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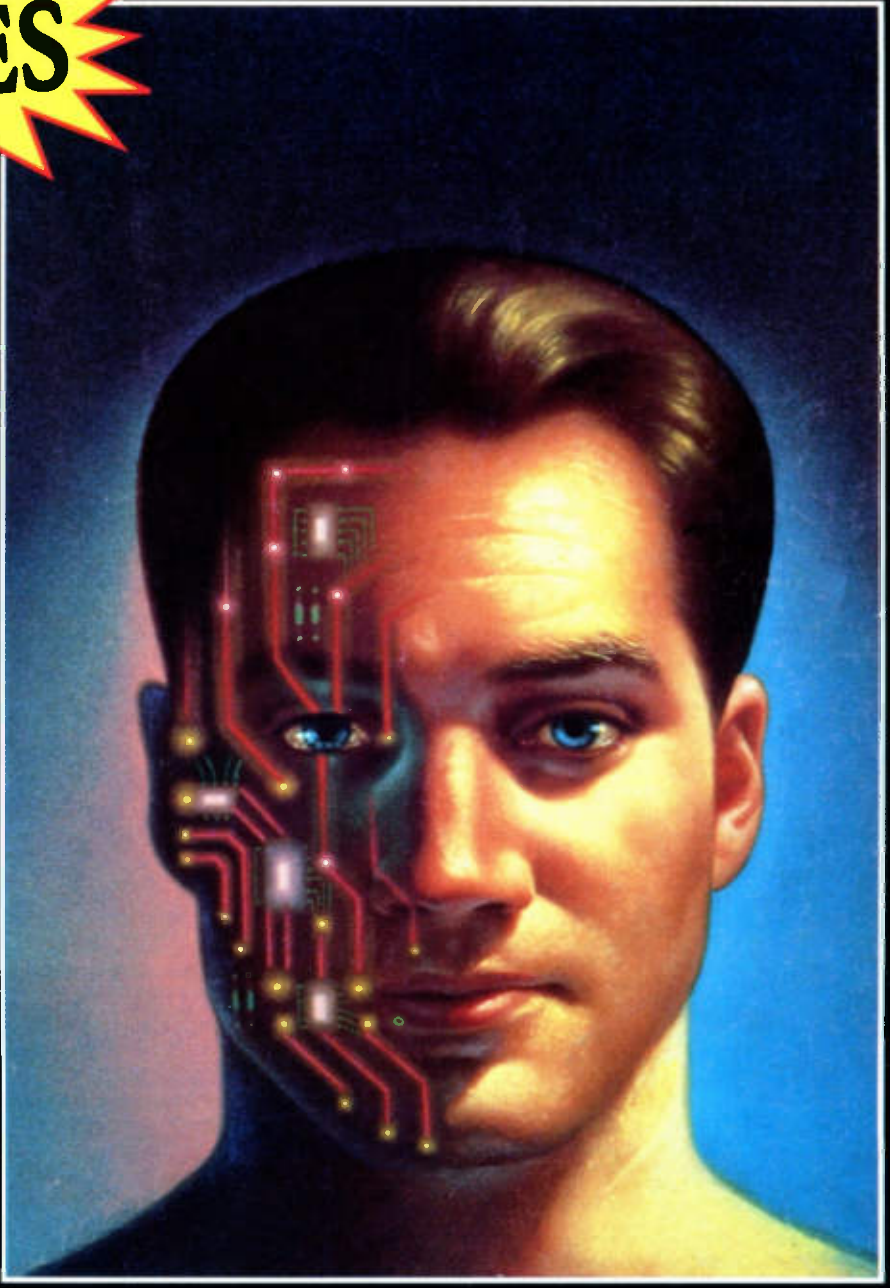

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ISSN 0262 3617
PROJECTS . . . THEORY . . . NEWS . . .
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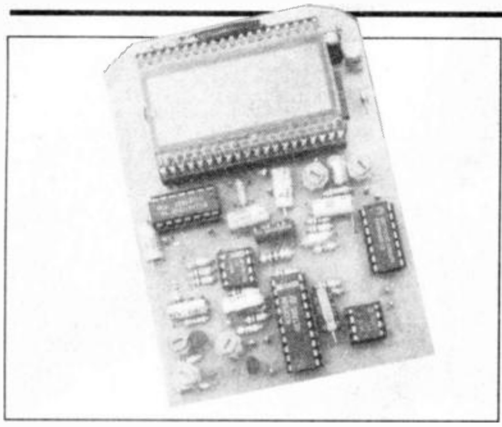
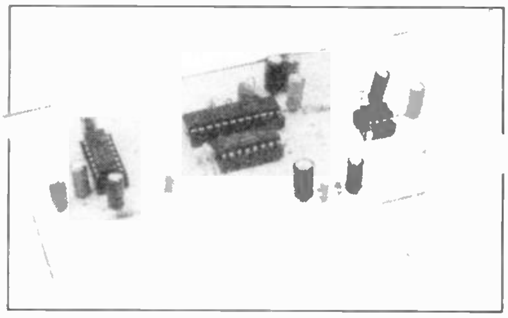
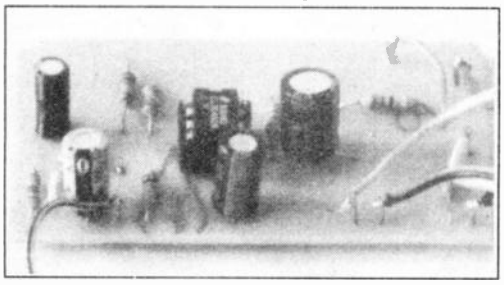
VOL. 24 No. 11 NOVEMBER 1995

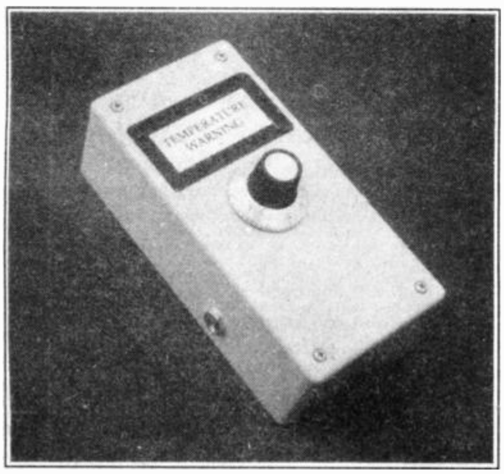
EVERYDAY PRACTICAL ELECTRONICS

The No. 1 Independent Magazine for Electronics Technology and Computer Projects









Projects

Series

Features

Our December '95 issue will be published on Friday, 3 November 1995. See page 831 for details.

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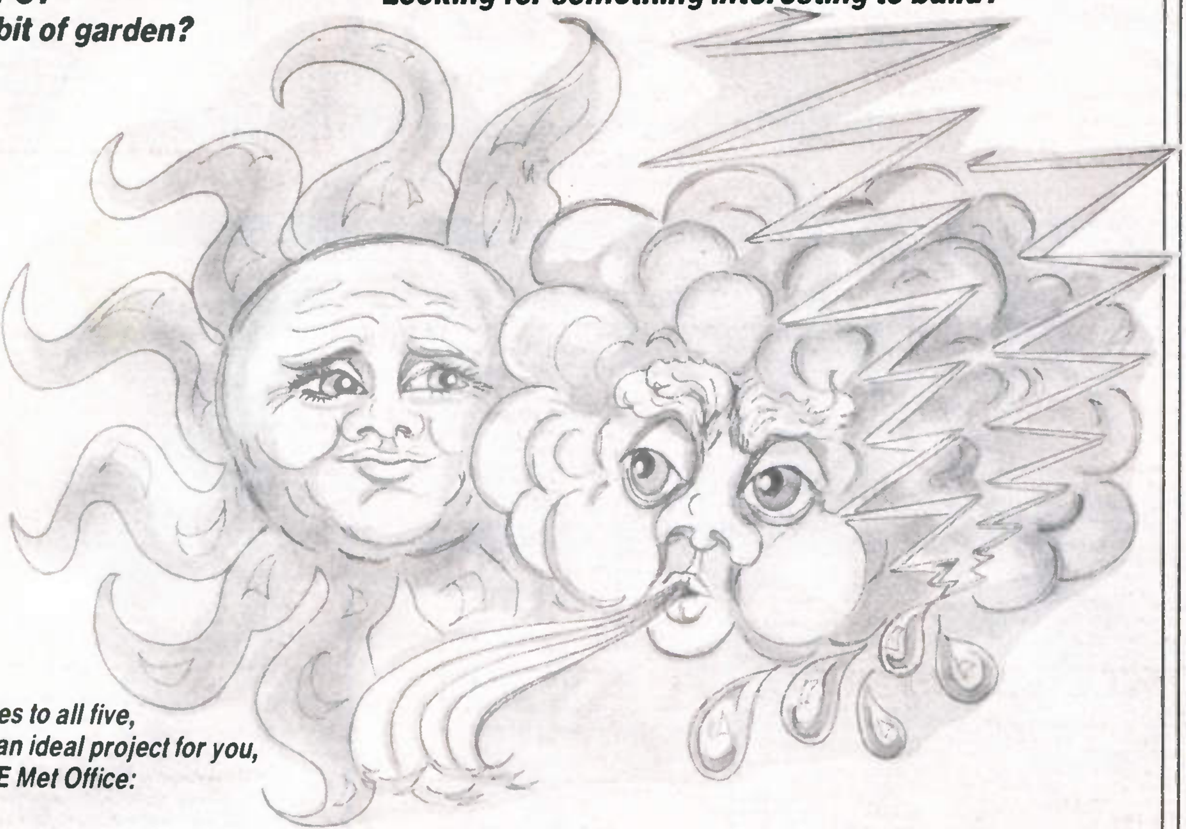

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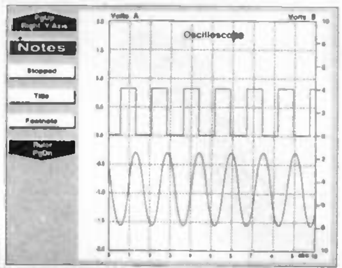

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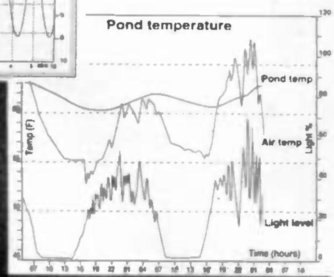

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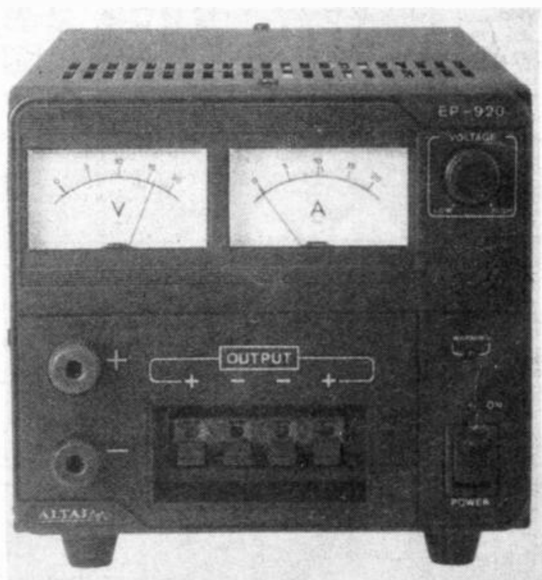

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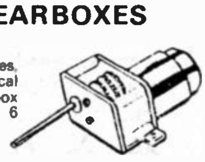

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DESIGNS

We are often asked to explain how to design electronic projects or why a certain value component was used in part of a circuit. it is not easy to provide answers because the background information and explanations required are often lengthy. What we normally do when faced with such questions is to point readers in the direction of our past *Teach-In* series and books, which cover various aspects of electronics theory.

But now, just about anyone should be able to design their own projects, with virtually no complicated calculations, simply by following our new *Teach-In '96* series starting in this issue. The series has been designed mainly for GCSE and A Level students (who need to build projects for their Electronics or Technology courses) but it will have a much wider appeal.

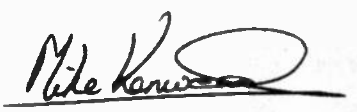
BASICS

Teach-In '96 makes no attempt to go over basic electronics theory – resistor colour codes, current flow, semiconductor theory, etc., have all been covered elsewhere – this new series is about using circuit building blocks to put together working projects of your own design. To illustrate the principles involved each monthly part will have an accompanying project which uses some of the modules to form a design for which full constructional details will be given. This month's project is the *Temperature Warning Alarm*.

BACKGROUND

If you are a new *EPE* reader, just getting started in this fascinating and rewarding subject, then you might need some more detailed information on components, current flow, semiconductor operation, digital gates, etc. – all this is available in our *Teach-In No.7* book for just £3.95 – it even includes some free software for PC users (see our *Direct Book Service* pages for full details). This book will provide background theory for those who need it.

Of course, if you get stuck with any aspect of electronics from general principles to project building, we will try to help through our Readers' Enquiries Service (see the notes on the right) or through Alan Winstanley's *Circuit Surgery* column.



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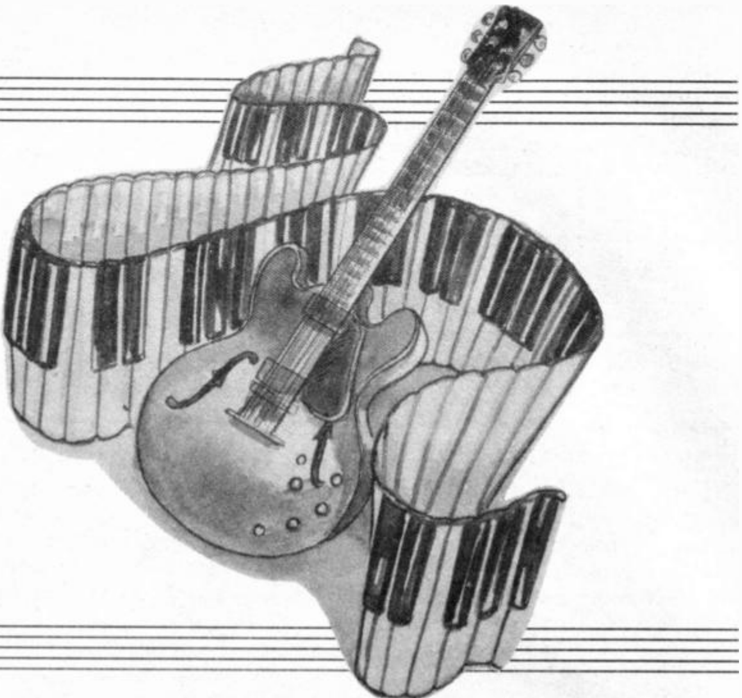


DIGITAL DELAY LINE

JOHN CHATWIN

An affordable, easy to construct, simple delay line to run your guitar, keyboard or microphone through. Uses a special digital delay processor chip that will give you stunning effects!

THESE days, with the huge advances in LSI technology, affordable digital delays for audio use are no longer the big deal they used to be. Even so, for the hard up musician, or home studio enthusiast, a high quality delay line is likely to be one of the most expensive pieces of auxiliary equipment he or she purchases.

In the past, that is, up until the 1970s, the only realistic way to produce long delays for audio applications was to use some form of tape delay. In its simplest form this just consisted of a tape recorder with more than one play/record head.

Signals were recorded onto the tape at the first head, and then played back by the second. The output from the second head could then be mixed with the original signal to create an echo effect. The time it took for the tape to travel between the two heads determined the length of the delay, so the delay time could be varied by moving the position of the playback head, or changing the speed of the tape.

ECHOES

When commercial tape echo machines were produced, they often had either a movable playback head to vary the delay time, or were fitted with a number of fixed playback heads at various positions along the tape. Instead of the reel-to-reel tape arrangement of a tape recorder, the tape was usually spliced into a continuous loop which revolved at a relatively high speed, to improve on signal quality.

Most tape echo machines utilised ¼inch tape and recording heads. Fig. 1 shows the layout of a typical tape echo machine like the "Watkins Copycat", which is still very popular today. A fully electronic version was launched a few years ago but doesn't seem to have had the same appeal.

You will see from the diagram that there is an erase head at the end of the line of playback heads. This is necessary to wipe the tape after each revolution to stop noise building up.

A well known modification for this type of machine involved putting a switch in series with the erase head to disconnect it, allowing the recorded sounds to continuously circulate on the tape loop. However, unless care was taken when turning the head on and off, clicks and other noise were also introduced onto the tape.

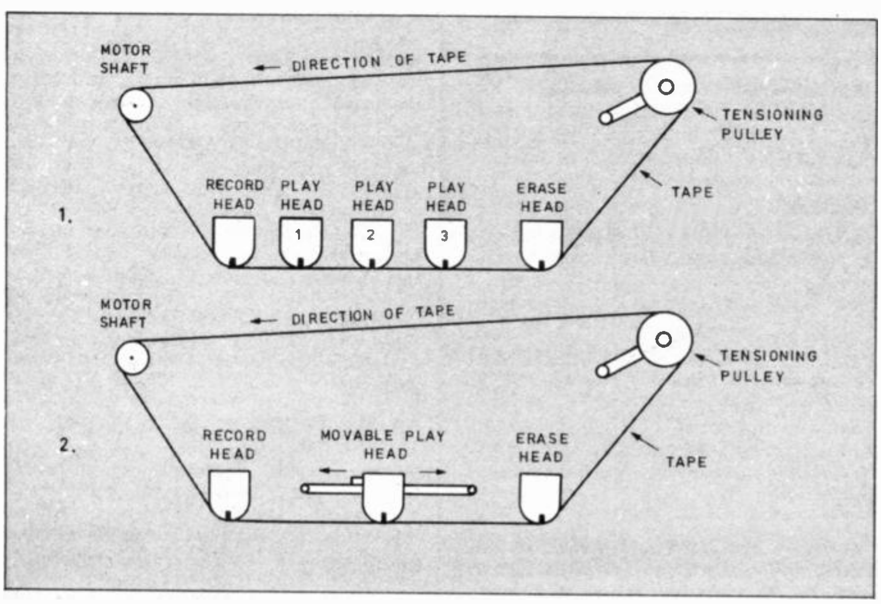


Fig. 1. Set-up for a typical tape echo machine, still very popular today, using fixed playback heads (1) and movable head (2).

ELECTRONIC DELAYS

Because of the drawbacks involved with tape delay machines, like poor reliability and relatively low signal quality, most delay units these days are purely electronic. There are two main types of electronic delay line: *Analogue* and *Digital*.

Bucket Brigade

Analogue delay lines use hundreds of minute capacitors etched onto an i.c. to store amounts of charge relating to an input signal. These delay lines are sometimes called "Bucket Brigade Delays" or BBDs because of the way signals are passed along them.

Analogue delay lines are still quite widely used, but are limited to the production of relatively short delays – no more than 50ms or so – because of the noise and distortion they tend to introduce. They are mostly used for producing modulated effects such as "chorus" and "flanging" which only require a few milliseconds of delay.

Digital Numbers

Digital delays work by converting incoming audio signals into digital numbers, which are stored in a memory and then fed out and converted back into audio.

Because the audio information is stored in digital form, there is no noticeable degradation of signal quality as it passes through the delay. This allows long high quality delays to be produced realistically.

Even though the cost of purely electronic delays has come down to reasonable levels, building a complete digital delay unit from scratch is quite an undertaking, especially if you only want something to mess about and experiment with. Fortunately for the home constructor, there are several self-contained digital delay systems available in single chip form, which only require a few extra components to get them up and running.

The main chip in this project is an HT8955 digital signal processor, which can be used in conjunction with a 64K or 256K DRAM to produce maximum audio delay times of 200ms and 800ms respectively. The signal quality produced by the HT8955 is remarkably good considering that it only has 10-bit A/D – D/A conversion. (Professional audio digitising usually has at least 16-bit definition, and it is becoming more common to see 32-bit systems).

What makes the chip worth looking at is its price – around £5 – which is nothing when you consider that the average 8-bit A/D converter chip costs more than this on its own, and the HT8955 has all the converters, timing circuitry, control logic and filters built-in.

If you are after a simple digital delay to run your guitar or keyboard through, and you're not too bothered about stunning noise performance, this project is for you.

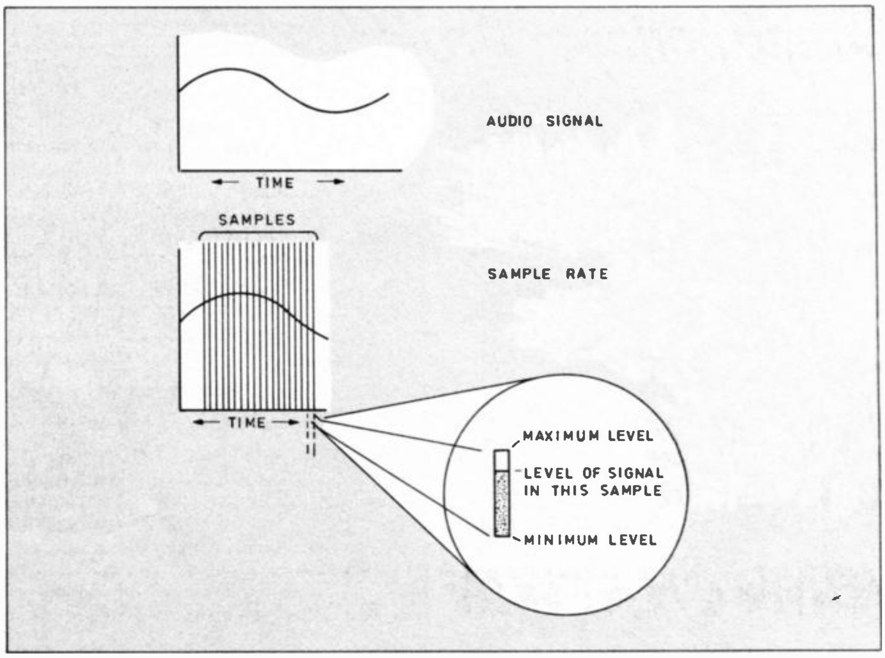


Fig. 3. The sample rate of the converter determines the accuracy.

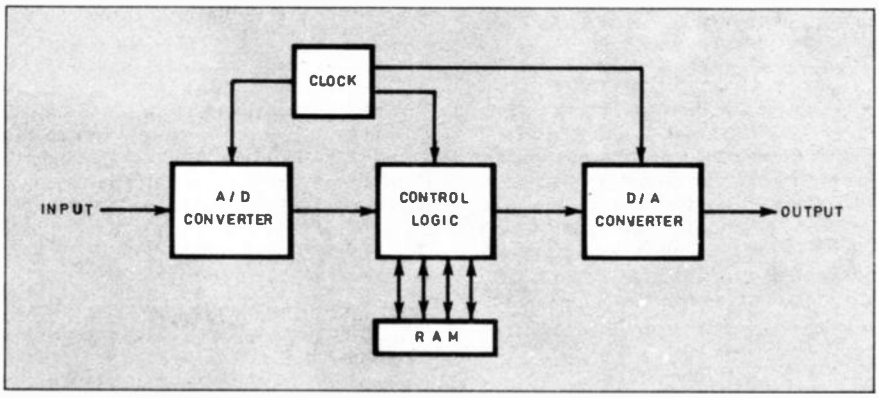


Fig. 2. Block diagram for the Digital Delay Line

DIGITAL DELAY

If you look at the block diagram shown in Fig. 2 you can see how a basic digital delay system works. Signals coming to the input are first passed through an analogue-to-digital converter (ADC). This circuitry takes a sample of the signal level at regular intervals and converts it into a digital number.

The accuracy of the converter depends on the number of bits it has available to convert the signal, see Fig. 3. In an 8-bit system the level of the signal could correspond to any number between 0 and 255 (11111111 in binary = 255). A 16-bit system gives far greater resolution with any given sample converted into a binary number between 0 and 65535.

The rate at which samples are taken is also important and it is generally considered that for accurate digitisation, the sample rate should be at least twice the maximum frequency to be handled by the system. For audio signal processing, which would deal with frequencies up to about 20kHz, the sample rate should be at least 40kHz. – That is, 40,000 samples taken every second.

In the real world, sample rates that are much lower will give acceptable results. Sampling is also complicated by the fact that high frequency signals are more difficult to "track" accurately than low frequency ones, so a sample and hold circuit is needed to keep the input to the converter at a steady level for the duration of the sample.

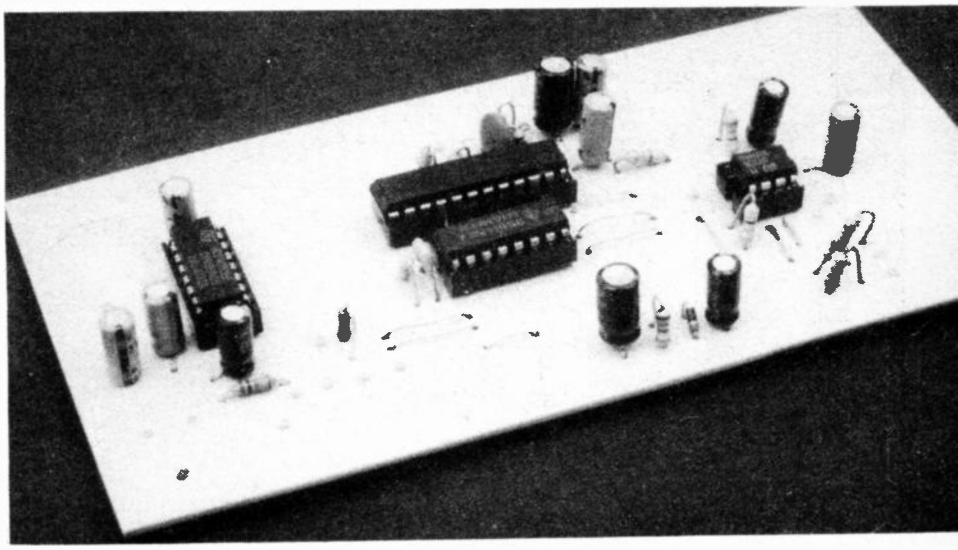
From the A/D converter, the digital numbers relating to each sample are fed into some form of memory, usually RAM. In the case of the 8955 processor, the converters use a form of pulse code modulation, which is a less common conversion method, but only requires a memory that is one bit wide. In a more conventional system the numbers would be fed into each address in blocks of 8-bits (or 16-bits in a 16-bit system, 32-bits in a 32-bit system etc).

When the delay line is working, the control circuitry takes each sample and loads it into an address in the memory. When the memory is full, it goes back to the first address and starts again.

Before each address is loaded, however, the information already stored is read out to the D/A converter which outputs a corresponding analogue signal. In this way a delay is produced that relates to the size of the memory, and the rate at which it is filled. The whole system is synchronised to ensure that the A/D, D/A converters, memory addressing and control logic all work together.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Digital Delay Line is shown in Fig. 4. The



operation is quite straightforward as most of the work is done by IC2, the 8955 processor.

Audio input signals at socket SK1 are fed, via capacitor C1, to IC4 which is a 4053 three-pole two-way bidirectional switch. This i.c. is wired as an electronically controlled double-pole double-throw (d.p.d.t.) by-pass switch that routes the input signals to the delay circuit, or straight to the output, depending on how the Effects switch S2 is set.

With switch S2 closed, signals pass to the input of IC1a and on to the delay circuit. When S2 is open, the input signals are fed directly to the output via capacitor C16. An l.e.d. D1 is wired to S2 via a current limiting resistor (R13) so that it lights to indicate when the delay is connected. If you don't want to bother with this by-pass arrangement, you can simply take an output from the negative side of capacitor C11, and input signals via the negative side of C2.

DELAY

When the delay is in circuit, signals pass from IC4 to the input pre-amplifier formed around IC1a. This is half of a TL072 dual low-noise op.amp. Any general purpose op.amp could be used here, but a low noise example is recommended as the noise performance of the 8955 is not wonderful, and anything that can be done to reduce noise levels throughout the system is worthwhile.

Wired as a conventional inverting amplifier, IC1a has its gain set by VR1. Potentiometer VR1 acts as the Input Level control and can be used to trim the input to accept both high and low level signals. This makes the circuit usable with virtually any electronic instrument or mic.

Capacitor C4 is connected across the feedback path of IC1a to get rid of any high frequency noise that may appear. Resistor R4 acts as an "end stop" for VR1.

From IC1a output, pin 7, the signals pass into the main signal processor IC2, via capacitor C5. You can see from the internal block schematic diagram of the 8955 shown in Fig. 5, that the i.c. has its own on-board pre-amp., and if absolute simplicity is required, signals could be inputted directly to pin 2 without the need for the external preamplifier.

However, it was found that the addition of IC1a made the circuit a little more versatile and controllable. Once inside the 8955, the audio signal is digitised by the A/D converter and fed into the connected RAM, IC3.

As mentioned earlier, the 8955 (IC2) can be used with either a 4164 64K DRAM i.c. which gives a maximum 200ms delay, or a 256K 41256 i.c. which gives 800ms. Both these memory chips have the same pinouts and can be swapped for one another.

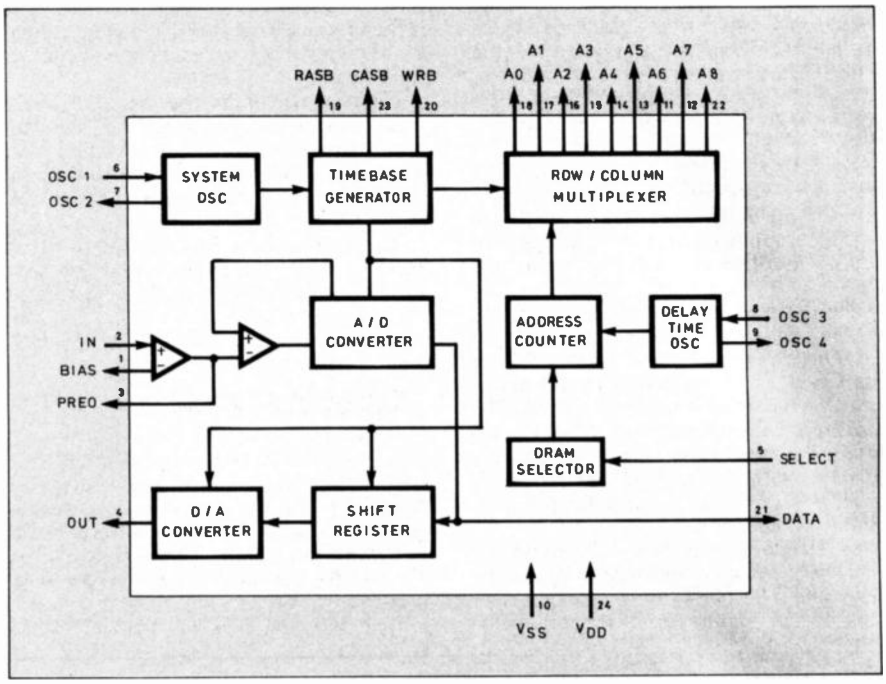


Fig. 5. Internal structure of the 8955 digital signal delay processor.

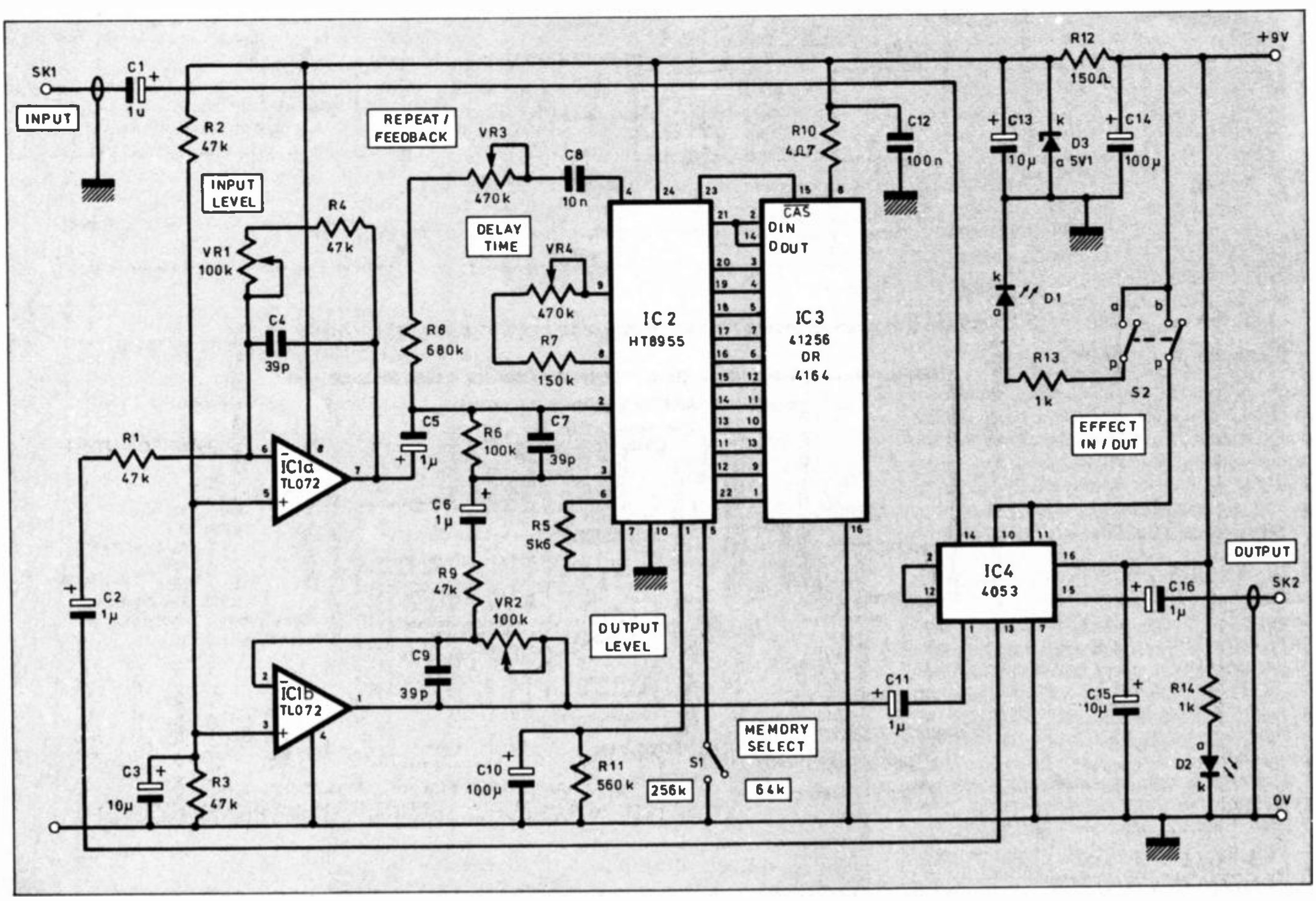


Fig. 4. Complete circuit diagram for the Digital Delay Line.

The only adjustment that needs to be made to the circuit is the logic state of pin 5 on IC2. For the 4164, pin 5 should be left open. If you are using the larger 41256 you need to connect pin 5 to "ground" (0V).

The 8955, IC2, has two internal oscillators. One controls the sample rate, and the other controls the timing and synchronisation circuits for reading and writing information to and from the memory.

The delay time oscillator is controlled by the resistance between pin 8 and pin 9. Potentiometer VR4 and resistor R7 are connected, in series, across pins 8 and 9 to allow the delay time to be varied. The resistance between pins 6 and 7 (R5) controls the sampling rate. If you want to experiment with the frequency of this oscillator, you can swap resistor R5 for a 10 kilohm potentiometer.

To enable repeat echo effects to be produced, some of the output from the delay line (IC2 pin 4) must be channelled back to the input, pin 2. Potentiometer VR3 acts as a Repeat or Feedback control by allowing more or less of the output to be fed back.

Resistor R8 limits the action of VR3 and reduces the possibility of runaway feedback when the control is fully open. The value of R8 is not critical and can be adjusted to give any maximum feedback level you may require.

The output from the delay line is taken from pin 3 of IC2. From here it is passed to an output buffer IC1b, formed around the remaining half of the TL072. The gain of this stage is controlled by VR2 which acts as an Output Level control.

POWER ON

Because IC2 and IC3 require a 5V supply, resistor R12 and Zener diode D3 are connected to drop the 9V supply down to a suitable level. The circuit is intended to be powered by a PP3 type battery, but if a suitable 5V power supply is available, D3 and its associated components can be omitted.

Both IC1 and IC4 will operate over a wide range of voltages. In this case IC1 is connected to the 5V supply, while IC4 runs directly from the 9V rail.

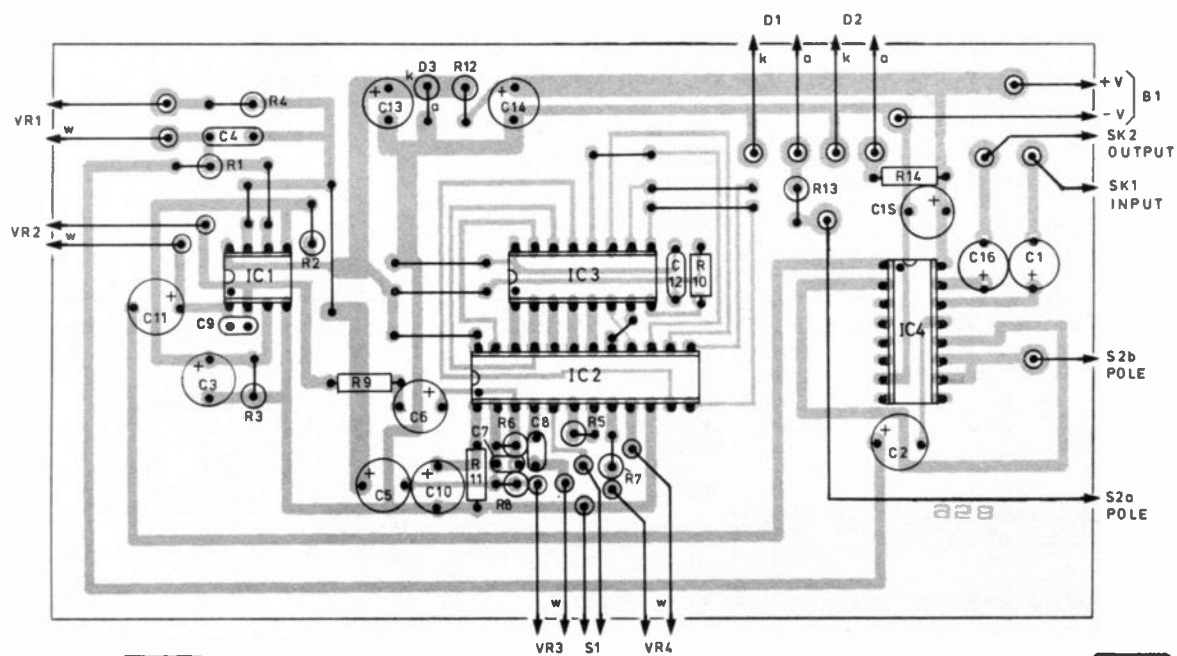
Capacitors C12 to C15 are power supply decoupling capacitors. Light emitting diode D2 and its current limiting resistor R14 form a power supply On indicator. This can be omitted if not required.

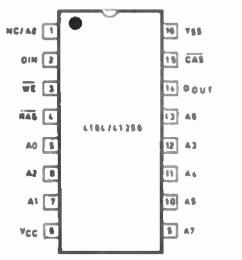
CONSTRUCTION

If you use the p.c.b. pattern shown here, construction should present no serious problems, as the layout is reasonably well spaced out. The printed circuit board (p.c.b.) topside component layout and full size copper foil master pattern are shown in Fig. 6. This board is available from the *EPE PCB Service*, code 958.

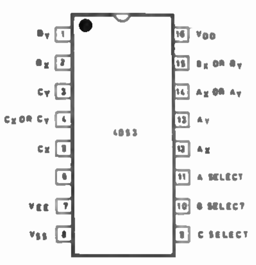
When assembling the p.c.b., remember to connect all the wire links. These should be soldered in first along with the i.c. sockets. This should be followed by the resistors, diodes and capacitors. Pay careful attention to the polarities of the diodes and electrolytic capacitors.

You might have difficulty getting hold





DRAM



3-POLE 2-WAY ELECTRONIC SWITCH

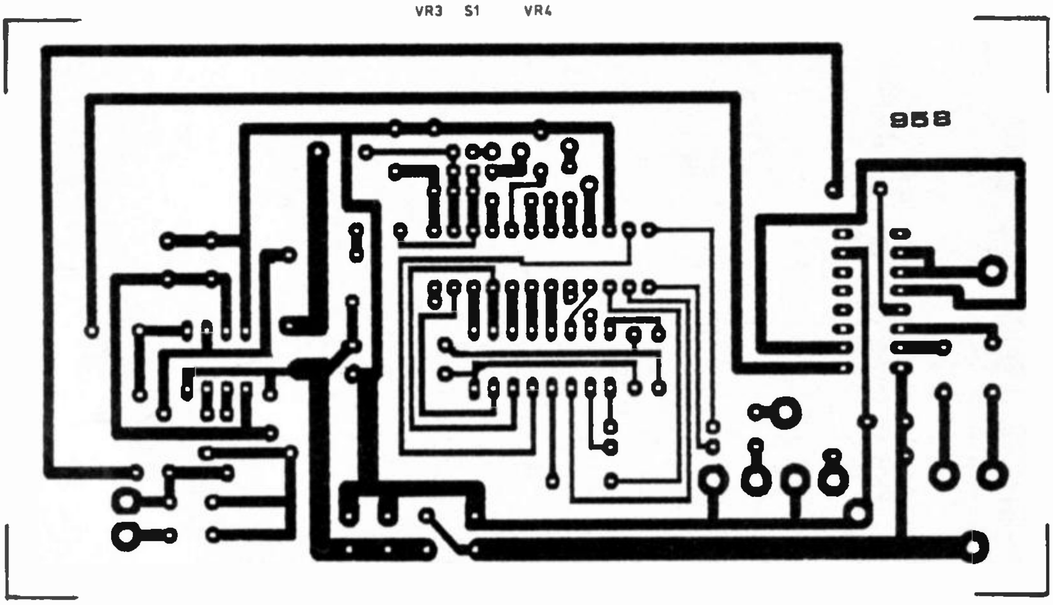


Fig. 6. Printed circuit board component layout and full size copper foil master pattern for the Digital Delay Line. Note the tiny link between IC2 pin 17 and IC3 pin 7.

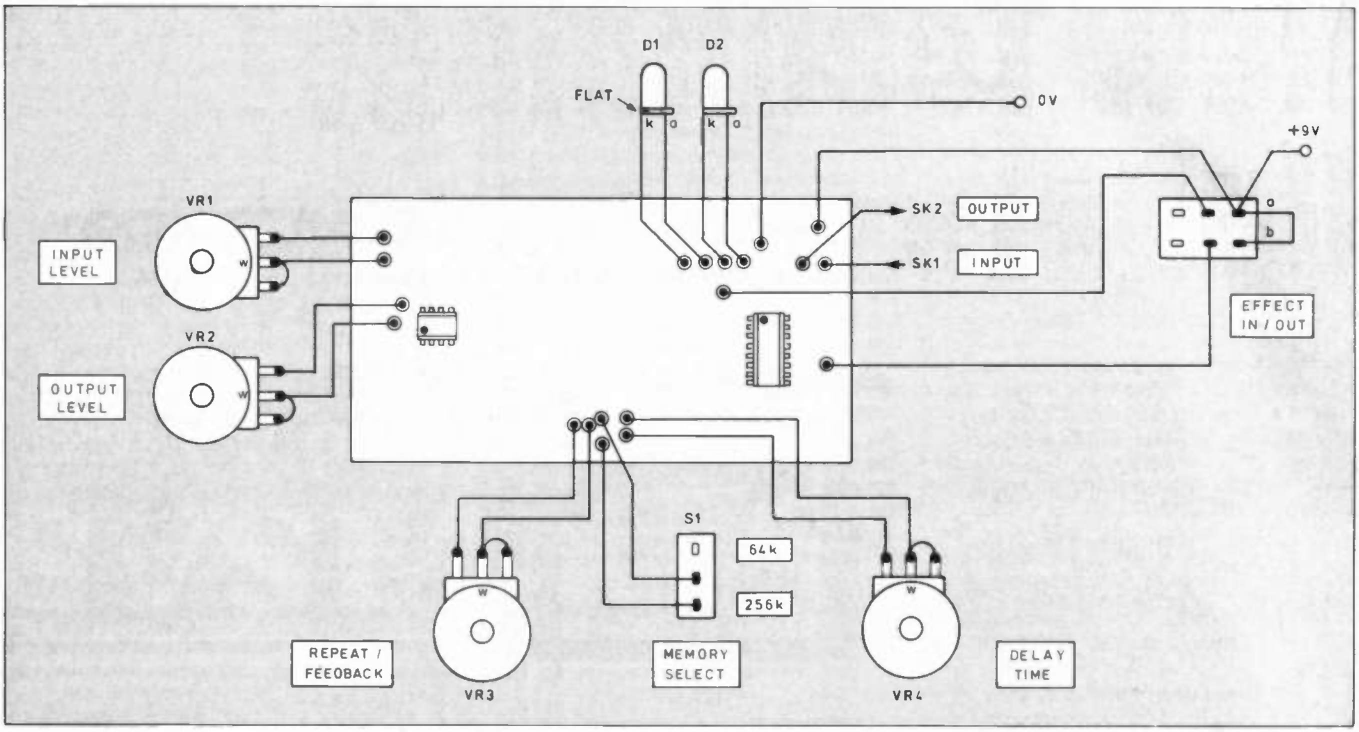
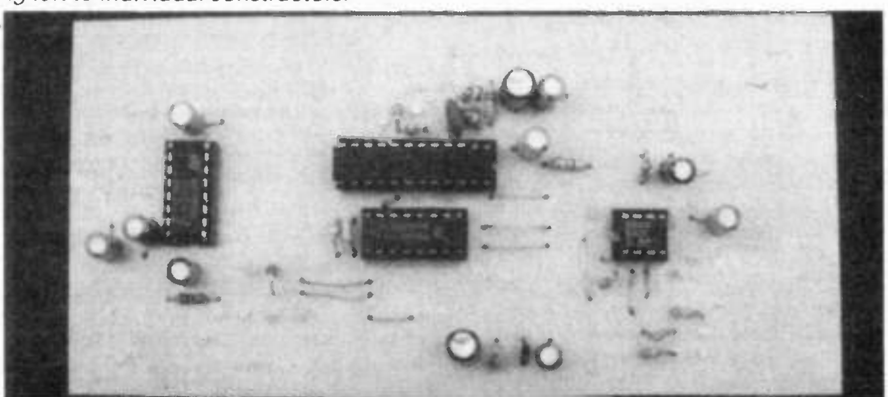


Fig. 7. Interwiring details from the p.c.b. to the off-board components. The completed circuit board is shown below and should be housed in a metal case – size and type being left to individual constructors.

of a suitable socket for the IC2, as most stockists only seemed to have 24-pin in wide format. This is no problem really, as you can easily use three 8-pin sockets mounted side by side. If you do this, you may have to file down the ends of the middle socket a little to make it fit onto the p.c.b.

All the off-board connections to the p.c.b. are shown in Fig. 7 and, to keep noise levels low, these should be as short as possible. It's a good idea to "earth" the control potentiometer cases to a central point, and take any screening earths from this same point.



COMPONENTS

Approx cost guidance only **£30** *excluding case & batt.*

Resistors

R1, R2, R3, R4, R9	47k (5 off)
R5	5k6
R6	100k
R7	150k
R8	680k
R10	4Ω7
R11	560k
R12	150Ω
R13, R14	1k (2 off)

All 0·25 W 5% carbon film

See SHOP TALK Page

Potentiometers

VR1, VR2	100k rotary carbon, lin. (2 off)
VR3, VR4	470k rotary carbon, lin. (2 off)

Capacitors

C1, C2, C5, C6, C11, C16	1µ radial elect. 16V (6 off)
C3, C13, C15	10µ radial elect. 16V (3 off)
C4, C7, C9	39p ceramic (3 off)
C8	10n ceramic
C10, C14	100µ radial elect. 16V (2 off)
C12	100n polyester

Semiconductors

D1, D2	3mm red l.e.d. (2 off)
D3	BZY88 5·1V Zener diode
IC1	TL072 dual low-noise op.amp
IC2	HT8955 CMOS digital audio signal delay processor
IC3	41256 (256K) or 4164 (64K) Dynamic Random Access Memory (DRAM)
IC4	4053BEY 3-pole 2-way bidirectional switch

Miscellaneous

SK1, SK2	mono jack socket (2 off)
S1	min. s.p.s.t. toggle switch (optional)
S2	min. d.p.d.t. toggle switch
B1	9V battery (PP3), with clips or "battery eliminator" type power supply (see text)

Printed circuit board available from the *EPE PCB Service*, code 958; metal case, size to choice; 8-pin d.i.l. socket; 16-pin d.i.l. socket (2 off); 24-pin d.i.l. socket – see text; control knob (4 off); l.e.d. clips (2 sets); multistrand connecting wire; solder pins; solder etc.

If you are going to mount the Delay in a metal case – which is a good idea, as it can be earthed to provide highly effective screening – you can bolt a large solder tag inside to act as the main "earth" (0V) point.

TESTING

When testing the Digital Delay Line start off with all the controls set to minimum and connect it up to a suitable instrument and amplifier. If you have a crystal earpiece, you could use this instead, to monitor the output of the circuit.

Switching S2 on and off should cause l.e.d. D1 to light. With the l.e.d. on, gradually turn up the Output Level control VR2. If you can hear a certain amount of background noise coming from the delay line this means that it should be working OK.

Next, gradually turn up the Input Level control (VR1) until you can hear a signal, then play about with the settings of VR4 and VR3 to check that the Delay time and feedback controls are working. Be careful with VR3, as it is liable to cause "shrieking feedback" to set in if you push it too far with a large input.

When everything is checked out you can adjust the input and output level controls to get the lowest levels of noise and distortion. □

New Technology Update

Ian Poole looks at the effects surface-mount technology is having on today's electronic production. He also finds that passive components have undergone radical changes.

SURFACE mount technology is well established now. To prove this one only has to look inside a new television, video, computer or any other piece of high technology electronics. While conventional leaded components are still widely available, and should be for very many years to come, surface mount technology is taking over much more of today's electronic production.

Surface mount technology offers many advantages. Initially it was introduced to enable components to be "picked and placed" more easily using machines. Leaded components are not at all easy to place automatically. Their leads have to be bent exactly to shape, and even then they are likely to miss the holes slightly and cause the assembly line to stop.

The leadless surface mount components are much easier to place. Being rectangular and having metallised ends, as seen in Fig. 1, they only need to be placed onto the pads on the board. Even then they can be slightly out of position. When they are soldered the surface tension of the melted solder pulls them back into position.

Another advantage is obviously size. Anyone looking at today's surface mount components will see that they are much smaller. As they do not have leads to be attached at either end it is possible to make components very much smaller.

As the "legs" of i.c.s are not mounted through holes in the boards, but are placed down onto pads, the leads can be much closer together. Standard logic i.c.s are often in "SO" or small outline packages and have double the lead density of the d.i.l. packs.

Other more complicated i.c.s can have higher lead densities. One package called a quad flat pack can have leads spaced every 20 thou. These packages often have 96 or more pins.

Naturally, these packages have to be handled very carefully as once the pins are bent it is virtually impossible to get them back into place. This can easily ruin a very expensive i.c., even though it may be perfectly functional inside.

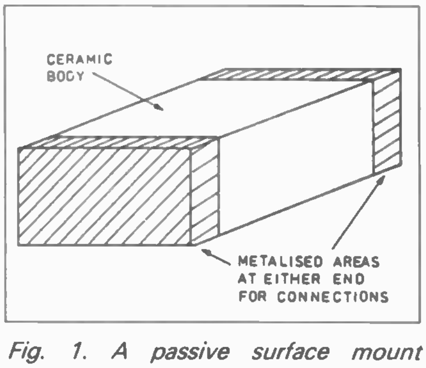


Fig. 1. A passive surface mount component.

Table 1: Standard Outlines for SMD Components

Type	Size (mm)	Typical Power Dissipation (Resistors Only)
0402	1·0 × 0·5	
0603	1·6 × 0·8	0·0625
0805	2·0 × 1·25	0·0625
1206	3·2 × 1·6	0·125
1210	3·2 × 2·5	0·425
1812	4·5 × 3·2	
2010	5·0 × 2·5	0·500
2220	5·7 × 5·0	
2225	5·7 × 6·3	
2512	6·3 × 3·1	1·000

Even Smaller

While i.c.s have been the focus of a lot of attention, passive components have by no means been left out in the cold. They have been steadily reduced in size.

Initially, components in 1206 and 1210 packages (see Table 1 for their sizes) were widely used. Now the 0805 package is the most popular, and it is expected to retain this position for a couple of years.

However, smaller packages are starting to be used. The 0603 one is already well established and many new products are using it.

Further into the future it is anticipated that passive components will be in an 0402 package (1·0mm × 0·5mm). Industry forecasts anticipate that this will become the standard size after the turn of the century.

It is also forecast that it will remain a standard for longer than the other styles, since gains in space and cost will be very small with even smaller packages.

They will naturally be very difficult to handle and on top of this it will be very difficult to manufacture components cheaply in packages this small. For capacitors it may be physically impossible to put large values into these packages.

Resistors also are not exempt from restrictions. The smaller the packages the smaller the power dissipation capability.

The familiar leaded resistors usually have a power dissipation of a quarter of a watt. 1206 resistors are usually specified at an eighth of a watt and 0805s can usually dissipate only a sixteenth of a watt.

Even smaller resistors will dissipate smaller amounts. Even with the trend to 3V logic and much lower power dissipations, resistors below 0402 sizes may not be man enough for the job.

Passive Development

Shortly after equipment started to be built with surface mount components, failures began to be noticed if the board was flexed. It was found that capacitors were particularly sensitive.

Normally leaded components are far more rugged in this respect as they have a certain amount of wire lead between the board and the body of the component to take up the strain. Surface mount components have none and the effects of any movement are far more serious.

Resistors tend to be more resilient as their construction is simpler. Capacitors with an internal construction like that shown in Fig. 2 are more sensitive and crack quite easily. Often the crack is not obvious, but even so it stops the component working.

Manufacturers responded to this problem very quickly. One of the reasons which was reported as being a cause was that the technology was relatively new and manufacturers were trying to put too much into the very small packages. As a result of this, many design engineers never use values at the extreme of a range of components. To overcome the problems the manufacturers developed new thinner dielectrics which enabled more resilient components to be made.

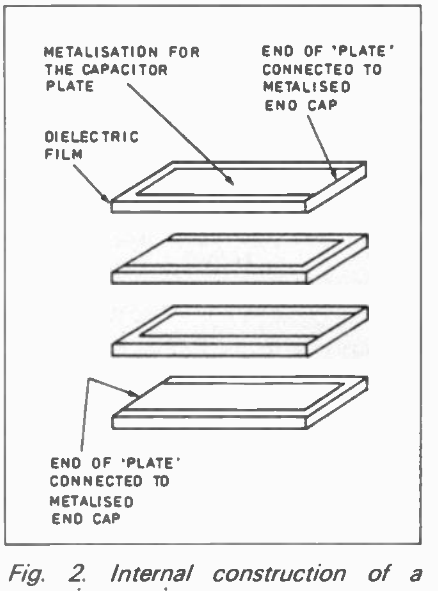


Fig. 2. Internal construction of a ceramic capacitor.

Pick and Place

Another reason for the failures was found to be the early pick and place machines used for placing the components onto the boards. These were very harsh when they put the components down onto the boards.

Now these machines are far more sophisticated. They treat the components much more carefully, and as a result of this and the improvements in component technology the number of failures are very much reduced.

General Reliability

Nowadays electronic equipment is far more reliable than it used to be. One of the reasons is the improved assembly methods which are now used.

Pick and place machines are now capable of placing components reliably to within a few thou. of the correct positions. Often automated optical monitoring systems are used to implement this – just one of the many developments introduced on these very complicated machines.

To demonstrate the reliability, one only has to look at a modern day PC or television. These fail comparatively infrequently and this is a major achievement when one considers the amount of circuitry inside them.

Compare one of today's colour televisions complete with teletext, NICAM sound and all the latest state of the art circuitry to the much simpler televisions of the sixties. Today's sets are expected to last for at least seven or eight years without failure. Even fifteen years ago this would not have been possible.

Manufacturing Methods

The methods used by equipment manufacturers in general also help in the reduction of failures. Boards should not be passed through processes where they are subject to bending stresses.

Often boards come in with a "biscuit" around their edge. This is to enable them to be handled more easily at various stages in manufacturing. However, when they are broken out of the biscuit this can cause bending of the loaded board with components. Obviously, this is an area where improved care is needed.

With some major improvements and many more minor ones today's electronic equipment has become very reliable. Much of this is due to new manufacturing techniques including the use of surface mount technology.

Ohm Sweet Ohm

Max Fidling

Breakfast Feast

Having scoffed my breakfast with my usual zeal, Piddles too having munched a bowlful of cat food noisily, the early morning "clank" from the front door told me that the post had just arrived. I skipped over to see what loot had arrived for me today.

Aha! A familiar brown padded bag resting on the mat told me that my latest consignment of electronic bits had landed. I opened the bag with a flourish to reveal a treasure trove of glittering goodies, nestling within a variety of polythene bags.

Sweeping my breakfast utensils to one side, I tipped the parts onto the kitchen table and started to sift through them, checking them off methodically against the paperwork to ensure that all was present and correct, and trying to prevent them falling into a few errant blobs of sticky marmalade. Ultrabright light emitting diodes – a new handyman's knife – a few bulb holders with 6V bulbs – a piezo sounder and a length of zip wire, a strange assortment, you might think!

But there was method in my madness! You see, a few days earlier I had been flicking through my diary and had spotted that the dreaded Halloween was fast approaching. In previous years the Fidling household had had its fair share of these young *Trick or Treat?* visitors, replete in their plastic capes, pointed hats and masks, accompanied by the veiled threat that if I didn't cough up some of my hard earned cash, various unmentionable curses, hexes and generally nasty things might happen! This time, though, I had hatched an elaborate plan. I intended to wreak revenge with a jolly jape!

Pumpkin Head

An acquaintance of mine at the local horticultural society took great pride in growing the most enormous vegetables, and I had therefore reserved an awesome pumpkin specially for this October occult event. I collected it that same day in my wheelbarrow and trundled it round to the workshop. Then I set about it with my newly-delivered handicraft knife, opening up the pumpkin and scooping out the middle. (The Boss used the middle bit to make some plumptious pumpkin pie.)

Humming to myself, I scraped the pumpkin out until only the shell remained, chopping out the eyes, mouth and nose using skilful scalpel movements, like a famous plastic surgeon creating a new personality. A few offcuts fell to the floor and Piddles, nearby, wandered over and nosed them inquisitively.

Soon the features of a pumpkin mask materiaiised – Hammer Horror Films would have nothing on this, if my scheme went according to plan, I mused, as I hacked and shaped the bulbous vegetable.

The electronics content had been assembled earlier using the motley variety of parts delivered early that morning. A sound effect generator reminiscent of a screeching vampire bat (a beast common in my neighbourhood, speaking from experience) was included for good measure – hence the piezo sounder – and this also flashed several ultra-bright l.e.d.s. in the gaping toothy mouth of the pumpkin.

Not content with that, I had built a lamp flasher using a 555 astable driven from a 9V battery which powered a couple of 6V bulbs. The lamps were positioned behind the eyes of the pumpkin and a quick test confirmed that they blazed with a Xenon-like quality, guaranteed to put the wind up anyone!

For good measure I included a simple musical tone generator, though the fact that this melody circuit played "The Yellow Rose of Texas" was neither here nor there. Piddles, rummaging around in the workshop, duly ignored all the commotion as usual.

In order to power the vampire vegetable, I arranged for a generous length of zip wire to trail out of the pumpkin and I connected this to an external battery connector for a test. By snapping the battery onto it at the appropriate moment, the pumpkin burst into its spine-tingling repertoire of blinding flashing lights and screeching!

Surprise Witness

With a flash of inspiration I worked out a way of hanging the petrifying pumpkin in the front porchway, and furthermore I managed to hook the various electronic effects into the doorbell's mains transformer nearby, dispensing with the need for a battery. Pushing the doorbell activated a monostable timer which powered up the pumpkin – and Hey Presto, I was in business! By now it was early evening and duly elated, I installed the veggie in the porch where it swung from the ceiling menacingly.

All went well until the next morning, a Sunday. I heard the doorbell ring and – you guessed – my new brainchild sprang into life, playing "The Yellow Rose" tunefully, screeching and flashing its features in a manic manner. Then I heard a commotion outside, and the letterbox flap clanged as someone hastily pushed something through before retreating very hastily back up the path.

Oh, dear! I wasn't sure who the visitors were to begin with, but I can imagine the look on their faces as they quickly stuffed a copy of *The Watchtower* through my letterbox and fled followed by a petrified Piddles!

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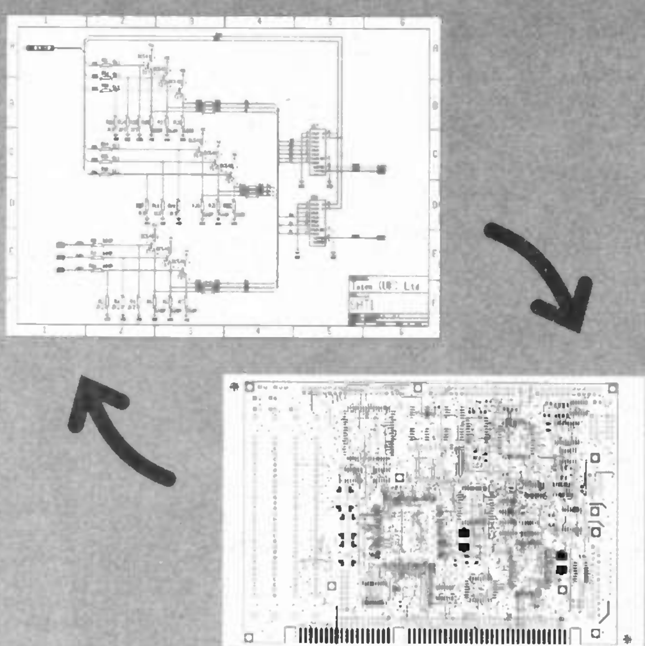

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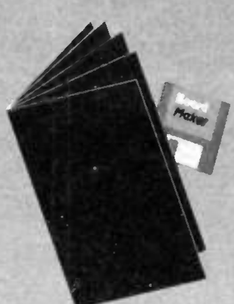

For futher information contact
Tsien (UK) Limited
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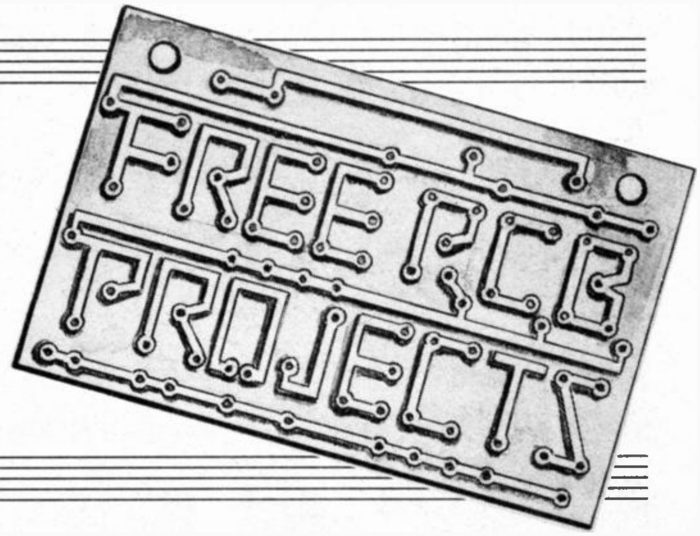
Cambridge, PE16 6UT
Tel 01354 695959
Fax 01354 695957
E-mail Sales@tsien.demon.co.uk

tsien

Constructional Project



VIDEO ENHANCER

ROBERT PENFOLD

Boost your home video pictures with this low-cost, easy-to-build enhancer. Another simple project for last month's FREE Multi-Project PCB.

THE BOOM in camcorder sales has been accompanied by a similar growth in the range of video accessories on offer. Many of these are quite complex and expensive devices, but there are some very simple but useful video accessories that can be home constructed at low cost. The video accessory featured here is a basic enhancer, or "crispener" as they are also known in video circles.

Camcorders have steadily improved over the years, but most still lack the bandwidth needed for true broadcast standard quality. In fact it is only some of the hi-band models that offer something close to real broadcast quality recordings.

There is no simple add-on that will genuinely convert a low cost camcorder into a top-notch professional recorder. However, a simple enhancer can give what are subjectively deemed to be much sharper results.

FINE DETAIL

Video Enhancers operate by applying some high frequency boost to the processed signal. The more complex types only provide boost to parts of the signal that will benefit from it, and these are roughly equivalent to a "dynamic noise limiter" used on an audio signal.

Applying this selective boost to a high frequency video signal is much more involved than equivalent processing of an audio signal. The Video Enhancer described here therefore uses the simple alternative of a fixed amount of high frequency boost. In audio terms, it provides the same function as a simple tone control, and it is the video equivalent of an audio treble booster.

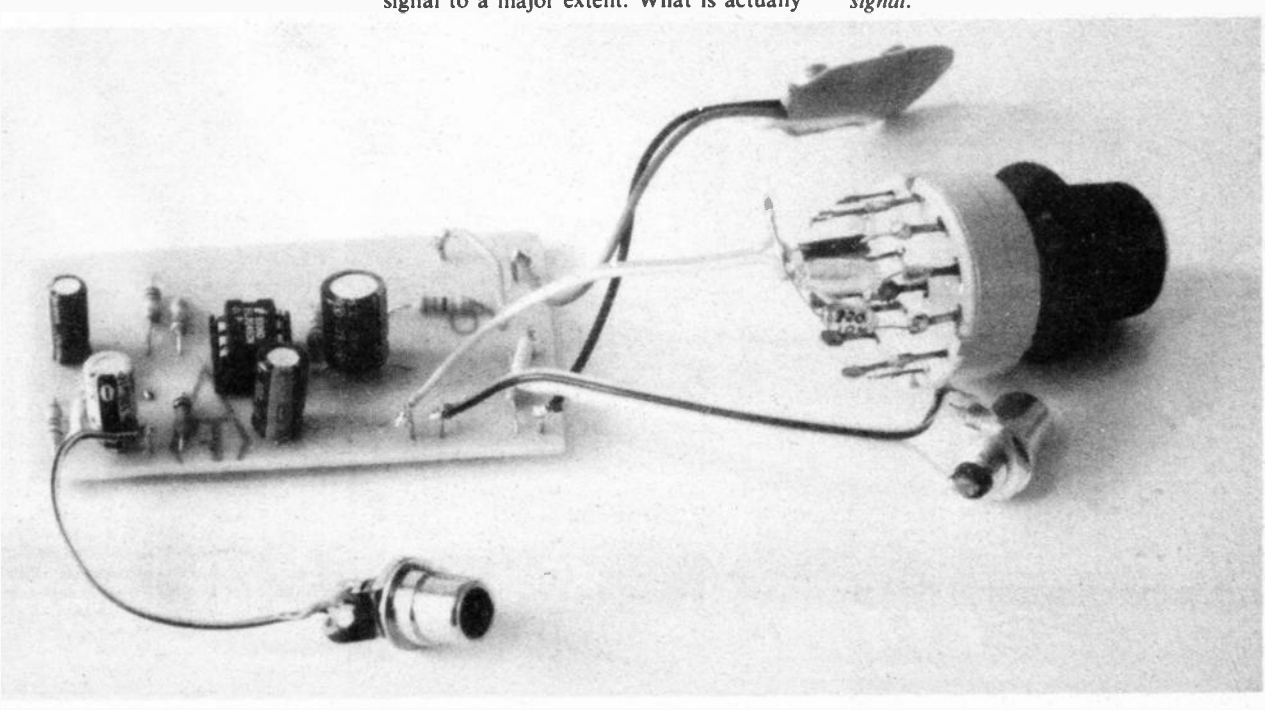
Adding some high frequency boost does not actually increase the bandwidth of the signal to a major extent. What is actually happening is that the contrast of the picture is boosted somewhat, particularly in areas where there is a lot of fine detail.

This increased contrast is perceived by viewers as an increase in the picture's definition. In reality the picture is not actually any sharper, as viewing the screen at close range will soon reveal. At normal viewing distance though, the illusion is maintained, and the picture appears to be significantly "crisper".

Exactly where and when it is best to use a video enhancer is a contentious issue. It is certainly necessary to take care that the enhancer is not used on a recording that has already been enhanced. Some promote the use of an enhancer when making the first copy of a tape.

The more generally accepted way of utilizing an enhancer is to use it between a recorder and a monitor when playing back a tape. This is an entirely safe approach, since it does not involve any doctoring of a recorded signal, and cannot result in any damaged recordings. On the other hand, it means that you cannot "improve" a tape that will be played back by someone who does not possess an enhancer.

Note: This device is only intended for use with a standard PAL composite video signal. It cannot be used to process a ***UHF*** *television signal, or any form of* ***RGB*** *video signal.*



CIRCUIT DESCRIPTION

The full circuit diagram for the Video Enhancer appears in Fig. 1. It is basically just an operational amplifier used in the non-inverting mode, but an ordinary op.amp is unsuitable for use in this particular application.

The amplifier has to deal with signals at frequencies of up to a few megahertz, and two volt or so peak-to-peak. An ordinary op.amp cannot provide the bandwidth required in this application, and does not have a high enough slew-rate either. In other words, it cannot provide the large and rapid changes in output voltage that a video circuit must provide.

These days there are plenty of wide bandwidth operational amplifiers that appear to be well suited to this application, but most of these are current feedback types. These are not easy to use in a circuit such as this, where a capacitor is used to provide frequency selective negative feedback.

The EL2045CN specified for IC1 is one of the few *voltage* feedback operational amplifiers that has the necessary bandwidth, slew-rate, and output current drive for this application. It is perhaps slightly over-specified, with a bandwidth of 100MHz at a voltage gain of two. The full power bandwidth is 4·4MHz and the slew rate is 275 volts per microsecond.

Resistor R1 shunts the input of the amplifier to produce a suitably low input impedance. Resistors R2 and R3 bias the input of the amplifier and capacitor C2 provides d.c. blocking at the input.

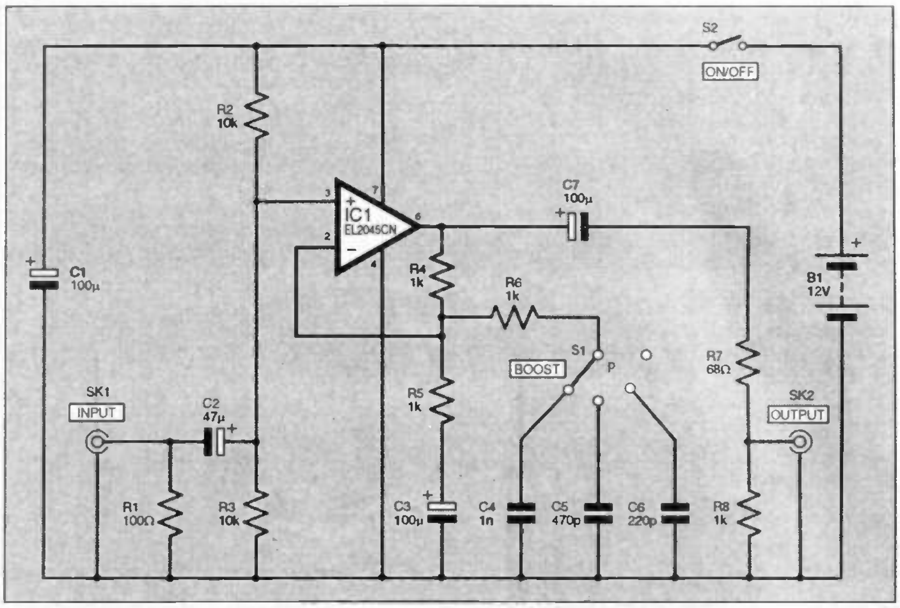


Fig. 1. Complete circuit diagram for the Video Enhancer.

Resistors R4 and R5 are the negative feedback network, and these set the basic closed-loop voltage gain of the circuit at two times.

A voltage gain of unity is required, but the EL2045CN is only guaranteed to provide stable operation at voltage gains of two or more. Resistors R7, R8, and the input impedance of the monitor (or whatever) connected to socket SK2 form an attenuator that gives an overall voltage gain of unity.

FREQUENCY BOOST

The high frequency boost is applied by shunting a small capacitor across resistor R5. This reduces the amount of negative feedback and boosts the gain of the circuit, but only at high frequencies where the impedance of the capacitor is low in comparison to that of R5. Resistor R6 limits the amount of boost at the highest frequencies to a reasonable level.

COMPONENTS

Resistors
- R1 100Ω
- R2, R3 10k (2 off)
- R4, R5, R6, R8 1k (4 off)
- R7 68Ω

All 0·25W 5% carbon film

See SHOP TALK Page

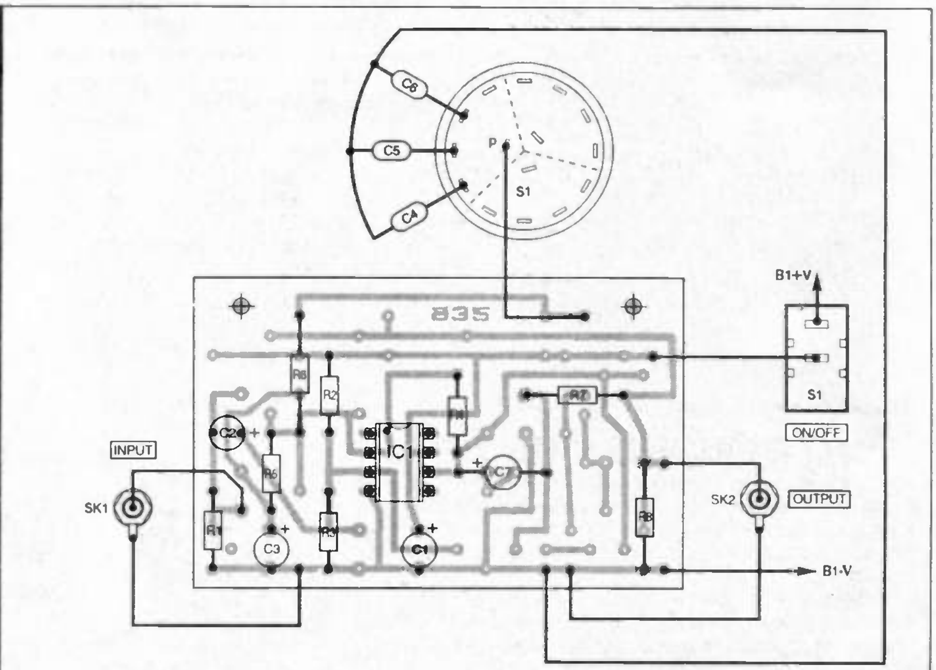
Capacitors
- C1, C3, C7 100µ radial elect. 16V (3 off)
- C2 47µ radial elect. 16V
- C4 1n polyester
- C5 470p polystyrene
- C6 220p polystyrene

Semiconductor
- IC1 EL2045CN low power, wideband video op.amp

Miscellaneous
- SK1, SK2 standard, chassis mounting, phono socket (2 off)
- B1 12V battery pack, (8 × HP7 size cells in holder)
- S1 3-pole 4-way rotary switch (see text)
- S2 s.p.s.t. min.toggle switch

Printed circuit board available from the *EPE PCB Service*, code 932 (or *Free* with last month's issue); aluminium case, size to choice; 8-pin d.i.l. holder; control knob; PP3 type battery clip; multistrand connecting wire; single-sided soldering pins (8 off); solder, etc.

Approx cost guidance only **£14** *excluding Batts.*



Note: None of the projects in the Multi-project PCB series use ALL the copper pads on the board, in most cases more than 50 per cent of the holes are left vacant. This makes it essential to double-check the positioning of each component, before soldering in place.

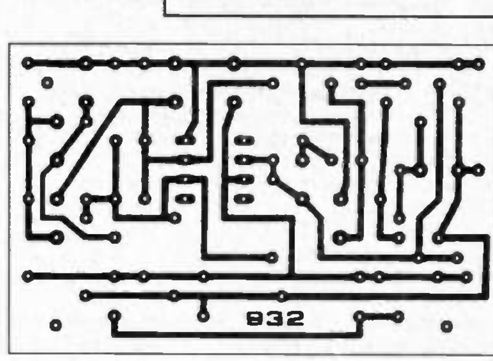


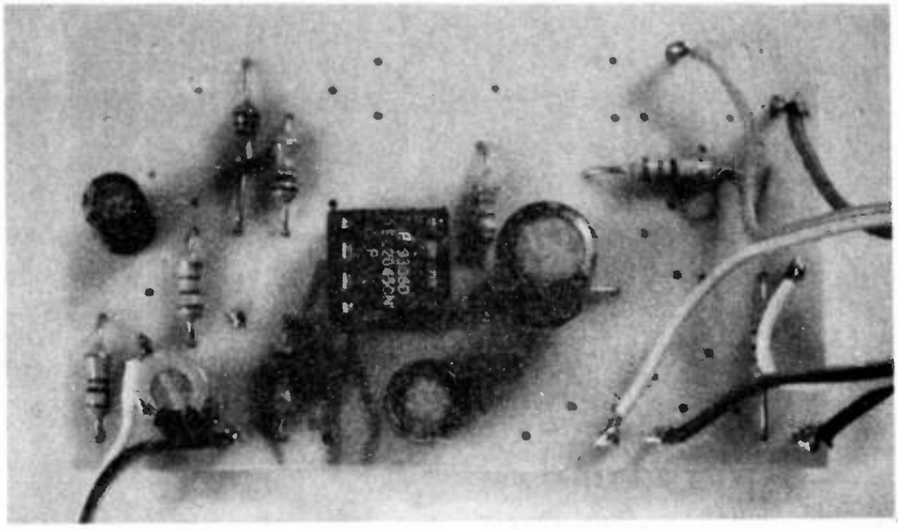
Fig. 2. Printed circuit board component layout, interwiring details and full size copper foil master.

Switch S1 provides three levels of high frequency boost. With capacitor C6 switched into circuit only the highest frequencies receive a significant amount of boost. Using C5 boosts a somewhat wider range of frequencies and C4 boosts a much wider frequency range.

The wider the frequency band that is boosted, the stronger the effect provided by the Enhancer. The fourth position of S1 provides a flat frequency response, and provides a quick and easy way of removing the high frequency boost.

There is a slight flaw in this simple form of enhancer. It boosts both the picture modulation and the synchronisation signal. However, the degree of boost is limited to a point that does not seriously distort the synchronisation signals. The unit should not, therefore, affect picture stability even when set for maximum boost.

Although the EL2045CN has a very wide bandwidth, its current consumption is not very high. The current consumption of the circuit is only about 6mA, which makes battery operation perfectly practical. Eight HP7 size cells in a holder provide a suitable power source.



CONSTRUCTION

Using the FREE printed circuit board (p.c.b.) from last month's issue should make construction of the Video Enhancer project fairly trouble-free. If, you missed last month's issue you can purchase a back issue (£2.50), or you can obtain extra p.c.b.s from the *EPE PCB Service*, code 932, for the sum of just £3.

The actual size underside printed circuit copper foil pattern, plus the topside component layout and interwiring details are provided in Fig. 2. IC1 is not a static-sensitive component, but it is sufficiently expensive to warrant the use of an i.c. holder. Fit single-sided solder pins to the board at the points where connections to the off-board components will be made.

A standard 3-pole 4-way rotary switch is used for S1, but in this case only one pole is used. Capacitors C4 to C6 are not fitted on the p.c.b., but are instead mounted on the tags of the rotary switch S1. There should be no difficulty mounting them on S1 provided the tags and the ends of the leadout wires are first tinned with solder prior to making the connections.

The input and output connectors are phono sockets, which are now the standard type of connector for use in amateur video equipment. The unit is wired into the video system using ordinary screened phono leads.

TESTING

For initial testing it is best to connect the Video Enhancer between the output of the camcorder and the input of the monitor or television set. The effect of the unit can then be seen immediately.

Enhancement is more obvious with some pictures than with others. Expect little difference at any setting of "boost" switch S1 with a low contrast picture that lacks fine detail. The effect will be readily apparent with any level of boost if the picture has some fine detail that has plenty of contrast. It will even appear to increase sharpness in parts of the picture that contain some fine detail but are slightly out-of-focus.

The best setting for S1 is a matter of personal preference, but if in doubt it is best to settle for less boost rather than more. □

PLODDING ALONG THE ROAD

Motorists beware – the definitive speed trap has arrived!

– by Hazel Cavendish

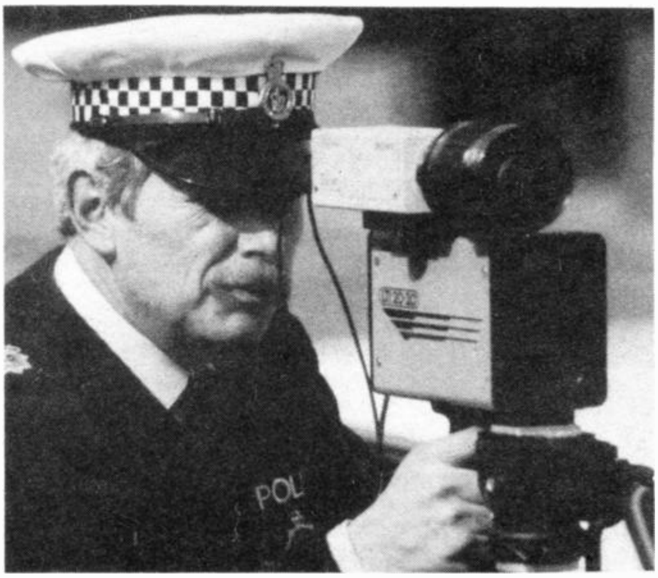
THE fact that lasers are being used successfully to detect speeding motorists is already unpopular with many, but combine them with a powerful Automatic Number Plate Recognition system and a high speed camera, they can possibly do more to halt the slaughter on our roads than anything currently available to the Police.

So what is so new? Police have had radar to trap speeding motorists for over 30 years, and even automatic car number plate recorders are no real novelty. However, now a powerful consortium of leading companies has designed the most scientific electronic trap ever launched against the speeding motorist. It is dramatically effective.

Between them, Thames Valley Police and Kent Constabulary have booked around 37,000 drivers for speeding in the last 12 months, using a hand-held speed detection device which uses the same laser technology as the new system. The new system is able to provide the same success rate as the hand-held version but at a lower running cost. It negates the need for manual operation and is able to reduce the administrative task involved in processing prosecutions.

PC REPLACES PC

If officially approved, the new system will remove the necessity for a policeman to be stationed holding a laser in an obvious spot like a motorway bridge. Instead, pictures of speeding motorists will be taken by remote cameras placed at selected locations varying from day to day, with photos downloaded to a computer network linked to the Police National Computer. The consortium expects it to be available and in place in many police forces early next year.



The hand-held speed detection front end.

The new system has been developed under the umbrella of International Computers Limited, a member of the Fujitsu group – a long-established company which originated in Britain. They claim the laser, camera and computer together can present evidence which supports legal requirements for a police decision, and is able to be used in court if required.

ICL have managed the integration of the technology and together with the other consortium members have been able to overcome the difficulties of integrating cameras, speed measurement equipment and information processing. One major advantage of the system is its modular nature; each element of the system has been proven in a working environment, and that gave the consortium the confidence to press ahead with the integration exercise. A good example of this is the laser equipment which has been provided by Tele-Traffic (UK) Ltd. Their hand-held laser gun has been proved to be a very successful speed detection device by a number of UK police forces. The software, which is written by Roke Manor Research Ltd., can operate independently from the laser and will react to input from a variety of sources. Input can be provided directly from virtually any video camera, ranging from standard camcorders to highly specialised models, depending on the requirements of the customer. Input can also be provided from pre-recorded material so that recognition can be achieved after the event. This also means that the software is able to be used with existing CCTV recording systems.

Captured on camera and computer. The number plate has been obscured deliberately!

TARGET DATA

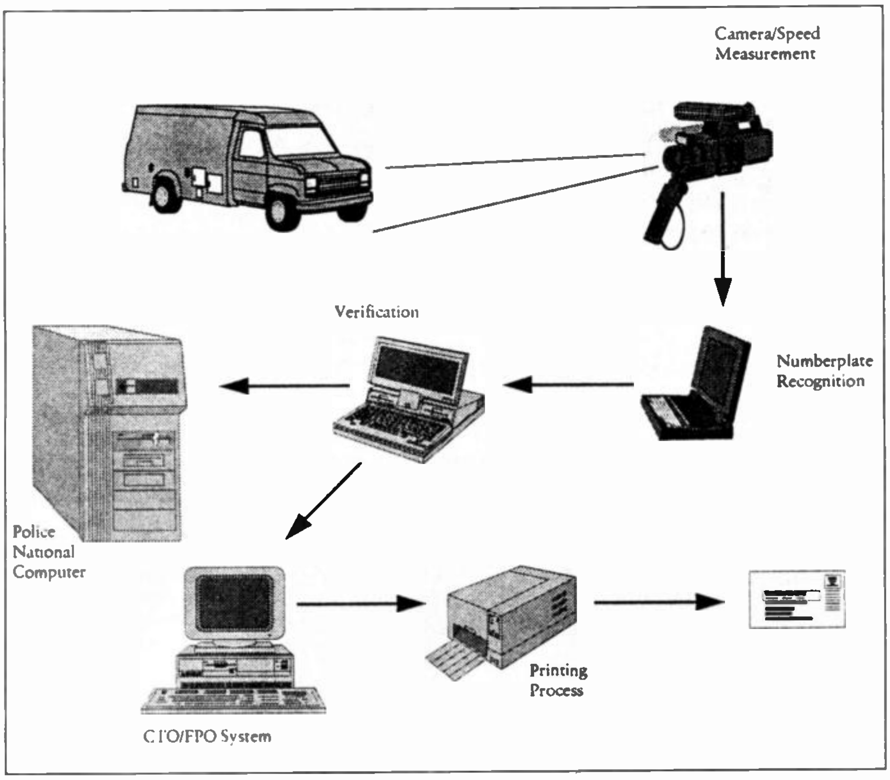
The system constantly monitors traffic in a target lane. From the laser information, the system is capable of making the speed calculation of an individual vehicle in one third of a second. If this speed is recognised as being over the set threshold, then the speed, date and time are recorded, the image of the vehicle is captured and the number plate details extracted. All of this data is then stored on magnetic disk which is located at the roadside. This saved data can be transferred at any time to the fixed penalty office for processing.

At the fixed penalty office, a police officer will view each record to ensure that a prosecution can be made. Additional information, such as keeper/driver, will be provided by a direct interface to the Police National Computer. If all is in order, a comprehensive record of the offence will be passed electronically to the fixed penalty computer. This information will then be processed and a ticket will be printed and sent out.

LAW ABIDING SAFETY

In all of this process, the only human intervention is that of the police officer who views each record. This is a requirement of Law, not the system. If an offence is contested, then the driver can either view the evidence on the computer terminal, or the recorded image can be printed.

Because the new system records images digitally, it will not run out of film and so does not require the manual intervention needed by current systems. It will remove most of the paperwork from a traffic policeman's duties and one policeman in a control room should be able to monitor a number of cameras placed at strategic places where accident statis-



System diagram for the Enforcement process.

tics have revealed the need for stringent measures against speeding.

Peter Gay, Support Manager of Tele-Traffic, with a lifetime's experience as a traffic cop in Warwickshire, vehemently defends the new system which he declares will target the driver who is a menace to society. "I have absolutely no qualms about promoting this new system", he says. "The greater part of my life has been spent dealing with the tragedies caused by speeding." He comments further that the system is very efficient and that those who are repeatedly caught exceeding the speed limit will clock up sufficient penalty points to put them off the road. Tele-Traffic agree with his belief that this new system will provide the police with an essential tool to assist them in their efforts to provide Britain with safer roads.

INFRA-RED LASER

The laser system behind this Draconian measure determines speed by evaluating the time of flight of very short pulses of infra-red light. This method is fundamentally different and inherently superior to the Doppler process used in radar guns, because the target speed is measured directly from the change of position of the target rather than by inference from a Doppler frequency shift. It cannot be fooled by rotating or vibrating objects and can discriminate between approaching and departing targets, and gives an accurate zero speed for stationary targets.

The system uses an infra-red semiconductor laser diode with several important properties which make it the ideal choice for speed measurement. It emits a narrow cone of radiation from a very small area, allowing the light to be collimated into the very narrow beam that gives this laser its pin-point targeting ability. The diode switches on and off extremely quickly – in less than one billionth of a second – giving the laser its superior timing accuracy.

Like all lasers, the diode emits only a very narrow band of frequencies, which allows the detector to be "tuned" to the exact wavelength of the diode, enabling the laser to operate during daytime when there is a lot of background radiation from the sun. (The instrument only "sees" the laser light, all other radiation being filtered out.)

Finally, as the diode emits in the infrared portion of the electromagnetic spectrum, it is invisible to the human eye and cannot be a distraction to drivers. The makers claim that there is no risk of damage to the eye even after three hours of continuous exposure as the output is only one twentieth of the light power of a typical TV remote control.

WALKING BLUES?

Barbara Garratt, a director of Tele-Traffic, was asked what they called the new system. "I'm afraid we just call it the ANPR – the Automatic Number Plate Recognition" she said. "We haven't been able to think of anything better." *(PC PLOD, perhaps - Police Computer Public Laser Offence Detector? Ed.)*

ECO CHARGER

An innovative new battery charger which can extend the life of disposable alkaline batteries, as well as rechargeable NiCad ones, is now available in the UK.

Ideal for hifi and electronics enthusiasts who use battery operated products, the revolutionary Eco Charger has passed all European and British safety standard tests and can help consumers to save money and care for the environment at the same time.

Available in the UK from Contemporary Games plc, the Eco Charger is manufactured by Saitek. It recharges all popular battery sizes and up to four batteries can be inserted at any one time.

This user friendly product has a liquid crystal display which gives at-a-glance information about the condition of each battery being charged, including the time needed for full recharge and the battery life remaining and it has a built in microprocessor to ensure optimum performance.

Substantial savings can be made on the purchase of batteries due to the extended life Eco Charger gives to a disposable battery. If a radio cassette is used for two hours a day for one year, it has been calculated that a family recharging these batteries with the charger could save £53. At the same time damage to the environment will be reduced because less batteries are being dumped in landfill sites.

"This only represents the saving which can be made on one household item " comments Verena Goo of Contemporary Games. "Imagine how much a family could save if they use Eco Charger for all their battery operated appliances."

Eco Charger has a recommended retail price of £39.99 and is currently available through retailers including Harrods, The Gadget Shop and The Leading Edge. For more details contact Contemporary Games on 0181 577 1700.

WHERE IT'S AT

Interlinks '95 exhibition, presented by the Royal Society and the Royal Academy of Engineering. Shows how science and engineering have contributed to innovation and wealth creation in the UK. 18 and 19 October 1995, 10.00 to 16.30, at 6 Carlton House Terrace, London SW1. Tel: 0171 839 5561.

★ ★ ★

Vintage Electric Musical Instrument Auction: 5 November at 1 p.m., Oaks and Partners Salerooms, Star House, Sandford, Crediton, Devon, EX17 4LR. Tel: 01363 774627.

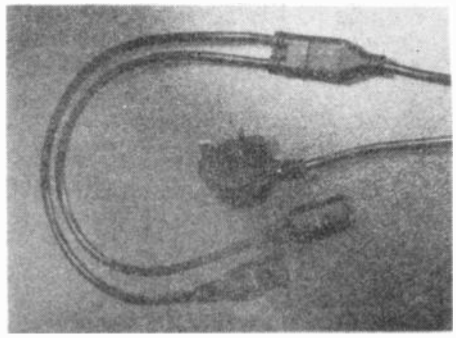
★ ★ ★

All Micro Show (AMS9), 11 November 1995, Bingley Hall, Stafford Show Centre, Stafford. 10.00 to 16.00. Tel: 01473 272002.

★ ★ ★

The *5th Great Northern Hamfest* takes place on 12 November 1995 at the Metrodome leisure complex in Barnsley Town Centre, S. Yorks, opening at 11 a.m. Contact Ernie Bailey (G4LUE) on 01226 716339.

UP THE JUNCTION



Running out of sockets into which to plug your PCs and peripherals? Perhaps changing the cabling to them instead of adding more sockets might help. In which case the range of Y-junction cord sets available from Genalog could be of interest to you.

One version of the set has a single junction allowing two IEC320 connectors to be moulded. Another has two junctions providing three connectors. Units are available from stock with three plug options, British BS1363/A, International EN60 320-2.2E and European (Shuko) CEE (7) VII.

Standard cable lengths are 2.5m or 3m, but sets can be manufactured to meet specific length and colour requirements.

For more information, contact: Genalog Ltd., Dept. EPE, Gills Green Oast, Gills Green, Hawkhurst, Kent, TN18 5ET. Tel: 01580 753754.

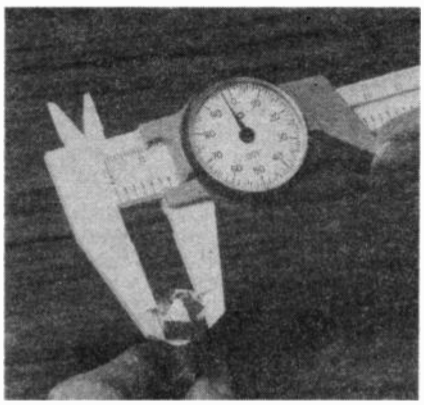
MEASURING DOWN TO IT

If you're tired of straining your eyes in the workshop trying to read the sizes of small items on a traditional steel caliper, the new QuickDial caliper could provide a low-cost answer. It's not electronic, but stalwart electronics hobbyists will know that even non-electronic items of test gear have their place in the workshop.

The Torqueleader range of equipment has had two versions of this caliper added to it, the QD MET 150 for metric dimensions up to 150mm, and the QD IMP 6 for imperial measurements up to six inches. Their prices are £20.20 and £22.99 respectively.

Swiss made, these precision instruments are manufactured in lightweight corrosion proof durable polyamide. Meeting the Internationally accepted accuracy standard DIN862, precise measurement is available in four modes, external, internal, depth and step dimensions. The clearly scaled dials can be zeroed and reading is made easy with non-glare glass. A useful fraction/decimal/millimetre conversion table is included with each tool.

For further information contact: MHH Engineering Co. Ltd., Dept. EPE, Gosden Common, Bramley, Guildford, Surrey, GU5 OAJ. Tel: 01483 892772.



P.C.B. ONE-OFFS

Readers looking for a one-off printed circuit board manufacturing service will be interested to learn of the new service offered by Etch-Tech Boards. This service offers hobbyists, educational establishments and other low volume users of p.c.b.s a very cost-effective route to custom p.c.b. production.

Market research conducted by Etch-Tech identified that many low volume p.c.b. users do not require silk screen legends, solder masks or plated-through holes, all of which add to the cost.

Their new hobbyist service offers single-sided and double-sided conventional p.c.b.s at a cost of 12 pence per square centimetre single-sided, and 18 pence per square centimetre double-sided. The largest board size available through this service is 15cm x 25cm.

For more details and a self-quote pack, simply send your name and address to: Etch-Tech Boards, Dept. EPE, PO Box 1566, Salisbury, Wilts, SP1 3XX.

NEW HEXFETS

International Rectifier has added new devices to its family of hermetic power HEXFET devices in a TO257AA package. Rated at 100W, these devices fill the gap that exists between low-power (less than 20W) TO39 and high power (150W) TO254AA packages.

The devices are available in *n* or *p* channel configurations with voltages ranging from 60V to 500V. They weigh less than 5g and offer high power dissipation in a small package.

For further information, contact International Rectifier, Holland Road, Hurst Green, Oxted, Surrey, RH8 9BB. Tel: 0883 713215.

UK LEADS EUROPE'S CHIPS

One of the world's leading electrical and electronic engineering companies, Siemens, is to build its latest project in Britain. This will consolidate the UK's position as the semiconductor centre of Europe. As a result, 1800 new jobs will be created in the North East.

Welcoming Seimens' decision to build a new £1.1 billion semiconductor plant in Hadrian Business Park, North Tyneside, Deputy Prime Minister Michael Heseltine said:

"This is a landmark success for the UK economy. The Seimens plant is the largest single high-tech investment ever made in Britain and puts us at the forefront of world semiconductor technology."

PLASTIC SEMICONDUCTORS

Philips Research Laboratories in Holland are understood to have succeeded in producing simple plastic electronic devices using semiconducting polymers.

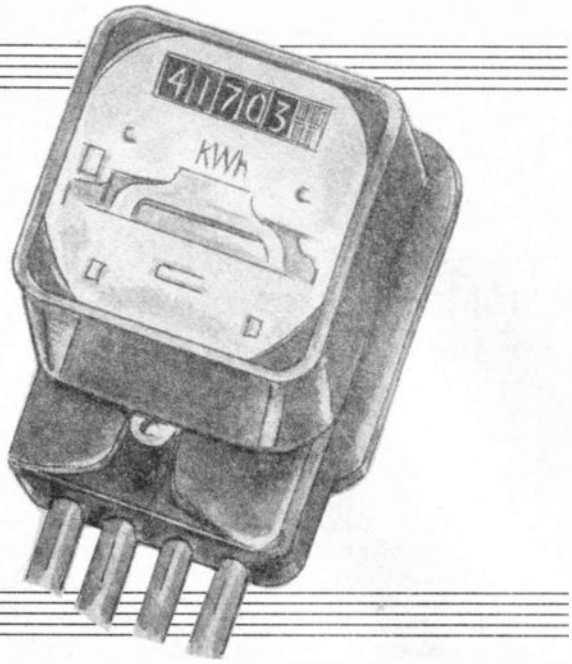
It is possible that the techniques involved may ultimately allow production of circuits on substrates of glass or plastic, instead of using silicon.

PIECE FOR THE WICKED

Habitual experimenters will know the benefits that desoldering wick has when components need to be removed from a board. When placed on the solder joint and heated with the iron, the wick simply sucks up excess solder allowing the component lead to be readily extracted from its hole.

Cobonic of Guildford are now offering prime quality Swiss made (Spirig) 3S-Wick desolder wick at 44p per 1.5m antistatic spool. The 3S-Wick leaves minimal flux residue on desoldered joints, preserving their solderability even after months of storage.

For a FREE sample of 3S-Wick, contact: Cobonic Ltd., Dept. EPE, 32 Ludlow Road, Guildford, Surrey, GU2 5NW. Tel: 01483 505260.



50Hz FIELD METER

JOHN BECKER

Know the strengths of the 50Hz electromagnetic fields generated by the electrical equipment within your home.

POSSIBLE danger to health from the electromagnetic fields around us, those of 50Hz in particular, is a matter which has received much publicity over the last several years. The issue was first raised in 1979 when it was reported that the proportion of children dying from cancer that resided in homes adjacent to high current power lines was greater than that in the population as a whole.

Much research into what has become a highly complex issue has since ensued, but the response from official sources has tended to state that the evidence is still inconclusive. Extracts from a lengthy document published by the National Radiological Protection Board (NRPB) are quoted at the end of this article.

It is pertinent to point out that it is not only 50Hz electromagnetic fields which have been cited in connection with health hazards, particularly regarding the promotion of cancer. Radiated fields across the whole frequency spectrum from d.c. up into the gigahertz region are being quoted in this context. Such frequencies, of course, are all around us in many forms, including radio transmissions.

METER PURPOSE

In *EPE* January '95, a general purpose *Magnetic Field Detector* was published. It was designed by Andy Flind and displayed the relative strengths of changing electromagnetic fields on a ten-step l.e.d. bargraph, but did not quantify the field values and was basically "untuned".

The purpose of the 50Hz Field Meter described here is to quantify the strengths of the 50Hz fields found around the home in more exact numerical terms which can be compared with statistics quoted by authorities such as the NRPB. Knowing numerical values, meter users can decide if they should encourage their family to keep a greater distance between themselves and the more strongly radiating appliances. Electric blankets are a particular subject to be considered.

Readers should be aware that the length of time spent in proximity to an electromagnetic field is also an important factor. This meter does not measure exposure duration, only instantaneous field strength.

The units in which the meter displays its readings are expressed in milligauss, up to 1999. One gauss is the C.G.S. system unit of magnetic flux. The equivalent unit in the S.I. system is the Tesla (T), with one Tesla being equal to 10000 gauss. Both units are in common use.

The meter is a battery powered handheld unit with a 3·5-digit liquid crystal display (l.c.d.).

BLOCK DIAGRAM

The block diagram for the complete 50Hz Field Meter is shown in Fig.1. In a nutshell, the a.c. electromagnetic field strength picked up by a sensor is amplified, range selected and passed through a 50Hz bandpass filter. The d.c. component of the signal is then extracted and decoded into a numerical form which is output to the l.c.d. The clock divider and voltage inverter seen in Fig. 1 are purely "housekeeping" functions for the correct operation of the filter and decoder/driver.

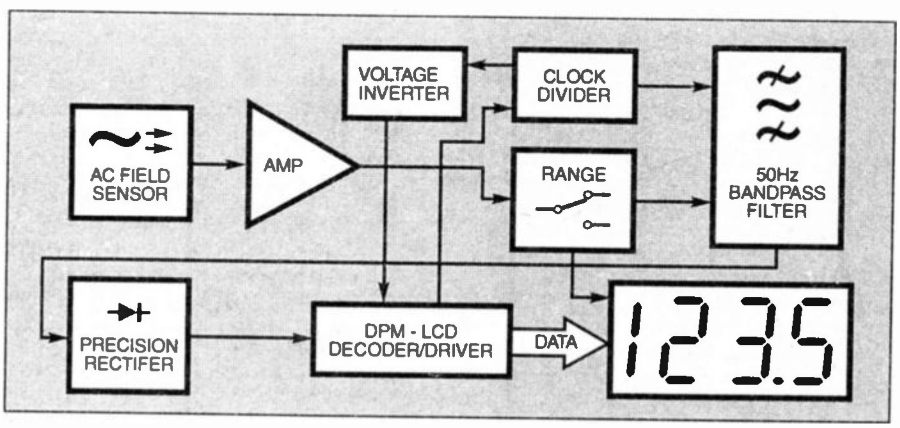
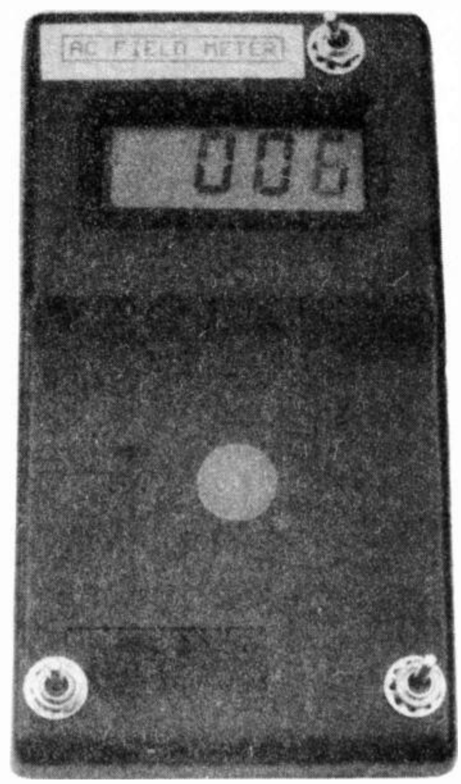


Fig. 1. Block diagram for the 50Hz Field Meter



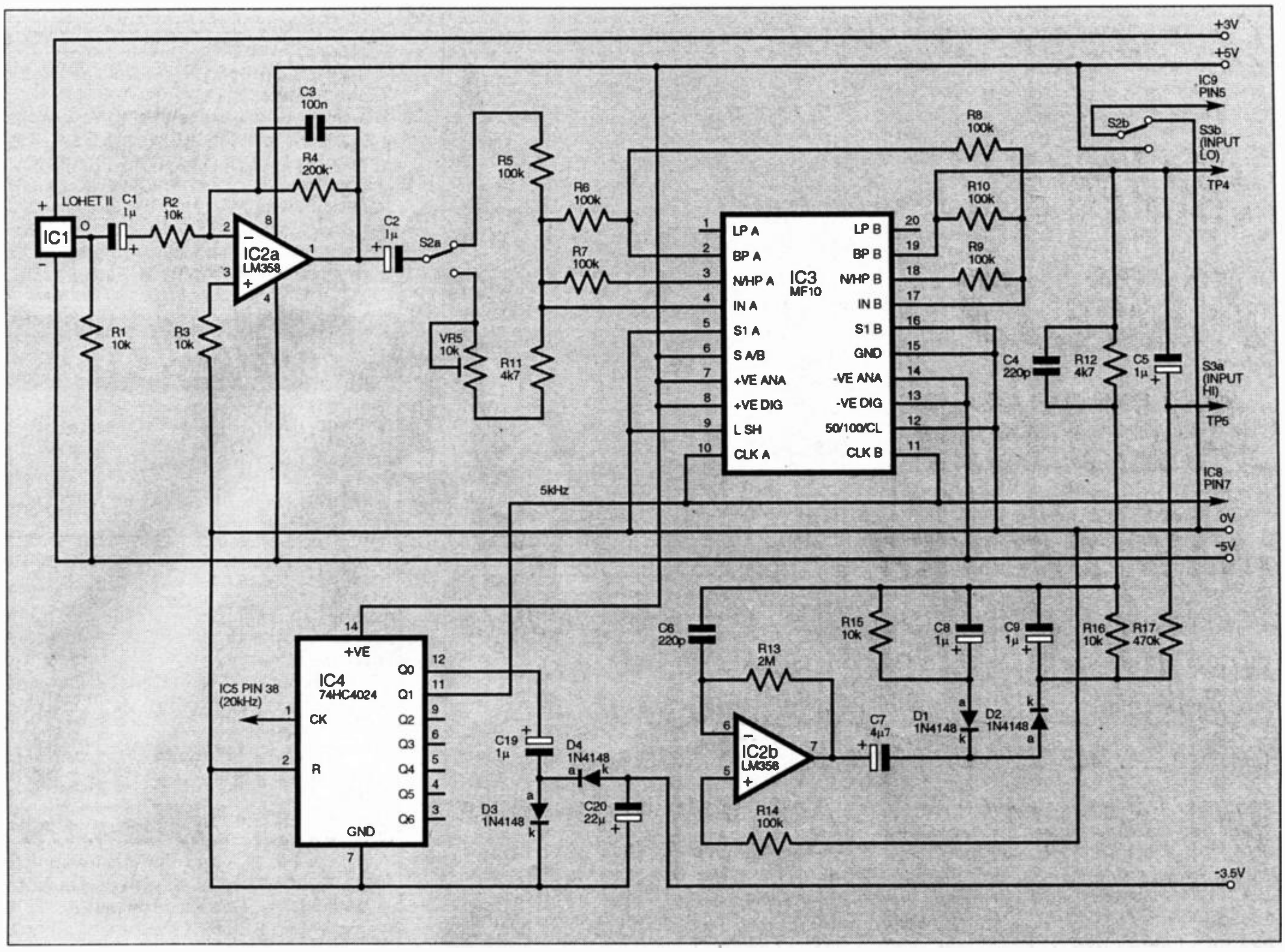


Fig. 2. Circuit diagram for the sensor and first stages of signal processing.

At the heart of the meter is a Hall-effect device which has been specifically designed to produce an output voltage proportional to the intensity of the electromagnetic field to which it is exposed, whether it is static or alternating (d.c. or a.c.). The device used is the Lohet II (also known as the SS94A1) manufactured by Micro Switch, a division of Honeywell. It is a high performance i.c. with a very low temperature drift. Regular readers will recall that it was used in the *EPE Seismograph* of September '94.

The Lohet II is capable of detecting fields of up to ±400 gauss and has a typical sensitivity of 5·0mV per gauss (5µV per milligauss) at 25°C, within a tolerance range of 4·90mV to 5·10mV. The quoted gain drift due to temperature is ±0·02%/°C.

Typically, the strength of 50Hz fields to be found around the home are in the order of 100 microgauss to 20 gauss (0·01µT to 2000µT) at between 3cm and 30cm. Consequently, the sensor is being used at the lower end of its sensing range and so its output needs amplifying before a quantitative field value can be sensibly shown on the display. The circuit diagram in Fig. 2 shows the sensor, IC1, and the first stage of signal processing.

SENSOR STAGE

The sensor is powered at the recommended typical d.c. voltage of 8V, the derivation of which is discussed later. The maximum supply range permissible is between 7·6V and 8·4V. At 8V, the sensor draws about 13mA, excluding the current flowing into the load resistor R1. In proximity to an a.c. electromagnetic field, the sensor produces an equivalent a.c. output voltage which is coupled via capacitor C1 to the inverting op.amp stage around IC2a.

A gain of about 20 is given to the signal by this stage, as determined by resistors R2 and R4, thus setting an output value from IC2a of 100µV per milligauss. Capacitor C3 provides a degree of attenuation to high frequency signals above the required 50Hz mains frequency.

FILTER STAGE

From IC2a, the amplified signal is fed through capacitor C2 to a ×1/×10 gain selecting network around switch S2a and then to the dual switch-mode filter IC3. With switch S2a set as shown, the signal path is through resistor R5 and the bandpass amplitude as output by IC3 remains unchanged.

The alternative path selectable by S2a, through preset potentiometer VR5 and resistor R11, increases the effective signal gain by about ten. Preset VR5 provides for precise adjustment of the gain.

Switch mode filter IC3 is the familiar MF10 device. It has two independent filtering stages which can be configured for all four normal filtering modes: low pass, bandpass, high pass and notch. In this application both stages are used as bandpass filters, the output from stage A feeding into stage B via resistor R8. Stage B outputs the filtered signal from pin 19.

The chip requires a clock signal to be applied to both stages at a frequency 100 times that of the central frequency required from the input signal. Thus, in this application, the required 50Hz signal needs a control clock frequency of 5kHz. As will be seen, the clock signal is derived from the 20kHz master oscillator within the l.c.d. decoder/driver chip (IC5 in Fig. 3). Binary counter IC4 divides the 20kHz signal by four to produce a 5kHz signal at output Q1 (pin 11). This is fed jointly to both clock inputs of IC3.

Counter IC4 is also used to generate the negative voltage required by the l.c.d. driver. The 10kHz signal from IC4 output Q0 (pin 12) is inversion rectified in a standard manner by capacitor C19 and diodes D3 and D4. Capacitor C20 smooths the rectified output, resulting in a negative voltage of approximately −3·5V.

RECTIFIER

From IC3, the filtered signal takes two paths. The first is direct to one of two differential inputs of the l.c.d. decoder/driver IC5. The second path is through the precision rectifier circuit around IC2b. This circuit is a conventional, though less frequently seen, configuration for deriving a full wave rectified d.c. voltage from a low amplitude a.c. signal.

The rectified d.c. output, from the junction of resistor R17 and capacitor C5, is taken to the second differential input of IC5. Between them, R17 and C5 provide additional smoothing of the relative levels between both signals feeding to IC5.

DISPLAY DRIVER

Integrated circuit IC5 and the display which it drives are shown in the circuit diagram of Fig. 3. The two processed signals, from IC3 pin 19 and the rectifier around IC2b, come first to switch S3. In its

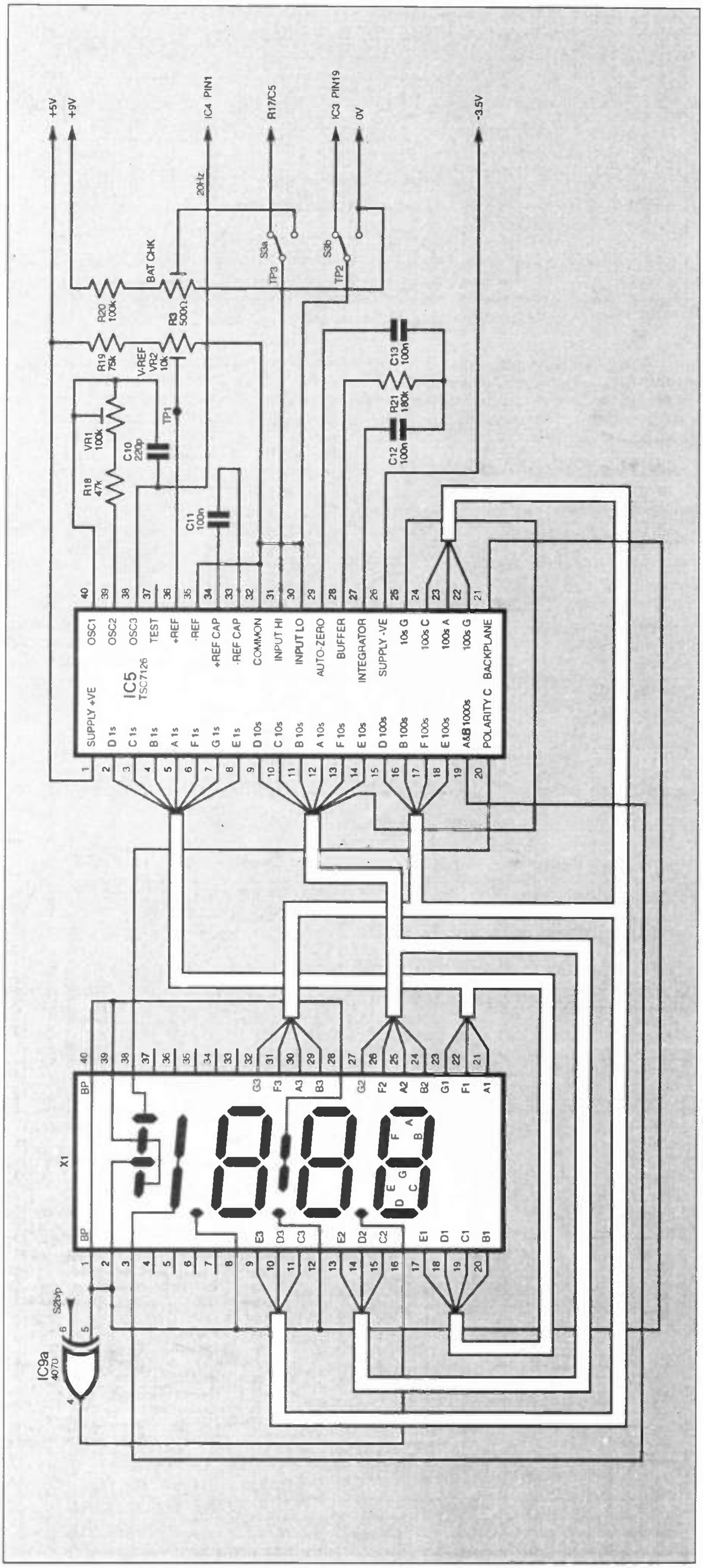


Fig. 3. Complete display circuit diagram.

principal mode, S3 routes the two signals to IC5's differential inputs at pins 30 and 31. In its other mode, S3 selects the battery check function.

Correct operation of IC5 is subject to the accuracy of a reference voltage and the generation of a master clock frequency. The reference voltage is supplied by the potential divider formed by resistor R19 and preset VR2, the latter providing for fine adjustment. The clock frequency is set by resistor R18 and capacitor C10,

COMPONENTS

Resistors

R1 to R3, R15, R16	10k (5 off)
R4	200k
R5 to R10, R14, R20	100k (8 off)
R11, R12	4k7 (2 off)
R13	2M
R17	470k
R18	47k
R19	75k
R21	180k
R22	2k2

All 0·25W 5% carbon film or better

Potentiometers

VR1	100k
VR2, VR5	10k (2 off)
VR3	500Ω
VR4	1k

All sub-min round preset

See SHOP TALK Page

Capacitors

C1, C2, C5, C8, C9, C15, C16, C19	1μ elect. radial 16V (8 off)
C3, C11 to C13	100n polyester (4 off)
C4, C10	220p polystyrene (2 off)
C6	220n polyester
C7	4μ7 elect. radial 16V
C14, C17 (2 off)	47μ elect. radial 16V
C18	470μ elect. radial 16V
C20	22μ elect. radial 16V

Semiconductors

D1 to D4	1N4148 signal diode (4 off)
IC1	Lohet II Hall-effect sensor
IC2	LM358 dual op.amp
IC3	MF10 dual switch mode filter
IC4	74HC4024 binary counter
IC5	TSC7126 l.c.d. decoder/driver
IC6, IC7	78L05 regulator, 5V 100mA (2 off)
IC8	7660 voltage converter
IC9	4070 quad 2-input XOR gate

Miscellaneous

S1	s.p.s.t. min. toggle switch
S2, S3	d.p.d.t. min. toggle switch (2 off)
X1	3·5-digit l.c.d.

Printed circuit board, available from the *EPE PCB Service*, code 959; 8-pin d.i.l. socket (2 off); 14-pin d.i.l. socket (2 off); 20-pin d.i.l. socket; 40-pin d.i.l. socket (2 off); PP3 battery, with clip; plastic case 145mm × 80mm × 139mm (maximum height) with l.c.d. viewing slot and battery compartment; connecting wire; cable ties; solder, etc.

Approx cost guidance only **£54**

together with preset VR1 which allows the frequency to be finely tuned.

Also imperative to IC5's conversion process is the integrating network comprising capacitors C12 and C13 and resistor R21. The values of these components are not too crucial and require no trimming.

Voltages presented to IC5's differential inputs are sampled at a rate dependent upon the master clock frequency. Each clock step causes a capacitor to charge up by a predetermined amount, as set by the reference voltage. When the capacitor charge equals the voltage difference between the two inputs the conversion is complete and the step count value, suitably decoded, is output to all l.c.d. digits.

The output voltages are squarewave modulated, as is required by l.c.d.s, so that only an a.c. signal is output. Simultaneously, the l.c.d.'s backplane is also squarewave modulated at the same frequency, but in an opposite phase to the data signals. The backplane frequency is a sub-multiple of the master frequency, about 20Hz.

The right hand l.c.d. decimal point is not controlled by IC5. It is activated by switch S2b in Fig. 2 when the ×10 gain range is selected. The voltage selected by S2b, high or low, determines the relative phase relationship between the input and output signals of Exclusive-OR (XOR) gate IC9a. The backplane signal is fed to IC9a pin 5 and when the gate's pin 6 is held high by S2b, the output at pin 4 is of opposite phase, so activating the decimal point. (The signal connections to IC9b and IC9c on the p.c.b. are for tracking convenience only and play no active role.)

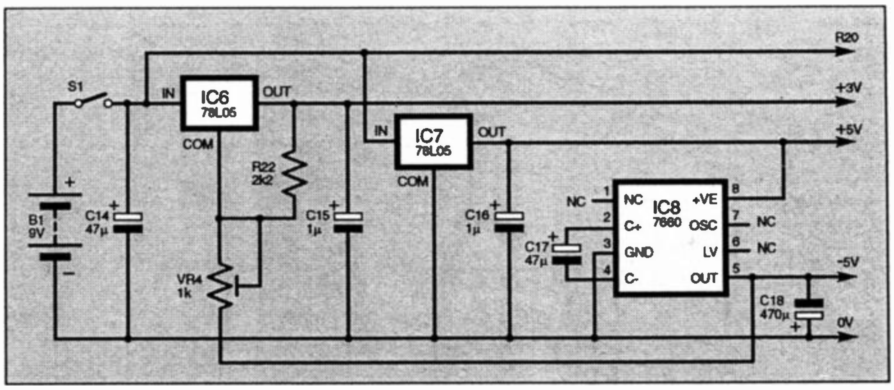


Fig. 4. Circuit diagram for the multi-voltage power supply.

POWER SUPPLY

Power for the 50Hz Field Meter is supplied by a 9V PP3 battery, as shown in the power supply circuit diagram of Fig. 4. The circuit produces four different voltage outputs. Direct from the battery, +9V goes to the battery check potential divider R20/VR3 in Fig. 3. VR3 adjusts the display output reading to match the actual battery voltage. Regulator IC7 outputs +5V to IC2, IC3, IC4, IC8 and IC9.

Voltage converter IC8 generates an output voltage which, when unloaded, is almost exactly the inverse of the positive supply voltage. In this instance, the latter is +5V so the output is −5V. This voltage is supplied to sensor IC1, op.amp IC2 and filter IC3. The current which can be output by IC8 is insufficient to supply the negative voltage required by decoder/driver IC5, hence the use of the additional inverter driven by counter IC4, as described earlier.

Regulator IC6, nominally a +5V output device, is biassed by resistor R22 and preset VR4 (with current flow into the −5V line to produce a +3V output which supplies the positive voltage to sensor IC1. Since the other power connection to IC1 is

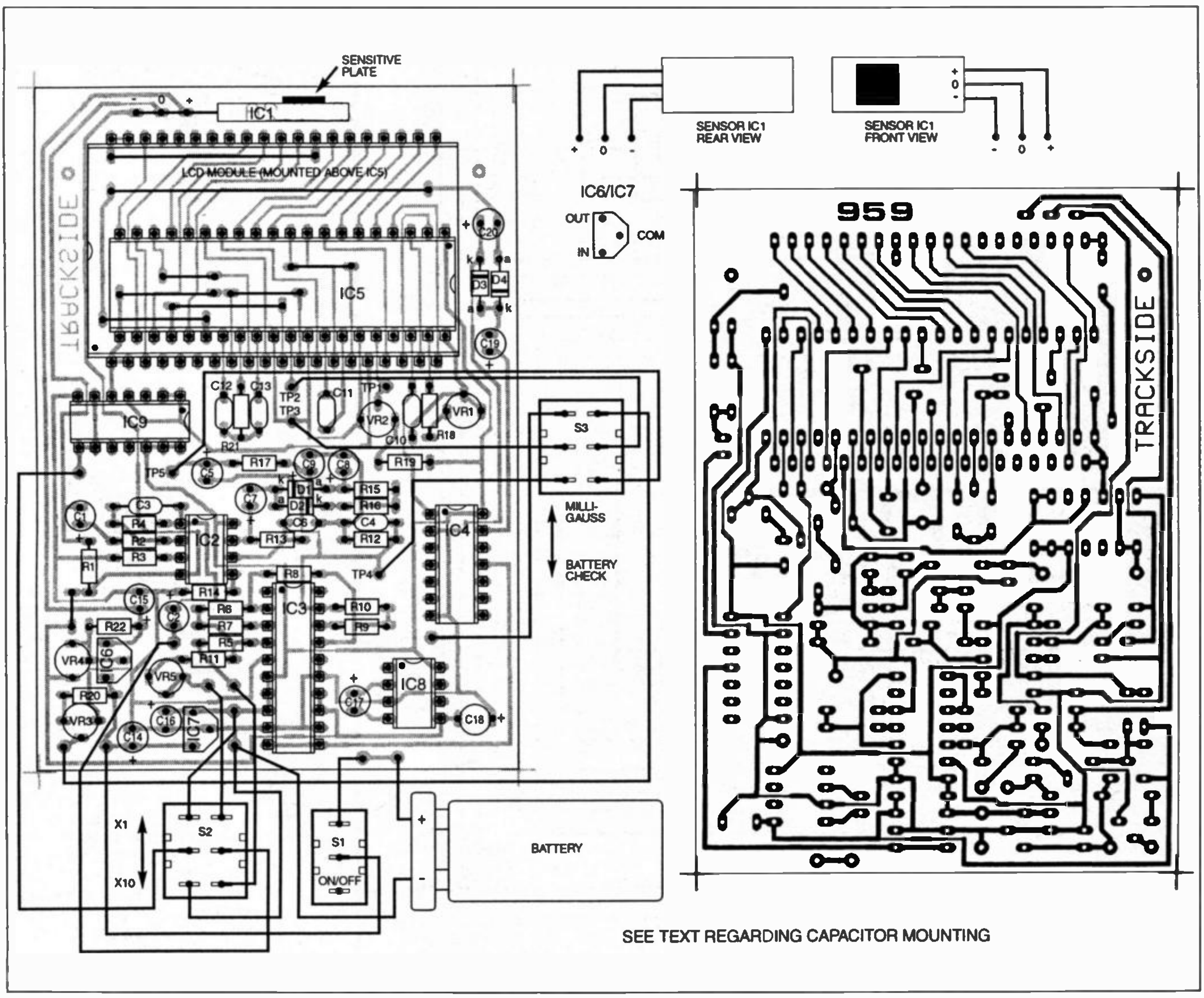
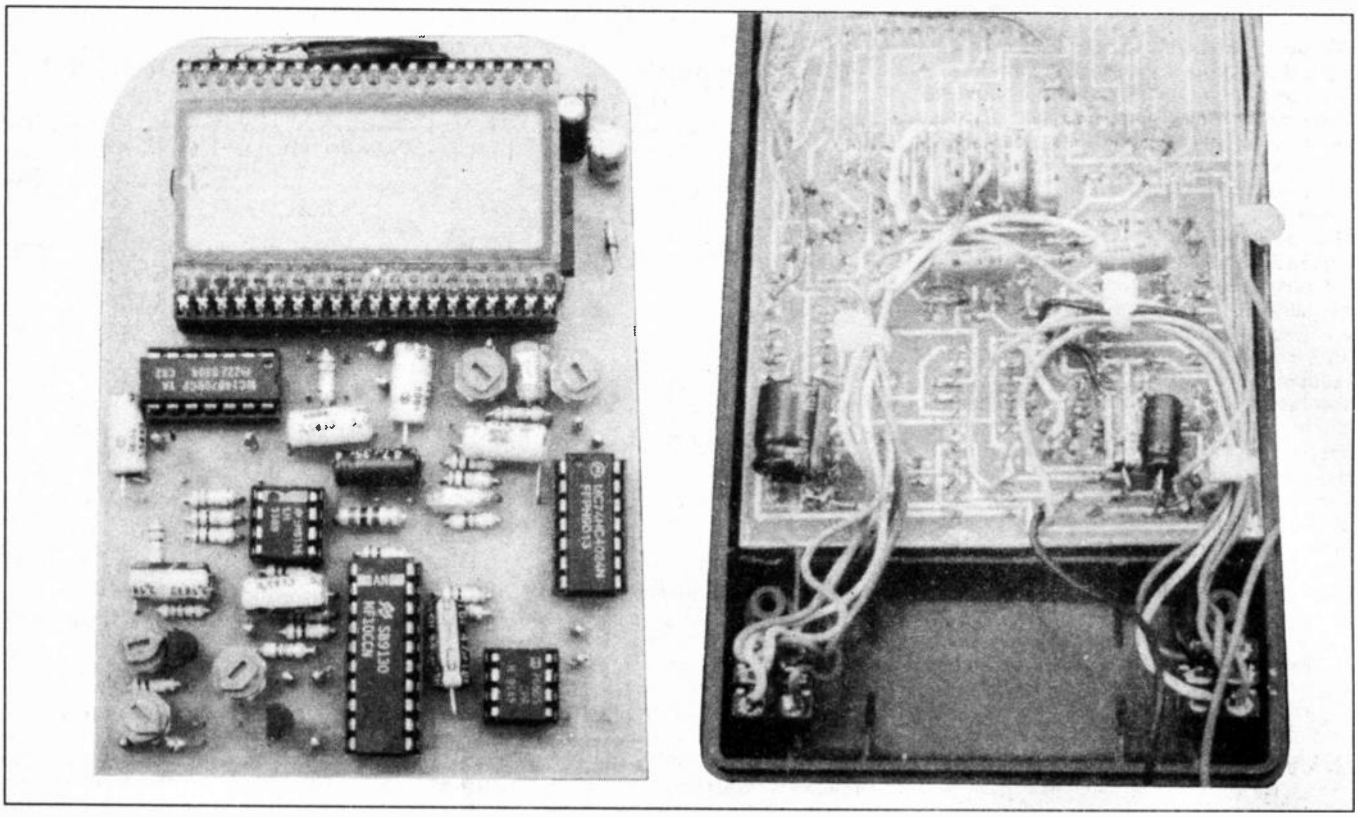


Fig. 5. Component layout details and full size copper foil track master pattern for the 50Hz Field Meter printed circuit board.



supplied by −5V, the required 8V potential across IC1 is achieved. This arrangement may seem complicated but it enables IC1 to be supplied at 8V even when the battery voltage is getting low. As IC1 is capacitively coupled to IC2a, the slightly unusual powering method does not adversely affect the a.c. signal processing.

In practice, the negative output voltage from IC8 falls when loaded by IC1, and so the actual voltage set by VR4 is greater than the nominal value of +3V.

CONSTRUCTION

The single printed circuit board (p.c.b.) for the 50Hz Field Meter holds all components except the switches. Its component layout, wiring details and life size copper foil track master pattern are shown in Fig. 5. It is available from the EPE PCB Service, code 959.

First, trim the corners off the p.c.b. so that it fits into the suggested handheld case, avoiding the screw pillars. Begin assembly of the board by making all the on-board wire links. These are eventually covered by the l.c.d. and IC5 so must be correctly made at this stage. Resistors and diodes can be soldered in next, observing the correct polarity for the latter.

Dual-in-line (d.i.l.) sockets should be mounted next, ensuring that all their legs pass through the holes. 40-pin sockets for the l.c.d. of the height and width required are not available, consequently two normal 40-pin sockets need to be cut in half lengthwise. Solder one pair into the board, then push the other pair into the first, double-decker fashion.

The remaining components can now be assembled. Electrolytic capacitors and the 3-pin regulator i.c.s must be correctly orientated. Capacitors C1, C2, C5, C7, C8, C9, C15 and C17 are mounted flat on the normal component side of the board. C14, C16 and C18 are mounted flat on the p.c.b. trackside. The foregoing 11 capacitors need their legs bending at right angles to suit horizontal mounting. Polyester capacitors C3, C6, C11, C12 and C13 are mounted vertically on the p.c.b. trackside. This arrangement minimises the board profile so that it fits into the case.

Sensor IC1 is mounted on the board as shown at the top of Fig. 5. First, though, black insulating tape should be wrapped around its body, one layer will do, to keep light from its sensitive plate. When in use, if light gets to the plate it can adversely affect the sensor's output, especially if the light source is powered at 50Hz.

Extension wires need to be connected to the legs of IC1 and bent at right angles to the sensor's body, enabling it to be mounted sideways as shown. Vertical mounting would prevent the case from being closed. It will probably be found easiest to solder the extension wires into the board first, bend them to shape, and then solder the sensor to them. It is a bit fiddly, but is preferable to bending the fragile legs of the sensor, which have been known to break if so treated!

HANDHELD CASE

A standard handheld plastic case measuring 145mm × 80mm × 139mm (maximum height) was used in the test model. This included a pre-cut viewing slot for the display, and a battery compartment. Three holes for the switches need to be drilled in its lid, as seen in the photographs.

Once wired to the switches, the p.c.b. slots snugly into the case and does not need to be bolted down, being held reasonably securely in position when the case is closed. It may be necessary to trim the case's internal partitions and unused mounting points to allow the board and connecting wires to fit.

TESTING

Thoroughly check the assembled board for bad soldering and incorrectly positioned components. Use a good eye-level magnifier to check the tracks for solder shorts, especially where tracks pass between i.c. legs.

Regard all i.c.s as being prone to static damage, so touch an earthed item to discharge static from your body before handling them.

Plug in IC8, but before plugging in the l.c.d. and the other d.i.l. chips, do a voltage check on the board. For all checks, except the one for 8V, the common meter probe (black) is connected to the negative side of the battery, which is the 0V line as shown in the circuit diagrams.

Switch on and check for +5V at IC7 output. Appropriately connect the meter probes across the two supply pins for IC1 and adjust preset VR4 until +8V is achieved. If these voltages are not available, within about five per cent, switch off and recheck the assembly.

Switch off and insert the l.c.d. and remaining i.c.s. Take care that all legs slot into the socket holes and that none fold under in the process. Switch back on and recheck the voltages, which should remain about the same as before. Also check that about −3·5V is present at the junction of D5 and C20, although this value is not critical and may be smaller. An arbitrary number below 2000 should be seen on the display.

BATTERY CHECK

Switch S3 to Battery Check. Adjust preset VR2 until a reference voltage of 200mV is present at test point TP1. This setting is based on an ideal sensor output voltage relative to field strength and subsequent stage gains. The accuracy of the setting will depend on normal manufacturing tolerances for the components involved throughout the circuit. Since it is unlikely that a precisely known field strength will be available, no advice can be offered on fine tuning the voltage to offset tolerance factors.

Switch S2 to ×10 to turn on the l.c.d. decimal point. Read the precise positive voltage of the battery, then adjust preset VR3 until this value, to one decimal place, is displayed on the l.c.d., e.g. 9·3V. Switch

S3 back to Monitor, and S2 to × 1, which should also turn off the decimal point.

Place the unit so that the sensor faces close to a mains radiating source, the switched-on transformer of the workshop power supply, for example. The number displayed on the l.c.d. should rise as the sensor gets closer to the field source. Note that the orientation of the field to the meter significantly affects the reading.

Once a field of reasonable strength has been located, secure the unit in that position, e.g. tape it to the workbench. Adjust preset VR1 until the l.c.d. shows a maximum value reading. Allow time for the circuit to stabilise between adjustments. This action sets the master clock oscillator to the optimum frequency required for the 50Hz filter circuit, as output by counter IC4 pin 11.

Switch S2 back and forth between × 1 and × 10, adjusting preset VR5 until the times ten relationship between the two display readings is correct. Again allow a few seconds between each switching to let the circuit stabilise. The decimal point should be on when in × 10 mode.

The 50Hz Field Meter is now ready for use.

FURTHER INFORMATION

The following information has been extracted from *Electromagnetic Fields and the Risk of Cancer*, a booklet published by the National Radiological Protection Board in 1992. Their address is: NRPB, Chilton, Didcot, Oxon OX11 0RQ.

* The highest magnetic flux densities to which most people are exposed arise close to domestic appliances which incorporate motors, transformers and heaters. The flux density changes rapidly with distance from appliances and, whereas at 1m distance the flux density will be of the same order as the background levels, e.g. 10-300nT, at 3cm distance magnetic flux densities may be as high as 2mT from devices such as hair dryers and can openers. There can be wide variations in flux densities from similar appliances. (See Table 1.)

* Whereas exposure to most household appliances is intermittent, exposure to magnetic fields from electric over-blankets can be prolonged. The flux density for a 1cm blanket/body separation is in the range 2000-3000nT and in the range 50-450nT for the head.

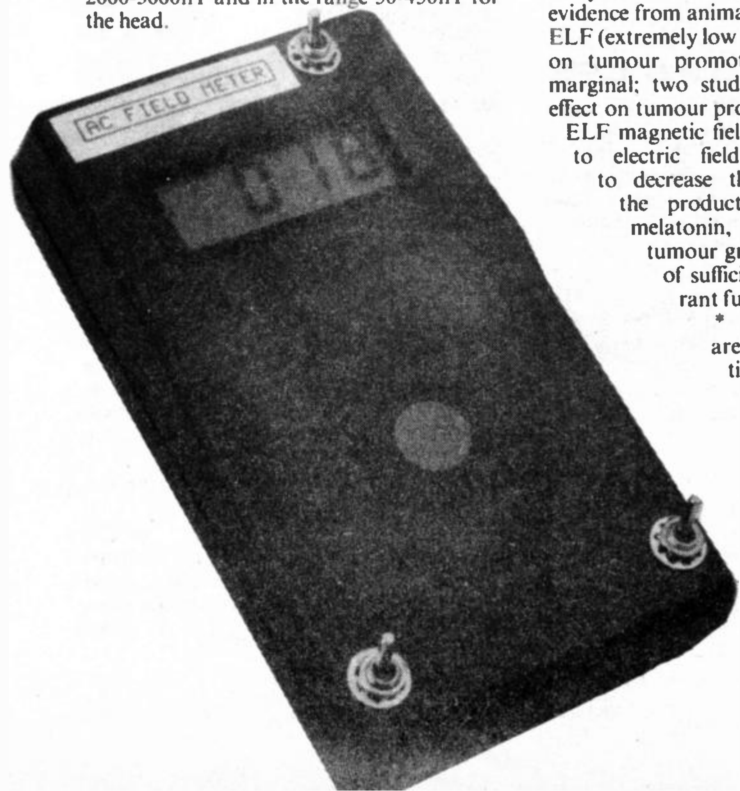


Table 1.
50Hz magnetic flux densities at varying distances from examples of household appliances (source NRPB).

	Magnetic flux density (μT)/distance		
Appliance	**3cm**	**30cm**	**1m**
Can openers	1000-2000	3·5-30	0·07-1
Clothes dryers	0·3-8	0·08-0·3	0·02-0·06
Clothes washers	0·8-50	0·15-3	0-·01-0·15
Dishwashers	3·5-20	0·6-3	0·07-0/3
Drills	400-800	2-3·5	0·08-0·2
Fluorescent desk lamps	40-400	0·5-2	0·02-0·25
Food mixers	60-700	0·6-10	0·02-0·25
Hair dryers	6-2000	<0·01-7	0·01-0·3
Irons	8-30	0·12-0·3	0·01-0·025
Microwave ovens	75-200	4-8	0·25-0·6
Ovens (conventional)	1-50	0·15-	0·01-0·04
Portable heaters	10-180	0·15-5	0·01-0·25
Refrigerators	0·5-1·7	0·01-0·25	<0·01
Shavers	15-1500	0·08-9	<0·01-0.3
Television sets	2·5-50	0·04-2	<0·01-0·15
Toasters	7-18	0·06-0·7	<0·01
Vacuum cleaners	200-800	2-20	0·13-2

The typical magnetic flux density for a 400kV power line at midspan is 40μT, and 8μT at 25m from midspan.
1 microtesla (μT) = 10 milligauss

* Several epidemiological studies have been carried out that ... dealt mainly with the use of electric blankets. Whilst the studies did not incorporate measurements of the associated electromagnetic fields, it has been estimated that the use of an electric blanket would typically increase magnetic field exposure by 82 per cent relative to background, with a likely range of 31-345 per cent.

(The studies focussed on the use of over-blankets. These are generally kept switched on during the night, whereas under-blankets are normally used only to pre-heat the bed.)

* Time varying electromagnetic fields up to 100kHz are not mutagenic (do not produce mutations) and are therefore unlikely to initiate cancers. The experimental evidence from animal studies for an effect of ELF (extremely low frequency) electric fields on tumour promotion or progression is marginal; two studies reported a lack of effect on tumour progression of exposure to ELF magnetic fields. Prolonged exposure to electric fields has been reported to decrease the night-time peak in the production and secretion of melatonin, a possible inhibitor of tumour growth. These studies are of sufficient importance to warrant further investigation.

* There are additional areas of biological investigation in which effects of electric and magnetic fields up to 100kHz have been described which may have health implications but which are not well understood. These areas include possible effects of exposure on circadian rhythms and on prenatal and postnatal development.

* While there is suggestive evidence of an association between childhood cancer and residential electromagnetic field exposure, the methodological shortcomings of the studies are such that the evidence is insufficient to allow conclusions to be drawn.

* Information on adult cancers does not suggest that residential electromagnetic field exposure is a risk factor, but data are too sparse to permit firm conclusions.

* It cannot be concluded either that electromagnetic fields have no effect on the physiology of cells, even if the fields are weak, or that they produce effects that would, in other circumstances, be regarded as suggestive of potential carcinogenicity. In general, the available experimental evidence weighs against electromagnetic fields acting directly to damage cellular DNA, implying that these fields may not be capable of initiating cancer in a manner that parallels that of ionizing radiation and many chemical agents.

* In the absence of any unambiguous experimental evidence to suggest that exposure to these electromagnetic fields is likely to be carcinogenic, in the broadest sense of the term, the findings to date can be regarded only as sufficient to justify formulating a hypothesis for testing by further investigation.

* ... it is not possible at present to use published data from human health studies as a sound basis for the formulation of exposure restrictions.

The latest information from the NRPB, dated 12 Sept. '95, states that:

* *Epidemiological studies on the health effects of electric power lines had shown that there was no persuasive background evidence that power frequency fields could influence any of the accepted stages of cancer.* □

INTERFACE

Robert Penfold

A FEW months ago several *Interface* articles were devoted to using the PC printer ports as general purpose input/output ports. A design for an analogue-to-digital converter was included, and this used a ZN448E converter plus multiplexing to permit its outputs to be read via four of the printer port's inputs.

This multiplexing is unavoidable as there are eight outputs on the ZN448E but only five inputs available on a PC printer port.

Bit-by-Bit

This month we will consider an alternative approach to the problem, which is to use a Serial Analogue-to-Digital Converter. The advantage of the serial approach is that it requires just three lines (two outputs and one input) in order to interface the converter to a computer.

The data is read in on one line, and the other two lines are used to control the converter. Although this analogue-to-digital converter is presented as a PC add-on, it should be usable in practically any situation where analogue-to-digital conversion is required, but only a very limited number of input/output lines are available.

A TLC548IP 8-bit A/D Peripheral i.c. is used as the basis of the converter, and pinout details for this 8-pin d.i.l. chip are provided in Fig.1. The two reference inputs (pins 1 and 3) set the maximum (Ref +) and minimum (Ref −) input voltages covered by the converter.

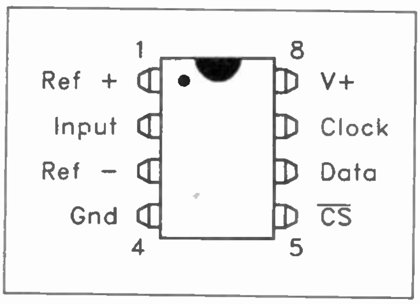


Fig. 1. Pinout details for the TLC548IP analogue-to-digital converter chip.

It could be useful to provide the "Ref −" with a positive bias in order to effectively null an offset voltage on the input signal, but in most cases this terminal is simply connected to ground. The input voltage range is then from zero volts to the reference voltage supplied to "Ref +".

The "$\overline{CS}$", "Data", and "Clock" terminals are the three terminals that connect to the printer port. The timing diagram of Fig.2 helps to explain the way in which the chip is controlled, and data is read from it.

In order to take a reading the chip select input must be taken low. The first bit of data (bit 7) can then be read on the data output.

A clock cycle must then be supplied to the clock input so that the next bit can be read. This process is continued until all eight bits of data have been read, one-by-one, from bit seven through to bit zero. The chip select ($\overline{CS}$) input is then returned to the high state.

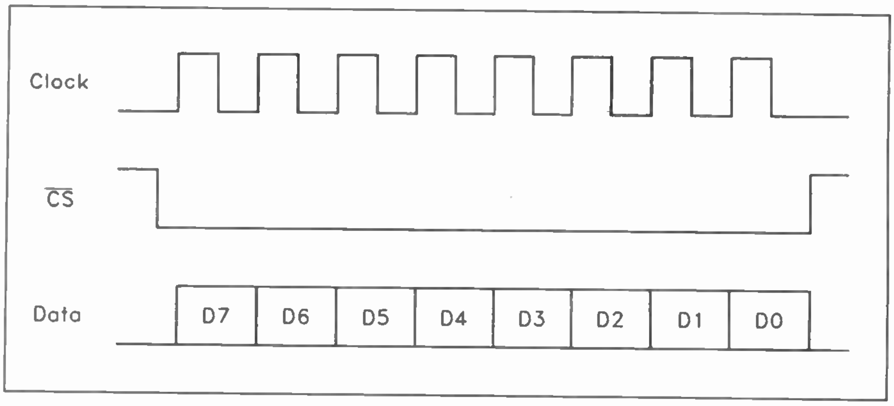


Fig. 2. Timing diagram for the TLC548IP. The clock signal does not have to be a regular pulse train.

Although the clock signal is shown as a regular train of pulses in Fig.2, in most applications it is not a conventional clock signal provided by an oscillator. It is a control signal provided by the computer, and in many cases it will have irregular timing. This does not have a detrimental effect on the operation of the TLC548IP.

Free Sample

The TLC548IP does not have a "start conversion" control input, or any form of "conversion completed" status output. However, it does have a built-in sample and hold circuit.

The latter samples the input during the first 3·5 cycles on the clock input. After a further half clock cycle it goes into the hold state. A new conversion is started automatically when the data has been read and the chip select input has been returned to the high state.

The converter is a successive approximation type, and the conversion process is controlled by a built-in system clock. It takes 32 system clock cycles to complete a conversion. Each conversion takes no more than 17µs and, where necessary, a timing loop must be used to prevent readings being taken at an excessive rate.

The maximum theoretical sampling rate is over 45,000 conversions a second, but in practice it would be difficult to achieve a rate as high as this. It would certainly be necessary to control the converter using some well thought out assembly language routines. The TLC548IP is fast enough for most applications though, and it could probably be used for simple audio digitising.

Old Hat

Interfacing to the computer is simplified by having a fresh conversion made as soon as the previous one has been read. However, when using the TLC548IP you must bear in mind that the data read from the device might be old data.

For example, if the converter is used as part of a temperature interface which is used

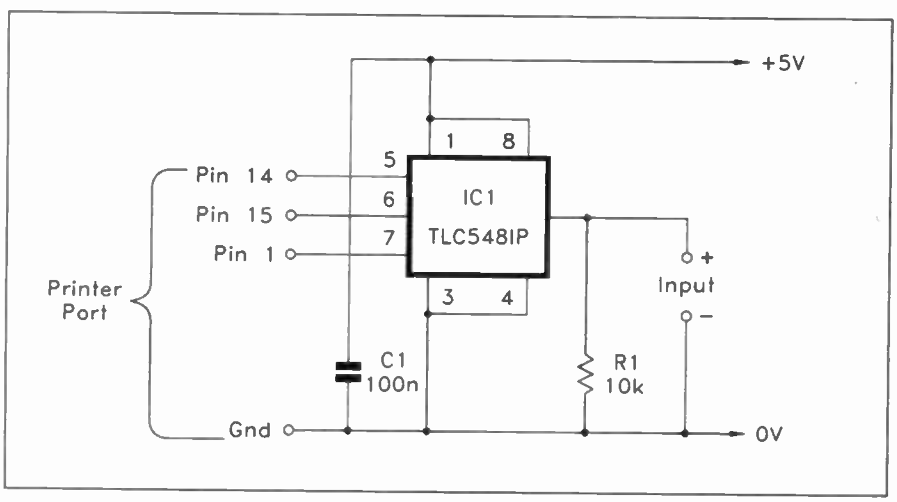


Fig. 3. Circuit diagram for the Analogue-to-Digital Converter.

to take readings every half hour, each time a reading is taken, it is actually the temperature from half an hour ago that is read. This is due to the fact that the conversion was made immediately after the previous reading was taken. It is then half an hour before this data is read.

Obviously, there should be no difficulty in writing the software to compensate for this problem. Probably the easiest solution is to simply take two readings in rapid succession, with the result of the first reading being dumped, and the up-to-date data in the second reading being utilized.

The problem is less severe in applications where readings are being taken at a high rate. The gap between a conversion being made and the data being read is likely to be too short to be of any practical significance. However, bear in mind that the first reading in the series could be old data, and should be discarded.

ADC Circuit

The circuit diagram for the Analogue-to-Digital converter is shown in Fig. 3, and as will be apparent from this, few discrete components are required. In fact the only essential discrete component is supply decoupling capacitor C1.

Resistor R1 simply ties the input of the converter to earth so that it is not left "floating", and this component is only needed when experimenting with the converter. In a practical application the input will normally be fed from an amplifier, sensor, or whatever, and R1 is then unnecessary.

The Ref − input at pin 3 of IC1 is taken to ground, and the Ref + input at pin 1 is taken to the +5V rail. This gives the converter a nominal input voltage range of zero to five volts. Obviously other reference voltages can be used where appropriate, and for critical applications it would probably be necessary to feed pin 1 from a highly stable reference source.

There are many possible ways of interfacing the converter to a PC printer port. The method shown in Fig.3 has the data read on the "Error" input, the clock signal provided by the "Strobe" output, and the chip select input under the control of the "Linefeed" output. Fig.4 provides connection details for the printer port connector, which is a male 25-way D-type connector.

Software

The GWBASIC program listing, set out in Listing. 1, shows the basic steps needed in order to read the converter. Although the converter is very simple as far as the hardware interfacing is concerned, the serial approach greatly complicates the software.

The program must generate the right levels on the two outputs, while reading in each bit of data on the input line. The two outputs are at address &H37A (or &H27A for port two), and they are at bits zero (clock) and one (chip select). Both lines are made available via internal inverters, so they are set high using a value of zero, and low using values of one and two respectively.

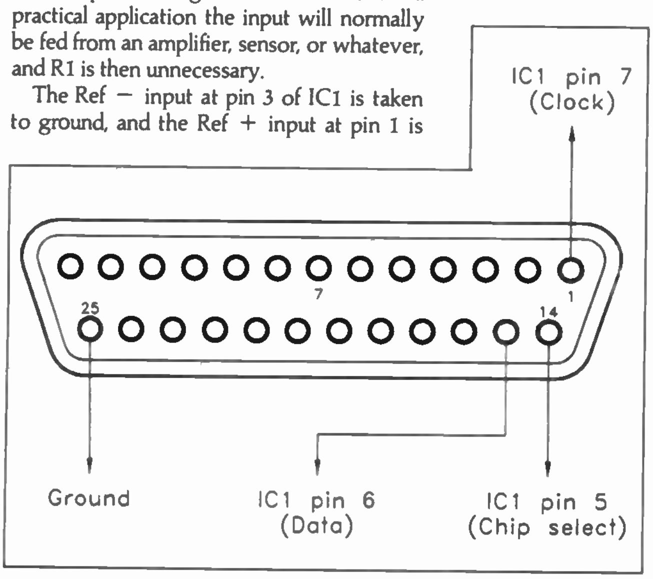


Fig. 4. Suggested method of connection to the PC printer port.

The first lines of the program simply set up the converter so that it is ready to be read. More or less the same routine is then repeated eight times, as each bit is read in and processed. The "Error" input line is at bit three of address &H379 (or &H279 for port two).

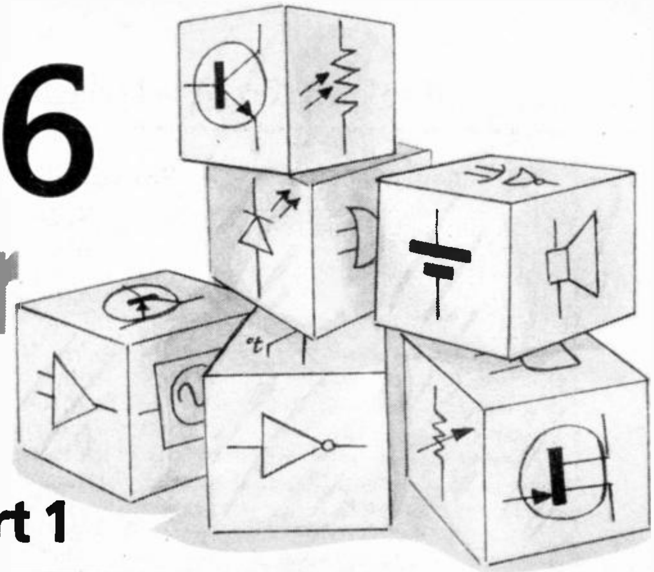
Except when bit three is read, the returned value must be multiplied or divided by the appropriate amount to effectively shift it into the correct bit of the returned value. A running total of the corrected values is kept in variable "X", and this provides the full value from the converter when all eight bits have been read.

In use the converter seems to work very well, providing excellent accuracy and stability. It probably represents the simplest means of providing a PC with an Analogue-to-Digital converter. It is also a very inexpensive means of providing a PC with this facility, since the TLC548IP only costs about £4.

Listing.1: LTC548 A/D Converter Program

```
10  REM A/D converter program
    (TLC548)
20  OUT &H37A,1
30  OUT &H37A,3
40  OUT &H37A,2
50  X = INP(&H379) AND 8
60  X = X * 16
70  OUT &H37A,3
80  OUT &H37A,2
90  Y = INP(&H379) AND 8
100 Y = Y * 8
110 X = X + Y
120 OUT &H37A,3
130 OUT &H37A,2
140 Y = INP(&H379) AND 8
150 Y = Y * 4
160 X = X + Y
170 OUT &H37A,3
180 OUT &H37A,2
190 Y = INP(&H379) AND 8
200 Y = Y * 2
210 X = X + Y
220 OUT &H37A,3
230 OUT &H37A,2
240 Y = INP(&H379) AND 8
250 X = X + Y
260 OUT &H37A,3
270 OUT &H37A,2
280 Y = INP(&H379) AND 8
290 Y = Y/2
300 X = X + Y
310 OUT &H37A,3
320 OUT &H37A,2
330 Y = INP(&H379) AND 8
340 Y = Y/4
350 X = X + Y
360 OUT &H37A,3
370 OUT &H37A,2
380 Y = INP(&H379) AND 8
390 Y = Y/8
400 X = X + Y
410 OUT &H37A,3
420 PRINT X
430 OUT
```

TEACH-IN '96



A Guide to Modular Circuit Design

Max Horsey **Part 1**

DURING this series of articles, a range of circuit modules is examined, divided into Input, Processor and Output sections. Where possible, a choice of modules is offered within each section.

Each of the ten Parts of the series is accompanied by a constructional article explaining how a complete project may be devised by employing the modules described, together with a p.c.b. design. Each project will be one of many possible ideas that could be implemented and it is hoped that readers will design for themselves a variety of circuits by combining modules provided in the whole series.

The proposed range of modules covered by the series is detailed in Table 1.1. Each module is chosen to link easily with adjacent modules in the same Part, but modules may also be linked with modules in other Parts of the Series.

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THERE can be little more satisfying than creating a circuit diagram, designing the layout and finishing with a working project. Many people quickly learn the art of designing a layout on a printed circuit board (p.c.b.), breadboard (prototype board) or stripboard (Veroboard), but fewer attempt to design the basic circuit.

The problem – as with many things – is knowing where to start. Having identified a problem, should the solution be based on a transistor circuit, logic gates, op.amp, or a mixture? How do you know that your solution is the best? How do you select your components from the vast range on offer? Where do you find the data you need? Above all, is your mathematics up to all the calculations needed to work out resistor and capacitor values?

The answer is that, given a few simple ground rules, none of these questions need pose a major problem. Circuits always divide into sections or modules. You can even use other people's designs for each module, linking the modules together to make your own unique arrangement. Not only will you have the satisfaction of creating your own circuit, but you will be in a much better position to test and fault find.

DIVIDING UP A CIRCUIT CONCEPT

Having divided a circuit concept into separate **modules**, each module can then be represented as a block diagram, such as the example shown in Fig. 1.1.

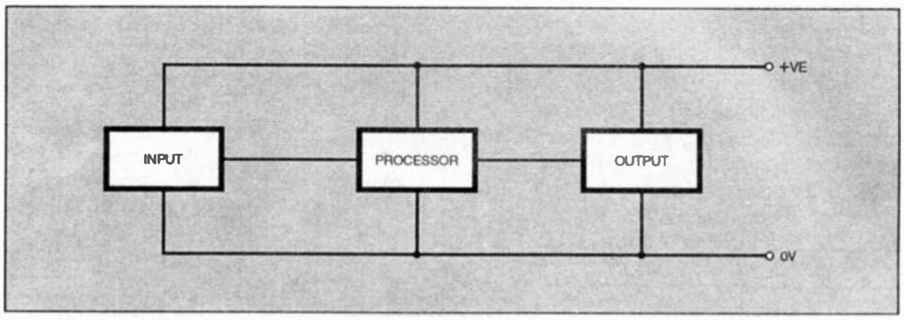


Fig. 1.1. Example of a typical modular block diagram.

Select the modules you require, one **Input** module, one **Processor** or amplifier, and one **Output** module. Join their positive rails together, join their 0V rails together, and link the output of one module to the input of the next to make the finished circuit diagram.

POWER SUPPLY

For all the modules described in this series, it is generally assumed that a power supply of 12V d.c. is needed, since this is commonly required for relays, sirens, solenoids etc. If an integrated circuit (i.c.) is employed which requires a lower voltage, a suitable voltage regulator circuit will be provided. If you choose logic i.c.s from the CMOS 74HC series instead of the CMOS 4000 series suggested, a d.c. supply of 4·5V or 5V should be employed.

It is important to use a decoupling capacitor across the power supply rails, i.e. connected between positive and 0V (or negative) in the circuit. This is to smooth out any irregularities in the supply voltage. The size required depends upon the current drawn by the circuit, but a value of 1000 microfarads (µF) will be adequate for most purposes. Sensitive circuits (e.g. latches, which may latch accidentally) will also benefit from a 0·1µF (100n) capacitor across the supply rails, fitted near the i.c.

LOGIC I.C.s

Circuits which require the use of logic i.c.s may be constructed using the CMOS 4000 series. Although these are slower than more recent i.c. types, such as the 74HC and 74AC series, for example, they still remain the least fussy range in terms of operating voltage and ease of use.

They can operate on supplies from about 3V to 18V, compared to the 2V to 6V recommended range for the 74HC chips. All CMOS i.c.s, though, are sensitive to static electricity and the simple precautions required are discussed later.

Virtually all of the circuits which require logic i.c.s could also be constructed around the CMOS 74HC series. Note, though, that the pin layouts are different in most cases. For example, a quad two-input NOR gate is available as a CMOS 4000 i.c. and denoted "4001B". The equivalent 74HC version is denoted "74HC02" and its pin arrangement is different (see Fig. 1.14). Conversely, the CMOS 4024 counter i.c. is also available as the 74HC4024 which *does* have the same pin arrangement.

Although the 74HC range can operate at much higher speeds (typically around 20MHz) than the CMOS 4000 series (typically around 4MHz), high speeds are not required in any of the circuits in this series of articles. (Very high operating speeds can cause difficulty in some types of circuit and printed circuit board layout can affect performance.) The 74HC series can deliver more current from their outputs than is available from the 4000 series, typically 25mA and 4mA per output, respectively.

It is usually possible to mix 74HC and 4000 series chips in the same circuit, in which case they must ALL be powered from a supply of 4·5V or 5V.

PART 1 MODULES

The modules examined here are:

INPUT MODULES: Light and Temperature Sensing

PROCESSOR MODULES: Single Transistor, Op.amp, Logic Gate, and Schmitt Trigger

OUTPUT MODULES: L.E.D., Single Transistor, Darlington Pair, Relay

By combining these modules, the following project ideas can be made:

Table 1.1. Proposed schedule of modules and projects for *Teach-In '96*

PART	A INPUT MODULE	B PROCESSOR	C OUTPUT MODULE	PROJECT
1	Light/temperature sensor	Transistor Op.amp Logic gate amp Schmitt trigger	*npn* driver *npn* Darlington driver Relay circuit	Temperature Warning Alarm (1A+1B+1C)
2	Alarm switches	Timers: Simple delay A.C. coupling CMOS logic monostable 555 monostable	Fail-safe output (*npn*) Fail-safe output (*pnp*) Power supply failure warning	Alarm Unit with entry/exit and siren timers (2A+2B+2C+1C)
3	Switches Touch sensor Moisture sensor	Latching relay: Thyristor NOR latch Bistable	Motor speed control Motor direction control (relay) (transistor)	Automatic Camera Panning System (3A+2B+3B+3C)
4	Astables: CMOS gates 741 555	Decade counter and chaser	L.E.D. series resistor	Vari-speed Auto Dice (2 times 1 to 6) (4A+2B+4B+4C)
5	I.R. receiver	Encoder/decoder D-type bistable T-type bistable J-K bistable Logic control	Pulsed Darlington output	Infra-Zap (5A+1B+2B+4A+4B+ 5B+1C+5C)
6	Switch debouncer: R/C monostable	Interface for counter module Binary/BCD counter	Liquid crystal decoder/driver/display	Event Counter (6A+6B+6C+4A) (free standing or linked with Project 5)
7	Clock pulses: A.C. mains Astable Crystal oscillator	Diode logic gates Divider	7-segment driver with 7-seg. l.e.d. display	Countdown Timer (max. 99m 59s) with bleep (7A+1B+7B+7C+1C)
8	Sound (input) (including op.amp) Signal mixer Position to voltage sensor	VU processor i.c.	*pnp* transistor driver	VU Warning with Buzzer (8A+8B+8C)
9	I.R. transmitter	Missing pulse detector: 555 CMOS gate	Relays Reed switch	I.R. Twin Beam Break Detector (9A+2B+9B+9C+1C 5A+5B+1B)
10	Magnetic pickup sensor	Frequency to voltage converter i.c.	VU display (as Project 8, but with linear i.c.)	Motor/Shaft Speed Display (10A+10B+10C)

Note: Later parts may be subject to review.

- Automatic light (switches on when it gets dark)
- Light beam detector
- Fridge alert (monitors temperature, buzzes if too high)
- Ice warning (e.g. alerts if your loft is freezing)
- High temperature warning (e.g. for tropical fish)
- Automatic fan

LIGHT SENSING INPUT MODULES

A choice of two light sensors is offered: a light dependent resistor (l.d.r.), or a phototransistor, as shown in Fig. 1.2 and Fig. 1.3. In each case the circuit provides an output voltage which varies according to changes in light level. You must select whether you want the voltage to rise or fall, depending on what is required by the next (Processor) module.

Both circuits in Fig. 1.2 employ an l.d.r. as the sensing device. When the light level increases, with the first circuit the output voltage rises, but falls with the second one.

Adjustment is provided by the variable resistor (potentiometer). The one kilohm (1k) resistor is required to prevent excess current flowing if the variable resistor is set to zero resistance.

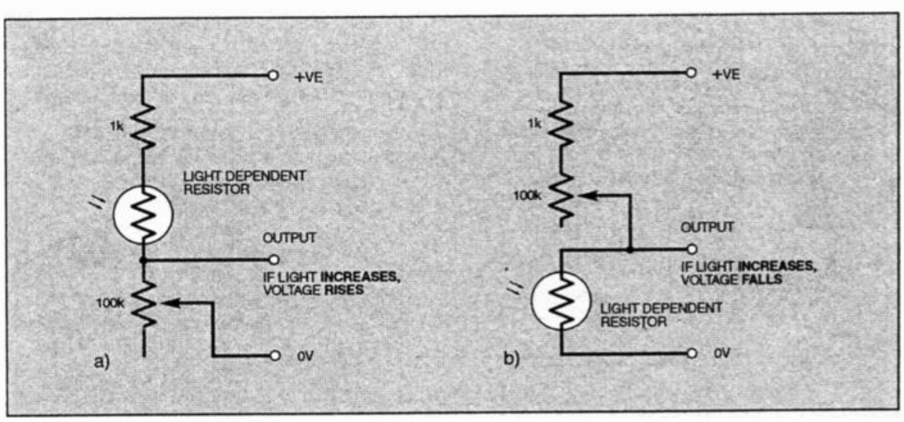


Fig. 1.2. Using a light dependent resistor in two light sensing configurations.

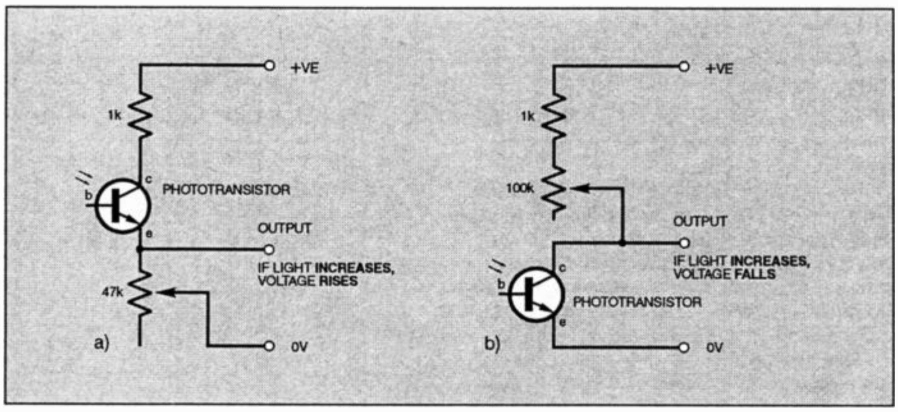


Fig. 1.3. Using a phototransistor in two light sensing configurations.

ADVANTAGE:
L.D.R.s are easy to use, and are very sensitive to changes in light level.

DISADVANTAGE:
L.D.R.s react slowly to changes in light level.

PHOTOTRANSISTOR CIRCUIT

The l.d.r. of Fig. 1.2 is replaced by an *npn* phototransistor in the two circuits shown in Fig. 1.3. A phototransistor behaves differently to an l.d.r., but this does not affect the way in which it can be employed. Note that the base lead (b), if fitted, is *not* used in this application. Darlington phototransistors may be used in more sensitive applications. (Darlington devices are described later.)

ADVANTAGE:
Phototransistors react much more quickly than l.d.r.s to changes in light level.

DISADVANTAGE:
Phototransistors are less sensitive than l.d.r.s to small changes in light level, although this is less true of the Darlington versions.

SENSING TEMPERATURE

In the circuits shown in Fig. 1.4, a thermistor is used to sense temperature. Any type of thermistor may be used, but the one assumed in Fig. 1.4 is a negative temperature coefficient (NTC) type, with a value of about 4k7 at room temperature. The term "negative temperature coefficient" means that as the temperature of the thermistor **rises**, its resistance **falls**.

In each of the two circuits, an output voltage which varies according to changes in light level is provided. You must select whether you want the voltage to rise (Fig. 1.4a) or fall (Fig. 1.4b), depending on what is required by the next (Processor) module.

NOTE: If the circuit of Fig. 1.4b is used with a transistor amplifier (Processor Module A), the 10k variable resistor should be replaced by a 470k type.

PROCESSOR MODULES

Four amplifier/switching circuits are presented as the Processor Modules in this Part:

a. Single transistor switch
b. Op.amp switch (including a Schmitt trigger version)
c. Logic gate switch (from the CMOS 4000 series)
d. Schmitt trigger switch based on a logic gate

SINGLE TRANSISTOR SWITCH

Any small signal transistor, e.g. BC108, BC184L, BC549 etc., can be used in the switching circuit shown in Fig. 1.5.

Resistor R1 limits the current flowing into the base of the transistor. When the voltage at the input to R1 is below about 0·5V, the base (b) of the transistor is biased below its turn-on threshold. Consequently, the transistor is turned fully off and the output voltage at its collector (c) is therefore equal to the positive supply line voltage (assuming that no load other than resistor R2 is connected to it.)

As the input voltage at R1 rises above 0·7V, the increasing current flowing into the transistor's base causes the transistor to turn on and the current flowing through its collector to emitter (e) path rises. As a result, the voltage drop across the collector load resistor R2 increases, and the output voltage falls. With sufficient current flowing into the base, the voltage at the collector will fall to the voltage level of the emitter, i.e. to 0V. In this condition, the transistor is said to be turned fully on, or in saturation.

The level of input voltage at R1 which is required to turn the transistor fully on depends principally on the transistor's gain and the values of R1 and R2, particularly the latter. Increasing the value of R2 will result in the transistor becoming fully turned on by a lower input voltage at R1. Other factors, though, such as ambient temperature, also affect the input/output voltage relationship. Typically, with R1 and R2 at the values shown in Fig. 1.5, when the voltage at the input to R1 is about 1·4V the transistor will be turned fully on.

Note that the circuit **inverts** the input: input 0V, output positive; input sufficiently positive, output 0V. The Input and Output modules must allow for this inversion.

The output current available at the transistor's collector depends upon the supply voltage and the value of load resistor R2: with a 12V supply and a 1k resistor, it will be about 12mA. The choice of transistor must take into account the total current that it is required to sink when turned fully on.

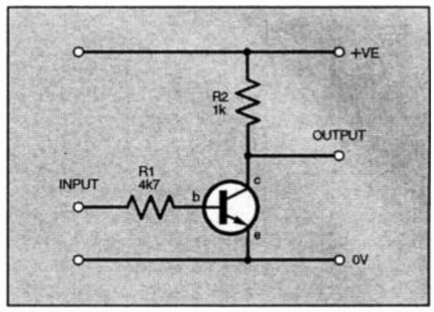


Fig. 1.5. Switching circuit using a single transistor.

To sum up the single transistor switch of Fig. 1.5:

ADVANTAGES:
Quick and easy to construct
A significant output current can be available
No handling problems
Inexpensive

DISADVANTAGES:
Less sensitive than Processor module choices (b) and (c)
Unpredictable voltage gain

OP.AMP SWITCH

The switching circuit shown in Fig. 1.6 is based around an op.amp (operational amplifier) wired as a comparator. Although there are op.amps designed specifically for use as comparators, any standard single op.amp, such as a type 741, can be used for the purpose in this series of articles. The following functions of the pin numbers conform to those of all standard single op.amps:

Pin 7 is the positive power supply connection.

Pin 4 is the negative power supply connection.

Pin 6 is the output.

Pin 2 is the **inverting** input, represented by a minus (−) sign.

Pin 3 is the **non-inverting** input, represented by a plus (+) sign.

Pins 1, 5, and 8 serve various other functions and must not be connected in this application.

This information is shown diagrammatically in Fig. 1.14.

Basically, op.amps are designed for use with a **dual-rail** power supply, i.e. positive, 0V and negative. However, in many instances it

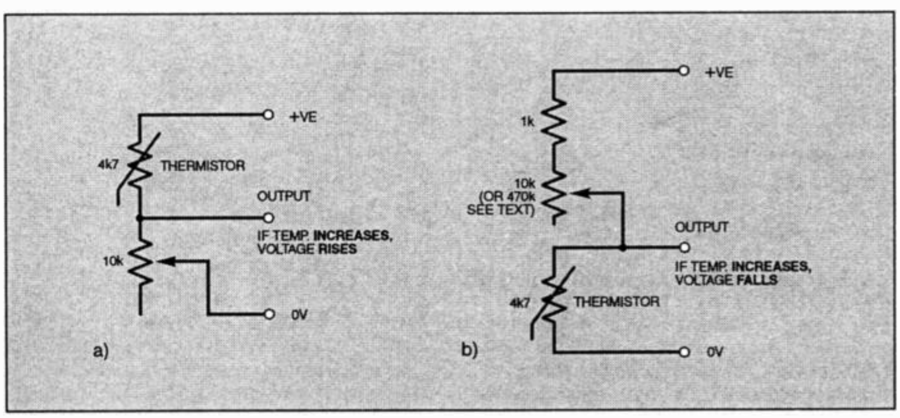


Fig. 1.4. Two temperature sensing circuit configurations based around a thermistor.

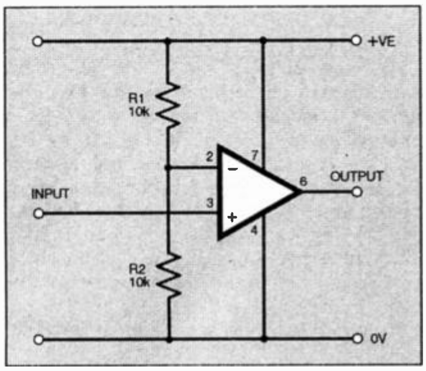


Fig. 1.6. Using an op.amp as a circuit switch.

is possible to power an op.amp circuit to run from a single-rail supply, as is done in Fig. 1.6.

The two resistors R1 and R2 hold the inverting input, pin 2, at a reference voltage. In this instance, R1 and R2, being of equal value, set the reference voltage at half the supply voltage. Their relative values may be changed to set other reference voltages for other applications.

If the voltage on the non-inverting input, pin 3, is less than the reference voltage, the output voltage at pin 6 will be low. Conversely, if the non-inverting input voltage is more than the reference voltage, the output will be high.

The terms *High* and *Low* are relative, and the actual voltage level extremes will depend on the type of op.amp used, its power supply voltages and the load resistance to which it is connected. As a very general rule, an op.amp's output voltage extremes can probably be assumed to be about 1V above and below the negative and positive power line voltages, respectfully. There are, though, some specialist op.amps which have an output voltage swing which comes close to the full power rail voltage. The LM311N comparator is one such op.amp.

The output current available also depends upon the type of op.amp chosen and the power supply voltage, but, generally speaking, it can probably be assumed that at least 5mA is available, and possibly more. Op.amps have internal current limiting and cannot be killed if their outputs are short circuited.

Reference to data sheets will be needed to establish the expected voltage swing for a particular op.amp and its ability to sink and source currents at a specific supply rail voltage.

In the circuit as shown in Fig. 1.6, it will be seen that the output switches in the same direction as the input, in other words, the circuit is non-inverting. If required, though, it is possible to swap the connections to the op.amp's pins 2 and 3, to make the circuit output an inversion of the input direction sense.

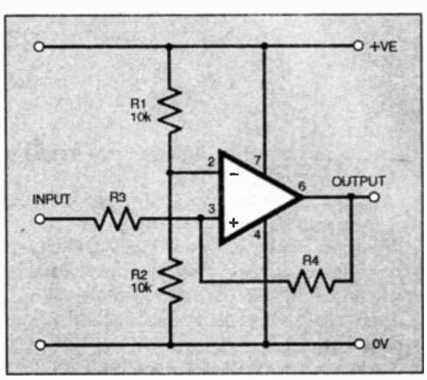


Fig. 1.7. Non-inverting op.amp Schmitt trigger circuit.

NON-INVERTING OP.AMP SCHMITT TRIGGER

In general, the circuit shown in Fig. 1.6 will provide good switching results. However, it is sometimes useful to reduce the sensitivity. For example, a circuit which switches on a light automatically at dusk may hesitate at the change-over point, making the light switch on and off several times. To counter-act this behaviour, positive feedback may be used as shown in Fig. 1.7, providing hysteresis.

Note the addition of two extra resistors, input resistor R3 and feedback resistor R4. The values of these resistors affect the reduction in sensitivity. This type of arrangement is known as a non-inverting Schmitt trigger circuit.

The exact changeover points at which the output will switch relative to the input voltage can be calculated, but as a simple rule for this series of articles, make feedback resistor R4 variable (say a 100k preset), and use a 10k resistor for R3 at the input.

INVERTING OP.AMP SCHMITT TRIGGER

The inverting Schmitt trigger circuit shown in Fig. 1.8 obeys similar rules to the circuit of Fig. 1.7, but the output behaves in the opposite direction. In this circuit, resistor R3 is connected between pin 3 and the potential divider pair, R1 and R2.

A reasonable starting value for R3 would be 10k, in which case feedback resistor R4 could be a fixed 47k type, or a 100k preset. In many applications for inverting op.amp Schmitt triggers, R3 may be omitted (replaced by a direct link). Experiment for the best results.

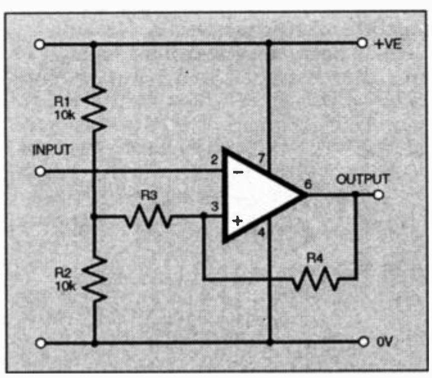


Fig. 1.8. Inverting op.amp Schmitt trigger circuit.

To sum up the op.amp switches shown in Fig. 1.6 to Fig. 1.8:

ADVANTAGES:

Very high voltage gain
Easy to handle
Predictable results within data sheet specifications
Positive feedback can be added, making the design very flexible

DISADVANTAGES:

The extreme output voltage swing is usually smaller than the power supply voltage
A few pence more expensive than a transistor
More connections

LOGIC GATE SWITCH

An example of a logic gate switch is shown in Fig. 1.9. Almost any logic gate can be used in this circuit: AND, NAND, OR, NOR, and of course Inverter (NOT gate) and Buffer functions. The use of a CMOS 4001B is suggested.

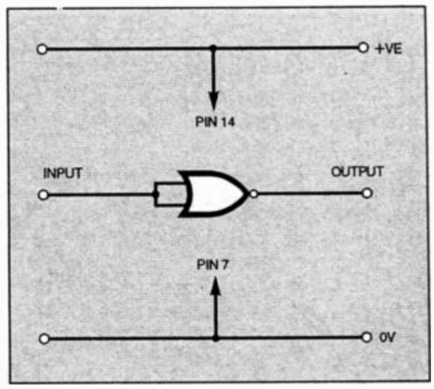


Fig. 1.9. NOR gate logic switch.

This is a 14-pin i.c. which contains four two-input NOR gates. It has been chosen because it is very useful in other applications, and there are three spare gates which could be used elsewhere in the same circuit.

The two inputs of the chosen gate are connected together as shown. This turns the NOR gate into a single input inverter, or NOT gate. Any of the four gates may be used, and all the pin numbers are shown in Fig. 1.14. The inputs to any unused gates should be connected to one of the supply rails, either +VE or 0V, as most convenient.

A CMOS 4000B series gate requires almost no input current. The output current available depends on the power supply voltage and the maximum output voltage acceptable. Typically, with a 5V supply and a Logic 1 output voltage of 4·6V these gates can provide an output current of about 0·88mA. A current of about 4mA is available if a Logic 1 voltage of 2·5V is acceptable. The available current rises with increased supply voltages.

As a rule-of-thumb, if the input voltage is less than about half the supply voltage, the output will be positive. If the input voltage is higher than about half the supply voltage, the output will be 0V. As a study of manufacturer's data sheets will show, in reality, the threshold levels are more clearly defined than this. In general, though, the output can be thought of as changing state when the input crosses the half supply voltage point.

However, if the input signal level is only changing slowly, the output voltage will not necessarily change state cleanly, but may tend to waver around a mid-way level as the input voltage changes. This can result in ill-defined logic states being presented to a subsequent gate, often resulting in several high speed pulses being developed at its outputs during the critical transition period.

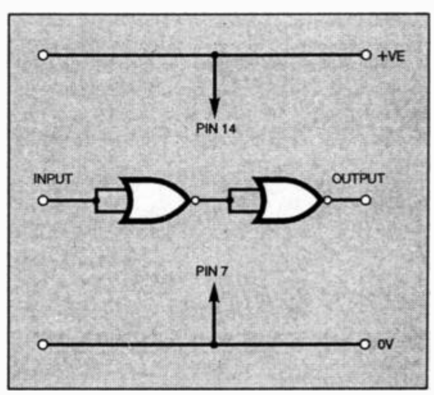


Fig. 1.10. Two NOR gates connected in series speed the output response in respect to slowly changing input voltages.

Note that a NOR gate **inverts** the input logic state. The Input and Output modules must allow for this inversion. Two NOR gates could be used in series to restore the logic state polarity. Alternatively, an OR gate could be used instead.

USING TWO GATES

The use of two inverting gates in series provides a much swifter output logic change with respect to slowly changing input voltage levels, as well as restoring the logic state polarity. Inverting gates include NOR, NAND and NOT (inverter). A circuit using two NOR gates is shown in Fig. 1.10.

As the input voltage rises above about half the supply voltage, the output switches rapidly from logic 0 to logic 1 (i.e. from 0V to close to the supply voltage). Conversely, if the input falls to less than about half the supply voltage the output will switch back to logic 0. As stated above, this type of circuit is prone to generating transient output pulses when the input voltage is only changing slowly across the threshold points.

SCHMITT TRIGGER LOGIC SWITCH

A Schmitt trigger switch based around two NOR gates takes the example shown in Fig. 1.10 a stage further by introducing positive feedback, as shown in Fig. 1.11. This type of circuit helps to avoid the generation of high speed output pulses during slow input voltage transitions. There are, though, some applications where these transient pulses are unimportant.

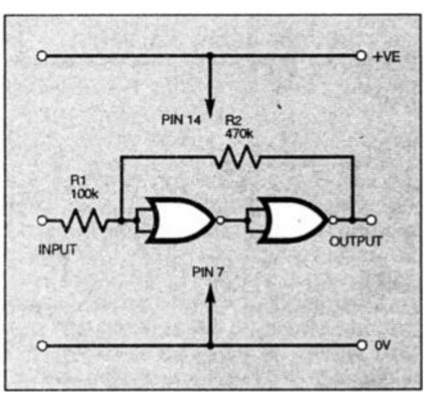


Fig. 1.11. Schmitt trigger logic switch.

Resistor R1 is inserted into the input path, and R2 provides the feedback. Using the resistor values indicated, the input has to rise to about two-thirds of the power supply voltage before the output will switch to logic 1. Before the output will switch back to logic 0 the input has to fall to about one-third of the supply voltage. There is no hesitation as the input voltage moves past the threshold trigger voltage points. This effect can be very helpful, although it makes the circuit appear to be less sensitive. The trigger threshold levels can be changed by altering the relative values of R1 and R2.

Logic gates are available in which the Schmitt trigger circuitry has been incorporated as part of their design. For example the CMOS 4093B contains four Schmitt two-input NAND gates. These gates have fixed trigger threshold points.

CMOS PRECAUTIONS

CMOS inputs have a very high impedance, which is generally useful, but this makes them more prone to damage from high static electricity voltages. Such voltages can be spontaneously generated in your body and may often be sufficient to destroy a CMOS chip. The following precautions will help you to avoid damage from static electricity:

1. Connect all unused **inputs** to 0V or to the +VE power rail. (Do not connect unused **outputs** to anything.)
2. Touch an earthed object before touching the pins of the i.c.
3. Use an i.c. socket, and plug in the i.c. last.

Once the chip is installed in the circuit the other components will conduct away static charges and its pins may be touched without too much concern, although still try to ensure that you have discharged static from yourself before doing so.

To sum up the Logic Gate switches in Fig. 1.9 to Fig. 1.11:

ADVANTAGES:

Very sensitive
Require virtually no input current
Use very little supply current (can sometimes be left permanently connected to batteries without running them down too fast)
Useful if the circuit requires further logic gates, since each i.c. houses four or more gates

DISADVANTAGES:

Can be damaged by static electricity
Unused inputs must be connected to one of the supply rails
There are 14 pins to connect correctly

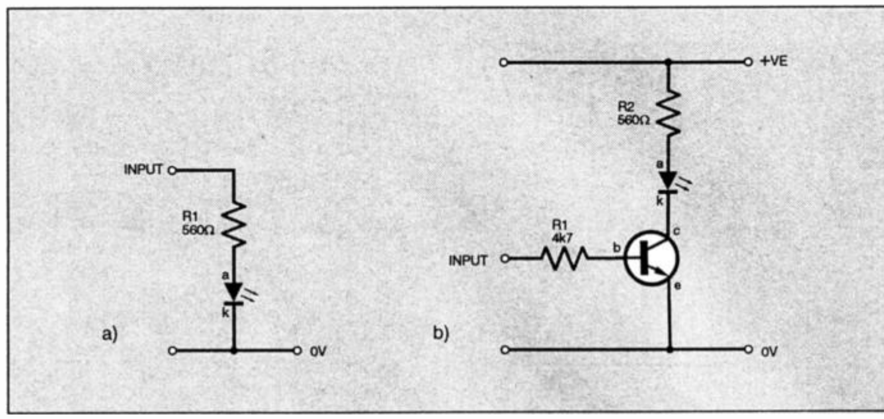


Fig. 1.12. Two methods of controlling an l.e.d. (a) passive (b) active

OUTPUT MODULES

The type of output circuit required will depend upon the device being driven. If only a simple l.e.d. indicator is required, the circuit shown in Fig. 1.12a could be connected to the output of any of the Processor circuits discussed so far, though the l.e.d. will not be very bright. (Low current, high brightness l.e.d.s are available which would improve matters.)

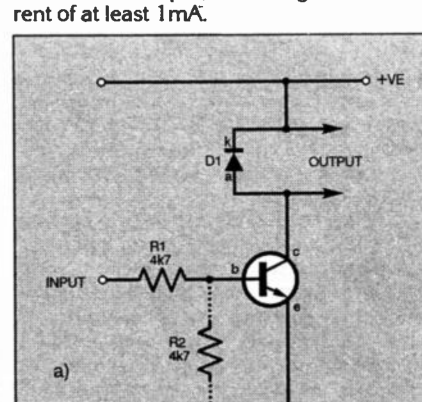
Resistor R1 limits the current flowing through the l.e.d., although this will also be limited by the current available from the preceding stage, which, as already discussed, may only be a few milliamps.

However, if used with Processor Module A (the Single Transistor switch in Fig. 1.5) the l.e.d. and its resistor may replace resistor R2, as shown in Fig. 1.12b, resulting in a much brighter display.

More substantial currents can be controlled by the output modules shown in Fig. 1.13, which are basically variations of the circuit in Fig. 1.12b.

SINGLE TRANSISTOR OUTPUT

A single transistor represents an easy way of amplifying the available voltage and current, as shown in Fig. 1.13a. If a high gain type is used, such as BC108, BC184L or BC549 etc., then it is safe to assume that at least 100mA is available to a collector load on the output, assuming a base current of at least 1mA.



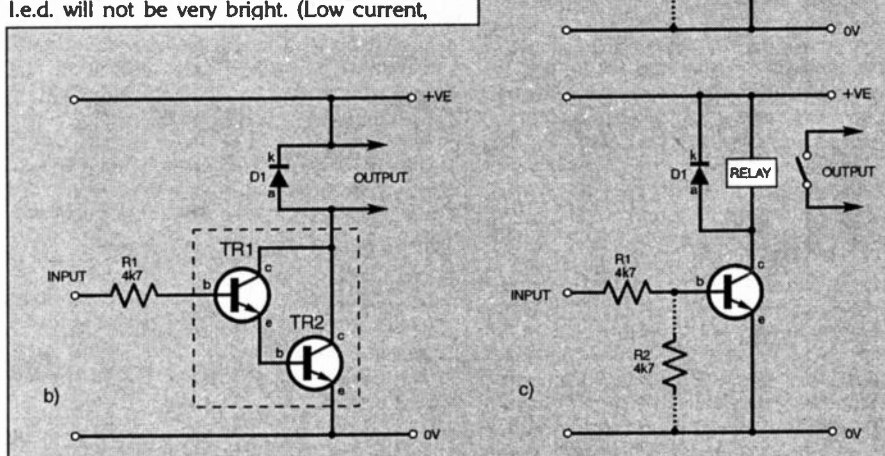


Fig. 1.13. Three suggested output module circuits: (a) single transistor, (b) Darlington, (c) Relay.

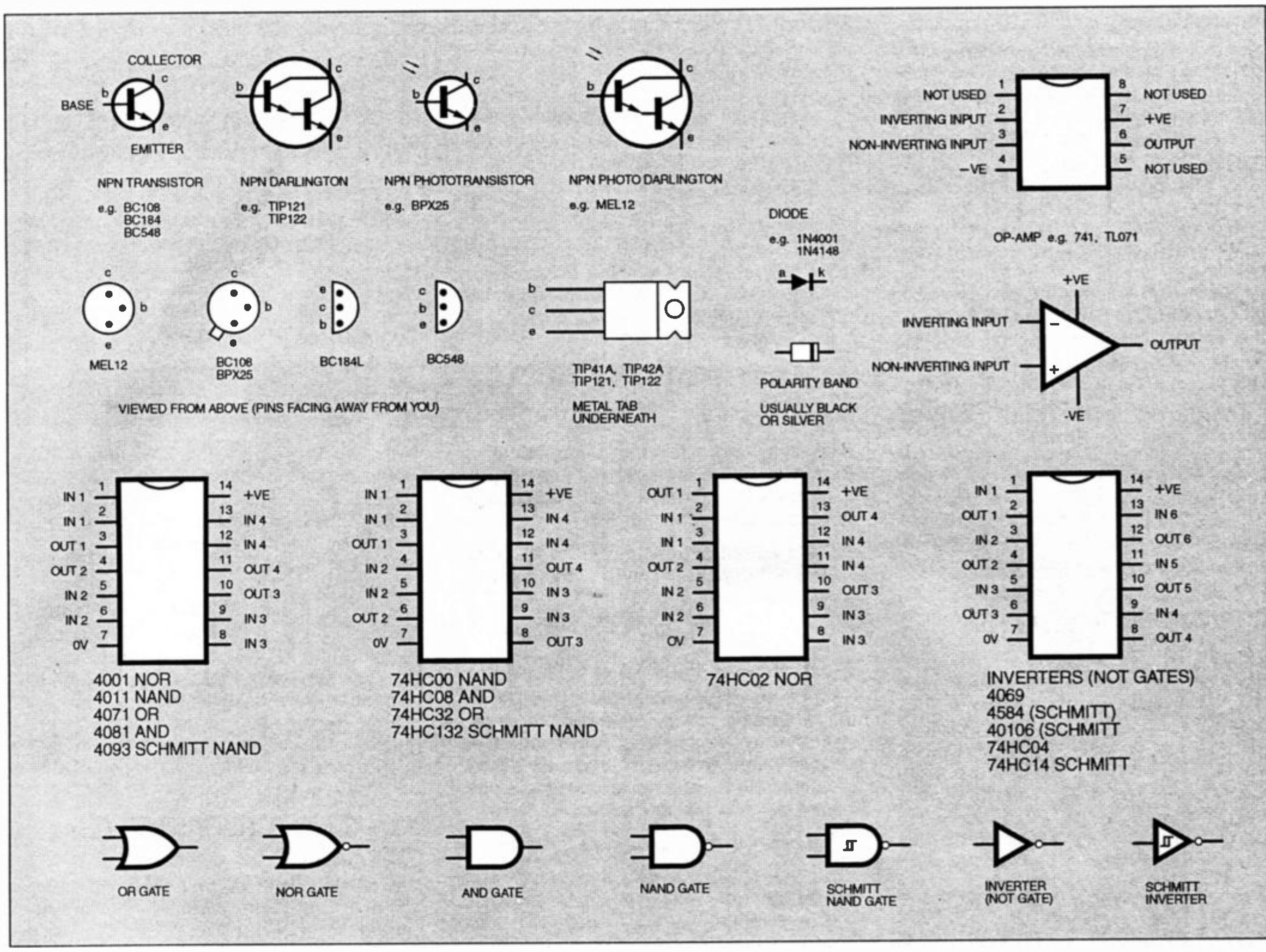


Fig. 1.14. A selection of useful circuit diagram symbols.

If the voltage at the input is less than about 0·5V the output device is switched off. If the input voltage is somewhat greater than 0·7V the output device is switched on. The output device is connected between the positive power rail and the collector, as shown by the arrows.

Some electromagnetic devices, such as relay coils and motors, produce voltage spikes, especially at the moment when they are switched off. Diode D1 inhibits these spikes, so preventing damage to the transistor. Any silicon diode, such as a 1N4148 or 1N4001, can be used. Be sure to connect the diode the correct way round, i.e. the band indicating the cathode (k) must be connected to the positive power supply rail. It may be omitted if the circuit is used to drive non-inductive loads.

This circuit may be interfaced to any of the Processor circuits described earlier. However, a small complication arises if it is interfaced to one of the op.amp circuits:

Many op.amps, it will be recalled, have an output voltage swing which is less than the power rail voltages. Since the lowest typical output voltage of about 1V is higher than a silicon *npn* transistor's turn on threshold of about 0·7V, the transistor cannot be turned fully off by the op.amp without a small circuit change.

This change simply amounts to adding a resistor (R2) between the base (b) of the transistor and the 0V power rail. Between them, this resistor and the existing R1 form a potential divider which reduces the minimum voltage at the transistor's base to less than the threshold voltage. With resistor R1 at 4k7 as shown in Fig. 1.13a, the additional resistor should also have a value of about 4k7, so halving the minimum voltage presented to the base.

DARLINGTON OUTPUT

"Darlington pair" is the name given to the arrangement of two transistors configured as shown in Fig. 1.13b. Transistor TR1 is a small, low power, high gain type, such as BC108 or BC184L. TR2 is a high power (but low gain) type such as TIP41A.

When connected as shown they act as one transistor with a high gain and high power; in other words the best of both worlds. Devices such as lamps, sirens, motors etc. can be connected to the output of this circuit, as indicated by the arrows.

On a 12V supply, the input current required is less than 1mA. The maximum output current available is about 3A. Diode D1 must be included for the reasons given above.

The dotted box in Fig. 1.13b indicates that a **single** Darlington-configured transistor may be employed. It looks like a single high power transistor, but it also contains the smaller high gain transistor. It is often less expensive than two separate transistors, and easier to connect. The only disadvantage is that fewer types are available, but in this application, types TIP121 or TIP122 will do exactly the same job as the pairs of transistors mentioned above.

Since the input threshold voltage for a Darlington is typically twice that for a normal silicon single transistor (above about 1·4V), this circuit may be driven by one of the foregoing op.amp circuits without the addition of an extra potential-dividing resistor.

RELAY OUTPUT

The relay shown in Fig. 1.13c provides complete electrical isolation between the output and the device being controlled. This would be important if, for example, a mains powered lamp is to be controlled by the circuit.

The transistor is a small low power high gain type, such as BC108 or BC184L. The relay coil is connected between the positive rail and the collector (c) of the transistor. (It may, in some cases, be connected to a different positive power rail to that serving other parts of the circuit.) The diode across the relay coil removes voltage spikes as described above. It can be any silicon type, such as a 1N4001 or 1N4148. The relay contacts are connected in the same way as the contacts of a switch.

On a 12V supply, the input current required by the transistor is about 1mA. The maximum current available for the relay coil is about 100mA. A relay coil with a resistance of 150 ohms or more should be used.

The output current available from the relay contacts will depend upon the type of relay selected – browsing through component suppliers' catalogues will reveal the wide choice available.

As with the circuit of Fig. 1.13a, this circuit may need the extra base resistor if driven by one of the op.amp circuits.

To sum up the three output modules of Fig. 1.13:

SINGLE TRANSISTOR

ADVANTAGES:

Inexpensive and simple
Operates silently
Output can be rapidly switched on and off if needed

DISADVANTAGES:
The output device (lamp, buzzer etc.) uses the same power supply as the circuit
The output device is not electrically isolated from the circuit
Only a modest current is available at the output

DARLINGTON PAIR

ADVANTAGES:
Inexpensive
Operates silently
Output can be rapidly switched on and off if needed
A substantial current is available at the output

DISADVANTAGES:
The output device (lamp, motor etc.) uses the same power supply as the circuit
The output device is not electrically isolated from the circuit

RELAY

ADVANTAGES:
Provides a clean switching action
Provides complete electrical isolation so that mains voltages can be controlled
Relays with several pairs of contacts are available

DISADVANTAGES:
Contacts can burn out with frequent use
For the previous reason, repeated on/off switching is best avoided
Comparatively slow to respond
Requires a spike suppression diode
Consumes a lot of current
Makes a clicking noise

REALISING YOUR DESIGN

You should now be in a position to make a selection based on exactly what the circuit is required to do. There is no single correct way. Different designers will arrive at different conclusions – all of which may be equally valid. The choice may depend upon personal preference, or prejudice, but try to compare all the facts fairly.

You may consider omitting the second module (Processor or Amplifier), and connect the Input and Output modules directly. This will probably be satisfactory with the l.d.r. as the input sensor, but the other devices will benefit from the extra module. If in doubt (or preferring to avoid lots of calculations), experiment.

Having decided on what the circuit must do, take the following steps:

1. Draw a block diagram of its requirements.
2. Select the modules which will fulfill these needs
3. Draw the complete circuit diagram, not forgetting at least one decoupling capacitor as described earlier, and possibly an on/off switch.
4. Label all the parts: resistors R1, R2, etc., transistors TR1, TR2 etc.
5. Insert all the values or "types", e.g. 10k, BC108 etc.
6. Construct the circuit, either temporarily (e.g. on prototype board, often known as breadboard), and/or permanently on a printed circuit board or stripboard.
7. Test the circuit.

TESTING THE CIRCUIT

Although the following testing and fault finding advice relates to the modules described in this article, the basic principles apply to any circuit which is to be tested.

Test the finished circuit with care, remembering that mistakes in the design or layout could cause damage to components. If a power supply is available which can have its output current limited to a low value, 100mA for example, test the circuit using this supply first. Naturally, the power supply voltage should match the requirements of the circuit under test, i.e. 12V for a 12V circuit.

If the circuit is intended to control motors, solenoids or other devices which require more than 100mA, temporarily replace such devices with a low value of resistor, of 1k for example, using a voltmeter to check the voltage swing across the resistor. Do not connect a meter in place of the intended load since excess currents could flow through it if set on an incorrect range and an unlimited power supply is used.

Connect up the supply, and adjust the variable resistor (potentiometer) of the Sensor module. In most cases it should be possible to switch the output on or off by turning the pot from one extreme to the other. Set it so that the output is just on or just off. Change the light level (or temperature) and see if the output switches the way it is intended.

Once it has been established that the circuit is working, use a 12V power adaptor or battery pack as required.

FAULT FINDING

If the circuit worked the first time it was tested, you were either very competent or very lucky. Just one slight fault could stop a circuit working. The challenge then is to correct the fault without getting depressed!

The following guide will help:

1. Examine the circuit, checking for obvious faults such as "dry joints" (i.e. connections not soldered properly and not connecting), and short circuits. Use a powerful magnifying glass to check these points.
2. Check that all components (except resistors and non-polarised capacitors) are fitted the correct way round. Has the i.c. been plugged into its socket?
3. Check all the resistor values, then the values and codes of other components.

If the circuit still fails to work as intended, use a voltmeter as follows:

1. Connect the negative lead of the voltmeter to the 0V rail in the circuit.
2. Connect the positive voltmeter lead to the positive rail in the circuit. The voltmeter should read 12V.
3. Use the positive voltmeter lead as a probe, checking the voltages around the circuit. Do they correspond to what is expected?
4. Check the positive and 0V pins of any i.c.s in the circuit. Do they read 12V and 0V, respectively?

Now track down the fault to a particular module:

Connect the probe to the output of each module and adjust the sensor pot as before. Do the outputs behave as described in the text?

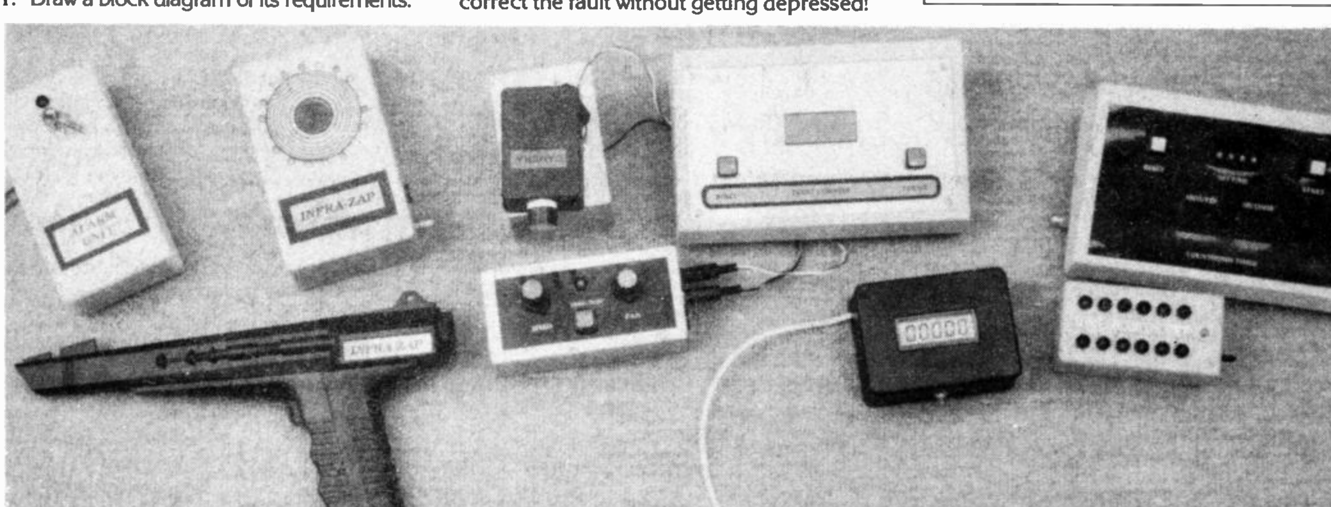
Once it is known which module is at fault, examine the components and their connections in that area very carefully. If new components have been used, the problem is much more likely to be a poor, or incorrect, connection than a faulty component. Should it be suspected that a component really is faulty, particularly a semiconductor such as a transistor or i.c., it is usually easier to substitute another of the same type rather than try to test the device itself.

IN PART TWO

Alarm switches, timers and fail-safe outputs are the modules examined.

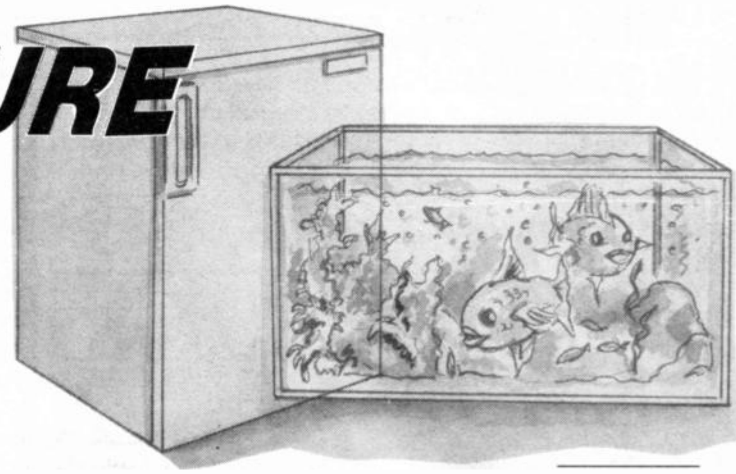
Example Project

The Temperature Warning Alarm (elsewhere in these pages) shows how these modules can be combined in a practical application



Some of the projects to be published in connection with Teach-In '96.

TEMPERATURE WARNING ALARM

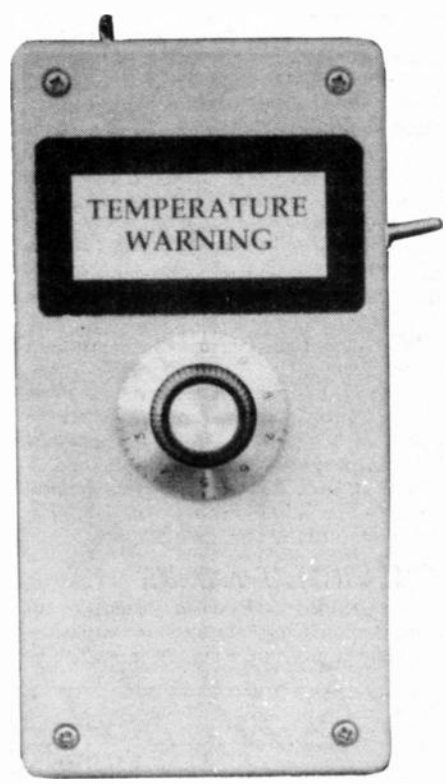


MAX HORSEY
PCB DESIGN BY DAN RUSBY

Modular monitoring sounds the alarm when the going gets hot. Illustrates how Teach-In '96 Part One might be applied

This article is based on the information provided in *Teach-In '96* Part 1 and shows how modules may be selected and combined to produce a working project. The project is designed to activate a buzzer if the temperature of a sensor rises above a preset level. It could be used to monitor the temperature of a fridge, freezer, power supply unit, television, or tropical fish tank.

Throughout this article, figure numbers prefixed "Fig.1." refer to drawings in *Teach-In '96*. Thus Fig.1.1, Fig.1.2, Fig.1.3 refer to the same figure numbers of *Teach-In '96*. Other figure numbers, e.g. Fig.1, Fig.2, etc. refer to drawings in this article.



DESIGN POINTS

The first stage of designing a circuit is to make a list of the essential design points:

1. The circuit is to be housed in a case with a remote sensor which may be fixed to the equipment being monitored
2. It is to be powered by a battery (or mains adaptor)
3. It is to activate a buzzer or siren if the temperature rises above a preset level

BLOCK DIAGRAM

Next, the block diagram needed is drawn, as shown in Fig. 1. In this design there are three modules involved: Temperature Sensor, Amplifier and Siren. Respectively, these represent the Input, Processor and Output modules previously shown in Fig. 1.1.

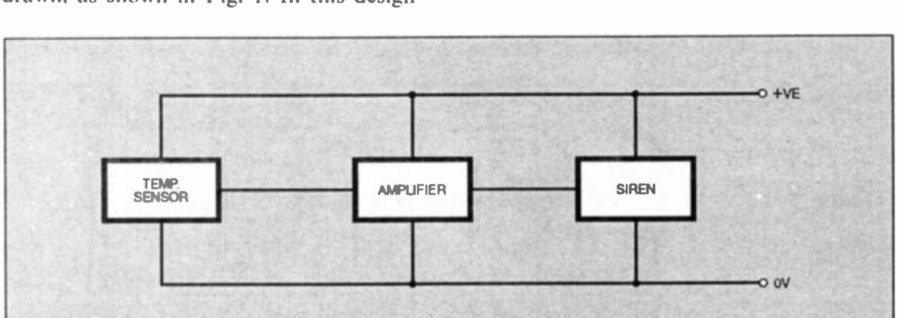


Fig. 1. Block diagram for the Temperature Warning Alarm.

INPUT MODULE SELECTION

For the Input module, the suggested temperature sensing device is a thermistor. It is cheap and robust and, given a suitable Processor module, is more than sensitive enough for this application. The circuit modules available were shown in Fig. 1.4.

The choice of Input module, Fig. 1.4a or Fig. 1.4b, is determined by the requirements of the Processor module.

PROCESSOR MODULE SELECTION

The choice of Processor module, previously presented in Fig. 1.5 to Fig. 1.11, is between those designed around the Single Transistor, Op.amp, and CMOS Logic Gate. All these devices will amplify the small change of voltage at the output of the Input module. However, a scan through the advantages and disadvantages of each module reveals that the transistor gain is unpredictable, and that a single transistor is unlikely to provide the gain required by this particular circuit.

The choice is now between an op.amp, of which the 741 is typical, and a CMOS logic gate, such as a 4001B NOR gate. The op.amp seems a likely candidate and could do a good job. However, the circuit is to be permanently connected to a battery, and low current consumption is therefore vital. In this respect, the CMOS logic i.c. wins handsomely – it uses virtually no current at all when its inputs are in a stable state – as they will be if the temperature of the device being monitored is normal.

As only one amplifying module is required, the use of the CMOS 4001B i.c. may seem wasteful since it contains four two-input gates. However, it is no more expensive than a 741 op.amp and although the i.c. is designed for logic circuit use, it can work very happily as an amplifying module.

A look back at Fig. 1.9 to Fig. 1.11 shows three possible arrangements: the use of a single gate as an amplifier, or a pair of gates to provide a faster output voltage swing, or a Schmitt trigger arrangement.

The single gate version may produce a rather hesitant sound from the siren at the threshold between "safe temperature" and "danger". The Schmitt trigger version would reduce the sensitivity of the circuit, and a thermistor is not particularly sensitive anyway. This leaves the second arrangement, the two-gates configuration shown in Fig. 1.10.

OUTPUT MODULE SELECTION

There is insufficient current available from the output of a CMOS 4000 series gate to drive all but the least demanding buzzers. Consequently, the Output module required is essentially a current amplifier. If the current required by the buzzer is less than 100mA, the Single Transistor module of Fig. 1.13a, for which a low current transistor such as a BC184L is suggested, will be sufficient. If more current is required, the transistor could be replaced by one capable of sinking it, such as a 2N2219, for example. Alternatively, a Darlington pair could be considered, as shown in Fig. 1.13b. A mains operated buzzer would necessitate the use of a relay, for which the circuit of Fig. 1.13c would be suitable.

A glance at component catalogues reveals a wide selection of buzzers which require less than 100mA. The single transistor output of Fig. 1.13a has been chosen here. The transistor will be switched on when its input is made positive.

The chosen Processor module is "non-inverting", in other words, if its input is made positive its output will follow suit. This means that the temperature sensor module must produce a rising voltage as the temperature rises. The circuit shown in Fig. 1.4 achieves the requirements.

DRAWING THE FINAL CIRCUIT

It is now possible to draw a preliminary combined circuit diagram for the Temperature Warning Device, as shown in Fig. 2.

There are, though, still some details to be decided upon, i.e. pin connections, for example.

To determine the input and output pin numbers of the 4001B NOR gate which could be used, refer back to Fig. 1.14. It really makes little difference which gates are chosen, so on this occasion the chosen gates are those whose inputs are pins 1 and 2, 12 and 13, respectively. The corresponding outputs are pins 3 and 11.

An important point to remember when designing circuits employing CMOS i.c.s, is to not leave any unused inputs unconnected. The spare inputs, in this instance pins 5, 6, 8 and 9, can be connected to 0V or to the positive power rail, as most convenient, so that they are not "floating". Here it is convenient to connect them to 0V. Leave the spare output pins (4 and 10) unconnected.

CURRENT CONSUMPTION

There is a refinement worth making to the Sensor circuit. Whenever the circuit is connected to a battery, current will flow through the thermistor and variable resistor. With a 9V supply, this current will be in the order of 1mA if the circuit of Fig. 1.4a is used as shown.

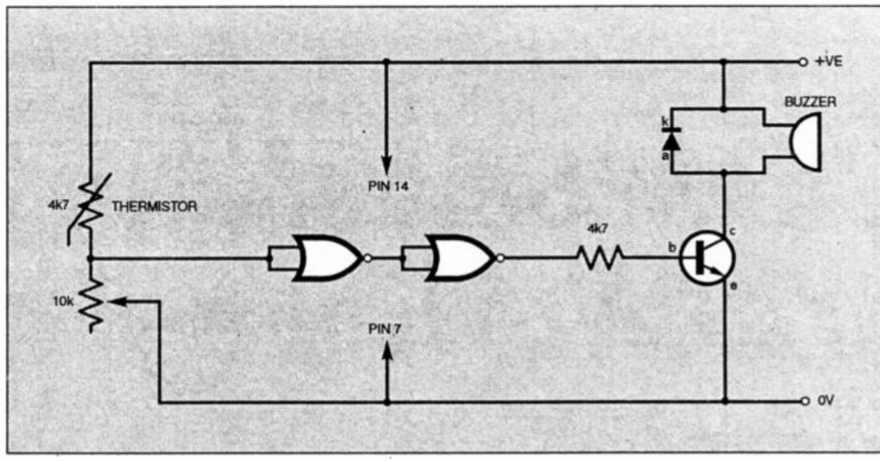


Fig. 2. Preliminary combined module circuit diagram.

This is because the total resistance between the positive and 0V rails will be roughly the value of the thermistor (4k7) at room temperature, plus the value of the variable resistor, which will be set to about the same value (4k7), giving a total of about 10k ohms. Since current = voltage divided by resistance (I = V/R), the current in this case will be 9/10k = 0.0009A, or approximately 1mA.

If the circuit is powered from a suitable mains adaptor, or from a battery and used only intermittently, current consumption will not be a problem (although in some designs the extra heat generated may be a problem). However, if the circuit is permanently connected to a small battery, it is worth reducing the current consumption as much as possible.

A CMOS gate requires virtually no current at its inputs. The wasted current can therefore be reduced by using a higher value thermistor, say 100k (at 25°C) and a higher value variable resistor to match, say 220k. The current flowing through this component pair will now be about 0·045mA.

With such a high value input resistance, about 200k, there is a slight risk that electrical noise might cause problems, especially if the thermistor is connected to the circuit via long leads. Although it may not be necessary in some circumstances, a 100nF (0·1µF) capacitor (C1) connected between the inputs of IC1a and 0V will help to ensure stability and reliability.

DECOUPLING

As explained in *Teach-In '96* Part 1, all circuits should have at least one capacitor connected across their supply rails. This is especially true if the circuit is operating a buzzer or other electrically noisy device. An electrolytic capacitor (C3) of about 470µF will be large enough for this type of circuit, and a 100nF capacitor (C2) will soak up any tiny noise spikes which large capacitors tend to ignore.

Combining all these additional details, and adding a power supply on/off switch (S1), the final circuit diagram is arrived at, as shown in Fig. 3.

THE NEXT STEP

Unless very confident about the circuit design, the next step should be to test the circuit before designing the printed circuit board (p.c.b.) or stripboard layout. Prototype boards (often called breadboards) are also available for this purpose, and components can easily be removed for experimenting and redesigning. It has to be said, though, that many people dislike using a prototype board because it is fiddly, and if the circuit does not work it may be hard to know if the problem is caused by a circuit design fault, or a simple wiring mistake.

CONSTRUCTION

On this occasion, since the example circuit has been designed and tested for publication, there is no need to design your own p.c.b. as one is already presented in Fig. 4! This board is available from the *EPE PCB Service*, code 960.

Begin assembly of the p.c.b. by inserting the i.c. socket, followed by the smaller components, checking that the diode is fitted with its polarity band facing the correct way. Resistor R2 and capacitors C1 and C2 can be fitted either way round,

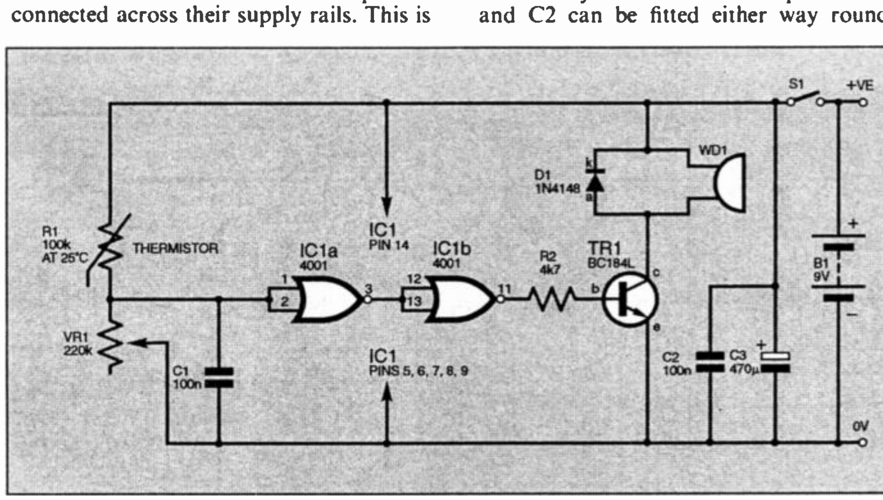


Fig. 3. Final circuit diagram for the Temperature Warning Alarm.

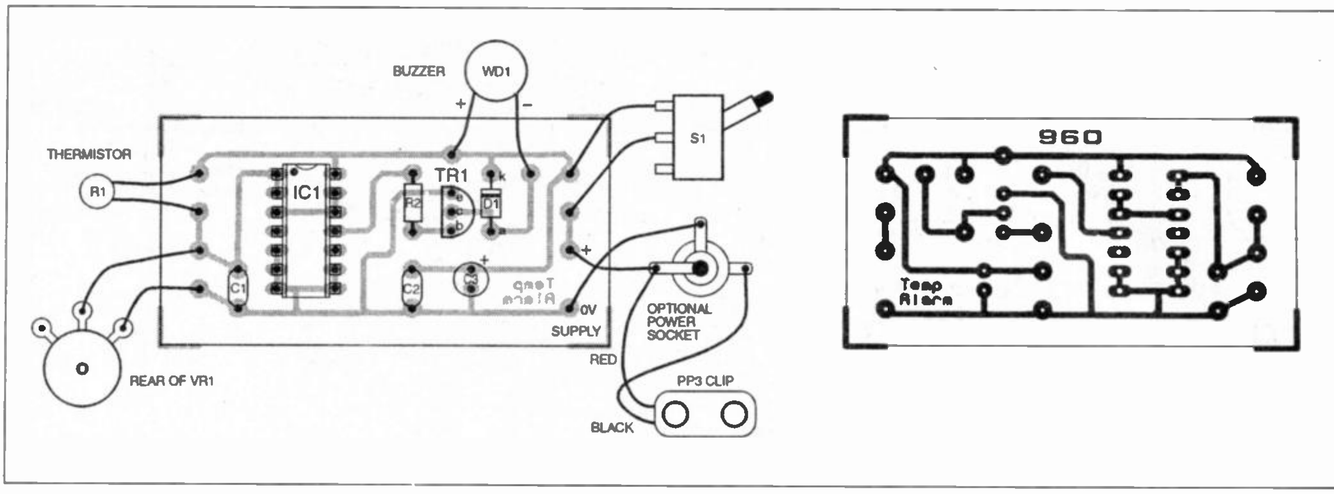


Fig. 4. Printed circuit board component layout and full size underside copper foil track master pattern.

COMPONENTS

Resistors
R1 NTC thermistor, 100k at 25°C
R2 4k7 0.25W 5% carbon film

See SHOP TALK Page

Potentiometer
VR1 220k rotary lin.

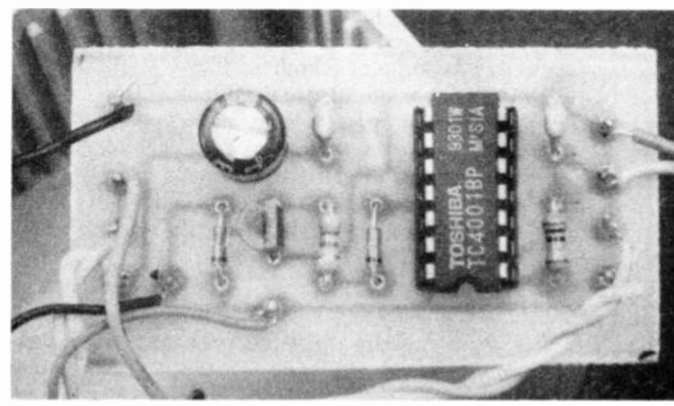
Capacitors
C1, C2 0·1μ (100n) ceramic disc (2 off)
C3 470μ radial elect. 16V

Semiconductors
D1 1N4148 signal diode
TR1 BC184L *npn* transistor
IC1 4001B quad 2-input NOR gate

Miscellaneous
B1 9V PP3 battery
S1 min. s.p.s.t. toggle switch
WD1 solid state buzzer (9V or 12V)

Printed circuit board, available from the *EPE PCB Service*, code 960; 14-pin d.i.l. socket; PP3 battery clip; power socket (see text); plastic case 64·5mm × 129·5mm × 42·5mm; knob for VR1; 1mm terminal pins; connecting wire; solder etc.

Approx cost guidance only **£10**



but electrolytic capacitor C3 and transistor TR1 must be orientated as shown. The negative end of an electrolytic capacitor is normally indicated by arrows.

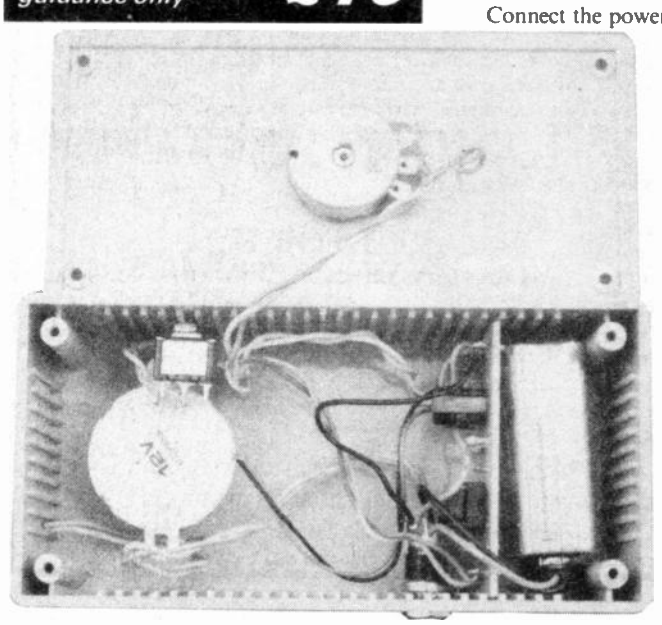
It is suggested that terminal pins are inserted into the p.c.b. to which the off-board components can be readily wired and soldered. Ensure that the buzzer and battery clip are connected the correct way round. It is unimportant which way round the thermistor R1 is connected.

An optional power supply socket is shown in Fig. 4. When a 9V or 12V mains adaptor is connected, the battery will be disconnected automatically. If the socket is not required, connect the red wire attached to the PP3 clip directly to the positive terminal pin on the p.c.b. and connect the black PP3 lead directly to the 0V terminal.

Finally, insert the i.c. into its socket, **taking special care to briefly earth your fingers** (by touching an earthed metal object) before removing the i.c. from its protective package or foam. Ensure that the i.c. is fitted with the notch as indicated.

TESTING

Connect the power supply, switch on and adjust potentiometer VR1. With VR1 connected as shown, a higher temperature trigger level is selected when it is turned clockwise. It should be possible to make the buzzer switch on and off by turning the pot. one way or another. If the buzzer does not sound, or cannot be silenced, then switch off and check for faults.



If all is well, set the pot until the buzzer is not quite sounding. Warm the thermistor in your fingers. After a brief pause, the buzzer should sound. When retesting, remember that the thermistor may take several minutes to cool down.

FAULT FINDING

If the circuit does not behave as expected, refer to the Fault Finding section in *Teach-In '96* Part 1. Once the visual checks are complete, use a voltmeter as described. Be aware that the positive side of the buzzer is permanently connected to the positive rail. The negative side of the buzzer will also be positive when the buzzer is not sounding. When the buzzer is activated, the transistor will turn on, causing the voltage at the negative side of the buzzer to fall to 0V.

THE CASE

A small plastic case is used to house the p.c.b. and other components. The p.c.b. fits into the groves of the case, with space for a PP3 battery just behind, as seen in the photograph. Begin by drilling holes for the switch, potentiometer, thermistor and for the sound to escape from the buzzer. A hole for a power supply socket should be drilled at this stage if it is intended to operate the project from a mains power adaptor.

The thermistor may be fixed so that it stands proud of the case, or bent over and glued to the edge of the case. Alternatively, it may be connected via long leads if remote operation is required. Insert the p.c.b. and make all the necessary connections. Finally, glue the buzzer to the inside of the case, and insert the PP3 battery. □

PART TWO

In Part Two of *Teach-In '96*, alarm switches, timers and fail-safe outputs are examined. An Alarm Unit with entry/exit and siren timers is presented as an example of how the module ideas can be used.

INGENUITY UNLIMITED

Our regular round-up of readers' own circuits. We pay between £10-£50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit tips, not simply mechanical or electrical ideas. Ideas must be the reader's own work and **not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should preferably be typed or word-processed, with a brief circuit description showing all relevant component values. Please draw all circuit schematics as clearly as possible.

Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset, BH21 1PF. They could earn you some real cash!

Melody Sound-to-Light

– a bright and tuneful display

A METHOD of synchronising a simple light show to a musical chip is given in the circuit diagram Fig. 1. Here a display of eight rows of four l.e.d.s advances with each musical note. IC2 is a UM66 3-pin melody chip selected to generate the desired tune.

When power is applied to IC2, the sequence plays once and then stops. Power must be re-applied to initiate a further rendition. IC1 is a 555 astable which will constantly re-enable the tune chip and repeat the melody.

However, the maximum supply voltage of the UM66 range is 3·3V, hence a simple Zener diode supply is used based around two 500mW 2V7 types (D1, D2). TR1 is a directly driven transistor amplifier and the melody is played through loudspeaker LS1.

Each musical note when present also biases transistor TR2 on, which shunts capacitor C2 to ground. In the absence of a note C2 charges which causes the op.amp IC3 to change state at a point determined by preset potentiometer VR1.

The output from IC3, pin 6, provides a clock pulse for IC4, a 4022 divide-by-eight counter. Each of its outputs drives a buffer transistor sequentially to illuminate a series of four light-emitting diodes (l.e.d.s). The light display then advances with each successive musical note.

Adaptable Displays

Novel displays could be formed from arranging the l.e.d. rows to form parts of concentric rings or other shapes. By replacing one l.e.d. with an opto-isolator l.e.d., the design could possibly be adapted to readily control low-power mains lighting instead.

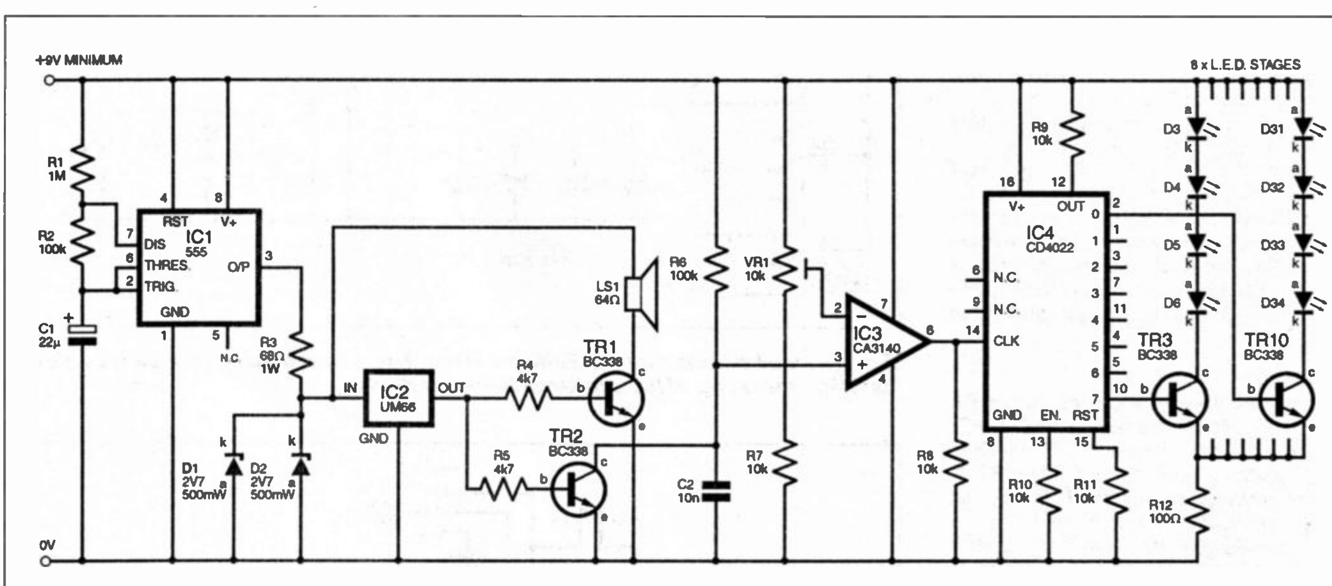


Fig. 1. Sound-to-Light circuit diagram, using the "special" UM66 melody chip. Note that the eight-stage display output only shows the first (TR3) and last (TR10) stages.

C. Brown,
Witham,
Essex.

Dalek Voice Simulator

– EXTERMINATE!

MY CIRCUIT design shown in Fig. 2 is a "fun circuit" which produces a *Dr. Who* "Dalek voice" effect by chopping an audio signal at a low frequency. The best frequency seems to be around 50Hz to 90Hz and this is generated by IC1, a 555 timer.

Unlike an ordinary 555 astable multivibrator, the arrangement shown is a "hysteresis" oscillator *(also seen in the Siren Circuit of Fig. 6 – A.W.)* which frees the 555 internal discharge transistor (pin 7) to act as a chopper, shunting the signal to 0V internally.

The "chopped" frequency is set by VR1 which is adjusted to give the most realistic sound. The input signal should be in the region of 50mV to150mV r.m.s. from a low impedance source, e.g. possibly a dynamic microphone, to avoid clipping the signal. The diode D1 is optional, and prevents the signal from losing symmetry if overdriven.

The output signal is fed to an external amplifier. The two d.c. blocking capacitors C1 and C2 are optional and are only needed if there is any d.c. bias present on the input signal side. I recommend as a test signal, the instruction "EXTERMINATE!" be used.

W. Gray,
Farnborough,
Hants.

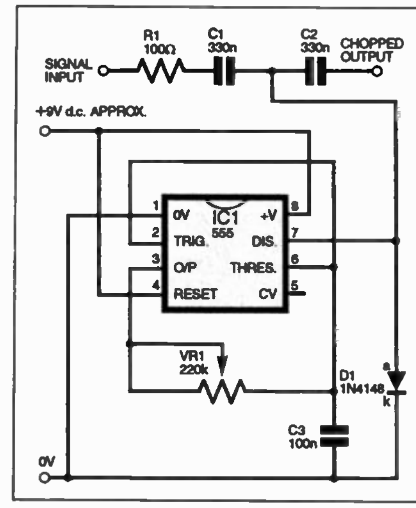


Fig. 2. Circuit diagram for the Dalek Voice Simulator.

Enlarger Timer – for ner prints

NEEDING an Enlarger Timer to replace an elderly 555-based design, this fairly accurate design is also suitable for colour work and is depicted in Fig. 3. Unlike many simple timer designs, this unit is based around the LM3905N 8-pin d.i.l. precision timer i.c. which repeats the timing period very consistently with little drift, though the accuracy of the timer depends on the tolerance of the components used. *(Note, this chip is described in National Semiconductor's data for its LM122 Precision Timer family. Device available from* ***Cricklewood Electronics****, London, Tel. 0181 452 0161 – A.W.)*

In the circuit diagram of Fig. 3, IC1 is an LM3905N timer whose period is determined by an external *RC* network selected by switches S1 and S2. The formula for the time period is $t = R.C$ where t is in seconds, R is in ohms and C is in Farads.

Switch S1 is a single-pole 12-way rotary type which selects appropriate timing resistors R1 to R11. S2 is a 3-pole 4-way rotary switch which progressively adds C1 to C3 *in parallel* with C4, thereby adjusting the timing capacitance range. In conjunction with the one per cent resistor network R1 to R11, each 1µ/1M pair represents a one second period and hence the maximum possible period is 44 seconds.

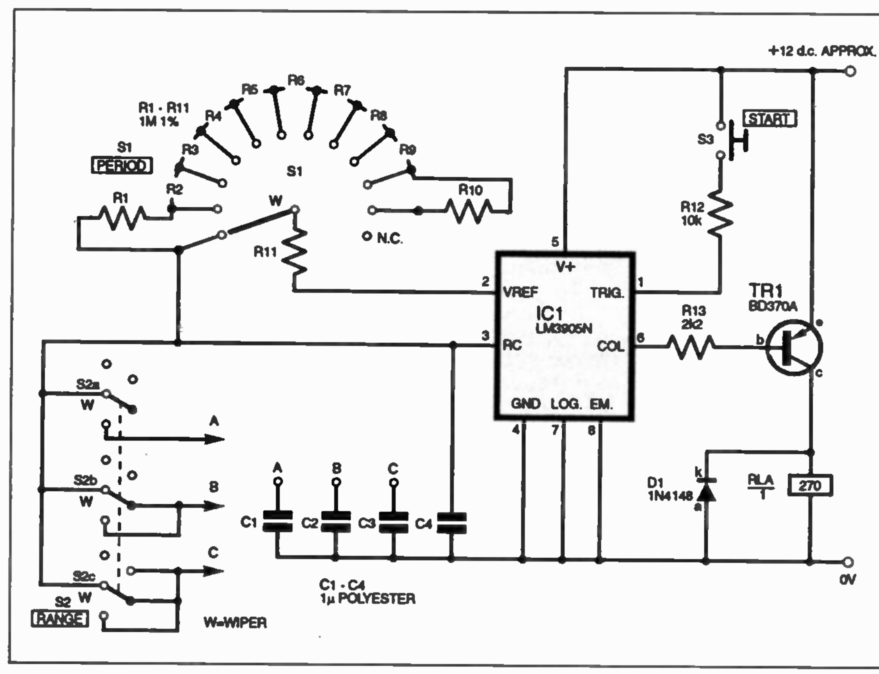


Fig. 3. Circuit diagram for the Enlarger Timer. The relay contacts must be capable of handling the rating of the appliance being controlled.

Timing

Timing is initiated by closing switch S3. A floating output transistor *within* IC1 drives a *pnp* buffer transistor TR1 which in turn operates a mains-rated relay RLA. The circuit requires roughly a 12V rail, and the relay coil is chosen accordingly.

The i.c. will operate from 4·5V to 40V d.c. and a standard full-wave power supply may be used, see Fig. 4. The relay contacts RLA1 switch on the enlarger bulb and a separate "Focus" switch (S5) can be included across the mains relay contacts (or perhaps drive the relay coil manually) if desired.

In spite of the advantages which manufacturers have in terms of buying power, I think this design will prove most satisfactory and it can be constructed very economically. It was certainly much cheaper than any I could have purchased ready-made.

Syd Mercer,
North Leverton,
Notts.

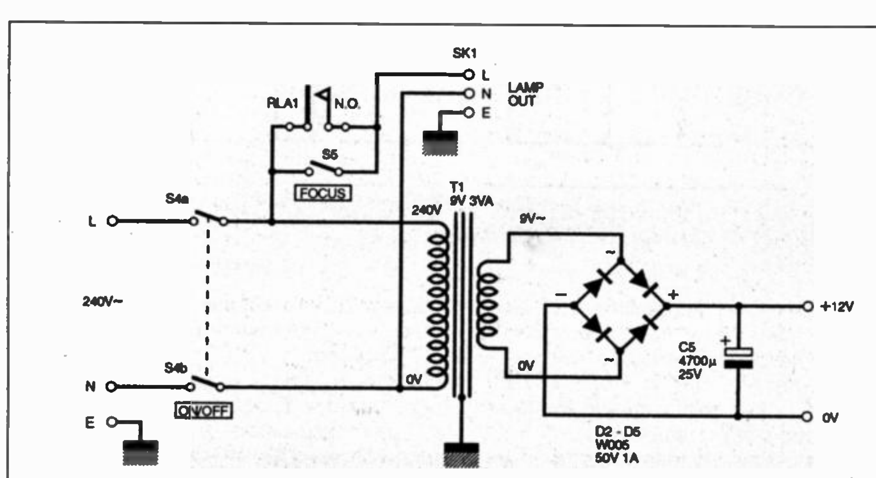


Fig. 4. Suggested power supply circuit for the Enlarger Timer.

Capacitor Leakage Tester – for valve amps, etc.

SEEING the *EPE* design for a *High Voltage Capacitor Reformer* July 1995's issue, reminded me of another problem associated with capacitors in old valve amplifiers, and the tester I built to resolve it. The coupling between amplifier stages typically uses a capacitor connected between anode of one stage and the grid of the next. Because of the high potential present at the anode, it does not take much leakage to affect the grid bias of the subsequent stage. Leakage too small to detect on a multimeter can reduce the gain through the amplifier.

My circuit design shown in Fig. 5 is sufficiently sensitive to detect 50 megohms or more. It is mains powered to generate a realistically high voltage for testing, but component values have been chosen to minimise any associated hazards.

In Fig. 5, the voltage divider resistors R1 and R2 are placed across the Live and Neutral mains input, and draws only 0·5mA so heat dissipation is minimal. The output charges the electrolytic capacitor C1 to about 160V over a period of about 15 seconds.

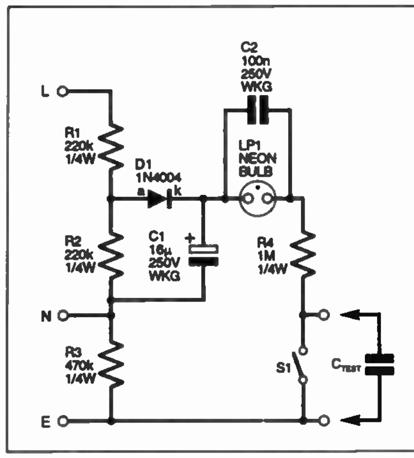


Fig. 5. Capacitor Leakage Tester circuit diagram.

When closed, the single-pole switch S1 will cause the neon bulb LP1 to flash, when a working voltage is reached. The switch is then opened. The neon strikes when the voltage across its terminals reaches 60V or so.

In a Flash

With a "sound" capacitor connected across the probes, there is no charging path for C2. If, however, the capacitor under test is leaky, then the neon bulb will flash at a rate dependent upon the degree of leakage – typically, from roughly 5Hz for a dead short to once every four seconds at 20 megohms.

It is *not* suitable for testing leaky electrolytic types. If the test capacitor has a high capacitance then the neon may flash a few times when it is first connected. ***Obviously caution is required when dealing with these high voltages.*** After disconnecting from the mains, close switch S1 and the neon flash will discharge C1, which could take a minute or so.

Jim Warren,
Bath.

Siren Generator – an alarming noise!

AN ADAPTABLE Siren Generator circuit with a multitude of uses is shown in Fig. 6. It is based around a 556 twin timer chip, IC1. An audio tone is created by one timer section and is directly coupled to the driver transistor TR1. The other half of the timer is used to modulate the frequency of the audio tone using the control voltage pin terminal of the audio oscillator section, pin 11.

If capacitor C2 is omitted from the circuit, a twin-tone alarm generator will be created. However, with C2 in place as shown, a "wailing" tone is produced. Capacitor C1 governs the rate of tone change and the l.e.d. D1 flashes, for extra effect.

A waterproof Mylar-coned 8 ohm loudspeaker was used for LS1 and the volume may be adjusted for different impedances by altering the value of resistor R5. The circuit operates from approximately a 9V rail.

S. M. Spencer,
Sleaford,
Lincs.

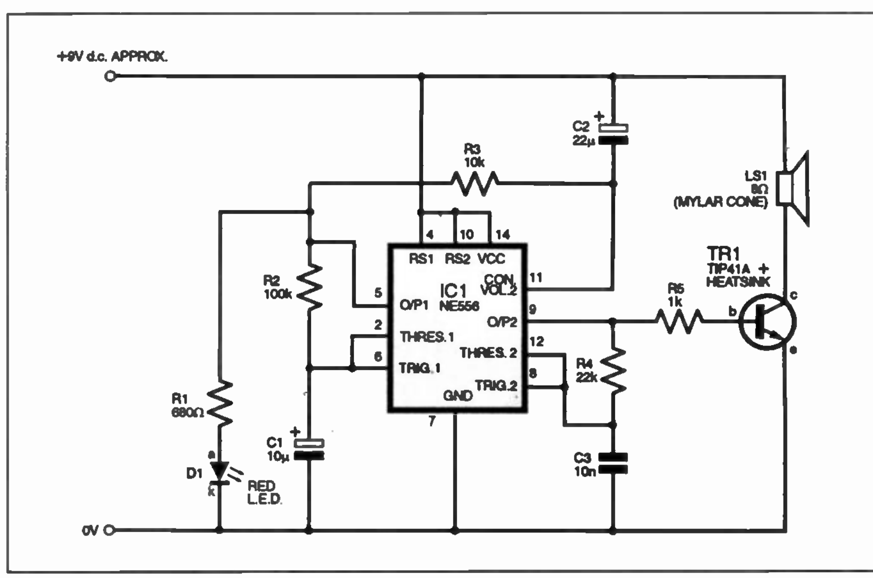


Fig. 6. Circuit diagram for the Siren Generator.

READOUT

Dear Mike,

I remember, as a boy, buying the first copy of *Everyday Electronics* in South Africa. In fact you have been such a long-running editor yourself that I have a picture of you shuffling to your desk every morning with a walking stick!

I must commend you first on a most interesting and innovative magazine – also very thorough for its quality. Quite un-English, in fact. I must also commend you on being such an accessible and "listening" editor.

Recently I inherited a huge pile of *Everyday Practical Electronics* magazines from an enthusiast who passed away, and I greatly enjoyed reading them. As I read them, I noticed what I see as two major shifts in empahsis in the magazine over the years.

The first was a huge increase in the component count and complexity of projects (despite increasing integration of the components)! The second was some loss of the personable atmosphere of the magazine.

It is not unusual now to find projects using 50 plus components, and in some issues, if I'm not mistaken, not a project with less (barring the educational articles, that is).

However, on the plus side, these are good projects, and often they are also a demonstration of good theory and technique. But perhaps the magazine could benefit from printing one simple (yet innovative?) project in each issue. *Ingenuity Unlimited* redresses the balance to some extent.

On the second score, I see much of the British character as being summed up in, perhaps, informal cordiality and jocularity. Unfortunately, in recent years, in the press, this appears to have fallen to commercial pressures. Rather have an additional page of advertising than a couple of personable letters.

Past *Everyday Electronics* issues had many personable aspects, such as the *Letters* page, *Counter Intelligence*, *Jack Plug and Family*, and so on. An undue empahsis on efficient use of space and scientific excellence may be to the detriment of a magazine's personable atmosphere. It may become more nutritious, but have less flavour.

You wouldn't like to be a minister for a year? I have a large church in a picturesque urban seaside holiday resort. You can see the pastel ocean from the front gate. I'd pay your fare to take my place, and I'd take over *Everyday Practical Electronics* for a year. How often do you receive an offer like that?

Rev. Thomas Scarborough,
Cape Town, South Africa.

Thank you for the interesting letter and job swap offer; unfortunately I don't think I would make a very good Minister but my family might be pleased with a year's break from me! This is the first time I have received such an offer – the next best was a pet monkey in exchange for a year's subscription – also declined! I should say that I still feel relatively young and don't yet need a stick, but I did start working on Practical Electronics *in September 1968 (I was very young!).*

We still keep a number of simple projects in EPE *but since the merger with* PE *we are also endeavouring to cater for a wider range of experience.*

On a lighter note we now run Ohm Sweet Ohm *by Max Fidling which I hope you enjoy. All your points are taken with interest and, along with others, will help to shape future issues. Thank you – Ed.*

DEVELOPMENTS IN RADIO BROADCASTING TECHNOLOGY

IAN POOLE

Far from being relegated to second place against television, sound radio is alive and kicking, and undergoing much improvement.

MANY new and exciting developments are taking place in the world of radio broadcasting. Often television seems to take the headlines. With NICAM digital stereo sound recently established, satellite and cable television being used increasingly and developments with new standards for high definition television, it may appear that sound radio has been relegated to second place.

This is far from the truth. Over the years there have been many developments in radio, ensuring that it is keeping up with the latest technology, and providing what the listener needs.

First Broadcasts

The first radio broadcast transmissions used amplitude modulation (a.m.). During the 1920s and 1930s long and medium wave (l.w. and m.w.) stations appeared in large numbers especially in the USA. Even in the UK, a network of transmitters was quickly established bringing programmes to virtually all parts of the country.

Short wave (s.w.) broadcasts were also introduced providing a very useful service. The famous BBC World Service was initially set up to keep all parts of the Empire in touch with London by receiving a broadcast at least once a day. Now it provides a service which is respected all over the world. In times of conflict it is looked upon as the service which provides the most impartial news and comment.

A.M. Transmissions

Amplitude modulated transmissions are still used today on the long, medium and short waves. A large number of stations, both BBC and Independent Radio use it, proving that a.m. can still provide an effective service.

Radio broadcasts using a.m. work by superimposing the sound vibrations onto the amplitude of the radio frequency signal as shown in Fig. 1. In the transmitter, a radio frequency signal or carrier is generated. This is passed into one input of a stage known as a modulator. Then the audio signal is passed into another input so that it can modulate the level of the carrier.

In the modulation process other signals known as sidebands are generated, as seen in Fig. 2. If the modulating signal was a single 1kHz tone then two further signals would be found 1kHz either side of the main carrier.

Music and speech contain a variety of frequencies, and therefore two sidebands are found either side of the main signal. It can also be seen that the overall bandwidth of the signal is twice that of the top frequency to be transmitted.

Current standards separate different channels in the medium wave by 9kHz. This means that the top frequencies which can be transmitted on the long and medium wave bands are very limited. On the short wave bands where the channel spacing is only 5kHz matters are even worse.

Whilst a.m. may appear to have many limitations it still has a number of advantages. One of the main ones is its simplicity allowing a.m. radios to be manufactured very cheaply.

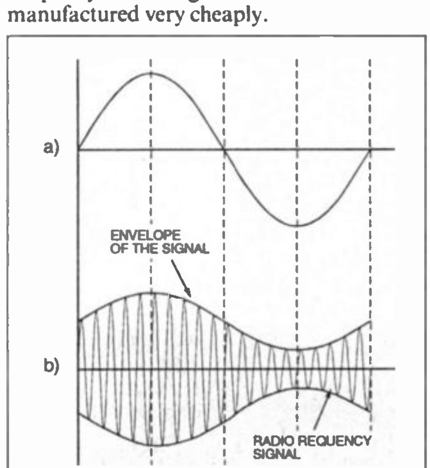


Fig. 1. Amplitude modulated signal waveform: a) modulating waveform; b) amplitude modulated signal.

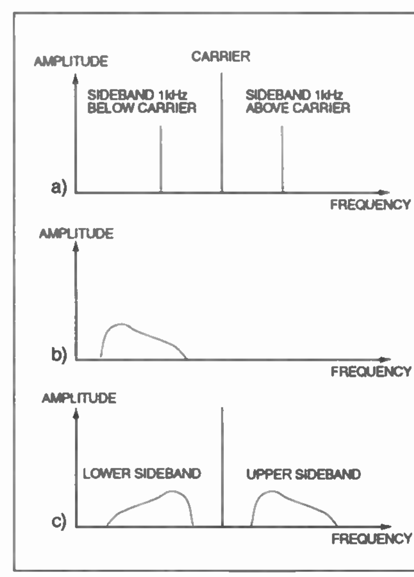


Fig. 2. a) Spectrum of an a.m. signal modulated by a 1kHz tone; b) spectrum of a typical audio signal; c) spectrum of a typical amplitude modulated signal.

The detectors or demodulators which convert the radio signal coming out of the intermediate frequency (i.f.) stages back into an audio signal are very simple. A simple diode detector, such as that shown in Fig. 3, is generally all that is used.

This operates by rectifying the signal and leaving just "one side". This is then filtered by the capacitor to remove the radio frequency (r.f.) components and leaving the original audio amplitude.

Simple diode detectors have a number of limitations. For example, they cause large amounts of distortion when the level of modulation rises. To overcome this and other problems a detector known as a synchronous detector is sometimes used. These are normally found in short wave radios because they give some immunity to the effects of selective fading found on s.w. frequencies.

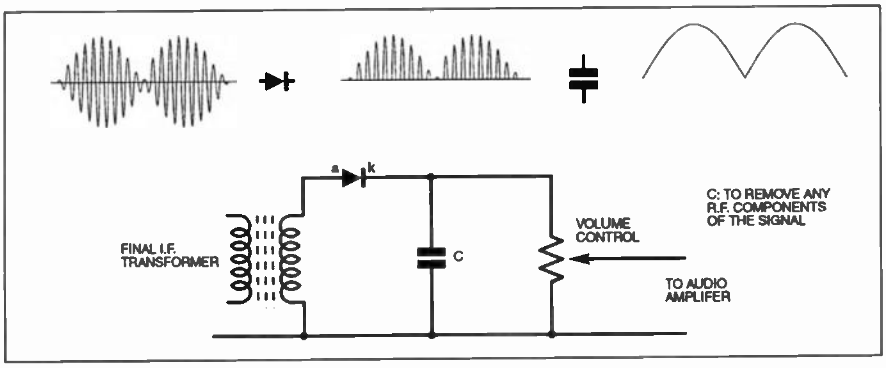


Fig. 3. Using a simple diode detector to convert the original signal back to audio.

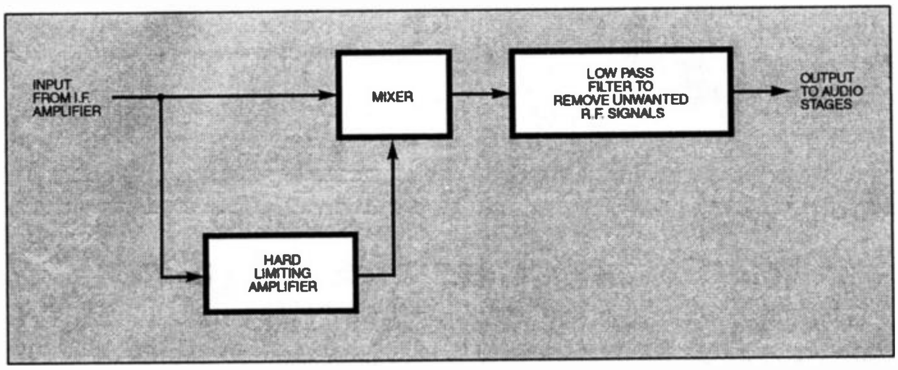


Fig. 4. Block diagram for synchronous detector, used in short wave to combat fading.

The synchronous detector has to mix a signal on the same frequency as the carrier with the incoming a.m. signal. There are a number of ways of generating this extra signal. One method is to have a very narrow filter to extract only the carrier, but this assumes that the signal has to be on exactly the right frequency. Another is to use a phase-locked loop.

The most versatile is to feed the incoming signal into a very high gain amplifier, as shown in Fig. 4. This will act as a limiter and remove any modulation, leaving only the carrier. It also has the advantage that it will work over a wide band of frequencies. Therefore there is no need for the signals coming out of the i.f. stages of the receiver to be exactly in the centre of the pass-band.

Synchronous detectors have only recently been used to any real degree, though many of the shortcomings of a.m. are still apparent. Even in the late 1930s and 1940s, developments in radio technology soon meant that higher audio quality was demanded.

The old a.m. transmissions lacked the frequency response demanded, and they were also susceptible to noise. Improving the frequency response was possible, but gaining the improvement in noise performance was not so easy and as a result other methods were employed.

Frequency Modulation

For many years people had investigated methods of improving the noise performance of radio systems. It had been thought that frequency modulation (f.m.) might prove to be the answer. Initially, this was not the case because the thinking of the day had reasoned that the bandwidth needed to be reduced to decrease the amount of noise picked up.

It took a brilliant American named Edwin Armstrong to turn this thinking on its head. Instead of reducing the bandwidth, he actually increased it. In a demonstration performed in 1935 he showed that a significant improvement could be gained.

Shortly after this, the first v.h.f. f.m. stations were launched in the USA. They soon proved that a great improvement in performance could be achieved, and the number of applications for f.m. broadcast licences rapidly increased.

The Second World War halted the development of domestic broadcasting in the UK. It took until 1954 before the BBC announced it was to launch its first regular f.m. service. It was very successful and soon the network of transmitters spread to give coverage over most of the UK.

Unlike a.m. where the sound vibrations are superimposed onto the radio frequency signal by varying the amplitude of the signal, f.m. translates the variations in the audio signal into variations in frequency. In this way the carrier is made to sweep up and down or deviate in line with the instantaneous voltage of the modulating waveform, as shown in Fig. 5.

This system has the advantage that noise which is generally amplitude related can be reduced to very low levels. In addition to this, it is possible to achieve a wide audio response by increasing the deviation on the carrier.

Today's v.h.f. f.m. transmissions use a deviation of ±75kHz, and occupy a bandwidth of 200kHz. For this increase in bandwidth they are able to give a much improved background noise level. In addition, they provide an audio frequency response up to 15kHz. This is adequate for most hi-fi applications.

To demodulate f.m. a more complicated circuit is required than for a.m. A number of circuits exist for this, and circuits like the Foster-Seeley and Ratio Detector shown in Fig. 6 were very common a number of years ago. These circuits use the phasing of signals around transformers to enable the frequency variations to be converted into voltage variations.

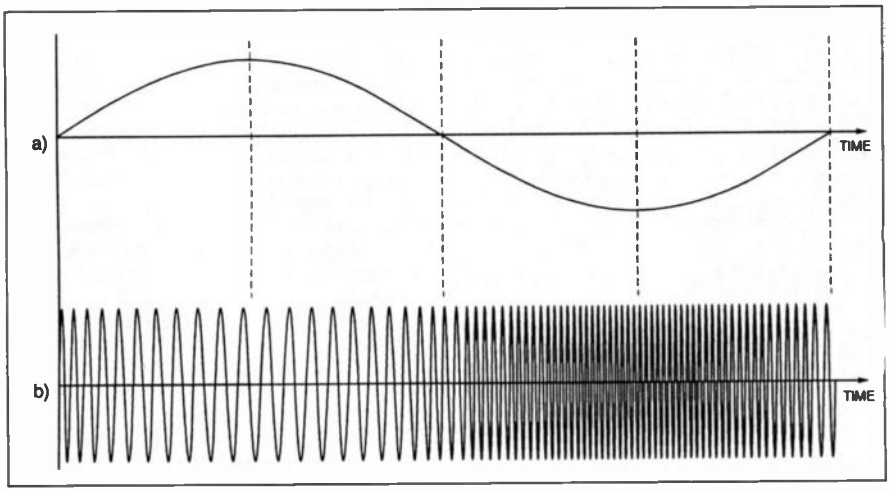


Fig. 5. Frequency modulated signal: a) audio waveform; b) frequency modulated signal.

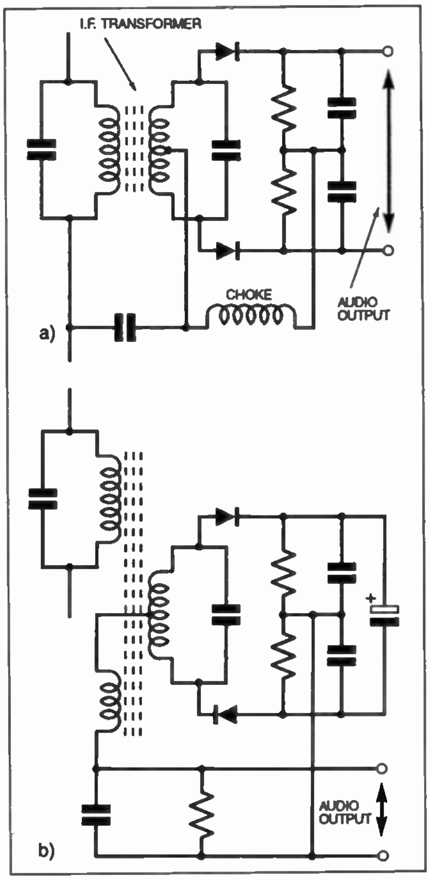


Fig. 6. Foster-Seeley (a) and Ratio Detector (b) circuits for f.m. demodulation.

Nowadays, phase-locked loops are widely used as they offer excellent performance. They are relatively cheap because they do not use the specialised coils which are comparatively expensive to manufacture. In operation, the phase-locked loop tracks the incoming signal as its frequency varies. The oscillator tuning voltage corresponds to the required audio and this is tapped off and amplified as the demodulated audio signal.

Stereo

After f.m. was established it became apparent that stereophonic transmissions could give significant improvements in performance. The system which is in use now allows mono radios to pick up the full stereo transmissions without any degradation in performance. The way in which this is achieved is by adding the additional stereo information above the normal audio range. The transmitter still transmits the mono audio in the normal way.

This corresponds to what would normally be heard in both left and right channels if they were added together i.e. L + R. If a signal corresponding to the left channel minus the right i.e. L − R is transmitted then it is possible to generate the left channel only by adding the two signals together and the right only by subtracting them.

The next problem is to find a way of transmitting the L − R signal. This is relatively simple to achieve. The standard f.m. transmissions can transmit signals with a much greater bandwidth than the standard audio required. The mono or L + R signal is transmitted in the normal way. Then the L − R signal is placed above the normal audio range by modulating the information onto a 38kHz subcarrier.

The carrier itself is suppressed so that only the sidebands are present. This is like placing an a.m. transmission just above the audio band and then removing the carrier.

To help reconstitute the signals in the receiver a pilot tone at exactly half the 38kHz is added to the transmission just above the audio range at 19kHz. All of this information, the L + R, signal, the 19kHz pilot tone and the L − R sidebands are frequency modulated onto the f.m. signal (see Fig. 7).

When the signal is picked up by the receiver, it passes through all the radio frequency processing stages and is finally demodulated to regenerate the audio signal with all the additions. If the set is mono only then the signal can be passed into an audio amplifier where only the L + R mono signal will be heard. If the set has a stereo facility then the demodulated signal will be fed into a stereo decoder. Today all the facilities required for this can be contained in a single chip.

First, the decoder will look for the 19kHz pilot tone. If it is not present it will know that the transmission is only mono and it will not attempt any stereo decoding. If the subcarrier is present it will pass into a doubler circuit to generate a 38kHz signal, or it can be used to synchronise a 38kHz oscillator as shown in Fig. 8.

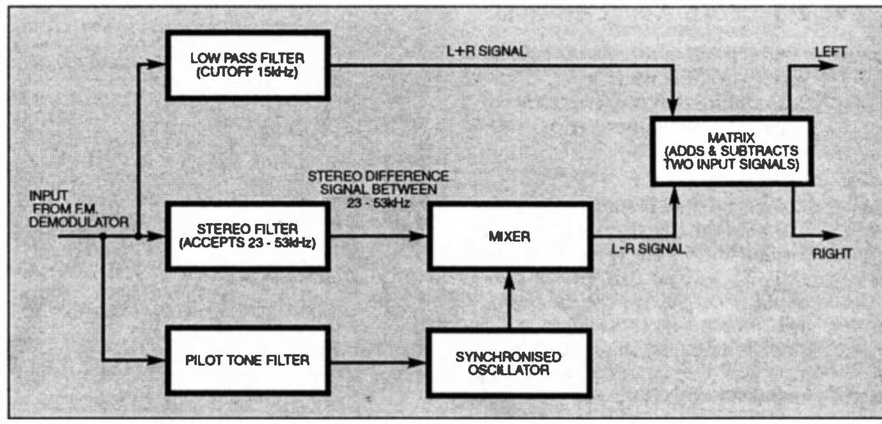


Fig. 8. Block Diagram of a typical stereo decoder.

The 38kHz signal and the sidebands are then fed into a mixer where the L − R signal is regenerated. Having both L + R and L − R signals it is then just a matter of demultiplexing the two signals by adding and subtracting to produce the left and right signals. These are then amplified separately in the normal way by a stereo amplifier.

Radio Data System

The idea of placing additional information onto a subcarrier can be used in other ways. One which has been introduced over the last few years is called RDS or Radio Data System. Using this system, data is transmitted along with the audio signal. There is plenty of room for expansion of the types of data sent.

The system originated as a result of the difficulty in tuning radios. It is a familiar the problem. When tuning around the v.h.f. f.m. band, it is possible to pick up a wide variety of stations, and the only way of identifying them is to listen until the next news slot when there is a station identification. Car radio users also have problems as they drive along, moving from the service area of one transmitter to the next. In trying to resolve these problems, as well as a number of others, RDS was born.

Data is transmitted above the audible band, as in the case of the stereo transmissions. This time the carrier for RDS is located at a frequency of 57kHz, i.e. three times the stereo pilot tone frequency.

A system of phase modulation is used to carry the data. In many respects phase modulation is very similar to frequency modulation, but instead of altering the frequency of the signal a phase change is added. Whilst the phase change is taking place the frequency of the signal changes and then returns to its normal value.

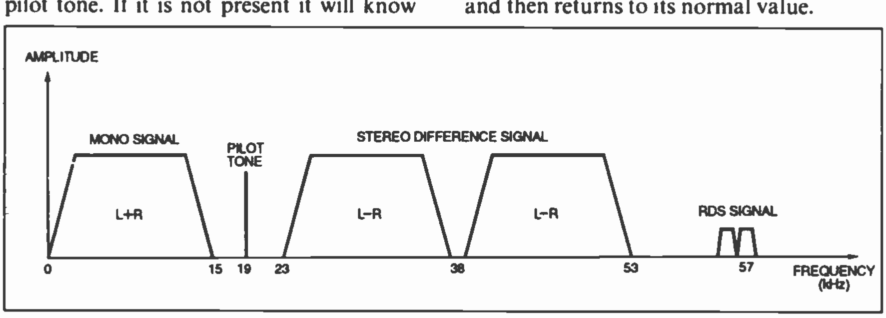


Fig. 7. Spectrum of the modulation applied to a v.h.f. f.m. transmission (signal includes stereo Radio Data System (RDS)).

Being above the audio and stereo multiplex segments of the transmitted signal, the RDS signal does not interfere in any way with either of these audio signals. In this way, the system maintains complete compatibility with existing sets and transmissions.

To reconstitute the data, the receiver uses the 19kHz pilot tone in the demodulation process. For mono transmissions, a tone has to be generated within the receiver. The tolerance for this is 6Hz and it can normally be generated without any major difficulties.

Once the data has been recovered it needs to be processed. This is normally achieved using a microprocessor. In view of the number of functions on most of today's sets, a processor is a natural progression. It also enables many of the facilities provided by RDS to be implemented without much additional hardware.

RDS provides a number of very useful facilities. Along with the frequency value, the radio will store an identification code for the station. With this code the radio can confirm that it remains with the listener's choice of station by displaying the name of the station e.g. "BBC R4", etc. An alternative frequency code is also transmitted. This provides the radio with a list of frequencies in the area on which the same station may also be found. The receiver can compare all the frequencies in the list so that it can pick the one with the best signal.

Travel News

Another useful feature of RDS is that it enables travel announcements to be heard more easily. Stations that carry regular travel bulletins carry a code to indicate this. The receiver will then be able to indicate whether travel bulletins are transmitted or not.

In addition to this, a code is transmitted when an announcement is under way. This can be used by the set to turn up the volume if it is set to a low level or pause a cassette and turn onto the radio station.

Sets marked EON (Enhanced Other Networks) have the ability to retune from one station to another when an announcement is under way. Currently only the BBC transmit the codes for EON. Even so it is still a very useful feature, and the BBC advise anyone buying a car radio with RDS to make sure it has the EON facility. If it does then it will be marked with the distinctive EON logo.

The transmission of EON requires a high degree of coordination between the different transmitters in a network. To achieve this, the BBC use a central computer. When a BBC local radio station is

Table 1 RDS Abbreviations

AF: **Alternative Frequencies**
A list of a station's frequencies in adjacent transmitter areas. This enables the receiver to choose the best signal.

CT: **Clock Time and Date**
Data containing time and date information for the receiver to display. This signal enables the radio to display exactly the right time, and does not loose or gain time as do self contained ones. It also adjusts itself to changes between BST and GMT (UTC).

EON: **Enhanced Other Networks**
Information transmitted giving the radio a cross reference to other stations for Travel service and other features.

MS: **Music/Speech**
This allows for the relative levels of speech and music to be altered.

PI: **Programme Identification**
This is a station code which is used in conjunction with AF data to provide automatic tuning to the best signal for a chosen service.

PIN: **Programme Identification Number**
This signal identifies a given programme and allows the radio to turn itself (and possibly a recorder) on for that programme.

PTY: **Programme Type Selection**
A code which allows for the selection of listening by one of 15 types of programme rather than by the station.

PS: **Programme Service Name**
Data which enables the name of the station to be displayed by the receiver.

RT: **Radio Text**
This allows information about the programme to be displayed by the radio.

TDC: **Transparent Data Channel**
This allows for data to downloaded via RDS.

TP/TA: **Travel Service**
These signals enable the travel information to be heard, regardless of the choice of listening.

about to transmit a traffic message this is flagged to the central computer. In turn this sends commands to the relevant national network transmitters which indicate in their RDS data that a traffic message is about to take place on a particular local station. This enables the receiver to tune to the local station to pick up the traffic message. Once the message is over, the flag is removed and the radio can return to the national network programme again.

For any radio equipped with RDS there are a large number of abbreviations for the facilities available. These are summarised in Table 1.

A.M. Data System

Anyone thinking it is difficult to identify stations in the v.h.f. f.m. waveband will have even more problems on the short wave bands. It is hardly surprising to find that a similar system has been proposed for use in this respect.

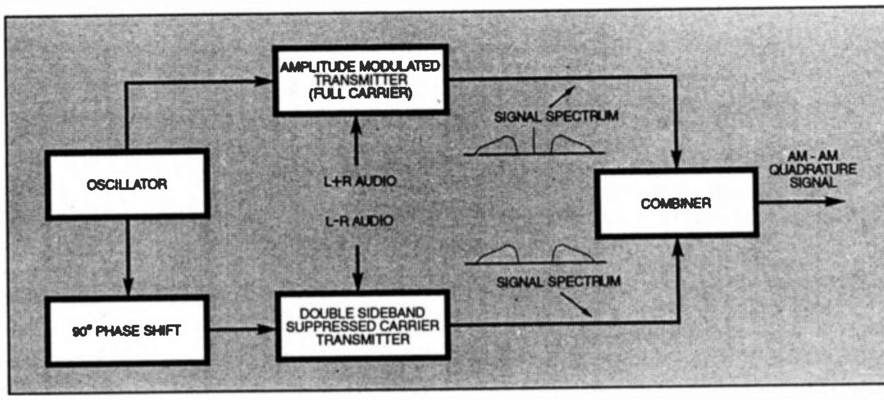


Fig. 9. Generation of a.m. quadrature signals.

Known as AMDS (A.M. Data System), it is still in its experimental stages, although a number of stations, including the BBC World Service, have added it to some of their broadcasts to investigate its operation and performance.

In the proposals which have been put forward, many of the facilities found on RDS are included. Alternative frequencies are of particular use, together with the programme or station name. Traffic announcements are also included in the specification, although more for the medium wave transmissions which are likely to be local in nature.

Unlike v.h.f. f.m., where it is possible to put in another subcarrier above the audible range, the bandwidth available with a.m. means that other methods need to be sought. In fact, the carrier is phase modulated with a maximum data rate of 200 bits per second. Since the detector for the audio signal responds to the amplitude variations, any phase modulation is not likely to be audible. In this way both the audio and data can be transmitted alongside one another.

C-QUAM

A major growth area in broadcasting is v.h.f. f.m. With high quality sound, stereo and now RDS it is attracting people away from the traditional medium wave transmissions. This was felt particularly acutely in the USA where many stations only had medium wave allocations and wanted to encourage people back from v.h.f. One of the ideas for revitalising the a.m. transmissions was to introduce stereo. A number of methods were tried but the one which has gained the widest acceptance is the Motorola C-QUAM system.

C-QUAM stands for Compatible QUadrature Amplitude Modulation. It involves transmitting the mono or L+R signal by amplitude modulating the carrier in almost the normal way. The stereo information is then placed onto the carrier in quadrature, or 90 degrees out of phase, with the main signal. Normal a.m. receivers only see the L+R modulation and are still able to resolve signals without any unwanted effects. Stereo receivers are able to decode the information and pick out both channels quite easily.

The first stage in the development of C-QUAM signals was to generate an ordinary a.m. quadrature system. To achieve this, two signals are placed onto the same carrier, but one has its effective carrier shifted by 90 degrees. One way in which this can be achieved is shown in Fig. 9.

The standard a.m. transmitter carries the mono or L+R signal in the normal way. The L−R or stereo difference signal is used to amplitude modulate a second carrier. A circuit known as a balanced modulator is used to generate this signal. This has the effect of just generating the sidebands and removing the carrier. The two signals are then added together, amplified and transmitted. As the same carrier frequency is used the two sidebands overlap in terms of frequency, although they can be separated from one another in the receiver.

In the receiver, Fig. 10, the carrier is used to generate a reference signal to drive two balanced mixers used for the demodulation process. The reference is shifted by 90 degrees in one case, and the two signals used to demodulate the signal.

As a balanced modulator is sensitive to phase, one will only be able to demodulate the L+R signal and the other will only see the L−R signal. These two signals can then be demultiplexed in the same way as normal v.h.f. f.m. stereo transmissions by adding and subtracting them to give the left and right channels.

Unfortunately, in this basic form ordinary a.m. quadrature modulation is not satisfactory. Although it works well when

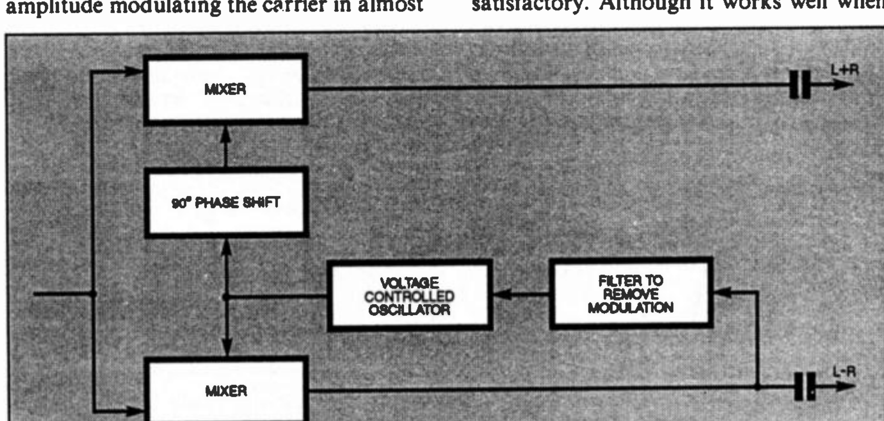


Fig. 10. Demodulation of a.m. quadrature signals.

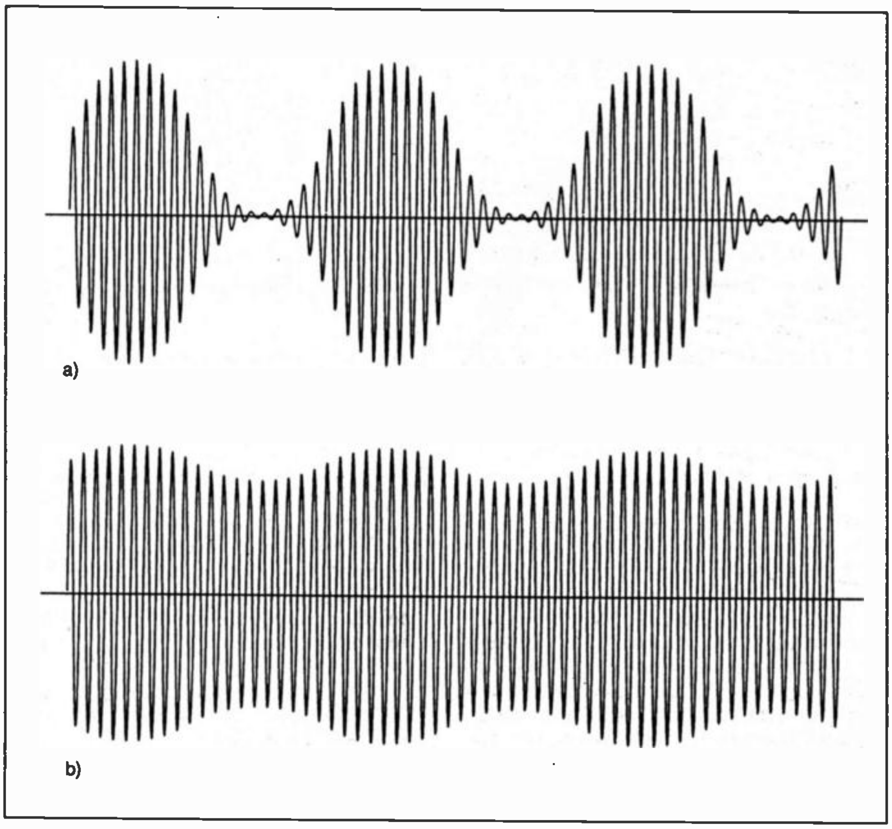


Fig. 11. Envelopes of a.m. quadrature signals: a) L + R modulation only (i.e. mono signal); b) L − R modulation only.

passed through the correct demodulator, it is not fully compatible with the majority of a.m. detectors in use because they will only see the amplitude information and this results in higher than normal levels of distortion.

When the L − R signal is zero there is no problem because the signal is just that from the ordinary a.m. transmitter. However, when the signal level from the L − R transmitter starts to rise, so do the distortion levels. The reason is that the L − R signal does not have its own carrier for use in the demodulation process. This can be seen from Fig. 11.

If a sine wave is transmitted as the L + R signal, it will appear like the waveform shown in Fig. 11a. This can be demodulated in the normal way by any radio and suffer no distortion. However, if the same signal is transmitted in only the left or right channel then only the L − R signal is present. In this case the signal will look like that shown in Fig. 11b.

If a normal mono receiver demodulated this then it is easy to see that the level of distortion would be very high! It can then be imagined that intermediate cases when both L + R and L − R signals are present will also have significant amounts of distortion dependent upon the level of the L − R content.

Phased Out

To overcome this problem and ensure that no difference is noticed by existing mono receivers, a very neat solution is used. The L + R audio is used to modulate the carrier in the ordinary way. Then phase information which would have been added to the resulting signal by the L − R signal is extracted and used to phase modulate the master oscillator of the transmitter. This generates a signal which is very nearly an a.m. quadrature signal, but is still compatible with existing receivers.

To make C-QUAM attractive for receiver manufacturers as well as the transmitter operators, Motorola produced an i.c. to demodulate C-QUAM signals.

A block diagram of the stages used in the receiver to demodulate C-QUAM signals is shown in Fig. 12. The envelope detector retrieves the L + R signal in the normal way. The signal is applied to a level control where it is converted into an a.m. quadrature signal. It now can be demodulated, using the two synchronous detectors or mixers and voltage controlled oscillator to extract the L − R signal. With the L + R and L − R signals the left and right channels can be reconstructed by addition and subtraction.

DAB

With the revolution in electronics making many new ideas feasible, researchers have been looking at the shortcomings in existing radio systems. Despite the relatively high quality v.h.f. f.m. transmissions, they cannot match the results achieved by the compact discs which are now commonplace.

Background noise, especially in stereo, and general fidelity could be improved if a new system was introduced. Car radio users also find problems as they travel along finding spots where the signal becomes distorted because of reflected signals being received at the same time as the main one.

Another problem is encountered when moving out of the service area of a transmitter, and having to locate the frequency of the next one. Without an enormous book of transmitter frequencies, this can be quite a difficult task. Selecting the correct station can also be a problem with so many signals to be picked up.

Whilst the last two of these problems are addressed to a large degree by the use of RDS, the basic system used for transmitting radio signals could be improved by the use of the latest i.c. technology. It is with this background that a new system of Digital Audio Broadcasts (DAB) have been proposed.

Switch-on

The ideas are now well advanced and the BBC have just "switched on" the world's first DAB service with transmissions in and around the London area. This will be quickly extended to include other main centres of population and their interconnecting roads. In this way a high quality service will be available for the maximum number of listeners at home as well as those on the move.

To develop the new DAB system, a large amount of research was invested in developing a system which would fulfil all

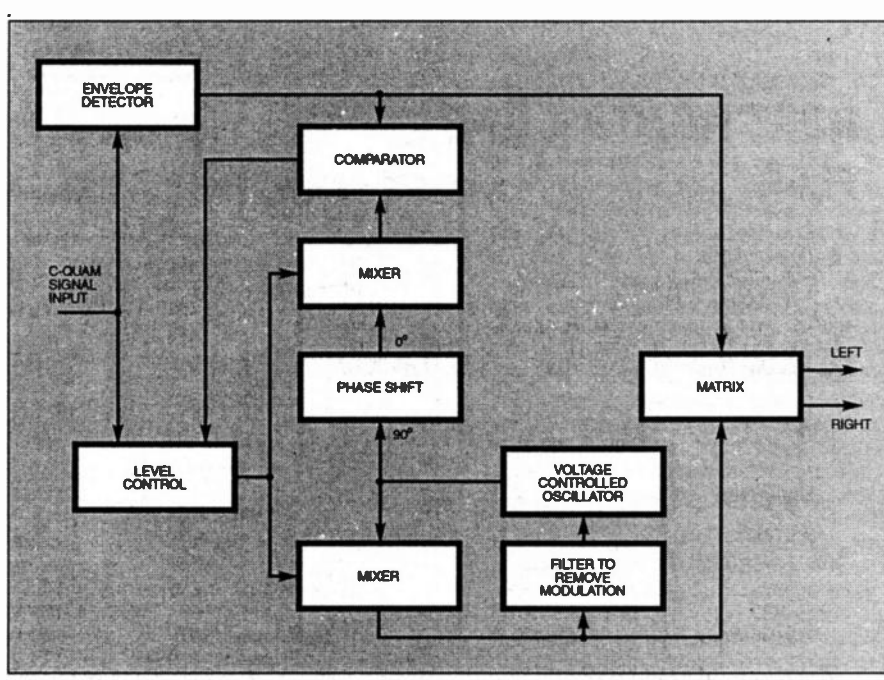


Fig. 12. Block diagram of a C-QUAM detector.

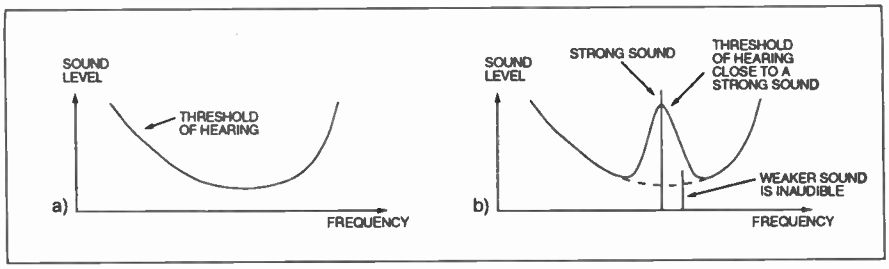


Fig. 13. Sensitivity of the human ear to sounds: a) threshold of hearing during silence; b) masking of a weak sound by a stronger one.

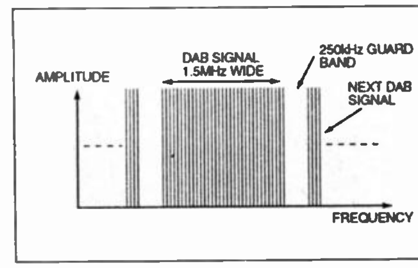


Fig. 14. Spectrum of a DAB Signal.

the requirements for well into the next century. Basically, it would be required to carry CD quality transmissions which can be picked up by home listeners as well as those in cars. A number of other requirements were also imposed on the new system. It should be capable of simple tuning, it should make efficient use of the spectrum, and it should be capable of being transmitted from either terrestrial or satellite transmitters.

On Reflection

The need for mobile use shaped much of the method of transmission. As happens with normal f.m. transmissions, similar signal reflections from digital transmissions will cause the data to become corrupted. One bit of data will merge into the next because the reflections can arrive many microseconds later.

This posed problems because the data rate of NICAM digital audio, which is very successfully used on television, is 728K bits per second. This does not suffer from reflection problems because the receiver uses a directional aerial. The aerial will be set up to obtain a reflection free signal because any reflections will cause ghosting on the picture as well as corruption of the digital audio.

To obtain freedom from the effects of reflection, a data rate of no higher than 7K symbols per second is needed. A single carrier with this data rate would not be able to support any form of high quality audio transmission. To overcome this, new techniques have been evolved enabling very high quality transmissions to be carried.

The first technique which is used involves only transmitting those sounds which the human ear can hear. It has been shown that the ear does not perceive all the sounds within its audio range. There is a minimum threshold level below which it cannot hear the sounds. This level increases for low and high frequency sounds, as shown in Fig. 13. It is also found that a high intensity sound will mask out other weaker ones close to it.

By using this principle and only transmitting the sounds which can be heard, a 20kHz audio signal can be transmitted using a data rate of just 128K bits per second – a sixth of that required if all the data is transmitted. Not only is this technique being used by radio, it has also been successfully used by the new digital compact cassette system (DCC) with the PASC coding system, and the Sony MiniDisc with ATRAC.

Whilst the audio coding gives a very useful reduction in data rate it is not sufficient to allow error free digital transmissions in the presence of reflections. To achieve this the data rate is reduced still further, but a number of different carriers are used in a system called CODFM (Coded Orthogonal Frequency Division Multiplex). In this way the data rate for each carrier can be kept low whilst allowing the whole signal to have sufficient capacity to carry all the data required.

Using the new system, 1500 low data rate channels will be used, occupying about 1·5MHz of spectrum. This signal will carry five stereo programmes which can be selected by simple pushbuttons on the front of the receiver. The overall channel spacing will be 1·75MHz so that a guard band of 250kHz is included between each set of channels, as shown in Fig. 14.

It is worth noting the improvement in frequency usage. Currently, each of the BBC's national services occupies 2·2MHz. This amount of spectrum is required because channels can only be re-used when there is no chance of signals from a distant transmitter causing interference.

With the new DAB system, the resilience to multipath signals also means that interference from other stations is not a problem, and frequencies can be reused as much as necessary to give the required coverage. This means that blanket coverage can be given without the need for retuning as a car moves from the coverage area of one transmitter to the next.

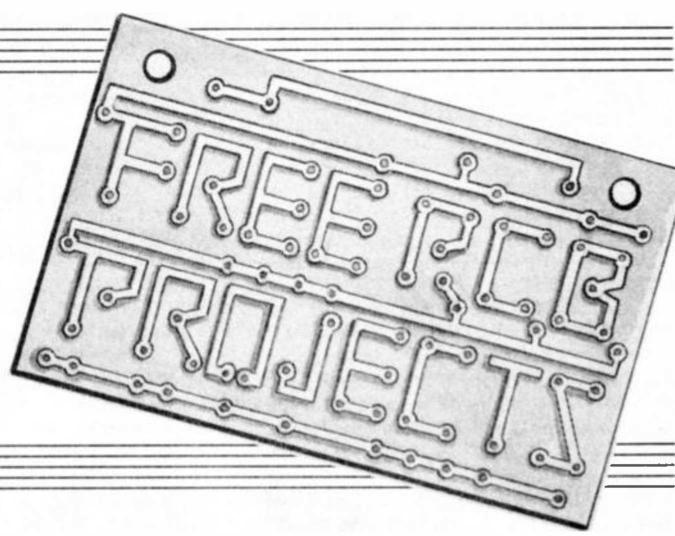
Receivers for the new system will rely heavily on a process called digital signal processing to reconstitute the audio from the signal. New specialised i.c.s are being designed and receiver manufacturers are well advanced in their designs. Although it is likely that the first sets will be expensive, they should fall in price as sales increase.

Conclusion

Radio has become an essential part of everyday life. There is an ever increasing number of stations, and people listen to the radio more than ever before.

From all the new ideas which are being introduced, it is obvious that research is keeping pace with all the requirements. In this way, radio is not being left in the dark ages. It is well up with the front runners in today's technology. □

Constructional Project



CURRENT TRACER

ROBERT PENFOLD

Use last month's FREE p.c.b. to build this really useful low current meter and track down those frustrating "hard-to-locate" faults.

IN ORDER to measure the current running through the copper track of a printed circuit board it is necessary to make a break in the track, and then connect a current meter across the break. The break in the track is easily mended afterwards, but this is clearly an undesirable way of doing things.

A current tracer offers a simple alternative which enables the current flow through a p.c.b. track to be roughly gauged without the need to make a cut in the copper.

RIGHT TRACK

A normal current meter uses the simple scheme of things shown in Fig.1a. The current to be measured is passed through shunt resistor R_s, and a voltage is developed across this resistor. This voltage is proportional to the current flow. The voltmeter connected across R_s can therefore be calibrated directly in current flow.

The sensitivity of the circuit is governed by two factors. One of these is the value of R_s, and the lower its value, the higher the full scale current of the circuit. The other factor is the full scale voltage of the voltmeter. The higher its full scale potential, the higher the full scale current of the circuit.

A current tracer uses what is essentially the same arrangement, with a shunt resistance and a voltmeter (Fig.1b). The shunt resistance is the resistance through a short piece of track between the test prods.

The problem with this method is that the resistance through the piece of track is likely to be very low indeed. In order to maximise the shunt resistance the test prods should be positioned as far apart as possible, but with a modern circuit board it will not normally be possible to use a track length of more than about 20mm. Even if the track is very thin, such a short length is unlikely to have a resistance of more than a few milliohms.

This problem is compounded by the fact that the current flow through the track will often be quite low. For example, the current flow through a power rail track of an operational amplifier is typically only about one to five milliamps.

It is worth bearing in mind that a current flow of one milliamp through a one milliohm shunt resistance produces an output voltage of just one microvolt. The voltmeter circuit in a practical current tracer must therefore have a very high sensitivity, since it must respond to what will often be a matter microvolts, rather than millivolts or volts.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Current Tracer appears in Fig. 2. The circuit is basically just an operational amplifier used as a d.c. inverting amplifier. Normally a circuit of this type would be powered from dual balanced supplies, but in a simple application of this type it is acceptable to use a single supply rail plus a supply splitter.

In this circuit resistors R2, R3, and capacitor C2 provide the centre-tap on the supply rails. This effectively becomes the zero volt "earth" rail, with the battery supplying dual balanced 4·5V supplies.

Resistor R1 sets the input resistance of the circuit, and it is acceptable to use quite a low value here due to the very low source resistance of the input signal. As explained previously, this will be just a small fraction of one ohm.

The closed-loop voltage gain of IC1 is equal to R4/R1, or 3300 times (330/0·1 = 3300) in other words. If switch S1 is set to select resistor R5 instead of R4, the voltage gain is equal to R5/R1, or some 33000 times (3300/0·1 = 33000). This gives the unit two sensitivities, with R4 being used for normal checking, and R5 being switched into circuit when checking for very low currents.

VOLTMETER

The voltmeter is comprised of resistor R6 and meter ME1. As the latter is a centre-zero meter, the unit will respond to input currents of either polarity, and will indicate the polarity of the input signal. The value of resistor R6 sets the full scale sensitivity of the voltmeter circuit at about plus and minus 3·3V.

The full scale input sensitivities of the circuit as a whole are approximately one millivolt and 100 microvolts. The unit will therefore respond to inputs as low as a few microvolts. No overload protection is required for ME1, because the output voltage swing from IC1 is too low to produce a serious overload.

OPERATIONAL

Good results will only be obtained from this circuit if a suitable operational amplifier is used for IC1. In an application of this type the a.c. characteristics of the op.amp are of little importance. It is a precision d.c. type that is needed.

The problem in using a "bog standard" device in this circuit is that small offset voltages at the input of the device appear greatly amplified at the output. In fact, they are amplified by an amount equal to the op.amp closed-loop voltage gain.

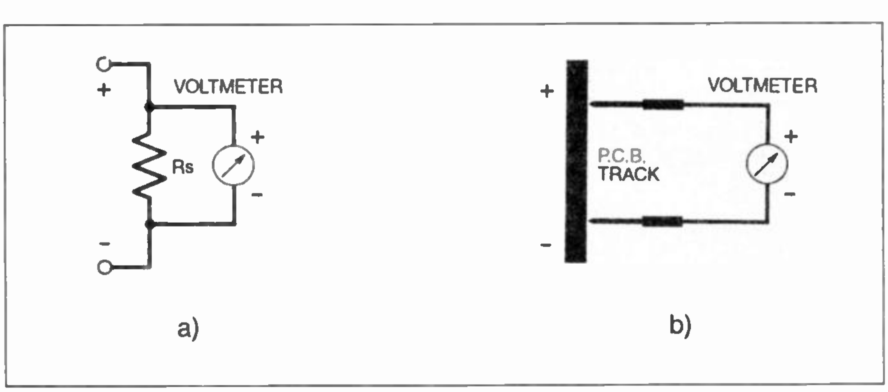


Fig. 1a. Conventional current meter circuit and (b) the current tracer uses the p.c.b. track as the shunt resistance.

The closed-loop gain is very high, particularly with resistor R5 switched into circuit, giving a large error in the output voltage. This would result in the meter ME1 giving a high reading with no input voltage, which would in turn give unusable results.

A precision operational amplifier is guaranteed to have extremely low input offset voltages, giving a very low output offset even when used at high voltage gains. With resistor R5 selected using switch S1, and the two test prods connected to one another, the specified operational amplifier provides a very low output offset voltage. Any offset registered on the meter should be barely discernible. The circuit should work well using other precision operational amplifiers, but it has only been tested using an OPA177GP for IC1.

Although it might look as though the meter ME1 is connected with the wrong polarity, it is in fact shown correctly in the circuit diagram Fig. 2. The amplifier is an inverting type, but ME1 has its negative terminal connected to the output of IC1. This effectively counteracts the inversion through the amplifier, so that positive input voltages produce a positive reading on ME1.

The current consumption of the Current Tracer is only about 2·5mA to 3mA. A small, PP3 size, battery is suitable as the power source.

CONSTRUCTION

If you have not already used last month's *FREE* p.c.b., then this useful Current Tracer is an ideal project for the specially designed Multi-Project PCB. If you require extra p.c.b.s these are available from the *EPE PCB Service*, code 932.

The printed circuit component layout, full size foil master pattern and wiring for the Current Tracer appear in Fig. 3. Construction of the circuit board is largely straightforward, but be careful to fit resistor R4 between the right pair of holes. It fits over two of the unused holes in the board.

In theory at any rate, it is better if IC1 is not fitted into an i.c. holder, but is soldered direct to the board instead. In practice it is unlikely that direct connection to the board would provide any significant improvement in performance.

Although the OPA177GP is not a static sensitive device it is still probably best to use an i.c. holder for this component. Fit single-sided solder pins to the board at the positions where connections to off-board components will eventually be made.

COMPONENTS

Resistors
R1 100Ω
R2, R3 2k2 (2 off)
R4 330k
R5 3M3
R6 33k
All 0·25W 5% carbon film

See SHOP TALK Page

Capacitors
C1 10µ radial elect. 25V
C2 4µ7 radial elect. 50V

Semiconductor
IC1 OPA177GP precision, low-noise, op.amp

Miscellaneous
ME1 100µA-0-100µA panel meter
S1 s.p.d.t. min.toggle switch
S2 s.p.s.t. min.toggle switch
B1 9V battery, PP3 size

Printed circuit board available from the *EPE PCB Service*, code 932 (or *Free* with last month's issue); plastic or metal case, size to suit meter and p.c.b.; pair of test prods and leads; 8-pin d.i.l. socket; PP3 type battery clip; multistrand connecting wire; single-ended solder pins (9 off); solder, etc.

Approx cost guidance only **£16** *excluding Batt.*

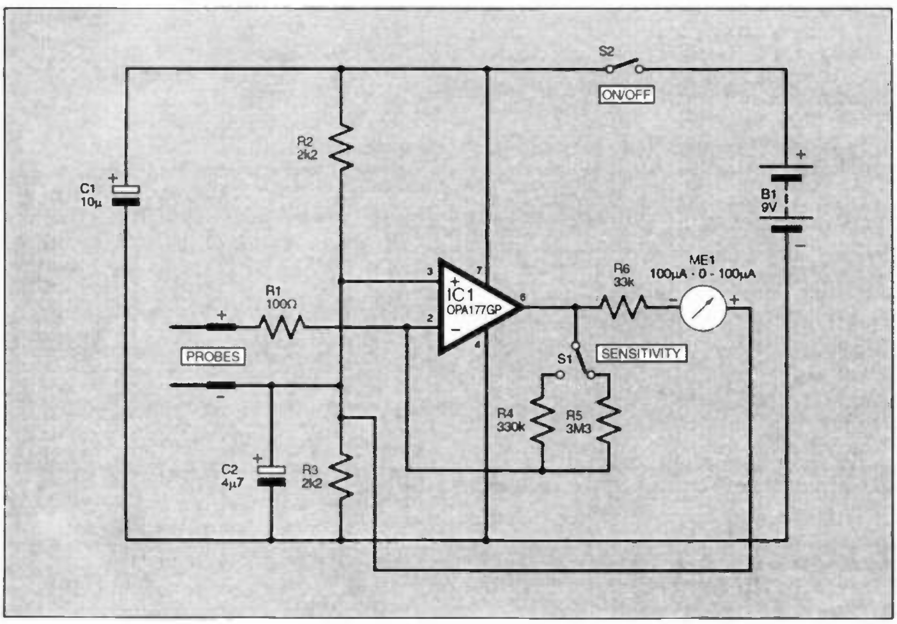
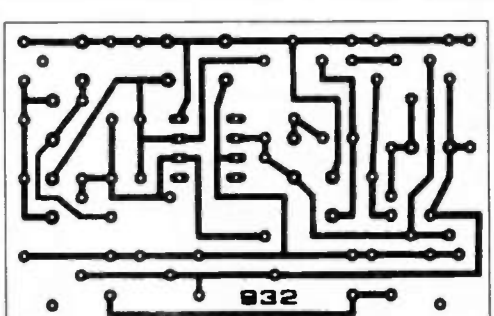
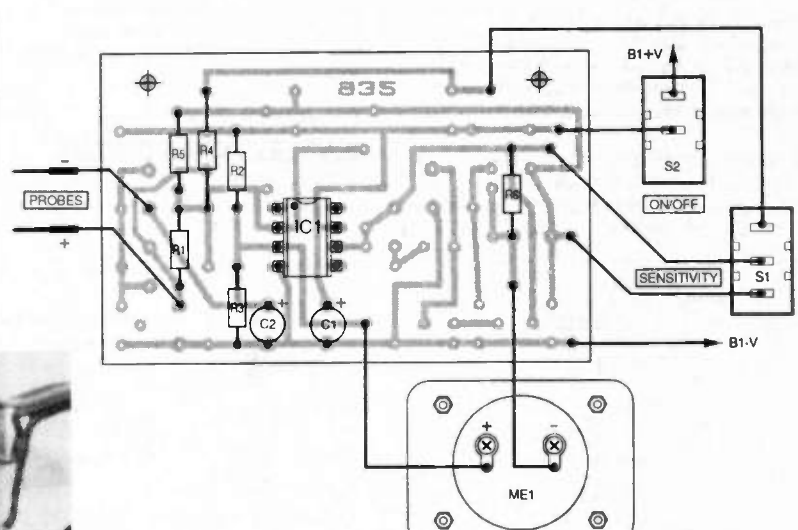


Fig. 2. Complete circuit diagram for the Current Tracer.





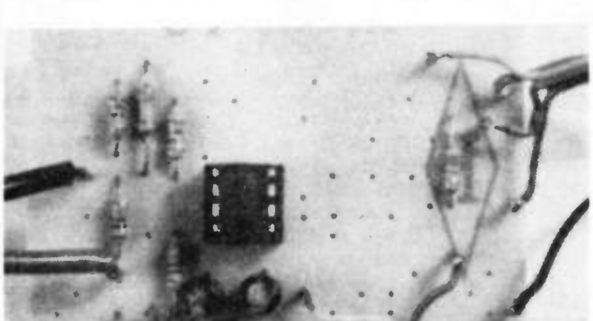


Fig. 3. Printed circuit board component layout, interwiring details and (top left) full size copper foil master for the Current Tracer. The completed p.c.b. is shown left.

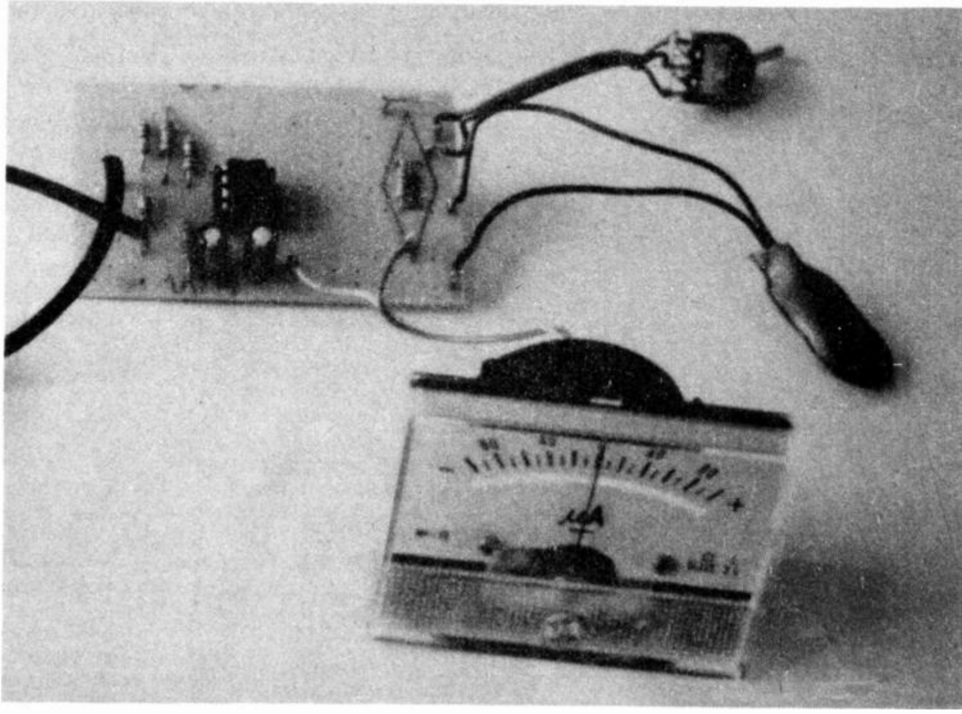
CASE

Virtually any small to medium size plastic or metal case will accommodate this project. Mechanically there is only one awkward aspect of construction, and this is making the large cut out for the meter. Most panel meters require a 38mm diameter main mounting hole, but it would be prudent to check this point before cutting the hole.

In the absence of any special tools for cutting this size of hole, an "Abrafile" or a fretsaw probably represent the easiest ways of making the cutout. It is advisable to carefully cut just *within* the perimeter of the required cutout, and then file it out to size using a half-round file. The meter itself can then be used as a sort of template to help locate the positions of the four smaller (3·3mm dia.) mounting holes.

Most test leads are fitted with two or four millimetre plugs at the non-probe end. The connections between the board and the test leads can be made via suitable sockets fitted on the front panel.

However, better results might be obtained if the plugs are cut from the leads, and the leads are then soldered direct to the pins on the circuit board. A couple of entrance holes for the leads will, of course, be needed in the font panel.



The completed Current Tracer awaiting a suitable case. The size of case will depend on the meter used.

IN USE

When using a simple tester of this type it is essential to realise that it cannot be used to accurately measure the flow of current. It can only be used to "roughly" gauge the current flowing through a p.c.b. track, which is all that is normally required.

The best way to use the tracer is to make some tests on a few working projects, noting the sort of reading to be expected for various levels of current flow. Remember that the readings are higher if the probes are well separated, and lower if the measurement is made across a short piece of track. Having made a wide range of checks on a few projects, you will know what to expect when using the unit in earnest, and should soon spot any readings that indicate a fault.

In general it is possible to use the Current Tracer to check current flows down to about one milliamp, provided the measurement can be made across about 10mm or more of track. Currents of much under one milliamp are beyond the capabilities of this tester. It can, therefore, be used for such things as checking the supply current flowing into most integrated circuits, transistor amplifier stages, etc., but it is not suitable for testing low current bias circuits and the like.

It is possible that high current flows could produce readings beyond full scale, even on the lower sensitivity range. It is possible to keep readings within range though, by simply testing the current flow through a shorter piece of track.

The normal safety precautions must be taken when making tests on MAINS powered equipment. Those of limited experience should only use the Current Tracer to make tests on battery powered equipment. □

SHOP TALK
with David Barrington

Digital Delay Line

The digital audio signal processor chip type HT8955 may prove elusive to find at your usual local component stockist. The one used on the prototype board was purchased from **Maplin** and is designated as a "Voice Echo", order code AE14Q.

The 41256, 4164 DRAMs and the 4053BEY 3-pole 2-way electronic switch i.c. should be readily available. They are certainly listed in most of our component advertisers catalogues.

Another small problem may arise concerning the 24-pin i.c. socket for the signal processor. It would appear that most suppliers only carry the wide pin spacing format.

This should be no problem really, as you can easily use three 8-pin d.i.l. sockets mounted side by side. If you do adopt this solution, you may need to file down the ends of the middle socket to allow it to fit on the p.c.b.

The Delay printed circuit board is available from the *EPE PCB Service*, code 958 (see page 911). The choice of metal case is left to the individual, but choose one that is fairly robust and has plenty of room inside. Also, do not forget to provide a "common" earth point somewhere on the case.

Video Enhancer

Although there appear to be plenty of op.amps on the market that seem to be well suited for use in the *Video Enhancer*, another project for last month's *Free* p.c.b., most are current feedback types and cannot be used in this circuit. The EL2045CN specified here is one of the few *voltage* feedback op.amps with the necessary characteristics and came from **Maplin**, code AJ57M.

If you missed last month's issue, with the Free cover mounted p.c.b., you can purchase a back issue (see page 894), or you can purchase extra boards from the *EPE PCB Service*, code 932.

The Video Enhancer can only handle standard PAL composite video signals. It cannot process a u.h.f. television signal or any form of RGB video signal.

50Hz Field Meter

Scanning through the list of components required to build the *50Hz Field Meter*, only the special Hall effect sensor and some of the semiconductors are likely to cause local sourcing difficulties.

The Lohet II Hall effect sensor (code 650-548), the MF10 switch mode filter (302-407) and the TSC7126 l.e.d. decoder/driver (303-652) are all RS devices. These can be ordered through their mail order outlet, **Electromail** (☎ *01536 204555*).

The close-track printed circuit board is available from the *EPE PCB Service*, code 959 (see page 911).

Temperature Warning Alarm (Teach-In '96)

The first of our *Teach-In '96* back-up projects is a simple *Temperature Warning Alarm* and all the components should be readily available. The thermistor can be a miniature disc type (**Greenweld**) or a min. bead type provided it is rated as specified.

The small printed circuit board is available from the *EPE PCB Service*, code 960. The warning buzzer must be a solid-state type.

Distortion Effects Unit and Current Tracer

There is not too much to report on concerning the *Distortion Effects Unit* and *Current Tracer*, both designed for last month's *Free* p.c.b. (See *Video Enhancer* comments for extra p.c.b.s).

The low-noise op.amps NE5534A (Distortion) and OAP177GP (Tracer) both originated from **Maplin**, codes YY68Y and AD56L respectively.

It might be worth contacting advertisers like **Greenweld, J&N Factors** and **Bull Electrical** as they often have "special discounts" on small panel meters.

QUALITY KITS - QUAZY PRICES!!

SURVEILLANCE

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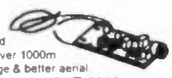
MTX - Miniature 3V Transmitter



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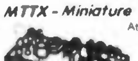
MTTX - Miniature Telephone Transmitter



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MISCELLANEOUS

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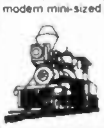

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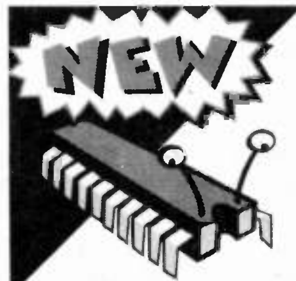

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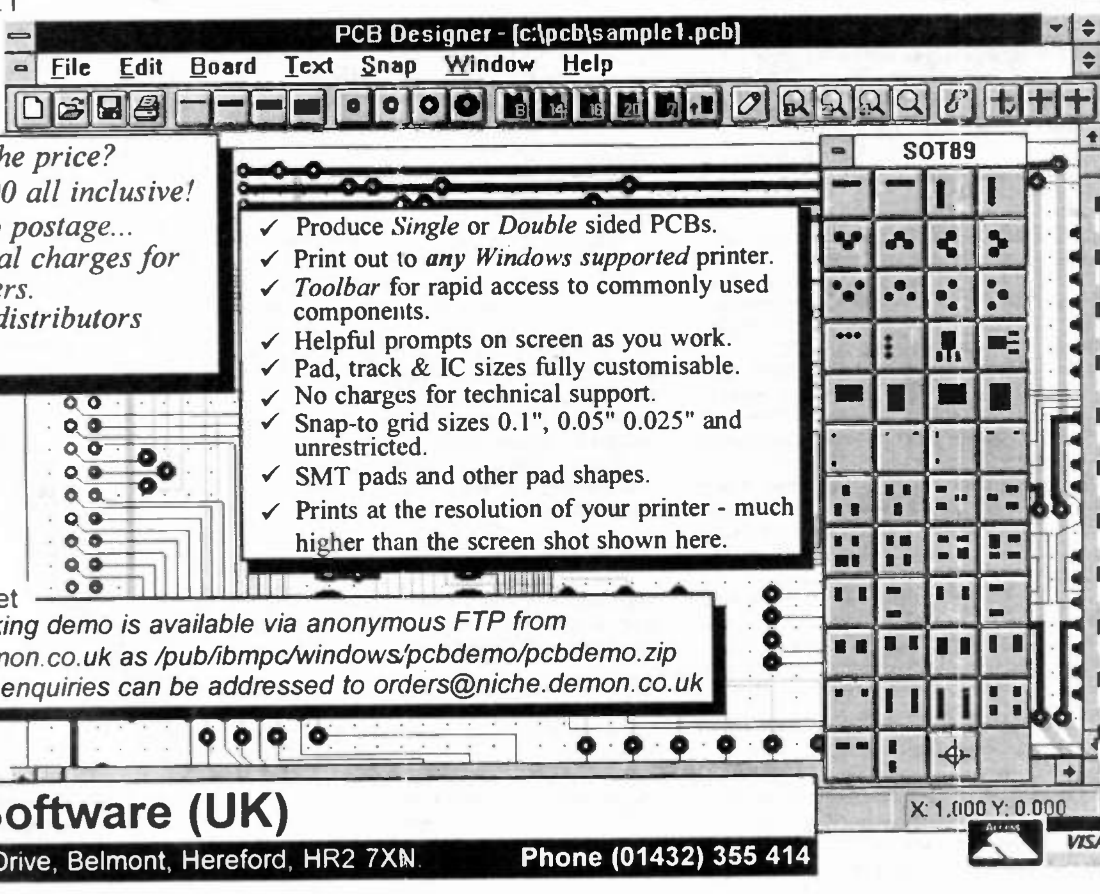

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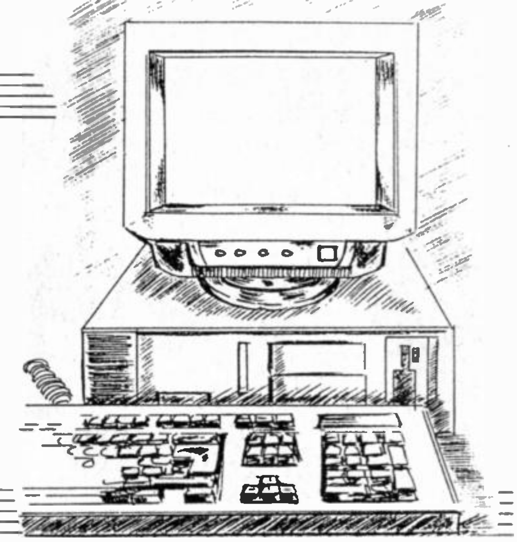


TURNPIKE FOR WINDOWS

ALAN WINSTANLEY

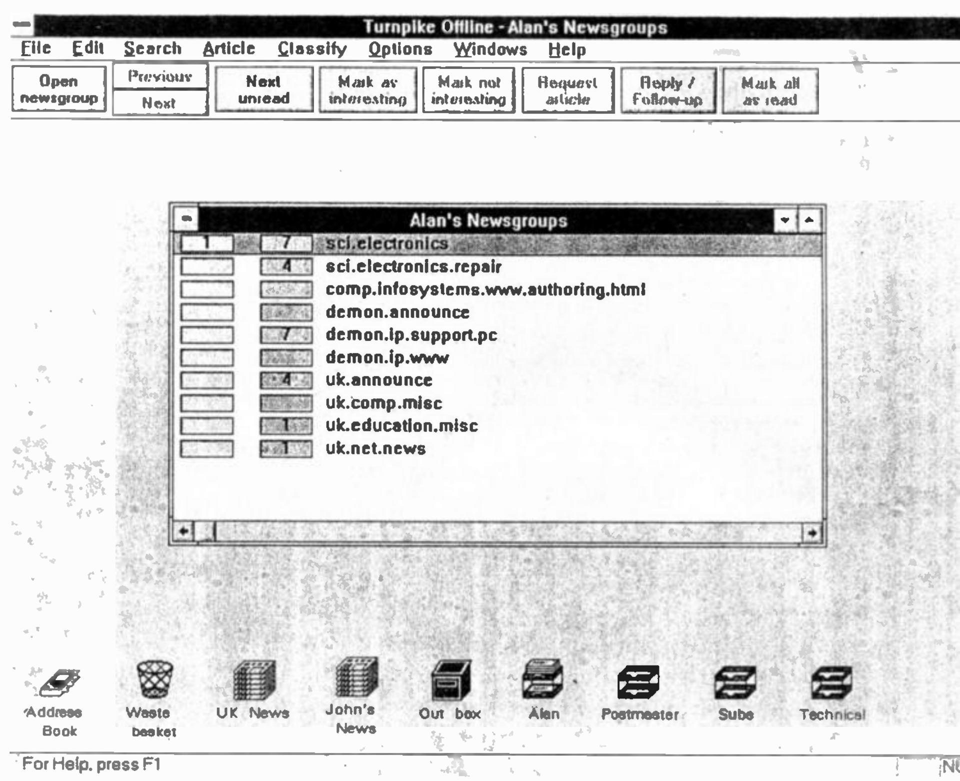
A look at a new British Internet software package that's been on trial here at EPE

BRITISH software firm *Turnpike Ltd* has introduced friendly new Windows-based Internet software which will be the answer to the prayers of many struggling net surfers and Emailers.

The versatility and attractiveness of Microsoft Windows appeals to most users and has spawned several Internet software packages for the venerable Windows GUI. *Turnpike for Windows* may quickly find a receptive audience, especially amongst those still struggling with DOS-based software and itching to make the leap into Windows.

A straight-out-of-the-box system, *Turnpike for Windows* offers a graphical front end to aid your Internet meandering, and will handle all your Email as well as Usenet News (newsgroups) graphically and effectively. All Windows Internet packages require a separate "Winsock" and TCP/IP stack to interface with the protocols of the internet, since this is not provided in Windows 3.1.

Many choose to buy versions of Peter Tattam's popular *Trumpet Winsock*, available from several sites on the Internet. Turnpike has its own built-in winsock, though, having bought in the know-how from the USA – or you can use your system's existing one.



Turnpike *window showing mail boxes and news groups.*

Appreciative Package

The software is attractively packaged and arrives with three reasonable manuals which the novice will especially appreciate. After running the simple set-up routine, you're left with just two Windows icons – the *"Connect"* dial-in function, and *"Turnpike Off-line"* where Email is dealt with simply and efficiently off-line through a system of In-Tray, Pending Tray and Out Box icons. Email can be reviewed, edited or filed away from here, and incoming mail can be sorted automatically into trays in various ways (e.g. mail from your biggest customer).

An Address Book function keeps track of all the Email addresses used, and acts as a filing cabinet for all stored messages. A wastebasket icon handles drag-and-drop disposal of redundant post. The software is MIME compliant and it handles multiple user names as separate "Letter Trays", which can be set to flash as icons when they receive mail.

Multiple signature selection is included: quickly swap your sig. for something more appropriate, when the occasion demands. Overall I found that *Turnpike's* mail handling was very straightforward, and unlike some packages I've tried, it worked immediately!

Extra-Extra

"Usenet" news is a system of holding open conversations world-wide on a relevant subject, when anyone can chip in with a message. *Turnpike* enables users to gather various Usenet groups together on "news stands" – perhaps one for electronics, another for hobby or for other users, etc.

What came as a delight, compared to Demon's DOS-based offering for example, was the way that it depicts news "threads" in a tree directory, so that at a glance it's possible to see who is following up on whom, and then you can concentrate on parts of the overall thread which are of most interest to you. Navigating them did get a bit tortuous with lengthy threads, though.

Markers are used to enable users to highlight certain news threads as "Interesting" or "Uninteresting", so that you can focus on them straight away instead of trawling through scores of irrelevant messages later on – an absolute boon in busy newsgroups. It all greatly simplifies the chore of wading through news.

A "Killfile" function seemed very clear in plain English, and simple to use with several selection modes available. It also enables you to print out in a neat and tidy style, any postings or mail which may catch your eye, instead of just an ungainly and unreadable screen dump.

Of great significance are the "Decode/Encode" functions. These will automatically construct graphics images (JPEGs or GIFs, for instance) from any encoded files, or vice versa. There is no longer the need to decode batches of separate files manually to obtain the graphic image – *Turnpike* handles this in one shot. Concerned parents should be aware that this will make it *much* easier for other users to decode undesirable graphic files which have been transmitted over the Internet, though you do have the initial password protection in any case.

File Transfer Protocol (FTP)– exchanging files by computer – is another area in which they have bought-in the technology, and it seemed to work extremely well. It displays familiar Windows-style directory trees of both the local *and* remote server, so you can home in on your target file very quickly indeed.

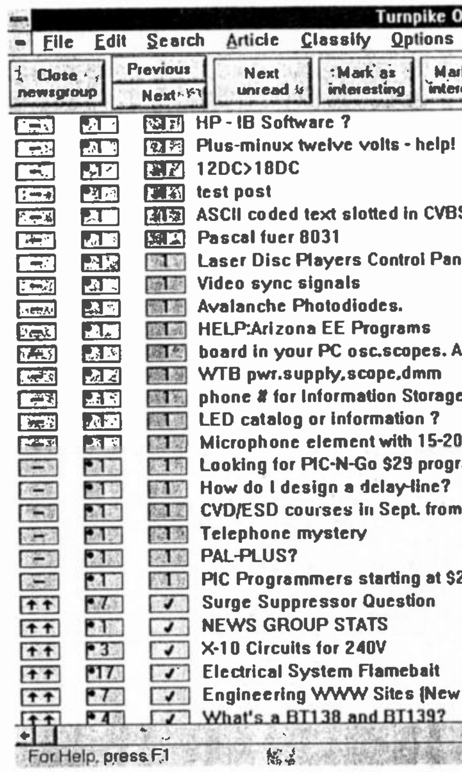
I found this an absolute boon, especially as I am a DOS/ Windows, not a Unix, user and since many FTP servers are based on Unix, I struggle sometimes with paths when trying to navigate around them! The Turnpike software uses drag-and-drop so you really can FTP much more easily than you may have before, the graphical tree display making everything much more navigable.

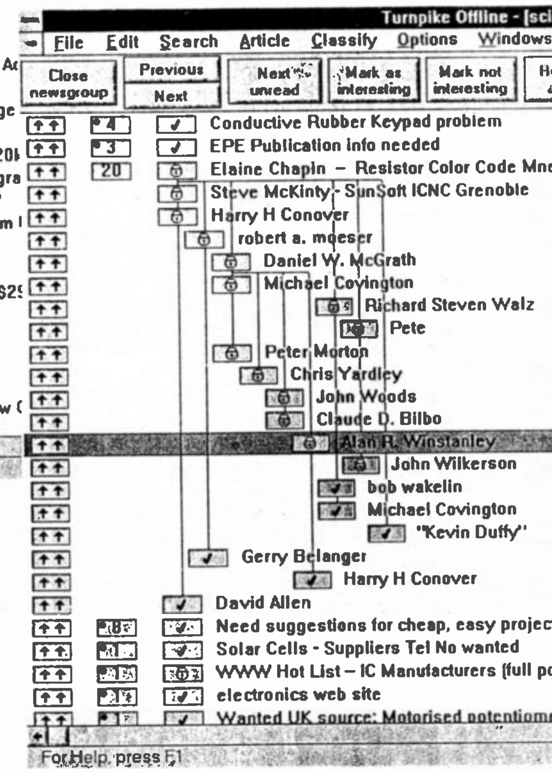
Dial-A-Dialogue

Clicking on the "Connect" icon pulls up the dial-in dialogue box. They have clearly done their homework here, and commendably they include dial-in scripts for every known UK service provider, so you should have absolutely no difficulties in this respect. You can also configure new PoPs with a little file editing, and I found that I could also create my own modem initialisation file for my very non-standard fax-modem, by editing a pre-existing config. file.

In short, I had no problems configuring and getting this entire Windows software up and running quickly and easily, which is more than I can say for any other I've tried. A bit of experience in finding and editing files will be useful though, but there's nothing drastic involved.

Currently a World Wide Web (WWW) viewer isn't included but will be offered free of charge to registered users when it's available, says Turnpike. Meantime, you can use your own Netscape or Mosaic WWW Browser, which I did successfully when researching October's *Circuit Surgery*, no problems at all; you can run other third party programs through *Turnpike's*





Above, window showing newsgroup and thread topics. Right, newsgroup expanded to show "tree" structure.

own winsock too. Telnet, Finger and Ping are also available, accessible by Windows buttons.

A few minor niggles but nothing significant – the Help screens aren't often context-sensitive and I prefer an option to "follow up" with a choice of quoting, or not quoting, the previous posting (or mail); *Turnpike* always quotes it all, so some editing is needed. I found the need to enter a password every time I ran the software, a bit of a nuisance though others will welcome it.

Scheduled log-ins (at night during quieter periods, say) aren't catered for. At £49.95 including VAT and P&P, *Turnpike* is well worth it if, like me, you're fed up of pulling your hair out or staring at an unhelpful >net prompt!

Overall, it's a commendably hassle-free and confidence-boosting way of getting to grips with Email, news and more. A network version is promised soon. *Turnpike for Windows* costs £49.95 including VAT and P&P from ***Turnpike Ltd, Dept EPE, Dorking Business Park, DORKING, Surrey, RH4 1HN.*** Tel: 01306 747747. Fax: 01306 747749 http://www.turnpike.com. Email enquiries to info@turnpike.com □

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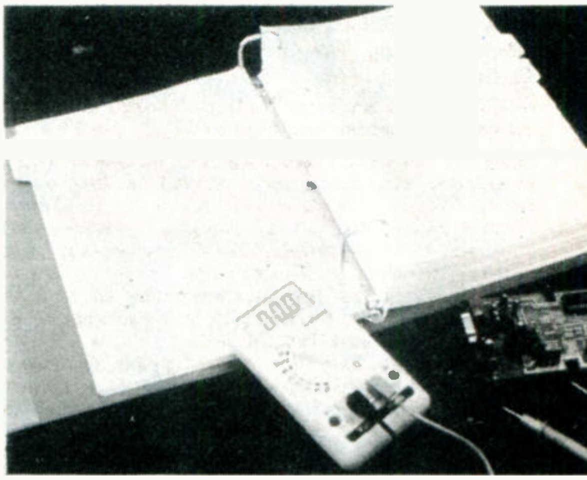

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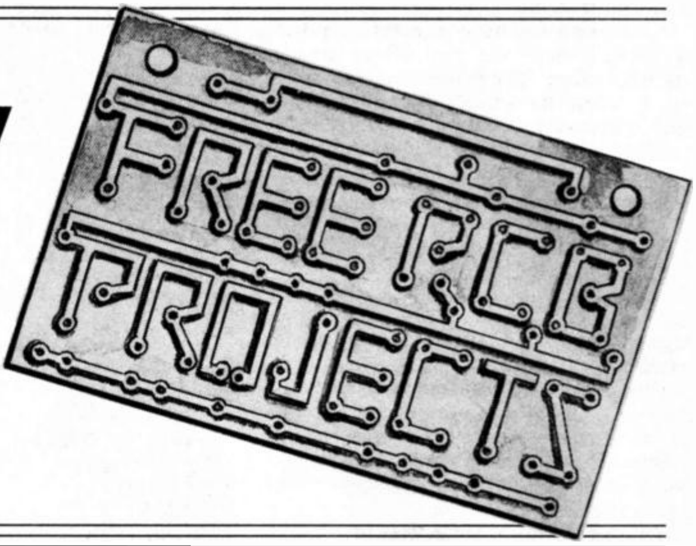


DISTORTION EFFECTS UNIT

ROBERT PENFOLD

Forget the overdrive, go for the soft approach and your friends will be raving over your performance. – It's the classic Hendrix sound. An ideal project for last month's Free p.c.b.

THE distortion effect (which is also known as "fuzz" and "overdrive") is probably the best known guitar effect. All distortion units provide the same basic function, which is simply to add distortion products to the processed signal.

There are several ways of producing the distortion products though, with each one producing a different sound. The term "distortion" actually covers a range of related effects.

CLIPPING

Some distortion units produce a very severe form of distortion where the input signal is replaced by a pulse signal at the fundamental input frequency. This method totally loses the character of the original signal, and it is a method that has never achieved widespread acceptance. The more popular method of producing the distortion is to use "clipping."

The clipping process is best explained by referring to Fig. 1. The top waveform Fig. 1a is the input signal, which in this example is a clean sinewave type. The waveform of Fig. 1b shows the effect of what is termed "hard" clipping.

With this type of clipping the signal is unaffected until a certain positive or negative signal voltage is reached. Once this voltage is reached, the signal voltage can not increase significantly, no matter how large the input voltage is made.

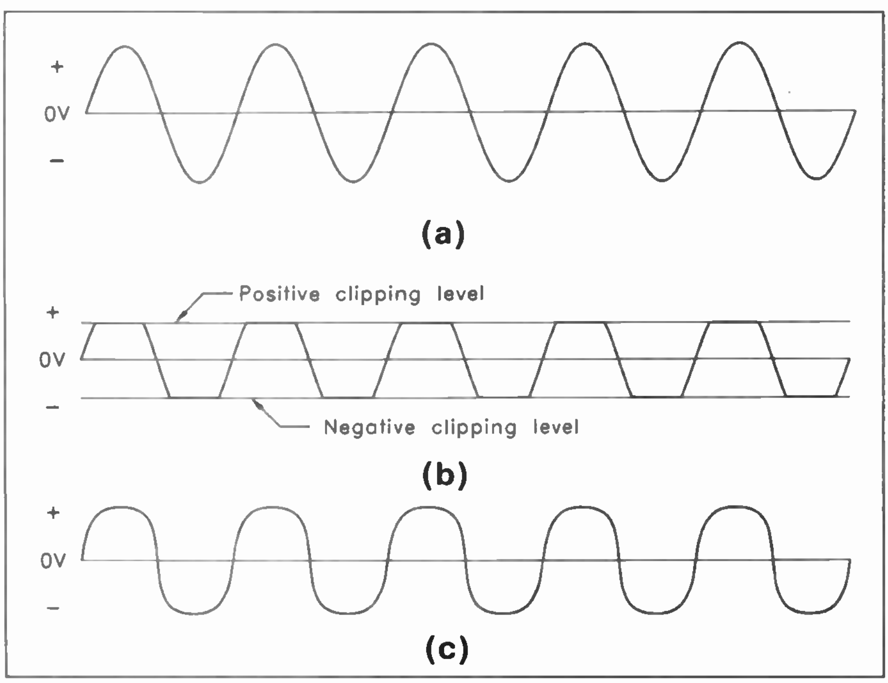


Fig. 1. Waveforms showing the difference between hard and soft clipping: (a) input signal; (b) hard and (c) soft clipping.

With anything other than simple pulse signals, the effect of hard clipping on the waveform is very self evident. The change in the sound is at least as obvious. The abrupt nature of the clipping results in severe harmonic distortion, with strong high frequency harmonics being produced as a result.

Also, the output signal from a guitar normally has a high initial level that decays quite rapidly at first, and then dies away more slowly. This gives the characteristic "twangy" sound of the guitar. Hard clipping provides a volume level that does not vary significantly during the course of each note, giving what is more like an organ sound than that of a guitar.

This is the type of distortion that is produced when a semiconductor amplifier is driven too hard, and it is from this that the term "overdrive" is derived. At one time this was the preferred form of distortion for guitar effects units, but it seems to have become less fashionable in recent years. There are one or two practical problems with this type of distortion effect.

For many players the most major objection is that not only harmonic distortion products are generated. Strong intermodulation distortion is also produced.

The practical importance of this is that some very dissonant sounds are produced if two or more notes are played simultaneously. Others find that the strong high frequency harmonics produce an effect which is simply too harsh, and not musical enough.

GOING SOFT

The alternative to hard clipping is the soft variety. The waveform of Fig. 1c shows the effect of soft clipping on a sinewave signal. This is obviously similar to hard clipping, with the waveform being severely squashed. There is no rigidly defined clipping level though.

As the signal voltage increases, a point is reached where the gain of the circuit starts to reduce. The higher the input voltage is taken, the greater the reduction in gain. Increases in the input voltage always produce some increase in the output voltage, but at high input voltages a large increase produces very little change at the output.

When looking at the clipped waveforms, soft clipping appears to be a much milder form of distortion. In truth it still produces massive amounts of distortion, but the higher frequency harmonics are much weaker.

This gives a very different sound, which is far less "bright" than the effect provided by hard distortion. The sound is much "thicker", with strong middle frequency harmonics. In fact it is the classic "Hendrix" style distortion.

Soft distortion provides less intense intermodulation distortion. This makes it possible to play two or more notes at once without the discordant sounds associated with polyphonic hard distortion.

Although soft distortion does permit some variation in the output level above the clipping threshold, the envelope shape of the guitar is to a large extent removed. This retains the organ-like sound of hard clipping, together with the improved sustain period associated with distortion units.

CIRCUIT OPERATION

The Distortion Effects Unit described here provides a soft clipping effect, which is the type most players seem to require these days. The full circuit diagram for the Distortion Effects Unit is given in Fig. 2. It is basically just a non-inverting amplifier based on IC1.

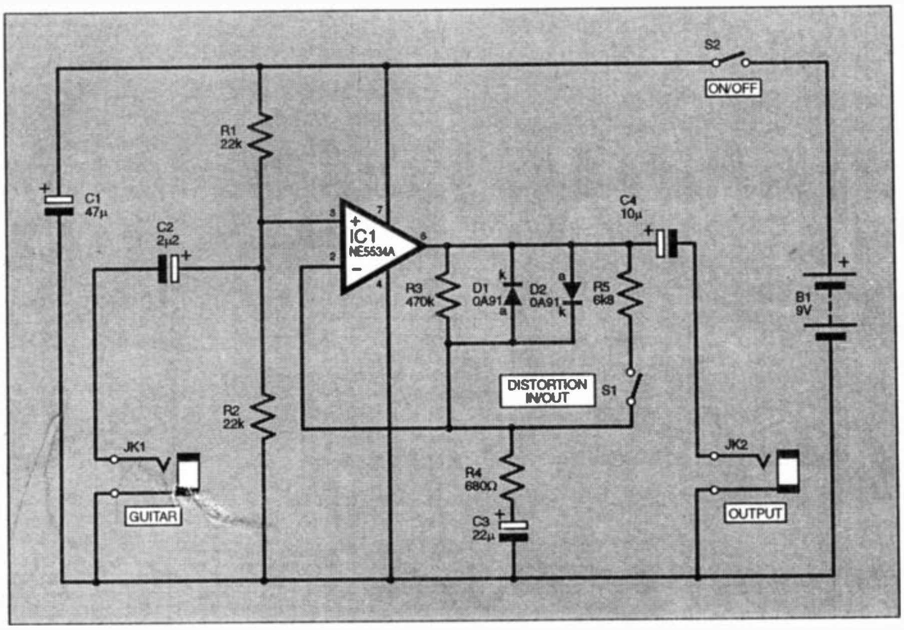


Fig. 2. Complete circuit diagram for the Distortion Effects Unit.

Resistors R1 and R2 bias IC1's non-inverting input, pin 3, and these set the input impedance at about 50k (kilohms). This is suitable for all normal guitar pick-ups. Electrolytic capacitor C2 provides d.c. blocking at the input.

With switch S1 open, resistor R3 and R4 form the negative feedback network, and set the closed-loop voltage gain of IC1 at about 690 times. The true closed-loop voltage gain is actually rather less than this, because diodes D1 and D2 shunt R3, providing increased feedback and reduced closed-loop gain.

Diodes D1 and D2 are germanium types, and their forward resistance falls steadily as the applied voltage is increased. They do not have a well defined forward conduction threshold voltage of the type associated with silicon diodes (and silicon diodes are unsuitable for use in this design).

The reduction in gain provided by D1 and D2 therefore depends on the output voltage of IC1. At low signal levels neither diode is brought into conduction, but their leakage currents result in some reduction in the feedback resistance, and some reduction in gain.

At higher signal levels, one or other of the diodes starts to conduct significantly, and reduces the closed-loop gain. D2 conducts on positive half cycles, and D1 conducts on negative half cycles. The higher the signal voltage, the lower the resistance of the diode, and the lower the closed-loop voltage gain of IC1. This gives the required flattening of waveform peaks, and a good soft distortion effect.

Closing switch S1 places the relatively low resistance of resistor R5 across the diodes. It is then mainly the resistance of R5, rather than that of R3 and the two diodes, that governs the closed-loop voltage gain of IC1. The circuit then acts as an amplifier having a gain of about ten times, and provides little distortion. Switch S1

COMPONENTS

Resistors
R1, R2 22k (2 off)
R3 470k
R4 680Ω
R5 6k8
All 0·25W 5% carbon film

See SHOP TALK Page

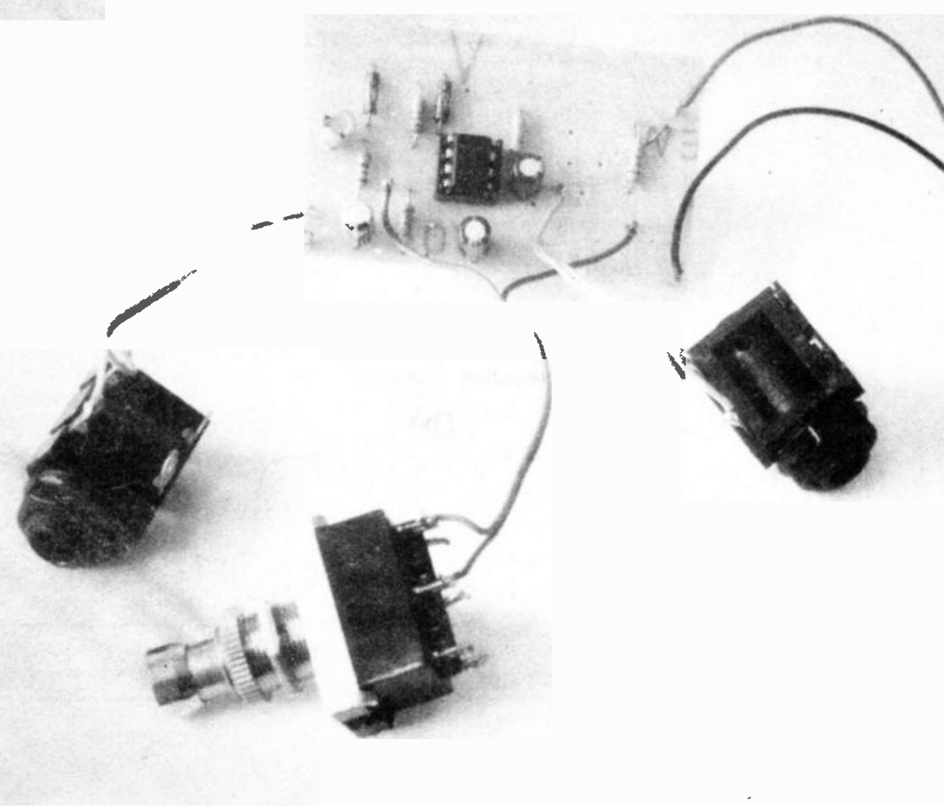
Capacitors
C1 47µ radial elect. 16V
C2 2µ2 radial elect. 50V
C3 22µ radial elect. 16V
C4 10µ radial elect. 25V

Semiconductors
D1, D2 OA91 germanium signal diode (2 off)
IC1 NE5534A low-noise op.amp

Miscellaneous
S1 s.p.s.t. heavy-duty pushbutton switch (see text)
S2 s.p.s.t. min.toggle switch
B1 9V battery, PP3 size
JK1, JK2 Standard 6·35mm insulated jack socket (2 off)

Printed circuit board available from the *EPE PCB Service*, code 932 (or *Free* with last month's issue); aluminium or diecast case, size to choice; 8-pin d.i.l. socket; PP3 type battery clip; multi-strand connecting wire; single-ended solder pin (8 off); solder, etc.

Approx cost guidance only **£15** *excluding Batt.*



therefore provides a means of switching the effect in and out.

A low-noise operational amplifier (op.amp) is used for IC1. The circuit adds a fair amount of gain into the signal path when the signal level is low, making the use of a low noise device well worthwhile, particularly if the unit is used with a low output pick-up. However, a less expensive device such as the LF351N is usable in this circuit. The current consumption of the distortion unit is about 4·5mA.

CONSTRUCTION

This Distortion Effects Unit fits quite well onto last month's *FREE* printed circuit board. (Extra boards are available from the *EPE PCB Service*, code 932). The actual size copper foil pattern, component layout and hard wiring being shown in Fig. 3. Do not overlook the short link-wire just to the right of resistor R5.

Germanium diodes are used for D1 and D2, and they are more vulnerable to overheating than the more familiar silicon types. It should not be necessary to use a heatshunt when soldering them in place, but only apply the soldering iron to each soldered joint for a second or so. Make quite sure that they are fitted the right way round at the first attempt! The NE5534A op.amp i.c. is not a static-sensitive device, but it is still advisable to use holder for this component.

On the prototype JK1 and JK2 are plastic-bodied insulated jack sockets. These have single break contacts which serve no useful purpose in this circuit. The two tags of each socket that connect to the switch contacts are therefore left unconnected. Open style jack sockets are, of course, perfectly suitable for use in this project.

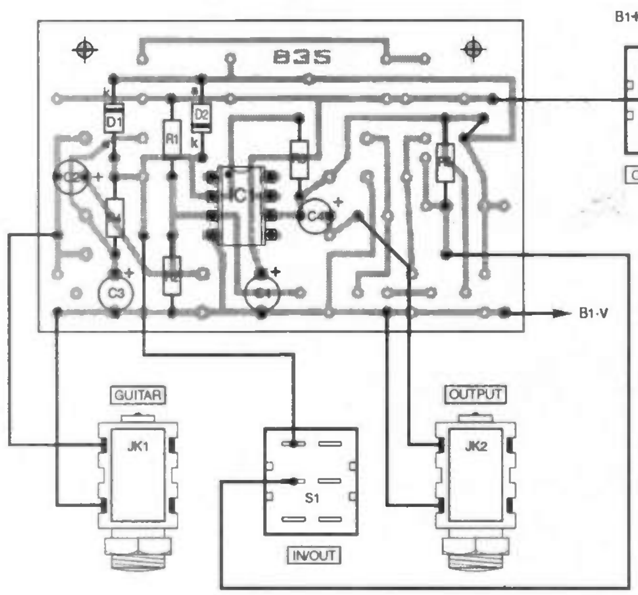
A pushbutton switch must be used for S1 as it is mounted on the top panel of the case so that it can be foot operated. This obviously requires the use of a heavy-duty pushbutton switch that can withstand the rough treatment it will inevitably be submitted to.

The usual choice is a successive operation type. With this type of switch it is operated once to switch in the effect, operated again to switch it out, operated a third time to switch in the effect again, and so on.

It might be difficult to find a heavy-duty switch of this type which has s.p.s.t. contacts. If necessary, the appropriate pair of contacts on a s.p.d.t. or d.p.d.t. switch can be used. A double-pole double-throw (d.p.d.t.) switch is used on the prototype, and a switch of this type is shown in Fig.3.

Switch S1 could be a large non-locking s.p.s.t. push-to-make switch. The effect would then be switched in under normal conditions, and switched out when the push-button is held down. Alternatively, using a push-to-break type will result in the effect being switched in when the switch is operated.

A tough case is needed for a project of this type, which precludes the use of most plastic boxes. Diecast aluminium boxes are very strong and are well suited to a project of this type. Unfortunately, they are also relatively expensive. A box of folded aluminium construction is just about tough enough, and provides a good low cost alternative.



Note: None of the projects in the Multi-project PCB series use ALL the copper pads on the board, in most cases more than 50 per cent of the holes are left vacant. This makes it essential to double-check the positioning of each component, before soldering in place.

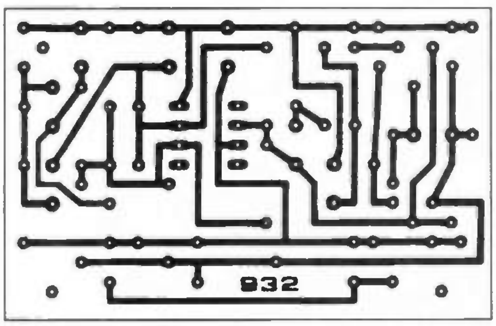
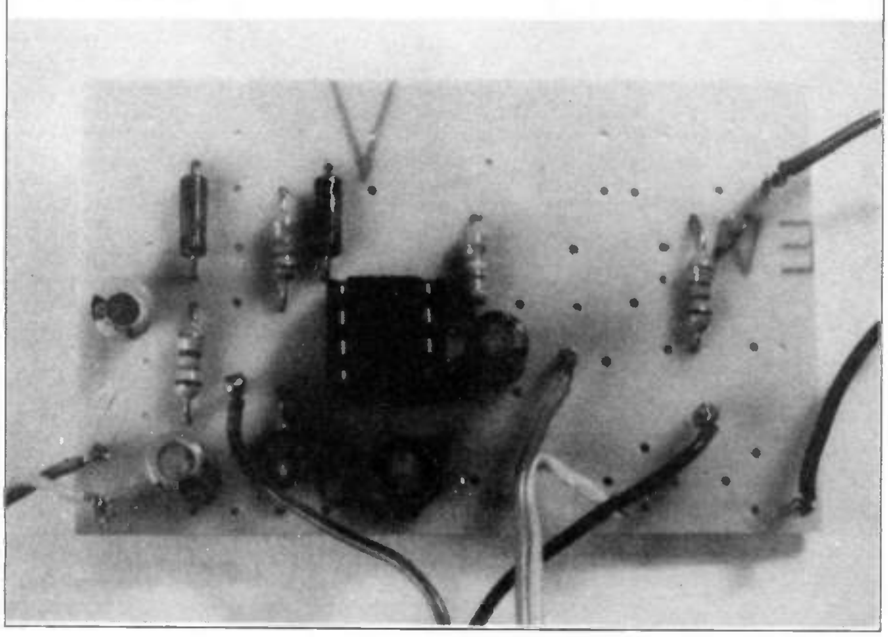


Fig. 3. Distortion Effects Unit printed circuit board (p.c.b.) component layout, interwiring details and full size copper foil master pattern. The completed board is shown below.



TESTING

The Distortion Effects Unit is connected between the guitar and the amplifier using a pair of ordinary screened jack leads. The distortion effect is not particularly subtle, and the effect of the unit on the processed signal should be very obvious.

The unit does not have a distortion level control, but with medium and high output guitar pick-ups the guitar's volume control effectively provides this function. Setting a high volume level will not actually have much affect on the volume, but it will give a higher distortion level. The circuit will work quite well with most low level guitar pick-ups, but the guitar's volume control will probably have to be set at maximum in order to obtain a reasonably high distortion level.

Bear in mind that the distortion unit, in common with all clipping type distortion units, adds a significant amount of voltage gain into the signal path. This increases the risk of problems with "hum" pick up, stray feedback, etc. This makes it necessary to take a little more care in order to obtain noise-free results. □

FOX REPORT

by Barry Fox

Focussing on Digital Video Standards

In mid July, Toshiba demonstrated the SD (Super Density) digital video disc system in London, but only to financial analysts and dealers like Dixons. At the last minute Toshiba's Koji Hase, the man in charge of SD, flew in from Japan. Once again he challenged Sony and Philips, developers of the rival MMCD DVD system, to negotiate a single standard deal. That now seems to be happening.

Toshiba and the SD Alliance have already ditched the clumsy idea of a double-sided disc and agreed that SD will be a single-sided disc, with double density achieved by recording two tracks at different depths and focussing first on one track and then the other. Sony has now agreed with Toshiba to share a common coding standard. That's the way the digital code is packaged with error correction before it is recorded on the disc.

Separation?

This leaves only one difference between the two formats. The Philips and Sony disc makes double depth recordings by adding an extra coating layer to a full thickness disc. The SD system achieves the same result by sandwiching two half-thickness pressings.

The main objection to the Philips/Sony approach is that the extra coating relies on a proprietary semi-reflective material developed by 3M. Pressing plants do not want to have to rely on 3M, or any single supplier, as their sole source of a key material.

There are no firms plans yet to make a player with the laser optics needed to play both types of disc. But the agreement on a common coding system leaves the door open. The two rival formats are now virtually the same.

Soundly Divided

In the background there has been another standards issue. This one involves the type of multichannel sound system to be used for DVD. Despite some last minute pitching by DTS, the Californian company which developed the sound-on-disc cinema sound system used for *Jurassic Park*, it now seems a foregone conclusion that both types of high density disc will use Dolby AC-3 for NTSC countries and Europe's Musicam for PAL countries.

This difference is perversely seen as a benefit by the Hollywood studios. It means they can make North American movie discs incompatible with European players, and so maintain the staggered release pattern that is currently made possible by the NTSC/PAL divide.

In the Red

The two consortia backing the rival high density disc systems, Philips and Sony on the one hand, and Toshiba, Time-Warner, Panasonic and others on the other hand, are both promising storage capacities of around ten times that of a normal CD or CD-ROM.

Both camps achieve this by using a red laser, instead of the infra-red devices used in existing CD players. The infra-red diodes in conventional CD players have a wavelength of 780 nanometres. The new red lasers to be used for high density CD have a wavelength of 650nm. The shorter wavelength lets tighter tolerance optics focus the beam into a smaller spot, and so read smaller information pits.

In the Blue

Both camps also promise a further increase in storage capacity when blue lasers are available. These have a much shorter wavelength (460-500nm) which allows the spot to be focussed onto even smaller pits. With blue lasers, the storage capacity could increase by another factor of five.

Blue l.e.d.s are already available from a few manufacturers. But they cost at least ten times as much as conventional red, green, orange or amber l.e.d.s. They only last half as long before burning out, and have unpredictable efficiency. The amount of light generated by a fixed current varies from diode to diode.

Blue lasers are already available, but only in the form of gas tubes. They are used for cutting CDs. Three major manufacturers, Panasonic, Sharp and Sony all make similar predictions on the availability of solid state blue lasers. Mass production is between three and five years away.

Rainbow's End?

Early diode prototypes worked only in pulses, in the blue/green (500-530nm) colour band. Sony was probably first to achieve continuous wave operation, in July 1993, with blue/green light. But the target remained pure blue in the band 460-500nm. Blue diode lasers are now working continuously in the laboratory, but life is short.

The target for domestic product is between 5,000 and 10,000 hours. Reliable, cost effective blue lasers should be in consumer equipment by the turn of the century. But by then the target will have moved on, to ultra violet diodes with even shorter wavelength and even tighter focus on even smaller pits.

Artful Aerial

"The picture you would expect from an outdoor aerial, from an indoor aerial", promises Rovic for the L30 Interial.

The Interial hangs on the wall like a picture, and as such is a lot less ugly than a bit of wire bent into the shape of small Yagi and sat on the set top. It's less likely to be affected by movement in the room, too.

The theory is that the walls of the building work like a waveguide, and there will usually be one spot in the room where reception is good. It could even be on the floor or top of a cupboard. Rovic admit that it can take a lot of time, trial and error to find the sweet spot.

I tried it in Sussex at a spot where I know a good roof aerial is essential. The Interial could not produce watchable pictures. Or if it can I did not persist long enough to hit the spot. In a London flat it did better than the wire loop that came with a portable TV. It's not magic but it is worth a try on money-back guarantee.

For real magic we shall have to wait for digital TV. I have seen demonstrations run by the BBC from Crystal Palace which show how a set-top aerial that can pull in only unwatchable analogue pictures, can deliver perfect digital pictures from a lower power transmission.

In the meantime I am interested in Rovic's promise of a VHF version for FM radio. Whereas most people have now learned that they must have a roof aerial for TV reception for good TV pictures, they still expect an audio rack system to work without an FM aerial. The bits of straggly wire that come with rack systems are near useless. As the Interial is designed to work against a room wall, an FM version might neatly sandwich behind a rack or loudspeaker.

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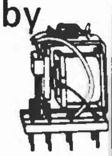

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Techniques

ACTUALLY DOING IT!

by Robert Penfold

I RECEIVE a fair number of readers' letters about all manner of subjects, including a few that pertain to my published projects! One recurring theme is readers who wish to build a project, but are having problems as it was published only as a circuit diagram with no circuit board or wiring diagrams.

If an article is published with just a circuit diagram, it is unlikely that the author has a detailed wiring diagram and a printed circuit or stripboard design for the circuit. The circuit was probably tested on a breadboard or using the wire-wrap method of construction.

The former is not really intended as a permanent construction method, and the latter produces final products that usually work very well, but are far from neat and are difficult to "clone". Many of the enquirers realise that detailed construction information is not available, and ask for general advice on how to convert a circuit diagram into a working project.

This topic has been covered in a previous *Actually Doing It* article, but as that was a few years (and several dozen pleas for help) ago, it is perhaps time for this basic process to be covered again.

We will consider the process of producing a stripboard layout rather than a custom printed circuit board, since many readers will probably not have the necessary tools and equipment to deal with do-it-yourself p.c.b.s. The stripboard approach requires nothing more than a pencil, some paper, and the stripboard itself.

IN AT THE DEEP END

An ability to read circuit diagrams is a prerequisite of designing your own board layouts, and it is assumed here that you can read circuit diagrams reasonably fluently. If you cannot do so, refer to last month's *Actually Doing It* article which covers this topic.

There are numerous ways in which a circuit diagram can be converted into a workable printed circuit or stripboard layout, but the method described here is one that I have used successfully for what must be many hundreds of projects. When using stripboard I have always preferred to dive straight in and start building, literally making up the layout as I go along.

Probably most beginners would prefer to produce a paper design first, and then build the "real thing." Alterations can be made more quickly and easily when drawing out a design, and it is less important to think ahead so that you do not "paint yourself into corners."

The method outlined here can be used with either approach. It can be applied to most circuits, but there are some types that are not well suited to stripboard. In particular, high gain high frequency circuits, v.h.f. and u.h.f. circuits, and high current circuits are likely to be problematic when built on stripboard.

Also, it is not well suited to circuits that connect direct to the mains supply, and any project that connects to the mains supply is not a good starting point for someone working out their first few board layouts. ***Avoid projects that connect to the mains supply until you have the necessary experience to deal with them safely.***

SPACED-OUT

When designing a custom printed circuit board it is normal to use a standard lead spacing for the resistors and each type of capacitor. Also, components are normally oriented "north-south", or occasionally "east-west", but not at odd angles.

It is possible to adopt a similar approach with stripboard layouts, but I would advise against this. It tends to result in circuit boards that are covered in link-wires, and it does not give particularly compact layouts.

It is more practical if *variable* lead spacing is used for resistors, and where practical for capacitors as well. It is easier to design stripboard layouts for capacitors such as Mylar types, which are printed circuit mounting components but with long leadout wires, than it is for polyester types which have printed circuit mounting pins on a fixed pitch. As far as possible it is best to avoid having components mounted at odd angles, but this can sometimes be necessary in order to save space by fitting components into otherwise unused areas of the board.

Mounting resistors on-end is something that is normally avoided with custom printed circuit boards. The problem with this method of mounting is that it is physically weak, with any pressure on the component tending to tear the copper strips away from the underside of the board.

Also, the components are easily pushed over, possibly causing their leadout wires to produce unwanted connections to the leadouts of other components. However, using a few vertically mounted resistors can help to keep stripboard layouts reasonably compact, but it is something that should be kept to a minimum.

DECISIONS, DECISIONS

Initially it is advisable to start with a simple project, even if you only draw-up the board design as an exercise. As with any design work, experience is a valuable asset.

As a simple example of producing a stripboard layout, we will produce a stripboard version of the Treble Booster circuit (Fig.1), which is one of the Multi-PCB projects featured in *EPE* October '95 issue.

Getting started is the most difficult part for beginners, with a lot of initial decisions to be made. Unless there is good reason to do otherwise, adhere to the convention of having the bottom copper strip for the 0 volts (0V) supply

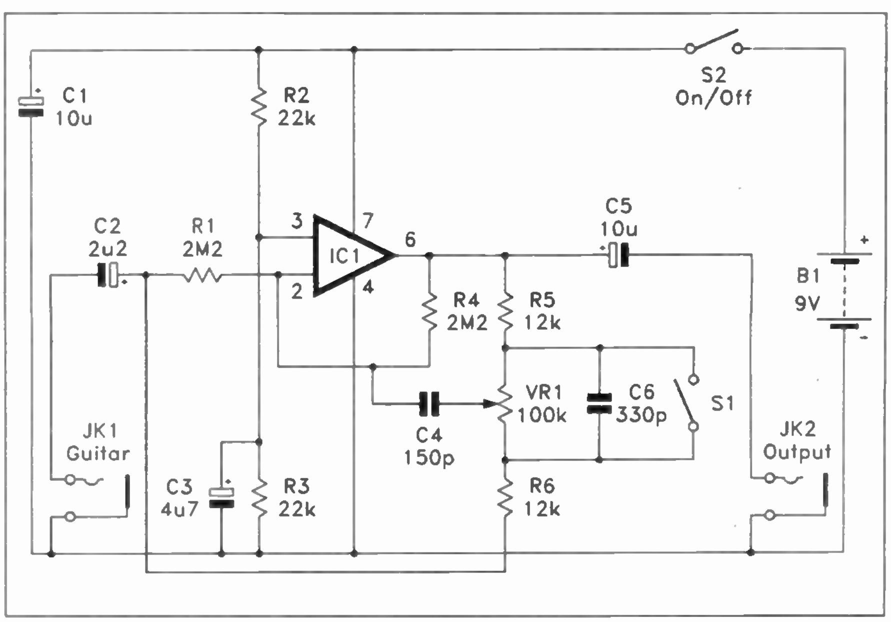

Fig. 1. The Treble Booster circuit diagram.

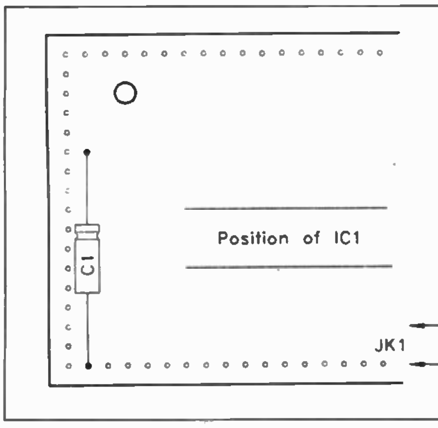

Fig. 2. The internal board layout, with only capacitor C1 in place.

rail, and the top one for the positive (+) supply rail.

Some board space must be reserved for mounting holes so that the board can be bolted in place inside the case. Completed stripboard panels are mostly quite light, and for small to medium size boards a couple of mounting holes should suffice. Usually about three to five strips at the top of the board are reserved for the holes.

Next a decision has to be made on the number of copper strips to be included between the power rails. Experience suggests that a minimum of about two strips above the integrated circuits, and four beneath are required. A complex circuit would probably require more than this, but we are only dealing with a simple circuit here.

Adding everything up, this gives four strips for the integrated circuit, two for the power rails, a total of six strips above and below the integrated circuit, and (say) five strips to accommodate the mounting holes. This gives a board 17 strips high.

The obvious starting point for the component placement is capacitor C1, which can simply be placed between the two power strips on the left hand side of the board. An exact position cannot be set for IC1 at this stage, but a couple of lines can be marked in to indicate the top and bottom rows of strips it will use. This gives an initial board layout along the lines of Fig.2.

PROGRESSING

It is now a matter of working across the circuit diagram from left to right, adding in each component. With the power rails in place, and the strips for IC1 selected, the positions of some components are to some extent selected for you.

For example, resistor R3 and capacitor C3 must connect between the copper strip that connects to pin 3 of IC1, and the 0V rail. Similarly, R2 connects between the strip that connects to pin 3 of IC1 and the positive supply rail.

Resistor R1 connects to the strip that connects to IC1 pin 2, and one of the otherwise unused tracks. There are a few options here, but I would be inclined to keep things simple with this resistor being connected between the IC1 pin 2 track, and the one that is four tracks lower down.

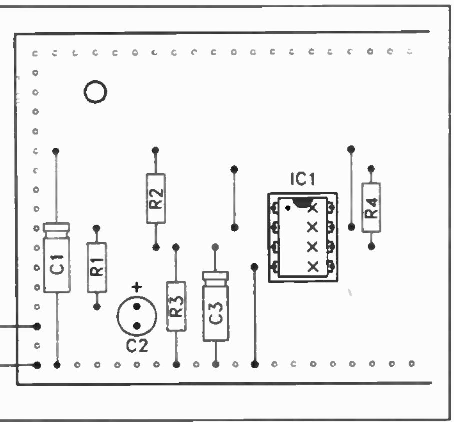

Fig. 3. Layout with the basic amplifier in place.

Capacitor C1 can then be positioned from the bottom R1 track to the track immediately beneath this. The connection points to the "jack" socket JK1 can then be added at the extreme left-hand side of the board.

With all the components to the left of IC1 now accounted for, IC1 itself can be added, together with link wires to provide it with connections to the power rails. To complete the basic amplifier circuit, resistor R4 must be added.

There is a slight problem with R4 in that it connects to strips on opposite sides of IC1. Fitting it over the top of IC1 is not a good way of tackling the problem, and it is better to go around IC1 with the aid of a link wire. I generally use one of the copper strips above the integrated circuit to provide the route around the device.

By applying these principles I ended up with the semi-complete layout of Fig.3, but there are numerous alternative layouts that would be functionally the same. Do not forget to include any necessary ***breaks*** in the copper strips. This layout only requires four breaks so far, between IC1's two rows of pins. These are indicated by the "***X***"s in Fig.3.

FINAL ANALYSIS

The final part of the board design is potentially a bit awkward as there are several off-board components to contend with. Some careful thought is needed in order to keep things reasonably neat and tidy.

Ideally the connections to each off-board component should be fairly closely grouped on the circuit board. Switch S1 could have its own connection points on the board, but it is probably easier and neater if it is simply wired across the appropriate two tags of potentiometer VR1.

The connections to VR1 can be handled by allocating to this component three of the copper strips beneath IC1. It is then just a matter of fitting resistors R5, R6, capacitors C4, C5 between the appropriate pairs of strips, and adding the take-off points for the leads to VR1.

This leaves one strip beneath IC1 unused, and this can be used for the negative lead of C5. Take-off points for the leads to JK2 can then be added, as can supply connection points.

I ended up with the final (but untested) layout of Fig.4. Note the break in the copper strip between the connecting leads of resistor R6. Again, there are numerous other layouts that would have provided the same result, and there is no single correct solution to this sort of problem.

With audio circuits it is usually desirable to have minimal stray feedback from the input to the output of the circuit. In this case I have used two breaks in the copper strip to which the input and output of the circuit connect. This discourages stray feedback, and also minimises any stray pick-up in the copper strip at the input of the circuit.

FEEDBACK

With linear circuits you always need to be careful about stray feedback through the copper strips. In particular, do not have any input wiring on one strip, and some of the output wiring on one of the adjacent strips.

Where feedback problems do occur, some additional breaks in the copper strips to isolate the unused sections will normally have the desired effect. In an extreme case some of the unused sections can be connected to the earth 0V rail. They will then act as screens which should substantially reduce any stray feedback.

Although the circuit featured here is quite a simple one, the basic principles apply to more complex circuits.

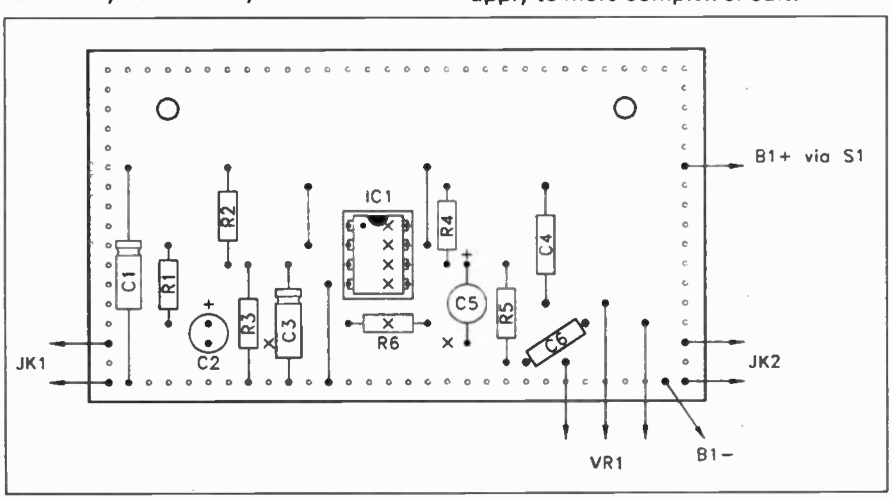

Fig. 4. The final (untested) board layout.

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The books listed have been selected by *Everyday with Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order to your door. Full ordering details are given on the last book page. For another selection of books see next month's issue.

PROJECT CONSTRUCTION

POPULAR ELECTRONIC PROJECTS
R. A. Penfold
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80 pages **Order code BP121** **£2.50**

HOW TO GET YOUR ELECTRONIC PROJECTS WORKING
R. A. Penfold
We have all built projects only to find that they did not work correctly, or at all, when first switched on. The aim of this book is to help the reader overcome just these problems by indicating how and where to start looking for many of the common faults that can occur when building up projects.
96 pages **Temporarily out of print**

AUDIO AMPLIFIER CONSTRUCTION
R. A. Penfold
The purpose of this book is to provide the reader with a wide range of preamplifier and power amplifier designs that will, it is hoped, cover most normal requirements.
The preamplifier circuits include low noise microphone and RIAA types, a tape head preamplifier, a guitar preamplifier and various tone controls. The power amplifier designs range from low power battery operation to 100W MOSFET types and also include a 12 volt bridge amplifier capable of giving up to 18W output.
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I. D. Poole
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Topics covered include: The equipment that is needed; Setting up the shack; Which aerials to use; Methods of construction; Preparing for the licence.
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H. C. Wright
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TESTING, THEORY, DATA AND REFERENCE

PRACTICAL ELECTRONICS HANDBOOK – Third Edition
Ian Sinclair
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R. A. Penfold
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Steve Money
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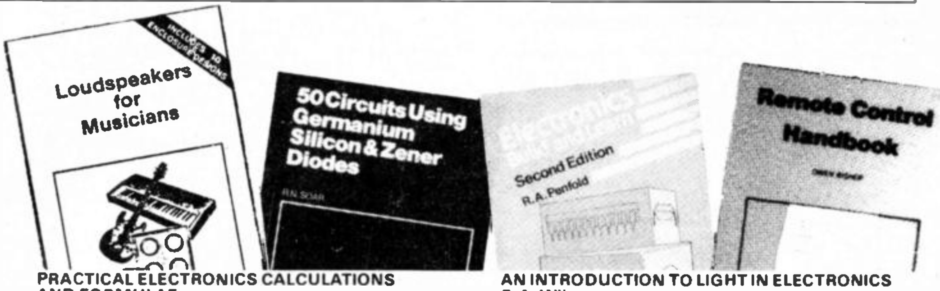

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REPORTING AMATEUR RADIO

Tony Smith G4FAI

AMATEUR MORSE TESTS

Over the last two months I have outlined two different ways to become a radio amateur; by taking the "full" Radio Amateur's examination or the Novice examination. The latter is the easier way but offers only limited facilities on the air.

Both routes offer two further alternatives. After passing the necessary exams, a Novice B or a "full" B licence can be obtained immediately, but these will only give access to amateur frequencies above 30MHz. To obtain a Novice A licence a five words per minute (5wpm) Morse test must also be taken, and the "full" A licence requires a 12wpm Morse test to be passed.

Novice A licensees have limited access to the amateur bands above and below 30MHz, and "full" A licensees have access to all amateur bands and permitted modes across the board.

NOVICE TEST

The Novice Morse test consists of a *receiving* and a *sending* test. The text for the receiving test is computer generated using a pre-recorded tape which also contains voice announcements.

Up to three candidates at a time receive the same test piece. This is followed by the sending test which is taken individually.

The receiving test requires the successful recognition of a minimum of 120 letters and seven figures in the form of a typical exchange between radio amateurs. The test lasts approximately six minutes.

Each character is sent at a speed of 12wpm with a longer than normal gap between each character and word, thus reducing the overall speed to 5wpm. More than six uncorrected errors result in failure.

The sending test is sent on a hand-key, and comprises not less than 75 letters and five figures. This must be sent at not less than 5wpm, taking approximately three minutes.

This is also in the form of a typical amateur radio contact. There must be no uncorrected errors, and no more than four corrections are permitted.

FULL TEST

The receiving test leading to a "full" amateur A licence involves the same number of letters and figures, and in the same form as the 5wpm test. It is sent on a manual key. The test lasts approximately three minutes, and up to six uncorrected errors are permitted.

The sending test is also similar in content to the slower test. It is sent by the candidate on a hand-key at not less than 12wpm, which should take approximately one minute 30 seconds. Again, there must be no uncorrected errors, and no more than four corrections are permitted.

Both tests can include various Q-codes, common abbreviations or procedural characters as used in amateur Morse contacts on the air. Examples are: QRM, interference; QRP, low power; QTH, location; GA, good afternoon; TU, thank you; WX, weather; AR, end of message; and so on.

ARRANGING A TEST

The Radio Society of Great Britain administers the Morse tests on behalf of the Radiocommunications Agency, and the tests are carried out by volunteer examiners appointed by the RSGB.

The cost of the 5wpm test is £13, and the 12wpm test is £18. Further details, application forms, and details of test centres across the country, are available from the RSGB at Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE. *Tel: 01707 659015.*

Subject to satisfactory medical evidence, special arrangements can be made for candidates with disabilities, including those with hearing, sight, or manipulation difficulties; and housebound or bedridden candidates can be tested at home.

Having passed a Morse test, it is not necessary to use the code on the air. However, many new licensees having taken the trouble to learn Morse do try it out and find it an intriguing and enjoyable way of communicating with other amateurs.

The form of the amateur Morse test, with its emphasis on the practical use of the code, is a great help in this connection, considerably easing the transition from "learning" to "using".

HOW NOT TO LEARN MORSE

There are a number of ways to learn Morse, but first of all there is one way not to do it. DON'T learn it by looking at a printed list of Morse characters and learning them by heart! That way brings problems, particularly if you aim to take the 12wpm test.

Up to a certain speed you can listen to a Morse signal, translate it in your mind to equate to the number of dots and dashes you learned from the list, and still have time to write it down before the next letter comes along.

However, as your receiving speed increases, you come to a "plateau", a point where you apparently can't go any faster because by the time your brain has sorted out one signal several more have arrived.

Then, to make further progress, you have to re-learn the code so that you can identify each character by its sound without any intermediate process. It is far better, therefore, to learn the code "by sound" in the first place.

TUITION AVAILABLE

There is Morse tuition available at local radio clubs and evening classes in many parts of the country. If you already have a receiver capable of tuning the amateur bands, there are slow Morse transmissions put out by the RSGB to assist learners.

There are Morse courses available on tape, Morse computer programs, and electronic random code generators. There are also a good number of books full of good advice and practice material, providing you don't actually learn the code from the lists they print!

MORSE TEST TO GO?

The Morse test is obligatory under international regulations laid down at World Radio Conferences (WRC) of the International Telecommunications Union. There is, however, much controversy about the test and, as reported in this column in August, the New Zealand government is to propose its abolition at *WRC-95* in October.

In a new development, Britain's Radiocommunication Agency (RA), in correspondence with the NZ Ministry of Commerce, has stated its position in this matter. It considers that Radio Regulation 2735 is outdated, and will support proposals for its suppression "because this would remove the international requirement for a mandatory Morse code test and allow us to consider other options".

The Agency says, however, that it will not be making any changes in the near future to the UK qualification requirements for amateurs without further consultation nationally and with other CEPT countries.

The latter are European countries that have common licence requirements, which include a Morse qualification, allowing temporary radio operation by amateurs when visiting each other's countries. If some of these countries dropped the test and others didn't, such agreements could well be invalidated.

ALTERNATIVES?

It is not certain that the New Zealand proposal will actually be discussed at *WRC-95* and it may have to wait for a later conference. These are held every two years and each one deals with specific areas of radio regulation.

Judging by comments from both the NZ and the UK administrations, even if a WRC voted to abolish the test, it would not disappear overnight. Also, the "other options" mentioned by the RA could mean an alternative licence qualification requirement.

It could still be a long time before the Morse test goes and, in the absence of anything more definite, my advice to those hoping to operate on the h.f. bands in the near future is to keep on with the Morse! Watch this column for news of developments as they occur!

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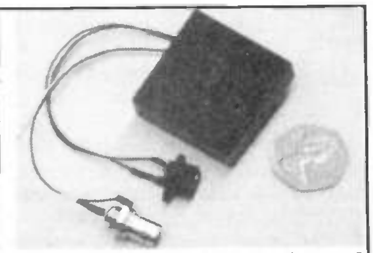

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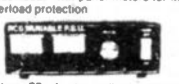

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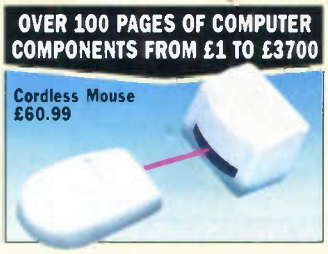

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