THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

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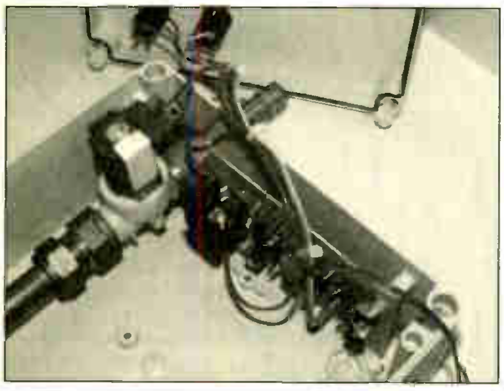

Projects and Circuits

Series and Features

Regulars and Services

Our July 2001 issue will be published on Thursday, 14 June 2001. See page 391 for details

NEXT MONTH

PIC TO PRINTER INTERFACE

This article describes how a PIC microcontroller can be used to independently control almost any Epson-compatible dot-matrix printer. An examination is first made of how Epson printers are controlled, using simple commands to illustrate how text and graphics can be printed under PIC control. Readers are encouraged to modify the basic PIC software to suit their own designs, adding extra printing features according to Epson's extensive manual, which is available for free download from Epson's web site.

As a practical example of PIC to printer control, the construction of a simple data logger is described. The logger inputs analogue data and plots it as a graph on the printer. Both fan-fold and cut-sheet paper can be used.

The logger has selectable sampling periods, ranging from once per second to once every 255 seconds (4.25 minutes). An hours-minutes-seconds clock facility is built into the controlling software.

NEW SERIES

PERPETUAL PROJECTS

This short series includes eight "perpetual" projects, all of which will continue to run indefinitely without attention. All are based on one small p.c.b. called a "uniboard". Each project is powered around the clock – perpetually – by a 1 Farad "Goldcap" capacitor and a small solar cell (no battery). Each is designed for continuous operation with a maximum of thirty minutes sunlight a day – in fact just five minutes sunlight *with the specified 300nW solar panel. The typical power requirements of one of these Perpetual Projects are more than* one thousand times *less than the requirements of an ordinary l.e.d. The various projects are: • L.E.D. flasher • Loop burglar alarm • Double door-buzzer • Door-light • Rain alarm • Gate sentinel • Bird scarer • Register*

Besides the projects listed here, the series includes nine suggestions for modifications. These include a single door-buzzer, broken beam beeper, power failure alarm, soil moisture monitor, thermistor, timer, liquid-level alarm, wake-up alarm, and a break contact alarm.

STEREO / SURROUND SOUND AMPLIFIER

An inexpensive, easy to build, stereo amplifier that can also produce pseudo surround sound when used with an existing amplifier. It's not Dolby Pro-Logic but the effect – considering the modest cost – is quite convincing. No doubt this neat little project will also find many other uses i.e. to amplify a personal stereo or as a test amp. in the workshop etc.

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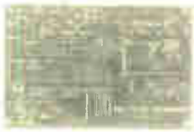

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3123KT	ATMEL 89xxx Programmer	£32.95
AS3123	Assembled 3123	£47.95

Atmel 89Cx051 and AVR programmers also available.

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3093KT	PC Data Acquisition & Control Unit	£99.95
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See opposite page for ordering information on these kits

ABC Mini 'Hotchip' Board

Currently learning about microcontrollers? Need to do something more than flash a LED or sound a buzzer? The ABC Mini 'Hotchip' Board is based on Atmel's AVR 8535 RISC technology and will interest both the beginner and expert alike. Beginners will find that they can write and test a simple program, using the BASIC programming language, within an hour or two of connecting it up. Experts will like the power and flexibility of the ATMEL microcontroller, as well as the ease with which the little Hot Chip board can be "designed-in" to a project. The ABC Mini Board 'Starter Pack' includes just about everything you need to get up and experimenting right away. On the hardware side, there's a pre-assembled micro controller PC board with both parallel and serial cables for connection to your PC. Windows software included on CD-ROM features an Assembler, BASIC compiler and in-system programmer The pre-assembled boards only are also available separately.

ABCMINISP	ABC MINI Starter Pack	£64.95
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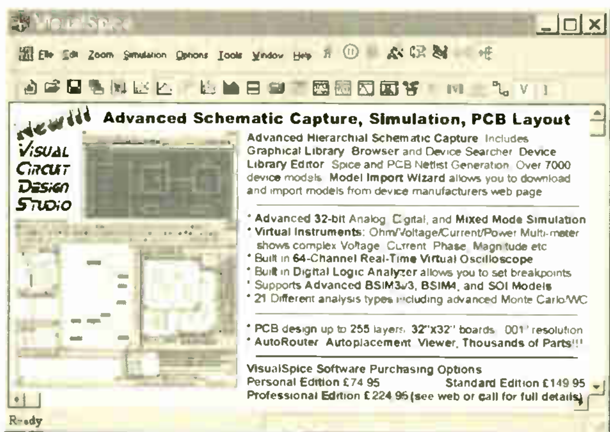

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AS3108	Assembled Serial Port Isolated I/O Controller	£69.95

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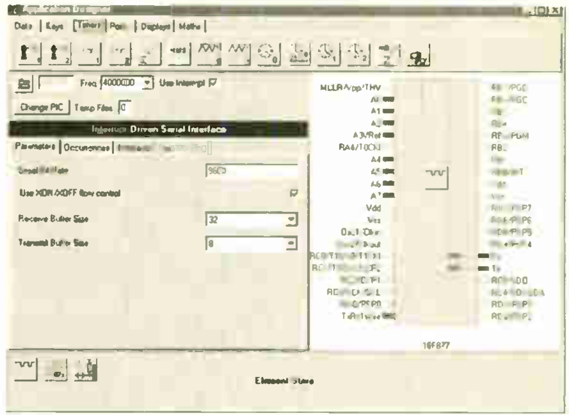

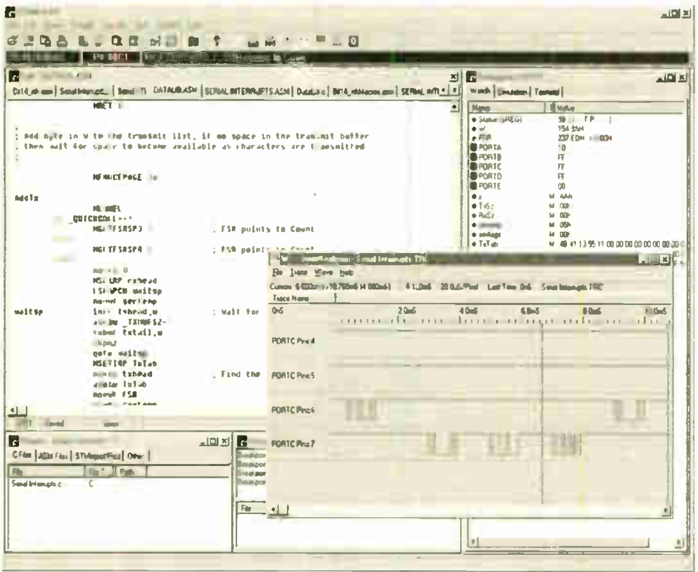

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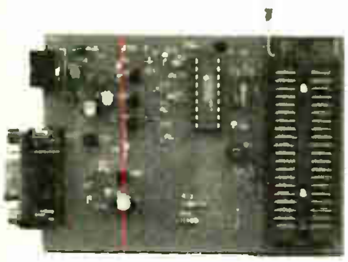

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WORRYING FIELDS

There has been much publicity lately about harmful fields – electromagnetic fields that is. Of course, our "Rife" supplement – *The End To All Disease* in the April issue – has also stirred up much comment, some of which seems to discount the facts presented out of hand. Might I suggest an open mind would be a better starting point. We have also been contacted by people who use this technology and claim good results. Suffice to say that the subject will run and run and hopefully will soon prove of general benefit to mankind.

Aubrey Scoon has been congratulated by many interested parties around the world for his well researched feature and a number of highly qualified people have added to the knowledge already assimilated. We hope to publish some follow up material in the fullness of time. To the one or two total sceptics, this was *not* an April Fool article, please read it again!

FIELD PROJECT

On a related subject this month's *Magfield Monitor* will enable investigation of all forms of magnetic field. So if you are worried about possible harmful magnetic fields around your home or place of work this project is well worth considering. It will, at the very least, make you aware of areas to be avoided, even if it is not possible to remove or screen the offending field "generator". Once again this area of research will go on and on, and no doubt we will see further revelations on the effects of low frequency electromagnetic fields in the future.

As we reported in *News* in the May issue the National Radiological Protection Board has issued a statement that "some epidemiological studies do indicate a possible small risk of childhood leukaemia associated with exposure to unusually high levels of power frequency magnetic fields".

Mike Kenward

AVAILABILITY

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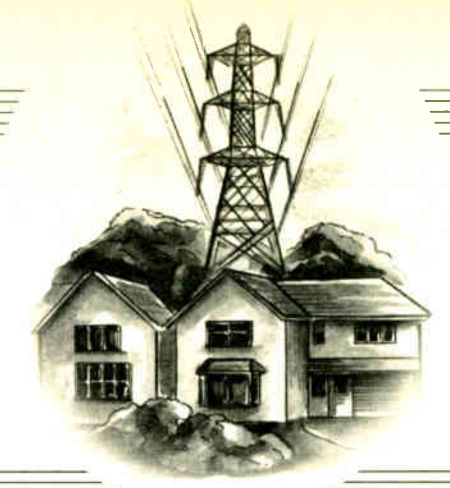
Constructional Project

MAGFIELD MONITOR



ANDY FLIND

MAGNETIC FIELD DETECTOR

A sophisticated fluxgate sensor monitors static and alternating magnetic fields, outputting processed signals to a meter and headphone amplifier.

WITH the recent news of links between power cables and childhood leukemia it is worth knowing if there are any strong electromagnetic fields around your home. This highly sensitive detector is based on an inexpensive magnetometer sensor. It will readily detect and indicate the relative strength of electromagnetic fields and will at least make you aware of any possible areas to avoid.

EARLIER SENSORS

The *Mood PICker* project, featured in *EPE* July '99, was a device which generated low-frequency alternating magnetic fields, which are thought by some to encourage desirable mental states, such as relaxation, creative imagery and restful sleep.

It followed an earlier but more complex project which performed the same task. In the August '99 issue, an associated design, the *Magnetic Field Detective*, was published. This was capable of demonstrating the presence of the weak, low frequency magnetic fields produced by these projects to give an idea of their relative strength.

Magnetic field sensor designs appear quite frequently in the electronic press, but most use either an inductor or a Hall effect device for detecting the fields, both of which lack serious sensitivity. Inductors suffer the additional disadvantage of being unable to sense static magnetic fields so they cannot detect the earth's natural field or the presence of stationary permanent magnets.

The *Detective* design overcame these problems by using an FGM-3 magnetometer device as the sensor. This is an extremely sensitive detector of absolute field strength but its output consists of a series of pulses having a mean frequency of about 64kHz. The device specification states that it is actually the *period* of these which changes in linear proportion to field strength.

Of course, this means that the frequency changes too, so the *Detective* simply mixed the sensor output with a similar reference frequency to generate an audio output, a technique similar to that used by BFO (beat frequency oscillator) metal detectors.

The resulting circuit was simple and very sensitive but, like the BFO metal detectors, irritating to listen to and difficult to adapt to other uses, such as operating a meter.

GREATER SOPHISTICATION

This design uses a more sophisticated circuit to measure the period of the FGM-3 output pulses and convert this to a voltage which can be amplified or processed in a variety of ways to make it far more useful. For example, a simple meter-driving circuit can be added and calibrated to read the earth's field, perhaps as the basis of an electronic compass or a marine navigation system.

Although the circuit uses a sample and hold technique, the output voltage is updated at a mean frequency of around 32kHz, so it will easily follow alternating fields well into the audio spectrum. All that is required to hear these fields, such as 50Hz radiation from mains appliances, is an amplifier and headphones.

In fact, both a meter and an amplifier can be connected simultaneously to the sensor circuit to provide a complete picture of the magnetic surroundings, a domain normally completely invisible. Users trying this for the first time will probably be astonished, not least by the all-pervading nature of the magnetic "hum" that usually permeates our living space.

FGM-3 SENSOR

The FGM-3 sensor is encapsulated in a 60mm long plastic tube with four connection pins projecting from one end as shown in Fig.1. Two of these are for the ground (0V) and +5V supply for the internal electronics, whilst a third is for a surrounding feedback coil, provided for applications which might require it. This is not used in this design.

The fourth pin is the output, which has a rail-to-rail rectangular waveform with a mean frequency of about 64kHz. According to the device data, the period of this varies in fairly linear proportion to magnetic field strength, which means the frequency varies in non-linear inverse manner. Thus it is desirable to convert the period rather than the frequency to a voltage output.

BLOCK DIAGRAM

A block diagram of the method used to achieve period-to-frequency conversion is shown in Fig.2. The output of the sensor

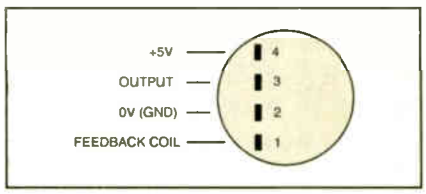


Fig.1. Pinout details for the FGM-3 sensor shown below.

drives control logic, which in turn operates three electronic switches. Initially, all three switches are open and a current generator supplies constant current through diode D1 into capacitor C1, so that the voltage across this capacitor rises at a uniform rate.

The final voltage reached depends directly on the time for which switch S1 remains open, which in this design is one complete period of the input, after which it is closed to divert the current to ground. During the next period, S3 is first closed briefly to transfer the voltage from C1 to capacitor C2.

Obviously, this causes the voltage across C1 to fall, but the whole cycle is repeated very rapidly and in a very short time C2 will attain the maximum voltage reached across C1.

Before the second period ends, S3 is opened again and S2 is closed to discharge C1. Then all three switches are opened again for the start of the next period and the entire cycle repeats. The buffer amplifier allows the voltage from C2 to be connected to other circuitry without loading it.

CIRCUIT DIAGRAM

The full circuit interpretation of the sensor block diagram of Fig.2 is shown in Fig.3. The output from the FGM-3 sensor is processed by the control logic consisting of quad NOR gate IC1, and 12-stage binary divider IC2 which divides by two to select the alternate periods.

Three logic output waveforms related in the manner shown in Fig.4 are generated, which for convenience may be referred to as Hold, Read and Reset. If it is assumed that the circuit is at point *A* in Fig.4, all three outputs are low, so transistors TR1 and TR2 are both *off*.

Component IC4, a CMOS 4007 device which comprises a dual transistor pair plus inverter, is wired as an electronic switch. At point *A* in Fig.4, consider it to be *open* and that a charging cycle is about to take place with a constant current of just under half a milliamp. This is sourced from the positive rail by a current generator formed by op.amp IC3a and transistor TR3.

Since TR1 and TR2 are off, this current flows through diode D1 into capacitor C7 causing the voltage across this capacitor to rise in linear fashion. At point *B* of Fig.4 the Hold output goes high and turns on transistor TR2. As a result, the current is diverted through this to ground and charging ceases. Existing charge is prevented from taking this path by diode D1.

Simultaneously, the Read output goes high, closing switch IC4 so that charge from C7 is transferred through resistor R7 to capacitor C8. The second op.amp, IC3b, buffers the voltage across C8 and presents it as output.

At point *C* in Fig.4, the Read function is turned off and Reset is turned on briefly to discharge C7. All three logic signals then return to the low state and the entire cycle is repeated.

The mean output frequency from the FGM-3 when placed horizontally in an east-west alignment is about 64kHz. With the divide-by-two action of IC2, the circuit operates at about 32kHz, though this changes considerably with the position of the sensor relative to the earth's field plus, of course, any other magnetic field sources within range.

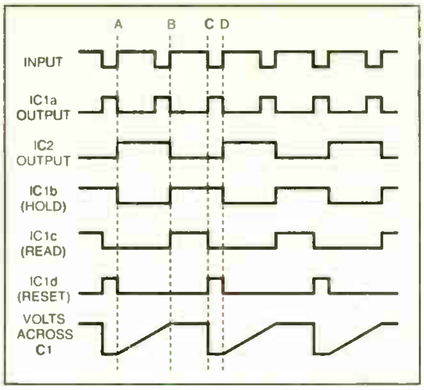


Fig.4. Logic outputs and timing waveforms for Hold, Read and Reset at various stages of the Sensor circuit.

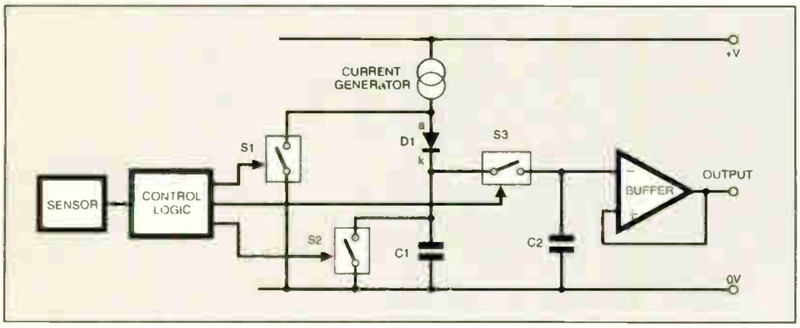


Fig.2. Block diagram for the Magfield Monitor sensor.

Completed Magfield Monitor.

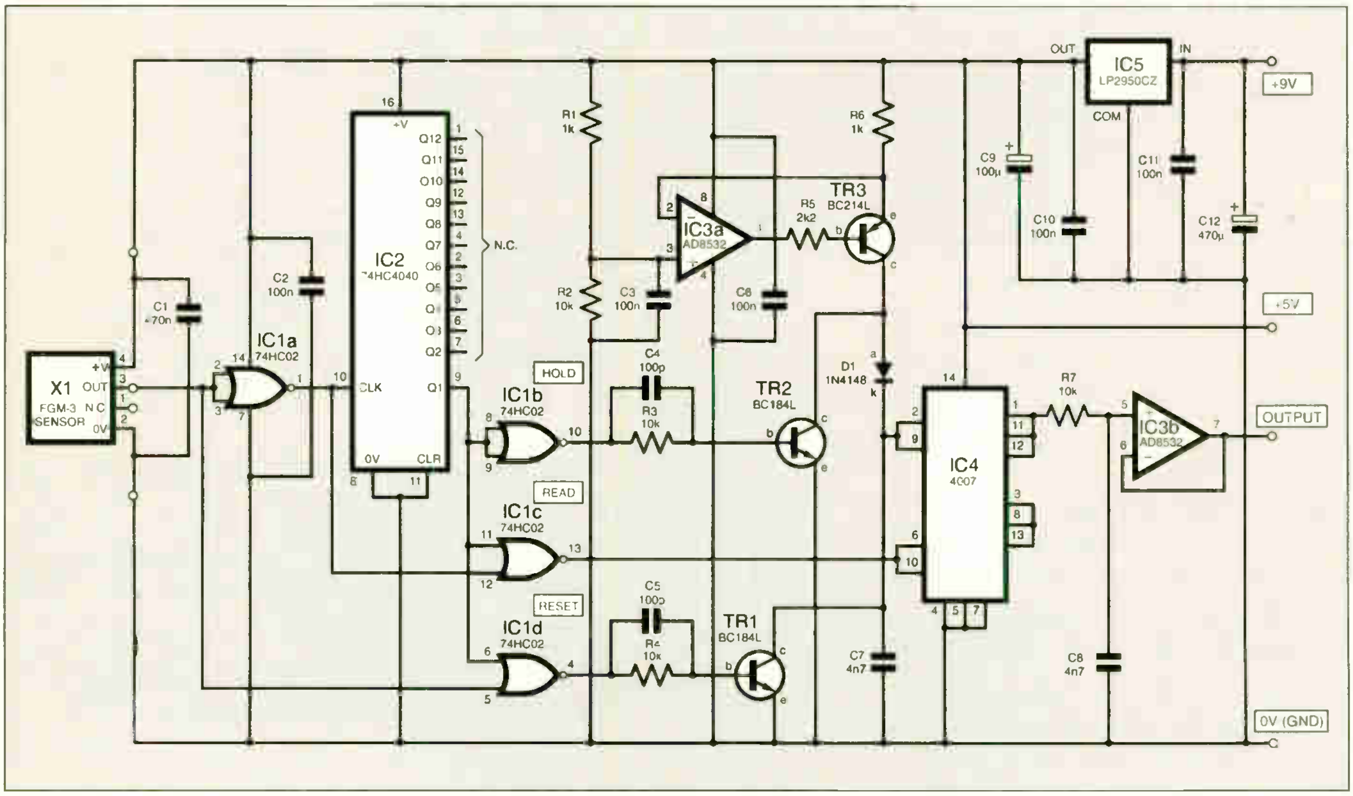


Fig.3. Complete circuit diagram for the sensor stage of the Magfield Monitor.

NOTABLE POINTS

Some points to note regarding this design include IC3, which features rail-to-rail inputs and outputs. Many other types of op.amp do not have this capability and simply will not work in the current generator stage used by this circuit. Only use the type AD8532 as listed.

High-speed types are used for IC1 and IC2 to keep propagation delays to the minimum. The 74HC02 quad 2-input NOR gate (IC1) has a different pinout from the more common 4001B, so the latter should not be tried as a substitute. The pinout details for IC1 and IC4 are shown in Fig. 5.

Finally, capacitors C4 and C5 were added at a late stage, as will be seen from the printed circuit board (p.c.b.) layout. Prior to the addition of these, the circuit worked satisfactorily but the 'scope revealed a small delay between the end of each reset pulse and commencement of the voltage ramp across capacitor C7.

Investigation revealed this to be caused by a slow turn-off of transistors TR1 and TR2, which are driven well into saturation when *on*. The addition of the two capacitors cured the problem. The circuit works quite happily without them but for operation to be exactly as intended they should be included.

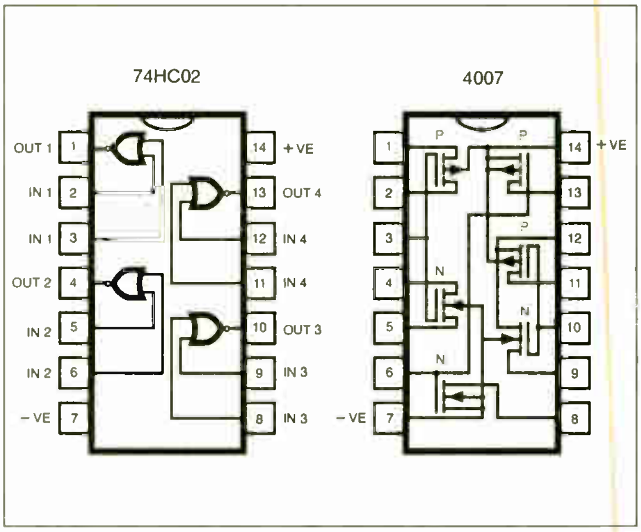


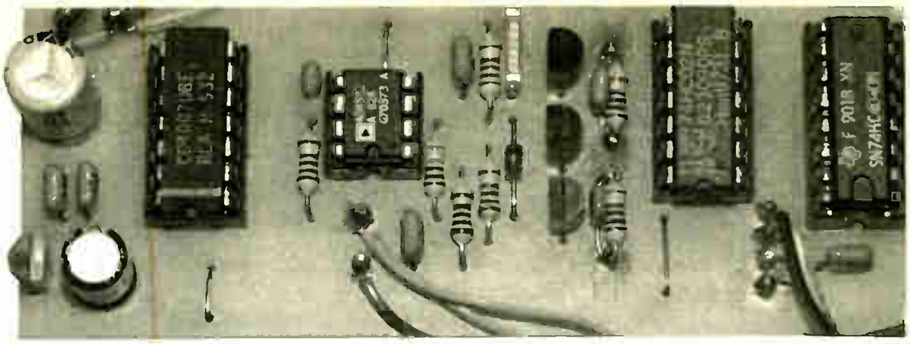
Fig.5. Pinout details for the 74HC02 and 4007 i.c.s.

The FGM-3 sensor, IC1 and IC2 all require a 5V supply so the entire circuit has been designed to work from this voltage, which is supplied via regulator IC5. This is a CMOS LP2950CZ micropower type, selected for its ability to work with a very low input-to-output differential, which makes it ideal for use with a 9V battery supply. A connection on the p.c.b. allows the 5V supply to be used by external circuits requiring a voltage reference, such as meter amplifiers.

CONSTRUCTION

The sensor circuit is built on a single-sided printed circuit board (p.c.b.) and the topside component layout and full-size copper foil master are shown in Fig. 6. This board is available from the *EPE PCB service*, code 302.

Construction of this circuit is fairly straightforward with the positions of all the components shown in Fig.6. As usual, the use of solder pins for off-board connections and dual-in-line (d.i.l.) sockets for IC1 to IC4 are recommended.



Completed prototype Sensor board. Note the resistor/capacitor combination for R3/C4 and R4/C5.

The method of fitting capacitors C4 and C5 is shown in detail above the component layout. These capacitors may be soldered to the resistors before these in turn are fitted to the p.c.b.

In the prototype, the FGM-3 sensor is connected via about 40cm of ribbon cable. Since the case contains a meter which has an internal magnet and a battery with a ferrous case, it is desirable to position the sensor some distance from these. Depending on the intended use, it may also be necessary to vary the position of the sensor relative to the box.

A socket is fitted to the sensor end of the cable to allow it to be plugged in. This is made from an eight-pin d.i.l. socket sawn carefully in half, which fits perfectly onto the FGM-3's pins. Note that a turned-pin socket will not fit these pins as they are too wide, but cheaper types are fine!

The 470n ceramic capacitor, C1, is soldered across the supply pins of the socket for local supply decoupling, and the lead connections are strengthened with heat-shrink sleeving. An advantage of this socket arrangement, apart from minimising the risk of damage to the sensor, is that it allows it to be used in other projects if desired. Details of it are shown in Fig.7.

TESTING

A compass will be found useful when testing this project! Before plugging in the

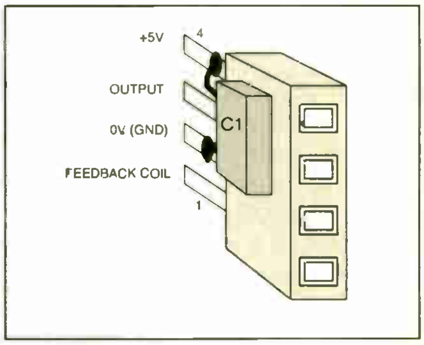


Fig.7. Cut-down 8-pin d.i.l. socket for the FGM-3 sensor. Note C1 across the +5V and 0V pins.

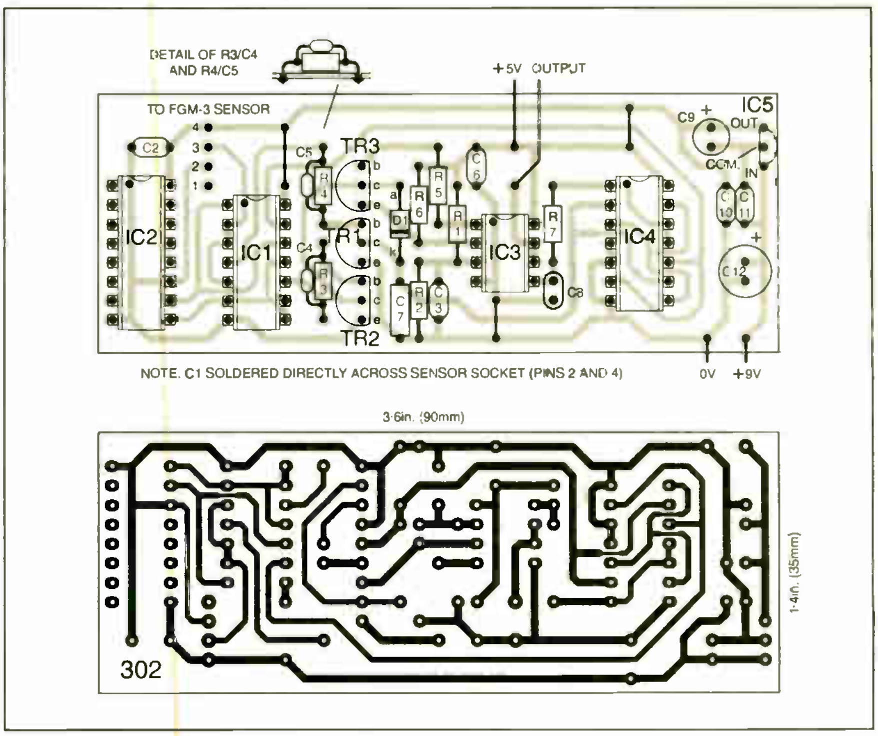


Fig.6. Printed circuit board component layout and underside copper foil master for the sensor board.

sensor or any of the i.c.s the +5V supply from IC5 should be checked. It can be measured at the +5V connection point on the board.

Following this, the sensor can be connected and tested on its own. It will draw about 14mA from the supply, and checking its output with a voltmeter will probably reveal a voltage of around 3·7V, *not* half the supply since the output is not necessarily a perfect squarewave. If an oscilloscope is available, the output can be viewed with this and the effect of sensor movement directly observed.

The next step is to insert IC1 and IC2 to complete the control logic. Some further tests are now possible.

First the output from IC2, pin 9, should be a perfect squarewave and therefore read exactly half the supply on a voltmeter. Pin 10 of IC1 should do likewise. Pins 4 and 13 will have lower voltages as they do not have perfect square waves, but a voltage somewhere between the supply rails should be observable on each.

There is no point in checking pin 1 of IC1 since if the output of IC2 is OK then this must be too!

Although this circuit only uses IC2 to divide by two it is actually a 12-stage divider, so plenty of lower frequencies, right down to audio and below, could be tapped when the circuit is working, by directly soldering connections to them.

Output 6, from pin 2, should be centred around 1kHz and may be heard as a whistle with the aid of an amplifier or headphones, the pitch of which should vary when the sensor is moved.

Finally, the remaining i.c.s can be inserted for a check of the complete circuit. The overall current consumption should be around 16mA, and the output voltage for the prototype is about 1·4V with the sensor placed on a horizontal surface in an approximately east-west alignment, varying from 1·9V to 1·0V as it is turned from north to south.

Moving it away from the horizontal will result in higher and lower voltages as it responds to the "dip" of the earth's magnetic field, which many readers may recall from their school physics.

SIMPLE ADD-ONS

A voltage signal by itself is not of much immediate use. Although many constructors will have plenty of ideas of their own regarding uses for the output of this board, there will be others who would prefer detailed description of useful add-ons, so here are a couple which can be constructed easily and quickly on stripboard.

They proved so fascinating with the prototype that all three were promptly fitted into a box with a battery, switch and control to turn them into a self-contained and easy-to-use unit.

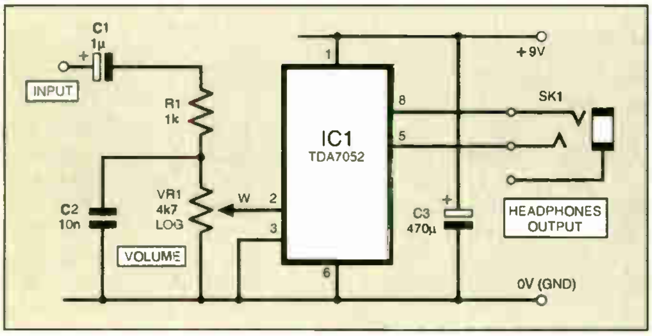
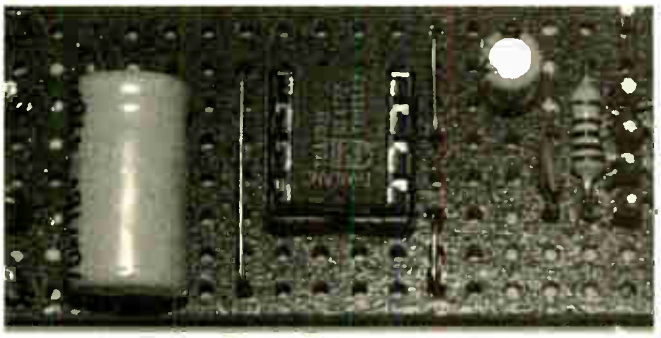


Fig.8. Circuit diagram for a simple add-on audio amplifier.



Stripboard component layout for the add-on amplifier.

AUDIO AMPLIFIER

The first is an audio amplifier using the TDA7052 amplifier i.c., which has a bridge output intended for use with low voltage supplies. This is a very simple amplifier to use, requiring only a volume control and four other components to make a complete circuit, as shown in Fig.8.

Capacitor C1 isolates the amplifier from d.c. voltage at the input, whilst allowing audio signals to pass. In this project, large input voltage swings occur due to movement of the sensor through the earth's field and these can overload the amplifier, causing an annoying "blocking" effect. The use of a fairly low value for C1, together with suitable values for resistor R1 and Volume control VR1, minimise this by producing a frequency "roll-off" below about 25Hz.

Resistor R1 and capacitor C2 attenuate noise and signals above the audio range. The only other component, capacitor C3, is a supply decoupler. The circuit is powered from the 9V battery supply and the input is connected directly to the output of the Sensor board. It is used with "Walkman" type headphones, with the socket wired so as to connect the earpieces in series.

CONSTRUCTION

Construction of the amplifier circuit is very simple, using a piece of 0·1in stripboard with eight strips of 17 holes. The

COMPONENTS

Approx. Cost Guidance Only **£40** *excl. case, meter & batt.*

Magfield Sensor Board

See SHOP TALK page

Resistors

R1, R6	1k (2 off)
R2 to R4, R7	10k (4 off)
R5	2k2

All 1% 0·6W metal film

Capacitors

C1	470n resin-dipped ceramic
C2, C3, C6, C10, C11	100n resin-dipped ceramic (5 off)
C4, C5	100p ceramic (2-off)
C7	4n7 polyester layer
C8	4n7 resin-dipped ceramic
C9	100µF radial elect. 16V
C12	470µF radial elect. 16V

Semiconductors

D1	1N4148 silicon diode
TR1, TR2	BC184L *npn* transistor (2-off)
TR3	BC214L *pnp* transistor
IC1	74HC02 quad 2-input NOR gate
IC2	74HC4040 12-stage binary ripple counter
IC3	AD8532 dual rail-to-rail op.amp
IC4	4007UB complementary pair plus inverter
IC5	LP2950CZ 5V 100mA micropower regulator

Miscellaneous

X1	FGM-3 fluxgate sensor
S1	s.p.s.t. min. toggle switch

Printed circuit board, available from the *EPE PCB Service*, code 302; plastic case (see text); PP3 battery connector; 8-pin d.i.l. socket; 14-pin d.i.l. socket (2 off); 16-pin d.i.l. socket; ribbon cable; solder pins; solder, etc.

Audio Amplifier

Resistor

R1	1k 1% 0·6W metal film

Potentiometer

VR1	4k7 min. rotary carbon, log

Capacitors

C1	1µ radial elect. 63V
C2	10n resin-dipped ceramic
C3	470µ radial elect. 16V

Semiconductor

IC1	TDA7052 amplifier

Miscellaneous:

SK1	6·35mm stereo jack socket, panel mounting

Stripboard, 0·1in, 8 strips x 17 holes; 8-pin d.i.l. socket; link wire; solder etc.

Meter Amplifier

Resistors

R1, R2, R4, R5, R9	10k (5-off)
R3	22k
R7	1k
R6	33k
R8	560k

All 1% 0.6W metal film

Potentiometers

VR1, VR2	10k 22-turn cermet preset, vertical top adjust. (2-off)

Capacitor

C1	100n resin-dipped ceramic

Semiconductor

IC1	LM358 dual op.amp

Miscellaneous

ME1	100µA moving coil meter

Stripboard, 0.1in, 8 strips x 17 holes; 8-pin d.i.l. socket breaks in the copper strips are shown in Fig.9, along with the component layout and link wire positions. The large capacitor C3 is fitted horizontally as shown to give a low profile. Care should be taken to observe correct polarity for this and C1.

The use of a d.i.l. socket is recommended for IC1. The completed amplifier may be tested independently. For this VR1 must be connected, at least temporarily. Note that this must be a 4k7 (or 5k) component and its presence is essential as the i.c. obtains d.c. input bias current from it.

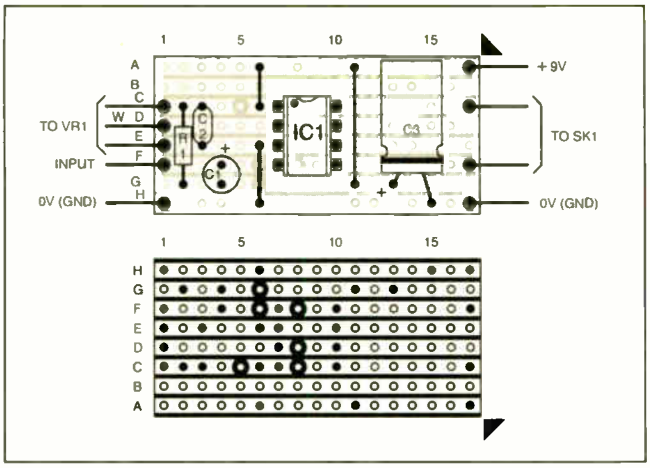


Fig.9. Audio amplifier stripboard component layout and details of breaks required in the underside copper strips.

When powered with 9V the circuit should draw about 5mA to 6mA supply current and the voltage at both output pins should be about half the supply, or 4·5V.

The headphones can be temporarily connected to the output and should produce no significant change in the supply current. There will probably be some audible hiss from the circuit which will be adjustable with VR1. Placing a finger on the input will usually result in hum, again adjustable. This confirms that the amplifier is working correctly.

This simple amplifier will probably find plenty of applications in other projects. It is capable of driving an 8Ω loudspeaker, although this is *not* recommended with this project as the resulting fluctuations in supply current may cause instability.

Additionally, many of the sounds to be heard originate from the 50Hz a.c. mains (60Hz in some countries) and such low frequencies are not reproduced well by small loudspeakers. Much better results are obtained from good quality headphones.

METER AMPLIFIER

The meter amplifier's circuit diagram is shown in Fig.10.

Preset potentiometers VR1 and VR2 provide Zero and Sensitivity calibration adjustment. The use of dual op.amp IC1 allows their action to be practically independent. Both op.amps are used in the inverting mode with their input working voltage set to about 1·5V by resistors R3 and R4.

The circuit is designed to use a standard 100μA moving coil meter which is biased for "centre zero" operation. It can be set-up so that when the sensor is in an east-west position it reads about half-scale, with equal deflection in either direction as the sensor is moved away from this position.

Current flowing to or from the input of the first stage through resistor R2 can be initially "balanced" by current from R1 set with the Zero adjuster VR1, so that the output is equal to the reference voltage from R3 and R4. This means that Sensitivity control VR2 will not have much effect on the Zero setting and could even be panel-mounted if preferred.

Current flowing through VR2 and R7 must, of course, be balanced by an equal and opposite current through meter ME1 and resistor R9, so the value of VR2 directly affects sensitivity. To obtain the "centre-zero" effect without spoiling the independence of this control, resistors R6 and R8 draw approximately 50μA from the input of IC1b, which again has to be balanced by current flowing through the meter.

The entire circuit draws very little current and is supplied directly from the 5V regulated output from the Sensor board.

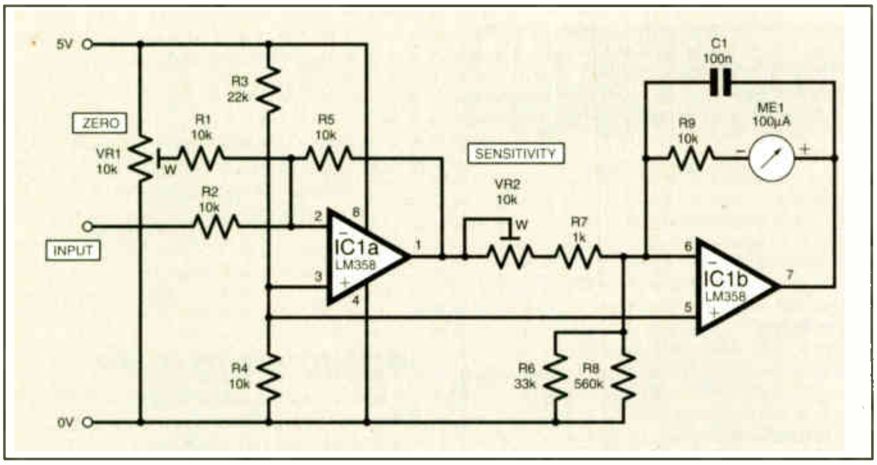


Fig.10. Circuit diagram for the add-on meter amplifier.

CONSTRUCTION

The meter circuit is constructed on a piece of 0·1in stripboard with 11 strips of 21 holes. The breaks and component positions are shown in Fig.11. There are nine links on this board, which should be fitted first. The two presets are 22-turn types which make adjustment easy. Although they can be inserted either way up, fitting as shown will result in clockwise rotation of either causing the meter to deflect to the right, giving a logical "feel" to the adjustments.

A d.i.l. socket is recommended for IC1 although this time the i.c. is the very inexpensive LM358.

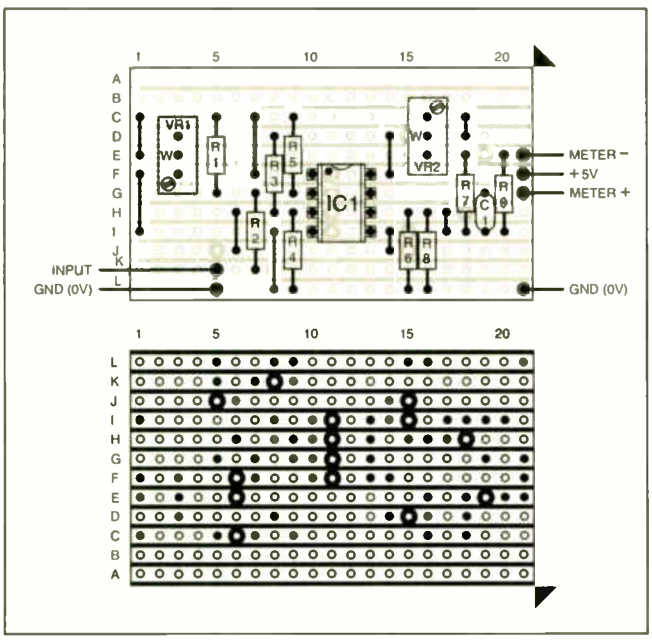
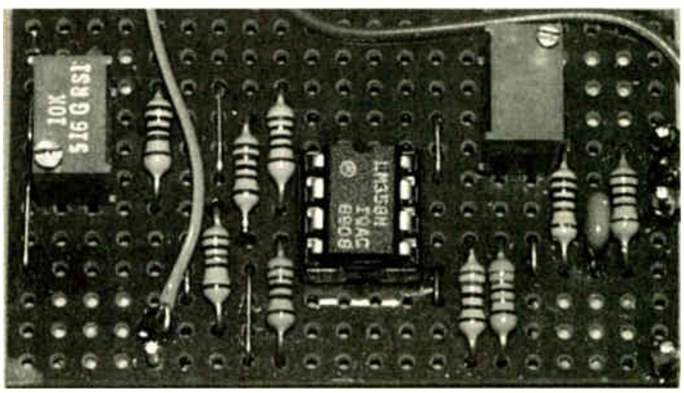


Fig.11. (left) Meter amplifier stripboard details and (below) component layout on completed circuit board.



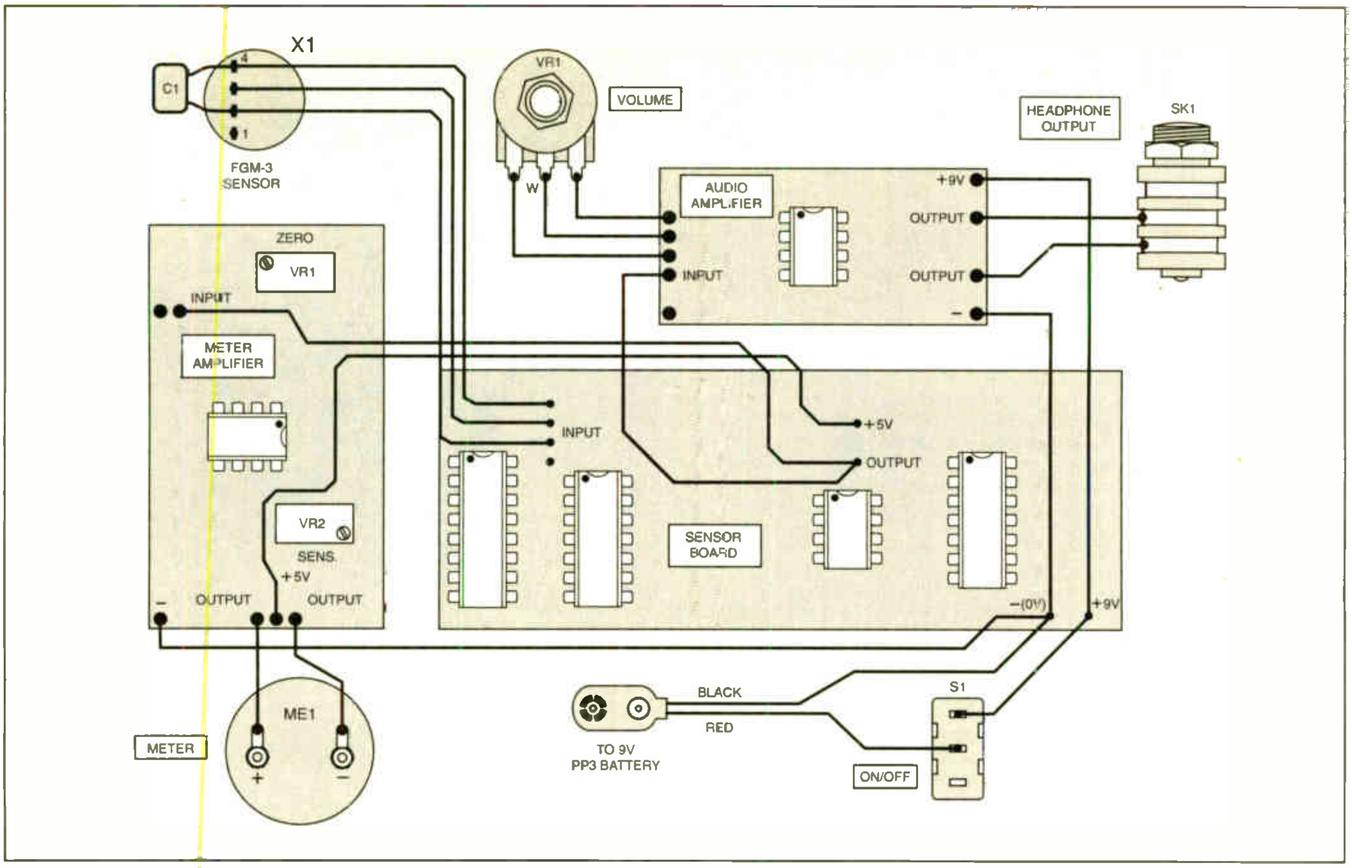


Fig.12. Interwiring details from the three circuit boards to the off-board components.

METER TESTING

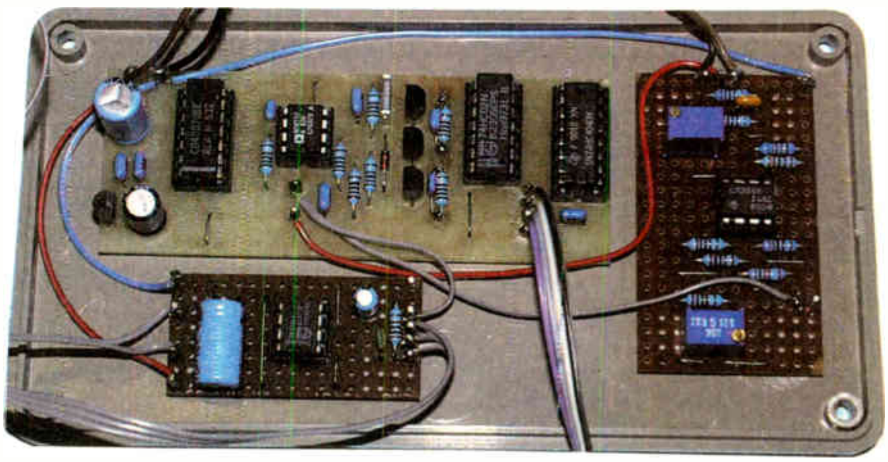
For testing the board, the meter should be temporarily connected and the circuit should be powered with 5V, preferably from a bench supply in the first instance. The supply current should be no more than a couple of milliamps. Preset VR2 should be set fully anti-clockwise at this point for lowest sensitivity, achieved by turning it until it clicks.

With the input open circuit, it should be possible to adjust the meter to centre-scale (50µA) with VR1. "Wet fingers" applied across the input and positive or negative supply should produce small deflections to the right and left respectively. If this is OK, the board can be connected to the 0V and +5V supplies and the output of the Sensor board.

With the sensor in an east-west position, VR1 should be trimmed to give a half scale reading, then the sensor can be rotated to north-south and VR2 set up to give the required amount of deflection. With care it is possible to set it up so that a horizontal sensor goes from one end of the scale for north to the other for south.

The prototype goes from positive (full scale) for north to negative (zero) for south. Greater sensitivity can be set with VR2, the maximum was found to be full scale for about eight degrees of rotation in either direction.

The general stability of the circuit suggests that increased gain could be used if required. A small problem with this circuit is that, since the meter contains a magnet and the unit will probably be operated by a battery with a ferrous case, movement of the sensor relative to the unit may upset the calibration. If this proves to be a problem the relative positions of sensor and control unit should be established before final calibration, or the two presets can be replaced by user-accessible front panel controls.



Completed sensor, audio amplifier and meter amplifier boards mounted in position on the base (lid) of the prototype case.

FINAL ASSEMBLY

The three circuit boards can be fitted into any case preferred by the constructor. The prototype used a grey ABS plastic case with dimensions of 150mm × 80mm × 50mm, reclaimed from the author's "junk box". It was already drilled for a meter and the volume control, having been salvaged from some long-forgotten previous project.

A PP3 battery holder was fitted into the side of the box and the three boards secured to the base with blobs of Blu-Tack where they are easily accessible for inter-connection and future experiments. Double-sided adhesive tape might be used if preferred. The wiring between the boards etc. is shown in Fig.12.

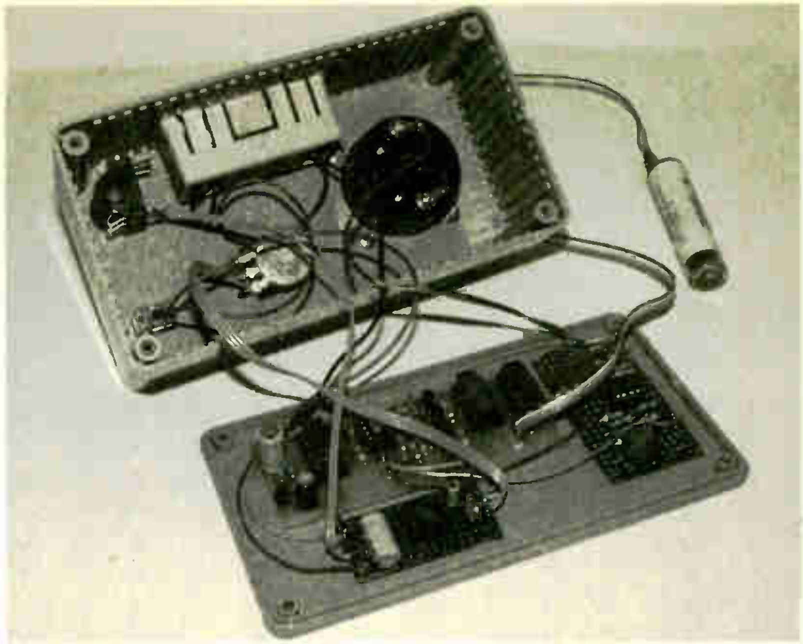
The headphone socket is a 6·35mm type and is wired so that the headphones are connected in series. Walkman type phones generally have 3·5mm plugs so they are used with an adaptor. A 3·5mm chassis socket could be used instead.

HUMMING NICELY

In use, the most fascinating aspect of this project for most constructors will probably be the sounds that can be heard with it. A 50Hz "hum" frequently sounds "different" from that heard with circuits using inductive sensors, and the sensitivity is in any case far greater than most of these.

Users will probably be astonished by the extent of the 50Hz magnetic field which surrounds so many of us nowadays. Anything containing a transformer normally radiates strongly but the field surrounding the domestic electricity meter is often even more powerful. Pole-mounted 415V power lines outside the author's house

The finished Magfield magnetic field detector



Interwiring between the front panel components and the circuit boards

were found to generate a field that could still be detected at a range of 100 metres.

Although the frequency response begins to roll off at about 500Hz the attenuation is very gradual and signals with frequencies of several kilohertz emanating from various items of digital electronic equipment, especially a small FAX machine, could be heard. The pulses from an analogue quartz wristwatch were audible up to about 5cm.

Of course, the signals from *Mood PICker* devices were loud and clear. Although these might be expected to be inaudible because their frequencies are below the amplifier's low-frequency roll-off, their outputs are digitally generated in steps at about sixteen times the nominal frequency, and these are clearly reproduced by the headphones.

This design's combination of audio output plus meter indication of static magnetic fields gives access to a whole new dimension, normally completely hidden, which should prove fascinating to all constructors of this project. □

News . . .

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

PLAYSTATION AND DVDS

Barry Fox explains why your DVD movie discs might not work

WHEN Sony launched Sony Playstation 2 in Japan, its DVD playback capability doubled the number of DVD players in the country over a single weekend. The same thing is happening in Europe but some proud owners are finding they cannot play movie discs. This is because they are trying for too good a connection!

PS2 comes with an AV output connection cable that ends in three phono plugs, for audio left, audio right and composite video. There is also a Euro-AV Connector plug that lets the same lead connect to the Scart socket on a TV set. An RF modulator is available as an optional extra. So is an S-Video cable. All these work equally well for games or movies.

But there is also an optional extra Euro-AV Cable with moulded Scart plug, and the PS2 can be set by the Menu options to feed RGB signals into the Scart socket of a TV. This gets the best possible picture quality for games.

But the PS2 deliberately blocks playback of movies in RGB output mode. This is because Macrovision copy protection only works on RF, composite or component S-Video playback.

RIPPING MUSIC

By Barry Fox

MP3 ripping is now a living room reality. Korean electronics giant Samsung is the first big brand name in household audio to offer a range of mini, midi and micro hi-fi systems with integrated MP3 ripper. Until now consumers have had to use a PC to download MP3 music from the Internet or "rip" CDs by converting the content into MP3 (MPEG-1, Layer 3) code. The PC must then be connected to a portable solid state player like the Diamond Rio, to transfer the music for portable playback.

Three new home audio stacks from Samsung (costing between £350 and £500) have a CD player, built-in MP3 encoder and dockable Yepp solid state player with 32MB SmartMedia card for 30 minutes recording time. The owner just plays a disc while transferring the music to the portable, without needing to own a PC or know anything about computers and computing.

SPLASHPROOF METERS

Lascar Electronics have introduced a new series of digital panel meters combining a low profile with miniature "component style" body. The SP series can provide splashproof protection to IP65 when the supplied silicon seal is fitted.

The range features 3.5 digit l.e.d. and l.c.d. readouts, auto-polarity and 200mV full scale reading. The l.c.d. versions include high efficiency l.e.d. backlighting.

Prices start at £17.95 plus VAT. For an introductory period all customers ordering five or more will receive a free digital multimeter.

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

RA WEBSITE RELAUNCHED

The Radio Communications Agency, the UK's Government body responsible for licensing civil use of the radio spectrum, has restructured its website. The RA's aims have been to make the site easier to use, to focus more on customers' areas of interest and provide more links to other sites.

New Topic pages have been added, plus an A-Z index for finding documents and links.

Browse **www.radio.gov.uk**.

MULTISIM UPGRADED

A new version of Multisim, the widely acclaimed circuit design and simulation tool for Electronics Workbench, is now available from Adept Scientific, one the world's leading suppliers of software and hardware products for research, scientific, engineering and technical applications for desktop computers.

Offering a flexible EDA (electronics design automation) solution with features to match products costing several times its price, Multisim 2001 is said to produce high quality designs in less time with "seamless" transfer to p.c.b. layout.

Internet access to millions of virtual parts via **edaPARTS.com** is among the highlights of this new version.

For more information contact Adept Scientific plc, Dept EPE, Amor Way, Letchworth, Herts SG6 1ZA. Tel: 01462 480055. Fax: 01462 480213.

E-mail: multisim@adeptscience.co.uk.

Web: **www.adeptscience.co.uk**.

SSE Phones Changed

SOLID State Electronics (SSE), whose excellent meter stands we featured in last month's News, have told us that BT has changed their phone and fax number prefixes! The numbers to now use are, Tel: 02380 769598, Fax: 02380 768315.

Maplin's Quarterly Cat

Maplin Electronics tell us that they have made it even easier for customers to keep up to date with the very latest in state-of-the-art technology with a new quarterly catalogue supplement "crammed with over 500 great products".

Packed with product pictures, information and offers, the supplement has over 60 pages of products and includes £45 of money-off vouchers and "buy one get one free" promotions.

The annual catalogue will continue to be published each September with supplements each Spring, Summer and Winter.

For more information contact Maplin Electronics, Valley Road, Wombwell, Barnsley S73 0BS. Tel: 01226 751155. Fax: 01226 340167.

Web: http://**www.maplin.co.uk**.

Bull Moves

Bull Electrical, the renowned wholesale electronic and hydroponic distributors, have moved to new premises. The new details are: Bull Electrical, Dept EPE, Unit D, Henfield Business Park, Shoreham Road, Henfield, Sussex BN5 9SL. Tel: 01273 491490. Fax: 01273 491813.

E-mail: sales@bull-electrical.com.

Web: **www.bull-electrical.com**.

Peak Electronics Move Too

Peak Electronic Design, well known for their component analyser designs, have moved as well. The details are:

Peak Electronic Design Ltd., Dept EPE, Kiln Lane, Harpur Hill Industrial Estate, Buxton, Derbys SK17 9JL. Fax: 01298 70046.

Other details remain the same, as Tel: 01298 70012.

E-mail: sales@peakelec.co.uk.

Web: **www.peakelec.co.uk**.

NEW PROTEUS MODELS

Labcenter tell us that since they launched Proteus VSM last summer, they have continued with a vigorous development program aimed at widening support for the most popular microcontroller families. They have now introduced models for the PIC16F87x and HC11 families.

The PIC16F87x family model is available as an add-on to the original VSM package for £100. The HC11 library costs £200.

Labcenter also offer an on-line update subscription service through which they inform subscribers of the latest releases. There is also a secure download area from which you can install them.

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

Rapid's New Cat

Receiving Rapid Electronics new catalogue (Apr-Sep '01) confirms what we have previous said about Rapid - that their cat is definitely one that all self-respecting electronics enthusiasts should have on their workbench.

We believe that we would only just be stretching the truth if we said that "everything you need is covered"! Around 800 pages, in full colour and well-presented format, the latest issue seems to affirm this – far too many products for us to begin to mention. Rapid appear to have sourcing connections with an enormous selection of manufacturers.

For more information contact Rapid Electronics Ltd, Dept EPE, Severalls Lane, Colchester, Essex CO4 5JS. Tel: 01206 751166. Fax: 01206 751188. E-mail: sales@rapidelec.co.uk.

Web: **www.rapidelectronics.co.uk**.

EOCS

Receiving the latest Electronic Organ Magazine from the Electronic Organ Constructors Society (EOCS) again allows us the opportunity to "plug" this worthwhile group of enthusiasts.

With a history dating back many decades, the EOCS welcomes anyone with a like-minded interest in electronic organs. Their magazine is published quarterly and includes articles of a diverse musical nature and written by the members. Meetings are held periodically at venues in London, Essex and the South Coast.

For more information contact Trevor Hawkins, Hon. Secretary, EOCS, 23 Blenheim Road, St Albans, Herts AL1 4NS. Tel: 01727 857344.

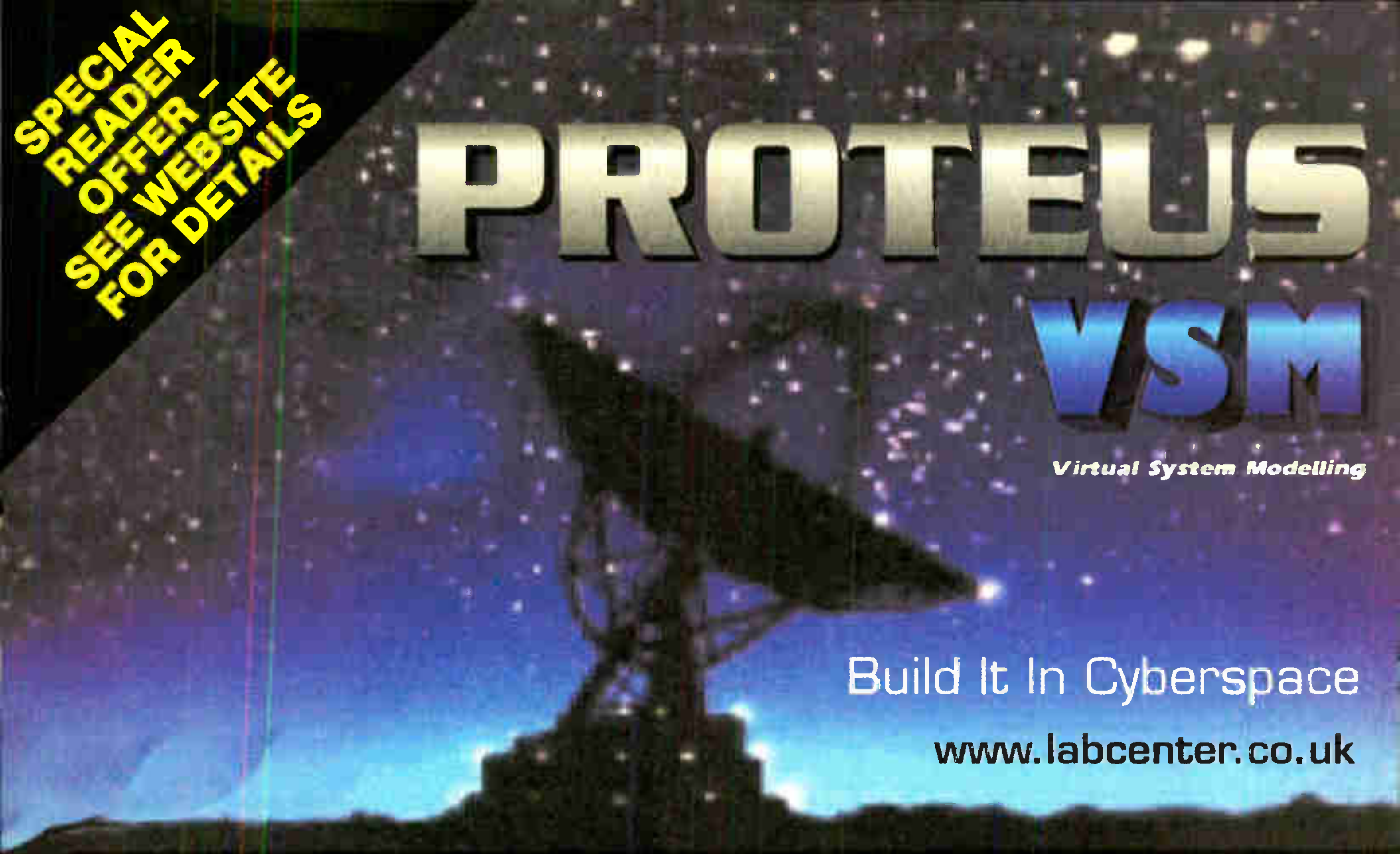
ELECTRONICS SHORTAGE

The UK Electronics Industry is under threat from skills shortages and a lack of investment in research and development, according to a recent report from KPMG, a leading global business adviser with offices in 157 countries.

Currently, the UK has the fifth largest electronics sector in the world, with annual revenues of $130 billion, out of a total $1 trillion revenues world-wide. The electronics industry has historically been a great success for the UK. It is the preferred location for the European headquarters of many of the major international electronics firms, the majority of which are US or Japanese owned.

KPMG compiled the report with assistance from the Federation of the Electronics Industry (FEI). A survey showed that 98 per cent of those questioned regarded skills shortage as the most pressing issue for industry. Over 90 per cent of those surveyed said that working with the education sector to alter the perception of the industry would help to improve public awareness and attract employees.

The report also states that 68 per cent of industry leaders called on the Government to place a higher priority on encouraging R&D, which at present is lagging behind the growth in the market and that this gap is widening.



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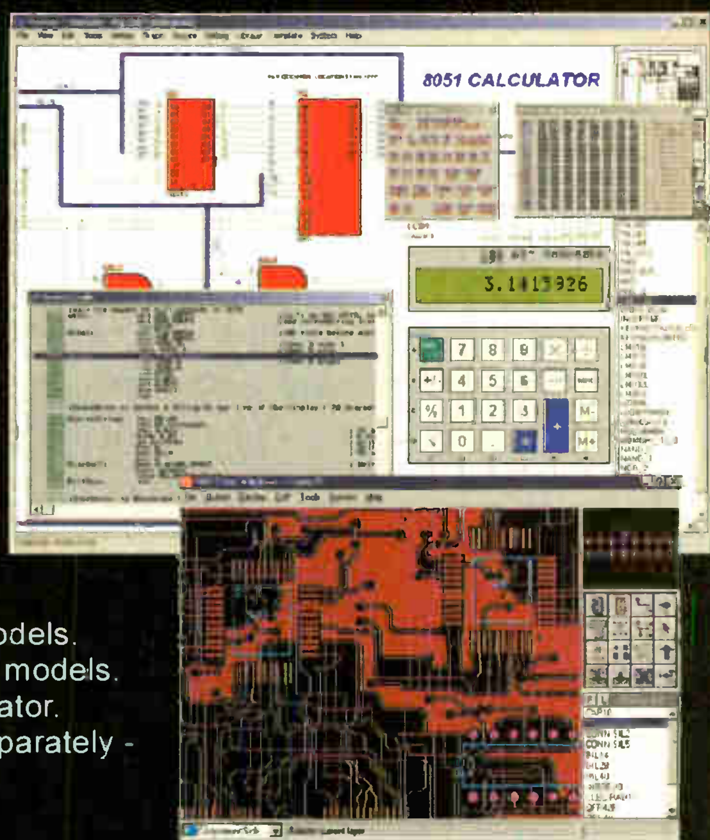

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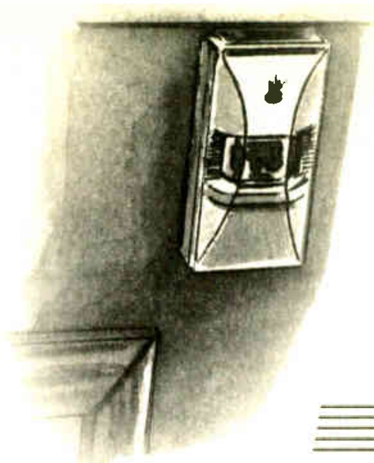
Constructional Project

DUMMY PIR DETECTOR

BART TREPAK



An extremely inexpensive way to fool would-be intruders

PERHAPS the biggest obstacle to fitting a burglar alarm in the home is the prospect of all the disruption caused by wiring door and window contacts and running wires all over the house back to the control unit. This has probably led many people to adopt an ostrich like approach, convincing themselves that "it will never happen to me".

Manufacturers have also realised this and have designed volume sensors, such as PIR (passive infra-red) devices which detect the body heat of an intruder entering the room. These avoid the need to wire up individual sensors to protect every door and window. Even the problem of connecting these devices to the control unit has been solved in some cases by utilising radio transmitters and receivers.

Coupled with the latest microprocessor technology, many domestic burglar alarms are now very sophisticated, but this does come at a price. So, having removed one obstacle to fitting an alarm, they have presented another.

FALSE ALARM

Even the latest micro-based design, however, does have two major drawbacks. It can be prone to false alarms and it only sounds the alarm *after* the burglar has broken in, often having caused considerable damage to a door or window in the process.

Whilst the alarm will then go off and the intruder will run off empty handed, the owner is left with the inconvenience of having to arrange for glaziers, or carpenters to come and repair the damage. It is much better to dissuade the burglar from attempting to break-in in the first place, rather than to detect and scare him off after he has.

DECEPTION

To this end, many householders fit a dummy bell box to the front of their house. The problem here is that although they are fairly inexpensive, they need to be mounted on an outside wall, which could require the purchase or hire of a ladder, or arranging for someone to do the job, adding further to the cost. Again this can mean that it is put off until later, and often too late.

Another problem is that, being mounted at a high level, it is likely to be missed (especially in the dark) and so not act as a deterrent at all.

The device described here overcomes all of these problems by mimicking a PIR sensor. With a cost of about £7 (excluding batteries.) and installation consisting of hammering a small nail into a plaster wall, a "sensor" can easily be placed in every room. If, of course, you have priceless antiques or irreplaceable family heirlooms to protect, then it is still a good idea to have a proper alarm fitted – just in case!

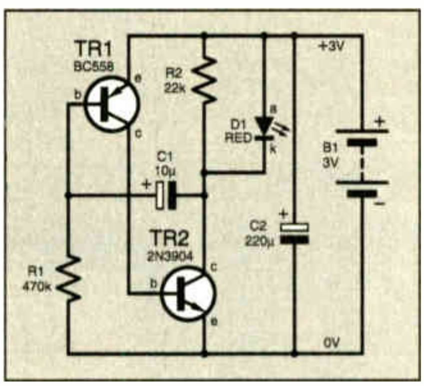


Fig.1. Circuit diagram for the Dummy PIR Detector.

The most important aspect of this design is not the electronics, but the final appearance of the device. It was built using a miniature sloping box similar to that employed in commercial PIR detectors.

To simulate the multi-faceted lens usually fitted to these units, a small piece of translucent plastic, cut from a plastic milk bottle (of the type used by most supermarket chains), was glued to front. To further add to the realism and indeed to attract attention to the unit, a flashing light emitting diode (l.e.d.) is mounted behind the "lens", as is the case with commercial detectors.

Initially, it was envisaged using a pseudo random binary sequence generator based on a shift register with Exclusive-OR feedback, or a combination of oscillators. These would cause the l.e.d. to flash at irregular intervals and simulate the normal operation of such units (which appear to flash randomly when in the stand-by mode).

These ideas were abandoned on the grounds of over complexity. No burglar, it seemed, would hang around deciding if the light was flashing regularly or randomly. The fact that it *looks* like a detector should be enough to convince a would-be intruder not to risk a break in.

CIRCUIT

The box will only accommodate two AAA-size 1·5V batteries so, without going to the expense of a voltage boosting circuit, only 3V is available for powering the l.e.d. This prevents the use of a standard flashing l.e.d. or a CMOS oscillator, which require a *minimum* of 3V to operate.

An ordinary multivibrator circuit could have been used, but in the end a complementary version of this was decided upon as this contains fewer components (see Fig.1). It works reliably down to a supply of 2V, by which time the batteries are all but exhausted.

The circuit only draws significant current when the l.e.d. is on and, because of the fairly long intervals between flashes,

COMPONENTS

Resistors
R1 470k
R2 22k
Both 0.25W 5% carbon film.

See SHOP TALK page

Capacitors
C1 10µ min. radial elect. 6·3V
C2 220µ min. radial elect. 6·3V

Semiconductors
D1 red l.e.d.
TR1 BC558 *pnp* transistor
TR2 2N3904 *npn* transistor

Miscellaneous
B1 1·5V AAA-size battery, with cell holders (2 off)

Printed circuit board, available from the *EPE PCB Service*, code 303; min. sloping front plastic case, 71mm x 44mm x 25mm approx.; plastic milk bottle (see text).

Approx. Cost Guidance Only **£7** *excl. batts.*

the average current is very low. Typical battery life is about six months.

The operation of this circuit is very simple. Assume initially that capacitor C1 is discharged and transistor TR2 is conducting so that its collector is at 0V, and the l.e.d. is therefore turned on. C1 will quickly charge up via the base-emitter junction of TR1. When the voltage across it has risen to within 0·6V of the supply voltage, TR1 will begin to turn off, because its base-emitter voltage will be less than 0·6V, which will also cause TR2 to turn off as well, so switching off the l.e.d.

With TR2 off, its collector will rise to the supply voltage and, because C1 has been charged to almost the supply voltage, the base of TR1 will rise to approximately twice the supply.

Capacitor C1 will now discharge slowly via resistor R1 and the base voltage of TR1 will slowly fall until it drops to 0·6V less than the supply. TR1 will now conduct, causing TR2 to conduct, and the sequence will repeat.

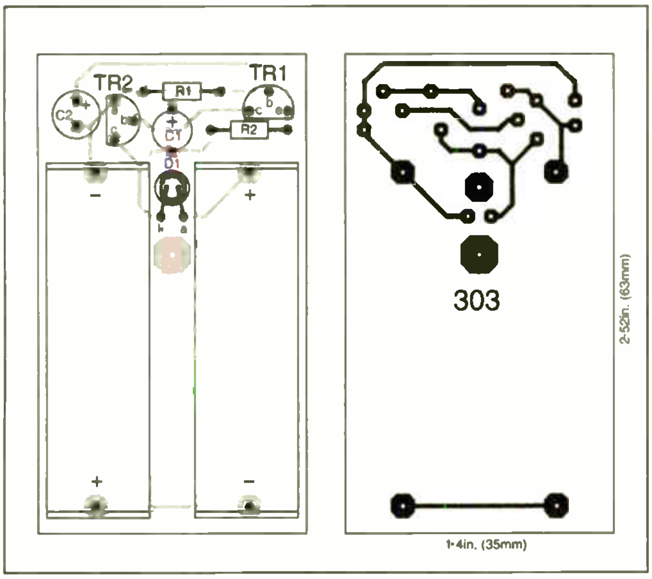


Fig.2. Printed circuit board component layout and full-size copper master.

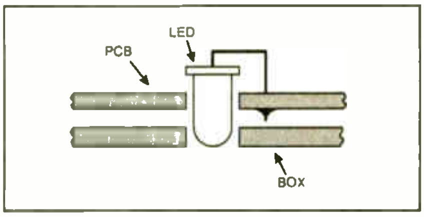


Fig.3. Suggested method of mounting the l.e.d. (D1).

TIME OUT

The time during which the transistors are conducting, and hence the time the l.e.d. is also on, is thus very short. The duration is governed by the time taken to charge C1 via the relatively low resistance of the base-emitter junction of TR1 and the effective emitter-collector resistance of TR2, which is conducting heavily. The time for which the l.e.d. is off, when both transistors are also off, is determined by the values of resistor R1 and capacitor C1.

Because of the relatively low supply voltage and the short period during which the l.e.d. is on (approximately 100ms), no resistor is required in series with the l.e.d., which results in a very bright flash even with a 2V supply. Resistor R2 is included to prevent the l.e.d.'s high off-resistance from upsetting the circuit.

CONSTRUCTION

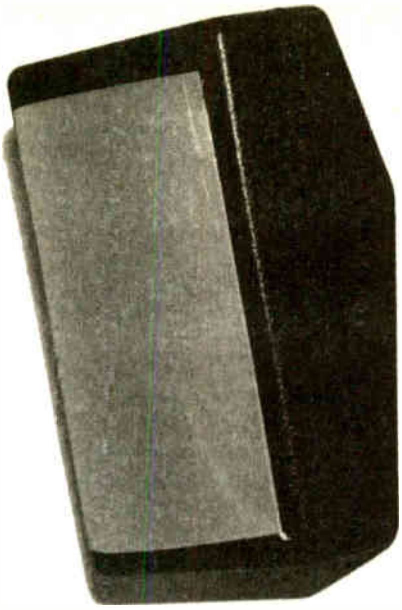
Construction should begin by first drilling a 5mm hole in the box to enable the l.e.d. to shine through. The size and position of this hole is not too critical as long as it is roughly in the correct place. The printed circuit board (p.c.b.) may be used as a template to determine roughly where to drill it.

A printed circuit board layout is shown in Fig.2, although for such a simple circuit designing your own stripboard layout would be quite acceptable. Drill the l.e.d. viewing hole to about 6mm diameter. Also drill the other near-central hole to suit the internal pillar of the case used.

Depending on the method of construction, the battery holders (wired in series) should either be mounted on the p.c.b. or glued to the box on either side of the internal pillar.

Assembly of the board should follow normal practice and care should be taken to ensure that all components are mounted correctly.

The l.e.d. is mounted on the component side but is bent back on itself to cause it to shine through the board as shown in Fig.3. To do this, the leads of the device should be carefully bent prior to it being soldered to the board. The leads should be held firmly in a pair of pliers and repeated bending should be avoided.



Completed unit showing curved "lens".

BOXING UP

The box should be finished off by gluing the "lens" to the front of the box. This can be made from a piece of 60mm × 35mm plastic cut from a milk bottle and stuck onto the recessed area on the front of the box. Alternatively, a more realistic appearance can be obtained by using a piece of plastic 60mm × 45mm and gluing only the longer edges to the box, thus giving a curved "lens" which is more normal in commercial PIR units.

The unit can be mounted on an internal wall by drilling a small hole in the back of the box and hanging it on a nail. This should preferably be on the wall opposite a window and if possible in a corner so that it is clearly visible from the outside.

For maximum effect, this should not be in direct sunlight as this will make the l.e.d. more difficult to see. From across the room the unit will look like the real thing, and have the same deterrent effect. □

Special Feature

CONTROLLING JODRELL BANK

OWEN BISHOP

An insight into how electronics plays a vital role in our investigations of the Universe.

THE Nuffield Radio Astronomy Laboratories, in the Department of Physics and Astronomy of the University of Manchester, are more often known to the general public by the name of their location, at Jodrell Bank. This is the first of a number of installations in the UK that we will be looking at in this occasional series on electronic control.

Each of these installations is to be taken as a case study of the way in which electronics plays a major part, usually an essential part, in the operation of the plant and other equipment at the site. Most of the examples are taken from industry but, to begin the series, we have chosen one of the major academic institutions in Britain. It is one that is of world-wide importance.

From these exemplary case studies we will develop an outline of the general principles of electronic control.

RADIO TELESCOPES

To most people, "Jodrell Bank" is the massive radio dish, 76 metres in diameter with a reflecting surface made up of 7100 welded steel panels (see photo opposite).

However, there are several other radio telescopes on the site, including the much smaller 13m telescope. This is under the control of one of the earliest computers built at Jodrell Bank which is a clone of one of the original Ferranti computers initially used. It is used for full-time observation of signals from the Crab Nebula.

The dish of the 76m telescope is mounted on two towers, allowing it to be tilted through all vertical angles from the horizontal to the vertical. These towers are part of a structure that can be rotated on a circular railway track to aim the telescope in any horizontal direction. Thus the telescope is fully steerable, and it is the control of the steering which is the main topic of this article.

The telescope began operation in 1957 and at that time it had an analogue control system. It was then known as the Mark I telescope. Since then various parts of the structure have been strengthened and the reflecting surface has been renewed. It then became known as the Mark IA telescope.

Its control system has been updated too in various ways until, since 1970, it has been almost entirely digital. In 1987 it was renamed the Lovell Telescope, in honour of Sir Bernard Lovell who played such a major role in originating and developing it.

Like most powerful astronomical telescopes, including both optical and radio telescopes, the Lovell telescope is a reflector. The dish is parabolic in section so that radio waves arriving from a distant source are focussed on a central point in front of the reflector.

A tower projecting from the centre of the reflector carries a focus box, into which the arriving radio waves are focussed. The focus box contains a radio receiver that is linked by cable to the computer in the control room of the observatory.

AIMING THE TELESCOPE

The telescope is under the control of a DEC MicroVAX 2 computer, which has 128KB of RAM and a 6GB hard drive. The computer is linked by cable to the control circuitry on the telescope structure.

The direction in which the telescope is pointing is resolved into two angles, elevation and azimuth. The angle of elevation is measured by shaft encoders (see Panel 1) situated at the bearings at the top of the two towers.

Each encoder sends elevation data to the central computer. The output from each encoder is a serial digital data stream with a frequency of 1MHz. This is too high a frequency for transmission as a synchronous signal over the lengthy connecting cables, so it is converted by circuits on the structure into an asynchronous digital data stream at 100KBaud before being sent to the control computer. The computer calculates the mean of the readings from the

The dish of the Lovell telescope at Jodrell Bank weighs 1500 tonnes. (Photo: Ian Morison)

PANEL 1. Gray-coded shaft encoder

The Gray-code shaft encoder provides a common technique for measuring absolute direction or angular position. A transparent disc is marked with a pattern in which binary codes of clear and opaque areas are arranged radially (Fig.1).

The codes are read by four optical sensors. Although the codes comprise all the 16 binary values 0000 to 1111, they are not in numerical order. They are arranged according to a Gray code. In a Gray code, the adjacent codes differ by only one bit. If the codes were to be arranged in numerical order, there could be confusion when one code changes to the next.

For example, two digits change as the code shifts from 1001 to 1010. It is difficult to align the optical sensors so that they all change at exactly the same instant. If the right-hand digit changes first, the value goes through the sequence 1001, 1000, 1010 (or 9, 8, 10 in decimal). If the right-hand digit changes last the sequence is 1001, 1011, 1010 (or 9, 11, 10 in decimal).

The situation is more complicated with some transitions, such as 0111 to 1000 in which all four digits change. Using a Gray code eliminates this problem.

The disc in the figure has a 4-bit code, which reads one of 16 different angular positions. This gives a resolution of 360/16 = 22·5 degrees. Increasing the number of bits increases the resolution of the encoder.

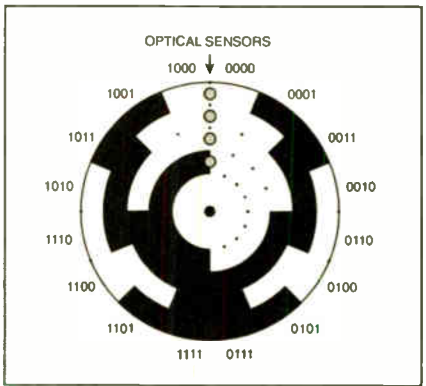


Fig.1. A shaft encoder disc, marked according to a 4-bit Gray code.

two encoders and this is taken as the angle of elevation.

There are three encoders for azimuth. One of these is a Gray code device similar to those used for elevation. The other two encoders are incremental encoders (see Panel 2). Data from the azimuth encoders is treated in the same way as that from the elevation encoders and cabled to the computer.

The averaged output of the pair of incremental encoders is combined with the output of the Gray encoder to produce a 21-bit code representing the whole 360 degrees of azimuth. The least significant bit of the code represents $360/2^{21}$ degrees, which is six seconds of arc.

Elevation and azimuth determine the telescope's direction of aim relative to the Earth's axis but ultimately the astronomer needs to be able to point the telescope at a particular object in space. The co-ordinates of astronomical objects are specified by two co-ordinates on the celestial sphere. These are right ascension (equivalent to celestial longitude) and declination (equivalent to celestial latitude).

CO-ORDINATE TIMING

The relationship between the terrestrial and the celestial co-ordinates varies with time. It changes as the Earth spins on its axis and as it progresses along its orbit around the Sun. The control computer of the Lovell telescope has routines which, given the sidereal (star) time, and the right ascension and declination of an object, can calculate the required elevation and azimuth of the telescope.

The algorithm incorporates two refinements. One is to allow for the refraction of radio waves by the Earth's atmosphere, a factor that becomes of increasing importance at low angles of elevation. The other factor included in the calculation is the extent to which the structure of the telescope sags under its own weight at different angles.

The operator has simply to key in the right ascension and declination of the object to be observed and the telescope is automatically aimed in the required direction.

ATOMIC CLOCK

The computer receives sidereal time signals from an atomic clock at the observatory. This is a Sigma-τ hydrogen MASER atomic frequency standard. *MASER* is an acronym for Microwave Amplification by Simulated Emission of Radiation.

A MASER is similar in principle to a LASER except that it operates at frequencies in the microwave band instead of at the frequencies of light waves. The clock depends on the quantum transitions within atoms that have been excited to a high energy state by subjecting them to high-frequency electromagnetic radiation, by microwaves at 1,420,405,752·8Hz in the case of the hydrogen MASER.

The first point about the MASER (and the LASER) is that the atoms can be excited only by radiation of exactly the correct frequency. Conversely, after the atoms have been excited they lose the energy and return to their unexcited state by emitting radiation that again is at exactly the same frequency.

It is thus possible to set up a chamber containing hydrogen and to excite the hydrogen atoms in such a way that they are continuously absorbing and emitting radiation. The system resonates at the fixed frequency. The oscillations are electronically coupled to a digital circuit that divides the frequency down to one that is usable for driving a clock.

The second point about the MASER is that the frequency depends only on events taking place within the atoms. It is totally unaffected by external physical conditions such as temperature and pressure, or by the age of the components of the clock. This makes an atomic clock highly stable. The stability of the hydrogen clock is 1 in 10^{14}, which is equivalent to one second in over three million years.

MOVING THE TELESCOPE

The telescope is moved by electric motors geared to the spindles at the top of each tower and drive units that carry the structure on the railway track. These are mains-powered motors of various kinds. The telescope's main computer automatically controls the action of these motors. The computer generates a pair of digital waveforms, one of which (A in Fig.3) is a precise square wave at 1kHz, and the other (B) has the same frequency but a variable mark-space ratio.

PANEL 2. Incremental encoder

An incremental encoder is used for measuring incremental direction or angular position. The transparent disc is marked with equally spaced bars (Fig.2). As the disc rotates, a logic circuit counts the number of bars passing through the beam of the optical sensor. This gives a measure of the angle turned by the shaft.

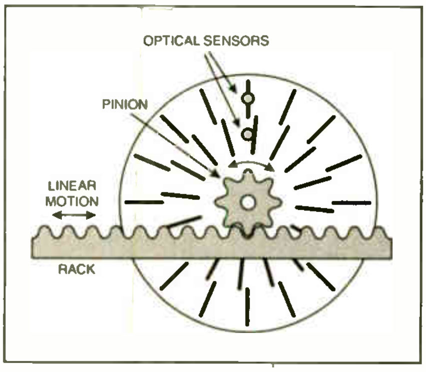


Fig.2. An incremental encoder disc, marked with two sets of radial strips in quadrature.

With a single set of bars, it is possible only to measure the angle turned, but not the direction of turning. The disc shown has two sets of bars, with one set displaced slightly with respect to the other. In terms of phase we say the second set is 90° out of phase (or in quadrature). By registering the relative timing of the pulses from the two optical sensors, it is possible for the logic circuit to decide the direction in which the disc has rotated.

In Fig.2 the assembly of disc and optical sensors moves from side to side. A gear wheel (pinion) on the shaft engages with the teeth of the stationary rack. It turns as it moves along the rack, spinning the disc as it goes. The number of bars counted is proportional to the distance moved along the rack. In this way the mechanism is used to measure linear displacement.

Applying this to the Lovell telescope, the rack is a horizontal circle concentric with the railway track that turns the telescope framework horizontally. The number of bars counted is proportional to the change in azimuth, or angular displacement in the horizontal direction.

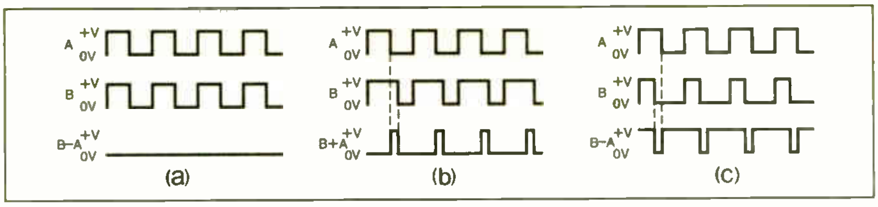


Fig.3. Motor speed is controlled by subtracting a constant square-wave signal (A) from a digital signal of variable mark-space ratio (B). (a) a 50% mark-space ratio produces 0V output, (b) a mark-space ratio greater than 50% produces positive output pulses, (c) a mark-space ratio of less than 50% produces negative output pulses.

The waveforms are synchronised so that their rising edges occur at the same instant. The waveforms are fed through opto-isolators and fed along a pair of two-conductor shielded cables to the motor control circuit on the structure. There, signal B is subtracted from signal A.

It can be seen from Fig.3a that, if the mark-space ratio of B is exactly 50 per cent, the signals cancel out at every stage and the output of the subtractor is a constant 0V. However, if the mark-space ratio is greater than 50 per cent (Fig.3b), a series of positive pulses is generated. The larger the ratio the longer the pulses. Conversely, the pulses are negative if the ratio is less than 50 per cent. The smaller the ratio the longer the pulses.

PULSE TO ANALOGUE

Next, the pulses are converted into an analogue signal. In early versions of the circuit a simple low-pass filter (Fig.4) did this. The output of the filter is a smoothly varying analogue voltage, the voltage ranging from –10V for a series of negative pulses of maximum length, to +10V for a series of positive pulses of maximum length.

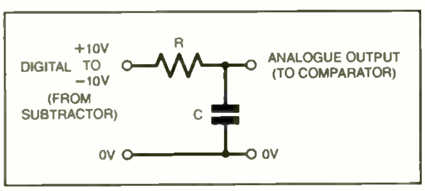


Fig.4. A low-pass filter smooths the positive and negative pulses to produce an analogue voltage ranging between –10V and +10V.

The filter has a time-constant of about two seconds which smooths the pulses satisfactorily and at as fast a rate as the Lovell telescope can respond to. However, smaller telescopes can be controlled by a faster-changing signal so a more sophisticated technique has been adopted for producing the control voltage.

This relies on measuring the time interval between the falling edges of the A and B waveforms (the distance between the vertical dotted lines in Fig.3b and Fig.3c) and detecting the order in which the falling edges occur. This data is then processed to produce the variable control voltage.

The complete control system is shown in Fig.5, including the production of the analogue control voltage as described. This goes to a switch by which the system can be placed on either automatic (computer) or manual control.

There is a control panel on the structure on which a manually operated variable resistor acts as a potential divider to produce a voltage ranging from –10V to +10V. It is thus simple in an emergency or when servicing the telescope, to switch from computer control to manual control.

TACHOMETER MONITORING

The control voltage, from either source, is compared with a voltage signal coming from a tachometer geared to the motor shaft. The tachometer voltage is proportional to the rate of rotation of the motor and its polarity depends on the direction of rotation. The output of the comparator is proportional to the difference between the control voltage and the voltage fed back from the tachometer. The polarities are such that the feedback is negative. In other words this acts to reduce the voltage difference to zero.

The output from the comparator, known as the error signal because it is proportional to the voltage difference, is fed to a power amplifier which produces a drive voltage to power the motor at the required speed. The tachometer is geared to the shaft of the motor, completing the drive-rate servo-control loop. In this way the motor is driven at the speed determined by the algorithms of the computer.

The drive signals produced by the computer have been generated by algorithms dependent upon the setting originally keyed in by the operator. It is one thing to calculate what motor speeds are required. It is another to be sure that the telescope is actually pointing in the required direction. For this purpose there is a second outer loop. This is a positional servo loop.

The encoders on the structure measure the elevation and azimuth of the telescope as described earlier and the computer reads their output 20 times a second. This information is used to determine if the telescope is aimed in the expected direction and, if not, to correct for this by increasing or decreasing the speed of one or more motors.

AVOIDING DISTORTION

A massive structure such as the framework of the telescope could become permanently distorted if it was attempted to move it too rapidly. The maximum allowable rates of change of elevation and azimuth have been calculated and incorporated into the algorithms of the computer.

For the Lovell telescope, the maximum angular velocity is nine degrees per minute in azimuth. The maximum angular velocity in elevation is six degrees per minute. Smaller telescopes may be moved more rapidly. Typically, the maximum velocities for small telescopes are up to 40 degrees per minute in azimuth and up to 10 degrees per minute in elevation.

When the telescope is to be aimed at an object, the operator keys in the declination and right ascension angles. Then the computer calculates the angular distance between its present position and its target position. The telescope is accelerated at the maximum allowable rates until it has reached its maximum allowable angular velocities in both axes.

The nested-loop control system shown in Fig.5 has the advantage that unexpected effects, such as those due to wind blowing on the dish, or snow on the structure, may all be taken into account. It can also compensate for the inevitable minor errors arising in calculating required motor speeds.

Under normal operating conditions, the system holds the telescope in position with a precision of a few ten-thousandths of a degree, both in elevation and in azimuth. Under high winds the precision is reduced to about one-thousandth of a degree.

When it is within five or six degrees of its target position a different routine comes into operation. The velocities are gradually reduced so as to decelerate the telescope (again at a maximum safe rate) and bring it to rest pointing in the required direction. It

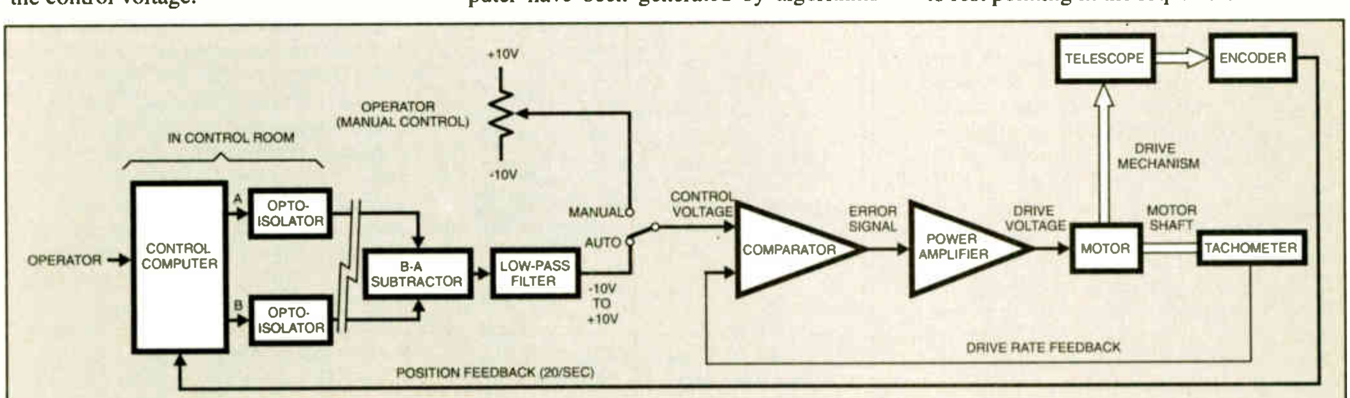


Fig.5. A double-loop control system is used to aim the Lovell telescope precisely in the required direction.

PANEL 3. Control loops

The simplest type of control system uses an open loop. In Fig.6 the temperature of a room is controlled simply by switching an electric heater on or off. The system is an open loop. The loop is closed if an operator checks on the room temperature periodically, decides if it is too hot or too cold, and switches the heater on or off accordingly.

It is a simple matter to install a mechanical thermostat switch for automatic temperature control (Fig.7). Or we can devise a circuit based on a thermistor to do the same thing.

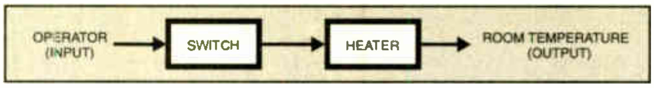


Fig.6. This open loop system requires an operator to control it.

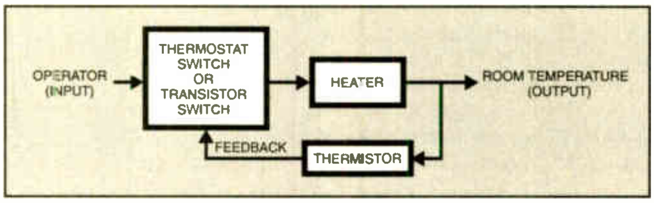


Fig.7. A thermostat is an example of a simple closed loop system with negative feedback.

The control loops used when moving the Lovell telescope are of the closed loop type but are much more complicated that the simple on-off (or bang-bang) system of Fig.6. They depend on complicated mathematical algorithms, including the use of look-up tables to correct for sagging of the structure.

This requires the inclusion of a computer in the control loop. It is programmed in assembler or in FORTRAN, a high-level language especially suitable for working with mathematical formulae.

turns to the new position precisely, without overshooting.

From then on, a third routine comes into action. This takes account of the rotation of the Earth and its changing location in its orbit. It calculates the elevation and azimuth required to keep the telescope pointing directly at the object while the Earth moves beneath it. The rate of turn needed for tracking the object is much less than that required for changing the aim of the telescope. The control system needs to be able to cope with rapid movements when pointing to a new target and with the much slower movements needed for tracking a celestial object.

ROTATION ARC

The telescope is subject to the restraint that the receiver is connected to the control room by a fairly massive cable. Consequently, the framework of the telescope cannot be rotated indefinitely in one direction. There are two modes of steering it in azimuth:

Turning clockwise from southerly directions, it cannot be turned further than 325 degrees.

Turning anticlockwise from northerly directions, it cannot be turned further than 265 degrees.

There is a region of overlap between 265° and 325° (Fig.8) which can be entered from either direction. The rule is that the telescope must always leave the region from the same direction by which it entered. This, too, has been written into the computer program.

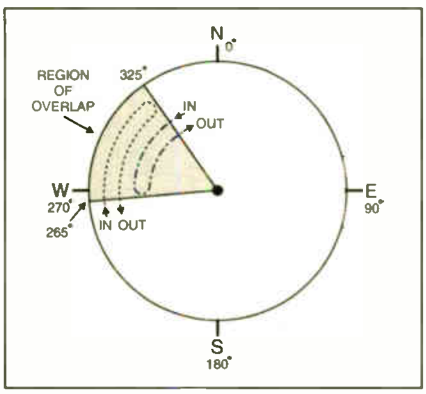


Fig.8. To avoid twisting the connecting cable, the telescope must always leave the shaded zone in the same direction to that from which it entered.

LIMIT CONTROL

As well as the feedback from the encoders, the motion of the telescope is also monitored by limit switches. These are simple mechanical switches triggered as the framework moves beyond a given limit position. Limit switches are a common feature of control systems. They provide a simple fail-safe readout that overrides the values calculated by the position control algorithms.

Algorithms rely on the encoders and the interpretation of the signals received from them. It is always possible that the encoders may fail, with the risk that the telescope may be driven into a position that will damage its structure, or snap its cable. Hence the need for robust limit switches to contain the telescope within safe bounds.

The Lovell telescope has two sets of limit switches in both axes of motion. As the telescope approaches its limit position, either in elevation or azimuth, a switch is tripped and a warning is sounded in the control room. This calls the operator to the control console to move the telescope back from the limit position under manual control.

If, in spite of this, the telescope moves further in the prohibited direction, a second limit switch is triggered. A second alarm signal is generated and the power to the motors is automatically cut off. At this stage an engineer must go out to the telescope to investigate the cause of the failure.

RECEIVERS

The receivers used in radio astronomy are designed to operate on one particular wavelength. A wavelength of 73cm is commonly used but the most important is the 21cm wavelength. This is the wavelength emitted by hydrogen gas, the most common element in the space between the stars.

For distant objects astronomers often use the 6cm wavelength to obtain finer resolution. Even shorter wavelengths are used, down to about 1·3cm. This allows a resolution of about 0·01 seconds of arc.

As far as the design of the receiver is concerned, restricting its operation to one particular wavelength (or more significantly, to one particular frequency) makes it possible to design the receiver for optimum performance at the given frequency. Astronomical signals are very weak, and it is essential to minimise electronic noise in the receiving and amplifying circuits.

One way of doing this is to employ a type of amplifier known as a parametric amplifier. Another approach is to minimise the noise-generating random motion of the charge carriers in the circuit by keeping the receiver at low temperature. Telescopes at Jodrell Bank often have their receivers cooled to 14K (kelvin), that is, to only 14 degrees above absolute zero.

The cooling system uses liquid helium as the refrigerant and operates on the same principles as a domestic refrigerator. The helium circulates in a closed system. At one point it is compressed strongly to liquefy it, which causes latent heat to be lost from the system. At another point, within the so-called cryostat, the pressure on the liquid helium is rapidly released, allowing it to evaporate. Evaporation requires latent heat and this is taken from the cryostat, where the radio receiver is housed, eventually reducing the temperature of the radio receiver to 14K.

Each radio receiver and its antenna is built as a unit to operate at a given wavelength. Different receivers are mounted on a carousel. This has the same function as the lens turret head used on a microscope or on a movie camera (before the days of zoom lenses). The head is rotated under the direction of the observer.

It may be necessary also to move the receiver closer to or further from the dish to bring the antenna to the focal point. Control of this motion is achieved by a number of rotary and linear actuators under the control of programmable logic controllers (PLCs).

MERLIN

Jodrell Bank is the centre of a network of radio telescopes in Britain known collectively as Merlin (Fig.9). This is short for Multi-Element Radio-Linked Interferometer Network. The reason for linking the telescopes is to increase the resolution of observations.

When we say that two astronomical objects are very close together, we mean that the angle between them, as seen from the Earth, is very small. A telescope with low resolution will fail to show them as two separate objects. Instead, we will see a single blurry object. The ability of a telescope to resolve two visually close objects partly depends on the aperture of the system. High resolution requires a large aperture or, in other words, a reflector of large diameter.

It is not only the actual diameter that counts, but also the ratio between the diameter and the wavelength of radiation being observed. Radio waves have much greater wavelength than visible light, so a radio dish has much lower resolving power than an optical telescope of equal diameter. There is a practical limit to the achievable diameter of a radio telescope but fortunately we are able to achieve an apparently large diameter by using other means.

This aperture synthesis is a technique applicable to radio telescopes, but not to optical telescopes. If the radio telescopes of Fig.9 are all aimed in the same direction, they may be made equivalent to a single large dish 230km in diameter. Or, more precisely, equivalent to a very large dish with most of the surface missing.

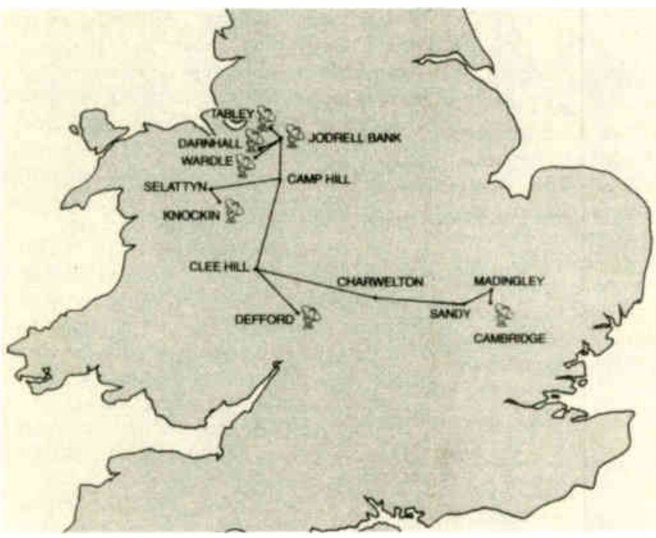


Fig.9. The Merlin array of radio telescopes and repeater stations showing the microwave links to Jodrell Bank.

Naturally, the synthesised dish is not able to receive signals at the full intensity with which a single complete 230km dish would receive them, but the signals it does receive are of high resolution. The resolution of Merlin is 0·05 seconds of arc when receiving radio of 6cm wavelength. This is a higher resolution than normally obtained with a ground-based optical telescope. It is equivalent to the resolution of the Hubble Space Telescope (see photo).

COMMUNICATION CONTROL

All the telescopes in the Merlin network are controlled from Jodrell Bank. As might be expected, electronics plays a major part in both communication and control. There are three channels of communication:

Control signals are sent to each telescope along a permanent landline. These signals originate in the computer and are sent at 9·6KBaud along lines with the relatively low bandwidth of an ordinary telephone line. An array of modems links the control computer to the landlines.

The data from each telescope is returned to Jodrell Bank along microwave links operating at 8GHz. These provide a high bandwidth for precise transmission of data in real time. This is analogue data, derived from the radio signals as they are received.

Microwave links in the L-band (16,000MHz) also carry timing signals to each telescope from the Sigma-τ hydrogen maser atomic frequency standard at Jodrell Bank. The system may also use timing signals from geo-positional satellites, precise to 10^{-7} seconds.

If the signals from the telescopes of Merlin are to appear as if they all come from a single dish, it is essential to allow for the differing times they take to reach Jodrell Bank from the individual telescopes. Timing signals are sent from Jodrell Bank to each telescope and back and the time for the return journey is measured.

MERLIN CORRELATOR

This information is used in a device known as the Merlin Correlator to calculate the amount by which each signal should be delayed so that all signals are all brought into step for analysis. Signals from individual telescopes may be delayed by up to several hundred microseconds.

The analogue signals from the telescopes are first digitised and then stored in memory in the correlator. Storage is organised as a cyclic memory in which the most recently received data replaces that which has been there for the longest time. Each memory bank has two pointers: one to indicate where to store the most recently received data word, and the other to indicate which is the next piece of data to be read, allowing for the required time delay.

The timing is such that a signal coming from a given part of the astronomical object and received as separate signals by the different telescopes is eventually recombined in the correlator, just as if it had been received from a single large-diameter telescope dish. We say the signal has been made coherent. It provides the high-resolution raw data used for subsequent analysis.

REMOTE CONTROL

Control of the Merlin telescopes is essentially remote control, so special provisions are essential. For example the data sent from the telescope may include pictures from five TV cameras located at the site. There is also provision for temporary breakdown of communications. If control signals are not being received for a short period, the computer at the remote telescope recognises this fact and continues to track the object automatically.

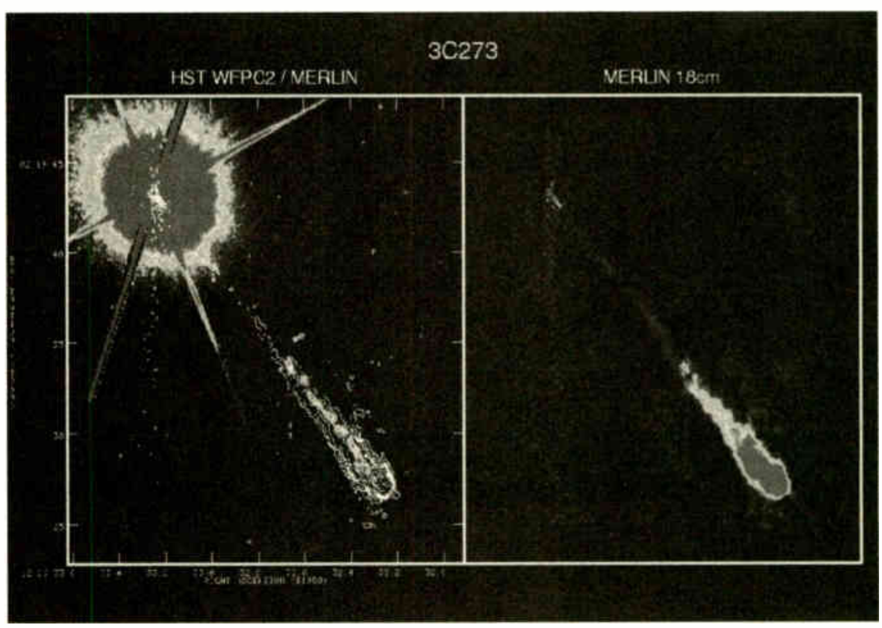
However, should this fault persist for 10 minutes, the telescope is switched off and is parked, pointing upward to the zenith. This position minimises damage from strong winds.

Conversely, the main computer continually checks to see that data is being received. Should there be a failure in this respect, the telescope is instructed to park. Then a warning is issued to the operator and an engineer has to visit the site to investigate the cause of the trouble.

This is just one illustration of the fail-safe approach of the control systems at Jodrell Bank, a feature shared with most other systems.

ACKNOWLEDGEMENT

The author thanks Ian Morison of NRAL for providing information and assistance in the preparation of this article. □



The quasar 3C273 as seen (left) by the Hubble Space Telescope and (right) by Merlin. The resolution of both views is approximately equal (Photo: NRAL, Jodrell Bank)

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 $3\frac{1}{2}$ 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 ★

C SOURCES

Dear EPE,

Regarding your reply to Ben Heggs in *Readout* April '01: C is still useful for microcontrollers (the company where I work have started using it instead of assembler). With C it is easy to guess what assembler the compiler will generate.

However, ANSI C forms a "subset" of ANSI/ISO standard C++ (almost a subset: C++ bans some valid C to try and catch programmer's errors etc). C++ is an Object Oriented programming language. So even when using a graphical windows C++ compiler such as C++ Builder, you can gradually move from C style procedural to C++ object-oriented programming.

The idea of object-oriented programming (OOP) is to make the creation of modern very large computer programs easier and less error-prone and help common/similar code to be reused.

Mr Stroustrup (creator of C++) thinks it might be best to learn C++ then C (he might be biased though!) but I learned C first before learning pre-ANSI C++ and I didn't find any problems. I think that this has the advantage that C is a small language whereas C++ is larger.

I can't recommend any general books on OOP as I learned it from an Open University software engineering module. The book I learned pre-ANSI C++ from was good but is obsolete now. I have the "official" C++ book *The C++ Programming Language* (third edition – most recent printing) which is useful as a reference but I wouldn't try to learn C++ from scratch from it.

Some useful sources of information for would-be C programmers are:

http://manuel.brad.ac.uk/help/.packlangtool/.langs/.c/.style.html for the Indian Hill *C Style Manual*.

The files **c99rationale.pdf** and **c9x_faq.pdf** are also useful (but very technical) and cover both the widely used C89 version of ANSI C and the very new ANSI C99. (I don't have web addresses so a search engine will be needed.)

Steve Summit's *C FAQ* from **http://www.eskimo.com/~scs/C-faq/top.html**.

http://www.msu.edu/user/pfaffben/writings/blp-stds/blp-stds.html is also useful.

I have found the errata for *The C Programming Language* (Second Edition)) which I recommended in Feb '01 *Readout* at **http://cm.bell-labs.com/cm/cs/cbook/2ediffs.html.** However, there doesn't seem to be anything too serious.

A free Windows Visual Borland C++ Builder 4 compiler (*PC Answers* Issue 90 Feb '01) can be ordered from:

PC Answers, Future Publishing Ltd, Cary Court, Somerton, Somerset, TA11 6TB. They cost £5.99 each plus £1 postage (£2 overseas).

If a web address has moved a search engine should find it when told to look for a site with the exact phrase "Personal Coding Standards" in the title of English language websites.

Alan Bradley, via the Net

Thank you Alan for your various E-mails and for such extremely helpful information.

WHAT PIC INFO?

Dear EPE,

I have been interested in basic electronics for about a year. Now I want to progress and start to use PICs. Can you please suggest reading material, software and the hardware which would program the widest range of PICs.

Nicholas Bishop, via the Net

Microchip's own MPASM/MPLAB system is the most versatile programming, assembly and test facility, and which can be downloaded free from **www.microchip.com**. *Microchip are the manufacturers of PICs and thus fully support the entire range.*

I believe that my PIC Tutorial *of Mar-May '98 is still the best tutorial through which to learn about PICs when you have had little or no previous experience with them. It has its own DOS-based programming facility available as a combined software/hardware suite. An enhanced version of this is* PICtutor *which is available on CD-ROM and includes an on-screen* Virtual PIC *simulator which allows you to experiment with code before you write a software program. It runs through Windows.*

My PIC Toolkit Mk2 *is also an excellent programming facility. It has additional features for translating between the two programming dialects MPASM and TASM and will run under Windows or DOS. It has been designed principally for the PIC16x84 and PIC16F87x series of 14-bit EEPROM-based microcontrollers.*

DISCHARGING NI-CADS

Dear EPE,

In *Circuit Surgery* Sept '00 you mention that, in order to avoid the "memory effect", Ni-Cad batteries should be discharged to 0·9V per cell before they are recharged. You also mention the danger of causing reverse polarity if the battery is discharged to a lower voltage.

I always discharge the 4·8V batteries of my video camera through a 2·7Ω resistor before recharging them. In order to prevent the voltage from inadvertently dropping below 4 × 0·9 = 3·6V, I connect five 1N4001 diodes in series with the battery and resistor. I found that the voltage drop across each diode is 0·76V and the total voltage drop is therefore 3·8V which is close enough to the required 3·6V. A suitable Zener diode could also be used instead.

**Andries Retief,
Faerie Glen, Pretoria, South Africa**

We are pleased to pass on your tip, thanks Andries.

LINUX

Dear EPE,

Following on from Matt London's letter about Linux (*Readout* April '01), I too believe the world is too Microsoft oriented. Whilst Linux may never replace Microsoft's operating systems for general desktop use, there is no reason why Linux shouldn't be the operating system of choice for electronics enthusiasts.

It is true that Linux has a steep learning curve, and is often perceived as difficult to get to grips with. But Linux was – and still is – written by enthusiasts for enthusiasts. In my view, electronics enthusiasts should treat using Linux – and writing programs to run under Linux – as another discipline within the hobby.

The mindless, headlong desire for the latest "super computer" has left many old yet perfectly usable computers redundant. These computers are (usually) more than adequate to successfully run Linux.

I believe the potential uses of these computers, particularly when running Linux, have been overlooked by electronics enthusiasts and the amateur electronics press. Such uses include command and control applications, automation, data logging and data analysis.

The majority of these applications do not need, or even benefit from, a graphical user interface. They often, however, demand a stable, reliable, multi-user, multi-tasking operating system with networking capabilities. In addition, development tools for writing and maintaining applications programs should be readily available, and at low cost.

Linux is a true multi-user, multi-tasking operating system which, with the availability of software released under the Free Software Foundation's GNU public licence, fulfils all the above requirements. And you can still have a graphical user interface – the X-Windows system – if you want.

Programming under Linux is mainly in C, although PERL is very popular too, particularly in connection with active web pages. As programs are often distributed in source-code form, compatibility issues are far less of a problem than with many other operating systems.

With Linux coming of age, and with an abundance of cheap computer hardware, now is surely the time to relegate Microsoft's operating systems to the support of word processors and let Linux take on the serious stuff!

**Philip Cadman,
Dudley, West Midlands, via the Net**

So, then, Philip is another convert to Linux, of which there seem to be quite a number of you. Who's going to be the first to offer us a simple project that makes use of Linux? Contact Editor Mike if you have a suggestion for one. I've not yet been exposed to it (other than to see that PC-World sell it inexpensively).

CORRECTION

Paul Fellingham's web address quoted on P351 of May '01 should read: **www.g7fjc.freeserve.co.uk/electronics.htm.**

Thank you Arthur Dyas for querying it!

RIFE PROVOKES CONTROVERSY

A fair bit of correspondence resulted from publishing Aubrey Scoon's End to All Disease *article in the April '01 issue. The following comments variously came in via snail-mail, E-mail or were posted on our Chat Zone site. They have been edited to keep the length reasonable. We leave the concluding comments to Aubrey.*

D. McClosda: This article is fascinating even if half true! Could anybody produce a TTL input circuit suitable for the author's sample, 500kHz to 2MHz?

Simon Barrell: I am planning to use John Becker's *PIC-Gen* of July '00 to provide the TTL input. I know for a fact that certain educational institutions in this country have been "zapping" paramecia for a number of years. However, out of propriety I think you will find that their researches are under the general heading of "Radio Diathermy".

Bruce Clothier: To say an article is half true is like saying one is only slightly pregnant. I assume this is an April Fool's joke. It's not easy to tell, because the article is so long. I did look up the website, which resembles the work of a crank: it looked like total gibberish to me. I still couldn't tell if it was meant as a spoof.

Isabel Hindbo: I have been using a RifeBare device for more than a year and have found it to live up to all the information I have been able to find on it. The Internet is loaded with information on many devices that are further developments using Rife's original findings. They are using devices of this kind in many countries of the world. We just seem to be a little slow or reluctant to believe.

Peter Crowcroft (Hong Kong): You have been conned with the article on Rife. It is pure pseudoscience and it has been known to be for years. You should know better than to get out of the electronics publishing field you do so well and suspend your natural skeptical mechanisms. For detailed technical references see **http://www.quackwatch.com** and search on "rife". It is one thing to publish TENS circuits, but to support pseudoscience in your Editorial will only do harm to your publication. It is beneath you to raise a strawman argument of "powerful organisations with a vested interest in suppressed development".

Mark G. Lester BA (Hons), ITEC, BTAA, BTER, AMFPPTh, I.C.M: I have been using the Rife/Bare machine in my clinic – The Finchley Clinic (North London) – for almost three years. I am an holistic therapist using a number of modalities, and my involvement with electro-medical devices also includes Electro-Crystal therapy. My web site is at **www.thefinchleyclinic.co.uk.**

D.J. Butler, St Annes, Lancs: I must congratulate you on some of the more unusual articles that have appeared over the last year, in particular the March and April 2001 issues. Nick Field's and Aubrey Scoon's articles were like a breath of fresh air. Readers may like to know that there is a book available through Amazon Books entitled *The Lakhovsky Multiple Wave Oscillator Handbook* compiled by Thomas J. Brown. In the book, multiple wave oscillators and radio cellular oscillators are discussed, the history of the devices, treatment of disease, the effects on body cells etc. It also contains information on building various devices, both valve and solid state, including a couple of Tesla coils.

Steve Ierodiaconou (Athens, Greece): This is one of the most interesting articles I have read yet, anywhere, and I am now telling everyone I know about the amazing Rife and his discoveries. In fact both my parents are doctors and I'm sure they will be very interested to read the article. But what surprises me greatly is that the medical firms oppressed this knowledge instead of taking it up as soon as it became promising.

Norman L. Smith: As a reader of wireless, electronic, constructor, *et al* magazines for over 60 years and I thought that I had seen a wide variety of projects but was astonished by the technology, corruption and Agatha Christie intrigue in the article. As an associated aside, a recent article in a national newspaper stated that scientists have discovered that cats can cure their broken bones and other organs because when they purr it is not to show pleasure but the audio frequency produced is part of their healing mechanism, hence their nine lives!

Aubrey Scoon: The article is not a spoof or a joke, it's completely serious. The April publication was an unfortunate coincidence.

As for the length, I tried to explain as clearly and simply as possible the whole history and background. If I had simply said: "There was a guy called Rife who cured cancer with a strange machine in 1920 and was persecuted by the AMA/FDA/CIA/NSA (or whatever)" do you think it would have sounded more credible? I tried to give information in the article that you won't easily find anywhere else. It's precisely for that reason that the article is so long.

I mention several websites in the article, but none have anything to do with me and I'm not endorsing their content. There are a lot of crank sites out there as well as a lot of (well intentioned) misinformation. But there is real and useful information on some of these sites.

The prototype circuit in the article won't work properly at 500kHz to 2MHz. It was only designed to work at a limited range of audio frequencies between approx 20Hz and 2kHz. At higher frequencies the transistors won't switch quickly enough, there will be significant distortion and the reactance of the coil would be so high that you wouldn't get any real power through it. As for a suitable TTL source, you could use a 555 driven at 5V or any standard signal/pulse generator. I'm currently working on a suitable pulse generator which I hope to submit to *EPE* when it's finished.

I agree, however, that a critical attitude is needed here. Don't believe everything you're told. Like any controversial issue there is a lot of spin and hype from both sides. But at the same time keep an open mind – the truth is out there (!) but only if you're willing to look for it! *AS*

TIMES OF CHANGE

Dear EPE,

After a break of some 20 years it is with great pleasure that I find myself buying and reading your magazine once again. My lack of purchase was due, in the main, to a change in occupation from an electronics based job to a computer based job.

At the time, I was required to learn about strange operating systems, system administration duties and techniques, software development, and project life cycles. It all seemed wonderful, challenging, and interesting.

Not to say quite lucrative too. However, all this information input removed me from my school-boy interest in electronics that secured my job in the first place, and over the past years I have felt a craving to re-instigate the satisfaction of designing and building electronic circuitry that would do something that I thought was useful at the time.

Last year I was introduced to a copy of *EPE* by a friend that had information about intelligent l.c.d.s. I read the article, and several others using my friend's back issues, and realised that amateur electronics had come a long way in 20 years. Of course this must be so, I thought in retrospect, technology itself has advanced leaps and bounds too. There in your magazine were circuits and software for PIC applications, with l.c.d.s as output devices that could be designed and built for a reasonable price that would have knocked the spots off projects published when I first dabbled. My interest in electronics has been re-awakened, and I now look forward to each month's issue of *EPE* for stimulus and component sourcing.

Harry Purves, Tyne & Wear, via the Net

Welcome back Harry! Yes, it all moves forward, including us.

ADVOCATING DELPHI

Dear EPE,

Pursuing the theme of the best languages for projects involving a PC interfaced to magazine related projects, I emphasise Delphi!

The development environment is *so* nice to use. You can do anything – elegantly, nicely, works quite soon – in Delphi that you can do in C or C+... not so nicely, easily. Computer magazine cover discs have appeared with free copies for hobby use. At least at one point, there was an educational (i.e. no commercial use) version with "How to.." book at only £35. I could go on and on, but I won't, beyond saying that I taught computing up to A-Level. See my webpages for info on Delphi-to-user projects, and Delphi tutorials: **ourworld.compuserve.com/homepages/TK_Boyd/Tut.htm www.arunet.co.uk/tkboyd/ ele.htm**

Tom Boyd, via the Net

Hi Tom, yes I'm familiar with your interesting sites and commend them to readers.

ELECTRONIC COMPASS

Dear EPE,

Hello. I'm trying to track down a UK source of analogue compass sensors.

Have you ever done any kind of "electronic compass" project that might use such as device?

Anthony Jarvis, via the Net

Four years ago Speake & Co were proposing to do a device for compass monitoring, but I have heard no more about it. Interestingly, Andy Flind's Magfield Detector *in this issue uses a Speake detector, so I have the company's contact details to hand: Speake & Co Llanfapley, 6 Firs Road, Llanfapley, Abergavenny, Monmouthshire NP7 8SL. Tel/fax: 01600 780150. E-mail:* **speake@elvicta.fsnet.co.uk.**

CANUTE IN AFRICA

Dear EPE,

I must congratulate John Becker on his effort in producing code and construction details for the *Canute Tide Predictor* (June '00). It was I who suggested that he might design a PIC-based unit that had an l.c.d. display and be less power-hungry than his original *Tide Meter* published in *PE* July '92.

The latter was a hit at our RCYC and a few more were home-built by local yachties. My unit sits proudly next to other equipment in my ham shack and provides high-to-low-to-high info accurate enough for our needs (as Editor Mike would agree... tide extremes here are only two metres at springs).

My *Canute* will be an additional member of my yacht's instrumentation.

After monitoring for some weeks the predicted times are well within allowable tolerance and not that far away from PC-based *WXTide* referred to in the article. Well-done!

Now for another (selfish?) request. How about a PIC-based barometer design that will indicate pressure-trend over the previous 24/48 hours? That will be a useful tool for many yachties!

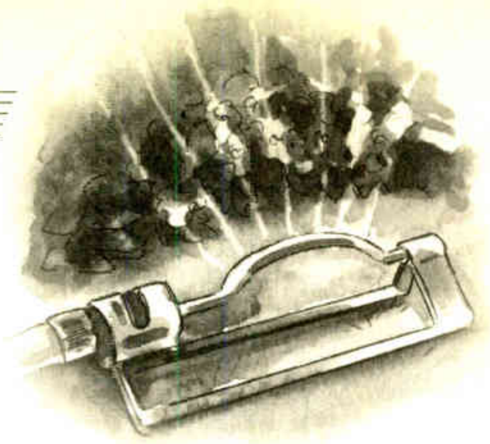
Johan van Rooyen,
Cape Town, South Africa,
via the Net

Yes, Johan, I well remember your original suggestion and much enjoyed designing Canute *as a result of it. It's great to know of its success with you (and of the continuing role my original 1992 design plays).*

I am thinking about doing a general-purpose Weather Centre (which I hope can be fully solid-state) and shall probably include pressure sensing and recording.

Constructional Project

HOSEPIPE CONTROLLER



TERRY de VAUX BALBIRNIE

Save money – conserve water!

BEFORE moving to their present home, the author's family were fortunate in having an unmetered mains water supply. They could, therefore, use as much water as they needed for a fixed annual service charge.

Times have changed. In the present house, water consumption is "clocked-up" by an outside meter. At the time of writing, the supply company charge 77p per cubic metre (1000 litres). They also make a sewerage charge, for which it is assumed that 90 per cent of the water drawn from the supply is returned through the drains. For this service they charge £1·06 per cubic metre.

The true cost of using one cubic metre of water is therefore almost £2, or 0·2p per litre. It is actually slightly more than that because there is a standing charge (a fixed amount which does not depend on the volume of water used) on both services. Of course, the actual cost of using water will depend on which supply company you use. Even so, it serves to illustrate how significant amounts of money may be saved by using this resource wisely.

WATER MANAGEMENT

One area where potentially large amounts of water can be wasted is in the garden. However, for many people the use of a hosepipe (lawn sprinkler, etc.) is practically essential. Useful amounts of water may be stored by collecting rain in water butts but there is a limit to what can be achieved this way. In practice, this means that much of the water needed must be drawn from the mains supply.

To avoid unnecessary cost, it is essential to manage the supply carefully and to use any hosepipe for as short a time as practicable. When measuring the rate of flow from the author's own garden hosepipe, it was found that with the tap turned "full on" it discharged more than 12 litres of water per minute – that is, 720 litres per hour. The cost of one hour of operation would therefore be around £1.50.

A PROPER TURN-OFF

The Hosepipe Controller described here saves water by turning off the supply after a preset time. The prototype is mounted on an outside wall close to an existing mains water tap.

Note that the specified solenoid valve may not operate satisfactorily from a very low-pressure supply (for example, water obtained from a water butt). There is a specified lower limit of 0·2 bar, which corresponds to a height of about two metres of water.

On the front of the unit are manual Start and Stop pushbutton switches. On the sides are the hose connectors, one for the inlet and one for the outlet. A piece of hose connects the inlet to the water tap and the hosepipe is connected to the outlet port.

This is the simplest method, although the unit could be set up as part of a fixed distribution system in a greenhouse.

TIME-OUT

Once the Hosepipe Controller has been triggered using the Start switch, it begins a flow of water and turns it off automatically after a preset time. Operation may be cancelled before the end of the natural timing period by pressing the Stop switch.

There are three preset periods – 15 minutes, 30 minutes and one hour. The time required is selected via a group of small switches on the printed circuit board. The timings can be changed to suit personal requirements.

The circuit also has an automatic feature whereby water can be switched to flow for the preset time each day. This works by sensing the ambient light and triggering the unit when it falls below a preset level. While set to automatic it is possible to start and stop the flow of water manually.

If the controller is to be placed inside a garden shed or a small wooden housing, it will be necessary to make sure that enough light can reach the sensor if automatic operation is required.

The prototype is housed in a waterproof plastic box, which contains the circuit panel, a solenoid valve to control the flow of water, and a sealed 12V re-chargeable lead-acid battery.

BATTERY POWER

The unit is battery powered for safety reasons. Any mains-operated device situated outdoors, especially where water is involved, is potentially lethal if not constructed with due regard to electrical wiring regulations.

The use of a battery supply also allows greater freedom because the unit may be set up wherever a water supply exists. The battery should be of the totally sealed zero-maintenance type which may be mounted with any orientation.

In the prototype, the battery has a capacity of 3Ah (amp-hours) and this provides approximately 30 hours of water delivery

before the need to re-charge. While on standby, the current requirement is less than 1mA, which imposes very little drain on the battery.

Re-charging can be carried out using a commercial mains-operated unit designed for small 12V lead-acid batteries. Ordinary car-type battery chargers and those made for nickel-cadmium cells are not suitable. The battery must be removed from the unit to charge it. DO NOT use a plug-in mains adaptor.

SOLENOID VALVE

The solenoid that controls the valve consists of a coil of insulated copper wire and an iron core. The core is pulled inwards by the magnetic effect of current flowing in the coil, and this opens up a path between the water inlet and outlet ports. When the current is switched off, the core returns under the action of a spring and closes the opening.

The specified unit has a nominal 12V to 24V coil having a resistance of 57 ohms. Ohm's Law shows that about 200mA will flow from a 12V supply. When used in this circuit, some voltage losses exist and the operating current in the prototype was actually 185mA with a 12V supply. Tests prove that it will work satisfactorily down to at least 7V (drawing 120mA).

The solenoid's "operating current" is that which is needed to actually open it. A lower value "holding current" maintains it in the open state. This allows the battery charge to be conserved by reducing the coil current to approximately one-half of its nominal working value (100mA approx.) one second after the water has begun to flow. In this way, once the valve has opened, the current falls to the holding level.

Note that washing-machine type solenoid valves are made for 230V a.c. mains operation (having a high-resistance coil) and are *not* suitable for use with this design.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Hosepipe Controller is shown in Fig.1. Power is supplied by the 12V battery, B1, via fuse FS1 and diode D6. Potentially very large currents can flow from a lead-acid battery so a fuse is essential.

The diode provides protection should the battery be connected the wrong way round. It also introduces a forward voltage drop of about 0·7V, so the nominal supply voltage for the circuit is really only 11·3V. However, for simplicity, it is generally referred to as 12V in the text.

Most of the circuit receives current through another diode, D1, and resistor R21, with capacitor C7 acting as a voltage reservoir. These three components condition the supply to the more sensitive parts of the circuit, helping to prevent possible latch-up of IC2, caused by a dip in the supply when the solenoid operates. Whilst the diode and resistor introduce a further voltage drop of about 0·7V, this has no practical significance to the circuit's operation.

TIMING CONTROLS

The circuit's timing controls are provided by IC2 and IC3, both of which are configured as monostables (one-shot timers). IC3 controls the one-second period during which current is boosted to open the solenoid valve. IC2 then controls the period for which the water remains turned on.

When Start switch S5 is pressed, IC2's trigger input pin 6 is taken high. It then begins a timing cycle during which its normally-high output pin 3 is set low. When S5 is released, resistor R12 holds the trigger input in its low inactive state.

Assuming switches S2, S3 and S4 are all off, as shown, the timing period is set by resistors R7 and R8 and capacitor C2, connected to IC2's CR input pin 7.

When a trigger pulse is applied to pin 6, an internal bistable is set to the "run" state, an internal counter is set to zero, the CR pin is enabled and output pin 3 goes low.

Capacitor C2 now charges through resistors R7 and R8 until 80 per cent of the supply voltage exists across it. At this point (as detected by the CR pin), the counter is incremented by one and an internal transistor rapidly discharges C2 to 45 per cent of supply voltage. The cycle then repeats.

The output remains low until a count of 128 is registered whereupon it reverts to high. The total timing period is given by:

$$128 \times C \times R$$

where C is in farads and R is in ohms.

When IC2 output pin 3 goes high at the end of its natural timing period, it fully resets via its pin 5. During the course of timing, the Stop switch S6 can be pressed, to also cause a reset, with the output returning high.

The reason for using this type of timer is that much smaller values of timing components may be used compared to, for example, the 555 type.

OPERATING TIME

With just the resistance provided by R7 and R8, the timing will be a little more than one hour. With any of switches S2/S3 on, other resistors are connected in parallel with the R7/R8 combination, decreasing the overall timing resistance, and so reducing the timing period. The three periods principally catered for are nominally 60, 30, and 15 minutes. In practice, different units will probably produce slightly different timings.

Switch S4 provides a test function and sets a timing of about 15 seconds. This is useful when setting-up the circuit.

If different operating times are required, the values of the timing resistors (R7 to R11) can be changed. The higher the value, the longer the operating time.

While IC2 output pin 3 is low during the course of timing, so too is the inverting input (pin 6) of op.amp IC1b. The non-inverting input (pin 5) is held at one-half of the supply voltage (nominally 6V) by the potential divider consisting of equal-value resistors R13 and R14.

IC1b is used as an inverting comparator. During the course of timing, its output pin 7 is high, reverting low when timing has ended.

INITIAL TURN-ON

In a simple circuit, this high output from IC1b could be used to turn on the solenoid via a transistor, limiting the transistor's base current with a suitable value resistor.

However, the current drawn by the solenoid would be around 200mA for the full timed period. Since the solenoid can operate at a lower "holding current", it is more economical of power use to turn it on at the high current just for a short period, and then switch over to provide it with the lower current for the remainder of the required period.

When switch S5 is pressed, the current through resistor R15 causes transistor TR1 to turn on, so triggering the timer based around IC3. The timer generates an output pulse at pin 3 having a duration of about one second, as set by R19 and capacitor C6.

Via resistor R18, IC3's output pulse turns on Darlington transistor TR2, so switching on the solenoid at full power. At the end of the one second period, control switches over to low current mode, as provided in conjunction with IC1b and the circuit around Darlington transistor TR3.

At first power-on, IC3's reset input (pin 4) is maintained in a low state for a fraction of a second using capacitor C5. The capacitor charges through resistor R20 and the reset input goes high after the set *CR* period, so enabling the device. This prevents possible false triggering when the battery is first connected.

CONSTANT CURRENT

When the output of IC1b is high, current flows through resistor R16 to the base of TR3, a Darlington transistor configured as a constant current source.

The maximum voltage that can be applied to its base is approximately 2V, as limited by the three forward-biased diodes D3, D4 and D5 connected in series, each causing a voltage drop of about 0·65V.

For a Darlington transistor, which consists of two transistors in tandem, the voltage drop across its base and emitter is approximately 1·4V. Consequently, the maximum voltage on the junction of TR3's emitter and resistor R24 is about 0·6V. With R24 at the specified value of 5·6 ohms, a current of about 100mA results.

The current flowing in TR3's collector, and therefore through the solenoid coil, is virtually the same as that flowing through resistor R24 (the difference being the very small base current). If the current rises for some reason, the voltage across this resistor will increase. The voltage between the base and emitter will therefore fall and the transistor will be "turned down".

This will result in a smaller current flowing into the base via resistor R16, thus the emitter current is reduced and the constant current effect is maintained. If the current tends to fall, the reverse happens and the transistor "turns up".

The current stabilisation effect of TR3 is not precise because the base-emitter voltage is not exactly fixed. However, it is good enough for the present purpose. Resistor R24 may be substituted for one of a higher value (say, between 6·8Ω and 10Ω) to reduce the holding current. Conversely, it may be reduced to increase the current.

Diode D2 connected in parallel with the solenoid coil prevents the generation of a high-voltage pulse when the current is interrupted and the magnetic field in the core collapses. This could otherwise damage semiconductor devices in the circuit.

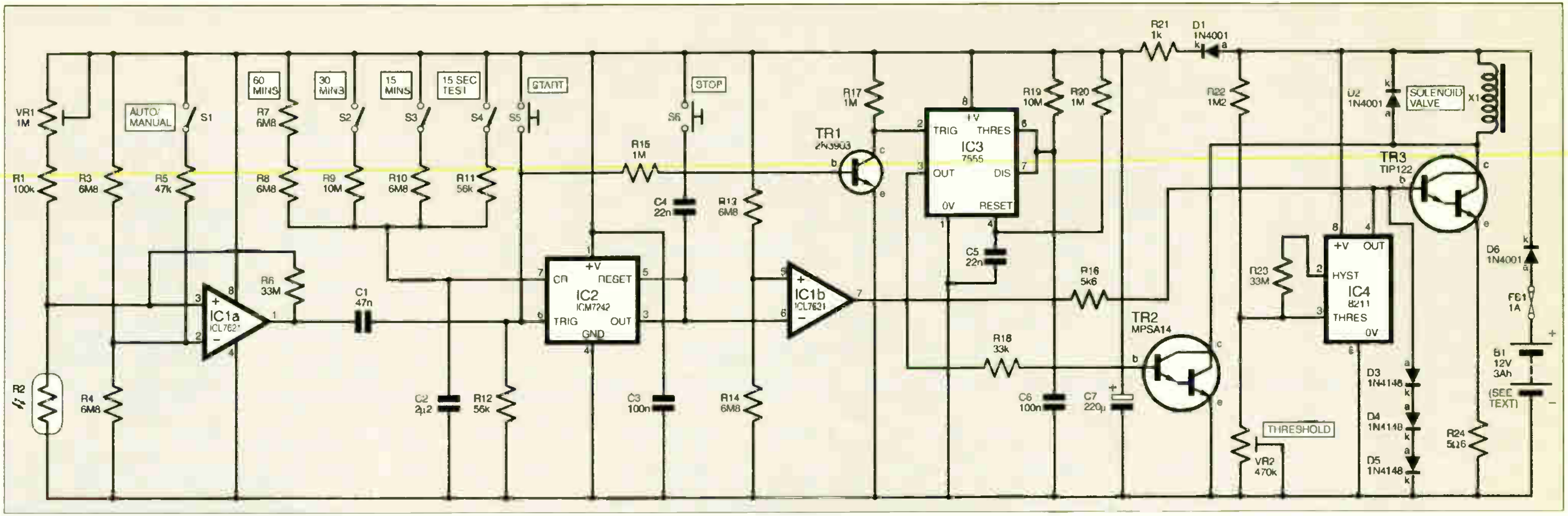


Fig. 1. Full circuit diagram for the Hosepipe Controller.

COMPONENTS

Resistors

R1	100k
R2	ORP12 light dependant resistor (l.d.r.) or miniature equivalent (dark resistance 1M or more)
R3, R4, R7, R8, R10, R13, R14	6M8 (7 off)
R5	47k
R6, R23	33M (2 off)
R9, R19	10M (2 off)
R11, R12	56k (2 off)
R15, R17, R20	1M (3 off)
R16	5k6
R18	33k
R21	1k
R22	1M2
R24	5Ω6 (see text)

All 0·25W 5% carbon film except R2.

See SHOP TALK page

Potentiometers

VR1	1M min. preset, vert
VR2	470k min. preset, vert

Capacitors

C1	47n metallised polyester 5mm pitch
C2	2µ2 metallised polyester 5mm pitch
C3, C6	100n metallised polyester 5mm pitch (2 off)
C4, C5	22n metallised polyester 5mm pitch
C7	220µ radial elect. 25V

Semiconductors

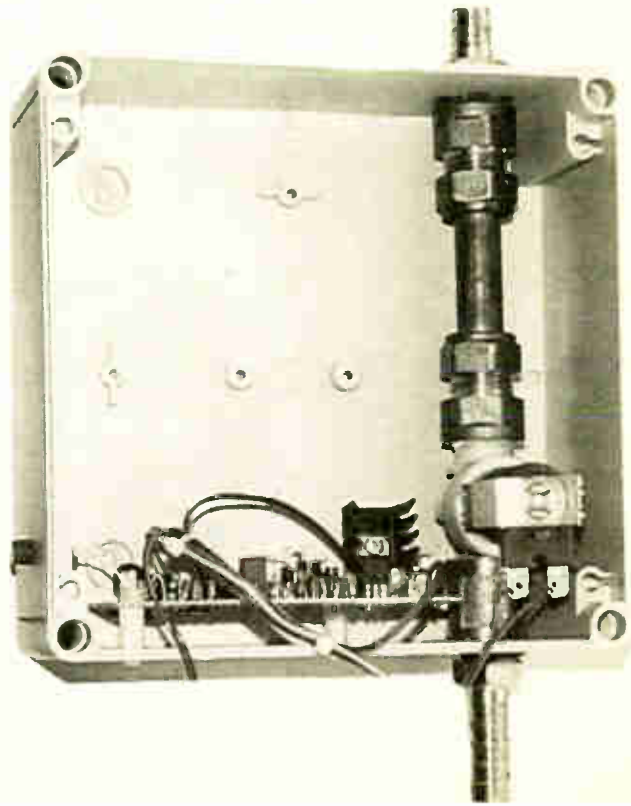
D1, D2, D6	1N4001 rect. diode (3 off)
D3, D4, D5	1N4148 signal diode (3 off)
TR1	2N3903 *npn* general purpose transistor
TR2	MPSA14 low power *npn* Darlington transistor
TR3	TIP122 medium power *npn* Darlington transistor
IC1	ICL7621 dual op.amp
IC2	ICM7242 timer
IC3	7555 low power timer
IC4	ICL8211 or MAX8211 voltage level detector

Approx. Cost Guidance Only* £40 *excl. batt. & plumbing.

Miscellaneous

FS1	1A 20mm quick-blow fuse
S1 to S4	4-way on-off d.i.l. switch module, p.c.b. mounting
S5, S6	splashproof pushbutton switch (2 off)
B1	12V 3Ah sealed lead-acid battery
X1	solenoid valve, mains water supply, 12V 57Ω coil

Printed circuit board, available from the *EPE PCB Service*, code 301; 8-pin d.i.l. socket (4 off); 20mm p.c.b. mounting fuseholder; waterproof case (see text); spade receptacle connector (2 off); stand-off p.c.b. supports (4 off); TO220 finned heatsink; silicone sealant; PTFE thread sealing tape; fibre washers; worm-drive (Jubilee) clips; 15mm copper tube; plumbing fittings as required.



POWER SAVING

With a nominal 100mA flowing through the solenoid valve, and assuming a 12V supply, the power consumed will be 1·2W, compared to 2·4W with the solenoid connected directly to a 12V supply and drawing 200mA. This power saving effectively doubles the operating time from one battery charge.

In the reduced-current (power saving) state and drawing 50mA, 6V approximately will exist across the solenoid valve and 6V between TR3's collector and the 0V line. This means that around 5·4V will appear across the collector and emitter, resulting in it having to dissipate more than 0·5W and requiring a small heatsink to be fitted.

BATTERY MONITORING

The circuit centred on IC4 is for low supply voltage sensing. The threshold voltage to be detected is provided via the potential divider based on resistor R22 and preset VR2, and applied to pin 3. If a voltage less than 1·15V (an internally-set reference voltage) is applied to IC4 pin 3, its open-collector output pin 4 will go low.

Preset VR2 allows adjustment to the operating point and is set so that with a battery voltage of 11V, the voltage applied to pin 3 will be 1·15V. Thus, when the battery voltage falls so that pin 3 is biased at less than 1·15V, pin 4 conducts and diverts current from the base of TR3, so switching off the solenoid.

Resistor R23 connected between pin 2 and pin 3 applies hysteresis feedback, which has the effect of raising the triggering voltage. The battery voltage needs to rise again to about 11·5V before the solenoid valve re-opens. This prevents undue repeated operation at the switching point.

Note that only transistor TR3 is disabled when the low voltage trip point is reached. The main circuit can still be triggered and the short-period monostable will still cause current to flow through the solenoid valve for one second. However, this has little effect on the overall battery drain.

SEEING THE LIGHT

Op.amp IC1a is associated with automatic triggering. This part of the circuit is activated only when switch S1 is off. With S1 on, only manual operation is possible.

Assuming S1 is off, IC1a's inverting input pin 2 receives a voltage derived from the potential divider consisting of resistors R3 and R4. Since these are equal in value, the voltage here will be nominally 6V. The voltage applied to the non-inverting input (pin 3) is derived from another potential divider, formed by resistor R1, preset VR1 and light-dependent resistor (l.d.r.) R2.

The resistance of an l.d.r. changes according to the brightness of the light falling on its sensitive "window" – the brighter the light, the lower its resistance will be. Normally, with bright daylight falling on it the resistance of the l.d.r. will be a few tens or hundreds of ohms, and in near-darkness several megohms.

In this circuit, the l.d.r. is situated some distance behind a hole in the case so the amount of light reaching its window is reduced. As a result, the resistance in bright daylight is a few tens of kilohms, rising to several megohms in darkness.

As the light level increases, the resistance of the l.d.r. (R2) falls and so does the voltage across it. While the surface of the l.d.r. is sufficiently illuminated, the voltage across it will be relatively small and the non-inverting input voltage of IC1a will be less than the inverting one. The op.amp will then be off with the output low. This has no further effect.

When the light level falls below a preset value, the voltage applied to the non-inverting input will exceed that at the inverting one. At the moment that the cross-over point is passed, a high-going pulse is applied to monostable IC2 input pin 6 via capacitor C1. This triggers it and the solenoid valve operates just as if it had been operated manually. Preset potentiometer VR1 provides an adjustment to the operating point in relation to the light level.

The operation of the light-sensing section of the circuit is largely independent of the supply voltage – as voltage rises or falls, both op.amp inputs will be equally affected and so the operating light level trigger point is unaffected.

Resistor R6, connected between IC1a output pin 1 and the non-inverting input pin 3, provides positive feedback. This sharpens the switching action at the critical light level and ensures correct operation. In between automatic operations, the unit may be switched on and off manually using S5 and S6 in the usual way.

With switch S1 on, resistor R5 is called into play. This now appears in parallel with R3. Since R3 has a much larger value than R5, its effect is small and the resistance may be regarded as the value of R5 alone. The voltage at the inverting input will now be almost the same as the positive supply, about 11·9V for a 12V supply.

No matter how dark R2 becomes and whatever the setting of VR1, the voltage at the non-inverting input cannot exceed this value. The op.amp, therefore, can never be triggered and its output will remain low. In this way, the light-sensing section is disabled.

CONSTRUCTION

Construction is based on a single-sided printed circuit board (p.c.b.). The topside

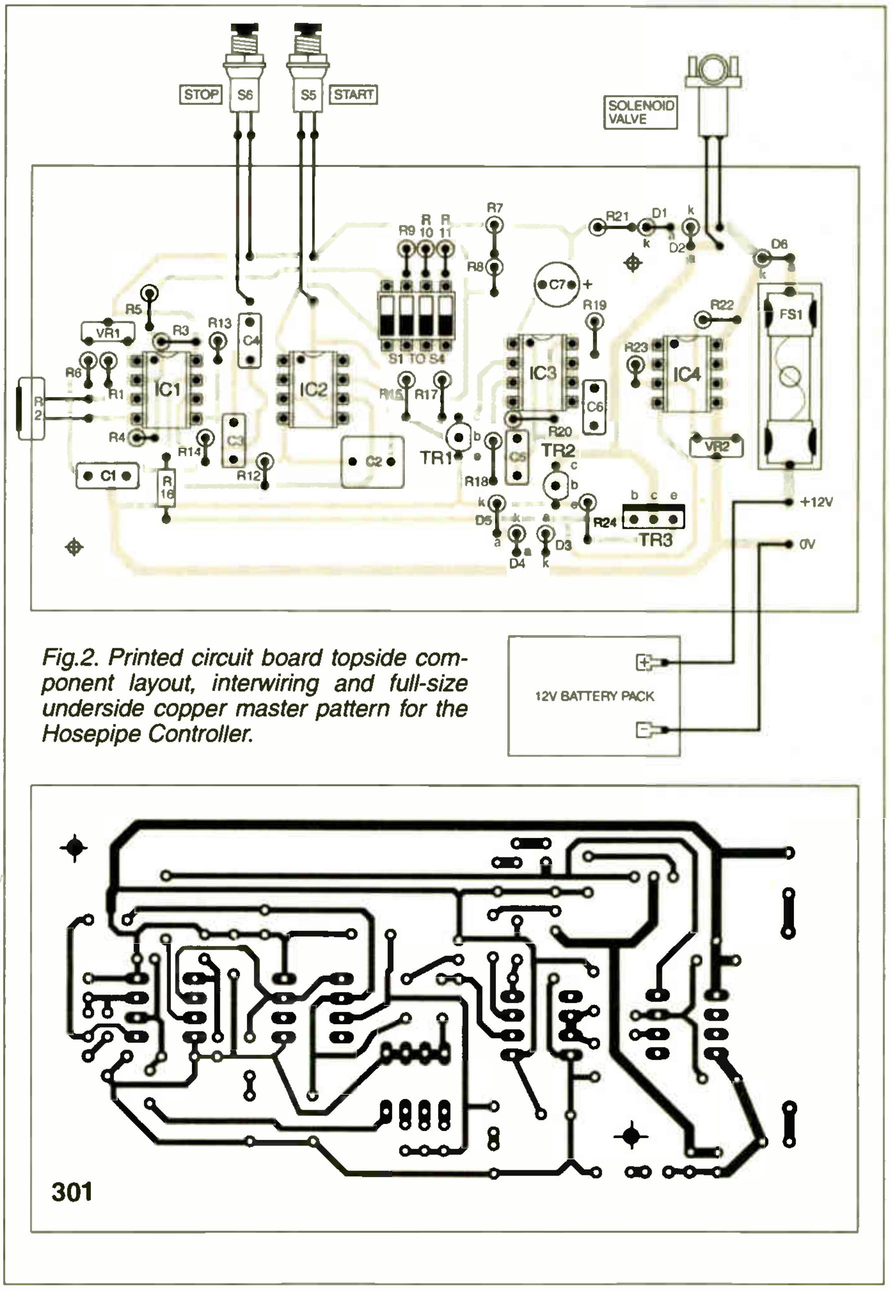


Fig.2. Printed circuit board topside component layout, interwiring and full-size underside copper master pattern for the Hosepipe Controller.

component layout and full size underside copper foil track master are shown in Fig.2. This board is available from the *EPE PCB Service*, code 301. Apart from the start and stop switches (S5 and S6), and the battery and solenoid valve, all components are mounted on the p.c.b.

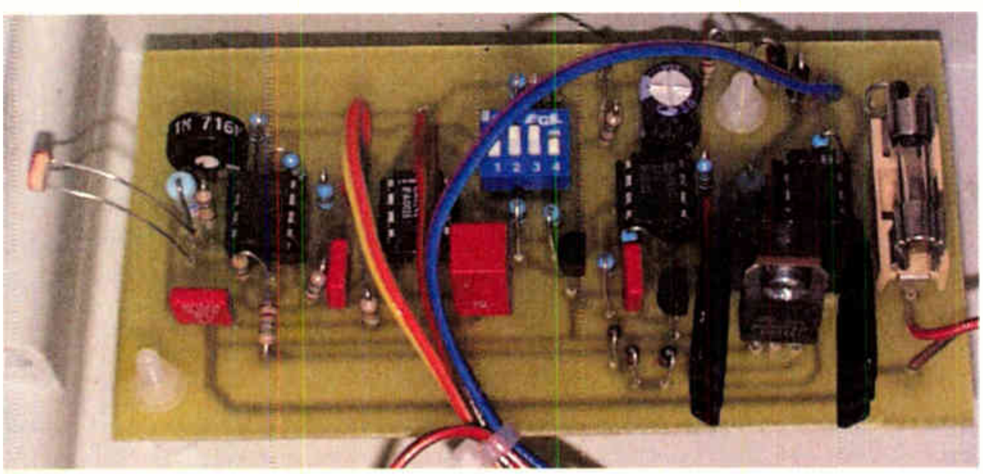
Begin by soldering the resistors and the two presets, VR1 and VR2, and the capacitors (apart from electrolytic capacitor C7). Note that capacitor C2 *must* be a non-electrolytic type.

If you would like to experiment with the value of R24 (to reduce the solenoid "holding" current) solder two short wire "stalks" to this position, and solder R24 to them. In this way, its value may be easily changed.

Add the fuseholder, i.c. sockets (but do not insert the i.c.s themselves yet) and the block of four d.i.l. switches S1 to S4.

Follow with the polarity-sensitive components – diodes, transistors and capacitor C7. Take care to solder all these the correct way round as indicated. Note that transistor TR3 is mounted with its metal backing towards the centre of the p.c.b.

Adjust preset VR1 to approximately mid-track position and VR2 fully clockwise. This latter adjustment will ensure that the "shut off" threshold is never reached, so this section is effectively disabled for the moment.



Completed printed circuit board mounted inside case. Note the l.d.r. has been carefully bent to align with the "light window" and also note the inclusion of a small finned heatsink for TR3.

LIGHT WORK

Solder the l.d.r. (R2) in position using the full length of its leads. Bend the "window" end so that it points away from the edge of the p.c.b. as shown in the photograph. Solder 20cm lengths of light-duty stranded connecting wire to the other off-board connection points.

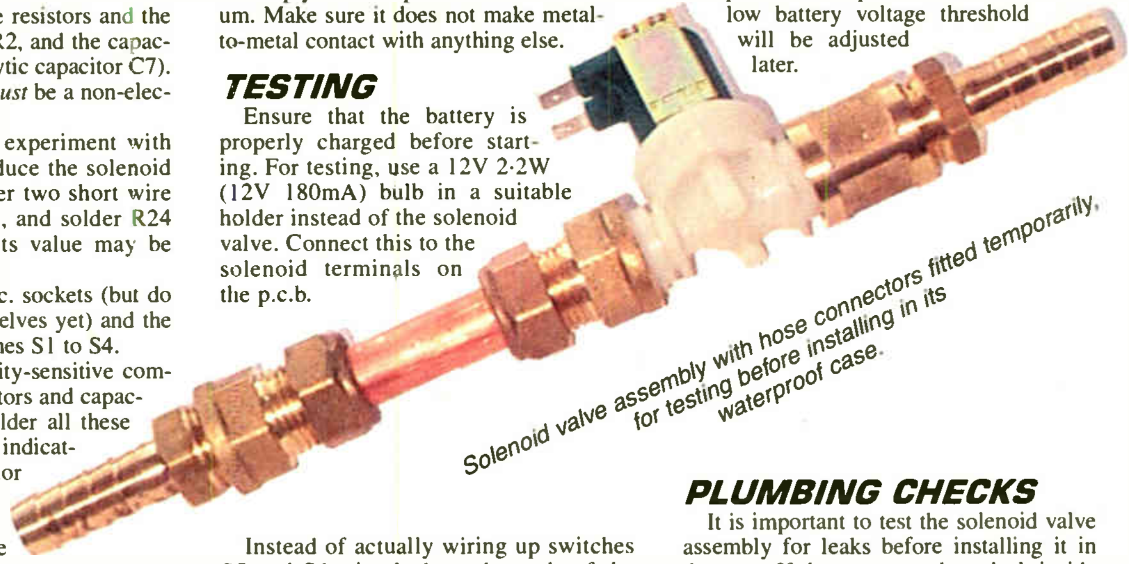
Fit insulated spade connectors on the end of the supply leads to match the battery terminals. It is necessary to use proper connectors here (rather than soldering) because the battery must be capable of being removed easily for recharging.

Having fully checked your assembly for errors, including bad solder joints, insert the i.c.s into their sockets, taking care that they are all placed the correct way round. Since these are all CMOS components, they could be damaged by static charge which may exist on the body. To be safe, touch something which is earthed (such as a metal water tap) before unpacking them and touching the pins.

Attach a small heatsink to transistor TR3. This could be a purpose-made device or simply a small piece of sheet aluminium. Make sure it does not make metal-to-metal contact with anything else.

TESTING

Ensure that the battery is properly charged before starting. For testing, use a 12V 2·2W (12V 180mA) bulb in a suitable holder instead of the solenoid valve. Connect this to the solenoid terminals on the p.c.b.



Solenoid valve assembly with hose connectors fitted temporarily, for testing before installing in its waterproof case.

Instead of actually wiring up switches S5 and S6, simply bare the ends of the Start and Stop wires so that they may be touched to-gether. Set the d.i.l. switches to S1 on (light-sensing disabled), S2 off, S3 off, S4 on (15 seconds test timing).

Insert the fuse into its holder and connect the battery, correctly observing its polarity. The bulb will probably remain off but if it does operate, it should go off after approximately one second (the short monostable timing).

Briefly touch the Start wires together. The bulb should light at full brightness for one second then more dimly for about 15 seconds. It may appear so dim that the filament can only just be seen glowing. Look carefully and, if in doubt about it operating, connect a voltmeter across it – a voltage of about 1V indicating the "on" state.

This relatively low voltage will be much higher when the solenoid valve is connected. It is a consequence of the resistance of the tungsten filament being much smaller when cool than when at full operating temperature. Check the stop action by touching the appropriate wires together while the circuit is in the course of timing. The bulb should go off instantly.

If all is well, check the other timings. Switch off S4. With both S2 and S3 on, the timing should be 15 minutes. With only S2 on, it should be 30 minutes and with both S2 and S3 off, it should be one hour. Note that these timings are approximate and will depend on component tolerances. The low battery voltage threshold will be adjusted later.

PLUMBING CHECKS

It is important to test the solenoid valve assembly for leaks before installing it in the case. If there were to be a leak inside the case, the electronic components could be damaged. Also, once the assembly has been sealed inside the case, it might be difficult to cure leaks by, for example, tightening joints.

The solenoid valve assembly should be constructed as shown in the photograph, complete with the hose connectors. The specified valve is threaded with 1/2 inch BSP male inlet and outlet ports, requiring the use of compression fittings.

Start by applying some PTFE thread sealing tape to the solenoid valve ends and screw on the bushes. Only a small amount of tape is needed – say, two turns. The copper tube should be inserted right up to the solenoid's internal shoulder.

Tighten the nuts using only moderate force. Over-tightening could distort the olives (compression rings) causing the joints to leak.

The specified valve has a direction of water flow shown by a small arrow on the bottom of the body. It is important that the water passes from inlet to outlet port in the direction of this arrow.

Attach the inlet connector to the water tap via a piece of hose. Secure it using a worm-drive clip. Attach a further piece of hose to the outlet connector using another worm-drive clip. Turn on the water supply. If any leaks show at the inlet side, turn off the water and re-make the joints as necessary.

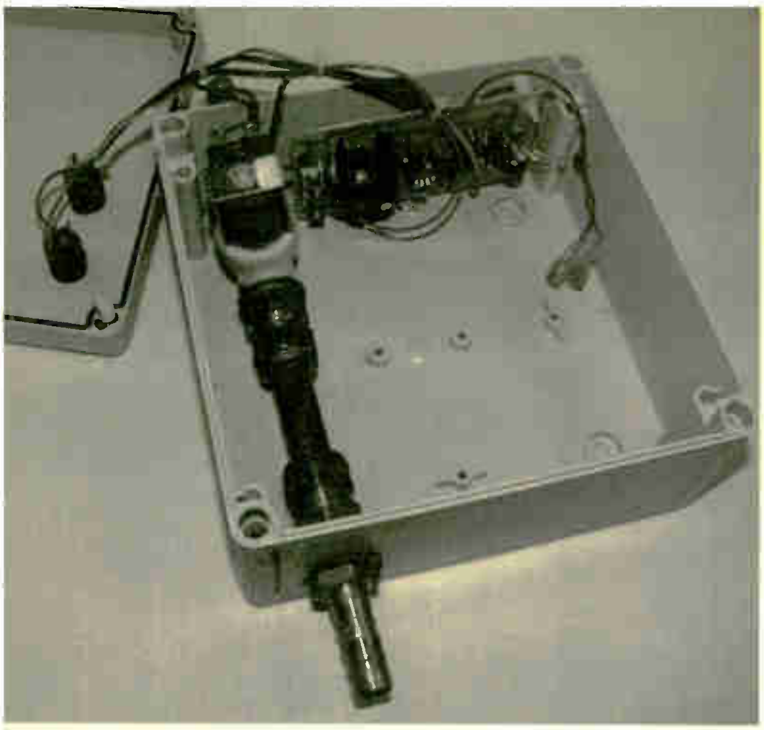
SOLENOID WIRING

The wires to the solenoid may be soldered in place, or spade connectors used. The polarity is unimportant. Use extension wires as necessary to keep the p.c.b. well out of the way of any water spray.

Connect the battery and touch together the Start wires. Water should issue from the free end of the hose and no leaks should show. If there are any, they must be corrected before proceeding. If all is well, remove the hose connectors.

CASE ASSEMBLY

The case may now be prepared, its size should be chosen to suit the size of battery



Layout of components inside the completed unit. The large "empty" area is reserved for the sealed lead-acid battery.

The low-voltage d.c. solenoid water valve unit mounted in one corner of the waterproof case.

it is to contain. How the valve assembly fits into it can be seen in the photographs.

Check carefully the proposed positions of the internal components. The battery should stand on the bottom of the box where it will be well supported and easily removed for charging.

Drill holes for the hose connectors – these must be the right diameter so that the threaded ends pass through with only a little clearance. Drill two holes in the back for wall mounting. Make holes for the switches and attach these using plastic waterproof covers (or use fully-sealed pushbutton switches).

The l.d.r. hole is drilled in the side of the panel that will face the ground. so that it cannot be covered by accident. Sufficient light will still reach it in this position.

In the prototype, this hole is weather protected by screwing into it the empty shell of a small discarded neon indicator, retaining only the lens, a short piece of the threaded body and the fixing nut. This gives a good appearance and is waterproof. Alternatively, you could attach a small piece of transparent plastic over the l.d.r. hole on the inside.

Drill holes for the plastic stand-off insulators on which the p.c.b. is to be mounted, positioned so that the l.d.r. window is immediately behind its protected aperture.

Silicone sealant must be used around all holes that are potential sites for the entry of rain water.

Use fibre washers as necessary on the inside to make up the exact length of the solenoid valve assembly so that it fits between the holes on the box. Apply a little silicone sealant around the ends and slide it in place.

The completed assembly should be a push-fit into the case. Check that the assembly is tight and self-supporting. There must be no movement between the hose connectors and the case.

Refer to Fig.3 and complete the internal wiring. Tidy the wiring by using cable ties.

Finish off by labelling the switches and inlet and outlet ports.

INSTALLATION

Attach the unit to the wall as desired, sealing the screws to prevent water entering. Couple up the inlet to the water supply using a piece of standard garden hose.

The effectiveness of the waterproofing can be tested by spraying the sealed unit with water for a few minutes. Remove the lid and check for signs of leakage. If necessary, dry it out thoroughly and add more sealant.

To set the unit's response to light, switch on d.i.l. switch S1, adjust preset VR1 so that the unit triggers with the correct amount of light. Do this by making small adjustments, replacing the lid and testing, repeating as necessary. The effect cannot be assessed with the lid off because more light will reach the l.d.r. than with it on.

Be aware that if you wish to use a permanent water inlet connection, rather than to an existing tap, there are various water regulations which must be followed. A qualified plumber can advise on the requirements. In the foregoing, it has been assumed that the existing tap has been fitted with due regard to these regulations.

POWER CUT-OFF

It is essential that a lead-acid battery is not allowed to run down *below* its "low point", of about 10·5V. If this happens, it begins to lose capacity and fails to accept a full charge. If it discharged further into a state of "deep discharge", it is likely to be ruined.

The circuit has been designed to switch off the solenoid before the low-point is reached. To provide a margin of safety, the solenoid should be inhibited when the voltage falls below 11V, by the correct adjustment of the circuit around IC4 using preset VR2.

Over a period of actual use, allow the battery to run down but keep a check on its terminal voltage from time to time. The first time this falls to about 11V, trigger the unit manually and adjust VR2 very slowly anti-clockwise to the point where the solenoid just cuts off.

This adjustment sets the level at which IC4 causes the solenoid power to be cut-off, preventing heavy battery discharge below its low point.

FROST DAMAGE

The unit is likely to be damaged if water is allowed to freeze inside the solenoid valve assembly. The resulting expansion could cause bursts and ruin the valve. If there is any possibility of freezing occurring, the unit must be thoroughly drained. □

New Technology Update

Silicon technology is still the mainstay of the semiconductor industry and is likely to remain so for some time, reports Ian Poole.

EVEN as much as ten years ago many of the industry experts were predicting the end of the road for silicon technology. The reduction in size was proving to be a problem and many thought that sub-micron feature sizes were only fiction. Coupled with this the speed of silicon was limited and people thought that other new technologies like gallium arsenide would become the standard.

However, this has not come true. Silicon technology is still the mainstay of the semiconductor industry and gallium arsenide has not gained the major slice of the market as many thought. Now new silicon based technologies are beginning to come more to the front. One of these – silicon germanium (SiGe) has been waiting in the wings for some time.

Interestingly, silicon-germanium technology was proposed by Shockley as early as 1951. However, it has only been since the early 1980s when it was pioneered at IBM that it has been possible to realise the technology in the laboratory.

Full Speed Ahead

The key advantage of SiGe is its speed. There are two main methods of increasing speed in a semiconductor device. One is to decrease the dimensions of the chip so that transit times are reduced. The other is to increase the electron mobility and hence increase the speed at which the carriers can travel. The SiGe combination is ideal to achieve this.

When germanium is introduced into the base area of a silicon transistor the band gap energy is changed increasing the mobility of the electrons in this region. In fact in an SiGe heterojunction bipolar transistor (HBT) the electric field generated by the presence of the germanium provides additional attraction to pull the electrons through the base region.

The smaller base band gap of the SiGe structure when compared to an equivalent silicon-only transistor enhances the electron injection. This enhances the current gain when compared to a silicon transistor. This permits the base to be heavily doped, lowering the total base resistance.

Other developments in the process enable the germanium levels to be graded across the base. This has the effect of increasing the electron velocity across the base region that thereby increases the frequency response of the device.

Whilst SiGe offers advantages in terms of performance, it has the further advantage that these devices can be manufactured in a silicon fabrication plant using standard processes. Gallium arsenide, on the other hand requires a special foundry.

Stressed Out

The development of SiGe technology has needed a considerable amount of research to enable the process to be optimised so that reliable devices can be made. Accordingly it has only been in recent years that viable techniques have been available that can use existing processes.

Whilst silicon and germanium have the same shaped crystal structure there is a difference between the lattice spacing between the two materials. The silicon is about 96 per cent that of the germanium. This would mean that if there was a junction between the two materials the mismatch would cause strains to be set up which would result in defects at the junction, preventing the devices from operating.

To overcome the problem a silicon germanium alloy having a spacing half way between the two substances is used. This enables a junction to be made from the silicon and the alloy. Although some stress remains in the structure it is much reduced and with careful manufacture no defects are formed.

The exact proportions of silicon and germanium in the alloy have to be carefully chosen. Increasing the amount of germanium improves the performance, but it also increases the likelihood of defects. Now the balance seems to have been reached using about 30 per cent germanium, and the remainder silicon.

BiCMOS

Whilst SiGe technology offers very high speeds and low power consumptions, now it can also be integrated with other processes very easily. Both CMOS and bipolar CMOS (BiCMOS) technologies, amongst others can be used.

This means that the high speed r.f. technologies can be interfaced to the more usual CMOS elements of a system, thereby allowing far greater levels of integration to be achieved.

Applications

One company that has taken up the developments on the new process is a start-up company named Ashvattha Semiconductor Inc. based in Jacksonville, Florida, USA. They claim that they have achieved a goal using SiGe that other companies have been struggling to reach for some time.

The company has found a way of overcoming the problems to allow the use of multiple front ends (receiver r.f. sections) on a single chip. This could slash the number of external components required for cell phones and open the way for many new wireless services. The possible reduction in the number of components is particularly attractive because the cost of components in the phone can, it is claimed, be reduced by up to 50 per cent and gives the option of allowing it to be used for other purposes.

They plan to unveil a dual-band Global System Mobile communications (GSM) chip complete with Global Position Satellite (GPS) as well as Bluetooth transmitter and receiver. To achieve this the chip uses the low power silicon germanium BiCMOS process. Developed by IBM and using a 0·25 micron process, it is claimed to be between 20 per cent and 40 per cent less power hungry than other standard BiCMOS processes.

Difficulties in developing this chip were significant as GPS signals are weak and hard to receive, especially indoors. When combined with the local receive and transmit circuitry for other functions in the chip, the noise generated makes it difficult to receive these signals.

A number of techniques have been employed to make this chip possible. One is its so called multimode frequency plan. Details of this are still secret and are being kept under wraps until the patents are fully filed. However, it is known that the idea involves the interaction of the low-noise amplifier, mixers and local oscillator to reduce the signal frequency before it is passed to the digital baseband processing area.

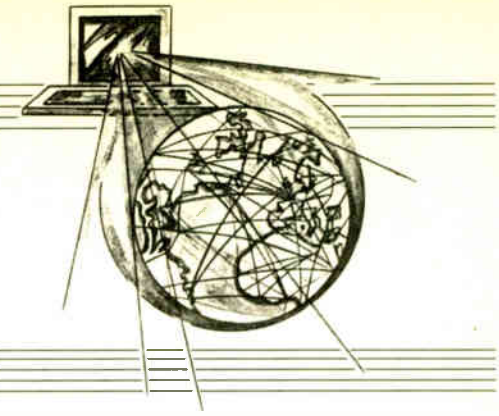
First Success

Ashvattha are the first to succeed in this area. A number of the major manufacturers have tried, but up until recently the technology was not available to achieve it. Nevertheless, other companies including Analog Devices, Qualcomm and Texas are all working towards the same goal.

As a result this will allow cellular phones to have many new features included as standard. Combined with the introduction of the new "3G" services this will enable mobile handsets to be considerably more powerful than they are today.

Whilst mobile phone technology will soon benefit from this new technology, many new applications are beginning to surface. Applied Micro Circuits Corporation have announced the world's first trans-impedance amplifier for 40Gbits per second applications. In other developments many high speed computer applications are being investigated and announced.

With all these new applications it appears that SiGe is set to make a significant impact on the semiconductor market in the coming years.



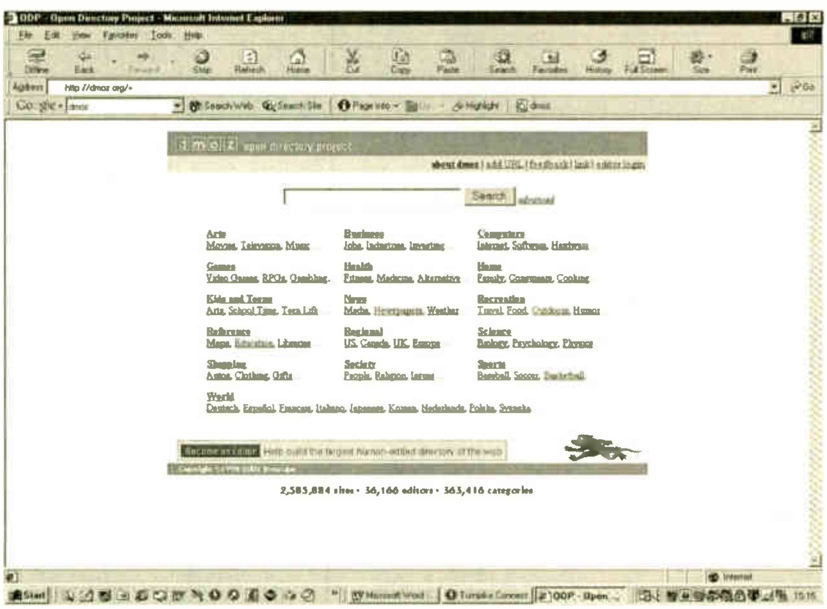
NET WORK

ALAN WINSTANLEY

Search And You Shall Find (usually)

REGULAR readers will recall that I recommended Google (**www.google.com**) as a slick search engine which is usually able to return relevant search results very quickly indeed. Google has the advantage of having a fast front end which is not bogged down with the usual portal-type advertisements and other distractions. The author makes use of the Google toolbar which displays constantly in his web browser, making a Google search very simple (see screenshot). You can download and install the toolbar from the Google web site.

The Google database is also used by Yahoo (**www.yahoo.com**), one of the original Internet search engines. It is always worth keeping several search engines in one's armoury because each tends to work in a different way, and there are times when even Google may fail to return suitable "hits". Alta Vista, Lycos or even Ask Jeeves (**www.ask.com**) and their UK counterparts are worth bearing in mind. One resource which is less widely promoted, but is worth bookmarking, is the Open Directory Project (ODP) at **www.dmoz.org**. There are various local editions in a number of countries, including the Netherlands, Spain and Switzerland. That little cartoon on ODP's page, incidentally, is Mozilla, the original Netscape mascot.



Human Interface

The ODP operates in much the same way as Yahoo. Unlike a traditional search engine, these directories do not strive to link to every URL, instead they use human beings to compile their own index of suitable web sites. The idea is to offer a focused resource which, in the words of Yahoo, provides its users with the best online "experience".

According to ODP, "as the web grows, automated search engines and directories with small editorial staffs will be unable to cope with the volume of sites. The Open Directory Project's goal is to produce the most comprehensive directory of the web, by relying on a vast army of volunteer editors." You can suggest URLs on-line at the ODP site, and you can volunteer to be an editor as well.

In general, the more "accurate" and useful a search engine becomes, the more opportunities it has for generating revenue by targeting advertising at repeat visitors; sometimes businesses can also buy prominence in search engine hits: Google now features "sponsored links" which are guaranteed to appear at the top of results.

Yahoo has been quite choosy in the past about what it decides to accept, but this may simply be because of the mountainous task faced by its editors who perhaps cannot cope with the volume of submissions made by web site owners. Many a webmaster has struggled with the thorny problem of a client site not being listed in Yahoo. Clients blame the web site designer, but they fail to realise that only Yahoo editors decide what they like the look of and what they will accept into their directory listing.

Businesses may now have to pay for the privilege of being listed at all in Yahoo and other search engines or directories: Yahoo wanted $199 to fast-track an application, but this is only to obtain priority consideration, with no guarantee that the site would be listed at all.

Ranked Highly

Trying to ensure that a web site is ranked highly in the search engines is now a black art. Usually, hidden meta tag keywords are deployed in web pages in the hope that this will influence the positioning in a search engine. Unfortunately these meta tags are no longer the be-all and end-all of web site positioning. Much time is spent thinking laterally, to list associated keywords that a potential customer may type into a search engine. Indeed software such as Dynamic Sub-mission 2000 Enterprise Edition (**www.submission2000.com**) can suggest these keywords for you.

However, search engine algorithms have increased in sophistication and they are now learning to recognise "spamdexing", where meta tags are used to place undue emphasis on particular words. An example might be a web site related to vacations in Florida, the meta tags for which could include every known Florida tourist attraction or golf course, in the vain hope that this might bias the search results and increase traffic to the web site.

Search engines can "read" and interpret web pages and may decide that if there is actually no mention in the content of any such tourist attractions, then the web page is trying to spamdex the search engine; hence the web page could actually be banned from that search engine altogether! Furthermore the mere mention of a trademark such as Walt Disney or Epcot could also cause pages to be banned from directories or search engines. (There is recent case history in which a web site owner placed competitors' names into his own keywords, in the hope that a search for his competitor would highlight his own web site instead. The web site owner was forced to modify the keywords or face legal action.)

Search engine positioning is now a serious and complicated business, helped by some powerful software tools which take care of submitting multiple pages to the best known web sites. If you're in the market for web site services, be sure to ask whether any search engine positioning feature is provided, and at what frequency they submit pages to the top ten search engines.

You can E-mail me at **alan@epemag.co.uk**.

SHOP TALK
with David Barrington

Magfield Monitor

The main item of concern when collecting together parts for the *Magfield Monitor* will be the special, low-voltage, highly sensitive flux-gate magnetometer sensor. The FGM-3 fluxgate sensor is obtainable (mail order only) from **Speake & Co. Llanfapley, Dept EPE, 6 Firs Road, Llanfapley, Abergavenny, Monmouthshire, NP7 8SL.** Tel/Fax 01600 780150. E-mail: **speake@elvicta.fsnet.co.uk**. We understand this will cost readers £17 all inclusive, and include the data sheet. All cheques/money orders should be made out to *Speake & Co. Llanfapley*.

The author states that you should *only* use the specified Analog Devices AD8532 dual, rail-to-rail, op.amp in this circuit. The only problem is that it has been discontinued by the original source (Maplin) and readers will, no doubt, have trouble locating a local source. However, we have discovered that **Farnell (☎ *0113 263 6311*)**, code 314-5888, currently have stocks. You could also try **ESR Components (☎ *0191 251 4363*** or ***http://www.esr.co.uk***) who produce some *EPE* projects in kit form.

Some readers may also find that the LP2950CZ micropower voltage regulator is difficult to purchase locally. It is listed by **Electromail (☎ *01536 204555*)** code 648-567, and **Rapid Electronics (☎ *01206 751166*)** code 82-0680.

The choice of meter and style of plastic case is left to constructors' individual preference. The Vero snap-in PP3 type battery compartment used in the model came from **Maplin (☎ *0870 264 6000*)** code XX33L. They also supplied the TDA7052 amplifier i.c. (code UK79L).

The sensor printer circuit board is available from the *EPE PCB Service*, code 302 (see page 457). The two pieces of stripboard for the audio amplifier and meter amplifier were cut from a larger sheet. Most of our components advertisers should be able to supply a suitable piece(s).

Dummy PIR Detector

The miniature, sloping-front box called for in the *Dummy PIR Detector* project may cause buying problems. This was ordered from **Maplin (☎ *0870 264 6000*)**, code KC96E. Some readers may be able to lay their hands on a disused/broken sensor unit from a commercial alarm system.

The semiconductors should be "off-the-shelf" items readily available from our components advertisers. The components list calls for miniature 6·3V working electrolytic capacitors, but 10V or 16V working types might be easier to obtain.

The small printed circuit board is availabe from the *EPE PCB Service*, code 303 (see page 457).

Hosepipe Controller

Just one or two devices need special attention when sourcing items for the *Hosepipe Controller* project. Most parts were purchased from **Maplin (☎ *0870 264 6000*** or ***www.maplin.co.uk***).

The 7242 timer (code NR51F), 7621 dual op.amp (code AV66W) and the ICL8211 voltage detector all come from the above company. They also supplied the splashproof switches (RD20W), the "high voltage" 33 megohm resistors (V33M) and the miniature l.d.r. (code AZ82D – 2MΩ dark) or the ORP12 (HB10L).

Obviously, the "special" for this project is the 12V d.c. water solenoid valve. The one in the prototype model was ordered from **Electromail (☎ *01536 204555*** or ***http://rswww.com***), code 342-023.

The printed circuit board is available from the *EPE PCB Service*, code 301. Most of our component suppliers should be able to come up with a suitable waterproof case. 12V 3Ah sealed lead-acid batteries are often available at discount prices from advertisers such as **Bull Electrical (☎ *01273 491490*), J&N Factors (☎ *01444 881965*) and Greenweld (☎ *01277 811042*)**.

PIC16F87x Extended Memory Use

The software is available on a 3·5in. PC-compatible disk (*EPE* Disk 4) from the *EPE* Editorial Office for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 457). It is also available *Free* from the *EPE* web site: **ftp://ftp.epemag.wimborne.co.uk/pubs/PICS/ PICmem**.

In-Circuit Ohmmeter

No problems should be encountered when ordering parts for the *In-Circuit Ohmmeter*, this month's final article in our Top-Tenner series of projects. Remember to specify the low power version of the voltage regulator, this is designated 78L05**CZ**.

The miniature, p.c.b. mounting, pushswitches are usually referred to as "click-effect" or "tactile" switches in catalogues. Likewise, the spring-loaded test probes are often described as probe-clips or hook clips.

PLEASE TAKE NOTE

Intruder Alarm Control Panel *(Apr/May '01)*

May '01, page 357 Fig.5. The main p.c.b. component layout shows some of the diodes incorrectly annotated and should be as follows:

D5 becomes D22; D6 becomes D11; D7 becomes D12;
D8 becomes D6; D9 ok; D10 becomes D8;
D11 becomes D10 and D12 becomes D5.
D22 becomes D7.

We apologise for these errors. The circuit and components list are correct.

The author states that the battery for the extension bell unit may have any voltage between 7·2V and 12V, and be rated at approximately 250mAh. Either a Ni-Cad or sealed lead-acid type may be used, mounted off the p.c.b. if too big to go on it.

Special Feature

PIC16F87x EXTENDED MEMORY USE

JOHN BECKER

How to use the additional memory banks of PIC16F87x devices.

QUITE likely it may have escaped the attention of many PIC-microcontroller users that the PIC16F87x devices have considerably more data memory available than is apparent at first glance. Under normal programming circumstances the available memory would seem to be 96 bytes, between hexadecimal 20 to 7F ($20 to $7F).

In fact, the PIC16F873 and PIC16F874 each have 192 bytes available, while the PIC16F876 and PIC16F877 each have 368 bytes. Making use of this additional memory is moderately straightforward, once you know how – but it took the author a while to understand how to use it successfully in a design that required it.

The aim of this article is to describe how the extra memory can be used.

PAGES RECAP

All PIC programming readers will be familiar with the concept of Pages (Banks) with regard to using such devices as the PIC16x84. For example, to set a Port's data direction register (DDR) for its pins to be inputs or outputs requires first that register $03 (STATUS) bit 5 is set so that register addresses from $80 and above can be accessed.

It is through these higher addresses that a number of functions, including DDR modes, can be set.

Continuing the example, to set Port B's pins RB0 to RB3 as inputs and RB4 to RB7 as outputs requires the following commands:

```
BSF $03,5          ; set for addresses
                   from $80 upwards
MOVLW %00001111    ; required data
                   direction code (0 =
                   out, 1 = in)
MOVWF $06          ; load data into Port
                   B's DDR (at $80 +
                   $06 = $86)
BCF $03,5          ; set for addresses
                   below $80
```

You will recognise that it is common for the commands BSF $03,5 and BCF $03,5 to be defined respectively as PAGE1 and PAGE0 at the start of a program through #DEFINE functions. It is usual too for Port B's DDR to be referred to as TRISB, while Port B itself is written to or read from under the EQUated pseudonym of PORTB. Register $03 is also usually EQUated as STATUS.

The above code is thus more likely to be recognised as:

```
PAGE1
MOVLW %00001111
MOVWF TRISB
PAGE0
```

The clearing of STATUS bit 5 (PAGE0) at the end of this sub-routine resets the address for registers below $80. In this mode, accessing register $06 now accesses PORTB itself rather than its DDR (TRISB).

FROM PAGES TO BANKS

The concept of Pages is easy to understand, although the term is, perhaps, slightly misleading in that Microchip, the manufacturers of PIC devices, actually refer to Pages as Banks, i.e. Bank 0 and Bank 1 for the PIC16x84.

The PIC16F87x series devices, though, have four Banks, as shown in Fig.1 and Fig.2. The first batch of registers in each Bank is associated with the device's Special Function Registers, such as PORTB and TRISB. Some registers are common to each Bank (PCL, STATUS, FSR etc). Others, such as PORTB and TRISB, can be accessed through two Banks each, in this case Bank 0/2 and Bank 1/3 respectively.

Below each set of special function registers within the Banks are shown locations that can be used for data storage. With Bank 0 of all four PIC16F87x devices, 96 bytes are available for data use, from $20 to $7F.

It is these 96 memory bytes which will be familiar to most readers who are using the PIC16F87x devices, or reading about projects designed around them.

As is evident from the PIC16F87x projects so far published in *EPE*, 96 bytes is normally adequate. The availability of additional memory, though, can be highly beneficial, as the author shows in his PIC Graphics L.C.D. Scope (*G-Scope*) published last month.

Study of Fig.1 shows that for the PIC16F876 and '877, Banks 0 to 3 each have available 80 data memory (general purpose) bytes which are independent from each other. Banks 2 and 3 have a further 16 bytes, which are also independent.

However, the upper 16 memory bytes of each Bank have a common root. Accessing any of these 16 bytes in any Bank automatically accesses those same locations in Bank 0 ($70 to $7F). As the author discovered, this common access to the upper 16 bytes is extremely advantageous.

For the PIC16F876/7, in Bank order, the available data memory locations total is 96 + 80 + 96 + 96 = 368 bytes.

Data memory is arranged somewhat differently in the PIC16F873/4, as shown in Fig.2. There are 96 bytes available in Bank 0, which are jointly accessed through Bank 2. Bank 1 has 96 bytes as well, also accessible through Bank 3, making a total of 192 bytes.

The remainder of this discussion concentrates on the PIC16F877 (and by implication the PIC16F876) which the author used in his *PIC G-Scope*. Similar principles apply, though, to the PIC16F873/4 devices.

DIRECT AND INDIRECT

There are first two formal matters to appreciate about accessing the Banks, which are determined by whether the Bank is being accessed *directly* (by equated name) or *indirectly* (via registers FSR and INDF).

When *directly* writing to or reading from memory locations in the Banks, the required Bank is nominated by the setting or clearing of STATUS register bits 5 and 6 (instead of just bit 5 as in the PIC16x84). The bits are referred to (equated) as RP0 (bit 5) and RP1 (bit 6). These select the Banks as shown in Table 1, and each Bank setting allows direct access to the full 128 byte addresses within it.

As with the familiar Page definitions, it is beneficial to define the setting or clearing of RP0/1 bits at the head of the program, as also shown in Table 1.

It is worth noting that the definitions PAGE0 and PAGE1 could be substituted for RP0LO and RP0HI if preferred (or any other names, for that matter).

INDIRECT ADDRESSING

When *indirectly* accessing the Banks

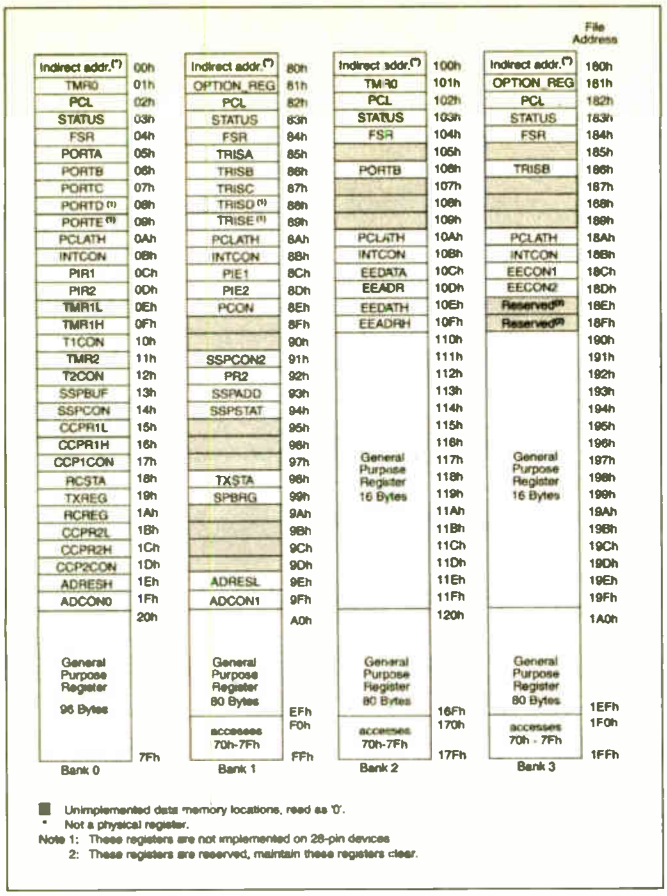


Fig.1. PIC16F877/876 register file map. Courtesy Microchip.

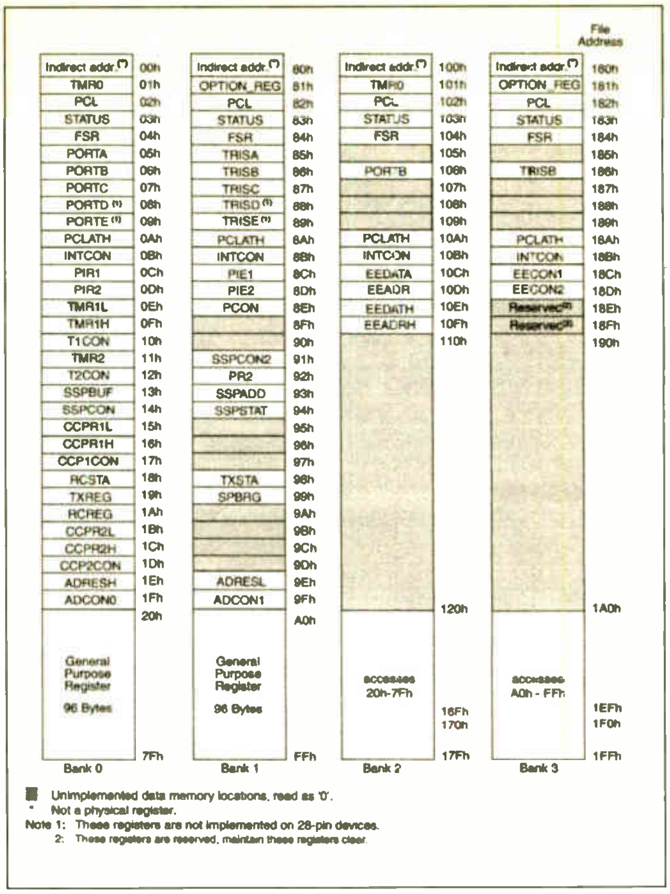


Fig.2. PIC16F874/873 register file map. Courtesy Microchip.

through the use of registers FSR (File Select Register) and INDF (Indirect File register), the setting of STATUS bits RP0 and RP1 is ignored (whatever their value). In this mode, 256 addresses can be accessed, either for the combined pair Bank 0 and Bank 1, or the combined pair Bank 2 and Bank 3.

The selection of the Bank pairs is made through the use of STATUS bit 7, known as the IRP bit. Bank 0 and Bank 1 are selected when bit 7 is low, Bank 2 and Bank 3 when it is high.

Because the banks are paired in indirect mode, it is expedient to consider them as two blocks, BLOCK0 and BLOCK1, selectable by STATUS bit 7. As such the command for block selection can also be defined at the head of the program. See Table 2.

Whether the selection is BLOCK0 or BLOCK1, the address required in FSR for use with INDF can be any between $00 and $FF, covering the full 256 bytes of that Block. The fact that each Block actually consists of two Banks is irrelevant to the indirect addressing mode.

It is important to note that the FSR and INDF registers are common to all Banks and Blocks. They can each be regarded as single registers which can be accessed universally from any Bank or Block.

Table 1. Bank Selection for Direct Access, plus suggested RP0 and RP1 STATUS bit definitions.

Bit 6 RP1	*Bit 5 RP0*	*Bank*	*Locations*	*Direct Access Address*
0	0	0	$00 to $7F	$00 to $7F
0	1	1	$80 to $FF	$00 to $7F
1	0	2	$100 to $17F	$00 to $7F
1	1	3	$180 to $1FF	$00 to $7F

DEFINITIONS

```
#DEFINE RP0LO BCF $03,5    ; clear STATUS bit 5 (RP0)
#DEFINE RP0HI BSF $03,5    ; set   STATUS bit 5 (RP0)
#DEFINE RP1LO BCF $03,6    ; clear STATUS bit 6 (RP1)
#DEFINE RP1HI BSF $03,6    ; set   STATUS bit 6 (RP1)
```

Table 2. Bank Selection for Indirect Access using STATUS bit 7, plus suggested Block definitions.

Bit 7	*Block*	*Banks*	*Locations*	*Indirect Access Address*
0	0	0/1	$00 to $FF	$00 to $FF
1	1	2/3	$100 to $1FF	$00 to $FF

```
#DEFINE BLOCK0 BCF $03,7 ; clear STATUS bit 7 (IRP)
#DEFINE BLOCK1 BSF $03,7 ; set   STATUS bit 7 (IRP)
```

In theory it is possible to set FSR for $00 and to access any of the 256 registers of a Block (up to $FF) via command INDF, incrementing FSR accordingly. It is unlikely, however, that indirect access to the Special Function Registers in the Blocks would ever be required, indeed unexpected results might occur in this situation.

It is to be expected that indirect access is only ever required to be made to the data memory locations. Because these memory bytes are not fully consecutive in a Block, being between $20 to $7F and $A0 to $FF in Block 0 for example, care must be taken when using indirect addressing not to stray from data memory locations to Special File Register locations.

ADDRESSING A DILEMMA

As can be seen, *indirect* addressing requires the use of memory address values that exceed $7F. *Direct* addressing, however, does not recognise address values above $7F. How, then, should named memory addresses have their values quoted in the EQUates configuration?

It is not known how the various proprietary PIC programming software packages deal with this problem. When writing the *EPE PIC Toolkit Mk2* (May/June '99) programming software, the author assumed that addresses would never exceed $7F for direct memory access and that any above that could cause problems for a PIC.

On that assumption, it is concluded that all memory addresses should continue to be expressed as values below $80 if they are to be accessed directly. Consequently, to convert such an address to suit the FSR register when requiring indirect access to values from $80 and above, the value's bit 7 is set immediately prior to loading it into FSR.

For example, data memory locations might have been named MEM20 to MEM6F, using the first 80 available bytes of Bank 0, and their equated values stated as $20 to $6F. Similarly, the first 80 data memory locations of Bank 1 might be named MEMA0 to MEMEF, for which the equated values also have to be $20 to $6F, making them suitable for direct access use in conjunction with setting bit RP0 (bit 5) of STATUS.

Table 3a. Direct access to PIC16F876/7 register addresses.

	RP1	*RP0*	*Access address*	*BLOCK value*
BANK0	0	0	$00 to $7F	irrelevant
BANK1	0	1	$00 to $7F	irrelevant
BANK2	1	0	$00 to $7F	irrelevant
BANK3	1	1	$00 to $7F	irrelevant

Note 1. Addresses $70 to $7F always access BANK0 $70 to $7F irrespective of the Bank from which they are called. See also Table 3c.

Table 3b. Indirect access to PIC16F876/7 register addresses (via FSR and INDF).

	BANK	*Access address*	*RP1/RP0 values*
BLOCK0	0	$00 to $7F	irrelevant
	1	$80 to $FF	irrelevant
BLOCK1	2	$00 to $7F	irrelevant
	3	$80 to $FF	irrelevant

Note 2. Addresses $70 to $7F and $F0 to $FF always access BANK0 $70 to $7F irrespective of the Block from which they are called. See also Table 3c.

All data memory locations MEM20 to MEM6F can be accessed according to their equated values either directly or indirectly. Locations MEMA0 to MEMEF can also be accessed *directly* via their equated values, but to *indirectly* access location MEMA0 (which is equated as $20), for example, the following commands must be used to convert the equated value to suit the FSR requirement:

```
MOVLW MEMA0        ; load the equated
                     address value ($20)
                     for MEMA0 into W
IORLW %10000000    ; set bit 7 of the
                     value (i.e. add $80)
MOVWF FSR          ; move the converted
                     address value ($A0)
                     into FSR
```

Setting the address value's bit 7 is the same as adding decimal 128 (or $80) to it, thus converting the equated value of MEMA0 from $20 to $A0 for loading into FSR. This allows register INDF to access the data memory location pointed to by the address in FSR, i.e. $A0.

The same principle is used for Bank 2, Bank 3 and Block 1, again noting that the equated address value never exceeds $7F if both direct and indirect address access is required to these Banks and Block.

If, however, Bank 1 or Bank 3 are *only* to be accessed *indirectly*, then it is permissible to use the actual address byte value as the equated value, i.e. MEMA0 could be equated as $A0 (instead of the previous $20).

BANKING RULES

It must be emphasised that Bank 2 and Bank 3 never have their locations equated as the *2-byte* values shown in Fig.1 and Fig.2 (i.e. location $120 would have the "1" prefix dropped from the equated value to become $20.

A point worth repeating is that for the PIC16F876/7, whichever Bank or Block is selected, accessing the upper 16 address bytes of that Bank or Block always accesses the addresses held in Bank 0 between $70 and $7F.

A schematic representation of the Bank and Block access control is given in Fig.3.

A summary of the rules which govern Bank and Block selection for any PIC16F876/7 register (either Data Memory or Special Function) is given in Table 3a and Table 3b.

EXAMPLE CODINGS

From the principle of Banks and Blocks, let's discuss an example of a practical subroutine as a demonstration, illustrated in part through Listing 1 and Listing 2. The full source code for the routine (slightly modified) is available as stated later.

For this example we take the situation where a data source is to be read 256 times and the resultant values stored in separate memory locations, using all four Banks for the storage.

In Listing 1 the data source is taken to be PORTD, although it could be any other source, such as an analogue-to-digital conversion via the PIC's own ADC. In the full source code, a counter value is incremented and its value is stored in the memory locations.

Having stored the 256 samples, the 64 values held in Bank 0 are recalled, converted to decimal and output to an alphanumeric liquid crystal display (l.c.d.). A short pause occurs between displaying each decimalised value. Listing 2 illustrates the commands.

The l.c.d. may be any standard device having at least one line of eight characters. The demo circuit diagram is shown in Fig.4 and could be built on stripboard (no layout is offered).

LISTED EXAMPLE

The programming dialect in the Listings and the example source code is TASM, but MPASM is only fractionally

Table 3c. PIC16F876/7 registers accessible from more than one address (Bank and Block settings are irrelevant)

BANK0	*BANK1*	*BANK2*	*BANK3*	*Direct address*	*Indirect address*
GPR	GPR	GPR	GPR	$70 to $7F	$F0 to $FF
INDF	INDF	INDF	INDF	$00	$00 or $80
PCL	PCL	PCL	PCL	$02	$02 or $82
STATUS	STATUS	STATUS	STATUS	$03	$03 or $83
FSR	FSR	FSR	FSR	$04	$04 or $84
PCLATH	PCLATH	PCLATH	PCLATH	$0A	$0A or $8A
INTCON	INTCON	INTCON	INTCON	$0B	$0B or $8B
TMR0		TMR0		$01	$01
PORTB		PORTB		$06	$06
	OPTION		OPTION	$01	$81
	TRISB		TRISB	$06	$86

LISTING 1. Data input and storage.

```
START:     RP0HI                  ; set for Bank 1
           RP1LO
           CLRF TRISB             ; set PORT B for all outputs (%00000000)
           MOVLW 255              ; set PORT D for all inputs (%11111111)
           MOVWF TRISD
           MOVLW %00000110        ; set timer for 1/25 sec (3·2768MHz xtal)
           MOVWF OPTION
           RP0LO                  ; set for Bank 0
; An LCD initialisation routine goes here. See source code.

; Start of sampling routine
           CLRF LOOP1             ; clear loop counter
           BLOCK0                 ; set for Block 0
           MOVLW MEM1             ; get address MEM1 (1st byte of 1st batch of 64)
           CALL GETBATCH          ; input & store 64 values from PORTD
           MOVLW MEM65            ; get address MEM65 (1st byte of 2nd batch)
           IORLW 128              ; set bit 7 high (%10000000 = 128 = $80)
           CALL GETBATCH          ; input & store 64 values from PORTD
           BLOCK1                 ; set for Block 1
           MOVLW MEM129           ; get address MEM129 (1st byte of 3rd batch)
           CALL GETBATCH          ; input & store 64 values from PORTD
           MOVLW MEM193           ; get address MEM193 (1st byte of 4th batch)
           IORLW 128              ; set bit 7 high (%10000000 = 128 = $80)
           CALL GETBATCH          ; input & store 64 values from PORTD
           GOTO PART2

GETBATCH:  MOVWF FSR              ; load FSR with value brought in on W
           BSF LOOP1,6            ; set loop value to 64 (it was previously cleared)
GETIT:     MOVF PORTD,W           ; input PORTD value & store into memory bank
           MOVWF INDF             ; at address pointed to by FSR
           INCF FSR,F             ; increment address held by FSR
           DECFSZ LOOP1,F         ; decrement loop counter, is it zero?
           GOTO GETIT             ; no, continue sampling
           RETURN                 ; end of sub-routine
```

different, in the way that some values are expressed.

At the beginning of the full source code, first the Bank and Block definitions discussed earlier are set. They are followed by the usual equates for the basic Special Function Registers and bit allocations for W, F, C, Z.

Allocated to registers from $70 to $7F are the equated values for the program variables associated with sample data input and output to the l.c.d. These are the locations common to all four Banks. In this program they are all directly accessed by name.

The four Banks of data storage memory used (64 bytes per Bank) are then equated for values between $20 and $5F. However, names are only given to the first location in each Bank, e.g. MEM1, MEM65, MEM129, MEM192. It is not necessary to name the other 63 locations in each Bank since indirect addressing of each Bank always commences at the first byte and continues consecutively.

It would be legitimate in the example program to equate MEM65 and MEM192 to $A0 rather than $20. This has not been done, though, so that the principle of adding $80 to a direct address to convert to a Bank 1 or Bank 3 indirect (FSR) address can be illustrated.

DECIMALISATION AND L.C.D. OUTPUT

The decimalisation routine is not shown in Listing 2 but can be studied in the full source code. Note that all its values are considered to be in Bank 3.

The routine which outputs data to the l.c.d. is the standard "library" routine used by the author in many published PIC projects. All its values are equated so that they can be accessed from any Bank, since they are placed between $70 and $7F, as stated.

PORTB is that through which the data is output to the l.c.d. As shown in Fig.1 and Table 3c, PORTB can be directly accessed through Bank 0 or Bank 2 and it is worth considering this in relation to the number of commands involved following decimal conversion through Bank 3.

To access PORTB through Bank 0, following decimalisation in Bank 3, would require that RP1 and RP0 were both set high prior to entering decimalisation (Bank 3). RP1 and RP0 would then require to be reset low to select Bank 0 for l.c.d. output.

However, two commands can be saved if the l.c.d. output routine is considered to be via Bank 2.

Thus, before commencing any outputting to the l.c.d. RP1 is set high and RP0 set low (selecting Bank 2). To access decimalisation it is only necessary to set RP0 high to change to Bank 3. Following decimalisation, RP1 can stay high, and RP0 can be set low to output to the l.c.d.

Whilst the saving of two commands may seem insignificant, it can be important to program speed in a looped situation where these same commands are frequently repeated. In the example program, 384 commands are saved in the 64-byte loop which writes to l.c.d. three times for each loop step.

MAIN PROGRAM

Following the basic program header discussed earlier, the program then commences to input data and store it in the memory blocks, as shown in Listing 1.

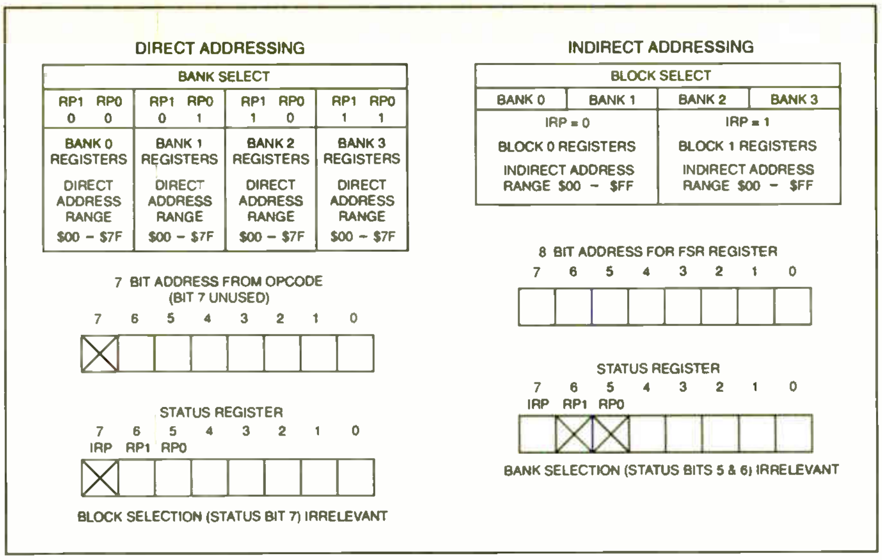


Fig.3. Schematic representation of directly and indirectly addressing Banks.

LISTING 2. Data recall from Bank 0, Block 0, for decimalisation and display.

```
PART2:     BLOCK0           ; set for Block 0
           MOVLW MEM1       ; get address MEM1 (1st byte of 1st batch of 64)
           CALL SHWBATCH    ; display values held in Bank 0 Block 0
HOLD:      GOTO HOLD        ; hold indefinitely
SHWBATCH:  MOVWF FSR        ; load FSR with value brought in on W
           MOVLW 64
           MOVWF LOOP1      ; set loop value to 64
GETVAL:    MOVF FSR,W       ; temporarily store FSR
           MOVWF FSRSTORE
           MOVF INDF,W      ; get value from address pointed to by FSR
           RP0HI            ; set for decimalisation variables held in BANK3
           RP1HI
           MOVWF COUNT0     ; put into LSB counter for decimalisation
           CLRF COUNT1      ; clear NMSB counter
           CLRF COUNT2      ; clear MSB counter
           BLOCK1           ; set for BLOCK1
           CALL DECIMAL     ; perform decimalisation (see full source code)
                            ; note that the 2 writes to FSR within the decimal
                            ; routine are ORed with 128
           BLOCK0           ; set for BLOCK0
           RP0LO            ; set for bank 2 for LCD output via PORTB
                            ; which can be accessed via Bank 0 or Bank 2.
                            ; Accessing via Bank 2 in this instance saves
                            ; two commands per Digit get/LCD write routine
                            ; See full source code for LCD routines
           MOVF FSRSTORE,W  ; recall previous FSR value
           MOVWF FSR        ; and put back into FSR
           MOVLW 0
           CALL LCDLIN1     ; set LCD address to line 1 cell 0
           BSF RSLINE,4
           RP0HI            ; set for Bank 3
           MOVF DIGIT3,W    ; get decimal digit 3
           IORLW 48
           RP0LO            ; set for Bank 2
           CALL LCDOUT      ; output decimalised value
           RP0HI            ; set for Bank 3
           MOVF DIGIT2,W    ; get decimal digit 2
           IORLW 48
           RP0LO            ; set for Bank 2
           CALL LCDOUT      ; output decimalised value
           RP0HI            ; set for Bank 3
           MOVF DIGIT1,W    ; get decimal digit 1
           IORLW 48
           RP0LO            ; set for Bank 2
           CALL LCDOUT      ; output decimalised value
           CALL PAUSIT2     ; pause for a while (see full source code)
           INCF FSR,F       ; increment address held by FSR
           DECFSZ LOOP1,F   ; decrement loop counter, is it zero?
           GOTO GETVAL      ; no, continue sampling
           RP0LO            ; finally set for Bank 0
           RP1LO
           RETURN
```

Three further points now arise. The length of the pauses called at various stages in the program is determined by the setting of TMR0 via the OPTION register. The value shown is in relation to a 3·2768MHz crystal clock.

Secondly, an l.c.d. initialisation routine is omitted from Listing 1, but shown in the full source code.

Thirdly, as stated earlier, data input via PORTD as shown in Listing 1, is replaced in the source code by accessing an incremental loop value (VALUE).

Listing 2 illustrates the recall of stored data in preparation for output to the l.c.d.

In the full source code the letter "S" (for Start) precedes the numeric data display. At the end of all required data being displayed, the letter "E" (for End) is shown. At this point the program goes into a continuous holding loop (HOLD: GOTO HOLD) and no more actions occur.

EXPERIMENTS

It is suggested that once you have assembled the demo circuit and observed the results when the program is run, you make various changes to it in order to reinforce your understanding of using Banks and Blocks.

Experiment 1

In the program as presented, only the data stored in Bank 0 is retrieved for outputting to the l.c.d. Amend the program so that the data held in the other Banks is accessed instead. The values displayed will confirm the correctness of the Bank you are accessing. The values are 0 to 63 for Bank 0, 64 to 127 for Bank 1, 128 to 191 for Bank 2 and 192 to 255 for Bank 3.

Experiment 2

Amend the program so that the decimalisation routine's registers are considered to be in Bank 2 instead of Bank 3.

Experiment 3

The 13 decimalisation registers may be placed in Bank 0 or Bank 1 instead. To what address values would you equate the named registers in either of these situations? Also consider the implications for which Bank is used when outputting via PORTB.

Experiment 4

Amend the program so that it inputs data via PORTD, as shown in Listing 1. The oscillator and 7-stage binary counter discussed in *Teach-In 2000* Part 6 (Apr '00) could be used as the data source fed into PORTD.

FULL SOFTWARE

The full source code for this demo is available from the *EPE* Editorial office on a 3·5inch disk, for which a nominal handling charge is made. It is also available for free download from the *EPE* web site at **www.epemag.wimborne.co.uk**. See this month's *Shoptalk* for details of both options.

The source code is written in TASM but may be translated to MPASM via the software for *PIC Toolkit Mk2* (May/June '99). Note that *Toolkit* version V2.4 was released in Nov '00. *Toolkit For Windows* (TK3) will be released in Autumn '01.

A complete data sheet (around 200 pages) for the PIC16F87x devices can be downloaded free from Microchip's web site at **www.microchip.com**.

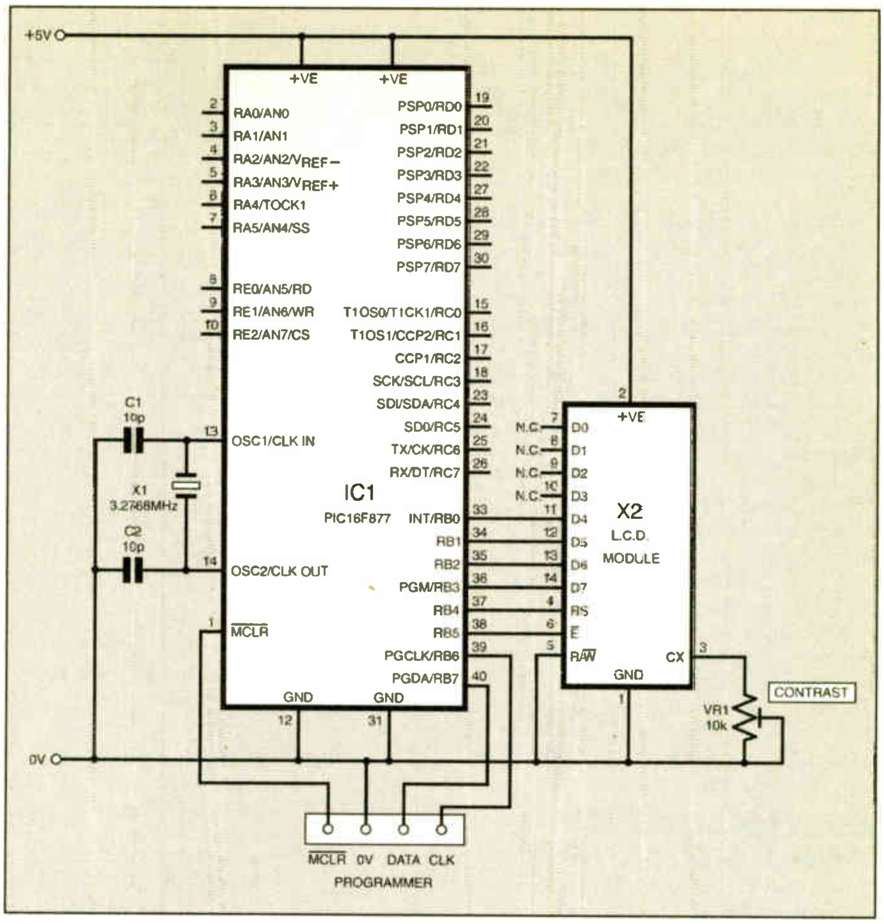


Fig.4. Circuit diagram for use with the demonstration software (see text).

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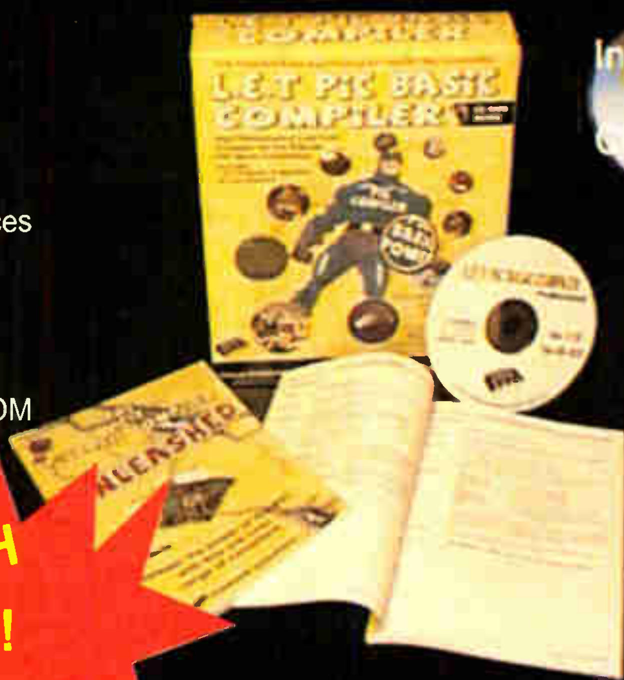

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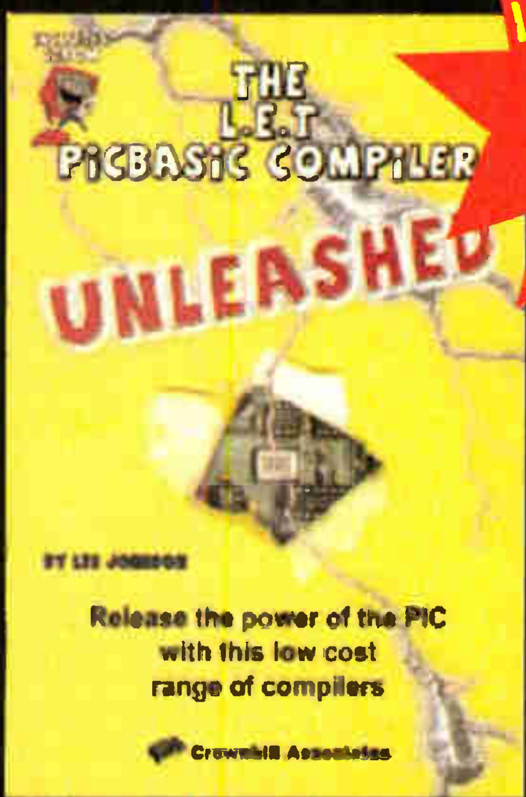

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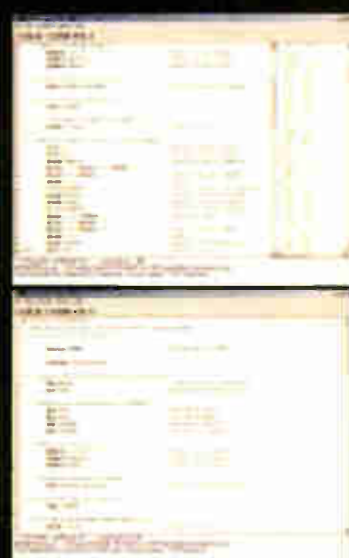

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PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

HAVING recently built a 1960's style short wave radio complete with two valves and a home made tuning coil, it became clear how much electronics has change in the last 30 to 40 years. In those days there were few printed circuit boards, and constructing anything electronic mainly involved metal bashing and hard wiring. Components were generally bigger and tougher than those of today.

Although not physically tough, one thing you did not have to worry about with valves was zapping them with static electricity. Static charges capable of destroying most semiconductors would just about get most valves up to their normal operating potential!

Big Build-up

Semiconductors, unlike valves, normally operate at quite low voltages and are very vulnerable to high potentials. Most semiconductors can withstand high currents for short periods, but an excessive voltage for a few microseconds can zap most semiconductors.

However, some components are more vulnerable to static than others. MOSFETs (metal oxide semiconductor field effect transistors) is the category that is most at risk, and this is due to the ultra-high input resistances of these components. An input resistance of a million ohms (megohms) or more is quite normal for a MOSFET.

Ordinary bipolar transistors have quite low input resistances and this usually results in static charges being leaked away before dangerously high potentials are reached. With MOSFETs static charges can build up until the device breaks down and a high current flows. This gets rid of the charge, but the device is likely to be destroyed in the process.

Discrete MOSFETs are little used in modern electronics, but many integrated circuits are based on some form of MOS technology. This includes all CMOS logic devices, such as the popular 4000 series components and the 74HC00 and 74HCT00 series. Many other digital chips are built using CMOS or some other form of MOS technology, as are some linear devices.

The original 7400 logic chips and the popular 74LS00 series are two exceptions amongst the logic families, and most audio chips do not use MOS technology either. Where a project does use vulnerable components the ones at risk should be clearly identified in the article.

Component catalogues sometimes indicate which devices can be damaged by static charges, and this information should always be available from the data sheet. These days many component retailers include data sheets on the CD-ROM versions of their catalogues, and data for practically every semiconductor ever made now seems to be available on the Internet. If in doubt, always assume that a device is static-sensitive.

Over in a Flash

MOS devices are the most at risk from static charges, but practically all semiconductors are "zappable". The difference is that MOS components can be damaged by quite small static voltages, and not just the sorts of charge that literally cause the sparks to fly.

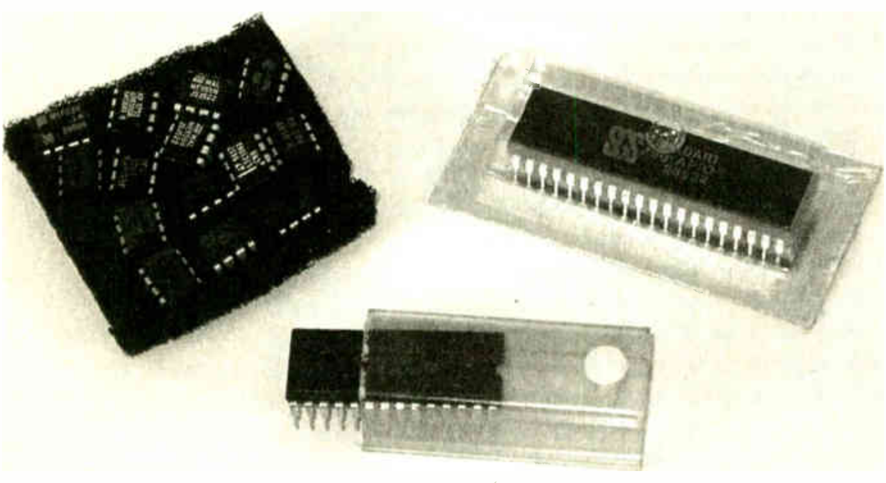


Fig.1. Examples of anti-static protective packaging. Conductive foam pad, anti-static bubble pack and a piece of plastic tube. The tube is designed to insulate the contents from static charges.

With a MOS component it is quite possible to pick it up and zap it in the process with no outward signs of anything being wrong. The component would fail to work, but you would have no way of knowing whether it was destroyed by static, damaged in some other way during construction, or it was simply faulty when you bought it. MOS devices can be damaged by relatively low voltages that you would not normally be aware of, but these voltages are often found in normal environments.

The situation is different with most other types of semiconductor. As pointed out previously, the low resistances associated with most semiconductors prevent the build-up of dangerously high voltages. However, the sudden introduction of a large static charge can cause serious damage. Complex integrated circuits are the most vulnerable to this type of thing, apparently due to the small physical size of the transistors. Components such as power transistors and high power rectifiers are the least vulnerable.

Semiconductors are less vulnerable once they are fitted to a circuit board, since they are then protected to some degree by the resistors and other components in the circuit. However, even components in a finished circuit board can still be damaged by large static discharges.

Precautions

Semiconductors are sometimes supplied in packaging that carries labels giving dire warnings about the consequences of handling the components without the protection of very expensive anti-static equipment. Fortunately, it is far from essential to use expensive equipment when dealing with even the most sensitive of components, and some simple precautions will suffice.

The most obvious precaution is to keep components away from any obvious sources of static charges. Probably the biggest generators of static electricity in modern homes are television sets and computer monitors. Other common sources are plastic covers on hi-fi equipment, some carpets, and pets that become highly charged when stroked.

In the past many clothes had a tendency to produce static charges, but these days manmade fibres are normally mixed with natural fibres, and this largely eliminates the problem. If there are any known sources of static charges in your house, keep semiconductors well away from them.

Another obvious precaution is to leave devices in their anti-static packaging until it is time for them to be fitted to the circuit board. This packaging takes numerous forms, including conductive foam, plastic tubes, blister packs, and conductive plastic bags. Three types of packaging are shown in Fig.1. The tubes are designed to insulate the contents from static charges.

Most other anti-static packaging takes the alternative route of short-circuiting all the pins or leads together. The point of this system is that it is not a high voltage *per se* that causes the damage, but a high voltage between two pins or leads. The short-circuits ensure that significant voltage differences cannot be produced between the pins or leads.

Sockets

When it is time for semiconductors to be fitted to the circuit board, try not to touch the pins or leads any more than is really necessary. Being realistic about things, it will not usually be possible to avoid touching them altogether unless you are equipped with an integrated circuit insertion tool. Even then it is likely that there will be awkward devices that need some manual straightening of the pins before they will fit into place.

In the case of MOS devices they should always be fitted in holders and *not* soldered direct to the circuit board. In fact, it is definitely a good idea to use holders for all d.i.l. integrated circuits. Do not fit the integrated circuits into place until the circuit board and all the wiring has been completed and thoroughly checked.

Holders are less important for discrete transistors other than MOSFETs, and are little used in practice. Where semiconductors are fitted direct to the circuit board they should be the last components to be soldered into place. Always use a soldering iron having an earthed bit.

Down to Earth

If you follow the simple procedures outlined so far it is unlikely that you will run into any problems with zapped semiconductors. There are further measures that can be taken, but these have to be regarded as something less than essential. Most of the anti-static equipment that is available is designed to keep static charges away from the work area and those working in it.

The problem with this type of equipment is that it is not particularly cheap. Something that may be worthwhile for professionals dealing with thousands of pounds-worth of components is not necessarily going to be viable for the amateur user. The equipment could cost more than the components it is protecting, while giving little real reduction in the risk of damage occurring.

Band Aid

If you will be dealing with a lot of expensive and very vulnerable components it might be worthwhile investing in some of the lower cost anti-static equipment. Probably the cheapest item of anti-static equipment is an earthing wristband.

Actually, three pieces of equipment are needed, which are the wristband itself, an earthing plug and a lead to connect the two, see Fig.2. The purpose of all this is to earth the user to the mains earth so that their body cannot carry a significant charge. Any charge will leak away to earth through the user's low body resistance and the cable.

As a safety measure the cable has a high value resistor in each of the connectors. If the earth lead should become "live" it would be difficult for someone to remove the wristband. The resistors have a combined value of several megohms so that the current flow would be far too low to cause any injury if anything should go seriously wrong. The currents involved with static charges tend to be quite small, so the resistors do not prevent any charges from rapidly leaking to earth.

Improvise

It is possible to improvise earthing equipment of this type, but it is probably best to either buy the real thing or not bother at all. There is no point in improvising something that protects the components but leaves you at risk! The bands, leads, and plugs are sold separately and collectively, with the latter generally being a bit cheaper.

As an alternative to using a wristband you can periodically touch something that is earthed. This should remove any charge from your body before dangerous voltages build up. You will also tend to absorb charges in the vicinity of the work area and discharge them to earth.

Any item of mains powered equipment that has an earthed metal chassis makes a good earthing point. Workshop power supplies, oscilloscopes, and PCs usually "fit the bill". You must touch bare metal such as a fixing screw and *not* paintwork. The equipment does not have to be switched on, but it must be plugged into the mains supply.

Earthing Mats

An earthing mat is made from a conductive material and it is used on the worktop. Like a wristband, it is earthed via a lead and mains earthing plug. Some are fitted with a lead terminated in a crocodile clip so that an earthed chassis can be used as the earthing point. This almost certainly represents the most effective low cost method of keeping static at bay.

With the components and circuit board on an earthed surface there is no real chance for static charges to build up. The user frequently touches the mat during the normal course of constructing projects, and therefore tends to remain static-free as well. Last and by no means least, having a large earthed object in the work area tends to leak away charges to earth and keep the whole work area at a low potential.

Although relatively cheap, it still costs a minimum of around £25 to £50 for an anti-static mat plus accessories, which is probably too much to interest most amateur electronics enthusiasts. It is possible to improvise a mat at lower cost, and this could be worthwhile when dealing with expensive chips that use MOS technology.

DIY Mat

Any piece of sheet metal of a suitable size will do. A crocodile clip lead connected to the metal via a solder tag enables the mat to be connected to an earthing lead and plug. In fact it can just be connected to the earth terminal of a bench power supply, etc.

When building and upgrading PCs the author has sometimes resorted to an earthed sheet of aluminium cooking foil as a temporary and very low cost solution, and this has always proved to be successful. A piece of foil glued to a thin sheet of plywood or MDF should give a cheap but more durable conductive mat.

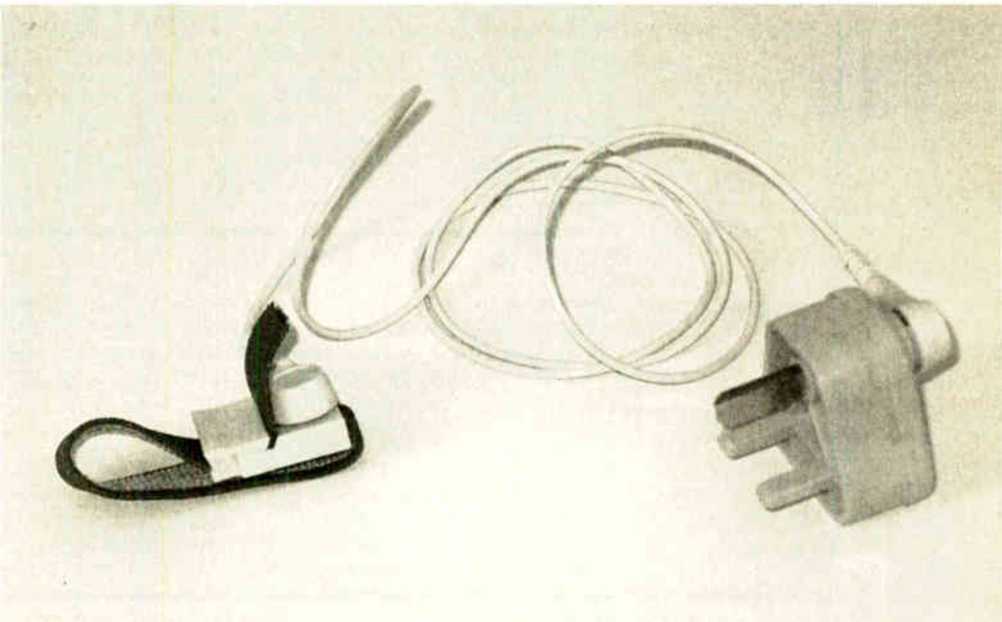


Fig.2. An anti-static "earthing" wristband consisting of the band itself, connecting lead and earthing plug. As a safety measure the lead has a high value resistor at each end of the cable. Only the earth pin of the plug is metal, the rest is plastic.

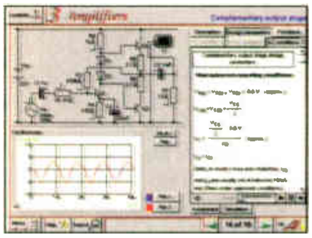
ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS

Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture, circuit simulation** and **p.c.b. design** software is included.
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

ANALOGUE ELECTRONICS



Complimentary output stage

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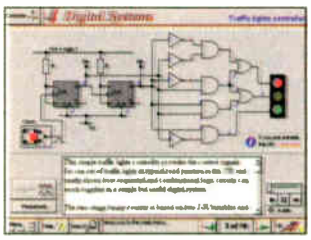
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS



Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
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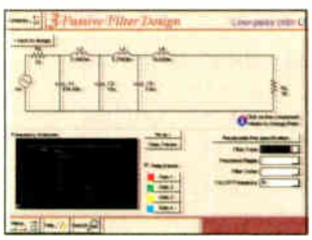
FILTERS



Filter synthesis

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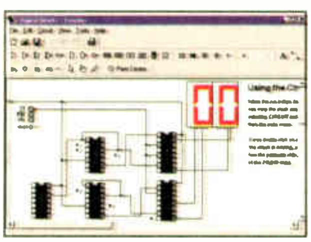
DIGITAL WORKS 3.0



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ELECTRONICS CAD PACK

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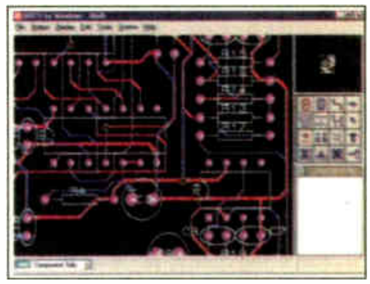

PCB Layout

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

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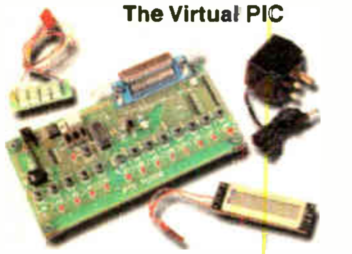

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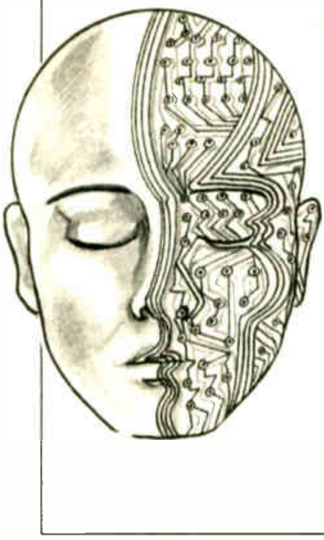

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Transistor Tester – In a Flash

SOME means of testing transistors is virtually a necessity for the home electronics workshop. A simple and inexpensive device that will give a "go-no-go" check for the majority of bipolar transistor types is shown in Fig.1.

Separate transistor test sockets are provided for testing *npn* and *pnp* devices, or test leads may be used. If the transistor is functioning properly the corresponding l.e.d. indicator will flash at roughly 2Hz. Separate l.e.d. indicators are used for *npn* and *pnp* devices.

In the circuit diagram an NE555 timer IC1 is used in square wave oscillator mode. Assuming an *npn* test device is connected, the transistor will be biased off when IC1 output (pin 3) goes low, and will conduct when pin 3 goes high. The l.e.d. D1, with current limiting resistor R5, will flash when a serviceable transistor is connected in the right configuration.

If the test transistor should happen to have a short circuit between the base and collector (c) this will result in a forward bias being applied to l.e.d. D1 each time IC1 output goes low, and D1 may flash dimly or not at all. If the test transistor is a short circuit between collector and emitter (e), then D1 will simply glow continuously, and it will fail to light at all if the test transistor is open circuit.

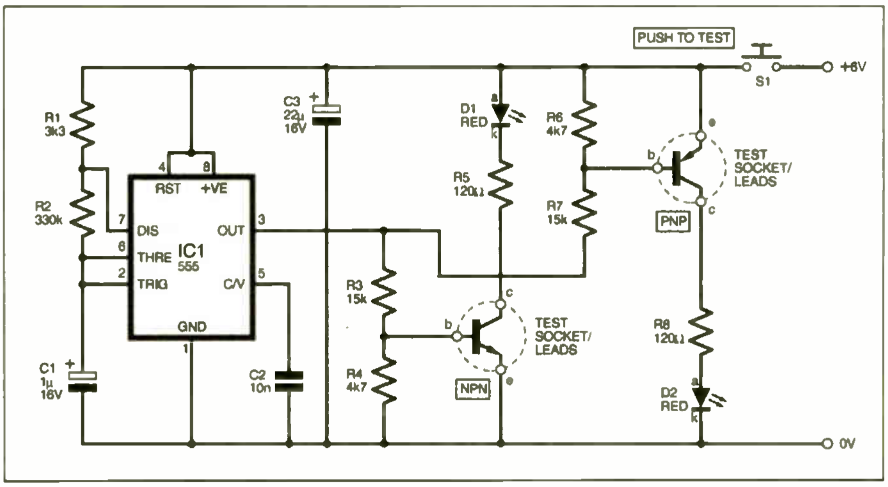

Fig.1. Circuit diagram for a simple "go-no-go" Transistor Tester.

The circuit works in the same way in *pnp* mode except that the *pnp* transistor is pulsed on when IC1 output is low.

Muhammad Mansoor Malik,
Rawalpindi, Pakistan.

DMM Auto Power Off – Power Guard

HAVING inadvertently left my digital multimeter (DMM) on several times and in the process exhausted the internal 9V PP3-type battery, a circuit that would act as an automatic off-switch was devised. After establishing that the meter consumes only about 0·5mA when switched on, it was decided that the whole project could be designed around a single CMOS chip.

The final circuit diagram is shown in Fig.2, which is a monostable based on IC1, a 4011BE (quad 2-input NAND). It is activated by the push-to-make "on" switch and with the component values shown, remains on for about 75 seconds. The quiescent power consumption of the circuit did not register on the microamp scale of a meter. No supply decoupling capacitor proved to be necessary.

The "on" output voltage was 9V under no load and the meter worked perfectly. The circuit could also be used for other low power devices such as calculators or small electronic games. As there was no room to fit the circuit in the meter it was fitted in a film cartridge under the case in such a way that it tilts the meter towards the user and so improves visibility.

Glyn Shaw,
Staines, Middlesex.

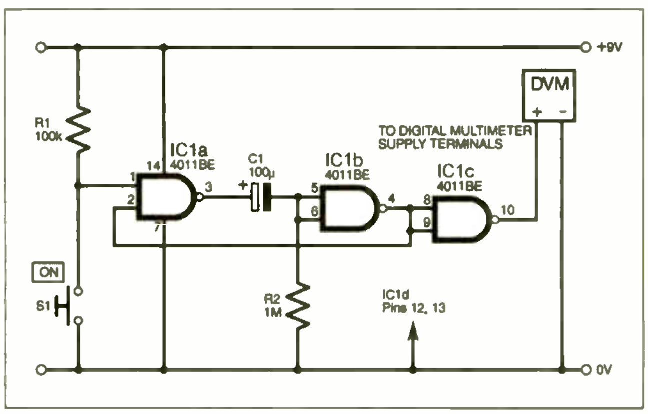

Fig.2. DMM Auto Power Off circuit diagram.

Broken Field Detector – Protective Shield

THIS simple circuit diagram (Fig.3) for a Broken Field Detector outperforms many other types of proximity detector, and is intended, in this bare-bones form as the basis for further experimentation.

It is well known that domestic electromagnetic fields cause eddy currents in the human body. This means that the body must absorb such fields. Rather than detect these eddy currents (as is usually done), this circuit detects that electromagnetic energy has "gone missing" from the environment.

Picture a human body passing between a live mains transformer and a pick-up coil. Over a distance of one metre, the body will absorb up to three-quarters of the electromagnetic radiation passing between the transformer and the pick-up coil. This is so even if only part of the body (e.g. a limb) intervenes.

Since the voltage induced in the pick-up coil may represent 100mV d.c. when rectified, this can be easily detected and used to sense (for instance) the presence of a person in a doorway or a passageway.

Circuit Details

In the circuit diagram of Fig.3 the a.c. field detected by the pick-up coil L2 is rectified by silicon bridge rectifier D1-D4, then fed to voltage comparator IC1, which detects any drop in the detected voltage. Sensitivity is adjusted by means of potentiometer VR1.

The pick-up coil can be any thickly wound coil, such as another transformer, a solenoid, or a motor winding. Mount a mains transformer (or an applicance that incorporates a mains transformer) in a position where your body will pass between it and the pick-up coil.

Begin testing with the pick-up coil about 60cm from a mains transformer which is powered up, and experiment with the orientation of both the transformer and the pick-up coil for maximum effect.

Rev. Thos. Scarborough,
Fresnaye, Cape Town, South Africa

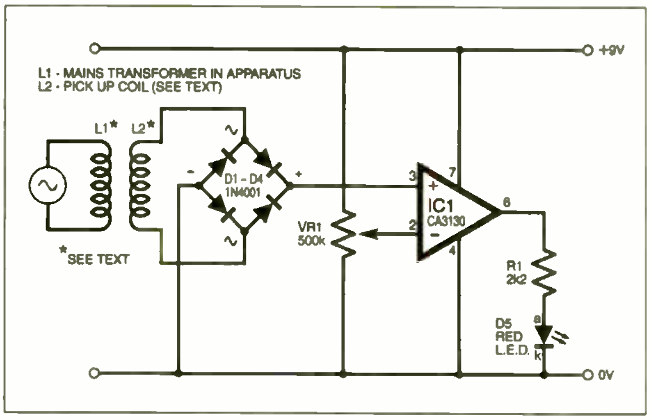

Fig.3. Circuit diagram for a Broken Field Detector.

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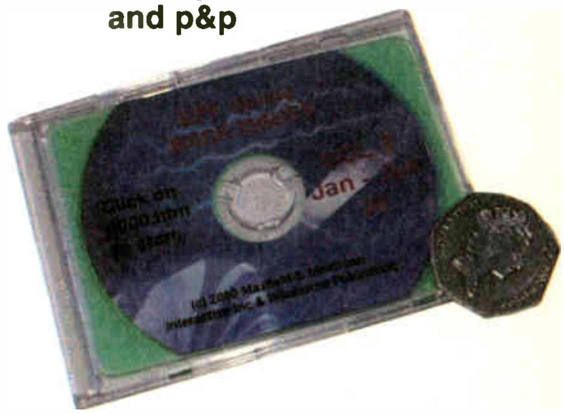

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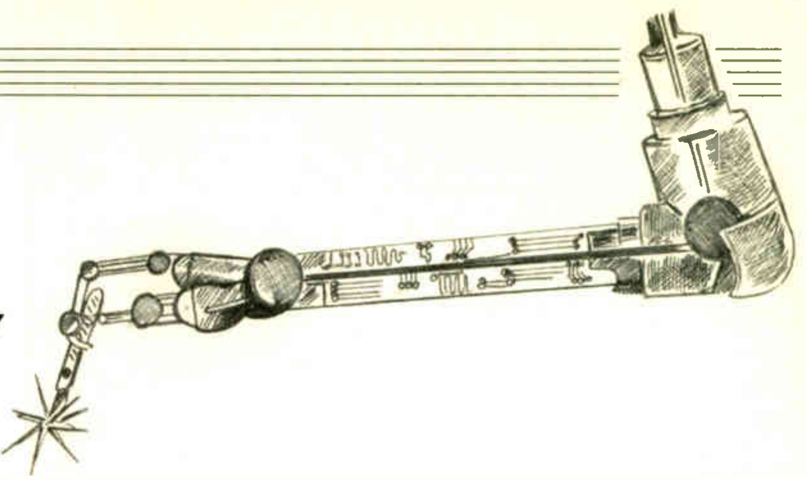


CIRCUIT SURGERY

ALAN WINSTANLEY and IAN BELL

We continue with the topic of impedance, and why "impedance matching" can be important. Also we briefly describe transmission lines, in a non-mathematical way – no anaesthetic required!

LIFE's hectic here at the Surgery! Last month in response to a reader's request we started a "mini tutorial" on impedance matching, prior to that we looked at Phase-Locked Loops (PLLs), and we have several more general discussions in the pipeline.

If you would like to suggest a subject please contact us, and remember we will also try to answer more specific readers' questions as well (but we cannot provide complete design solutions!). The purpose of this column is to encourage an understanding of electronics.

As always, we enjoy dealing with general electronics-related questions that we can get our teeth into and which will benefit other readers, but this column cannot help with microcontroller programming or the repair or modification of commercial equipment. Oh, and we can't offer an immediate reply by E-mail, we're sorry – *Ian and Alan.*

Impedance Matching

Last month's discussion on impedance matching was mainly taken up with making sure we understood what impedance was all about. We pointed out that there are a number of different scenarios and problems that come under the idea of "matching" in the loosest sense of that term.

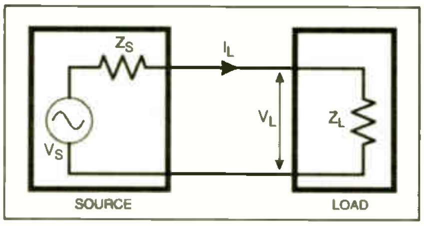


Fig.1. Source and load connected together.

We now return to the basic situation – that of a source with impedance Z_S, connected to load of impedance Z_L as shown in Fig.1. The "matching" problem is basically how to choose the most appropriate Z_L given that we know the value of Z_S. This depends on what we want to happen, so let's have a look at what's going on in Fig.1 to get a better idea of the influence of the relative values of the source and load impedances.

The two impedances form a *potential divider*. Thus the voltage across the load is given by:

$$V_L = \frac{Z_L}{(Z_S + Z_L)} V_S$$

We get this equation by using Ohm's Law ($V=IR$) to find the current through the two impedances (V_S divided by the total impedance), and then applying Ohm's Law again to get the voltage drop across Z_L (by multiplying Z_L by the current).

From the equation, we can see that if we want the *voltage* across the load V_L to be as large as possible, then Z_L must be much *larger* than Z_S (we are assuming Z_S is fixed). In fact if Z_L is *very much larger* than Z_S, then the load voltage is effectively equal to the source voltage.

The current in the load is given by:

$$I_L = \frac{V_S}{(Z_S + Z_L)}$$

Thus if we want the *current* in the load to be as high as possible, then we need to make Z_L *much smaller* than Z_S (again we are assuming Z_S is fixed).

Given that the term "matching" would imply that $Z_S = Z_L$ then the two scenarios we have just looked at – maximum V_L by making Z_L much *larger* than Z_S, and maximum I_L by making Z_L much *smaller* than Z_S – will indicate what happens when load and source are *not* "matched".

Most Appropriate

In general though, the question we should really be asking is *what is the most appropriate load for this source?*; matching in the sense of $Z_S = Z_L$ is not always what we want. For example, a high impedance input (where Z_L is much greater than Z_S) may be most appropriate for amplifying the voltage from a sensor. In fact, in very many cases, circuits are designed to have a much larger input impedance than the source impedance connected to it, so that "loading" does not modify the voltage at the input.

When connecting a source to an input such as an amplifier, the loss of (voltage) signal measured in decibels (dB) due to loading by the input impedance (load loss), can be calculated as follows (assuming a simple resistive source and load).

$$\textit{Load loss} = 20\log\left[\frac{R_L}{(R_S + R_L)}\right]$$

In general it's a good idea to have R_L about ten times larger than R_S if you want to avoid loading. This results in a load loss of less than 1dB.

Power Transfer

So what happens when $Z_S = Z_L$, and why might this be useful? The answer is that maximum power is transferred from source to load when the load and source are matched, and if it is power delivered to the load that matters, then we usually want the maximum power available.

In order to prove this, you have to resort to using calculus – why not try it, if you know how to differentiate? (Hint: find the maximum of the relationship between load power and load resistance. We suggest you use resistors rather than complex impedances to keep things straightforward).

The power transfer aspect of matching is important in power amplifier outputs. For example, consider a power amplifier producing a 30V r.m.s. signal with a 4 ohm output impedance; the powers into loads of various impedances are listed below.

Load	*RMS Power (4Ω source at 30V r.m.s.)*
1Ω	36W
2Ω	50W
4Ω	56W
6Ω	54W
8Ω	50W

See how the maximum power is obtained for a load of 4Ω – matching the source impedance. The maximum power delivered to the load is half of the power taken from the source at that point, as the load impedance increases above being equal to Z_S a greater proportion of the source's power ends up in the load, but the actual power delivered decreases.

If the required load and source impedances are not equal, they can be matched using a transformer as shown in Fig. 2. The transformer turns ratio primary to secondary (n_P/n_S) is chosen so that:

$$R_S = \left(\frac{n_P}{n_S}\right)^2 R_L$$

. . . in order to match the source and load, and obtain maximum power for the load. Matching transformers are quite commonly used with audio power amplifiers.

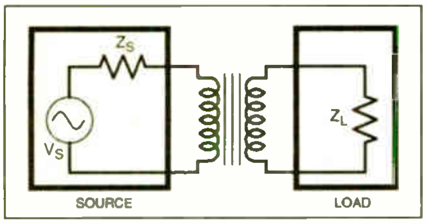


Fig.2. Matching impedances using a transformer.

The matching together of microphones with pre-amplifiers is another common requirement and is quite a complex area. Microphones are produced in high impedance (e.g. 10kΩ) and low impedance (e.g. 600Ω) varieties. High impedance microphones need to be matched to high impedance pre-amplifier inputs to prevent load loss (degrading the signal); however, some low impedance microphones can be connected to high impedance inputs successfully, although with a low input impedance input there is less pick-up (noise) due to pick-up of radiated signals.

To complicate the issue, long microphone wires may act as *transmission lines* (see below) so matching is more important if very long wires are used. Transformers can be used for this.

Transmission Lines

It is worth pointing out that Fig.1 does not apply to all situations where the issue of "matching" may arise. First, we mentioned the influence of the impedance of the lines last month and we'll look at this in detail in a moment. Second, not all "sources" are really sources in the sense of Fig.1.

Many sensors, for example, actually vary in impedance, but do not contain a voltage source. These may be connected to circuits such as bridges where the "input impedance" must be appropriate to form the bridge or potential divider circuit with the sensor. (*The use of sensors is something we will be looking at in a major new series commencing later this year.*)

In such situations we can always model the complete bridge circuit as the source and draw a circuit just like Fig.1, remembering that part of the source of Fig.1 may actually be inside the physical box containing the amplifier.

When wiring up small circuits operating at relatively low frequencies we often think of wires as being perfect conductors that do not have much influence on the circuit. Moving one step on from this, we may remember that a real wire has some *resistance*, so it might drop some voltage if we pass a high current through it, or we might realise the wire has some *capacitance* or *inductance* which may influence circuit performance in some way.

If this is the case we can regard the wire as, say, a single resistor or capacitor and take this into account in our "matching" calculations. For example Fig.3 shows Fig.1 redrawn for a situation in which the wire connecting the source and load has a significant resistance.

The view of a non-ideal wire being equivalent to a single resistor, capacitor, or combination of these works fine at relatively low frequencies and for relatively short wires. However, for very long wires, or very high frequencies for shorter wires, the signal takes a significant time to travel down the wire compared to one cycle of the signal's waveform. When this happens, we can no longer lump the impedance of the wire together into a single component as in Fig.3, because now different parts of the signal "see" different parts of the wire at different times.

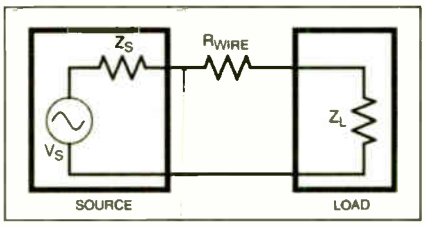


Fig.3. The wire connecting together a source and load may need to be taken into account. In this example it has a resistance.

Actually, the signal behaves more like a wave travelling in a pipe, and the wire is referred to as a *transmission line* (see Fig.4). Instead of a single lumped impedance, transmission lines are described by their *characteristic impedance*, which is the ratio of the voltage to current at any point on the wave travelling down the line.

Coaxial cables are often used in applications where they behave as transmission lines. They typically have characteristic impedances in the range of 50 ohms to 100 ohms.

Impedance matching is important when transmission lines are involved, because unmatched connections cause part of the wave on the line to be reflected back. It then travels back down the wire in the opposite direction and causes interference (just like criss-crossing ripples on a pond), which distorts the signal. The reflection, of course, also reduces the amount of power delivered to the load because some of the signal has gone off in the wrong direction!

In order to prevent signal loss and distortion, the characteristic impedance of a transmission line must be equal to the load and source impedances. Transmission lines must be terminated correctly even if the final end of the wire is not connected to a circuit input.

To analyse the behaviour of transmission lines in detail requires (as you might expect!) some advanced mathematics which is beyond the scope of this column. However, you can get a feel for what is happening by imagining a wave travelling down a channel filled with water.

If we connect this channel to another of exactly the same width and depth then the wave will carry on as if nothing has happened (i.e. the channels are matched). However, if we connect one water channel to another that is much wider or narrower, then the wave will get reflected off the edges or corners of the channels at the join, causing "interference" and a loss in power of the wave that continues in its original direction. *I.M.B.*

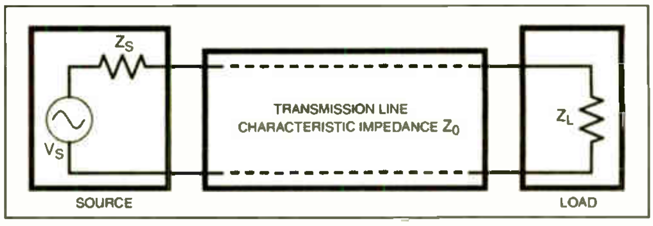


Fig.4. The wire connecting source and load may behave as a transmission line, in which case it should be matched to the source and the load. For matching $Z_S = Z_O = X_L$.

Selenium Rectifiers

After a hard winter I found that my car's battery charger had failed. Testing it with a multimeter I found that although there was an a.c. output from the transformer, there was none from the rectifier.

I cannot find any reference at all to the type of "plate" rectifier used. Is it repairable? ***A. Lovie, Banff, Scotland.***

If it is very old then by the sound of it, your charger could use selenium rectifiers, which were first used on older TV sets and radiograms. They have cylindrical bodies fitted with fins to dissipate heat. Disc-type rectifiers could also be fitted together to form selenium rectifier "stacks". Otherwise, your charger could use ordinary silicon rectifiers bolted to a heatsink to aid cooling.

Useful in high voltage circuits, selenium rectifiers were generally unreliable and fell into disuse, partly because of toxicity problems and also because of their bulky size. Vintage radio enthusiasts tell me that the first parts to fail are the selenium rectifiers, which they replace with modern silicon semiconductor types instead, taking care to use one with a suitably high peak inverse voltage (PIV).

High PIV ratings are probably not an issue for you so you probably have nothing to lose by swapping for, say, any 100V power rectifier or stud-mounted device capable of carrying higher currents (say 10A to 20A). A stud-type can be bolted to a heatsink, taking care not to short it to earth/chassis.

All the usual precautions are needed when handling unsealed lead-acid batteries which can deliver many hundreds of amperes peak. Avoid wearing metal wrist straps or bracelets (danger of serious burns), guard against acid spillage or splashes, cover the battery cells with a damp cloth and, due to the presence of hydrogen gas, avoid creating any sparks nearby. *ARW.*

Top Tenners

IN-CIRCUIT OHMMETER

OWEN BISHOP Project 10

This is the last of our short collection of stripboard projects, some useful, some instructive and some amusing, which can be made for around the ten pounds mark. The estimated cost does not include an enclosure.

THE last of our Top Tenners is a simple add-on for your multimeter that lets you measure the value of a resistor or other resistance while it is still attached at both ends to a circuit board. In-circuit measurements save a lot of time spent in unsoldering and resoldering, so you could find this project very helpful in the workshop.

OP.AMP

The circuit is based on an operational amplifier (op.amp), which is shown in Fig.1 wired as an inverting amplifier. The op.amp is powered by a dual supply (say, +9V and –9V), not shown in Fig.1 but see Fig.3.

An input voltage V_{IN} causes a current I to flow through a resistor R_{TEST}. It is a property of the op.amp that when wired as an inverting amplifier it always tries to equalise the voltages at its two inputs. The non-inverting (+) input is tied to the 0V rail, so it tries to bring the inverting (–) input to 0V too. This it does by swinging its output low, toward the negative supply rail.

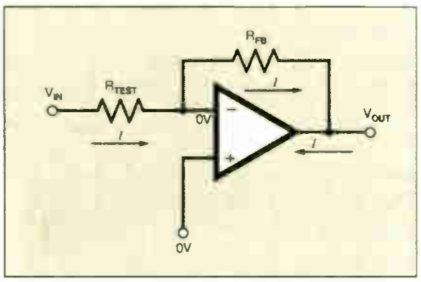


Fig.1. An op.amp wired as an inverting amplifier. It is powered by a dual 9V supply, not shown here.

If the inverting (–) input is at 0V, the voltage across R_{TEST} is V_{IN}. Applying Ohm's Law, we can say that:

$$I = V_{IN}/R_{TEST}$$

When current I gets to the inverting (–) input, only an exceedingly small part of the current can flow into it because the input impedance of the terminal is around 10^{12} ohms (a million megohms!). Instead, the current flows on through the feedback resistor R_{FB} and *into* the output terminal of the op.amp. This is the way the current actually goes, but the *effect* is just the same as if the (–) terminal was connected directly to the 0V rail. We say that the (–) terminal is a *virtual earth*. This feature is important in this month's project.

As we said, the output has swung negative, so there is no problem about current flowing into it. Now we have the resistor R_{FB} with a voltage V_{OUT} across it and a current I flowing through it. By Ohm's Law:

$$I = -V_{OUT}/R_{FB}$$

V_{OUT} is negative, so this keeps I positive. In both equations above, I is the same current so:

$$V_{IN}/R_{TEST} = V_{OUT}/R_{FB}$$

Rearranging this equation gives:

$$R_{TEST} = -(V_{IN} \times R_{FB})/V_{OUT}$$

If we already know R_{FB} and V_{IN}, all we have to do is measure V_{OUT} and then calculate the value of the in-circuit resistance, R_{TEST}.

ON-BOARD

In Fig. 2, the resistances in a circuit are represented by R_{TEST} (the one we want to measure), with R_X and R_Y connected to its ends. R_X and R_Y are unknown or even unknowable, but this does not matter. They each represent the effective resistances of all the other resistances on the test board, joined in series and/or in parallel.

Provided that R_X is not so small that it shorts V_{IN} to ground, we can ignore this resistance. R_Y is connected to the 0V rail at one end and to the inverting (–) terminal at the other end.

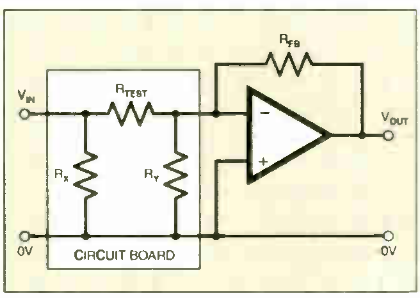


Fig.2. The op.amp connected to a circuit board.

The (–) terminal is a virtual earth and therefore R_Y has 0V at both ends. Consequently, no current flows through it and we can ignore R_Y. This leaves only R_{TEST}, and the current flowing through this is I, even though it is still connected to other resistances. The equation above applies.

COMPONENTS

Resistors

R1	1k	
R2	10k	
R3	100k	

All 0·25W 1% metal film

See SHOP TALK page

Potentiometer

VR1 — 100k submin. carbon preset or multiturn cermet, square type, top adjust. (optional, see text)

Semiconductors

IC1 — 78L05CZ 5V, low-power, voltage regulator

IC2 — TL071C op.amp, with j.f.e.t. inputs

Miscellaneous

S1, S2 — pushbutton "click" switch, press-to-make release-to-break (2 off)

S3 — 1-pole 3-way rotary switch and knob (optional, replaces green croc. clip)

Stripboard 0·1in. matrix, size 18 strips × 21 holes; 1mm terminal pins (11 off); 8-pin i.c. socket; PP3 type battery clips (2 off); crocodile clips (1 black, 1 green); miniature test clips (1 black, 1 red); multistrand connecting wire; solder; etc.

Approx. Cost Guidance Only **£5** excl. batts

PRACTICAL CIRCUIT

The full circuit diagram for the In-Circuit Ohmmeter is shown in Fig. 3. It has a dual (+9V and –9V) supply provided by two PP3 type batteries (B1 and B2). There are two pressbutton switches (S1 and S2) to turn on the power for an instant when a test is being made.

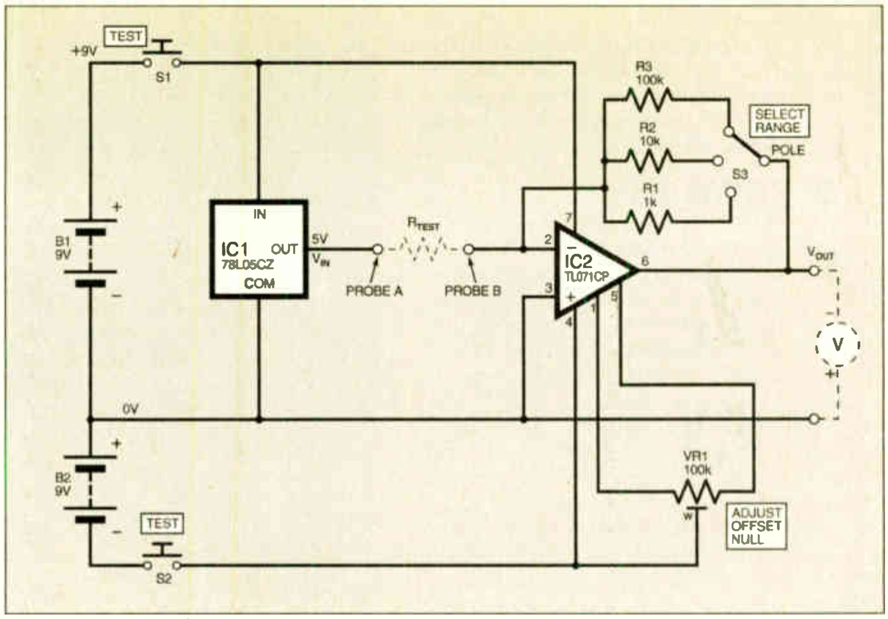


Fig.3. Complete circuit diagram for the In-Circuit Ohmmeter. Note the "negative" supply is provided by the second battery B2.

For precision, a 5V voltage regulator (IC1) is used to provide V_{IN}. Its output is connected to one end of the test resistor by a probe clip (*A*). A second probe clip (*B*) connects the other end of the test resistor (R_{TEST}) to the inverting (–) terminal of op.amp IC2. There are three feedback resistors of different values from which to select a suitable resistance range via optional rotary switch S3.

Although *in theory* the output of IC2 swings so as to bring both its inputs to the same voltage (0V), they do not reach exactly the same voltage. There is an *input offset voltage error* which, in the TL071, can be as much as 13mV. This means that the output will swing to bring the inverting (–) input (pin 2) to within about ±3mV which introduces an uncertainty into our reading of V_{OUT}.

This error is reduced by using the *offset null* pins (1 and 5) of IC2. These have a variable potentiometer (resistor) connected across them, with its wiper (w) wired to the –9V supply.

To null the offset, the two input pins are temporarily connected together, so that they are both at the same voltage. Then preset VR1 is adjusted until the output comes to 0V.

This offset null adjustment is not essential. You can omit VR1 if you will be satisfied with approximate measurements. Alternatively, use a precision op.amp, such as the OP27, which has a very small input offset voltage (0·03mV), though it is more expensive.

CONSTRUCTION

This simple circuit is built on a small piece of 0·1in. matrix stripboard, size 18 strips × 21 holes. The component layout and details of breaks required in the underside copper tracks are shown in Fig. 4. (Note there is no Row I.)

Although the theory is slightly complicated, the construction is simple and there should be no problems. VR1 can be a vertical miniature preset potentiometer, but you will find it much easier to null the offset if you use a multiturn potentiometer. The multiturn used in the prototype is a compact one, but those available from some suppliers have a longer case. Room has been left on the board for the longer type.

Ideally, the feedback resistors are selected by a rotary switch, but costs can be reduced by using three terminal pins and a crocodile clip. You can use crocodile clips for the test probes but proper test clips are better for attaching to short exposed portions of resistor wires, or to the pins of i.c.s.

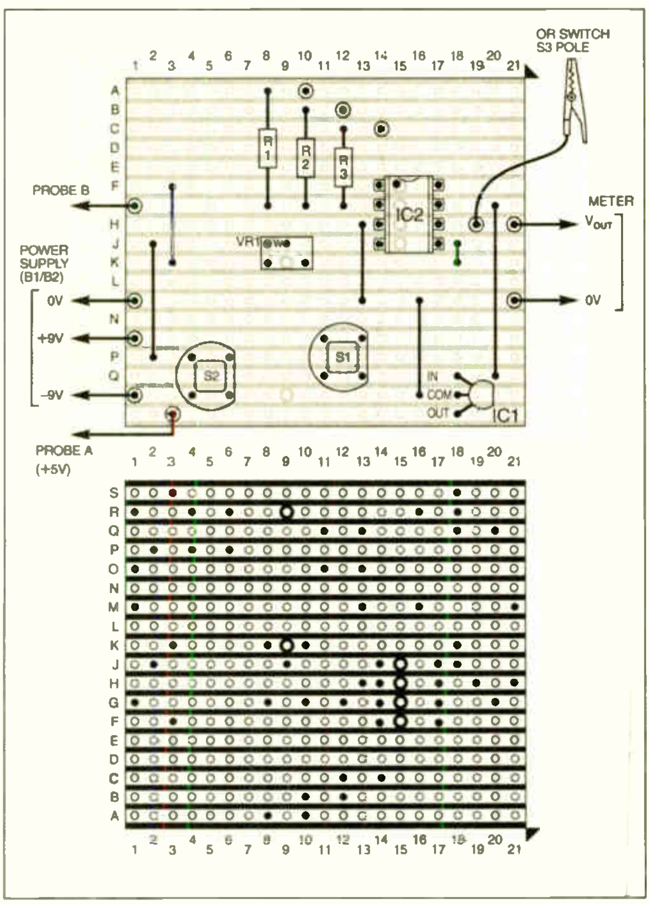
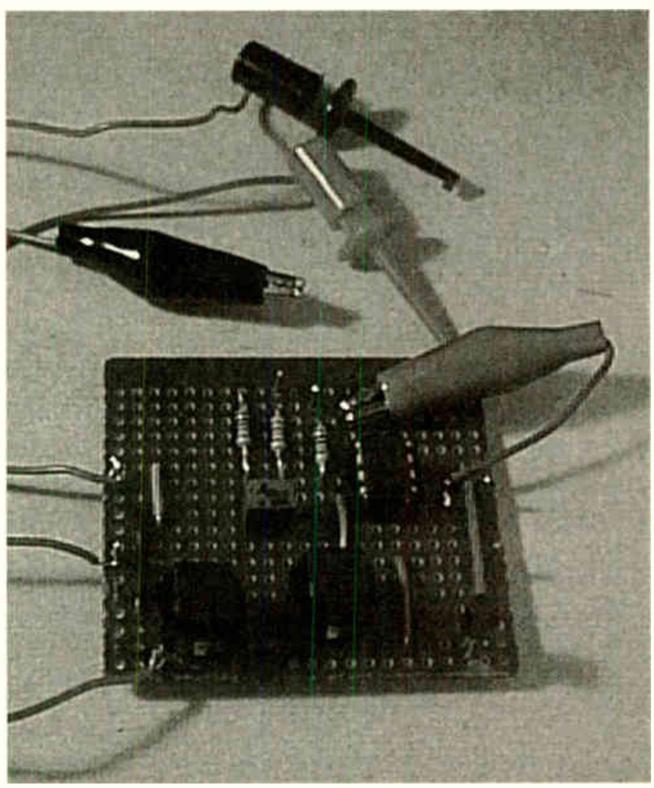


Fig.4. In-Circuit Ohmmeter stripboard component layout, wiring and details of breaks required in the underside copper tracks.



Completed prototype circuit board. The croc. clip on the right has replaced a rotary "range" switch in this version.

Connect test clips to the pins labelled Probe A (Red) and Probe B (Black). Connect a lead having a crocodile clip (preferably black) to the 0V power supply pin. This is for connecting to the 0V line of the "test board".

SETTING UP

Commence testing by placing two 9V batteries in the battery clips. Power is applied by pressing *both* buttons at the *same* time. Connect a testmeter (analogue or digital) to the output terminals and switch to the 10V range if your meter is not autoranging. Connect the meter *negative* terminal to the V_{OUT} pin.

Check the output from the voltage regulator (IC1). Probe A should be at 5V relative to the 0V line when the two pushbutton switches are pressed simultaneously.

Next clip Probe B to the 0V supply pin. This puts both inputs of the op.amp at 0V. Adjust preset VR1 until the output is as close as possible to 0V. It can be difficult to get to the exact point where the output swings between positive and negative. Get as close as you can, say, within ±50mV.

For a first trial, take a spare resistor and attach the probe clips to its wires. We used a 33 kilohms 5 per cent (33k 5%) resistor, and selected the 1k feedback resistor (R1). As V_{IN} is known to be 5V, V_{OUT} was found to be 153mV. Applying the formula (ignore the negative sign): $R_{TEST} = (5 \times 1000)/0{\cdot}153 = 32680 = 33k$. Well within limits.

Try some other resistors. Usually it is best to start with resistor R3 selected. If this makes the output swing too far negative (say, below –7 V) select R2. If the output is still too low, select R1.

Using a digital multimeter and the In-Circuit Ohmmeter to check-out suspect resistances on a "test-board".

IN-CIRCUIT TESTING

Switch off the normal power supply to the "test" board. Use the clipped lead to connect the 0V line of the In-Circuit Ohmmeter to the 0V line of the test board. Select a suitable feedback resistor (R1 to R3). Press the buttons of the two push-switches and read the voltage. Calculate the resistance, using the formula given earlier.

The unit can also be used for in-circuit testing of diodes. With the test current flowing through the diode (Probe A to anode, Probe B to cathode), output is several volts. With the reverse connection, output is only a few millivolts. Similar tests can be used for transistors.

The In-Circuit Ohmmeter works well for most test boards, but it may sometimes give an unexplained result. This can happen if there is a resistance or other current path (such as a diode or semiconductor junction) in parallel with the test resistor. In such cases, try reversing the probe connections. □

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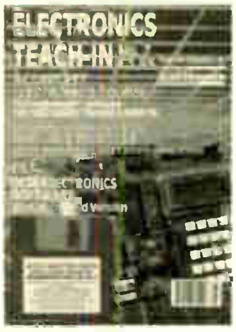

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Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. Explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages – large format **Order code BP901** **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Covers the new Vision Command System

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using Lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

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INTRODUCTION TO MICROPROCESSORS
John Crisp

If you are, or soon will be, involved in the use of microprocessors, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors, assuming no previous knowledge of the subject, nor a technical or mathematical background. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern microprocessors.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

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Theory and Reference

Bebop To The Boolean Boogie

By Clive (call me Max) Maxfield

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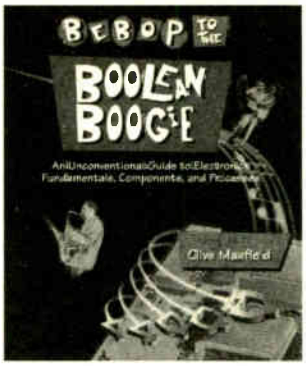
An Unconventional Guide to Electronics Fundamentals, Components and Processes



This book gives the "big picture" of digital electronics. This indepth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!).

Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day. . . .

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Bebop Bytes Back

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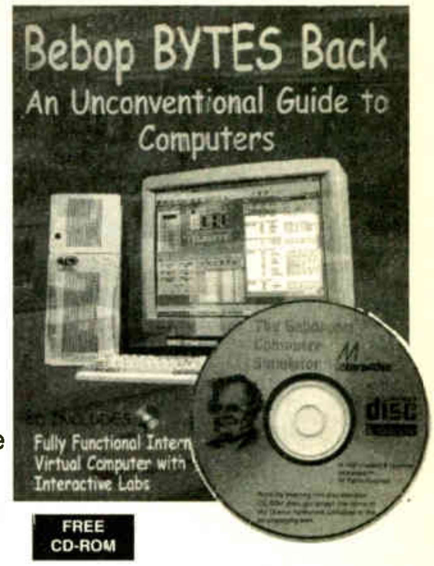

This follow-on to *Bebop to the Boolean Boogie* is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition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

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DIGITAL ELECTRONICS – A PRACTICAL APPROACH

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

Richard Monk

FREE SOFTWARE

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

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

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

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

DIGITAL GATES AND FLIP-FLOPS

Ian R. Sinclair

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

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

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

200 pages | **Order code PC106** | **£9.95**

NEWNES INTERACTIVE ELECTRONIC CIRCUITS CD-ROM

Edited by Owen Bishop

CD-ROM

An expert adviser, an encyclopedia, an analytical tool and a source of real design data, all in one CD-ROM. Written by leading electronics experts, the collected wisdom of the electronics world is at your fingertips. The simple and attractive Circuits Environment(TM) is designed to allow you to find the circuit or advice notes of your choice quickly and easily using the search facility. The text is written by leading experts as if they were explaining the points to you face to face. Over 1,000 circuit diagrams are presented in a standardised form, and you are given the option to analyse them by clicking on the Action icon. The circuit groups covered are: Amplifiers, Oscillators, Power, Sensing, Signal Processing, Filters, Measurement, Timing, Logic Circuits, Telecommunications.

The analysis tool chosen is SpiceAge for Windows, a powerful and intuitive application, a simple version of which automatically bursts into action when selected.

Newnes Interactive Electronic Circuits allows you to: analyse circuits using top simulation program SpiceAge; test your design skills on a selection of problem circuits; clip comments to any page and define bookmarks; modify component values within the circuits; call up and display useful formulae which remain on screen; look up over 100 electronic terms in the glosary; print and export netlists.

System Requirements: PC running Windows 3.x, 95 or NT on a 386 or better processor. 4MB RAM, 8MB disk space.

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Audio and Music

AN INTRODUCTION TO LOUDSPEAKERS AND ENCLOSURE DESIGN

V. Capel

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

148 pages | **Temporarily out of print**

PREAMPLIFIER AND FILTER CIRCUITS

R. A. Penfold

This book provides circuits and background information for a range of preamplifiers, plus tone controls, filters, mixers, etc. The use of modern low noise operational amplifiers and a specialist high performance audio preamplifier i.c. results in circuits that have excellent performance, but which are still quite simple. All the circuits featured can be built at quite low cost (just a few pounds in most cases). The preamplifier circuits featured include: Microphone preamplifiers (low impedance, high impedance, and crystal). Magnetic cartridge pick-up preamplifiers with R.I.A.A. equalisation. Crystal/ceramic pick-up preamplifier. Guitar pick-up preamplifier. Tape head preamplifier (for use with compact cassette systems).

Other circuits include: Audio limiter to prevent overloading of power amplifiers. Passive tone controls. Active tone controls. PA filters (highpass and lowpass). Scratch and rumble filters. Loudness filter. Audio mixers. Volume and balance controls.

92 pages | **Order code BP309** | **£4.49**

HIGH POWER AUDIO AMPLIFIER CONSTRUCTION

R. A. Penfold

Practical construction details of how to build a number of audio power amplifiers ranging from about 50 to 300/400 watts r.m.s. includes MOSFET and bipolar transistor designs.

96 pages | **Order code BP277** | **£4.49**

ELECTRONIC MUSIC AND MIDI PROJECTS

R. A. Penfold

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

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

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

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

Testing, Theory, Data and Reference

SCROGGIE'S FOUNDATIONS OF WIRELESS AND ELECTRONICS – ELEVENTH EDITION
S. W. Amos and Roger Amos
Scroggie's Foundations is a classic text for anyone working with electronics, who needs to know the art and craft of the subject. It covers both the theory and practical aspects of a huge range of topics from valve and tube technology, and the application of cathode ray tubes to radar, to digital tape systems and optical recording techniques.

Since *Foundations of Wireless* was first published over 60 years ago, it has helped many thousands of readers to become familiar with the principles of radio and electronics. The original author Sowerby was succeeded by Scroggie in the 1940s, whose name became synonymous with this classic primer for practitioners and students alike. Stan Amos, one of the fathers of modern electronics and the author of many well-known books in the area, took over the revision of this book in the 1980s and it is he, with his son, who have produced this latest version.

400 pages **Order code NE27** **£21.99**

ELECTRONICS MADE SIMPLE
Ian Sinclair
Assuming no prior knowledge, *Electronics Made Simple* presents an outline of modern electronics with an emphasis on understanding how systems work rather than on details of circuit diagrams and calculations. It is ideal for students on a range of courses in electronics, including GCSE, C&G and GNVQ, and for students of other subjects who will be using electronic instruments and methods.

Contents: waves and pulses, passive components, active components and ICs, linear circuits, block and circuit diagrams, how radio works, disc and tape recording, elements of TV and radar, digital signals, gating and logic circuits, counting and correcting, microprocessors, calculators and computers, miscellaneous systems.

199 pages (large format) **Order code NE23** **£13.99**

TRANSISTOR DATA TABLES
Hans-Günther Steidle
The tables in this book contain information about the package shape, pin connections and basic electrical data for each of the many thousands of transistors listed. The data includes maximum reverse voltage, forward current and power dissipation, current gain and forward trans-admittance and resistance, cut-off frequency and details of applications.

A book of this size is of necessity restricted in its scope, and the individual transistor types cannot therefore be described in the sort of detail that maybe found in some larger and considerably more expensive data books. However, the list of manufacturers' addresses will make it easier for the prospective user to obtain further information, if necessary.

Lists over 8,000 different transistors, including f.e.t.s.

200 pages **Order code BP401** **£6.45**

ELECTRONIC TEST EQUIPMENT HANDBOOK
Steve Money
The principles of operation of the various types of test instrument are explained in simple terms with a minimum of mathematical analysis. The book covers analogue and digital meters, bridges, oscilloscopes, signal generators, counters, timers and frequency measurement. The practical uses of the instruments are also examined.

Everything from Oscillators, through R, C & L measurements (and much more) to Waveform Generators and testing Zeners.

206 pages **Order code PC109** **£9.95**

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages **Order code BP239** **£3.45**

NEWNES ELECTRONICS TOOLKIT – SECOND EDITION
Geoff Phillips
The author has used his 30 years experience in industry to draw together the basic information that is constantly demanded. Facts, formulae, data and charts are presented to help the engineer when designing, developing, evaluating, fault finding and repairing electronic circuits. The result is this handy workmate volume: a memory aid, tutor and reference source which is recommended to all electronics engineers, students and technicians.

Have you ever wished for a concise and comprehensive guide to electronics concepts and rules of thumb? Have you ever been unable to source a component, or choose between two alternatives for a particular application? How much time do you spend searching for basic facts or manufacturer's specifications? This book is the answer, it covers resistors, capacitors, inductors, semiconductors, logic circuits, EMC, audio, electronics and music, telephones, electronics in lighting, thermal considerations, connections, reference data.

158 pages **Order code NE20** **£15.99**

PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
Robin Pain
This is not a book of theory. It is a book of practical tips, hints, and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialized.

The book covers: **Basics** – Voltage, current and resistance; Capacitance, inductance and impedance; Diodes and transistors; Op-amps and negative feedback; **Fault finding** – Analogue fault finding, Digital fault finding; Memory; Binary and hexadecimal; Addressing; Discrete logic; Microprocessor action; I/O control; CRT control; Dynamic RAM; Fault finding digital systems; Dual trace oscilloscope; IC replacement.

274 pages **Order code NE22** **£20.99**

AN INTRODUCTION TO LIGHT IN ELECTRONICS
F. A. Wilson
This book is not for the expert but neither is it for the completely uninitiated. It is assumed the reader has some basic knowledge of electronics. After dealing with subjects like Fundamentals, Waves and Particles and The Nature of Light such things as Emitters, Detectors and Displays are discussed. Chapter 7 details four different types of Lasers before concluding with a chapter on Fibre Optics.

161 pages **Order code BP359** **£5.45**

UNDERSTANDING DIGITAL TECHNOLOGY
F. A. Wilson C.G.I.A., C.Eng., F.I.E.E., F.I. Mgt.
This book examines what digital technology has to offer and then considers its arithmetic and how it can be arranged for making decisions in so many processes. It then looks at the part digital has to play in the ever expanding Information Technology, especially in modern transmission systems and television. It avoids getting deeply involved in mathematics.

Various chapters cover: Digital Arithmetic, Electronic Logic, Conversions between Analogue and Digital Structures, Transmission Systems. Several Appendices explain some of the concepts more fully and a glossary of terms is included.

183 pages **Order code BP376** **£5.45**

Project Building

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including:

Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.

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R. Bebbington
Contains 45 easy-to-build electronic projects that can be constructed, by an absolute beginner, on terminal blocks using only a screwdriver and other simple hand tools. No soldering is needed.

Most of the projects can be simply screwed together, by following the layout diagrams in a matter of minutes and readily unscrewed if desired to make new circuits. A theoretical circuit diagram is also included with each project to help broaden the constructor's knowledge.

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R. A. Penfold
Deals with the simple methods of copying printed circuit board designs from magazines and books and covers all aspects of simple p.c.b. construction including photographic methods and designing your own p.c.b.s.

80 pages **Order code BP121** **£4.49**

IC555 PROJECTS
E. A. Parr
Every so often a device appears that is so useful that one wonders how life went on before without it. The 555 timer is such a device.It was first manufactured by Signetics, but is now manufactured by almost every semiconductor manufacturer in the world and is inexpensive and very easily obtainable.

Included in this book are over 70 circuit diagrams and descriptions covering basic and general circuits, motor car and model railway circuits, alarms and noise makers as well as a section on 556, 558 and 559 timers. (Note. No construction details are given.)

A reference book of invaluable use to all those who have any interest in electronics, be they professional engineers or designers, students or hobbyists.

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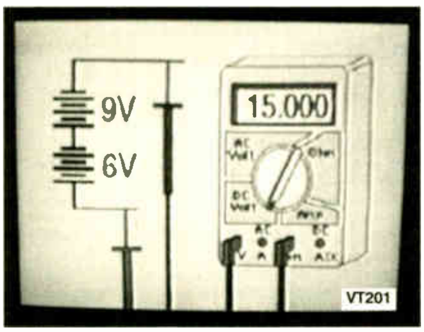

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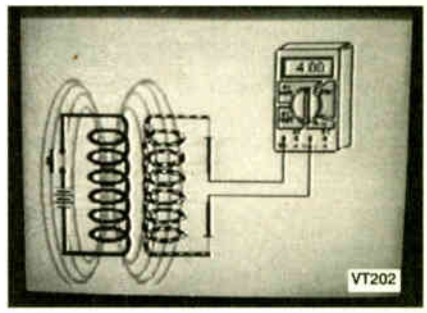

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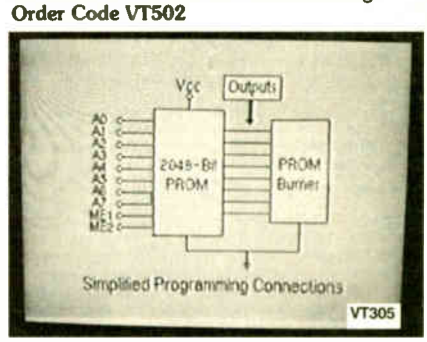

Each video uses a mixture of animated current flow in circuits plus text, plus cartoon instruction etc., and a very full commentary to get the points across. The tapes are imported by us and originate from VCR Educational Products Co, an American supplier. We are the worldwide distributors of the PAL and SECAM versions of these tapes. (All videos are to the UK PAL standard on VHS tapes unless you specifically request SECAM versions.)

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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*, Allen House, East Borough, Wimborne, Dorset BH21 1PF. Tel: 01202 881749; Fax 01202 841692; 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).**

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★Greenhouse Radio Link		200	£8.32
★PIC Altimeter		201	£8.15
Voice Processor	**OCT '98**	203	£7.18
IR Remote Control			
–Transmitter		205	£3.00
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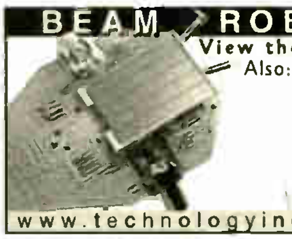
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