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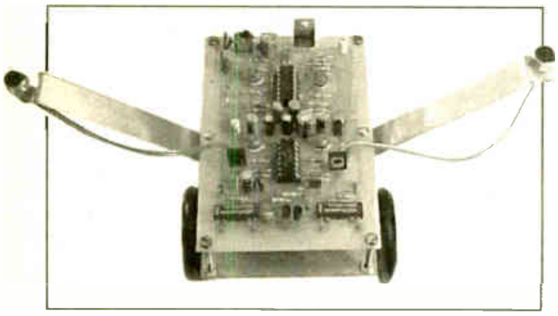

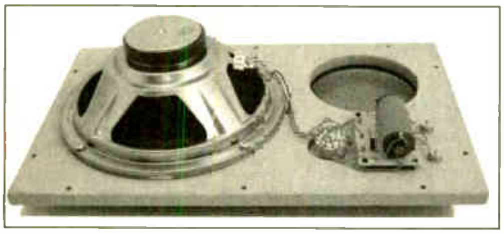

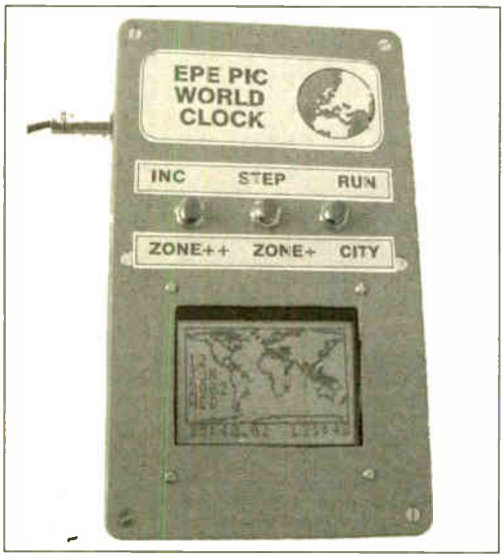

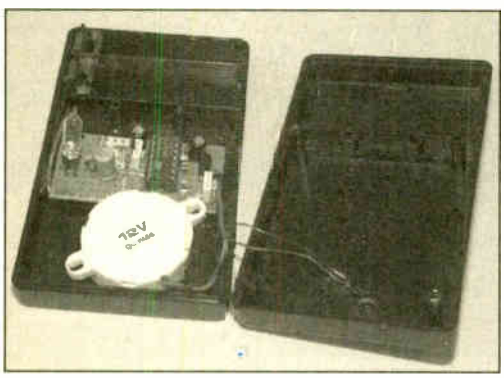

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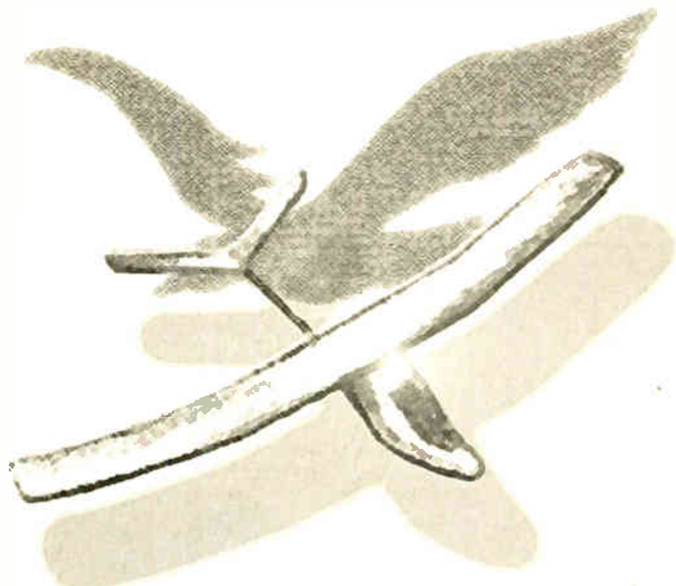
FREEBIRD

An automated flight control system for model gliders. Following a number of prototypes, this article describes how to make and install into a model glider a low cost electronic stabilisation system that helps model gliders to fly a little more straight and level. Glider flight times have been increased by an average of three times. The real power of Freebird is that the flight correction algorithm can be modified by re-programming a PIC16F84 microcontroller, which handles the attitude detection and flight correction, all in real time. A portable computer has been used in conjunction with EPE Toolkit Mk3, *to provide full "in the field" tuning of the software.*



EPE MORSE CODE READER

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- *A handheld unit receives Morse, via audio input (internal microphone), or direct signal connection or Morse key, and translates it for display on an l.c.d. screen.*
- *Using a PC, Windows-based software can input the signal being repeated from the handheld unit, convert and display the code on the monitor, and store the translation to disk. The unit can be used on its own, it is not necessary to use it with a computer.*
- *The PC software can also output Morse to the handheld unit, for display on its screen, or monitoring as an audio signal. There are several modes of output: translation of a text file to Morse; direct keying of alphanumeric characters for immediate translation to Morse; use of the keyboard as a Morse key with the duration of keypresses simulating Morse dots and dashes.*

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E-MAIL JUNK

I wonder why people bother to send out millions of junk emails? Presumably some sad individual is gullible enough to take them up on their "make $1,000,000 in your spare time" offer or wants to set up their own porn site. But one must wonder what level of response these people get from the rubbish they send out.

Out of 90-odd emails that came into the editorial office this morning, just under half of them were actually concerned with *EPE*, the rest were junk and simply deleted from our system. What is most annoying is that there seems to be no way of stopping this rubbish appearing – we have yet to find any software that can successfully weed it out.

At one time we suffered in the same way with junk faxes but, having registered with the Fax Preference Service, we have now largely overcome the problem; with the exception of one company that presumably thinks it is above the law.

FRIEND OR FOE

The Internet is a wonderful place if you want to find out anything – getting hold of electronic device data has never been easier – but it does have its problems and unfortunately we can only see these growing. I reflected on the world we live in last month and I guess this is just another facet of that.

On a brighter note, the technology has allowed us to get *EPE* into the hands of readers all over the world within a few minutes and at very little cost via our **www.epemag.com** *EPE Online* web site – check it out, particularly if you live outside of the UK and have difficulty obtaining issues of your favourite magazine (*EPE*, of course!).

The Chat Zone on our UK web site (**www.epemag.wimborne.co.uk**) has put readers around the world in touch with each other and it is wonderful to see the help some more experienced readers are prepared to give to anyone who asks, something I am sure is greatly appreciated by everyone. With very few exceptions, you readers are a great bunch.

Mike Kenward

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Constructional Project

PICKPOCKET ALARM

BART TREPAK

It's in the bag if you want to dodge the artful pickpocket

THERE is safety in numbers, or so the saying goes, and it is certainly true that one feels a lot safer even at night when walking along a busy high street than along a deserted side street or alley. Despite this, it is probably more likely that you will be robbed in a large crowd than in an almost deserted side street.

Large crowds are a favourite haunt of pickpockets who tend to ply their "trade" at football matches, train stations or such venues as the Trafalgar Square New Year's Eve celebration which has unfortunately become notorious for such activities.

These criminals normally work in pairs or groups of three and the usual method seems to be that one man will "accidentally" bump into the victim or obstruct him or her in some way – a likely occurrence in a crowd. While apologising profusely he thus distracts the victim from the activities of the second thief who actually does the deed.

If a third member of the team is present, he poses as a passer-by and the proceeds of the robbery are quickly passed to him. Even if the victim detects something untoward, the second thief can appear totally innocent as he will have no incriminating evidence on his person.

IN THE BAG

The skill of these people has to be seen (or not seen!) to be believed and relies on a basic human response. If somebody steps on your toe or bumps into you, the brain's attention is instantly directed towards this and is unlikely to register a light touch on some other area of the body, especially a relatively remote one such as a coat pocket.

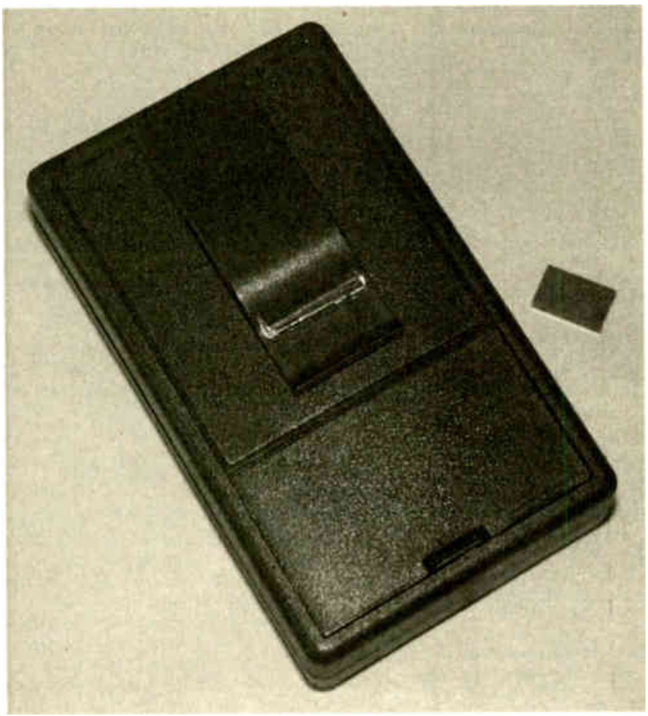
Women are perhaps even more vulnerable because they tend to keep all of their possessions in one neat package – a handbag – so that the thief is almost guaranteed in finding something more valuable than an empty pocket, and there is far less likelihood of the victim feeling anything.

The Pickpocket Alarm presented here is thus intended to provide a warning that the handbag is being interfered with. While not providing a deterrent, it should certainly give the would-be pickpocket something else to think about and either cause him to run off empty handed or at least prevent him from having another "dip" thus limiting your loss. Although it is designed primarily for a handbag, with a little ingenuity it could equally be applied to a pocket in a coat or jacket.

SENSOR

One of the biggest problems is choosing a sensor which can detect the presence of the thief's hand and this will, of course, depend to a large extent on the design of the handbag to which it is fitted. Initially, a proximity switch was considered, but this would probably be too unreliable and prone to false alarms.

The last thing that is required is to have an alarm which keeps going off in company, each time someone approaches the bag.



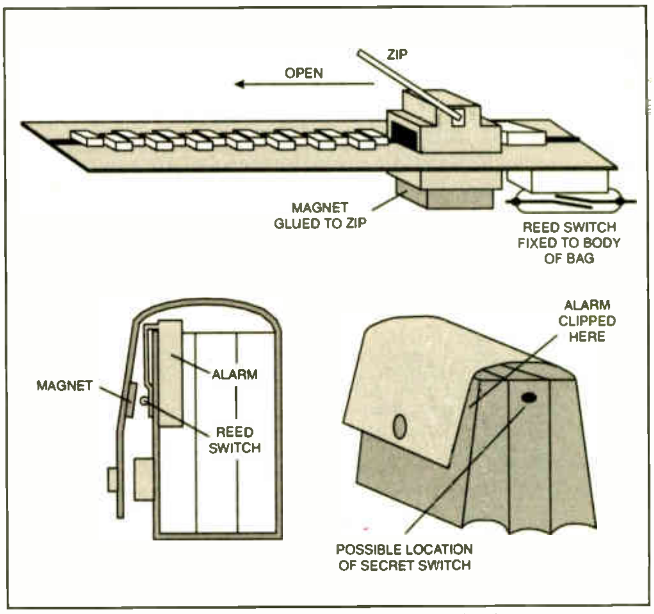


Fig.1. Some suggested ideas on how and where to mount the Pickpocket Alarm. The photograph on the left shows the reed switch mounted on the "pocket clip" and a small magnet to one side of the case.

Most handbags usually have some sort of flap or zip which must either be lifted or unzipped in order to gain access to the bag and this is probably the best area to consider when trying to think of a suitable sensor.

A small magnet mounted on the handbag flap or zipper and a reed switch secured on the body of the bag would appear to be the simplest solution. These components can be very small thus enabling them to be fitted unobtrusively in the bag.

Whilst the magnet is in close proximity to the reed switch, the contacts will be held closed and arranged to keep the alarm disabled. When the magnet is removed by lifting the flap or undoing the zip, the contacts will open thus triggering the alarm. Some handbags even have a magnetic clasp to hold the flap closed and if this is the case, it may be possible to utilise this magnet and save having to fit another one while the reed switch would be mounted in the bag and connected to the alarm unit via a small jack plug.

Another possibility, especially if the suggested case which has a "belt-clip" is used, is to mount the reed switch on the clip itself. This alarm unit can then be clipped to the bag under the flap (to which a magnet would be attached) thus removing the need for separate sensors or plugs and sockets.

IN SECRET

Naturally, the owner has to be able to get into her bag without the alarm being triggered and this can be simply achieved by having a secret push-to-make switch, which is pressed while undoing the bag, to mute the alarm. This would need to be unobtrusively fitted to the bag in a convenient position to enable it to be easily operated when required and this can also be connected to the unit via a lead terminated with a jack plug.

Here again, a switch of some sort mounted on or in the alarm unit itself would be preferable as this would make for a self-contained unit which could easily be transferred from bag to bag as required, without any modifications to the bags other than the fitting of a small magnet. In the prototype for example, a tilt switch was used for this purpose. These consist of two contacts mounted in a sealed chamber which contains a small globule of Mercury and this was arranged so that with the unit clipped into position in the bag, the contacts remain open. *(It is strongly recommended that a non-mercury tilt switch is used – see the* Shoptalk *page.)*

To operate the switch, the bag is tilted horizontally thus causing the mercury to move and bridge the contacts inhibiting the alarm. The arrangement illustrated in Fig.1 shows some possible solutions, although as mentioned previously, the final method adopted will depend largely on the handbag which is to be protected.

Another ploy adopted by some thieves when confronted by someone wearing a shoulder bag is to simply cut the strap and slip the whole bag from the victim. To protect against this eventuality, a thin wire could be threaded through or attached to the strap forming a normally closed loop. This may not be possible in all cases but if it is, this could be connected to the alarm just like another reed switch sensor via a jack plug.

DELAYED ACTION

To save fitting further switches to disable the alarm, especially in the event of a false alarm due to the owner forgetting to operate the secret mute switch before opening the bag, this switch should also switch off the alarm even after it has been activated. To save unnecessary embarrassment in this eventuality, the circuit has been designed so that operating the secret switch will instantly reset the circuit.

If the mute switch is not closed when the bag is opened, the alarm will sound briefly but will then mute for a short period (about one second) allowing it to be reset. If the switch is still not pressed following an alarm condition (usually because the thief will not know of its existence), the alarm will then continue to sound for a period of 20 seconds. This should be long enough to cause any pickpocket to beat a hasty retreat but if this is considered too short or too long a time, it can easily be altered by a simple change in a component value.

Ideally, there should be no need to arm the circuit and the alarm should interfere as little as possible with the normal use of the bag. This circuit automatically arms itself, requiring no special procedures to be followed, when the bag is closed and once open, it can be left in this condition indefinitely without the alarm going off. Only at the instant of it being opened does the user have to operate the secret mute switch to ensure that the alarm does not sound.

CIRCUIT DETAILS

The basic circuit diagram for the Pickpocket Alarm is shown in Fig.2. Circuit modifications to give a full 20 seconds alarm time out is given in Fig.4.

Rather than attempting to re-invent the wheel with oscillators and speakers, a ready made piezo sounder, WD1, is specified to produce the alarm itself These are readily available and produce a loud piercing sound over a range of supply voltages from 3V to 12V or more, making them eminently suitable for use with a 9V battery supply. The sounder WD1 is switched on by transistor TR1 which itself is controlled by a simple oscillator built around IC1d. This causes WD1 to switch on and off at around 1Hz when an alarm condition has been registered, producing a much more distinctive pulsating signal, further unnerving the would-be thief who will, no doubt, already be on edge no matter how experienced he or she may be.

Referring to the circuit waveforms illustrated in Fig.3, the output of gate IC1d charges and discharges capacitor C5 via

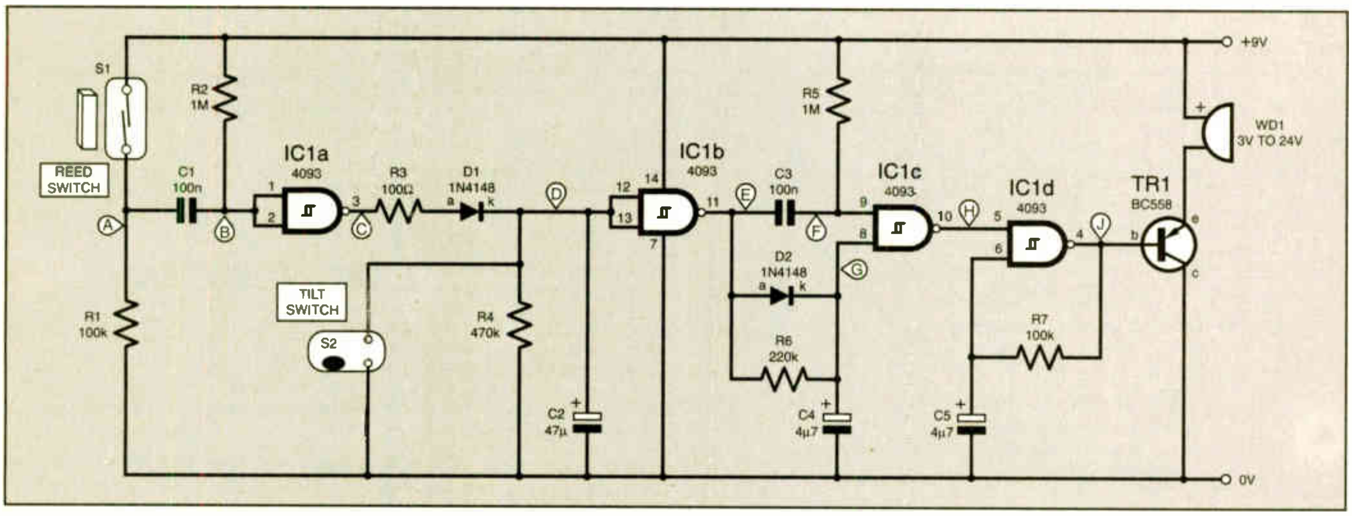


Fig.2. Basic circuit diagram for the Pickpocket Alarm. The ringed letters are the "take-off" points for the waveforms shown in Fig.3.

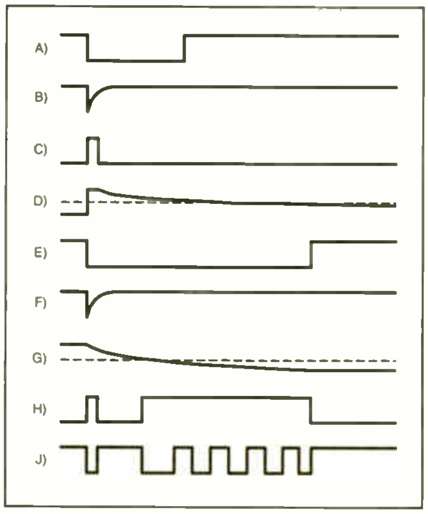


Fig.3. Typical waveforms at various points on the circuit.

resistor R7 causing the output at (J) to switch high and low at around 1Hz switching the sounder WD1 on and off at this frequency, via the driver transistor TR1. The output of oscillator IC1d is normally held high causing the sounder to remain off while the output of gate IClc is low. Since IC1c is a NAND gate, it functions as a NOR gate for negative logic levels so that either of its inputs (F or G) going low will cause its output (H) to go high and serve to enable the oscillator.

STAND-BY

In the stand-by condition, reed switch S1 will be held closed, via the magnet, and the voltage at point A will be at the positive supply rail. When the switch opens, due to the bag being opened, point A will go low and a short negative going pulse will be applied to the input of IC1a, wired as a logic inverter, so that its output (C) will go high briefly.

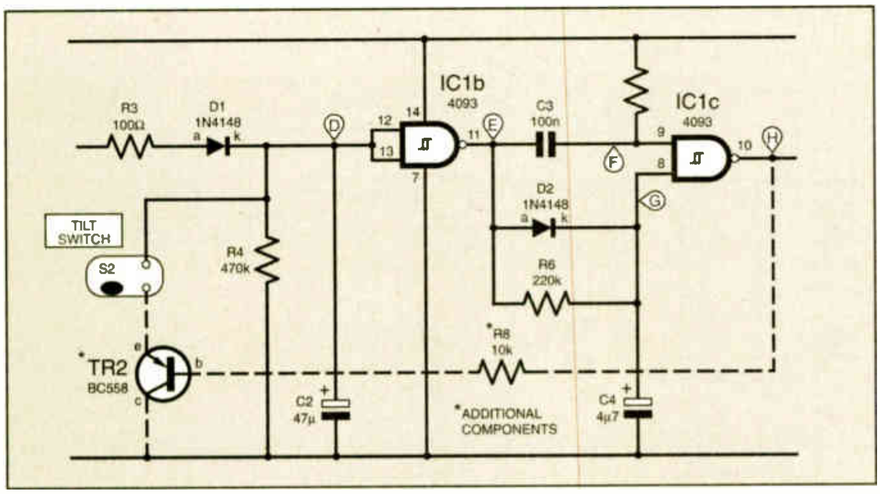


Fig.4. Circuit modifications to prevent alarm reset once triggered.

This will cause capacitor C2 to charge to about 9V via resistor R3 and diode Dl, provided the secret mute switch S2 remains open. If this switch is closed, capacitor C2 will be prevented from charging so that the output of IC1b will remain high and the alarm stays silent.

Assuming that C2 does charge, the input of gate IC1b will go high causing its output (E) to go low. Meanwhile, the output of IC1a will have gone low again and with diode Dl now reverse biased, capacitor C2 will commence discharging via resistor R4 so that output E will remain low for around 20 seconds. This time can be increased or decreased by increasing or decreasing the value of R4 and if very much longer alarm times are required, the value of C2 could also be increased.

While the output of gate IClb is high, capacitor C4 is charged to 9V via diode D2 so that both inputs of IClc are high and the alarm muted, but when this output goes low, point G will also go low briefly and so during this short period the alarm will sound. The values of capacitor C3 and resistor R5 are chosen to make this time about 100ms producing only a short bleep to serve as a warning that the bag has been opened.

If the secret switch is now operated, capacitor C2 will be instantly discharged causing the output of gate IC1b to go high again and the circuit will revert to its stand-by condition. This gives the legitimate user a second chance to switch off the alarm should they forget to do so while opening the bag. The thief, not knowing about the secret switch, will, of course, not do this and when capacitor C4 discharges via resistor R6 (which should take a further second or so) the other input of IClc (point F) will go low causing the alarm to sound until C2 has eventually discharged.

The alarm can still be silenced in this condition by operating the secret switch and this could be considered a disadvantage especially if a tilt switch is used to provide this function. This could be activated inadvertently by the thief if he attempted to snatch the bag despite the alarm going off. Since this alarm is only intended to provide a warning to the user and hopefully scare off the attacker, should matters progress to this point it would probably be best to allow the bag to be taken rather than risk injury if violence is threatened, in which case it would be immaterial whether the alarm continued to sound or not.

FULL TIME

If, however, you would prefer to have the alarm sound for the full 20 seconds or so, the circuit should be modified to include transistor TR2 and resistor R8 as shown in Fig.4. (Note that this modification is not shown in the circuit board layout drawings, but there should be plenty of room on the board for the two additional components.)

In normal operation when the alarm is not sounding, transistor TR2 will be turned on and will therefore have no effect on the operation of the circuit. Once the output of IC1c goes high and the alarm sounds however, TR2 will be turned off thus preventing switch S2 from discharging capacitor C2 causing the alarm to continue for its full term. Should this occur accidentally, the legitimate owner will also be unable to switch off the alarm and in this situation it may be a good idea to fit another reset switch on the alarm unit itself connected directly across C2.

The waveforms appearing at various points in the circuit, shown in Fig.3, should help in clarifying the operation of the circuit. The dotted lines signify the input threshold voltage of the CMOS gates within IC1 above which logic high is recognised.

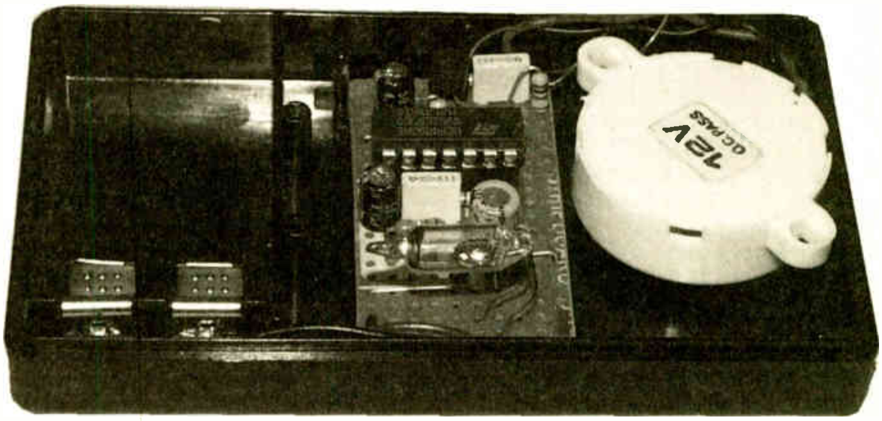
For clarity, this is shown as one voltage level at about half of the supply but in fact, the gates in the CMOS 4093 specified are Schmitt triggers which means that the input thresholds are different for rising and falling input voltages. This characteristic is very important in this circuit and apart from making the outputs switch cleanly even with slowly rising or falling input voltages, it makes it possible for ICld to function as an oscillator.

CONSTRUCTION

There are perhaps as many ways to build this circuit as there are types of handbag on the market so that the following should be regarded only as a guide. While the solution presented should be suitable for a great many types, it is best to consider first how and where the sensors will be mounted and only when this has been done should the construction of the unit begin.

If the sensor(s) and/or a reset switch are to be mounted on the bag itself, these should be fitted with jack plugs or some other type of connector with matching sockets on the alarm box. This will allow the alarm to be disconnected from the bag and fitted to another as occasion demands.

If a number of sensors are required (because the bag has multiple pockets or compartments for example) these should be wired in series so that any one sensor operating will cause the input to go low. For this reason too, any sockets fitted to the box should be switched types and arranged to short out should the sensor not be plugged in.



Internal view showing the battery contacts and siting of the alarm buzzer.

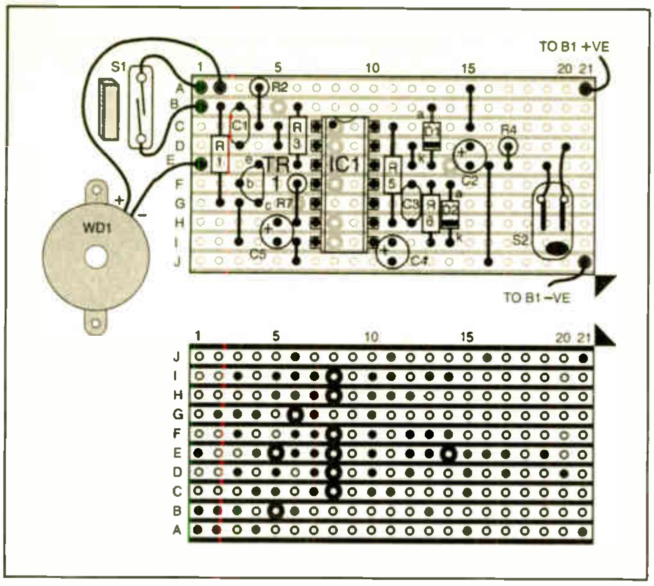
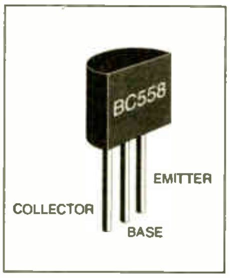


Fig.5. Stripboard component layout, off-board wiring and details of breaks required in the underside copper strips. The transistor pinouts are shown inset right.



COMPONENTS

Resistors

R1, R7	100k (2 off)	
R2, R5	1M (2 off)	
R3	100Ω	
R4	470k	
R6	220k	
R8	10k (see text)	

All 0·25 5% carbon film

See SHOP TALK page

Capacitors

C1, C3	100n polyester (2 off)
C2	47μ radial elect. 16V
C4, C5	4μ7 radial elect. 63V (2 off)

Semiconductors

D1, D2	1N4148 signal diode (2 off)
TR1, TR2	BC558 *pnp* transistor (2 off – see text)
IC1	4093 quad 2-input NAND Schmitt trigger

Miscellaneous

WD1	3V to 30V d.c. piezoelectric buzzer
S1	sub-min, normal open, reed switch with magnet
S2	tilt switch, non-mercury type if possible – see text

Stripboard, size 21 holes x 10 strips; plastic case, size 103mm x 62mm x 23mm, with battery compartment and pocket clip; 14-pin d.i.l. socket; 9V (PP3) battery; connecting wire; optional 3·5mm switched mono jack socket, with plug (see text); solder etc.

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

CIRCUIT BOARD

The stripboard topside component layout and details of breaks required in the underside copper tracks are shown in Fig.5. This board accommodates all of the components except the battery, sounder and optional jack sockets for connecting the sensors and the secret reset switch (if fitted). These are connected to the board by flying leads.

With this form of construction, it is just as important to break any connections that are not required as it is to make those that are and so construction should begin with breaking the copper tracks at the points indicated. This is best done with a special tool available for this purpose or by simply using a handheld 2·5mm twist drill. There are 10 track breaks required.

Once this has been done, the components may be fitted as shown. Note that there are a total of six links required and these can be made from discarded resistor leads.

As IC1 is a CMOS device, it is therefore prone to damage by static so it is best to use a 14-pin i.c. socket for this component. The i.c. being plugged in after all the other components have been fitted and the soldering completed. When inserting the i.c. ensure that it is inserted the correct way around.

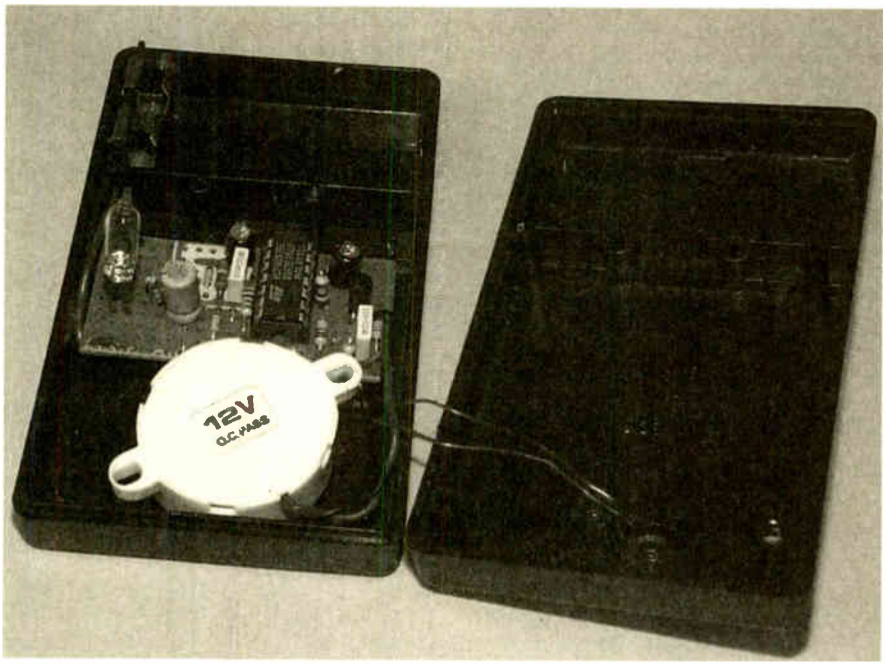
As mentioned, IC1 is a CMOS quad Schmitt NAND gate type 4093. Some readers may have a spare quad NAND gate type 4011 which, although having the same logic function and pinouts, is **not** suitable for use in this circuit.

Also, double-check that the transistor TR1 (and TR2 if used), diodes D1 and D2 and capacitors C2, C4 and C5, which are electrolytic devices, have been soldered on the board the correct way round. The electrolytics are normally marked either with a grey stripe on the body or a negative sign (sometimes both) adjacent to the negative lead which should be connected to 0 volts or the battery negative terminal. Transistor TR1 is a *pnp* device and although a BC558 has been specified, virtually any small *pnp* device can be used.

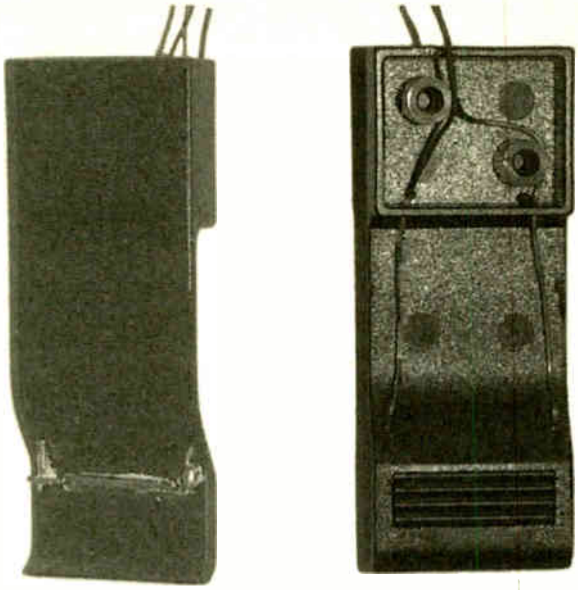
BOXING UP

The box specified has a battery compartment suitable for a PP3 type battery and special battery contacts which clip into the box are supplied. Red and black wires should be soldered to these contacts before they are fitted into the box and the free ends then connected to the appropriate points on the board.

It may be possible to fit the sounder inside the box in which case a suitable hole should be drilled in the box adjacent to it to allow the sound out and prevent it from being unduly attenuated. Some sounders (usually the louder ones) will be too large to fit inside the box in which case they will need to be mounted on the box or perhaps even remote from it. While a loud sound is of course preferable, especially as it is likely to be attenuated by being inside the bag, a reasonably loud volume will no doubt alert the user should any attempt to open the bag be made.



Completed unit showing general positioning of components and leads going to the clip-mounted reed switch on the outside of the case.



Outer face of the "handbag/pocket" clip (above left) showing position of the magnet-operated reed switch and (above right) the inner face showing the switch wiring, which passes through a hole in the case to the circuit board.

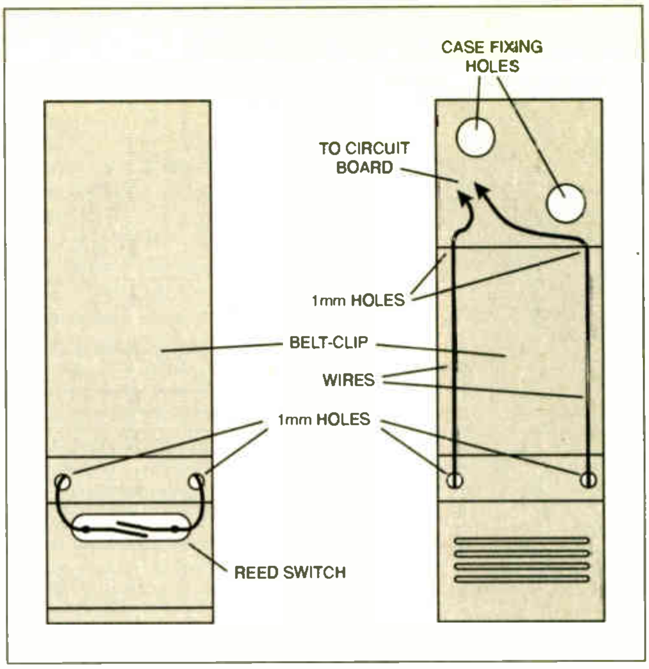


Fig.6. One suggested method of mounting and wiring the magnet-operated reed switch on the case belt-clip.

BELT-UP

The box also has provision for a "belt-clip" which can be mounted by drilling two 5mm holes in the positions marked and securing it with the screws provided. This will provide the possibility of clipping the alarm to the bag. Depending on the design of the bag, it may be possible to have the reed switch sensor S1 mounted on the clip itself leaving only a small magnet to be glued to the inside face of the bag flap adjacent to the switch, with further sensors (if required) added by fitting jack sockets as previously mentioned.

If this method of construction is adopted, the "belt-clip" should first be modified by drilling four 1mm holes in it, see Fig.6 and photographs. Two wires (28s.w.g. enamelled copper wire was used in the prototype) can then be passed through these holes and soldered to the reed switch as shown. The leads of the reed switch should first be bent at right angles to match the holes drilled in the clip so that a small neat solder joint can be made.

When bending the leads of the reed switch, extreme care should be taken as it is very easy to crack the glass and destroy the device. The leads must be gripped by a pair of pliers next to the glass body of the device and the bend made about 2mm from the glass seal.

Once the reed switch has been mounted, it should be encapsulated in Araldite to prevent damage. A small hole will also be required in the box adjacent to the two clip mounting holes to enable the wires from the sensor to be passed through for connection to the circuit board.

TESTING

Once assembly is complete, the unit can be tested by connecting a battery and placing a magnet near to the reed switch S1 and then removing it. This should cause the sounder to emit a short "bleep". If no further action is taken, the alarm should now emit a series of intermittent "bleeps" for about 20 seconds before switching off.

Replacing the magnet should have no effect but if it is removed again, the sequence should be repeated but this time the reset switch (S2) should be operated while the magnet is removed and this time no initial "bleep" should be sounded and the alarm should remain off. Finally, the unit should be triggered and reset after the initial "bleep" and once the full alarm has been started to check that the reset switch works in these situations.

If the modification of Fig.4 has been fitted, the reset switch should have no effect once the full alarm is sounding. There are no high frequency voltage changes in this circuit so that if necessary, the voltages at various points in the circuit can be followed by monitoring them with a multimeter and compared against the waveforms shown in Fig.3.

The Pickpocket Alarm can be mounted in a handbag for a final test when the operation of the circuit is satisfactory. A suitable position for the magnet should be found and this should be secured to the flap opposite the reed switch on the clip with a suitable adhesive – see Fig.1.

Hopefully further "field" testing will not be required but should it occur, the thief should be unable to commit his crime quietly, attracting more attention than he bargained for. □

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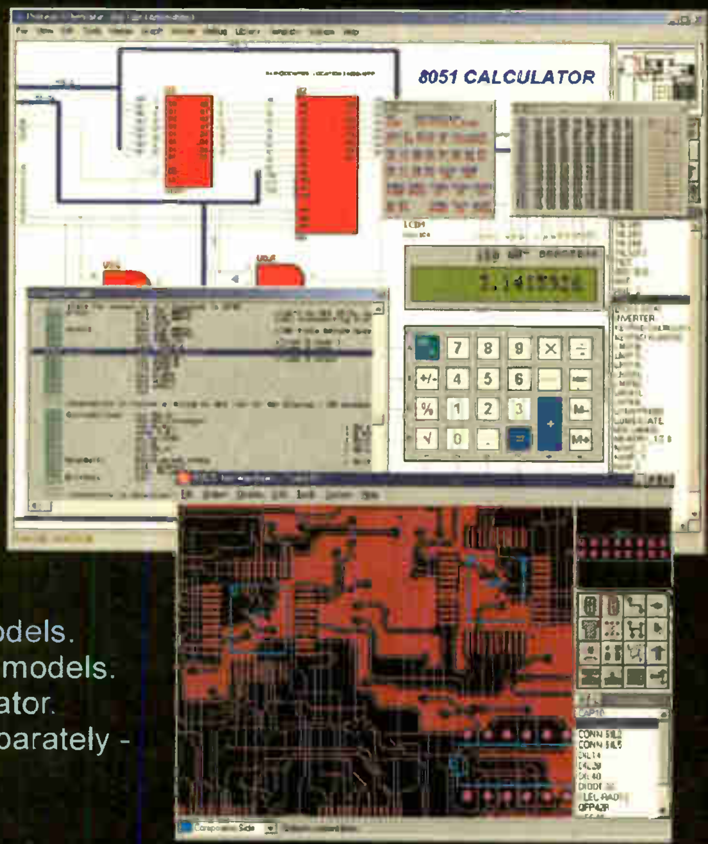

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New Technology Update

Strained silicon technology promises to enhance semiconductor performance, reports Ian Poole.

RESEARCHERS at IBM have discovered a new silicon based technology that promises some significant performance improvements. Called Strained Silicon-on-Insulator, it is claimed to enable electrons to flow through the semiconductor lattice much faster.

By depositing silicon onto a substrate with a wider lattice spacing than silicon, its lattice can be spaced further apart allowing the electrons to move with less resistance giving increases of 70 per cent in the electron speed. This can be reflected in an increase in the operating speed of the resultant chips of up to 35 per cent. This comes without the need of having to reduce the physical size of the transistors.

Strained Alignment

Expected to find its way into production within a year's time, the new technology uses the fact that atoms have a natural tendency to align themselves with one another, even when two different materials with different lattice structures meet. When silicon is deposited onto a substrate that has atoms spaced farther apart than the normal silicon structure, the result is that the silicon atoms tend to line up with the substrate material, and in this way the lattice of the deposited silicon is stretched or "strained".

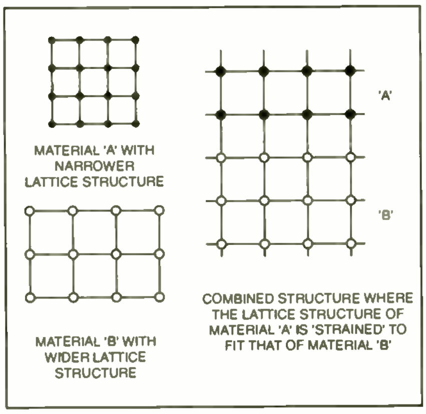


Fig.1. The strained crystal lattice.

In the process used by IBM, a silicon layer was deposited onto silicon-germanium as this can already be handled by existing fabrication plants. This process builds on the SiGe experience and technology that IBM are already using to good effect in some of their existing chips.

Now, with the addition of the strained silicon technology further improvements are being made. It can be seen from Fig.1 that the spacing in the strained silicon crystal lattice is greater than the non-strained version.

With the silicon lattice opened up in this way the free electrons collide less with the structure and accordingly they experience considerably less resistance and their mobility is increased. The advantage of this process is that considerable performance improvements can be made without having to alter the feature dimensions of the components within the chips to any significant degree.

Progress

Both *n* and *p* channel MOSFETs have been fabricated using the strained silicon on a silicon-germanium layer that was itself on an insulating substrate. In doing this the silicon-germanium layer on the substrate had a germanium content of between 15% and 25%. This enabled the advantages of increased carrier mobility from the strained silicon as well as those gained from using a Silicon-On-Insulator technology to be used.

In order to fabricate the CMOS chips the SIMOX process (separation by implanted oxygen) was used. However, it was known from previous work that it is difficult to achieve high levels of germanium when the silicon-germanium on insulator is used. The approach that was used to solve this problem involved wafer bonding techniques and a technique known as H-induced layer transfer.

Process

The fabrication process consists of several stages. First the substrate itself needed to be grown. The layers of silicon germanium were grown with levels of germanium between 15% and 25%.

Next, this epitaxial layer was implanted with hydrogen and polished using a process known as chemical-mechanical planarisation. This was required to reduce the surface roughness of the layer ready for bonding. It was reduced from 6nm to 8nm right down to around 0·5nm.

With this stage complete the silicon germanium wafer was bonded to the base silicon wafer using 300nm thickness of thermal oxide. This was then heat-treated and as a result of the previous hydrogen treatment the silicon germanium layer lattice relaxed. This completed the preparation of the silicon germanium on insulator substrate.

This was then smoothed and thinned down to between 200nm and 300nm so that an 18nm thick layer of strained silicon could be grown.

With the basic wafer in place the devices themselves were grown. A variety of configurations were used for development to prove the process and investigate any possible side effects.

The f.e.t.s that were grown had channel lengths of between 25 and 250 microns. The gate insulating oxide was 4nm thick and phosphorus was used for the *n*-type f.e.t. source and drain doping (see Fig.2) whereas boron was used for the *p*-type f.e.t. source and drain doping.

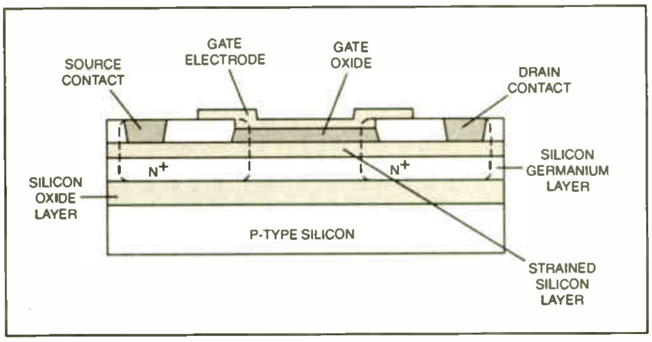


Fig.2. Structure of the strained silicon f.e.t.

Results

The results of the new techniques were analysed from a chemical and also from an electronic view point. The structure of the device was analysed to ensure that the fabrication had taken place correctly. A cross sectional image of the MOSFET was taken to ensure, particularly in the area of strain, that no dislocations had occurred.

A chemical analysis of the germanium content of the silicon-germanium layer was performed to ensure that it contained a level of germanium up to 25% and finally the degree of relaxation in the silicon-germanium layer was determined using X-ray diffraction. With the development complete the results of all these tests were found to be satisfactory.

The devices also needed to be tested electrically as well. The curves for the devices were plotted and found to show a considerable level of increased current drive. When compared to the C-V characteristics for the devices it was deduced that the increased performance was due to the increased electron mobility.

It was discovered, even in the early stages of development, that there was a 50% increase in mobility and it was expected that higher levels were possible. This has been proved to be true with levels of 70% now being reported.

Not only has the electron mobility been increased, but as expected so has the hole mobility. This means that combining all the advantages given by strained silicon along with those of silicon-germanium on insulator, considerable advantages can be gained in terms of speed and performance for high speed CMOS devices.

News . . .

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

VIEWING WAR GAMES

Nothing to watch on TV? Try the military channel, suggests Barry Fox.

HOME satellite buffs can spy on military spy planes with equipment costing under £500. The military has run out of communications bandwidth and is hiring space on commercial satellites. But the military is not using encryption technology which is widely available at consumer prices. Recent adverse publicity will now force a change, if only to avoid further embarrassment.

Satellite buffs in the UK began picking up strange signals from *Intelsat 2* at 37·5° West over South America, last November. John Locker uncovered the signal source as Unmanned Aerial Vehicles in the Balkans. The May issue of *What Satellite TV* magazine – published in April – detailed the extraordinary lengths Locker went to in trying to warn top brass in the Ministry of Defence and Pentagon, and the aircraft's base in Sicily. The mass media picked up the story and ran with it, largely without crediting the original source.

Says editor Geoff Baines, "Because the signals are not encrypted, all you need in Europe is an off-the shelf digital satellite receiver, and a 1-metre dish".

Chris Forrester, editor of industry newsletter *Satcoms Insider*, warns that the exposed Bosnian feed is only the tip of the iceberg.

"The US military rents about 10 per cent of Intelsat's capacity, and a similar amount from SES GE Americom. Serving the military in space is now big business for the satellite operators, whether for tele-medecine, non-sensitive battlefield logistics and multi-channel TV to soldiers and sailors. They have a huge bandwidth shortfall in their own secure military satellites".

Bandwidth Hogs

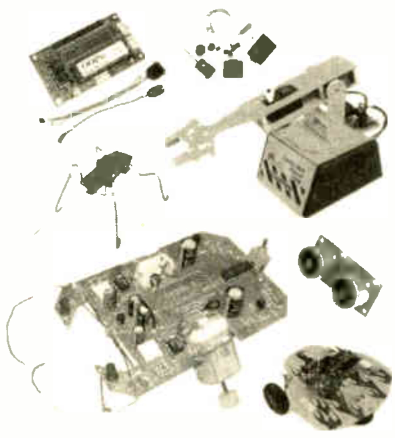
Forrester knows because he recently chaired a Military Battle Space conference at which 4-star US General Ed Eberhart, CiC North American Aerospace Defense Command, denied the military were "bandwidth hogs", saying "(bandwidth) simply makes us more efficient and effective, allowing for fewer casualties."

Klaus Becher, senior Fellow at the European Institute for Security Studies, said he expected US defence bandwidth requirements to grow from current demand of below 1 Gigabits/s to more than 10 Gigabits/s by 2010. Less than half can be satisfied by the US' own satellites; hence the need to rent space on commercial satellites.

According to Captain Dave Markham, head of the US Navy's Space & Communications Branch, the navy's demands, per vessel, have grown from a 75 baud teletype service back in the Vietnam War period to 9·6Kb/s during Desert Storm to 3Mb/s for aircraft carriers operating in the Persian Gulf and Arabian Sea today.

"Clearly someone has goofed in sending these unencrypted images" says Forrester. Encryption technology of military strength is now available at consumer prices and routinely used for cellphones, Pay TV and Internet home shopping. But someone inside the Pentagon either chose not to use it – or did not know enough about civilian technology to know how it could help the military.

TOTAL ROBOTS



A COLOURFULLY illustrated brochure has come through to us from Total Robots, who specialise in robotics, control and electronic technology. Amongst the products featured are some super-looking mobile "buggies", both on wheels and legs, that variously respond to light, sound and radio.

Also featured heavily is the OOPic, the first programmable microcontroller to use an object-orientated language. It is also a Programmable Virtual Circuit (PVC) that can be programmed in Visual Basic, C or Java syntax. Once programmed it just needs a battery to be clipped on and it's ready to control your project!

To complement these systems, an interesting selection of accessories is also available. It's a delight to page through this little brochure – get a copy for yourself by contacting Total Robots Ltd., Dept *EPE*, 49 Church Road, Epsom, Surrey KT17 4DN. Tel: 01372 741954. Fax: 01372 729595.

Email: enquiry@totalrobots.com.

Web: www.totalrobots.com.

SOLAR CHARGING MOBILES

THE new solar mobile phone chargers from Jayhawk utilise the latest in solar photovoltaic technology. They are wallet sized, lightweight and fold inside a hard case for protection. The chargers are suitable for Ni-Cad, Ni-mh and lithium batteries, and therefore suitable for most Nokia, Ericsson and Motorola phones. To use them, just plug the adaptor lead into your phone and face the solar panel to the sun.

As we go to press, the price has just been reduced to £25.00 including UK VAT and delivery. The chargers can be ordered from Jayhawk by visiting **www.eco-shop.co.uk** or calling 08707 300 111 and quoting the phone's make and model (and mentioning *EPE!*).

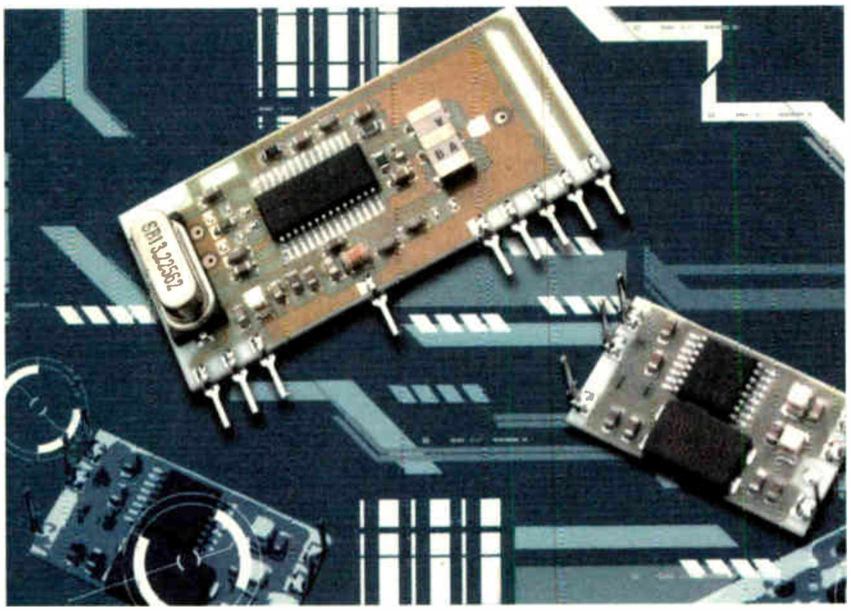
CHIPPING INTO MP3

IT never rains but it pours for the music industry. After CD burners and Napster, chip-maker Cirrus Logics says it is "paving the way for entirely new digital entertainment devices".

A new ARM-7 microprocessor works on the fly to decode and play any digital source of music, while simultaneously converting it to MP3 code for recording into flash memory or onto blank CDs. So music CDs and digital broadcasts can be compressed and copied while played – without the hassle of using a computer. The chips run on low voltage, so work in portable player-recorders. The starting price is $12.25, but is sure to fall fast as demand rises.

Barry Fox

IR TRANSDUCTION MODULES



R.F. SOLUTIONS tell us that their infra-red transmitter and detector modules give a robust and drop-in solution for many applications, such as automatic door opening and security systems, for instance.

The boards for both transmission and reception have a compact design and s.i.l. pins to enable vertical mounting into your p.c.b.s. The transmitted IR beam has a typical frequency of 400Hz and can be detected by the receiving module at a distance of up to 20 metres. They are suitable for use in harsh environments and in close proximity to other electrical devices.

For more information contact R.F. Solutions Ltd., Dept. *EPE*, Unit 21, Cliffe Industrial Estate, South Street, Lewes, E.Sussex BN8 6JL. Tel: 01273 488880. Fax: 01273 480661. Web: www.rfsolutions.co.uk. Email: sales@rfsolutions.co.uk.

BRA-VISSIMO!

RESEARCHERS at De Montfort University in Leicester have invented an electronics-based bra that aids the detection of breast cancer. They have installed miniature electrodes into the bra and these send minute currents through the breast tissue which are then detected and fed to a computer. Since healthy and cancerous tissues respond differently to the currents, abnormalities can be detected.

The technique is said to be capable of providing a more comprehensive result than that provided by X-rays and is expected to be 100 per cent reliable. Its simplicity makes it suitable for use by family doctors with only minimal training, and testing would only take a few minutes.

The team is led by Dr Wei Wang and they have been working in association with Leicester's Glenfield Hospital. Now the prototype will be tested and evaluated by Tianjin Virtual Bioengineering Co in hospitals in South East Asia. Professor Malcolm McCormick, Head of Postgraduate Studies at De Montfort University, says "This deal means that this piece of equipment can be tested in China, giving us a large amount of valuable data in a shorter time than would be possible in the UK. The scale of the Chinese health service means they can test this equipment more extensively than we could".

For more information browse **www.dmu.ac.uk/news/releases.**

Decoding Bletchley

BASED at Bletchley Park, the home of the famous World War II *Enigma* code breakers, MicroSpy Ltd are offering what they describe as a unique service to the electronics industry.

They comment that service engineers know only too well the problems associated with component obsolescence, especially when a faulty chip contains a special code pattern which is locked inside it and cannot be transferred to the replacement part.

This, say MicroSpy, is how their new service comes in beneficially. They can remove the plastic encapsulation of a coded chip and examine the silicon, from which they can identify the basic part, along with the original chip manufacturer. They say that unlocking the code pattern to generate a replacement part can be more difficult, but not impossible.

MicroSpy emphasise that the service only relates to *obsolete or discontinued* parts.

For more information contact MicroSpy Ltd., Bletchley Park, Bletchley, Bucks MK3 6EB. Tel: 01908 270007. Web: www.coderecovery.com.

Updating Greenweld

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For more information contact Solid State Electronics (UK), Dept. *EPE*, 6 The Orchard, Bassett Green Village, Southampton SO16 3NA. Tel: 023 8076 9598. Fax: 023 8076 8315. Web: www.sse-jim.co.uk. Email: solidstate@ssejim.co.uk.

AUTOMOTIVE 42V SYSTEMS WEB

DUPONT has launched a new web site that gives access to valuable resources in relation to the next generation of 42V electrical and electronic systems and components for vehicles. The site covers technical issues in six specific automotive systems, and includes such matters as electrical distribution, electronic controls and "X-by-wire" systems, etc.

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JUBILATIONS BREAK RADIO RECORDS

THE Special Golden Jubilee Amateur Radio Station set up at Windsor Castle as part of the celebrations, received 24,500 radio contacts from 130 countries around the world during its first six days of operation. This is a record for a UK based amateur radio Special Events Station over such a short period.

In response to the contacts made, the station transmitted a special address from the Duke of Edinburgh thanking radio amateurs from the Commonwealth and around the world for their support and good wishes.

The station was sponsored by the Radio Society of Great Britain and operated by the Cray Valley and Burnham Beeches amateur radio clubs.

For more information browse **www.rsgb.org/jubilee**, or contact RSGB, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE. Tel: 0870 904 7373. Fax: 0870 904 7374.


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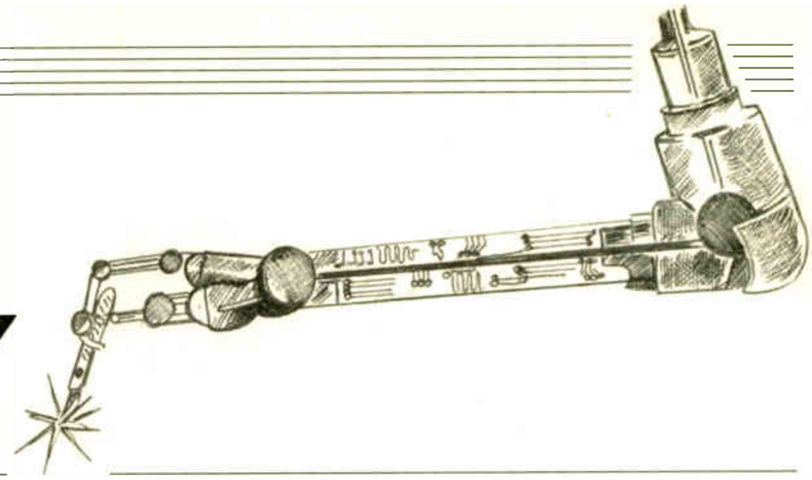
CIRCUIT SURGERY



ALAN WINSTANLEY and IAN BELL

Our surgeons offer a simple siren novelty that can produce US and British siren sounds, and we also look at superbright l.e.d.s and transformer ratings.

Mini Siren

Geoff Folkes asks by email: *"Please can you help with a project? I would like to make an oscillator which starts from 0V and then slowly rises in pitch and decays until it stops, like a siren."*

The siren effect is easy to achieve by using a 556 twin timer i.c. In the circuit diagram shown in Fig.1, IC1a is an oscillator driving a loudspeaker LS1 with a fixed audio frequency. A low frequency oscillator, IC1b, is connected to the control voltage (CV) terminal of IC1a via switch S1.

The effect of doing this is to change the switching thresholds of the audio oscillator. Hence the frequency of IC1a will be modulated by the operation of the l.f. oscillator, so you can obtain a variety of effects.

In its present form the circuit will produce a bleeper or twin-tone sound similar to many British emergency vehicles, but by adding a large capacitor, C3, via the selector switch S1, a wailing siren effect can be produced. You can experiment with different resistor and capacitor values as desired, and also possibly consider adding blue or red l.e.d.s with series limiting resistors to the output (pin 9) of IC1b to make them flash on and off in sympathy with the low frequency generator. *ARW.*

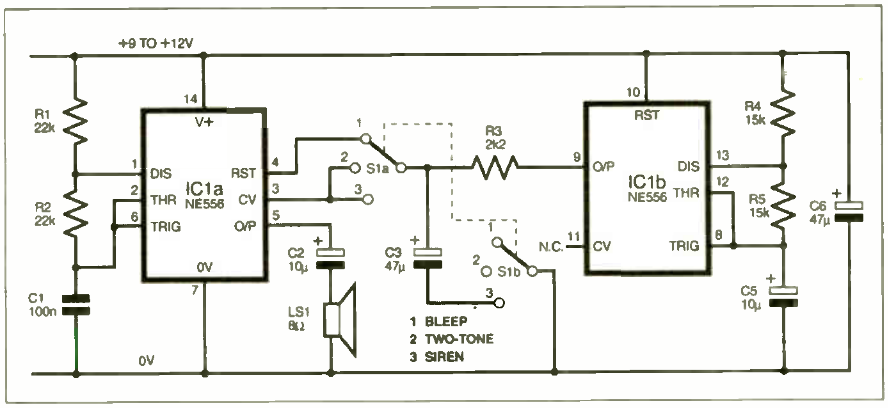


Fig.1. Circuit diagram for the switched-tone Mini Siren.

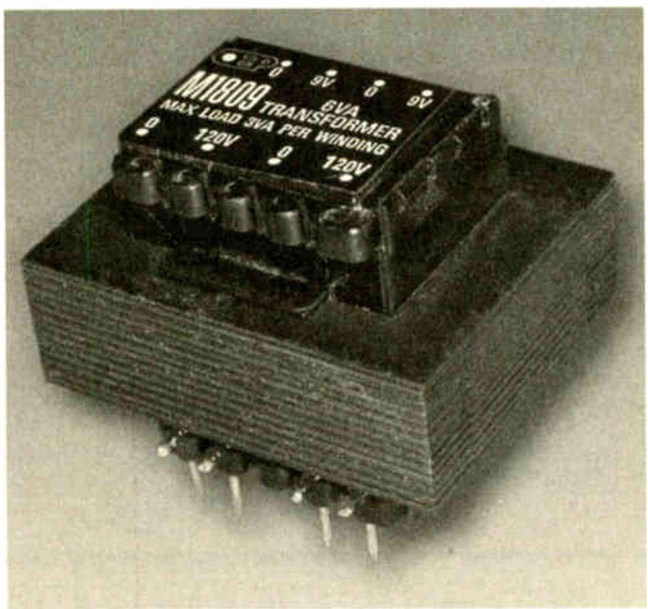
Size up these Transformers

My thanks to ***Joe Farr*** who asks by email: *"One of the components I like to salvage when stripping down surplus or scrap equipment are mains transformers, since they are quite expensive to buy. The problem is that whilst I can measure the secondary a.c. voltage, is there any way that the maximum current rating can be obtained?*

"Most of the transformers don't seem to have any meaningful markings on, and Internet searches don't tend to turn anything up."

It isn't really possible to measure the secondary current simply by judging from the transformer's dimensions. Very many transformers are custom wound to suit the equipment. If it is a reasonably standard type then you could perhaps guesstimate the VA rating (and hence the current value) by comparing the overall size of the transformer against suppliers' catalogues. Many experienced readers would probably be able to identify a 12VA or 25VA type by comparing them, but sometimes the same size bobbin and steel laminations are used for different VA ratings, so this method is not very reliable.

Also bear in mind that the voltages you measure will obviously be ***no load*** values. Due to the regulation of the transformer (or lack of it) I usually deduct 3V to 4V from this voltage to get a typical full load value. This may help to determine what the VA and current ratings are likely to be.



Transformer current ratings are derived from their VA value and voltage, which is usually shown on a label.

You could perhaps do what I did as an enterprising schoolboy 25 years ago – heaps of coils and windings gleaned from old transformers and motors were chucked onto a small bonfire to burn off the lacquer and plastic bobbins. The resulting copper coils were then hot-footed (literally) to a scrapyard where they were sold for cash. This helped me to finance parts for the latest projects appearing in *Everyday Electronics! ARW*

Dynamo Torch L.E.D.

Alan Bradley is a regular *Surgery* reader – and you may remember Alan's prize-winning *L.E.D. Dynamo Torch* in February 2002 *Ingenuity Unlimited.* Alan writes by email:

"I recently used my dynamo torch circuit in a cycle dynamo rear lamp (so it could reach full brightness at low speeds). I found that Farnell etc. don't list the industrial temperature range LM334 i.c. which I felt I should use (in case of cold weather).

"Is there any easy way to get industrial range i.c.s for home construction? I thought small companies making data recording equipment for harsh environments might have expected Farnell to stock them."

I would doubt the necessity of buying the low temperature versions of the LM334 device, as these are more for military and aerospace applications than the generally moderate climatic conditions like ours. I doubt if anyone would be seen bicycling at say –30 degrees Celsius (readers in Russia will doubtless prove me wrong!). You would probably have to try quite hard to damage an LM334 due to cold temperatures in your application.

From the part number I recognise the manufacturer to be National Semiconductor. The "LM" prefix indicates their "Linear Monolothic" family group (LF, where seen, means Linear Bifet and LP means Low Power). The 334 is the device number. A suffix indicates the package type, e.g. "N" would mean dual-in-line plastic.

It is the part number which is of interest here – National usually produce a 1**, 2** and 3** device type for their linear i.c.s. and it is the LM334 that is most widely available. One major difference is the guaranteed temperature range: the LM134 covers –55°C to +125°C; the LM234 is good for –25° to +100°C; and the LM334 is suited for a 0°C to 70°C. You can download the datasheet from National's web site at **www.national.com**.

As you can imagine there is only going to be demand for the wider operating temperatures from specialist customers (e.g. military, space and scientific designers), and distributors including Farnell would be able to order them specially. However they may not be ex-stock and there may be a minimum quantity involved. So it's probably best to stick to the parts that are most popular, Alan, which you can get off the shelf.

Incidentally, well done for your prize-winning entries to *Ingenuity Unlimited.*

ARW.

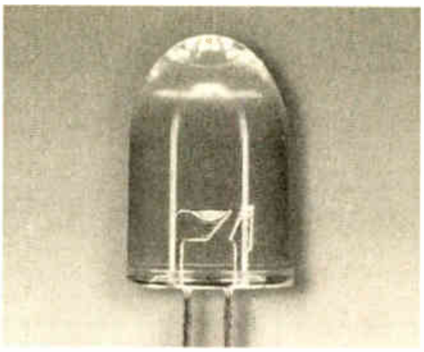
Brighter L.E.D.s

"Can you tell me the brightest 8mm l.e.d.s you can buy? I'm thinking of constructing the L.E.D. Super Torches *you featured in September 2001, but I want an extremely bright l.e.d. to work with."* Another query from ***Geoff Folkes*** by email.

This is quite a challenge, because high brightness devices are usually to be found in smaller packages e.g. 3mm or 5mm diameter, at least to start with when the technology first appears on the market. A component search on **www.globalspec.com** pointed to the Sunled brand who offer a 6,000mcd (millicandelas) 5mm type.

Another company, Agilent (the opto-electronics division hived off by Hewlett Packard) also offered a number of 5mm types. I could not find any larger bright white l.e.d.s. anywhere, and I gave up trying to search through Farnell's listing of 2,200 different l.e.d.s.

We offered two *L.E.D. Super Torches* in September 2001, a simple one with red l.e.d.s and a high efficiency white l.e.d. version based on a switched mode design. As its designer *Andy Flind* commented, white l.e.d.s are still state of the art for most people who haven't seen one, and they are usually astonished at the brilliance of them.



Toshiba Superbright LED in 10mm glass-clear encapsulated body.

The *White L.E.D. Super Torch* used three 5mm extreme brightness l.e.d.s. and a device offered by Maplin (part no. NR73Q) claims a luminous intensity of 1·56 candelas. These appear to be made by Nichia Corporation of Japan (**www.nichia.co.jp**), who amongst other things claims to have developed a commercial blue l.e.d. as far back as 1993. There were no 8mm white l.e.d.s listed on their web site.

If you want something brighter and larger then you have to look at other colours. Toshiba offers a clear 10mm body and ultra bright yellow chip, type TLYH190P, which is good for 30,000 millicandelas. Farnell list a similar device, part number 319-7311 (or 623-465 equivalent). Incidentally readers, Farnell's web site still has a silly gotcha – you need to omit any hyphens from catalogue part numbers when doing an online search. *ARW.*

Constructional Project

PIC WORLD CLOCK

JOHN BECKER

Graphically displays calendar, clock and global time-zone data.

RETURNING from holiday, Editor Mike commented to the author that he had seen an interesting world clock display at his hotel. It consisted of a world map across which was a series of light emitting diodes whose brilliance portrayed local time-zone daylight conditions. Could the author design one?

As with so many questions these days, it seemed that the Internet could well provide an answer. The first thing to ascertain was what such a clock might actually look like in detail. Search engine **www.google.com** was opened and told to search on various combinations of words such as *world*, *time-zone* and *clock*, amongst others.

World clock produced an astonishing number of web sites, but none that showed the display looked for. However, one of the sites revealed the screen dump shown in Fig.1. This set the author along a completely different thinking path.

In *EPE* Feb '01, his article *Using Graphics L.C.D.s* had been presented. Could this l.c.d. (liquid crystal display) be used to portray a world map? Following a letter about bitmaps and l.c.d.s from Javier Fernandez published in *Readout* Nov '01, the author knew that, in principle, it was possible to produce a screen dump of any image and process it for loading into a PIC microprocessor for output to a graphics l.c.d.

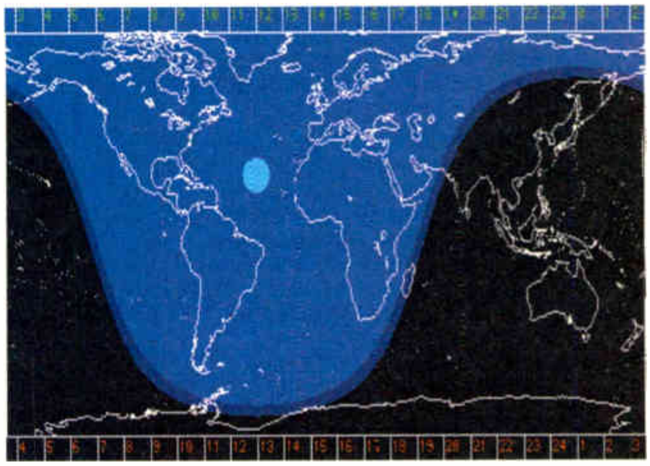


Fig.1. Real-time world clock as displayed by ***www.world-clock.org****.*

CLOCK PERFORMANCE

Before discussing *how* this was finally achieved, it is pertinent to say now that the end result is a PIC16F877-based circuit whose graphics l.c.d. shows the following:

- Simplified World map
- Current UK clock and calendar data
- Clock data for any other time-zone, adjustable via switches
- Flashing marker for sun's current highest position, i.e. true noon at that longitude (angle in relation to 0°, GMT, Greenwich Mean Time, London).
- Marker's position vertically (latitude) varies with the weeks and months throughout the year, spanning the Tropics of Capricorn and Cancer.
- Multi-paged text display of 150 major cities and their time-zone displacements in relation to GMT (e.g. New York –5 hours, Sydney +11 hours)
- Additional city time-zones can be readily added by those readers who have *PIC Toolkit Mk2 or Mk3 (TK3 V1.2 or higher)*.
- Accuracy of clock time-keeping adjustable via switches.
- Principal clock and calendar data stored in the PIC's non-volatile EEPROM (electrically erasable programmable read-only memory) for recall in the event of power failure.
- Runs from a mains powered 9V battery adaptor, plus standby battery back-up.

BITMAP CONCEPT

When the Print Screen button of a PC's keyboard is pressed, the image on-screen at that moment is copied into the Windows

Clipboard. This can then be pasted into the PC's Paint software via the path:

Start – Programs – Accessories – Paint – Edit – Paste – File – Save As

In his *Readout* letter, Javier referred to a web site that supposedly described how this could be done. Regrettably, it turned out that this site, and Javier's own, were no longer accessible when tried by the author. There were, though, enough clue's in Javier's letter for the author to experiment and find an alternative way.

It eventually turned out to be fairly simple. The saved screen dump shown in Fig.1 was first converted to a black and white image, and then inverted to show black detail on a white background (Fig.2).

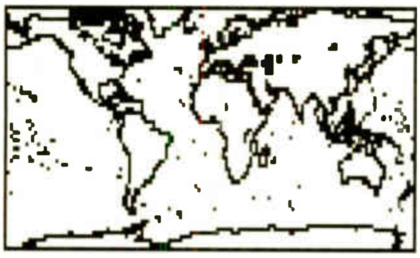


Fig.2. The image in Fig.1 was inverted to produce a black-on-white outline.

The graphics l.c.d. screen is 128 pixels wide by 64 pixels high. The screen dump image at this stage was too large and needed to be reduced in detail to fit the l.c.d. screen.

Next the image was "cleaned-up" by carefully using a combination of bit deleting and line clearing through Paint's toolbox. The image was then cut, the screen cleared and the image re-pasted to the very top left of the blank screen. At various stages during this process, the image was repeatedly re-saved in case of imminent errors.

Through Paint's Stretch/Skew option, the image was reduced in size to exactly 128 × 64 pixels. This image, of course, was of extremely low resolution and needed further cleaning-up to remove individual unwanted pixels (goodbye Hawaii!) which interfered with the main image required.

Inevitably, parts of Malaysia, the Mediterranean and North America had to be accepted as ill-defined (no offence, folks!). Ultimately, it turned out that the image also had to be rotated by 180° and flipped left to right (Fig.3).

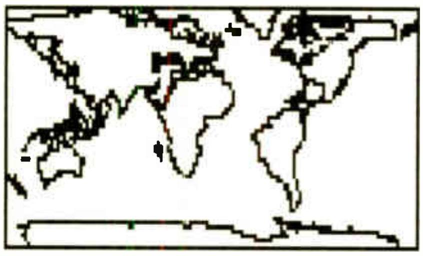


Fig.3. Final "doctored" image, flipped left to right.

(While doing the map changes, there was a certain feeling of kinship with Slartibartfast, who designed Norway in *The Hitch-Hiker's Guide*!)

Using QuickBasic (QB), it was then established which aspects of the saved file data were Paint format commands and which were image data. A program was written which split the required data from the rest, converted it from binary to decimal values, to which a prefix of several spaces and the PIC command RETLW were added. The author had ensured that exactly 128 × 64 pixel values were processed, resulting in 1024 commands.

The file was saved with a .INC extension so that the PIC could import it as an Include file.

It has to be said that the process was not actually as straightforward as suggested by the foregoing. There were many stages of experimentation with this hitherto unknown technique before a satisfactory result was achieved.

PIC JUMP CAPACITY

A parallel problem to be solved was how this data could be used with a PIC16F877. The author already knew that the PCLATH command could allow table data to be stored in PIC program memory beyond the basic limitation of the first 256 bytes.

The problem was, he had never used it before. Much PIC experimentation ensued (Microchip data can be very short in adequate detail on occasions!). Eventually, using various PCLATH values, it was found that not only could data tables be accessed in separate 256 blocks beyond program address 255, but that the data could be loaded as a single table containing almost as many RETLW data commands as there were program memory locations still available.

It turned out that not all jumps were accessible, however. The first address for any table has to be (at least) ADDWF PCL,F, which removes this location from the table's use. Additionally, only 254 locations in each subsequent block of 256 commands could be accessed. Trying to access the 255th always took the program counter PCL into the "unknown" (as far as it was concerned) with a resulting "hang-up" of the program (as when tables in the normal address block 0 to 255 are too long).

With the map data it did not matter if the 255th data byte was not used, since it was known to be a screen border character which could be sent to the l.c.d. separately.

It did matter, though, with the table of city time-zone factors (see later). These are also held as consecutive RETLW data values and without formatting spaces, to conserve space. Each final byte of each block could not be ignored as with the map. The solution was to insert an additional data byte at every multiple of 256 bytes. An asterisk was used, but it could be any character.

This table is also stored as an Include file.

PCLATH USE

Associated with using PCLATH for extended table jumps was the need to also use this command to access PIC addresses $0800 (decimal 2048) upwards. This was

LISTING 1. Map display routine (TASM dialect)

```
MAP:    clrf PCLATH          ; reset PCLATH to zero
        clrf ADRLSB          ; * set l.c.d. graphics column
        movlw 0              ; * set l.c.d. graphics line number to zero
        call GLINE           ; * set line length
        call SCREENADR       ; * set l.c.d. screen address to these values
        movlw AWRON          ; * load W with Auto Write On value
        call SENDCMD         ; * send this command value to l.c.d.
        clrf LOOPE           ; clear table address counter
MAP2:   movf LOOPE,W         ; load table address into W
        bsf PCLATH,3         ; set PCLATH for program memory block $0800
        call WCLOCK          ; call Map table commencing at $0800, return with
                             ; graphics display data
        bcf PCLATH,3         ; clear PCLATH from block $0800 to block $0000
                             ; but leave bits 0-2 unchanged
        call OUTDATA         ; * send table data to l.c.d. via prog in block $0000
        incf LOOPE,F         ; increment table counter
        incf LOOPE,W         ; inc counter again, but only into W
        btfss STATUS,Z       ; is it zero i.e. is table counter = 255
                             ; i.e. has end of 256 table block been reached?
        goto MAP2            ; not yet, so repeat data get and send
        movf PCLATH,W        ; yes, so is PCLATH now pointing to sub-page 3?
        andlw %00000111      ; limit check to within value of 7
        xorlw 3              ; do = 3 check
        movlw 1              ; preset W with value of 1 (for RHS border)
        btfsc STATUS,Z       ; is Status bit Zero = 1 (equality)?
        movlw 0              ; no, border not needed as map display ended
        call OUTDATA         ; * send appropriate border value to l.c.d.
        clrf LOOPE           ; clear loop counter to zero
        incf PCLATH,F        ; inc PCLATH for next table block of 256
        movf PCLATH,W        ; is table block count now = 4?
        andlw %00000111      ; limit check to within value of 7
        xorlw 4              ; do = 4 check
        btfss STATUS,Z       ; is status bit Zero = 1 (equality)?
        goto MAP2            ; not yet, repeat for next block
        clrf PCLATH          ; yes, fully clear PCLATH back to zero
        movlw AWROFF         ; * load W with Auto Write Off value
        call SENDCMD         ; * send this command value to l.c.d.
        return               ; return to main program
```

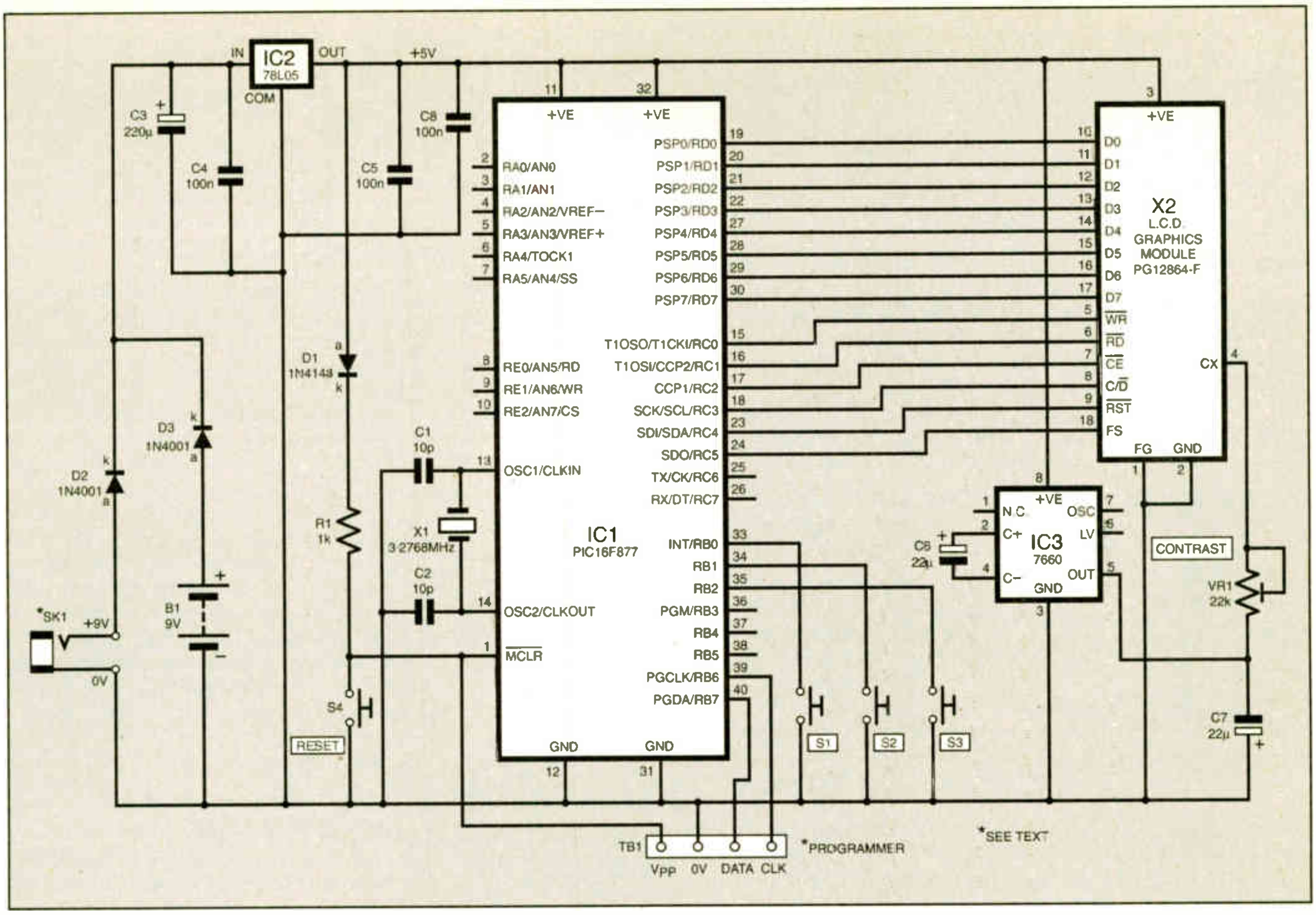


Fig.3. Complete circuit diagram for the PIC World Clock.

the author's first foray into that region, and also needed research.

Some readers may not appreciate that large-capacity PICs have this limitation. Program memory addresses are split into blocks of 2048, each of which requires PCLATH to be set accordingly, in addition to setting it for individual blocks of 256 within the main block when tables are embedded there. The 2048 limitation does not affect the PIC16F84, of course, since this only has 1024 memory locations anyway, but it can affect the PIC16F873 to 877 when the extra program memory capacity is required.

At the time the author was working on this PIC World Clock, John Waller's article *Using the PIC's PCLATH Command* had not yet been discussed with him, let alone published (as it was last month, July '02). Readers now have access to John's information so PCLATH will not be discussed further in detail here.

It is, however, appropriate to show an extract of the program listing associated with displaying the map. See Listing 1.

The commands and sub-routines called and marked by an asterisk are those which were discussed in detail in the *Using Graphics L.C.D.* article previously mentioned. All the graphics l.c.d. routines used are those discussed there, and used here as "library" routines.

CIRCUIT DIAGRAM

Whilst the software is the longest that author has written for a PIC (around 5500 commands), the circuit is one of the simplest. Its schematic diagram is shown in Fig.3.

The PIC16F877 is notated as IC1. It simply runs its program and controls the data output to the graphics l.c.d. X2. Additionally, it responds in various ways to switches S1 to S4 being pressed, more on this later.

If considering using a different l.c.d. to the Powertip PG12864 recommended, ensure that it is based on a Toshiba T6963C controller.

The PIC is powered at +5V, as supplied by regulator IC2, which may be powered at between about 7V and 12V d.c. Capacitors C3 to C5, plus C8, simply help to maintain power line stability.

As discussed in *Using Graphics L.C.D.s*, the Powertip graphics l.c.d. module requires a split supply of +5V, 0V and –5V. The latter is generated by the d.c.-to-d.c. voltage converter IC3. This produces a –5V d.c. output when powered from a +5V supply.

It is a switched-mode device (frequently seen in *EPE* designs) whose oscillation frequency is set by capacitor C6. The output voltage is smoothed by C7. The l.c.d. screen contrast is determined by the current flowing from its pin 4 (CX) into the negative line, and is controllable by preset VR1.

The PIC is operated at 3·2768MHz, as set by crystal X1 in conjunction with capacitors C1 and C2.

It can be programmed *in situ* from a PIC programmer such as *Toolkit Mk2 or Mk3.* The World Clock software and preprogrammed PICs are available as stated later.

Diode D1 and resistor R1 allow the PIC to be correctly controlled when being programmed. They also provide bias to Reset switch S4, whose function is described later. Do not omit these two components even if you do not intend to program the PIC yourself.

Terminal block TB1 provides access to the PIC's programming pins.

A "belt and braces" option is provide for power input. Surprisingly, the circuit draws around 18mA, much of which is demanded by the l.c.d. Even making use of the PIC's SLEEP mode with interrupts did little to reduce the overall consumption. Consequently, continuous operation of the clock from a 9V PP3 battery is unrealistic.

Instead, the unit should normally be powered from a battery adaptor having an output of around 9V d.c. A PP3 battery can be used as a back-up supply in the event of a mains power failure, and a battery holder is included on the printed circuit board (p.c.b.) for this purpose. Diodes D2 and D3 prevent the battery and adaptor supply from mutual interference, allowing the battery to take over if the mains supply fails.

CONSTRUCTION

The p.c.b., component and track layout details are shown in Fig.4. This board is available from the *EPE PCB Service*, code 363.

It has also been designed as a general purpose board for use in other simple PIC16F877/graphics l.c.d. applications. Consequently, additional holes are provided to allow access to the otherwise unused PIC port pins. They should be ignored in this application.

Commence construction by soldering in the several link wires, noting that a few are positioned below IC1 and IC3. Dual-in-line (d.i.l.) sockets should be used for both these i.c.s. Do not insert the i.c.s themselves until the first stage of power checking has been performed. The same caution applies to the l.c.d. as well.

COMPONENTS

Resistor

R1	1k 0·25W 5% carbon film

Potentiometer

VR1	22k min. round preset

See SHOP TALK page

Capacitors

C1, C2	10p ceramic, 0.2in pitch (2 off)
C3	220μ radial elect. 16V
C4, C5, C8	100n ceramic, 0·2in pitch (3 off)
C6, C7	22μ radial elect. 16V

Semiconductors

D1	1N4148 signal diode
D2, D3	1N4001 rectifier diode (2 off)
IC1	PIC16F877 microcontroller, preprogrammed (see text)
IC2	78L05 +5V 100mA voltage regulator
IC3	7660 d.c.-to-d.c. voltage converter

Miscellaneous

S1 to S4	min. s.p. push-to-make switch 0·2in x 0·25in pitch (4 off) (S1 to S3 may be panel mounting types, see text)
SK1	power socket for 9V battery adaptor
X1	3·2768MHz crystal
X2	PG12864-F graphics l.c.d. module, T6963-based

Printed circuit board, available from the *EPE PCB Service*, code 363; 8-pin d.i.l. socket; 40-pin d.i.l. socket; PP3 battery holder, p.c.b. mounting; 9V PP3 battery; 9V battery adaptor, mains powered; plastic case, 190mm x 110mm x 60mm (see text); 18-way ribbon cable or pin-header connector pair, p.c.b. mounting (see text); mounting bolts to suit; 1mm terminal pins; solder.

***Approx. Cost Guidance Only* £60** *excluding case & PSU*

Assemble the other few components in any order you prefer. Leave the battery holder until last.

Thoroughly check your board for poor soldering and other errors, and then connect the 9V mains adaptor. Check that regulator IC2 outputs +5V, within a few per cent. If not, switch off and remedy the cause of malfunction.

When testing, if the unit does not behave as expected, and when inserting or extracting the i.c.s, always disconnect the power.

When satisfied with the +5V output, plug in d.c. converter IC3 and check that it outputs –5V, again within a few per cent.

If this is satisfactory as well, connect the l.c.d. to its designated p.c.b. pins, which are in exactly the same order as on the l.c.d. itself. Ribbon cable was directly soldered to terminal pins on the prototype, but a p.c.b. mounting 0·1 inch pitch 18-way pin-header strip with connector could be used if preferred.

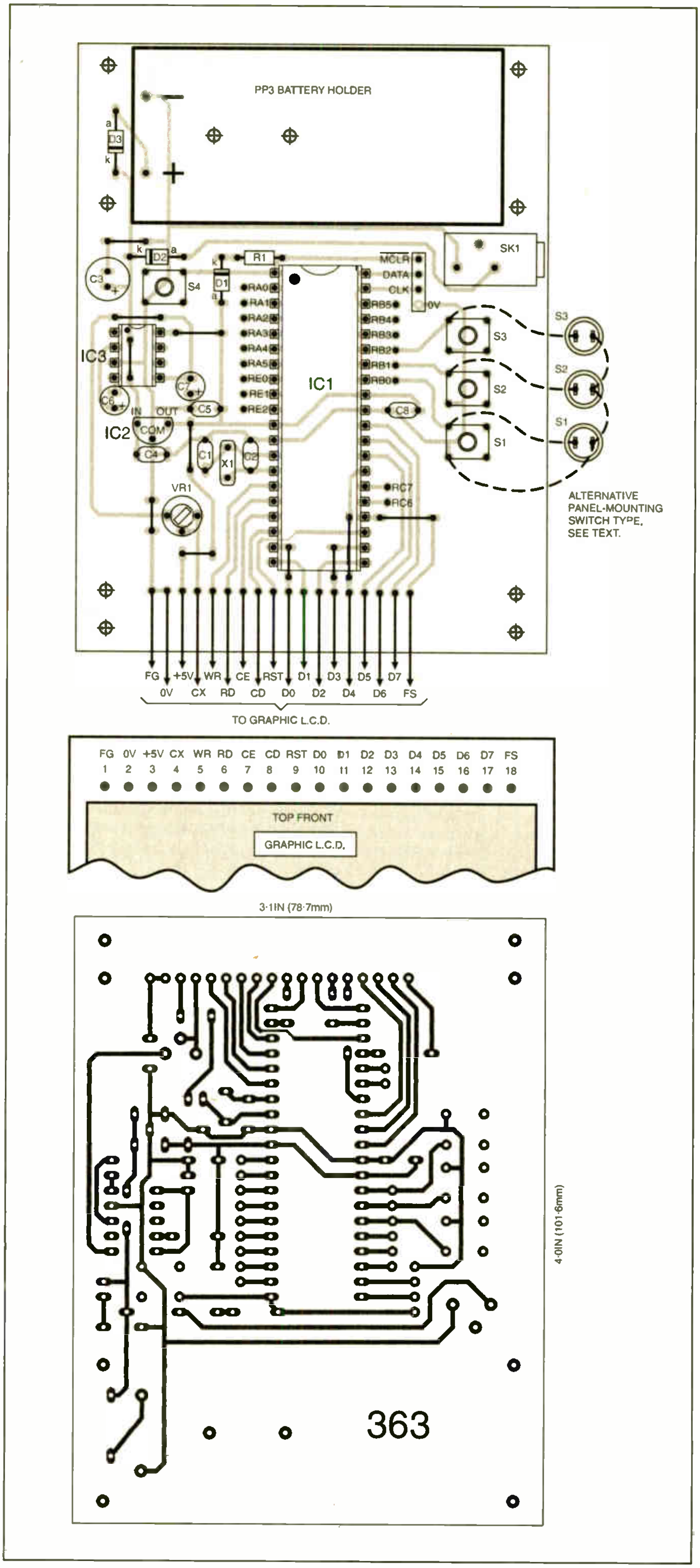
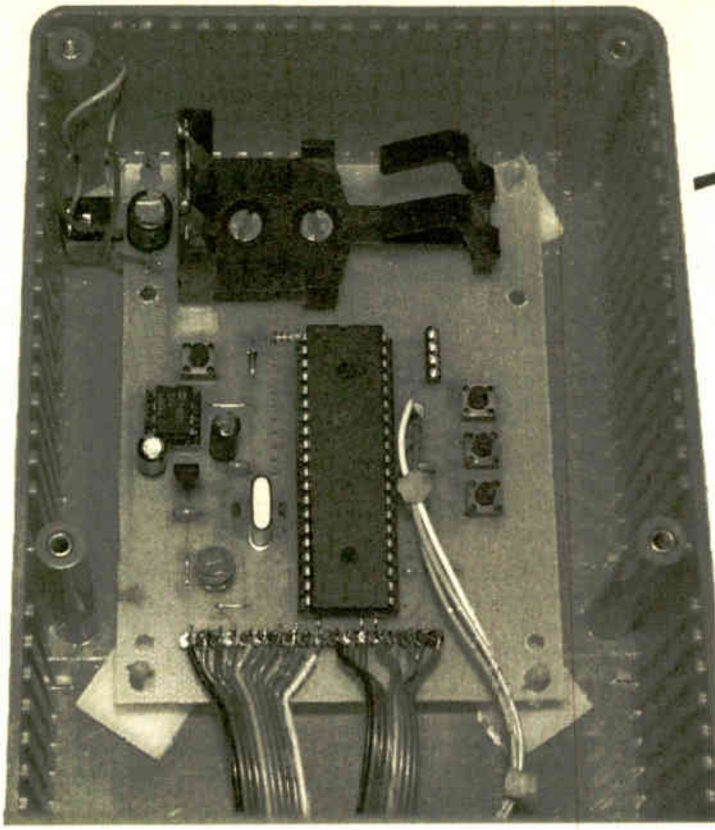


Fig.4. Printed circuit board topside component layout, full-size copper foil master pattern and wiring to the l.c.d. and off-board switches (see text).



Component layout on the completed prototype circuit board.

On powering up, adjust preset VR1 until a change in l.c.d. screen colour is observed. Adjust VR1 until the background shows a very light shade of blue (might be grey with some makes of l.c.d.).

Next the PIC can be inserted and, if it has not been preprogrammed, it can be programmed now, using a suitable programmer, as stated above.

ENCLOSURE

It was originally conceived that the PIC World Clock could look more interesting if not enclosed in a box. Consequently the p.c.b. was designed to be bolted behind the l.c.d., and for the "sandwich" to be bolted to a perspex sheet mounted in a low-cost picture frame. Access to the switches is then from behind the assembly.

Ultimately, however, the author used the same box as previously used in another design. As a result switches S1 to S3 and SK1 were mounted in the case (although S1 to S3 are still to be seen in the photograph of the p.c.b.). Do not mount S4 in the box leave it on the p.c.b.

SOFTWARE CHECKS

With the unit running under PIC control. the first action that will be seen is that the screen should show a display similar to that in photo below left. If necessary, adjust VR1 until the contrast is suitable.

Example screen in adjustment mode.

A rudimentary map of the world will be seen, with three lines of text superimposed on a partly blanked area.

Under the first 0 of the time (tens of hours) a cursor cell should be seen flashing. Pressing and releasing switch S1 steps this value on a cycle from 0 to 2 and back to 0. Set your current tens of hours now.

Pressing switch S2 steps the cursor to the units of hours. Using S1, these cycle through 0 to 9 followed by a rollover to 0 when the tens of hours show 0 or 1. If the tens show a value of 2, the rollover of the units is after 3 (24 hours clock).

Switch S2 progressively steps through the minutes digits. selectable by S1 again, with a rollover limitation of 59. To suit the program's correct use of calender factors, the next steps are to the tens and units of years, with a rollover after 99. It is worth noting that Microchip only guarantee retention of a PIC's program contents for 40 years, so a year value of 99 is grossly over-optimistic!

Next the month can be set. This cycles from JAN to DEC followed by rollover. Tens and units of days in the month are next, with rollover limits set by the conventional number of days in any named month, with automatic allowance for leap years if the month is FEB.

The named day of the week follows, MON to SUN, with a 7-day rollover.

CLOCK ACCURACY

The next press of switch S2 sets the program into clock accuracy adjustment mode. This is prefixed by the symbols +/– followed (when first used) by +0000, the cursor flashing on the forward-slash symbol. Switch S1 continues to step count values upwards, but S2 now causes a downwards count. The full range is –9999 to +9999.

Whilst the PIC is crystal controlled, when used in clock-type applications there is normally an inherent slippage of accuracy over time, partly due to the crystal frequency not being at an exact value, due to normal component tolerance factors. An additional slippage can occur because of very slight inconsistencies in the rate at which the PIC's internal timing counter is accessed.

In a long-term clock design, such as this is intended to be (40 years, anyway!), it is desirable that the clock rate can be adjusted in the light of experience, as with many types of normal clock.

To cope with this, the software has been written so that the amount by which the clock registers are incremented is adjustable according to externally set values.

In simple PIC clock designs, the TMR0 counter is set so that it rolls over at, say, every 1/25th of second. Counting 25 of these rollovers then equals a one-second time lapse.

In this design, though, TMR0 is set to roll over once every 1/50th of a second. On each occasion, a 3-byte counter has a preset value added to it. This includes an adjustment factor as set by the user. With no adjustment factor set, this counter rolls over once for every two TMR0 rollovers (i.e. at every 1/25th of a second).

When first used, the software sets the 3-byte counter to a decimal value held as MSB = 128, NMSB = 0, LSB = 0. Two additions of this value cause the MSB to rollover and set a separate register flag. Only if this flag = 1 is another counter incremented, whereupon the flag is reset.

Only when this counter has incremented 25 times is the seconds register incremented. In fact, for programming ease, the intermediate counter is preloaded with a value of 25, and then decremented down to zero, at which point it is reset to 25 and the seconds counter incremented.

It will be seen that if the 3-byte counter is preset with a value greater than 128, 0, 0, then its MSB rollover with be faster than just described. Similarly, the rollover will be slower if the preset value is lower.

Each unit of change, set via S1 or S2, in the adjustment count value shown on screen, represents one second of change every 4,194,304 seconds. There are approximately one million seconds in 11.5 days, so the potential for clock setting accuracy is good.

It is worth understanding, though, that a crystal's frequency can drift fractionally with temperature and age.

This technique was first used in the author's *Canute Tide Predictor* of June '00 and has proved remarkably accurate. Implementing any adjustment should only be carried out after several days of observation to determine how much the clock has drifted over that time, and then to apply an adjustment calculated in relation to the above four million ratio.

At this stage of use, the adjustment factor should left at zero.

GLOBAL DISPLAY

Having adjusted the clock and calendar values, press switch S3. This first stores the values to the PIC's EEPROM, where they remain even after power loss, to be recalled when power is restored. The screen is then cleared of the data setting display, to reveal the world map as below:

Typical World Clock display when in normal running mode.

To the left of the map are shown the calendar values, which will be kept updated for as long as the clock is powered. At the bottom left of the screen the current hours and minutes time is shown, plus a seconds counter. To the right is shown another hours and minutes display, prefixed by the letter L, meaning Local. Currently it will be showing the same time as the first clock.

One of the functions of the World Clock is to allow a principal time to be shown for the UK and for a secondary time to be shown in relation to any time-zone across the globe, i.e. Local time in that zone.

In the middle of the screen is a vertical dotted line passing through what would be seen as roughly London on a better definition display. Pressing switch S1 shifts this line to the east in large steps, of *about* 1 hour 30 minutes. The time-step values are automatically added to the UK time and displayed as the Local time for the longitude indicated by the line.

Having reached the eastern map edge, the line then reappears from the west. Crossing the full map represents 24 hours.

Pressing switch S2 moves the line in smaller increments, 128 steps across the screen. This allows the line to be more precisely set in relation to the map. The line can only be moved in an easterly direction. Its position is never stored to EEPROM and returns to its default position (UK) should power be lost and then restored (or the Reset switch, S4, pressed – see later).

SOLAR AND NATIONAL TIME-ZONES

Greenwich, UK, is regarded as having a longitude of zero. Because the Earth is roughly a globe, it is said to have a circumference of 360°. Consequently, for a 15° shift westwards of the sun from a noon position above Greenwich at 0° means a one hour time zone shift (24/(360/15)). Solar noon is now at this 15° position, and the time at Greenwich has become 1.00pm.

However, what about the time actually experienced by the positions under the solar noon position? What about *EPE* in Dorset, 2° west of Greenwich? Do we experience noon at 2° = 8 minutes later than Greenwich? No, of course not, when it's noon at Greenwich it's noon at *EPE!* (Although some of us might feel/wish it were actually 5pm . . .)

Interestingly, it was only with the increasing use of the railways, that, in 1884 at an international conference of 27 nations in Washington DC, national and international time-zones became rationalised, with Greenwich as the 0° meridian. Prior to that local noons were at different instants to each other. Improved transport systems though, required consistent timekeeping.

Generally speaking, time-zones change in steps of 30 minutes, although there are occasional differences, where a 15-minute step might occur.

As a result, France, for instance, is in a time-zone one hour ahead of the UK (+1 hour) even though much of it is due south of the UK. New York is five hours behind Greenwich (–5 hours), but because of the scale of the USA, Chicago for example has a time-zone displacement of –6 hours from the UK. Curiously, despite its size, China has only one time-zone.

TIMELY DILEMMA

These facts presented the author with an initial dilemma. Should the dotted time-zone line have its clock display incremented to suit solar time, or local time? And, if the latter, then *which* national time zone, since some countries along that line could have adopted different displacements in relation to Greenwich.

It was decided that the Local clock should only be incremented in steps of 30 minutes and in relation to solar noon. Thus most of France will appear to be in the same solar time-zone as the UK. Intelligent assessment of the line's position in relation to the displayed Local time must be used!

Only if a much larger display were to be used could there be any chance of tailoring regional time-zones to the geographic location under the line. In other words, a PIC and simple l.c.d. are not up to that degree of definition! If you need more accuracy, use a computer and browse appropriate sites via the Internet (such as listed later)!

To comply with the 30-minute stepped update, a look-up table is used, which allocates whether a value of 30 or 0 minutes is added to the Local time display at each increment of the line.

In early stages of program development, the Local time was in fact incremented according to actual solar time. This required a value of 11 minutes 15 seconds to be added for each of the 128 increments.

SOLAR SEASON

Whilst the sun appears to move round the Earth in a westerly direction, the Earth rotates eastwards to greet the rising sun, of course. Surprisingly, doing a "straw poll" recently, the author found that the correct answer was not always given. But even the illustrious SF author Arthur C. Clarke is said to have wrongly stated the Earth's direction of rotation in one of his books!

Because of the Earth's tilt on its axis, the sun's overhead position changes in latitude throughout the year as the Earth travels around sun. An indication of this has been added to the display. A flashing 4-pixel vertical line travels across the map indicating where solar noon is occurring.

The flashing noon line also changes position vertically throughout the year, traversing between the Tropic of Capricorn (northern hemisphere) and the Tropic of Cancer (southern). This is calculated in relation to the stated month and its numbered day, and makes use of more look-up tables. The position is only an approximation – don't navigate by it (hey, who's moved America?)!

CITY TIME-ZONES

Having discovered the benefits of using PCLATH with a large-capacity PIC, it became obvious that lots more table data could be added to the software. This resulted in City time-zone displacements being downloaded from the web, at **www.timeanddate.com**, whose information is presented in real time in relation to local time of the user, as follows, for example:

Addis Ababa	Tue 5 34 PM	Hanoi	Tue 9 34 PM
Adelaide	Wed 12 04 AM	Harare	Tue 4 34 PM
Aden	Tue 5 34 PM	Havana *	Tue 10:34 AM
Aklavik *	Tue 8 34 AM	Helsinki *	Tue 5 34 PM
Algiers	Tue 3 34 PM	Hong Kong	Tue 10 34 PM
Amman *	Tue 5 34 PM	Honolulu	Tue 4·34 AM
Amsterdam *	Tue 4 34 PM	Houston *	Tue 9 34 AM
Anadyr *	Wed 3 34 AM	Indianapolis	Tue 9:34 AM
Anchorage *	Tue 6.34 AM	Islamabad *	Tue 8:34 PM
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Atlanta *	Tue 10 34 AM	Kabul	Tue 7.04 PM
Baghdad *	Tue 6 34 PM	Kamchatka *	Wed 3 34 AM
Bangkok	Tue 9 34 PM	Kathmandu	Tue 8:19 PM
Barcelona *	Tue 4.34 PM	Khartoum	Tue 5.34 PM

*Example display of international time at **www.timeanddate.com**.*

Using QB, these were analysed, formatted into a look-up table, and imported to the PIC as another .INC file.

The following is an extract, in relation to New York, showing a –5 hours difference from UK time. Note the "&" end of name marker and the "*" 256-jump padder referred to earlier:

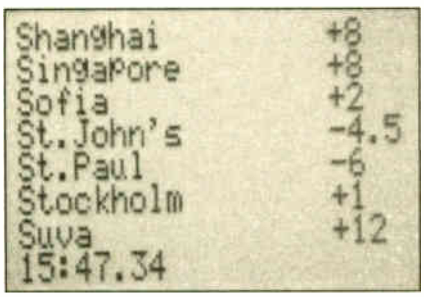
```
retlw 'N'
retlw 'e'
retlw 'w'
retlw ' '
retlw 'Y'
retlw '*'          ;256 rollover 3
retlw 'o'
retlw 'r'
retlw 'k'
retlw '-'
retlw '5'
retlw '&'
```

As supplied with the software, there are 136 city names, ranging from Adis Ababa to Zurich. They are called to screen by first pressing switch S3. This clears the map, and sets the screen area to 20 × 8 text character cells, instead of the previous 16 × 8. This width is not suitable for map graphics display since bits 7 and 6 of each screen data byte are ignored by the l.c.d.

The width is well-suited to text-only displays, however, allowing 20 characters per line instead the normal 16.

On entry to the City Time-zone display, the first seven cities are named, with their time-zone displacement from Greenwich shown to their right. On the eighth line at bottom left a continuation of the UK real-time clock count is shown:

Example of time-zone displacement data screen.



Another example of time-zone displacement data screen.

Pressing switch S1 or S2 "turns the page" to the next seven cities. The clock count continues as before. There are 19 pages that can be stepped through, with just three cities on the final page.

Pressing S1 or S2 when the final page is displayed rolls the display back to page 1. At any page, switch S3 may pressed to make a return to the map display. Re-entering the cities mode always starts the display at page 1.

The author briefly considered having a facility to automatically show the current time for each city, but decided that readers are perfectly capable of doing the mental maths and add the displacements to the UK time shown!

ADDING CITIES

Readers who have the *Toolkit TK3 V1.2* (or MPASM) software update can add their own cities to the TIME-ZONE.INC file, and then re-assemble and send to the PIC. Note that only the revised TK3 software (TK3 V1.2 or later) can handle PIC addresses from $0800 onwards.

There are over 3000 program memory locations that could be filled. However, if the TIME-ZONE table extends into the next 2048 block, changes to the PCLATH control (using PCLATH bits 4 and 3) would need to be made.

As things stand, 550 additional characters could be added to the .INC file without crossing the next 2K boundary, after $1FFF.

To add names, TK3's Include File Edit/View Facility can be used. First use its DIR button to select file TIME-ZONE.INC. Open the file via the Edit Incl button.

Split the city name into individual letters and enter them in order at an alphabetically suitable place within the file, in the same way that the other letters are treated. Follow the name with the time displacement value, and use the "&" symbol to indicate the end of that city's data. Do not use space (" ") characters unless they are part of the name.

City names can also be deleted.

Be aware that adding or deleting RETLW commands will affect the 256-jump allocation beyond that point. The author used DOS EDIT to correct for this as it has a good line counter. At each line count multiple of 256 (i.e. 256, 512, 768, 1024, 1280, etc) insert the RETLW '*' separator, as done in the original file, removing the author's inserts as necessary.

Failure to do so will not "crash" the program, but will cause one or more asterisks to be seen and with consequential non-display of some characters.

The final entry of RETLW '#' must be retained. Removing it could cause the PIC program to "crash" on the final page of city data display.

Re-save the file once corrected, reassemble from ASM to HEX and program the PIC with the new HEX code.

ZONE HOME ET!

It is perfectly feasible for non-UK readers to set their own time zone values into the clock in place of UK time. However, this will have two side-effects.

Firstly, the solar noon flashing line will continue to think that the time is still related to GMT. No facility to change this has been included.

Secondly, the city time-zone displacement text values will become invalid. This can be amended if *Toolkit TK3 V1.2* or MPASM is used.

Accessing the web site stated later, view the times quoted for the various cities in relation to the zone from which you have entered the site. Calculate and note the displacement. Amend the TIME-ZONE.INC file so that the new values replace the GMT ones. Then resave and proceed as described in the previous section.

GENERAL USE

There are three situations in which the calendar and clock data are stored to the PIC's data EEPROM: following a program reset after a total power failure restoration or by deliberate intent; at each midnight rollover; and when the Cities text display is entered.

To have updated the EEPROM on a more frequent regular timed basis would undesirably use up its theoretical life expectancy, which value could not be found in Microchip's data for the PIC16F877, but is believed to be about 10,000 write cycles. In fact, the author believes that over the years of using the same PICs over and over in different applications, the write cycle count has probably been well exceeded on several of them, without failure.

Should a Reset occur, the currently stored data will be recalled and displayed on-screen as first described earlier. In the event of a short halt in running, the time and calendar data will need little adjustment.

To allow the clock to be adjusted, a fourth switch has been included, Reset switch S4. This is connected to the PIC's $\overline{MCLR}$ line and physically resets the PIC so that it starts running the program from the beginning.

Any time or calendar values can now be adjusted, pressing the switches as before, ignoring any values that do not need adjustment. At any stage, if the remaining values do not need to be changed, press switch S3 to jump straight into map display mode.

Before using Reset switch S4, first press S3 to enter the City text display, which will cause the current time to be saved, for immediate recall following S4 being pressed.

TIMELY END

Apart from describing a novel time-zone clock-calendar, it is hoped that this article has provided you with further thoughts about using PCLATH, accessing very long look-up tables, crossing Page boundaries, and using screen dumps to obtain data for loading into a graphics l.c.d. via a PIC microcontroller.

May the sun always cross your zone!

RELATED WEB SITES

www.timeanddate.com/worldclock/. World Clock Time-zones – current times for global cities.

www.world-clock.org. Visual Map of the World's Time – Imagery by Matthew Kaufman, the site which inspired the l.c.d. map.

www.google.com. Excellent search engine – says it contains 1,960,000 sites related to searching on the command World Clock. Both the above sites are on the first page of its display.

www.greenwichmeantime.com/info/time-zone/htm. History of time-zones, plus related matters.

SOFTWARE

The software for the PIC World Clock is available on 3·5-inch disk (for which a small handling charge applies) from the *EPE* Editorial office. It is also available for free download from the *EPE* ftp site, which is most easily accessed via the click-link option at the top of the screen page when you enter the main web site at **www.epemag.wimborne.co.uk.**

On entry to the ftp site take the path PUB – PICS – WORLDCLOCK, downloading all files within the latter folder.

For information about obtaining components and preprogrammed PICs for this project, read the *Shoptalk* page in this issue. □

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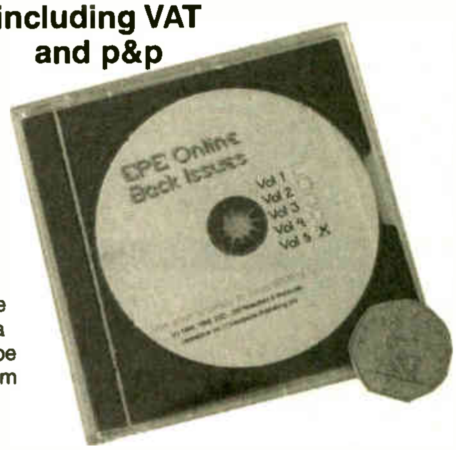

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Special Feature

EVOLUTIONARY ELECTRONICS

CHRIS MACLEOD AND GRANT MAXWELL

A revolution in evolution, and anyone can experiment with it

We hear about advances in electronics all the time – smaller circuits, faster chips, new devices and technologies. But there's another revolution happening, one that in a few years may change electronics forever and perhaps even lead to the development of the first truly intelligent machines. This new revolution is called Evolutionary Electronics.

One of the most interesting and unusual attributes of this revolution is its accessibility to hobbyists. The answers to the big questions aren't clear yet and the rewards for getting it right are immense. The experiments don't need million dollar machines or laboratories, just access to some good computing equipment and a degree of ingenuity.

A CASE FOR EVOLUTION

The idea is simple. Suppose that we want to make a machine so complex that we don't know how to design it. A good example would be the human brain – the most complex structure in the known universe. Where would we start? Well, we could look to nature; after all she has made incredibly complex machines – just look at us! But she's done this not with conscious design, but through the power of evolution by natural selection.

We all know what evolution is; it's a simple and elegant concept. If you take a population of animals which have random genes and leave them in a particular environment, those with good traits will survive and those that are not as fit will die. The animals which die may have problems like not being fast enough to outrun a predator or not tall enough to reach food.

The better-suited members of the population survive to breed and to mix and pass on their good traits to the next generation. In this way the population gets more suited for its environment and perhaps over many generations evolves into new species.

So, why not do the same with circuits? Set them up randomly, test how good they are (their fitness), and allow the best ones to survive and mix their traits (to breed!). Well, this can be done and it has been done with some very interesting results, as we will see. There are several ways of doing it, but the best known and most popular is called the Genetic Algorithm.

GENETIC ALGORITHM

The Genetic Algorithm, often called simply the GA, works like this. We code the system we want to evolve, in this case our circuit, as a string of numbers (we'll come back to this shortly). We then set up a random population of these strings, usually between fifteen and fifty strings. We test them all to see how well the circuits they represent work (of course, right at the beginning, none of them will work very well). We then make another, new population, out of the old one, by copying across the best strings. The better the fitness of a string in the old population, the more chance it has of appearing in the new one.

Having generated this new population out of the best members of the old one, we allow the strings to "breed" by swapping some of their numbers as shown in Fig.1.

23 42 12 | 89 02 10	Members of the population. The line represents the "Crossover point"		23 42 12 05 98 34	This is the pair after they have bred. Notice that they swap some of their information generating two new strings.
65 04 19 | 05 98 34			65 04 19 89 02 10	

Fig.1. Strings breeding.

This generates new strings. The idea is that some of these new strings will have the good traits from both parents and so be better than either.

The final part of the algorithm is called "Mutation" and is designed to add some variation into the population by introducing some new numbers to it. It simply involves choosing a few numbers from the strings and changing them by adding a random element. The algorithm is then repeated and after a few generations the circuits become fit enough to fulfil their functions (that's the theory anyway). You can use either real numbers as shown above or binary numbers.

CHOOSING GA VALUES

This sort of technique is particularly useful for designing circuits like filters. All you need is a software simulator. You can use the GA strings to generate netlists, and off you go. For example, take the sort of circuit shown in Fig.2.

You can set up the string as shown, fill it with random numbers, generate a population and watch it evolve. In this case, the fitness of the circuit is how close the simulated response is to the desired response as designed by you.

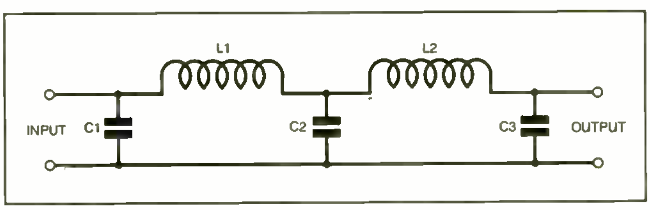

Fig.2. A typical filter circuit. In this case each string could be: L1, L2, C1, C2, C3.

CHOOSING GA CONNECTIONS

You can also get the GA to choose the wiring of the circuit (and even the components if you want). This time, rather than component values, the GA chooses which components are connected to which others. One way of doing this is shown in Fig.3.

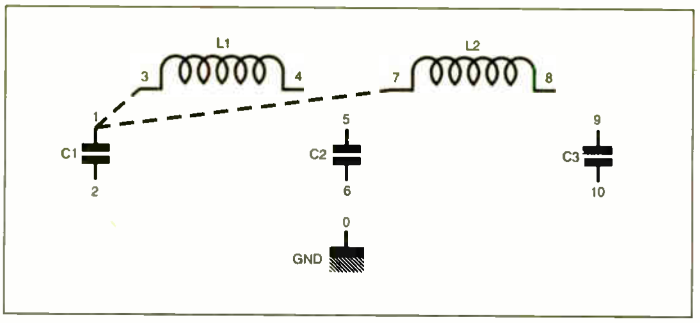

Fig.3. Letting a GA choose wiring topology.

Each wire in the circuit is given a node number. In this case a 11-bit number can encode the connections to a particular node. For example, if node one is connected to nodes three and seven as shown, the code would be 00010001000 the position of the "1"s being three and seven (the first node is zero). The total string length would then be eleven times eleven (one connection code for each node of the circuit) or 121 bits.

You can think up other schemes easily; for example, the algorithm can, if you code it to, choose both the wiring and the component values at the same time.

EVOLUTIONARY ALGORITHMS

Although Evolutionary Algorithms like the GA are useful for choosing components in complex circuits where tradeoffs have to be made, like filters, their real promise lies in Artificial Intelligence. The two tenets of Evolutionary Connectionism (using Artificial Evolution to make networks of components in an attempt to create AI) can be stated as questions and answers:

Q. *Is it possible to build a machine which is intelligent?*

A. *Yes, the brain is simply a machine and if nature can do it, eventually so can we.*

Q. *Is it possible to make a machine like this even if we don't understand how it works?*

A. *Yes, nature used evolution to build it and again so can we.*

Genetic Algorithms and their kin are being used right now to create Artificial Neural Networks (known as ANNs). These are networks of small processors, modelled on brain cells that can learn from experience, just like a real brain. Although these experiments have been quite successful in some respects there are many problems left to solve. After all, we haven't succeeded in making a brain yet.

PROBLEMS

Although there have been some huge projects to try and produce large intelligent systems using Artificial Evolution (like that by Hugo de Garis, which produced circuits with literally millions of elements in them) none have really succeeded yet. That's not to say that there haven't been some interesting results (Adrian Thompson for example has succeeded in evolving large numbers of digital gates into a circuit which did some interesting and unusual things).

So where is Artificial Evolution failing? The answer probably lies in the difference between it and "real" – biological – evolution. At first they may seem similar, but in reality there are some critical differences.

In biology, the wiring pattern of the processors (brain cells) is not coded directly into the DNA itself, in the way illustrated above in electronic circuits. In fact, the DNA in your cells doesn't hold enough information to directly wire-up even a small part of your brain. No, its action is different – and more subtle; what DNA actually does is produce Proteins.

PROTEINS

The Proteins are the universal machines of biology – your body is made up from them. They can react chemically, form rigid structures or perform a multitude of other tasks and, critically, they can self-organize like automata or a jigsaw puzzle into a greater and more complex whole.

So the system has two components: a code and the self-organizing machines which the code specifies. Because the machines can self-assemble, they can produce more complex structures than the code. Another important point is that because all these proteins are made up of only 20 different structural units, they can mutate into different forms easily and so evolution becomes possible. And, unlike the GA, whole sections of real DNA can be deleted, pasted into the wrong area or even reversed, by copying incorrectly – so adding more variation to the whole system.

FURTHER TRICKS

There are further tricks too. Proteins can actually lock to the parent DNA and stop it producing more of the protein (or a different protein). So parts of the code can be switched on or off. Released proteins set up "gradients", which in turn inhibit or excite other proteins in the organism building up patterns of material. In this way smaller and smaller details can be built as one protein triggers another; these symmetrical patterns of structure, reproducing at different scales, are sometimes called "fractal".

The result of all this activity is that the physical structure produced is not homogenous but modular, with delineated identifiable regions that perform specific tasks.

MODULAR SYSTEMS

The fact that the genes in your body produce a modular system is important. There is conclusive evidence to suggest that the brain is modular – for example, if you damage one part of it, you usually wipe out a very particular function.

Electronic systems too are modular; after all, you don't start designing a radio system out of one enormous mass of components; you start by designing oscillators, amplifiers, mixers and suchlike separately. The reasons for brain modularity are complex and not all of them are clearly understood as yet.

So, can we conceive of a system which can evolve modularity in this way? The answer is obviously yes, but the biological system is so complex that it may be almost impossible to reproduce accurately and the organizational element of processors is several levels removed from the protein level anyway; so we must turn to other methods capable of evolving modularity.

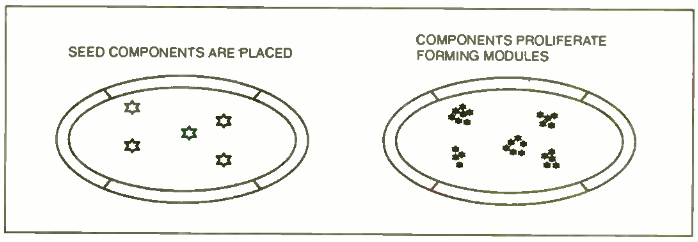

Fig.4. A biological approach to Evolutionary Electronics.

SOLUTIONS?

There are several different ways to introduce modularity into artificial evolution.

Firstly, we could try and code it into the string of the GA itself. This could perhaps be achieved by splitting the GA string into substrings, each of which represents a module. A similar proposal is to have a local string assigned to different parts of the network controlling how it evolves. This is representative of how the genes switch each other on or off as described above.

Another possibility is to try and model biology, not at the DNA level, but at the cellular level, by mimicking the way tissue is placed in the developing organism. This process is shown in Fig.4. The components first migrate to their places in the structure, then proliferate (become more numerous), then finally the wiring is set up locally (by an evolutionary algorithm).

From a pragmatic point of view, why not simply add modules to the circuit, as shown in Fig.5a and allow them to be wired locally by a Genetic Algorithm as in Fig.5b or Fig.5c? These are only some of the possibilities; others include using fractals, automata or special treelike rules to complete the circuit. Whatever way is chosen, it is likely that not only the circuit will have to grow, but also the system which it is controlling at the same time. This is

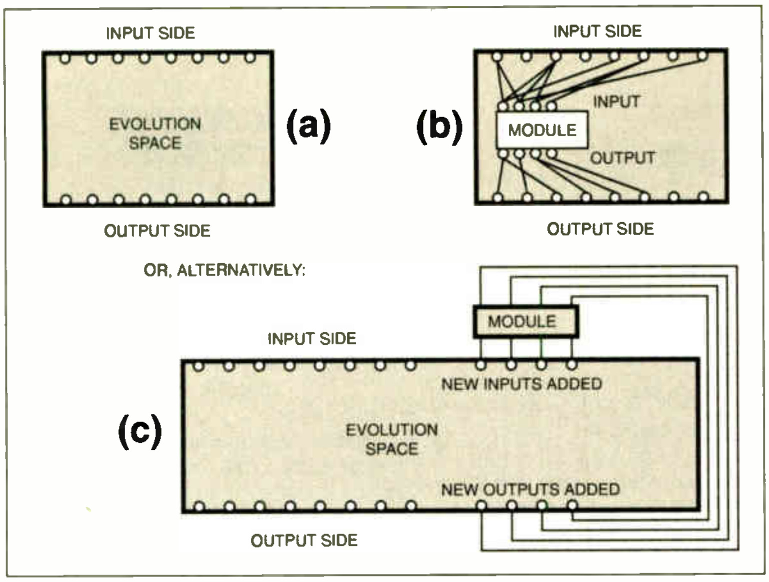

Fig.5. A more pragmatic approach.

because the brain of an organism did not evolve in isolation, but as part of the animal as a whole.

The exciting thing about Evolutionary Electronics is that we don't know the answers yet and the experimentation lies within the ability of the ambitious amateur. Not only that, but this area could hold great rewards for the future of electronics.

ACKNOWLEDGEMENT

The authors would like to thank Ann Barbara Reddipogu, Sethuraman Muthuraman, Niccolo Capanni and David McMinn for their contribution to this article. □

FURTHER READING

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Modular Evolution: C. MacLeod et al, Evolution and Devolved Action, in appendix B of: D. McMinn, *Using Evolutionary Artificial Neural Networks to Design Hierarchical Animate Nervous Systems*, PhD Thesis, The Robert Gordon University, 2002, available on request from the authors: email **chris.macleod@rgu.a.uk** or **g.m.maxwell@rgu.ac.uki**.

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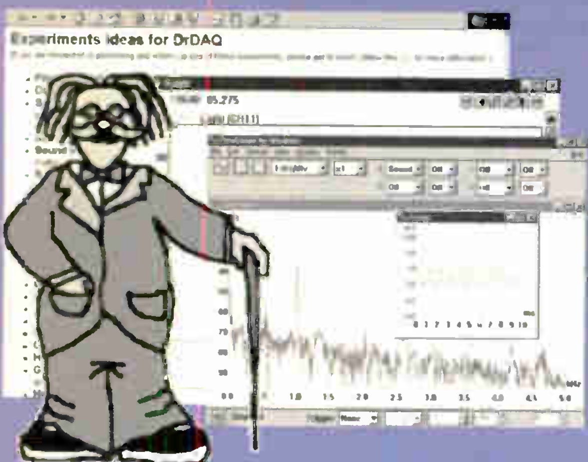

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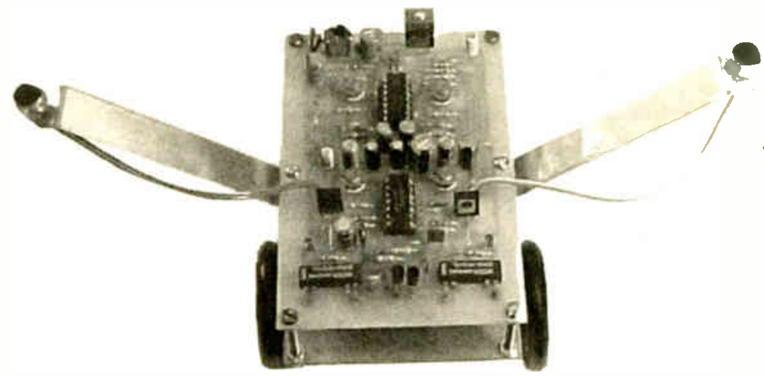
BIG-EARS BUGGY



THOMAS SCARBOROUGH

Clap your hands, "hear" comes Big-Ears! Our sound-activated mobile "pet" (buggy) will give hours of fun.

SOUND travels in waves as it moves through the air at a speed of roughly one-third of a kilometre per second. Sound also has *direction*, so that a sound wave will strike one ear one three-thousandth of a second before it strikes the other – assuming, that is, that one is standing sideways to the sound source.

By electronic standards, this is very slow. Considering that many op.amps will detect differences of just millionths of a second, a simple electronic circuit will easily pick this up. Even if two electronic "ears" are mounted relatively close to each other (say two or three centimetres apart), a modern integrated circuit will readily detect that a sound passed one "ear" before the other.

The circuit described here takes advantage of these basic characteristics of sound, triggering a switch when one "ear" hears a sound before the other – and vice versa. This is specifically applied to the small mobile robot, which we have called the Big-Ears Buggy. This is capable of responding to sound from three directions, and of driving up to the source.

APPLICATIONS

Although the "Big-Ears" Buggy is the application described here in detail, the circuit is potentially very diverse in application. Through the use of the two relays provided (RLA and RLB), there are many interesting possibilities – among them the following:

Since it is a very human trait to be able to respond to the direction of sound, the circuit may be used to seemingly imbue objects with human characteristics. For instance, two small motors wired to a pulley arrangement behind a painting of Great-Grandad would make his eyes move in your direction when you speak. Similarly, an advertising board could move to face talking shoppers, or a head could turn in people's direction.

It could be used as a novel audio "snap" indicator, or as an audio "Who was first?" indicator, finally settling any arguments as to who spoke first!

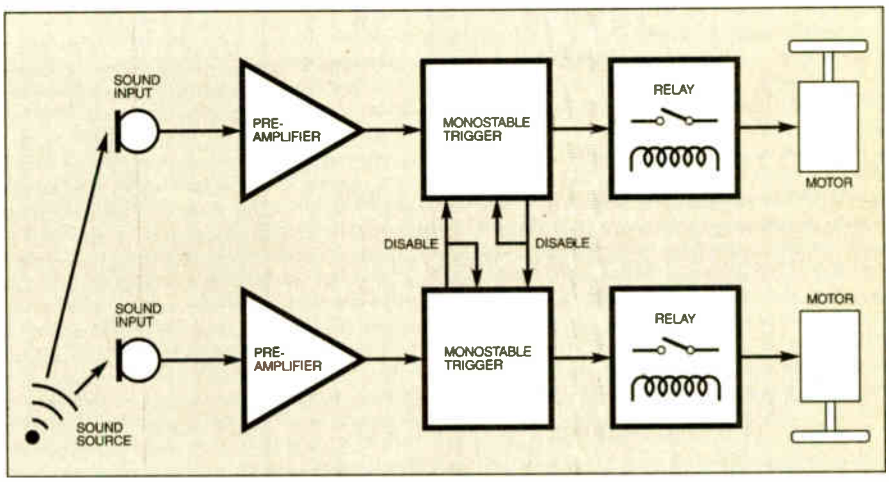


Fig.1. Basic block diagram for Big-Ears Buggy

It could also serve as an aid for the deaf, giving a visual indication that a sound is coming from a particular direction.

CIRCUIT DETAILS

The Big-Ears Buggy circuit itself is remarkably simple in concept, and is shown in block schematic form in Fig.1 and the full circuit diagram shown in Fig.2. At the heart of the circuit are two monostable timers. The first one to receive a sound input disables the other (as well as its own trigger input) so that only the relay which is closest to the sound source is activated.

Two inverting amplifiers, IC1a and IC1b, feed two non-inverting amplifiers (IC1c and IC1d), and two variable presets (VR1 and VR2) control gain. These preamplifiers directly clock monostable timers IC2a and IC2b. There are no coupling capacitors at the outputs, and this improves the ability of the preamplifiers to clock monostable timers IC2a and IC2b directly.

A TL074CN quad preamplifier is chosen here particularly for its fast slew rate – the slew rate determining the voltage rate-of-change as a function of time. A good slew rate is important, since the circuit needs to respond rapidly to any sound waves received.

An NE556N dual monstable timer, IC2, is chosen for its ability to trigger when pin 6 or pin 8 goes "low" (logic 0), while ignoring any voltages above one-third of supply voltage. This is in contrast with many logic devices, which enter a state of uncertainty between one-third and two-thirds of supply voltage, and would be less suitable here.

The maximum timing periods of IC2a and IC2b may be altered by swapping capacitors C15 and C16 for higher or lower values – higher values for longer timing periods, and vice versa. The component combinations of preset VR3, R20, C15 and VR4, R21, C16 allows the time periods, for which monostable timers IC2a and IC2b trigger, to be adjusted. A short time delay is provided, via the combination of capacitor C12 and resistor R17, at switch-on through reset pins 4 and 10, so that switching on does not activate the buggy.

Monostable timers IC2a and IC2b control the duration for which relays RLA and RLB are activated on reception of a sound signal. The on times of the monostable timers may be set between about 0·02 and 1·1 seconds.

The timing periods are calculated as t = 1·1 × C15 × (VR3 + R20) and t = 1·1 × C16 × (VR4 + R21). The outputs at pins 5 and 9 provide current for switching transistors TR3 and TR4, and in turn the relays.

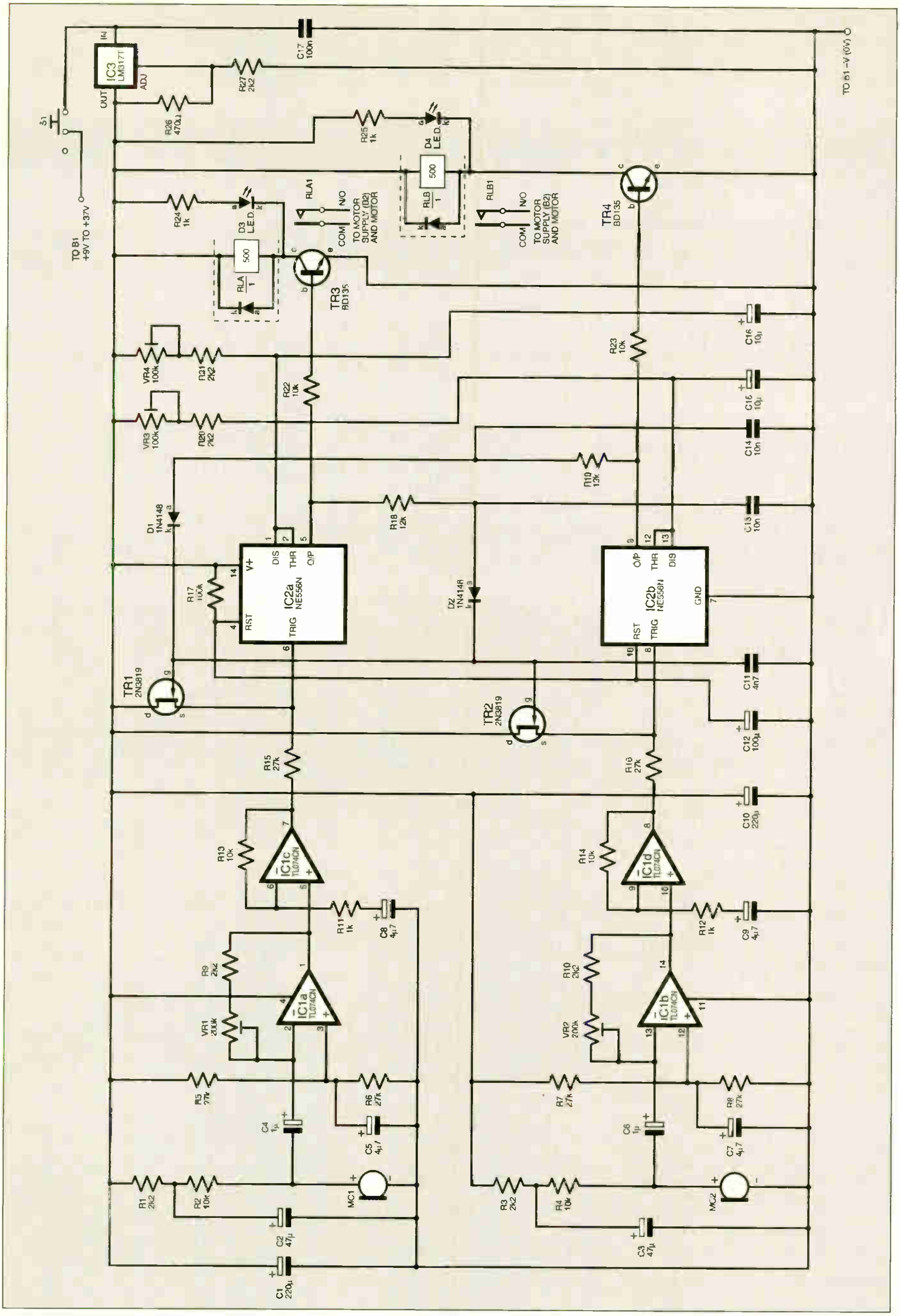


Fig.2. Complete circuit diagram for Big-Ears Buggy. Note that the motors (not shown here) are powered by a separate battery (B2).

Depending on the application for which the circuit is used, presets VR3 and VR4 are adjusted to give the required on times for the two relays – for example, to activate a pulley, or to turn on the motors for Big-Ears.

Depending on the motors used, and whether these will be running independently of one another or not (see cross-head Mechanical Assembly), VR3 and VR4 are adjusted accordingly. You might wish to make Big-Ears take long, trundling turns towards the sound source, or, on the other hand, short sharp turns. This hinges on the adjustment of monostable timers IC2a and IC2b – and, of course, on the speed of the motors, and the way they are wired up.

The most distinctive aspect of the design is the use of f.e.t.s TR1 and TR2. These disable the trigger inputs of both monostable timers when a sound wave is received, which they do by taking these inputs "high". Resistors R15 and R16 form potential dividers with the two f.e.t.s to make such switching possible. This happens so quickly that a sound wave striking one "ear" transducer will find the other "ear" already "deaf" by the time it reaches it. The circuit takes advantage here of the speed of electrical conduction (very fast) versus the speed of sound (slow).

INNOVATIONS

Transistors TR1 and TR2 are put to further use. The gain of the preamplifiers is relatively high. Due to audio feedback from the motors it would ordinarily be impossible to combine them with all but the bluntest of amplifiers.

However, a simple device is used to blank out the noise of the motors – in the form of capacitor C11. This is charged through diodes D1 and D2, and continues to hold the trigger inputs of IC2a and IC2b high through TR1 and TR2, until the motors stop turning.

In effect, the buggy "pricks up its ears" only when it has come to rest. If a motor takes longer to stop, the value of capacitor C11 may be increased to offer a longer period of blanking.

Capacitors C13 and C14 cause a very brief delay in the Big-Ears "hearing", so that both IC2a and IC2b are triggered at the same time (both motors turn) when a sound comes from directly ahead or behind. Thus, instead of responding only to two directions of sound, the buggy now responds to three. Capacitors C13 and C14 may be removed if a response to two directions only is required. Resistors R18 and R19 may be increased to widen the arc of frontal hearing, and vice versa.

The outputs of monostable timers IC2a and IC2b are used to switch l.e.d.s D3 and D4, as well as two reed relays (RLA and RLB), which may be used to switch a wide range of devices. These relays include integral diodes as protection against back-e.m.f.

Note that the specified reed relays have a maximum switched current of 1A, and a maximum switched power of 15W, up to 200V. Their operating voltage lies between 3·7V and 10V. Select other relays if higher ratings are required.

The benefit of voltage regulator IC3 is that the circuit may be used in conjunction with devices which have different power requirements. The regulator is set to just over 7V, so that the circuit may be used with any d.c. supply between 9V and 37V. The formula for calculating the output voltage of the regulator is $V_{OUT} = 1{\cdot}25 (1+R27/R26)$ volts. It is, however, best if the motors are supplied from a separate supply to avoid interaction and noise affecting the circuit.

CONSTRUCTION

Big-Ears Buggy is built up on a single-sided printed circuit board (p.c.b.) measuring 110mm × 75mm. This board is available from the *EPE PCB Service*, code 362. Details of the topside component layout, together with the full-size underside copper foil master pattern, are shown in Fig.3.

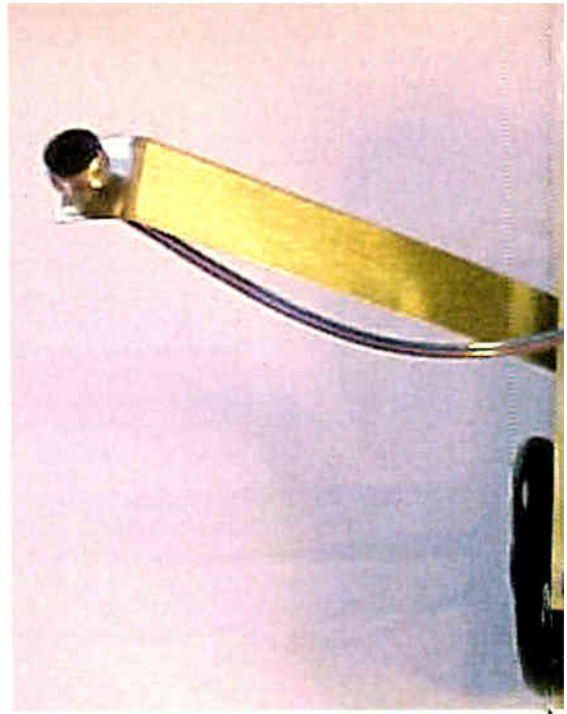
Begin construction by soldering in position the twelve link-wires. Continue with the lead-off solder pins and the two dual-in-line (d.i.l.) sockets.

Next, solder in place the slider switch S1, resistors, l.e.d.s, d.i.l. relays, capacitors, diodes, transistors, regulator IC3 and battery clip.

Field effect transistors TR1 and TR2 should be soldered with care, since these are more sensitive devices. So also are the electret microphones, which each contain an internal f.e.t. Finally, insert IC1 and IC2 in their d.i.l. sockets.

In the prototype, the electret microphone inserts were mounted on arms (ears), about 15cm from each other. This helps the buggy to distinguish sound waves better, and makes the adjustment of presets VR1 and VR2 less critical.

However, the microphones may be mounted as close as 3cm from each other with more delicate adjustment of the



Completed prototype Big-Ears Buggy showing the electret microphone inserts mounted on two aluminium "ears", about 22cm apart from each other.

COMPONENTS

Approx. Cost Guidance Only **£20** excluding extras & batt

See SHOP TALK page

Resistors

R1, R3, R9, R10, R20, R21, R27	2k2 (7 off)
R2, R4, R13, R14, R22, R23	10k (6 off)
R5 to R8, R15, R16	27k (6 off)
R11, R12, R24, R25	1k (4 off)
R17	100k
R18, R19	12k (2 off)
R26	470Ω
R28	2M2 (see text)

All ¼W 5% carbon film

Potentiometers

VR1, VR2	200k single-turn cermet preset, horiz. (2 off)
VR3, VR4	100k single-turn cermet preset, horiz. (2 off)

Capacitors

C1, C10	220µ radial elect. 50V (2 off)
C2, C3	47µ radial elect. 50V (2 off)
C4, C6	1µ radial elect. 50V (2 off)
C5, C7 to C9	4µ7 radial elect. 50V (4 off)
C11	4n7 ceramic
C12	100µ radial elect. 50V
C13, C14	10n polyester (2 off)
C15, C16	10µ radial elect. 50V (2 off)
C17	100n polyester
C18	470n polyester or ceramic (see text)

Semiconductors

D1, D2	1N4148 signal diode (2 off)
D3, D4	3mm l.e.d. (desired colours) (2 off)
TR1, TR2	2N3819 j.f.e.t. transistor (2 off)
TR3, TR4	BD135 *npn* transistor (2 off)
TR5	BUZ11 MOSFET (see text)
IC1	TL074CN quad j.f.e.t. op.amp
IC2	NE556N dual timer
IC3	LM317T 1·5A variable voltage regulator

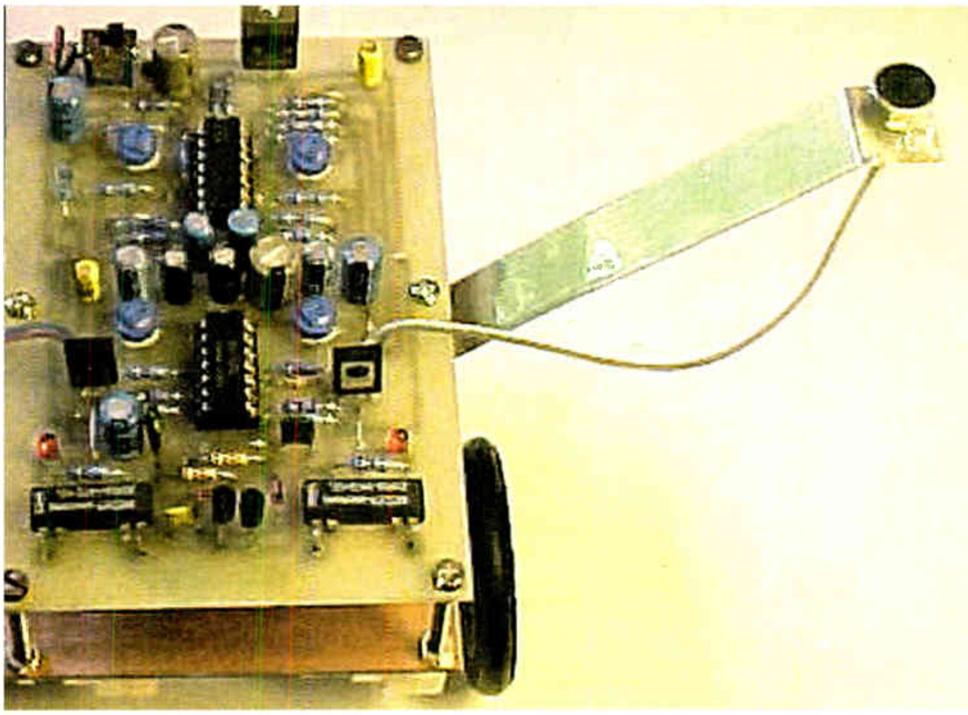
Miscellaneous

MIC1, MIC2	min. electret microphone insert (2 off)
RLA, RLB	s.p.n.o. reed type d.i.l. relay (2 off)
RLC, RLD	double-pole changeover relay – see text (2 off)
S1	s.p.d.t. ultra-min slider switch
S2	lever-operated microswitch (see text)

Printed circuit board available from the *EPE PCB Service*, code 362; 14-pin d.i.l. socket (2 off); link wire; multistrand connecting wire; 9V PP3 type battery (or desired d.c. voltage supply), with connecting clips (2 off); solder pins; solder etc.

EXTRAS

Solar motor, with gears (2 off – see text); large wheel (2 off); small rear wheel; baseboard, size 110mm x 75mm; resistors RX and RY (33Ω 5W and 22Ω 5W – see text); aluminium strips for microphone insert (ears) – 2 off; epoxy glue; M2·5 nuts and bolts etc.



presets, in which case the values of resistors R18 and R19 will also need to be reduced to readjust the arc of frontal "hearing" (try 6k8 for 5cm).

Be careful to observe the correct polarity of the electrolytic capacitors (these have various orientations on the board), and the correct orientation of the transistors, diodes, i.c.s, and the specified d.i.l. relays. The cathodes (k) of the l.e.d.s (D3, D4) will have a flat side on their plastic encapsulation. The negative terminals of the electret microphones are connected to their case.

SETTING UP

Begin testing of the completed p.c.b. by turning back (anti-clockwise) presets VR1 to VR4. Then turn them all up (clockwise) by about a quarter. Presets VR1 and VR2 adjust the buggy's sensitivity to sound, while VR3 and VR4 adjust the periods of time for which monostable timers IC2a and IC2b will trigger.

Attach a battery or d.c. power supply between 9V and 37V to the battery clip,

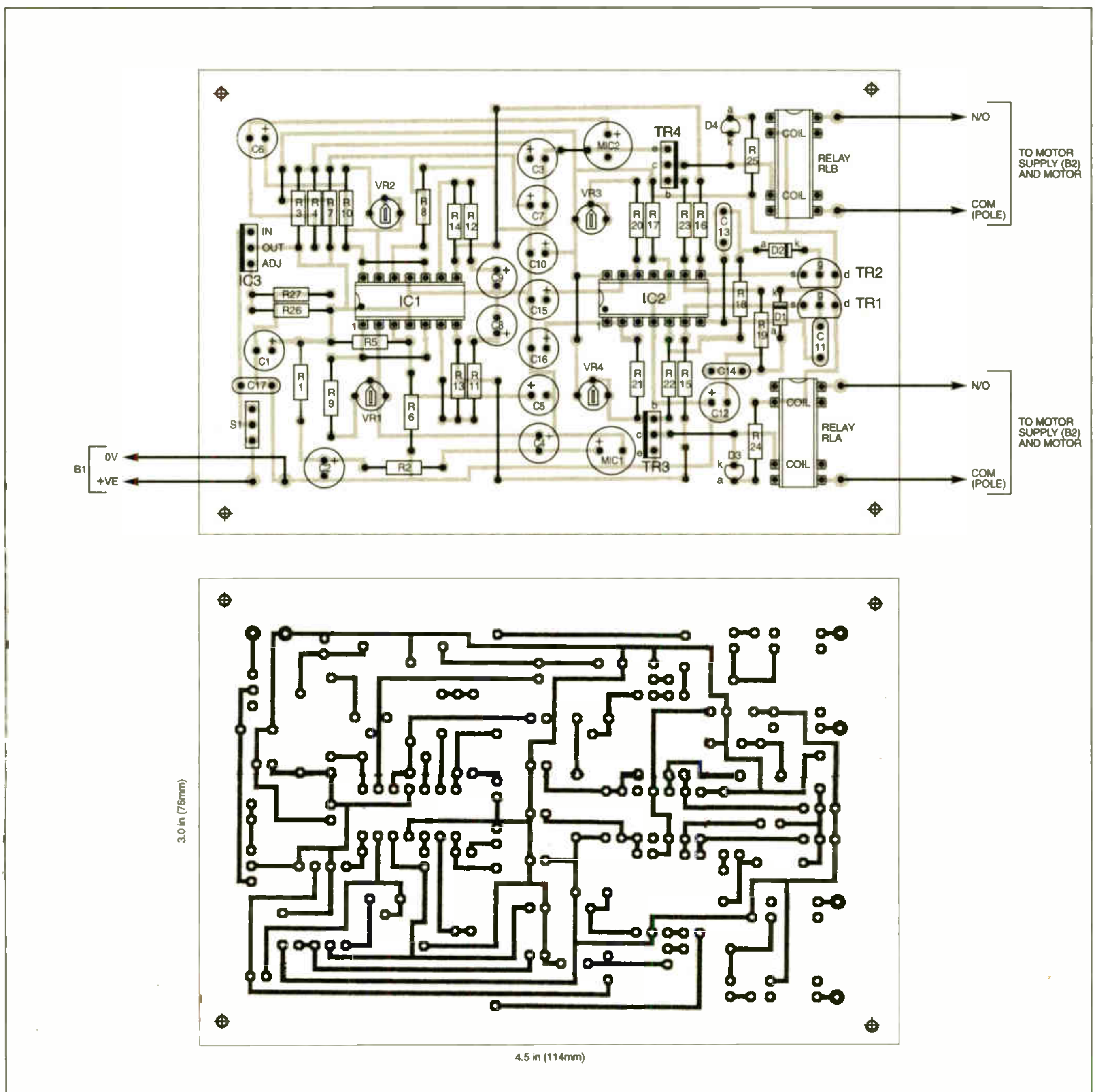
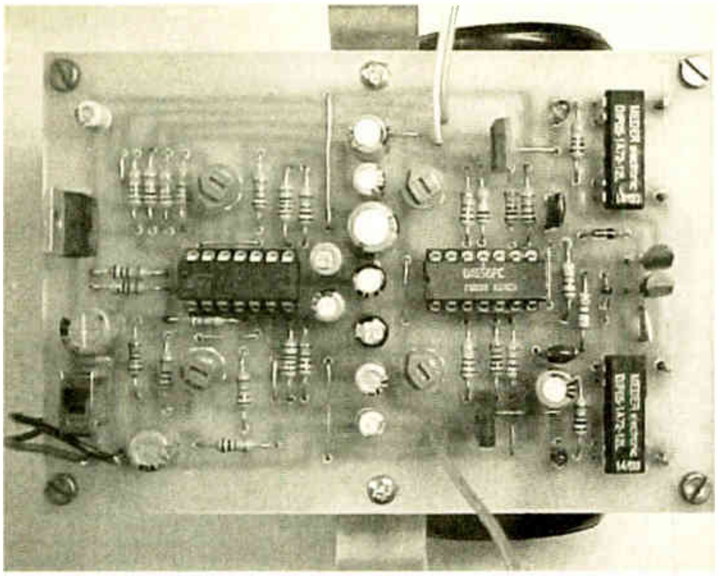


Fig.3. Big-Ears Buggy printed circuit board component layout and full-size underside copper foil master pattern.



observing the correct polarity. Switch on the buggy circuit board by means of slider switch S1.

Now stand to one side of the p.c.b. (in line with the two microphones), and clap. The l.e.d. at the near side of the circuit board should illuminate, and the corresponding reed relay briefly close. Stand at the other side of the p.c.b., and clap again. Again, the l.e.d. at the near side of the circuit board should illuminate, and the corresponding reed relay close.

Clapping directly in front or behind should cause *both* diodes to illuminate and both relays to activate. If they do not, the value of resistors R18 and R19 needs to be increased. If both l.e.d.s always illuminate, the value of these resistors needs to be reduced.

Presets VR1 and VR2 may be used to even out any imbalance between the sensitivities of the preamplifiers. These need to be fairly carefully balanced, so that IC1a and IC1b do not respond to different sound waves of different amplitudes. If the buggy tends to respond too much to sound from one side, increase the gain of the opposite side, or vice versa.

Above: Component layout on the completed printed circuit board.

MECHANICAL ASSEMBLY

Now we have completed the p.c.b. and tested it, we need to mount the board on a suitable "chassis" or baseboard. A general guide of the mechanical assembly can be seen in the accompanying photographs.

Two d.c. motors (with wheels) are mounted on a baseboard of equal size to the p.c.b. The baseboard is bolted to the p.c.b. with through-bolts at the four corners. Solar motors would be best suited here, since they do not stall as easily as other d.c. motors when slowed.

The two motors must be mounted in parallel with through-axles (not at 180 degrees, or there may be differences in torque), and are wired to each of the reed relays in such a way that the relays switch them on and off. A third wheel (which must be able to swivel as it trails the buggy) is mounted at the back. It is important that this wheel should touch the ground at a position that is central to the two wheels which are attached to the motors (see photo). If this wheel is not central, the buggy is likely to "list" to one side.

Instead of switching the two motors alternately when sound is received from the right or left, one motor may merely be *slowed* while the other is at full power. The wiring arrangement shown in Fig.4 may be used, whereby both motors will turn when a sound is detected from the right or left, but one will turn more slowly than the other through series resistor RX (if using solar motors, try about 33 ohms 5W to begin).

A series resistor RY (try 22 ohms 5W) may be inserted in a power line to prevent overload of the motors. If there are imbalances in the torque of the motors, a resistor together with series diode (e.g. the 1N4001 – orientated as required), may be wired in parallel with RX (more current now passes in one direction). Also test what effect presets VR3 and VR4 have on steering.

All in all, a fair bit of tweaking and experimenting may be required to get Big-Ears to operate smoothly.

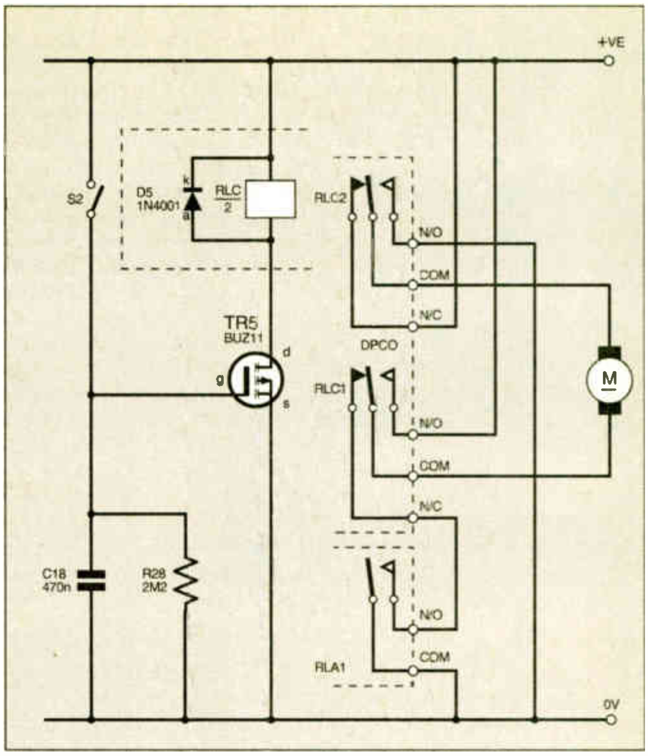


Fig.5. Circuit modifications for adding a simple "bump-and-reverse" feature. This is for one motor, a second relay (RLD), wired in parallel with RLC, will be needed for the other motor.

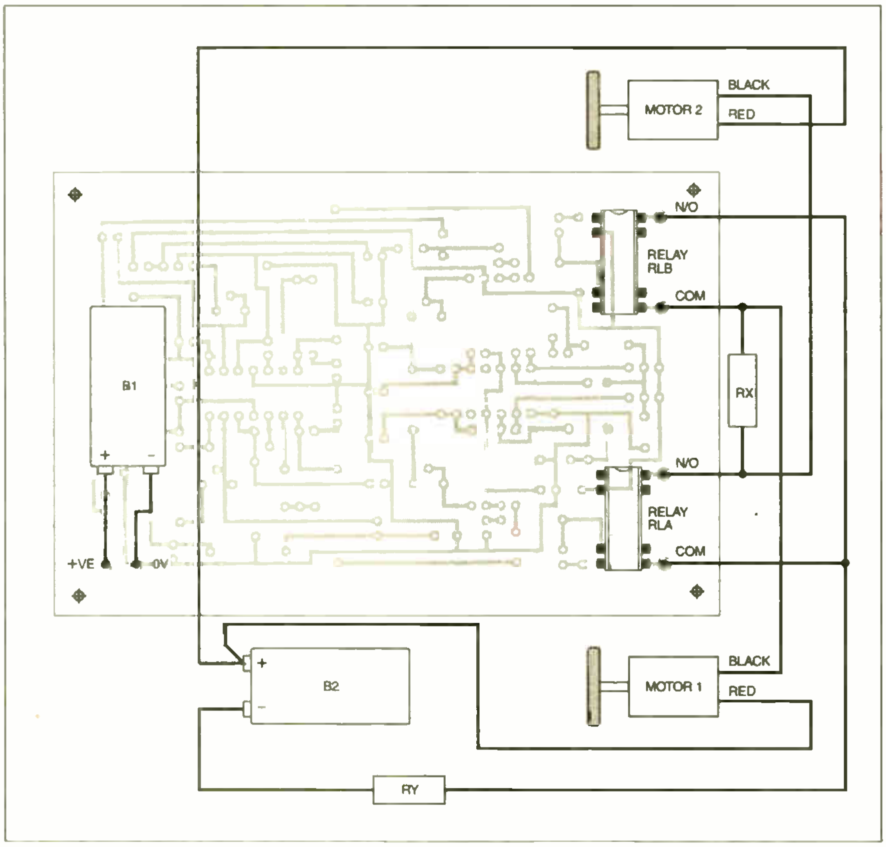
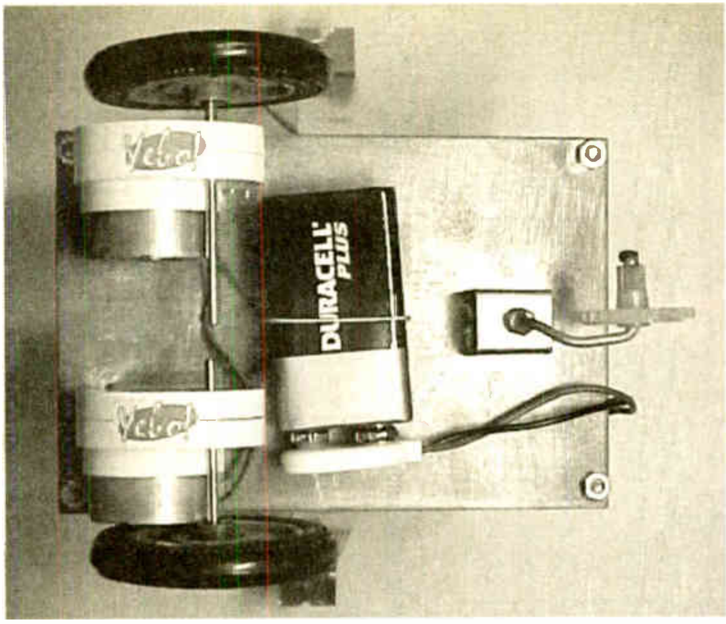
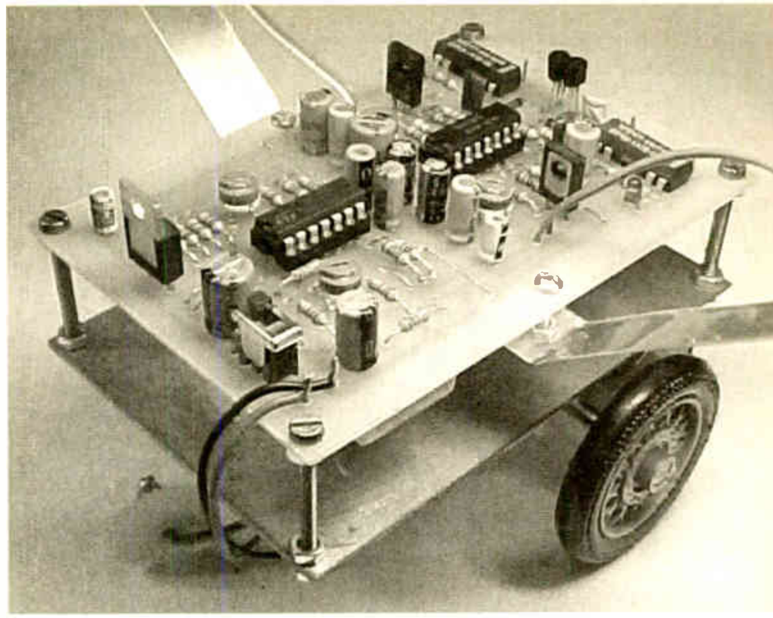


Fig.4. Interwiring from the circuit board and between the motors. Optional resistor RX controls the amount of "steer" and RY helps to prevent any possible overload of the motors.



Underside view of the prototype buggy. It has been found that powering the motors from a separate battery improves the performance of Big-Ears.



General buggy layout showing the p.c.b. mounted on the baseboard, one large motor-driven wheel and the small trailing wheel. Batteries can be sited between boards or below the chassis board.

BUMP-AND-REVERSE

A simple add-on circuit for a "bump-and-reverse" feature, which uses virtually zero current on stand-by, is shown in Fig.5. This is for one motor – wire a second relay coil (RLD) in parallel with RLC for both motors and repeat the circuit.

The switch S2 may be a sensitive lever-operated microswitch, the transistor any "logic MOSFET" (e.g. BUZ11), the value of capacitor C18 should be about 470n, and the additional relay a double-pole change-over (d.p.c.o.) type.

This will override the buggy's circuitry, and cause it to reverse directly out of a collision.

SUMMARY

Finally, the Big-Ears Buggy may be used for animation. For instance, if through-axles are used for the motors, circular discs may be mounted on the insides of the motors, and used to make a little person/animal pedal.

The vertical axle of the trailing wheel may rotate gears which cause the person's/animal's head to turn as the buggy changes direction. Another gear may be used to turn a steering column. Note that when the buggy reverses, it would turn their head to look backwards. □

Constructional Project

SIMPLE AUDIO CIRCUITS

Part 4 – Loudspeaker Enclosures, Tuning Oscillator and Resonance Detector

RAYMOND HAIGH

A selection of "pic-n-mix" low-cost audio circuits – from preamplifier to speaker!

ART and science collide in the design of loudspeaker enclosures and, transcending all the conflicting opinions, is the way a vibrating paper cone can reproduce sounds ranging from the human voice to a symphony orchestra with vivid realism.

Last month we discussed speakers and crossover networks. In this final instalment, enclosures and the simple test equipment needed to optimise performance are covered.

WHY AN ENCLOSURE?

Sound waves formed by the front of the speaker cone are out of phase with those at the back. If the pressure variations can leak around the cone there will be cancellation, particularly at low frequencies, and sound output will be reduced. The primary duty of the enclosure is, therefore, to prevent this leakage.

Speaker cones have a natural *resonant* frequency (just like a guitar string). The greater the mass of the cone, and the freer its suspension, then the lower the resonant frequency.

At resonance, very little energy is required to make the cone vibrate vigorously. This has electrical drawbacks, which were discussed last month. It is also undesirable from an acoustical point of view for speaker sensitivity to peak sharply at one frequency.

The second requirement of the enclosure is, therefore, to retain a volume of air which damps the cone and evens out the response of the system.

ENCLOSURE TYPES

Ignoring simple open baffles, there are four basic types of enclosure.

Infinite Baffles.

Infinite baffles are no more than sealed boxes filled with acoustic wadding to absorb the sound output from the rear of the speaker. Air trapped inside the box damps the cone, raising its resonant frequency by up to an octave (a doubling). Low frequency output falls off rapidly below resonance, and special speakers with high mass, high compliance (very low resonance) cones are sometimes used to offset the rise in resonant frequency.

Absorption of the energy delivered by the rear of the cone, together with the high cone mass, result in an acoustic efficiency as low as 1 per cent. Our Twin TDA2003 12·5W Amplifier (8·2W into 8 ohms: see Part One) requires a more efficient speaker than this if windows are to rattle.

Acoustic Labyrinth

Acoustic labyrinth enclosures are, in effect, a duct one quarter of a wavelength long at the speaker's resonant frequency (e.g., 7ft at 40Hz). Folding the fibreboard or plywood duct into a box shape produces a labyrinth, hence the name. Some designers fill the duct with acoustic wadding: others just line the interior surfaces.

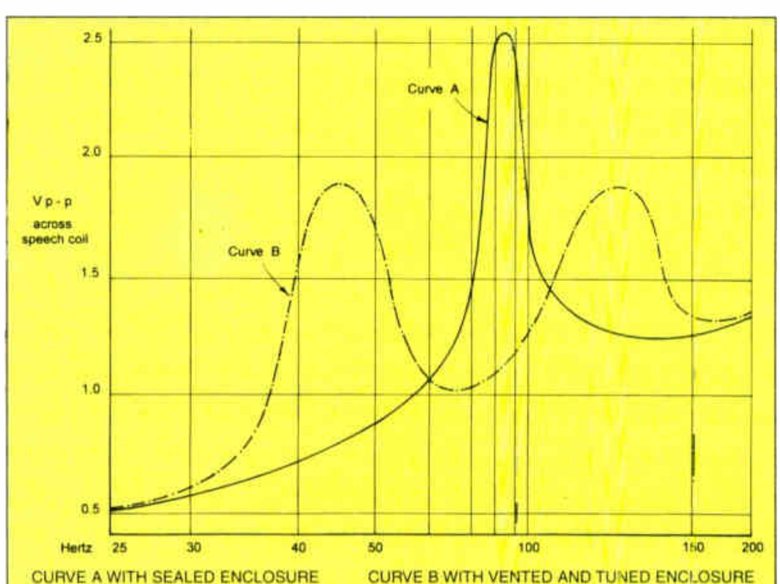


Fig.1. Speech coil impedance in region of resonance.

The quarter wavelength air column imposes the desired heavy damping on the cone at its resonant frequency. As frequency rises through an octave (i.e., towards 80Hz in our example) the air column approaches half a wavelength. The phase of the radiation from the rear of the cone is then inverted, and it emerges from the duct to reinforce that from the front, thereby increasing output.

Enclosures of this kind are not easy to construct or tune to suit different speakers. In our quest for good performance for a modest outlay of cash and effort, this highly regarded system has, therefore, to be rejected.

Horns

Loading the speaker cone with an expanding column of air in the shape of a horn results in very high efficiencies; of the order of 40 per cent to 50 per cent. The horn effects an impedance transfer: high at the throat and low at the mouth. The resulting heavy damping on the speaker cone, and the small cone excursions and low power input needed for a given sound output, greatly reduce distortion.

Many ingenious designs have been produced for folding large, low frequency horns into cabinets. However, cost, size, and complexity of design and construction remove this system from our consideration.

Bass Reflex

Bass reflex enclosures, also known as acoustic phase inverters, are based on the work of a German physicist, Herman Ludwig Ferdinand von Helmholtz (1821-1894).

Whilst exploring the nature of sound. he investigated the way air resonates inside vented chambers and close to the vent itself. The idea of mounting a loudspeaker in a Helmholtz resonator was patented, about half-a-century later, by A. L. Thuras.

Enclosures of this kind are simple and cheap to construct and tune. Efficiency is comparatively high: some authorities suggest 15 per cent to 20 per cent depending on the size of the loudspeaker (the bigger the better).

A reflex enclosure is, therefore, the natural choice when cost and effort are to be kept to a minimum and limited amplifier power demands good speaker efficiency.

HOW IT WORKS

A bass reflex enclosure is no more than a box with a small opening known as the "vent" or "port". The mass of air within the box is tuned, by the vent, to resonate at the same frequency as the speaker cone. This imposes heavy damping and results in two smaller resonances. one of lower and one of higher frequency than the unvented cone resonance.

Speaker output falls off rapidly below resonance, and the development of the lower frequency peak extends the speaker's bass response by almost an octave. Phase inversion takes place over most of the low frequency range, and output from the vent augments that from the front of the cone (the operation of the system is complex, and phase inversion does not occur at all frequencies).

Output falls off very rapidly below the lower peak but, in a well designed system, this will be in a region where there is little or no signal content.

The damping effect of the vented enclosure is displayed graphically in Fig.1. A plot of speech coil voltage against frequency, it represents variations in impedance which are intimately related to resonances in the system. The single resonant peak (curve A) developed when the vent is sealed contrasts with the two lower peaks (curve B) which form when the vent is opened. Correct tuning is indicated when the peaks are of equal magnitude (as is the case here).

DESIGN TECHNIQUES

Traditionally, designers matched enclosure resonance to the free-air resonance of the speaker cone on the basis of vent area being equal to effective cone area. This optimised low-frequency reinforcement by the vent but resulted in large enclosures.

Readers who like to build on a grand scale might find the formulae in Table 1 helpful. Much simplified, they relate speaker size and cone resonance to enclosure volume. The relevant speaker parameters are listed in Table 2.

Enclosures as large as this tune very broadly, and sizeable variations in vent area have only a modest effect on performance. As we shall see, enclosures can be too big, and it would be prudent to reduce the volume given by the formulae by, say, 25 per cent and tune to resonance by reducing the vent area or providing a duct.

When reflex enclosures are designed in this way, the *frequency* ratio between the two smaller resonances formed by tuning should be not less than 1·5:1 and not more than 2·4:1.

Crossover/Audio Filter selection switch and amplifier input terminals.

MODERN PRACTICE

During the 1960's, Australians, Neville Thiele and Richard Small, extended earlier loudspeaker research carried out by American, James Novak.

They were able to show that, for optimum performance, enclosure size is dependant upon the relationship between the damping effect of the enclosed air and the compliance of the cone suspension. If, when the enclosure vent is sealed, the frequency of the single resonant peak is 1·5 to 1·6 times the free-air resonant frequency of the cone, the relationship is correct.

Thiele and Small described an experimental method for determining suspension compliance, and produced formulae relating this, and other speaker properties, to enclosure size and vent area. Known as the Thiele-Small parameters, these speaker characteristics are now published by a number of manufacturers.

TABLE 1: TRADITIONAL ENCLOSURE DESIGN

Formulae relating enclosure volume to speaker cone size and resonant frequency

f res Hz	40	50	60	70	80	90	100	110
Vol cu ft	3R	2R	1·4R	1R	0·8R	0·6R	0·5R	0·4R

Notes:

(1) **F res** is the free air resonant frequency of the cone, in Hertz.
Vol is the internal volume of the enclosure in cubic feet.
R is the effective radius of the speaker cone in inches (see Table 2).

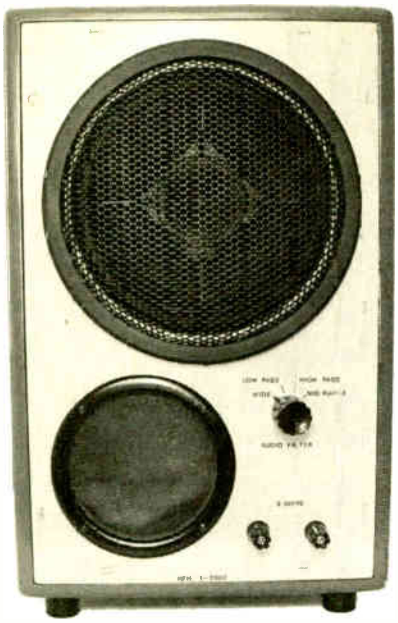
(2) These formulae are derived from traditional design procedures. Calculations in accordance with current practice, which relates cone compliance to enclosed air compliance, usually result in a smaller enclosure (see text).

(3) Although much simplified, the formulae will produce sufficiently accurate results (as size increases towards this maximum, tuning becomes less and less critical).

(4) Formulae are based on enclosure port area being equal to the effective cone area. See Table 2 for details of effective cone areas.

TABLE 2: LOUDSPEAKER DATA

Speaker Diameter (inches)	8	10	12	15	18
Effective cone radius R in.	3	3·75	4·75	6	7·5
Effective cone area sq. in.	28	44	71	113	177



D. B. Keel subsequently adapted the formulae for processing on a pocket calculator, but the procedure is still complicated. Readers with a mathematical turn of mind who want to optimise their enclosures in this way are urged to study the extensive literature on the subject.

BUILD AND TUNE

Theile-Small parameters are not usually available for the low cost, but often reasonable quality, speakers of Far Eastern origin (or for speakers in spares boxes). Even if they were, it is likely that many readers couldn't face the tedium of the calculations.

An alternative approach is to make an enclosure of manageable dimensions, having regard to the size of speaker, and then tune it to optimise performance.

Quite small enclosures can be tuned to frequencies in the 50Hz to 100Hz range. However, as volume is reduced vent area has to be reduced to secure resonance at a particular frequency.

Eventually, a point is reached when vent output is negligible and the enclosure is performing almost like a sealed box. Moreover, as size is reduced, the smaller, "stiffer" volume of air increases damping on the cone and its resonant frequency rises unacceptably.

The resonant frequency of a given vent and enclosure combination can be lowered by forming a duct or pipe behind the vent. The longer the duct the lower the resonant frequency. Although this involves more constructional effort, it does allow a reasonable vent area to be maintained when enclosure volume is small.

SIZE AND SHAPE

Speaker units were discussed last month, and it was clear that an extended and powerful low-frequency response becomes easier to achieve as speaker size is increased. It was suggested that speaker size ought not to be less than 8in, and this is especially true when an inexpensive unit is to be fitted.

Readers may wish to use even larger speakers for the advantages they offer: some highly regarded studio monitors comprise a 15in bass unit in a 5 cubic foot reflex enclosure.

Cabinet dimensions should not be exact multiples of one another, and some experts maintain that deep enclosures perform better than shallow ones. Greater depth also permits a longer duct.

Chamfers, formed around the enclosure front and reaching almost to the speaker aperture, are said to improve clarity at low frequencies, but this makes construction difficult. Keeping the front panel as narrow as possible is probably the best we can do to achieve this objective.

The vent can be any shape provided its smallest dimension is not less than one inch. Circular vents can be ducted with a length of cardboard tube, but some builders may find rectangular openings and box-form ducts easier to fabricate.

CABINET SIZES

The above requirements, together with the desirability of a reasonable vent area and the obvious influence of speaker diameter, tend to determine the smallest acceptable enclosure size. Suggested internal dimensions to suit standard speakers are listed in Table 3 and the general make-up of the enclosure is shown in Fig.2.

The enclosures for the 15in and 18in units are rather deep, and the speaker aperture and vent opening could be formed on the face with the larger dimension if desired (these cabinets are large enough for the cone to still be an adequate distance from what would then be the back).

Whilst the width of the front is determined by the speaker chassis and cannot be reduced much, the other dimensions can be changed to suit materials that are to hand or a particular space in a room. When making changes, try not to reduce the volume by more than 10 per cent or so (especially with the 8in. and 10in. units); and try to avoid dimension combinations that are exact multiples.

CONSTRUCTION

One of the best materials for cabinet construction, acoustically speaking, is medium density fibreboard (MDF). This material is reasonably heavy, easy to work, has a desirable "dead" quality and is inexpensive. Chipboard, blockboard and plywood are also perfectly acceptable.

Enclosures for the 8in., 10in. and 12in. speakers should be formed from 13mm (1/2in.) thick sheet with 19mm (3/4in.) square glued and screwed softwood corner fillets. The two larger enclosures require 19mm (3/4in.) material and 25mm (1in.) square fillets. One or two lengths of 25mm square softwood should be fixed across the larger enclosures, from side-to-side, near mid panel, to inhibit vibrations.

The construction must be air-tight. If any of the joints are less than perfect, apply liberal quantities of adhesive to fill the gaps. Use plastic foam draught excluder to seal the access panel.

MAKING DUCTS

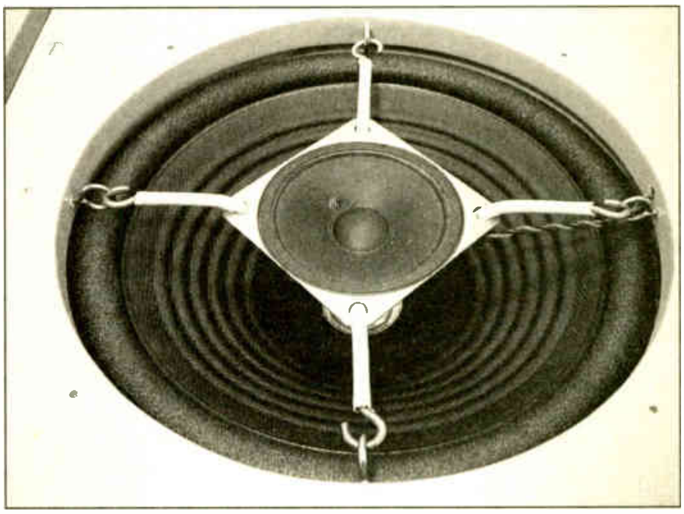
Ducts need not be as rigid as the enclosures, and hardboard (Masonite in the USA) or very thick cardboard are suitable materials. Circular ducts can be formed by applying paste to a long strip of paper or thin card and winding it around a food or paint container until a thickness of 3mm (1/8in.) or so has been built up.

Slide the duct from the former and place it somewhere warm for the paste to dry. It is not too difficult to combine two pipes to form an adjustable, telescopic duct.

TWEETER MOUNTING

Tweeters can be mounted axially in front of the bass speaker to avoid the need for another hole in the cabinet. Small hooks and eyes and the kind of springy wire used for hanging net curtains are ideal for this purpose.

If the wires are cut short to provide a little tension the speaker will be held firmly in place. Strong rubber bands could be used, but these may perish over time.



Using cutdown curtain wire, hooks and eyes to suspend the treble speaker over the bass speaker.

Bass reflex cabinets are resonators and acoustic treatment should be applied sparingly. The rear and top of the enclosure should, however, be lined with about 50mm (2in.) of cellulose wadding to prevent the reflection of mid-frequency sounds which could otherwise escape through the speaker cone and impair clarity.

Cellulose wadding can be obtained from upholsterers and craft shops (it is used for stuffing soft toys).

TESTBENCH SPEAKER

The accompanying photographs show an enclosure for an 8in. speaker, constructed in accordance with the earlier guidelines, and incorporating the crossover and audio filter unit described last month. It is intended for workshop use, and this is reflected in the style and type of finish. Constructors wanting "hi-fi" speakers will have their own ideas for giving the units a more domestic appearance.

The surface mounted grille is of the type fitted to musician's speakers. The bezel around the vent opening is formed from

TABLE 3: RECOMMENDED MINIMUM ENCLOSURE DIMENSIONS

Speaker Diameter	8	10	12	15	18
Width A	9·5	11·5	13·5	17	20
Height B	15	18	21	27	33
Depth C	12	14·5	17	21	24
Speaker Aperture diameter D	7	9	11	13·75	16·5
Vent diameter E	4	5	6	7	8
Vent area sq. in.	12·5	19·5	28	38	50
Minimum distance F	3	4	5	7	8
Enclosure Volume (cu. in.)	1710	3002	4820	9639	15840
Enclosure Volume (cu. ft.)	1	1·75	2·75	5·5	9

Notes:
(1) All dimensions are in inches unless otherwise stated.
(2) Enclosure volumes expressed in cubic feet are approximate.
(3) Enclosures produced to these dimensions must be tuned for optimum performance (see text).

LOUDSPEAKER ENCLOSURE . . . *YOU WILL NEED*

Bass Speaker: 8in. diameter, 8 ohms impedance, preferably with a free-air resonance below 70Hz (most speakers with a rolled surround will meet this requirement).

Moving coil treble unit, 8ohms impedance (see text).

Sheet of MDF, 1200mm x 600mm x 13mm (4ft x 2ft x 1/2in.) thick; softwood corner fillets 4m x 19mm square (13ft of 3/4in. square); glue and screws.

Speaker and vent grilles; material for any duct (see text); draught excluding strip; springy curtain wire and small hooks for mounting tweeter unit; finishing materials etc.

The parts list for the crossover unit was included with Part 3, last month.

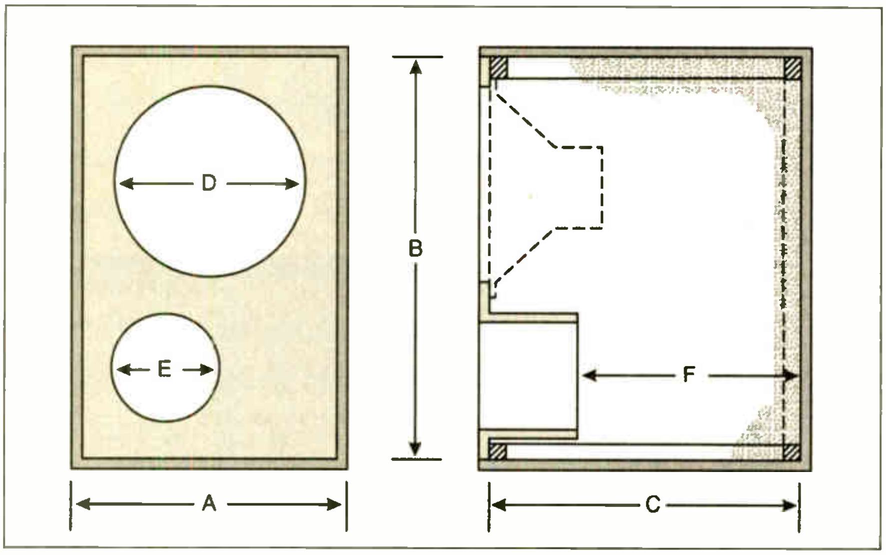
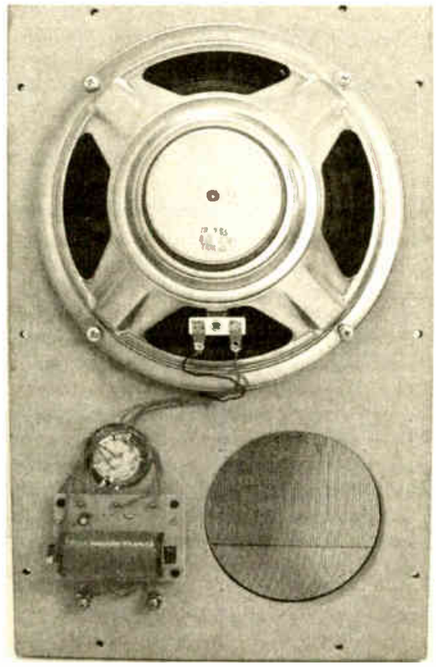


Fig.2. Front and side elevations showing the speaker and vent apertures. Recommended enclosure dimensions are listed in Table 3 above.



Main speaker and crossover filter (last month) mounted on the rear of the enclosure front panel.

Lining the rear of the cabinet with sound-absorbent wadding.

hardboard and nylon mesh is used as a screen. Bezel and mesh are spray finished matt black.

Photographs of the tweeter mounting were taken before the suspension wires were painted black to conceal them behind the grille. Car spray paints were used to decorate the cabinet, and the hard, smooth surface of the MDF makes it easy to obtain a good finish (spraying should be undertaken outdoors or where there is plenty of ventillation). Rub-down lettering, protected by varnish, is used for the panel annotations.

SPEAKERS

Manufactured in the Far East, the bass speaker used in the model is an inexpensive 8in. diameter unit with a rolled surround. Speakers of this kind are widely retailed and cost between £8 and £15 ($12 and $22).

A compliant suspension and robust cone give these units a free-air resonance in the region of 60Hz. Speakers with a free-air resonance much higher than 70Hz should be avoided if possible.

Suitable tweeters are readily available at a fairly reasonable cost. The paper-coned unit mounted in the prototype is a cheap surplus component.

It is sometimes desirable to adopt a cross-over frequency around 500Hz when large (15in. or 18in.) bass speakers are used. Suitable tweeters can be expensive, and experimentally minded readers may care to try one of the cheap Mylar cone speakers intended for alarm systems. The claimed frequency response extends up to 20kHz, and a 3in. or larger unit should cope with the lower cross-over frequency.

Chassis perforations should be covered with several layers of sticky tape to prevent interaction with the bass speaker. Alternatively, isolate the tweeter by mounting it inside a small box formed within the main enclosure. Fill the box with cellulose wadding. A 3in. diameter Mylar cone speaker performed better than the purpose-made tweeter mentioned above.

TUNING OSCILLATOR

In order to tune our enclosure we need some means of exciting and detecting resonances.

A simple Low Frequency Oscillator circuit diagram is shown in Fig.3, where IC1, a 741 op.amp, provides the necessary gain. A Wien bridge network, formed by C1, C2, R1, R2 and VR1a and VR1b, controls the phase of the positive feedback from IC1 output (pin 6) to the non-inverting input (pin 3). Potentiometer VR1 sets the frequency of oscillation.

Negative feedback, from the output to the inverting input (pin 2), determines the gain, thereby controlling the level of positive feedback. Gain should be as low as possible consistent with reliable oscillation over the full swing of Frequency control VR1. Negative feedback increases, and gain reduces, as the slider (moving contact) of preset potentiometer VR2 is rotated towards resistor R3.

The stabilising circuit usually incorporated into the negative feedback loop has been omitted in the interests of simplicity. Despite this, signal amplitude is constant over the frequency range and waveform is good when VR2 is correctly set.

OSCILLATOR CONSTRUCTION

Most of the oscillator components are assembled on a small single-sided printed circuit board (p.c.b.). This board is available from the *EPE PCB Service*, code 364.

The topside component layout, interwiring and full-size underside copper foil master pattern for the Low Frequency Oscillator board are shown in Fig.4. Solder pins, inserted at the lead-out points, simplify off-board wiring, and a holder for IC1 facilitates substitution checking.

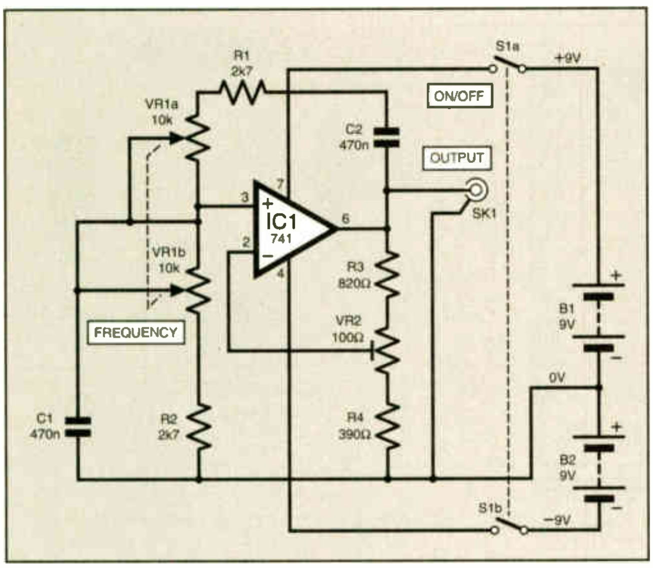
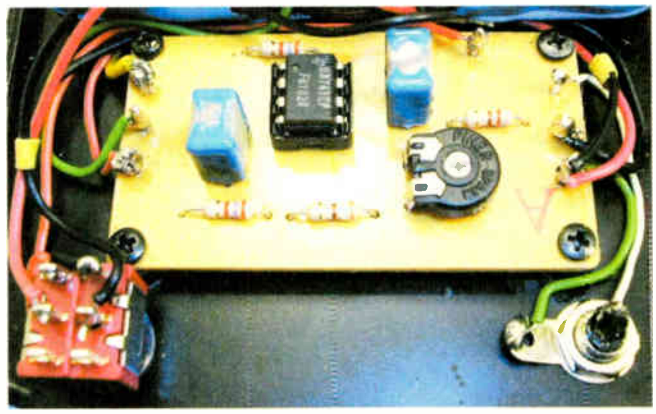


Fig.3. Circuit diagram for a simple Low Frequency Oscillator for loudspeaker resonance checking.



Component layout on the completed circuit board.

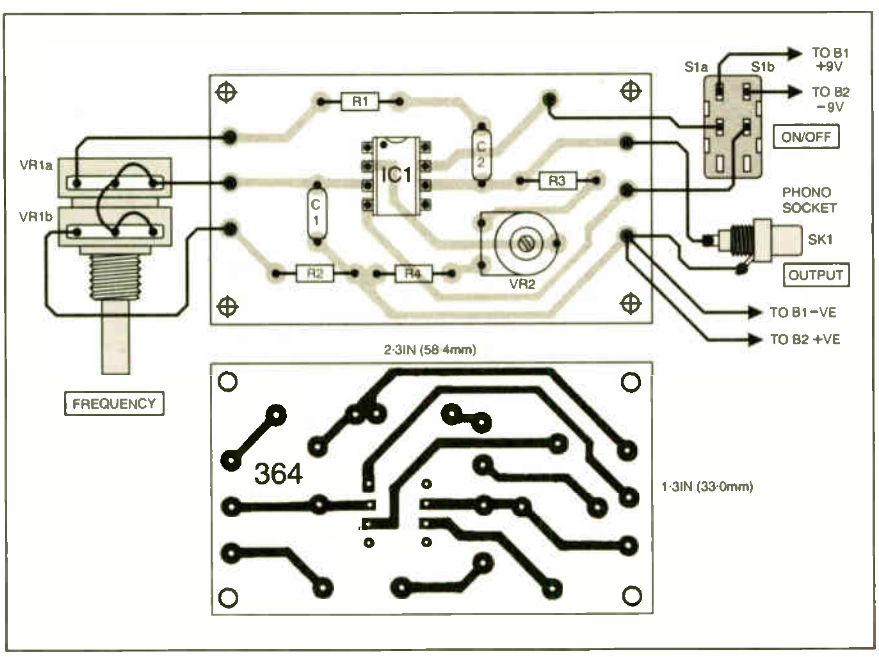


Fig.4. Low Frequency Oscillator printed circuit board component layout, interwiring to off-board components and full-size underside copper foil master pattern.

COMPONENTS

OSCILLATOR

Resistors

R1, R2	2k7 (2 off)
R3	820Ω
R4	390Ω

All 0·25W 5% carbon film

See SHOP TALK page

Potentiometers

VR1	10k dual-ganged rotary carbon, lin.
VR2	100Ω enclosed carbon preset

Capacitors

C1, C2	470n polyester layer, 5% tolerance desirable (2 off)

Semiconductors

IC1	741 gen. purpose op.amp

Miscellaneous

Printed circuit board available from the *EPE PCB Service*, code 364; small plastic case, size and type to choice; PP3 batteries and holders; pointed control knob; 8-pin i.c. holder; solder pins; multistrand connecting wire.

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

Packing the Low Frequency Oscillator components on the rear of the small plastic box lid.

Potentiometer VR1, On/Off switch S1, the p.c.b. and the batteries can be housed in a small plastic box. The compact internal layout inside the prototype unit is shown in the photographs.

It is not necessary to know the precise frequency to tune the enclosure, but an approximate idea is useful. Component tolerances will affect calibration, but the original dial should provide an approximate guide to the frequency control settings on other units. It is reproduced, full-size, in Fig.5.

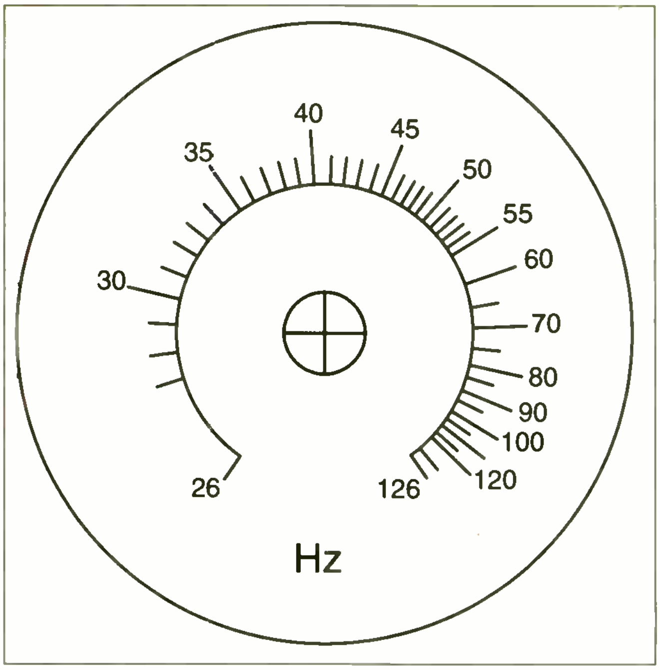


Fig.5. Full-size front panel dial as used in the prototype Low Frequency Oscillator.

RESONANCE DETECTOR

Some test meters, set to the lowest a.c. range, could be used to monitor the voltage developed across the speech coil. However, unless the meter is sensitive, the sound level from the speaker under test would be distressingly loud. Further, a resistor has to be wired in series with the speech coil to facilitate the test. This could make it difficult for the amplifier to deliver sufficient output to produce a reading on an insensitive meter.

Greater sensitivity can be achieved by rectifying the signal and measuring the resultant d.c. on the lowest testmeter range. A suitable loudspeaker Resonance Detector circuit is given in Fig.6, where diodes D1 and D2 are configured as a voltage doubler delivering almost the peak-to-peak value of the signal.

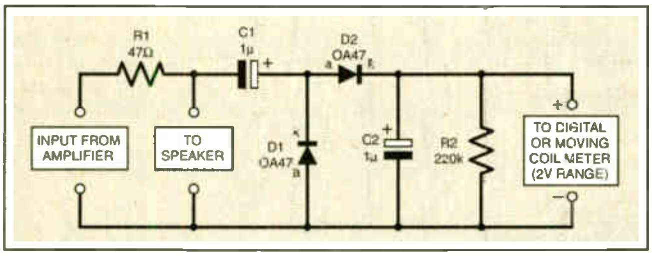


Fig.6. Circuit diagram for the loudspeaker Resonance Detector.

When the Resonance Detector unit is connected to a high impedance digital meter, reservoir capacitor C2 slows the response to voltage changes, and resistor R2 is included to reduce the delay.

Series resistor R1 increases the impedance of the signal source and magnifies the effect of changes in the impedance of the speech coil. The values of electrolytic capacitors C1 and C2 have been chosen to suit the frequencies involved.

DETECTOR CONSTRUCTION

All the components for the Resonance Detector are assembled on a small printed

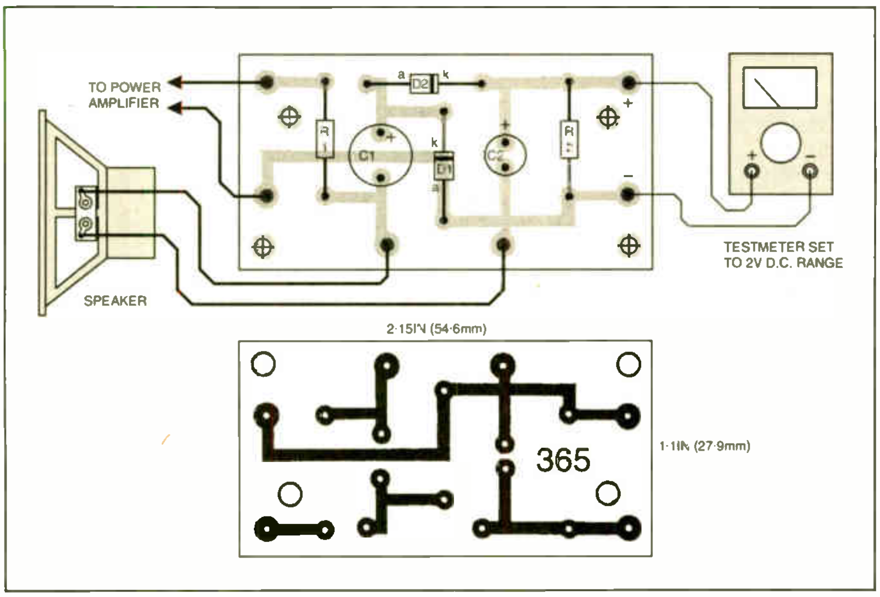


Fig.7. Printed circuit board component layout, interwiring details and full-size underside copper foil master for the loudspeaker Reasonance Detector.

COMPONENTS

RESONANCE DETECTOR

Resistors
R1 47Ω
R2 220k
All 0·25W 5% carbon film

See SHOP TALK page

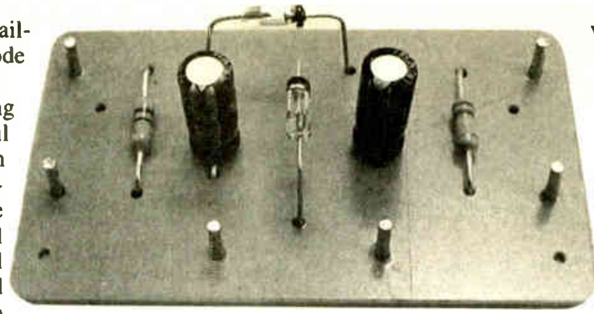
Capacitors
C1, C2 1µ radial elect. 25V (2 off)

Semiconductors
D1, D2 OA47 or OA90 germanium diode (1N914 silicon if lower sensitivity can be tolerated – see text) (2 off)

Miscellaneous
Printed circuit board available from the *EPE PCB Service*, code 365; multi-strand connecting wire; solder pins; solder, etc.

Approx. Cost Guidance Only **£6** *excluding speakers* circuit board (p.c.b.). This board is available from the *EPE PCB Service*, code 365.

The p.c.b. component layout, wiring and full-size underside copper foil master pattern details are illustrated in Fig.7. Construction is very straightforward and only the polarity of the capacitors and diodes needs special attention. Also, germanium signal diodes, D1 and D2, can be damaged by excessive heat and it is prudent to leave a good lead length and apply a heat shunt when soldering.



Completed circuit board for the Resonance Detector.

GENERAL SUMMARY

No difficulty should be encountered obtaining any of the materials and components needed for the construction of the loudspeaker enclosure and the setting up equipment. Details of the cross-over unit were given last month.

Silicon diodes (type 1N914) can be used in place of the germanium devices in the voltage doubling rectifier circuit of the Resonance Detector. The higher knee voltage (0·6V instead of around 0·2V) reduces sensitivity, but they will still reveal the resonance peaks when the sound from the speaker is not too loud, and this is the main requirement.

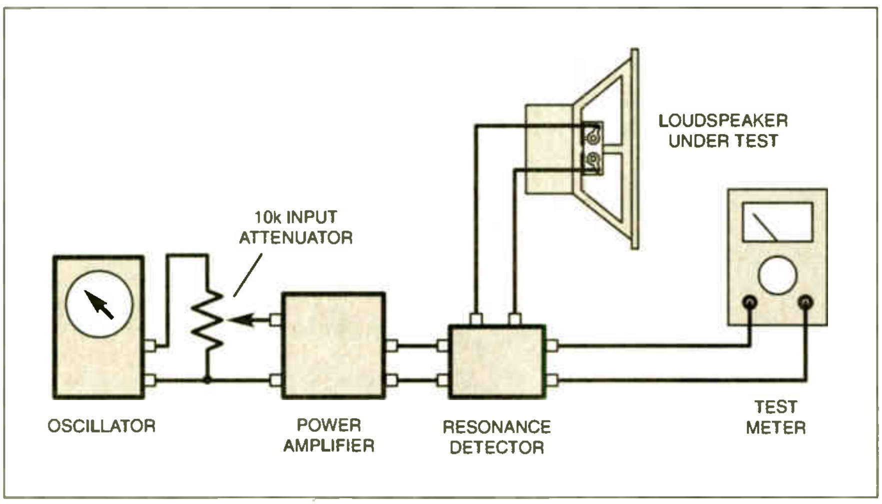


Fig.8. Block schematic diagram showing the interconnecting set-up for checking speaker resonances.

FREE-AIR RESONANCE

The free-air resonance of the bass speaker should be checked before embarking on the construction of the enclosure. To do this, wire up the test circuit shown in Fig.8. Details of the connections to the Resonance Detector are given in Fig.7. The Oscillator output is in the region of 4·5V r.m.s., and the 10 kilohm input attenuator potentiometer will have to be turned well down.

Hold the speaker, by the magnet, well away from other objects and sweep the Oscillator until the voltage across the speech coil peaks. The rise will be sudden and dramatic. Note the reading on the Oscillator dial. If an extended low frequency response is important, it ought not to be more than 70Hz.

ENCLOSURE TUNING

With the speaker now in the enclosure, connect it to the test circuit shown in Fig.7 (directly, ***not*** via the crossover). Seal the vent, sweep the oscillator and note the frequency and magnitude of the peak. It will now be at a higher frequency than the free-air resonance.

Open the vent and sweep the oscillator, again noting the frequency and magnitude of the peaks. If the tuning is correct (most unlikely), two peaks of equal magnitude will be revealed on either side of the original, vent-sealed peak.

If the higher frequency peak is of greater magnitude, the vent area is too small (or any duct attached to it too long). Enlarge the vent, or shorten the duct, and test again.

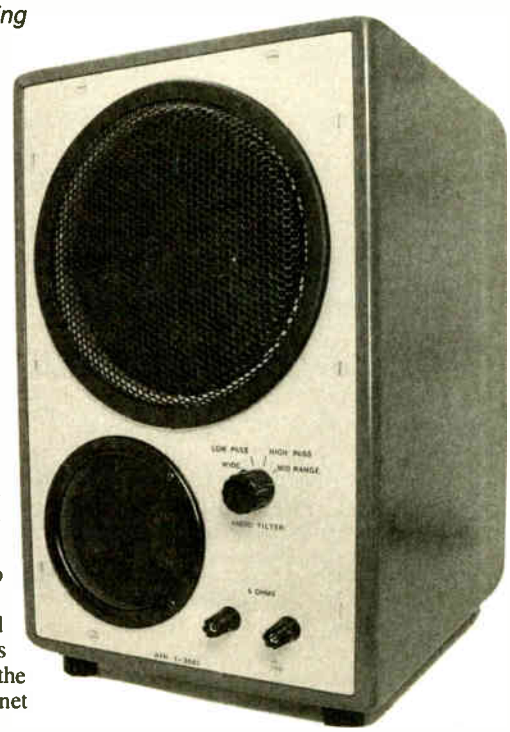
If the lower frequency peak is of greater magnitude (more likely with the design guidance given here), the vent area is too large or any duct is not long enough. Either reduce the vent area, add a duct, or increase the length of any duct already fitted, and test again.

Repeat the procedure until the two peaks are of equal magnitude. Some experts tune to a slightly higher frequency. This depresses the higher frequency peak and, it is claimed, results in a more uniform bass response. The impedance plot of the test bench speaker, after tuning, is given in Fig.1.

DUCTING

It is preferable to install a duct, rather than reduce vent area, in order to lower resonant frequency. Hold ducts in place with sticky tape during the setting up process.

If desired, a duct can be mounted externally and adjusted until its length is almost correct before fixing it behind the vent. Duct volume will then reduce cabinet volume, so err on the long side when adjusting its length in this way.



PERFORMANCE

The speaker unit has an extended bass response and, when driven by the 8W amplifier described in Part One (May '02), sound levels are more than sufficient for a domestic "hi-fi" installation.

Vent output makes a significant contribution at low frequencies (it will extinguish a candle held close to the aperture), and there are no audible resonances. The speaker is most certainly not a "boom box" with honking, one-note bass.

The middle range is clear but there is some colouration at high power levels with music that has a heavy bass content. Performance at the higher audio frequencies depends very much on the tweeter used: the enclosure is certainly worth something better than the cheap unit fitted in the prototype.

When the crossover network is switched to act as a "speech frequency bandpass filter", signals overlaid by noise are greatly clarified. Communications enthusiasts, or readers involved in surveillance, may find this circuit of interest. It certainly makes the unit more versatile as a bench speaker.

POWER CHECK

The Low Frequency Oscillator and Resonance Detector units can, of course, be used to investigate any speaker system. The rating of resistor R1 in the Resonance Detector is only sufficient for testing at comfortable listening levels. If speakers are to be checked at high power, fit a 5W component and use silicon instead of germanium rectifier diodes.

Although the test equipment will respond to very slight changes in venting, especially when the enclosure is small, only a refined ear could detect any audible difference, even when quite large adjustments are made. □

READOUT

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

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

WIN A DIGITAL MULTIMETER

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

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

★ LETTER OF THE MONTH ★

AUTO-TRANSFORMERS

Dear EPE,

I feel your readers should be aware that the use of auto-transformers in voltage changers for using American equipment in the UK is potentially lethal, but virtually all the commercial units are auto-transformers.

Given a piece of equipment designed for 120V and complying with its standards, the spacings between the user and the incoming mains will be OK for 120V. An adapter using an auto-transformer can conform to its standards but put the two together and you have a piece of equipment with 120V spacings connected to 230V mains which is NOT safe. The manufacturers will doubtless tell you that the side of the mains which is common is the Neutral and therefore it's OK, but as pointed out above – the Neutral side is also potentially lethal and it goes straight through into the 120V hardware with the 120V spacings.

All I can say is I won't have one in my house. I use one of those transformers used for building equipment. Surprise, surprise – they are totally isolating and they earth the centre of the secondary so each side is only 55-60V with respect to earth. Much, much safer.

I hope this has helps someone to avoid killing themselves.

Roger Warrington C.Eng MIEE, via email

Thank you for this vitally important caution, and for your very informative comments on X and Y capacitors in last month's Circuit Surgery.

MICROCHIP CODE

Dear EPE,

Following John Becker's *PIC16F87x Extended Memory* article (Jun '01), I have been setting up arrays in Bank 1, as they may be accessed indirectly from Bank 0, without changing banks. So I thought I would do the right thing and used the code published by Microchip to initialise all Bank 1 GPR (general purpose register) locations to zero. Disaster! Not only were the register values not set to zero, several other things went wrong too. One was the PIC would not respond to a hardware reset.

Then I looked more closely at the Microchip code, which is published in their Example 6.4, RAM Initialization, on page 6-15 of the *Mid-Range MCU Family Reference Manual*, December 1997. DS33023A. The published code is:

```
        MOVLW H'A0'
        MOVWF FSR
LOOP    CLRF INDF
        INCF FSR
        BTFSS STATUS,C
        GOTO LOOP
```

Well, of course, the code won't even assemble, the fourth line should be INCF FSR,F. That should have put me more on the alert than it did. When I did assemble and run this code, the strange things mentioned above occurred. I played around with the problems for some time to no avail. Then I looked yet again at the Microchip example, and the penny, which should have dropped long before, finally dropped.

The INCF instruction does not affect the Carry flag; it only affects the Zero flag. So the fifth line was changed to BTFSS STATUS,Z and all was well. This works because the last address to be set to zero is H'FF', and the pointer then increments to H'00', the Zero flag is set, and the loop terminates. Without the change, I can only assume all sorts of locations were being written to, both within and beyond memory, and the PIC did not like it!

This story shows that Microchip example code is not assembled and tested before being published. It is just written. Beware!

John Waller, via email

There seems to be a common opinion that Microchip do not necessarily show the optimum code structure, leaving many questions unanswered and the likes of you, me and crowd to resolve it!

I too have come across instances of MPASM code without F destination suffixes where they should be, and think that this is because the MPASM assembler might regard the lack of a suffix as indicating F by default, which is not logical since F = 1 and W = 0, and conventionally the lack of something indicates 0, not 1! And yes, C is not affected by INCF.

While investigating the F627/8, incidentally, I have come across several errors in the data sheet for those devices too.

MULTIPLE ALARM PINS

Dear EPE,

I have downloaded the April '02 edition of *EPE Online* and noticed that you would like suggestions for improving the *PIC Controlled Intruder Alarm*. Since I own a fairly advanced alarm myself, I found a few things that I think would fit this alarm well.

It should be possible to input several different PINs, so that each user or group of users can have their own. If this is used in a store, club or whatever where there are new people coming and going all the time, everybody does not have to learn a new code each time someone quits.

Another thing, maybe not everybody needs or is allowed to change the settings. Then this could also be regulated by setting which PINs can alter the settings. The rights to disarm various zones can be set for different PINs.

Stig Østvang, via email

Thank you for the suggestions. If I ever update it, I'll consider including them, but suspect I would find it difficult to implement several PINs through a PIC and appropriately scan for their valid use.

LM368 POWER-UPPING

Dear EPE,

Please thank Raymond Haigh for his recent articles on audio circuits. I have a question that I have not seen covered in any magazine dealing with audio circuits. The LM386 is a very popular device in many receivers on today's market, the trouble being relatively low output. How can the output from such a device be successfully coupled into a higher power amplifier (typically the TDA2002/2003 types as in Raymond's articles) without causing the obvious output-to-input impedance mismatch?

Just for the record, I have been a reader for probably forty years, and still enjoy construction, although mainly RF oriented.

D.J. Lacey, via email

Very best of wishes to a very long supporter! Raymond replies:

Thank you for your interest in the audio amplifier series. With reference to your query, no problems should be encountered connecting one i.c. power amplifier to another, provided they have separate power supplies (which they normally would have). The output is at a low impedance and the input of the "bigger" amplifier is at a higher impedance, which is a good situation to have when transferring signal voltage from one stage to another.

I anticipated that readers may wish to boost output in this way, and Fig.15 on page 427 of the June issue (Part 2) gives a circuit for connecting small radios, Walkman units etc, to another amplifier, and this should be satisfactory. All of the power amplifier circuits have an input blocking capacitor on the board, so they can be used safely in this fashion. If you have too much signal voltage from the lower power amplifier, reducing the 47Ω resistors to 22Ω or even 10Ω will make the volume control for your "bigger" amplifier operate more smoothly.

Raymond Haigh, via email

PHIZZY PICS

Dear EPE,

I saw recently about a *PhizzyB* that can be simulated on the PC using Windows and on the hardware, I also saw PIC16F84 tutorials, which is advanced for me.

I'm looking for the best text that can do the following: a text with step-by-step explanation like the *PhizzyB* basics (input, output, adding, shifting, etc) and seeing the results on the *PhizzyB* hardware using a PIC16F84 and later writing programs from C language, which I know and studied, to the equivalent assembly language using PIC16F84. Also a text that I can construct like the *PhizzyB* hardware including complete schematics and testing using PIC16F84 chip.

Kojitom, via email

My PIC Tutorial *of Mar-May '98 (three parts) is the simplest PIC text you are likely to find. There is nothing about it, though, that relates to* PhizzyB *(Nov '98 to Jun '99), or vice versa, and* PhizzyB *does not handle PICs. If you know C, however, you should have no difficulty in learning PIC assembler.*

SIGNIFICANT ELECTRONICS

I'm not a teacher but I work part-time in a school as a science lab technician. The school has offered to put me through teacher training as I'm the only member of staff with any kind of physics degree but I've turned them down.

You wouldn't believe how dull the science curriculum has become, apparently in the interests of getting everyone a pass at GCSE. The practical electrical part of the curriculum is now: cells in series, bulbs in series and parallel, the resistance of a piece of wire versus its length and thickness, simple electromagnet, electric motor, and making a cell from a lemon. I think that's all. There are demos of electrostatics, a bicycle dynamo, a solar cell and the field round a wire. That is five years work.

Avoiding law suits seems to play a part too. The radioactive sources are so weak that the Geiger counter barely registers them above background radiation. We cannot have anything stronger. If a mercury thermometer breaks we are supposed to evacuate the entire building (four labs) not just move the children from the affected area. This approach affects chemistry more than physics though as swathes of interesting experiments are no longer performed. You wouldn't believe how many "science" lessons end up as "we'll do a word search". It does not bode well for Britain as a scientific nation.

John North, via the EPE Chat Zone

John's comments were extracted from a set of several threads on the Chat Zone, *and which were felt to be worth repeating here. What comments do other readers have with regard to current technology teaching in schools? "Gary", for example, offered the following on the CZ:*

I remember physics at GCSE level, especially the electrical part, It was supposed to take about three weeks to complete the electrical part, we had to work from a booklet of circuits of bulbs and batteries in series and parallel, and various combinations of switches. You were supposed to build the circuits to verify their operation, I answered the whole booklet in one lesson without even building a circuit, the teacher wouldn't even look at the answers, because I had to do the experiments, what a complete and utter waste of my schooling time, I did every experiment only to prove that all my answers were right in the first place.

When we came to the electronics part the teacher kept getting diodes and NOT gate symbols mixed up, an easy mistake to make, I think NOT! This was eight years ago. So I can only surmise things have gotten worse, since my sister went through the same system, and I was surprised to find that they had cut out a lot of the stuff that I had to do.

Gary, via the Chat Zone

INGENIOUS SHOPABILITY

Dear EPE,

Regarding high voltage generators, as commented on in *Readout* July '02 – you don't do much shopping do you? Almost every butcher's shop and supermarket has a thing on the back wall with a circular UV type lamp to attract insects and a high voltage grid to zap them when they go for the light. As these butchers shop sets are so freely available in many retail catalogues, why is your correspondent trying re-invent the wheel?

On your comments about *Ingenuity Unlimited* (*Editorial* July '02), I have a certain sympathy with both sides. While I hold no brief for the "get rich quick rip off somebody else's idea" merchants, I also sympathise with the person who gets a good idea and sends it to various publications in the forlorn hope that one at least will publish it someday, and with the vagaries of publishers pigeon holes it can take years for something to surface and by that time any good inventor will be on the 1000th new idea and forgotten all about the earlier ones and who they were submitted to.

I have also noticed there is a huge gap in info and circuitry for add-ons using the computer USB 1 and 2 methods of connection. While I made my own games port to midi adapter, these newer generation of comps don't have that luxury and I had to buy a commercial USB adapter. The biggest need is for a USB to serial or parallel/LPT interface for all them semi-obsolete printers gathering dust. Seems to be an ideal PIC project for someone cleverer than me to get his teeth into.

G.S. Chatley, via email

Well G.S., you are right – I avoid shopping like the plague! But you've missed the point, correspondent Anthony Bankside doesn't want to buy an exterminator, he wants to invent one, and for it to be powered from a battery, presumably in remote locations where mains power does not exist. Many of us do not wish to always take the easy way out by buying something, and not only prefer to re-invent the wheel, but to also improve on it. It is our nature at EPE *to encourage electronics experimentation, building and learning, and that is what readers expect from us, and presumably why you too buy* EPE.

Regarding submissions, whatever bad experience you may have had with other publishers, don't "tar us with the same brush". We advise whether or not we accept, and what our terms of such acceptance are. What angered us with the submissions referred to was that their authors had signed a declaration that the offerings were their own work, which they were not, and thus had lied to us.

USB interfacing is a subject we hope to resolve through PICs, but we are waiting for Microchip to release a particularly suitable device that they have been forecasting for some time.

Thank you for making the other points in your email, but which are too many to reply to.

PIC-ING THEOLOGICALLY?

Dear EPE,

Thank you very much for the magazine *EPE*, it is really a God-send to electronics engineers.

I am in my final year now and it's time to present a project as part of my academic requirement, I am out of ideas, could you help me with any? I mean suggesting something nice, I am counting on *EPE* to puzzle my institution and to help me. I know you are the busy type and may not tolerate this type of letter, but I beg you to help me since *EPE* has always been my guardian in my electronics career. I wish to work with PICs though I know so little about them. Please help me.

Ubaka George, via email

Oh my, it does pull at the heart strings to turn down such a plea! But we simply do not have the time to consider and offer a specific suggestion, but with all the designs we publish each month we are sure that at least one of them should give you ideas!

To learn about PICs, read my PIC Tutorial *of March to May '98 (3 parts). Back-issue photocopies are available as stated in any recent issue of* EPE.

Thanks for your kind words.

WRITING FOR EPE

Dear EPE,

I am an aspiring electronics engineer, presently somewhere around my late sophomore year and have developed a couple of fairly simple projects using what I have learned up to this point. I was wondering if *EPE* has any interest in outside projects, what it would take to put an article together if there was interest and, of course, if there was some kind of compensation for doing so?

David Simanowitz, via email

*Yes we do publish "outside" projects - they all are, including mine as I write in my spare time. You can read about writing for us (and payment rate) through our ftp site (**write4us** is the folder you need to look for). Note, though, that it is best to send us a precis of the idea first to see if we are interested.*

COMPLEMENTARY PIC TRICK

Dear EPE,

This PIC Trick turns out to be a gem for its sheer simplicity. Quite a few processors have a Complement Carry instruction, but not the PIC. Although it is not a heavily used instruction it does have its uses.

```
; Complement Carry
; STATUS bits affected: C = NOT C, DC = old C

BCF STATUS,DC
INCFSZ STATUS,F
NOP
```

The first instruction clears the DC bit to ensure no other STATUS bits are changed. The second instruction has the effect of complementing bit 0 (Carry bit) and shifting bit 0 into bit 1 (DC). The INCFSZ instruction, not INCF, must be used as it does not affect any other STATUS bits. The NOP cancels the effect of skip if zero.

Peter Hemsley, via email

How superbly simple – now I must try to find a use for it, as I have successfully (and beneficially) done with so many of your offerings! Readers, if you have not yet discovered our PIC Tricks *folder on our ftp site, do so. There are many useful PIC routines there, many of them by Peter and which are extremely useful, as well as being neat and compact.*

Amonst the "tricks" are Peter's multiply, divide and BCD routines, all of which I use frequently, his square roots (this issue) will also be put there.

PIC RESOURCE

Dear EPE

I have come across what I think is a great product for PIC users. It is Pascalite, which, somewhat confusingly, is the name for some free software and a PIC product a bit like BasicStamp. Pascalite allows you to program PICs in a dialect of Pascal, the basis of Delphi.

Particularly commendable is the fact that anyone can download, free, the excellent fully working IDE. It's not a big download, only 480Kb, and is a simple, modest install. Of course, once you have that, you'll want (so the suppliers hope) to buy the hardware that it creates programs for. However, there is a simulator, so you can see how your program should work even without the hardware.

The full details are at **www.arunet.co.uk/tkboyd/ele1ps.htm** ("ee-ell-ee-one")

Tom Boyd, Chichester, via email

Thanks Tom – and I know your site is interesting in a general way as well. Readers have a browse of Tom's site!

TK3 BUG FIXED

At the beginning of June, loading problems with Toolkit TK3 V1.23 *(at that time newly updated) were reported. A corrected version was put on the ftp site in the middle of June but there is a workaround if you don't want to re-download, as was announced in the Chat Zone at the time.*

*The bug (runtime error 380) was to do with the new facility to add your own PICs and is too complicated to explain, but the workaround is to create the file **defaults_clear_record.txt** through Notepad and save it in the* TK3 *folder (it does not need any text in it).*

Those of you who simply overwrote the previous TK3 *files with those of V1.23 would not have deleted the above file and so should not have had any problem. It's only you who (wisely in the normal way – but not this time!) started afresh having safely copied the previous version to a folder elsewhere that should have had this problem.*

SQUARE ROOTS WITH PICS

PETER HEMSLEY

A neat routine that allows a PIC microcontroller to extract the square root of a number.

The use of maths routines in microcontrollers is becoming increasingly popular, as is evident in the PIC-controlled projects published in *EPE*. Recently, in the *EPE Chat Zone*, a reader was searching for a square root routine for use in calculating r.m.s. values of input data. It was this request which prompted the author to write such a routine for the PIC.

HOW TO FIND A SQUARE ROOT

There are various ways to find the square root of a number, the most popular being the Newton-Raphson method. This method uses successive approximation and has a fast convergence rate, but has a drawback in that it requires a division routine which is relatively long and slow.

The author's favoured method uses only subtraction and, of course, the obligatory bit shifting in the final assembly routine. To explain the algorithm some maths is obviously required but this will be kept simple, using examples where possible.

The square root of a number is easy to find, it is simply $N = X^2$, which is:

$$N = X \times X$$

From this expression it can be seen that X is the square root of N, so rearranging the expression for X on the left hand side it becomes:

$$X = N / X \qquad (1)$$

In other words the square root of a number is the number divided by its square root.

Notice that the expression is a division, so can we use a procedure similar to long hand division to find square roots? We shall find out. First though, let's examine how a number N can be expanded into component parts, as follows:

$$N = A_n \times 10^n + A_{n-1} \times 10^{n-1} + A_{n-2} \times 10^{n-2} + \ldots + A_1 \times 10^0 \qquad (2)$$

This is easy, it is simply the digits of the number multiplied by their respective powers of ten. Similarly N can be written as:

$$N = A_n \times 10^{2n} + A_{n-1} \times 10^{2(n-1)} + A_{n-2} \times 10^{2(n-2)} + \ldots + A_1 \times 10^0 \qquad (3)$$

Don't worry if you do not understand these expressions, it is just a mathematical way of representing a series. An example will make it clear:

$$9604 = 96 \times 10^2 + 04 \times 10^0 \qquad (4)$$

This time the powers of ten go up by two for each term, so there must be two digits to each term. The expression also contains the same number of terms as there are digits in the root of N. So if we can evaluate the root of each term we will then have the root of N.

Very few people could calculate the square root of a large number in their head, but most could do it if the number were an integer in the range of 0 to 99 and the answer were a single integer digit plus a remainder.

For example 69 would yield a square root of 8 since this is the largest integer which when squared gives a result of 69 or less, the remainder being $69 - (8 \times 8)$ which is 5.

PRACTICAL THEORY

Sounds too simple? Well, yes, of course it is. Unfortunately we cannot simply root each term because lower order terms contain portions of the higher terms which must be accounted for. To find a method of rooting each term, as an example we will square the number 27, expanding the long multiplication:

```
  27                 (5)
 ×27
 ---
  49    (7 × 7)
 140    (20 × 7)
 140    (7 × 20)
 400    (20 × 20)
 ---
 729
```

Now we work backwards to find the square root of 729 (which we know to be 27). Using the format of the expression in (3), but ignoring the powers of ten, split the number into digit pairs:

(0)7 29

The first term is (0) 7 and the integer root of 7 is 2 with a remainder of 3, and 2 is the first digit of the root, which is correct. Now, as is done in long hand division, append the next term (29) to the remainder:

329

The appended remainder is 329. Now we need to find the next root digit from this number, which is slightly more complex than the first. Taking the square root of 329 is clearly not going to give the correct answer. As previously stated, this is because it contains a portion of the higher terms which must be taken into account. If you add the first three terms of the multiplication in (5) you get:

$$49 + 140 + 140 = 329$$

or, expanding further:

$$7 \times 7 + 20 \times 7 + 7 \times 20 = 329 \qquad (6)$$

Now this looks suspiciously like the appended remainder, and in fact it is. The appended remainder is the sum of the first three terms in (5). What is not apparent from the above expression of (6) is that the terms two and three contain the previously found root (in this case, 2), so the expression of (6) can be re-written as:

$$7 \times 7 + 2 \times 10 \times 7 + 7 \times 2 \times 10 = 329$$

This can be expressed as:

digit × digit + current root × 10 × digit + digit × current root × 10

Which is reduced and re-arranged to:

(20 × current root + digit) × digit (7)

where current root is the square root found so far from higher order terms, and digit is the root digit to be found. Putting in the figures (20 × 2 + 7) × 7 = 329. The second digit of the root is therefore 7. Q.E.D.

THEORY INTO PRACTICE

Now, to put theory into practice, we will attempt to find the square root of 9604. The first two digits are 96, the square root of 96 is then 9 plus a remainder of 15. Thus the first digit of the answer is 9.

To carry the calculations further, the next two digits are appended to the remainder, therefore the new (appended) remainder becomes 1504. Using the expression of (7) a final expression for calculating the digits is:

(20 × current root + digit) × digit <= remainder

Putting numbers into the expression: (20 × 9 + 8) × 8 = 1504. Therefore the next root digit is 8, which is the largest integer that will fit into the expression. The square root of the whole number is 98. To summarize so far:

9604	
96	first two digits
–81	subtract 9 × 9
	current root = 9
15	remainder
1504	append next two digits (04)
–1504	subtract (20 × 9 + 8) × 8
	current root = 98
0	remainder

∴ the square root 9604 = 98

SQUARE ROOTS OF NON-INTEGERS

This example has been carefully chosen to avoid any complexities that may be encountered, but we have the basis of a method for calculating square roots. The method is not limited to integer numbers and to illustrate this we will now find the square root of 31·5 to an accuracy of four digits.

Splitting the number into digit pairs we get 31 and ·5, the 5 is not a digit pair so the number needs to be re-written as 31 · 50. Also, there are not enough digit pairs for the required number of calculations, so again re-write the number as 31 · 50 00 00.

The more observant reader may have spotted that the number of digit pairs needed is the same as the number of digits required in the root, in this case four. So the process becomes:

31 · 50 00 00	
–25	subtract 5 × 5
	current root = 5
6	remainder

At this point the decimal point is inserted into the answer, just as you would do in long-hand division. However, for purposes of calculating the remaining digits the decimal point (for now) must be ignored:

650	append next digit pair (50)
–636	using the formula
	subtract (20 × 5 + 6) × 6
	current root = 56
14	remainder
1400	append next digit pair (00)
–1121	subtract (20 × 56 + 1) × 1
	current root = 561
279	remainder
27900	append next digit pair (00)
–22444	subtract (20 × 561 + 2) × 2
	current root = 5612
5456	remainder

We could go on, but the required accuracy of four digits is in current root. All that remains to do is put in the decimal point at the appropriate place. The final result is 5·612.

Note there is a remainder at the end, this indicates there are more digits in the root. i.e. the result is a truncation of its true value. A more accurate value for this example would be 5·612486080, indeed the calculations could be repeated to obtain a result of this accuracy if so desired. If the remainder were zero then the result would be exact and any successive digits found would all be zero.

SQUARE ROOT ALGORITHM

From the above description we can now write a procedure to find the square root of a number.

Step 1. Starting at the decimal point, split the number into digit pairs, both to the left and right of the decimal point. If needed, append the number with 00 digit pairs.

Step 2. Find the integer square root of the most significant digit pair. This is the first digit of the root.

Step 3. Subtract the square of the digit from the digit pair to give the remainder.

Step 4. Append the next digit pair to the remainder to give a new remainder.

Step 5. Find the largest integer digit that satisfies the expression:

(20 × current root + digit) × digit <= remainder

This is the next digit of the root.

Step 6. Subtract the left side of the expression from the remainder.

Step 7. Go to Step 4.

LISTING 1

```
; Find the square root of a 24-bit number in NUMH, NUMM, NUML
; 12-bit result in ROOTH, ROOTL
; Temporary variables: REMDRH, REMDRL, COUNT
; 40 instructions
; Execution time: about 326-387 cycles.

SQRT    CLRF    ROOTL       ; Clear result
        CLRF    ROOTH
        CLRF    REMDRL      ; Clear work area
        CLRF    REMDRH
        MOVLW   0x0C        ; Loop counter
        MOVWF   COUNT
SQRLP   RLF     NUML        ; Shift two bits of
        RLF     NUMM        ; NUM into work
        RLF     NUMH        ; area
        RLF     REMDRL
        RLF     REMDRH
        RLF     NUML
        RLF     NUMM
        RLF     NUMH
        RLF     REMDRL
        RLF     REMDRH
        BCF     ROOTL,0     ; Clear prev test bit
        SETC                ; Insert new test bit
        RLF     ROOTL
        RLF     ROOTH
        MOVFW   ROOTH       ; Compare root
        SUBWF   REMDRH,W    ; and remainder
        SKPZ
        GOTO    TSTGT
        MOVFW   ROOTL
        SUBWF   REMDRL,W
TSTGT   SKPC
        GOTO    REMLT
        MOVFW   ROOTL       ; Subtract root
        SUBWF   REMDRL      ; from remainder
        SKPC
        DECF    REMDRH
        MOVFW   ROOTH
        SUBWF   REMDRH
        BSF     ROOTL,1     ; Set root bit
REMLT   DECFSZ  COUNT
        GOTO    SQRLP       ; Next root bit
        CLRC
        RRF     ROOTH       ; Adjust root
        RRF     ROOTL
        RETURN
```

BINARY SQUARE ROOTS

As previously stated the algorithm is not restricted to integers, but for the binary implementation that follows only integer values will be considered. As usual with maths, a binary implementation is easier than the decimal equivalent, this is mostly due to binary digits having only two possible values, 0 or 1.

The value of 20 in the previous decimal expression is derived from two times the numeric base of 10. Working in base 2 requires a new expression, which is two times the numeric base of 2. Therefore the new expression is:

$$(4 \times \text{current root} + \text{digit}) \times \text{digit} <= \text{remainder}.$$

In the decimal example you probably solved the expression by guessing at the root digit and substituting it into the expression. Because binary digits have only two possible values the expression reduces to:

$$(4 \times \text{current root} + 0) \times 0 = 0$$

or

$$(4 \times \text{current root} + 1) \times 1$$
$$= 4 \times \text{current root} + 1$$

This leads to an easy method of finding the root digit by comparing the appended remainder with 4 × current root + 1. If the remainder is the greater value or they are equal then the root digit is 1, otherwise it is 0.

Previously, the first digit pair was treated differently to the rest in that the expression was not used to find the first root digit. In order to make the procedure more consistent by treating all digit pairs equally, it is easy to show that the expression can be applied to the first digit pair. If current root is initially set to zero then the expression for the first digit pair reduces to digit × digit <= remainder, which is exactly how the first root digit was found.

Using the above information we will now find the square root of binary 01010001:

Set current root = 0, Set remainder = 0.

01 01 00 01	split number into digit pairs
001	append first digit pair to remainder
001	multiply current root (0) by 4 and add 1
0	both are equal so subtract
	current root = 1
001	append second digit pair to remainder
101	multiply current root (1) by 4 and add 1
	remainder is less than, don't subtract
	current root = 10
00100	append third digit pair to remainder
1001	multiply current root (10) by 4 and add 1
	remainder is less than, don't subtract
	current root = 100
0010001	append forth digit pair to remainder
10001	multiply current root (100) by 4 and add 1
	both are equal, subtract
	current root = 1001
0	remainder
	square root = 1001

PIC SQUARE ROOT ROUTINE

The author's implementation of the square root algorithm for the PIC, written in MPASM dialect, is shown in Listing 1. This listing is on the *EPE* ftp site. The easiest access route is via the main *EPE* web page at **www.epemag.wimborne.co.uk**, click on *ftp site (downloads)* then take the path PUB – PICS – PICtricks.

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RF Data Spike Avoider – Spike Free

THE TEMPERATURE in the writer's greenhouse is transmitted to the house as a 13-bit data stream over a 418MHz radio link. Logic 0s and 1s are sent as short and long pulses, and a 14th bit provides a High/Low alarm. The temperature is transmitted every second.

It was found that the system worked well for a while but then intermittent interference caused erratic reception. It was noticed that the interference usually lasted for only a few seconds and consisted of a large number of spikes. Re-positioning the small Tx/Rx helical aerials, and adding some screening, helped but did not cure the problem.

The solution, which has proved generally effective, is to count the number of received pulses each second, and if the count is greater than the expected number of signal pulses in one second (i.e. 14) then the temperature display is prevented from changing for a few seconds – until the interference ceases.

The RF Data circuit diagram is shown in Fig. 1 and uses standard 4000 CMOS devices. The Schmitt trigger IC1a tidies up the signal from the receiver and IC1b inverts it, triggering the monostable IC2. This removes the reset on decade counters IC3 and IC4 for a period of 800ms.

If a count of more than 14 is reached then the output of the AND gate IC5 goes high and triggers IC6, the second monostable, for about 2·5 seconds, inhibiting the display change. If a further burst of interference is received, the cycle repeats. Holding the display static for a few seconds does not matter as the temperature changes only slowly in the greenhouse.

A possible refinement would be to inhibit the display change circuit if the pulse count is less than 14 or greater than 15 but this may not be worthwhile as the interference usually contains many more than 14 pulses.

Stephen Stopford,
London

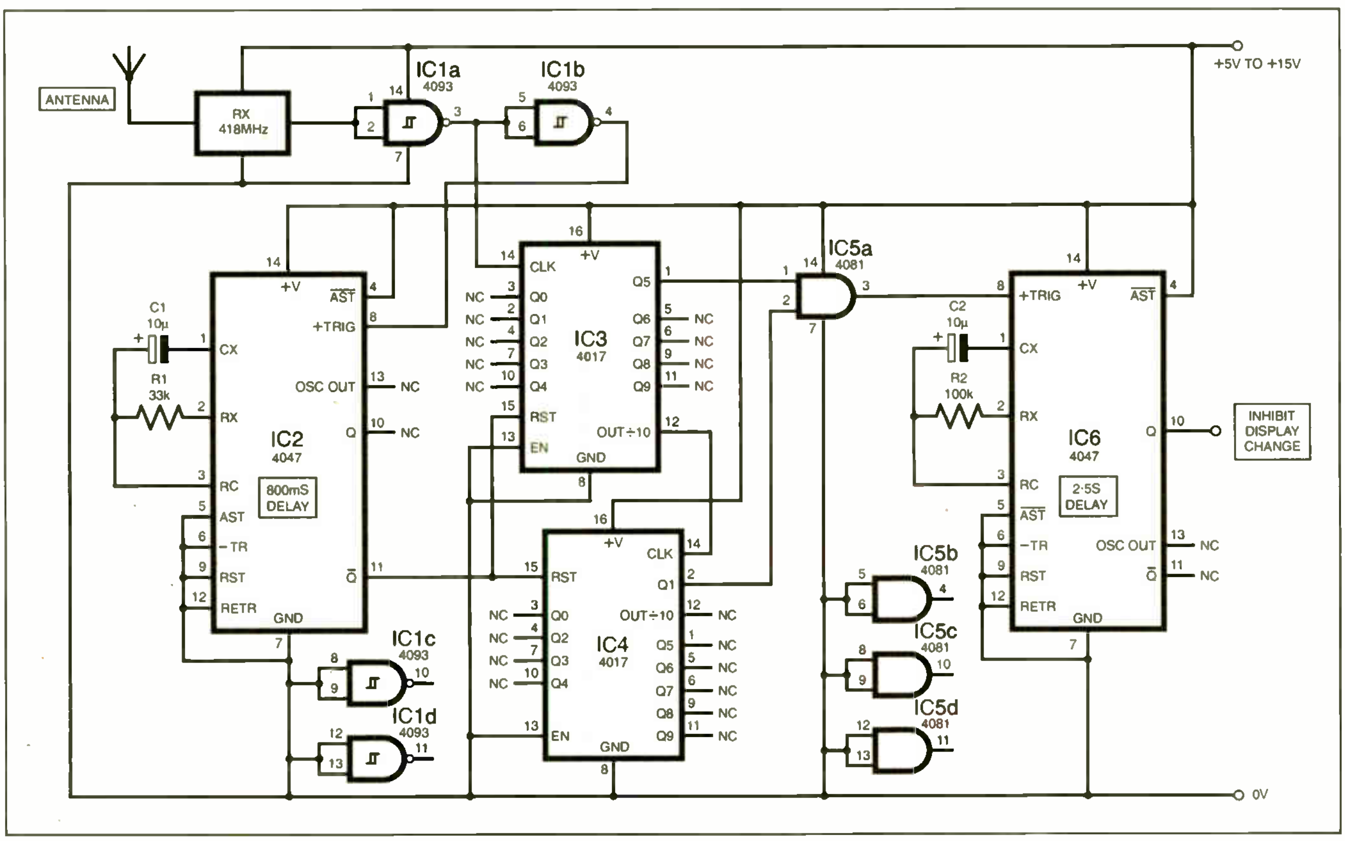
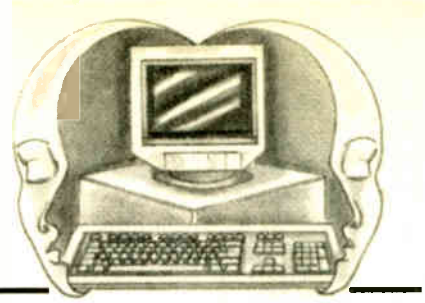


Fig. Circuit diagram for the RF Data Spike Avoider.

INTERFACE



Robert Penfold

USING MSCOMM TO RECEIVE SERIAL DATA

THE previous *Interface* article covered the subject of using Visual BASIC with the built-in MSCOMM ActiveX control to send data from the serial port. In this article using MSCOMM to receive serial data will be considered.

It is only fair to point out again that MSCOMM is not included with all versions of Visual BASIC. You need a reasonably up-to-date version and at least the Professional edition. Also, it is not included with the free versions such as Visual 5.0 BASIC CCE.

Instant Access

Bear in mind that the MSCOMM ActiveX file (MSComm32.ocx) must be accessible to compiled programs that use this method of accessing the serial ports. You will therefore need to include this file with any MSCOMM programs that you supply to other people. However, no third party add-ons such as Inpout32.dll are required, and programs that use MSCOMM should be fully compatible with all 32-bit versions of Windows, including Windows XP and its predecessors.

Remember that it is necessary to load MSCOMM into Visual BASIC in order to utilise its facilities. Select Components from the Project menu and tick the checkbox for the MSCOMM component. It will be called something like Microsoft Com Control plus a version number. You do not have a suitable version of Visual BASIC if this component is not listed.

Assuming it is present, operate the Apply and Close buttons, and an icon for the new component will then appear in the Toolbox. This component can be loaded from the Toolbox to the form in the normal way. It will not be visible when the program is run, so it can be placed in any vacant space on the form.

On Trial

In order to try out MSCOMM as a means of receiving data, place a command button on the form and label it "Exit". Then add a label component and set it to use a fairly large font so that it will make a good digital readout. It will be used to display the received 8-bit values in decimal form. You should then have something like Fig.1.

These three subroutines are then added to the command button, form, and MSCOMM respectively.

```
Private Sub Command1_Click()
MSComm1.PortOpen = False
End
End Sub

Private Sub Form_Load()
Dim SerByt As String
MSComm1.RThreshold = 1
MSComm1.InputLen = 1
MSComm1.Settings = "19200,N,8,1"
MSComm1.CommPort = 1
MSComm1.InputMode =
  comInputModeText
MSComm1.PortOpen = True
End Sub

Private Sub MSComm1_OnComm()
If MSComm1.CommEvent = 2 Then
  SerByt = MSComm1.Input
Label1.Caption = Asc(SerByt)
End If
End Sub
```

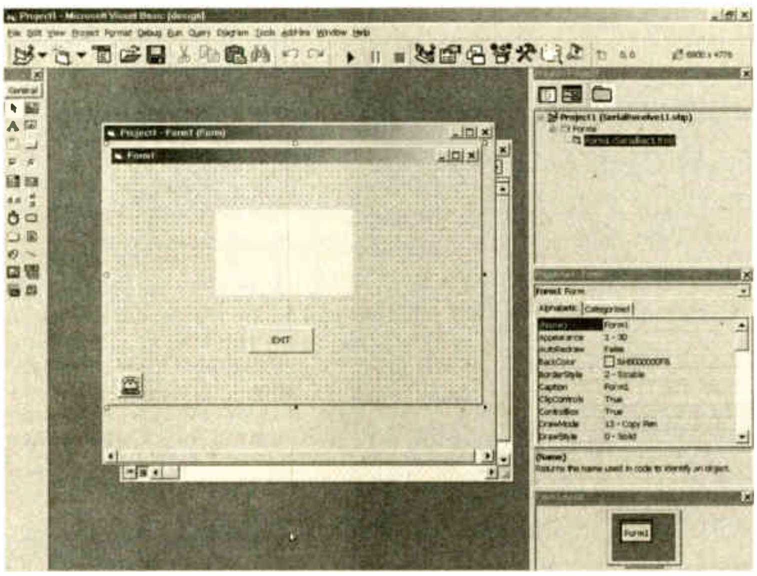


Fig.1. The completed form, ready for the program to be added.

The subroutine for the command button simply ends communication with the serial port and closes the program. A string variable (SerByt) is defined in the first line of the subroutine for the form. This is used to store received data. The remaining instructions in this subroutine open communications with the serial port and set the appropriate parameters.

As explained in the previous *Interface* article, the serial port can be configured by selecting the MSCOMM icon on the form and using the Properties window. However, the parameters can be set via the program, and having a standard setup routine assigned to the form is perhaps a neater way of handling things.

The functions of some instructions in this routine are fairly obvious, and they select the required serial port, enable communications with it, and set the word format, etc. One of the less obvious parameters is the InputMode. There are two choices, which are input modes 0 (binary) and 1 (text).

On the face of it, the binary mode is the most appropriate for interfacing projects, but in practice it seems to be necessary to use the text mode. Like sending data via MSCOMM, this necessitates the use of string conversions, but it does actually work.

Eventing

There are two basic methods of receiving serial data, which are polling and the event driven method. Polling just means checking the port at regular and frequent intervals to see if any fresh data is available. This method works well enough but is not very efficient.

MSCOMM makes it easy to use the event driven method where an OnComm() event is generated every time X bytes of data have been received. The program then responds to this event by reading the new bytes of data and processing them. The program does not do any direct monitoring of the serial port.

The RThreshold parameter controls the number of bytes that are needed to trigger an OnComm() event. For this initial example, the bytes are read one at a time, and RThreshold accordingly has a value of 1.

The InputLen setting determines the number of bytes that will be read from the receiver buffer each time the program fetches serial data. This will normally have the same value as RThresold so that an OnComm() event is generated after X bytes have been received, and those X bytes are then read by the program. In this case the program is operating on a byte-by-byte basis, so RThreshold and InputLen both have a value of 1.

Over Two You

It is the subroutine for the MSCOMM component that actually reads the serial port and prints the returned value on the label. A form of IF...THEN loop waits for CommEvent to return a value of 2.

There are seven types of events numbered from one to seven, and the following are the events that trigger them:

Number	Event
1	Send
2	Receive
3	Change in the CTS line
4	Change in the DSR line
5	Change in the CD line
6	Ring detect
7	End of file

In this case the appropriate number of bytes being received must trigger the routine, and hence a value of 2 is used. When a CommEvent occurs and it has this value, the data from the serial port is stored in the string variable called SerByt.

When interfacing to projects it is normally an exchange of numeric data rather than strings that is required, but the raw ASCII values are easily extracted from string variables using the Asc() function.

This function is used in the line of code that writes the received values to the label, and it is therefore eight-bit values from 0 to 255 rather than string characters that are displayed.

This is the opposite process to the one used in the transmitter program described previously. A double conversion process such as this is clearly a cumbersome way of sending and receiving data, more direct approaches failed to work at all.

A good way of testing the serial receiver program is to couple the serial ports of two PCs. One can be used with the transmission program described in the previous *Interface* article, and the other can be used with the receiver program. Only two connections are required between the two serial ports, and these are shown in Fig.2.

Make sure that the lead is connected to the two PCs the right way around. With both programs running, any value sent from the transmitting PC should almost instantly appear on the receiving one. Screen shot Fig.3 shows the program in action.

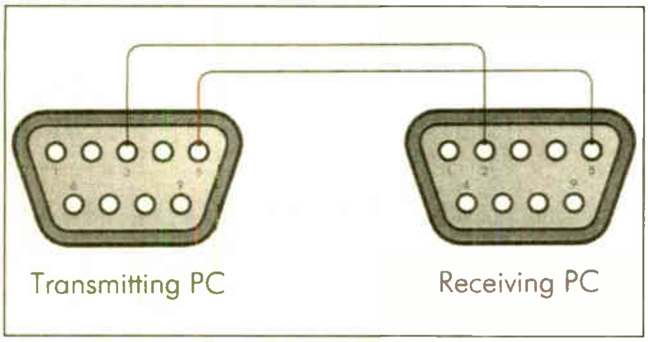


Fig.2. Linking the serial ports of two PCs. Make sure the leads are connected to the PCs the right way round.

Multiple Bytes

Reading single bytes is sufficient for many practical applications, but it is sometimes necessary to read groups of bytes. A serial interface can only handle eight bits at a time, so 16-bit words have to be sent as two bytes and then merged into a 16-bit value again by the PC's software.

With something like a temperature interface that has five sensors, it would probably be more convenient to send and read the data in groups of five bytes. The program is easily modified to handle groups of bytes, and it is just a matter of adding four more label components and using the following program:

```
Private Sub Command1_Click()
MSComm1.PortOpen = False
End
End Sub
Private Sub Form_Load()
Dim SerByts As String
MSComm1.RThreshold = 5
MSComm1.InputLen = 5
MSComm1.Settings = "19200,N,8,1"
MSComm1.CommPort = 1
MSComm1.InputMode =
  comInputModeText
MSComm1.PortOpen = True
End Sub
```

```
Private Sub MSComm1_OnComm()
If MSComm1.CommEvent = 2 Then
  SerByts = MSComm1.Input
Label1(0).Caption = Asc(Mid$(SerByts,
  1, 1))
Label1(1).Caption = Asc(Mid$(SerByts,
  2, 1))
Label1(2).Caption = Asc(Mid$(SerByts,
  3, 1))
Label1(3).Caption = Asc(Mid$(SerByts,
  4, 1))
Label1(4).Caption = Asc(Mid$(SerByts,
  5, 1))
End If
End Sub
```

This program operates in fundamentally the same way as the original, but RThreshold and InputLen have been given a value of five so that data is read in the form of five-byte groups. When five bytes have been received they are stored in the variable called SerByts as a five-character string. As before, the Asc() function is used to convert the string characters into corresponding eight-bit numeric values.

Fig.3. The program is correctly receiving and displaying bytes of data.

However, there is the added complication that each character must be extracted from the group of five, and this is achieved using the Mid$ function. The first number in this function selects the position of the character, and the second number determines the number of characters that are processed.

Thus, values of three and one select just the third byte in the string. Even with large groups of bytes it is easy to select any desired byte using this method.

The program in operation is shown in Fig.4. The transmitting program has started at a value of 234, and the value has then been incremented five times so that values from 235 to 239 have been transmitted. These have been displayed correctly on the five label components.

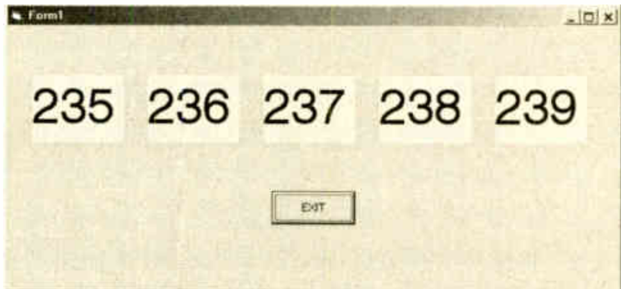


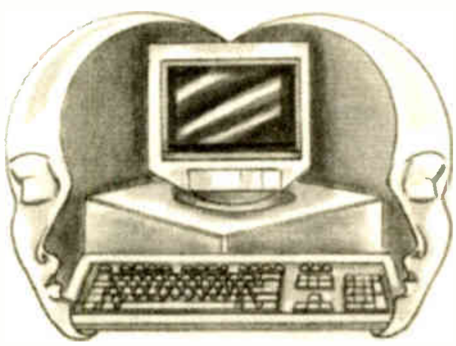
Fig.4. A group of five bytes have been displayed correctly. The transmitting program has started at 234 and then incremented five times so that values of 235 to 239 have been transmitted.

Finally

While MSCOMM has clearly not been designed with project interfacing in mind, it can be adapted to this application quite easily. Sending and receiving data admittedly requires cumbersome conversions, but these do not really complicate the software very much.

The advantage of using MSCOMM rather than direct control of the serial ports is that it avoids the need for any third party add-ons, and it ensures compatibility with any 32-bit version of Windows. Programs that use MSCOMM should therefore be compatible with any Windows operating system from Windows 95 through to Windows XP.

Remember that directly accessing the hardware ensures that programs are not compatible with Windows NT4, 2000, or XP. Hopefully, MSCOMM will also give compatibility with future versions of the Windows operating system.



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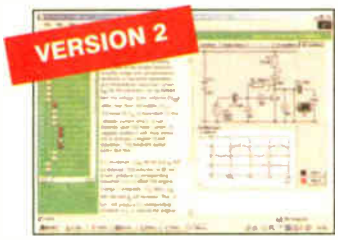

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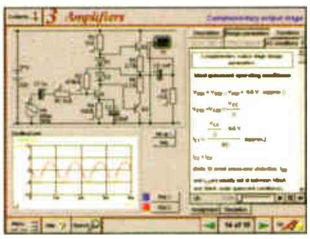

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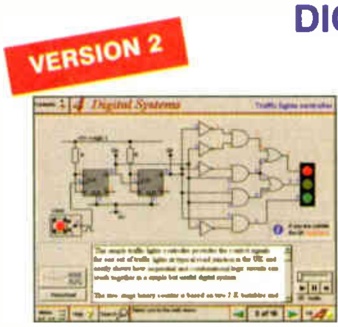

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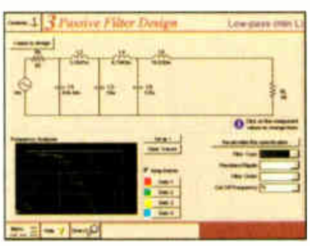
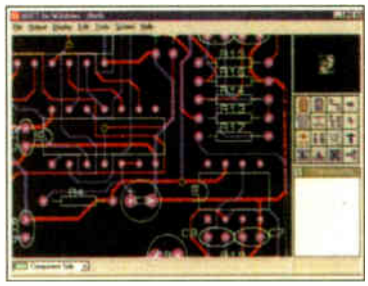


Filter synthesis

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

ELECTRONICS CAD PACK



PCB Layout

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

NEW

ROBOTICS & MECHATRONICS

Case study of the Milford Instruments Spider

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

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

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

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

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

PICmicro TUTORIALS AND PROGRAMMING

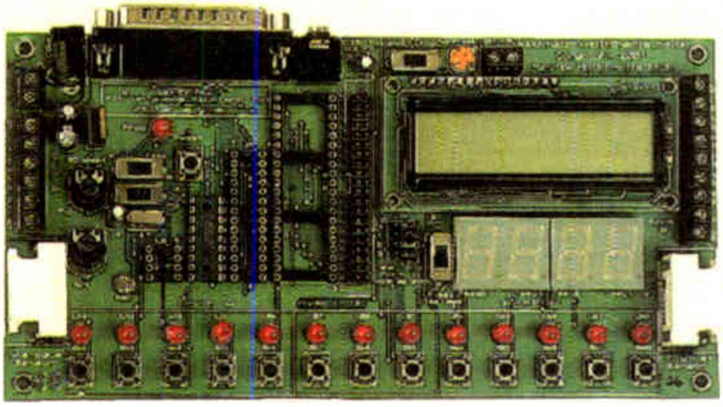
HARDWARE

VERSION 2 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

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

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



£145 including VAT and postage

12V 500mA plug-top PSU (UK plug) £7

25-way 'D' type connecting cable £5

SOFTWARE

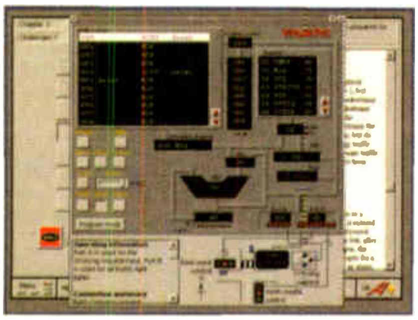
Suitable for use with the Development Board shown above.

ASSEMBLY FOR PICmicro V2

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V2.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes. The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro 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.



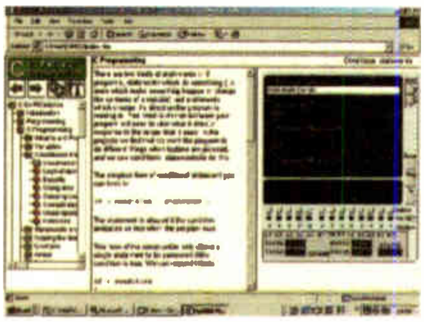
Virtual PICmicro

'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.

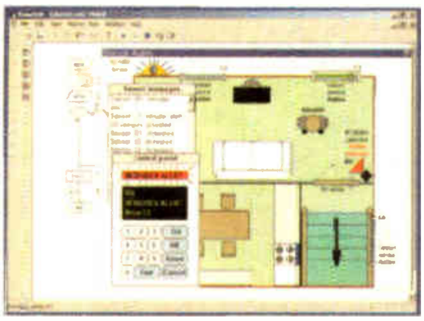
FLOWCODE FOR PICmicro

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:

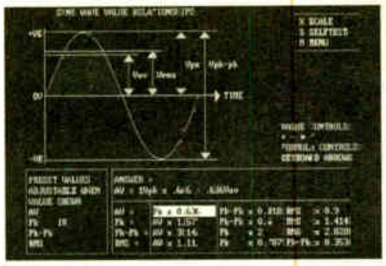
(Order form on next page)

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

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

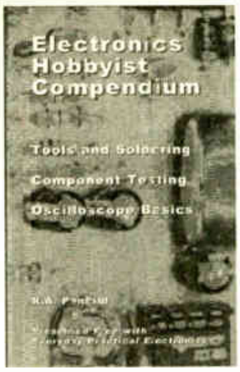
TEACH-IN 2000 – LEARN ELECTRONICS WITH EPE

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



Sine wave relationship values

FREE BOOK WITH TEACH-IN 2000 CD-ROM



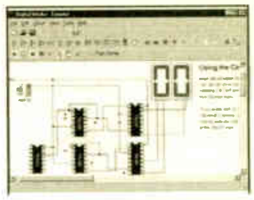
Each part has an associated practical section and the series includes a simple PC interface so you can use your PC as a basic oscilloscope with the various circuits.

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

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

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

DIGITAL WORKS 3.0



Counter project

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

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

ELECTRONICS IN CONTROL

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

Single User £29 inc. VAT. Multiple User £39 plus VAT
Student copies (available only with a multiple user copy) £6 plus VAT
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MODULAR CIRCUIT DESIGN

VERSION 3

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

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

Single User £19.95 inc. VAT. Multiple User £34 *plus* VAT
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ELECTRONIC COMPONENTS PHOTOS

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

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

Price £19.95 inc. VAT

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

CD-ROM ORDER FORM

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- ☐ **Assembler for PICmicro**
- ☐ **'C' for PICmicro**
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Note: The software on each version is the same, only the licence for use varies.

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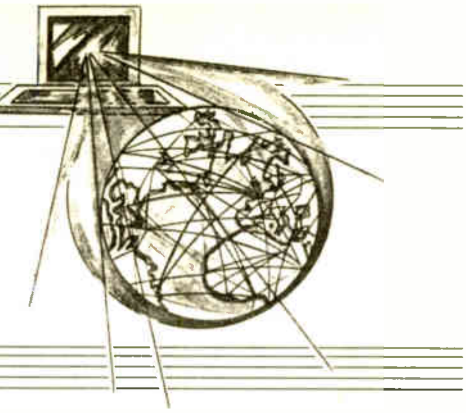
NET WORK

ALAN WINSTANLEY



'Popular' Viruses

JUST at the moment the virus scene appears to be more active than ever if my germ-laden incoming email is anything to go by, and a couple of particular viruses seem to be causing more than the usual amount of trouble. How up to date is your anti-virus software?

Many viruses are merely primitive attempts to dupe the recipient into opening a file attachment. After a while some "popular" viruses are easily recognisable and can quickly be deleted. Usually I would recommend file attachments should *never* be opened unless you recognise the sender *and* you have scanned the file for viruses. However, bear in mind that the sender's name can easily be forged: I was recently the recipient of a virus that actually appeared to have been mailed out by myself! Since I maintain a rigorous anti-virus regime and I do not use the Windows Address Book, it was impossible for me to have transmitted that particular virus. If you do receive a virus from someone then, depending on the virus in question, remember that the sender's address may well have been falsified, so you should not be tempted to unleash a torrent of abuse against the hapless sender.

Often it is a mixture of lack of experience and poor computer hygiene that results in a virus or worm infiltrating a computer system. Every Internet user ought to shoulder some responsibility for ensuring that they do not propagate any viruses, and the only way to do that is to maintain up to date anti-virus software. Some ISP's (including the one used by *EPE*) also use hardware firewalls to filter out much of the dubious E-mail, which helps to conserve their own network resources as well.

An increasing number of viruses spread themselves by using the Windows Address Book. The virus might have its own built-in SMTP mailer which it uses to replicate itself and mail itself out again, often without the knowledge of the system owner. This problem is likely to worsen as the uptake of broadband Internet access goes up and background noise rises as a consequence.

False Alarms

One of the more sinister variants of virus to recently come along purports to be from "Microsoft Security Corporation Center". The email attaches a file which is said to be "the latest version of security update, the '15 Jun 2002 Cumulative Patch' update which eliminates all known security vulnerabilities affecting Internet Explorer . . . and is discussed in Microsoft Security Bulletin MS02-005" it says. The diatribe implores you to run an attached file number *q216309.exe* – a filename that an experienced computer user would recognise as a typical Microsoft Knowledge Base type of filename.

"You don't need to do anything after installing this item" says the viral email – except disinfect the system that you just infected with the W32.Gibe@mm virus. The audacity and mentality of the perpetrators of these viruses defies belief.

Far more annoying has been the major outbreak of **W32.Klez.H@mm** which started to appear in March 2002 and is still going strong, making it one of the most troublesome viruses ever. However, it is thought that the increasingly widespread use of anti-virus tools has helped to limit the damage. Klez is another type that mails itself out over the local area network, or over the Internet using the Windows Address Book or ICQ database. It will also happily send out a random file contained on the local system, which may or may not be confidential. I have received over 80 of these files, which Norton Anti Virus 2002 (buy online from **www.symantec.com**) has intercepted and quarantined automatically.

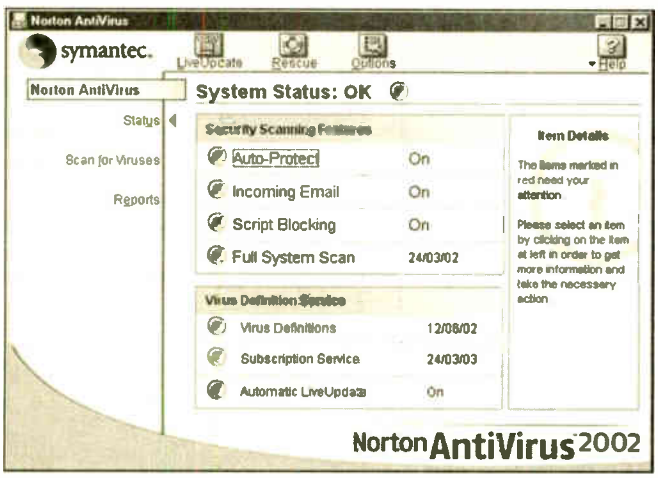
When all the signs are there that a new virus is breaking out and the traffic is becoming overwhelming, it makes sense to interrogate (poll) your mailbox and delete any suspicious mail directly from the server (always a satisfying job), or use a web-based mail system instead (a topic which will be covered in a future article). Norton Live Update also keeps itself topped up with the latest anti-virus signatures, which it downloads periodically.

Anti Virus Free for Some

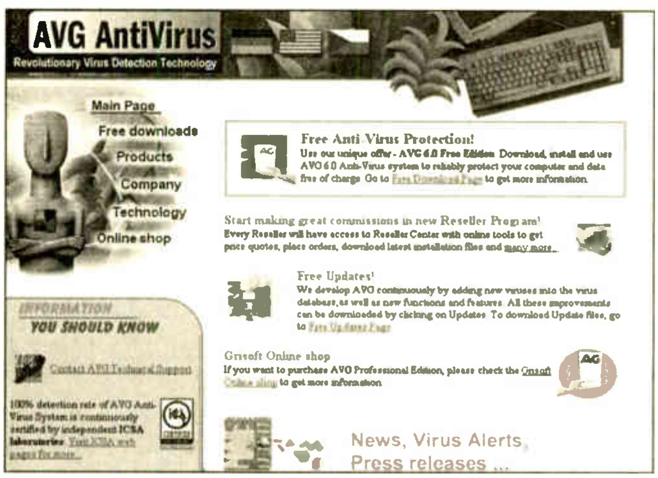
If you don't want to buy a software licence for your computer, then one anti-virus program that continues to be popular is **AVG 6.0 Free Edition** from **www.grisoft.com**. Grisoft is the US-based marketing front for a company based in the Czech Republic, and it has developed DOS and Windows AV software since 1990. Due to an unfathomable licensing agreement, it is stated that UK users can download a freeware version, otherwise you will probably qualify for just a 30 day trial. Several *Net Work* readers have emailed to say how happy they are with the product (especially if it's free). It has all the usual AV features including auto updates and a scheduler, and it will tack a gratifying little "certified virus free" text onto your outgoing emails. A paid-for professional edition of AVG offers more features.

Earlier this year I tried to download this software from the Grisoft web site onto my Windows ME laptop but failed because the server was too busy. Later on I loaded the freeware version from a cover CD, but it was not possible to download the latest virus update because the server was still inaccessible. I felt this to be quite a poor performance.

Having tried again today, I am pleased to say I successfully downloaded AVG 6.0 from the web site, (a 5MB file), helped by a superb piece of freeware that I will be describing in next month's *Net Work*. You can email me at **alan@epemag.demon.co.uk**.



Norton AntiVirus 2002 system.



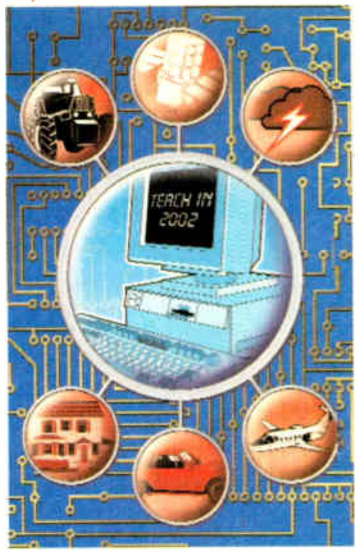
The popular AVG 6.0 AntiVirus system.

EPE Tutorial Series

TEACH-IN 2002

Part Ten – Advanced Sensors and Radio Telemetry Systems

IAN BELL AND DAVE CHESMORE



Making Sense of the Real World: Electronics to Measure the Environment

In this the final part of *Teach-In 2002* we look at some aspects of the future of sensing. As with all electronics it is the continuing miniaturisation and more extensive networking which will play a large role in the developments we will see.

Bioscience has been described as being the key technological area of the 21st century, just as electronics and computing were in the 20th. Whether this is true or not we will certainly see great advances in biologically orientated electronic sensing, including the detection and analysis of DNA molecules.

Wireless networking of sensors, particularly of arrays of low-power sensor elements will provide further interesting developments.

This month we will also be looking at using wireless techniques to convey sensor data from source to destination, but for a single "node" rather than an array. The *Lab Work* will provide you with the opportunity of building a radio link for any of the sensors we have discussed in this series.

THE FUTURE OF SENSORS

The future of sensors is small, smart, low power and networked. Silicon electronic sensors for light and temperature are well established and easily integrated with electronics, but until about ten years ago many other quantities, such as acceleration, required separate bulky sensors.

MEMS (Micro Electro Mechanical Systems) are overcoming this problem and there is currently a lot of research and commercial development in this area. As we mentioned last month, the electronics integrated with a sensor (or sensors) does not have to be just a couple of transistors; you can have amplifiers, filters, digital signal processors, microcontrollers, memory and optical or radio communications systems.

So a sensor chip can be very "smart" performing complex signal processing to extract data from the sensors, compensating for non-ideal sensor behaviour, and adapting its activities to changing conditions or external instructions. It can then send this data over a communications network to the user who needs the data.

In Fig.10.1 are shown the three levels of integration from zero integration through integrated sensor and signal conditioning to full integration with embedded control – so-called "smart" or "intelligent" sensors.

An example of these developments is the Smart Dust project at the University of Berkley which aims to produce a complete sensor/communication system that can be integrated into a cubic millimetre package. Such a device would include a thick film battery, solar cell, power capacitor, signal processing (analogue and DSP), control electronics (microcontroller), MEMS sensors, and optical communications, including a laser diode with a MEMS mirror to provide beam steering.

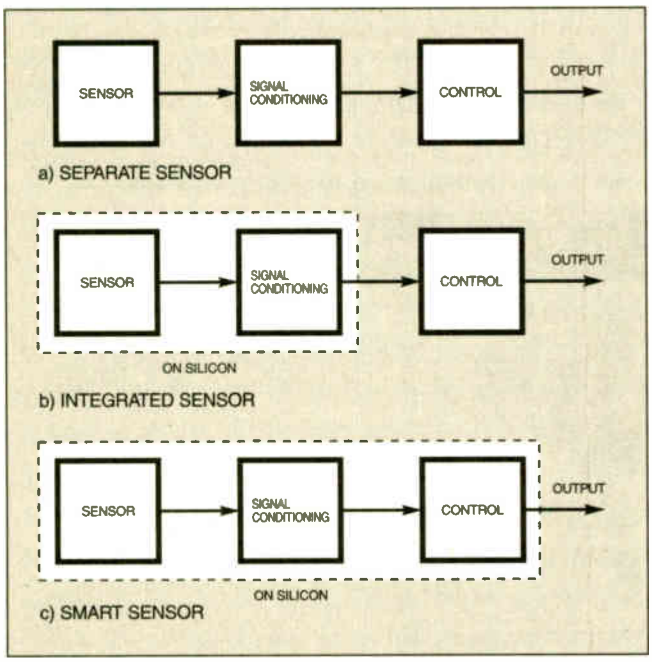


Fig.10.1. Levels of integration.

MEMS TECHNOLOGY

In general terms MEMS use the technology developed for integrated circuit fabrication to create tiny moving parts (hence the *Micro Mechanical* part of the name). In practice the fabrication of MEMS may require some special processing due to the potentially conflicting requirements for creating high quality circuit components and mechanical parts (e.g. in the temperature used during fabrication), but fundamentally the procedures are those of standard integrated circuit fabrication and mechanical parts can be created on the same silicon as electronic circuits (hence the *Electro* part of the name).

This means that the mechanical structures can be very closely linked with the controlling and signal processing electronics, to form complete electro-mechanical systems (hence the *Systems* part of the MEMS name).

ACCELERATION SENSORS

One of first commercial applications of MEMS was in acceleration sensors, which can measure or detect tilt, acceleration, shock and vibration, with a key application being in car airbags. Analog Devices produced the first fully-integrated. single chip MEMS-based accelerometers in 1991. A device from the Analog Devices ADX series was used in the *Pocket g-Meter* project in *EPE* July '00.

We discussed acceleration sensing in general in Part 5. Analog Devices' MEMS accelerometers are based on a suspended beam of polysilicon held on a spring-like tether structure (see Fig.10.2). *Polysilicon* is short for polycrystalline silicon – silicon not in single crystal form – which is used for MOS gates, resistors and capacitors in integrated circuits.

The beam is created by depositing the polysilicon on top of an area of "sacrificial" silicon dioxide and then etching away the

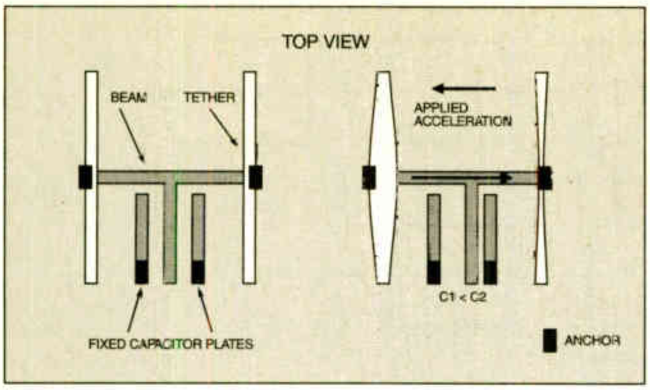


Fig.10.2. MEMS acceleration sensor. From Accelerometer Design and Applications *by James Doscher, Analog Devices (www.analog.com).*

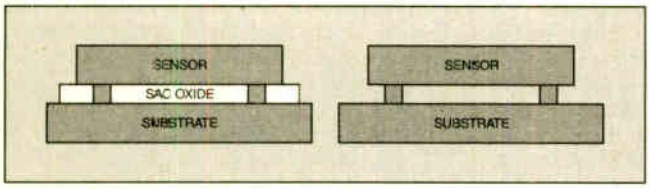


Fig.10.3. Forming a suspended sensor element. Analog Devices (www.analog.com).

oxide to leave the silicon suspended (Fig.10.3). The sensor element is then free to move under acceleration forces. The beam is attached to one half of a capacitor with the other plate fixed so the capacitance changes as the beam moves.

In fact two fixed plates are used to produce a differential capacitance, so that the relative capacitance between the two fixed plates and the moving plate changes under applied acceleration, as shown in Fig.10.2.

As we have seen earlier in this series, the use of differential sensor structures and signals helps to reduce noise and errors. The acceleration sensor i.c. is able to test itself by using additional capacitor plates to produce electrostatic forces on the beam causing it to move.

MEMS GAS SENSING

Micro-mechanical techniques may also be used to make heating elements that can be used in platinum (Pt) catalytic gas sensing. Combustible gases can be detected because the combustion changes the temperature of the Pt catalyst and hence its resistance.

Conventional sensors of this type are large, slow and power hungry, but Sandia National Labs in the US have produced a prototype MEMS gas sensor that overcomes these disadvantages. The sensor uses suspended platinum coated polysilicon filaments. The filaments can be electrically heated to 500°C using only 70mW of power. Recall the amount of power needed to operate the gas sensors in Part 8 (typically 800mW)!

Combustion on the surface of the filament increases its temperature, changing the resistance. A control circuit reduces the voltage across the filament to keep the resistance (and filament temperature) constant. Thus a drop in the control voltage indicates the presence of combustible gas.

MAGNETIC SENSORS

Earlier we saw how the Hall effect was used to build magnetic sensors. Such devices can be included on chip, but other magnetic sensors can be built using MEMS techniques. Micromachined parts can move under the influence of a magnetic field, either like a compass needle (if the movable part is magnetised), or in a similar way to a moving coil meter if a current is passed around a loop on a suspended structure. This movement is then detected by changes in capacitance, in a similar manner to that described for the accelerometer, or the piezoelectric effect can be used to detect the stresses caused by the movement.

CHEMICAL SENSORS

Microscopic mechanical structures have mechanical resonance properties just like larger structures do. For example, a polysilicon cantilever beam will vibrate at a particular frequency just like a tuning fork. If the beam is coated with a substance which will bond very selectively with the ions or molecules of the chemical of interest, we can build a sensor for that chemical. If the chemical is present it will bond to the sensor beam, changing its mass and hence its natural frequency of vibration.

Such a MEMS device also needs a means to create vibration in the sensors (e.g. piezoelectric, electrostatic etc.) and measure its movement to determine the resonate frequency (e.g. capacitive or piezoresistive).

BIOLOGICAL SENSORS

Sensing of the complex chemicals involved in biological processes is a challenging and potentially revolutionary area in which a great deal of research is being conducted. It is possible to build micro-scale chemical reactors to perform the chemical tests needed to detect complex organic molecules such as enzymes. These techniques can even be used to detect particular DNA sequences.

The chemicals (the sample being tested and those used in the test) can be moved around the chip in micromachined channels using microscopic mechanical pumps and valves, or by electrochemical means (e.g. electrochemical pumping). Such systems can perform conventional chemical analysis techniques such as electrophoresis on a very small scale and much faster than conventional apparatus. Measurements are made using electrochemical, fluorescence or optical techniques. These systems are known as Micro Total Analysis Systems (abbreviated to μTAS).

Another advanced biological sensing approach is to use living cells. These are placed near silicon sensors (e.g. on the surface of a chip), which detect the reaction of the cells to the chemicals of interest. Although there are a lot of difficulties in using cells as sensors – they are fragile and have a limited lifetime, they act as amplifiers of chemical signals.

One cell will send messenger molecules to other cells, which in turn react in a similar way. The result can then be detected electronically.

Potential applications of advanced biological sensors include assisting disease diagnosis, automatic control of drug delivery to patients, pollution monitoring, and accurate detection of alcohol and other intoxicating substances in drivers (a super breathalyser!).

WHAT A SMELL!

Another good example of an advanced sensor is the so-called **electronic nose** which has an array of slightly different sensors that are sensitive to odours. The correct name for such sensors is **organoleptic** and they aim to emulate the human olfactory system (the nose).

We know that human noses are very sensitive to smells, which are combinations of chemicals. Some animals, such as moths, are able to detect individual molecules of sex chemicals known as pheromones. Humans also emit pheromones but we are not so sensitive to them.

So far we have looked at single sensors and how their signals are processed. Arrays of sensors are obviously more complex. In the simplest case, each sensor in the array will respond to a different signal so the overall output to a particular signal would be from one sensor only.

In electronic noses, however, each sensor may be sensitive to various chemicals and the output of the array is difficult to interpret. A schematic diagram for an electronic nose is shown in Fig.10.4.

In many cases, we do not try to interpret the output but use artificial intelligence, often in the form of an **artificial neural network** (ANN) to perform complex analysis. An ANN is a simulation of the human brain in that it performs many operations simultaneously in parallel. An ANN is composed of many **neurons** usually in several layers, each neuron being a simple analogue of a real brain cell. Each neuron has many inputs and only one output and

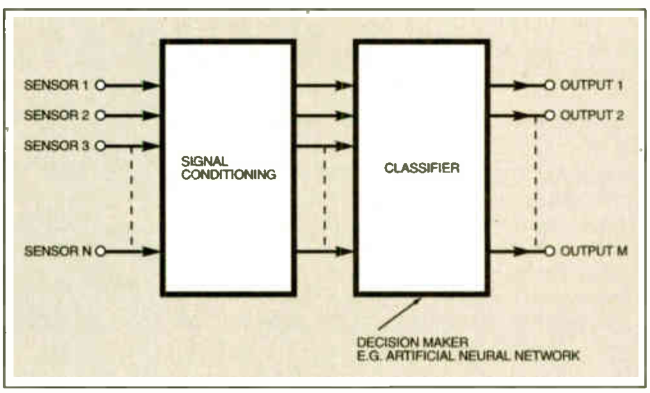


Fig.10.4. Schematic diagram for an electronic nose.

many neurons are connected together in parallel to mimic the massively parallel operation of the human brain.

There are at least 30 different types of neural network! The inputs are connected to the sensor array and the outputs indicate the results. The ANN is trained to recognise particular smells so, for example, smell 1 would be passed over the array and the ANN trained so that output neuron number 1 is high and all others low. The ANN is **trained** with all smells and then tested with unknowns.

What can electronic noses be used for? There appear to be many applications, including:

- Testing the quality of beer and wine
- Detecting and recognising diseases
- Determining how smelly manure is
- Testing food quality – similar to beer
- Recognising individuals by their smell. The film *Alien Resurrection* used breath to identify people as a security measure.

One major problem with current electronic noses is the difficulty in making two devices identical – each sensor built will have slightly different properties.

REMOTE MONITORING VERSUS REMOTE SENSING

In previous parts of this series we discussed the idea of remote sensing where information about an object is obtained without any physical contact. Examples include photography, multispectral sensors for detecting pollution, thermal sensors for temperature and even the human ear!

The difference between remote *sensing* and remote *monitoring* is that the latter uses sensors that are in contact with the object and information is usually transmitted over a radio link to a receiver. The sensor can be placed in a different location, often many kilometres away. In order to achieve this we need a **radio telemetry** system, which consists of several functional parts as indicated in Fig.10.5. These are:

At the transmitter:
- sensor and associated circuitry including a control unit (often a microcontroller)
- modulator
- radio transmitter
- transmitting antenna

At the receiver:
- receiving antenna
- radio receiver
- demodulator and control unit
- output

The modulator is a device that converts the sensor signal into a form suitable for transmission at the appropriate carrier frequency, such as 433MHz.

Why do we need to modulate? Say we have a signal that is varying at 300Hz and we wish to transmit it over 1km. We can't simply add an antenna to the output of the sensor and expect the 300Hz signal to be transmitted for the reason that the antenna would need to be a substantial proportion of the wavelength of the signal. We can calculate this for a 300Hz signal:

Wavelength, frequency and the speed of light are related by $c = f\lambda$ so $\lambda = c / f = 3 \times 10^8 / 300 = 1 \times 10^6$m, which is 1000km! The antenna would need to be at least a quarter of this for a good coupling, i.e. the antenna would be 25 times as long as the transmission distance! We would also need a receiving antenna the same length.

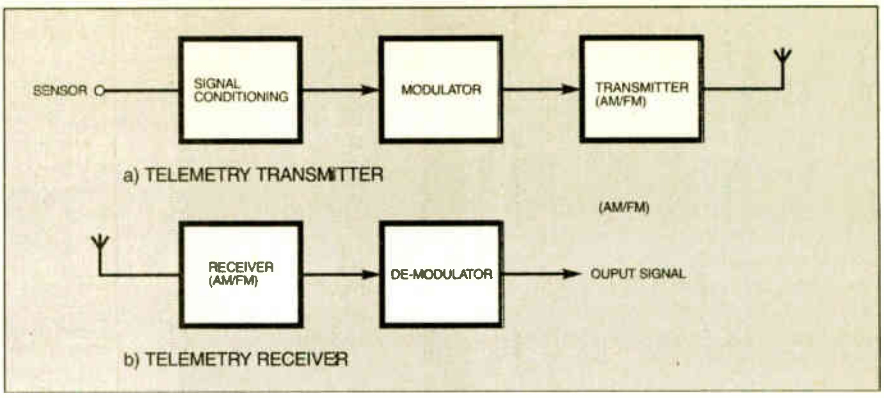


Fig.10.5. Schematic diagram of a telemetry system.

We therefore need to change the frequency from 300Hz to some higher frequency that will give us a small antenna and still achieve good coupling. For example, we could choose one of the licence exempt frequencies – 433MHz will give a 1/4 wave antenna length of 17cm.

We need to preserve the 300Hz signal so we use a modulator that varies the 433MHz **carrier** wave in accordance with the amplitude of the modulating signal, our 300Hz signal. This can be achieved in a number of ways – amplitude modulation (AM), frequency modulation (FM) and more complex combined amplitude and frequency modulation.

In AM, the amplitude of the signal determines the amplitude of the carrier, whereas in FM the amplitude of the signal determines the carrier's frequency. Fig.10.6 shows the principle of AM and FM using a sine wave as a modulator.

Another example is the transmission of data along a fibre optic cable. We cannot just put an electrical signal down a fibre optic cable as it is an extremely good insulator. We need to use an appropriate carrier which, in this case, is light. The data then modulates the light level, which can be detected at the remote end by a photosensor.

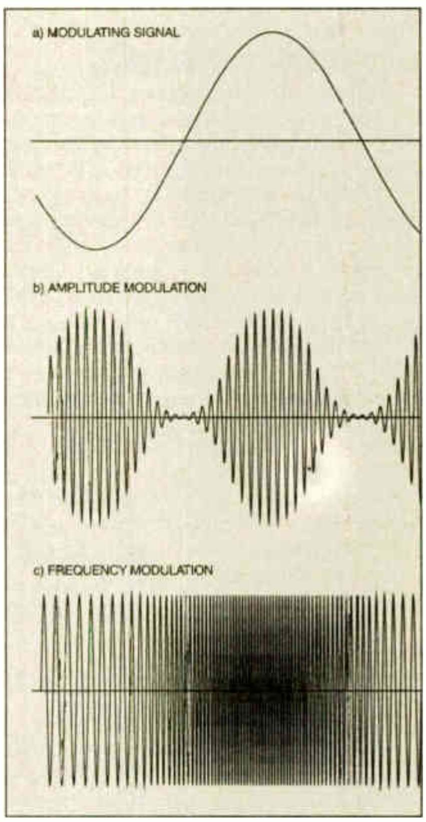


Fig.10.6. Amplitude and frequency modulation.

DOING IT DIGITALLY

Digital data can be transmitted in a similar manner to analogue, the equivalent modulation schemes being called **amplitude-shift keying** (ASK) and **frequency-shift keying** (FSK), and there is another called **phase-shift keying** (PSK). Fig.10.7 shows the operation of ASK, FSK and PSK where the amplitude/frequency/phase of the carrier is changed by a discrete amount depending whether a logic 0 or logic 1 is being transmitted. We concentrate on digital modulation here since this is used in telemetry systems.

ASK is the simplest form of digital modulation since all we are using is the presence of the carrier for a logic 1 and its absence for a logic 0. In the *Lab Work* we will be using an AM transmitter to transmit digital data by simply turning it on and off. FSK uses two carrier frequencies and PSK inverts the carrier for a logic 1 (inverting is equivalent to a phase shift of 180°).

Each modulation scheme has its advantages and drawbacks. ASK, for example, is the simplest to implement but has the worst performance. PSK is the most difficult to implement but has the best performance, and FSK is in between. The performance of a modulation scheme is defined as the signal-to-noise ratio needed at the receiver to guarantee a particular error rate. Digital data will be corrupted if the noise level is too high, generating bit errors.

To illustrate this, we will use ASK. The carrier is only present when a logic 1 is being transmitted so the receiver will pick up the signal plus noise for a logic 1 and noise only for a logic 0. If the noise level is high enough, the receiver will "see" the noise as a logic 1 when in fact nothing was transmitted. In FSK and PSK, there is always signal plus noise so the amount of energy needed for a given error rate is less.

THE RADIO SPECTRUM

Table 10.1 gives a broad outline of the radio spectrum available for communications. As you can see, the spectrum is divided into bands, each band increasing in frequency by a factor of 10. Each band starts at 3 and ends at 30. All bands have names, such as very low frequency (VLF), and the manner in which they propagate and the distance over which signals can be transmitted depend on the frequency.

Table 10.1 The Radio Spectrum

Designation	Name	Frequency Range	Communication Distance	Applications
ELF	Extremely Low Frequency	300Hz – 3kHz	BLOS, Worldwide	Submarine communications
VLF	Very Low Frequency	3kHz – 30kHz	BLOS, Worldwide	Global location systems
LF	Low Frequency	30kHz – 300kHz	BLOS, 1000's km	Long distance AM broadcast stations
MF	Medium Frequency	300kHz – 3MHz	BLOS, 100's km	Regional AM broadcast stations
HF	High Frequency	3MHz – 30MHz	BLOS, Worldwide	Military and amateur radio
VHF	Very High Frequency	30MHz – 300MHz	BLOS, 100's km	Regional FM broadcast stations
UHF	Ultra High Frequency	300MHz – 3GHz	LOS, 10's km	FM broadcast and TV stations, satellite links
SHF	Super High Frequency	3GHz – 30GHz	LOS, km	High speed point-to-point links, satellite links
EHF	Extremely High Frequency	30GHz – 300GHz	LOS	Research

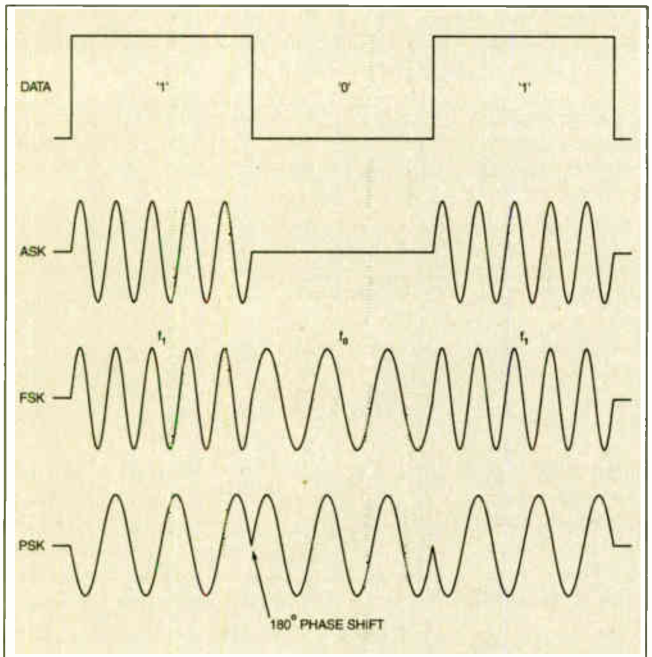


Fig.10.7. ASK, FSK and PSK modulation.

We don't have space to cover each band in detail but we will describe some of the more interesting bands and propagation mechanisms. We need first to define two terms – **LOS** (line-of-sight) and **BLOS** (beyond line-of-sight). These describe how far signals can go.

LOS means *optical* line-of-sight, i.e. the straight line distance. In general, the higher the frequency the less the signal gets "bent" over the earth and the more LOS it is (see Fig.10.8). This is why microwave transmitters and receivers must be visible to each other, whereas we can receive VHF signals from transmitters over the horizon. Let's look at some bands:

ELF and VLF (extra low frequency and very low frequency). Frequencies in these bands have very long wavelengths and propagate worldwide using the ionosphere and the ground as a wave guide. They are used mainly for communications with submarines since only long wavelength radio waves penetrate sea water to any appreciable depth.

LF (low frequency). This is commonly known as "long wave" and signals propagate over thousands of kilometres. The band is used for long range radio broadcasts.

MF (medium frequency). Commonly known as "medium wave" and is used for radio broadcasts. Transmission is not as far as LF.

HF (high frequency). This is an interesting band as there are two main methods of radio propagation. The first is **groundwave**, where signals are parallel to the ground and communication distance is less than MF. The other mode is **skywave** where signals are bounced (actually *refracted*) from layers of ionized gases in the ionosphere (100km to 300km above sea level). Much longer distances can be achieved, even worldwide by multiple "hops" where the signal is bounced between the surface and ionosphere several times. HF is used for radio broadcast, the military and amateurs.

VHF (very high frequency). Most FM radio broadcast stations are in this band. Transmission distance is almost LOS. One unusual propagation mechanism is called *meteor scatter* and relies on reflecting signals from trails left by meteorites when they burn up in the atmosphere. Most people will be aware of meteorites leaving trails in the sky; these do not occur very often but usable trails can be generated by dust grains as small as 1mg. These occur every 30s or so and last for up to 1s, giving a low data rate system at up to 2000km. One successful system is called **SNOTEL** and transmits information on snow levels for the whole of Northern Canada.

UHF (ultra high frequency). UHF is perhaps best known for television channels. It is LOS.

It is beyond the scope of this series to delve too deeply into the radio spectrum. More details on it and its uses can be found on the Radiocommunications Agency's web site: **www.radio.gov.uk**. This site also gives details of licences and licence exempt frequencies.

DATA COMMUNICATIONS

Data must be transmitted in a *serial* form over radio, which means that we need to change any *parallel* data, such as that from an ADC, into serial form for transmission and then back into parallel form at the receiver.

This also brings up the idea of **synchronisation**, in other words, how does the receiver know which data bit has arrived? There are a number of ways to achieve synchronisation, including transmitting known data bit sequences that the receiver can recognise and adding data formatting to the data stream.

We will only look at the simplest and most familiar – the **UART** (universal asynchronous receiver transmitter) which uses the **start bit** and **stop bit** principle. Fig.10.9 shows the format where the data is preceded by a logic 0 and followed by a logic 1. This means the receiver can detect the beginning of a data word (usually eight bits) by a negative edge (1-0) transition. It then knows that the next eight bits are data. You may be familiar with this format as it is used in computer serial ports (RS-232).

There is sometimes an additional bit after the data, known as the **parity bit** – this is used as an error checker. Parity can be **even** or **odd**. If the number of logic 1s in

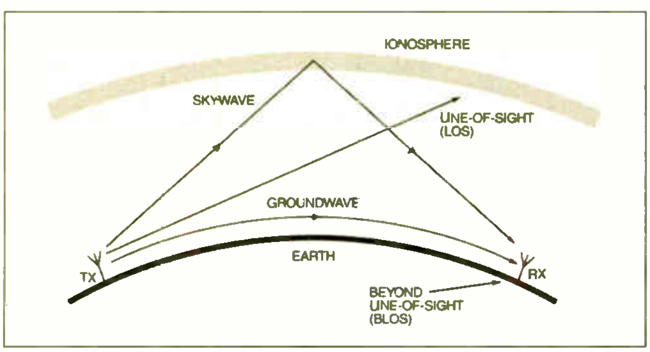


Fig.10.8. How radio signals propagate.

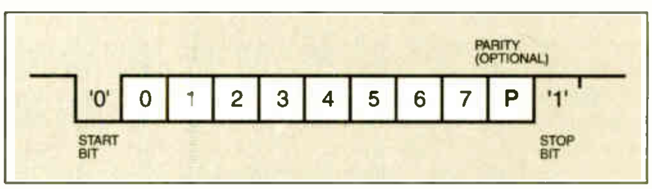


Fig.10.9. RS-232 data format.

the data word is odd then the parity bit is 1 for even parity, and 0 for odd parity. After reception, the parity is calculated on the received data and if an error has occurred, it will be incorrect. A single parity bit can only detect odd numbers of errors.

One other problem is that of synchronising data clocks. If data is transmitted at, say, 1000 bits/second, then we need a clock at the receiver operating at exactly the same frequency to clock the data into a shift register to convert back to parallel form. If the clocks are not exactly the same, received data may not be correctly clocked.

Clocks also tend to drift with temperature and component ageing. How do we overcome this? A UART achieves this by restarting the clock every time a start bit is detected so that any drift is very small. In practical UARTs the clock is 16 times the data rate and is divided down to give a narrow clock pulse at the middle of each data bit.

The other synchronisation problem lies with the receiver knowing when a message is arriving and possibly where from. This is achieved by adding a header to the message; this header is unique and is searched for by the receiver. Only when a correct header has been received does the receiver know that the data bits follow. Headers can provide additional information such as message number, message source and data type.

In addition to the header, data is often followed by error checking bits, the most widespread known as a **cyclic redundancy check** (CRC). The CRC is calculated from all the data bits and recalculated at the receiver. Any difference means that errors have occurred in the message. A 16-bit CRC can detect up to 99·98 per cent of all possible error combinations in messages of any length. Fig.10.10 shows a typical message format with a header and CRC.

Fig.10.10. Typical message format.

Radio receivers often have an automatic gain control (AGC) to ensure the received signal is as strong as possible. If an AGC is present, then it is advisable to precede the header with a number of bit reversals to ensure the AGC is at the correct level.

WIRELESS RECEIVER NETWORKS

If you can build very small (electronic and MEMS based), very low power, smart sensors with wireless communications then some interesting possibilities emerge, particularly if you deploy networks of such devices that can coordinate among themselves. These networks are known as **Wireless Integrated Network Sensors** (WINS) and could potentially contain hundreds or thousands of nodes. Fig.10.11 shows the structure of a typical WINS node.

These devices could literally be scattered over an area of interest in the outdoor environment, or installed in large numbers in buildings, for example, by embedding them in ceiling tiles. Individual WINS nodes have limited communication range, but data can be moved around from node to node (known as multi-hop communication) until it reaches a base station where the sensors are monitored, or provide a gateway to a longer-range communication system or computer network. See Fig.10.12.

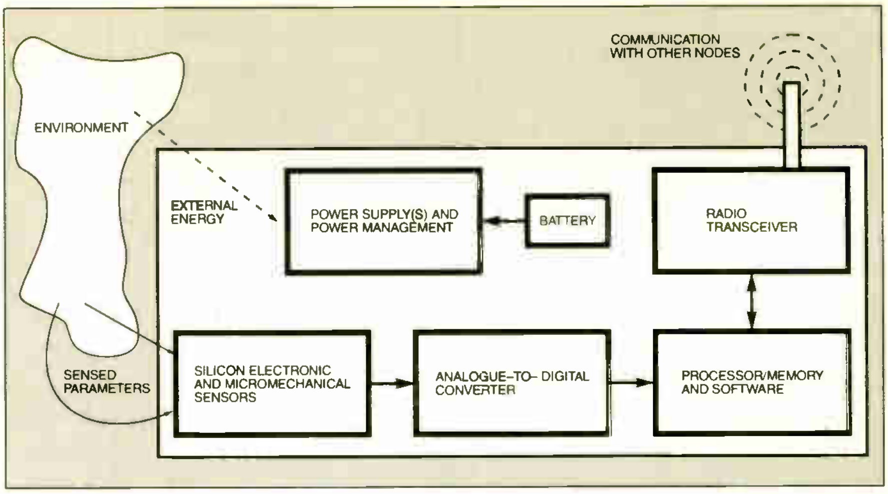


Fig.10.11. Typical WINS node.

Nodes near one another can exchange data for analysis or decision making purposes, and possibly organise themselves into clusters to make more efficient use of resources, or for improved analysis of the sensed environment. See Fig.10.13.

Effective communication protocols and efficient use of resources are key areas of research in WINS technology. WINS systems can differentiate between local and global variations (something which affects all sensors, or just some of them) and networks of sensors can achieve better signal-to-noise ratio than a single "powerful" sensor.

Example applications include monitoring of seismic activity to provide improved earthquake warning systems, and use by the military to detect movement of vehicles by the disturbance they cause to the local magnetic field. In the latter case, larger area natural fluctuations in the Earth's magnetic field would be picked up by a large number of sensors, not just those close to a vehicle. Such an application was recently promoted by UCLA for a wireless magnetometer MEMS chip which they have developed.

There are many other systems and protocols for creating sensor networks, such as the **Controller Area Network** (CAN), for which there are dedicated i.c.s and even microcontrollers with embedded CAN interfaces.

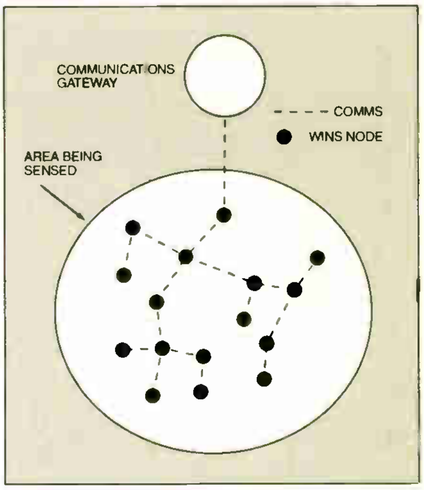


Fig.10.12. WINS system used to sense an area of interest.

POWER SOURCES

If sensors are to operate free from wiring then power is an important consideration, particularly if we need self-sustaining devices such as in WINS applications. Even in buildings where it would seem that power is readily available, independently powered sensors have a lot of advantages.

The cost of sensors for environmental control of buildings is increased significantly by power and data wiring, and installation and maintenance labour costs are very high. If the sensors have their own power source and use wireless communications these infrastructure costs are greatly reduced and much larger numbers of sensors can be deployed.

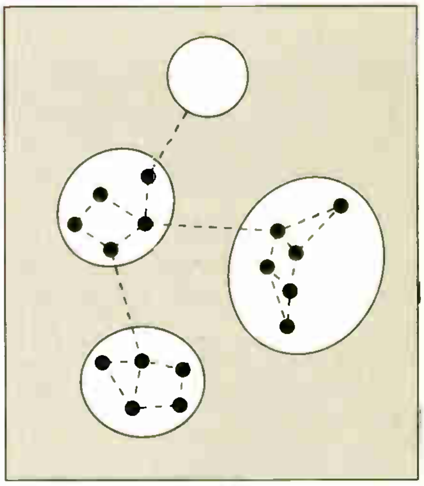


Fig.10.13. WINS nodes organised as clusters.

A lot of research effort has been undertaken in recent years in low power electronic circuit design, this work has been driven by the demand for high performance mobile products such as phones, and by the need for very long battery life in applications such as implanted medical electronics. So we can build circuits that do useful work on little power – which we need for WINS – but we still need *some* power.

Battery technology is improving but still does not provide particularly good power per unit volume and weight. Micro scale fuel cells capable of using fuels such as butane and diesel to generate electrical power in the range of say 10mW to 500mW may be preferable to batteries for powering WINS nodes and research is being conducted in this area.

Fuel and batteries do not last for ever, so there is great interest in self-powered systems which do not use a battery, but employ *power harvesting* or *power scavenging*. These systems obtained their power from the environment or from a person wearing or carrying the sensors, or from other electronic systems.

The use of light, through solar cells, is well known in this respect, but other sources of power are available and may be more useful in some situations. The idea of getting power from the motion of walking by building a piezoelectric generator into shoes has been quite widely publicised recently. Other forms of energy from the human body, including heat and movement, are being investigated. In buildings, vibration and ambient radio frequency energy and thermal gradients can be harvested to power sensors.

EXPERIMENTS

In the following *Lab Work* we give you the opportunity to experiment using radio transmission of sensor data and to make use of it after reception.

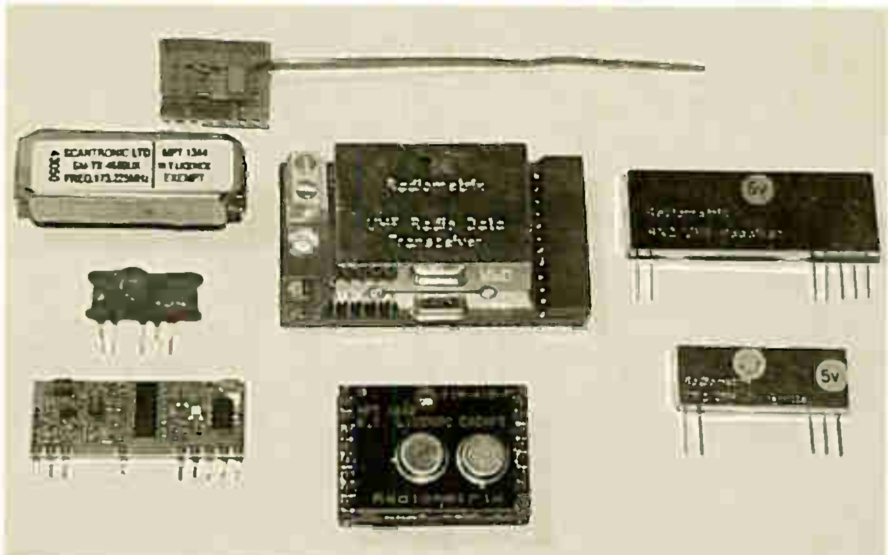
TEACH-IN 2002 – Lab Work 10

DAVE CHESMORE

RADIO TELEMETRY SYSTEMS

IN this final Lab Work we offer you the opportunity to experiment with your own telemetry system. The readily-available AM transmitter and receiver operate at 433MHz. You should ensure that you also obtain and study their relevant data sheets for detailed descriptions of antenna design, etc. See this month's *Shoptalk* page for information on where to buy them.

They are licence exempt radio devices because they are type approved, low power and use the 433MHz licence exempt frequency, such as is used in car alarm and immobilizer systems. There are other licence exempt frequencies, 173MHz and 868MHz for example, for which type approved modules are available, but we have chosen 433MHz AM transmitters and receivers as they are low cost; FM transmitters and receivers are more expensive.



Several licence exempt transmitter and receiver modules. In these Lab Works *we use the transmitter at the top left, and the receiver at bottom left.*

Lab 10.1 Telemetry Demonstration

Two simple circuits for testing the AM Transmitter and Receiver are shown in Fig.10.14 and Fig.10.15. The transmitter consists of a variable frequency square wave oscillator based on the Schmitt trigger NAND gate, IC1a, that we have previously used in this series. IC1b is used as a buffer to stop loading of the oscillator when the transmitter is connected. Potentiometer VR1 varies the frequency.

The transmitter module is a 2-pin device (see Fig.10.16a for the pinout details) which should be mounted as close to the circuit as possible. Resistor R2 limits the module's operating current to around 5mA.

The aerial should be about 9cm long and made of fairly stiff wire. We soldered the module and aerial to a small piece of stripboard, as shown in the photograph above.

The receiver module's pinout is shown in Fig.10.16b and is very simple to operate. The aerial is identical to the transmitter's.

Construct the two circuits on separate boards and, if possible, use two power supplies. The transmitter can operate on 9V if R2 is changed to 2k2Ω but the receiver needs a 5V supply.

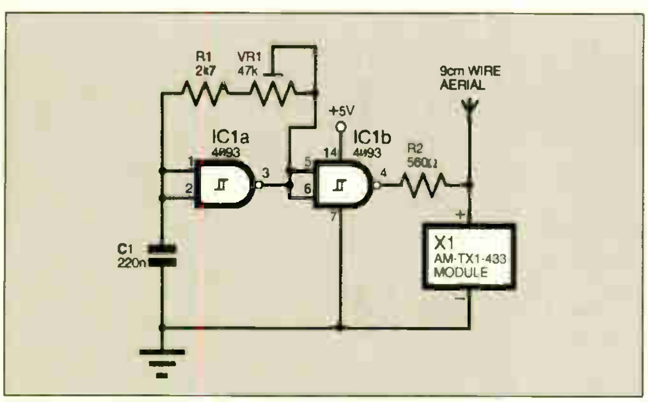


Fig.10.14. AM telemetry demonstration Transmitter.

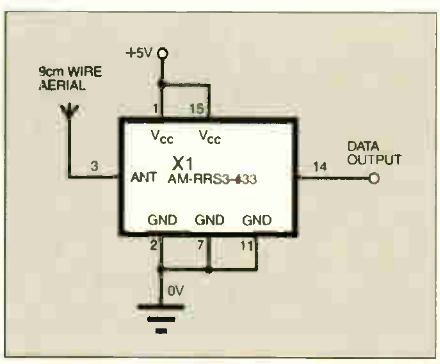


Fig.10.15. AM telemetry demonstration Receiver.

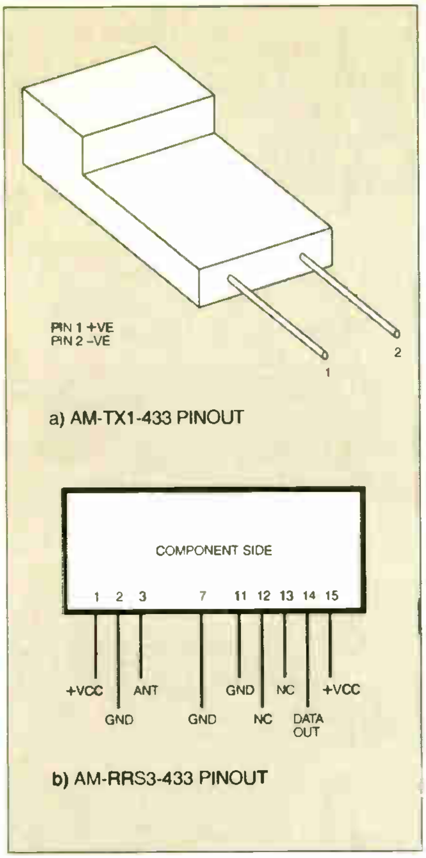
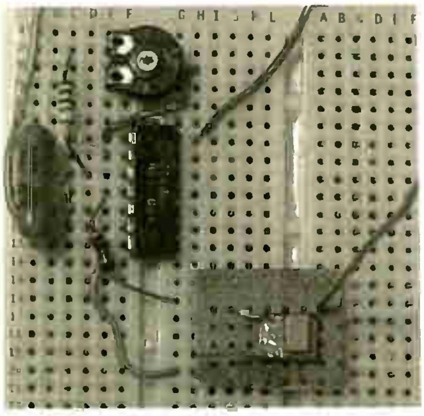


Fig.10.16. Pinouts of transmitter and receiver.



Breadboard layout for the transmitting circuit in Fig.10.14. Note that the transmitter module has been mounted on a small offcut of stripboard.

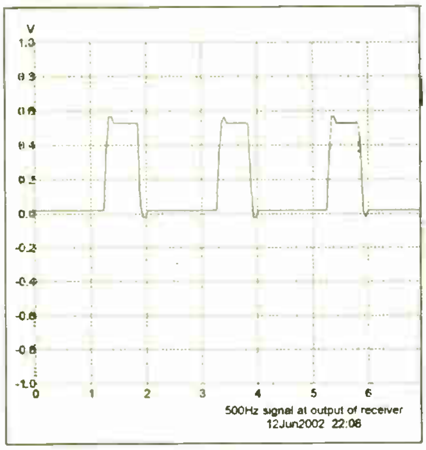


Fig.10.17. Example of signal at the receiver's output for a 500Hz transmitted squarewave.

COMPONENTS

Approx. Cost Guidance Only

£26 excl. hardware

See SHOP TALK page

Lab 10.1 Telemetry Transmitter

Resistors
R1 2k7
R2 560Ω
All 0·25W 5% carbon film.

Potentiometer
VR1 47k preset

Capacitor
C1 220n polycarbonate

Semiconductor
IC1 4093 quad 2-input Schmitt NAND gate

Miscellaneous
X1 AM-TX1-433 433MHz AM transmitter module
Small offcut of stripboard (see photo)

Lab 10.1 Telemetry Receiver

X1 AM-RRS3-433 433MHz receiver module

Lab. 10.2 Anemometer Transmitter

Resistors
R1 560Ω
R2 56k
R3 390Ω
R4 4k7
R5 680Ω
All 0·25W 5% carbon film.

Semiconductor
TR1 BC108 or equivalent *npn* transistor

Miscellaneous
X1 SG-2BC reflective photointerruptor (from Part 7, see text)
X2 AM-TX1-433 433MHz AM transmitter module

Lab. 10.2 Anemometer Receiver

X1 AM-RRS3-433 433MHz receiver module
Other components as for Lab.7.2 (Part 7)

Lab 10.3 V-to-F Transmitter

Resistors
R1 5k6
R2 100k
R3 2k2
R4 12k
R5 3k3
All 0·25W 5% carbon film.

Capacitors
C1 10n ceramic
C2 1n polycarbonate

Semiconductors
IC1 RC4151 or XR4151 voltage-to-frequency converter
IC2 4013 dual D-type flip-flop

Miscellaneous
X1 AM-TX1-433 433MHz AM transmitter module

Lab. 10.3 F-to-V Receiver

Resistors
R1 120k
R2 3k3
R3 4k7
R4 10k
R5 to R7 12k (3 off)
R8 5k6
R9 100k
All 0.25W 5% carbon film.

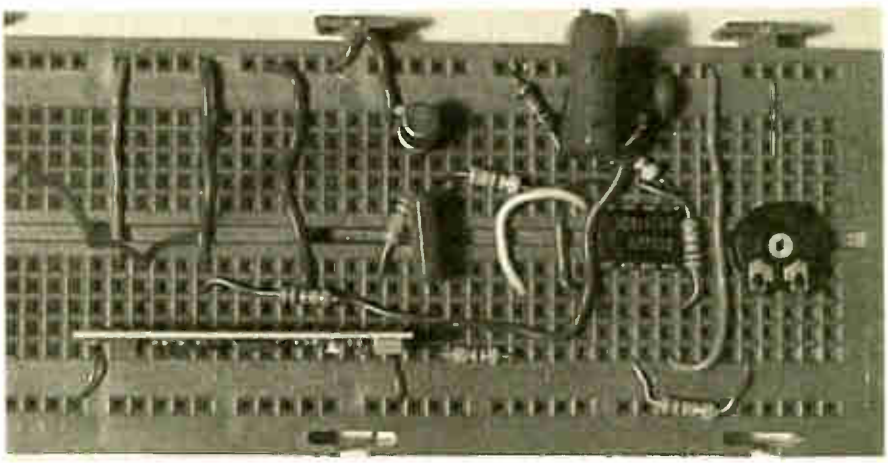
Potentiometer
VR1 47k preset

Capacitors
C1 100n polycarbonate
C2 10n ceramic
C3 1n polycarbonate

Semiconductors
TR1 BC108 or equivalent *npn* transistor
IC1 RC4151 or XR4151 voltage-to-frequency converter

Miscellaneous
X1 AM-RRS3-433 433MHz receiver module

N.B. Some components are repeated between Lab Works.



Breadboard layout for the receiving circuit in Fig.10.21.

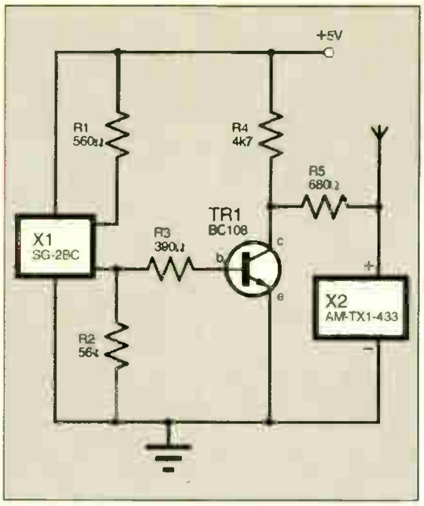


Fig.10.18. Anemometer transmitter. Sensor XI is that in Part 7 Fig.7.22.

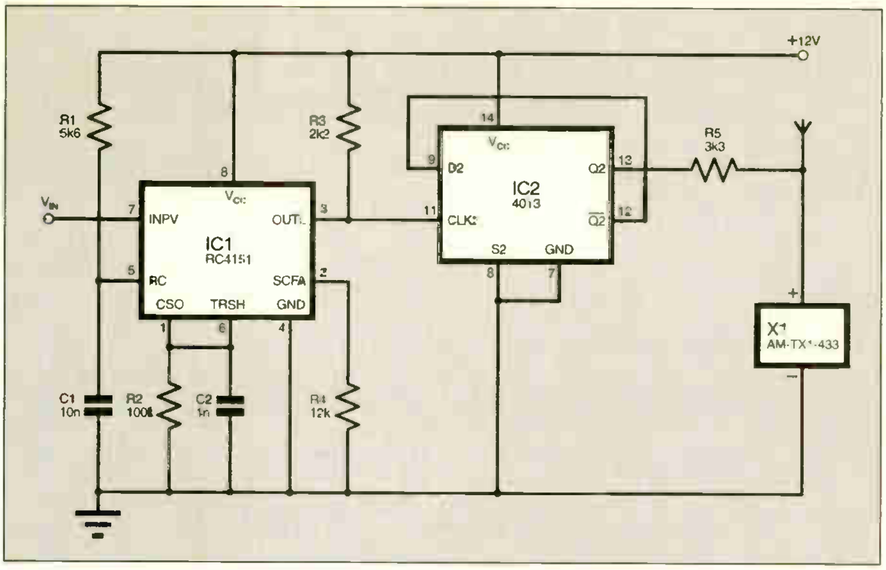


Fig.10.20. Voltage-to-frequency converter and transmitter.

There are two experiments that can be done with these circuits – to establish the effect of transmission distance and the effect of the transmitted data rate. You should be able to achieve at most 1·2kHz (equivalent to 1·2kbps) over distances of several tens of metres. Fig.10.17 shows a typical received signal at 500Hz.

Lab 10.2 Remote Anemometer

This Lab is based on Lab 7.2 in Part 7 (May '02). In that Lab, we designed a circuit to measure wind speed using an optical sensor. Here, we use the same circuit as in Fig.7.22 but separate the anemometer sensor from the rest of the circuit and add a telemetry unit. Fig.10.18 shows the sensor and transmitter and Fig.10.19 the receiver.

If you compare these two circuits to Fig.7.22 you will see that the sensor's output from transistor TR1 is connected to the AM transmitter and the output of the receiver is fed into the pulse accumulation circuit.

Note that the circuit has not been optimised for low power consumption but forms the basis for other circuits. For example, you could use a rechargeable battery, solar panel and a 5V regulator to give continuous operation. The anemometer could then be placed in a remote location such as on a roof.

Lab 10.3 Transmitting Analogue Signals

One problem we have with radio telemetry, such as that used here, is that it is not

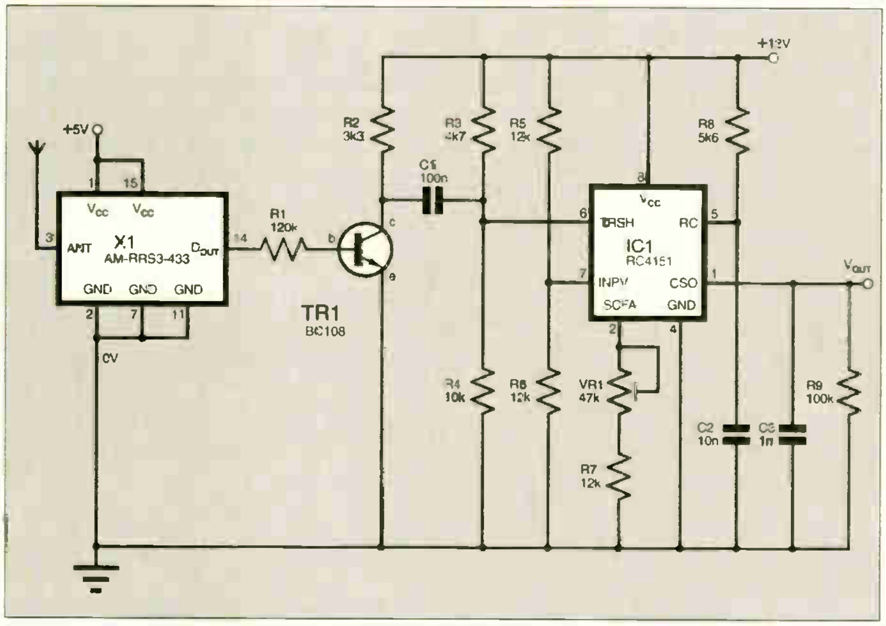
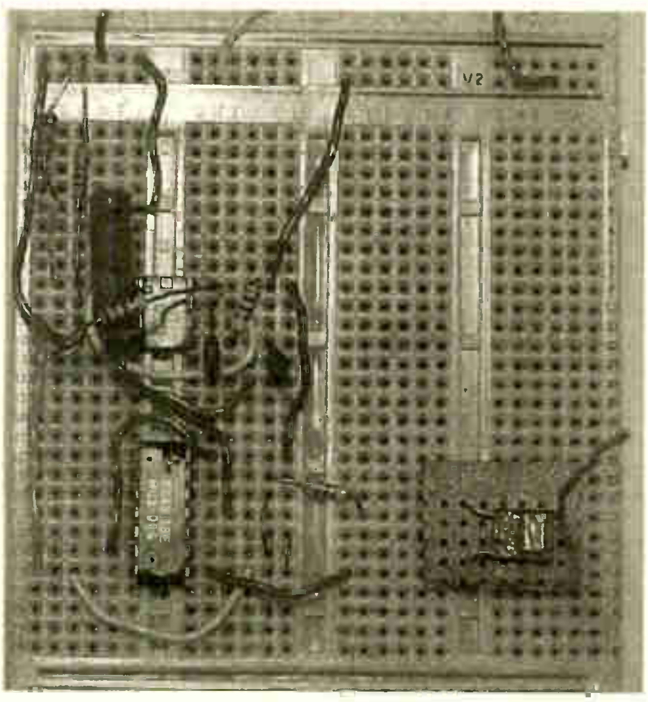


Fig.10.21. Frequency-to-voltage converter and receiver.

Right: Breadboard assembly for the transmitter in Fig.10.20.



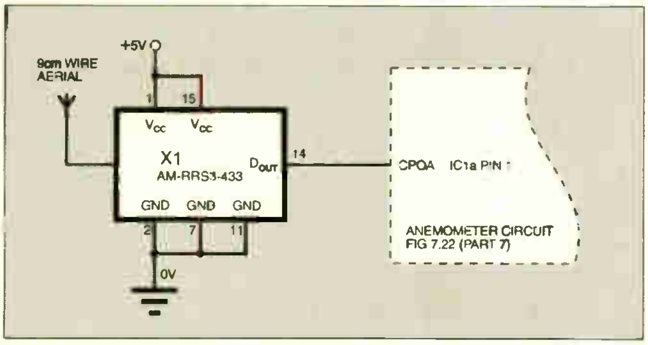


Fig.10.19. Anemometer receiver circuit. Fig.7.22 is shown in Part 7 (May '02).

easy to transmit analogue signals. We need to convert them into digital form in one of several ways, the most common being analogue-to-digital conversion and voltage-to-frequency conversion. A-to-D conversion usually produces data in parallel form which must be converted to serial form for transmission, and, after reception, back again. The circuits for doing this are shown in Fig.10.20 and Fig.10.21.

They both use the same integrated circuit, an RC4151 or the equivalent XR4151, which can provide V-to-F and F-to-V conversion. A data sheet for the XR4151 can be found at the Exar web site at **www.exar.com/products/XR4151.html**. You should consult the data sheet for a full explanation of the device's operation.

The transmitter circuit converts an input voltage into a pulse train at approximately 400Hz per volt. The duty cycle of the output pulses varies depending on the frequency so a D-type flip-flop (IC2) has been added to convert the pulses into a square wave at half the frequency. The D-type flip-flop has been converted into a toggle flip-flop by connecting the inverse ($\overline{Q2}$) output to the D input.

Note that the V-to-F converter needs a minimum of 8V to operate correctly. Here we are using 12V and the resistor connecting the transmitter module (R5) is increased to 3k3 to maintain a 5mA current.

The receiver circuit uses the RC4151/XR4151 "in reverse" to convert the input frequency into a voltage. Note that the receiver module needs 5V. The RC4151, though, needs at least 8V and is powered here at 12V. The receiver's data output also has a relatively high impedance so transistor TR1 serves two purposes – buffering and increasing the output to 12V.

The sensitivity in V/Hz can be changed using potentiometer VR1 and this should be varied until the input voltage changes at the transmitter are mirrored at the receiver.

Finally, we point out that these circuits are for *experimentation only*, to illustrate the use of a telemetry system.

IN CONCLUSION

The *Teach-In 2002* authors hope that you have enjoyed this 10-part series, and that you now have a fuller understanding of what sensors are, what you can do with them, and that it has given you ideas about how you might put them into applications of your own.

We trust, too, that the extensive coverage we have given to op.amps in relation to their use in sensing circuits has also enlightened you and given you an insight into the importance of tailoring interfacing circuits to suit the sensors and their end applications.

If you have any queries directly related to this series, you can write to the author's c/o the Editorial address, or you can email them at **teach-in@epemag.demon.co.uk** (no file attachments or general electronic queries please). □

SHOP TALK
with David Barrington

Pickpocket Alarm

As mercury is such a dangerous and toxic substance, we strongly recommend that the mercury "tilt" switch called for in the *Pickpocket Alarm* is replaced by a non-mercury type. It you do use a mercury switch we suggest it be of the metal-cased type.

Fortunately, the glass envelope type, as used in the author's prototype model, now seems to be very hard to find and, in view of the fact that the glass envelope is easily fractured, we recommend readers do not waste valuable time searching for this device. A suitable replacement miniature "non-mercury" hermetically sealed tilt switch is currently listed by **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***) and carries the order code DP50E.

The neat handheld case, with detachable belt/pocket clip, was also purchased from the above company, code KC95D. This case has an integral battery compartment, with a separate access cover, and comes complete with battery terminal, pocket clip and all self-tapping fixing screws.

Most of our components advertisers should be able to offer suitable miniature, glass envelope, reed switches with magnets and a 3V to 12V d.c. piezoelectric buzzer. The rest of the components should be readily available "off-the-shelf".

PIC World Clock

Only the l.c.d. graphics display module should give rise for concern when shopping for components for the *PIC World Clock* project. The author used a Powertip PG12864 monochrome Supertwist (STN) graphics display module, with an on-board Toshiba T6963-based controller chip.

As far as we are aware, this display module only appears on the **RS Components** listing, code 329-0329, and can be ordered from any *bona-fide* RS stockists, including some of our advertisers. You can order direct (*credit card only*) from RS on ☎ ***01536 444079*** or on the web at ***rswww.com***. The current listed price is £37.46 plus an additional post and handling charge will be made. A world of caution – observe all the anti-static precautions when handling and storing this device.

For those readers unable to program their own PICs, a ready-programmed PIC16F877 microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £10 each (overseas add £1 p&p). The software is available on a 3·5in. PC-compatible disk (*EPE* Disk 5) from the *EPE* Editorial Office for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 619).

It is also available for *FREE* download from the *EPE* ftp site, which is most easily accessed via the click-link option at the top of the screen page when you enter the main web site at **www.epemag.wimborne.co.uk**. On entry to the ftp site take the path **pub/PICs/Worldclock**, downloading all files within the latter folder.

The clock printed circuit board is available from the *EPE PCB Service*, code 363 (see page 619).

Big-Ears Buggy

The specified dual-in-line (d.i.l.) packaged reed type relay used in the prototype *Big-Ears Buggy* was purchased through an RS Components dealer, code 291-9710. It can be ordered direct (*credit card only*) from RS on ☎ ***01536 444079*** or on the web at ***rswww.com***.

Since the buggy was first built and written-up, it was found that the preamplifier stages suffered false triggering caused by the motors. This was cured by using a separate battery for the motors. It was also found that small solar motors are best suited for the buggy as they do not seem to stall so easily as other d.c. motors when slowed down. Also, they appear to take/need less drive current.

Regarding the motors. The author used Yebo Electronics solar motors and gearboxes, code BCL91G. We understand that a UK source for these is **Harrogate Electronic Services** (☎ ***01423 564353***), code MSGB1. It may be worth investigating motors stocked by **Milford Instruments** (☎ ***01977 683665*** or ***www.milinst.com***) and **Total Robots** (☎ ***01372 741954*** or ***www.totalrobots.com***).

The sub-miniature omni-directional microphone insert used for the buggy's "ears" came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***). This should be ordered as code FS43W.

The buggy printed circuit board is available from the *EPE PCB Service*, code 362.

Simple Audio Circuits–4

Most parts needed to construct the *Workbench Loudspeaker Enclosure, Low-Frequency Oscillator* and the *Resonance Detector*, this month's Simple *Audio Circuits* projects, should be "shelf items". The Crossover Unit components were covered in last month's *Shoptalk* page.

When selecting a loudspeaker, you may care to take a look at the excellent range of speakers stocked by **BK Electronics** (☎ ***01702 527572*** or ***www.bkelec.com***), they should have one to cater for all tastes. The speaker used by the author is a **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***) type, code GL14Q.

The two small printed circuit boards are available from the *EPE PCB Service*, codes 364 (Osc.) and 365 (Res Det.) respectively (see page 619).

Teach-In 2002 – Lab 10

The licence exempt 433MHz AM-TX1-433 Transmitter and AM-RRS-433 Receiver modules used in this month's final instalment of *Teach-In 2002 Lab Work* came from **R.F. Solutions** (☎ ***01273 488880*** or ***www.rfsolutions.co.uk***). You could also checkout the 433MHz modules from **Bitz Technology** (☎ ***01753 522902*** or ***www.bitztechnology.com***).

The voltage-to-frequency converter type Exar XR4151 came from **Farnell** (☎ ***0113 263 6311*** or ***www.farnell.com***, code 562-701. They also stock the miniature reflective photointerruptor opto-switch type SG-2BC, code 491-366. If you are offered the RC4151N or RC4152N from your local supplier it should be OK for these circuits.

PLEASE TAKE NOTE

EPE StyloPIC *(July '02)*

Page 490, Fig.2. An LM13700 can be used instead of an LM13600 (IC4) if you wish.

Using the PIC's PCLATH Command *(July '02)*

The diagrams in Fig.1 and Fig.2 should be transposed.

EPE TEACH-IN 2000 CD-ROM

The whole of the 12-part *Teach-In 2000* series by John Becker (published in *EPE* Nov '99 to Oct 2000) is now available on CD-ROM. Plus the *Teach-In 2000* interactive software covering all aspects of the series and Alan Winstanley's *Basic Soldering Guide* (including illustrations and Desoldering).

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R. A. Penfold

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Along with the electric guitar, sections are also included relating to acoustic instruments. The function of specialised piezoelectric pickups is explained and there are detailed instructions on how to make your own contact and bridge transducers. The projects range from simple preamps and tone boosters, to complete active controls and equaliser units.

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Printed circuit boards for most recent *EPE* constructional projects are available from the PCB Service, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. All prices include VAT and postage and packing. Add £1 per board for *airmail* outside of Europe. Remittances should be sent to **The PCB Service, *Everyday Practical Electronics*, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset BH22 9ND. Tel: 01202 873872; Fax 01202 874562; E-mail: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.wimborne.co.uk/shopdoor.htm.** Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only).**

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photostats of articles are available if required – see the *Back Issues* page for details.

Please check price and availability in the latest issue.

Boards can only be supplied on a payment with order basis.

PROJECT TITLE		Order Code	Cost
★*EPE* Icebreaker – PCB257, programmed PIC16F877 and floppy disc	MAR '00	Set only	£22.99
★Micro-PICscope	APR '00	259	£4.99
★Multi-Channel Transmission System	MAY '00		
– Transmitter		264 } Set	£6.34
Receiver		265 } Set	
Interface		266 } Set	
★Canute Tide Predictor	JUNE '00	267	£3.05
★PIC-Gen Frequency Generator/Counter	JULY '00	268	£5.07
g-Meter		269	£4.36
★EPE Moodloop	AUG '00	271	£5.47
Quiz Game Indicator		272	£4.52
Handy-Amp		273	£4.52
Active Ferrite Loop Aerial	SEPT '00	274	£4.67
★Remote Control IR Decoder **Software only**		–	–
★PIC Dual-Channel Virtual Scope	OCT '00	275	£5.15
Handclap Switch	NOV '00	270	£3.96
★PIC Pulsometer **Software only**		–	–
Twinkling Star	DEC '00	276	£4.28
Festive Fader		277	£5.71
Motorists' Buzz-Box		278	£5.39
★PICtogram		279	£4.91
★PIC-Monitored Dual PSU–1 PSU		280	£4.75
Monitor Unit		281	£5.23
Static Field Detector (Multi-project PCB)		932	£3.00
Two-Way Intercom	JAN '01	282	£4.76
UFO Detector and Event Recorder			
Magnetic Anomaly Detector		283 } Set	£6.19
Event Recorder		284 } Set	
Audio Alarm		285 } Set	
★Using PICs and Keypads **Software only**		–	–
Ice Alarm	FEB '01	287	£4.60
★Graphics L.C.D. Display with PICs (Supp)		288	£5.23
Using the LM3914-6 L.E.D. Bargraph Drivers			
Multi-purpose Main p.c.b.		289 } Set	£7.14
Relay Control		290 } Set	
L.E.D. Display		291 } Set	
★PC Audio Power Meter **Software only**		–	–
Doorbell Extender: Transmitter	MAR '01	292	£4.20
Receiver		293	£4.60
Trans/Remote		294	£4.28
Rec./Relay		295	£4.92
EPE Snug-bug Heat Control for Pets	APR '01	296	£6.50
Intruder Alarm Control Panel			
Main Board		297	£6.97
External Bell Unit		298	£4.76
Camcorder Mixer	MAY '01	299	£6.34
★PIC Graphics L.C.D. Scope		300	£5.07
Hosepipe Controller	JUNE '01	301	£5.14
Magfield Monitor (Sensor Board)		302	£4.91
Dummy PIR Detector		303	£4.36
★PIC16F87x Extended Memory **Software only**		–	–
Stereo/Surround Sound Amplifier	JULY '01	304	£4.75
Perpetual Projects Uniboard–1		305	£3.00
Solar-Powered Power Supply & Voltage Reg.			
MSF Signal Repeater and Indicator			
Repeater Board		306	£4.75
Meter Board		307	£4.44
★PIC to Printer Interface		308	£5.39
Lead/Acid Battery Charger	AUG '01	309	£4.99
Shortwave Loop Aerial		310	£5.07
★Digitimer – Main Board		311	£6.50
– R.F. Board		312	£4.36
Perpetual Projects Uniboard–2			
L.E.D. Flasher — Double Door-Buzzer		305	£3.00
Perpetual Projects Uniboard–3	SEPT '01	305	£3.00
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– White L.E.D.		315	£4.28
★Sync Clock Driver		316	£5.94
★Water Monitor		317	£4.91
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PIC Toolkit Mk3		319	£8.24
Perpetual Projects Uniboard–4. Gate Sentinel, Solar-powered Bird Scarer and Solar-Powered Register		305	£3.00

PROJECT TITLE		Order Code	Cost
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Lights Needed Alert		321	£5.39
Pitch Switch		322	£5.87
Capacitance Meter – Main Board (double-sided)		323 } Set	£12.00
– Display Board (double-sided)		324 } Set	
★★PIC Toolkit TK3 – **Software only**		–	–
4-Channel Twinkling Lights	DEC '01	325	£6.82
Ghost Buster – Mic		326 } Set	£5.78
– Main		327 } Set	
★PIC Polywhatsit – Digital		328 } Set	£7.61
– Analogue		329 } Set	
Forever Flasher	JAN '02	330	£4.44
Time Delay Touch Switch		331	£4.60
★PIC Magick Musick		332	£5.87
Versatile Bench Power Supply		333	£5.71
★PIC Spectrum Analyser	FEB '02	334	£7.13
Versatile Current Monitor		335	£4.75
Guitar Practice Amp		336	£5.39
★PIC Virus Zapper	MAR '02	337	£4.75
RH Meter		338	£4.28
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★PIC Controlled Intruder Alarm	APR '02	339	£6.50
★PIC Big Digit Display	MAY '02	341	£6.02
Washing Ready Indicator		342	£4.75
Audio Circuits–1 – LM386N-1		343	£4.28
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– TBA820M		345	£4.44
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Software programs for *EPE* projects marked with a single asterisk ★ are available on 3.5 inch PC-compatible disks or *free* from our Internet site. The following disks are available: **PIC Tutorial** (Mar-May '98); **PIC Toolkit Mk2 V2-4d** (May-Jun '99); ***EPE* Disk 1** (Apr '95-Dec '98); ***EPE* Disk 2** (1999); ***EPE* Disk 3** (2000); ***EPE* Disk 4** (2001); ***EPE* Disk 5** (Jan 2002 issue to current cover date); ***EPE* Teach-In 2000**; ***EPE* Spectrum**; ***EPE* Interface Disk 1** (October '00 issue to current cover date). ★★**PIC Toolkit TK3** software (Nov '01) is on CD-ROM. The 3.5 inch disks are £3.00 each (UK), the CD-ROM is £6.95 (UK). Add 50p each for overseas surface mail, and £1 each for airmail. All are available from the *EPE PCB Service*. All files can be downloaded *free* from our Internet FTP site: **ftp://ftp.epemag.wimborne.co.uk.**

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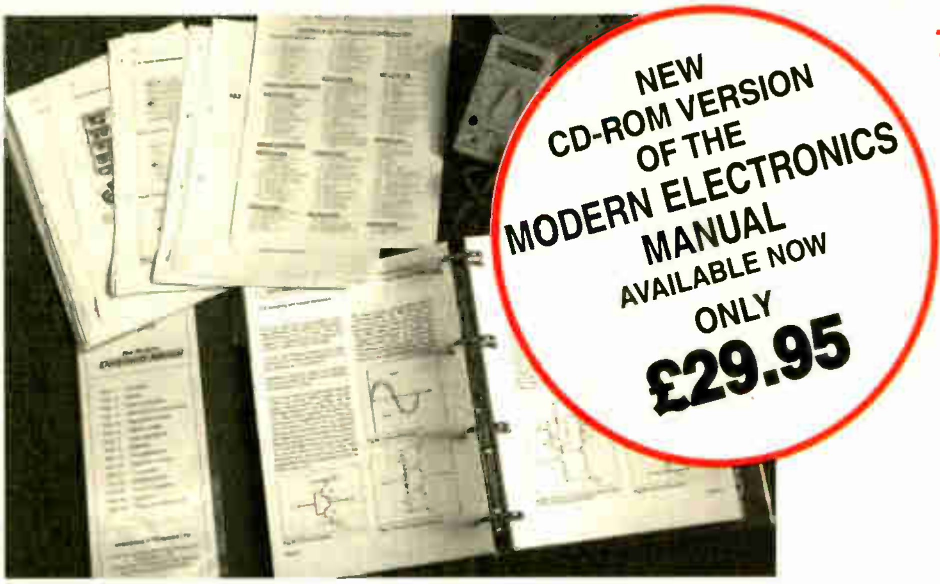

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