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VOL. 33. No. 5 MAY 2004
Cover illustration by jgr22

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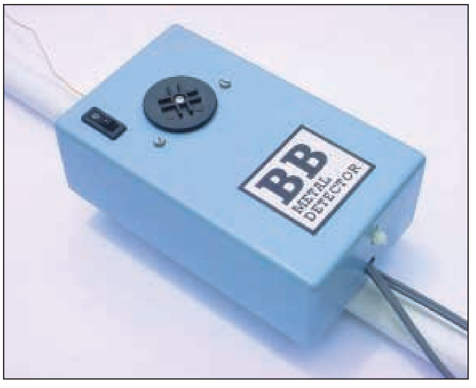
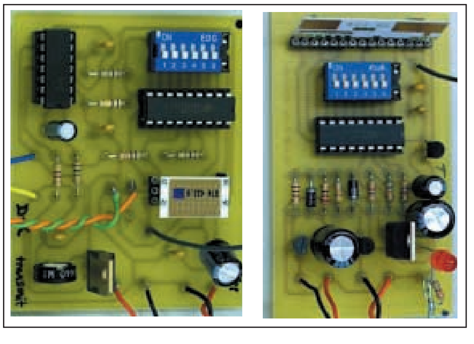



## Projects and Circuits





## Series and Features



## Regulars and Services





***Our June 2004 issue will be published on Thursday, 13 May 2004. See page 295 for details***

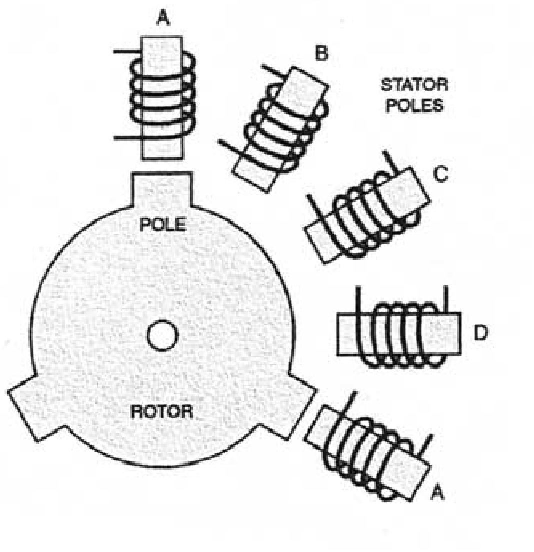
# NEXT MONTH

## PIC QUICKSTEP

*A simple and versatile stepper motor driver and controller. For mechanical applications requiring precise control, stepper motors offer many advantages over simple d.c. types. They can start and stop virtually instantly and move in tiny, precise increments. Forward and reverse operation is simple. Accurate speed control is easy to achieve through step rate, and shaft position may be tracked simply by counting the steps. There is a downside though, since electronic circuitry is required to generate the coil drive sequence needed for operating these motors.*

*Special stepper driving i.c.s are available but these usually offer only one out of several possible drive methods and they often draw too much supply current for battery applications. Additional circuitry is usually required to generate step and direction inputs so it's often a better idea to use a custom programmed microcontroller i.c. for complete step sequence control and perhaps also the controlling system.*

*This project will drive the four-phase unipolar type of stepper motor and has provision for single-step forward or reverse and continuous stepping forward or reverse with variable speed control over three speed ranges.*




## MIDI SYNCHRONOME

*Need help to improve your musical time-keeping when recording with MIDI instruments? This project could help!*

*This article describes a novel metronome that will automatically synchronise to the clock messages output by most MIDI (Musical Instrument Digital Interface) instruments and computer sequencers. Furthermore, this design not only provides the usual time-keeping "click" but also simulates the swinging arm of a mechanical metronome with nine light-emitting diodes (l.e.d.s).*

## CRAFTY COOLING

*Crafty Cooling explains the Peltier effect, describing how commercial Peltier modules work, their efficiency and considerations in using them. It goes on to describe the construction of a simple drinks cooler that can be run from a car battery.*

## CLINICAL ELECTROTHERAPY

*This feature article starts by looking at some early developments in medical electricity and goes on to describe some current day clinical applications across the whole spectrum, including some areas of research and pioneering technology. It covers such subjects as: Phototherapy; Radio Waves; Ultrasound; Functional Electrical Stimulation including BIONS, Neuromodulation, Deep Brain Stimulation; Electro-diagnosis; Kirlian Photography and Galvanic Skin Resistance. The article also provides links to many interesting web sites.*

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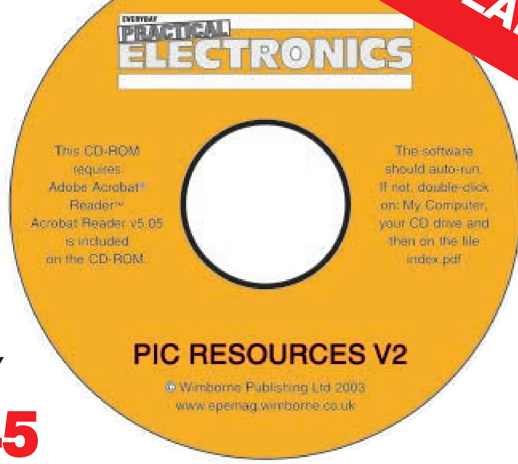


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THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

**VOL. 33 No. 5** **MAY 2004**

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## SURPRISE!

In the March issue one of our *EPE Online* Editors, Clive (Max) Maxfield, reviewed the *Amateur Scientist* CD-ROM for us. This was not a product that we were previously aware of but Max, being based in the USA and a regular reader of *Scientific American*, introduced us to the resource which contains every *Amateur Scientist* column ever published in the magazine – that's over 1,100 articles and projects. We were impressed by the CD-ROM, as was Max, but what took us totally by surprise was the impression it made on you, our readers.

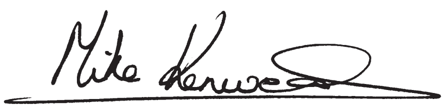
The CD-ROMs come from the USA and therefore each order takes a week or so to arrive. We ordered enough to get us off the ground and last a few weeks – or so we thought – but within the first two days of the magazine "hitting the streets" we had sold out. During the first two weeks of the magazine being published we had to re-order four times. So if your order was a little delayed in arriving we apologise, but it was simply down to the amazing popularity of the CD-ROM.

Needless to say, we now have a regular stock of the item which, we guess, will go on selling steadily. It does show that you, our readers, are interested in the wider aspects of science and not just pure electronics. Having thought about it, we should have realised that this would go well as there has always been a strong interest in what might be termed peripheral electronics projects – things like John's Seismograph, the Virus Zappers, Mood Changers, Earth Resistivity Loggers, Pipe Descalers etc., that we have published over the years. The unusual has often proved to be the most popular.

If the *Amateur Scientist* CD-ROM is of interest – maybe you missed Max's review (shame on you – why not take out a subscription to make sure you don't miss anything else?) – then you will find it advertised in our *Direct Book Service* pages.

## SUBS

Whilst on the subject of subscriptions, let me point out that with a sub. you presently get 12 issues for the price of 10, or 24 issues for the price of about 18½. You also avoid any cover price rises for the extent of your subscription and you get your copy posted to you before it appears on the bookstalls. With more and more pressure on newsstand shelf space a subscription may prove to be essential if you are not near to a large town with a large newsagent.





### READERS' TECHNICAL ENQUIRIES

**E-mail:** techdept@epemag.wimborne.co.uk
We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years old. Letters requiring a personal reply *must* be accompanied by a **stamped self-addressed envelope or a self-addressed envelope and international reply coupons.**

### PROJECTS AND CIRCUITS

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.
A number of projects and circuits published in *EPE* employ voltages than can be lethal. **You should not build, test, modify or renovate any item of mains powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.**

### COMPONENT SUPPLIES

**We do not supply electronic components or kits** for building the projects featured, these can be supplied by advertisers (see *Shoptalk*).
**We advise readers to check that all parts are still available before commencing any project in a back-dated issue.**

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# LOW-FREQUENCY WIEN OSCILLATOR

EDWIN CHICKEN

*A simple low-cost sinusoidal signal generator to add to your workshop*

THIS article describes a very useful low-frequency signal generator that is simple to make at low cost. Standard-sized components are used to provide a functional and reproducible piece of electronic test equipment.

Powered by a 9V battery at 10mA, it produces a sinusoidal signal of reasonably constant amplitude at about 2V peak-to-peak over a frequency range of approximately 10Hz to 140kHz.

## WIEN BRIDGE OSCILLATION

In the early days of telegraphy by wires, Wheatstone produced a d.c. bridge-circuit for the measurement of electrical resistance. By adding two capacitors to Wheatstone's bridge, Wien converted it to an a.c. bridge capable of measuring capacitance, inductance, and frequency. Wien's dual resistor/capacitor (RC) circuit as shown in Fig.1 was later adopted as the feedback circuit by which to convert an amplifier into an oscillator.

Two factors are of importance to produce oscillation. First, the amplifier's a.c. output/feedback voltage must be in phase with that appearing at its input terminal, i.e. zero phase-shift between input and output. This can be achieved by using the Wien circuit as the feedback element, because phase-shift is zero at a particular frequency determined by the values of the RC components. Second, the amplifier's voltage-gain must be equal to or greater than unity.

Unfortunately, at its frequency of zero phase-shift, the Wien circuit acts as an attenuator such that its output voltage falls to one third of the input voltage. This means that the amplifier needs to have a voltage gain of at least ×3 to overcome that feedback attenuation before it can be persuaded to oscillate. That is where the versatility of an op.amp can be harnessed, with its inverting and non-inverting input terminals.

The op.amp's ×3 gain can be very easily set by two resistors connecting to its inverting input terminal, so leaving its non-inverting input terminal free to be used with the Wien feedback circuit to make the op.amp act as an oscillator. Fig.2 illustrates such a basic arrangement.

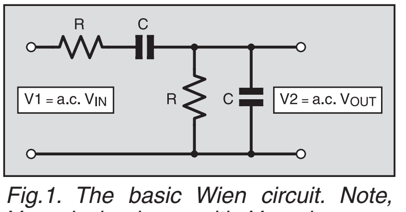



*Fig.1. The basic Wien circuit. Note, $V_{OUT}$ is in-phase with $V_{IN}$ when a.c. frequency $f=1/2\pi RC$.*

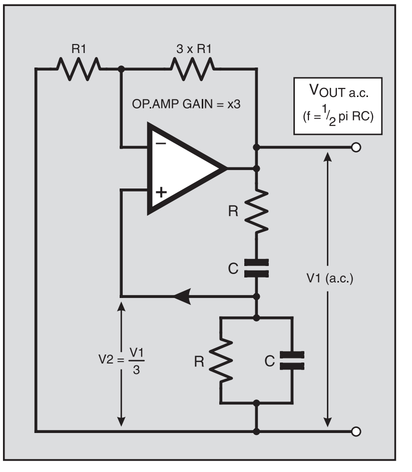



*Fig.2. The Wien circuit as the feedback element in an oscillator*

## OSCILLATION FREQUENCY

Which leads us to frequency of oscillation? Well, as mentioned earlier, the condition of zero phase-shift required for oscillation occurs with the Wien circuit at one particular frequency. If the two resistors are made to be of equal value R, and likewise the two capacitors of equal value C, the frequency of oscillation is then given by the simple formula:

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

where:

$f$ is in hertz; R is in ohms
C is in farads

Clearly, changing the value of either R or C will change the frequency. But remember, that means changing two resistors or two capacitors by the same amount.


## CIRCUIT DESCRIPTION

The finalised Low-Frequency Wien-Oscillator circuit is shown in Fig.3. It uses op.amp IC1a with its output at pin 1 connecting back to its non-inverting input at pin 3 via a Wien RC circuit with switchable ranges, see Table. Quite independent of the Wien feedback circuit, the amplifier gain is set by resistors R5 and R6 at its inverting terminal, pin 2, to a level that overcomes the attenuation of the Wien circuit.

The output frequency can be altered by simultaneously varying either the two capacitors C or the two resistors R of the Wien feedback circuit (see Fig.2). In either case it is imperative that the relative values of the twin components are maintained equal throughout the frequency-adjustment procedure.

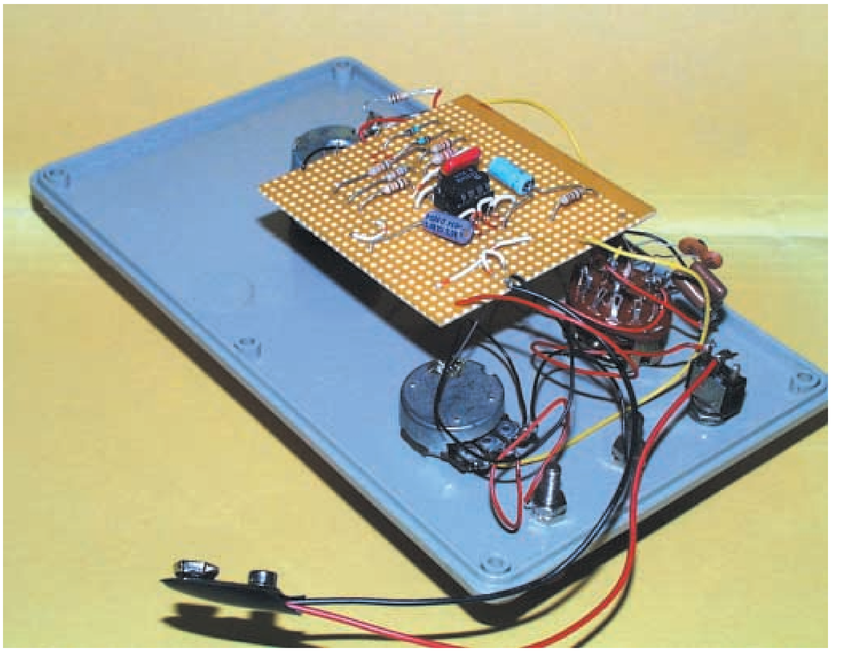
## DUAL CONTROL

This could be achieved by using a twin-ganged variable capacitor, but in practice the picofarads capacitance swing of readily available twin-capacitors would not produce an acceptable frequency span, and their prices are formidable. So for both economic and practical reasons, it is better to use a dual-potentiometer of high ohmic value and preferably of linear law.

However, in order to produce the wide frequency span given by this oscillator, it is necessary to use four switched equal-value capacitor-pairs in conjunction with the variable dual-potentiometer, as shown in Table 1.

Potentiometer VR1 is a dual-ganged 100kΩ linear control with each section wired as a variable resistor, and this can be used in conjunction with a calibrated dial to select the frequency. The dual-gang ensures that the two resistance values remain equal as the control knob is rotated. In series with each of the variable resistors is a fixed 10kΩ resistor, R3 and R4, to set a sensible limit to the upper frequency of each range by preventing the variable-resistance from falling to zero.

If left unchecked, the peak-to-peak swing of the oscillatory voltage at IC1a's output pin 1 could become clipped at its peaks. So, to ensure that the output voltage is sinusoidal in shape and remains at a sensibly constant amplitude as the frequency is varied, the gain-setting feedback circuit associated with the amplifier's inverting input is modified by the inclusion of two back-to-back silicon diodes, D1 and D2, plus series resistor R7.



*Circuit board and components mounted on the rear of the front panel.*

These components auto-adjust the feedback as the oscillatory voltage increases, in such a way as to restrict the output amplitude to about 2V peak-to-peak without noticeable distortion of the sinewave.

The chosen op.amp type CA3240 is a

**Table 1: Frequency span using switched capacitor-pairs.**

| | | | |
|---|---|---|---|
| Ranges 1, 2, 3, 4 | VR1a + R3 = VR1b + R4 | | |
| Range 1 | C1 = C5 | to span | 10Hz to 140Hz |
| Range 2 | C2 = C6 | to span | 100Hz to 1400Hz |
| Range 3 | C3 = C7 | to span | 1·0kHz to 14·0kHz |
| Range 4 | C4 = C8 | to span | 10kHz to 140kHz |

**Frequency Ranges**

| | | | |
|---|---|---|---|
| RANGE 1 | 10Hz | to | 140Hz |
| RANGE 2 | 100Hz | to | 1400Hz |
| RANGE 3 | 1kHz | to | 14kHz |
| RANGE 4 | 10kHz | to | 140kHz |

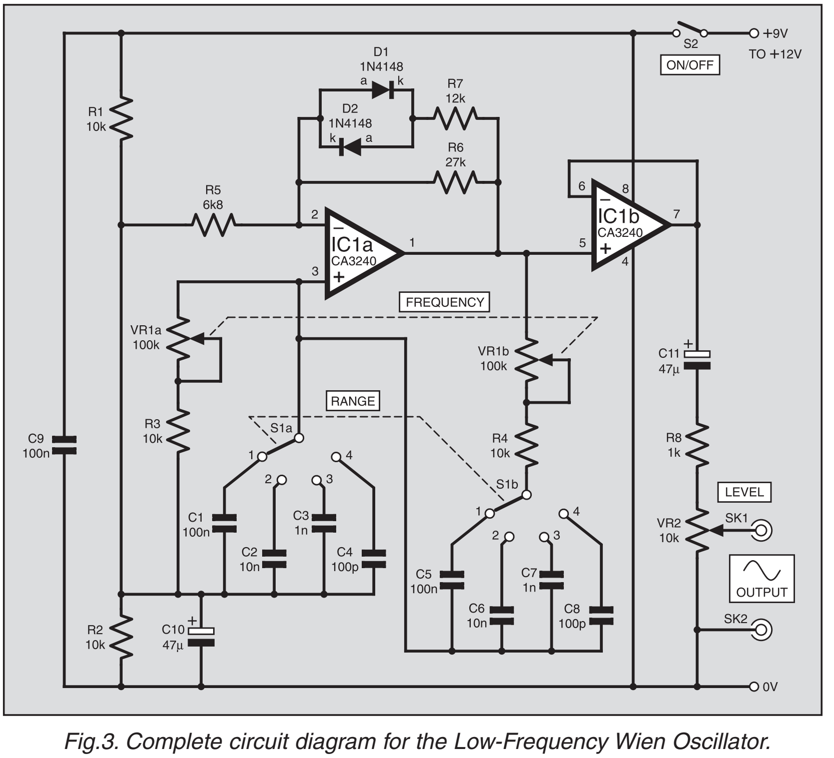



*Fig.3. Complete circuit diagram for the Low-Frequency Wien Oscillator.*

## COMPONENTS

**Resistors**
R1 to R4 10k (4 off)
R5 6k8
R6 27k
R7 12k
R8 1k
All 0·25W 5% carbon film or better.

**See SHOP TALK page**

**Potentiometers**
VR1 100k dual-gang rotary carbon, lin.
VR2 10k rotary carbon, lin.

**Capacitors**
C1, C5, C9 100n ceramic disc (3 off)
C2, C6 10n ceramic disc (2 off)
C3, C7 1n ceramic disc (2 off)
C4, C8 100p ceramic disc (2 off)
C10, C11 47µ radial elect. 16V (2 off)

**Semiconductors**
D1, D2 1N4148 signal diode
IC1 CA3240 dual f.e.t. input op.amp

**Miscellaneous**
S1 3-pole 4-way rotary switch
S2 s.p.s.t. min. toggle switch
SK1, SK2 4mm terminal post (2 off, 1 red, 1 black)

Stripboard, 26 holes x 23 strips; 8-pin d.i.l. socket; battery clip; knobs (3 off); 1mm terminal pins; plastic case to suit; connecting wire; solder, etc.

*Approx. Cost Guidance Only* **£10** *excl. case*

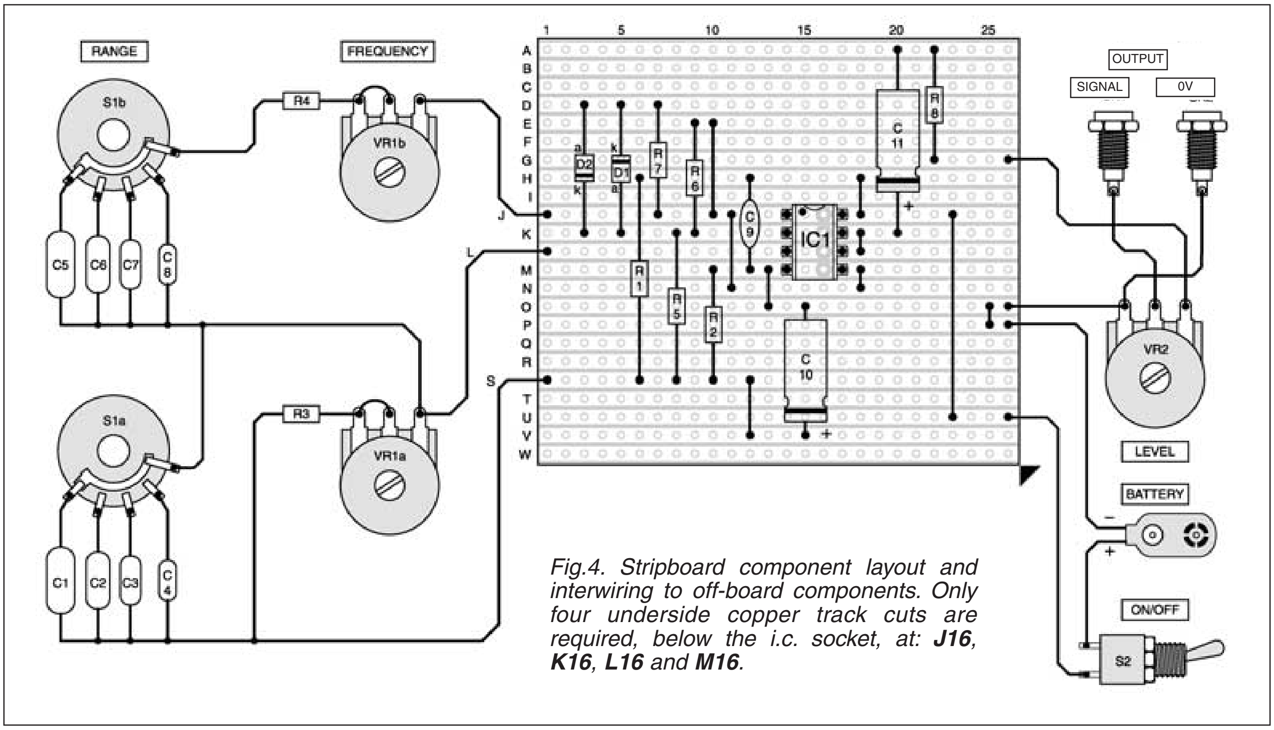



*Fig.4. Stripboard component layout and interwiring to off-board components. Only four underside copper track cuts are required, below the i.c. socket, at: **J16**, **K16**, **L16** and **M16**.*

dual f.e.t.-input device, the high impedance of which does not adversely affect the frequency-determining Wien circuit. The other op.amp of the duo, IC1b, is used as a unity-gain buffer-amplifier to isolate the Wien circuit from the external load. The oscillatory output voltage from it at pin 7 connects via capacitor C11 to potentiometer VR2 which serves as an output level control. Resistor R8 in series with VR2 safeguards the output port of the buffer amplifier against overload.

## CONSTRUCTION

The circuit is constructed on stripboard, as shown in Fig.4. The board layout has been designed for ease of construction rather than economy of material, with only four track-cuts being required behind the d.i.l. socket for IC1.

Make the track cuts first, preferably using the special tool available for the purpose. Then assemble in ascending order of size, ensuring that the components are correctly positioned and soldered.

Screening of the finished circuit is not necessary, so a plastic-box with lid is used as the container. All off-board components are mounted on the lid and connected to the stripboard via normal stranded p.v.c. hook-up wire.

Blu-Tack or similar may be used to secure the board and battery within the box.

The frequency dial shown in Fig.5 can be photocopied and glued to the lid behind VR1's fixing nut. Note that due to manufacturing tolerances of the Wien components, the frequencies of the finished oscillator may be slightly different from those shown on the sample dial.

The actual frequencies may be checked by using a frequency counter, or an oscilloscope. With the latter, measure the time-period T of the output waveform, and then use a calculator to evaluate frequency, f = 1/T

Power supply for the unit can be from a 9V PP3 battery or from a stabilised 12V source. □

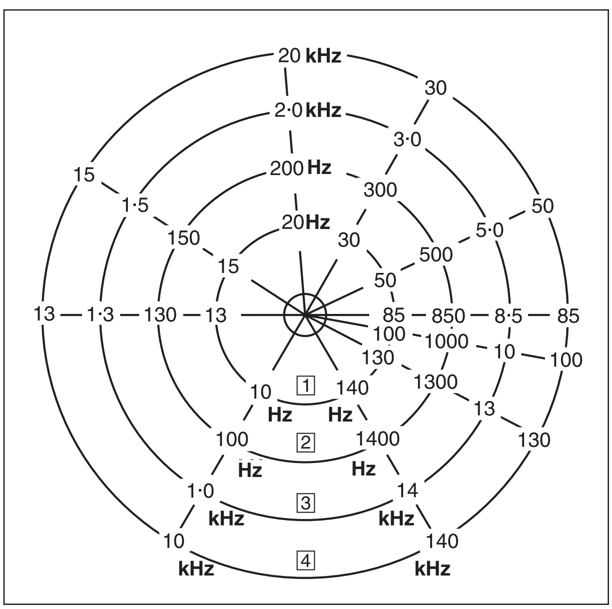
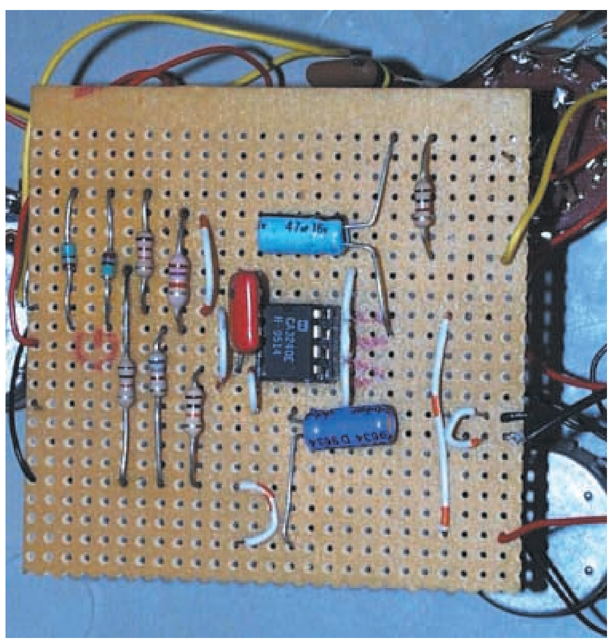



*Fig.5. The prototype front panel Frequency dial (not to scale) can be photocopied and glued behind VR1's control knob.*



*General layout of components on the circuit board.*

# News . . .

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

# MACROVISION VS MAPLIN

**Macrovision's rigid application of copyright laws defeat "video enhancer" sales including those by Maplin. Barry Fox reports.**

VENDORS beware. Macrovision is aggressively using the new European copyright laws to stop the sale of devices that strip analogue copy protection from DVDs and VHS cassettes. Anyone attacked by Macrovision will have to destroy offending items, with total loss of investment. Maplin Electronics Ltd has already had to destroy its entire stock of "video enhancers".

In a press release issued in February, David O'Reilly, Commercial Director of Maplin, said: "We acted promptly on this matter because it its important for us to provide our customers with products that do not contravene the law. We have discontinued these items following the change in the legislation, and out of respect for the law."

## Saving Face

The release had been nearly two months in preparation, while the two companies tried to agree on face-saving wording. So what went out told only a small part of the story.

Maplin, with over eighty stores across the UK and a large mail and Internet order operation, had bought in a large stock of Video Conditioners, for the Christmas market. They were advertised in the chain's Christmas catalogue, on special offer for £24.99, instead of £39.99.

The device "makes high quality copies to video tape" and is "useful for DVDs, digital TV, VHS etc" said the advert, with a note "Warning, this removes copy protection. Copyright owners' permission may be required to make copies".

Macrovision was not satisfied with the disclaimer and also rejected Maplin's defence that the Conditioners got rid of teletext or time code.

"A device can do that without getting rid of Macrovision" said Martin Brooker, Macrovision's product "policeman" in the UK.

## Al Capone Strategy

Macrovision can take direct action under Patent law, as well as Copyright law, because the company patented not just its protection systems but every imaginable defeat mechanism as well. So the company can sue companies that make or sell Video Conditioner Macro-buster boxes.

Martin Brooker calls it the Al Capone strategy. The FBI could not nail the notorious gangster for being a gangster, so got him on tax-evasion charges instead.

Within a few days of Maplin's Christmas catalogue going out, the Conditioner devices had been cleared from all stores and the mail order web site. "It's because of legal action", said store staff.

"We had to remove this item from sale. I do not know who will be allowed to sell this", says Maplin HQ's Customer Services.

Macrovision insisted that all Maplin's Conditioners be destroyed, rather than returned to the makers, to stop them getting back into the marketing chain. Other dealers and mail order companies will be told to do the same. Macrovision is already going after twenty more of what it describes as the "usual suspects".

# BIONIC LEGS

"ABOUT time . . .", recently exclaimed reader Boris on our Chat Zone (via **www.epemag.wimborne.co.uk**), quoting a web address, but saying no more. Intrigued, this news writer went into the site quoted, **http://news.bbc.co.uk/1/hi/sci/tech/3502194.stm**. Yes, how right Boris – very useful! The BBC's site had a news story stating that US researchers had developed strap-on robotic legs to allow people to carry heavy loads over long distances.

Further browsing the web revealed the story's source, the Berkeley Robotics Laboratory. As part of a US defence project, the lab has developed the Berkeley Lower Extremity Exoskeleton, or *Bleex*, for use mainly by infantry soldiers.

Bleex consists of a pair of mechanical metal braces plus a power unit and a backpack-like frame. It has over 40 sensors and hydraulic mechanisms which calculate how to distribute weight in a manner similar to that of the human nervous system. A large rucksack is carried on the back, containing an engine, control system and space for a payload.

The control system needs no direct measurements from the human or from the human-machine interface. "There is no joystick, no keyboard, no push button to drive the device," says Homayoon Kazerooni, director of the Robotics and Human Engineering Laboratory at the University of California. Somewhat surprisingly, though, the motive power is provided by an internal combustion engine (no sneaking up on the enemy under silent battery power then?). On a full tank Bleex runs for about two hours.

Laboratory test subjects have walked around in the 45kg (100lbs) exoskeleton plus a 31·5kg (70lbs) backpack and reported that it felt like they were carrying little over 2kg (5lbs). For more information, browse the BBC's above site, and **www.me.berkeley.edu/hel/bleex.htm**.

# DENIAL OF SERVICE WEB ATTACKS

**Barry Fox**

DISTRIBUTED Denial of Service attacks recently shut down the Internet site run by Unix and Linux software company SCO. The Recording Industry Association of America (RIAA) had its site shut down after bringing law suits against music downloaders. Cyber security analyst Mi2g estimates that a single wave of DDoS attacks can now cost industry $1bn.

## Cyber Bandits

Executive Chairman DK Matai thinks there is much worse to come, unless technical fixes like IBM's can be shown to work in practice: "It is getting harder for criminal syndicates to make money from drugs, moving immigrants and contraband. So they are moving into cyberspace. Syndicates have always been involved in extortion. They are now using DDoS. They wait until there is a grand slam sporting event and ask for $40 or $50 thousand not to shut down an online gambling site that day".

IBM has now filed patents on a new scheme to stop DDoS. By patenting its defence against DDoS, IBM has revealed the secret to hackers. IBM has refused to comment on why it published. Internet Service Provider Demon did not want to comment either.

"Network security is a growing concern for operators" it says in US patent 2004/39938, revealing that the hackers are now exploiting the three-way handshake used by commercial websites.

A legitimate customer sends the site a request for service and the site responds with an acknowledgement message. The customer's PC should then complete the handshake with a final acknowledgment message. Information can then be sent to and from the web site.

The hackers are sending requests for service which have a phoney or "spoof" Internet address for reply. So the site is sending acknowledgments to Internet addresses that cannot respond properly. This leaves the three-way handshake uncompleted and the victim web site swamped with half-open connections.

"The attacking system simply continues sending spoofed requests faster than the pending connections expire", says IBM.

The simple solution, just shutting down open connections quickly and automatically, will not work, says IBM. Data traffic on the Internet is routinely delayed, by line congestion, message routing and temporary storage by communicating sites, and this "latency" is impossible to predict. It varies from minute to minute. If spoof connections are shut down quickly, legitimate requests for service also get shut off. Business is lost and customers get angry.

## Secret Service

IBM's answer is two-pronged. The site continually monitors Internet latency, by checking the time of all messages coming in and out, and measuring the time taken for replies to come back. The site also continually switches its connection entry points or "ports", according to a secret pattern. The pattern is sent to the customer only after the customer has replied and thus been proved legitimate.

The ports are switched at a speed which suits the latency at any given moment - slowly if the Internet is congested, and fast if traffic is moving quickly. Only legitimate requests for service, which come from legitimate customers, can hop ports and remain connected. Any attack request for service is very quickly disconnected. Disconnections are made faster than new requests arrive.

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# GPS Protects Movies

**BARRY FOX**

Hollywood loves the idea of digital cinema, because when movies are distributed electronically by satellite or cable there will be no need to transport expensive 35mm film in cans. Encrypting the transmitted signal should stop unauthorised reception, but the protection system completely collapses if a pirate simply steals legitimate equipment.

Boeing promises tighter security (US 2003/204739) with a system that has a built-in GPS position locator. When the equipment is installed in a cinema, Hollywood indexes the location. Before a movie is sent to a cinema, the transmitter interrogates the receiver to check its current location. If there is a mismatch, because the equipment has been moved, the movie is not sent.

# POWERFUL PRIDE


LASCAR Electronics tell us that they "have broken the mould" with a new compact and aesthetically designed power supply which they say "will soon become commonplace in workshops and engineering departments everywhere".

The PSU 130 is a benchtop power supply with an adjustable output from 1·5V to 30V at up to 1A. The output voltage can be accurately adjusted to within 0·1V across its entire range. The selected voltage and current drawn are clearly displayed on a large backlit l.c.d. The unit features over-voltage, over-current and short-circuit protection, preventing accidental damage to it. The output terminals are standard 4mm sockets. It has a compact non-slip footprint of only 135mm × 140mm, and it can be angled to suit varying operating environments.

The PSU 130 is priced at £49.85 plus VAT, and discount is available for volume orders.

For more information, contact Lascar Electronics Ltd, Dept EPE, Module House, Whiteparish, Salisbury, Wilts SP5 2SJ. Tel: 01794 884567. Fax: 01794 884616. Email: lascar@netcomuk.co.uk. Web: www.lascarelectronics.com.

# Smellyphones, Smellyvision and Solitons

**Turn on the tap for dirty phone calls and mucky movies! Water companies are getting into the comms business via the sewers. Andy Emmerson explains.**

FIRST came Roald Dahl's *Revolting Rhymes*, then books such as *Disgusting Digestion* and other titles in the *Horrible Science* series. Although the success of these books for children does not seem to be matched by similar titles for adults, it's pretty clear that children and parents alike enjoy having their stomachs turned these days.

This month I shall jump on the same bandwagon, so I hope you don't start reading this article while you're having a meal. The subject is what goes on in sewers, although it's really pretty clean stuff.

The bottom line is that competing telecomms carriers, anxious to extend service into the heart of densely developed metropolitan areas without the cost, delay and disturbance of digging up the roads to lay their cables, are tapping existing channels below our feet – the sewers. It's a clever move but not without risk, nor is it as simple as some might think. So we had better delve a bit deeper to see what's happening and why.

## SEWER SUPERHIGHWAY

The fundamental notion is simple: there are sewers running along every street and drains feeding into those sewers from every home, office and factory. Optical fibres are thin and flexible, and have almost limitless bandwidth. On that basis it ought to be easy to install a brand-new communications superhighway reaching every potential subscriber, supplying telephones, radio and television programmes, the Internet and all manner of other broadband services.

That's what BerliKomm has done in the German capital, Berlin. Established to exploit the communications assets of the company responsible for water supply in Berlin, it operates an optical fibre network 1,500km long with three fibre rings to create a broadband network of vast capacity. Its strategy of offering free calls on its own network scored instant recognition with Berliners, but equally noteworthy is the way it has laid the bulk of its new network in water mains and sewers.

Special technology was used to make these pipes and channels suitable for carrying its comms cabling, with robot machines installing the cable at speeds as high as 200 metres a day. Whilst sewers may not be everyone's first choice of working environment, no-one can deny the network now provides BerliKomm an ideal and exclusive means of reaching every home and business in Berlin.

## DOWN THE PAN

Successful as this has been in Berlin, the same cannot be said for a similar scheme in Britain's capital that went straight down the toilet. Starting in October 2001, Lattice, a utility company that was once part of British Gas, invested £400m in a company called 186k to create a brand-new optical fibre network, part of which was a joint venture with Thames Water, offering broadband access through London's sewage network. The name of this venture was Urband but if the name doesn't ring a bell, it's not surprising since the scheme was written off, along with £250m of the investment, seven months later.

Despite this spectacular failure, another water utility (Scottish Water) aims to confound its critics by launching a similar operation in Edinburgh, Glasgow, Dundee, Perth and Inverness. Its partner in this operation is Scottish optical fibre company Fibrelink, which has already invested a rather modest £200,000 in the initiative.

A pilot scheme has begun at Rosyth, Fife and uses Fibrelink's sewer cable system, developed in partnership with Swiss fibre company Brugg. Fibrelink claims its cables will cost far less to lay than previous attempts, which relied on new ducts laid in the sewers. The new venture uses loosely laid cables, slung from hooks.

## MERCURY'S MAINS

Ingenious as the idea of using sewers is, novel it is not. The pioneer was Mercury Communications Ltd, a Cable & Wireless subsidiary that held the distinction of being the first telecomms carrier to be licensed to compete with British Telecom. Just before the new company came into being, another much older one came to an end. This was the London Hydraulic Power Company, which since 1871 had supplied high-pressure water over a wide area of London to operate lifts, cranes, presses and similar equipment.

Central pumping plants supplied this hydraulic power through a vast network of mains. At its peak, just before the outbreak of war in 1939, the company was pumping more than 1·6 billion gallons of water annually at 700lb per square inch, supplying more than 8,000 machines. Wartime bomb damage, the greater flexibility of electric motors and the departure of many manufacturing firms from central London, led to a decline in the company's activities post-war and pumping ceased in 1977.

Control of the company was acquired in 1981 by a group led by Rothschilds, which recognised the importance of the pipe network for the coming generation of communications systems. The network of 150 miles of pipes, ducts and conduits was sold for £1·2 million in 1985 to Mercury Communications Ltd, now owned by Cable & Wireless Ltd, and since that time many miles of optical fibre cable have been laid in this network.

Amusingly the system was offered first to British Telecom, which rejected the network on account of the high cost of converting the pipes to carry communications, and the fact that its networks already reached into every building. It was only realised after the event that a better move might have been to buy the system just to prevent it falling into the hands of its new competitor!

## SOLITON SOLUTION

There's an even older connection between waterways and optical comms, going back a remarkable 170 years. A wave phenomenon discovered at that time solved a problem for modern optical fibre transmissions. The solitary wave or *soliton* effect was discovered by John Scott Russell in 1834 in the Union Canal just outside Edinburgh.

Out for some fresh air on horseback, he noticed a barge being drawn fairly rapidly along the waterway by a pair of horses. When the boat eventually stopped, the bow wave continued to advance "at great velocity, assuming the form of a large solitary elevation, a well-defined heap of water which continued its course along the channel apparently without change of form or diminution of speed".

What he had observed was a most unusual wave that did not break up, spread out or lose strength over distance, qualities that would later be ideal for fibre-optic communications networks carrying information at a rate of millions of solitons per second.

Of optical fibres Russell had no inkling, but convinced that he had fallen on something noteworthy, the young scientist followed the wave on horseback as it rolled on at about eight or nine miles an hour, but lost sight of it after a chase of a couple of miles. Afterwards he built an experimental tank in his garden to continue his studies of what he dubbed the Wave of Translation, but failed to enthuse others of its merit.

The concept seemed destined to remain a scientific curiosity until the 1960s when studies into non-linear wave propagation revealed that many phenomena in physics, electronics and biology could be described by the mathematical and physical theory of the soliton. In the 1980s the technique was applied to optical communication and it's delightfully apt that a main optical fibre from Edinburgh to Glasgow runs beneath the self-same towpath that Russell used back in 1834.

# COPING WITH LEAD-FREE SOLDER

BILL MOONEY

*What are the alternatives to using lead-based solder when it is banned internationally in 2006?*

LEAD will soon be phased out of electronics, but there is no "drop-in" replacement for our trusty old 60/40 rosin-cored solder. Worse still, the new lead-free technology is not fully compatible with traditional lead based components.

Lead (Pb) will be banned internationally in most electronics products from 2006. The pace of the transfer to a lead-free electronics industry has quickened and several manufacturers have already converted to lead-free production.

This action comes under the Restriction of Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) EU directives and has already impacted on service engineers and some professional electronic workshops. But electronics hobbyists and many smaller workshops are largely unaware of the change and its consequences.

## NOT SO SIMPLE

Unfortunately, the changeover will require more than simply reaching for the new Pb-free solder and dumping the old stuff. The legislation is far reaching and even threatens the use of colophony (rosin) – our favourite flux. Just in case that is not a big enough challenge there are also requirements for a low VOC (Volatile Organic Compounds) content and, of course, halide-free emissions.

The very components we buy and the printed circuit boards we use could soon be lead-free finished. The soldering characteristics will be different and will vary as no single finish yet dominates the market. Tin/silver (Sn/Ag) and tin/silver/copper (Sn/Ag/Cu), also gold/nickel (Au/Ni) bi-layer and Bismuth (Bi) alloys are examples, but development continues.

Other finishes such as 100% tin with its tin whisker-growth problems are also possible.


Rosin-cored TSC solder.

We might have expected good compatibility between lead-free solder and the lead-based finish on present components. But to add to our problems, even slight amounts of lead contamination have deleterious effects on lead-free technology. This finding is so important that separating the technologies is a priority for manufacturers. Rather than implement a gradual change, they must plan an expensive switchover to lead-free.

If you attempt to work on a cellphone, minidisk, PC etc. there is an increasing chance of it being lead-free. Repairing this with your trusty old 60/40 solder wire will definitely produce a less than perfect result.

We can learn to live with the best lead-free alloy available at this time namely tin/silver/copper (TSC); see later.

Other solders such as tin/zinc, tin/copper, bismuth containing alloys like tin/silver/bismuth and low melting aluminium formulations will further confuse the situation. Let alone the possibility of conductive adhesives, which are under development. Considering that soldered joints are the most common cause of circuit malfunction and that the best lead-free TSC solder is "not optimal"; we could be set for interesting times.

Table 1 shows the current solder choices for general electronic work.

## ALLOY OPTIONS

The move to lead-free electronics has turned out to be very difficult. From a huge range of possibilities, over 200 alloys have reached the serious testing stage over the last 10 years. No trouble-free "drop-in" alternative to rosin-cored 60/40 tin/lead formulation has so far been produced.

As for the silver-loaded low melting point solder (LMP) favoured for surface mount (SM) production and hand soldering surface mount devices (SMDs) there is no alternative and we must learn to work with TSC. For commercial SM production the higher temperature can mean working under nitrogen gas to reduce oxidation.

**Table 1. Current solder choices for general electronic work**

| *Alloy* | *Melting point* | *Typical product* | *Comment* |
|---|---|---|---|
| 60/40 Sn/**Pb** | 188°C | Ersin Multicore 0.8mm | Traditional, widely used rosin-cored solder wire |
| 62/36/2 Sn/**Pb**/Ag | 179°C | Multicore Smart 0.5mm | Low Melting point (LMP) solder for SM work |
| 95·5/3·8/0·7 Sn/Ag/Cu | 217°C-220°C | Multicore Ecosol TSC 0·7mm wire (RS Components) | Target replacement for 60/40, mildly active rosin-free flux |
| 95·5/4/0·5 Sn/Ag/Cu | 217°C-220°C | Shenmao TSC 1mm wire TSC (Maplin) | Target replacement for 60/40 rosin mildly active flux |
| 96·5/3·5 Sn/Ag | 221°C | Multicore MX200 1.2mm wire (Maplin) | Active core, tough solder for mechanical work inc. jewellery, aluminium, stainless. |

The metallurgy of solder formulation is complex, involving dedicated laboratories for its development. For practical purposes its melting behaviour is fundamental.

Pure metals melt at a specific temperature, for example lead melts at 327°C and tin melts at 232°C. An alloy is a mixture of metals and its melting point is lower than the melting point of its components.

Eutectic alloys have specific proportions of each metal component and exhibit a sharp melting point. For example, the 63%/37% tin/lead eutectic melts at exactly 183°C. The more common 60/40 solder is slightly off the eutectic ratio and melts over a small temperature range in which it is "pasty", this improves the working properties. The pasty range, therefore, exists between an upper temperature referred to by metallurgists as the "Liquidus" (above which the alloy is fully liquid) and a lower "Solidus" temperature (below which the alloy is completely solid). The paste is a complex mixture of liquid eutectic and solid metal or metal compound crystals and is the stuff of metallurgy. Metallurgists use phase diagrams to describe these mixtures.

The choice of metal is determined by many factors, including cost, toxicity, chemical reactivity, melting point and its behaviour in alloys. In particular, a metal is required to melt at a temperature around 200°C and to have good affinity for other metals found on electronic components. The choice in order of diminishing toxicity is restricted to:

Lead (Pb) > silver (Ag) > antimony (Sb) > copper (Cu) > tin (Sn) > indium (In) > zinc (Zn) > bismuth (Bi)

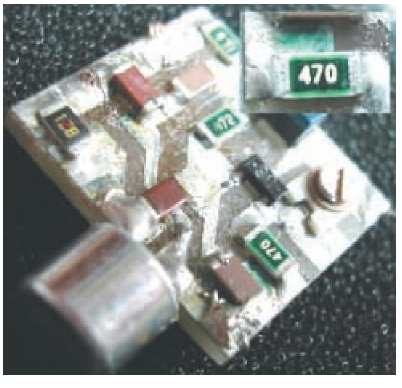


*Fig.1. Use of SA (tin/silver) solder wire for a surface mount project.*

Some of the best alloys found so far contain silver which can be a concern in landfills. Silver increases the surface tension of the solder, degrading its wetting properties. But it lowers the melting point and improves conductivity. Safer metals have inferior soldering behaviour or are expensive. Silver is about 200 times the cost of lead but small amounts are effective. Tin is 10 times more expensive than lead but the reduced life cycle processing costs (refining and disposal etc.) result in a similar solder price to the user.

## GIVE IT SOME TSC

Tin/silver (SA) alloy wires have been around for some time but they have a higher melting point starting at 221°C and tend to have a reactive flux core. These have adequate wetting properties and are easy to use, even on aluminium and stainless steel with suitable flux. But the higher temperature required can make the soldering action sluggish and circuits must be solvent cleaned after use.

A typical SA product is Multicore MX200 18s.w.g. wire with a mildly active flux. This is a very useful product to have around for mechanical work, jewellery and even some heavy electronic contact work, but is not the best choice for light circuit work.

Workable ternary (three metals) alloys have resulted from a frenzy of research. For our purposes a tin/silver/copper alloy seems to be the closest we will get to a 60/40 replacement. This is often referred to as TSC or SAC (Sn/Ag/Cu). These are very near eutectic compositions such as 95·91% tin/3·42% silver/0·67% copper. Slight variants abound such as 95·5/3·8/0·7 (Sn/Ag/Cu).

All have initial melting temperatures in the range 217°C to 220°C and have slightly inferior wetting power compared to most lead-based solders. Typically, a 1mm TSC solder wire will contain about 3% of a synthetic non-corrosive flux core, but rosin-based variants are available at this time. The tin-based alloys are less lustrous than 60/40 solders and have a slight yellow/gold cast. They are also mechanically stronger than the lead based technology.

A big problem with the new alloys is their high melting temperatures. An increased melting point from about 188°C for 60/40 to about 220°C for the TSC may not seem too important, but above 230°C we are reaching the thermal limit for many support materials.

Breakdown of adhesives, de-lamination of copper tracks, cracking of component packages, breakdown of solder-masks and oxidation rates, all accelerate rapidly. For production this means even narrower process windows. But all of these effects impact on hand soldering, making the process that bit more problematic.

## MAKING THE CHANGE

The author's first venture into lead-free consisted of populating a small surface mount circuit on a pre-tinned printed circuit board. This was a worse case test with the MX200 SA solder wire. LMP solder wire would normally be used for SMDs with a melting point some 42°C lower!

The higher melting temperature of the SA solder was immediately obvious. It took longer to achieve good solder flow and full wetting of the surfaces. Similarly, the joint cooled very fast. The tin/silver alloy was dull and lacked the brighter reflective finish of the traditional 60/40 solder. This appearance was in part due to lead contamination from the tinned p.c.b., see Fig.1.

This high temperature stress was positively cruel to the little SMDs. It is likely that over several tests, or if the circuit was subjected to temperature cycling, defects would appear. But for test purposes it was possible to produce an adequate working circuit with a lead-free solder.

The MX200 solder contains an active flux and after a few days, green salts (Fig.1) appeared in places. Experience has shown that this flux can lodge permanently inside components such as trim pots even after cleaning, leading to noisy unreliable circuits. With serious lead contamination, corrosive flux and high melting point solder stressing the chip components, this approach is not seriously recommended. The point is, **don't just grab the first lead-free product you see**.

## BEST OPTION

The target 60/40 replacement is the TSC solder wire with a synthetic or rosin flux core. For the second test, the author selected a 95·5/3·8/0·7 TSC wire with rosin-free synthetic flux core. It was compared directly with 60/40 on clean new stripboard.

A 12W Antex iron was used with a standard iron coated bit. The bit was well tinned with tip cleaner and sponge before making the test. The tip cleaner was lead-based because there is currently no lead-free tip cleaner available.

The high melting point again resulted in just noticeably longer times to achieve solder flow. Unfortunately, the flux evaporated rapidly and wetting ceased before the solder flow was complete. Also, the underlying wetting characteristics of this alloy are inferior to the old 60/40. Given these negatives it could be expected that the results were not as good as we are used to, see Fig.2.

The TSC is generally inferior to the 60/40 reference standard. In all cases the joints have a "dirty" appearance with traces of slag-like deposits. Lead contamination from the tip cleaner was in part responsible for this behaviour. The poor wetting resulted in uneven edges of the solder mass. If we had no alternative, a circuit made in this way would work well enough, after reworking the odd "dry joint". But there is plenty of room for improvement.


*Fig.2. Comparing TSC lead-free solder to standard 60/40.*

## LEARNING TO USE TSC

To achieve good results with TSC, the same good practice must be followed as for traditional solder. Particular issues to consider when using TSC can be summarised as follows:

1. Type and level of flux
2. Lead contamination
3. Iron power rating
4. Existing solder (for rework)
5. Component finish

The tests described above used 0·7mm TSC wire with a synthetic flux core, the preferred material from an ecological standpoint. But loss of flux and poor flux performance are responsible for the barely acceptable result. Stepping back in technology to a rosin-cored 1mm TSC wire (Shenmao) produced an excellent joint as shown in Fig.3.

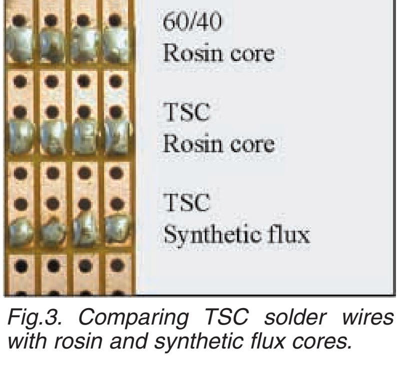


*Fig.3. Comparing TSC solder wires with rosin and synthetic flux cores.*

This clearly shows the power of rosin as a flux. For all practical purposes, this is as good as the rosin-cored 60/40. Although a close look at the 60/40 solder blobs reveals that they are slightly flatter due to better wetting of the copper by the lead-based alloy. The synthetic flux cored TSC test is repeated for comparison and again shows poor spreading.


## FLUX PENS

A flux pen is an essential tool even when working with lead-based materials, but is probably indispensable in the lead-free world and certainly during the transitional period. In any case, the lead free solders have inherently poor wetting properties and need the support of a good flux. The rosin based pens give excellent wetting and do not necessarily require cleaning, as rosin is a very adequate finish.

The newer no-clean pens also work very well for enhancing the thinner TSC solder wires which have a low flux content. Thinner solder wires are preferable for modern leaded components to make perfect joints with ideal amounts of solder. For surface mount chips, thinner wire ensures the minimum solder loading. Intolerance to rosin fumes may dictate the use of a synthetic formulation, although a fume extractor is still advised.

Two flux pens from Circuit Works were used by the author to test the effect on the performance of a 0·7mm synthetic-flux cored TSC wire, as shown in Fig.4.

Both products produced good wetting and clean solder pads from this low flux solder wire. Care is required when selecting flux pens as some are very corrosive. Fig.4 also shows the effect of a flux pen with a very corrosive water soluble flux a few hours after soldering.

These reactive materials give good rapid wetting but should be avoided for small component work. If in doubt, do a small test as above, looking for green copper salts on a permanently wet surface.

## LEAD CONTAMINATION

Looking closer at even the best TSC result reveals another problem. Low levels of lead contamination interact with tin compounds to produce an uneven surface on the solder as it drops below the melting point. The tin compounds present in the lead-free solder are not soluble in the lead.

Lead-rich zones follow the hottest areas as the solder cools and therefore end up at the point where the iron tip was removed from the solder blob. This "phase" separation of solder produces a poor surface appearance, as shown in Fig.5.

Unfortunately this is not just skin deep. If strength tests were done on a number of lead-contaminated soldered joints the results would be disturbing. Contaminated joints are generally weaker and there is a wider spread in strength results, due to random zones of lead and tin compounds. Typical laboratory reports show that as little as 1% lead contamination can reduce joint strength by 75%.

0603, 0402 scale. Even the commercials can't cope with the new 0204 full stop sized chips.

## DILUTED EFFECT

At this time, most lead probably comes from the component and p.c.b. finishes and from tip cleaners. Unfortunately, we will have to live with the lead-based component finish for some time.

Making a joint with TSC, then using a solderwick to strip the contaminated solder can reduce the lead level. The joint can then be remade with fresh TSC. This may be worthwhile in critical cases where reliability must be assured.

For the purist, lead contamination from printed circuit board coatings can also be diluted by repeatedly adding TSC solder wire and removing it with solderwick. This is more important with p.c.b.s which have not been air knifed and have small solder blobs at the pad corners. But for most projects this would only be recommended where a joint is to be mechanically or thermally stressed. A soldered switch anchor/contact or power device would need careful inspection.

The effect of a dilution in lead contamination is shown in Fig.6. A joint was repeatedly remade with TSC after a deliberate lead addition from some 60/40. The first blob on the left is dull and highly crystalline. The iron carries lead over to subsequent joints. But after four additions of TSC the surface becomes progressively brighter and stronger. Although a small grey spot persists, as total removal of lead is difficult and the TSC ternary will separate slightly under harsh conditions.

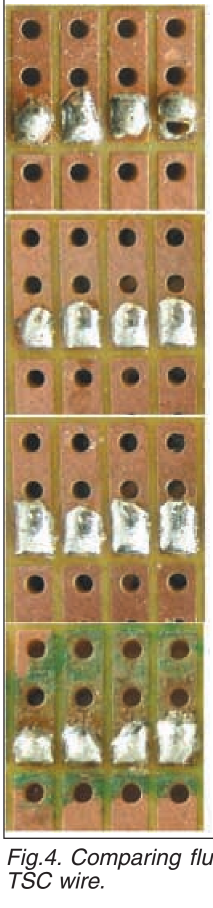


*Fig.4. Comparing flux pens on 0·7mm TSC wire.*

*Fig.5. Lead contamination seen as a mottled surface.*

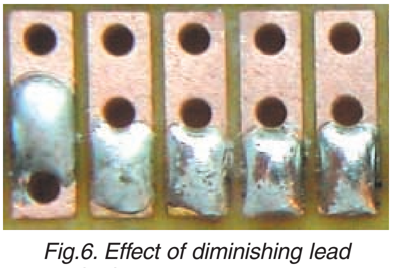

*Fig.6. Effect of diminishing lead content.*

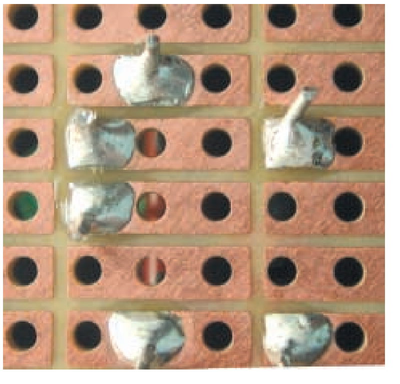

*Fig.7. A completed circuit board using rosin based TSC with leaded components.*

A slightly longer or shorter soldering time or a different temperature profile can lead to big changes in the structure of the contaminated joint. For small electronic projects, this may not be too serious, but where mechanical stress is present, particularly coupled with heat dissipation from power devices, reliability will be compromised. At the other end of the scale, the smaller joints used for surface mount devices are more likely to fall victim to contaminated spaces in the solder mass.

For 1206 and 0805 sized chips this is not so bad but a little care is suggested at the

The biggest present use of TSC solder will be for normal leaded components with their present lead-based finish. From the tests described above, the simplest approach is to use a rosin based TSC. To evaluate this, several new and clean leaded resistors and capacitors were selected. The result was some very adequate solder joints, as shown in Fig.7.

Close inspection shows some impurity and duller surfaces than we would expect from 60/40. On this scale the contaminated area is not a major portion of the joint and the circuit function should be satisfactory for signal level use. Of course, the component leads are still surrounded by a lead rich zone and experience will show how it would cope with heavy current.

## TIP CLEANING

It is difficult to avoid frequent use of tip cleaners with lead-free solder for getting an iron tip back to working condition. The extended time at higher temperatures, coupled with more chemically reactive environment, can lead to rapid coating of the iron tip with a tough varnish-like organic film. This film can only be removed by the somewhat aggressive use of a tip cleaner like the familiar Multicore TTC product in a 15g tin.

The tip is then wiped clean with slightly moist rather than wet sponge, because water attacks the iron (Fe) coating. Any weakness in the iron coat will lead to ingress of tin-rich solder, which rapidly dissolves the copper core of the bit.

Once the tip is well cleaned and tinned, some TSC solder wire can be added and wiped off a couple of times to dilute the lead contamination from the tip cleaner. More aggressive, last resort, tip cleaners are based on copper or iron wool in a small container, or a home-made version using kitchen stainless steel scouring pad in a small bottle. Pushing the iron tip into this will readily defeat the tarnish and any debris falls to the bottom of the container.

## IRON TEMPERATURE

By far the most popular soldering irons are unregulated. The heater, usually 12W or 25W, slowly feeds its energy into the copper mass of the bit, taking some 90 seconds to reach working temperature. When the tip is applied to the surface to be soldered, heat is dumped from the bit, aided by the excellent thermal conductivity of its copper core. The temperature of the work-piece and the solder rapidly rises to the solder melting point. At this point the human feedback system operates.

The flux rapidly flows across all surfaces, sweeping away surface dross and oxide layers. The solder flows, enveloped in a protective liquid flux coating, wetting all surfaces. The eye detects when this process is complete and the iron is removed. Although the tip is at about 350°C, the solder and the metals being joined only reach probably 220°C. Soldered joints must be made quickly, say under three seconds.

If the system stops working, due to poor wetting for example, the operator continues to apply heat and damage can occur, like de-lamination of tracks, overheating of components and so on. Another response is to add excessive solder to get more flux into the system. With higher melting TSC solder the heat capacity of the bit can be drained before the melting point is reached and the operator now relies on the slower rate of heat generated in the heater to pump up the temperature.

This extended time means that the heat has travelled further along the tracks and component leads. The flux will be decomposing and evaporating at this high temperature. Experience with TSC so far suggests that for small clean joints the same iron will suffice, but the extra pumping time needed to get 30°C higher is noticeable. For bigger joints and a snappier job a higher power iron may be considered, depending on what scale you are working.

Simpler temperature controlled irons can suffer from a time delay of several seconds between the demand signal for more heat and its delivery. This can still make soldering sluggish with the higher melting lead-free solder. More sophisticated control systems (e.g. JBC advanced stations) have a rapid recovery time of less than a second and are a pleasure to use.

## REWORK

Dealing with the existing solder on a circuit under repair is likely to be problematic. There is no method available for easily determining the composition of solder used, although lead test papers similar to those used for paint testing may work. At this time the most obvious solution is to attempt the rework with TSC and plenty of flux. Professional repair workshops have reasonable access to product information. The surface mount industry is particularly advanced in rework technology with a wide range of advanced rework and inspection equipment available.

## GO GREEN NOW

The changeover to lead-free is likely to take some time and we must get used to dealing with increasingly mixed technologies. Although our component stock, and indeed most devices purchased at present, are likely to be aimed at a lead-based industry, we can switch to lead-free solder now.

With a little care, good results are possible with lead-free TSC solder. We can continue circuit construction by using flux pens, good tip cleaning, and sensibly dealing with lead contamination. But like every other aspect of electronics, the art of soldering will get more complex and cannot be taken for granted. □

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For information on conventional soldering techniques, read Alan Winstanley's well-acclaimed article on the subject, *Basic Soldering Guide*. This is available for free download via **www.epemag.wimborne.co.uk**, taking the Resources click-link from our home page.

Constructional Project

# IN-CAR LAPTOP PSU


## TERRY de VAUX-BALBIRNIE


*Laptop operation for the outwardly mobile*

MANY laptop (notebook) computers require a power supply having an output of between 14V and 23V. This makes it difficult to operate them from a car battery or other 12V source. One method would be to use a mains inverter (to give 230V a.c. from the 12V d.c. input) then connect this to the mains power adaptor supplied with the computer.

However, not everyone has an inverter and if this were to be its only use, buying one would be hardly worthwhile. Also, it would be a clumsy, bulky method and the efficiency of the arrangement would be low due to the losses at each stage.

### ELEGANCE

The more elegant solution described here involves the use of a "boost switching regulator". This provides the necessary increase in d.c. voltage and stabilises the output so that it remains substantially constant despite changes in load and/or input voltage. The finished device is fairly efficient operating at between 83 per cent (at maximum power output) and 90 per cent (under a light load).

### CURRENT SITUATION

The current drawn by a laptop computer comprises two parts. The first operates the actual electronic circuits. Its value will depend on the particular laptop used, its operating voltage and, to some extent, the application in hand. Most of the time, it is likely to be in the region of 1A.

The second element is the current used to charge the battery and its value will depend on the state of charge. When fully charged, the current will fall to a low value. When the battery is "flat" it will be at its highest – perhaps 2A. It can be seen that the total current requirement of a laptop may be 3A or more with a "flat" battery.

A graph of maximum current available from this Power Supply Unit (PSU) against voltage output is shown in Fig.1. This is based on measurements made on the prototype unit using a 12V input. It will be seen that, for example, some 2A is available at 24V, 2·5A at 20V and 3A at 15V.

If the input voltage fell below 12V, the maximum current would fall. In practice, a well-charged car battery will maintain 12V minimum so this is a reasonable assumption. The maximum output power (current multiplied by voltage) is 45 to 50 watts approximately.

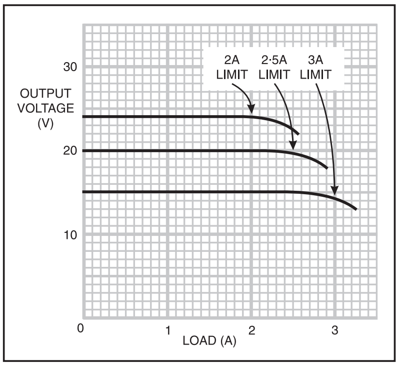



*Fig.1. Graph showing maximum current against voltage output.*

### TRICKY QUESTION

So how can this power supply successfully operate a laptop computer if it may be incapable of delivering sufficient current under all conditions?

The trick is to use it *either* to charge the battery (with the laptop switched off) *or* to power it (with the battery fully charged) – not both at the same time. This will usually be found convenient.

In use, the laptop's battery will then "top up" any temporary high current needs. In fact, it may be found that the power supply will charge the battery when it is only partially discharged and operate the computer at the same time.


The user will soon find out what is possible using his or her particular machine.

### INITIAL CHECKS

Before building this unit, it is important to make some checks using your own laptop. This will confirm that the circuit is likely to be suitable. ***However, due to the limited number of laptops checked with this circuit, no guarantee can be given that it will work correctly in every case.***

Look at the label on the computer's existing mains adaptor to determine the operating voltage. The power supply unit described here is suitable only for computers requiring between 14V and 23V.

Note that the input voltage is not the same as the battery voltage. The author's HP Omnibook needs a 19V input as did a Dell Insipiron tested. These both used a 14·4V nominal battery pack. A Toshiba Satellite needed a 15V supply and used a 10·8V battery. The battery voltage is a few volts less than that of the supply because a higher voltage than its own is needed to charge it.

### A BREAK IN

Check the laptop's current requirement to make sure it is less than that available. With a 19V machine, it can be assumed that 2·5A will be available from the new unit (see graph – Fig.1). For a 15V laptop, 3A would be available.

To measure the current drawn, make a simple "break in" circuit that will allow monitoring under various conditions. This consists of a line socket to match the plug on the existing mains adaptor and a plug of the same type as that needed for the laptop's input (see Fig.2).

The 19V laptops tested used the same standard "power-in" plug. The Toshiba needed a similar plug but having a larger diameter "pin". Note: the size of the pin may be found using a set of drill bits of known diameter in the output plug on the mains adaptor.

The plug and socket are linked through short pieces of wire (*5A rating minimum*) but including a 0·05 ohm fixed resistor connected in series with the positive one. You could connect two 0·1 ohm resistors in parallel to obtain this value if it is more convenient. This arrangement allows a digital voltmeter (DVM) to be used to measure the voltage developed across the resistor and hence find the current (since many readers will not have a suitable ammeter to measure the current direct).

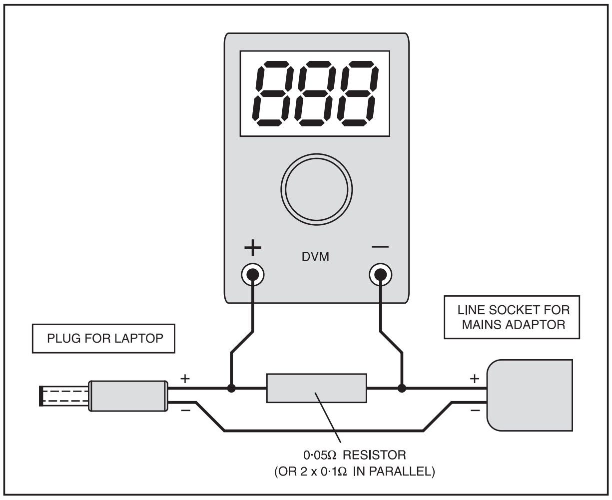



*Fig.2. Set-up for monitoring Laptop current.*

According to Ohm's Law, for each amp of current flowing, there will be 50mV (0·05V) "dropped" across the resistor. For example, a 75mV "drop" would indicate 1·5A. Such small voltage losses will not affect correct operation of the computer.

Using this set-up, measure the maximum current needed to charge the battery (that is, using a discharged unit and with the computer switched off). This was found to be a little over 2A for the 19V machines and some 2·5A for the 14V one – well within the capability of the power supply.

Now allow the battery to charge fully (note the current falls to a low value), switch the laptop on and measure the current again. This will find the current needed for the actual computer. This was found to be around 1A for each machine. In these cases, it will not be possible to charge the battery from "flat" and use the computer at the same time.

## CIRCUIT DETAILS

The full circuit diagram for the In-Car Laptop PSU is shown in Fig.3. The nominal 12V input (the car battery supply derived from the cigar lighter socket) enters via terminal block TB1, fuse FS1 and the pair of diodes D1 and D2 connected in parallel.

The diodes provide reverse-polarity protection and, being Schottky devices introduce only a small voltage drop – some 0·3V to 0·5V depending on the load. The reason why *two* diodes are used rather than one is to share the current between them (and hence the power dissipation).

Fuse FS1 provides protection in the event of a short-circuit at either input or output. Current flows to capacitor C1 and charges it to provide a small reserve of energy.

IC1 is a boost switching regulator and most of the control circuitry is already built into it. Its pinout details are shown in Fig.5. Current enters at pin 5 (V+) and returns to 0V at pin 3. Capacitor C2 connected directly between the supply pins decouples it and promotes stability.

The network comprising resistor R1 and capacitor C3 in series connected to pin 1 (compensation), is necessary for the correct operation of internal circuitry. With a supply in place, the "switch" (pin 4) will now turn on and off at 100kHz (a frequency set by internal components). When "on" pin 4 is connected to the 0V rail.

## ENERGY EXCHANGE

Suppose for the moment that the switch (IC1 pin 4) is *on*. Current flows from the supply through inductor L1 and via the switch to the 0V rail. Diodes D3 and D4, connected in parallel, do not conduct because their common anode (a) is at 0V (due to the "earthing" effect of the switch) while the cathodes (k) are at output voltage. They are therefore reverse biased.

The current flowing is limited by the inductance of L1 as energy is "soaked up" in its core as the magnetic field builds up. Given sufficient time, the inductor's core would magnetically saturate and the current would rise to a very high value.

However, by the time the current rises to some intermediate level, the switch turns *off*. Now, the magnetic field in the inductor's core collapses rapidly. This induces a high reverse voltage in its winding so that the end connected to IC1 pin 4 rises above that of the supply.

The energy then discharges through the pair of diodes D3 and D4 in parallel (as with D1/D2 to share the power dissipation), and is stored in capacitor C4. A voltage greater than that of the supply therefore builds up across this capacitor. It can be seen that the energy stored in the inductor while the internal switch is *on*, is transferred to the capacitor when it is *off*.

## ON BALANCE

The voltage appearing across capacitor C4 is applied to the potential divider consisting of resistor network VR1/R2 (upper arm) and R3 (lower arm). Preset VR1's sliding contact may then select a fraction of the voltage at the junction of R2 and R3 and this is monitored by IC1's feedback input (pin 2).

An error amplifier built into IC1 compares the voltage at pin 2 with a 1·23V reference. If the voltage rises above this value, the switch lowers its peak current and has the effect of reducing the output voltage to restore balance. If the feedback voltage falls below the reference voltage value, the peak switch current increases.

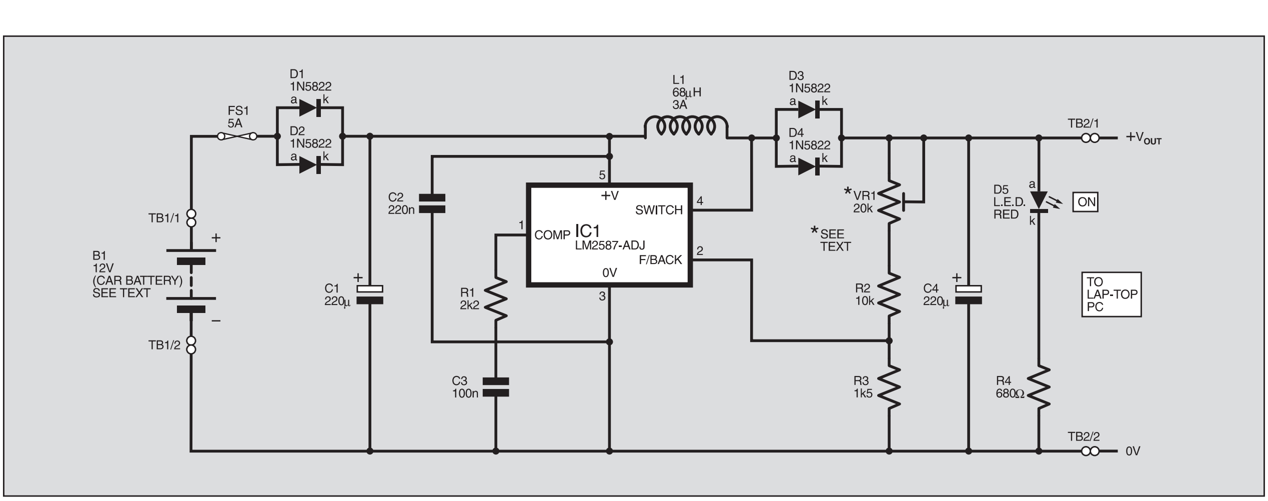



*Fig.3. Complete circuit diagram for the In-Car Laptop Power Supply Unit (PSU).*

In this way, the output voltage is maintained at the required value despite changes in external conditions (load and input voltage). All that is needed is to adjust preset VR1 to provide the correct output voltage at the end of construction.

Light-emitting diode, D5, operates in conjunction with current-limiting resistor R4 and provides the "on" indicator.

## CONSTRUCTION

Construction of the In-Car Laptop PSU is based on a single-sided printed circuit board (p.c.b.). This board is available from the *EPE PCB Service*, code 443. The topside component layout and actual size copper master pattern are shown in Fig.4.

Commence construction by drilling the two mounting holes in the positions indicated. Solder fuseholder FS1 and the two pieces of terminal block TB1 and TB2 in place. Follow with inductor L1 and all resistors (including preset VR1). It makes for much easier adjustment later if you use a *multiturn,* top adjustment, type preset for VR1.

Some of these devices have an in-line pin arrangement while others have a triangular pinout. Either type can be accommodated on the p.c.b. so use the holes that correspond. A standard vertical preset could be used but adjustment would be more difficult.

Add the four Schottky diodes D1 to D4, taking care over the polarity of each. Follow with all capacitors taking care over the polarity of electrolytic units C1 and C4. Note that capacitor C4 must be of a *low impedance* type while C1 (which has the same value) could be a standard type.

Add regulator IC1 noting the orientation – its flat (metal) face towards the top edge of the p.c.b. Carefully bend the pins as necessary to make it fit. Take special care when soldering IC1 in position because it is a relatively expensive device and will be damaged by excessive heat.

Before soldering the l.e.d. in place, extend its leads (if necessary) using single-strand connecting wire so that the top will

Component layout on completed circuit board.

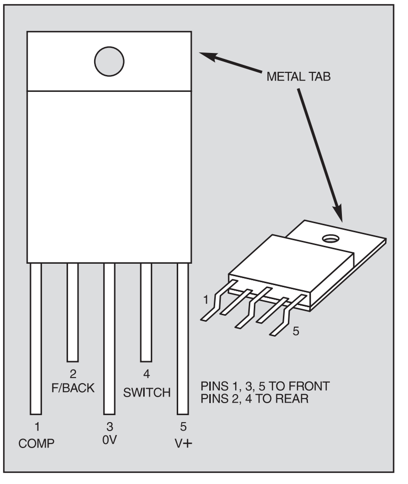




*Fig.5. Pinout details for the LM2587.*

## COMPONENTS


See SHOP TALK page


**Resistors**

| | |
|---|---|
| R1 | 2k2 |
| R2 | 10k |
| R3 | 1k5 |
| R4 | 680Ω |

All fixed 0·25W 5% carbon film

Test resistor(s): one 0·05 ohm or two off 0·1 ohm. Any power rating above 1W (see text)

**Potentiometer**

| | |
|---|---|
| VR1 | 20k min multiturn preset (top adjustment) or standard 22k preset, vert (see text) |

**Capacitors**

| | |
|---|---|
| C1 | 220µ low impedance or standard axial elect. 25V |
| C2 | 220n polyester |
| C3 | 100n polyester |
| C4 | 220µ low impedance axial elect. 25V |

**Semiconductors**

| | |
|---|---|
| D1 to D4 | 1N5822 3A Schottky diode (4 off) |
| D5 | 3mm red l.e.d. |
| IC1 | LM2587-ADJ boost regulator |

**Miscellaneous**

| | |
|---|---|
| L1 | 68µH inductor, 3A rating minimum |
| FS1 | 5A 20mm quick-blow fuse and p.c.b. fuseholder |
| TB1, TB2 | 2-way p.c.b. screw terminal block – 5mm spacing (2 off) |

Printed circuit board, available from the *EPE PCB Service*, code 443; aluminium box, size 112mm × 62mm × 31mm external; plastic stand-off insulators (2 off); rubber strain-relief grommets (2 off); plug and line socket to match input on computer (for testing); car cigar lighter type plug; twin wire, rated at 5A minimum for input and output leads; heat transfer paste; solder etc.

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

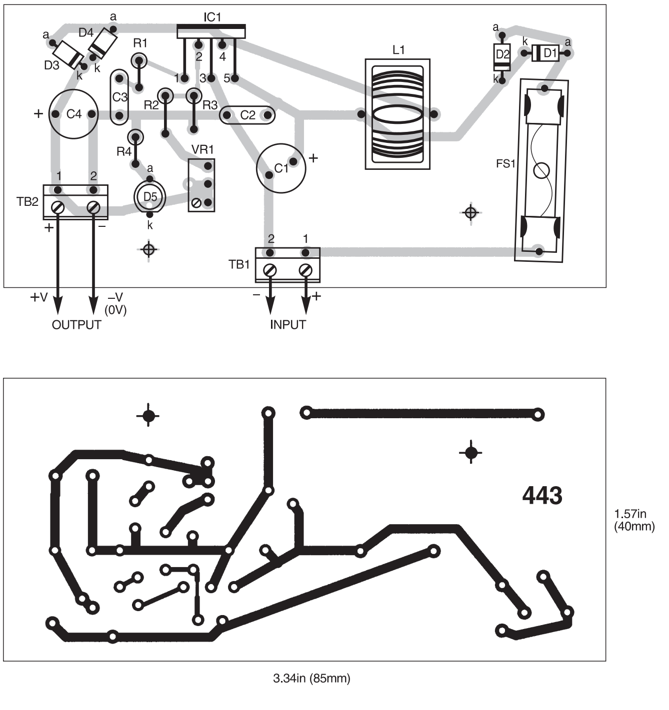




*Fig.4. Printed circuit board component layout, full-size copper foil master pattern and wiring for the Laptop PSU.*

end up slightly higher than the lid of the case (so that it will show through a hole drilled for it later). Solder it in position taking care over the polarity. Adjust preset VR1 sliding contact to approximately mid-track position.

## TESTING

*Note that a metal box* ***MUST*** *be used to house this circuit since it will behave as a heatsink for IC1. For the prototype unit, a diecast enclosure (sprayed black) was used. However, other types of aluminium box should be suitable as long as everything fits.*

In operation, up to 10W of the input power will be wasted. Most of this is given off as heat by only a few components. IC1 itself will dissipate some 4W, the inductor 3W approximately and the input and output diodes, D1 to D4, some 0·75W each.

To remove the heat safely from IC1, it must have an adequate heatsink – hence the use of a metal box. The i.c. metal tab is internally connected to 0V so that, in use, the case will assume 0V (battery "negative" potential). Metal parts of the car are also at 0V so this is acceptable practice.

With IC1 tab pressed against the side of the case, mark holes in the base of the box to correspond with the p.c.b. mounting holes. Mark also positions for two holes to accept the strain-relief rubber grommets that will be used to protect the Input and Output wires passing through the box. Drill these holes through.

Attach the p.c.b. temporarily on short plastic stand-off insulators so that the underside soldered joints remain several millimetres clear of the base of the box (to avoid short circuits). Mark the position of the hole in IC1 tab and also the position of a few ventilation holes in the side of the box in the region of the input and output diodes. Remove the circuit panel again and drill all these holes.

It would be wise to apply a little thermal transfer compound to IC1 tab (the surface that makes contact with the case). This will help in conducting the heat away.

Now re-mount the circuit board and attach IC1 firmly to the side of the case. *Make sure its pins are not left under any strain*. Drill a hole in the lid for the l.e.d. to show through (but do not fit the lid). Insert the rubber grommets in their holes and add the fuse.

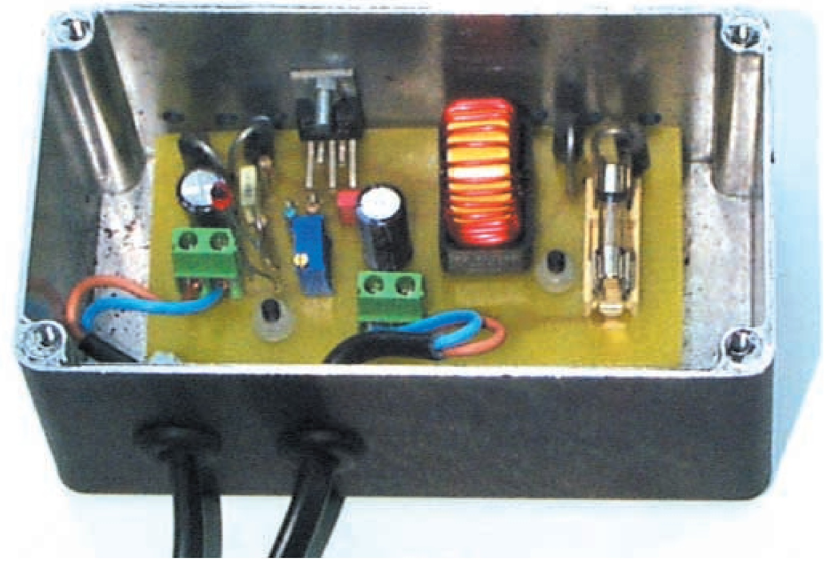
## FINISHING OFF

Make up an Input lead to connect the unit to the car's cigar lighter socket. The wire used should be rated at 5A *minimum* and should not be any longer than necessary (say, one metre maximum) to avoid an excessive voltage drop. Fit the correct type of plug on one end. Pass the other end through one of the rubber grommets and connect the wires to terminal block TB1 taking care over the polarity.

Plug the unit into the supply (***not with the engine running***). The l.e.d. should light up. Apply the voltmeter probes to TB2 terminals and adjust preset VR1 to provide the required voltage. At this point, and to save time later, charge up the laptop battery fully, using the computer's mains adaptor.

Make up a laptop connection lead (using the same type of wire as that used for the Input) with the correct type of plug on the end. As with the input lead, this should not be any longer than necessary. Pass the end of the wire through the remaining rubber grommet and connect it to TB2. *Make sure you observe the input polarity of the computer* – this might be indicated next to its socket. Apply strain relief (tight cable ties, for example) to both input and output leads leaving a little slack inside the case.

Drill a few ventilation holes in the lid of the box. Fit the lid but do not screw it down yet. Adjust the position of the l.e.d. so that its top protrudes slightly through the hole drilled for it. Make any adjustments as necessary.



*Finished power supply showing the p.c.b. mounted in a diecast box.*

## FINAL TESTING

*Before connecting the laptop to the new supply, re-check the output voltage and polarity since mistakes here could damage the computer. Note that the unit MUST NOT be used with the car engine running.*

With the battery fully charged from the mains, connect the laptop computer to the new supply and check for correct operation. Feel IC1 and diodes D1 to D4 at intervals to make sure they are not overheating. It is normal for them to become quite warm.

Allow the battery to run down again and check that it charges correctly with the computer switched off. If this is not satisfactory, check the voltage near the computer using the break-in arrangement (Fig.2) used earlier to make sure it does not fall below the correct operating value.

## HIGH SIDE

It seems that manufacturers often set the output voltage of their mains power supplies slightly on the high side of the nominal value. The author has found that this is commonly around 3% more. For example, for 19V laptops, the actual voltage may be found to be 19·5V approximately.

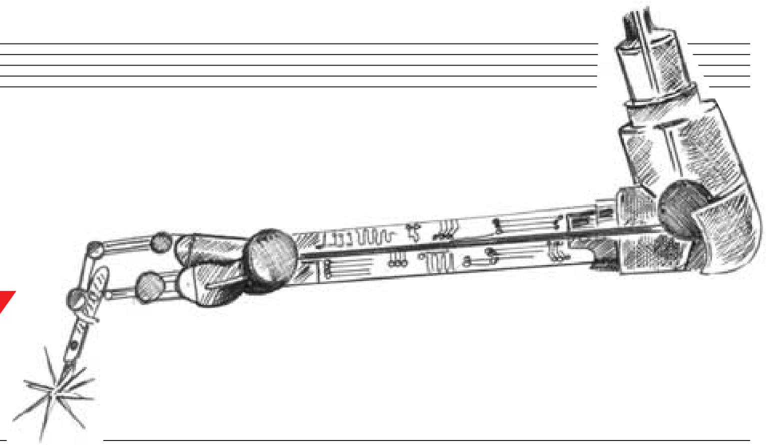
Presumably, this allows for voltage drops along the wiring so that the voltage at the computer input is always maintained at 19V minimum on full load. If operation still proves to be unsatisfactory, set the new unit's output voltage to the same value as that provided by the existing mains power supply as measured by an accurate voltmeter.

*In use, the unit should become only warm. However, if it is delivering high power over a prolonged period, it will become quite hot. If this is so, make sure it is placed so that this will not damage any heat-sensitive parts of the car such as plastic parts.*

## FINAL POINT

Take care to avoid using this power supply for long periods and run down the car battery. A typical car battery has a capacity of 40Ah (amp-hours). If 2A is drawn, it will be run down in 20 hours and there could be insufficient capacity to start the car after a much shorter period of use. Make sure the car is regularly used to keep the battery charged but *YOU MUST NOT* operate this device with the engine running.

# CIRCUIT SURGERY



ALAN WINSTANLEY
and IAN BELL

***MOSFETs in parallel, confusing capacitor values and scientific notation are demystified by our Circuit Surgeons***

## More On Power

LAST month we discussed inverter circuits and made brief reference to the use of paralleled power MOSFETs in such circuits. This month we pick up this theme in more detail and look as some of the issues in designing and building circuits employing this useful technique.

Power MOSFETs can be used wired in parallel in order to increase their power (specifically current) handling capability. Manufacturers could simply make larger devices, but paralleling several discrete devices has the advantage that standard packages can be used; super-large devices would require expensive special packaging.

MOSFET gates do not require large amounts of drive current, so drive circuits for paralleled power MOSFETs do not have to be significantly different or more powerful than drive circuits for single devices. However, we do have to take care with how to wire up the drive signals and we will return to this shortly.

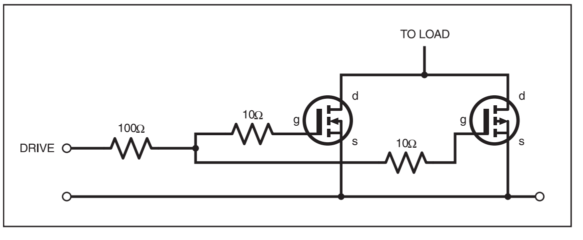



*Fig.1. Paralleled MOSFETs with differential gate drive resistors.*

## Current Account

When two or more electronic devices, such as transistors of any type, are used in parallel, one device may take more than its fair share of current. This is due to differences in the electrical parameters of the individual devices. Imbalance may also be caused by poor layout of the circuit when constructed. If the drain/source wiring to each MOSFET in a parallel set has a different impedance there will be an imbalance in the currents.

Remember that in high current circuits voltage drops across wires and solder joints may be quite large, particularly if the construction quality is poor. Parallel MOSFET wiring must be as symmetrical as possible and all high-current handling connections must be carefully made and use appropriate gauges of wire. High power switching circuits do not tolerate shoddy construction!

Fortunately, a small amount of current difference in paralleled MOSFETs (due to inherent individual differences) does not cause significant problems. Increased device temperature (in the device taking more current) will increase its resistance, opposing any further increase in current. This relationship is described as a "positive temperature coefficient of drain to source ON resistance".

## Cool It

If the ON resistance temperature coefficient was negative the device taking most current would get hotter and take more current, which would make it hotter, and take yet more current. This situation, which is called "thermal runaway", does not occur in paralleled MOSFETs. However, the non-equal sharing of current means the continuous current rating for MOSFETs should be derated by around 20% for paralleled use. The relative imbalance increases as more devices are paralleled and this should also be taken in account.

If the MOSFETs in a paralleled set are able to attain significantly different temperatures then this may exasperate any differences between their characteristics. The devices should be mounted on the same heatsink so that they are all at more or less the same operating temperature.

Paralleled devices may not all switch on or off at the same time, again due to variations in individual devices. Power MOSFETs can handle very large currents (i.e. greater than their continuous rated value) for short durations. This means that one device in a paralleled set can handle all the current for the very short time before its slightly slower companions switch on.

Dynamic effects – the processes which occur in very short times as devices switch – are very important in power switching circuits such as inverters and switch mode power supplies. Unfortunately they may be particularly difficult for hobbyist to observe as this requires the switching waveforms to be captured on a suitably fast and accurate oscilloscope. However, this does not mean that good design practices cannot be followed!

## Lack of Symmetry

Lack of symmetry in the gate drive to paralleled MOSFETs will worsen the dynamic imbalance we have just mentioned. These signals are sensitive to the wiring inductance and so these connections must be as short as possible, as close together as possible (if the wires are not close they may form an "inductive loop"), and all must be the same length.

Parasitic reactances occur in the MOSFET package and in the circuit connections. These are unwanted capacitances and inductances which are inherently part of the wiring and structure of the device.

Unfortunately, they can result in feedback around the transistors which can result in high frequency (above 100MHz) oscillations, typically triggered as the devices switch. They can be seen as bursts of oscillation if you are able to observe the circuit with a sufficiently fast oscilloscope.

The parasitic oscillations may be reduced by using a small value differential resistor of typically 10 ohms value at each gate, connected to a common resistor of typical value 10 to 100 ohms – see Fig.1. Separate drive circuits may also be used, for example a push-pull transistor pair or set of paralleled CMOS NOT gates driving each MOSFET. These drive circuits should be placed very close to their respective MOSFETs. *I.M.B.*

## Capacitor values

*As a newcomer to hobby electronics, I am attempting to build the* Bat-Band Convertor *published in* EPE *March 2004. I am trying to identify capacitor C1 in the components list, which calls for 470p polyester. In both Maplin's and Squires' catalogues the polyester capacitors are given in nanofarads and microfarads, e.g. 470nF poly film or 0·0047µF poly layer, or 0·047µF poly layer, 0·47µF poly layer etc. Could you please advise what I need? Many thanks,* ***R S Mullins by e-mail.***

Capacitance values and multipliers can be very puzzling for beginners to deal with, but with a little practice all becomes clear. The main problem is that the farad, the unit of capacitance in coulombs per volt, is almost always too large a unit when used in microelectronics. According to the formula C=Q/V, a capacitance (C) of one farad equates to a charge (Q) of one coulomb where the potential difference (V) equals one volt.

We don't measure very short distances in metres: we would use e.g. millimetres instead. It is therefore common to use multipliers of farads to describe smaller values. Specifically we use microfarads (µF), nanofarads (nF) and picofarads (pF) to save having to write lots of zeroes and decimal places.

## Pain-Free

Some simple maths can be applied that helps us deal with awkward values, and it's pain-free, as we'll show. For those unfamiliar with scientific notation, a value of 100 can be written as $1 \times 10^2$ (i.e. ten squared, or 1 with two zeroes after it). A value of 1,000,000 is the same as $1 \times 10^6$ – i.e. 1 followed by six zeroes. One billion is easily written as $1 \times 10^9$ in scientific notation. And a value of 67,480,000 equals $6{\cdot}748 \times 10^7$ (6·748 × ten to the power of seven, the 6·748 being called the *mantissa* and the power of 7 being the *exponent*.) In these examples, multiplying by a power of ten is the same as moving the decimal point one place to the right.

## Sub zero

Looking at values of less than one, as in the case of capacitor values, scientific notation comes to the rescue to save us the chore of writing lots of zeroes. Starting with the microfarad, this is one millionth of a farad, which can also be written as $1 \times 10^{-6}$ – note the minus sign before the exponent. The Greek letter $\mu$ (mu) denotes "micro" or $10^{-6}$.

Even smaller is the picofarad (pF), equal to $1 \times 10^{-12}$ farads. Usually, such small capacitor values are associated with high frequency or radio circuitry. For very many years (in magazine publishing anyway), the microfarad and picofarad were the two multiplier values generally used. The nanofarad is $1 \times 10^{-9}$ farads and came into popular use as a halfway stage between pico and microfarads.

It is customary for us to omit the "F" in Parts Lists and circuit diagrams, to help avoid cluttering the page with too much detail. Sometimes you may also see in print, the multiplier letter being used as a decimal point identifier, so that 4p7 is the same as 4·7pF. The letter "u" may be used on the internet or emails to denote microfarads: 4u7 is 4·7microfarads, and 100u would be 100µF. The abbreviation "mfd" is also used for microfarads.

The question posed by our reader is how to interpret these values when ordering the components shown in the Parts Lists. In the *Bat-Band Converter* project, capacitor C1 is shown as 470p (i.e. 470pF). From the simple conversion table, you can deduce that this is the same as 0·47nF. I did find it hard to locate such a low value polyester capacitor, because ranges typically start at 1nF. You may need to consider another dielectric such as a ceramic type instead.

**Table 1: Capacitor value multiplier conversion table**

| Picofarads (pF) | Nanofarads (nF) | Microfarads (µF) |
|---|---|---|
| 1pF | 0·001nF | – |
| 10pF | 0·01nF | – |
| 100pF | 0·1nF | 0·0001µF |
| 1,000pF | 1nF | 0·001µF |
| 10,000pF | 10nF | 0·01µF |
| 100,000pF | 100nF | 0·1µF |
| 1,000,000pF | 1,000nF | 1·0µF |
| – | – | 10µF |
| – | – | 100µF |
| – | – | 1,000µF |

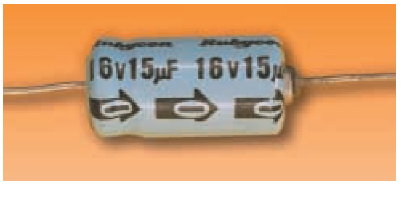
## Identification

Another important aspect relates to the correct identification of components. Over time, manufacturers have used a series of contradictory lettering schemes, and it can be almost impossible to fathom out the capacitor values judging from the confusing markings employed.

The problem is that the components are often so small that codes have to be used to denote the capacitance, tolerance and voltage. The codes can be almost indecipherable, so in practice it is best to compare parts against suppliers' delivery notes, and make sure that capacitors are labelled properly and stored to avoid confusion in the future.

You will see from Table 1 that to convert from one multiplier to the next, simply move the decimal point three places in the appropriate direction. Personally, I manage by remembering that 100nF is 0·1µF and 1nF is 1,000pF, and I work everything else from that. Any supplier's catalogue that includes a helpful conversion table always gets the thumbs-up from *Circuit Surgery! ARW.*

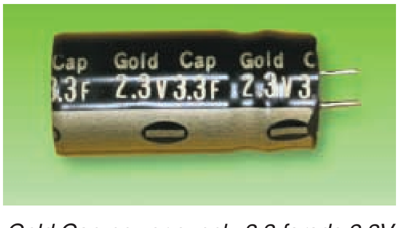
**EXAMPLE CAPACITORS**



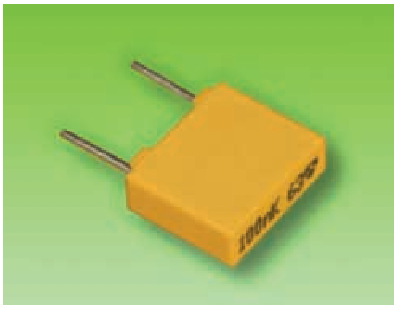
Electrolytic axial 15µF 16V


10nF (0·01µF) polyester capacitor

33pF ceramic capacitor



Gold Cap power supply 3·3 farads 2·3V


Polyester 100nF 63V capacitor

100pF 1kV (1,000V) ceramic capacitor

# READOUT

Email: john.becker@wimborne.co.uk

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

**All letters quoted here have previously been replied to directly.**

## WIN AN ATLAS LCR ANALYSER WORTH £79

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

The Atlas LCR automatically measures inductance from 1$\mu$H to 10H, capacitance from 1pF to 10,000$\mu$F and resistance from 1$\Omega$ to 2M$\Omega$ with a basic accuracy of 1%.

## ★ LETTER OF THE MONTH ★

### SKEGGY DOES IT!

Dear EPE,

Reading the *Letter of the Month* in the March '04 issue reminded me of my first acquaintance with your magazine. A few years ago I was more or less forced to end my career in industrial electronics after two and half years. Quite suddenly I turned from professional to hobbyist again and went looking for a magazine that would fit in this new situation. Soon I realised that most of the magazines I knew in my pre-professional life did not exist any more and those that had survived were either for professionals or desperately trying to look like that.

But being on holiday in England one lucky day (a rainy day in Skegness!)I came across *EPE* and immediately knew, *this is it*. Your magazine still has the spirit of the sixties when electronics was quite new and fun, while at the same time it is very much in touch with the world of today.

I gave myself a subscription for my birthday and have enjoyed every issue since then, especially Raymond Haigh's series on radio. Now I do finally understand why the 2-transistor radios from the 60s worked so well.

I would like to pay my respects to your staff for providing so much reading pleasure every month.

**Simon Franke, Nijverdal, Holland**

*Ah, Simon, such is the influence of Skeggy. In childhood days I discovered many of its benefits – and how it lived up to its one-time advertising slogan of "Skegness is so bracing", especially on its beaches! In fact, in those days (WW2 time), most of the beaches were mined against potential invasion, but there were still stretches where the public could wander (and get legs windswept with sand!)*

*But, yes, we do maintain our own tradition while embracing the new. Moreover, Mike, Dave and I have all been involved with* EE, PE *and* EPE *since they began and believe that our combined experience helps us to produce a magazine that reflects our interest in electronics, as well as yours.*

*We offer a very warm welcome to you (and a splendid Atlas LCR Analyser)!*

### SPAM WASHING

Dear EPE,

I saw the letter in the March issue about Mailwasher that mentioned bouncing spam. I can't emphasise too strongly that you should *not* do this. The address of a spam message is almost invariably bogus, as the last thing the sender wants is a reply or for someone to trace him and shut him down, so the bounce just clogs up the system. If not bogus, it will be the address of some innocent bystander whose address has been hijacked. The author would be doing everyone a favour if he deleted this "feature".

**Jonathan Silverlight, via email**

*Indeed, Jonathan, you emphasise my statement about not cluttering the web. Curiously, from the spam that used to overload us at HQ before we installed filtering, we could see that the spammers were actually offering services for which they hoped to get "customers" to apply, and so had reply addresses attached. Thankfully, we are now pretty much free of spam, and even the deluge of* MyDoom A *virus-alerts attached to received emails has dropped recently (none at all today as I write this, compared to several hundred at the peak).*

*I notice on the bottom of your email the message "Save the Hubble Space Telescope!". I agree! There should be no question about its future. As an inquisitive species we* need *to know what's out there, and from those observations to one day deduce how it all started.*

### PRIZE DELIGHT

Dear EPE,

Just when I was thinking of hanging up my trusty multimeter and taking a long break from running short courses for my senior cits, your letter arrived advising me that I had won first prize in the *Ingenuity Unlimited* competition.

Needless to say, I am absolutely delighted to receive it and my thanks must go to *EPE* for choosing my project over (I thought) much cleverer designs; and to Pico for their generous contribution.

Yes, the oscilloscope will certainly add fresh interest to our hobby but my present involvement didn't start as a hobby. Far from it. As an Industrial Engineering manager in large companies, it was soon obvious to me that with the ever increasing use of electronic controls in manufacturing processes, I had to add this branch of engineering to my qualifications. And my introduction to it in the early years was through *Everyday Electronics* and later, *Practical Electronics*.

As a matter of interest, I started my career as an "Engineer Improver" (quaint title!) at Bush Radio Ltd in West London, a then subsidiary of the J. Arthur Rank Organisation, during WW2.

**Tony Lee, Old Reynella, South Australia**

*Thanks, Tony, nice to hear from you! All our best wishes.*

### STABILISING TANKS

Dear EPE,

In response to the letter from R. Griffin in March '04 *Readout*, I have some thoughts to offer him. The use of the servo with a servo tester as a driver is fine. He might even be able to use a single servo with mixed inputs from the R/C and level sensor, using a mixer circuit. It might be simpler to use two servos, one for elevation, and one for levelling. His problem is the level sensor – I think a pendulum is probably the best solution, but rather than connecting it directly to the potentiometer, make it free swinging, and detect the position with an optical device.

If he needs a simple variable resistor then the pendulum bob can be set up to hang partially blocking the light path from an l.e.d. to an l.d.r. Any movement of the pendulum will vary the light input on the l.d.r. and change its resistance. He will need around 10mA at 2V to drive the l.e.d. If a voltage divider is required, then the l.e.d. needs to illuminate two l.d.r.s, with the pendulum shadowing one or the other as it moves. This might be too sensitive to small movements, so he could consider mounting the whole gadget in a sealed box with some thin oil to provide some damping action.

**Peter Gee, via email**

*Many thanks Peter for responding to R. Griffin. If a pendulum is being considered, I would also add that a magnet and Hall Effect sensor pair as I used in my* Seismograph *of April/May '04 might be encouraged to do the job. The technique is very sensitive, so would need damping, but it requires very little current compared to an l.e.d.*

### OLD BOB

Dear EPE,

Regarding Bryan Epps' suggestion (Feb '04) about an Old Bob type of column, you said that it would be difficult to sustain. Have you ever considered that out there in *EPE* reader land there are probably lots of very experienced electronic/computer/software etc. people who have interesting and probably funny anecdotes to tell.

How about a Wafflers' page – logo of a waffle (potato or otherwise) in colour at the top? I would distinguish this from the *Readout* page since it would be for a different purpose, would not have to be a regular monthly page – just when you had enough to justify it.

The description of Old Bob rang a bell and I found a bound copy of the *Radio Constructor* 1956-57 (my only remaining copy – the rest seem to have got lost in one of my many moves) containing articles about Smithy and his assistant, Dick.

Anyway, congrats on your magazine, I will be renewing my subscription. For various reasons I gave up home electronics about 10 to 12 years ago and only decided to get involved again when I retired. Since then I have been taking your magazine, joined the EOCS and bought a *TK3* kit. I am glad to see that in the intervening period you have kept up the standard. The only other mag that I subscribed to many years ago started to get rather "twee" – i.e. totally unnecessary use of colour, colour wash across pages and yucky overprinting. If I remember correctly a certain R. A. Penfold also had a go at them! I cancelled the subscription.

Comparing the current Maplin catalogue with the one of 10 to 12 years ago is quite instructive, and rather sad, lots of the bits I used are no longer stocked.

Keep the flag flying.

**Alex Duncan, via email**

*Many thanks Alex for also reminding us about Smithy and Dick, and for your other suggestions, which we'll keep in mind (sorry, but we can't influence anyone on what's in their catalogue though!).*

*R.A., of course, is the Robert Penfold who regularly writes for us. Very many readers have benefitted from his authoritative features and designs over the years, including myself.*

## PIC LCF METER – Unwittingly disproving conventional wisdom

*Following publication of my* PIC LCF Meter *in Feb '04, I received several comments of satisfaction from readers, but on the Chat Zone (via* ***www.epemag.wimborne.co.uk****) a few postings appeared from readers who were having difficulties with frequency stability in Capacitor mode.*

*My immediate response was that I had used the standard configuration for inverting logic gates in oscillatory mode and that I had used the technique for decades without problems, as had many other contributors to the various electronics magazines over many years.*

*Asked the make of NAND gate I used, I replied that it was the HEF4011BP (Philips).* ***Myo Min*** *responded that "both CD4011BCN and TC4011BP worked perfectly" for him. But it was obvious that other readers did indeed have problems with the 4011s they were using. There was also a suggestion that a Schmitt trigger gate, such as the 4093, might solve the problem.*

*I said that I would look into the situation, which I did and my findings are quoted presently. But there were other postings on the CZ in this context which I feel are worthwhile sharing with you. It puts a very different light on what I and many others have regarded as a standard configuration:*

**Testing the Concept**

**Rob S:** Having seen the problems people are having with this circuit, I decided to breadboard it to see what happened. I had no 4011, so I used an MC14001 (a Motorola equivalent of the 4001 NOR gate). I do not claim that my results are always repeatable, but I'm sure some readers are seeing what I've seen.

I started with the 10k/1k/1nF values as used in the *LCF Meter*. To avoid loading the circuit with the oscilloscope, I used a third gate as a buffer and used the scope on the output of that. The power supply had a 220nF capacitor across the MC14001 power pins. The results were very interesting.

Using my buffer to probe the output of the second gate (the one driving the capacitor) gave a reasonable clock of sensible frequency (200kHz). However, using the buffer to probe the output of the first gate (the one driving the 1k resistor) gave very different results! Although the 200kHz clock was still visible on the scope, there was severe ringing on every clock edge. Where there should have been one clock edge, there were many.

What is happening is that as the oscillator gets close to the switchover point, the first gate (which is in an analogue region where it isn't really designed to operate) starts to oscillate at something like 6MHz. The second gate (which isn't designed to handle a 6MHz clock with analogue signal levels) cleans this up to give a more respectable clock. Of course, once the second gate starts to change state, the positive feedback through the capacitor helps to give a clean transition. The second gate, with its positive feedback, is cleaning up a thoroughly dirty clock.

Here's one of the problems: in the *LCF Meter*, the clock is being taken from the first gate (into the NAND gate which combines it with the inductance oscillator output). Since that NAND gate won't have exactly the same analogue characteristics as the second gate in the oscillator, and has no positive feedback, it doesn't clean up the high frequency ringing but passes it on to the PIC. In this sort of oscillator, the clock is usually taken from the second gate. The fact that the *LCF Meter* takes the clock from the first gate, putting a messy analogue signal into a non-Schmitt gate, is half the problem here.

**Brand Loyalty**

**Terry Mowles:** Regarding the manufacturer of the 4011 not being a problem. I used to build humidity sensors for computerised greenhouse setups which used 4011s. The only ones that would work in the circuit were Philips ones, other brands just refused to work at all. So it may just be possible that the 4011 brand is the cause of the problems.

**Pseudo-Random**

**Rob S again:** It's curious to see how this classic circuit is causing so many problems. I wonder, in hindsight, what proportion of projects have used this oscillator to do nothing more critical than drive a speaker – an application in which the 6MHz ringing on the edges would go unnoticed.

A few years ago I built a surf sound generator (simulating the noise of the sea) from a Maplin project. This contained a pseudo-random number generator to control the wave volume. The configuration will be familiar to some readers – an RC oscillator similar to the one in the *LCF Meter* clocked a shift register with some outputs fed back to the shift register input via XOR gates.

The surf generator would work fine for a while, and then suddenly stop making any noise. What had happened was that the shift register had somehow got itself full of zeroes. Those readers who are familiar with pseudo-random number generators will realise that this is the one state that the shift register can't get out of, and the one state that it should never have got into given that it had started working OK.

The problem was that the classic RC oscillator was ringing – generating multiple clock edges on each cycle – at a frequency too high for the shift register. At some point when the shift register was almost full of zeroes the register got clocked several times, too fast for a "1" to be fed back to the input, and the register ended up at all zeroes, at which point it was stuck. I found a way of tweaking the RC oscillator to clean up the clock, and from then on the circuit worked reliably.

**Capping**

**Mike:** This has been the most interesting project that I have worked on in years. Like most hobbyists, I enjoy a working product at the end of a project. However, to me, the learning experiences that come with making it work are the true value. I'd like to thank John Becker for developing the concept and to everyone that has offered their input over the past few weeks.

Rob's experimental results paralleled my own findings actually working with a 4011 in circuit, although he understood what he was seeing while I was simply guessing at the cause. I appreciated his detailed explanation of the steps he took. As for brand/manufacturer of the 4011, I tried CD4011s from TI and RCA with identical results. I should note that I am using a 9V battery as a power source so noise from an external power source was not a factor.

Having built three meters, I can say that adding a 43pF cap (a value derived by trial and error rather than calculation) does make the oscillator function in the desired frequency range, around 200kHz, rather than at the 6MHz I get without it. With the addition of this cap alone, I found that the meter would measure low value caps from 100pF up to about 10nF with fair accuracy, but a 1% cap with a value of 0·1uF only measured 65nF. Adding a 68pF cap at the input to the PIC (pin 12) solved this problem, with the 0·1uF cap now reading 100·45nF, and had no adverse affect on lower value readings or in measuring inductances.

This fix would appear to be repeatable since, as I said, I have built three of these meters and all work correctly. I would recommend that anyone adjusting the offset in their meter use caps of known value/accuracy and test several different values to insure that the results are linear.

Again, I really want to thank John for a most interesting project and learning experience.

**Final Findings**

*I later posted on the CZ the results of my findings when using different makes of 4011 in the* LCF Meter *when in Capacitance mode:*

HEF4011BP no problems
HCF4011BE parasitic oscillation at 6MHz
MC14011BCP parasitic oscillation at 2MHz
RS4011B parasitic oscillation at about 4MHz

Whilst a 4093 NAND Schmitt trigger can be used for capacitance measuring, the inductance mode cannot work with a Schmitt because of its hysteresis preventing oscillation occurring with LC feedback.

The parasitic oscillations were cured by putting a 68p cap between 4011 pin 5 and 0V (e.g. pin 7).

Further investigation showed that increasing the value of R4 from 1k to 2k helped with those 4011s prone to parasitic oscillation in cap mode. This reduces the initial surge current from 5mA to 2·5mA into/out of C7 at the moment of IC3b's logic change. This beneficial effect was especially noticeable with high values of external capacitor being measured. However, the use of 2k affects the capacitance calculation and so would require a modification to the program to compensate. Those of you with PIC programming facilities can experiment with this. The formula for R4 = 1k as the program stands for calculating C is:

$C = 1/(\pi \times 1 \times F)$, where $\pi$ is calculated as 22/7

For R4 = 2k, the formula becomes:

$C = 1/(\pi \times 2 \times F)$, therefore $\pi$ can now be taken as 44/7

Consequently the cap calc statement at line 580 (line count taken through DOS Edit) currently saying "**movlw 22**" should be changed to "**movlw 44**". It should be noted, though, that increasing R2 to 2k will roughly halve the maximum capacitance that can be measured before the software's time-out routine is triggered. It would also require (ideally) that R3 should be increased to 20k to maintain the 10:1 ratio between R3 and R4.

**Conclusions**

In conclusion, if your 4011 is giving problems, simply adding a capacitor of about 68p between pins 5 and 7 seems to be the simplest workable option (I would also have tried 47p had I had some free. I did try 10p, but that was insufficient). Another option is to purchase a Philips HEF4011BP as I use without problems in my own unit.

An intriguing situation. Thanks to all of you who contributed to this topic on the CZ (and to Mike for his kind comments).

Finally, in the course of this discussion, a minor bug in the software was found and fixed, affecting Inductance mode when measuring large values. The amended code was placed on our Download site in early March.

## STAR STRUCK

Dear EPE,

Many thanks for printing my letter in the March '04 issue. I was surprised to see it featured as the Star Letter and delighted to receive my prize of the Atlas LCR Analyser.

However, this now gives me a problem – I wrote before because the PIC-based *LCF Meter* in Feb '04 was one that I could not envisage as being built solely from discrete components. Consequently, I was keen to build the project and gain more experience with PICs. Receiving Peak's analyser, though, negates the need to build the project! What a dilemma – how can I convince my wife that I need two of these devices?

**Martin Cox,**
**Halifax, via email**

*That Atlas unit is superb, Martin! I double-checked my* LCF *against a borrowed one during early development stages. Atlas (Peak Electronic Design), though, have done such an excellent job and there are many aspects of its software which I could not even attempt to match without involving myself in months of programming.*

*You could try selling the frequency merits of mine to your wife, while also holding a bunch of flowers to add to your chances of success!*

# BEAT BALANCE METAL DETECTOR

THOMAS SCARBOROUGH

*A new genre of detector that is inexpensive and easy to build.*

THIS project was born of the intuition that not all had been thought of in terms of metal detector design. To the best of our knowledge, this project represents a new genre of metal detector, being a hybrid between beat frequency operation (b.f.o.) and induction balance (i.b.). The author has dubbed it "beat balance", or b.b. for short, thereby giving a nod to each of the two principles which underlie it.

The result is a very simple design that is capable of greater sensitivity than that of a b.f.o. detector whilst offering high levels of immunity to voltage and temperature variations and to ground mineralisation, together with good discrimination.

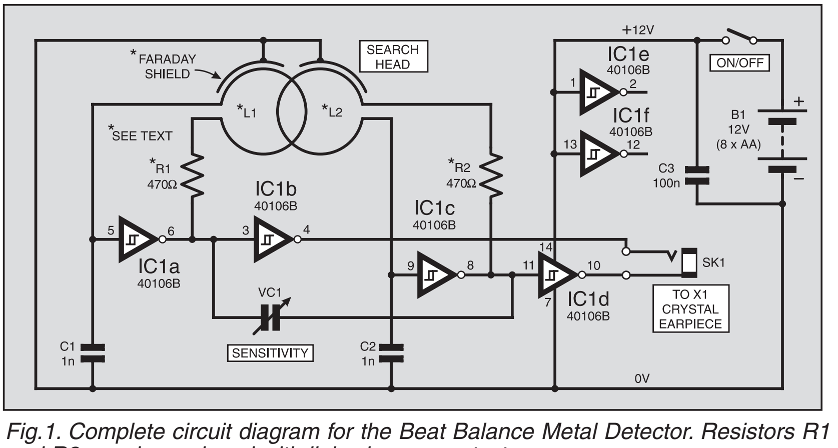



*Fig.1. Complete circuit diagram for the Beat Balance Metal Detector. Resistors R1 and R2 may be replaced with link wires – see text.*

## OVERVIEW

Instead of using a search and a reference oscillator as with b.f.o., or a transmit and a receive coil as with i.b., the b.b. detector uses two search oscillators with i.b.-style coil overlap.

As will be seen from the circuit of Fig.1, these oscillators may be very simple in design. In this circuit, each comprises just two components plus a search coil. The frequencies of these oscillators are then mixed in similar fashion to a b.f.o., to produce an audible heterodyne.

On the surface of it, the b.b. design would seem to represent little more than a twinned b.f.o. detector. However, what makes it different above all else, and significantly increases its range, is that each coil modifies the frequency of the adjacent oscillator through mutual coupling. This introduces the "balance" that is present in an i.b. detector, and boosts sensitivity well beyond that of a b.f.o.

Beyond this, all that is required is a means to control the mixer output frequency, so that the detector may be tuned. This could be accomplished in a number of ways, but the method chosen here is a variable capacitor wired between the two oscillator outputs.

## CIRCUIT DETAILS

The full circuit diagram for the Beat Balance Metal Detector is shown in Fig.1. A 40106B CMOS hex Schmitt inverter gate is used for each of the two oscillators IC1a and IC1c. These are pushed almost as fast as they will go without producing noise or instability, oscillating at around 150kHz.

Current drain is fairly high, and depending on the make of IC1, may be as high as 20mA. In order to reduce current consumption, resistors R1 and R2 may be inserted in series with each of the search coils, L1 and L2. Note, however, that the higher the values of R1 and R2, the less the sensitivity of the detector. The author substituted link wires for the two resistors, and a number of i.c.s. were "soak tested" like this without any trouble.

While nearly all makes of 40106 i.c. should work in this circuit, it does make a difference which one is selected. The author recommends the SGS-Thomson HCF40106BE or the Philips HEF40106BP. The Motorola MC4106BCP should be avoided if possible as it was found to be too "noisy" in this application.

Inverter gates IC1a and IC1c are wired as *LC* oscillators. Since an inductor resists a.c. (called reactance), the search coil impedes the charging and discharging of the timing capacitor. As in the case of a b.f.o., as soon as metal comes near, the inductance of the coil increases, and the frequency of the search oscillators shifts.

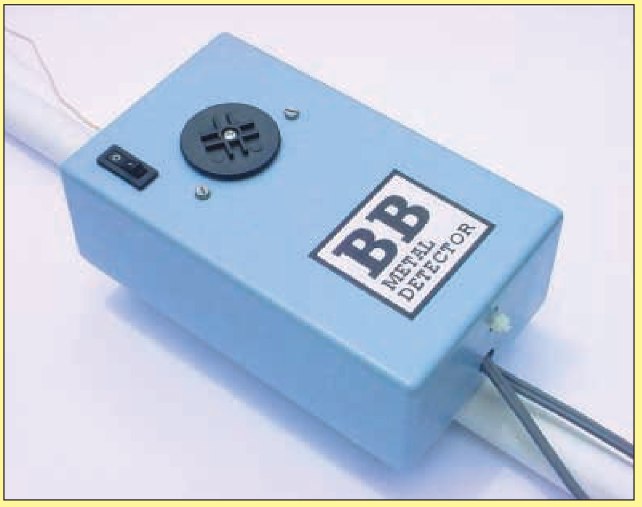
A buffer (IC1b and IC1d) is used for each of the two oscillators IC1a and IC1c, so that the crystal earpiece does not unduly load the oscillators. The inputs to the two unused inverters are "tied" to one of the supply lines.

## STRONG INFLUENCE

This leads us to the one distinctive feature of "beat balance". Not only does the presence of metal alter the frequency of a search oscillator, but, as in the case of i.b., it influences the adjacent coil as well. In fact both coils influence each other through mutual coupling, thus greatly enhancing the sensitivity of the design.

Variable capacitor VC1 further couples the two inductors (that is, search coils), thus offering a means of controlling the balance of the detector. Almost any variable capacitor should work in this position, and the author used one which he pulled out of an old shortwave receiver.

The frequencies of the two oscillators are mixed in the earpiece itself, thus obviating the need for a mixer. If any earpiece other than a capacitive one is used, a 100nF capacitor should be wired in series with the earpiece.




*Completed detector unit showing the Sensitivity control knob (disc), on/off switch and search head cable entry.*

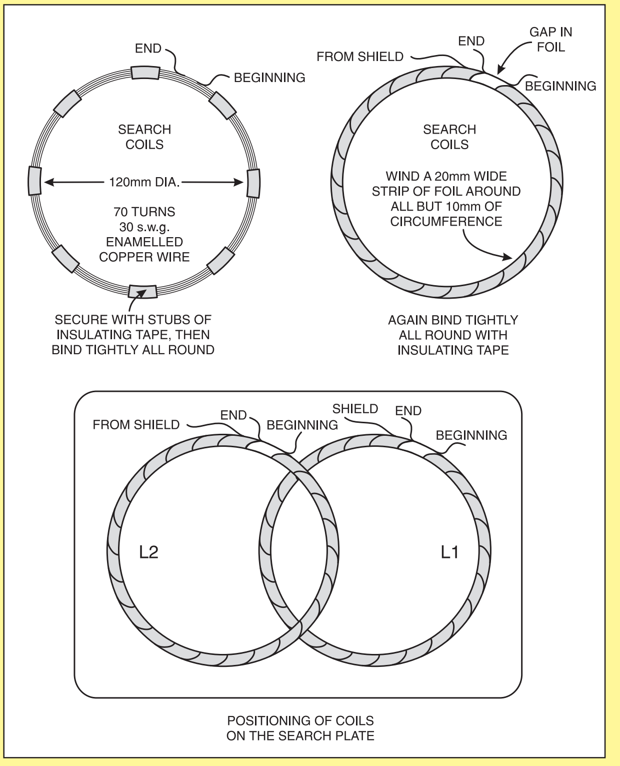



*Fig.3. Suggest coil winding details and general positioning of coils on the search head plate. The full coil winding sequence is shown in the photographs.*

## CIRCUIT BOARD

The Beat Balance Metal Detector's printed circuit board measures just 50mm × 50mm. The topside component layout, wiring details and full size copper foil master are shown in Fig.2. This board is available from the *EPE PCB Service,* code 444.

This is a sensitive circuit where high frequencies are present, therefore the author recommends that IC1 should be soldered directly to the p.c.b., and that high grade components should be used throughout. Be reasonably quick with the soldering iron.

Since IC1 is a CMOS device, anti-static precautions should be observed when handling (first discharge your body to earth). Also, leave the mounting of IC1 on the p.c.b. until the last possible moment to avoid any possibility of "burn-out" when soldering other components on the circuit board.

Begin construction by soldering the solder pins, the two link wires, and jack socket SK1 in position. Then solder the two resistors (or use link wires) and the three capacitors to the p.c.b.

Solder the battery clip to the solder pins as shown, inserting the on-off switch in the positive lead. Take care to wire the battery leads the correct way round, since a mistake here could destroy IC1.

## BOXING-UP

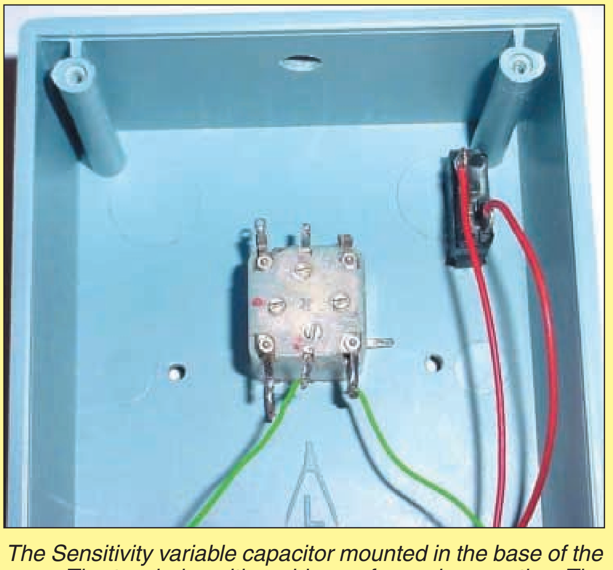
The circuit board is mounted in a small plastic case, size to choice. Holes should be drilled in the base of the case, at one end, to accept the on/off switch and for fixing the "tuning" capacitor VC1 and p.c.b. The resulting space at the other end is to accommodate the battery pack. Holes should be drilled in the opposite ends of the box to allow entry for the earpiece jack plug and search coils screened leads.

Secure the coil leads, at the entrance hole, with a cable-tie for strain relief purposes. Cable ties are also used at the circuit board end – see photographs.

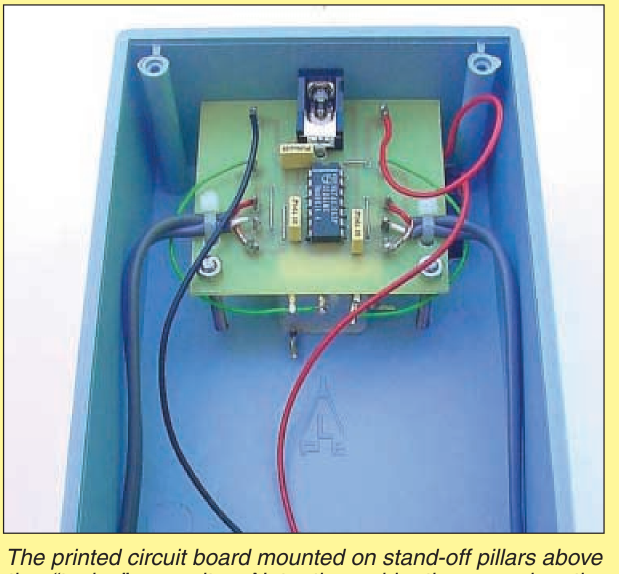
Use lengths of insulated wire to connect VC1. An insulated knob is required for VC1 to minimise capacitive coupling. In the author's prototype, VC1 was clamped underneath the p.c.b. That is, the p.c.b. was bolted on top of VC1.

## COIL WINDING

The winding of the two search coils is relatively easy and is not too critical. The full coil winding and suggested construction details are shown in Fig.3. Each search coil is made of seventy turns of 30s.w.g. (0·315mm) enamelled copper wire wound on a 120mm diameter former.

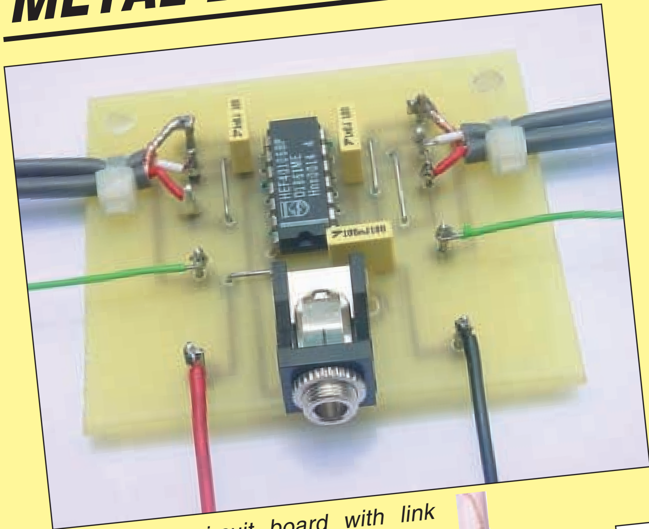


*The Sensitivity variable capacitor mounted in the base of the case. The two holes either side are for p.c.b. mounting. The larger hole in the end wall is for the jack socket.*



*The printed circuit board mounted on stand-off pillars above the "tuning" capacitor. Note the cable ties securing the screened figure-8 microphone cable from the search coils.*

# BEAT BALANCE METAL DETECTOR



Completed circuit board with link wires replacing R1 and R2.

## Characteristics . . .

The main characteristics of the Beat Balance Metal Detector may be described as follows:

- Depending on the way it is designed, a b.b. circuit potentially offers the same sensitivity as an i.b. type
- It requires no receiver amplifier or level detector, thus greatly simplifying the design and reducing cost. The present circuit uses just five components (plus search coils), yet matches the performance of a budget i.b. detector
- Both search oscillators are identical, therefore the detector offers high immunity to voltage and temperature variations. This obviates the need for compensation circuits, including voltage regulation
- Each search coil has the opposite response to metal, thus it has a high degree of immunity to ground mineralisation. At the same time, it offers good discrimination at the point where the coils overlap

## COMPONENTS

**Resistors**
R1, R2 — 470Ω (2 off – see text)
All 0·25W 5% carbon film

See SHOP TALK page

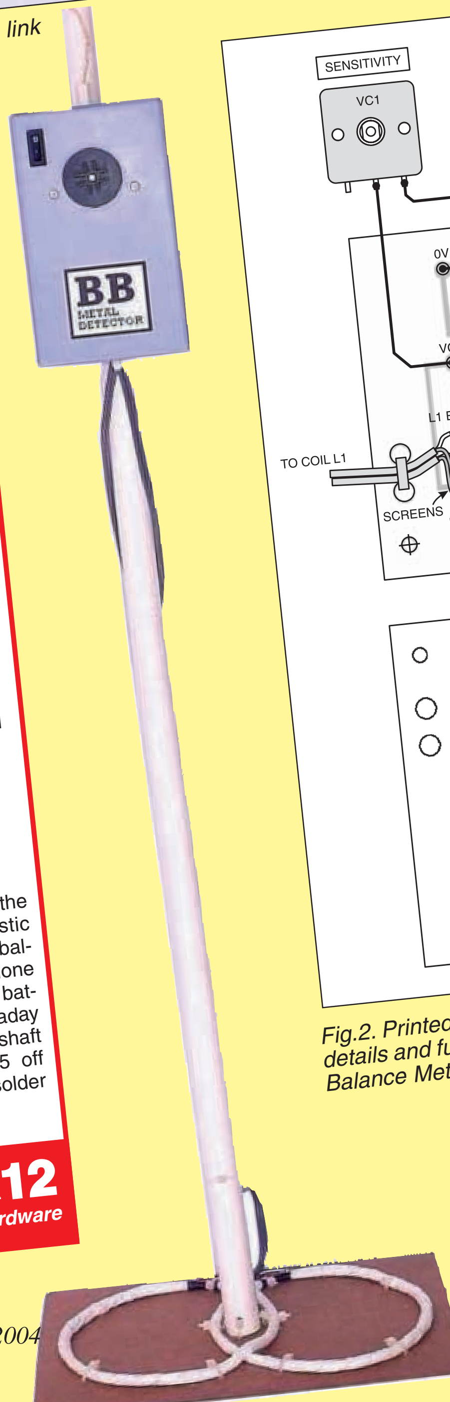
**Capacitors**
C1, C2 — 1n polyester (2 off)
C3 — 100n polyester
VC1 — 5p to 140p polythene dielectric variable capacitor

**Semiconductors**
IC1 — 40106B hex Schmitt inverter (see text)

**Miscellaneous**
S1 — s.p.s.t. min. toggle switch
SK1 — 3·5mm p.c.b.-mounting mono jack socket
L1, L2 — 30 metres 30s.w.g. (0·315mm) enamelled copper wire for the search coils (2 off)
X1 — crystal earpiece with 3·5mm jack plug
B1 — 12V battery pack (8 × AA), with holder

Printed circuit board available from the *EPE PCB Service*, code 444; plastic case, size and type to choice; 3m balanced (figure-8) screened microphone cable; plastic control knob or disc; battery clips; aluminium foil for Faraday shield; hardware for base plate, shaft and handle; 2·5mm cable ties (15 off minimum); solder pins; link wires; solder etc.

*Approx. Cost Guidance Only* **£12** *excl. batts & hardware*





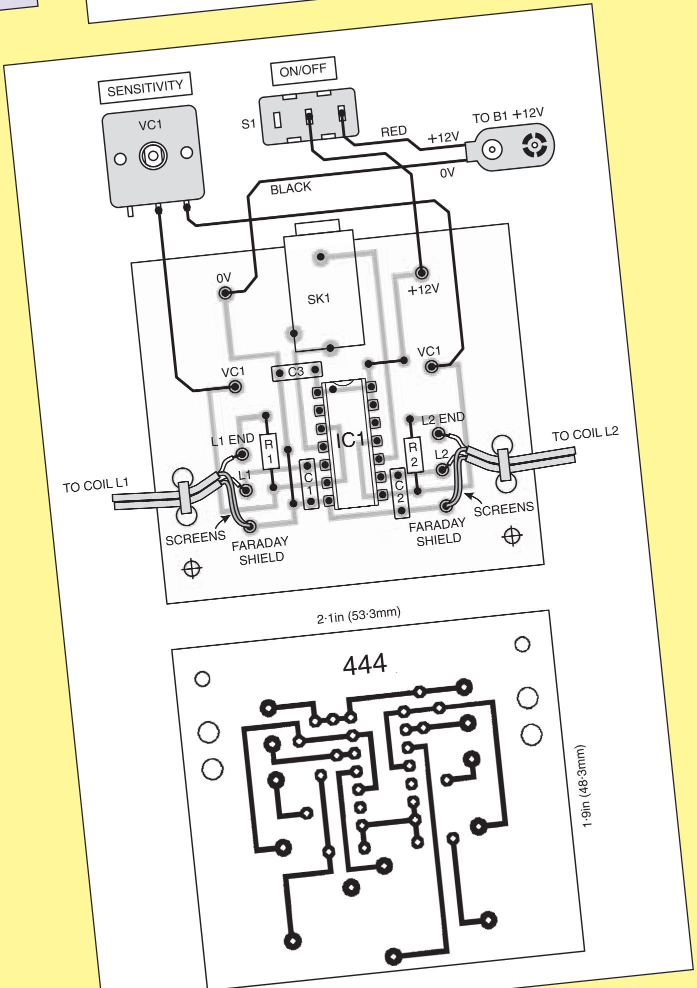
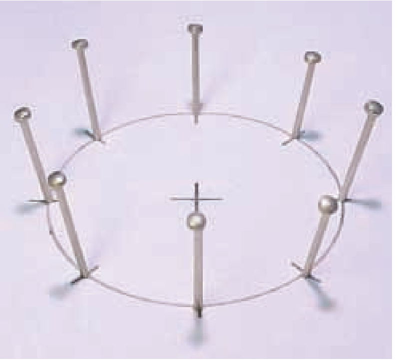




*Fig.2. Printed circuit board topside component layout, wiring details and full-size underside copper foil master for the Beat Balance Metal Detector.*



*Search coil "pin guide" former, splayed outwards, in a 120mm diameter circle.*

*Enamelled copper wire (30s.w.g.) wound around the guide pins.*

*Strips of insulating tape used to hold coil windings together.*

*Taped-up coil and start of the Faraday shield; bared wire.*

*Tin-foil Faraday shield, awaiting final covering of insulating tape.*

You must keep track of the beginning and end wires of the coils, since the turns need to "point in the same direction" when the coils are fixed on the search head. The orientation of the coils can ultimately make 20% difference to sensitivity.

Using 30s.w.g. enamelled copper wire, wind 70 turns on a 120mm diameter former. You can create the former by using a piece of stiff card or softwood with a series of guide pins or nails stuck in a circle around the required size former diameter. The heads of the pins should be splayed slightly outwards to help hold the windings in position.

A little give and take is permissible in the winding of these coils. Each coil, once it has been wound, is temporarily held together with stubs of insulating tape passed under the coil and pressed together over the top.

Scrape the enamel off the ends of the search coils' enamelled copper wires, ready for soldering them to the connecting cables. These should be balanced (figure-8) screened microphone cable, as opposed to twin-core "stereo" cable.

Once a coil has been wound, it is tightly bound by winding insulating tape around its entire circumference.

## FARADAY SHIELD

Each coil now needs the "protection" of a Faraday shield. Faraday electrostatic shields are essential. These serve to reduce ground effect and capacitive coupling in particular.

Twist a 100mm length of bare wire round each coil, over the insulating tape. This provides electrical contact for the Faraday shield, and is soldered to the connecting cable's screen. The shields will eventually be connected to the 0V line, via the bared wire and cable screen, at the p.c.b.

Beginning at the base of the bare wire, wind long, thin strips of aluminium or tinfoil around the circumference of the coil, so that no insulating tape is still visible under the foil – but the foil should not complete a full 360 degrees. Leave a small gap (say 10mm) so that the foil does not meet after having done most of the round.

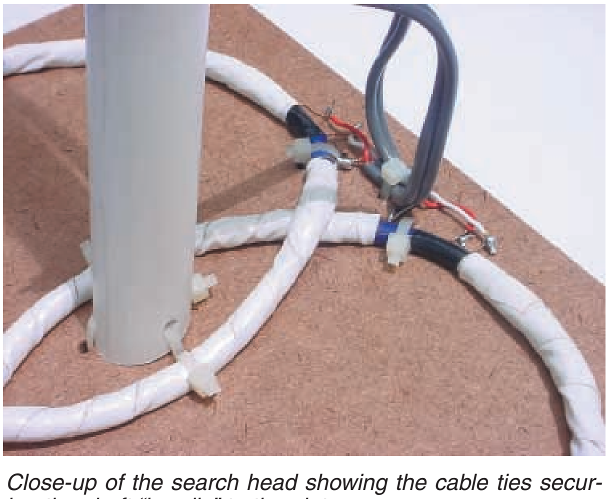
Do this with each coil. Each coil is now again tightly bound with insulating tape around its entire circumference. Attach each of the coils to quality balanced, screened microphone cable and solder the other ends of the cable to the p.c.b.

## HARDWARE

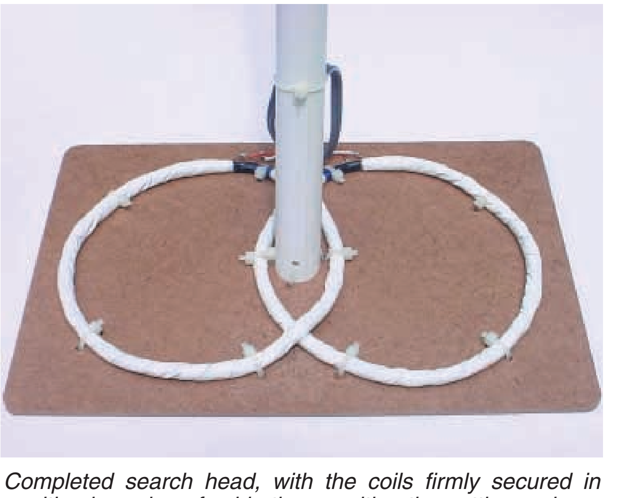
The author chose a hardware construction commensurate with the simplicity of the design. A suggested construction method, using p.v.c. piping, is shown in the photographs. We need to part tune the search coils before we complete the assembly and final setting-up.

Use a stiff, *non-metallic* plate for the search head. Any base will do, on condition that it is rigid. Hardboard (or masonite) is both stiff and easy to work with, and the author cut up a masonite clipboard for this purpose.

Begin by placing the two coils on the search head plate, directly on top of one



*Close-up of the search head showing the cable ties securing the shaft "handle" to the plate.*



*Completed search head, with the coils firmly secured in position by a ring of cable ties, awaiting the potting resin.*

another (that is, "meshed"), with their turns "pointing in the same direction". Turn Sensitivity control VC1 to its mid-position. Switch on the detector – then move the coils slowly apart.

When the coils have all but been separated from one another, a tone will be heard in the crystal earpiece. Adjust the coils' position so that this is a low tone – then drill holes in the coil plate and use cable ties (at least four for each coil) to fasten the coils in this position on the search head.

Once the cable ties have been tightened, carefully bend the coils, until a low tone is again heard in the crystal earpiece. To lower the frequency, create a greater overlap of the two coils (i.e. a larger segment in the middle), and vice versa.

To construct a shaft, saw the end off a length of p.v.c. piping at a 25 degree angle. Drill holes through the pipe close to its bottom end, and holes through the centre of the search plate. Then bind the pipe to the search plate with cable ties. (Do NOT use any metal fittings or fasteners on the search head.) The pipe (or shaft) will be fixed permanently to the search plate when clear polyester resin is poured (see below).

## POTTING-UP

The two coils need to be set rigidly in position on the search head, and the author recommends that they be potted in clear epoxy resin, which is available from most hardware stores, together with the necessary hardener or catalyst. A section of one coil should be left exposed where the two coils intersect, so as to enable final fine adjustment. This section of coil may be temporarily isolated with Blu-tack, which is later removed.

Be sure to plug the holes beneath the search head before pouring the resin, since it is very runny, and sticks faster than many glues!

The control box containing the circuit was tied to the shaft with cable ties, with a little all-purpose glue assisting. Cable ties were further used to bind the cables to the shaft. No hand grip was attached to the prototype, but the shaft was kept long at the top (see photograph), so as to rest against the back of the forearm as the shaft was gripped with the hand.

## SET-UP

To set up the b.b. detector, switch on the control unit and "tune" it for a low tone in the crystal earpiece. Bring a metal item close to the coils. It will be found that one coil causes the tone in the crystal earpiece to rise, while the other causes it to fall.

The author's prototype had no difficulty detecting an old English penny at 150mm (6in.) in air, although he would wish to guarantee only 125mm (5in.), there being a number of factors which influence sensitivity. Large metal objects will be discerned at half a metre. At close range, the b.b. detector is capable of picking up a pin.

## IN USE

When in use, hold the search head close to the ground, sweeping it slowly to and fro. While the detector is very stable, it will inevitably require readjustment by means of Sensitivity control VC1, particularly immediately after switch-on.

The author found this to be a "good natured" metal detector. It was easy to build, easy to set up, and a joy to use. It represents a basic implementation of a new idea, and the author looks forward to seeing designs that develop the concept to its full potential in years to come. □

# SHOP TALK

## with David Barrington

### EPE Teach-In '04 – Part 7

A few new items appear in this month's instalment of *Teach-In '04* series. The main parts being the miniature **R.F. Solutions** (***www.rfsolutions.co.uk***) 433MHz remote radio modules and the Holtek encoder and decoder i.c.s. Incidentally, free download radio module data sheets are available from the above web site.

The AM-RT4-433 transmitter and the AM-HRR3-433 receiver modules used in the test experiments can be purchased from **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), code 43-0200 (trans.) and 43-0210 (rec.) or from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***) as a pair, under stock code VY48C.

The Holtek HT12E encoder and the HT12F decoder i.c.s seem to be fairly widely stocked. If any readers do experience difficulty sourcing these i.c.s, they are listed by Rapid (see above) as codes 82-4076 encoder and 82-4074 decoder. The same company also supplied the Meggitt HDP-07-C1 moisture sensor, code 61-0982.

The three printed circuit boards are available from the *EPE PCB Service*, code 445 (trans.), 446 (rec.) and 447 (moisture) respectively – see page 361.

### In-Car Laptop PSU

Some readers may have problems tracking down the boost switching regulator type LM2587-ADJ used in the *In-Car Laptop PSU* projejct. This came from **Farnell** (☎ ***0870 1200 200*** or ***www.farnellinone.co.uk***), code 596-851. It is also listed by **RS Components** (☎ ***01536 444079*** or ***rswww.com*** – credit card only), code 853-567.

The *low impedance* electrolytic capacitors and the 68µH 3A inductor used in the prototype also came from Farnell (see above). The order codes are 345-1185 and 552-276 respectively.

The printed circuit board is available from the *EPE PCB Service*, code 443. Although the author does not indicate it in his article, the multiturn, top-adjust, preset is a standard cermet type.

Finally, you must **NOT** use the PSU with the car engine running. Also, take care to avoid extended use and run down the vehicle's battery.

### Low-Frequency Wien Oscillator

We do not expect readers to have any buying problems when shopping for components for the *Low-Frequency Wien Oscillator* project. The CA3240 dual f.e.t. input op.amp should be stocked by most of our components advertisers.

The author originally specified a 2-pole 4-way switch for the Range selection switch. However, readers are advised to purchase a 3-pole 4-way rotary switch as a two-pole version does not appear in any catalogue. It just means ignoring one of the poles and associated connecting tags. You may find a 2-pole 6-way version and then adjust the end-stop as required.

### Beat Balance Metal Detector

The polythene dielectric variable tuning capacitor, used in the *Beat Balance Metal Detector* project, will normally be found listed as a "transistor radio" type and consists of an antenna and oscillator section, plus trimmers. They are currently stocked by **ESR Components** (☎ ***0191 251 4363*** or ***www.esr.co.uk***), code 896-110 and **Sherwood Electronics** (see page 364), code CT9. The favoured a.m. "spread" is 20pF to 126pF, plus trimmer. The range indicated in the components list is not critical and these should be OK for this circuit.

We understand that nearly all makes of 40106 Schmitt inverter i.c.s should work in this simple circuit. However, the author's "soak tests" have indicated it does make a difference as to which manufacturer's device is used. He recommends the SGS-Thomson HCF40106BE or the Philips HEF40106BP chips be used. The Motorola MC type should be avoided for the reasons given in the article.

The printed circuit board is available from the EPE PCB Service, code 444 (see page 361). The hardware will have to be purchased from a DIY superstore or local plumbing supplier.

### PLEASE TAKE NOTE

**PIC Virus Zapper Mk2** *(Dec '03)*

Page 849 and 851. Transistor TR8 in the circuit diagram Fig.3 should be a *BC184L* and not as shown. Resistor R23 is missing from the parts list and should be 100 ohms.

Under the side-head "Matching Transistors" (page 851), TR3 and TR5 should read *TR5 and TR6*.

**PIC LCF Meter** *(Feb '04)*

The software bug affecting frequency stability for larger inductance values has been fixed and the revised code was placed on our Downloads site in early Mar '04. Also see *Readout* in this issue for discussions on capacitor stability.

**Bat-Band Convertor** *(Mar '04)*

Some constructors have reported a problem with acoustic feedback, which varies according to the receiver and the earpiece used. Happily there is a solution, namely to insert a simple 15kHz second-order high-pass filter between IC1c and IC1d, to remove lower frequency feedback.

This is done by removing the link wire between pins 8 and 12 on the p.c.b., and substituting it with two 1nF capacitors in series. Pin 12 is taken to 0V through a 10kΩ resistor, and the junction between the two 1nF capacitors is similarly taken to 0V through a 10kΩ resistor. The 10kΩ may be reduced for more stringent filtering, and the overall gain of the Convertor may be increased by raising the values of R6 and/or VR2.

**Loft Light Alarm** *(Apr '04)*

Page 236, Fig.1. The value of the l.e.d. ballast resistor R2 in the circuit diagram should, of course, be 470 ohms and not as shown. The components list is correct.

# EVERYDAY PRACTICAL ELECTRONICS BACK ISSUES

We can supply back issues of *EPE* by post, most issues from the past three years are available. An *EPE* index for the last five years is also available at **www.epemag.wimborne.co.uk** or see order form below. Alternatively, indexes are published in the December issue for that year. Where we are unable to provide a back issue a photocopy of any *one article* (or *one part* of a series) can be purchased for the same price. Issues from Nov. 98 are available on CD-ROM – see next page – and issues from the last six months are also available to download from **www.epemag.com**. Please make sure all components are still available before commencing any project from a back-dated issue.

## DID YOU MISS THESE?

### JAN '03

**PROJECTS** ● *EPE* Minder ● F.M. Frequency Surfer ● Wind Speed Meter ● PICAXE Projects–3 (Chaser Lights).
**FEATURES** ● Who Really Invented The Transistor ● TechnoTalk ● Circuit Surgery ● Practically Speaking ● New Technology Update ● ● Ingenuity Unlimited ● Net Work – The Internet Page.

### FEB '03

**PROJECTS** ● Wind Tunnel ● Brainibot Buggy ● Back To Basics–1 (Hearing Aid, Audio Power Amplifier) ● Tesla High Voltage Transformer.
**FEATURES** ● In The Bag ● Techno Talk ● Circuit Surgery ● New Technology Update ● Interface ● Ingenuity Unlimited ● Net Work – The Internet Page.

### MAR '03

**PROJECTS** ● Wind-Up Torch Mk II ● 200kHz Function Generator ● Driver Alert ● Back-To-Basics–2 (Metal Detector, Simple Timer).
**FEATURES** ● Ingenuity Unlimited ● Practically Speaking ● Techno Talk ● New Technology Update ● Circuit Surgery ● Peak LCR Component Analyser Review ● Net Work – The Internet Page.

### APR '03

**PROJECTS** ● Atmospherics Monitor ● Intelligent Garden Lights Controller ● Back-To-Basics–3 (Touch Light, Plant Watering Reminder) ● Earth Resistivity Logger–Part 1.
**FEATURES** ● Ingenuity Unlimited ● Techno Talk ● New Technology Update ● Circuit Surgery ● Interface ● Network – The Internet Page ● *SPECIAL SUPPLEMENT* – EPE PIC Tutorial V2–Part 1.

### MAY '03

**PROJECTS** ● Super Motion Sensor ● Earth Resistivity Logger – Part 2 ● Door Chime ● Back-To-Basics–4 (Live Wire Detector, Medium Wave Radio).
**FEATURES** ● Ingenuity Unlimited ● Techno Talk ● Practically Speaking ● Circuit Surgery ● Net Work – The Internet Page ● *SPECIAL SUPPLEMENT* – EPE PIC Tutorial V2 – Part 2.

### JUNE '03

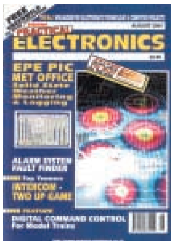
**PROJECTS** ● Fido Pedometer ● PICronos L.E.D. Wall Clock–Part 1 ● Back-To-Basics–5 (Mini Theremin, Twilight Switch) ● Radio Circuits–1 (Crystal Set, MK484 TRF Receiver, Headphone Amplifier).
**FEATURES** ● Ingenuity Unlimited ● Techno Talk ● Interface ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page ● *SPECIAL SUPPLEMENT* – EPE PIC Tutorial V2 – Part 3.

### JULY '03

**PROJECTS** ● EPE Mini Metal Detector ● Low Range Ohmmeter Adaptor Mk2 ● Radio Circuits–2 (Q-Multiplier, MW Reflex Radio, Speaker Amplifier) ● Ultimate Egg Timer ● PICronos L.E.D. Wall Clock – Part 2.
**FEATURES** ● Ingenuity Unlimited ● Circuit Surgery ● Techno Talk ● Practically Speaking ● Flowlog Lite Review ● Net Work–The Internet Page.

### AUG '03

**PROJECTS** ● EPE PIC Met Office–1 ● Alarm System Fault Finder ● Master/Slave Intercom ● Electronic Two-Up ● Radio Circuits–3 (Regenerative Receivers).
**FEATURES** ● Digital Command Control for Model Trains ● Ingenuity Unlimited ● Circuit Surgery ● Interface ● Techno Talk ● New Technology Update Net Work – The Internet Page.



### SEPT '03

**PROJECTS** ● PIC-A-Colour ● Vibration Alarm ● Priority Referee ● EPE PIC Met Office–2 ● Radio Circuits–4 (Tuning Systems).
**FEATURES** ● Using the PIC's "High" Operator ● Practically Speaking ● Ingenuity Unlimited ● Techno Talk ● Circuit Surgery ● Net Work – The Internet Page.

### OCT '03

**PROJECTS** ● RC Car Wars ● Serial Interface for PICs and VB6 ● Practical Radio Circuits–5 (Super Regen. Receiver) ● Spooky Bug.
**FEATURES** ● PIC Breakpoint ● Ingenuity Unlimited ● Interface ● Techno-Talk ● New Technology Update ● Net Work – The Internet Page.

### NOV '03

**PROJECTS** ● PIC Random L.E.D. Flasher ● Cardboard Clock ● Practical Radio Circuits–6 (S.S.B. and Direct Conversion Receiver) ● Anyone At Home?
**FEATURES** ● Teach-In 2004 – Part 1 ● Ingenuity Unlimited ● Practically Speaking ● Techno Talk ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page.

### DEC '03

**PROJECTS** ● PIC Nim Machine ● Practical Radio Circuits–7 (Superhet Tuner) ● PIC Virus Zapper Mk2 ● Christmas Cheeks.
**FEATURES** ● Teach-In 2004 – Part 2 ● Electrotherapy ● Circuit Surgery ● Ingenuity Unlimited ● Techno Talk ● High-Speed Decimal To Binary For PICs ● Interface ● Network – The Internet Page.

### JAN '04

**PROJECTS** ● Car Computer ● Practical Radio Circuits–8 (Dual-Conversion SW Receiver) ● Bedside Nightlight ● PIC Watering Timer.
**FEATURES** ● GPS to PIC and PC Interface ● Practically Speaking ● Teach-In 2004 – Part 3 ● Ingenuity Unlimited ● Techno Talk ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page.

### FEB '04

**PROJECTS** ● PIC LCF Meter ● Sonic Ice Warning ● Jazzy Necklace ● PIC Tug-of-War.
**FEATURES** ● Surface Mount Devices ● Circuit Surgery ● Teach-In 2004 – Part 4 ● Interface ● Ingenuity Unlimited ● Techno Talk ● Net Work – The Internet Page.

### MAR '04

**PROJECTS** ● Bat-Band Convertor ● Emergency Stand-by Light ● MIDI Health Check ● PIC Mixer for RC Planes.
**FEATURES** ● Teach-In 2004 – Part 5 ● New Scientist CD-Rom Review ● Circuit Surgery ● Techno Talk ● Ingenuity Unlimited ● Practically Speaking ● Net Work – The Internet Page.

### APRIL '04

**PROJECTS** ● EPE Experimental Seismograph Logger 1 ● Infra-Guard Monitor ● Loft Light Alarm ● PIC Moon Clock.
**FEATURES** ● USB To PIC Interface ● Ingenuity Unlimited ● Teach-In 2004 Part 6 ● Interface ● Techno Talk ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page ● Pull-Out – Semiconductor Classification Data.

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## Mouse Trapped Indicator – A Tail To Tell

HUMANE (non-killing) mousetraps give no indication that they have operated so a mouse could remain in captivity for a long time, causing it much distress. One answer would be to add a switch which closes whenever the trap is operated, but this is impossible without interfering with the mechanism and thereby possibly rendering the trap unusable.

The Mouse Trapped Indicator circuit in Fig.1 was designed for use with a *Trip Trap* mousetrap obtainable from most pet shops. Ideally, the constructor should make the trap detachable from the circuit and batteries, allowing it to be taken to a field for the mouse to be released.

Diode D1 on one side of the trap transmits an infra-red beam to a receiver, D2, on the other side. When the trap is operated a small plastic flap moves into position interrupting the beam, which in turn sounds the alarm.

While the trap is untriggered, the flap remains horizontal (Fig.2a) so the unhindered beam from diode D1 reaches D2, lowering its resistance. In this situation transistor TR1 conducts and its collector voltage is held at 0V. With switch S1 set to Immediate, pin 9 of NAND gate IC1c is also held low, inhibiting the oscillator based around IC1c and IC1d.

When the trap is operated, the flap moves to a vertical position (Fig.2b) obstructing the beam, and so TR1 collector voltage goes high, enabling the oscillator. The tone is output at IC1d pin 11 and controls transistor TR3, which drives loudspeaker LS1.

### Silent Night

Rather than being alerted during the night, the user may wish to be alerted only during daylight of the following day, thereby minimising sleep disruption! Photodiode D3 is placed near a window and detects the amount of ambient light falling on it, i.e. daylight.

When sufficient light is present, the voltage at the emitter of transistor TR2 will go high. If IC1a pin is held high because a mouse has triggered the trap, the output at IC1b will turn on the oscillator when switch S1 is in the Delayed position. If the trap operates during darkness the oscillator remains disabled.

For the circuit to work properly, diode D2 must be shielded from external light sources and must be aligned with D1.

The oscillator tone may be changed by using different values for resistor R6 and capacitor C2. An active buzzer could be used in place of a loudspeaker.

Finally, follow the trap manufacturer's guidelines on locating and baiting the trap, and releasing the mouse.

**C. Embleton, Darlington, Co. Durham**

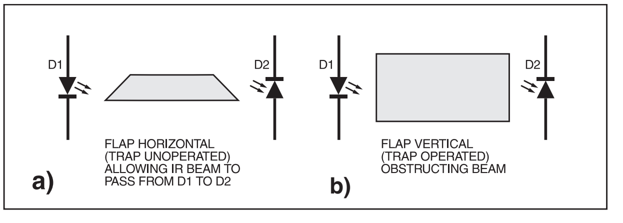


*Fig.2. Operation of the trap flap.*

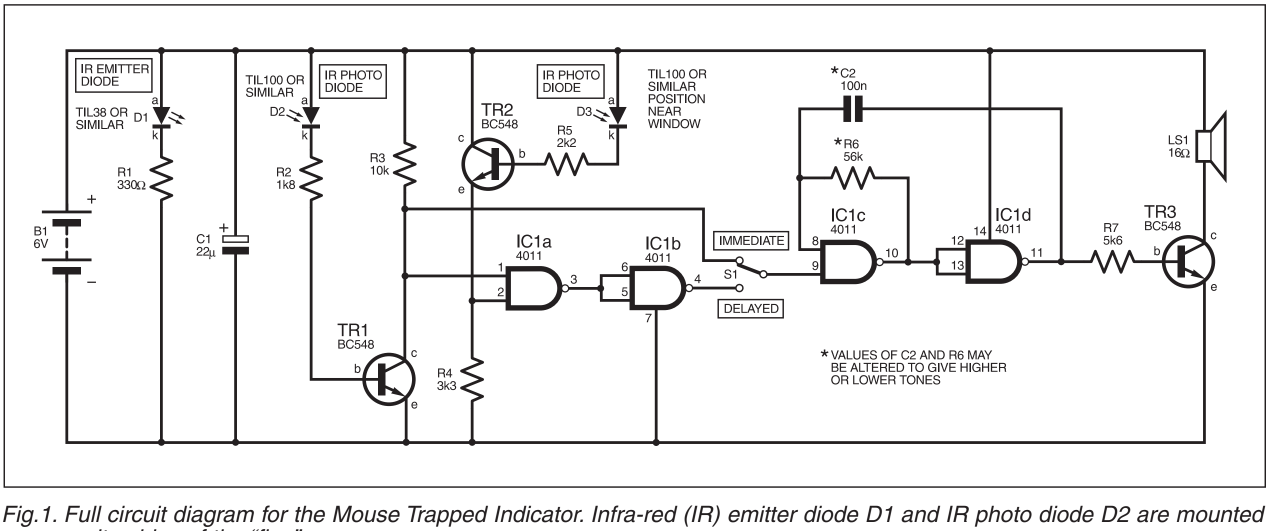


*Fig.1. Full circuit diagram for the Mouse Trapped Indicator. Infra-red (IR) emitter diode D1 and IR photo diode D2 are mounted on opposite sides of the "flap".*

# Proximity Switch – An Attractive Alternative

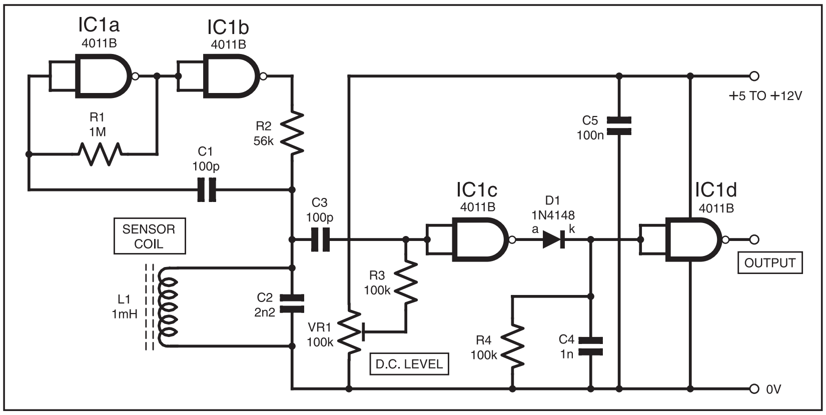


Fig.3. Circuit diagram for a Proximity Switch.

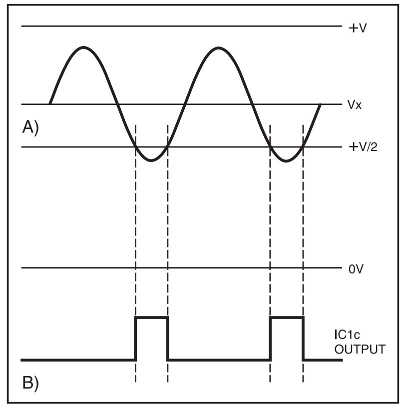


Fig.4. Switching waveforms.

THE circuit diagram shown in Fig.3 can be used to replace a microswitch or reed switch in applications where the use of a device with mechanical contacts is undesirable. Resistor R1 biases gate IC1a into a linear mode. Its output drives IC1b which drives the resonant parallel *LC* circuit comprised of inductor L1 and capacitor C2.

Overall positive feedback is applied through capacitor C1 so that the circuit oscillates, the frequency being about 120kHz with the component values shown. Resistor R2 limits the drive power to the resonant circuit so that the signal amplitude across L1 and C2 is about 3V peak-to-peak.

Inductor L1 is a small ferrite bobbin-type choke. If a metal object approaches it, a current will be induced within the object and this drains power from the choke, causing the amplitude of oscillation to fall. The output of the oscillator is applied to the input of IC1c through capacitor C3, with an adjustable d.c. level applied from the preset VR1.

This can be set so that when no metal is present the output from IC1c only just switches on the negative peaks of the signal as shown in Fig.4. This shows the input to IC1c at (A), where $V_x$ is the bias voltage from VR1, with the output from IC1c at (B).

On the approach of a metal object the amplitude drops and the output pulses from IC1c cease.

When present the output pulses keep capacitor C4 charged via diode D1 so that the output of IC1d is low. When they cease the voltage across C4 falls rapidly due to the discharging action of resistor R4, which causes the output of IC1d to change state, from low to high. Thus, a high output indicates that a metal object has been detected.

## Detection Range

The detection range depends on the target object and the type of metal of which it is made, although the circuit responds to both ferrous and non-ferrous metals. Ranges of up to 10mm are not difficult to achieve. The closer the target when switching occurs, the sharper the action.

There is a small region where the output pulses at the oscillator frequency, but in many applications this probably won't be a problem. Increasing value of capacitor C4 or resistor R4 will reduce this effect but will increase response time. A modification to reverse the output polarity so that it switches from high to low is given in Fig.5.

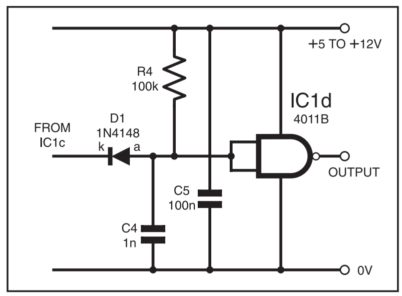


*Fig.5. Circuit modification to reverse the output polarity.*

Capacitor C2 should be a low temperature coefficient type. Decoupling capacitor C5 may not be necessary, depending upon the position of other decouplers used.

The circuit is a bit sensitive to supply voltage changes, so ideally it should have a regulated power supply. The current consumption is around 200$\mu$A with a supply of 5V. Although shown constructed from the four gates of a CMOS 4011B, four inverting gates of any type could be used, including four of the six in a 40106 hex inverter.

**Andy Flind, Somerset**

# Versatile D.C. Power Controller – Attention To Duty

THE load in Fig.6 is controlled by pulse width modulation (PWM), generated by the circuit around timer IC2 according to the formula:

Duty cycle = ((R1 + (VR1 / 2) / (R1 + R2 + VR1)) × 100%

Diode D1 is used to bypass resistor R2 and half the effective resistance of the "lower" section of VR1, allowing the duty cycle to be varied from 0·01% to 99·9%.

The output at IC2 pin 3 is fed directly to power MOSFET TR1 to control the load. For loads greater than 3A, a heatsink must be used with TR1.

The circuit is powered at 12V, regulated down to 8V by IC1. Capacitors C1, C2 and inductor L1 prevent noise being fed back into the power line when the load is being switched. Diode D2 prevents the generation of back-e.m.f. when switching inductive loads. It should be changed to a high power version if the load is greater than 3A.

**Myo Min, Yangon, Myanmar**

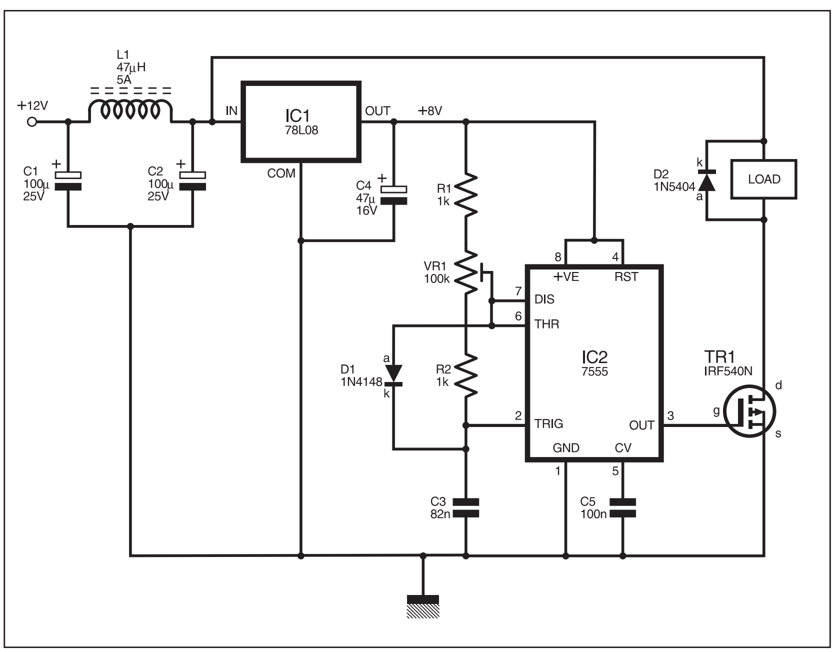


Fig.6. Versatile D.C. Power Controller circuit diagram.

# TEACH-IN 2004

## Part Seven – Moisture Detection and Radio Links

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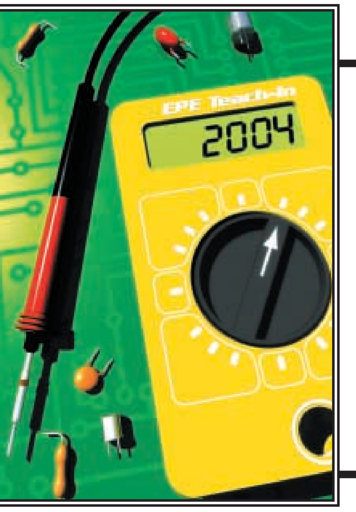



**How to apply electronics meaningfully – the aim of this 10-part series is to show, experimentally, how electronic components function as part of circuits and systems, demonstrating how each part of a circuit can be understood and tested, and offering advice about choosing components**

A SIMPLE water sensor makes a perfect "starter project", but designing a system which is reliable in the longer term is a little harder! Interestingly, major manufacturers of hosepipe equipment have had limited success in producing a system which measures when your plants need watering, and only applies the water at that time. Yet every year, hundreds of school students produce projects which do just this. The only drawback is that they would not last for the minimum guarantee period!

In this part we discuss how moisture can be detected, and then describe how an associated radio link can be set up. A fail-safe system will be devised, which illustrates the application and the use of further astable circuits. The system was created for use in a cellar which was prone to flooding, but it can be used to detect any sort of leaks or moisture detection, etc.

### DETECTING MOISTURE

We examined a simple moisture detector in Part 2, Fig.2.2, and it is reproduced here in Fig.7.1. Transistor TR1 can be any high-gain *npn* type, such as a BC549. When moisture bridges the "touch contacts", a small electric current flows through resistor R1 and into the base (b) of TR1, and this is sufficient to turn on the transistor. The transistor acts like a switch, and so allows current to flow via the buzzer, WD1.

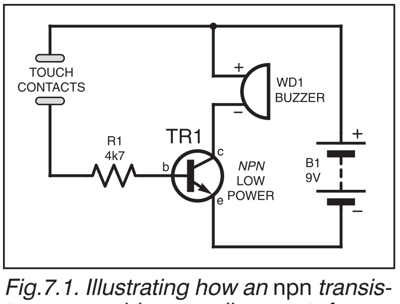



*Fig.7.1. Illustrating how an* npn *transistor can enable a small current, from a moisture sensor for example, to trigger a buzzer.*

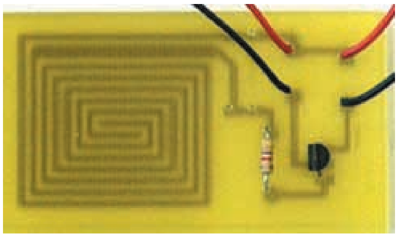


*Photo 7.1. Moisture sensing printed circuit board.*

An example of a suitable implementation for a moisture detector is shown in Photo 7.1. This printed circuit board (p.c.b.) is available from the *EPE PCB Service*, code 447, see later. You could, though, make an equivalent using stripboard, joining alternate tracks together and connecting them back to a breadboard assembly of Fig.7.1. The buzzer will sound if moisture bridges across between the tracks. Even the moisture in your breath could trigger it!

This detector will survive long term use as it is generally dry, and so no current is flowing. However, if made wet for a long period, the copper tracks will deteriorate due to a combination of oxidation (which causes copper to turn green), and electrolysis, where the flow of electricity between the tracks will cause the copper tracks to disintegrate. Even a roller-tinned ready-made p.c.b. will suffer in time.

### POTENTIAL CONTROL

An immediate problem, though, is the lack of control over the system in Fig.7.1. The sensitivity of the circuit depends upon the particular transistor in use (ignoring the influence of the actual distance between the sensing tracks). So a "lively" transistor (i.e. one with a high gain) will cause the circuit to respond more quickly than a transistor with a lower gain. In some circumstances, the circuit may respond inappropriately; in a damp cellar, for example, the buzzer may sound all the time. We need to control the response.

In earlier parts we have shown how a potentiometer can be used to control the sensitivity of circuit. A potentiometer is really a variable potential divider (previously discussed in Parts 1 and 2). It is appropriate to discuss now the principles of a potential divider in a bit more detail.

A potential divider (or voltage divider) is simply two or more resistors in series between two voltage levels. Consider the circuit in Fig.7.2. If the two resistors are of equal value, say 1kΩ, the voltage at their junction (call it the "output") will be half of the supply voltage. In this case the supply is 12V so the output will be 6V. (Also see Part 3 where the values of resistors in potential dividers were discussed – the "Rule of Ten").

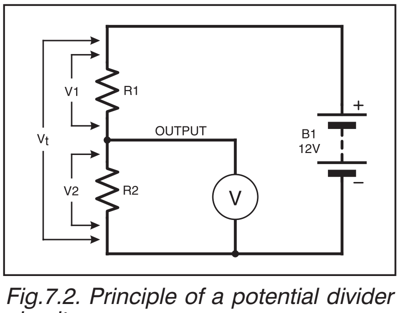



*Fig.7.2. Principle of a potential divider circuit.*

If the two resistors are of different values, the situation is more complicated! There are several ways of calculating the voltage at the output; you could for example, use Ohm's Law to find the current flowing and hence calculate the voltage difference (potential difference) across each resistor.

The generally favoured method is by means of ratios. This makes use of Ohm's law without it being obvious. In Fig.7.2, Vt is the total supply voltage, in this case 12V. V1 is the voltage across resistor R1, and V2 is the voltage across R2:

The total voltage Vt = V1 + V2

Also, Vt / (R1 + R2) = V1 / R1
= V2 / R2

Suppose R1 = 2kΩ and R2 = 4kΩ. We already know the voltage Vt to be 12V. To calculate the output voltage V2 we say:

12 / (2k + 4k) = V2 / 4k
hence 12 / 6k = V2 / 4k
thus V2 = 12 × 4k / 6k = 48k / 6k = 8V

Since Vt = V1 + V2, it thus follows that V1 = 4V.

Potential dividers are employed in virtually every analogue electronic circuit, and play a major part in sensor circuits, whether for moisture, temperature or light, etc.

Suppose we change resistor R1 in Fig.7.2 for a resistive sensor (one whose resistance changes with the surrounding conditions). Resistor R2 remains as a fixed resistor, whose resistance should roughly match the resistance of the sensor when under average conditions. Then, if the sensor's resistance decreases, the output voltage will rise; or if it increases, the voltage will fall.

If we wish the output voltage to fall rather than rise when the sensor's resistance decreases, simply swap the positions of R1 and R2.

It is often very difficult to predict the value of the fixed resistor to match the sensor's resistance in all circumstances. So it is wise to replace it with a variable resistor (potentiometer, or pot). This is illustrated in Fig.7.3. It is preferable to use a preset type of pot rather than one with a control knob.

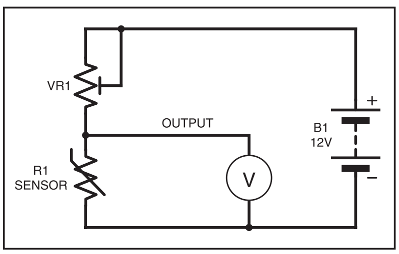



*Fig.7.3. A preset potentiometer and resistive sensor as a potential divider.*

Note that it is good practice to connect the spare end of the potentiometer to the wiper (moving contact), so that any dust inside the pot cannot cause an open-circuit. The value of the pot is not critical (within the "Rule of 10" proviso referred to earlier), as long as it is fairly well above the expected resistance required.

## PROCESSING THE OUTPUT

We have already examined the main types of processing circuit, based on transistors (Part 2), op.amps (Part 3) and logic gates (Part 4). They all have relative advantages, including:

- Transistors: quick, easy and cheap. Plenty of current available, wide voltage range, but can die readily if misused.
- Op.amps: easily controllable and more forgiving of misuse.
- Logic gates: particularly useful if you also wish to digitally process the signal together with other signals, e.g. using AND, OR functions etc.

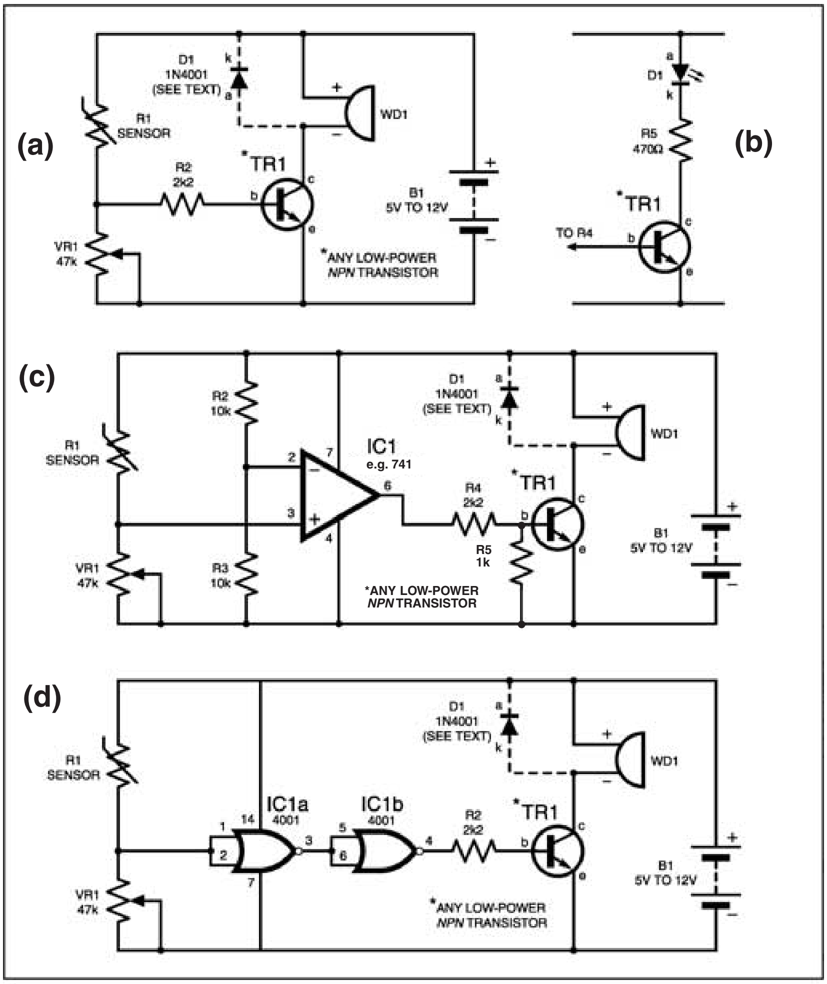



*Fig.7.4. Three techniques for monitoring a resistive sensor, plus l.e.d. output instead of a buzzer.*

Note that op.amp and logic gate circuits may (depending on type) also require a transistor on their output to supply sufficient current to drive a device such as a buzzer or motor.

## PRACTICAL CIRCUITS

Three circuits suitable for interfacing with a resistive sensor are shown in Fig.7.4 (*a*, *c* and *d*). You could experiment using a light dependent resistor (l.d.r.) such as an ORP12, or a temperature sensor such as a thermistor (an n.t.c. type rated for 5kΩ at 25°C is suggested), but it is intended later that the moisture sensor referred to above should be used.

The circuit in Fig.7.4a interfaces the sensor to a single *npn* transistor, TR1. Notice that the sensor has been placed on the upper of the potential divider. This means that when its resistance falls, the voltage at the divider's output will rise, eventually turning on TR1. The transistor is shown driving a buzzer (WD1), though in practice this could be a solenoid, motor etc.

The circuit in Fig.7.4b shows how an l.e.d. instead of a buzzer could be driven by transistor TR1. This circuit also applies to the circuits in Fig.7.4c and Fig.7.4d about to be described.

Remember that transistor TR1 must be capable of switching the current required by the buzzer etc., and that a protective diode (D1) should be fitted if an inductive item such as a motor or solenoid is used. These points were covered in Part 2.

It should be noted that the circuit in Fig.7.4a does not adhere to the "Rule of Ten" (Part 3), in that the value of resistor R2 is likely to be far lower than the resistance of sensor R1.

The circuit in Fig.4a is cheap and cheerful, but the buzzer will not switch on cleanly, and accurate control may be difficult. A better solution is shown in Fig.7.4c. Here an op.amp is wired as a comparator. This provides a much better and cleaner response. It has been connected so that as the resistance of the sensor falls, the transistor will switch on. This type of circuit was discussed in detail in Part 3.

The circuit in Fig.7.4d shows how logic gates can be used as the interface. The gates are based on a CMOS 4001 NOR gate, but in practice any type of gate (AND, NAND, NOR) can be employed providing the logical conditions required are obeyed, as discussed in Part 4.

Remember that the inputs of unused gates must be connected to a definite logic level, such as 0V (i.e. not left "floating"). You should also discharge static electricity from your body before handling CMOS devices, as also discussed in Part 4.

Referring to Fig.7.4d, there is always a danger that if the resistance of the sensor changes very slowly, the output of the two gates can waver. However, circuits (c) and (d) could easily be converted to a Schmitt trigger action if required, and the principle for Fig.7.4c was discussed in Part 3. To provide the equivalent action for Fig.7.4d, a

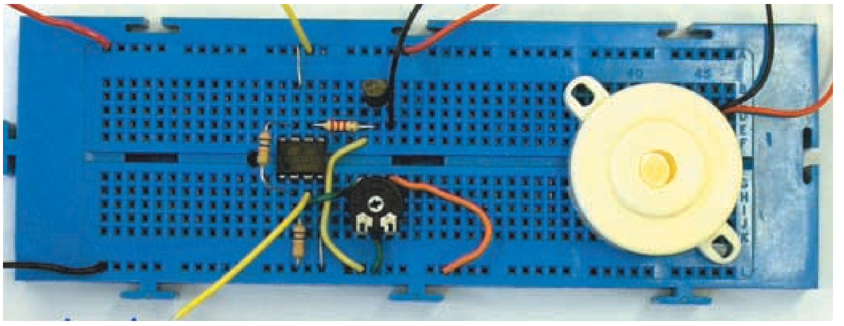


Photo 7.2. Breadboard test assembly for the circuit in Fig.7.4c.

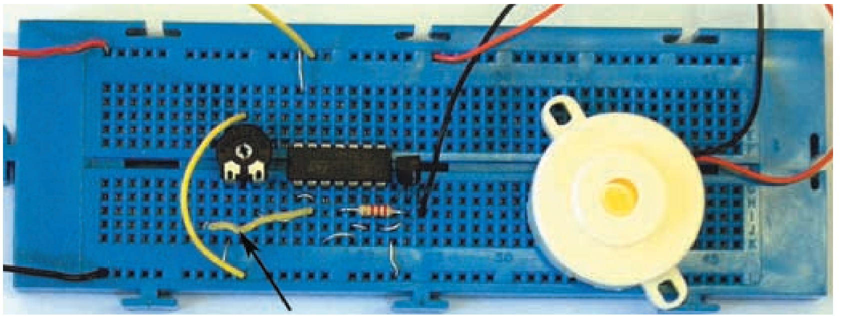


Photo 7.3. Breadboard test assembly for the circuit in Fig.7.4d.

CMOS 4093 quad Schmitt trigger NAND gate could be used.

All the circuits described so far require a direct current (d.c.) to flow through the sensor. In the case of a moisture sensor, this can cause the electrodes to wear out due to electrolysis (as said earlier). If an alternating current (a.c.) is used, electrolysis is less likely to occur and so the electrodes (p.c.b. or stripboard tracks in this case) last much longer.

This aspect is beyond the coverage of this *Teach-In* part, but the information on a.c. coupling given in earlier parts of this series should help you to experiment.

Should you wish to experiment further with moisture sensing, a browse through a good catalogue will reveal a number of moisture sensors now available, including the Meggitt type HDP-07-C1 (Rapid code 61-0982). This tiny sensor has a resistance of less than 1kΩ when dry, rising to many thousands of ohms when wet. It is not designed to be permanently wet, but provides a reliable indication of "dryness". The resistance of the sensor can be tested with a multimeter.

The whole business of moisture sensing has been spurred on recently by the use of air conditioners, automatic tumble dryers, and the sensors used in video recorders and camcorders to ensure that the revolving heads are absolutely dry.

## RADIO COMMUNICATION

The area being monitored for moisture content, such as a cellar, is often out of earshot of the user, and so a link is needed in order that the warning buzzer can be heard. A long cable could be considered, but the cost of low-power radio modules has fallen to the extent that these provide an easy solution.

The pair of radio modules shown in Photo 7.4 illustrates their size in relation to a small coin (5p). The smaller of the two modules is the transmitter. Note that these and similar modules are designed for information transfer, not speech.

In the UK, the use of 418MHz for this type of application has been phased out, and 433MHz is recommended. Other frequencies available "off the shelf" include 315MHz and 868MHz. Always check that the frequency proposed is allowed in the country concerned, to ensure that your system does not interfere with other users.

In practice, the range of these modules is quite short (less than 100 metres), and so you are unlikely to suffer from or cause radio interference.

Note that in the UK, 433MHz is a legal frequency to use without a transmitting licence, on the assumption that the modules are purchased ready built and tuned, and are not tampered with!

## CHOOSING RADIO MODULES

At present, radio modules designed for amplitude modulation (a.m.) are a little cheaper than those designed for frequency modulation (f.m.). In general, f.m. is more immune from interference and should have a longer range, though in practice a.m. modules have been found to work very well, and so are suggested for use in the cellar link described here.

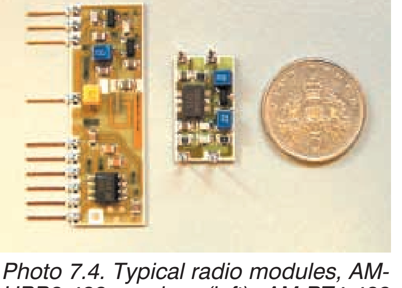


Photo 7.4. Typical radio modules, AM-HRR3-433 receiver (left), AM-RT4-433 transmitter (centre), and a 5p coin for scale.

Any compatible pair of modules can be chosen, but the range available can easily cause confusion, and so some suggestions may help:

**Transmitter**

A suitable a.m. transmitter is type AM-RT4-433. (Also available is type AM-RT5-433, which is electrically identical, though with a different pin layout.) The pinouts for the AM-RT4-433 are shown in Fig.7.5.

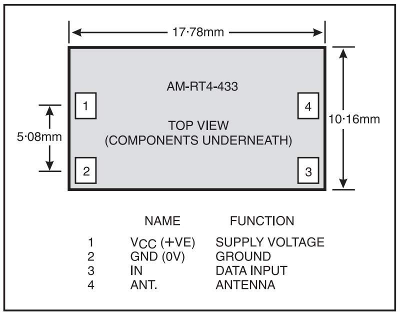



Fig.7.5. Pinouts for the AM-RT4-433 transmitter module.

The antenna (aerial) should be a straight piece of wire, having a length of 15cm. Note that increasing the length of the antenna may reduce the range. If the antenna is bent around the casing of the circuit, the range may also be reduced, though this might not matter in the application proposed. The power supply can be between 2V and 14V.

**Receiver**

A compatible a.m. receiver is type AM-HRR3-433. This is designed for a 5V supply and has a rather limited voltage range of 4·5V to 5·5V (a range which ***must not*** be exceeded). A low power version is available, namely AM-HRR6-433, and if the receiver is battery powered, this could be useful, if more expensive. In addition, a low voltage (3V), low power version is available, the AM-HRR8-433.

Pinouts for the AM-HRR3-433 are shown in Fig.7.6. Don't be caught out by the curious pin numbering system, where missing pins still count as numbers.

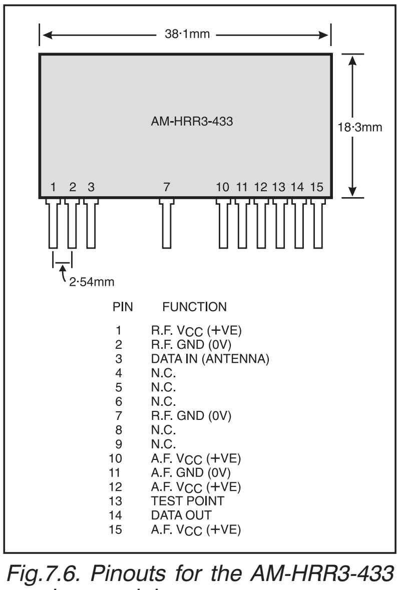



Fig.7.6. Pinouts for the AM-HRR3-433 receiver module.

As with the transmitter, the antenna should be a piece of straight wire of length 15cm, and connected to pin 3. The r.f. (radio frequency) section of the module has its own power supply where pin 1 is positive, and pin 2 is ground (0V), and although these are powered from the same supply as the rest of the circuit, some care is needed to ensure that they are free from interference from other parts of the project. A decoupling capacitor of about 100nF connected physically close to these pins should remove such interference.

The positive power supply should also be connected to pins 10, 12 and 15. The 0V rail should be connected to pins 2, 7 and 11. Pin 13 is a test point and is generally left unconnected (from which the received signal strength can be measured). It should be found that the data output at pin 14 is an accurate replication of that at the data input pin on the transmitter module.

Data sheets for the transmitter and receiver modules can be downloaded free from **www.rfsolutions.co.uk**.

## ENCODERS/DECODERS

It is possible to input a signal directly into the transmitter module, and receive the message from the receiver. However, the system will be prone to stray interference, and therefore fairly unreliable. An encoder/decoder pair of i.c.s when used with the system can provide a more reliable link. Several such i.c.s are available, and the ones considered here are from Holtek, namely the HT12E (encoder) and HT12F (decoder), whose pinouts are shown in Fig.7.7.

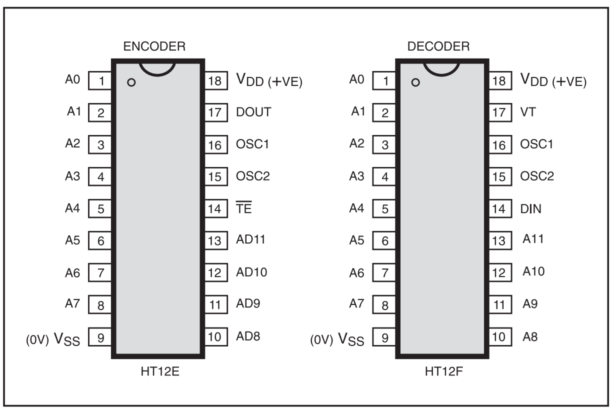



*Fig.7.7. Pinouts for the Holtek HT12E and HT12F encoder/decoder i.c.s.*

Both i.c.s can operate on a supply of between 3V and 12V, though a 5V supply is ideal. The pins labelled A0 to A7 and AD8 to AD11 are used to set the code, by connecting a certain combination to 0V. In other words, if you connect say, A1 and A6 to 0V on the encoder, you must also connect A1 and A6 to 0V on the decoder. Unused coding pins of these devices may be left unconnected as they have internal pull-up resistors which prevent them from floating. There are 4096 code variations available ($2^{12}$).

Data sent by any nearby system using the same radio frequency will not interfere with your system unless the same pins are tied to 0V. A set of small d.i.l. (dual-in-line) switches can be used to set the required code, if you wish to be able to change it, otherwise a certain combination of pins can be connected to 0V permanently using link wires.

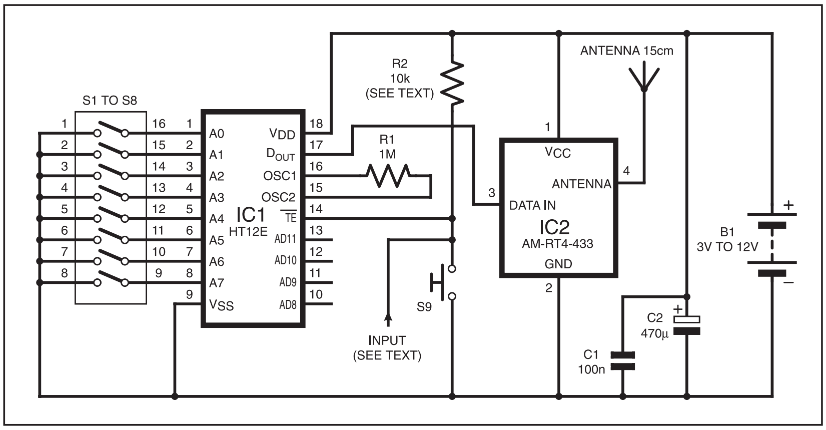



*Fig.7.8. Encoder and transmitter circuit.*

Note that transmitters on the same frequency *can* still jam each other, but the unique coding will at least prevent the data crossing from one system to another. We show later that the transmitter can be used to produce only a brief pulse, so reducing the chance of interference to others.

It is also worth noting that on the encoder, pins 10 to 13 are labelled AD8 to AD11, whereas the same pins on the decoder are labelled A8 to A11. These are the manufacturer's notations, but the pins have the equivalent coding effect.

The pins labelled OSC1 and OSC2 are designed to allow a single resistor to set the oscillating frequency. Hence on the encoder, a 1MΩ resistor will set a frequency of about 3kHz. This does not concern the user directly, except that the decoder frequency must be 50 times higher, i.e. 150kHz. Hence a 51kΩ resistor must be connected across the OSC (oscillator) pins on the decoder. (In tests the exact value of this resistor did not seem important, and the more standard value of 56kΩ should be fine.)

The HT12E encoder sends the signal when pin 14 ($\overline{TE}$) is connected to 0V. When the signal is successfully received and then decoded by the HT12F, pin 17 (VT) switches high.

## TRANSMITTER CIRCUIT

The full schematic for the encoder and transmitter circuit is shown in Fig.7.8. IC1 is the encoder, and resistor R1 sets its oscillator frequency. As stated earlier, encoder address pins A0 to A7 can remain unconnected, but if they are wired through a d.i.l. switch module (S1 to S8) as shown, they can set the address to ensure that neighbouring systems do not cause mutual interference. We have chosen to leave pins AD8 to AD11 unconnected, but these too can be used to further encode the system.

Resistor R2 biases pin $\overline{TE}$ (transmit enable) high, allowing switch S9 to pull it low when pressed, so causing IC1 to transmit the code on its encoding pins as a serial stream of highs and lows (binary 1s and 0s) from output pin DOUT. When not transmitting, this pin remains high. Transmitter module IC2 only transmits when its Data In pin is at 0V.

An external control source can be used instead of switch S9 (as we show next), but note that this source must only provide control signals whose logic voltage levels are the same as those of the power supply, otherwise damage could occur.

The circuit consumes very little power unless switch S9 is pressed. Even then the power consumption is quite low.

Capacitors C1 and C2 decouple the power supply, C1 removing spikes, and C2 removing larger ripples. Since C2 is electrolytic it must be connected with its positive side as shown.

## TRANSMITTING SENSOR DATA

We can now connect the transmitter module's $\overline{TE}$ input to one of the moisture sensing modules shown in Fig.7.4. One point to watch is that this input requires a 0V pulse to trigger the transmitter. All three modules in Fig.7.4 (*a*, *c* and *d*) can achieve this, taking the output from the collector TR1 in all cases. For the moment, though, we will adopt the op.amp circuit in Fig.7.4c as this is the most sophisticated circuit of the three.

It is also recommended that you replace the buzzer with an l.e.d. in series with a resistor of 470Ω, as shown in Fig.7.4b. The l.e.d. will be useful for testing, and you will not hear a buzzer in the cellar anyway. Note that if the "fail-safe" version of the system is required, you can adopt the circuit in Fig.7.4d, as shown later.

Since the sensor will normally be dry, a simple pair of conductors can be used to make a sensor. These can be formed from tracks on a piece of stripboard, or you can use the p.c.b. shown for the breath sensor. The circuit is configured to react if the resistance of the sensor falls, and this means that moisture across the tracks will cause the output of op.amp IC1 in Fig.7.4c to go high. This in turn switches on transistor TR1 and the l.e.d. As the collector of TR1 switches from high to low, this is the ideal point from which to trigger the input of the transmitter circuit.

If you wish to use the commercial Meggitt sensor mentioned earlier, you can

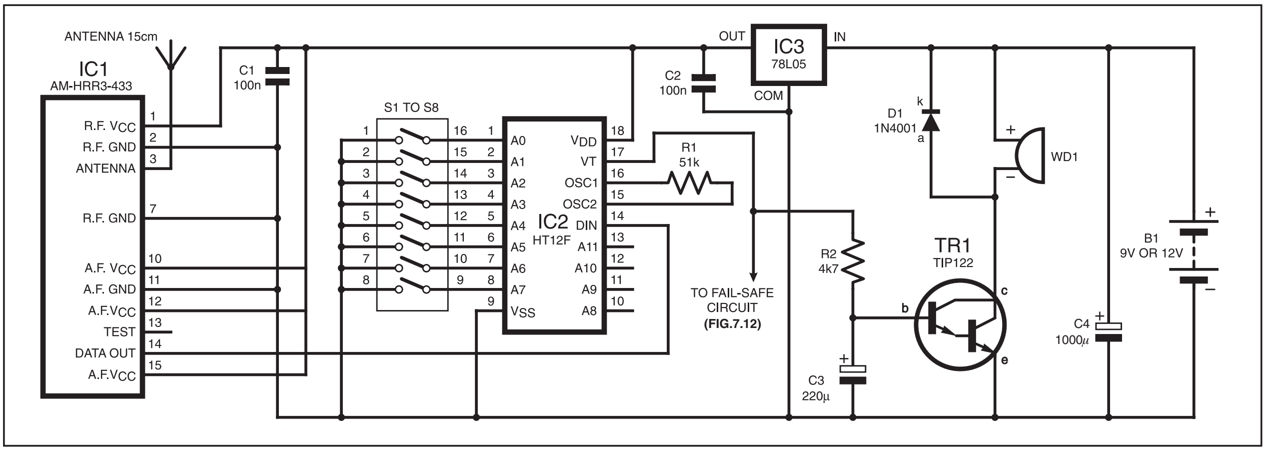



*Fig.7.9. Receiver, decoder and driver circuit.*

either exchange resistor R1 with preset VR1, or exchange the connections to IC1's inputs 2 and 3.

## RECEIVER CIRCUIT

The circuit for the receiver and decoder is shown in Fig.7.9. The receiver module, IC1, is a fairly straightforward device to wire up, since most of the connections go to positive or 0V. Note that capacitor C1 should be connected physically close to the r.f. power supply pins (1 and 2).

The output from the receiver module is connected to the data input (DIN) of decoder IC2. The oscillator frequency for this is set by resistor R1, and the value of 51kΩ produces the required 150kHz.

Address pins A0 to A11 must be at exactly the same settings as in the transmitter's IC1 encoder, i.e. either remain unconnected, or joined to 0V, either as link wires or via switches S1 to S8 if used.

When a correctly encoded signal is received, pin 17 (VT) goes high, and this triggers Darlington transistor TR1, via buffer resistor R2, and hence turning on buzzer WD1. A Darlington is suggested as a loud buzzer or siren may be required, needing more power to drive it. Diode D1 is required if the buzzer is likely to produce "back e.m.f.", as commented earlier. If in doubt, include D1 as it will do no harm.

Capacitor C3 is optional, but serves to delay the turning on of transistor TR1 (and the buzzer) when only short pulses from IC2 pin VT are received. This eliminates an irritating bleep from the siren every second or so, caused by the repetition of the fail-safe pulse (about to be described). Only if a flood has occurred does C3 charge sufficiently to turn on the siren.

As said, the supply voltage must in the range 4·5V to 5·5V to suit the receiver. Regulator IC3 reduces to 5V the power supply voltage (which may be between 9V and 12V), with capacitors C2 and C4 helping to provide power smoothing.

## FAIL-SAFE OPTION

At present, if our flood detection system were to fail, it would do so silently! In other words, if the power supply of the transmitter fails there is no indication of the problem at the receiver. What we need is a fail-safe system – a system which transmits a regular radio pulse just to show that all is well.

The classic heart-beat fail-safe monitor will be described in detail next month, but for this flood detection application, we will describe a simple system which fulfils the present need.

We will start with the transmitter, and develop a circuit which supplies regular brief pulses. Each pulse will be like repeatedly pressing switch S9 in Fig.7.8 for a very short time.

A circuit which supplies regular pulses is known as an astable, and an astable based on logic gates was shown in Part 4 Fig.4.26 and Fig.4.27. This type of astable has an equal mark-space ratio, in other words the time for which the output is high is equal to the time for which it is low, as shown in Fig.7.10a. What we require is a long mark (remember that the transmitter only transmits when its input is at 0V), and a short space, as shown in Fig.7.10b.

An astable circuit, based on NOR gates, and which can have its mark-space ratio changed is shown in Fig.7.11. Both gates feed a capacitor and resistor network, namely R2/C2 and R3/C3. This allows independent control over the mark/space ratio.

The inclusion of l.e.d.s D1 and D2 (and their ballast resistors R4 and R5) is for visual monitoring purposes only and are not essential to the operation of the circuit.

## MARK-SPACE CALCULATION

We can easily calculate the time for which the output at IC1b pin 4 is high. This is given by:

Time = 0·7 × R2 × C2

The units can be a little confusing (seconds, ohms and farads), but if the resistance is in megohms (MΩ), and the capacitance is in microfarads (µF), then the time will be in seconds, hence:

Time = 0·7 × 1MΩ × 1µF = 0·7 secs

The time for which the output at IC1b pin 4 is low is given by:

Time = 0·7 × R3 × C3

Note that the value of C3 is stated as 100nF. As you should know, 100nF is the same as 0·1µF, hence:

Time = 0·7 × 1MΩ × 0·1µF = 0·07 secs

So the mark-space ratio is 10 to 1, not surprising since C2 is ten times larger than C3. When this circuit is connected to the transmitter circuit, transmission will occur when the output of IC1b pin 4 is low, so we will have a short burst of radio signal, and a long period of silence.

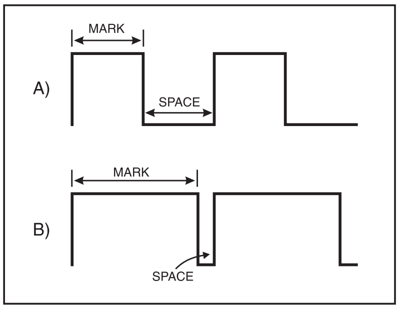



*Fig.7.10. Illustrating mark-space ratio differences.*

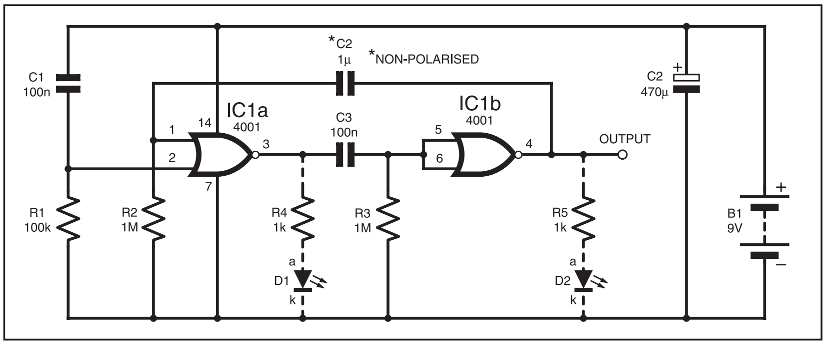



*Fig.7.11. Astable circuit with a non-uniform mark-space ratio.*

## CONSTRAINTS

A longer interval between radio bursts is an advantage, especially if other transmitters in the vicinity are operating on the same radio frequency. However, it is preferable to use non-polarised capacitors to ensure timing reliability. In this context, the values of 1$\mu$F for C2 and 1M$\Omega$ for R2 should not be exceeded.

We could reduce the time for which the radio signal is active by reducing the value of C3 or R3 or both, but we need to ensure that the transmission is long enough for a stable and reliable signal to be decoded. As it is, the signal is transmitted for just under a tenth of a second.

There are many ways of controlling the transmission and we will look at some next month in Part 8.

## RECEIVER MONITORING

Again, there are many methods for monitoring a received signal, and we will also review monostable options next month. For now, we will keep it simple, and we will assume that the regular "all is well" fail-safe pulse is transmitted and encoded on the same channel as the alarm signal. The Holtek encoder/decoder system does in fact allow for the use of more than one encoded/decoded channel, but using a single channel does allow the designer more options in the transmitting/receiving system.

Look again at the receiver circuit shown in Fig.7.9. According to the results of the formulae just discussed, the VT output from IC2 will go to high for 0.07s with an interval of 0·7s. If a flood occurs, we need the VT output to go high and stay high for the duration of the flood, or until the system is reset.

We also need a circuit which sounds an alarm if the regular signal from the transmitter stops. Whilst there are sophisticated circuits which can do this, the simple one shown in Fig.7.12 will do the job.

When the VT output of decoder IC2 in the receiver circuit goes high, transistor TR2 in Fig.7.12 switches on, and so the voltage at its collector (c) falls to zero. Hence any charge on capacitor C5 is removed, and TR3 is switched off.

When the VT output goes low, TR2 switches off, and so current flows via resistors R4 and R5, slowly charging up C5. If no further positive pulses are produced by VT, then C5 will continue to charge, and eventually enough current will flow via diode D2 and resistor R6 to switch on TR3, and hence sound the buzzer, WD2. But if during or following the charging of C5, the VT pin goes high, TR2 will turn on and C5 will quickly discharge via the low-value resistor R5.

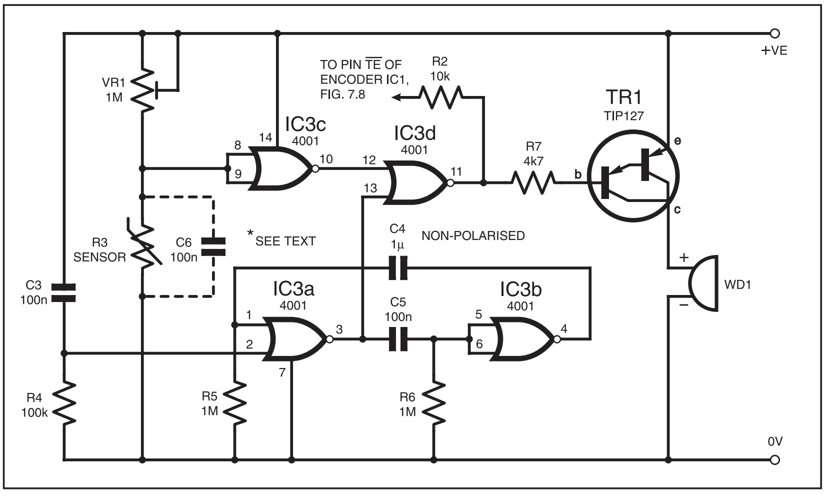



*Fig.7.13. Using a quad NOR gate as the sensor status monitor, and 10:1 astable, plus fail-safe monitoring.*

Transistor TR2 is needed as an interface since the current available from the VT output is quite low. Resistor R5 protects TR2 against heavy current flow when C5 discharges. Diode D2 provides a voltage drop of about 0·7V between C5 and the base of TR3 to speed the latter's response to the falling voltage on C5.

When the output of the astable in Fig.7.11 is connected to the input of the transmitter circuit and the transmitter is working correctly, buzzer WD2 in Fig.7.12 will stay silent. If the link is broken the buzzer sounds.

Note that when testing the transmitter/receiver pair you can run both circuits from the same power supply. It is preferable that you keep the transmitter and receiver assemblies several metres apart otherwise incorrect operation may occur.

It should also be noted that if a breadboard is used as the assembly medium, the reliability of the reception may be impaired by the additional capacitance imposed by the breadboard's internal connection strips. Similarly, stripboard could also cause similar problems unless the track lengths are kept short (separate unwanted lengths using a stripboard cutting tool).

A small solid-state buzzer is suggested for WD2 to differentiate it from the siren, WD1, which indicates a flood.

Note that the siren may be replaced with an l.e.d. (and series resistor) during the testing stage to avoid suffering many loud and penetrating soundings!

Alternatively, you could join the collector of TR3 to the collector of TR1 in order to use the siren for both jobs. Depending upon the current requirement of the siren, you might have to use a Darlington for TR3, such as a TIP122.

## FINAL TRANSMITTER

The astable circuit in Fig.7.11 uses two NOR gates (IC1a and IC1b) of a quad NOR package. When combining this circuit with the transmitter in Fig.7.8, the spare gates can be used as the interface for the moisture sensor circuit, as shown previously in Fig.7.4d. The resulting circuit is shown in Fig.7.13.

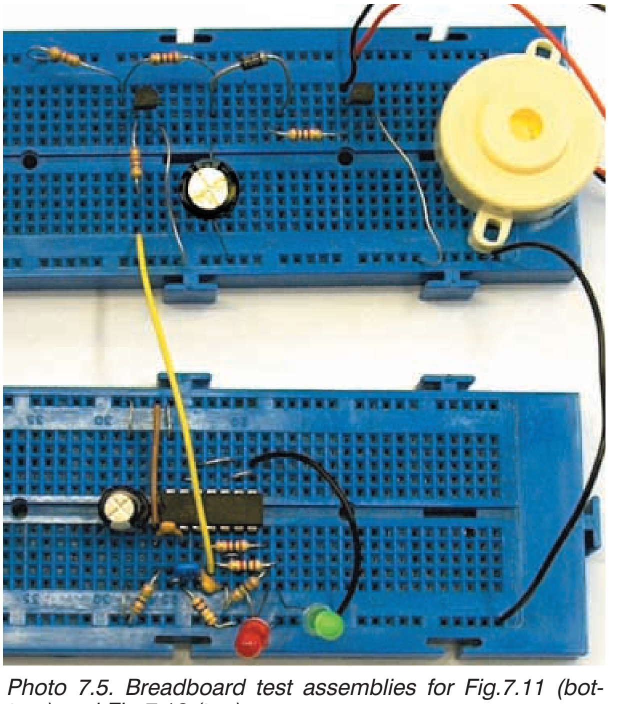


*Photo 7.5. Breadboard test assemblies for Fig.7.11 (bottom) and Fig.7.12 (top).*

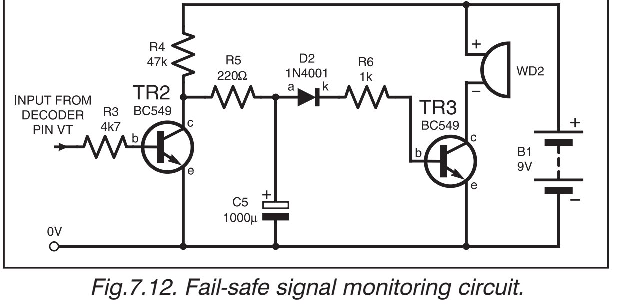
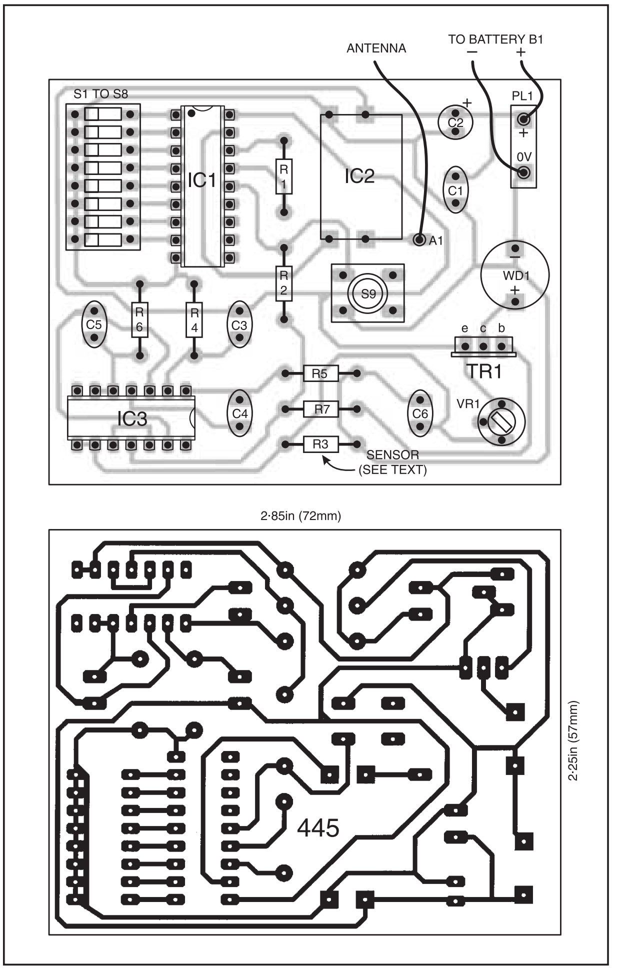
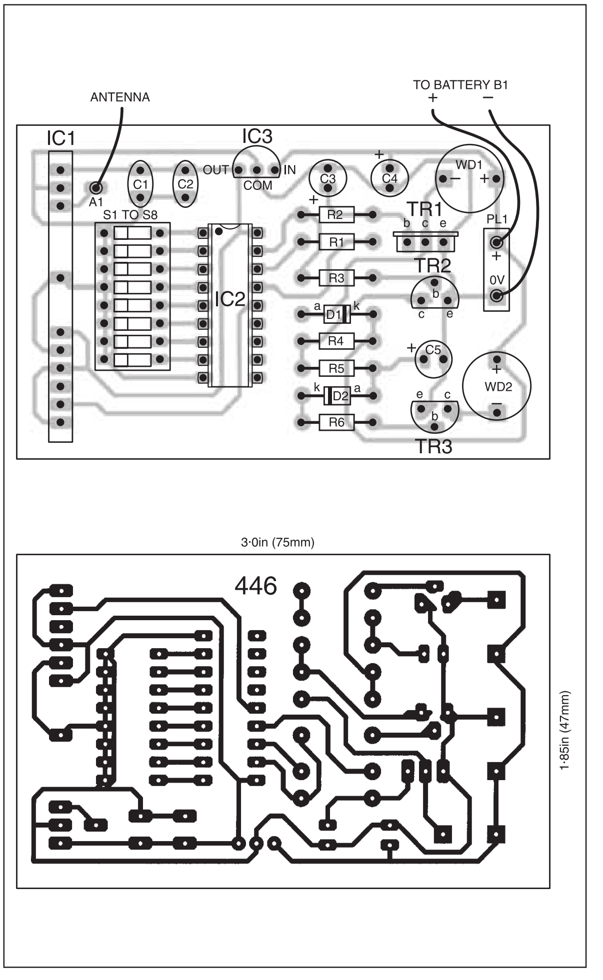
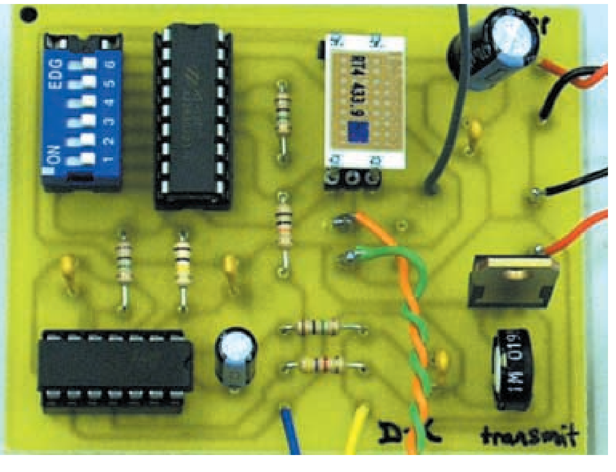
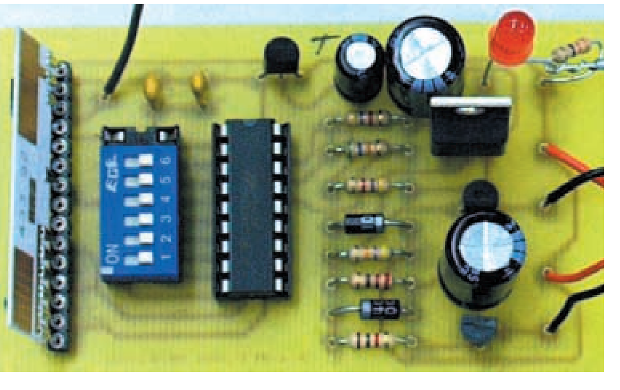



*Fig.7.12. Fail-safe signal monitoring circuit.*

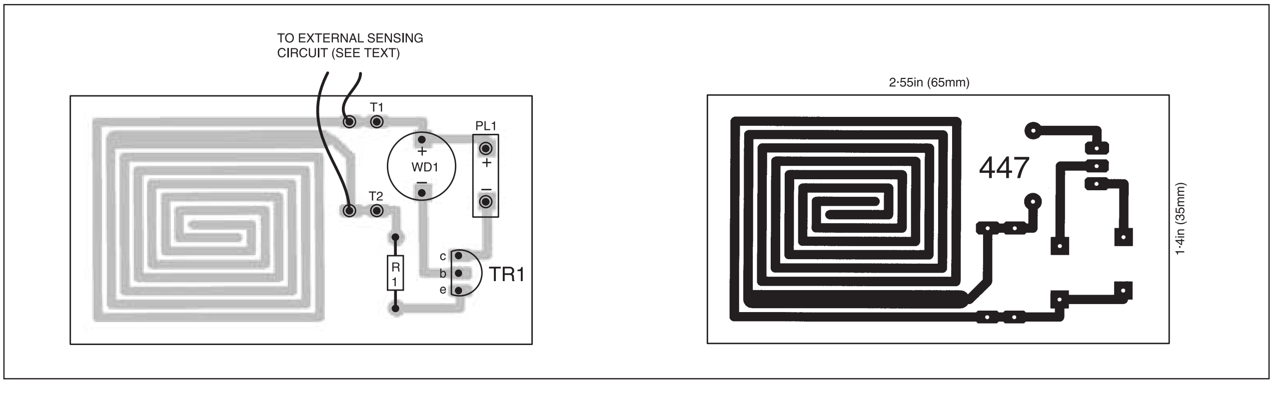




*Printed circuit board component and track layouts for the transmitter (Fig.7.14, left), receiver (Fig.7.15, right) and the moisture sensor (Fig.7.16, below).*



Note firstly that to use this circuit with that in Fig.7.8, the latter's resistor R2 should be removed. It has been placed between IC3d output pin 11 and the $\overline{TE}$ pin of encoder IC1 in Fig.7.8. As the output from IC3 pin 11 is normally high, wiring R2 in this way will not alter its effect, and it allows switch S9 still to be used as a test switch to force the circuit to transmit.

The sensor circuit is based around IC3c, but the sensor itself (R3) and the adjustment preset (VR1) have been swapped compared to the circuit in Fig.7.4d. Pin 10 of IC3c will normally be low when the sensor is dry (assuming that the simple moisture sensor discussed previously is employed). If a flood occurs, the resistance of sensor R3 will fall, causing the voltage at pins 8 and 9 of IC3c to fall, so causing IC3c pin 10 and IC3d pin 12 to go high.

A glance at a NOR gate truth table (see Part 4) will show that if either input is high (logic 1), the output will be low (logic 0). Consequently, if IC3d's input pin 12 is high, its output pin 11 will go low, triggering the $\overline{TE}$ pin of encoder IC1 in Fig.7.8.

Capacitor C6 is optional, and only needed if the wires between the sensor and the circuit are quite long (e.g. more than about one metre). Long wires can pick up induced interference, and this could trigger the circuit. The capacitor bypasses the interference to 0V, so eliminating the problem.

The astable module is based on IC3a and IC3b and is a slight variant of that in Fig.7.11. In particular note that the output is taken from pin 3. It is then connected to input pin 13 of IC3d. In this circuit, if pin 3 is low, this will be copied to pin 13, and the state of IC3d's output pin 11 will then depend upon the output logic of the sensor gate, IC3c pin 10. But if pin 3 of IC3a goes high (to transmit an "all is well" signal) then pin 11 will go low. Read Part 4 if you need to refresh your memory about NOR gates.

Components R7, TR1 and WD1 are optional, and can be used if an indication that the transmission system works is required. The transistor is a *pnp* Darlington. It works the opposite way round to the more usual *npn* type of transistor, in that it switches on if the base voltage falls by (in this case, being a Darlington) 1·4V below the voltage at its emitter. The buzzer suggested for WD1 is a small solid state type, hence no protective diode is required to prevent damage caused by back e.m.f.

## PRINTED CIRCUIT BOARDS

The p.c.b.s are available from the *EPE PCB Service* for this part of the Teach In series. Note that the transmitter and receiver boards are only available as a pair.

The p.c.b. which holds the sensing and transmission circuits of Fig.7.8 and Fig.7.13 is available as order code 445. Its track layout and assembly details are shown in Fig.7.14.

A board for the receiving circuits of Fig.7.9 and Fig.7.12 is available as a order code 446. Its track layout and assembly details are shown in Fig.7.15.

Assemble the boards in order of ascending component size, ensuring that polarity sensitive components such as diodes, transistors, i.c.s and electrolytic capacitors are inserted the correct way round. Sockets must be used for the d.i.l. i.c.s. Do not insert the i.c.s until you have thoroughly checked the correctness of your soldering and component positioning, and of the power supply.

Ensure that you discharge static electricity from your body before handling the i.c.s, all of which should be treated as CMOS devices, by touching an earthed item of equipment.

The board for the moisture sensor shown in Photo 7.1 has an ordering code of 447, and its track layout details are shown in Fig.7.16. Ignore the components seen in Photo 1 as these are not required for this board's use with Fig.7.8.

However, if you want to use the board for moisture detecting as discussed at the start of this part, the components are those shown in Fig.7.1. They may be left in when using the board with Fig.7.8.

## NEXT MONTH

Next month in Part 8 we show some more elegant pulse generators with a much larger mark/space ratio, and further missing pulse detectors.

## COMPONENTS

*Approx. Cost Guidance Only* **£28** *excl. batts & hardware*

### Transmitter (Fig.7.8 and Fig.7.13)

See **SHOP TALK** page

**Resistors**

| | |
|---|---|
| R1 | 1M |
| R2 | 10k |
| R3 | sensor (see text) |
| R4 | 100k |
| R5, R6 | 1M (2 off) |
| R7 | 4k7 |

All 0·25W 5% carbon film, or better.

**Potentiometer**

| | |
|---|---|
| VR1 | 1M min. vertical preset |

**Capacitors**

| | |
|---|---|
| C1, C3, C5 | 100n ceramic disc (3 off) |
| C2 | 470$\mu$ radial elect. 16V |
| C4 | 1$\mu$F non-polarised 15V |
| C6 | 100n ceramic disc (optional – see text) |

**Semiconductors**

| | |
|---|---|
| TR1 | TIP127 *pnp* Darlington transistor |
| IC1 | HT12E encoder |
| IC2 | AM-RT4-433 a.m. transmitter module |
| IC3 | 4001 CMOS quad NOR gate |

**Miscellaneous**

| | |
|---|---|
| S1 to S8 | d.i.l. switch module (optional – see text) |
| S9 | min. s.p. push-to-make switch |
| WD1 | low power active piezoelectric buzzer, 12V |

Printed circuit board, available from the *EPE PCB Service*, code 445; 18-pin d.i.l. socket; 16-pin d.i.l. socket; 14-pin d.i.l. socket; antenna (see text); connecting wire; solder, etc.

### Receiver (Fig.7.9 and Fig.7.12)

**Resistors**

| | |
|---|---|
| R1 | 51k |
| R2, R3 | 4k7 (2 off) |
| R4 | 47k |
| R5 | 220Ω |
| R6 | 1k |

**Capacitors**

| | |
|---|---|
| C1, C2 | 100n (2 off) |
| C3 | 220$\mu$ radial elect. 10V |
| C4, C5 | 1000$\mu$ radial elect. 16V (2 off) |

**Semiconductors**

| | |
|---|---|
| D1, D2 | 1N4001 rectifier diode (2 off) |
| TR1 | TIP122 *npn* Darlington |
| TR2, TR3 | BC549 (or similar) *npn* transistor (2 off) |
| IC1 | AM-HRR3-433 a.m. receiver module |
| IC2 | HT12F decoder |
| IC3 | 78L05 +5V 100mA regulator |

**Miscellaneous**

| | |
|---|---|
| S1 to S8 | d.i.l. switch module (optional – see text) |
| WD1 | siren (see text) |
| WD2 | low power active piezoelectric buzzer, 12V |

Printed circuit board, available from the *EPE PCB Service*, code 446; 18-pin d.i.l. socket; 16-pin d.i.l. socket; 14-pin d.i.l. socket; antenna (see text); connecting wire; solder, etc.

**Moisture Sensor**

(Components in Fig.7.1 not required for use with Fig.7.8). Printed circuit board available from the *EPE PCB Service*, code 447

## FLoPSI COMPETITION PRIZE WINNERS

The prize winners for the FLoPSI Competition run in the December '03 and January '04 issues are as follows:

**1st PRIZE – Sony Digital Camera** – Jim Fell, Peterborough. An electric vehicle display.

**2nd PRIZE – Sony DVD Player** – T. K. Boyd, Tangmere. A CPU retrofit cooling fan monitor.

**3rd PRIZE – Sony Portable CD Player** – Damien Audley, Edinburgh. Temperature indicator for home brewing.

The ten winners pulled from the prize draw who each receive a FPSI 1010 Evaluation Kit are: Bob Syers, Tiverton; Christine Cardy, Felixstowe; Bernard Grabowski, Aylesbury; Bruce Stevenson, Manchester; Alasdair Constable, Beverley; Mr Kamlesh, West Harrow; Stuart Pearson, Grangemouth; John Rainbow, Yeovil; Martyn Thomas, Bath; Matthew Lee, Aberystwyth.

We would like to thank Lascar Electronics (**www.lascarelectronics.com**) for sponsoring the competition.

# PICmicro TUTORIALS AND PROGRAMMING

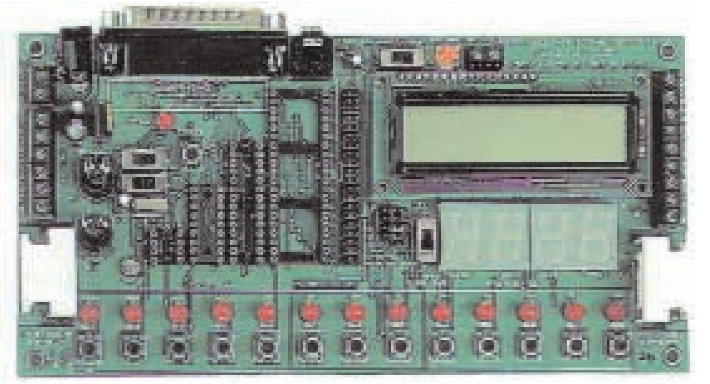
## HARDWARE

### VERSION 2 PICmicro MCU DEVELOPMENT BOARD

***Suitable for use with the three software packages listed below.***

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

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



**£145 including VAT and postage**

**12V 500mA plug-top PSU (UK plug) £7**

**25-way 'D' type connecting cable £5**

## SOFTWARE

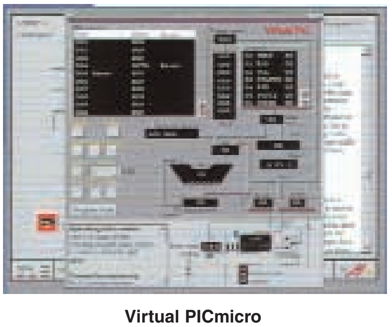
***Suitable for use with the Development Board shown above.***

### ASSEMBLY FOR PICmicro V2

**(Formerly PICtutor)**

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

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



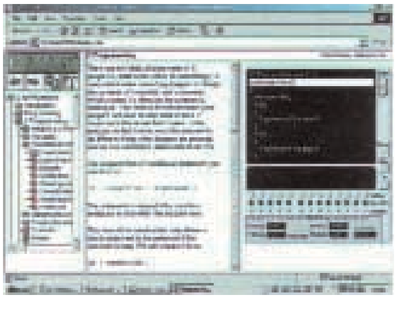
**Virtual PICmicro**

### 'C' FOR PICmicro VERSION 2

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

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

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



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

### FLOWCODE FOR PICmicro

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

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

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

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

**Burglar Alarm Simulation**

## PRICES

**Prices for each of the CD-ROMs above are:**

***(Order form on next page)***

| | |
|---|---|
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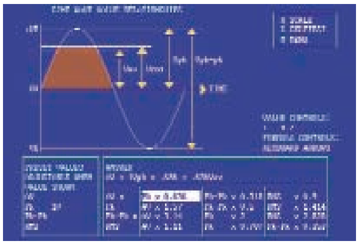
| **Institutional (Schools/HE/FE/Industry)** | **£99 *plus* VAT** |
| **Flowcode Institutional** | **£70 *plus* VAT** |
| **Institutional 10 user (Network Licence)** | **£249 *plus* VAT** |
| **Site Licence** | **£599 *plus* VAT** |

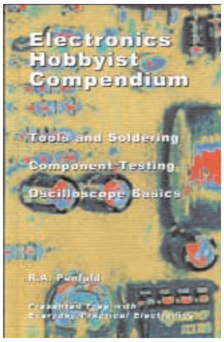
***(UK and EU customers add VAT at 17.5% to "plus VAT" prices)***

# TEACH-IN 2000 – LEARN ELECTRONICS WITH EPE



Sine wave relationship values

## FREE BOOK WITH TEACH-IN 2000 CD-ROM




*EPE*'s own *Teach-In* CD-ROM, contains the full 12-part *Teach-In* series by John Becker in PDF form plus the *Teach-In* interactive software (Win 95, 98, ME and above) covering all aspects of the series. We have also added Alan Winstanley's highly acclaimed *Basic Soldering Guide* which is fully illustrated and which also includes *Desoldering*. The *Teach-In* series covers: Colour Codes and Resistors, Capacitors, Potentiometers, Sensor Resistors, Ohm's Law, Diodes and L.E.D.s, Waveforms, Frequency and Time, Logic Gates, Binary and Hex Logic, Op.amps, Comparators, Mixers, Audio and Sensor Amplifiers, Transistors, Transformers and Rectifiers, Voltage Regulation, Integration, Differentiation, 7-segment Displays, L.C.D.s, Digital-to-Analogue.

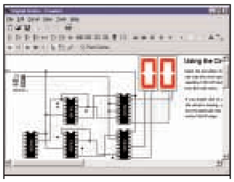
Each part has an associated practical section and the series includes a simple PC interface (Win 95, 98, ME **ONLY**) so you can use your PC as a basic oscilloscope with the various circuits.

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

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

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

# DIGITAL WORKS 3.0



**Counter project**

*Digital Works Version 3.0* is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability • Software for simulating digital logic circuits • Create your own macros – highly scalable • Create your own circuits, components, and i.c.s • Easy-to-use digital interface • Animation brings circuits to life • Vast library of logic macros and 74 series i.c.s with data sheets • Powerful tool for designing and learning.

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**VERSION 3**

Contains a range of tried and tested analogue and digital circuit modules, together with the knowledge to use and interface them. Thus allowing anyone with a basic understanding of circuit symbols to design and build their own projects. Version 3 includes data and circuit modules for a range of popular PICs; includes PICAXE circuits, the system which enables a PIC to be programmed without a programmer, and without removing it from the circuit. Shows where to obtain free software downloads to enable BASIC programming.

Essential information for anyone undertaking GCSE or "A" level electronics or technology and for hobbyists who want to get to grips with project design. Over seventy different Input, Processor and Output modules are illustrated and fully described, together with detailed information on construction, fault finding and components, including circuit symbols, pinouts, power supplies, decoupling etc.

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

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

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Signature: . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

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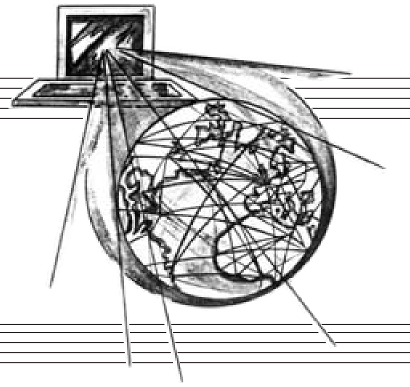
# NET WORK

ALAN WINSTANLEY



## On the E-hotspot

BRITISH Telecom (BT) continues to ramp up its ADSL broadband services and boast about their almost universal coverage, which is all very well if you live in a densely populated area that is a sufficiently short distance from an ADSL-enabled exchange. The number of telephone exchanges being given a trigger level is rising, but the provision of the service is always subject to distance and line tests (which are beyond BT's control) and those sometimes-impossible trigger levels (which aren't).

In previous years, when the rise of dial-up access started to fuel demand for second telephone lines, BT's technical solution was to "DACS" (digital access carrier service) a phone line, in effect sharing a wire with other users to provide two lines in one. The downside is that it hampers drastically a 56K dial-up service, which often fails to scrape much above 20K or so on a DACSed line.

I know of a domestic dial-up user with a 56K modem who thinks that 25K through their line is quite normal, and they are completely oblivious to the fact that it has been DACSed. Very many users are still reliant on dial-up access but at long last the attention is now focusing on the plight of those who will never obtain ADSL and will depend on e.g. satellite or wireless networks for broadband instead.

Last year I mentioned WRBB (Wireless Rural Broadband), a credible-looking ISP that promised much but has so far failed to materialise in the region. At the time, WRBB demonstrated file transfers over an 802·11g wireless LAN and that was about it.

Closer to home, satellite access provided by E-hotspot (**www.e-hotspot.co.uk**) looks extremely promising, offering a 2Mb connection for £29.99 per month. At a local presentation there were many new subscribers eager to sign up on the spot, thereby ensuring that a critical mass of new users would be achieved. E-hotspot was the first local Internet satellite provider eager and willing to survey and install a service with just a minimum number of users signed up.

Satellite is not suited to, for example, online gaming due to the latency but will be the absolutely perfect solution for many users. Strange new aerials have now sprouted in a nearby village, and I hope to report on local experiences in coming months. Whether my own office is in line of sight of the local node is currently being investigated.

## Pole-axed

Regular readers of this column may recall from previous articles that I highlighted the plight of the official telegraph pole outside my home. It carries three phone lines including my dial-up access line (no ADSL of course), and I am fortunate enough to have a raw line (that has not been DACSed) straight through to the exchange that allows me to surf at up to 50·6Kbps. In this respect, Tiscali dial-up (**www.tiscali.co.uk**) has proved to be generally robust and in my experience has been more dependable over the years than my original Demon Internet service (the ISP that hosts the **epemag.demon.co.uk** mailbox). However, it has only been through arguing with BT and refusing to be fobbed off that I have managed to retain an un-DACSed line.

So far, not bad, until BT arrived last week without warning to chop down all three phone lines and migrate them to another pole, resulting in two days' of lost phone lines – and when reconnected, the numbers were crossed. This is almost on a par with the time when I picked up my phone only to hear another party's ISDN data humming over the earpiece. In spite of everything, I managed to limp along with email by running a laptop through a mobile phone until the phone lines were restored: it is worth having a contingency plan in place.

## Under Pressure

When ADSL broadband arrived in some neighbouring towns at the end of 2003, I was invited to the BT launch and what was painfully clear was that although they were talking up the service aimed at local businesses, BT struggled to demonstrate any business-orientated applications for broadband at all, except perhaps videoconferencing. Instead we were treated to some examples of music and media downloads. There is probably never going to be a single killer app. for broadband; it simply enables us to work faster and smarter doing what we do already. A 14MB critical Windows update can be fetched in less than five minutes, for example.

Just a few weeks ago, I learned that local businesses were being targeted by intense sales efforts on the part of BT, supported by local business development agencies, who want business users to sign up to BT ADSL broadband. In the event, there is mounting evidence that BT Openworld is using its market strength not only to sell broadband services to businesses but also to gain their web site hosting business as well.

BT Openworld's advice encourages customers to re-configure their domain and email setup to point it away from their regular ISP and towards BT instead. In so doing, they risk losing their existing web site altogether, having severed the link with their old web host who is left merely to handle the domain name setup and nothing else.

When customers who have their own domain want to use, for example, ADSL from BT, then in order to send outgoing emails showing their domain as the sender (e.g. *FROM: mydomain.co.uk* rather than *FROM: joe.bloggsuser123@btinternet.com*), it is necessary to buy an additional package from BT Openworld to allow for this outbound mail relaying. The BT "Internet Business Pack" add-on immediately cranks up the cheapest price by 33%, yet this feature is available at no extra cost from a number of other ISPs whose ADSL may be cheaper anyway.

A static IP address, where needed (e.g. for virtual private networking, also useful for videoconferencing), also comes in the same add-on package from BT but may well be a free option provided by other cheaper ISPs. Check the specs carefully before you buy.

## Worrying Trend

What is worrying about BT marketing techniques is that broadband customers are also being encouraged to use web and mail forwarding for their existing business domain, and point it to their BT service instead. I have to say that an emerging trend is one of "the blind (BT sales) leading the blind (unsuspecting buyers who ask the wrong questions)". Whilst BT's generally excellent technical staff may understand the implications of reconfiguring domain names, BT sales staff appear not to.

In fact, very little of BT Openworld's present marketing thrust seems to deal with the very many cases where customers already own their own web site and domain name, and simply want to buy some broadband access. It is perfectly possible for users to continue with the current supplier of their own domain name, web and email hosting, and just use a broadband service bought in from elsewhere – it's just like switching dial-up suppliers, and there should be no need to pay extra for outbound domain mail relaying.

The simple issue of buying a plain broadband service from BT Openworld is downplayed in favour of BT acquiring a business's domain and web site as well, always assuming the customer hasn't lost his web site and that it will run on BT's servers anyway. There is not just a land grab for ADSL services going on at the moment: many smaller independent ISPs that have invested in bandwidth and web hosting now run the risk of seeing their core business shrink due to the country's largest telecommunications business having grabbed the customer's web site and email when all that the customer really wanted was a broadband Internet service.

Constructional Project

# EXPERIMENTAL SEISMOGRAPH LOGGER

JOHN BECKER

Part Two

*Long-term data recording of the Earth's rock and roll events*

LAST month the electronic circuits were discussed, construction of the p.c.b.s and pendulum assembly described and some preliminary tests outlined. The remainder of this article now explains the use of the PC interface software.

Open the folder to which you copied the VB6 software and double-click the **Seismograph.exe** icon. A screen similar to that shown in Part One will appear, but without waveform detail, and having the upper section showing the information in the first screen dump below.

The main area is dominated by eight horizontal "picture" boxes, numbered 0 to 7. It is to these boxes that seismic data waveforms are plotted, commencing at the left of box 0, traversing across the screen to the right, continuing from the left of box 1, etc. During live recording, when box 7 has been filled, box 0 is cleared and the program again plots data to it.

At intervals which depend on the sampling rate, or the type of recorded data being re-input from disk, vertical marker lines are drawn to give an indication of data timings. A label (coloured yellow) states the period indicated by the markers.

Hover the mouse over any control to reveal a "tool tip text" box which gives brief details of the function.

## COM PORT ADDRESS

A choice of two COM port (serial interface port) addresses has been provided, COM 1 (h378) and COM 2 (h278). It is not possible to use this software with a USB port.

Two "radio" buttons are provided for COM port selection. Click the one required. This choice is stored to disk and recalled each time the program is run. It may be changed again later if desired.

## TEST MODE

The facility to test the sensor and control boards via the PC software has been provided. Click the Test Input button to activate it.

This clears most of the control buttons and labels on the screen, sets the Test Input button to read Stop, and reveals a Details ×4 tick box, which will be explained in a moment.

The program now inputs serial data from the PIC unit and displays it as waveforms.

Each of the picture zone boxes is set for a width of 300 samples. Data is plotted to it as soon as it is received. The effective sampling rate, though, depends on the rate at which the PC can plot each data value, which will depend on the operational speed of your PC.

Test mode allows you to readily check that the PC is inputting the serial data (you might have chosen the wrong COM port, or failed to connect the cable, for example).

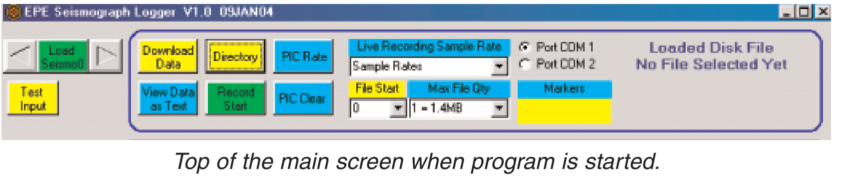
It also allows the Sensor board's preset VR2 to be adjusted so that in the absence of any vibrational signal, the waveform shows as a steady line placed midway down the active zone box. The final positioning of the sensor in relation to the magnet, both vertically and horizontally, is also best done in Test mode.

If data is not being received, an advisory panel appears saying so (there is a one-second timeout for this). A "list" box below it states the time at which data failed to arrive, and when data input has been restored.

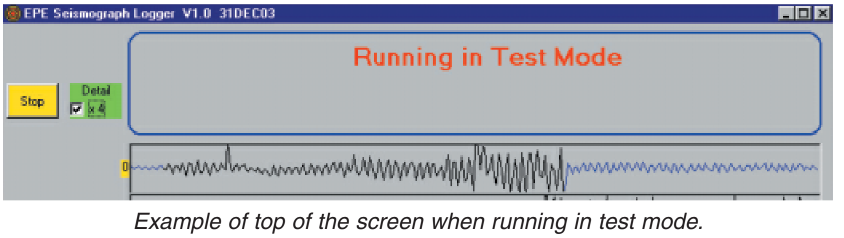
The Detail x4 tick box when ticked causes the data amplitudes to be multiplied by four, and drawn in black instead of the normal dark blue.

Timing markers are not shown in this mode.

Click the Stop button to exit Test mode, on which the hidden controls and labels are re-shown.




*Top of the main screen when program is started.*

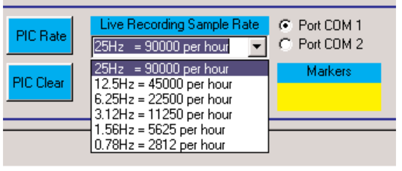



*Example of top of the screen when running in test mode.*

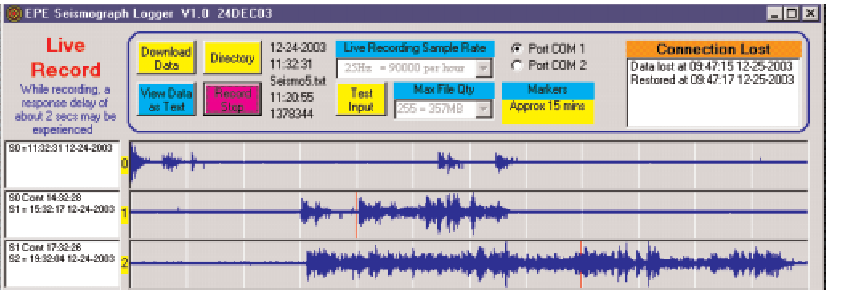
## DISK SAMPLING RATE

As said in Part 1, the PC software inputs data at 9600 Baud from the PIC unit at a sampling rate of 25Hz. The Baud rate is fixed but the sampling rate at which the data is stored to disk can be changed. At the top centre of the screen is a drop-down (Combo) box below the caption Live Recording Sample Rate. The box's default shows a rate of 25Hz, which represents 90,000 samples per hour being recorded to disk.

Click on the arrow at the right of the Combo box to reveal the full list of sample rates available. The highest rate is 25Hz, the others are binary divisions of that rate, shown to the nearest two decimal places as 12·5Hz, 6·25Hz, 3·12Hz, 1·56Hz and




*Combo box for selecting the data storage to disk rate.*




*Example of part of the screen during recording mode.*

0·78Hz, with the equivalent number of samples recorded per hour shown alongside.

Clicking on any item in the list selects that rate. The value is recorded to disk for future recall. It may be changed by the same method at a later date if preferred.

## SAMPLING QUANTITY

Obviously, the amount of data which a hard drive can hold depends on the space available! Consequently, a choice of maximum data quantity is provided. Data is recorded to disk as several files used cyclically. The files are named with an identity number, e.g. **Seismo0.txt** as the first one, **Seismo1.txt** as the second, etc.

Each file is closed when its contents reach 1,440,000 bytes (approx 1.406MB) and the next one opened. The maximum file size has been set so that data can be copied to a standard 3·5in 1·44MB disk (with room to spare) if later required, for examination on another PC, for example.

Having reached the maximum number of files that has been chosen, the numbering starts again at zero, the data that was previously recorded into that file name being lost.

Each sample is stored to disk as fixed field length text values between 0 and 999, i.e. 000 to 999 (ADC sampling values between 1000 and 1023 are taken as 999). Each value is followed by a comma, suiting the files to subsequently processing them via Microsoft Excel, or similar, or just for viewing as a text file through a text editor such as Wordpad, for example.

At a sampling rate of 25Hz, one file of data represents 360,000 samples, spanning a period of 14,400 seconds, i.e. about four hours. At this rate you would need just over six files to cover a period of 24 hours, about 8·6MB of data.

You must use your discretion about the sampling rate and file quantity. Obviously, though, a higher sampling rate will provide better definition of recorded seismic event waveforms.

The Combo box below the caption Max File Qty allows the maximum number of files to be selected, from 1 to 256. To change the quantity of files, click the box's arrow and from the drop-down list click-select the quantity required. The list also displays the equivalent total capacity that this number of files represents.

A file quantity of 256 obviously consumes a very large amount of hard drive space, around 358·4MB, and is unlikely to be acceptable to most systems that are in everyday use. However, this quantity may be realistic if a PC is dedicated solely to seismographic recording. A maximum quantity of 256 files recorded at 25Hz represents a total recording time of 1024 hours, or 42 days 16 hours approximately.

The author has several older and replaced PCs, one of which has been put to use for long-term seismic monitoring. It is likely that many readers have spare PCs too, having upgraded to later systems.

Using a dedicated PC also allows it to be stored in a remote location suited to where the pendulum assembly is installed.

## STARTING FILE NUMBER

Another Combo box (File Start) allows you to select the file number at which a recording session starts. Click the box and select any of the numbers, which run from 0 to 255.

Normally you would select 0 (file **Seismo0.txt**). The option to select another number was put in following a brief mains power failure (blackout) during this design's development, which caused the PC to reboot. This number selection allows the recording session to be restarted at the next consecutive file number so that previously recorded data in completed files is not overwritten following such a situation. The file number required can be established from the dates and times at which files are created (via Windows' folders display facility, for example – also see later).

Incidentally, the only way to keep a PC running during a power blackout is to use an Uninterruptible Power Supply (UPS). These typically use a heavy-duty 12V battery whose power is converted to 230V a.c. or 110V a.c. to suit the PC. They are not cheap, and cannot keep the PC running for extended periods, but do allow a controlled shut down.

This Combo box selection is not stored to disk and a number should always be selected prior to starting any recording if it is other than the default value of zero.

## LIVE RECORDING

To start live recording of data, ensure that the PIC unit is powered and the interfacing serial cable is connected to the correct serial port socket on the PC. Then just click on the button marked Record Start.

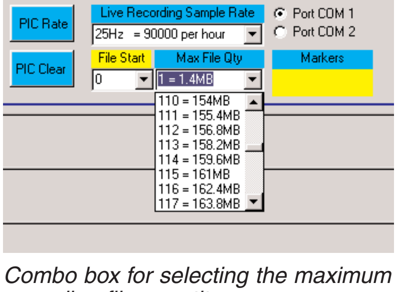
The button's caption changes to Record Stop and data now streams into the PC at 25Hz, to be recorded to disk at the rate selected.

As with Test mode, a timeout (two seconds) is triggered if data fails to arrive during recording. The advisory box appears, plus the list showing time of loss, and restoration if applicable. The same information is also recorded to disk, under file name **SeismoDataLoss.txt**, which can be examined once recording has been terminated.

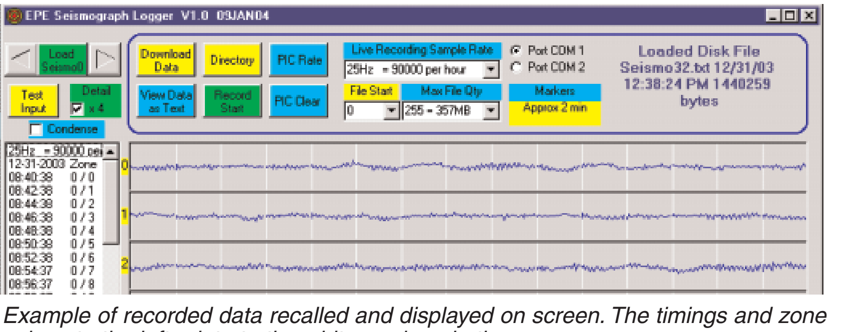
Additionally, a vertical black line is drawn on screen, indicating the point at which data loss occurred. Simultaneously, in the file being used for live recording, three asterisks and a comma ("***,") are recorded, and that particular line is then ended, with the current time appended.

Data is actually input in blocks of 100 bytes, but is not processed until each block has been received. While each block is being input, the software routine only responds to the incoming data, ignoring any mouse generated commands until the block has been fully received. Consequently, there can be a delay of up to about two seconds before such commands are actioned.

To stop the live recording, click on the Record Stop button, which then reverts to the caption of Record Start when the current data block has been received. At this point the currently-open recording file is automatically closed. The software then waits for your next instruction.




*Combo box for selecting the maximum recording file quantity.*




*Example of recorded data recalled and displayed on screen. The timings and zone values to the left relate to the white markers in the zones.*

When live recording starts, a small text area to the right of the four main buttons displays the starting date and time. As recording progresses, the time at which each fresh data batch is processed, the file to which it is being recorded, and the current file size are also displayed.

At the same time, data is also output to the screen's display areas as a waveform representing the sample values. The progress will appear to be very slow since each screen display box is set in this mode to show 270,000 samples across its width, representing 10,800 seconds, i.e. three hours.

Note that at different sampling rates, the amount of data displayed in each box will vary accordingly, but the program has been written so that each box still represents a period of three hours. The eight boxes thus cover a 24-hour period.

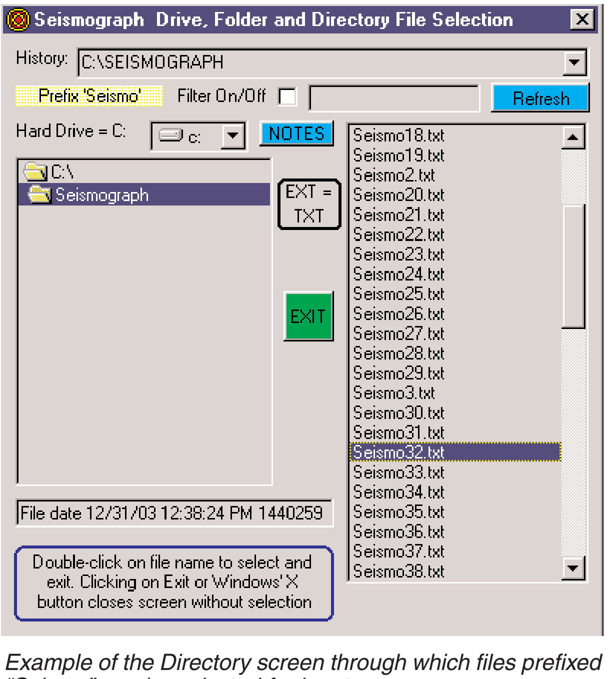
To the left of the screen in this mode, eight list boxes are shown, one for each display box. These show the times at which the numbered disk files are opened. Red markers in the display boxes also indicate when this action has occurred.

During the recording to disk, the files have their data split into "sentences" having a length of 12,000 bytes. As each sentence is completed, the current time is appended to it.

Once recording has ended, any listed file in these boxes can have its name clicked for it to be input for viewing. The function can only be used once though, as the list boxes are closed by the action. There are other ways to view file data, as described presently.

## DISPLAY PERMANENCE

During live recording, data is displayed under a VB6 option which causes the display to be regarded by the screen as "permanent" until intentionally changed. This means that if the Screen Saver appears, for example, the data will be re-displayed automatically when the Screen Saver is closed (subject to the above-mentioned delay).




*Example of the Directory screen through which files prefixed "Seismo" can be selected for input.*

This option is not provided for displays created from recorded file data. This is because the VB6 system is far slower in the "permanent" mode than in normal display mode. It was felt that the convenience of faster display updating outweighed the advantage of "permanence".

In this mode, if the Screen Saver appears, or an action is taken that causes another screen to be displayed, when that screen is closed waveforms will be missing from the display boxes. They can be restored by re-selecting the same file data source.

## FILE RECALL

Recorded data, whether it is "live" or downloaded from the PIC unit, can be input for display via the Directory button. Clicking this button reveals a sub-screen arranged so that any PC drive, folder and file path can be selected.

The facility is a variant of that used in many of the author's VB6-based programs. There is an accompanying text file that can be accessed via the NOTES button on the screen, which gives notes on its use. These will not be repeated here.

Suffice to say, that having located the file you want, single-click on it to show the date and time it was created in a text box to the left of the screen. To load the file for viewing as waveforms on screen, double-click its name.

Once loaded, the same data may also be viewed as a text file by clicking on the View Data as Text button.

Recorded files contain data about the sampling rate that applied when they were opened for recording. When a file is input from disk for viewing, the sampling rate is also recalled, and used to set the appropriate display marker span periods. This information is shown in the yellow box near the top of the screen.

As said, data is recorded in sentences with an appended time stamp. When data is input from disk, as each of these sentences is recalled, its time stamp is added to a list box at the left of the screen, to which display box and marker count values are added.

Once the data has been fully input and displayed, you may click on any of the list lines to select that line's data for display as a horizontal (time-expanded) enlargement. The screen is set so that each complete line's data fills all eight display boxes, and the markers are spaced to suit.

A further enlargement option is provided by the tick box marked Display ×4. When ticked, sentence waveform amplitudes are multiplied by four.

To re-display the full disk data, click on either of the two upper list lines.

Be aware that the rate at which file data is drawn on screen is very much dependent on your PC's operational speed. On the author's Windows ME 1·2GHz PC it takes about one second to plot a full file of 1·4MB samples, but on his Windows 95 1·2MHz PC it takes about 28 seconds.

To speed display of complete files (as opposed to viewing just sections of them), 40 samples are ORed before plotting the result to screen (it is the screen drawing that takes the time). With selected section viewing, *all* samples are plotted to screen.

## CYCLED VIEWING

Having recorded live data, there will be several files involved, all prefixed by "Seismo" followed by a number. Instead of calling these up via the Directory button, they can be accessed in order numerically, upwards or downwards, by using the click-buttons at the top left of the screen.

The central button of these three, marked Seismo0, loads that file for display. Clicking the right arrow button loads the next numbered file, Seismo1 at this time. Clicking it again loads Seismo2, etc. Clicking the left arrow loads the previous numbered file.

In the ascending order direction, when the maximum number of files that have been allocated have been viewed, the number rolls over to zero again. In descending order, from zero the number rolls over to the maximum file allocation.

If the number of files actually recorded is fewer than that allocated, the unused file numbers are bypassed.

It should be noted that if several longterm recording sessions have taken place, some later file numbers may be associated with a previous recording session. The file numbers for the latest session can be obtained by using the Directory's time and date viewing option, described above.

Alternatively, Windows' own folder details viewing facility can be used, in which the dates and times of file creation can be listed. A loaded file's time and date details are also shown in the File Loaded box at the top right of the main Seismograph screen.

Most of the "live data" files will likely contain nothing of significance. Any that you do consider to be worth keeping should be opened via the View Data as Text button and resaved under any name of your choosing, but prefixed by "Seismo" and with the ".txt" extension so that they can be located via the Directory option. They may also be renamed using Windows' own Rename facility.

If a wanted "live" file is not renamed, it will eventually be over-written when fresh data is recorded.

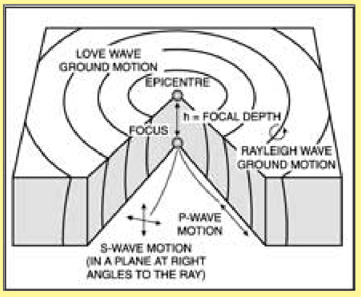
## PIC DOWNLOAD

To download data from the PIC unit's memory bank, the PC should not already be recording live data. If necessary, click the Record Stop button to stop live data input.

Downloading is started by first clicking on the PC screen's Download Data button. A sub-screen then appears, displaying a Start button. Click it to start the download. This action sends the command "S" (for Start) to the PIC. The PC then waits for two seconds to allow the PIC software to complete whatever action it is performing.

## SEISMIC WAVES

There are four principle wave motions generated by an earthquake, as shown below. The P-waves (primary) and S-waves (secondary) travel through the body of the earth, while Rayleigh and Love waves travel along the earth's surface.




Best observations of the waves generated are made within the period range 0·5 and 2·0 seconds for body waves, and 10 to 60 seconds for surface waves. (Source: *Understanding the Earth*, Artemis Press, 1975, Open University set book.)

The rate at which seismic waves propagate through the earth depends on the nature of the rock through which they pass. The range is typically between 1·5km/s to 8km/s.

## EARTHQUAKE SCALES

The magnitude of an earthquake is a measure of the amount of energy released. Each earthquake has a unique magnitude assigned to it. This is based on the amplitude of seismic waves measured at a number of seismograph sites, after being corrected for distance from the earthquake.

The strength of an earthquake is usually measured on one of two scales, the Modified Mercalli Scale and the Richter Scale.

**Richter Scale**

The Richter scale is logarithmic, an increase of one magnitude unit represents a factor of ten times in amplitude:

| | |
|---|---|
| 1 to 3 | Recorded on local seismographs, but generally not felt |
| 3 to 4 | Often felt, no damage |
| 5 | Felt widely, slight damage near epicentre |
| 6 | Damage to poorly constructed buildings and other structures within tens of kilometres |
| 7 | "Major" earthquake, causes serious damage up to 100km |
| 8 | "Great" earthquake, great destruction, loss of life over several hundred kilometres |
| 9 | Rare great earthquake, major damage over a large region over 1000 kilometres |

**Mercalli Scale**

The Modified Mercalli Scale is a rather arbitrary set of definitions based upon what people in the area feel, and their observations of damage to buildings around them. It uses Roman numerals:

| | | |
|---|---|---|
| I | Instrumental | Detected only by seismographs |
| II | Feeble | Noticed only by sensitive people |
| III | Slight | Resembling vibrations caused by heavy traffic |
| IV | Moderate | Felt by people walking; rocking of free standing objects |
| V | Rather strong | Sleepers awakened and bells ring |
| VI | Strong | Trees sway, some damage from overturning and falling objects |
| VII | Very strong | General alarm, cracking of walls |
| VIII | Destructive | Chimneys fall and there is some damage to buildings |
| IX | Ruinous | Ground begins to crack, houses begin to collapse and pipes break |
| X | Disastrous | Ground badly cracked and many buildings are destroyed. There are some landslides |
| XI | Very Disastrous | Few buildings remain standing; bridges and railways destroyed; water, gas, electricity and telephones out of action |
| XII | Catastrophic | Total destruction; objects are thrown into the air, much heaving, shaking and distortion of the ground |

**Mercalli and Acceleration**

| *Mercalli* | *Acceleration* |
|---|---|
| I to II | 1cm/s |
| II to III | 2.5cm/s |
| III to IV | 5cm/s |
| IV to V | 10cm/s |
| V to VI | 25cm/s |
| VI to VII | 50cm/s |
| VII to VIII | 100cm/s |
| VIII to IX | 250cm/s |
| IX to X | 500cm/s |
| X to XI | 750cm/s |
| XI to XII | 980cm/s |

**Scale Comparison**

| *Severity* | *Scale* Mercalli | Richter |
|---|---|---|
| Mild | I to III | 0 to 4.3 |
| Moderate | IV to V | 4.3 to 4.8 |
| Intermediate | VI to VII | 4.8 to 6.2 |
| Severe | VIII to X | 6.2 to 7.3 |
| Catastrophic | XI to XII | 7.3 to 8.9 |

On receipt of the "S" the PIC causes the l.c.d. screen (if installed, see Part 1) to display the message Waiting For PC Trig on its top line. It then waits for the PC to send "G" (Go), on receipt of which the l.c.d. displays the message SERIAL OCX TO PC and sends an acknowledgement message back to the PC.

The message quotes the data source title, the PIC's sample rate, the number of memory chips installed, and the memory address last used.

On receipt of the message, data is then transferred in blocks of 1024 bytes, with handshakes exchanged between them. Data is continuously sent until all memory contents have been downloaded. The PIC then reverts to sampling seismic data, carrying on from the memory address at which it left off.

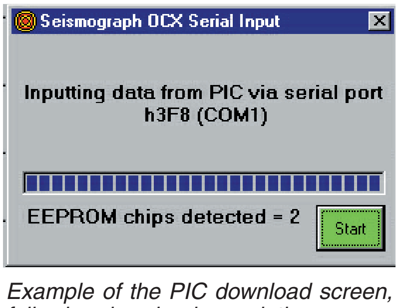
The download process takes about 35 seconds per memory chip and cannot be stopped once started, except by disconnecting the power. During download, a bargraph displays the progress. Incoming data is stored to a temporary binary file, **Store.txt**.

The PC continues to expect download data blocks until either all expected blocks have been received, or a timeout has been exceeded. In either case, the screen reports which event has occurred.

Following a complete download, the temporary binary file is opened and data is retrieved, converted to numerical text values separated by commas (as with Live Recording). However, the data has been downloaded in address sequence from zero upwards. It is now split into two files, one for all data prior to the current memory recording address, and one for all data following it.

The two files are then re-input and output to a final text file in the correct time sequence, so that the most recent sample is at the end of the file. This file is prefixed with "Seismograph" followed by a unique date and time stamp identity, e.g. **Seismograph 06DEC03 15.17.52.txt**. Each sentence is also terminated with an approximate time value, calculated backwards from the time that the download started.

On completion of the download process, this file is automatically selected for input, and its contents are plotted to the screen. At other times, downloaded data files can be opened for viewing in the same way as with the Live Recording files. The display markers are positioned in relation the PIC's




*Example of the PIC download screen, following download completion.*

## PENDULUM MOTION

**Simple Pendulum Formula**

The period of a pendulum's swing is directly related to the distance between its pivot point and the centre of the pendulum's mass. This distance is not necessarily the same as the distance to the centre of the weight at the end of the pendulum since the mass of the suspension apparatus also plays a part.

By changing the distance between the centre of the mass and its suspension point, the pendulum can be tuned to different earth movement frequencies.

Essentially, the actual weight of the mass does not affect the swing rate. The mass is only there to provide inertia for the moving half of the sensor. However, the physical size and shape of the weight will affect where the centre of total mass is actually located.

The following formula for calculating the oscillation period of a simple vertical pendulum reveals that there are practical difficulties involved for monitoring the lower frequencies of the surface waves:

$$T = 2\pi\sqrt{(L/g)}$$

where:

T = period of oscillation
L = length of the pendulum in metres (from its pivot point to the centre of its mass
g = acceleration of free fall (often referred to as the acceleration due to gravity)
$\pi = 22/7$

Rearranging to make L the subject the formula becomes:

$$L = (T^2 \times g) / 2\pi^2$$

Taking g as its standard value of 9·80665 $m/s^2$, and calculating for different values of T, the following results are obtained:

| Period (T) in Seconds | Swings per per Minute | Pendulum Length Metres | Pendulum Length Feet |
|---|---|---|---|
| 0·5 | 120 | 0·06 | 0·20 |
| 1 | 60 | 0·25 | 0·81 |
| 2 | 30 | 0·99 | 3·26 |
| 5 | 12 | 6·21 | 20·35 |
| 10 | 4 | 55·89 | 183·37 |
| 30 | 2 | 223·38 | 732·70 |

**Golitsyn (Garden Gate) Formula**

The Golitsyn pendulum is a variant of a *compound* pendulum, and is also known as a *Garden Gate* pendulum. Searching the web, several formulae for compound pendulums were found. The site at **www.seismik-AG Monschau.htm** gives a formula specifically for the Garden Gate variant:

$$T = 2\pi\sqrt{(B/\tan\theta)/g)}$$

Relating this to Fig.2 (Part 1) and substituting the letter L for B:

T = period of oscillation
L = distance between pivot A and the centre of pendulum mass
$\theta$ (pronounced *theta*) = angle between centre of pivot A and the centre of pendulum mass

For a given value of L, the period varies with angle $\theta$, e.g.:

L = 0·2482055 metres (the L value for a simple pendulum swinging with a period of 1 second)

| Angle $\theta$ | Period (seconds) |
|---|---|
| 1 | 7·56 |
| 44·5 | 1 |
| 89 | 0·12 |

**QBasic Example**

A program routine written in QBasic which calculates the Garden Gate period in relation to angle $\theta$ accompanies the Seismograph software, and is named **SeismoPendulum.txt**.

Note that in the program values for *theta* of 0 and 90 degrees cannot be used as their tangent is zero, and as any value divided by zero is infinite, programs such as QBasic cannot handle it, and crash. However, *theta* can be given fractional values, and so angles very close to 0 or 90 can be used.

Experimentation with the QBasic routine (which can be readily translated into a Visual Basic routine) shows that *extremely* long periods can be achieved for angles between 1 and approaching 0. An angle of 0·01 degrees would result in a period of 75·67 seconds.

Note that the centre of mass is not the centre of the weight, as the mass of the pendulum beam also contributes to the total mass.

sampling rate for this file, and the yellow panel confirms the spacing as before.

There is another text file created during download. This simply shows the byte values downloaded before they are combined into one value. The file has no use other than for informative interest (basically the author's!). It is always named **SeismographOrigData.txt**.

## PIC LINK BUTTONS

The buttons marked PIC Rate and PIC Clear were described earlier. They are used when setting the PIC's sampling rate and when clearing its memory bank.

## FURTHER PROCESSING

The PC interface program's main facilities have now been described. There are two other options now available, both subject to other programs that might be available with many PCs.

Windows 95, 98 and ME users should be able to do screen dumps to Windows' own clipboard of any display on the screen. At any time of your choosing, press the keyboard's Print Screen key. This puts the screen image onto the clipboard.

Now click the Windows Start button and select Programs/Accessories/Paint. Then select Edit and click Paste. This pastes the clipboard image into Paint, from where it can be printed to paper and/or stored as a bit-map image (BMP) to disk.

It is understood, however, that the screen dump facility via the Print Screen key may not be available with Windows XP, NT and 2000. Reader feedback on this to the Editorial Office would be appreciated.

The screen dump facility can also be used during live recording, the time that it takes is only short and no significant sample loss should occur if you are quick.

The other option probably available to many readers is to import either type of recorded data text file to Microsoft Excel, or other similar spreadsheet software that has data analysis and graphing functions. Discussion of such software, though, is beyond the scope of this article.

## DAMPING

In the author's previous seismograph, and in some others found on the web, a pendulum damping mechanism was used. This causes the pendulum's swing to become stationary more quickly than its own momentum allows following a vibration event.

One common method is to attach a small plate to the bottom of the pendulum and fractionally immerse it in an oil bath. The drawback is that the damping also reduces the sensitivity of the pendulum to small vibrations. With this Experimental Seismograph Logger, damping has not been included and so far the author has not missed it.

One intriguing technique found on a few websites, but which has not been explored, uses a rectangular aluminium or copper plate attached to the pendulum's suspension wire. To each vertical support a strong magnet is attached, opposite the plate.

The theory seems to be that if the plate swings lemgth-wise between the magnets, a magnetic field develops in it, which helps to counteract the momentum of the swing, and stopping its motion earlier than would gravity on its own. By its nature, though, the pendulum's motion must probably be parallel to the magnets, thus requiring a directionally sensitive pendulum assembly.

## CONCLUSION

All that remains now is for you to permanently install the Experimental Seismograph Logger hardware in a suitable place, well away from possible physical interference.

As part of that installation, it would be worthwhile to enclose the pendulum assembly so that it is not subjected to draughts, which could set the pendulum in motion. The type of corrugated enclosure used by gardeners to protect sensitive plants and young trees would seem to be suitable.

While browsing the web, though, it was found that some people go to extreme lengths to enclose their seismographs. Such techniques include enclosing the mechanics in thermal blankets of various types, and then installing the whole assembly into concrete-lined pits, with robust bolts securing them to the floor, and with levelling adjustment screws to ensure precise alignment.

The orientation of the assemblies relative to compass North is another factor discussed on various web sites. Whereas the pendulum discussed in this article will respond to seismic waves coming from any horizontal direction, some assemblies are specifically designed to only respond to waves coming from particular compass points, typically in North/South or East/West directions.

A third sensing direction is also possible with some seismographs, although not with the assembly described here. Those assemblies respond to vertical tremors rather than horizontal ones. It would appear that really sophisticated seismic monitoring stations sense all three directions simultaneously.

## WEB SOURCES

When researching the web for information about d.i.y. seismographs, the author mainly used **www.google.com** as the search engine. Searching on words such as *seismograph, seismology*, and *seismometer* in conjunction with other search words such as *sensor, pendulum* and *sampling*, etc., many useful sites were found, far too many to quote, but here are a few to start you off:

**psn.quake.net**
**www.seismicnet.com**
**www.bryantlabs.net**
**www.infiltec.com**
**www.hometown.aol.com**
**www.quakes.bgs.ac.uk/event_page.htm**

Other words worth searching on are Lehman, Shackleford-Gundersen, Golitsyn (and Galitzin), Richter.

Interestingly, many of the links offered by some sites eventually took the searches to sites associated with Redwood, California – could that be the seismic d.i.y. centre of the world?

And while on the subject of web searches – the author expresses his wonderment at how, in the ten years since making his previous seismograph, for which he researched via real books in local and county libraries, the world of information has acquired such a marvelously accessible stay-at-home library as that provided via the Internet.

You might care to try using a spring between the pendulum's eyebolt and its suspension wire to make it sensitive to vertical tremors (friend and reader Nick Tile says that his part of Essex has experienced vertical tremors).

You might also try using different lengths of pendulum, extending the length of the plumbing pipe supports accordingly. There is enough information on the Garden Gate type of pendulum, in Fig.2 and the Pendulum Motion panel, for you to experiment with that too if you are feeling adventurous.

The author has reviewed many hours of recorded earth movement patterns. Many are obviously related to traffic intensity (as with his previous seismograph, traces over the recent Christmas period declined almost to zero). Other traces, though, could have been caused by other earth movements.

Let the author know via *EPE* how you get on with this Experimental Seismograph Logger! □


## ACKNOWLEDGEMENT

The author thanks Nick Tile for his help during the development of this design.

# PIC N' MIX

ANDREW JARVIS

**Our periodic column for your PIC programming enlightenment**

## PICing up the introductory threads to our latest PIC resource!

WELCOME to PIC n' Mix, the new column specially written for Microchip PIC microcontroller enthusiasts. As the name might suggest, it is hoped that the content of this page over the coming months will be a real mixed bag in which there will be a little something for everyone.

High on the agenda will be the opportunity to address some of the questions and issues that are frequently raised by readers when developing their own PIC projects or studying the *EPE* learning materials that have been so well received. Inevitably, some of this will be fairly detailed, but it won't be all in-depth assembler and binary.

In addition to looking at the current issues and developments of interest with regard to PICs, we'll occasionally take a step back to view the bigger picture, and sometimes even peek over the fence to see what's happening with other microcontrollers and operating systems.

### FLASHING L.E.D.S

Some people might say that all this PIC material is just hype and that we're going to a lot of trouble to flash a couple of l.e.d.s. But since the arrival of the microcontroller (MCU), and in particular the PIC16F8x family with on-chip flash memory in 1996, we have witnessed an extraordinary change in the way people think about solving problems with electronics, which in turn has brought along with it a new breed of hobbyist.

Put simply, the fundamental difference between now and then is this: in the olden days, a microprocessor like the Motorola 6805 or the Zilog Z80 needed a host of other components on the circuit board to make it do anything useful. Development tools were outside your budget and detailed information about the devices was not easy to find. Even as the first programmable PICs arrived with their integrated peripheral functions, they were primarily "One Time Programmable" (OTP), which meant that you had to be really sure that your code worked before you burned it onto the chip, no iterative development cycles unless you could afford the UV erasable part and the EPROM (electrically programmable read-only memory) eraser.

These days, PICs are bulging with new capabilities. They are inexpensive, have flash memory, are coded from full featured IDEs (integrated development environments) and programmed in some cases with little more than a PC and a couple of resistors. If you get stuck, the Internet is ready to help with questions or find you a datasheet for just about anything you need. More than perhaps ever before, firmware is replacing discrete components on the p.c.b. Electronics has never been so much fun!

### BURIED TREASURE

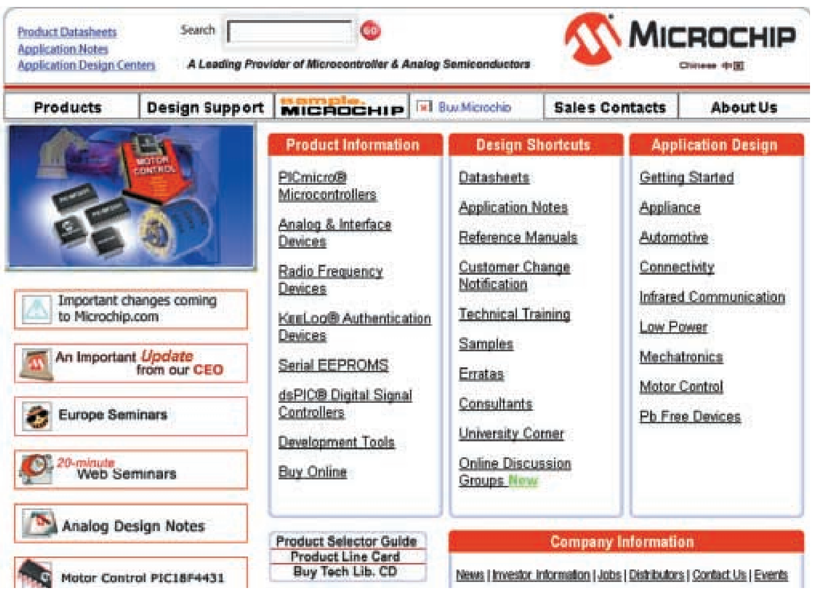
According to Microchip's own 2003 annual report for investors, they are now the number one supplier of 8-bit MCUs based on worldwide shipments. These PICs are the ones that you typically see in *EPE* projects; their basic features include the processor, volatile memory for data storage, non-volatile memory for program storage, and peripheral features that include serial communications and analogue-to-digital converters.

The "8-bit" part of the name comes from the size of the data memory bus, which is eight bits wide (however, the instruction word of the mid-range devices is sized differently at 14 bits, which is sometimes a source of confusion). Closely related to the 8-bit MCUs are the 16-bit digital signal processors (dsPICs). More on these another time.

Most MCUs, PICs included, are created for specific applications and markets, which sadly from our perspective tend not to be the low volume special interest "hobby" projects, whose inventors go around buying things in ones. Luckily, there are a few good reasons why despite this, PICs have been cheerfully adopted by amateur enthusiasts.

Most importantly, they are cheap and readily available. Then there is the abundance of third party learning materials and example code, together with plenty of high quality data sheets, application notes and free development software from Microchip and other third parties.

Finally, the "wordplay" is less demanding. It's much easier to incorporate "PIC" into a tremendously witty name for your latest creation than say, "AVR" (guilty as charged!).




*The Microchip website* ***www.microchip.com****, home of the PIC microcontroller, first port of call for datasheets and application notes.*

### PICS GALORE

With over two billion PICs shipped in the last decade or so, the next question is where are they all? Assuming that not all of them have ended up in *EPE* projects, and even allowing for the 22 I've just counted on my desk, there's potentially a lot of spares out there – and they may be closer than you think.

As a rough guess, you could have anything up to 100 MCUs in your house and car right now. They're in your dishwasher, microwave oven, washing machine, TV, video, DVD player, toys, games console, computer, central heating controller, even the doorbell. Basically, anything with a sensor, display, keypad or motor is a good bet. Most of mine are in the remote control collection I appear to have developed over the last few years.

Of course, how many of these devices actually contain PICs is harder to say. It's not easy to find such detail for off the shelf consumer goods – manufacturers are understandably guarded about specific design matters. It is, though, a lot more straightforward to find the general application areas that Microchip are targeting. A closer look at the organisation of their website shows that application notes are arranged into areas that include automotive, appliance, mechatronics, motor control and connectivity. Each of these areas can be cross-referenced with PIC devices, which makes it really easy to mine the site for any information that you need.

## ARTFUL APPLICATIONS

As you look through these application areas, it might occur to you in a strange "life imitating art" type of way, that there is a fair amount of symmetry with *EPE* projects and articles published over the last few years. Examples that spring to mind include hosepipe and watering controllers, airbags, l.c.d. and keypad connectivity, infrared decoders, alarm systems and robots. Interestingly, the *Brainibot Buggy* (Feb '03), a low cost educational buggy based on the PIC12C508, appears to have gone the opposite way and become a commercial product, as listed on the Rapid Education website.

## X MARKS THE SPOT

So despite hobby projects having no real impact on sales figures, it would appear that PICs are still doing well and you need not fear that the learning curve you are scaling will collapse beneath you (it might get steeper though!). Success on the high street, which is really all we can measure as consumers, depends on getting the devices into high profile, high volume products.

A good example of how they have done this is the Microsoft Xbox games console – leading edge home entertainment technology. Sitting pretty next to the NVIDIA graphics processing unit and the Intel 733MHz CPU is a PIC16LC63A. This 20MHz 8-bit MCU has 4K of program memory, serial I/O and is, according to Microchip, easily adapted for appliances and consumer applications. So it would seem.

Quite what it's actually doing in there is anyone's guess, but I'm sure it's kept well away from the polygons. It's most likely that in something like a games console, a PIC MCU will be using its peripheral functions to do something like monitoring the front panel, perhaps waiting for you to press a button or, inevitably, flashing a couple of l.e.d.s.

## NEXT BYTES

Next time we'll take at look at some low-cost PIC programmers and include a potted history of *EPE Toolkit TK3*.

In future issues Andrew will be taking a look at such things as (in no particular order): analysis of instruction cycle timing calculations; using third-party software with TK3; PIC16F87xA differences; introduction to the newer flash PICs and a TK3 hardware modification for them; PicKit1 emulation for TK3; introduction to MPLAB IDE; Visual Basic scripting; Linux users and PIC support; and lots more, some of which will depend on what you, the readers, suggest.

# PRACTICALLY SPEAKING

## Robert Penfold looks at the Techniques of Actually Doing It!

When first starting electronic project construction it usual to settle for building either kits or published designs that include detailed information about constructing each gadget. In both cases there should be diagrams that have physical representations of the components, together with a stripboard or custom printed circuit board (p.c.b.) design. Constructing these projects is therefore possible even if you have no technical knowledge and cannot read circuit diagrams.

You can go on in this fashion indefinitely, but before too long most constructors find the need to build a project where they have nothing more than a circuit diagram, plus (perhaps) a few notes on the gadget in question. There are numerous circuits published in books and on the Internet, and they are to be found in *EPE* in features such as *Ingenuity Unlimited*. The ability to build projects working from just a circuit diagram is a tremendous advantage, and greatly increases the range of projects that fall within your scope.

### Some Symbolism

Simple methods of designing circuit boards have been covered in this feature in the past, but there is an essential prerequisite to board design that has to be conquered first. It is essential to learn how to read circuit diagrams. Actually, even if you have no wish to design your own circuit boards it is still worthwhile learning to read circuit diagrams.

Most articles and books on electronics theory contain circuit diagrams, and will make little sense unless you understand at least a few of the fundamentals. If there is something in the wiring of a project that is unclear to you, referring to the circuit diagram will usually clarify matters.

Learning to read circuit diagrams is not very difficult, but you have to be prepared to learn the circuit symbols for the more common components. A selection of some common circuit symbols and the components that they represent is shown in Fig.1.

It is important to realise that there will inevitably be stylistic differences from one source to another. In most cases these are quite small and there

**Table 1: Component Identification Letters**

| Letter(s) | Component | Letter(s) | Component |
|---|---|---|---|
| B | Battery | PL | Plug (any type) |
| BY | Battery | Q | Transistor |
| C | Capacitor (any fixed value type) | R | Resistor (fixed value) |
| CH | Chassis | RL | Relay (coil or contacts) |
| CRT | Cathode ray tube | RV | Potentiometer or variable resistor |
| CSR | Thyristor or triac (controlled silicon rectifier) | S | Switch |
| D | Diode (any type including rectifiers, photodiodes, and l.e.d.s) | SK | Socket (any type, but JK is often used for Jack types) |
| E | Earth | SW | Switch |
| FL | Filter (usually a ceramic, crystal, or mechanical type) | T | Transformer (any type including r.f.) |
| FS | Fuse | TC | Trimmer capacitor (preset variable capacitor) |
| IC | Integrated circuit | Th | Thermistor |
| IFT | Intermediate frequency transformer | TL | Earphone or headphones |
| JK | Jack socket (any type) | Tr | Transistor |
| L | Inductor | TR | Transistor |
| LP | Lamp (neon or filament, but not a l.e.d.) | U | Integrated circuit |
| LS | Loudspeaker | V | Valve (any type except CRT) |
| M | Motor | VC | Variable capacitor |
| ME | Meter | VR | Variable resistor or potentiometer |
| MIC | Microphone | WD | Warning device (buzzer, bell, etc.) |
| PCC | Photo conductive cell (a photoresistor such as a cadmium sulphide cell) | X | Crystal |

is unlikely to be any confusion. Unfortunately, for many components there are actually two or more totally different symbols in use. This tends to become very apparent if you obtain circuits from the Internet, where the American versions of the symbols are quite common.

## Some Dualism

This dualism is not really a major problem, since it is usually quite easy to determine the type of component that a symbol represents by looking at the legend showing its value or type number. For example, a component having a value in kilohms (kΩ) is clearly some form of resistor, while one in microfarads ($\mu$F) shows that the component is a capacitor.

The prefix in the type number usually permits the precise identification of the component. Again though, there are variations in the prefixes used. For example, in the UK the transistors are normally marked TR1, TR2, etc., whereas they are labelled Q1, Q2, etc. in the USA and some other countries.

A range of type number prefixes and the corresponding components types are given in Table 1. Once you have learned the prefixes, which should be pretty straightforward provided you are already familiar with the names of the common components, it should not be difficult to identify a component even if it has the most zany of circuit symbols.

## Boxed In

The "proper" symbols for the various types of resistor are the rectangular box versions. Although they are not the current British standard the old zigzag symbols are still used a great deal in the UK. They are, of course, used for the circuit diagrams in *EPE*. Both sets of symbols are included in Fig.1.

At one time there was a plan for the rectangular resistor symbol to be used for any component having two leads. The marking beside the symbol (R1, C1, L1, etc.) would then be the only way of determining the type of component represented by the symbol. Many circuits based on this system were actually produced.

This system had the advantage of making it easy for the crude computer based drawing systems of the time to produce circuit diagrams. It made circuit diagrams quite difficult to read though, which is presumably why it was something less than universally popular. It has now been largely phased out. However, you may still encounter circuit diagrams of this type, and they seem to be quite common on the Internet.

In general, circuits obtained from the Internet tend to be difficult to follow. There is no true international standard for circuit symbols or prefixes, and many of the symbols used are only approximations anyway. Some seem to be drawn using word processors and a lot of ingenuity rather than using some form of drawing program.

Most circuit diagrams can be sorted out with the aid of some common sense and a bit of effort. Trying to produce a circuit board when working from a circuit diagram that is "as clear as mud" more or less guarantees a fair number of errors. Always redraw any cryptic circuit diagrams so that you have something that is clear and easy to follow.

## Going Dotty

Obviously, a circuit diagram must show all the connections between the components, and these are represented by lines. This is not usually as simple as having a lead on one component connecting to a lead on just one other component. Especially with supply lines, connections often run from component to component, perhaps joining dozens of components together. There is no problem in representing complex wiring on circuit diagrams, but it is inevitable that some lines have to cross other lines even though they do not actually make connections.

Confusion is avoided by using a dot where two lines meet and connect, but no dot is used where lines cross without any connection being made. Long ago it was the convention to have one wire loop over the other to indicate a crossover with no connection being made. This method is still used to a limited extent, but is no longer part of the British standard, and seems to be little used outside the UK. The circuit in Fig.2 helps to explain the way in which interconnections are represented on circuit diagrams.

## Real World

With a well drawn circuit diagram it is quite easy to see how everything connects together. There are one or two slight complications, such as dealing with polarised components and semiconductors that have more than two leads.

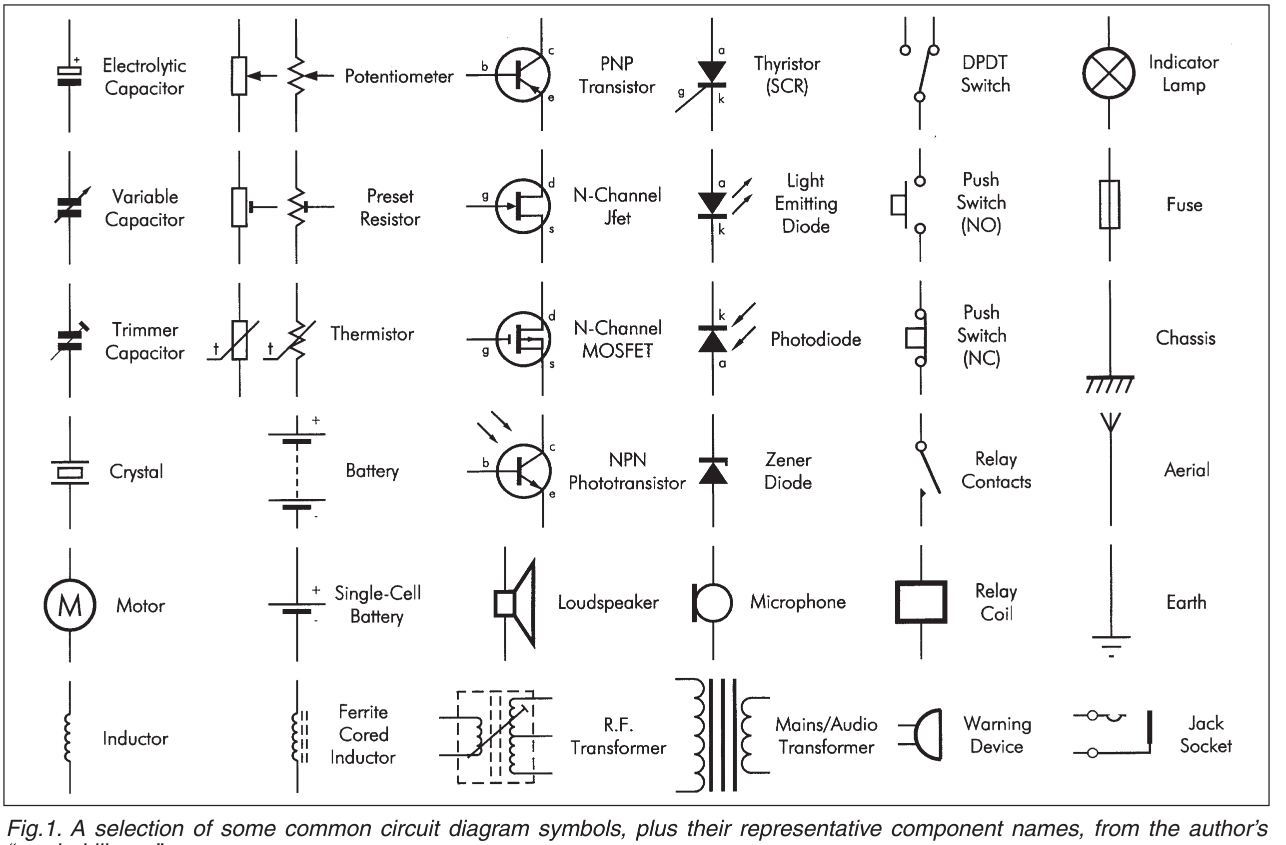



*Fig.1. A selection of some common circuit diagram symbols, plus their representative component names, from the author's "symbol library".*

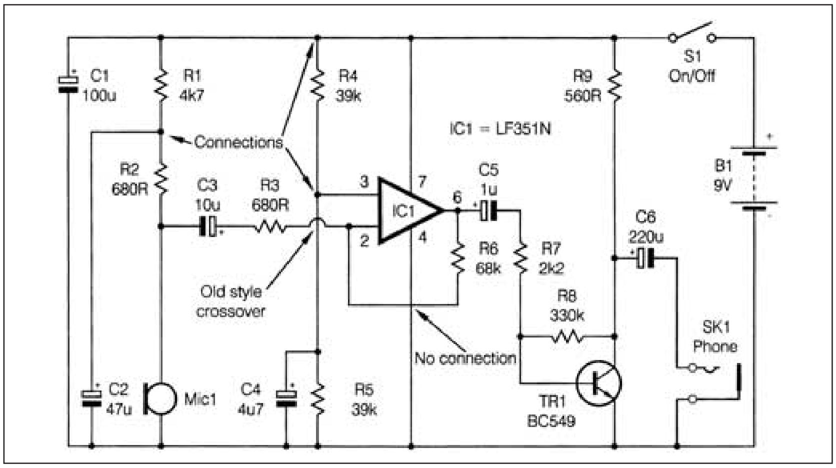



*Fig.2. Dots are used to indicate that there is a connection from one line to another (or component to another) in a circuit diagram.*

Polarised components mostly have their polarity indicated via the circuit symbol, such as the "hollow" line to indicate the positive terminal of an electrolytic capacitor. In most cases there are also plus and minus signs to indicate the polarity of a component, letters to identify the terminals of transistors, and so on. There is usually little scope for confusion to creep in.

Matters are usually less straightforward when dealing with the real world components, but sorting things out should not be too difficult for anyone having a reasonable amount of experience at building electronic projects. They will be well used to dealing with electrolytic capacitors and other polarised components. Polarised capacitors, like their circuit symbols, are usually marked with plus and (or) minus signs, making it easy to get them connected correctly.

It is probably semiconductors that are the most problematic, particularly transistors. These have a variety of case styles, with each one often having more than one leadout configuration. The fact that a transistor is in the same case as a device you have used before does not mean that it will have the same leadout configuration. In fact, it is quite likely that it will use a different configuration.

It is essential to seek out the leadout diagram for any unfamiliar semiconductor. The larger component catalogues usually contain leadout diagrams for most of the listed transistors and other simple semiconductors.

There is also a massive amount of semiconductor data available on the Internet. Just enter the relevant type number and "data" or "datasheet" into a good search engine and you should be directed to plenty of pages that provide data on the device in question. In most cases the full datasheet in PDF format will be available, and this will obviously include a leadout diagram.

Remember that the convention is for transistor leadout diagrams to be base views. In other words, they show the devices viewed looking at the side from which the leads emanate. The same is true for other simple semiconductors such as thyristors.

## Integrated Circuits

The opposite convention is used for integrated circuits (i.c.s), which are normally shown as top views. Most integrated circuits are represented by rectangles in circuit diagrams, but amplifiers are usually represented by a triangle. Also, logic gates and inverters are represented by special circuit symbols.

There is normally more than one logic element in each integrated circuit, so a suffix letter is added to the label of each element. A three gate device that is IC5, for example, would have the three gates labelled IC5a, IC5b, and IC5c.

Some symbols for integrated circuits are shown in Fig.3. In each case the input or inputs are on the left and the output is on the right.

The symbols are important when trying to follow the operation of a circuit, but they are of less relevance when working out a board design. It is the pin numbering that is important, and it is just a matter of matching each pin number on the circuit to its physical equivalent on the actual device.

Most integrated circuits have d.i.l. (dual in-line) encapsulations, and therefore have essentially the same method of pin numbering. The pin numbers increment in a counter-clockwise direction, with pin 1 indicated by a line, notch, or dimple on the device case. Anyone who has built a few projects should be familiar with this system. With the more exotic devices it is necessary to resort to data in component catalogues or on the Internet in order to sort out the pin numbering.

## Other Identities

Diodes and rectifiers are produced in a range of shapes and sizes. The bar in a diode symbol is at the cathode (k or +) end of the component. Most diodes and rectifiers have a corresponding bar marked around the body of the component next to the cathode lead. A few lack the bar and are instead slightly narrower at this end of the body. The idea behind this system is that it roughly equates to the arrowhead section of the symbol.

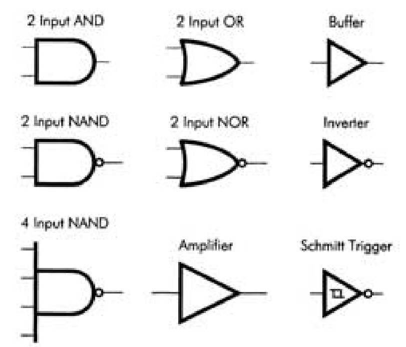



*Fig.3. Circuit symbols for some integrated circuits. Most are represented by a rectangle*

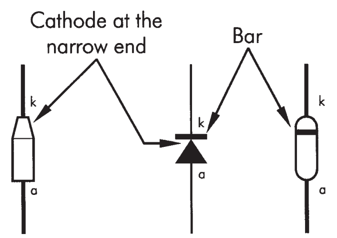



*Fig.4 (above). Diodes and rectifiers usually have physical similarities with the diode circuit symbol.*

Either way, the similarities between the symbols and the real world components make it easy to match one to the other (see Fig.4). Note that where a diode has several bands it is the wider one that indicates the cathode (k) lead.

Potentiometers can be a bit awkward as there is often nothing in the circuit diagram to indicate which end of the track is which. There will sometimes be "CW" and or "CCW" markings, which respectively indicate the clockwise and counter clockwise ends of the track (as viewed from the front). Without some technical knowledge it is otherwise a matter of using trial and error. Switches and sockets can usually be sorted out with the aid of some continuity checks.

With unusual components, which seem to feature in many projects these days, connection details will usually be available from the retailer's catalogue and the manufacturer's web site. It should also be included within the published article.

Do not use the "suck it and see" approach with this type of component. It might be safe to do so, but there is a real risk of causing some expensive damage and there are also the safety issues to consider. Delving into component catalogues and online data is almost certain to produce the information you require.

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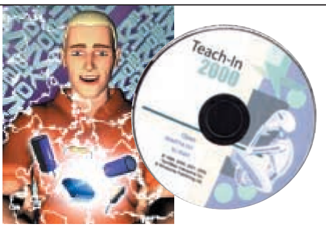


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Since *Foundations of Wireless* was first published over 60 years ago, it has helped many thousands of readers to become familiar with the principles of radio and electronics. The original author Sowerby was succeeded by Scroggie in the 1940s, whose name became synonymous with this classic primer for practitioners and students alike. Stan Amos, one of the fathers of modern electronics and the author of many well-known books in the area, took over the revision of this book in the 1980s and it is he, with his son, who have produced this latest version.

*400 pages* **Order code NE27** **£23.99**

**GETTING THE MOST FROM YOUR MULTIMETER**
**R. A. Penfold**

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

*96 pages* **Order code BP239** **£5.49**

**DIGITAL GATES AND FLIP-FLOPS**
**Ian R. Sinclair**

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

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

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

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# MUSIC, AUDIO AND VIDEO

**QUICK GUIDE TO ANALOGUE SYNTHESIS**
**Ian Waugh**

Even though music production has moved into the digital domain, modern synthesisers invariably use analogue synthesis techniques. The reason is simple – analogue synthesis is flexible and versatile, and it's relatively easy for us to understand. The basics are the same for all analogue synths, and you'll quickly be able to adapt the principles to any instrument, to edit existing sounds and create exciting new ones. This book describes: How analogue synthesis works; The essential modules every synthesiser has; The three steps to synthesis; How to create phat bass sounds; How to generate filter sweeps; Advanced synth modules; How to create simple and complex synth patches; Where to find soft synths on the Web.

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**Ian Waugh**

MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music?

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**ELECTRONIC PROJECTS FOR VIDEO ENTHUSIASTS**
**R. A. Penfold**

This book provides a number of practical designs for video accessories that will help you get the best results from your camcorder and VCR. All the projects use inexpensive components that are readily available, and they are easy to construct. Full construction details are provided, including stripboard layouts and wiring diagrams. Where appropriate, simple setting up procedures are described in detail; no test equipment is needed.

The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.

*109 pages* **Order code BP356** **£5.45**

**ELECTRONIC MUSIC AND MIDI PROJECTS**
**R. A. Penfold**

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

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

Projects covered: Simple MIIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit. ~~£10.95~~

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**THE INVENTOR OF STEREO – THE LIFE AND WORKS OF ALAN DOWER BLUMLEIN**
**Robert Charles Alexander**

This book is the definitive study of the life and works of one of Britain's most important inventors who, due to a cruel set of circumstances, has all but been overlooked by history.

Alan Dower Blumlein led an extraordinary life in which his inventive output rate easily surpassed that of Edison, but whose early death during the darkest days of World War Two led to a shroud of secrecy which has covered his life and achievements ever since.

His 1931 Patent for a Binaural Recording System was so revolutionary that most of his contemporaries regarded it as more than 20 years ahead of its time. Even years after his death, the full magnitude of its detail had not been fully utilized. Among his 128 patents are the principal electronic circuits critical to the development of the world's first electronic television system. During his short working life, Blumlein produced patent after patent breaking entirely new ground in electronic and audio engineering.

During the Second World War, Alan Blumlein was deeply engaged in the very secret work of radar development and contributed enormously to the system eventually to become 'H2S' – blind-bombing radar. Tragically, during an experimental H2S flight in June 1942, the Halifax bomber in which Blumlein and several colleagues were flying, crashed and all aboard were killed. He was just days short of his thirty-ninth birthday.

*420 pages* **Order code NE32** **£17.99**

**VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR**
**R. A. Penfold**

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

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

Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply. ~~£10.95~~

*124 pages* **Order code PC115** **£5.45**

**PC MUSIC – THE EASY GUIDE**
**Robin Vincent**

How do I make music on my PC? Can I record music onto my PC? What's a sequencer? How can I get my PC to print a music score? What sort of a soundcard do I need? What hardware and software do I need? How do I connect a keyboard to my PC?:

Just a few of the questions you've probably asked. Well, you'll find the answers to all these questions, and many more, in this book. It will show you what can be done, what it all means, and what you will need to start creating your own music on your PC. It's an easy read, it's fully illustrated and it will help you understand how a computer can be used as a creative music tool.

It covers soundcards, sequencers, hard disk digital audio recording and editing, plug-ins, printing scores with notation software, using your PC as a synthesiser, getting music onto and off the Internet, using Windows, sample PC music set-ups, FAQs, a glossary, advice on hardware and software, and a list of industry contacts.

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**R. A. Penfold**

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**Robert Penfold**
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Topics covered include: the PIC register set; numbering systems; bitwise operations and rotation; the PIC instruction set; using interrupts; using the analogue to digital converter; clock circuits; using the real time clock counter (RTCC); using subroutines; driving seven segment displays.

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**A. Flind**
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Various circuits using inductors and capacitors are covered, with emphasis on stable low frequency generation. Some of these are amazingly simple, but are still very useful signal sources.

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**Robin Pain**
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Simple circuit examples are used to illustrate principles and concepts fundamental to the process of fault finding. This is not a book of theory, it is a book of practical tips, hints and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialised.

The fundamental principles of analogue and digital fault finding are described (although, of course, there is no such thing as a "digital fault" – all faults are by nature analogue). This book is written entirely for a fault finder using only the basic fault-finding equipment: a digital multimeter and an oscilloscope. The treatment is non-mathematical (apart from Ohm's law) and all jargon is strictly avoided.

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**R. A. Penfold**
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*120 pages* **Order code BP335** **£5.45**

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**R. A. Penfold**
Getting started with logic circuits can be difficult, since many of the fundamental concepts of digital design tend to seem rather abstract, and remote from obviously useful applications. This book covers the basic theory of digital electronics and the use of CMOS integrated circuits, but does not lose sight of the fact that digital electronics has numerous "real world" applications.

The topics covered in this book include: the basic concepts of logic circuits; the functions of gates, inverters and other logic "building blocks"; CMOS logic i.c. characteristics, and their advantages in practical circuit design; oscillators and monostables (timers); flip/flops, binary dividers and binary counters; decade counters and display drivers.

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# AUDIO AND MUSIC

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**John Linsley Hood**
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Contents: Active components; Valves or vacuum tubes; Solid-state devices; Passive components; Inductors and transformers; Capacitors, Resistors, Switches and electrical contacts; Voltage amplifier stages using valves; Valve audio amplifier layouts; Negative feedback; Valve operated power amplifiers; Solid state voltage amplifiers; Early solid-state audio amplifiers; Contemporary power amplifier designs; Preamplifiers; Power supplies (PSUs); Index.

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**R. A. Penfold**
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A must for audio enthusiasts with more sense than money!

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**VALVE AMPLIFIERS**
**Second Edition. Morgan Jones**
This book allows those with a limited knowledge of the field to understand both the theory and practice of valve audio amplifier design, such that they can analyse and modify circuits, and build or restore an amplifier. Design principles and construction techniques are provided so readers can devise and build from scratch, designs that actually work.

The second edition of this popular book builds on its main strength – exploring and illustrating theory with practical applications. Numerous new sections include: output transformer problems; heater regulators; phase splitter analysis; and component technology. In addition to the numerous amplifier and preamplifier circuits, three major new designs are included: a low-noise single-ended LP stage, and a pair of high voltage amplifiers for driving electrostatic transducers directly – one for headphones, one for loudspeakers.

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**Vivan Capel**
This book contains all that a working musician needs to know about loudspeakers; the different types, how they work, the most suitable for different instruments, for cabaret work, and for vocals. It gives tips on constructing cabinets, wiring up, when and where to use wadding, and when not to, what fittings are available, finishing, how to ensure they travel well, how to connect multi-speaker arrays and much more.

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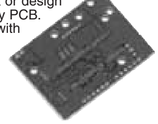

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