298 (Ancilliary); bell/siren to suit (see text).

Approx. Cost Guidance Only **£9** *excluding case.*

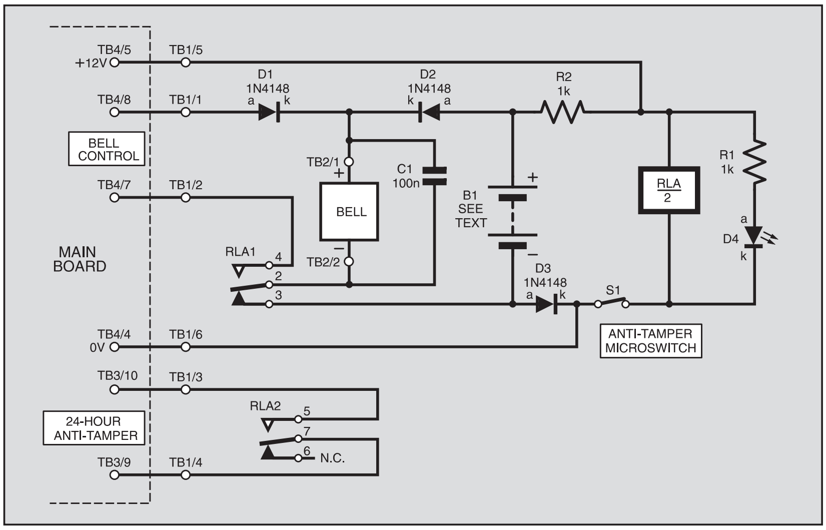


Fig.3. Circuit diagram for the external bell unit.

Power to the bell unit is jointly from the main controller and from the bell battery (B1 in Fig.3). This powers relay RLA, in which condition the bell is turned off by the relay contacts, RLA1. If the main power fails, the bell battery takes over, still activating the relay. Light emitting diode D4 indicates when the power is present across the relay coil.

An anti-tamper microswitch (S1) is included in the bell controller housing. If this normally-closed circuit is broken, the bell will sound, even if the bell battery is the only source of power.

The relay also controls the circuit from the main unit's anti-tamper detection. If the bell is interfered with, the main circuit responds, causing the indoor loudspeaker to sound at full volume.

It is strongly recommended that the bell circuit is used in order to provide the protection required under BS4737.

When fitting the SAB battery, it is suggested that a normal 250mA NiCad pack is used. The amp-hour endurance of this battery size is not unduly long so that, in the event that the main power to the control panel fails for legitimate reasons, the

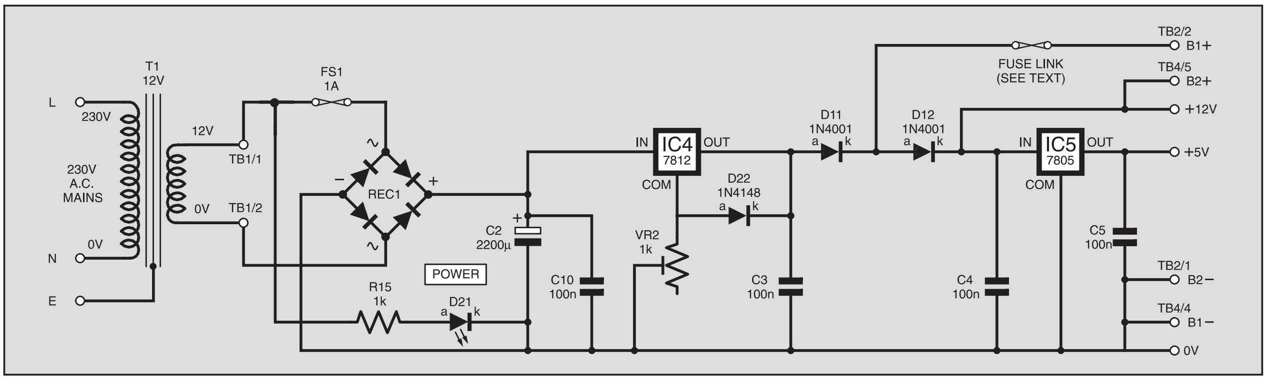


Fig.4. Circuit diagram for the power supply.

sounder will not operate for more than 40 minutes maximum.

The easiest configuration is to use 6-core cable between the panel and the SAB, which should be enclosed in the external bell box.

POWER SUPPLY

The system is principally mains powered, but has additional twin-battery back-up facilities, for which 12V sealed lead acid batteries rated up to 7AH are recommended. In the event of the mains supply failing, the battery back-up takes over.

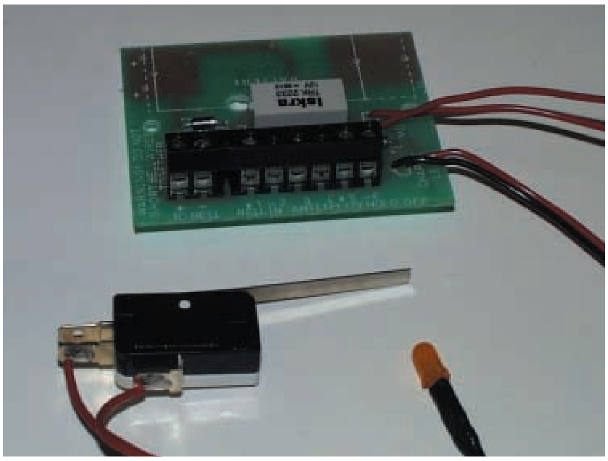
Power requirements for the alarm control panel are 12V at 1A and 5V regulated at up to 1A maximum. The main requirement of the 12V supply is to drive the sounders and strobes.

Referring to Fig.4, the power supply includes transformer T1, bridge rectifier REC1, smoothing capacitor C2. Fuse FS1 protects the system in the event of a power output short-circuit.

The rectified output voltage is regulated at 12V by IC4, which has a maximum output current rating of 1A. The output from IC4 is also connected to another voltage regulator, IC5. This provides +5V to IC1, IC2 and IC3.

Both back-up batteries, B1 and B2, are kept trickle-charged via diodes D11 and D12. Preset potentiometer VR2 allows the correct charging voltage to the principal battery, B1, to be set at 13·85V, as recommended by the manufacturers.

On the printed circuit board, track feeding to the connector for B1 is deliberately "thinned". This acts as a fusible link in the event of a catastrophic short circuit within the system, as might be caused by a malicious intruder.



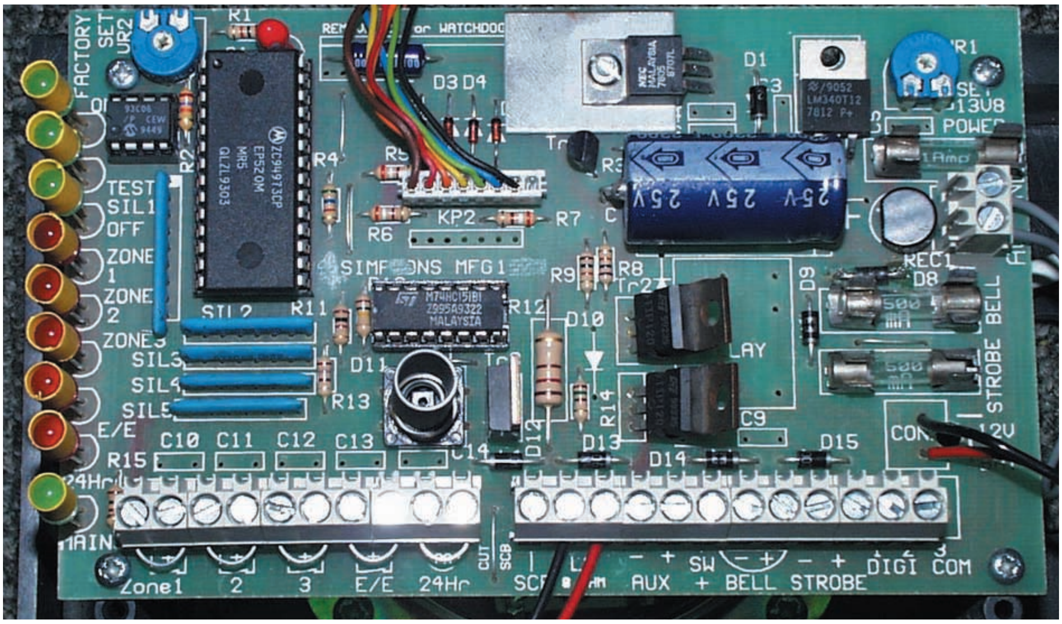
Extension bell unit printed circuit board and anti-tamper microswitch.

The Auxiliary 12V D.C. output normally services the PIRs and other detectors used in the system. Typical current requirements of such devices are in the region of about 20mA per unit.

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

There are two printed circuit boards for the system, the main control board, and that for the additional bell control unit. Both boards are available, as a pair, from the *EPE PCB Service*, codes 297 (Main) and 298 (Bell).

Next Month: Full constructional details, testing and setting-up.



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

READOUT

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

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

WIN A DIGITAL MULTIMETER

A $3^1/_2$ digit pocket-sized l.c.d. multimeter which measures a.c. and d.c. voltage, d.c. current and resistance. It can also test diodes and bipolar transistors.

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

★ LETTER OF THE MONTH ★

MAINS RATED CAPACITORS

Dear EPE,

As a recently retired safety engineer for BSI, I was somewhat disturbed to see the design for the *Doorbell Extender* in the March '01 issue.

The problem lies in the coupling capacitor C1 in both the transmitter and receiver. I am aware of all the warnings given about using quality components and knowledge of mains circuitry etc., but a 400V capacitor *is not good enough*.

The UK domestic mains is Installation Category 2, which means that it can have up to 1500V spikes with respect to earth on both the live and the neutral. This is one of the reasons why the safety standards require that capacitors connected between mains and earth are certified as "Y" capacitors. They are rated at 250V or 400V but they are tested at 2500V and designed not to fail short circuit. Capacitors across the mains ("X" caps) are also required to be certified because other types have been known to catch fire when they fail.

Any units built to the design given would certainly fail any basic safety test because the requirement is a test at 1500V a.c. or 2121V d.c. between mains and earth. Although there may be no possibility of a shock hazard within the units as built (depending on accessibility to the secondary circuits), there is still a possibility of causing a shock in other equipment.

I was told when I joined BSI that the UK ring mains specification allows for the earth to go to 240V for a period not exceeding 400ms (presumably while the fuse thinks about blowing). If that were to happen then any other equipment on the same ring could have its chassis at 240V for what is admittedly a short time. Unfortunately it doesn't take very long to die!

Furthermore, if the secondary is accessible then the cap should either be a "Y1" cap or two "Y2" caps in series. The basic principle is for there to be two levels of protection for the operator. The "Yl" cap is considered as two levels. Otherwise a "Y2" cap and the earth would normally be OK but with that dodgy cap and secondary circuitry with no other isolation – I for one wouldn't trust it.

Roger Warrington C.Eng MIEE, via the Net

Thank you for your interesting and informative letter. We have to admit that we should have picked up the requirements for this design. (See the Please Take Note *on page 281.)*

PLEASE "C" TO IT!

Dear EPE,

In your reply to Alan Bradley's letter in *Readout* Feb '01, you asked for readers thoughts on the C programming language. I would definitely be interested to see some of the software in the magazine written in C. As an electronics student I have to learn C for my course, but I had already been using the language for several years previously. My only other (limited) experience is with BASIC (GWBASIC, QBASIC, etc.) and I found the change to using C a huge improvement.

Ben Heggs, via the Net

Thanks Ben, we'll keep it mind.

However, I've been giving further thought to programming languages in general. I understand that C (and its derivatives) is not necessarily the best way forward.

For some time Object Orientated programming has become increasingly important to professional software designers and I believe that they regard C as being a "procedural" language which can lead to different techniques being employed to achieve the same end. In this context it appears that Object driven programs have greater long term "stability" in that Objects are unique, designed for only one method of use, and so programmers can more readily understand what code structures are meant to do, irrespective of who wrote them. In effect, it appears that they are "black boxes" which perform a single dedicated task, with just one access point.

Whilst such matters may not be of immediate concern to EPE *readers, it is something that I think should be considered as we progress ever onwards into more sophisticated programming languages. I appreciate that readers who have only just grasped one language, such as PIC or QuickBASIC or Visual Basic, may be reluctant to climb the learning curve of yet another, perhaps I should now open up the discussion to include not only C, but also Object Orientated languages as well. So let's be hearing from all who know about such things (which I do not, as yet).*

GRAPHICS L.C.D.S

Dear EPE,

When I read your *Using Graphics Liquid Crystal Displays* (Feb '01) I thought that the following Web addresses might be of relevant interest to your readers:

http://ourworld.compuserve.com/homepages/steve_lawther/t6963C.htm

http://www.digisys.net/timeline/lcd.html

http://www.citilink.com/~jsampson/lcdindex.htm

http://www.apollodisplays.com/apolloframel.htm

http://www.flat-panel.com/

Prof. Dr Eugenio Martin Cuenca, Universidad de Granada, Spain

Thank you very much, there appears to be some most interesting material available. I wish I had known about it before I started delving into graphics l.c.d.s!

ALFAC TAPES WANTED

Dear EPE,

I am 66 years old, disabled and cannot draw circuit plans. However, I found that by using Alfac precision tapes, circles and i.c. transfer pads I could manage to do a circuit for etching. Now I find that I can no longer obtain them and may have to give up my electronics hobby, which is the only thing I seem to live for now.

As a last resort I thought I would write to see if you could help, or could it be possible to ask if any readers had any they no longer use. If so, would they kindly think of me. I used to buy them from Maplin but they have discontinued selling them and cannot provide me with Alfac's address.

Please, I desperately need help!

John E. Horton, Deal, Kent

Editor Mike received John's plea for help and looked into it. He replied directly saying that this is a problem which we are unable to find a solution to. He did a search on the Web and could not find a UK supplier of Alfac products. Unfortunately these items are simply no longer in use in industry. Can any readers help John?

UFOs AND AURORAS

Dear EPE,

I read with interest, the *UFO Detector/Recorder* (Jan '01). In particular, the ingenuity of Raymond Haigh's chart recorder is inspiring. I built something similar ten years ago for my father, not for detecting UFOs, but for early warning of auroras and the subsequent enhancement of h.f. and r.f. propagation, we're both radio hams.

The original idea for the detector came from an article in an astronomical magazine. It showed a powerful magnet suspended in a jam-jar full of oil, to slug the movement, and a linear Hall device to detect the tiny perturbations. The jamjar detector was installed in the attic and detected the presence or absence of my car on the drive 50 feet away, seeing perturbations of the Earth's magnetic field proved to be easy too.

Then came the difficult bit, how do we record the output? A visit to a radio rally provided an old X/t recorder for £5. It just needed restringing. Several yards of fishing line later and exhaustion of my vocabulary of swearwords, I managed to restring it. Rolls of chart were expensive but the results were worth it. So, to the point of this missive. Hard copy recording of analogue events is hard work. What is needed is a cheap and easy method.

Most people these days use a computer and printer. Some people have bought new colour printers and failed to sell their dot matrix printers, they're in their box in the loft. A PIC-based analogue to Centronics "box" would be very nice! Z-fold paper for week-long recording, very cheap A4 for shorter periods. One, two or three inputs and variable "chart" speed? Date stamp? X/t grid? Have a think boffins, it'll make a good project.

Andy Daw, G1DSF, Stone, Staffs

Seems a feasible idea, Andy, and one which I believe I can achieve. Watch EPE*!*

SLOW CLOCKING PICS

Dear EPE,

I am in the process of studying your admirable *PIC Tutorial* (Mar-May '98) for which, as a lone worker, I have cause to be grateful and no doubt is a sentiment shared by hundreds of others. You really are to be congratulated for all the effort and planning which must have gone into covering all that material without losing that fragile thread of novice perception.

It strikes me as I progress, that it would be extremely useful if one could somehow disable the PIC's clock and instead step through the program by means of a debounced press switch during which each file register in use would be displayed showing the updated value (seeing is believing!). Perhaps it could even be refined so that the value could be made to blink on and off during the step it changed.

On a different subject, what is the easiest and/or quickest method of composing a library of electronic symbols for use in drawing schematic circuits on a computer? Also how do you add the annotations when the schematic is completed?

Pat Alley, via the Net

Thanks for your kind comments, PIC Tut *has indeed been well-received. Its CD-ROM version includes the* Virtual PIC *facility which does as you suggest as an on-screen simulation. Also, have a look at* EPE PIC Icebreaker *(Mar '00) which is a real-time PIC in-circuit emulator, programmer, debugger and development system.*

All commercial printed circuit board design software contains symbol library and text annotation facilities (and much, much more). Obtain some of the free-demos from advertisers who supply such programs – you are likely to be astonished at what can be done, and very cheaply too!

SYNCHRONOUS MOTORS

Dear EPE,

I have recently acquired a quite rare and valuable clock from the USA which operates on 110V 60Hz. The principal of operation is that of a mains synchronous motor, and in order to keep accurate time it therefore needs to operate at 60 cycles.

I know there is no problem with the voltage requirement but I have been unable to source a PSU that can deliver 110V at 60Hz. Is this something your magazine has featured in the past, or could you suggest a source/circuit diagram (I could build one myself if need be)? I have been advised by one local components retailer that this will be very expensive to achieve in any event – do you agree with this opinion and if so where does the expense lie?

Chris Betts, via the Net

Regrettably, Chris, your retailer is correct, it would be expensive to convert your clock to run from the UK 230V 50Hz mains supply.

One way of tackling it, though, would be to design a crystal-based logic gate squarewave oscillator, running at 5V (say). A waveform shaper would then be used to convert the squarewave to a well-shaped sinewave. This could then be fed into a step-up transformer to convert the sinewave voltage to 110V a.c.

There are many transformers available in the UK that have a 110V a.c. winding that can be used. Remember that any transformer can be used either way round (a matter discussed in Teach-In 2000 Part 10 *– Aug '00). For example, a transformer designed for 110V a.c. mains input and 6V a.c. output can be used for 6V a.c. input and 110V a.c. output. In this instance, though, the input current required would about 18 times (110/6) that required at the output.*

Presumably you would also want the clock to still run from the a.c. mains. This would require a UK mains power supply to generate a regulated 5V d.c. output to supply power to the oscillator.

So the set-up all becomes a bit bulky, although to build it experienced constructors would not find it too difficult or expensive. But, certainly, to have it commercially designed and made for you could be bank-breaking!

Readers, send suggestions for other ways of tackling the problem to Readout*, please!*

SHORTER BCD CONVERSION

Further to the discussions about binary to decimal conversion in *Readout* Sept, Nov, Dec '00, I have modified Steve Teal's code, which required 1957 cycles, so that it completes in 1242 cycles!

Steve's code doubles his Travelling Total (TT), but this only grows slowly and initially only one digit is needed to handle it. Yet the subroutine always doubles the whole of TT, so almost half the RLF multiplications do 2 × 0 + 0 = 0, and are superfluous. By studying the worst case (all 24 bits = 1) it soon appears that we only need to involve a new decimal digit for every three binary digits. The 08 in Steve's listing could be called **cycles**, to start at 01 and increment after every three bits. Another counter (**octcnt**) ensures the repetition of that whole procedure just eight times.

In the following listing (written in MPASM), the commands to delete are shown "remmed out" with a semicolon, and the new lines are notated as such.

```
bin2dec:
    clrf dec0
    clrf dec1
    cIrf dec2
    cIrf dec3
    cIrf dec4
    cIrf dec5
    cirf dec6
    cIrf dec7
;   movlw 18        ; deleted
    clrf cycles     ; new
    movlw 08        ; new
.    movwf octcnt   ; new
ctloop:             ; new
    incf cycles     ; new
    movlw 03        ; new
    movwf bitcnt
bitloop:
    rlf bin0
    rlf bin1
    rlf bin3
    movlw dec0
    movwf FSR
;   movlw 08        ; deleted
    movfw cycles    ; new
    movwf deccnt
decloop:
    rlf INDF
    movlw 0xF6
    addwf INDF,0
    btfsc STATUS,0
    movwf INDF
    incf FSR
    decfsz deccnt
    goto decloop
    decfsz bitcnt
    goto bitloop
    decfsz octcnt   ; new
    goto octloop    ; new
    return
```

Michael McLoughlin, St Albans, Herts

Astonishing, Michael, and there we were thinking it couldn't get any faster. Dare we think that's true now for your *code – or not?!*

GRAPHIC GRATITUDE

Dear EPE,

Thank you, thank you, thank you!

I've not written to a magazine before, but have just got hold of the *Using Graphics Displays with PICs* supplement (Feb '01) and it is exactly what I need! Reading the bit on "Data denial", it could have been written by *me* following my experiences with the data sheet. I'm currently debugging my PIC program for the Toshiba T6963, and hopefully, with the help of your article, I should get success soon!

Sian Armstrong, via the Net

Your gratitude makes all the hassle I experienced worthwhile. Thank you Sian!

NO MISSED CALLS

Dear EPE,

David Corder's *Missed Call Indicator* (*IU* Dec '00) does everything claimed and he is fully deserving of the prize awarded for it. With my version, there was an initial hiccup in that it refused to latch, but this was cured by increasing the value of R4 from 1M to 10M. A 3mm red l.e.d. was found to be bright enough when driven from one gate only, hence R9 was omitted.

The current consumption when active averaged about 2mA and when quiescent was of the order of a microamp. To guard against possible problems due to an aged battery, the 3V rail was decoupled with a 100nF and a 4μ7F capacitor.

Vince Wraight, Basildon, Essex

Excellent news! Thanks Vince.

TESLA LIGHTNING

Dear EPE,

I'd like to say what a great project Nick Field's *Tesla Lightning* (Mar '01) looks like being. After months of head crunching PIC routines this is like a breath of fresh air (or should I say ozone). Many thanks.

Mick Tinker, via the Net

We too thought Nick had something significantly different when he offered it to us. Nice to see that a few of you have made contact with Nick via his special web site at ***www.tesla-coil.co.uk/epe/****.*

LINUX VIRTUES

Dear EPE,

I've been a subscriber to *EPE* for five years or so, and it's a fantastic read. I've been following the development of programming language debate with interest.

I've been using Linux for six years, and love it. I'm also a big C programmer, but I spent many years (since I was four in fact, I'm now 20) programming Basic, from Sinclair Basic, through a number of others, eventually programming QuickBASIC on DOS 6.22. I've not yet found a reasonable Basic interpreter for Linux, but I haven't been looking, as I can now achieve most things I need in C.

I've done the odd couple of programs that talk "direct to the metal" (so to speak), directly addressing the hardware. Using this method, it's no problem to read/write individual lines on the serial and parallel ports. I find the interface Linux provides to the hardware fairly easy to use (from a C programmer's point of view), certainly having seen some of the VB code to address the hardware without the use of libraries to implement peek/poke/in/out.

Personally, I think that the world is too Microsoft orientated. I'm not saying everyone should use Linux – far from it – Linux is not the most intuitive system in the world. But I object to Microsoft charging the prices it does (even at an educational price) for software that is not always the best written in the world.

I have Linux systems that have been operational for over 180 days without a crash, unlike Windows, which seems to die once or twice a week. Sure – you can crash a program on Linux, but it won't bring down the rest of the system – a big plus when you're writing software that talks to the hardware directly.

I hope these comments might make those who are competent with PCs to stop and think. If they are interested, **http://www.linux.com/** has information about what Linux could do for you.

Matt London, Cheshire, via the Net

Linux is just beginning to be a Readout *subject. Your additional comments are welcomed, Matt. Thanks.*

PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

PROBABLY one of the biggest disincentives to actually "taking the plunge" and building your first project is the fear of failure. It almost certainly acts as a deterrent to those who have some experience at electronic project construction, and wish to build more ambitious projects than they have attempted in the past.

In both cases the fears are not totally unfounded in that things can go wrong and there is no guarantee that a completed project can be made to function. On the other hand, the chances of success are very good these days.

In the past some methods of construction were not particularly reliable, and there were a few dodgy components on sale. Modern construction methods are relatively easy to copy, and faulty components are extremely rare indeed.

Tarnished Oldies

It is perhaps worth making the point that most of the recently published designs are checked far more thoroughly than some of those published in the past. The record of *EPE* over the years is very good in this respect, but if you "dig up" an old design from another magazine it might have a fair sprinkling of errors.

It is unlikely that there will be anyone willing or able to assist with corrections, so you are on your own with this type of thing. Even if you are a fairly experienced constructor and the parts for an old project can still be obtained, it has to be regarded as a risky venture.

Wherever possible stick to projects that have been published in the last couple of years or so.

Simple Life

Even if you do restrict yourself to recent designs, things can still go wrong if you do not proceed with care and attention. However, most problems are easily spotted and sorted out.

An important piece of advice for beginners at practically any creative hobby is to remember that it is not a race. There is a temptation to rush the job in an attempt to get the finished article as soon as possible. The aim should be to make a neat job of things and get everything right, rather than to finish as soon as possible.

Another temptation for beginners is to start off with a grandiose project that will impress the family and friends. With modern construction methods a large project is not necessarily that much harder to build than a small project, but it is still advisable to start with something fairly simple and straightforward.

The smaller the project, the less the risk of an awkward problem occurring or a mistake being made. The chances of success may not always be massively improved, but they will still be significantly enhanced.

It is certainly worth repeating the warning that *beginners* should *not* build mains powered projects. Battery powered projects should be safe to build, and equally safe to fault-find if the finished unit fails to perform. Mains powered projects are risky to build unless you know exactly what you are doing, and even more risky to check for faults – the mains can kill!.

Heat of the Moment

Having built a project, if it clearly fails to work when it is first switched on it is not a good idea to leave it switched on. There could be a fault that is causing high currents to flow somewhere in the circuit, and this could easily lead to some expensive damage unless the power is switched off fairly rapidly.

If there is the characteristic smell of hot components and the circuit is only intended to operate at low power levels, not only should the unit be switched off, but it should not be switched on again until the likely cause of the problem has been located and corrected.

If you have a multimeter it is good idea to check the current consumption when initially trying out a new project. In cases where the current flow is clearly "over the top", switch off at once. If the current flow seems reasonable but the project does not work properly, it should be safe to leave the unit switched on so that some further checks can be made.

Being realistic, a beginner will not have the necessary technical expertise to make a full range of meaningful voltage checks to track down the problem. Even so, a multimeter is more than a little useful when trying to locate faults. You can check that the supply is making it to the on/off switch, and getting past the on/off switch when the unit is switched on.

Faulty components are rare these days, but battery clips that do not connect properly are not exactly a rarity, and some "cheap and cheerful" switches are perhaps a little less consistent than they should be. With a multimeter you can also check that the supply is reaching the appropriate places on the circuit board, such as the supply pins of the integrated circuits.

A multimeter usually has a continuity tester setting that can be used to check for unwanted short circuits and breaks in wiring or copper tracks on circuit boards. The cheapest of analogue or digital instruments is adequate for this type of thing.

Clean Sweep

Experience shows that the most likely place for faults to occur is on the underside of the circuit board. Circuit boards have become more intricate over the years, with ever more connections crammed into smaller areas. This has greatly increased the risk of short circuits between copper tracks due to small blobs or trails of excess solder.

Really, the circuit board should be cleaned and thoroughly checked for short circuits before it is installed in its case. If this check was not made previously, then it should certainly be carried out early in the proceedings when a new project fails to work. Some dismantling of the project will be required, but it is essential to get good access to the underside of the board in order to check it properly.

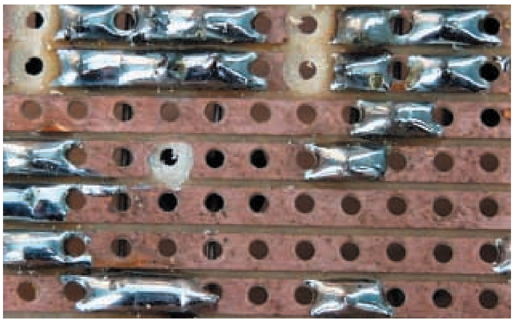


Fig.1. The break just left of centre looks a little dubious, and is!

Excess flux tends to accumulate on the underside of circuit boards, making it difficult to see small pieces of excess solder. Clean away all the excess flux using one of the special cleaning fluids that are available, or simply scrub the underside of the board using an old toothbrush. This second method has the advantage that it will probably remove any loose pieces of solder that are causing problems.

With the board properly cleaned, and even if you have good eyesight, some solder blobs or trails might be almost impossible to spot. A loupe or magnifying glass greatly increases the chances of finding any solder bridges. Search the board methodically so that any short circuits that are present will not be overlooked. If you have a continuity tester or a multimeter with this facility, use it to double-check for short circuits.

Any solder bridges that are found can usually be wiped away with the hot tip of a soldering iron. Alternatively, they can be carefully cut away using a modelling knife.

While inspecting the board keep an eye out for any other problems. In the case of a stripboard, have all the breaks in the strips been cut properly, or are there one or two thin lines of track left in place?

In Fig.1, the break just to the left of centre looks suspicious due to its lack of symmetry. There is actually a very thin line of copper still in place just above the supposed break. That is quite sufficient to maintain continuity.

Modern components and solders make it difficult to produce bad soldered joints, but not impossible. If any joints have an odd appearance, with an asymmetric shape or a dull crazed finish it would be as well to remove the solder and redo the joint.

Some printed circuit boards have extremely fine tracks. Are there any cracks or other breaks in the tracks? A continuity tester can be useful for checking for a proper connection through any "weakest links" in the copper track.

Do some of the joints have an obvious shortage of solder, or have any joints been missed out altogether? Redo any joints where you have been a bit economic with the solder.

Check and Check Again

When you are sure there are no problems on the underside of the board, reassemble the project and recheck the component layout. Are components such as electrolytic capacitors, diodes, transistors and integrated circuits fitted the right way round?

Carefully check the markings on the components against the polarities and orientations shown in the component overlay. With most components the correct orientation is fairly obvious, but we are all capable of making the odd error here and there. With transistors, have any of the leadout wires become crossed over and fitted in the wrong holes?

The markings on most integrated circuits are perfectly clear, but some have extraneous labels and moulding marks that can confuse matters. Look carefully to make sure that the notches, dimples, and lines that indicate pin one really are what you think they are. If in doubt, examine the chip using a loupe or magnifying glass. With a careful visual inspection you should be able to see which marks are "the real thing".

Getting Physical

If there are any link-wires, make sure that they join the right pairs of holes. Check every component to make sure that each one is in the right place. Try giving each component a firm tug. This will often bring to light any "dry" or missing joints, with one lead of the component pulling free of the board. It will also show up any components that have suffered major physical damage.

Most components are physically very tough, but there are some exceptions. In particular, you need to be careful when dealing with glass bodied diodes and open construction capacitors, such as some printed circuit mounting types (see Fig.2). Try to avoid bending the leadout wires close to the body of glass cased diodes, since this can result in the lead breaking away. Avoid doing anything that puts a strain on the glass body.

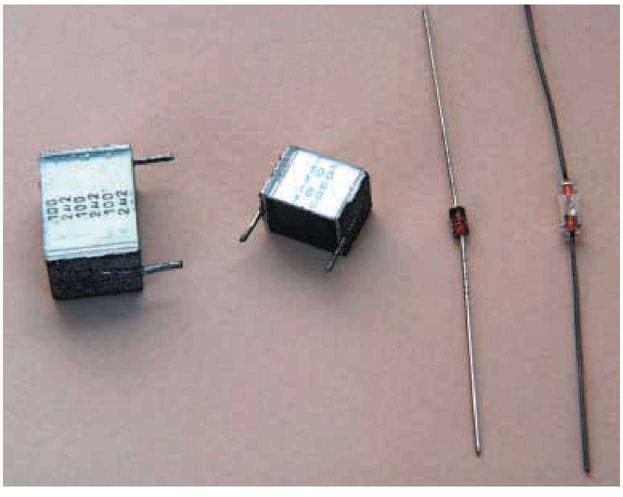


Fig.2. Uncased capacitors (left) and glass diodes are not the toughest of components.

With the uncased capacitors there are two potential problems. Any outward pressure on the leads tends to tear them away from the body of the component. Taking too long when soldering them into place produces a similar result with the leads effectively being desoldered from the body.

Modern uncased capacitors are tougher than those from a few years ago, but care still has to be exercised when fitting them on a circuit board. If any forming of the leads is required in order to fit them in place, proceed carefully, holding the leads in place on the body.

Do any of the components show signs of overheating? Taking too long to solder components in place can damage them even though there may be little outward sign of any problems. If a component has been subjected to too much heat it will usually change colour slightly. Also, it will usually have a noticeably shinier or duller appearance.

Are there any components that show any of these signs when compared to similar components on the board?. It is probably worthwhile replacing any component that looks a little "off colour".

Testing – Testing

If you have a multimeter it should be capable of resistance measurements, and it may have other ranges that are suitable for component testing. Most test meters have a diode checking facility, and many also have a built-in transistor tester. If you are lucky there will also be capacitance ranges.

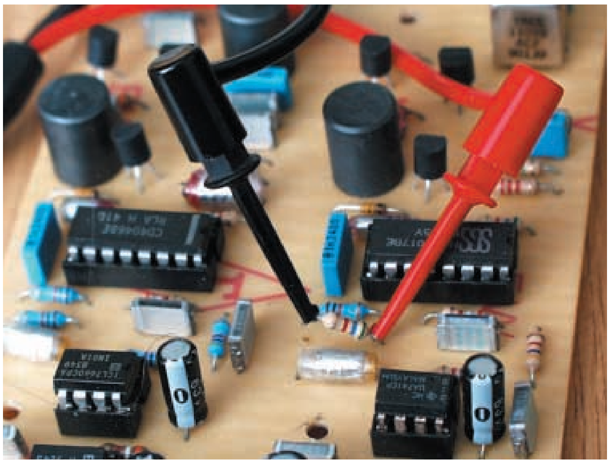


Fig.3. Semi in-circuit testing of a resistor.

Where possible, test any dubious looking components, but bear in mind that they cannot be tested in-circuit. With two-lead components at least one lead must be disconnected from the circuit board before a measurement is made, otherwise readings can be affected by other components in the circuit (see Fig.3). A few test meters have a simple in-circuit test facility for transistors. Where no in-circuit facility is available it is easier to completely remove devices from the board for testing, rather than leaving one lead connected to the board.

Careless errors can easily occur in the hard wiring, so it is well worthwhile checking this very thoroughly, making sure that every connection is present and correct. Where a project works to some extent, but some of the controls seem to work erratically or not at all, the hard wiring is the first place to start checking.

Many constructors find it helpful to check each wire against the wiring diagram and then mark it on the diagram. Where there is a lot of wiring this makes it easier to spot any missing connections.

Rotary switches are a common cause of problems. It is easy to get all the connections to the outer ring of tags shifted by one tag, so check this point very carefully. Do the switches simply operate the opposite way round to what you were expecting (on is off, etc.)?

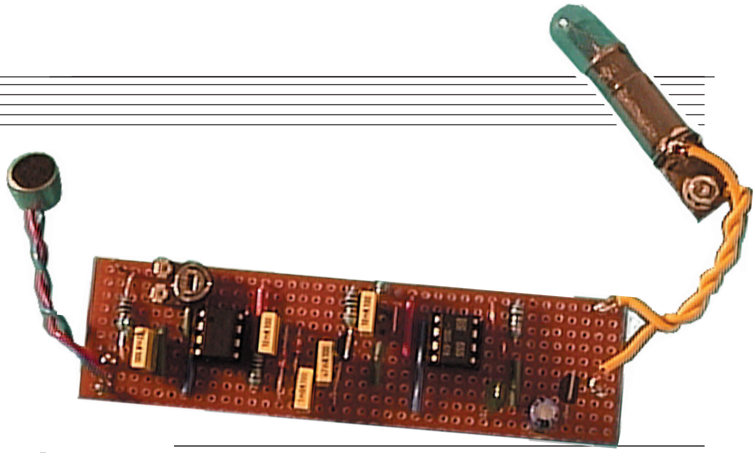
Finally

Errors in electronics publications are relatively rare these days, but they can still occur. If a project is giving problems it is a good idea to check later issues of the magazine for corrections.

If there seems to be a major discrepancy between the circuit diagram and the wiring and layout diagrams, the publisher will often be able to supply a quick answer if there is a problem. In most cases though, if your project accurately matches the published design it will work. When dealing with a problem project it helps to keep this in mind.

Top Tenners

SOUND TRIGGER



OWEN BISHOP

Project 8

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

A sound-operated trigger has many applications. The circuit diagram in Fig.1. shows how it can be used to switch on a low voltage lamp. The lamp might be a porch lamp, or a child's bedside night-light, or a lamp on a dark stairway or corridor.

When the circuit is triggered by a sudden sound, the lamp comes on and stays on for about 50 seconds. This allows time for someone to negotiate the stairs or make their way along the corridor, or perhaps to find the switch of the usual lighting and turn it on. A lamp that comes on whenever a noise is heard in the vicinity is also an effective intruder deterrent.

In general, the circuit is most sensitive to a sharp, crisp sound, such as a handclap. It is less likely to be triggered by ordinary conversation or passing traffic.

SWITCHED ON

The output stage of this project is a MOSFET transistor, which is capable of switching up to 500mA. If the project is powered by a 12V supply, a low voltage filament lamp may be used to provide a reasonable amount of light. For brighter lighting, it is possible to substitute a more powerful lamp switched by a transistor such as a VN66AF, which switches up to 2A.

The circuit can be used for switching other electrical devices such as:

- An audible warning device such as an electric bell, a solid-state buzzer or a siren.
- A relay: use this to switch a more powerful lamp, or a motor.
- A model railway locomotive; the circuit is triggered by blowing a whistle, causing the locomotive to start.

The circuit can be run on a 6V supply for switching a device that operates at 6V.

HOW IT WORKS

The Sound Trigger circuit diagram of Fig.1 consists of six distinct stages, and most stages are coupled to the following stage through a capacitor. The first stage is the electret microphone, MIC1, which depends for its action on the changes in capacitance that occur between a fixed plate and a plate that is being vibrated by sound.

There are several kinds of capacitive microphone, but the electret type has a permanent charge across the capacitor, produced by heating the dielectric during manufacture while maintaining a strong electrical field between the plates. The microphone is then cooled and the electric charge remains.

An electret microphone includes an f.e.t. amplifier and requires a current to power it. This is supplied through resistor R1. A voltage signal is generated across the microphone when sound is detected and this signal passes across the capacitor C1 to the operational amplifier, IC1.

AMPLIFIER

This amplifier, which has f.e.t.. inputs, is used in inverting mode with its gain set by the ratio of resistors R2 and R3 to 100.

The trimmer potentiometer VR1 is used to adjust the voltage at the non-inverting (+) input to make it equal to the steady voltage at the inverting (–) input in the

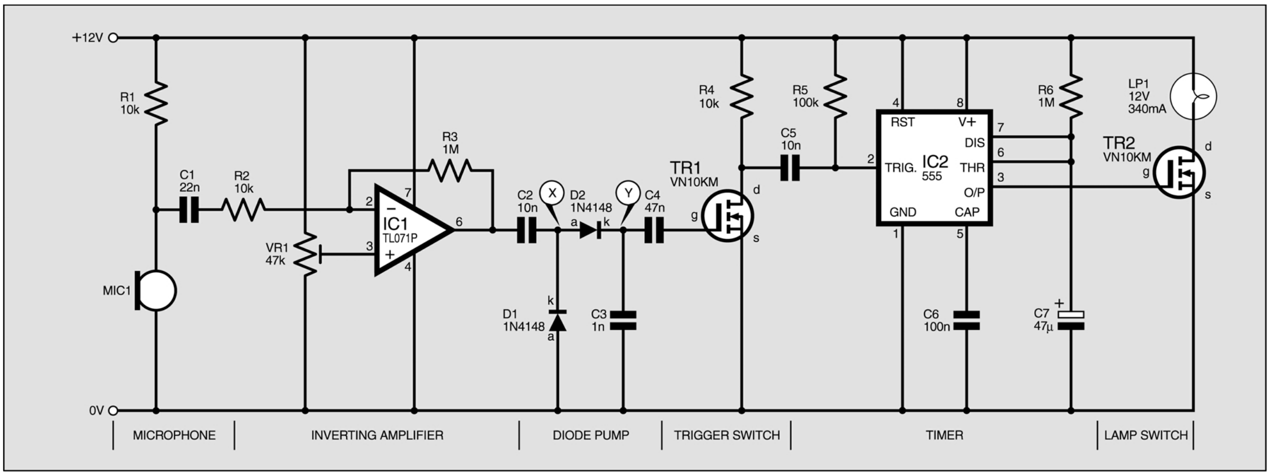


Fig.1. Complete circuit diagram for the Sound Trigger showing the six distinct stages.

absence of sound. The output of the amplifier then sits midway between the two power rails.

When sound is received, the output voltage of the amplifier (at pin 6) swings above and below the midway voltage. This alternating signal passes across capacitor C2 to the next stage.

DIODE PUMP

A single positive swing of the output of the op.amp is too short to trigger the timer, and is cancelled when the voltage swings negative. To avoid this cancelling, we use a "diode pump'' to rectify the signal and to produce a cumulative effect.

The action of this depends on two facts:

- Current can flow through a diode in only one direction (apart from a relatively small reverse leakage current).
- When the voltage on one plate of a capacitor is changed suddenly, the voltage on the other plate immediately changes by the same amount and in the same direction.

Consider point X at the junction of diodes D1 and D2, see Fig.1. As the voltage from the op.amp (IC1) swings in the positive direction, the voltage at the junction of capacitor C2 and diode D2 (point X) swings positive by the same amount. Current flows through diode D2 and a charge builds up on capacitor C3, causing the voltage at Y to rise. Because of the charge gradually flowing away through D2, the voltage at X does not rise as high as that of the output of IC1.

When the voltage of the output of IC1 swings low, the voltage at X swings in the negative direction, by *the same amount*. Because X was previously at a lower voltage than the output, this takes X down to a negative voltage. Therefore, current now flows through diode D1 from the 0V line. The voltage on the plate rises towards 0V. On the other hand, the charge that has accumulated on capacitor C3 cannot flow back again through D2.

The overall effect is that the flows of current through the diodes raise the voltage at X as well as the voltage at Y. The two voltage rises are in series, so are added together. The alternating output from the op.amp is converted to a sustained signal of approximately double the peak voltage.

The multiple vibrations of a burst of sound (for example, a blast on a whistle) result in a continuous high voltage developing at Y. In other words, a positive pulse is generated, which switches on MOSFET TR1 via C4.

TIMER

When transistor TR1 is switched on the voltage at its drain (d) terminal falls from +12V to below +4V, which is enough to trigger timer IC2. This is wired as a monostable multivibrator, which then produces a single high output pulse from pin 3. This in turn switches on a second transistor TR2 and current flows through the lamp LP1.

The length of the pulse from IC2 depends on the values of R6 and C6 according to the equation:

$$t = 1{\cdot}1RC$$

With the values given in Fig. 1, the pulse lasts for just over 50s. For other applications, you can select different pulse lengths by choosing appropriate values for R6 or C6.

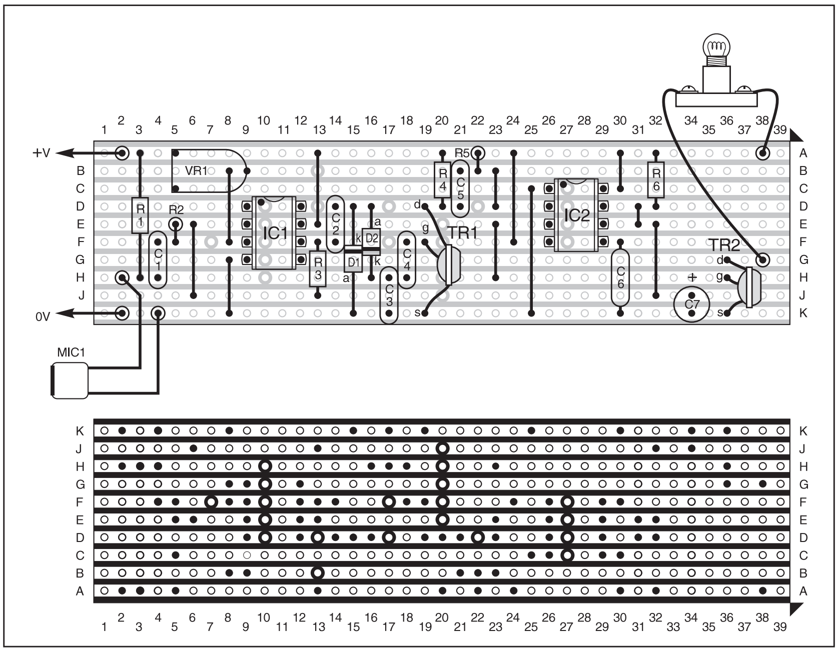


Fig.2. Sound Trigger stripboard component layout, wiring to microphone insert and lampholder, and details of breaks required in copper tracks.

POWER SUPPLY

The circuit takes around 340mA when the lamp is lit. It is, therefore, best powered by a heavy-duty battery, such as two 6V lantern batteries in series.

It will run for just over 200 hours using four D-type alkaline cells in a battery holder. Alternatively, use a 500mA 12V d.c. unregulated mains adapter. For other applications, it may be operated on a 6V supply and then requires less current.

CONSTRUCTION

This simple Sound Trigger is built on a small rectangle of 0·1in matrix stripboard, size 10 copper strips by 39 holes. (Note there is no row *I*.) The component layout, wiring and details of breaks required in the copper tracks are shown in Fig.2. The board layout is fairly straightforward and assembly should cause no problems. The use of i.c. sockets is recommended for IC1 and IC2.

It is best to build the Sound Trigger stage-by-stage, starting with the microphone stage, and testing the output of each stage as you go. Depending on the exact type of microphone used, there is a preferred working voltage, which is obtained by using a suitable value for resistor R1.

The microphone used in the prototype had a preferred voltage of 4·5V, but could be operated over the range 1·5V to 12V. There is a reasonable amount of adaptability here; with the 10 kilohms dropping resistor (R1) the voltage across MIC1 was found to be 7·8V, which is within the acceptable range.

Checking the operation of the circuit is easy if you have an oscilloscope, but its responses can be detected quite well using a digital multimeter. At this stage, tapping the microphone results in very small but irregular variations of voltage at the junction between R1 and MIC1. If you fail to detect a signal, do not worry at this stage.

COMPONENTS

See SHOP TALK page

Resistors

R1, R2, R4	10k (3 off)
R3, R6	1M (2 off)
R5	100k

All 0·25W 5% carbon film or better

Potentiometer

VR1	47k miniature carbon preset, horizontal

Capacitors

C1	22n polyester film
C2, C5	10n polyester film (2 off)
C3	1n polyester film
C4	47n polyester film
C6	100n polyester
C7	47µ radial elect. 35V

Semiconductors

D1, D2	1N4148 silicon diode (2 off)
TR1, TR2	VN10KM, MOSFET *n*-channel transistor (2 off)
IC1	TL071CP, operational amplifier, bi-f.e.t. inputs
IC2	555 timer

Miscellaneous

MIC1	electret microphone insert
LP1	12V 340mA filament lamp

Stripboard, size 10 strips × 39 holes; 1mm terminal pins (5 off); 8-pin d.i.l. i.c. socket (2 off); lamp socket (MBC or to fit LP1); battery holder or connector for d.c. supply unit; connecting wire; solder, etc.

Approx. Cost Guidance Only **£8** ***excluding batts.***

Adding the inverting amplifier gives a larger signal.

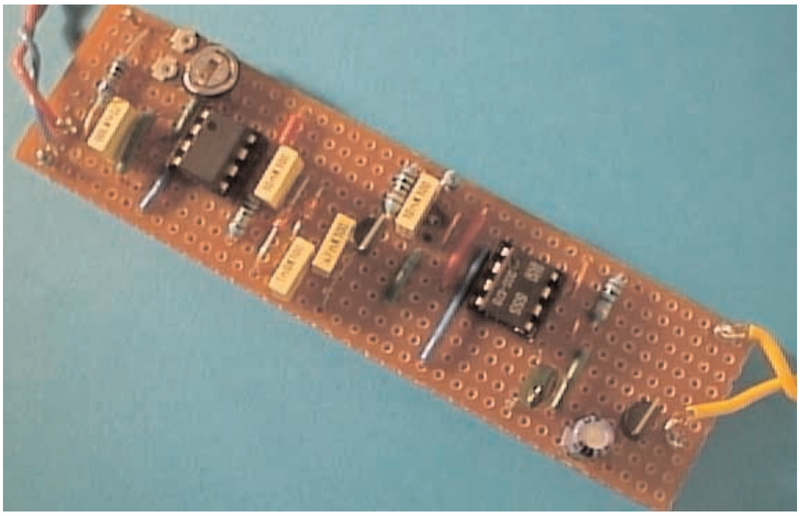
AMPLIFIER

Next, build the amplifier stage (IC1). The purpose of preset VR1 is to allow the voltage at the (+) input of IC1, at pin 3, to be set to equal the quiescent voltage at the (–) input (IC1 pin 2). It also has the function of adjusting the sensitivity of the circuit.

With the two input voltages exactly equal, the output voltage at IC1 pin 6 is close to 6V. This allows sound to make the output swing freely in either direction and gives the most sensitive setting.

As the action of the diode pump depends on the amount of voltage swing, restricting the swing reduces the pumping action. Setting the output voltage higher or lower restricts the amount by which it can swing, so reducing sensitivity. For the present, adjust preset VR1 to bring the output of the op.amp as close as possible to 6V.

When adding the diode pump stage, take care to get the diodes the right way round. They usually have a black band around them at the cathode end (marked *k* in the diagrams). Test the "pump" by monitoring the voltage at point Y. It normally rests at a few tens of millivolts above zero but rises sharply to 5V or more when the microphone is tapped. A digital meter may not readily detect this unless it has a "record" function, but the peak is easy to see on an oscilloscope.



Close-up of the completed circuit board showing the general layout of components.

ON TIME

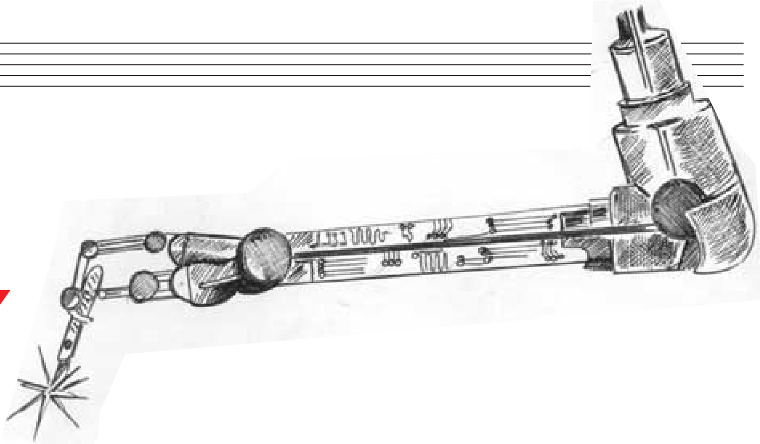
The next stage is the timer. Before inserting IC2 in its socket, check the voltages at the socket for pin 2. This is normally very close to 12V, with a sharp drop to around 4V when the microphone is tapped. This downward spike is hard to detect with a multimeter.

Insert IC2 in its socket and check that its output at pin 3 rises from 0V to 12V when the microphone is tapped. If it does not, suspect the connections to pin 2 through C4, TR1 and C5.

The circuit will certainly need some checking and preset VR1 may need setting, so it is advisable to solder a 100kΩ resistor (or any other close value) in parallel with resistor R6. This shortens the "on" time to 5s, and makes testing much speedier.

When completed, the circuit responds to claps, bangs and whistles at distances of a few metres from the microphone. It also responds to spoken phrases at distances of around half a metre. □

Regular Clinic



CIRCUIT SURGERY

ALAN WINSTANLEY and IAN BELL

Bravely our surgeons explore the depths of phase-locked loops, or skim the surface anyway.

LAST month we looked at the basic principles of phase-locked loops (PLLs) in response to reader ***Malcolm Wiles***' request. His colleagues would spend their lunchtimes in the pub talking about PLLs but Malcolm never found out what they were until now!

As he suspected, they are pretty useful devices, but they can be quite complex – so there's plenty to talk about (and a vast volume of books and academic papers on the subject if you care to look . . .)

PLLs Continued . . .

This month we will take a look at the 4046, a 16-pin PLL chip from the 4000 CMOS logic series, which is probably one of the most popular PLL devices amongst those hobbyists who use them. The pin-out of the 4046 is shown in Fig. 1, whilst Fig. 2 shows an internal block diagram and the connection of the key external components required in even the most basic 4046-based PLL.

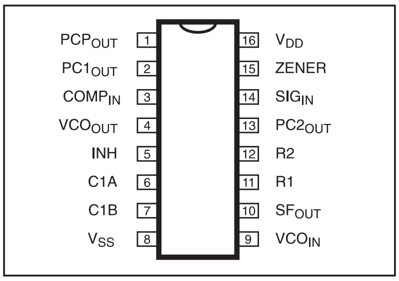


Fig.1. Pinout details for the 4046 CMOS phase-locked loop i.c.

You will recall from last month's column that the main parts of a PLL are the phase comparator, the VCO and the low-pass filter. The 4046 contains the first two of these (in fact there are two phase comparators to choose from); however, the low-pass filter is made using external components (resistor R3 and capacitor C2 in Fig. 2).

Pin 10 (SF_{OUT}) provides a source follower from the low-pass filter output (VCO input), so that this signal appears as the voltage across R_{SF} and can be used elsewhere in your circuit without loading the filter. If pin 10 is not used it should be left open-circuit (i.e R_{SF} is not required).

Pin 15 is connected to an internal Zener diode of about +7V. This may seem a bit strange, but the 4046 is very sensitive to supply voltage variation and the Zener is provided in case it is needed to help regulate the supply to the chip.

Locking On

To use the PLL you need to decide on the "lock" range frequencies (which determines the VCO frequencies and hence C1, R1 and R2), the low-pass filter values (R3 and C2), and which phase comparator to use. None of this is trivial but we do not have the space here to discuss it in great detail.

If you want to get the best out of the 4046 you need to consult the data sheets and application notes from the manufacturers. These are usually available from their web sites, for example going to **www.philips.com** and searching for 4046 or HEF4046B should get you access to data sheets in Adobe Acrobat PDF format. You will need Acrobat Reader for this, and if it is not already on your system it is available as a free download from **www.adobe.com**.

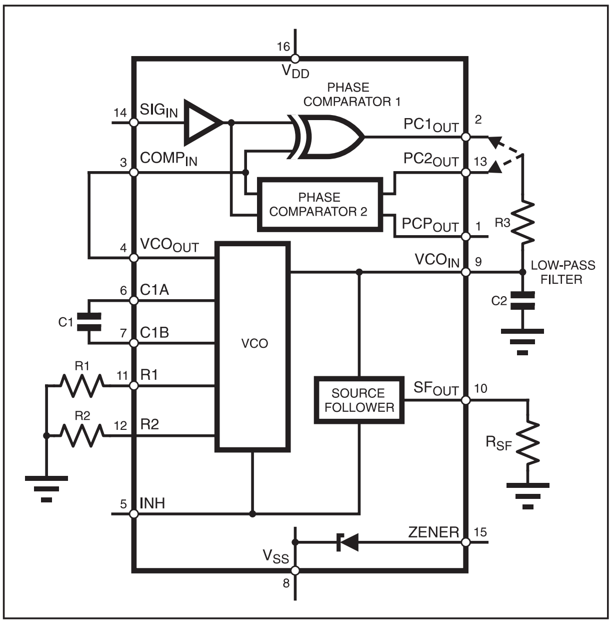


Fig.2. Block schematic of the internal structure of the 4046 phase-locked chip, together with external low-pass filter components (R3 and C2).

That's Typical

In a typical PLL design, you will know either the VCO centre frequency (f_o, which it produces when the control voltage is around half the supply voltage), or you will know the required lock range (f_{min} to f_{max}), which will be centred on the VCO centre frequency.

If you know f_{max} you can select suitable values for resistor R2 and capacitor C1 using graphs provided on the data sheet. The ratio R2/R1 is related to the ratio f_{max}/f_{min} so now you have R2 (and assuming you know f_{min}) you can select R1 using another graph given in the data sheet.

The VCO can also be operated in "no offset" mode with R2 open circuit. In this case you set f_{max} as twice the VCO centre frequency and select R1 and C1 from yet another graph on the data sheet.

The two phase comparators operate on different principles and have different characteristics, benefits and potential problems. Phase comparator 1 is simply an XOR gate as depicted by the internal circuit diagram of the 4046 (Fig.2.). The waveforms associated with it are shown in Fig. 3a.

The VCO output is connected directly to the phase comparator reference input ($COMP_{IN}$) on pin 3. The input signal itself should be capacitively coupled to the signal input (SIG_{IN}) on pin 14. When using phase comparator 1, the signal and reference inputs must both have 50 per cent duty cycle in order to achieve the maximum lock range.

Phase Two

Phase comparator 2 is more complicated than phase comparator 1. It is a *state machine* which changes state when logic transitions occur on either the signal or reference inputs. Depending on the current state of phase comparator 2, it outputs a logic 1, a logic 0 or a high impedance state.

Table 2: Phase Comparators Compared

Property	***Phase Comparator 1 (pin 2)***	***Phase Comparator 2 (pin 13)***
Lock range	Full VCO range f_{min} to f_{max}	Full VCO range f_{min} to f_{max}
Capture range	Depends on low-pass filter	Equal to lock range
Signal noise rejection	Good	Poor
Will it lock on harmonics of f_o?	Yes	No
Effect of input duty cycle	Best performance at 50%	Does not matter
Output when fully out of lock	f_o (the VCO centre frequency)	f_{min}

Table 1: Phase Comparator 2 output truth table

Signal frequency (f) and phase (Φ)	***$PC2_{OUT}$***	***PCP_{OUT}***
$f_{signal} > f_{reference}$	Mainly 1	Mainly 0
$f_{signal} < f_{reference}$	Mainly 0	Mainly 0
$f_{signal} = f_{reference}$ Φ_{signal} lags $\Phi_{reference}$	Mainly 1	Mainly 0
$f_{signal} = f_{reference}$ Φ_{signal} leads $\Phi_{reference}$	Mainly 0	Mainly 0
$f_{signal} = f_{reference}$ $\Phi_{signal} = \Phi_{reference}$ PLL is locked	High impedance	1

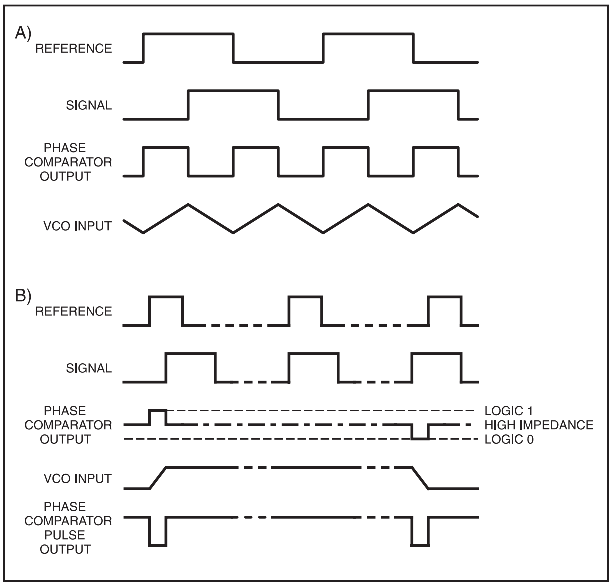


Fig.3. (a) Phase comparator 1 typical waveforms and (b) some typical waveforms for phase comparator 2.

In effect phase comparator 2 produces two bursts of pulses to charge or discharge the filter capacitor as required, but is otherwise disconnected from the filter.

Phase comparator 2 also has another output called PCP_{OUT} (phase comparator pulse output) on pin 1 which can be used to tell when the PLL is locked. Table 1 shows the outputs produced by phase comparator 2 under various conditions. Typical waveforms for phase comparator 2 are shown in Fig.3b. Some of the properties of the phase comparators are compared in Table 2.

Table 1 and Table 2 only scratch the surface when investigating phase-locked loop applications – 500-page text books are available showing much more of the same!

On Time

The loop filter should use the longest *RC* time possible for the application. This depends on the speed with which the input frequency changes.

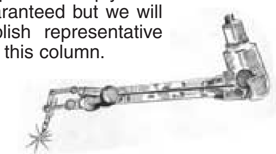
If the *RC* time constant of the loop filter is too long the PLL will not move fast enough to track changes. If it is too short, the VCO frequency will jump around too much, in the worst case responding to individual cycles of the input signal.

The performance of the PLL can be improved by using a resistor in series with C2 (e.g. from the "negative" side of C2 in series to ground, but not shown on Fig. 2). This produces damping in the loop filter and makes the PLL more stable. A typical value for this resistor is about a tenth of the value of R3.

As you can see Malcolm, phase-locked loops can be as complex as you want to make them. We can't hope to cover them in any further depth in this column, and there's probably no substitute for testing typical device chips on a workbench armed with a signal generator and a good oscilloscope. At least you now have an introduction to them, and you'll be able to bluff your way through dinner time sessions with your hardware colleagues at the pub! *I.M.B.*

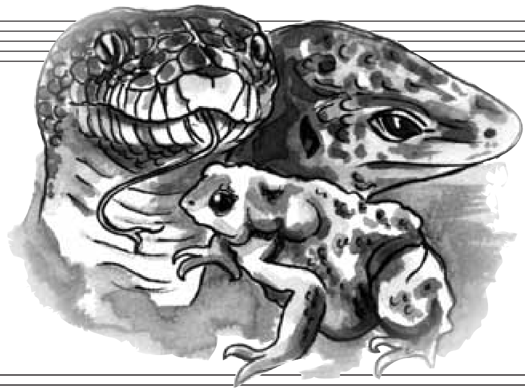
CIRCUIT THERAPY

Circuit Surgery is your column. If you have any queries or comments, please write to: Alan Winstanley, *Circuit Surgery,* Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset, BH21 1PF, United Kingdom. E-mail (no attachments) **alan@epemag.demon.co.uk**. Please indicate if your query is not for publication. A personal reply cannot be guaranteed but we will try to publish representative answers in this column.



Constructional Project

EPE SNUG-BUG



MIKE DELANEY

A 4-channel personal "central heating" system, with sensors, for your tropical pets home.

KEEPING tropical pets is a rewarding and popular hobby. In order that the pets thrive the temperature of the environment must be maintained to within a few degrees and pet stores supply heating pads and thermostatic controllers for this purpose. If more than one habitat is involved then a separate controller/pad system should be used for each, especially if the habitats are located any distance apart or are in different rooms of the house.

This article describes a 4-channel thermostatic controller intended for use with up to four (dry) heat pads. The temperature range is designed to be from about 25°C to 40°C, though each pad may be individually calibrated to the user's requirements.

Fish tanks and other *wet* environments where the heating device needs to be immersed in water are *NOT* dealt with in this article, since there may be certain safety issues unknown to the author – the author's children have snakes and toads only.

DESIGN CONSIDERATIONS

The most important features considered when designing the circuit were:

- Safety – the sensors must be well isolated from harmful voltages.
- Cheap sensors requiring minimal wiring.
- Good noise-immunity on the sensors, allowing long wired connections.
- Easy to interface to the mains supply and no mains interference.
- Good temperature control stability.
- Easy to calibrate and change temperature ranges.
- The circuit should be as simple as possible, requiring only a basic grasp of project construction.

CHOICE OF COMPONENTS

A good deal of thought was given to the type of sensors to use. Three possibilities presented themselves: thermistors, thermocouples and semiconductor sensors. Thermocouples would be a good choice but require special interfacing – a "cold junction compensation" circuit – and expensive cable and connectors to work correctly. Active sensors, like the LM35 from National Semiconductors, need three-core cable, and in the author's experience, can require a lot of attention with regard to decoupling if long cables are used.

This left only one possibility – thermistors. These are easy to use, have good linearity, fast response time and are simple to incorporate in a bridge circuit (more of this later). No special connectors or cables are needed. They are simply resistive devices.

The thermistors chosen are 10 kilohm NTC types. The value of 10k is the manufacturer's quoted typical resistance of the device at either 20°C or 25°C. This value decreases with an increase in temperature (hence NTC – negative temperature coefficient).

Having this relatively low resistance greatly reduces the risk of noise pick-up on the connecting cables. The prototype has been successfully tested with 25 metres of light-weight mains cable in a typical home environment.

MAINS SWITCHING

Most domestic appliances such as refrigerators and deep-freezers switch the mains current by way of mechanical relays. These will be heard clicking on and off periodically, and on older appliances will also be heard on any a.m. radio within a hundred yards radius! This noise is caused because the relay switches irrespective of the mains supply waveform.

Fortunately to reduce mains-borne noise there is a simple, if more expensive, solution open to us called "solid-state relays". These fully encapsulated devices comprise an optical isolating/coupling device driven by low voltage d.c. and a mains phase sensor which both combine to control an internal triac. A triac is a bi-directional switch which has the ability to switch mains voltage of either phase, giving "full-wave control".

The point on the mains waveform at which switching will take place is governed by an internal phase sensor, and is

allowed to happen only when the phase is very close to zero volts. Thus, it is only a matter of turning on what is effectively an l.e.d. to obtain *silent* switching of the supply to the heater pads.

A GOOD REFERENCE

In order to make sure the temperature remains constant over time a good voltage reference i.c. is used. The actual device chosen needed to satisfy two major criteria: it must be stable, and it must be able to drive a couple of milliamps at least without "running out of steam".

This is necessary because the thermistors are low resistance types, and there are up to four connected at any one time. Of course, it would be possible to use a normal Zener diode circuit with an op.amp buffer, but this was not aesthetically pleasing, it would take up more p.c.b. area and could add to circuit drift.

Looking through some components catalogues produced the ideal device from Analog Devices, the REF-03CNB which is a 2·5V reference with a load current rating of 20mA. Available in a standard 8-pin package, the published stability data is also more than satisfactory for the project.

HOT UNDER THE COLLAR

Calibration of any type, be it frequency, wind speed, altitude etc. brings with it a chicken-or-egg situation. Before it is possible to set up your measuring device it is necessary to know the value of the input, but how do you know its value in the first place?

Fortunately, as far as this project is concerned there are reasonably accurate thermometers available at pet stores for checking the temperature within the ranges which interest us. Absolute accuracy is not critical, it is not as if we are keeping a volatile liquid within very tight limits, so it is sufficient to use a standard thermometer as our reference sensor.

BRIDGE WORK

Temperature measurement is carried out using a resistive bridge circuit, where one leg of the bridge is connected to the thermistor and the other to the reference voltage. By comparing the voltage across the thermistor it is possible to determine whether its resistance, and hence the temperature, is above or below the preset value from the reference. It is then a simple matter of switching the heater on or off as needed.

CIRCUIT DETAILS

The full circuit diagram for the *EPE* Snug-Bug is shown in Fig.2. As each "channel" is identical, only the action of one will be described here.

A reference voltage of 2·5 Volts is produced by IC1, a REF-03 8-pin d.i.p. device from Analog Devices. This reference is used to drive the bridge components in each of the four sensor circuits.

The bridge configuration may not be immediately apparent to the less experienced constructor and one sensor circuit is reproduced, in simplified form, in Fig.1. As this shows, the reference voltage is applied to one end of thermistor TH1, and also to one end of the R13, VR1, R14 divider chain. The bridge is then "closed" on both of these legs to ground (0V) via one end of R1 and one end of R14.

The output of the bridge is applied to IC2a, one quarter of an LM339 comparator, the output from the thermistor connecting to the non-inverting input (pin 5), and VR1 wiper connecting to the inverting input (pin 4). Varying the wiper position of VR1 will, therefore, vary the voltage applied to the inverting input, pin 4, and as the thermistor resistance varies with temperature, the voltage on pin 5 of the IC2a will also vary. When the voltage on the non-inverting input is greater than that on the inverting the output on pin 2 will go high.

Consider what happens as the temperature applied to thermistor TH1 increases. Since the NTC thermistor's resistance *decreases as the temperature increases* the voltage applied to the non-inverting input will *increase* and the output of IC2a will go high when the voltage from the thermocouple is greater than the voltage from the control potentiometer VR1.

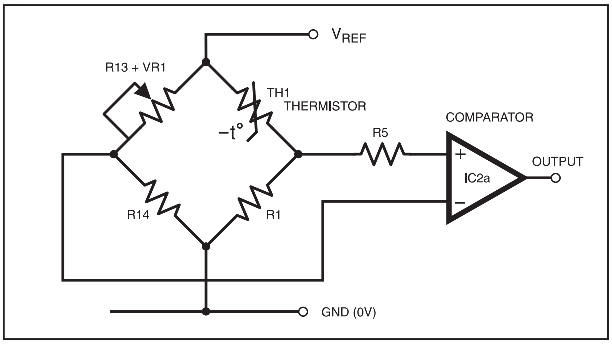


Fig.1. Simplified bridge circuit for one thermistor sensor.

Looking at the full circuit diagram, Fig.2, it can be seen that in order for the opto-coupler (l.e.d.) within IC3 to turn on the output from IC2a must be *low* so that it sinks current. Thus, increasing temperature will turn IC3 off, and decreasing temperature will turn it on. In order to turn IC3 off when there is no thermistor plugged in the full reference voltage (V_{REF}) is connected to the non-inverting input automatically through socket, SK1.

The compact and neat wiring inside the completed unit.

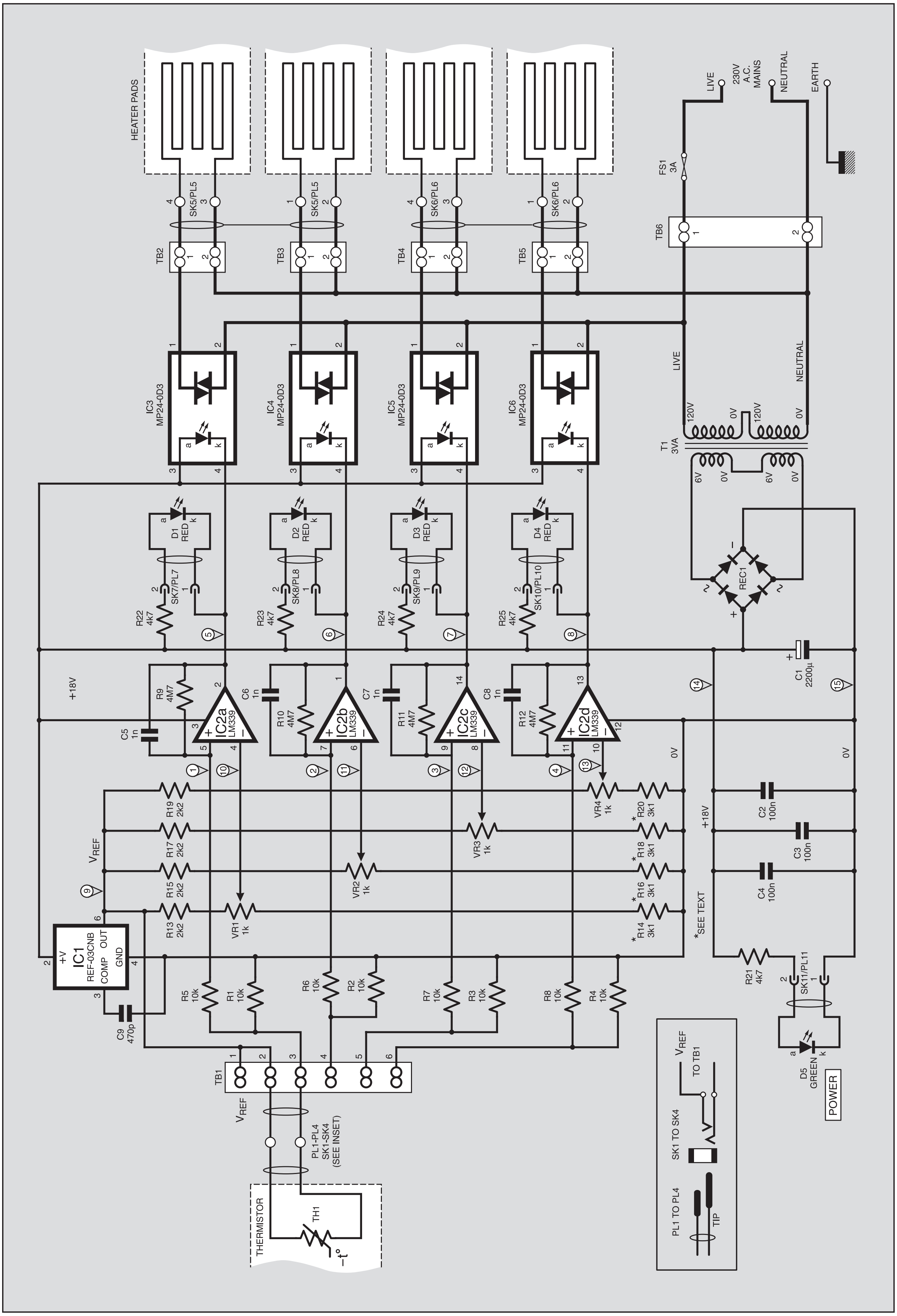


Fig.2. Complete circuit diagram for the EPE *Snug-Bug heat control centre for pets.*

Resistor R9 provides positive feedback (hysteresis) around comparator IC2a, ensuring that switching is clean with capacitor C5 preventing any tendency for high frequency oscillation of the comparator.

Four l.e.d.s (D1 to D4), with current limiting resistors (R22 to R25) are included in parallel with the opto-triacs IC3 to IC6 to confirm operation of each channel. The l.e.d.s in the working design are high output types to reduce current consumption. If different types are used the four resistors may be changed to suit.

POWER LINKS

The power supply is a very simple affair, comprising a transformer, full-wave rectifier and smoothing components. A power "on" indicator l.e.d. with its associated resistor are also included.

Several wire links have been included in the layout, both to assist in the layout and also to provide useful test points (TP1 to TP15).

CONSTRUCTION

The *EPE* Snug-Bug is built on a Eurocard size printed circuit board (p.c.b.) and the component layout and full-size underside copper foil master is shown in Fig.3. This board is available from the *EPE PCB Service*, code 296.

Assembling the p.c.b. should present no problems. Start by fitting the resistors and wire links and fit the mains transformer last. Use good quality i.c. sockets for IC1 and IC2, turned pin types are preferred. Do not fit the i.c.s until preliminary testing is completed.

Capacitors C5 to C8 may need to have their wires bent slightly in order for them to fit on the p.c.b. This should be done using fine nosed pliers, taking care not to damage the components.

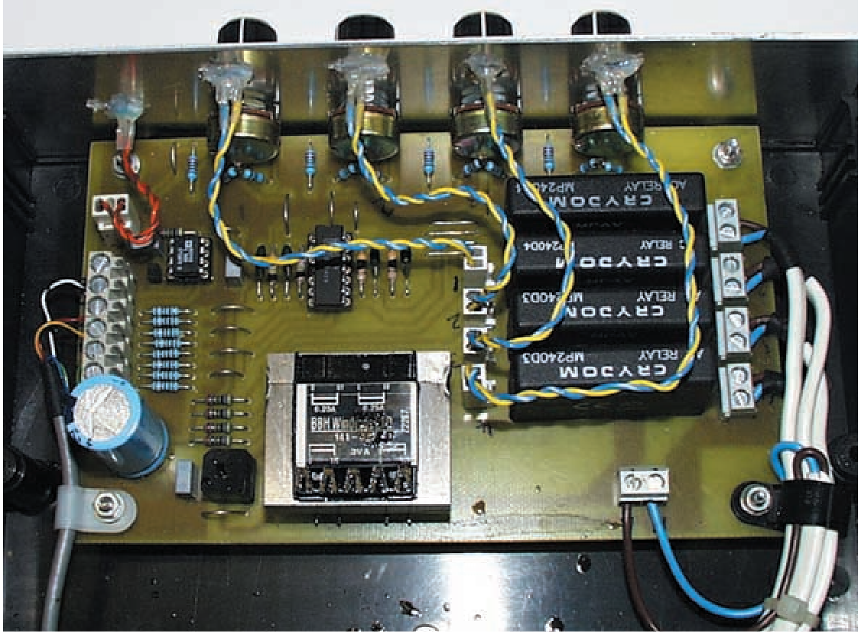
In order to set the maximum and minimum voltages on the control potentiometers' wipers, the prototype used a value of 3·1 kilohms (3k1) for resistors R14, R16, R18 and R20 which is not a preferred value. This value is obtained by using two resistors in series for each, one 1k5 and one 1k6, numbering the second resistor R14a etc. on the board component layout in Fig.3.

INTERWIRING AND BOXING-UP

Interwiring between the front and back panel mounted components and the circuit board is shown in Fig.5. The general positioning of components inside the specified case can be seen in the photographs.

In the prototype unit, the four temperature control potentiometers (VR1 to VR4) are p.c.b.-mounting types and are soldered directly to the p.c.b. and mounted through the fascia with spacers placed between the fascia panel and each control. This makes for a neat and quick assembly, but requires more care when drilling the panel. To assist in this there is a detailed drilling diagram (Fig.4) included, but p.c.b. solder pins and connecting wires may be used if desired.

The front panel l.e.d.s (D1 to D4) are mounted through plastic insulating collars of the type used to isolate TO-3 style screws, and are fixed in place using a glue gun. Each l.e.d. is connected to the p.c.b. using a Molex connector and wire (see



Component layout on the prototype p.c.b. and wiring to the front panel l.e.d.s. You can just see the series resistors in front of the potentiometers.

COMPONENTS

Approx. Cost Guidance Only £77 excluding heat-pad & case.

See SHOP TALK page

Resistors

TH1 to TH4	min. bead thermistor: resistance @ 25°C 10kΩ ±1% (4 off – see text)
R1 to R8	10k (8 off)
R9 to R12	4M7 (4 off)
R13, R15, R17, R19	2k2 (4 off)
R14, R16, R18, R20	1k6 (4 off) } 3k1 see text
R14a, R16a, R18a, R20a	1k5 (4 off) } 3k1 see text

All 0·6W 1% metal film, except where stated

Potentiometers

VR1 to VR4	1k min. rotary carbon, lin. (4 off)

Capacitors

C1	2,200 radial elect. 25V, pin pitch 7·5mm
C2 to C4	100n polyester (3 off)
C5 to C8	1n mylar film (4 off)
C9	470p resin-dipped ceramic

Semiconductors

D1 to D4	3mm red l.e.d. (4 off)
D5	3mm green l.e.d.
IC1	REF03GP 2·5V precision voltage reference
IC2	LM339 quad voltage comparator
IC3 to IC6	MP240D3 opto-triac, with zero switching: input 3·5V to 32V d.c.; output switching 3A @ 240V a.c. (4 off)
REC1	100V 2·5A bridge rectifier (1KAB10E)

Miscellaneous

SK1 to SK4	3·5mm mono switched jack socket, plastic body, panel mounting (4 off)
PL1 to PL4	3·5mm mono jack plug (4 off)
SK5, SK6	4-pin 2A 250V mains socket, chassis mounting (Bulgin SA2368 – 2 off)
PL5, PL6	4-pin 2A 250V mains line-plug, with shielded pins (Bulgin SA2367 – 2 off)
SK7 to SK10	2-way 2·54mm (0·1in.) pitch pin header (4 off)
PL7 to PL10	2-way pin connector (4 off) and crimp terminal (8 off)
SK11/PL11	3-way pin header, connector, crimp terminal (remove centre pin – see text)
TB1	6-way 16A terminal block, p.c.b. mounting
TB2 to TB6	2-way 16A terminal block, p.c.b. mounting (5 off)
T1	3VA mains transformer, p.c.b. mounting, with 0V-6V, 0V-6V secondaries
FS1	3A 20mm fuse, with panel mounting fuseholder

Printed circuit board available from the *EPE PCB Service*, code 296; plastic (ABS) case, with aluminium front and back panels, size approx. 203mm (w) x 178mm (d) x 63mm (h); 220V/240V 7W heater pad, size approx. 150mm x 280mm (6in. x 11in.) (4 off); 8-pin d.i.l. socket; 14-pin d.i.l. socket; plastic 15mm diameter, collet fixing, knob (4 off); strain-relief grommet; p-clips (2 off); plastic spacer (4 off); 3mm csk bolts, nuts and washers (4 off each); mains cable (see text); multi-strand connecting wire; heatshrink and rubber sleeving; solder, etc.

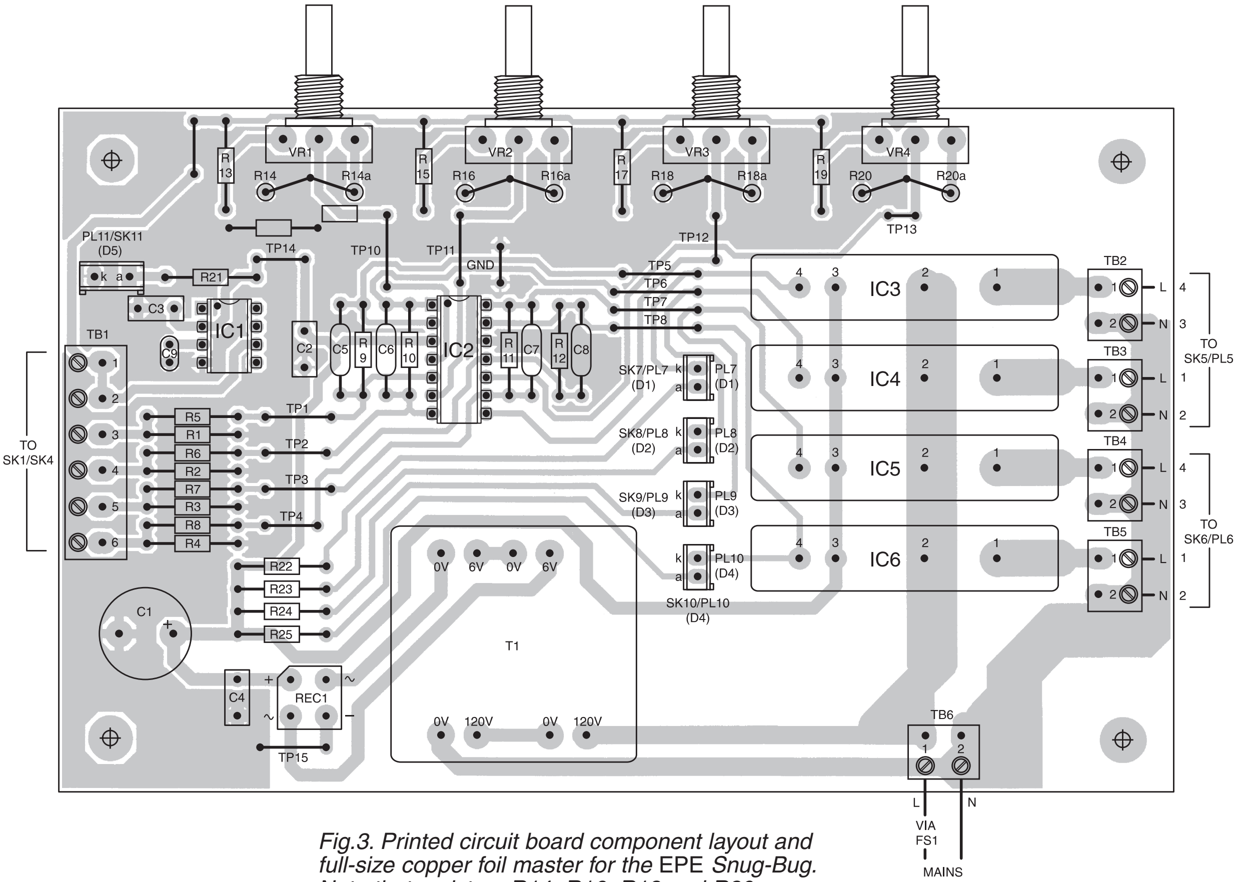
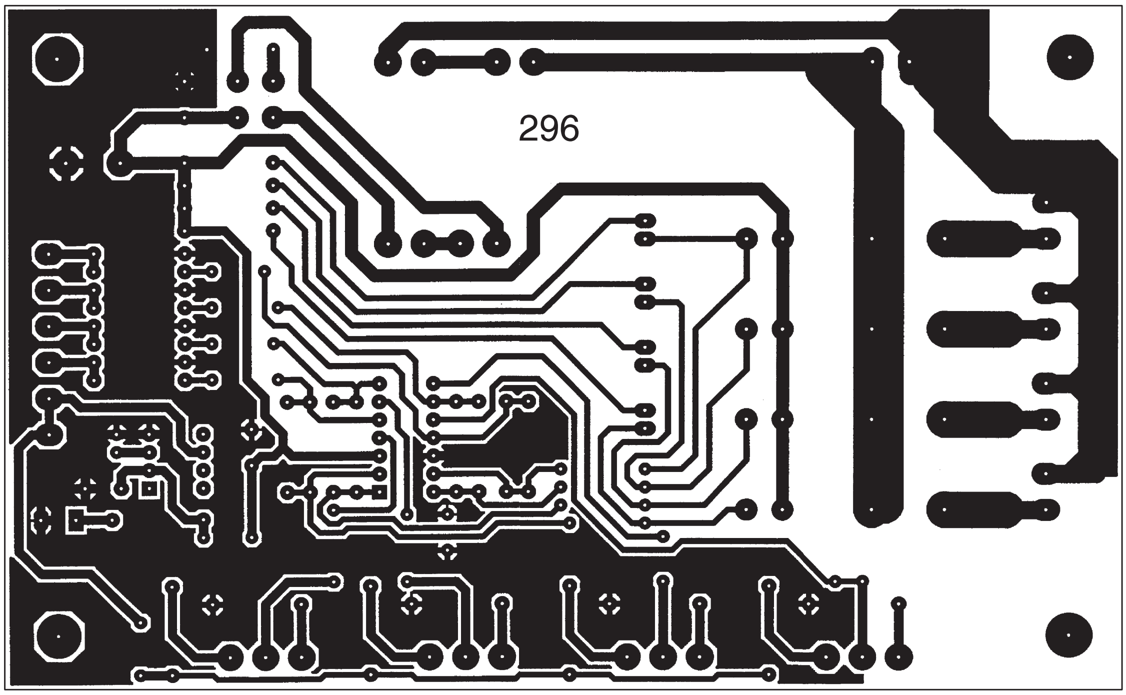


Fig.3. Printed circuit board component layout and full-size copper foil master for the EPE *Snug-Bug. Note that resistors R14, R16, R18 and R20 are made up of two resistors wired in parallel. See text and components list.*



3·88in. (97mm)

6·25in. (156mm)

photographs), photographs though again these may be soldered directly to solder pins instead and the l.e.d.s mounted in conventional plastic holders.

The power on indicator l.e.d. is connected using a three-pin Molex plug and socket with the centre pin removed. This was done to facilitate removal of the circuit board during initial testing whilst maintaining a reasonable thickness of ground copper.

The board terminal blocks TB2 to TB5 are 2-way p.c.b. mounting types rated at 16A, with 5mm pin spacing. The connectors SK5 and SK6 for the switched supplies (from TB2 to TB5) to the heater pads are panel mounting four-way mains types rated at 2A. ***Only correctly rated and safety protected connectors for SK5/PL5 and SK6/PL6 should be used!***

Standard 3·5mm mono jack plugs and sockets are used to connect the thermistors, *the sockets should be the type with break contacts*. One word of caution: the author has found that it is possible to buy "standard" plugs which do not make a good connection to the wipers in "standard" sockets. This causes the thermistor to appear intermittent or completely open circuit (see fault-finding later). Buying both plug and socket from the same supplier and careful testing is recommended.

A fuse rated at 5A should be used in the mains input line, along with a cable relief grommet and P-clips and cable ties for all of the cables.

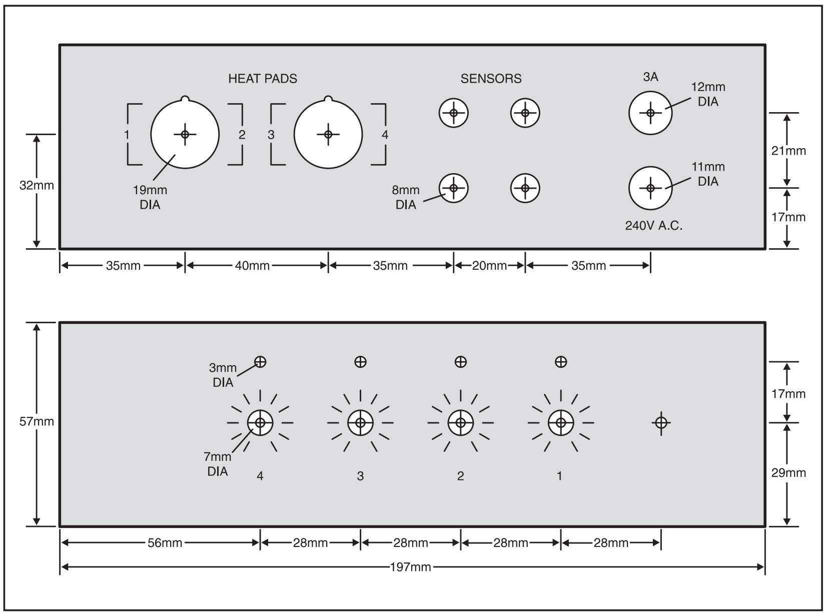


Fig.4. Drilling and dimension guide for the aluminium front and rear panels.

Table 1: Test Point Voltages

Test Point TP No.	*TP Name*	*Voltage*	*Comments*
1–4	Non-Inverting (IC2) Inputs	*	Varies with temperature
5–8	Output	1·2V to V_{CC}	Almost rail-to-rail
9	V.Ref.	2·50V	Stable reference voltage.
10–13	Wiper (VR1 to VR4)	1·23V to 1·62V	Varies depending upon pot. wiper position.
14	Supply Voltage (V_{CC})	18V d.c.	
15	Supply Zero	0V	

Notes on the test point voltages: *TP1 to TP4 – this should be approximately 1·25V d.c. but will depend upon the temperature of the thermistor. TP15 – all voltages shown are measured with respect to this point 0V (Gnd).

THERMISTOR PROBES

Two types of thermistor are available (see *Shoptalk* page), one has p.t.f.e. insulated leads ready fitted and the other has bare wires. Whichever type you choose it is desirable to insulate *all* connections using heat-shrink sleeving and silicone rubber after soldering. Waterproofing will help to prevent corrosion of the wires and eventual sensor failure.

The type of wire used to connect the thermistors to the control unit is not critical. The author has successfully used single-core screened ("microphone" cable) and also unscreened lightweight mains cable. If a long run is required it is probably better to use mains cable since it is easy to fix to skirting boards etc and is stronger than lightweight types.

Make sure the thermistor leads are fully insulated.

TEST AND CALIBRATION

Be aware that mains voltages are present at various points on the circuit board and case back panel. Use insulating tape to cover exposed joints on the underside of the board.

To carry out tests and calibration you will require the following equipment:

Digital multimeter; mono 3·5mm plug, on which the centre (tip) and outer solder connections have been connected together; small lump of Blu-Tack or similar; two 2cm thick (approximately) pieces of polystyrene slightly larger than the heater pad/s; heater pad/s wired to the output plug/s; thermistor/s wired to 3·5mm jack plug/s.

The rear panel sockets, fuse and mains cable positioning.

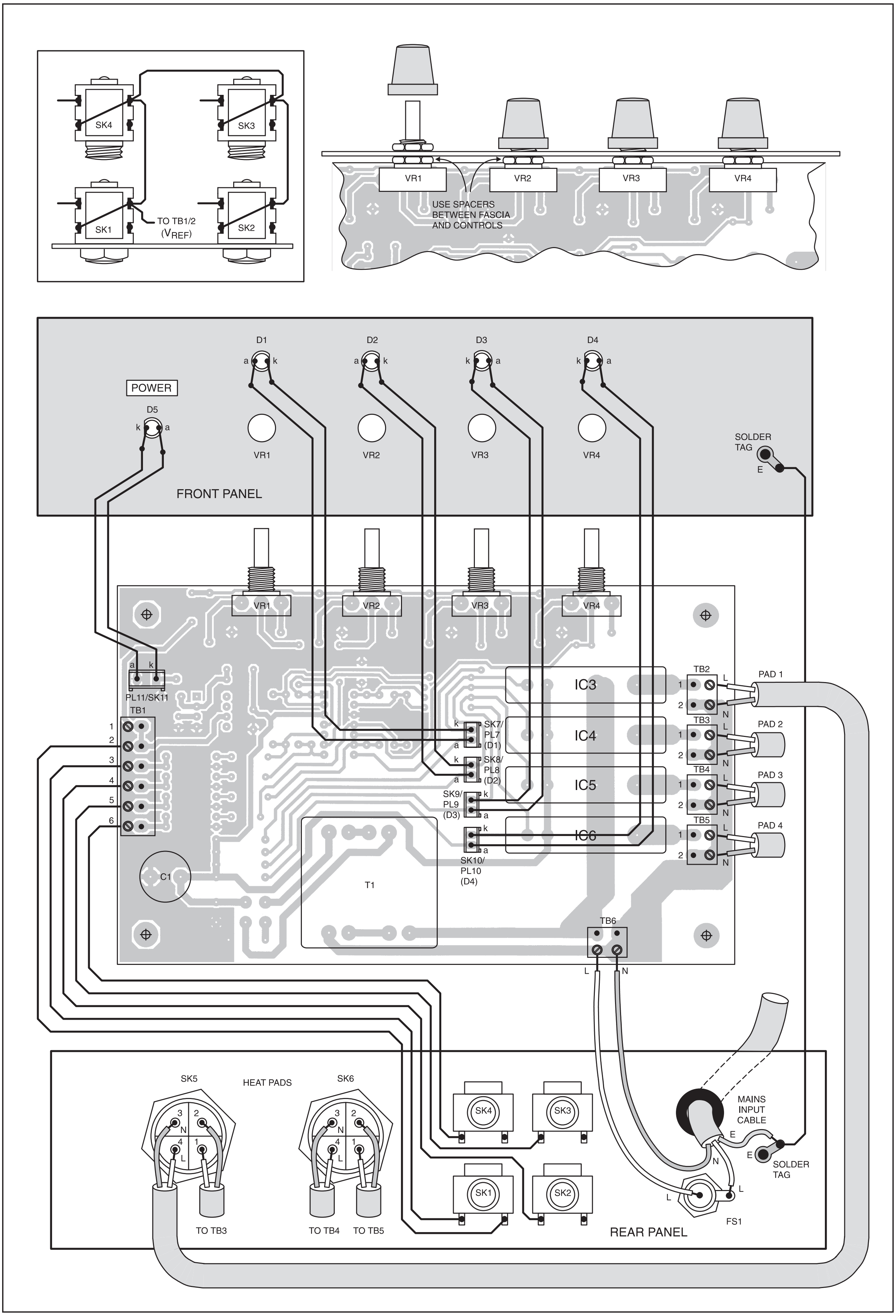


Fig.5. Interwiring from the circuit board to front and rear panel mounted components. The inset diagram (top left) shows the interwiring between to the switched jack socket tags.

Before applying power carefully check that all the components are placed correctly and there are no solder bridges or dry joints.

As mentioned earlier, several wire link test points have been included on the circuit board to assist fault finding. These are shown as numbered "Ice Cream Cornets" (the author's children's description!) on the circuit diagram, Fig.2. Table 1 shows typical voltages and these should be measured using a digital voltmeter.

Initial testing should be carried out without the thermistors connected to confirm that the outputs from the comparators are high and l.e.d.s D1 to D4 are off. Check that each of the outputs from the control pots at test points TP10 to TP13 changes as they are turned and that the l.e.d.s remain off.

Now plug the temporary 3·5mm "shorting plug" into each thermistor socket (SK1 to SK4) in turn and check that the comparator outputs go low and the l.e.d.s turn on. Once again, adjusting pots VR1 to VR4 should not have any effect, the shorted out channel must remain on.

THERMISTOR CHECK

Having completed these checks plug in the thermistor probes. It should be noted that there are two REF connections on terminal block TB1, both pin 1 and pin 2, and it does not matter which is used for which probe. This was done in order to make it easier to connect multiple wires to the one connector.

Embed all of the thermistors and the "standard" glass thermometer bulb in the Blu-Tack and allow time for the temperature to stabilise. When this has settled adjust each of the four controls and confirm that each channel l.e.d. turns on and off, and do so at the same position provided the temperature is between the lower and upper thresholds. If the ambient temperature is outside of these limits re-position the thermistors etc. to suit.

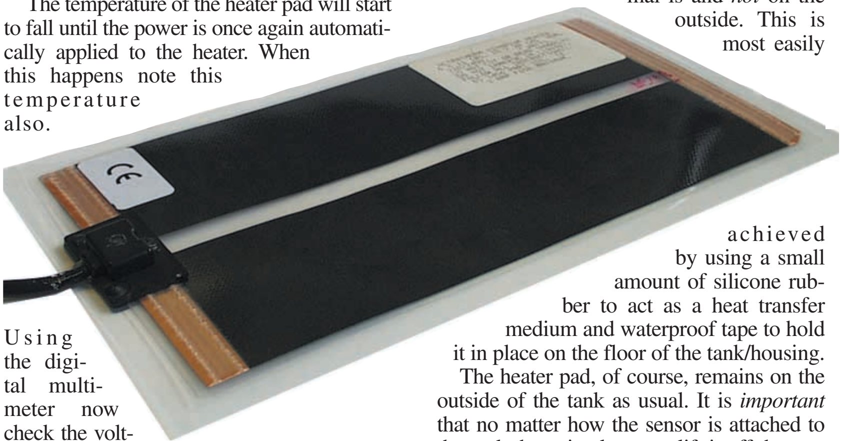
Check the voltage outputs from the thermistors, test points TP1 to TP4 inclusive. The "typical" voltage here (Table 1) applies ONLY to the author's unit measured at 20°C – thermistors vary slightly. Nevertheless, the voltages should be within a few millivolts of those shown when the temperature is 20°C.

HEAT CHECK

If all appears to be correct ***turn off the supply*** and connect one heater pad, say in Channel One position. Using the Blu-Tack stick the thermistor and thermometer to the pad. Insulate the heating pad using two pieces of polystyrene so that it makes a "sandwich" and place a book on top to ensure good thermal contact.

Apply the mains and turn the relevant pot. fully counter-clockwise so that the channel l.e.d. turns off. Now advance the control so that the associated opto-triac switches and power to the heater pad is turned on. Check that the temperature of the pad increases and that the controller switches the power off when the upper temperature limit is reached. Note this temperature from the thermometer.

The temperature of the heater pad will start to fall until the power is once again automatically applied to the heater. When this happens note this temperature also.



Using the digital multimeter now check the voltage present at the test point TP10 (for Channel One) and make a note of this.

It is now possible to check the operation of the other three channels by plugging the thermistor and heater pad into each of the other channels in turn and setting the control pots so that the same voltage is present on all the wipers (TP11 to TP13). This should result in the pad temperature remaining the same to within a degree or so.

FINAL SETTING

Next check the other three heater pads and thermistors by making polystyrene sandwiches and monitoring the temperature of each with the pot wiper voltages set identically to Channel One. This will confirm the accuracy of each thermistor and bridge components.

When you are satisfied that the circuit is functioning correctly set each channel to whatever temperature span is desired by changing the values of series combination resistors R14/a, R16/a, R18/a and R20/a and repeating the calibration process.

INSTALLATION

It is now simply a case of installing the thermistors in the animals' environments, monitoring the temperature switching points and noting the position of the control knobs when the desired temperature is achieved.

When installing the thermistors it is important that the temperature *inside* the environment is monitored, i.e. where the animal is and *not* on the outside. This is most easily achieved by using a small amount of silicone rubber to act as a heat transfer medium and waterproof tape to hold it in place on the floor of the tank/housing.

The heater pad, of course, remains on the outside of the tank as usual. It is *important* that no matter how the sensor is attached to the tank the animal *cannot* lift it off the surface being sensed.

FAULT FINDING

If the circuit does not work, referring to the list of voltages in Table 1 should allow analysis to component level. Incorrectly placed components, solder bridges and bent i.c. pins are the first things to check for.

As mentioned earlier, the only problem encountered during the building of the Snug-Bug was caused by incompatibility between the thermistor jack plugs and sockets. This problem is easy to check for – measure the voltage present at the non-inverting inputs of the comparator (IC1) when the thermistors are plugged in. If any of them gives a zero reading then the thermistor is open-circuit. □

SHOP TALK
with David Barrington

EPE Snug-Bug

A number of components needed for the *EPE Snug-Bug* project will not be available through readers' usual local sources and will have to be specially ordered. One of the most costly items in this project is the Crydom MP2410D opto-triac ("solid-state" relay), this was purchased from **Farnell** (☎ ***0113 263 6311*** or ***www.farnell.com***), code 269-785.

They also provided the specified, 10kΩ at 25°C, NTC thermistors. Two versions are available, insulated leads code 679-446 and non-insulated leads code 679-409. The prototype case, with aluminium front and rear panels, came from them, code 722-625.

The REF03GP 2·5V voltage reference source (code 411-097), the IR 1KAB10E bridge rectifier (code 371-208) and the 3VA mains transformer, with independent secondary windings, code 141-471 all came from the above source.

The prototype model uses 3·5mm mono, plastic-bodied, switched jack sockets and right-angled matching plugs obtained from **Maplin** (☎ ***0870 264 6000***), codes CX93B and FA37S. They also supplied the 4-pin 2A mains rated Bulgin output socket (SA2368) and line-plug (SA2367), codes HL34M and HL33L respectively.

The Euro-card sized printed circuit board is available from the *EPE PCB Service*, code 296 (see page 305).

Intruder Alarm Control Panel

The reason we are able to quote such a "competitive" price for the *Intruder Alarm Control Panel* project is because **Delta Consultants** have kindly made the "special" components available to constructors at very favourable prices.

The specially masked EP520M security microcontroller chip is available for the sum of only £3.50 and the keypad, together with lead, metal plate and label, is priced at £2.50. They will also supply the anti-tamper, p.c.b. mounting "click" switch and activating spring (60p), the 8 ohm 12W loudspeaker (£2.75) and alarm panel case (£5.50). They can also supply the p.c.b.-mounting relay for the Bell Unit and is quoted at £1.65.

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

We understand generous quantity discounts are available, e.g. 10 off EP520M £2.25 each; 50 off £1.50 each.

The 8-pin non-volatile memory i.c. type 93C06EN should be widely stocked. It is certainly listed by **Maplin** (☎ ***0870 264 6000***), code ADP16.

The two printed circuit boards for this project are available from the *EPE PCB Service*, codes 297 (main board) and 298 (ext. bell), see page 305.

Sound Trigger

A problem has arisen regarding a supplier for the VN10KM *n*-channel MOSFET called up in the *Sound Trigger*, this month's Top Tenner project. On investigating a recent request for a source for this low-power MOSFET device, some suppliers indicated that it had been discontinued and others that it was out of stock but were expecting new deliveries eventually.

Further enquiries have revealed that **Farnell** (☎ ***0113 263 6311*** or ***www.farnell.com***) are quoting the VN10KLS as a direct replacement. Their order code is 334-5282; we understand that it is not currently listed in their catalogue. This device has not been tried in this circuit.

You could try the author's suggestion, for driving a more powerful lamp, and use the VN66AF currently listed by Maplin (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code WQ97F.

Wave Sound Effect

We do not expect readers to experience any component buying problems for the *Wave Sound Effect* unit, this month's Starter Project. Most of our component advertisers should be in a position to supply the parts or suitable equivalents, including a medium size plastic or metal case.

Incidentally, almost any small *npn* silicon transistor should be capable of producing the required "noise" source (TR1) for this circuit. The other transistors can be any high gain silicon *npn* devices, such as the 2N3704. However, you will need to check the pinout identifications before mounting on the circuit board.

PLEASE TAKE NOTE

Body Detector *Mar '01*

Page 178, Fig.7. The lead from the pole of switch S1a should go to the circuit board at point ***R2*** (diode D3 anode end) and not as shown.

Doorbell Extender *Mar '01*

It has been pointed out that as both capacitors C1 are connected between the mains supply and Earth they should be a "*Class Y*" type.

A suitable 10nF Class Y capacitor is currently listed by Maplin (***0870 264 6000*** or ***www.maplin.co.uk***), code JA96E.

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FEATURES ● Teach-In 2000–Part 6 ● Ingenuity Unlimited ● Technology Timelines–3 ● Circuit Surgery ● Interface ● Telcan Home Video ● Net Work – The Internet.

MAY '00

PROJECTS ● Versatile Mic/Audio Preamplifier ● PIR Light Checker ● Low-Cost Capacitance Meter ● Multi-Channel Transmission System–1.
FEATURES ● Teach-In 2000–Part 7 ● Technology Timelines–4 ● Circuit Surgery ● Practically Speaking ● Ingenuity Unlimited ● Net Work – The Internet ● *FREE* Giant Technology Timelines Chart.

JUNE '00

PROJECTS ● Atmospheric Electricity Detector–1 ● Canute Tide Predictor ● Multi-Channel Transmission System–2 ● Automatic Nightlight.
FEATURES ● Teach-In 2000 – Part 8 ● Technology Timelines–5 ● Circuit Surgery ● Interface ● New Technology Update ● Ingenuity Unlimited ● Net Work – The Internet.

JULY '00

PROJECTS ● g-Meter ● Camera Shutter Timer PIC-Gen Frequency Generator/Counter ● Atmospheric Electricity Detector–2.
FEATURES ● Teach-In 2000–Part 9 ● Practically Speaking ● Ingenuity Unlimited ● Circuit Surgery ● PICO DrDAQ Reviewed ● Net Work – The Internet.

AUG '00

PROJECTS ● Handy-Amp ● EPE Moodloop ● Quiz Game Indicator ● Door Protector
FEATURES ● Teach-In 2000–Part 10 ● Cave Electronics ● Ingenuity Unlimited ● Circuit Surgery ● Interface ● New Technology Update ● Net Work – The Internet.

SEPT '00

PROJECTS ● Active Ferrite Loop Aerial ● Steeplechase Game ● Remote Control IR Decoder ● EPE Moodloop Power Supply.
FEATURES ● Teach-In 2000–Part 11 ● New Technology Update ● Circuit Surgery ● Ingenuity Unlimited ● Practically Speaking ● Net Work – The Internet Page.

OCT '00

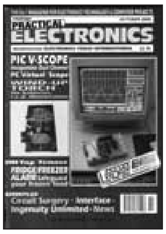
PROJECTS ● Wind-Up Torch ● PIC Dual-Chan Virtual Scope ● Fridge/Freezer Alarm ● EPE Moodloop Field Strength Indicator.
FEATURES ● Teach-In 2000–Part 12 ● Interface ● Ingenuity Unlimited ● New Technology Update ● Circuit Surgery ● Peak Atlas Component Analyser Review ● Net Work – The Internet Page.

NOV '00

PROJECTS ● PIC Pulsometer ● Opto-Alarm System ● Sample-and-Hold ● Handclap Switch.
FEATURES ● The Schmitt Trigger–Part 1 ● Ingenuity Unlimited ● PIC Toolkit Mk2 Update V2.4 ● Circuit Surgery ● New Technology Update ● Net Work – The Internet ● FREE Transistor Data Chart.

DEC '00

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



JAN '01

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

FEB '01

PROJECTS ● Ice Alert ● Using LM3914-6 Bargraph Drivers ● Simple Metronome ● PC Audio Power Meter.
FEATURES ● The Schmitt Trigger–Part 4 ● Ingenuity Unlimited ● Circuit Surgery ● New Technology Update ● Net Work – The Internet ● *Free* 16-page supplement – How To Use Graphics L.C.D.s With PICs.

MAR '01

PROJECTS ● Doorbell Extender ● Body Detector ● DIY Tesla Lightning ● Circuit Tester
FEATURES ● Understanding Inductors ● The Schmitt Trigger–Part 5 ● Circuit Surgery ● Interface ● New Technology Update ● Net Work – The Internet Page.

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We can also supply back issues of *ETI* (prior to the merger of the two magazines) for 1998/9 – Vol. 27 Nos 1 to 13 and Vol. 28 No. 1. We are not able to supply any material from *ETI* prior to 1998. Please put *ETI* clearly on your order form if you require *ETI* issues.
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M04/01

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EPE ONLINE STORE – Books, PCBs, Subscriptions, etc.

VOL 3 CONTENTS

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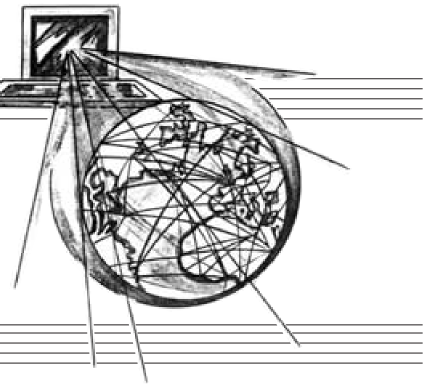
NET WORK

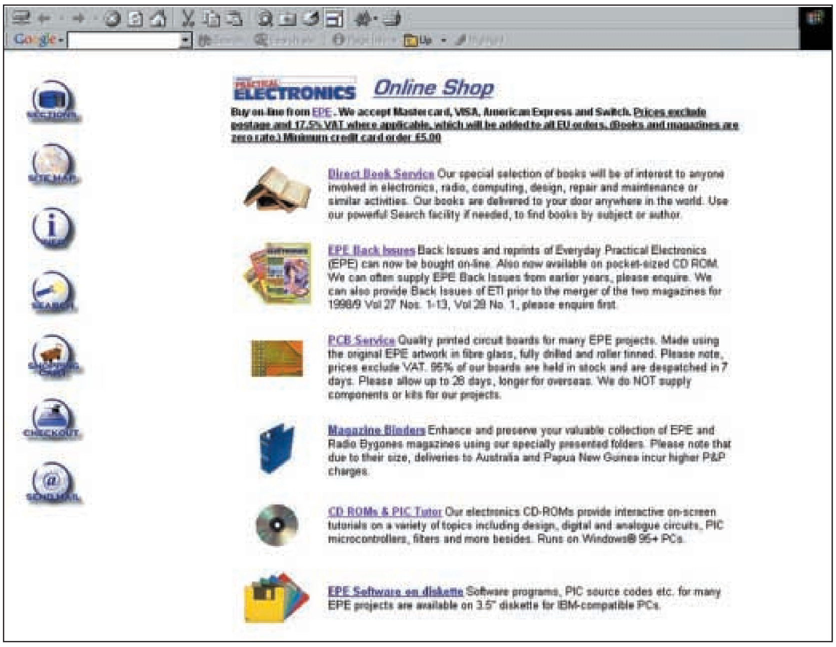


ALAN WINSTANLEY

EPE Online Shop

REGULAR users of the *EPE* web site will know that we recently launched our new shopping cart service. Now you can purchase back issues of *EPE* via the Internet, together with project printed circuit boards all at the same time. We have also added the entire range of books from the *Direct Book Service*, including those speciality books offered by our sister magazine *Radio Bygones*. You can read a comprehensive description of a book's contents and usually view a colour image of book and magazine covers. Our selection of magazine binders, CD ROMs and Ucando videotapes completes the line up of products available through the new *EPE* shopping service.

The system offers all the usual facilities that customers would expect in a comprehensive shopping cart. Each distinct product area is contained in a "Section", and you can easily navigate around the shop using the Site Map if needed. A powerful search engine will display all related products (e.g. back issues and corresponding p.c.b.s) when you enter a project name or keyword.



As a further service, you can also order article reprints from any back issues of *EPE* which are now out of print. Simply type in the *issue month* and *article name* when you do your shopping, and it will be added to your shopping cart. Then proceed to the checkout when you are finished, enter your details and payment method, and the order will then be transmitted *securely* to the Orders Department for attention.

The new shop is at **www.epemag.wimborne.co.uk/shopdoor.htm** where you can view service announcements and FAQs, before entering the secure area itself – the shopping cart is held on a secure server, and all customer order data is encrypted at all times for security and peace of mind. *Please be aware this is a different service from our American-based* EPE Online *(**www.epemag.com**) which sells its own range of books and CD ROMs.*

Postscript

We have worked hard to bring all those "reader essentials" together under one roof, so that you can now place a single order to cover all your requirements. A quick scan through the *EPE* mail order advertisements in this issue will show that there is a very wide variety of electronics-related products available directly from *EPE*, including books, videos and CD ROMs as always, but due to the way that the product range has gradually evolved over the years, there are a number of different postage rates in force. In fact, it is calculated that, across the board, there were nearly one hundred combinations of product and postage available!

Attempting to translate that into a simple on-line shopping cart service has been challenging to say the least, and ultimately a more radical approach needed to be adopted. Therefore, there are some initial differences between our on-line shop and the more traditional mail-order service that *EPE* will continue to offer.

However, we have attempted to iron out the obvious anomalies in postage and deliveries by taking an overall "swings and roundabouts" view. This means we have managed to greatly simplify things for everybody, while keeping magazine mail-order and on-line shop prices broadly in line with each other.

As we say in the FAQ, the choice is now yours, but you should note that prices shown in the on-line shop *apply only to Internet orders*. We think that most customers will soon prefer the great convenience of the on-line shop, but traditional mail order coupon, phone or fax sales will continue to be available for those preferring to purchase that way.

A Taxing Time

For the benefit of our many overseas readers, the most important difference is that all "on-line" prices *exclude* Value Added Tax (VAT, currently 17·5%), as well as postage charges. Orders from customers in all EU (European Union) countries will be subjected to VAT, the value of which will be clearly shown on the on-line shopping cart. Orders from outside the EU, are ***not*** charged VAT.

Next, postage: all on-line prices ***exclude*** postage, as the shopping cart "knows" the weight of each product (or average weight, in the case of magazines and p.c.b.s), so the postage cost is calculated on the *total* weight of the order. Postage also depends on destination – we deliver to most countries around the world, and customers outside the EU will usually be offered a choice of air or surface mail deliveries.

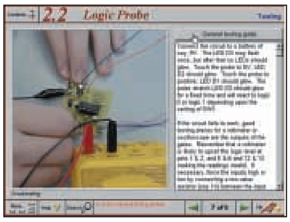
We think this is the fairest and most transparent method to implement. Again, the system is programmed with the postage rates to each country, and so the postage options are calculated by the shopping cart and clearly shown to the customer.

At all times, you can view your current shopping cart, and delete or amend products as necessary, and customers will be able to see the total value of orders, including postage and VAT where levied, before they decide to enter their payment details and confirm their order. You will always be offered a comprehensive receipt and order reference number, which you should print off and keep.

The payment options have also increased: *EPE* can now accept Mastercard, VISA, American Express and Switch debit cards (but *not* Electron cards). So have a go – buy on-line from *EPE*!

ELECTRONICS CD-ROMS

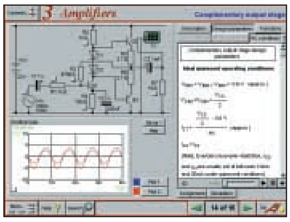
ELECTRONICS PROJECTS



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.

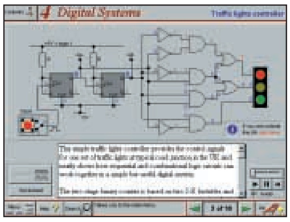
ANALOGUE ELECTRONICS



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.

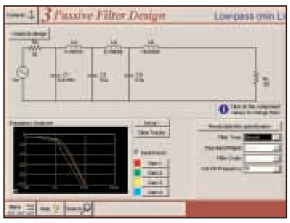
DIGITAL ELECTRONICS



Virtual laboratory – Traffic Lights

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

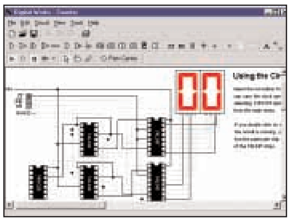
FILTERS



Filter synthesis

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

DIGITAL WORKS 3.0



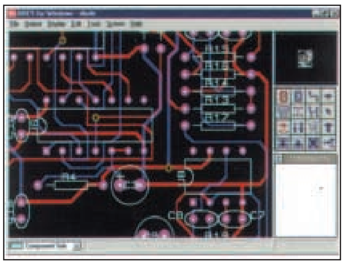
Counter project

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

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

ELECTRONICS CAD PACK

NEW



PCB Layout

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

"C" FOR PICMICRO MICROCONTROLLERS

NEW

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

PRICES

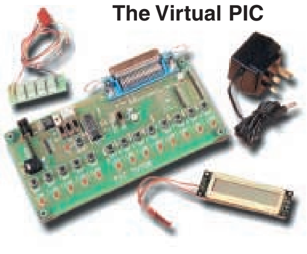
Prices for each of the CD-ROMs above are:

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

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

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

The Virtual PIC



Deluxe PICtutor Hardware

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

HARDWARE
Whilst the CD-ROM can be used on its own, the physical demonstration provided by the **PICtutor Development Kit**, plus the ability to program and test your own PIC16x84s, really reinforces the lessons learned. The hardware will also be an invaluable development and programming tool for future work.
Two levels of PICtutor hardware are available – Standard and Deluxe. The **Standard** unit comes with a battery holder, a reduced number of switches and no displays. This version will allow users to complete 25 of the 39 Tutorials. The **Deluxe** Development Kit is supplied with a plug-top power supply (the **Export** Version has a battery holder), all switches for both PIC ports plus l.c.d. and 4-digit 7-segment l.e.d. displays. It allows users to program and control all functions and both ports of the PIC. All hardware is supplied **fully built and tested** and includes a PIC16F84.

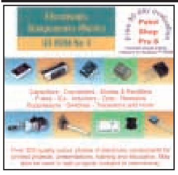
PICtutor CD-ROM

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

HARDWARE

Standard PICtutor Development Kit . . . .£47 inc. VAT
Deluxe PICtutor Development Kit . . . .£99 *plus* VAT
Deluxe Export Version . . . .£96 *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

ELECTRONIC CIRCUITS & COMPONENTS + THE PARTS GALLERY

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. 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. Selections include: ***Components, Components Quiz, Symbols, Symbols Quiz, Circuit Technology***

Hobbyist/Student...£34 inc VAT
Institutional (Schools/HE/FE/Industry)..£89 *plus* VAT
Institutional 10 user (Network Licence)..£169 *plus* VAT

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

MODULAR CIRCUIT DESIGN

This CD-ROM 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.
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 Version £19.95 inc. VAT
Multiple User Version £34 *plus* VAT

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

Minimum system requirements for these CD-ROMs: PC with 486/166MHz, VGA+256 colours, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 95/98, mouse, sound card, web browser.

CD-ROM ORDER FORM

B3

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- ☐ **Analogue Electronics**
- ☐ **Digital Electronics**
- ☐ **Filters**
- ☐ **Digital Works 3.0**
- ☐ **Electronics CAD Pack**
- ☐ **C For PICmicro Microcontrollers**
- ☐ **PICtutor**
- ☐ **Electronic Circuits & Components +The Parts Gallery**

Version required:
- ☐ **Hobbyist/Student**
- ☐ **Institutional**
- ☐ **Institutional 10 user**

Note: The software on each version is the same, only the licence for use varies.

- ☐ **PICtutor Development Kit – Standard**
- ☐ **PICtutor Development Kit – Deluxe**
- ☐ **Deluxe Export**

Note: The CD-ROM is not included in the Development Kit prices.

- ☐ **Electronic Components Photos**
- ☐ **Modular Circuit Design – Single User**
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Note: The software on each version is the same, only the licence for use varies.

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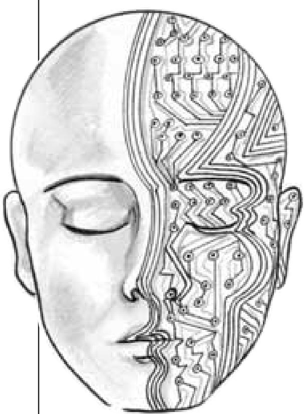

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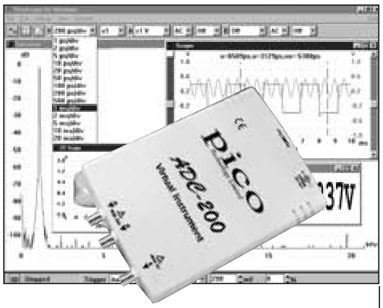


12V Sealed Lead/Acid Charger – Cyclic Battery Use

CONSTRUCTORS have often been advised that it is unwise to charge a sealed 12V lead/acid battery directly from a simple "car type" charger which usually consists of a transformer, bridge rectifier and a meter that gives some indication of the charging current. There are good reasons for this, including the fact that a simple car battery charger is not suitably current limited and can quickly sizzle a badly discharged sealed lead/acid battery.

It is recommended that the charging current for a sealed lead/acid battery is limited to 25 per cent of the battery's Ah (Ampere-Hour) rating. For example, an 8Ah battery can supply one amp over an eight hour period, four amps over two hours and eight amps over one hour and so on.

It is unlikely that the output voltage from a standard charger is suitable for charging a 12V sealed lead/acid battery. A constant and stable voltage of between 2·4V and 2·5V per cell is required for cyclic charging which equates to 14·4V to 15·0V for a 12V battery. However, the circuit diagram of Fig.1 shows a method of charging sealed lead/acid batteries using a basic car battery charger with the aid of an L200 voltage/current regulator chip.

The off-load output voltage from a typical basic car battery charger is 13·0V as measured, which is taken to a 2,200µF 50V electrolytic capacitor C1. This smoothes the charger output and increases its available d.c. voltage to just over 20V, providing enough "headroom" to overcome the voltage drop across the L200 regulator and diode D1.

On The Limit

The value of the current limiting resistor (R1 to R6) is determined by measuring the open circuit voltage across pins 2 and 5 of the L200 (with power applied to its input). This is the reference voltage and should be in the region of 450mV which is divided by the required output current (2·0A maximum). For example, V_{ref}/required current = 0·45/0·2 (200mA) = 2·25 ohms.

The output of the charger has an adjustable current limit, consisting of six low value resistors wired to a 1-pole 6-way wafer switch. This enables the current to be reduced, enabling a good range of sealed lead/acid batteries to be charged. The resistor/switch combination is connected between pin 2 and pin 5 using short leads.

The diode D1 prevents any current flowing from the battery being charged, through the potential divider (R7 and VR1) should the charging source be removed with the battery connected. With the selected current limit resistor in circuit and power applied to the input of the regulator IC1, adjust VR1 for a voltage of between 14·4V to 15·0V as measured between the cathode (k) of diode D1 and 0V line.

When the above adjustments are complete the battery may be connected and the charger switched on and left as the battery will automatically draw less current as it reaches its charged state. A full charge should take about 10 to 14 hours.

This can be monitored by the ammeter of the battery charger, but a more accurate method is to monitor the voltage across the current limiting resistor using an external voltmeter. The actual charging current can then be determined by the application of Ohm's Law, i.e. the voltage across the switched resistor network / the value of resistance in ohms.

(Readers wanting to know more about the L200 should check Andy Flind's feature article "Using The L200CV" *in* EPE *July 1998 – ARW).*

David Allen,
Cheltenham, Glocs.

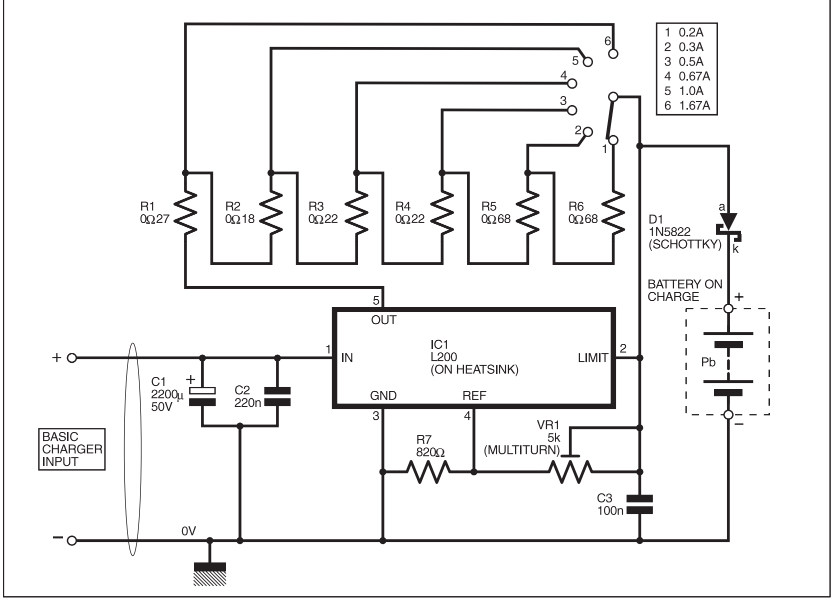


FIg.1. Circuit diagram for the 12V Sealed Lead/Acid Charger. (The low-ohm resistors (R1 to R6) can be from the W21 series.)

Audio Preamplifier – Some Gain

A simple preamplifier was needed to drive a rather insensitive audio amplifier which required about 500mV peak-to-peak input to obtain a reasonable output. Unfortunately, the source (a rather old guitar pickup) did not deliver much in the way of drive, being only a few millivolts. Using a design that was found to be reliable in the past (a d.c. coupled configuration with an emitter follower output – see Fig. 2a), did not produce nearly enough drive, the voltage gain being in the order of about 100 times.

The first stage of the preamp produces all the voltage gain and is proportional to transistor TR1's load resistor, in this case 6k8 (R4). Increasing the value of this resistor to increase the amplifier gain is, of course, possible, but it was estimated that it would need to be increased by approximately 4 or 5 times.

New Addition

This would restrict the current in TR1 to a few tenths of a milliamp, severely curtailing its gain and defeating the object. This called for a different approach and the result is shown in Fig.2b.

The original 6k8 load resistor was replaced with a transistor (TR3), the object here being twofold: firstly TR3 can be biased to restore the original d.c. conditions, i.e. TR1 will now pass the current originally intended (about 0·7mA).

Second, and most importantly, the load seen by TR1 will now be the a.c. resistance of TR3, which is considerably higher than its d.c. resistance. Therefore, TR1 now sees the output impedance of TR3, and TR1's amplification factor is boosted.

To set up the d.c. conditions, adjust the 20 kilohm (*more likely to be 22k)* variable potentiometer VR1 so that about 4·5V appears on the collector (c) of transistor TR1. If you require a gain control, then a small potentiometer of about 100 kilohms can be connected at the input side of capacitor C1.

The circuit worked well and produced a voltage gain in excess of 600 times, along with good temperature stability – more than adequate for the purpose in hand.

A. Lippett,
Stafford.

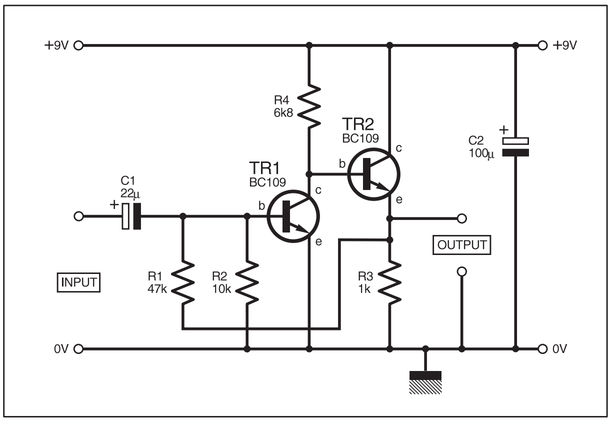


Fig.2a. Original basic preamplifier circuit.

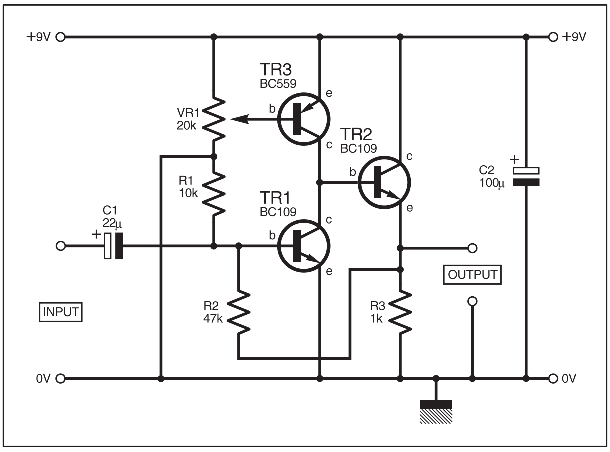


Fig.2b. Circuit diagram for the simple Audio Preamplifier.

Model Police Car L.E.D.s – In A Flash

My youngest child (aged 8) loves police cars, but his attempts to add blue l.e.d.s to model police cars were simply not realistic enough for the discerning junior enthusiast. So the circuit of Fig.3 was devised to simulate the alternate flashing strobes seen on British police cars. This was well received, and now many of these circuits have been built and look very convincing indeed in the dark!

The circuit around IC1a forms a square wave oscillator, the frequency being adjustable by VR1 to give the best effect. This square wave is buffered by 1C1b and in turn drives the decade counter IC2. Outputs from the counter Q0/Q2, and Q7/Q9 are in turn diode ORed to give alternating double pulses.

Capacitors C2 and C3 with resistors R3 and R5 differentiate the pulse time in conjunction with the output drivers 1C1c to ICIf. This produces a short pulse (30ms) which enhances the flashing effect and adds to the illusion. The output drivers in turn drive a pair of hyperbright blue l.e.d.s D5 and D6.

It is worth spending a little extra on using really bright l.e.d.s if the best effect is to be obtained. A 6V camera battery or four AAA cells gives a long life in a small package. In use adjust VR1 to give the best effect.

Kate Turner,
St. Leonards on Sea, East Sussex.

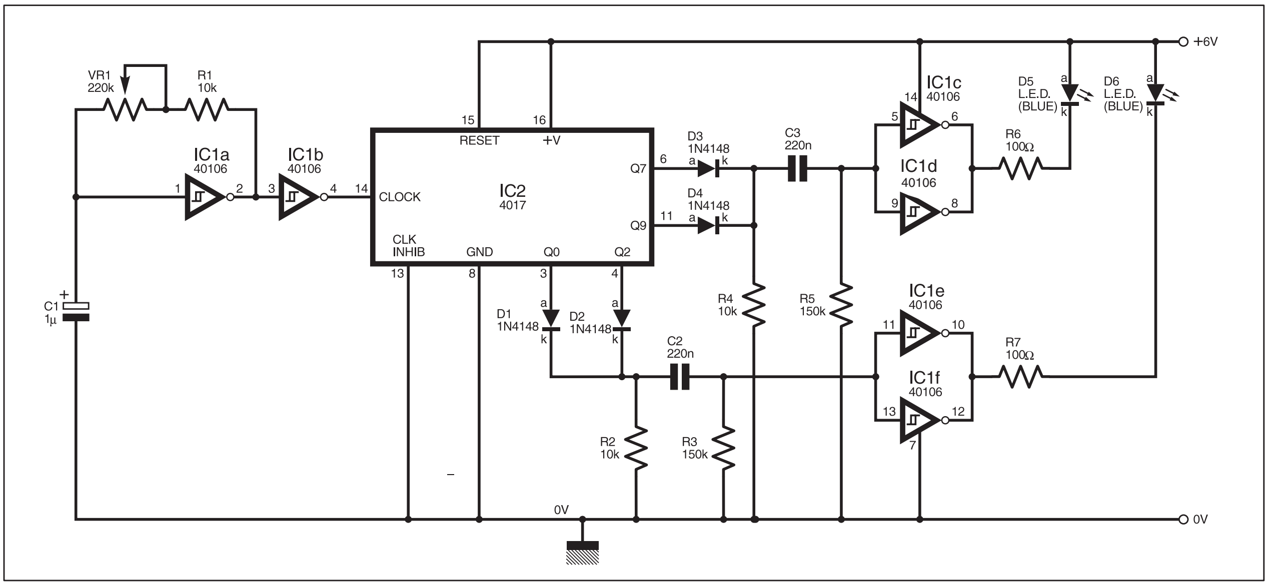
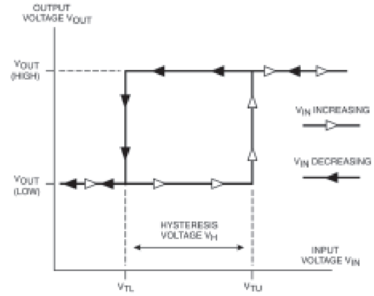


Fig.3. Circuit diagram for a Model Police Car L.E.D.s (Fuzzlite) simulator.

Special Series

THE SCHMITT TRIGGER



ANTHONY H. SMITH

Part 6

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

Further Digital Applications

IN Part Five of this series we saw how "digital" Schmitt trigger devices from the 4000 series and 74HC/HCT logic families could be used both as interface components, and also as the active elements in various other functions. This month, we'll examine another important interface circuit, the contact debouncer, and we'll see how the Schmitt's unique behaviour can be put to use in a variety of oscillator and modulator circuits. We'll also see how the Schmitt can be used in more complex functions such as a frequency meter and a clock pulser.

ASTABLE MULTIVIBRATOR

We will start by examining the Schmitt's role in what is, perhaps, its simplest application – the astable multivibrator, or square wave oscillator. The basic circuit and its associated waveforms are shown in Fig.6.1, where IC1a could be a Schmitt inverter from the 40106B or 74HC/HCT14, or could be a 2-input Schmitt NAND from the 4093B or 74HC/HCT132 (if a NAND is used, one of the two inputs should be tied high, the other connected to capacitor C1 and resistor R1 as shown).

During period T_H when the output, V_{OUT}, is high, V_C (the voltage across C1) rises exponentially as C1 charges via R1. Eventually, when V_C reaches the Schmitt's positive-going threshold voltage, V_{T+}, the output rapidly changes state and goes low.

Capacitor C1 now begins to discharge via R1, and during period T_L the capacitor voltage V_C decreases exponentially until it reaches the negative-going threshold voltage, V_{T-}. At this point, V_{OUT} goes high again, and the process repeats, producing a rectangular output signal with period $T = T_H + T_L$.

HITTING THE RAILS

The output voltage of CMOS logic devices from the 4000 series and 74HC/HCT family will swing from the negative to the positive supply rail, *provided* the output is not excessively loaded. The actual output characteristics vary from one type of device to another, but as a rule of thumb we can assume the output will swing rail-to-rail if the output current is kept below ±100µA. Consequently, for a lightly loaded output, the time periods T_H and T_L are given by:

$$T_H = \tau \ln \left\{ \frac{V_{CC} - V_{T-}}{V_{CC} - V_{T+}} \right\} \text{ (seconds)}$$

and:

$$T_L = \tau \ln \left\{ \frac{V_{T+}}{V_{T-}} \right\}$$

where τ is the circuit time constant, $\tau = C1 \times R1$, and ln denotes the natural logarithm. V_{CC} is the positive supply voltage (usually denoted V_{DD} for the 4093B and 40106B).

The frequency of oscillation, F_{OUT}, is given by:

$$F_{OUT} = 1/T = 1/(T_H + T_L) = \frac{1}{\tau \ln \dfrac{V_{T+}(V_{CC} - V_{T-})}{V_{T-}(V_{CC} - V_{T+})}} \text{ (Hz)}$$

The expressions for F_{OUT}, T_H and T_L will provide accurate results provided T_H and T_L are much larger than the *propagation delays* of the device used for IC1a. Therefore, for the 74HC14 and 74HC132, the equations will be accurate up to an operating frequency of about 5MHz; for the 4093B and 40106B, the expressions hold true to about 500kHz.

The astable in Fig.6.1 was built using a 74HC14 inverter for IC1a, and values of 1nF and 100kΩ were selected for C1 and R1, giving a time constant τ = 100µs. With the supply voltage, V_{CC}, set to 5V, the switching thresholds were measured as V_{T-} = 1·68V and V_{T+} = 2·70V. Using these values in the timing equations above, we find that T_H = 36·7µs, T_L = 47·4µs, and F_{OUT} = 11,883Hz. The actual, measured values were T_H = 38·9µs, T_L = 48·4µs and F_{OUT} = 11,455Hz.

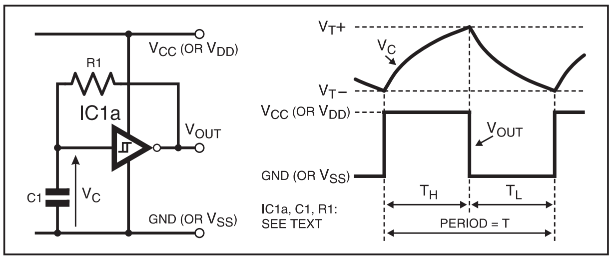


Fig.6.1. Astable multivibrator circuit diagram and waveforms.

A STABLE ASTABLE

Like the pulse stretchers described last month, the astable oscillator is highly tolerant of changes in supply voltage. For applications where V_{CC} (or V_{DD}) is not regulated, such as simple battery-powered circuits, F_{OUT} would, ideally, remain constant as the voltage changes. In this respect, the simple astable performs well.

For example, with the supply voltage *decreased* by 20 per cent from 5V to 4V, the test circuit's output frequency decreased by only 7·5% to 10,593Hz. With V_{CC} *increased* by 20 per cent from 5V to 6V, F_{OUT} was found to increase by just 5·3% to 12,063Hz.

The frequency stability was even better when the 74HC14 was replaced by a 40106B. With the same timing components and a 5V supply, the output frequency was 12,953Hz. With the supply increased by 200 per cent to 15V, the increase in F_{OUT} was only 6·8 per cent! Although the Schmitt-based astable can never compete with a crystal-based oscillator in terms of frequency stability, the performance is remarkably good considering its inexpensive simplicity.

CHOICE OF COMPONENTS

When selecting suitable values for the timing components of Fig.6.1, capacitor C1 should not be too small, otherwise the presence of stray capacitance, together with IC1a's input capacitance, will have a noticeable effect on the values of T_H and T_L. Generally, these additional (and somewhat unpredictable) capacitances will have negligible effect if C1 is greater than 100pF. There is no upper limit on the value of C1: values of several hundred microfarads can be used where a large time constant is required.

Remember that resistor R1 acts as a load on the output (together with any other load), so small values of timing resistor should be avoided or the output will not swing rail-to-rail. In most cases, R1 should be no less than ten kilohms (10kΩ), although lower values may be used if high frequency operation (i.e., small τ) is required. Where practicable, values of 100kΩ or more will give best results. The upper limit is around one megohm (1MΩ); larger values should be used with caution, since IC1a's input current may have unpredictable effects on the values of T_H and T_L.

Power consumption is also affected by the choice of C1 and R1. For example, with C1 at 100pF and R1 at 100kΩ, giving a time constant τ = 10µs, the test circuit described above oscillated at 117kHz, and the supply current was 576µA.

However, with C1 increased to 10nF and R1 reduced to 1kΩ, again giving a time constant τ = 10µs, the circuit oscillated at roughly the same frequency (107kHz), but the supply current had increased by almost 200 per cent to 1·68mA. Clearly, the larger value of C1 means that more energy is required to charge and discharge the capacitor, resulting in greater power consumption.

VARIATIONS ON A THEME

By adding an extra resistor and one or two diodes, the astable can be adapted to produce different waveforms as shown in Fig.6.2.

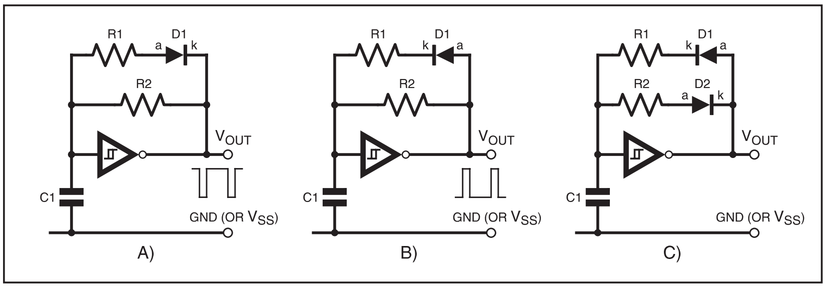


Fig.6.2. Circuit variations on the astable multivibrator.

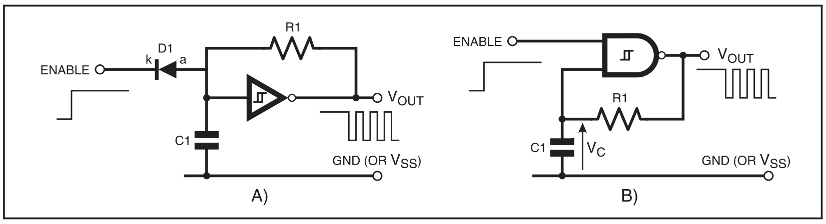


Fig.6.3. Two methods of "gating" an astable oscillator.

In Fig.6.2a, resistor R1 now appears in series with a diode D1, and a second timing resistor R2 is fitted in parallel with them. When the output is high, D1 is reverse biased, blocking any current flow through R1, and capacitor C1 charges via R2 only. However, when V_{OUT} goes low, diode D1 now becomes forward biased, allowing current to flow through resistor R1. Consequently, C1 discharges through the parallel combination of R1 and R2, and as a result, period T_L can be made much shorter than T_H.

Diode D1 has been reversed in Fig.6.2b, such that C1 charges via R1 in parallel with R2 when V_{OUT} is high, but discharges only via R2 when V_{OUT} goes low. Therefore, period T_H can be made much shorter than T_L.

The circuits of Fig.6.2a and Fig.6.2b allow for adjustment of the output duty cycle, and can be used to generate a train of narrow negative-going or positive-going pulses, respectively. However, they have the disadvantage that one of the output periods is affected by changes in the other.

By adding a second diode (D2) as shown in Fig.6.2c, T_H and T_L can be adjusted completely independently of each other. In this circuit, C1 charges only via R1 and discharges only via R2. Therefore, the width of T_H can be adjusted by varying the value of resistor R1 without affecting T_L, and T_L can be adjusted by varying R2 with no effect on T_H.

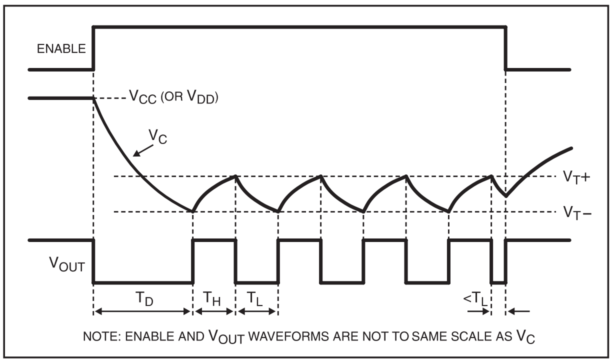


Fig.6.4. Typical waveforms for the NAND gated astable.

GATED OSCILLATORS

Two methods for "gating" an astable oscillator are illustrated in Fig.6.3. In both cases, the astable starts to oscillate when the ENABLE signal goes high, and oscillation stops when ENABLE goes low. Being able to gate the astable is a common circuit requirement, either for functional reasons, or as a means of saving power.

In Fig.6.3a, a low level at the ENABLE input forward biases diode D1, thereby clamping the voltage on capacitor C1 to a diode drop above GND (or V_{SS}). Since this is below the inverter's negative-going threshold voltage, V_{T-}, the output is forced high. However, when ENABLE goes high, D1 becomes reverse biased allowing C1 to charge via R1. The astable is now free to oscillate. If the "direction" of D1 is reversed, the astable will run when the gating signal is low, and will stop when it goes high.

The alternative circuit shown in Fig.6.3b does not require a diode, and instead makes use of the NAND function provided by a 74HC132 or 4093B. When ENABLE is low, the NAND output is forced high, and C1 charges via R1 until V_C equals the high level output voltage, namely V_{CC} (or V_{DD}) when the output is lightly loaded.

When ENABLE goes high, the NAND output is forced low and C1 starts to discharge via R1. The circuit now behaves like the simple, inverter-based astable described above, with capacitor C1 charging and discharging repeatedly. Exactly the same expressions are used to determine T_L, T_H and F_{OUT}.

TRUNCATION

Typical waveforms for the NAND gated astable are shown in Fig.6.4. As soon as ENABLE goes high, V_{OUT} goes low and there follows a delay, T_D, while V_C decays exponentially toward V_{T-}. Proper oscillation then commences, with V_C rising and falling between the two switching thresholds, and the circuit continues to oscillate until ENABLE goes low.

However, if ENABLE goes low part way through a low period (T_L) as shown, V_{OUT} is immediately forced high, thereby shortening the low pulse. This *asynchronous* behaviour "truncates" the period of the last cycle.

For applications where this is unacceptable, the addition of a second NAND gate as shown in Fig.6.5 can be used to eliminate the truncation completely. The two, cross-coupled NAND gates function as an S-R (set-reset) latch, where the active low $\overline{\text{ENABLE}}$ signal provides the "set" input, and the timing capacitor voltage, V_C, constitutes the "reset" input. We can understand how the circuit works by referring to the waveforms in Fig.6.6.

While $\overline{\text{ENABLE}}$ is high, IC1a's output, V_{OUT}(a), is forced low, preventing the astable formed around IC1b from oscillating. When $\overline{\text{ENABLE}}$ goes low, V_{OUT}(a) goes high, allowing the astable to run. IC1b's output, V_{OUT}(b), now oscillates at a frequency F_{OUT} as determined by the equation given earlier. So far, the circuit behaves in exactly the same manner as the single NAND astable described earlier.

However, should $\overline{\text{ENABLE}}$ go high during one of V_{OUT}(b)'s low periods as shown, the last cycle is not truncated. It is only when

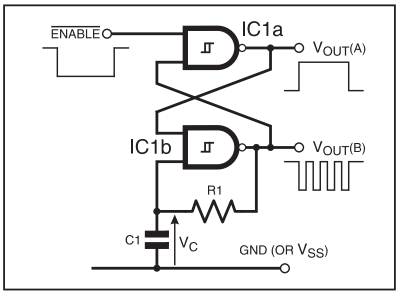


Fig.6.5. Adding a second NAND gate eliminates pulse truncation.

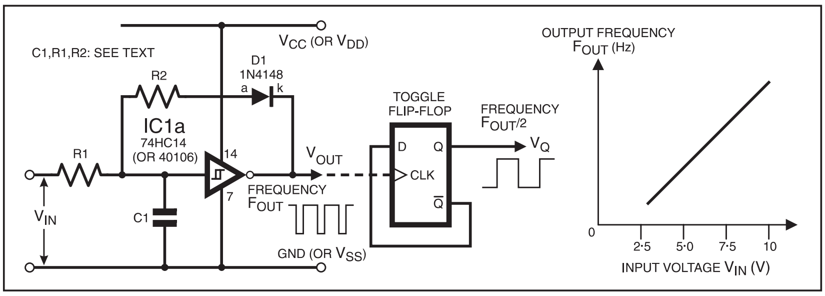


Fig.6.7. Adapting the astable to form a voltage controlled oscillator (v.c.o.).

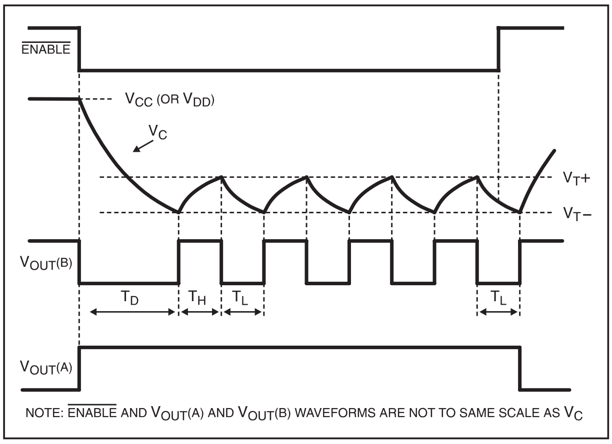


Fig.6.6. Typical waveform for the dual NAND gated astable circuit of Fig.6.5.

V_{OUT}(b) goes high at the end of the low period (T_L) that V_{OUT}(a) goes low (since IC1a's inputs are now both high), thereby disabling the astable. Although the circuit still exhibits a delay, T_D, when first enabled, the last cycle is never truncated and the astable always outputs a series of *whole* cycles.

If the gating signal is a ''proper'' digital signal, IC1a does not need to be a Schmitt NAND. However, it is often convenient to use two NANDs from the same Schmitt package, such as a 74HC132 or 4093B.

VOLTAGE CONTROLLED OSCILLATOR

By adding an extra resistor and a diode, the simple astable of Fig.6.1 can be converted to a *voltage controlled oscillator*, or v.c.o., as shown in Fig.6.7, where the input voltage, V_{IN}, is a d.c. voltage that can take any value from V_{T-} to more than 20V.

To understand how the circuit works, assume that V_{OUT} is high such that diode D1 is reverse biased. Timing capacitor C1 charges via resistor R1, and the capacitor voltage rises exponentially toward the value of V_{IN}.

However, when the voltage on C1 reaches IC1a's positive-going threshold voltage, V_{T+}, V_{OUT} goes low, forward biasing D1, and C1 starts to discharge via R2 and D1. The capacitor voltage now decreases exponentially; when it reaches IC1a's negative-going threshold voltage, V_{T-}, V_{OUT} goes high, reverse biasing D1, and C1 is now free to charge up again via R1.

Provided resisitor R2 is smaller than R1, the resulting output signal is a series of negative-going pulses of constant width, defined only by IC1a's thresholds, C1, R2 and V_D, the voltage drop across diode D1. However, the width of the positive-going portion of V_{OUT} depends on IC1a's thresholds, C1, R1 and V_{IN}. Since input voltage V_{IN} is variable, the period of the output signal, and hence the output frequency, will change with V_{IN}. As V_{IN} is increased, C1 charges more quickly causing the output period to decrease, and the frequency increases as shown by the graph.

Note that V_{IN} can exceed the positive supply voltage, V_{CC} (or V_{DD}). The maximum value is determined by the ratio of resistor R1 to R2. When V_{OUT} goes low, R1 and R2 form a potential divider which ''pulls down'' the voltage on C1. If V_{IN} is too high, the divider will be unable to pull the capacitor voltage below V_{T-}, in which case V_{OUT} will remain continually low.

When V_{OUT} is high and D1 is reverse biased, C1 charges only via R1. Therefore, in order for the capacitor voltage to cross IC1a's positive-going threshold, V_{IN} must be $\geq V_{T+}$. This establishes the lower limit for the input voltage.

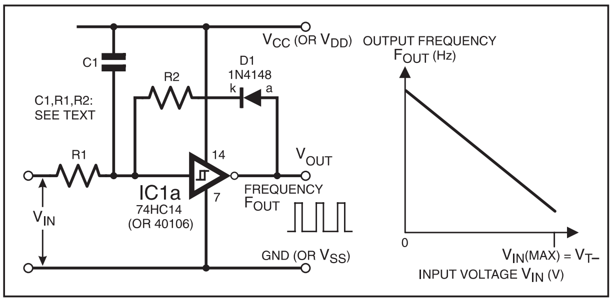


Fig.6.8. Circuit for a voltage controlled oscillator with an inverse voltage/frequency characteristic.

LINEAR RELATIONSHIP

The performance of the circuit shown in Fig.6.7 was tested using an inverter from the 74HC14 for IC1a (although any other Schmitt device could be used). Values of R1 = 100kΩ, R2 = 3·3kΩ, and C1 = 1nF were chosen for the timing components.

With a supply voltage of 5V, the positive-going threshold voltage, V_{T+}, was measured as 2·75V. Therefore, it was decided to set the input voltage's (V_{IN}) lower limit to 3·0V. The upper limit of V_{IN}, at which V_{OUT} went continually low, was found to be 35·6V, although the circuit's response had become highly non-linear below this value.

The relationship between output frequency, F_{OUT}, and V_{IN} was found to be very linear for an input voltage of 3·0V to 5·0V, and reasonably linear over the range of 5·0V to 10·0V. Beyond this, the relationship deteriorated, with the graph starting to curve significantly for values of V_{IN} above 15V. The useful operating range was V_{IN} = 3·0V to 10·0V, corresponding to an output frequency range of 6·0kHz to 62·4kHz.

By feeding the v.c.o. output to a toggle-connected flip-flop as shown in Fig.6.7, a squarewave output can be obtained at V_Q having a constant 50 per cent duty cycle at all frequencies. However, note that the frequency at V_Q will be half that at V_{OUT}.

INVERSE RELATIONSHIP

By connecting capacitor C1 to the positive supply (V_{CC}) and reversing the ''direction'' of diode D1 as shown in Fig.6.8, we obtain a v.c.o. which has an inverse relationship between V_{IN} and F_{OUT}, that is, F_{OUT} decreases as V_{IN} is increased. To understand the circuit's behaviour, assume that input voltage V_{IN} = 0, and V_{OUT} is low such that D1 is reverse biased.

Capacitor C1 charges up via resistor R1, causing the voltage across C1 to increase exponentially. Consequently, the voltage at IC1a's input *decreases* exponentially. Eventually, when this voltage reaches IC1a's negative-going threshold voltage, V_{T-}, V_{OUT} goes high, forward biasing D1.

Capacitor C1 now starts to discharge via R2 and D1, causing the voltage at IC1a's input to rise exponentially. The rate at which C1 discharges is determined by the supply voltage V_{CC}, by IC1a's thresholds, by the values of C1, R1, R2, and by V_{IN} and V_D, the voltage drop across D1. However, if R1 is much larger than R2, input voltage V_{IN} will have little effect on the rate of C1's discharge which will be controlled mainly by resistor R2.

When IC1a's input voltage reaches the positive-going threshold voltage, V_{T+}, V_{OUT} goes low. Therefore, the output signal consists of

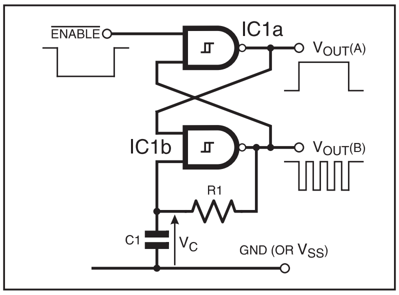


Fig.6.5. Adding a second NAND gate eliminates pulse truncation.

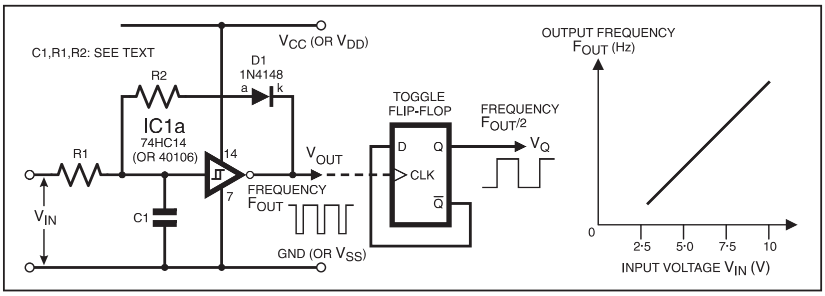


Fig.6.7. Adapting the astable to form a voltage controlled oscillator (v.c.o.).

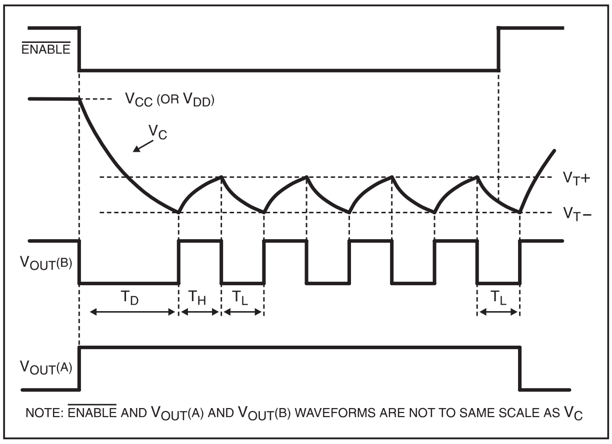


Fig.6.6. Typical waveform for the dual NAND gated astable circuit of Fig.6.5.

V_{OUT}(b) goes high at the end of the low period (T_L) that V_{OUT}(a) goes low (since IC1a's inputs are now both high), thereby disabling the astable. Although the circuit still exhibits a delay, T_D, when first enabled, the last cycle is never truncated and the astable always outputs a series of *whole* cycles.

If the gating signal is a "proper" digital signal, IC1a does not need to be a Schmitt NAND. However, it is often convenient to use two NANDs from the same Schmitt package, such as a 74HC132 or 4093B.

VOLTAGE CONTROLLED OSCILLATOR

By adding an extra resistor and a diode, the simple astable of Fig.6.1 can be converted to a *voltage controlled oscillator*, or v.c.o., as shown in Fig.6.7, where the input voltage, V_{IN}, is a d.c. voltage that can take any value from V_{T-} to more than 20V.

To understand how the circuit works, assume that V_{OUT} is high such that diode D1 is reverse biased. Timing capacitor C1 charges via resistor R1, and the capacitor voltage rises exponentially toward the value of V_{IN}.

However, when the voltage on C1 reaches IC1a's positive-going threshold voltage, V_{T+}, V_{OUT} goes low, forward biasing D1, and C1 starts to discharge via R2 and D1. The capacitor voltage now decreases exponentially; when it reaches IC1a's negative-going threshold voltage, V_{T-}, V_{OUT} goes high, reverse biasing D1, and C1 is now free to charge up again via R1.

Provided resisitor R2 is smaller than R1, the resulting output signal is a series of negative-going pulses of constant width, defined only by IC1a's thresholds, C1, R2 and V_D, the voltage drop across diode D1. However, the width of the positive-going portion of V_{OUT} depends on IC1a's thresholds, C1, R1 and V_{IN}. Since input voltage V_{IN} is variable, the period of the output signal, and hence the output frequency, will change with V_{IN}. As V_{IN} is increased, C1 charges more quickly causing the output period to decrease, and the frequency increases as shown by the graph.

Note that V_{IN} can exceed the positive supply voltage, V_{CC} (or V_{DD}). The maximum value is determined by the ratio of resistor R1 to R2. When V_{OUT} goes low, R1 and R2 form a potential divider which "pulls down" the voltage on C1. If V_{IN} is too high, the divider will be unable to pull the capacitor voltage below V_{T-}, in which case V_{OUT} will remain continually low.

When V_{OUT} is high and D1 is reverse biased, C1 charges only via R1. Therefore, in order for the capacitor voltage to cross IC1a's positive-going threshold, V_{IN} must be $\geq V_{T+}$. This establishes the lower limit for the input voltage.

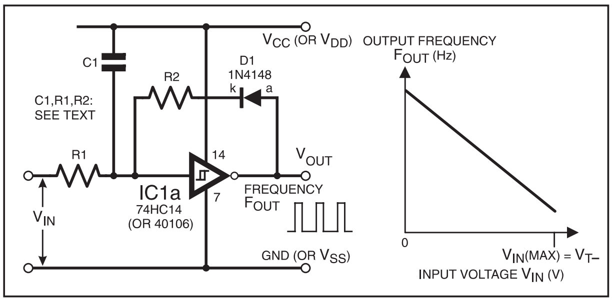


Fig.6.8. Circuit for a voltage controlled oscillator with an inverse voltage/frequency characteristic.

LINEAR RELATIONSHIP

The performance of the circuit shown in Fig.6.7 was tested using an inverter from the 74HC14 for IC1a (although any other Schmitt device could be used). Values of R1 = 100kΩ, R2 = 3·3kΩ, and C1 = 1nF were chosen for the timing components.

With a supply voltage of 5V, the positive-going threshold voltage, V_{T+}, was measured as 2·75V. Therefore, it was decided to set the input voltage's (V_{IN}) lower limit to 3·0V. The upper limit of V_{IN}, at which V_{OUT} went continually low, was found to be 35·6V, although the circuit's response had become highly non-linear below this value.

The relationship between output frequency, F_{OUT}, and V_{IN} was found to be very linear for an input voltage of 3·0V to 5·0V, and reasonably linear over the range of 5·0V to 10·0V. Beyond this, the relationship deteriorated, with the graph starting to curve significantly for values of V_{IN} above 15V. The useful operating range was V_{IN} = 3·0V to 10·0V, corresponding to an output frequency range of 6·0kHz to 62·4kHz.

By feeding the v.c.o. output to a toggle-connected flip-flop as shown in Fig.6.7, a squarewave output can be obtained at V_Q having a constant 50 per cent duty cycle at all frequencies. However, note that the frequency at V_Q will be half that at V_{OUT}.

INVERSE RELATIONSHIP

By connecting capacitor C1 to the positive supply (V_{CC}) and reversing the "direction" of diode D1 as shown in Fig.6.8, we obtain a v.c.o. which has an inverse relationship between V_{IN} and F_{OUT}, that is, F_{OUT} decreases as V_{IN} is increased. To understand the circuit's behaviour, assume that input voltage V_{IN} = 0, and V_{OUT} is low such that D1 is reverse biased.

Capacitor C1 charges up via resistor R1, causing the voltage across C1 to increase exponentially. Consequently, the voltage at IC1a's input *decreases* exponentially. Eventually, when this voltage reaches IC1a's negative-going threshold voltage, V_{T-}, V_{OUT} goes high, forward biasing D1.

Capacitor C1 now starts to discharge via R2 and D1, causing the voltage at IC1a's input to rise exponentially. The rate at which C1 discharges is determined by the supply voltage V_{CC}, by IC1a's thresholds, by the values of C1, R1, R2, and by V_{IN} and V_D, the voltage drop across D1. However, if R1 is much larger than R2, input voltage V_{IN} will have little effect on the rate of C1's discharge which will be controlled mainly by resistor R2.

When IC1a's input voltage reaches the positive-going threshold voltage, V_{T+}, V_{OUT} goes low. Therefore, the output signal consists of a train of positive-going pulses of almost constant width. Since V_{OUT} is now low, capacitor C1 is free to charge up again via R1 at a rate determined by V_{IN}.

If V_{IN} is at a low level, the voltage drop across R1 – and hence the current through it – will be relatively large, causing C1 to charge rapidly. In turn, this causes the negative-going portion of the output signal to be relatively short, resulting in a high frequency.

On the other hand, if V_{IN} is at a high level, C1's charging current will be relatively small, and it will take longer for IC1a's input voltage to fall to V_{T-}. Therefore, the negative-going portion of the output signal to be relatively long, resulting in a low frequency. Therefore, the output frequency decreases as V_{IN} is increased.

INPUT VOLTAGE CONSTRAINTS

The upper limit of V_{IN} is determined by IC1a's negative-going threshold voltage, V_{T-} : if V_{IN} exceeds V_{T-}, it will be impossible for the inverter's input voltage to go below this threshold, and the output will go continually low.

For a single-rail supply circuit, V_{IN}'s lower limit is simply zero (i.e., GND or V_{SS}). However, if a negative supply is available, V_{IN} may be taken negative (that is, V_{IN} may go below GND or V_{SS}). The maximum negative limit is determined by V_{CC} (or V_{DD}), V_D, V_{T+} and by the ratio of resistor R1 to R2, since when V_{OUT} is high it must be possible for the R1/R2 potential divider to pull the inverter's input voltage above V_{T+}.

Provided these constraints are met, the circuit of Fig.6.8 will produce a fairly linear, inverse relationship between V_{IN} and F_{OUT}. A test circuit was built using an inverter from the 40106B; V_{DD} was set to 15·00V, resulting in thresholds of V_{T-} = 5·75V and V_{T+} = 8·45V. Therefore, the maximum value of V_{IN} is 5·75V.

With values of R1 = 100kΩ, R2 = 3·3kΩ, and C1 = 1nF chosen for the timing components, the circuit performed well with input voltages (V_{IN}) of 0V to 5·5V, producing a corresponding output frequency (F_{OUT}) range of 2·5kHz to 410Hz.

FREQUENCY – BY THE DOUBLE!

When clocked by a periodic input signal, the toggle-connected flip-flop mentioned above provides a simple means of halving the clock frequency and producing an output signal with a constant 50 per cent duty cycle.

However, in cases where it is necessary to *double* a signal's frequency, some other technique must be used. A solution which makes use of the "digital differentiator" techniques introduced last month is shown in Fig.6.9.

The logic level input signal, V_{IN}, is applied to inverter IC1a, and also to the C1/R1 differentiator network. IC1a's output is fed to a similar differentiator, C2/R2. The differentiated signals V_{R1} and V_{R2} appearing across resistors R1 and R2 are rectified by diodes D1 and D2 and the resulting unipolar signals are combined at the input to IC1b.

The circuit's operation is illustrated by the accompanying waveforms. The rising edge of V_{IN} is differentiated by C1/R1, producing a positive-going, exponential "spike" across R1, having a peak value equal to V_{CC}. The inverted version of V_{IN} at IC1a's output (not shown) is differentiated by C2/R2, producing a negative-going, exponential spike across R2, having a peak value equal to $-V_{CC}$.

On the falling edge of V_{IN}, the polarities of the spikes are reversed: V_{R1} swings down to $-V_{CC}$, and V_{R2} swings up to V_{CC}. Diodes D1 and D2 ensure that only the positive-going portions of V_{R1} and V_{R2} are coupled through to resistor R3, such that V_{R3} consists of a train of positive-going spikes, each of amplitude $V_{CC} - V_D$, occurring on both the rising *and* falling edges of V_{IN}. These spikes are "squared up" by Schmitt inverter IC1b, whose output consists of a train of negative-going pulses at *twice* the frequency of V_{IN}, that is, $F_{OUT} = 2 \times F_{IN}$.

OUTPUT PULSE WIDTH

The width of the negative-going output pulse, T_O, will depend on the time constants τ_1 (= C1 × R1) and τ_2 (= C2 × R2), and also, to some extent, on the values of T_H and T_L, the width of V_{IN}'s high and low periods, respectively.

The design procedure is to identify the *maximum* input frequency, and hence determine the *minimum* values of T_H and T_L. Then, select C1 and R1 such that τ_1 is roughly equal to $T_H/5$, and select C2 and R2 to make τ_2 roughly equal to $T_L/5$. For the case where V_{IN} is a square wave with a 50 per cent duty cycle (i.e., $T_H = T_L$), simply make $\tau_1 = \tau_2 = T_P/10$, where T_P is the minimum period of the input square wave. Resistor R3 should be approximately ten times the value chosen for R1 or R2.

If the time constants are chosen correctly, the circuit will output a series of constant-width output pulses at a frequency $F_{OUT} = 2 \times F_{IN}$ for all values of F_{IN} up to the maximum value established above.

A test circuit was built from Fig.6.9 using two inverters from the 40106B for IC1a and IC1b (note that IC1a may be a non-Schmitt inverter if V_{IN} is a well-shaped digital signal). The supply voltage, V_{DD}, was set to 5·0V. A 50 per cent duty cycle square wave having a maximum frequency of 250Hz was used as the input signal, such that the minimum value of T_P was 4ms. With 3·3nF capacitors selected for C1 and C2, and 100kΩ resistors chosen for R1 and R2, the time constants were each 330µs (roughly a tenth of T_P). A value of 1MΩ was selected for R3.

TEST CIRCUIT PERFORMANCE

The performance of the test circuit was as follows: at all frequencies up to 250Hz, the output pulse width, T_O, was found to be constant at 210µs, and the pulses occurred at twice the frequency of the input signal as desired. At frequencies higher than 250Hz, the output pulse width started to decrease, although the circuit continued to double the input frequency properly for F_{IN} as high as 1·8kHz.

One thing to bear in mind about this circuit is that T_O becomes a very small fraction of the output signal period at low values of F_{IN}. That is, the duty cycle of the output signal becomes very large as the input frequency is reduced.

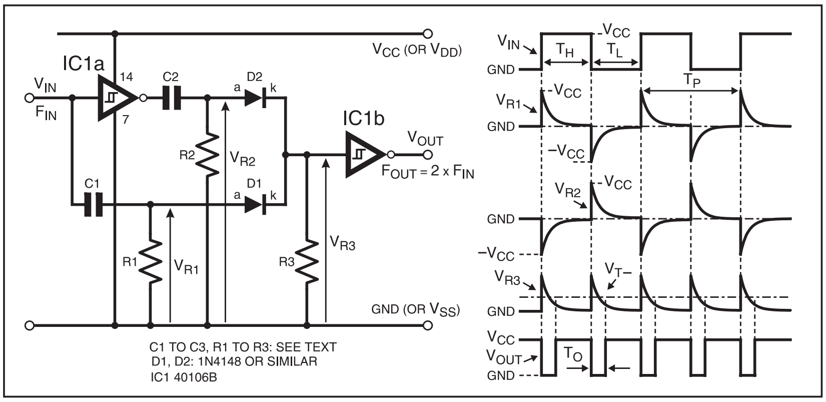


Fig.6.9. Circuit diagram and typical waveforms for a frequency doubler.

PULSE WIDTH MODULATION

We saw in Part Four of this series how an operational amplifier Schmitt trigger can be adapted to form a *pulse width modulator*, that is, a circuit in which the pulse width – and hence the duty cycle – of a rectangular waveform is controlled by a *modulating* voltage. With the addition of a few extra components, the "digital" Schmitt trigger can also form the basis of a PWM (Pulse Width Modulation) circuit.

One example is shown in Fig.6.10, where two, *complementary* transistors, TR1 and TR2, are used to charge and discharge a timing capacitor, C1. To understand how the circuit works, assume that the voltage, V_C, on C1 has been falling and has just reached the negative-going threshold, V_{T-}, of the Schmitt inverter, IC1a, such that V_{OUT} goes high, taking *pnp* transistor TR1's emitter to V_{CC} (or V_{DD}). We are now at the beginning of period T_H.

The base-emitter junction of *npn* transistor TR2 is now reverse biased, so it has no effect on C1's voltage. The base-emitter junction of *pnp* transistor TR1, however, is forward biased, allowing its collector current, I_{C1}, to flow through diode D1 into capacitor C1. The timing capacitor now starts to charge up, and V_C rises linearly at a rate determined by I_{C1} and the value of C1.

Transistor TR1's collector current is determined by the product of its base current, I_{B1}, and its current gain, h_{FE1}, that is, $I_{C1} = I_{B1} \times h_{FE1}$. In turn, base current I_{B1} is determined by resistor R1 and the voltage drop across it. As the input voltage, V_{IN}, increases, the voltage across R1, and hence I_{B1}, decreases. This, in turn, decreases TR1's collector current, I_{C1}, reducing the rate at which C1 charges.

Eventually, when timing capacitor C1 has charged sufficiently for V_C to reach the inverter's positive-going threshold voltage, V_{T+}, the output immediately goes low, and time period T_H ends. Clearly, T_H is *inversely* proportional to I_{C1} (decreasing I_{C1} will reduce the rate at which C1 charges up, causing V_C to rise more slowly, hence making T_H longer). Therefore, increasing V_{IN} (which decreases I_{B1} and I_{C1}) will result in a corresponding increase in T_H.

COMPLEMENTARY BEHAVIOUR

With the output V_{OUT} now low, such that TR2's emitter is at the same potential as GND (or V_{SS}), we are now at the start of the low period, T_L. The base-emitter junction of *pnp* transistor TR1 is now reverse biased, so it has no effect on capacitor C1's voltage. However, the base-emitter junction of *npn* transistor TR2 is forward biased, allowing its collector current, I_{C2}, to flow through diode D2, thereby discharging C1. The capacitor voltage, V_C, now starts to decrease linearly at a rate determined by I_{C2} and the value of C1.

Transistor TR2's collector current is given by $I_{C2} = I_{B2} \times h_{FE2}$, where I_{B2} is the base current and h_{FE2} is the current gain. Now, as the input voltage, V_{IN}, increases, the voltage across R1, and hence I_{B2}, also increases. This, in turn, increases both I_{C2} and the rate at which C1 discharges.

Eventually, when C1 has discharged sufficiently for V_C to fall to the inverter's negative-going threshold voltage, V_{T-}, the output (V_{OUT}) immediately goes high again, and time period T_L ends. We see that T_L is *inversely* proportional to I_{C2} (decreasing I_{C2} will reduce the rate at which C1 discharges, causing V_C to fall more slowly, hence making T_L longer). Therefore, decreasing V_{IN} (which decreases I_{B2} and I_{C2}) will result in a corresponding increase in T_L.

We can summarise this process by noting that the complementary action of TR1 and TR2 means that an increase in V_{IN} causes an increase in T_H and a decrease in T_L; in other words, increasing V_{IN} also increases the output duty cycle. Conversely, decreasing V_{IN} causes a decrease in T_H and an increase in T_L, thereby reducing the output duty cycle.

Diodes D1 and D2 are required to prevent the base-collector junctions of transistor TR1 and TR2 becoming forward biased by V_{IN} and R1 when they turn "off". Also, to prevent "avalanching" of the reverse-biased base-emitter junction of either transistor when "off", it is necessary to limit the supply voltage, V_{CC}, to a maximum of around 5V.

DESIGN PROCEDURE

In order for the circuit of Fig.6.10 to work properly, it is necessary to ensure that the transistors are not turned "hard on" (i.e., saturated), otherwise capacitor C1's charge and discharge currents will be determined by the inverter's output sink and source currents, rather than by the transistors' base currents.

Now, a device like the 74HC14 can sink and source up to 4mA, so it is best to limit I_{C1} and I_{C2} to a value much less than this, say around ±500µA maximum. Therefore, for each transistor, we must ensure that I_B(max) is less than ±500µA/h_{FE}(max). For the BC546 and BC556 transistors shown in Fig.6.10, h_{FE}(max) is around 500, so we must ensure that I_B(max) is less than ±1µA.

When transistor TR1 is "on", $I_{B1} = (V_{IN} - V_{B1})/R1$, where V_{B1} is the base potential of TR1. If we take TR1's forward-biased base-emitter drop, V_{BE1}, as 0·6V, then when TR1's emitter is at 5V (when V_{OUT} is high), we find that V_{B1} = 4·4V. Now, if V_{IN} can take any value from 0V to 5V, then I_{B1}(max) = (0 – 4·4)/R1. Therefore, in order to make I_{B1}(max) < –1µA, we require R1 > 4·4MΩ.

If we perform the same analysis for I_{B2}, we find that I_{B2}(max) = (5 – 0·6)/R1 (assuming TR2's forward-biased base-emitter drop, V_{BE2} = 0·6V). Therefore, in order to make I_{B2}(max) < 1µA, we again require R1 > 4·4MΩ. A suitable, preferred value for R1 is 4·7MΩ.

OUTPUT JITTER

A "test set-up" of the circuit diagram of Fig.6.10 was built using a value of 4·7MΩ for resistor R1 and 100nF for timing capacitor C1. An inverter from the 74HC14 was used for IC1a, and the supply voltage, V_{CC}, was set to 5·0V.

The resulting relationship between V_{IN} and output duty cycle was found to be quite linear; the duty cycle was 14·6 per cent at V_{IN} = 1·0V, rising to 90·4 per cent at V_{IN} = 4·0V. The output frequency, however, varied non-linearly with V_{IN}, peaking at 313Hz when V_{IN} was approximately 2·5V (i.e., when $V_{IN} = V_{CC}/2$).

With capacitor C1 reduced to 10nF, the relationship between V_{IN} and duty cycle was largely unchanged, but the output frequency was much higher, peaking at 2·2kHz for V_{IN} = 2·5V. The operating frequency is higher because a smaller capacitor can charge and

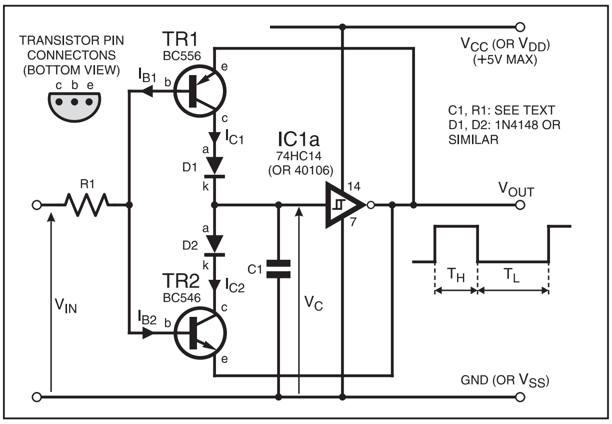


Fig.6.10. Circuit diagram for a pulse width modulator (PWM) employing complementary transistors.

discharge much more quickly than a large value for a given range of collector current.

Although the circuit performed reasonably well, the output signal was subject to considerable *jitter* at fairly low (< 1·5V) or fairly large (> 3·5V) values of V_{IN}. This is not surprising, considering that the base current of the appropriate transistor will be very small at this point, perhaps less than 100nA, and hence subject to the effects of circuit noise.

Although the duty cycle is modulated by V_{IN}, it is really the collector currents which control the charging and discharging of C1, and so the duty cycle will be affected by anything which "upsets" these currents. For example, changes in h_{FE} (e.g.: due to temperature drift) will affect I_C, as will changes in V_{BE} (which influence I_B, and hence will affect I_C).

AN IMPROVED PWM CIRCUIT

Another "improved" Schmitt-based PWM circuit, in which a complementary transistor pair again provides the charge and discharge currents for timing capacitor C1, is shown in Fig.6.11. However, unlike the previous circuit (Fig.6.10), the collector currents are largely independent of changes in transistor current gain and base current values, and so the performance tends to be much more stable and predictable.

The potential divider formed by resistors R1 to R4 controls the transistors' base voltages, V_{B1} and V_{B2}. The input voltage, V_{IN}, is applied to the mid-point of the potential divider, such that varying V_{IN} also varies V_{B1} and V_{B2}. Transistors TR1 and TR2 function as switched current sources which charge and discharge timing capacitor C1 at a rate determined by their base voltages. Resistor R5 behaves as a common emitter resistor shared by both transistors.

Assume that V_{OUT} has just gone low at the start of period T_L. Transistor TR1's base-emitter junction is reverse biased, turning it "off". Transistor TR2's base-emitter junction, however, is forward biased, allowing collector current I_{C2} to flow through TR2, discharging C1, and causing capacitor voltage V_C to fall.

If TR2's current gain, h_{FE2}, is large, its collector current will be roughly equal to its emitter current, that is, $I_{C2} \approx I_{E2}$. Now, I_{E2} is set by TR2's emitter voltage and by the value of R5, and in turn, the emitter voltage is given by $V_{B2} - V_{BE2}$, where V_{BE2} is TR2's forward-biased base-emitter voltage. Therefore, $I_{E2} = (V_{B2} - V_{BE2})/R5$. Since V_{BE2} and R5 are fixed, I_{E2} will vary only in response to changes in V_{B2}, which in turn varies with changes in V_{IN}. For example, increasing V_{IN} causes V_{B2} to rise, resulting in a corresponding increase in I_{E2}.

Eventually, when I_{E2} has discharged C1 sufficiently for V_C to fall to the inverter's negative-going threshold voltage, V_{T-}, the output immediately goes high again, and time period T_L ends. We see that T_L is *inversely* proportional to I_{E2} (increasing I_{E2} will increase the rate at which C1 discharges, causing V_C to fall more quickly, hence making T_L shorter). Therefore, increasing V_{IN} (which increases I_{E2}) will result in a corresponding decrease in T_L.

SYMMETRY

With the output (V_{OUT}) now high, at the start of period T_H, TR2's base-emitter junction is now reverse biased, turning it "off". Transistor TR1's base-emitter junction, however, is forward biased, allowing collector current I_{C1} to flow through TR1, charging C1, and causing capacitor voltage V_C to rise.

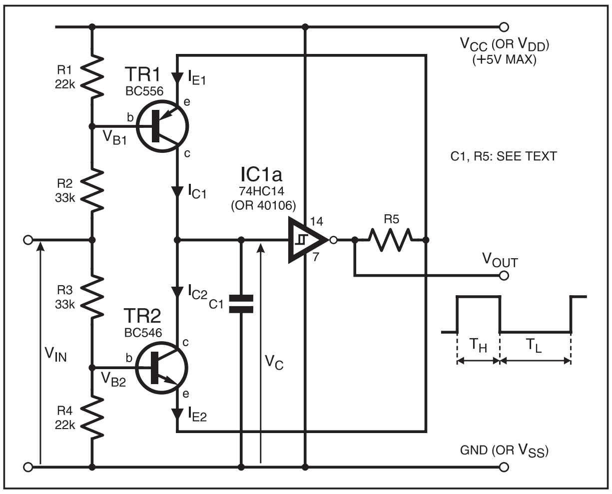


Fig.6.11. An alternative Schmitt-based PWM, again using complementary transistors.

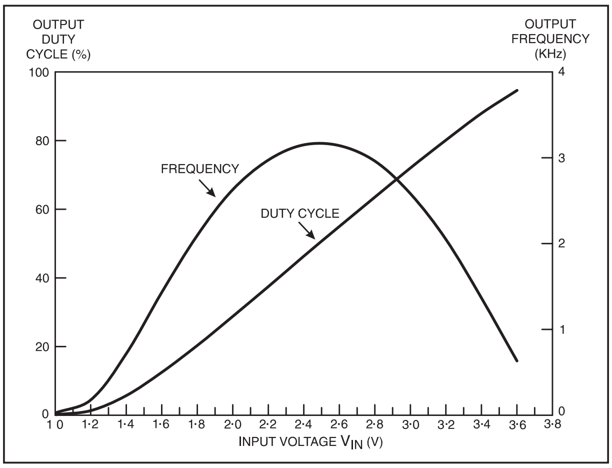


Fig.6.12. Graphs showing frequency and duty cycles versus V_{IN} for the PWM.

Table 6.1: Data used to plot waveforms of Fig.6.12.

V_{IN} (V)	1·0	1·2	1·4	1·6	1·8	2·0	2·2	2·4	2·6	2·8	3·0	3·2	3·4	3·6
Duty Cycle (%)	0·20	1·28	5·72	12·59	20·46	28·80	37·32	46·04	54·68	63·34	71·91	80·20	88·17	94·64
Freq. (kHz)	0·03	0·17	0·71	1·43	2·09	2·62	2·98	3·16	3·15	2·96	2·58	2·04	1·36	0·64

Like transistor TR2, TR1's emitter current, I_{E1}, depends on resistor R5 and the emitter voltage, which in turn depends on V_{B1} and V_{IN}. Increasing V_{IN} will cause a corresponding increase in TR1's emitter voltage, thereby *reducing* the voltage across R5 and causing I_{E1} to decrease. Again, if the transistor current gain is large, then $I_{C1} \approx I_{E1}$, such that C1's charge current is effectively equal to I_{E1}.

Eventually, when I_{E1} has charged C1 sufficiently for V_C to rise to the inverter's positive-going threshold voltage, V_{T+}, the output immediately goes low again, and time period T_H ends. Therefore, T_H is *inversely* proportional to I_{E1} (decreasing I_{E1} will decrease the rate at which C1 charges, causing V_C to rise more slowly, hence making T_H longer). Therefore, increasing V_{IN} (which decreases I_{E2}) will result in a corresponding increase in T_H.

It can be seen that there is a kind of "symmetry" to the way the switched current sources function. Increasing V_{IN} (which increases I_{E2}) results in a corresponding decrease in T_L; at the same time, the decrease in I_{E1} results in a corresponding increase in T_H. The net result is an increase in the output duty cycle. Therefore, varying the input voltage changes the emitter potentials and thus varies the charge and discharge currents, such that the duty cycle varies in direct *linear* proportion to V_{IN}.

VOLTAGE CONTROL

Provided the transistors' current gains are large enough, their base currents will have negligible effect on the circuit's behaviour. In fact, it is only the *voltages* around the transistors which control the charging and discharging of capacitor C1. Changes in h_{FE} and base currents have little effect on the duty cycle; the circuit is stable and exhibits negligible "jitter".

With equal resistor values for R1 and R4, and R2 and R3, as shown in Fig.6.11, the potential divider also behaves "symmetrically". For example, when $V_{IN} = V_{CC}/2$, the voltage across resistor R1 will be the same as that across R4. Therefore, provided the transistors' V_{BE} values are roughly the same, the voltage across R5 when TR1 turns on will be the same as when TR2 turns on, such that $I_{E1} = I_{E2}$. Consequently, C1's charge and discharge currents will be the same, resulting in $T_H = T_L$, that is, 50 per cent duty cycle.

Using the values for R1 to R4 shown in Fig.6.11, the output duty cycle is given by:

$$\text{Duty Cycle} = \frac{0{\cdot}4V_{IN} - V_{BE}}{0{\cdot}4V_{CC} - 2V_{BE}} \times 100\%$$

(V_{BE} = forward-biased base-emitter voltage).

This expression shows that duty cycle is directly proportional to input voltage, and it can be seen that V_{IN} must be greater than $V_{BE}/0{\cdot}4$ for the circuit to work. Taking $V_{BE} = 0{\cdot}6V$, this suggests that V_{IN} must be at least 1·5V, although in breadboard tests the circuit was found to produce very low duty cycles with V_{IN} as low as 1V. Also, substituting $V_{CC}/2$ for V_{IN}, the equation shows that duty cycle = 50 per cent.

The two graphs shown in Fig.6.12 plot the performance of a test circuit built using a 74HC14 inverter with V_{CC} = 5·0V (like the previous circuit, the supply voltage should be limited to around 5V to prevent avalanching of the transistors' reverse-biased base-emitter junctions). Values of 10nF and 5·6kΩ were selected for C1 and R5.

Notice how the duty cycle varies linearly from 2% to 95% over a range of V_{IN} from 1·2V to 3·6V. (V_{IN} cannot go much below 1·2V or much above 3·6V, otherwise there is insufficient base voltage to bias the transistors "on".) As predicted by the symmetry of the R1 to R4 potential divider, the duty cycle is roughly 50% when V_{IN} = 2·5V (i.e., $V_{CC}/2$).

Like the previous PWM circuit shown in Fig.6.10, the output frequency changes non-linearly with V_{IN}, and varies by as much as 15 to 1 over the range V_{IN} = 1·2V to 3·6V, peaking at about 3·2kHz when V_{IN} is roughly equal to $V_{CC}/2$.

Capacitor C1 and resistor R5 should be selected according to the operating frequency range required. For example, with a value of 5·6kΩ for R5 and C1 reduced to 1nF, the peak frequency is increased to around 31kHz. However, C1 should not be made too small (100pF is a suitable minimum value) otherwise the duty cycle response starts to become non-linear.

SPARE PARTS ONE-SHOT

Last month, we saw how two Schmitt NAND gates could be used to form a non-retriggerable monostable multivibrator (sometimes called a "one-shot"). We now look at an alternative non-retriggerable monostable circuit which requires a single Schmitt inverter, a flip-flop and a transistor.

The circuit diagram and its waveforms are shown in Fig.6.13, and can be particularly useful where these parts are unused, or "left over", elements in a design. As a bonus, the circuit generates two, *complementary* outputs at V_{OUT} and $\overline{V_{OUT}}$.

The flip-flop, IC1a, is a positive-edge triggered, D-type flip-flop from the 74HC74, although most other flip-flops having complementary outputs (Q and $\overline{Q}$) would suffice. To understand the circuit's behaviour, assume that the flip-flop is in its reset state, such that Q is low and $\overline{Q}$ is high.

When the input trigger pulse, V_{IN}, arrives and clocks the flip-flop, Q (V_{OUT}) immediately goes high; at the same moment, $\overline{Q}$ goes low, turning off *npn* transistor TR1. Timing capacitor C1 now starts to charge exponentially via timing resistor R1. Eventually, when the capacitor voltage, V_C, reaches the positive-going threshold, V_{T+}, of IC2a, its output immediately goes low. This resets the flip-flop, causing Q and $\overline{Q}$ to return to their original, stable states, and terminates the output pulse, T_{OUT}.

Provided resistor R1 is large enough not to load IC1a's Q output, we can assume that Q's voltage equals V_{CC} when it goes high, such that:

$$\text{Output Pulse Width, } T_{OUT} = \tau \ln\left\{\frac{V_{CC}}{V_{CC} - V_{T+}}\right\} \text{(seconds)}$$

where the time constant τ = C1 × R1.

At the end of T_{OUT}, when $\overline{V_{OUT}}$ goes high, TR1 turns on and rapidly discharges C1. The capacitor voltage, V_C, quickly falls below IC2a's negative-going threshold, V_{T-}, at which point IC2a's output goes high, bringing the flip-flop out of its reset state.

The device used for TR1 is not critical; any small-signal *npn* transistor with adequate current gain should suffice.

NON-RETRIGGERABLE

Since IC2a's output is low only for a very brief time, the circuit is ready to accept another trigger pulse almost as soon as T_{OUT} has ended. Note that any trigger pulses that arrive while V_{OUT} is high have no effect on the circuit, which cannot be retriggered until T_{OUT} has ended. This is illustrated by the second of the V_{IN} pulses which cannot clock the flip-flop because V_{OUT} is already high.

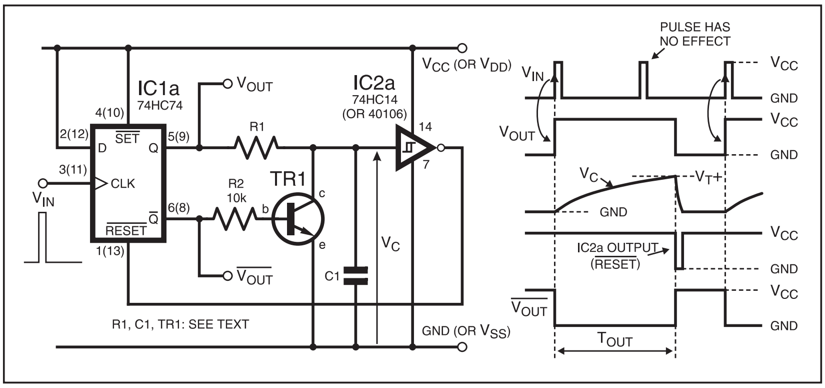


Fig.6.13. Circuit diagram and its waveforms for a non-retriggerable monostable constructed from "unused" parts.

The actual value of T_{OUT} will be influenced by tolerances in C1 and R1, and also by variations in supply voltage and V_{T+}. Nevertheless, provided resistor R1 is not too large (< 1MΩ), the actual value of T_{OUT} agrees closely with the value predicted by the expression above.

For example, a test circuit was built using a 74HC14 inverter for IC2a, and the supply voltage, V_{CC}, was set to 5·0V, resulting in a value of 2·74V for V_{T+}. Nominal values of 100kΩ and 10nF were chosen for R1 and C1, although the measured values were 99·9kΩ and 10·08nF, such that T_{OUT} predicted by the equation above is 800µs. The actual, measured value was found to be 806µs.

The circuit of Fig.6.13 is extremely good at "stretching" narrow pulses. With R1 and C1 increased to 1MΩ and 10·68µF, a trigger pulse just 100ns wide resulted in an output pulse of 8·9 seconds, some 89 million times greater than the input pulse width!

Although T_{OUT} could be finely tuned by using a variable resistor (potentiometer) for R1, the circuit is not intended for precision timing applications, where a device like the 74HC221 would be a better choice. Nevertheless, where a design happens to have an unused flip-flop and Schmitt inverter available "for free", the circuit provides a simple and cost-effective way of implementing the "one-shot" function.

FREQUENCY METER

With the addition of a few resistors and capacitors, the monostable circuit of Fig.6.13 can be converted to a simple Frequency Meter which displays the reading on a 3½-digit, 200mV DVM (digital volt meter) module. The "add-on" circuit is shown in Fig.6.14, where V_{OUT} is the Q output of flip-flop IC1a in Fig.6.13.

The circuit is effectively a frequency-to-voltage converter, and works on the principle that the *average* value of a series of *constant width, constant amplitude* pulses is directly proportional to their frequency. Therefore, by averaging the voltage of the pulses, the result displayed on a DVM provides a direct indication of frequency.

The averaging function is provided by C2/R3 and C3/R4 which together form a simple, two-pole, low-pass filter. For the circuit to work properly, it is essential that the input pulses are of constant width: this is why the filter circuit must be preceded by a non-retriggerable monostable. Resistors R5 and R6, and trimmer preset VR1, allow the output voltage, V_M, to be adjusted to compensate for tolerances in the monostable circuit.

The circuit is intended to display a full-scale frequency of 2kHz on the DVM, that is, a reading of 199·9mV corresponds to a frequency of 1·999kHz. Therefore, it is important that the monostable's pulse width, T_{OUT}, must not exceed 500µs (the period of 2kHz), or the meter will go overrange. It doesn't matter if T_{OUT} is somewhat less than 500µs, as this can be accommodated by trimming VR1.

COMPONENT VALUES

For the monostable timing components, values of 3·3nF ±5% and 120kΩ ±1% should be used for C1 and R1 respectively. A single inverter from the 74HC14 Hex Schmitt trigger inverter i.c. should be used for IC2a, and the 5V (V_{CC}) supply voltage should be regulated to within ±4% (this can easily be achieved using a 78L05 regulator).

The resistors used in the filter circuit (Fig.6.14) should all be ±1% types, and VR1 should be a multiturn preset potentiometer with a maximum tolerance of ±10%. The tolerance of capacitors C2 and C3 is not critical: ±10% parts are adequate. The DVM must have a full-scale range of 200mV, and its input impedance must be at least 10MΩ (a lower impedance would "load" the filter network and could affect the results).

To calibrate the circuit, flip-flop IC1a should be clocked at a frequency near full-scale (say, 1,950Hz), and preset VR1 should be adjusted to produce a corresponding reading on the DVM (in this example, it would be 195·0mV). The meter will then provide a direct indication of frequency with a reading error of around ±1% maximum.

Note that by preceding the monostable circuit with a series of decade frequency dividers (such as the 74HC190 or 74HC390), the circuit can be adapted to display any frequency in decade ranges up to about 20MHz. Furthermore, if the input signal is fed to the Schmitt trigger interface circuit described in Fig.5.3 of last month's article, the frequency meter is capable of responding to a variety of different waveshapes.

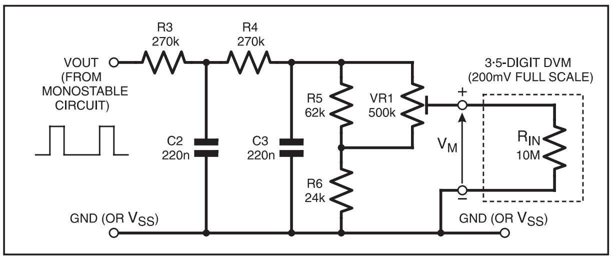


Fig.6.14. An add-on filter circuit for frequency-to-voltage conversion.

BOUNCING CONTACTS

Perhaps one of the Schmitt's most ubiquitous applications is that of contact "bounce" suppression. Switch and relay contacts have inherent elasticity; when they close, the kinetic energy in the moving parts causes the contacts to bounce back and forth many times before finally settling down. The result is a series of contact interruptions, each of which will generate a narrow pulse when used in an electronic circuit.

In certain applications, contact bounce is not a problem, but in others, such as circuits featuring counters and shift registers, the phenomenon can wreak havoc on the circuit's behaviour. The duration of the bounce period (the time during which the contacts are unstable), and the number of pulses generated will depend on the type and quality of contacts used. Bounce periods of several hundred microseconds are common, although this may be as long as 20ms for some contacts.

Incidentally, contact bounce also occurs when contacts open, although this is usually less severe than when they close, and is often a result of changes in contact resistance that occur when the contacts separate.

Many techniques exist for eliminating the effects of contact bounce. In microcontroller or microprocessor circuits, software routines can be employed to "filter out" the glitches produced when the contacts close.

In hardware, monostables, latches, flip-flops and specialised "debouncing" i.c.s can be used to provide immunity to contact bounce. However, in terms of simplicity, the Schmitt trigger debouncers shown in Fig.6.15 are often hard to beat.

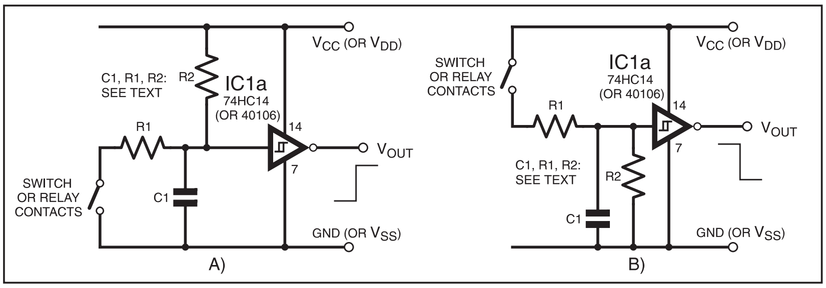


Fig.6.15. Two circuit arrangements for Schmitt-based debouncers.

PULSE FILTER

The circuit in Fig.6.15a provides a low-to-high level change in output, V_{OUT}, when the contacts close, whereas that in Fig.6.15b generates a high-to-low level change. Both circuits rely on the low-pass filtering action provided by capacitor C1 and resistor R1.

In Fig.6.15a, R2 is a *pull-up* resistor which ensures V_{OUT} is low while the contacts are open. When the contacts close, the junction of R1/R2 is pulled down below the Schmitt's negative-going threshold, and capacitor C1 filters out the bounce pulses which would otherwise appear, such that the signal at the Schmitt input makes a "smooth" transition from V_{CC} (or V_{DD}) to a low level. Therefore, V_{OUT} makes just one, "clean", low-to-high transition when the contacts are closed.

In Fig.6.15b, C1, R1 and R2 provide exactly the same function, except that R2 behaves as a *pull-down* resistor such that V_{OUT} is held high while the contacts are open. In both cases, the time constant formed by C1 × R1 should be made large enough to filter out the worst-case number of bounce pulses likely to occur. In other words, the time constant must be longer than the maximum anticipated bounce period.

Also, the ratio of R1 to R2 must be chosen carefully such that the inverter's input voltage can be pulled below the *minimum* negative-going threshold (Fig.6.15a) or above the *maximum* positive-going threshold (Fig.6.15b) when the contacts close. For a 74HC14 inverter working on a 5V rail, values in the region of 100kΩ for R1 and 680kΩ for R2 are usually suitable.

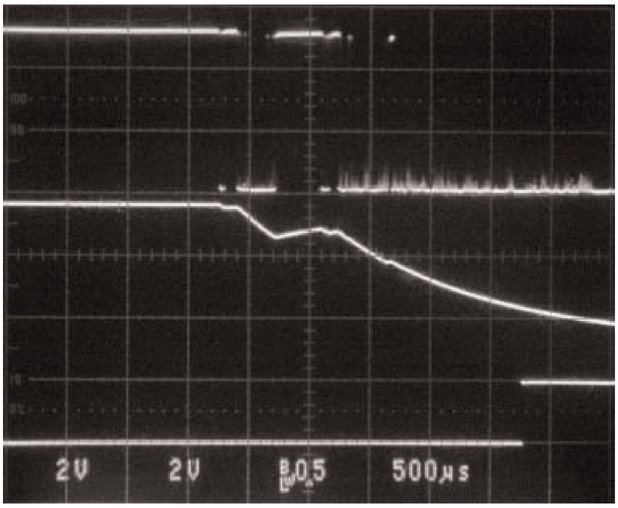


Fig.6.16. Waveforms for contact debouncer shown in Fig.6.15a. Top trace: Switch contact bounce (2V/div.). Middle trace: Filtered signal at Schmitt trigger input (2V/div.). Bottom trace: Schmitt trigger output, V_{OUT} (5V/div.). Timebase: 500µs/div.

WAVEFORMS

The oscillograph in Fig.6.16 shows the waveforms observed for the debouncer circuit of Fig.6.15a, using values of 100kΩ and 680kΩ for R1 and R2, and 10nF for C1. The top trace illustrates the contact bounce: in this example, the bounce period lasts for about 1·5ms, during which the contacts open and close more than twenty times.

The middle trace shows the filtered signal at the inverter's input. In this example, the C1/R1 time constant of 1ms is more than adequate to filter out the bounce pulses, but for more severe cases, C1 could be increased to around 100nF.

The bottom trace shows how V_{OUT} goes high about 2·5ms after the contacts first start to close. In most cases, this delay will be of no consequence, but in certain circuits (e.g.: where contacts are used in timing applications) it may be necessary to take it into account, particularly if a very large value has been chosen for C1 to eliminate excessive bounce.

SINGLE OR MULTIPLE PULSER

We conclude our look at the "digital" Schmitt trigger by combining some of the elementary circuits introduced in this article and the previous one to create a more complex function.

The circuit diagram Fig.6.17 shows an Auto-Repeating Pushbutton Pulser. A single press of the pushbutton switch, S1, generates a single, positive-going pulse of width T1 at the output. However, if switch S1 is held closed long enough, the circuit "auto-repeats", that is, it generates a continuous train of pulses of width T2 until the pushbutton is released.

Components C1, R1, R2 and IC1a form the debouncer: operation is exactly the same as the debouncer in Fig.6.15b, but with the Schmitt NAND replacing the inverter. Therefore, when switch S1 is closed, a high-to-low transition is produced at the output of IC1a. This low-going pulse is differentiated by C4 and R4, producing a negative-going "spike" at the input to IC1d. Since IC1d's other input is high at this point, the NAND function results in a positive-going pulse at V_{OUT}. The width of this pulse, T1, is determined by the C4/R4 time constant; this part of the circuit should be familiar as the "digital differentiator" shown in Fig.5.9 in last month's article.

While switch S1 is closed and IC1a's output is low, capacitor C3 charges via R3, and the voltage at their junction gradually falls. If S1 is opened, IC1a's output goes high and C3 is rapidly discharged via diode D1. However, if S1 remains pressed long enough, C3 will charge sufficiently for the voltage at IC1b's input to fall below its negative-going threshold voltage.

OPENING THE GATE

When this happens, the astable oscillator formed by IC1b, IC1c, C2 and R5 is "gated" on and starts to run (this part of the circuit is the same as the gated astable shown previously in Fig.6.5). The time taken for capacitor C3 to charge sufficiently to "enable" the oscillator constitutes the delay denoted T_D, and depends on the C3/R3 time constant.

During this time, capacitor C4 has become fully charged (the C4/R4 time constant is much smaller than the C3/R3 time constant),

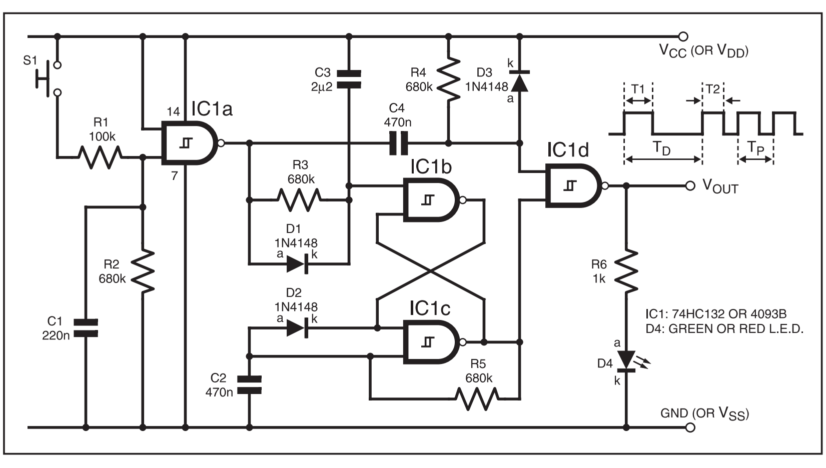


Fig.6.17. Circuit diagram for an auto-repeating pushbutton pulser.

and so the voltage at the junction of C4/R4 is high. This allows the astable pulses output by IC1c to propagate through IC1d, and appear inverted at V_{OUT}.

The width of the auto-repeating pulses, T2, and the period of oscillation, T_P, depend on the values selected for C2 and R5. Diode D2 is not essential, but without it the width of the first astable pulse (T2) will be slightly longer than the pulses that follow.

Notice that the pulser requires only one integrated circuit, either the 74HC132 or the 4093B. The circuit was tested using a 74HC132, with a supply voltage, V_{CC}, of 5·0V. Using the capacitor and resistor values shown in Fig.6.17, the width of the first pulse, T1, was 238ms. The delay, T_D, from the switch being closed to the first of the auto-repeating pulses was 1·85s. Pulse width T2 was measured as 120ms, and the pulses repeated at a rate of 4·7Hz (i.e., T_P = 212ms). Note that these are all typical values, and will vary with component tolerance and changes in Schmitt threshold voltages.

Normally, the pulses at V_{OUT} would be fed to a digital circuit like a counter or shift register. However, light emitting diode D4 can be used to provide visual indication of the pulses; series resistor R6 should be selected for optimum brightness. This kind of auto-repeating function is often found in products like electronic clocks, where a single press of the pushbutton increments or decrements a variable just once, and a continuous press rapidly increases or decreases the variable.

SPECIALITY SCHMITT DEVICES

Throughout this series, we've seen how the Schmitt trigger can be used not just as an interface circuit, but also as the central element in a variety of other functions. In view of its versatility, and the fact that hysteresis is indispensable in many applications, the Schmitt has been integrated into many "specialised" devices.

Next month, in the final part of this series, we'll see how the Schmitt trigger's unique characteristics are used in a wide range of devices, from optocouplers to voltage monitors.

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If you require a microcomputer for business applications, or a high quality home computer, an IBM PC or compatible is often the obvious choice. They are competitively priced, and are backed up by an enormous range of applications programs, hardware add-ons, etc. The main difficulty for the uninitiated is deciding on the specification that will best suit his or her needs. PCs range from simple systems of limited capabilities up to complex systems that can happily run applications that would have been considered beyond the abilities of a microcomputer not so long ago. It would be very easy to choose a PC system that is inadequate to run your applications efficiently, or one which goes beyond your needs and consequently represents poor value for money.

This book explains PC specifications in detail, and the subjects covered include the following: Differences between types of PC (XT, AT, 80386, etc); Maths co-processors; Input devices (keyboards, mice, and digitisers); Memory, including both expanded (EMS) and extended RAM; RAM disks and disk caches; Floppy disk drive formats and compatibility; Hard disk drives (including interleave factors and access times); Display adaptors, including all standard PC types (CGA, Hercules, Super VGA, etc); Contains everything you need to know if you can't tell your EMS from your EGA!

128 pages **Order code BP282** **£5.45**

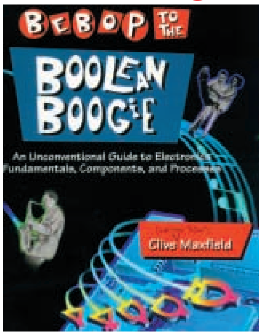
Theory and Reference

Bebop To The Boolean Boogie

By Clive (call me Max) Maxfield

Specially imported by *EPE* – *Excellent value*

An Unconventional Guide to Electronics Fundamentals, Components and Processes



This book gives the "big picture" of digital electronics. This indepth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!). Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day. . . .

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DIGITAL ELECTRONICS – A PRACTICAL APPROACH

With FREE Software: Number One Systems – EASY-PC Professional XM and Pulsar (Limited Functionality)

FREE SOFTWARE

Richard Monk

Covers binary arithmetic, Boolean algebra and logic gates, combination logic, sequential logic including the design and construction of asynchronous and synchronous circuits and register circuits. Together with a considerable practical content plus the additional attraction of its close association with computer aided design including the FREE software.

There is a 'blow-by-blow' guide to the use of EASY-PC Professional XM (a schematic drawing and printed circuit board design computer package). The guide also conducts the reader through logic circuit simulation using Pulsar software. Chapters on p.c.b. physics and p.c.b. production techniques make the book unique, and with its host of project ideas make it an ideal companion for the integrative assignment and common skills components required by BTEC and the key skills demanded by GNVQ. The principal aim of the book is to provide a straightforward approach to the understanding of digital electronics.

Those who prefer the 'Teach-In' approach or would rather experiment with some simple circuits should find the book's final chapters on printed circuit board production and project ideas especially useful.

250 pages | **Order code NE28** | **£17.99**

Bebop Bytes Back

FREE CD-ROM

By Clive "Max" Maxfield and Alvin Brown

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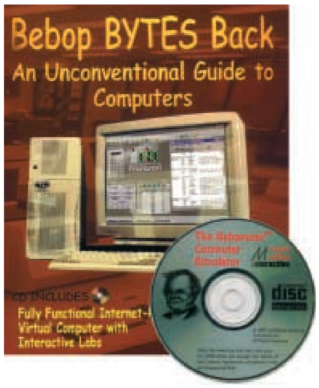
An Unconventional Guide To Computers



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This follow-on to *Bebop to the Boolean Boogie* is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design. . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the accompanying CD-ROM (for Windows 95 machines only) contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the book contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers.

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DIGITAL GATES AND FLIP-FLOPS

Ian R. Sinclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

Topics such as Boolean algebra and Karnaugh mapping are explained, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.

No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic.

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Music, Audio and Video

AN INTRODUCTION TO LOUDSPEAKERS AND ENCLOSURE DESIGN

V. Capel

This book explores the various features, good points and snags of speaker designs. It examines the whys and wherefores so that the reader can understand the principles involved and so make an informed choice of design, or even design loudspeaker enclosures for him – or herself. Crossover units are also explained, the various types, how they work, the distortions they produce and how to avoid them. Finally there is a step-by-step description of the construction of the *Kapellmeister* loudspeaker enclosure.

148 pages | **Temporarily out of print**

ELECTRONIC MUSIC AND MIDI PROJECTS

R. A. Penfold

Whether you wish to save money, boldly go where no musician has gone before, rekindle the pioneering spirit, or simply have fun building some electronic music gadgets, the designs featured in this book should suit your needs. The projects are all easy to build, and some are so simple that even complete beginners at electronic project construction can tackle them with ease. Stripboard layouts are provided for every project, together with a wiring diagram. The mechanical side of construction has largely been left to individual constructors to sort out, simply because the vast majority of project builders prefer to do their own thing in this respect.

None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

138 pages | **Order code PC116** | **£10.95**

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR

R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

124 pages | **Order code PC115** | **£10.95**

COMPUTERS AND MUSIC – AN INTRODUCTION

R. A. Penfold

Computers are playing an increasingly important part in the world of music, and the days when computerised music was strictly for the fanatical few are long gone.

If you are more used to the black and white keys of a synth keyboard than the QWERTY keyboard of a computer, you may be understandably confused by the jargon and terminology bandied about by computer buffs. But fear not, setting up and using a computer-based music making system is not as difficult as you might think.

This book will help you learn the basics of computing, running applications programs, wiring up a MIDI system and using the system to good effect, in fact just about everything you need to know about hardware and the programs, with no previous knowledge of computing needed or assumed. This book will help you to choose the right components for a system to suit your personal needs, and equip you to exploit that system fully.

174 pages | **Temporarily out of print**

THE INVENTOR OF STEREO – THE LIFE AND WORKS OF ALAN DOWER BLUMLEIN

Robert Charles Alexander

This book is the definitive study of the life and works of one of Britain's most important inventors who, due to a cruel set of circumstances, has all but been overlooked by history.

Alan Dower Blumlein led an extraordinary life in which his inventive output rate easily surpassed that of Edison, but whose early death during the darkest days of World War Two led to a shroud of secrecy which has covered his life and achievements ever since.

His 1931 Patent for a Binaural Recording System was so revolutionary that most of his contemporaries regarded it as more than 20 years ahead of its time. Even years after his death, the full magnitude of its detail had not been fully utilized. Among his 128 patents are the principal electronic circuits critical to the development of the world's first electronic television system. During his short working life, Blumlein produced patent after patent breaking entirely new ground in electronic and audio engineering.

During the Second World War, Alan Blumlein was deeply engaged in the very secret work of radar development and contributed enormously to the system eventually to become 'H2S' – blind-bombing radar. Tragically, during an experimental H2S flight in June 1942, the Halifax bomber in which Blumlein and several colleagues were flying, crashed and all aboard were killed. He was just days short of his thirty-ninth birthday.

420 pages | **Order code NE32** | **£15.99**

HIGH POWER AUDIO AMPLIFIER CONSTRUCTION

R. A. Penfold

Practical construction details of how to build a number of audio power amplifiers ranging from about 50 to 300/400 watts r.m.s. includes MOSFET and bipolar transistor designs.

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Circuits, Data and Design

PRACTICAL ELECTRONIC FILTERS
Owen Bishop
This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.
The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rythm sequencer and a multi-voiced electronic organ.
Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.
88 pages **Order code BP299** **£5.49**

ELECTRONIC HOBBYISTS DATA BOOK
R. A. Penfold
This book should tell you everything you are ever likely to want to know about hobby electronics, but did not know where to ask or refer. Comprehensive contents pages makes it easy to quickly locate the data you require.
The subjects covered include: Common circuits, and related data (including helpful graphs and tables of values); Colour codes for resistors, capacitors and inductors; Pinout details for a wide range of CMOS and TTL devices, plus basic data on the various logic families; Pinout details and basic data for a wide range of operational amplifiers; Data and leadout information for a wide range of transistors, FETs, power FETs, triacs, thyristors, diodes, etc; General data including MIDI message coding, radio data, ASCII/Baudot coding, decibel ratios, etc.
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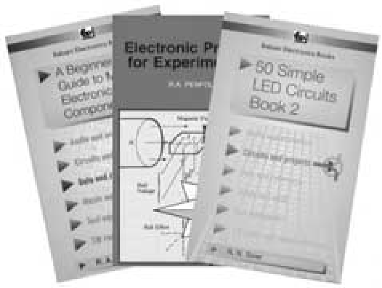

50 SIMPLE LED CIRCUITS
R. N. Soar
Contains 50 interesting and useful circuits and applications, covering many different branches of electronics, using one of the most inexpensive and freely available components – the light-emitting diode (LED). Also includes circuits for the 707 common anode display.
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CIRCUIT SOURCE BOOK 1
A. Penfold
Written to help you create and experiment with your own electronic designs by combining and using the various standard "building block" circuits provided. Where applicable, advice on how to alter the circuit parameters is given.
The circuits covered in this book are mainly concerned with analogue signal processing and include: Audio amplifiers (op.amp and bipolar transistors); audio power amplifiers; d.c. amplifiers; highpass, lowpass, bandpass and notch filters; tone controls; voltage controlled amplifiers and filters; triggers and voltage comparators; gates and electronic switching; bargraphs; mixers; phase shifters, current mirrors, hold circuits, etc.
Over 150 circuits are provided, which it is hoped will be useful to all those involved in circuit design and application, be they professionals, students or hobbyists.
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R. A. Penfold
This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".
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E. A. Parr
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CIRCUIT SOURCE BOOK 2
R. A. Penfold
This book will help you to create and experiment with your own electronic designs by combining and using the various standard "building blocks" circuits provided. Where applicable, advice on how to alter the circuit parameters is provided.
The circuits covered are mainly concerned with signal generation, power supplies, and digital electronics.
The topics covered in this book include: 555 oscillators; sinewave oscillators; function generators; CMOS oscillators; voltage controlled oscillators; radio frequency oscillators; 555 monostables; CMOS monostables; TTL monostables; precision long timers; power supply and regulator circuits; negative supply generators and voltage boosters; digital dividers; decoders, etc; counters and display drivers; D/A and A/D converters; opto-isolators, flip/flops, noise generators, tone decoders, etc.
Over 170 circuits are provided, which it is hoped will be useful to all those involved in circuit design and application, be they professionals, students or hobbyists.
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R. A. Penfold
Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded "seen it all before" syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different. No doubt many of the projects featured here have practical applications, but they are all worth a try for their interest value alone.
The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.
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R. A. Penfold
While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.
The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.
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ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:
Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.
In fact everything you need to know in order to get started in this absorbing and creative hobby.
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R. A. Penfold
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