THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EVERYDAY PRACTICAL ELECTRONICS

Vol.31 No.12

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Battery operated door alarm

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77 KILO LIFT MAGNET. These Samarium magnets measure 57mm x 20mm and have a threaded hole (5/16th UNF) in the centre and a magnetic strength of 2·2 gauss. We have tested these on a steel beam running through the offices and found that they will take more than 170lb. (77kg) in weight before being pulled off. Supplied with keeper. £19.95 ea. Ref MAG77.
HYDROGEN FUEL CELL PLANS. Loads of information on hydrogen storage and production. Practical plans to build hydrogen fuel cell (good workshop facilities required). £8 set. Ref FCP1.
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CCTV CAMERAS FROM £25. Check out our web site at **www.cctvstuff.co.uk** and **www.home-cctv.co.uk**.
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180R.P.M. MAINS MOTOR. Induction type, 90mm x 70mm, 50mm x 5mm shaft, 12A continuous rating, thermal protected. £22, Ref MGM1.
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MAMOD 1313 TE1A TRACTION ENGINE. Attractive working model of traditional steam engine, £91, Ref 1313.
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FM BROADCAST BAND HIGH POWER TRANSMITTERS can be viewed and bought online at **www.veronica-kits.co.uk**.
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PORTABLE X-RAY MACHINE PLANS. Easy to construct plans on a simple and cheap way to build a home X-ray machine! Effective device, X-ray sealed assemblies, can be used for experimental purposes. *Not a toy or for minors!* £6/set, Ref F/XP1.
TELEKINETIC ENHANCER PLANS. Mystify and amaze your friends by creating motion with no known apparent means or cause. Uses no electrical or mechanical connections, no special gimmicks yet produces positive motion and effect. Excellent for science projects, magic shows, part demonstrations or serious research and development of this strange and amazing psychic phenomenon. £4/set, Ref F/TKE1.
ELECTRONIC HYPNOSIS PLANS & DATA. This data shows several ways to put subjects under your control. Included is a full volume reference text and several construction plans that when assembled can produce highly effective stimuli. This material must be used cautiously. It is for use as entertainment at parties etc only, by those experienced in its use. £15/set, Ref F/EH2.
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VOICE SCRAMBLER PLANS. Miniature solid-state system turns speech sound into indecipherable noise that cannot be understood without a second matching unit. Use on telephone to prevent third party listening and bugging. £6/set, Ref F/VS9.
PULSED TV JOKER PLANS. Little handheld device utilises pulse techniques that will completely disrupt TV picture and sound! Works on FM too! *Discretion advised.* £8/set, Ref F/TJ5.
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MICRO SCALES. Measure 1g to 120g, 1g resolution, 80mm x 110mm, 3 AAA batteries required. £49.94. Ref SCALEB.
ALTERNATIVE ENERGY CD, packed with hundreds of alternative energy related articles, plans and information etc. £14.50. Ref CD56.
WIRELESS DRIVEWAY ALARMS. Detect someone entering your driveway, 400ft. range, no wiring, will protect any entrance, uses built-in PIR detector. £24.99. Ref DWA.
NICKEL PLATING KITS. £55. Ref NIK39A.
GOODIE PACKS. 10kg packs of clearance items, mainly suitable for the electronics enthusiast! Ref 10KGP.
WHEELCHAIR MOTORS. Left and right hand, new and secondhand, 100s in stock. New ones £99 each, secondhand £59, returns £19.95. Geared, 24V, complete with electric brake.

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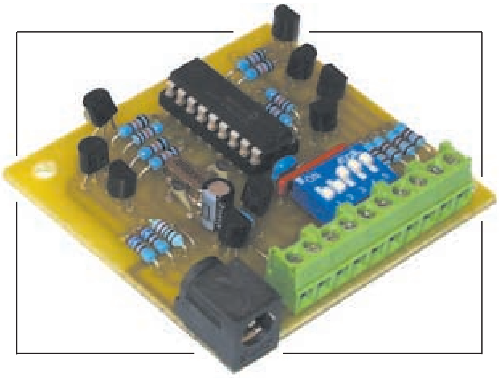


Projects and Circuits

Series and Features

Regulars and Services

Our January 2003 issue will be published on Thursday, 12 December 2002. See page 843 for details

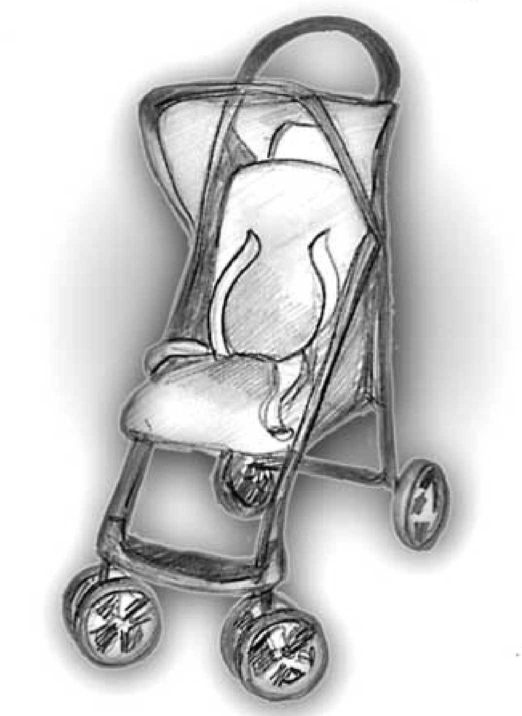
NEXT MONTH

EPE MINDER

Looks after your personal belongings – maybe even your children!

The EPE Minder consists of two type approved transmitter units and a receiver. If either transmitter becomes separated from the receiver, a buzzer in the latter part will sound. The receiver is fitted with a switch to allow the use of only one transmitter if required. This system was originally designed as a two-channel child alarm (to protect either a single child or two children at the same time) but many other applications spring to mind. For example, one transmitter could be placed inside a briefcase and another in a coat pocket. If the user forgot to pick up either of these items and walked away, the buzzer would sound in the receiver.

The operating range is adjustable and the system can operate over a range of up to 12 metres in the open air. It will also work throughout several rooms indoors if required.



PIC WIND SPEED MONITOR

This wind speed monitor (anemometer) is intended for use in a variety of sports-type activities, such as track events, sailing, hang-gliding, kite and model aircraft flying, to name but a few. It can even be used to monitor the wind conditions in your garden. Using ultrasonic techniques, it is a solid-state design, has no moving parts and does not need calibrating. It was designed and tested in conjunction with a commercial airflow sensor and a professional wind tunnel.

A probe is pointed in the direction from which the wind is blowing and a screen displays the rate at which the wind is moving between two ultrasonic sensors. The readout is on an alphanumeric liquid crystal display (l.c.d.), with readings shown in metres per second, feet per second, kilometres per hour and miles per hour. The resolution is to the nearest tenth of a metre per second, from zero up to around 50mph, and possibly higher.

F.M. FREQUENCY SURFER

A v.h.f. receiver covering the range 88MHz to 119MHz based on the TDA7000 i.c. which provides virtually all the active circuitry including phase-locked loop detection. In use, the receiver scans different types of transmissions in quick succession, including commercial wideband f.m. broadcasts, aeronautical communications, fixed and private mobile radio, Citizen's Band on the lower frequency channels and occasionally shortwave transmissions via satellite.

***PLUS* PICAXE PROJECTS PART 3 AND ALL THE REGULAR FEATURES**

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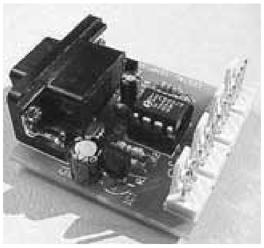
Our electronic kits are supplied complete with all components, high quality PCBs (NOT cheap Tripad strip board!) and detailed assembly/operating instructions

● **2 x 25W CAR BOOSTER AMPLIFIER** Connects to the output of an existing car stereo cassette player, CD player or radio. Heatsinks provided. PCB 76x75mm. **1046KT. £24.95**
● **3-CHANNEL WIRELESS LIGHT MODULATOR** No electrical connection with amplifier. Light modulation achieved via a sensitive electret microphone. Separate sensitivity control per channel. Power handing 400W/channel. PCB 54x112mm. Mains powered. Box provided. **6014KT £24.95**
● **12 RUNNING LIGHT EFFECT** Exciting 12 LED light effect ideal for parties, discos, shop-windows & eye-catching signs. PCB design allows replacement of LEDs with 220V bulbs by inserting 3 TRIACs. Adjustable rotation speed & direction. PCB 54x112mm. **1026KT £15.95; BOX (for mains operation) 2026BX £9.00**
● **DISCO STROBE LIGHT** Probably the most exciting of all light effects. Very bright strobe tube. Adjustable strobe frequency: 1-60Hz. Mains powered. PCB: 60x68mm. Box provided. **6037KT £28.95**
● **ANIMAL SOUNDS** Cat, dog, chicken & cow. Ideal for kids farmyard toys & schools. **SG10M £5.95**
● **3 1/2 DIGIT LED PANEL METER** Use for basic voltage/current displays or customise to measure temperature, light, weight, movement, sound levels, etc. with appropriate sensors (not supplied). Various input circuit designs provided. **3061KT £13.95**
● **IR REMOTE TOGGLE SWITCH** Use any TV/VCR remote control unit to switch onboard 12V/1A relay on/off. **3058KT £10.95**
SPEED CONTROLLER for any common DC motor up to 100V/5A. Pulse width modulation gives maximum torque at all speeds. 5-15VDC. Box provided. **3067KT £12.95**
● **3 x 8 CHANNEL IR RELAY BOARD** Control eight 12V/1A relays by Infra Red (IR) remote control over a 20m range in sunlight. 6 relays turn on only, the other 2 toggle on/off. 3 operation ranges determined by jumpers. Transmitter case & all components provided. Receiver PCB 76x89mm. **3072KT £52.95**

PRODUCT FEATURE

COMPUTER TEMPERATURE DATA LOGGER
PC serial port controlled 4-channel temperature meter (either deg C or F). Requires no external power. Allows continuous temperature data logging of up to four temperature sensors located 200m+ from motherboard/PC. Ideal use for old 386/486 computers. Users can tailor input data stream to suit their purpose (dump it to a spreadsheet or write your own BASIC programs using the INPUT command to grab the readings). PCB just 38mm x 38mm. Sensors connect via four 3-pin headers. 4 header cables supplied but only one DS18S20 sensor.
Kit software available free from our website.
ORDERING: 3145KT **£23.95** (kit form);
AS3145 **£29.95** (assembled);
Additional DS18S20 sensors **£4.95** each



● **SOUND EFFECTS GENERATOR** Easy to build. Create an almost infinite variety of interesting/unusual sound effects from birds chirping to sirens. 9VDC. PCB 54x85mm. **1045KT £8.95**
● **ROBOT VOICE EFFECT** Make your voice sound similar to a robot or Darlek. Great fun for discos, school plays, theatre productions, radio stations & playing jokes on your friends when answering the phone! PCB 42x71mm. **1131KT £8.95**
● **AUDIO TO LIGHT MODULATOR** Controls intensity of one or more lights in response to an audio input. Safe, modern opto-coupler design. Mains voltage experience required. **3012KT £8.95**
● **MUSIC BOX** Activated by light. Plays 8 Christmas songs and 5 other tunes. **3104KT £7.95**
● **20 SECOND VOICE RECORDER** Uses non-volatile memory - no battery backup needed. Record/replay messages over & over. Playback as required to greet customers etc. Volume control & built-in mic. 6VDC. PCB 50x73mm. **3131KT £12.95**
● **TRAIN SOUNDS** 4 selectable sounds : whistle blowing, level crossing bell, 'clickety-clack' & 4 in sequence. **SG01M £6.95**

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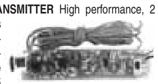

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REWRITING HISTORY

Just about all modern electronics is based on the transistor in one form or another and ever since 1947 most people have believed that this little marvel of semiconductor technology was invented at Bell Labs by Bardeen, Brattain and Shockley – we no longer believe this! Looking back into the archives our contributor Andy Emmerson has unearthed some fascinating facts – he has also found an interesting red herring along the way.

It is not so much rewriting history as simply bringing the truth to everyone's notice. It just shows how we tend to believe what we are told. We now believe the transistor actually first saw the light of day around 1910, although the name was not coined until it was "re-invented" at Bell Labs some 37 years later. There was also a patent on the field effect transistor in 1933. See next month's issue for the full story – even Roswell gets a mention!

While on the subject the *Alternative Uses For Transistors* feature in this issue makes fascinating reading. As they say, there are more ways than one to skin a cat! The very simple nature of a basic transistor allows it to be connected in a number of ways the device designers (and, no doubt, the "inventors") never intended, or even envisioned. This unusual feature will no doubt encourage plenty of experimentation.

WRITING HISTORY

Not only has Andy dug up the story mentioned above, he has also come up with a whole range of fascinating topics on today's technology. Topics like Hotspots – a new era for community internet access; Ultra Thin Batteries – applications in contactless smart cards; No Hiding Place – new recognition surveillance techniques; Broadband by Powerline – will it be resurrected?; Viruses on Mobiles – not a myth; VoIP – Voice over Internet Protocol; Internet at Risk – 96 per cent of UK traffic through one exchange!; Drive-By Hacking – security on wireless local area networks; Tempestuous Times – modern eavesdropping James Bond style. The list goes on and next month Andy brings you the lowdown in the first of a new regular *Techno Talk* page.

Mike Kenward

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Constructional Project

VERSATILE PIC FLASHER

STEVE CHALLINOR

Enhance your Christmas decorations or your child's ceiling with this versatile PIC-controlled flasher display

BEHIND this design was an idea to make an interesting ceiling display for a child's bedroom. One of the author's colleagues had seen a display of blue lights in a shopping centre and wanted to know if the author could duplicate this.

The lights needed to be slowly increasing and decreasing in brightness and behaving in a random fashion. Thereby was perceived a means by which the author could lull his own insomniac toddler to sleep, and so set to work immediately!

TAKE YOUR PIC

Basing the system on a PIC microcontroller, it was found that the results were so pleasing that it was thought to be of interest to *EPE* readers – but absolutely no guarantee about the sleep remedy!

The original idea has been expanded to create a number of different effects, so that apart from the slow and soothing bedroom display, quite a number of other display options are possible. Preprogrammed PICs are available as stated later for the benefit of readers who do not have PIC programming facilities.

There are five dual-in-line (d.i.l.) switches which select a total of thirty-two possibilities. There are eight outputs, but the light emitting diodes (l.e.d.s) may be chained together to multiply this number. There is too much going on to notice if two or more l.e.d.s are doing the same thing!

APPLICATIONS

Apart from the ceiling display, one variant is a wall display, with a luminous moon crescent mounted on a circle of black card and eight blue l.e.d.s scattered over the rest of the circle. Another is a star, again for wall mounting, with 21 l.e.d.s of different colours. Again this is a wall display but it would make an excellent star for the Christmas tree, or why not a miniature tree for the interior of the car? There must be many imaginative applications.

Although an l.e.d. display was in mind from the outset, the open collector outputs can sink up to 500mA, thus it would also be possible to drive filament bulbs. This could drive the Christmas tree lights in a new way (after substituting a normal bulb for the flasher bulb). This *only* applies to low voltage types, though, with a +24V supply and multiple strings of low voltage bulbs. However, this article only discusses the l.e.d. version.

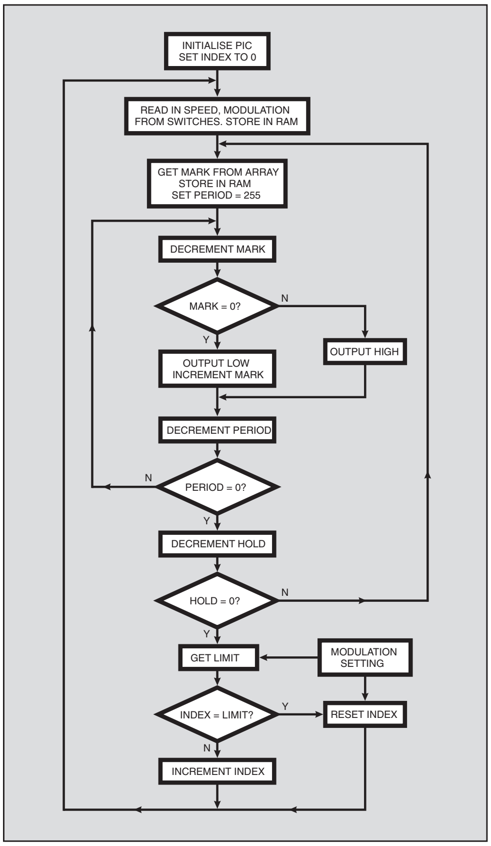


Fig.1. Flow chart for the PIC Flasher.

Looking at his own tree lights in this way, which are +24V and have eight strings of ten 2·4V bulbs, the author wondered is this could be matched using the PIC. However, the problem was the way in which the strings were interlaced, which seemed like a headache to sort out!

The star display is found to be most effective where all the l.e.d.s can be seen together. The ever-changing outputs create a fascinating display.

LIGHTING CONCEPT

Ideally, the light output should be analogue, with the l.e.d.s varying from fully on to fully off. However, the author refused to entertain the idea of eight digital-to-analogue converters with associated drivers. Instead the circuit uses Pulse Width Modulation (PWM), with the mark/space ratio controlling the brightness of the l.e.d.s – space fully off, mark fully on.

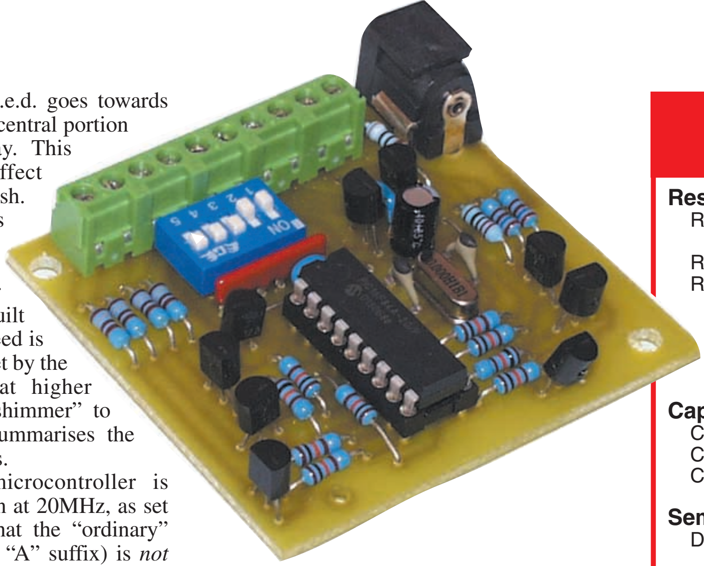
The mark is obtained from an array in programmed PIC memory, which may be termed the *brightness profile*. Thus one complete cycle, from off to maximum and back to off again is obtained as the program reads in values from the whole array. However, each output has a slightly different array length, giving a continual shift in phase between the outputs and hence an apparently random effect.

Each value of mark/space is repeated a number of times to give control over the speed of flashing. Referring to the flow chart in Fig.1, the core operation is the central loop where the mark is decremented to see whether to output a high or a low. The output is set high as long as the mark is non-zero, then low for the rest of the period (the space).

This is repeated up to eight times according to speed and then for every other mark in the array (about two hundred of these) at the same time as jumping about between all eight outputs. This keeps the PIC busy enough not to require delay routines, with the oscillator running at top speed, 20MHz.

CIRCUIT DIAGRAM

Referring to the circuit diagram in Fig.2, switches S1a and S1b set the speed. Switches S1c and S1d control the depth of modulation, meaning how far from fully on the l.e.d. goes towards off, i.e. selecting just a central portion of the brightness array. This gives a pulsating effect rather than an on/off flash.



Switch S1e selects between two brightness profiles. One is smooth, but the other has a high speed flash built into the profile. The speed is related to the controls set by the other switches, and at higher speeds gives an "icy shimmer" to the display. Table 1 summarises the settings for the switches.

The PIC16F84A microcontroller is shown as IC1 and is run at 20MHz, as set by crystal X1. Note that the "ordinary" PIC16F84 (without the "A" suffix) is *not suitable* for this design since it has not been manufactured to run at the 20MHz rate required.

The switches S1a to S1e are biased normally high by five resistors. These are within a single resistor module, marked as RM1. The status of the switches is read by the PIC's Port A lines, RA0 to RA4.

The l.e.d.s are controlled by the PIC's RB0 to RB7 lines. They control the switching of transistors TR1 to TR8, via current limiting resistors R1 to R8. As said earlier, the transistors are used in open-collector mode to drive the l.e.d.s, with resistors R10 to R17 limiting the current flow.

The PIC16F84A's Port B is capable of sourcing a maximum of 100mA or sinking 150mA, so it would be feasible to directly control eight single l.e.d.s. However, the provision of the open collector transistors allows several l.e.d.s to be chained together for this larger display.

The number chained will depend on the voltage supply, with roughly 1·8V per

Table 1: Mode switches settings (0 = switch on)

S1a	*S1b*	*Speed*
0	0	Fast
1	0	Medium fast
0	1	Medium slow
1	1	Slow
S1c	***S1d***	***Modulation***
0	0	100%
1	0	50%
0	1	25%
1	1	12·5%
S1e		***Profile***
0		Smooth
1		Flash

l.e.d. required (double this for blue or white) with enough voltage left over to provide a sensible current limiting resistor.

COMPONENTS

Resistors

RM1	10k 5-way commoned resistor module, s.i.l.
R1 to R8	10k (8 off)
R9	1k
R10 to R17	see Table 2

See SHOP TALK page

Capacitors

C1, C2	10p ceramic (2 off)
C3, C5	100n ceramic (2 off)
C4	100µ radial elect. 10V

Semiconductors

D1 to D8	l.e.d., see text regarding quantities and styles
TR1 to TR8	BC337 *npn* transistor (8 off)
IC1	PIC16F84A microcontroller, preprogrammed (see text)
IC2	78L05 +5V voltage regulator

Miscellaneous

S1	5-way d.i.l. switch, p.c.b. mounting
X1	20MHz crystal
TB1	2-way terminal block, p.c.b. mounting (5 off)
SK1	2·1mm d.c. power socket, p.c.b. mounting

Printed circuit board, available from the *EPE PCB Service*, code 377; 18-pin d.i.l. socket; display construction material

Approx. Cost Guidance Only **£16** ***excl. l.e.d.s***

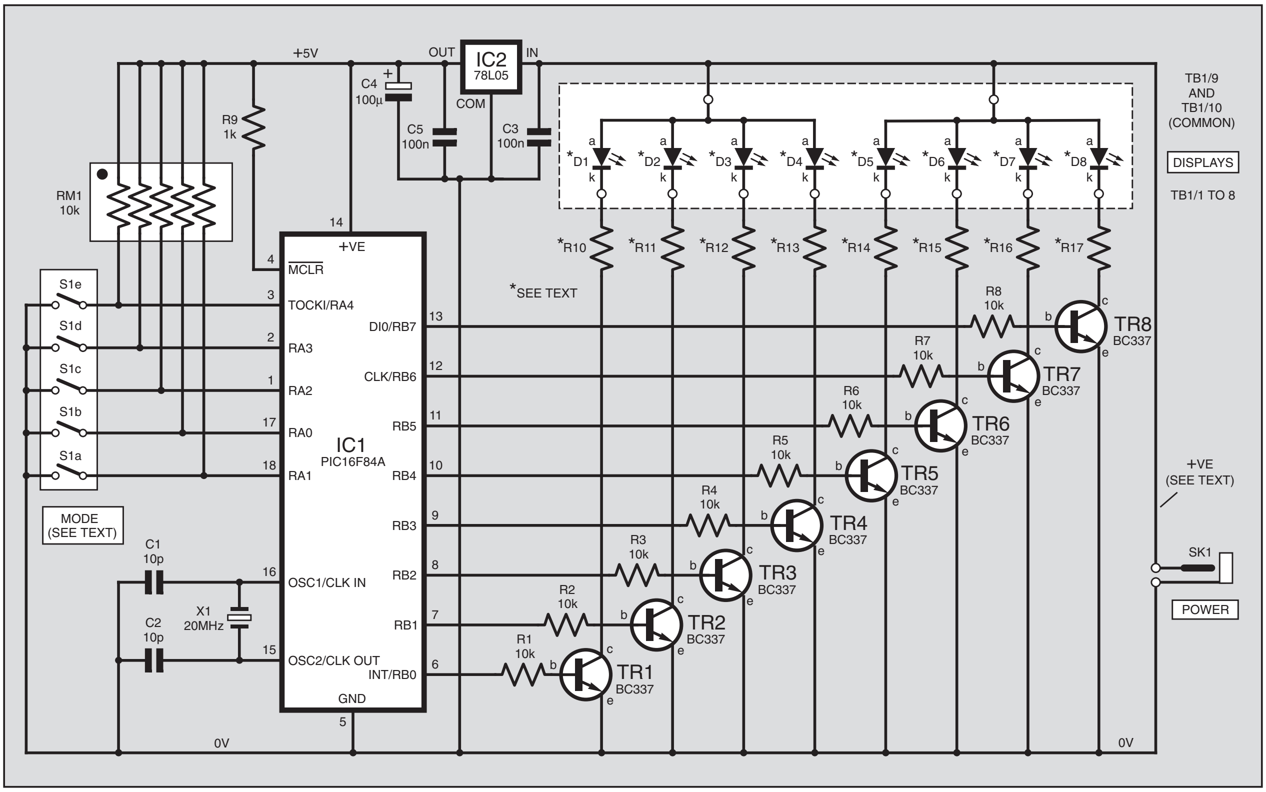


Fig.2. Complete circuit diagram (except power supply – see text) for the Versatile PIC Flasher.

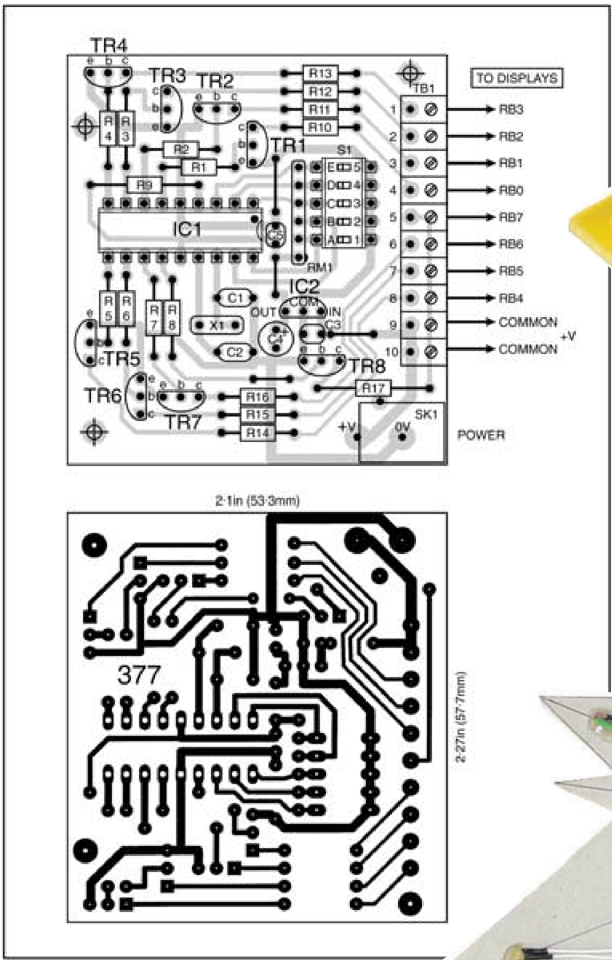
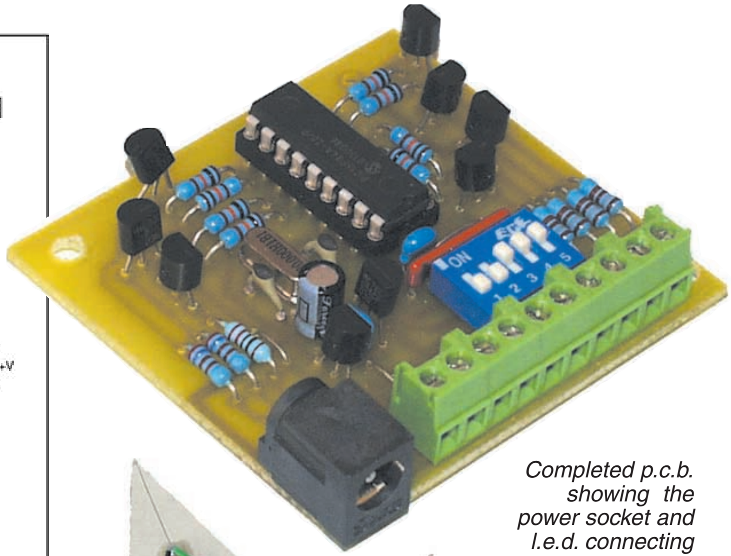
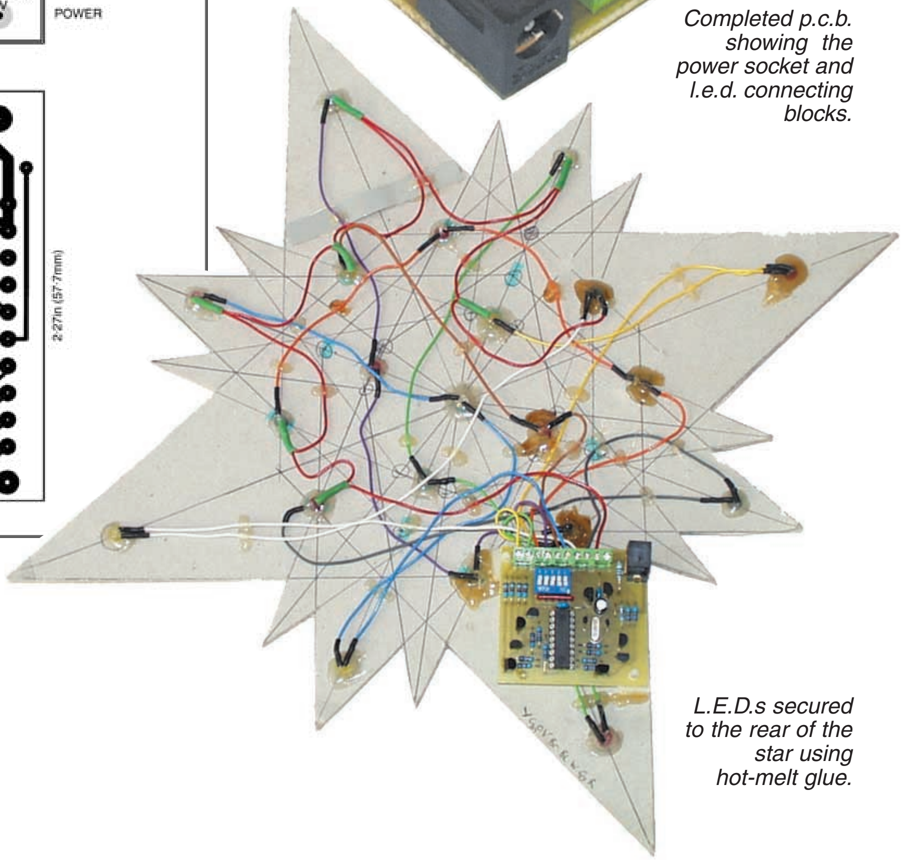


Fig.3. Flasher printed circuit board component layout, full-size copper foil master and lead-off wires to the l.e.d. "chains".



Completed p.c.b. showing the power socket and l.e.d. connecting blocks.



L.E.D.s secured to the rear of the star using hot-melt glue.

Table 2 shows suitable resistor values to use with a power supply of +12V or +24V. These values are very conservative as the peak current is only reached at the peak of the profile, and this is only a very small part of the overall cycle.

It is worth considering which l.e.d.s to use to suit ambient lighting conditions. For normal room lighting, "standard" l.e.d.s are far too dim, although for a night-time ceiling display they would be fine. However, for use in a normal room lighting situation, super-bright, ultra-bright and even hyper-bright l.e.d.s are available with output intensities comparable with filament bulbs, and these will be suitable for the majority of applications.

In the prototype, diffused 5mm l.e.d.s having 400mcd intensity were used. They provide a wide viewing angle which works very well for wall displays. Should you want to go for even larger displays, there is an abundance of different intensities and sizes available to choose from.

Voltage regulator IC2 provides the PIC with the +5V required. The regulator may be fed with any d.c. voltage between about 7V and 24V or so. The l.e.d.s are powered from the input voltage supply, not by the +5V from the regulator.

Table 2: L.E.D. current limiting resistor values for +12V and +24V power supplies

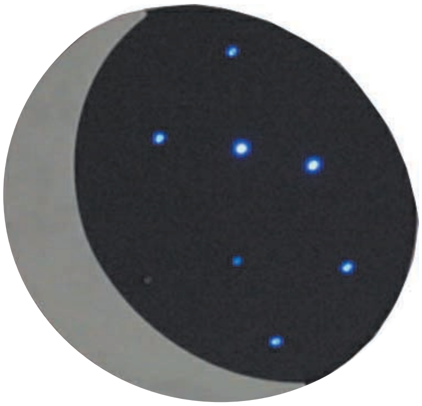
L.E.D.s per output (n)	*R10 to R17 at 20mA*				
	Red/Yellow/Green	*Blue*	*White*	*One Blue +n(R/Y/G)*	*One White +n(R/Y/G)*
		+12V Power Supply			
1	470Ω	390Ω	470Ω	270Ω	330Ω
2	390Ω	180Ω	270Ω	220Ω	220Ω
3	330Ω	–	–	120Ω	150Ω
4	220Ω	–	–	–	–
		+24V Power Supply			
3	1K	560Ω	680Ω	680Ω	820Ω
4	820Ω	390Ω	560Ω	560Ω	680Ω
5	680Ω	220Ω	390Ω	470Ω	560Ω
6	560Ω	–	220Ω	390Ω	470Ω

CONSTRUCTION

The printed circuit board (p.c.b.) component and track layout details are shown in Fig.3. This board is available from the *EPE PCB Service*, code 377.

Assemble the board in order of component size. Use a socket for the PIC16F84A, IC1. Do not insert the PIC until you have checked the correctness of the output voltage from regulator IC2.

The prototype p.c.b. was glued to the back of a Christmas Star and Moon cut from stout card. Holes were punched into the card and the l.e.d.s pushed through and secured using holt-melt glue.



Prototype wall mounted luminous "moon" with blue l.e.d. "stars" mounted on the black "sky".

The l.e.d. quantity and the order in which they are connected is entirely up to the user.

Remember, though, that each l.e.d. has a voltage drop across it and so there is a limit to the number of l.e.d.s that can be connected in series in relation to the power supply voltage. There is also a limit to the number of l.e.d.s that can be used in parallel without overloading their driving transistor, or the power supply.

Having wired up the l.e.d.s, there are then just two external wires required, to the chosen power supply.

There are no great requirements for the power supply. A plug mounted type should suffice, with a rating of 250mA. There's no necessity for it to be regulated either, as the PIC is powered via the +5V regulator.

Having completed the assembly, apply power (without the PIC inserted) and check that the output voltage from IC2 is +5V. Always disconnect the power supply before making changes to the construction.

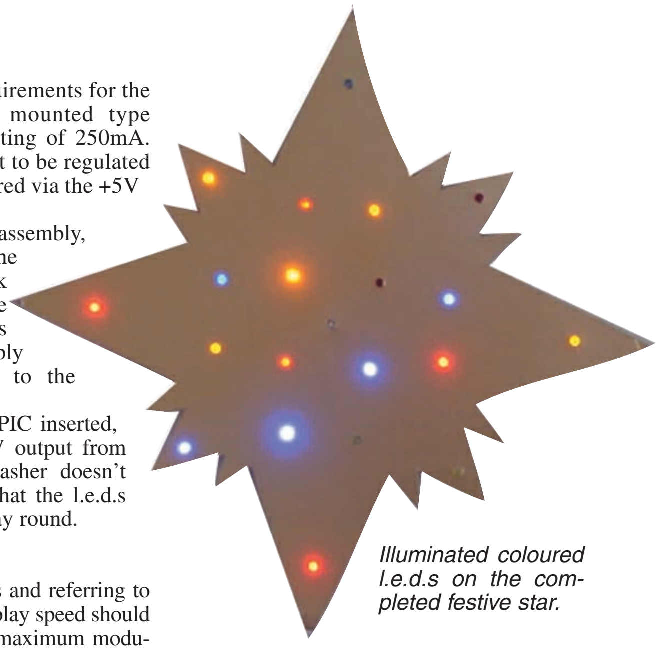
With the programmed PIC inserted, check again that the +5V output from IC2 is correct. If the flasher doesn't work straight off check that the l.e.d.s are connected the right way round.

SETTING UP

Using the d.i.l. switches and referring to Table 1, the maximum display speed should be selected together with maximum modulation (the l.e.d.s should go from fully off to fully on) and with a smooth brightness profile. Then it's just a matter of finding the most suitable settings according to situation and taste. There are thirty-two possibilities.

SOFTWARE

The software is available for free download from the *EPE* ftp site. This is most easily accessed via the main page of the *EPE* web site at **www.epemag.wimborne.co.uk**. At the top is a click-link saying **FTP site**



Illuminated coloured l.e.d.s on the completed festive star.

(downloads), click it then click on **PUB** and then on **PICS**, in which screen you will find the Versatile PIC Flasher folder.

The software can also be obtained on 3·5-inch disk (Disk 5) from the Editorial office. There is a nominal handling charge to cover admin costs. Details are given on the *EPE PCB Service* page, and in this month's *Shoptalk*, which also gives details about obtaining preprogrammed PICS.

Enjoy your display of PIC Noelogy! □

New Technology Update

"Spin doctors" come up with a new type of transistor, reports Ian Poole

THERE is an enormous variety of different transistors that are available these days. There are the obvious types such as bipolar and field effect transistors. However, there are other new technologies that are surfacing that are neither bipolar nor field effect transistors.

One new type that offers a considerable amount of promise is known as the *spin transistor*. It is expected to have widespread applications in areas from non-volatile memories to magnetic sensors. Developed at Oxford University under Dr John Gregg, its operation is based around a three terminal device that is sensitive to magnetic fields.

Basics

The new technology relies on the fact that electric currents flowing in ferromagnets are carried by electrons with two different types of spin. The first has a spin parallel to the magnetisation whilst the second has its spin in an anti-parallel direction.

It is found that the electrons with the different types of spin can be differentiated from one another because the carrier mobilities of the two types are very different. Whilst it is possible to flip the electrons so that they have the opposite spin, this takes place relatively slowly. This means that it is possible to control and monitor the electrons in ferro-magnetic materials to encode, store and read information.

The spin devices operate by transferring electrons with a particular type of spin from one area of the device to another where its state or spin is subsequently read. The spin of an electron can change as it travels, but it takes a given distance for this to occur.

This distance is dependent upon the material through which the electron is passing and may vary between a few nanometres to a few microns or micrometers. For devices to be able to operate satisfactorily, the dimensions within the devices must be of an order smaller than the distance required for the electron spin to change or flip.

Spin Transistors

The transistor grew out of the discovery in 1988 of a phenomenon known as Giant Magnetic Resistance (GMR). This enabled some spin transistors to be developed that could detect magnetic fields. These were three terminal devices in which the current flowing through one terminal could be controlled by the application of a magnetic field across the other two.

Whilst these devices represented a very useful step forward in technology, their usefulness was limited by the fact that gains were always less than unity. Now, the new research undertaken at Oxford has built on this technology and enabled it to be brought up to a stage where it can be used in real applications. As a result patents have been taken out and these are owned by Isis Innovation Ltd.

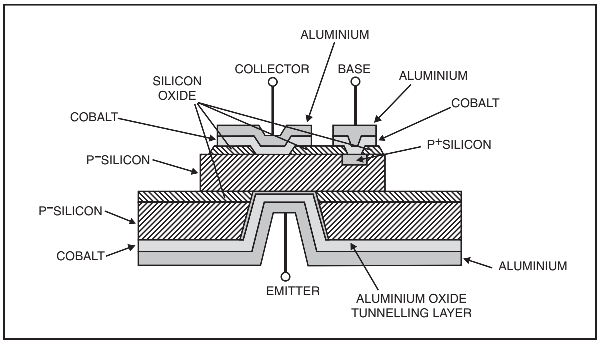


Fig.1. Internal structure of the spin transistor.

The spin transistor has three layers, and these can be considered as analogous to a normal bipolar transistor. There is a paramagnetic layer, called the base that is sandwiched between two ferromagnetic layers, the collector and emitter. Within the transistor the ratio of the electrons with different spins in the base region is altered so that it is not 1:1.

The collector region is also constructed so that it prefers to absorb electrons with one spin rather than another. If the magnetisation of the emitter is fixed by an external pinning layer, then it is only the magnetisation of the collector that will be affected by external fields, that will in turn affect the current flow.

Results

Much development has been undertaken with the new technology. The first devices were all metal. Although this provided a useful research tool, the actual spin effects were masked by unwanted spurious effects and responses. Gain levels were well below unity and the output voltage variations were only measured in nanovolts.

By changing the structure to a more sophisticated semiconductor structure, significant improvements have been seen. However, the development of the new structure has not been easy and several stages of improvements were required to reach the current level of performance. But even now the researchers indicate that further development is required.

One of the main problems they faced was that when the ferromagnetic metals were deposited onto the semiconductor, silicides were formed at the junction. These tended to depolarise the electrons, resulting in random polarisation of the electrons rather than having them polarised as needed for the correct operation of the transistor.

The problem was overcome by adding a very thin layer of aluminium oxide, only about 1·5nm thick, between the emitter and base. The electrons were able to tunnel through the aluminium without the depolarisation created by the silicides. This provided a significant improvement in the performance and also in the consistency between devices.

A further advantage of the layer is that it allows the tunnelling barrier to be varied. This alters the energy of the electrons entering the base region and allows the magnetic sensitivity to be varied. Plans are also in hand to investigate the performance advantages that might be created by introducing a second barrier between the base and the collector.

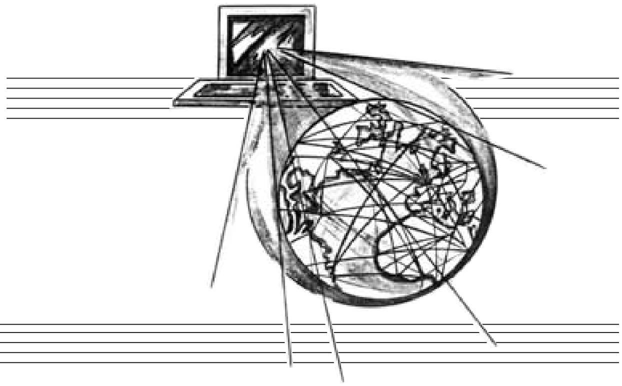
Applications

The new technology has a number of potential applications and no doubt as time progresses and the development continues, more will be found. The technology has a large potential and is expected to be used in many applications including high sensitivity magnetic field sensors for automotive, robotic and mechanical engineering applications.

Of these the automotive industry is expected to be the largest user as the requirement for electronic sensors is growing rapidly because of the need to automate and control more functions within cars. Much of this has arisen out of the need to improve engine management systems and reduce emissions, along with the need to develop more efficient braking systems.

For applications purely within the field of electronics they could be used in data storage applications. Here they have the advantage that they are non-volatile and do not require power to maintain their memory state.

The new spin transistor has many applications and in view of the large markets that are open for its use, their seems to be a real opportunity for it to make a significant impact.



NET WORK

ALAN WINSTANLEY

Tune in to WorldSpace

Buried in several of the major electronics' suppliers catalogues you may find a scant mention of WorldSpace radio receivers, but the WorldSpace Corporation satellite system promises to be a major new area of consumer entertainment, and in some regions it could actually be a lifesaver. The world wide web proves to be the vital link in learning about the system's capabilities, and this month's *Net Work* looks at this emergent digital radio service and also reviews a typical receiver.

Broadcasting data, text and multimedia as well as radio transmissions via its three geostationary satellites (*AfriStar*, *AsiaStar* and *AmeriStar*), WorldSpace (**www.worldspace.com**) is poised over Europe and Africa, Asia and the Americas. As their web site shows, each satellite transmits three beams totalling some 80 to 120 different channels, including the 30 or 40 radio channels that can be heard on a special WorldSpace digital receiver.

There are a number of mono and stereo compatible tuners available, manufactured under licence by JVC, Sanyo, Hitachi, Panasonic and others, each one using the custom-made Starman chipsets to process and decode the CD-quality digital radio transmissions. WorldSpace claim that for the first time, digital broadcast technology is now being built into small, portable radio receivers.

Typical WorldSpace digital radio receiver with detachable antenna, from Sanyo

All the receivers feature a removable miniature antenna connected via a screened cable, which must be properly aligned for azimuth and elevation to receive the broadcasts. The writer has been trialling the Sanyo receiver over the past few months. This portable unit has battery or mains operation, backlit l.c.d., program memories, clock/timer and remote control, carrying strap and detachable dish.

Experience on location in northern England – well within the stated coverage of an *AfriStar* beam – showed that the indoor dish setup could be a little tricky, but when the dish was aligned, reception was of a remarkable crystal-clear broadcast quality with none of the hiss, fade or crackle that we associate with analogue radio reception. Some channels are broadcast in stereo and the mono-speakered Sanyo has a headphone jack and line-out to fed into a hi-fi, as well as an optical output.

Reporting In

Readers can check coverage for their region by visiting **www.worldspace.com/technology/coveragemaps/index.html** where coverage of the three satellites is shown. A line-of-sight view of the satellite is preferable, and the Sanyo receiver worked fine when the small dish was placed indoors on a window ledge with a clear view of the southern skies. The bad news was that the receiver could not receive any programs at all when located in the office, as the walls and ceiling were in the way!

Stations that are available include World Radio News, Bloomberg and a wide variety of specialist music channels including England's BBC Radio 1, Radio Caroline, European pop and some Arab and African stations. You can even hear about political life in the Fiji Islands, seasonal power cuts in Sweden, music from Kenya or the latest from CNN, and a number of languages are available. The *AfriStar* satellite covers Africa and Europe, a program guide is available at **www.worldspace.com/products services/programguides/afristar_guide.html**

Prime Time

The receivers provide for the decryption of pay-broadcast channels via a password input. A number of premium-rate subscription-based programs are being launched, so I asked Jane DiVito of WorldSpace UK what the costs implications are likely to be.

Radio Caroline, for example, which is presently undergoing test transmissions, will eventually be encrypted and it will cost listeners £59.88 (US$92) per year paid in advance to receive them; there are some special offers available for early birds. The company is also excited about the forthcoming launch of NPR (National Public Radio, **www.npr.org**) on satellite, which will be an encrypted service that will be of great interest to ex-patriots and US service personnel serving overseas.

The receivers hint at future expansion possibilities as they have a data port that it is claimed will transform a receiver into a PC-compatible multimedia receiver; no sign of any peripheral hardware yet though. The Sanyo has an optical output for e.g. a Minidisc receiver, and Hitachi receivers are proving popular because of their additional AM/FM wavebands.

Readers in the UK with any queries on availability and pricing can call the WorldSpace London office on 020 7494 8200, or, of course, check their web site for more details and overseas contacts.

Screenshot of the WorldSpace web site satellite coverage.

Going, going . . .

Last month I suggested Email Filtering (**www.emailfiltering.co.uk**), which is a paid-for service that intercepts spam from your mailbox, leaving you to fetch the remaining genuine emails from their own secure servers. The quality of service (as measured by the numbers of spam mails blocked) is rising steadily and EMF has now refined their service further with their enigmatically named "List R" filter.

The company remains very tight-lipped about this latest enhancement, but I can report that the success rate has leapt noticeably, now with a consistently very high rate of interception. Some spams sneak through however: notably those risible "African" emails based on the well-known fraud involving the alleged export of millions of dollars (and the attempted separation of you from your money).

See you next month for more *Net Work*.

You can email Alan at **alan@epemag.demon.co.uk**

News . . .

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

LATER AND SLOWER 3G COMMS

After all the fuss about the superlative merits of the next generation of cellphone technology, the latest news is greatly disappointing. Barry Fox reports.

IT's official. 3G will not just be later than expected, the data rates will be much slower than promised and the first 3G services will not even use the new high frequency bands which over a hundred companies round the world had beggared themselves to licence – they will use existing GSM and GPRS technology.

Nokia has ousted Motorola to become the world leader in cellphones and hoped to launch the first commercial 3G service with Finnish network Sonera at the end of September. Joint invites from Nokia and Sonera promised "their 3G launch on 26 September". But somewhere between the invitations going out and the big day, the launch turned into another test and trial – like the 3G experiment being run by BT on the Isle of Man, and Hutchison in the UK. Despite high profile publicity Hutchison has so far only given a thousand Motorola handsets to "friendly users" in the UK and Italy to see how they work.

Finishing Fudge

The failure to launch in Finland left both Nokia and Sonera fudging with GSM demonstrations and talking about the need to "distinguish between 3G radio technology and 3G services".

Nokia had started hedging bets ahead of the event by promising a mobile phone movie service in Finland, using existing GSM networks. At the annual Emmy awards in Los Angeles, Nokia promoted picture transmission by sending snapshots of the stars over GSM networks using MMS (Multimedia Messaging Services) phones. Nokia claims GSM GPRS speeds of up to 60Kbps (more realistically 40Kbps).

The Nokia/Sonera demonstration of video transmission was not even live. Very poor quality video images, with around ten fuzzy pictures a second, were shown from files previously transmitted, stored in memory and then replayed at the very low resolution (128 × 96 pixels).

Nokia's publicity material now refers to GPRS as "making possible the first true 3G services like MMS". 3G services, says Anssi Vanjoki, Executive VP Nokia Mobile Phones, are just cellphone services that are "more visual and easier to use". They can be delivered either by existing 2G GSM and 2.5G GPRS (General Packet Radio Service) networks which operate in the 900MHz and 1800MHz bands, or new 3G UMTS (Universal Mobile Telecommunications System) networks which use the WCDMA (Wideband Code Division Multiple Access) radio technology which operates in the 2.1GHz band.

Nokia and Sonera switched on a WCDMA trial only in parts of Helsinki, Tampere, Turku and Oulu in January, and introduced MMS on GSM in June. 3G technology, says Vanjoki, will not be ready for commercial trials until the end of this year or beginning of next; there will be no consumer launch until tests prove "seamless interoperability. We shall not launch until everything is ready and working properly. Consumers are not forgiving. They are demanding".

Says Sonera, "The 3G services launched this autumn will operate initially in the present mobile network."

Little Faster Than Modems

Early talk of 3G quoted data speeds of 2Mbps, and promoted the idea of high quality moving video as a revenue-earner. The Nokia 6650 camera-phone will capture 640 × 480 VGA images and uses MPEG-4 video compression. But it displays only 128 × 96 pixels and Nokia now puts the practical limit for WCDMA at 384Kbps. The new 6650 phone has been "limited" to 128Kbps for downlink reception and 64Kbps for uplink transmission. Sonera has limited its network to 64Kbps in both directions – only slightly faster than a conventional phone modem. Says Anssi Vanjoki, "There is no way in practice higher data rates could be guaranteed".

Vanjoki and Harri Koponen, Sonera's CEO, say they hope to have 3G working reliably by the end of the year and if "commercial, political and business issues" can be solved, start selling 3G handsets for business use. Consumers cannot expect to use 3G until sometime in 2004, with a mass market not starting until 2005.

Harri Koponen Sonera's CEO admits the industry has not yet even been able to achieve interoperability even with GSM multimedia messaging; pictures can only be sent over a single network, e.g. Orange to Orange in the UK. "It is not a trivial thing, he says. "It is taking us a lot of time".

It is not hard to see why the International Telecommunications Union recently described 3G and the mobile Internet as "the biggest gamble the telecommunication industry has ever taken on". For more information browse **www.itu.int/osg/spu/publications/sales/mobileinternet/**.

Customise Your Cellphone

THANKS to **coverfrenzy.com**, you can now create your unique mobile phone cover with a picture of your choosing! Website **coverfrenzy.com** is new and lets you design your own mobile phone back cover. The image can be anything from a photograph, drawing or design of your own choice and all on the click of a mouse.

If it's inspiration you're looking for, there is also the Stars Gallery on the site, which offers a library of celebrity images on-line.

All you have to do is log on to **coverfrenzy.com** and simply position your chosen image on the phone template on-screen, position and size it to your preference. You can also add a text message, choose a free ring tone and even email a copy to your friends. Within a week, the finished cover is delivered to your door with a complementary front cover, all for just £19.25, including P&P.

Currently covers can be designed for Nokia handsets 8310, 3210. 3310/3330 and 8210. There are plans to add more handset models and manufacturers shortly.

We are told that the process used to apply an individual image to the mobile phone is new, patented technology provided by MiCyte Ltd. The images produced are of true photograph quality and are highly resistant to surface damage. So, get mobile – scan in your favourite *EPE* cover and log on to **coverfrenzy.com** and really impress your friends!

R.F. SCREENING

AS those of you who are into building circuits that can radiate into the electromagnetic spectrum should know, there are stringent regulations about keeping such radio frequency (r.f.) emissions to a minimum. To provide an "instant fix" when constructing equipment prone to r.f. radiation, Microponents Ltd of Birmingham have introduced a patented R.F. Screening System.

The system is very flexible, allowing the building of screening enclosures of various sizes, shapes and heights. The kit can currently be purchased directly from Microponents, although distribution rights will soon be issued.

For further information contact Andrew Owen, Commercial Manager, Microponents Ltd., Dept EPE, PO Box 162, 30 Curzon Street, Birmingham B4 7XD. Tel: 0121 380 0100. Fax: 0121 359 3313. Email: sales@microponents.com. Web: www.microponents.com.

RATTLED?

OH YES, lots of you are going to love the novelty (and potential usefulness!) of the CD that we've received at the News Desk! It's titled *The Rattler* and is described as a Car Audio Test and Measurement Set-Up CD.

It is aimed at anyone who wishes to find those unwanted and noisy vehicle rattles and to accurately set up their in-vehicle audio system. There are around 70 tracks of various test tones and frequency sweeps. There are also four printed charts which provide an absolute reference guide when used in conjunction with certain CD tracks.

In the belief that any undesirable and unlocated noise in a vehicle could indicate a potential major repair cost, this CD could prove to be an absolute money saver when used as instructed.

For more information contact Broadcast Communication UK Ltd., Dept EPE, 155 Coventry Road, Ilford, Essex IG1 4RD. Tel: 020 8554 3588. Fax: 020 8554 8835. Email: bcluk@aol.com. Web: www.audio-repairs.com.

EASY-PC V6

NUMBER One Systems have told us that they have released Easy-PC for Windows Version 6.0. The original, and renowned, Easy-PC printed circuit board design package was first released in the late 1980's and has undergone various enhancements since then. Some of the new features include online design rule checking, library creation wizards, optimising vias, importing DXF files, colour by net in schematics, easy find and add components, single-shot processing, alignment of selected items, highlighting of unconnected pins, save/load colour files and more toolbars.

Existing customers are offered a cost-effective upgrade priced at £117. The list price for the full Easy-PC V6.0 product is £397. Delivery is quoted at £6.50.

For further information contact Number One Systems, Dept EPE, Oak Lane, Bredon, Tewkesbury, Glos GL20 7LR. Tel: 01684 773662. Fax: 01684 773664. Email: info@numberone.com. Web: www.numberone.com.

Electronic Eyesight

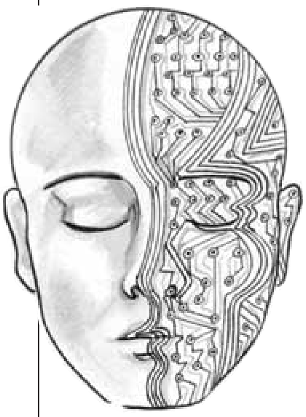
ACCORDING to a story in the *Daily Mail* on 17 September '02, an artificial retina has been invented which allows sight to be restored to those suffering certain types of blindness in which some of the retinal cells are undamaged.

The artificial retina is a chip about 2mm wide, says the story, with 3500 to 5000 light sensors that convert light energy into electrical signals, which then directly stimulate the remaining cells in the retina. The system has already been implanted in several patients, who now experience varying degrees of sight restoration. It has also been found that the damaged retinal cells can be prompted to rejuvenate by the presence of the implant.

The technology allows the chip to be implanted behind the retina, where it is held in place by the pressures within the eye itself. It is powered by the light entering the eye and does not need additional connecting wires or batteries.

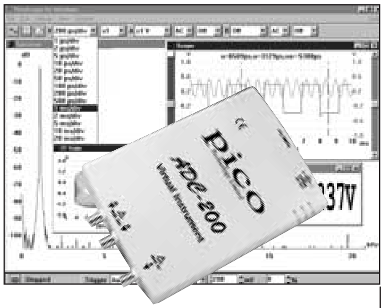
If larger scale trials and the experiences of those who have already had the chip implanted are successful, the technique could become available for more general use within about five years.

The technology is being reported on at the International Congress of Eye Research in Switzerland later this year. The *Daily Mail*'s web site is at **www.dailymail.co.uk**.



INGENUITY UNLIMITED

Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited,* Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown Dorset BH22 9ND. (We **do not** accept submissions for *IU* via E-mail.)
Your ideas could earn you some cash **and a prize!**



WIN A PICO PC BASED OSCILLOSCOPE WORTH £586

- 100MS/s Dual Channel Storage Oscilloscope
- 50MHz Spectrum Analyser
- Multimeter ● Frequency Meter
- Signal Generator

If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC based oscilloscope could be yours.
Every 12 months, Pico Technology will be awarding an ADC200-100 digital storage oscilloscope for the best IU submission. In addition, a DrDAQ Data Logger/Scope worth £69 will be presented to the runner up.

Fluid Finder – Relatively Simple

THE circuit diagram show in Fig.1. is capable of distinguishing between different liquids, or, alternatively, of helping to determine their purity. It may also be used to measure the level of highly corrosive liquids that would devour many types of probe.

A critical element of the formula used to determine the capacitance of a parallel-plate capacitor is the relative permittivity of the dielectric, or the dielectric constant (ε_r). Relative permittivity is defined as "capacitance with a material as the dielectric" divided by "capacitance with a vacuum or air as the dielectric".

Although the circuit is relatively crude, it will determine relative permittivity to within a fraction of one percent. It will therefore distinguish unfailingly between e.g. distilled water, tap water, and milk, and reveals vast differences between fluids such as water, alcohol, and oil.

Circuit Details

At the heart of the circuit is a custom-built parallel-plate capacitor C1, the "plates" of which are sealed in epoxy resin and separated by an air space. It is clipped into a liquid to determine its relative permittivity, which in turn is deduced from the capacitance measured by means of potentiometer VR1.

The frequency of RC oscillator ICla-IC1b is fed to a digital bandpass filter IC2a-IC2b, then VR1 is adjusted until l.e.d. D4 illuminates. The relative permittivity of distilled water (which can be designated as x) is then measured as 100,000 –VR1 ohms, and then the relative permittivity of any other fluid maybe calculated as:

$$(100{,}000 - \mathrm{VR1}) \times (78/x).$$

This assumes that the relative permittivity of distilled water is 78. Needless to say, a quantity of distilled water is first required to determine the value of x. It is available from most garages for topping up car batteries.

The digital filter IC2 goes either "high" or "low" at output pin 9 until the desired frequency (about 100kHz) is presented at the input. In this case a square wave at output pin 9 is detected by means of simple diode pump D2-D3 and C4-C5. When C5 charges, the input of IClc goes "high", and l.e.d. D4 illuminates. The l.e.d. D1 is included for easier adjustment, as this shows whether the output is "high" or "low". With the oscillator typically operating at around 100kHz, this would be multiplied by 78 if distilled water were replaced with air, which has a relative permittivity of about 1. Switch S1 is provided so that IC1 and IC2 are not overdriven in the absence of a liquid.

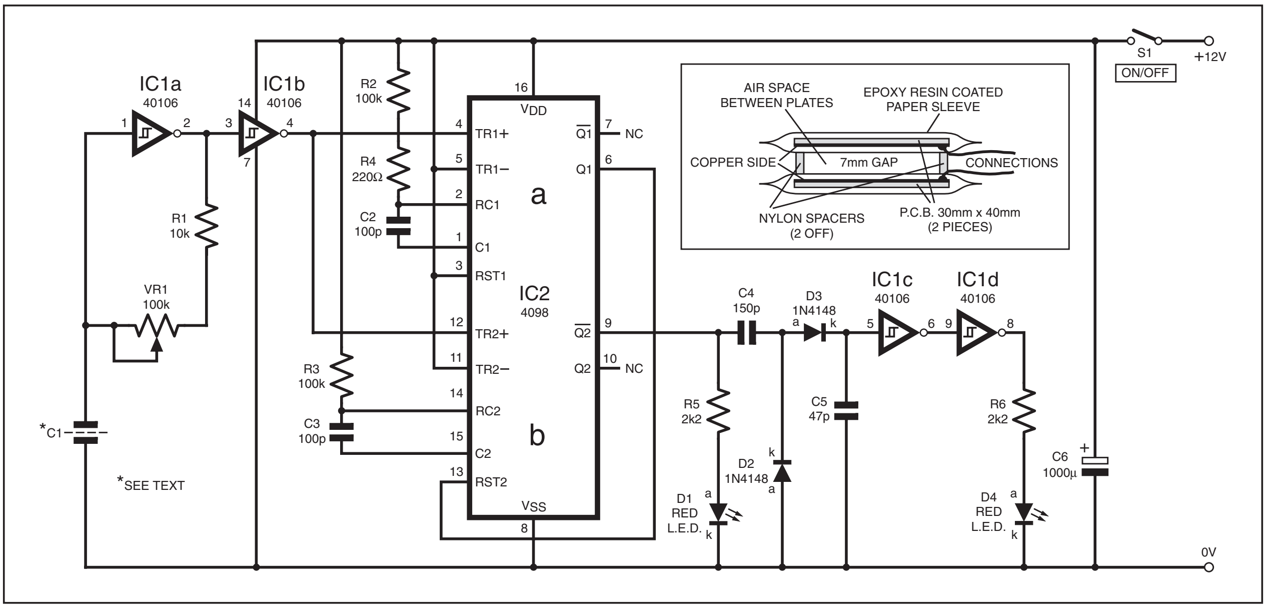


Fig.1. Circuit diagram for the Fluid Finder. The sensor "capacitor" assembly is shown inset.

Capacitor Details

The capacitor Cl was made from two plates of copper-clad board measuring 30mm × 40mm, with the copper foils facing inwards. These were soldered to wires and then sandwiched in 80gsm paper, which was coated twice with epoxy resin. The prepared plates were mounted 7mm apart with nylon spacers.

The accuracy of the Fluid Finder is determined by resistor R4 which may be decreased for greater accuracy. Note that capacitor C1 is affected by body capacitance, so keep it a few centimetres away from any part of the body for a more accurate reading.

Rev. Thomas Scarborough, Fresnaye, South Africa

Switched Mode L.E.D. Nightlight – Lighter Nights

ORDINARY plug-in night light bulbs tend to have a short life and using solid-state lamps is a sensible alternative. In the circuit diagram of Fig.2, ten ordinary bright yellow l.e.d.s. in series were used with a step-up switched-mode driver for minimum power consumption, powered by a small 9V adaptor.

An astable oscillator based on a 555 timer is formed around IC1, running at 50kHz, with diode D1 setting a duty cycle closer to 50%. This is used to drive TR1, an *n*-channel MOSFET power transistor. When TR1 is on, current flows through coil L1, magnetising its core. When TR1 turns off L1 induces a current through D2 and C3 to illuminate the ten l.e.d. array (D3 - D12).

The use of a high frequency means that the l.e.d.s illuminate at a constant value. When the output voltage is approximately 22V (required to light the l.e.d.s), the voltage across resistor R5 causes TR2 to switch on, which reduces the pulse width. In this way, the voltage is regulated at 22V, and preset VR1 should be adjusted as required. A toroid is suggested for L1. Capacitors C1 and C3 should ideally be switched-mode compatible types and have a low ESR.

Myo Min, Myanmar

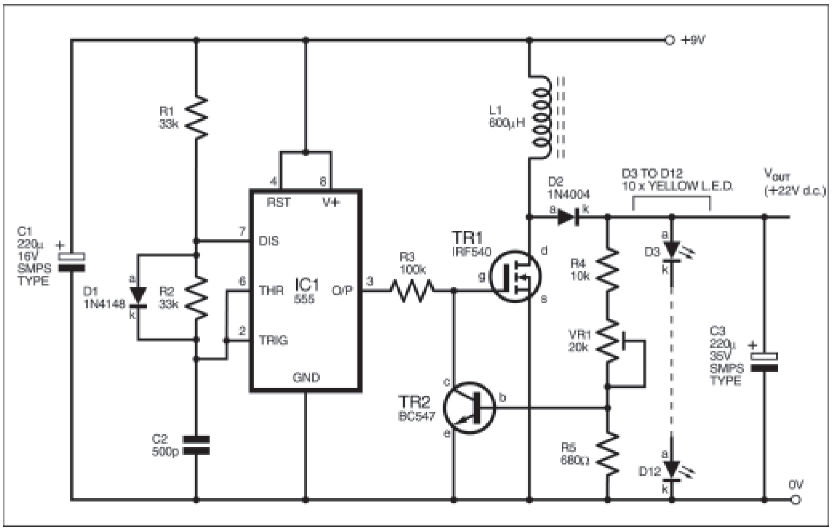
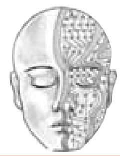


Fig.2. Circuit diagram for the Switched Mode L.E.D. Nightlight.

WHY NOT SEND US YOUR CIRCUIT IDEA?
Earn some extra cash and possibly a prize!



SHOP TALK
with David Barrington

Versatile PIC Flasher

The PIC microcontroller used in the *Versatile PIC Flasher* project ***must*** be the one with the suffix A, i.e. PIC16F84**A**. For those readers unable to program their own PICs, a ready-programmed PIC16F84A (20MHz) microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £5.90 each (overseas add £1 p&p). The software is available on a 3·5in. PC-compatible disk (*EPE* disk 5) from the *EPE* Editorial Office for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 909). It is also available *Free* from the *EPE* ftp site: **ftp://ftp.epemag.wimborne.co.uk/pub/PICs/PICflasher.**

The terminal block TB1, mounted directly on the p.c.b., is made up from five 3·81mm 2-way interlocking screw-terminal blocks. Most of our components advertisers should be able to supply, but if you have any problems they are currently listed by **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), code 21-1655. They also supplied the p.c.b. mounting 2·1mm d.c. power socket, code 20-0970.

The printed circuit board is available from the *EPE PCB Service*, code 377. The type, colours and quantity of l.e.d.s is left to individual choice.

Door Defender

If you intend using a similar small plastic case to the one depicted in the photographs to house the *Door Defender* project, you will need to purchase a "low-profile", key-operated switch. Alternatively, go for a larger (depth) case, whichever is the cheaper option. The switch used in the prototype came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***). code FE44X.

The same company also supplied the plastic moulded, surface mounting, reed switch/magnet, code YW47B. Most of our components advertisers should be able to advise on a suitable buzzer.

PICAXE Projects Pt.2 – Temperature Sensor ● Voltage Sensor ● VU Indicator

Ready-programmed HEX versions of the PICAXE-18 microcontroller for the *PICAXE Projects* can be purchased (*mail order*) from **M. P. Horsey, Electronics Dept, Radley College, Abingdon, Oxon, OX14 2HR**, for the inclusive sum of £5.90 each (overseas add £1 p&p). Specify for which project the PICAXE is wanted and *make cheques payable to Radley College*.

Software for these designs (except PICAXE programming software) is available on a 3·5in. disk (Disk 5) from the *EPE* Editorial Office for the sum of £3 each (UK), see page 909. It is also available for *Free* download from the *EPE* ftp site.

The "special" serial lead was supplied by **Revolution Education** (☎ ***01225 340563*** or ***www.rev-ed.co.uk***), stock code AXE025. They also supplied the PICAXE programming software.

The same master printed circuit board is used for all the projects in this short series. It is available from the *EPE PCB Service*, code 373. All other components appear to be "off-the-shelf" devices. However, you do need to specify the **L** suffix when ordering the BC184L transistor as other 184's have differing pinout arrangements.

EPE Hybrid Computer

Most of the components for the *Hybrid Computer* appear to be mainly standard devices and only a few items could be classed as specials. Starting with the "heart" of the project, the BASICMicro Atom microcontroller compiled BASIC module can be purchased from **Milford Instruments** (☎ ***01977 683665*** or ***www.milinst.com***), code 1-316. Make it clear that it is the 24-pin version you want. When you purchase this microcontroller, also enquire about a CD-ROM containing the ATOM software.

The Omron (G5V-2 series) 5V d.c. 50 ohms coil p.c.b. mounting relays were obtained from **Farnell** (☎ ***0113 263 6311*** or ***www.farnell.com***), code 179-350. They also supplied the vertical, snap-in, p.c.b. mounting rotary pots. (VR1 to VR10), code 918-878.

The large double-sided printed circuit boards (codes 375 (Main) and 376 (Atom)) are available from the *EPE PCB Service* – see page 909 for details and prices.

PLEASE TAKE NOTE

Digital I.C. Tester *(Oct '02)*

Page 720, Fig.2. L.E.D. D4 should be reversed so that the anode (a) lead goes to pin 17 of IC3. The circuit diagram is correct.

Ingenuity Unlimited *(Nov '02)*

Page 825 *Wien Oscillator.* Fourth paragraph, second equation should read $\sqrt{(R2/VR1)}$

Page 827, *Tape Tone Index Marker* (Fig.4). The wrong callsign was attributed to Fred Knight which should have been G4GAN. We apologise to Dave McQue G4NJU for using his callsign. We understand that the oscillator (IC2) is based on Dave's original circuit idea.

Transient Tracker *(Nov '02)*

It has been pointed out that Class-Y capacitors are for use between mains and Earth and *NOT* directly across the mains supply as indicated in *Shoptalk* (page 823).

Class-X types are, of course, meant for continuous operation/connection across the mains supply. But they should *NOT* be used where failure would expose anyone to an electric shock hazard.

DOOR DEFENDER

STEVE DELLOW

Keep an armed guard on your door or valuables with this self-contained, truly portable, low-cost audio/visual alarm

WHETHER we are brave enough to admit it or not, we all suffer varying degrees of paranoia when it comes to the doors in our life. Was that someone sneaking in the front door? Did we leave the back door open? Where's the padlock on the shed door? Should we have a mortise or a night latch?

The list goes on and on . . . There isn't a day goes by when we don't suffer some stress event associated with a door!

Perhaps the circuit described here might help put some of those fears at rest. The Door Defender is a simple circuit intended to monitor the opening and closing of a single door, but it could easily be expanded into a comprehensive system.

It can be used with any type of internal or external opening, and consumes very low current in standby. For instance, the long battery life would make it ideal for protecting a garden shed. On the other hand, its small size could allow it to be a portable unit for protection when travelling.

DESIGN OVERVIEW

It was decided to create a door monitoring circuit based on the reliable reed switch and magnet method. This would feed information into a circuit designed to indicate whether the door was open or shut. An "arming" sequence would begin with the door closed i.e. you're getting ready to leave, followed by a turn of a keyswitch to apply power to the circuit. The unit would signal that it had entered the arming sequence which prompts you to open the door and leave, closing it behind you.

The action of opening and shutting the door would be detected by the circuit which would then move into an "armed" mode. The next time the door was opened, the system would immediately turn on and latch the alarm. This would only be cleared by switching off the unit with the keyswitch, even if the door was closed again.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Door Defender is shown in Fig.1. Power for the circuit comes from a 9V alkaline battery, which is ideal to supply the CMOS i.c.s that control the alarm process. As mentioned earlier, a reed switch, S2, is used to detect the opening and closing of the door. These items are standard in most burglar alarm systems and are usually employed to monitor the entry/exit route.

They consist of two main components – the reed switch and a magnet. When the two are positioned adjacent and "in-line" i.e. when the door is properly closed, the reed switch physically aligns itself with the lines of flux from the magnet, causing the contacts to close. They are generally good enough to detect a door even slightly ajar.

Unfortunately, like all switches, the reed type is liable to "bounce" when closing. In other words, the contacts do not necessarily come together cleanly, and for a very brief fraction of a second, they may open again one or more times before they finally settle. The bounce may appear to us to be over very quickly, but in logic terms, it is a lifetime, and the circuit will detect every "bounce" as an opening and closing of the door! The ideal recipe for a very confused circuit!

Components R2, C1 and IC1b come to the rescue here, forming a "debounce" circuit. Basically we are using an *RC* slowdown network to drive the Schmitt trigger gate IC1b. The low-pass filter formed by resistor R2 and capacitor C1 smoothes out the bounces of the switch contacts so that IC1b makes only one transition. A time constant of 10ms to 25ms is generally enough.

ON GUARD

Now that we have a clean reliable signal telling us what the door is doing, we can

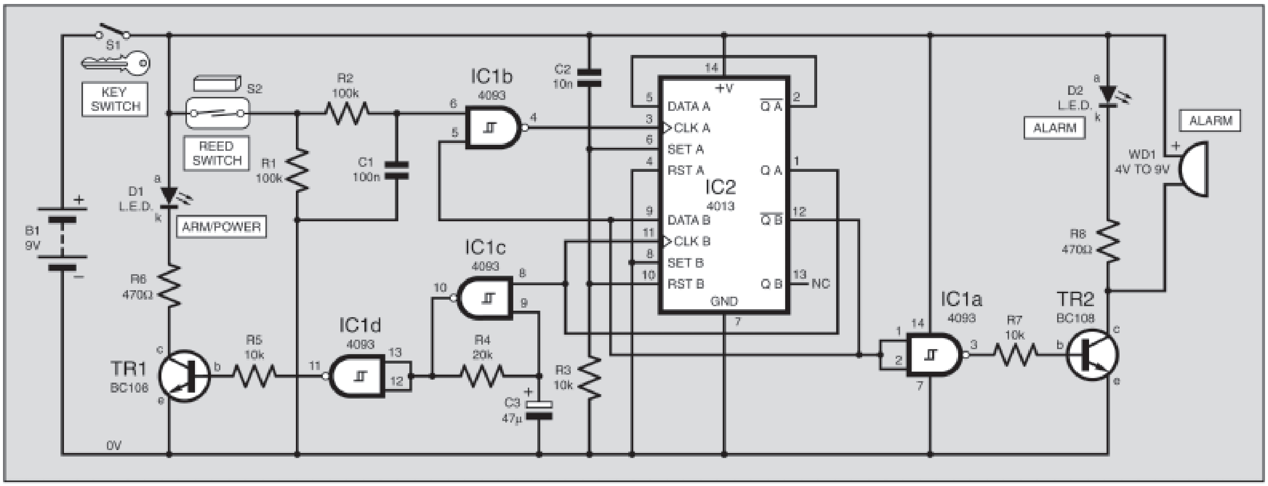


Fig.1. Complete circuit diagram for the Door Defender.

start doing something useful with that information.

When we look carefully at the design concept, it becomes clear that we need to produce a circuit that remembers the sequence of door movements so that we can correctly control the alarm operation. In a more complicated system we might use a microcontroller, but here the sequence is so simple we can use a couple of bistables, or flip-flops.

These circuit blocks are characterised by the fact that they are stable in one of two logic states (as opposed to monostables, which are stable in only one state, and astables, which continually oscillate between the two). The condition they adopt is dependent on changes of logic state at two or more inputs.

The type of flip-flop used here is a D-type (Data type), which is designed for data-related applications where it is desirable to "remember" the state of an input at a point in time defined by a clock signal. In this circuit it is actually wired as a T-type (Toggle-type), which results in the Q output "toggling" (switching to the opposite logic state) every time there is a rising edge at the clock input.

Since the flip-flops can adopt either state at power-up, it is important to perform a reset operation every time at switch on. Components C2 and R3 form a rather unorthodox yet effective reset circuit. When power is applied, the "hot" end of resistor R3 initially goes high (about 9V), but this voltage drains away very quickly down to zero. Despite this voltage fall, it is high for long enough to put the two flip-flops into the desired states – IC2a has its Q output forced high, whereas the Q pin on IC2b is forced low. So we know we are starting from the same point every time.

ARMED GUARD

At power-up, we want to enter the "Arming" mode because we are getting ready to leave the room, and the circuit signals this visually by flashing l.e.d. D1 – just like an expensive system! This is driven by an oscillator formed around IC1c – it is configured so that the output cycles between high and low logic states at a rate of about 1Hz, this frequency being controlled by capacitor C3 and resistor R4.

The Q output of IC2a (pin 1) enables the oscillation process – the l.e.d. D1 will only flash if it is high. Therefore, in this enabled state IC1c now operates as a simple inverter.

While IC1c is operating as an inverter, pin 10 will always be the opposite logic level to pin 9, and when this pin is below the switching threshold, pin 10 is high and charge flows onto C3, causing the voltage on the capacitor to rise towards the supply voltage . . . but it never gets there! When the voltage on pin 9 reaches the upper Schmitt input threshold, the output switches i.e. pin 10 goes low, and the charge on capacitor C3 starts discharging again, the rate being controlled by resistor R4. Now the voltage falls (exponentially) towards the ground rail (0V), but once again, it never arrives. As the lower Schmitt threshold is reached it's all change again, and pin 10 returns to a high state.

Because of this process the voltage on pin 9 moves continuously between the two threshold levels, producing an output

voltage at pin 10 that oscillates between supply and ground. That is one way to turn a standard l.e.d. into a flasher! The chosen values give a rate of about 1Hz.

To protect the charge/discharge process, we introduce a buffer stage in the form of IC1d. This is because we need to push some charge into transistor TR1 to make it drive the "Arming" l.e.d. – this way we do not upset the charge that's moving around in the R4/C3 circuit. Series resistor R6 limits the current through the l.e.d. to a safe level, about 15mA.

The circuit remains in this state, with l.e.d. D1 flashing, until you open the door in preparation for departure.

Reed switch S2 detects the opening of the door, causing the voltage at the junction of resistors R1 and R2 to fall to 0V. The input conditioning at IC1b converts this to a logic level change that is fed into the clock input pin 3 of IC2a. The arrival of a rising edge (a change of state from low to high logic level) toggles the flip-flop and the Q output goes low, switching off "Arming" l.e.d. D1. Although the clock input to IC2b at pin 11 is connected to the Q output of IC2a, there is no change to its state, as it sees a *falling* edge.

ABSOLUTE MAYHEM

The closing of the door causes no further changes to the circuit, apart from the clock input to IC2a (pin 3) returning to the low state. There is no change to either of the flip-flop outputs as their clock inputs only respond to *rising* edges, and the Door Defender now settles into "Monitoring" mode – both the l.e.d.s are off, and it consumes very little current making sure that the battery is kept fresh for Alarm action!

Everything happens when the door reopens! – breaking the magnet/reed switch "influence". A rising edge into the clock input of IC2a at pin 3 toggles the state of its outputs – the Q output moves from low to high which is a rising edge. This logic change is also seen at the clock input to IC2b (pin 11) causing it, too, to toggle the state of its outputs, since it is also wired as a T-type. The change in the state of IC2b sounds the alarm!

Using IC1a as a buffer to drive transistor TR2, the low output from pin 12 of IC2b brings on the Alarm l.e.d. D2 and also "fires" the warning Alarm sounder WD1. You may also note that the Arming l.e.d. starts flashing too! Absolute mayhem – just what we want!

COMPONENTS

See SHOP TALK page

Resistors

R1, R2	100k (2 off)
R3, R5, R7	10k (3 off)
R4	20k
R6, R8	470Ω (2 off)

All 0·6W 10% carbon film

Capacitors

C1	100n disc ceramic
C2	10n disc ceramic
C3	47μ min. radial elect. 16V

Semiconductors

D1, D2	5mm l.e.d. red (2 off)
TR1, TR2	BC108 *npn* low power transistor (2 off)
IC1	4093 CMOS quad 2-input NAND Schmitt trigger
IC2	4013 CMOS dual D-type flip-flop

Miscellaneous

S1	single-pole make/break miniature round key-operated switch
S2	2-piece plastic moulded reed switch, with magnet
WD1	4V to 9V min. buzzer
B1	9V alkaline battery (PP3 type), with clips

Stripboard, size 21 holes x 23 strips; plastic handheld box, with battery compartment, size 105mm x 62mm x 28mm approx; 14-pin d.i.l. socket (2 off); multistrand connecting wire; wire links; solder pins; solder etc.

Approx. Cost Guidance Only **£16.50** *excl. batt.*

Now, the design requirement is that the Alarm shall continue to sound even when the door is shut again – in other words it "latches" until the authorised keyholder turns the power off. This is where the connection between IC2b pin 12 and IC1b input pin 5 comes in to play.

At switch-on, the reset circuit ensures that this line is high, and this allows the reed switch signals through to IC2a. We already know that IC2b toggles when the circuit goes into Alarm mode. This immediately changes the signal to IC1b and disables the gate, preventing further door signals being processed.

As long as pin 5 (IC1b) is low, the output of the gate can never go high and create a rising edge – the circuit is "latched" in the Alarm mode, and continues to sound no matter how many times you open and close the door! A turn of the keyswitch S1 is the only way.

CONSTRUCTION

The original concept was that the finished unit could be easily fixed to a bedroom or workshop door. The chosen enclosure results in a very compact fit but produces a handy little "Defender". There's no reason why it could not be housed in a larger box, especially if you're thinking of expanding the circuit to create a full blown intruder detection system.

Construction should commence by preparing the case to accept the off-board components. A general layout guide can be seen in the accompanying photographs. Note the cutouts in the stripboard.

Start by preparing the stripboard to the suggested shape, the layout will be dictated by the off-board components used, particularly the clearance required for the keyswitch S1. Once you have cut the board to the desired shape, temporarily place it in the base of the case and check for a satisfactory fit.

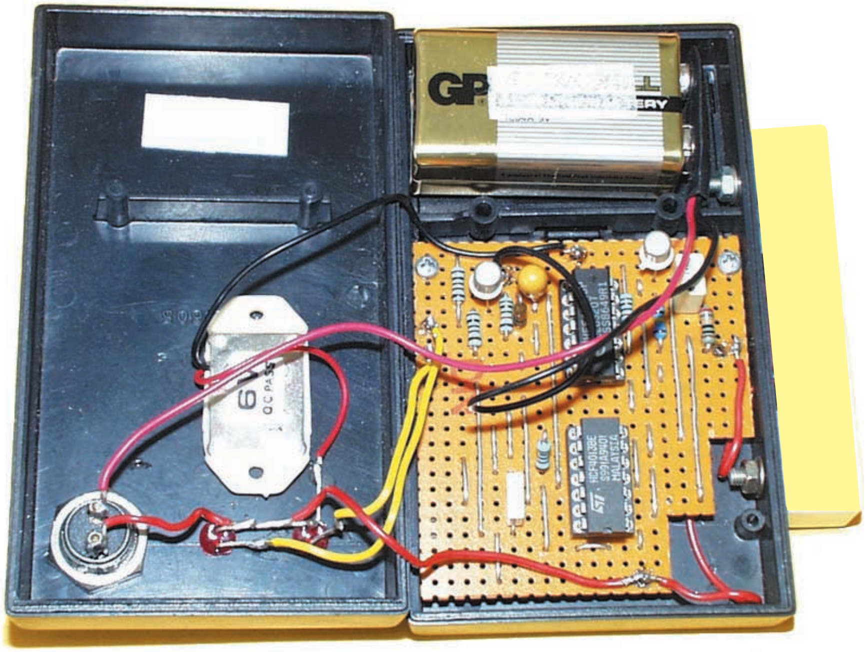
When you're happy, remove it and begin to make the breaks in the copper tracks – there are 24 in all. A small handheld twist-drill or a dedicated stripboard cutter tool will do the trick. Examine the board carefully after each cut to make sure that the break is clean and complete – a magnifying glass will help here.

The stripboard topside component layout and details of breaks required in the underside copper tracks are shown in Fig.2. The interwiring details to the off-board components are also shown in this diagram. The reed switch housing is bolted on one of the outside case panels – see photograph.

Fit all the lead-off solder pins and wire links – quite a tedious job but it helps define the layout. Again, keep checking against the layout drawing at every opportunity. Once all the links are in place, solder in the two 14-pin i.c. sockets, making sure that they're the right way round. Don't fit the chips yet.

Next, the resistors can now be added. Most lie flush to the board, but a few stand almost vertical. Then it's on to the capacitors – C3 is polarity conscious so check that the positive (+) lead is in the right hole.

The final components are the two transistors. Again, have a careful look at Fig.2 to be sure that you've identified their pins correctly and then solder them in position.



Completed wiring between the two halves of the case.

Before continuing, take time to check the circuit board just one more time. It is not only a case of confirming that all the components are in the right place but also that there are no solder splashes, bridges, etc. on the copper side.

BOARD CHECK

The next job is to do some basic checks on the circuit board. Set your multimeter to the lowest resistance scale and measure across the +V and 0V terminals. What you

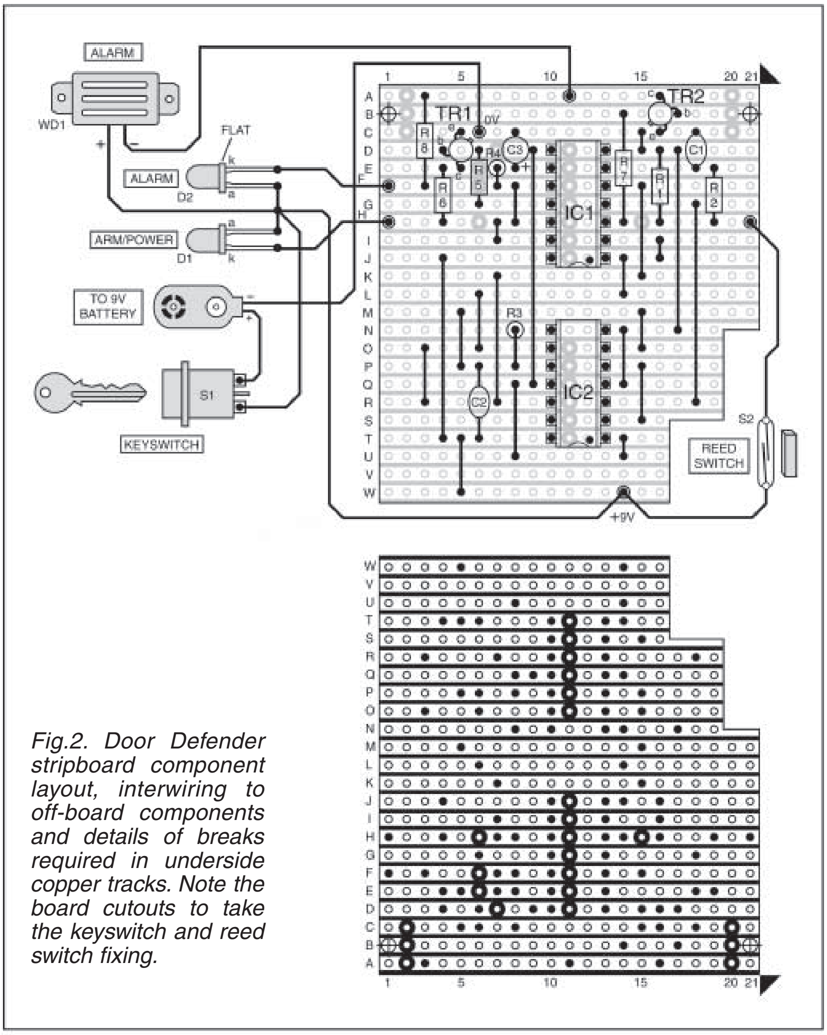


Fig.2. Door Defender stripboard component layout, interwiring to off-board components and details of breaks required in underside copper tracks. Note the board cutouts to take the keyswitch and reed switch fixing.

are looking for here is any short circuit between the rails, i.e. less than one or two ohms.

Once the multimeter is giving good news, attach a 9V battery across the same terminals. Check that there is a nice steady voltage across pin 7 and pin 14 of the i.c. sockets. If everything is okay go ahead and finish the installation.

FINAL ASSEMBLY

Start by taking the reed switch and attaching two lengths of wire to the internal terminals – measure the resistance across them. In isolation, the reading should be open circuit but if you bring the magnet alongside the reed switch there's a point where the contacts close. This is a good test to see if you've wired it up correctly and that the switch responds to the presence of the magnet. Make sure that the contacts open again when the magnet is removed.

The reed switch module can now be securely attached to the case side panel and the circuit board screwed securely in place. Now it's just a matter of doing the wiring-up – connecting the l.e.d.s, reed switch, buzzer, keyswitch, and battery clip as shown in Fig.2.

Finish by doing another multimeter check to confirm that no short circuits have crept in, and that the keyswitch S1 is working correctly. If everything looks good, insert the two i.c.s in their holders. Orientation is everything here, so make absolutely sure you've got them the right way round. Don't mix up the 4013 and 4093 and look out for pins bent underneath!

TESTING

Testing of the Door Defender is quite simple. Turn off the keyswitch, fit the battery, and temporarily tape the magnet block in line with the reed switch S2. Now turn the key to apply power to the circuit. Neither of the l.e.d.s should be lit and the buzzer WD1 should be silent.

Now detach the magnet, moving it well away from the reed switch. The "Arming" l.e.d. D1 should begin flashing, indicating that the circuit has detected that the contacts have opened. Now bring the magnet back in-line with the reed switch. The Arming l.e.d. should go out.

Finally, remove the magnet again. This time, both l.e.d.s (D1, D2) should light and buzzer WD1 sound. Replacing the magnet will have no effect and the only way to reset the system is by turning the keyswitch. If all is well, the box can be screwed together and the system is ready for use!

IN USE

The Door Defender will be found useful in all sorts of applications, although it should not be used in an unattended public position as it does not have an automatic cut-off time-out for the alarm sounder. Installation requirements are not critical, simply that the magnet and reed switch parts are consistently aligned when the door/window is shut. Also, there is no reason why the reed switch needs to be mounted on the box – you could locate the alarm unit remotely and run a cable to the sensor (reed/magnet). The intruder would be unaware of detection!

You could pack it in your suitcase and use it to protect a hotel door, or monitor movements in and out of the workshop. Perhaps it might work as a child alarm, warning you if Junior has found their way into your den or wandered from their bedroom/playroom? What about using it to protect your toolbox from prying little hands?! Whatever the need, it can be quickly set up and provide sterling service.

If you're feeling adventurous, why not expand the basic system to create something more comprehensive? Further switches could be added (normally closed types wired in series) to monitor windows and other doors, while the l.e.d.s could be replaced with relays or opto-isolators to drive floodlamps, strobes, or sirens. There's nothing like going over the top! □

ALTERNATIVE USES FOR TRANSISTORS

NED STEPHENS

A look at the other uses to which transistors can be applied

TRANSISTORS have many uses which are well known, such as amplifiers, oscillators and switches, but have many further uses, some of which are not as well known. A knowledge of these other uses can be helpful when a particular component is not immediately available but is required for gadgeteering or experimentation.

For instance, if a Zener diode of a particular voltage is needed for a constructional project, but is not available in the spares box, then it may be possible to use a transistor instead. Transistors may also be used in place of signal diodes, rectifier diodes, varicap diodes, tunnel diodes, constant current sources, and even solar cells.

In some cases, a transistor pressed into such service may be superior to a purpose made part and may reduce the circuit's total parts count.

SIGNAL DIODES

When a current is passed through a diode in the forward direction, the diode acts as a non-linear resistor, such that the effective resistance is large at small voltages, but reduces as the voltage increases. This has the effect that there is no appreciable current flow through the diode until the voltage across it has risen above a certain value. In the case of a germanium diode this is approximately 0·3 volts, and in the case of a silicon diode it is about 0·7 volts.

If you wish to detect a small r.f. voltage in a crystal set, for instance, then it is better to use a diode with the lowest possible voltage drop, i.e. a germanium one.

So much for standard practice – results are better if we use a transistor instead. A transistor measured with an ohmmeter appears to be two diodes, one connected from base to emitter and the other between base and collector. Either of these apparent diodes may be used as real diodes, the third connection of the transistor being left open circuit.

We can, however, do better than this by connecting the base of the transistor to the collector and using that common connection as one diode connection, whilst the other diode connection goes to the transistor emitter, making a so-called "superdiode". Which of these connections is the diode anode (a) and which is the cathode (k) depends on whether you are using a *pnp* or an *npn* transistor.

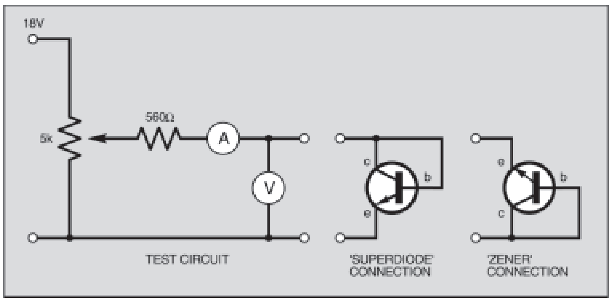


Fig.1. Test circuit for "transistor" superdiode and Zener diode.

Table 1: Forward voltage drop comparisons

Diode	Construction	Emitter-base junction at 100μA	Superdiode at 100μA
OA91	Germanium diode	0·184V	
1N914	Silicon diode	0·509V	
2N1307	Germanium transistor	0·137V	0·077V
AC128	Germanium transistor	0·105V	0·046V
OC71	Germanium transistor	0·097V	0·038V
BC107	Silicon transistor	0·610V	0·553V
BCY31	Silicon transistor	0·511V	0·487V
2N3904	Silicon transistor	0·640V	0·627V

Due to the amplifying action of the transistor, the effective resistance of this new superdiode is as low as, or lower than, that of a purpose built diode, so that its use in signal circuits will enable the detection of smaller r.f. voltages. Table 1 shows forward voltage drops of base-emitter junctions and superdiodes, and the drops of germanium and silicon purpose built diodes for comparison.

We see that this trick of connecting a transistor as a superdiode is much more successful with germanium transistors than with silicon. With germanium the forward voltage drop may be more than halved, but for all the many different types of silicon transistor that were tried the forward voltage was only reduced by about 10 per cent or so.

It is apparent that a germanium transistor connected as a superdiode, i.e. with the base connected to the collector, begins to conduct in the forward direction with much smaller applied voltages. In order to check out the characteristics of this new device the circuit of Fig.1 may be used.

Sample curves of an OC72 germanium transistor used in this fashion are shown in Fig.2, along with the curve of a germanium diode type OA91 for comparison. Practical tests with a standard crystal set circuit show that a germanium diode is indeed better than one made of silicon, but a germanium r.f. transistor in the superdiode configuration is best of all.

RECTIFIER DIODES

Large power transistors may be used as rectifiers in this fashion and, as above, germanium transistors used in the superdiode configuration at low currents show much more reduction of forward voltage drop than do silicon types. The list in Table 1, however, is for signal diodes and refers to only small diode currents. It should be noted that the voltage drop at higher currents will be less for silicon than for germanium, so that when substituting components germanium should be used for low currents and silicon for anything above about 10mA.

It must be remembered that the current flow is through the base-emitter junction of the transistor, which is not its normal mode of operation. The author has been unable to find any data relating to the maximum permissible base currents. However, data books listing transistor saturation voltages quote the base current used, in the case of the BD239 this is 200mA and for a BUX98 it is 4·0 amps (Ref.1), with most silicon power transistors quoted as using base currents between these two figures. Using transistors in place of rectifier diodes at these current levels will be fine, but care should be taken if exceeding them by a large margin.

ZENER DIODES

If the superdiode connection is used in the reverse direction then it will be seen that the transistor now exhibits a Zener characteristic. Several different types of transistor were tested using the circuit in Fig.1 to see which Zener voltages were available. The results are shown in Table 2.

Table 2: Transistors as Zener diodes

Transistor	*Voltage*	*Transistor*	*Voltage*
2N3553	5·57	BFY18	8·11
2N3703	6·06	BSY26	8·15
2N2846	6·18	2N13l07	8·22
2N4037	6·35	BC148	8·38
BFX29	6·40	BFX85	8·44
2S847	7·16	BSX23	8·72
BSY27	7·38	BC639	8·83
2N3904	7·66	BC109	9·05
BC107	7·97	2N696	9·21
2N1613	8·08	BSY85	9·43

The same formula may be used except that the constant should be approximately doubled, i.e. to approx. 1·10((R1 + R2)/R2) volts. The methods of connecting these "Zeners" is shown in Fig.4.

LOW LEAKAGE DIODES

If a diode with infinitesimal reverse leakage current is required then one can be made from an ordinary *n*-channel f.e.t. By connecting the drain and source leads together and using this connection as the diode cathode and the f.e.t. gate as the anode then such a diode is obtained. These anode and cathode connections should be reversed if using a *p*-channel f.e.t.

Several species of f.e.t. were tested and the reverse current in all cases was undetectable with the equipment to hand, whilst in the forward direction the f.e.t.s behaved as normal silicon diodes with conduction beginning when biased by around 600mV. This again is not the normal f.e.t. mode of operation and care should be taken that the f.e.t. is not overloaded, as the manufacturers have not designed the device with gate current in mind.

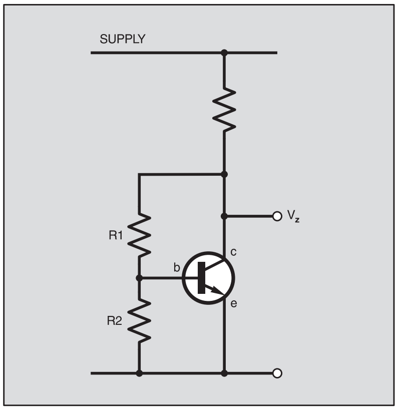


Fig.3. Circuit for selecting the Zener voltage by varying the ratio of R1, R2.

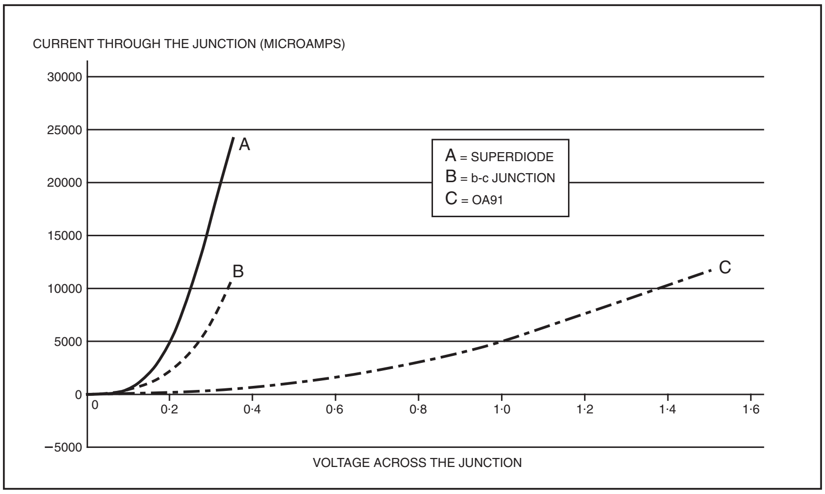


Fig.2. Forward biased germanium junctions.

These were all measured with a current of 1mA flowing through the device. In some cases several different individual transistors with the same type number were tested and all gave results within five per cent of each other.

In addition to the use of a transistor in this fashion to obtain a fixed Zener voltage, we may connect one in a way that we are able to select our own Zener voltage. By connecting a transistor as shown in Fig.3, a "Zener" may be made with any desired Zener voltage by varying the ratio of the two resistors.

For instance, when using a BC109 at a current of 1·0mA, the Zener voltage is given by 0·63 ((R1 + R2)/R2) volts. Examples of this method are: using R1 = R2 = 10kΩ the Zener voltage is 1·25V, and using R1 = 30kΩ, R2 = 10kΩ then we obtain 2·50V, both measured with a Zener current of 1·0mA.

Plotting the voltage/current curves of this connection shows that there is quite a high slope resistance, but this may be overcome by using a Darlington transistor, or two transistors wired as such, and with this lower slope resistance better voltage stabilisation will result.

VARICAP DIODES

Diodes used in the reverse bias mode exhibit capacitance between the anode and cathode connection, the capacitance decreasing as the applied voltage is increased. Diodes used in this fashion are known as *varicap diodes*, and are specially made so that this characteristic is exhibited to a greater extent than in normal signal diodes.

Varicaps are commonly used in tuned circuits in the r.f. stages of TVs and car radios to enable then to be tuned electronically with no moving parts. Radio amateurs have for many years used cheap general purpose diodes in place of the more expensive varicap diodes, but it is unusual to use a transistor instead, even though it is simple to achieve results with them.

The test circuit of Fig.5 was built and the frequency measured with different values of tuning capacitor to enable the stray capacitance to be calculated. The oscillator frequency was then set at precisely 6·0MHz and the transistor under test was connected. The resulting oscillator frequency was measured at different tuning voltages to enable the capacitance swing to be calculated.

The results are shown in Table 3 for various types of transistor, the maximum frequency and minimum capacitance figures refer to a tuning voltage of 12V, whilst the minimum frequency and maximum capacitance figures refer to zero tuning voltage.

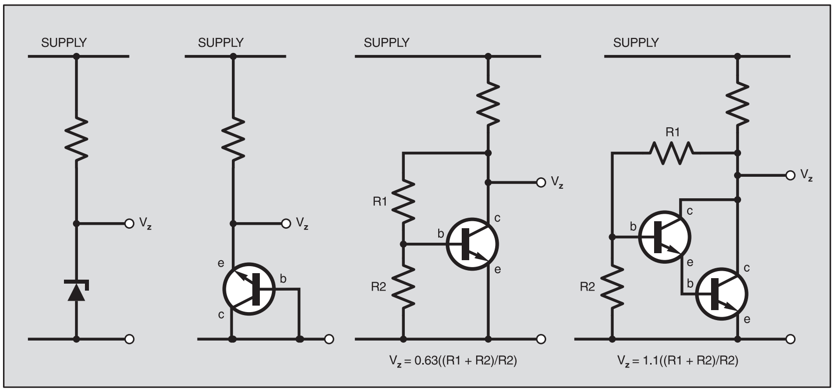


Fig.4. The use of transistors as Zener diodes.

Whilst it is easy to tune an oscillator in this fashion, the use of tuning transistors in the signal circuits of radios may lead to disappointment as, although the transistor used has a large capacitance swing, it may have a low Q. Because of their relatively large leakage currents, germanium transistors will be worse in this respect than will silicon transistors.

Due to the need to keep the transistor "diodes" reverse biased, only *pnp* transistors have been used with this test circuit, although it would be possible to use *npn* types if the polarity of the tuning voltage rail were changed.

CONSTANT CURRENT SOURCES

Constant current sources, whilst not seen very often, are very useful field effect devices which over a large voltage range will keep the current through the device at a given value. Motorola have a range 1N5283 to 1N5314, which have preset currents between 0·22mA and 4·70mA (Ref.2), Siliconix have a similar range which has device numbers easier to understand, i.e. CR390 has a constant current of 3·9mA and CR470 has a constant current of 4·7mA. These devices may be easily made from f.e.t.s (field effect transistors) by connecting them as shown in Fig.6a.

Looking at I_{dss} in transistor characteristic tables gives some idea of the constant current that can be obtained, but this will only be approximate because the spread in characteristics of f.e.t.s is quite wide. For example, the 2N3823 is quoted with a figure between 4mA and 20mA, and the 2N4391 between 50mA and 150mA (Ref.1). We can, however, obtain any current value less than I_{dss} by inserting a resistor in the source lead of our chosen f.e.t., as in Fig.6b.

A sample of 2N3819 that was tested with no source resistor gave a constant current of 12mA. When 100 ohms was inserted, the current was 9mA, 7·5mA with 200 ohms, and 6mA with 300 ohms. A sample of 2N4391 with no resistor gave 55mA, which dropped to 25mA, 15mA, and 11mA when used with 100, 200 and 300 ohms respectively. The only things to bear in mind when using f.e.t.s as constant current sources is that the maximum permitted voltage across the device is around 30V and the dissipated power should not exceed the device rating.

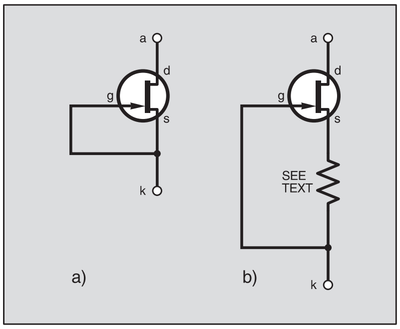


Fig.6. Constant current source using f.e.t.s.

SOLAR CELLS

Back in the dim distant past of transistors, their cases were constructed of glass, which was painted black on the outside to stop light affecting the innards. One of the common transistors then available, an OC71, a *pnp* germanium a.f. transistor, was also made in another version, OCP71, which in effect had a hole in the paint so that it could be used as a phototransistor.

What the manufacturers did not tell us, however, is that if all the black paint was scraped off an OC71, or any other glass transistor of similar construction, then it could be used as a photovoltaic cell to generate electricity. Brightly lit it will produce up to 160mV when not driving a load, although this drops off sharply when a load is applied.

As an experiment, the author cut the top off a BC109 and the voltage in full sunlight was measured. An output of 400mV was obtained when measured on a digital voltmeter. However, when loaded with a moving coil meter it gave no discernible output due to the high internal resistance of the very small junction area which was illuminated, the inside of a BC109 still being pretty lightproof even with its top cut off.

Table 3: Transistors as varicap diodes

Transistor	Measured Frequency Max MHz	Min MHz	Calculated Capacitance Min pF	Max pF
2N1132	5·82	5·65	6·4	13·0
2N1303	5·92	5·86	2·8	4·9
2N1307	5·93	5·83	2·4	6·0
2N4036	5·77	5·55	8·3	17·2
BCY31	5·81	5·47	6·78	20·7
BFX29	5·81	5·75	6·8	9·1
OC201	5·76	5·52	8·7	18·5

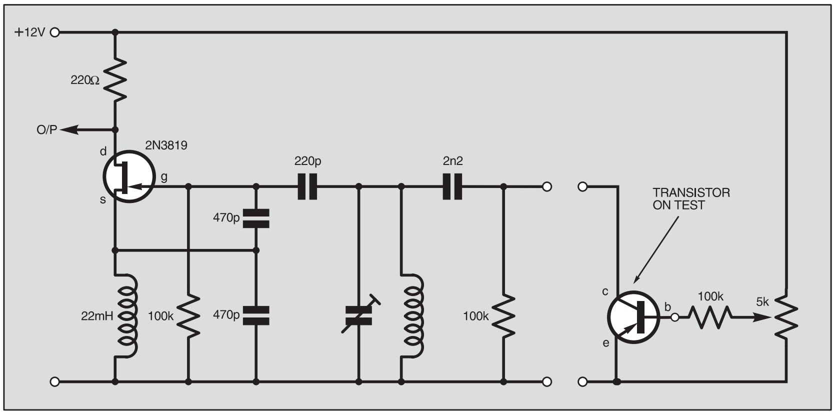


Fig.5. Test circuit for using transistors as varicap diodes.

Metal cased power transistors such as the 2N3055 may also be used as solar cells if the top of the metal case is carefully sawn away. Output voltages around 0·7V were obtained at currents up to about 15mA by using one junction, and double this by using both junctions, i.e. by using the base of the transistor as one connection and the collector and emitter tied together as the other.

NEGATIVE RESISTANCE DEVICES

Tunnel diodes are rare but useful two terminal devices which exhibit a region of "negative resistance" over a small applied voltage range, enabling amplifiers and oscillators to be easily built. Silicon tunnel diodes show this effect when biased between 65mV and 420mV, gallium arsenide between 150mV and 500mV, and germanium from 55mV to 320mV (Ref.3). They were more popular in years gone past, though, and are now difficult to obtain.

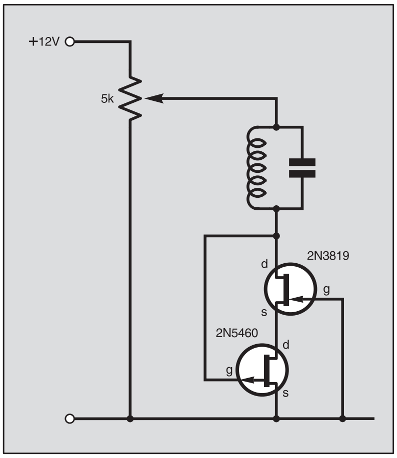


Fig.7. Using n and p-channel f.e.t.s in a lambda configuration to produce a "tunnel diode" effect oscillator circuit.

By using an *n*-channel f.e.t. in connection with a *p*-channel f.e.t. the same negative resistance effect may be obtained cheaply and simply, although in this case the applied bias is somewhat higher. This combination of two different types of f.e.t. is called a *lambda* circuit, one of which was constructed from a 2N3819 *n*-channel f.e.t. and a 2N5460 *p*-channel f.e.t., connected to an old 10·7MHz i.f. transformer, as shown in Fig.7.

The power supply voltage was varied and it was found that the circuit oscillated with bias voltages between 2·7V and 6·5V, although it was found impossible to measure these values precisely due to the circuit suddenly jumping from one current value to another as the supply voltage was increased. Nevertheless, the circuit oscillated well at the 10·7MHz test frequency used. This really is a simple and easy little oscillator circuit and deserves to be more widely known.

CONNECTING IT ALL TOGETHER

Having explored a constant current source and a constant voltage source, the

References

1. Mullard Semiconductors Quick Reference Guide 1982.
2. Motorola Semiconductors Condensed Catalogue.
3. *Semiconductors, Basic Theory and Devices*, I. J. Kampel, Newnes-Butterworth.

two can now be connected together to form a low current stabilised power supply which may be used to supply the lambda circuit. The tuned circuit attached to the lambda circuit can be tuned by a *pnp* transistor taking the place of a varicap diode pair (Fig.8).

The total circuit for a simple oscillator circuit thus consists of five transistors, two resistors, a fixed capacitor and a tuned circuit. This may be reduced even further if the "varicap" part of the circuit is not required.

You may well be asking whether this unlikely looking circuit does actually work: after an initial 30 minutes wait for the circuit to achieve thermal equilibrium (during which time the frequency drifted by 113Hz), the oscillator output frequency was measured with different supply voltages. The results are shown in Fig.9, which shows that for best results the supply voltage should be kept within the range 6V to 18V, the output frequency varying by only 26Hz between these voltage limits.

Varying the tuning voltage from zero to 10V reduced the output frequency by 550kHz. The circuit of this oscillator shows that transistor substitution is well worth doing as the component count is very small and the only component selection required is that the transistor acting as a Zener should have its "Zener" voltage within the negative resistance range of the lambda circuit, i.e. between 2·7V and 6·5V.

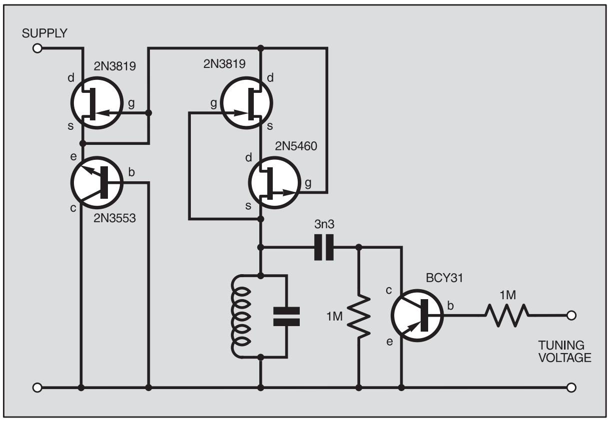


Fig.8. Simple oscillator circuit using an npn transistor to tune the lambda-based circuit.

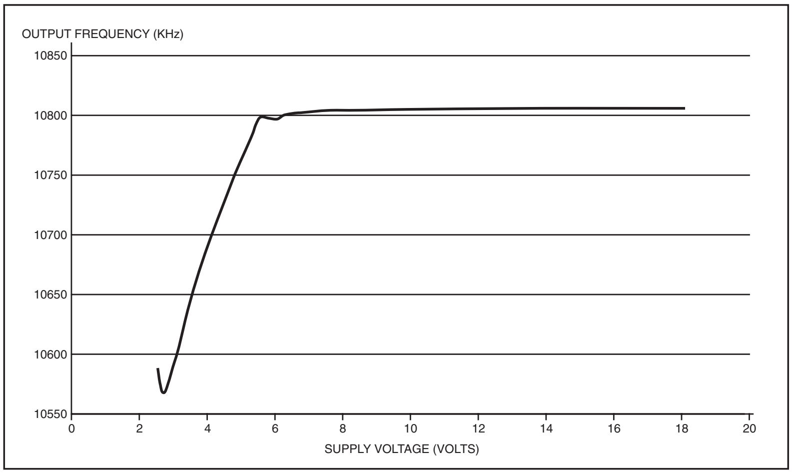
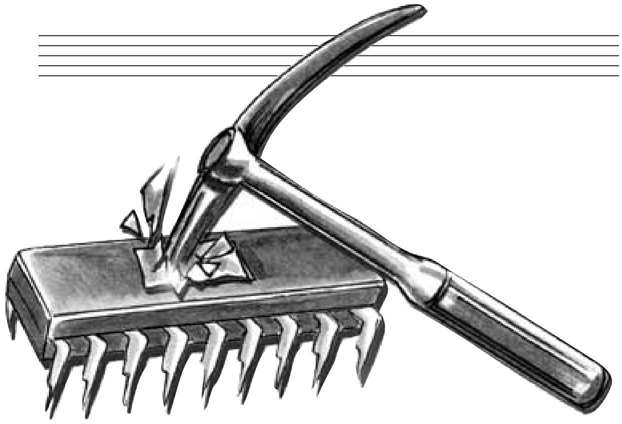


Fig.9. Negative resistance oscillator output frequency.

PICAXE PROJECTS



MAX HORSEY

Part 2 – Temperature Sensor, Voltage Sensor, VU Indicator

Using the PICAXE system, you do not need specialised equipment or knowledge to program the PIC microcontrollers used in these designs.

LAST month we described three projects based on the PICAXE-18, a microcontroller based on the PIC16F627 device but which is programmed by using a version of BASIC via a serial link connected to your PC-compatible computer. The projects were an Egg Timer, Dice Machine and a Quiz Game Monitor and used the PICAXE's digital options. This month we describe three applications which employ this device's analogue inputs:

- Temperature Sensor
- Voltage Sensor
- VU Indicator

Details of obtaining the devices and their software are given later.

GENERAL CIRCUITRY

The general purpose circuit diagram for all nine designs in this three-part series, is repeated here from Part 1, in Fig.1. Each of the circuits to be described is a variant of that shown in this figure, and just the essential changes are shown as separate diagrams.

In the circuits to be described, push-button (push-to-make) switches S2, S3 and S5 are omitted, and pin RA0/AN0 (IC1 pin 17) is used as an analogue signal input. In other applications, pins RA1/AN1 and RA2/AN2 of the PICAXE-18 can also be used as analogue inputs.

With the BASIC dialect used by the PICAXE-18, the command **readadc 0,b0**, is all that is required to configure RA0/AN0 as an input to read an analogue voltage. The zero (0) in this case refers to RA0/AN0, to read from another analogue

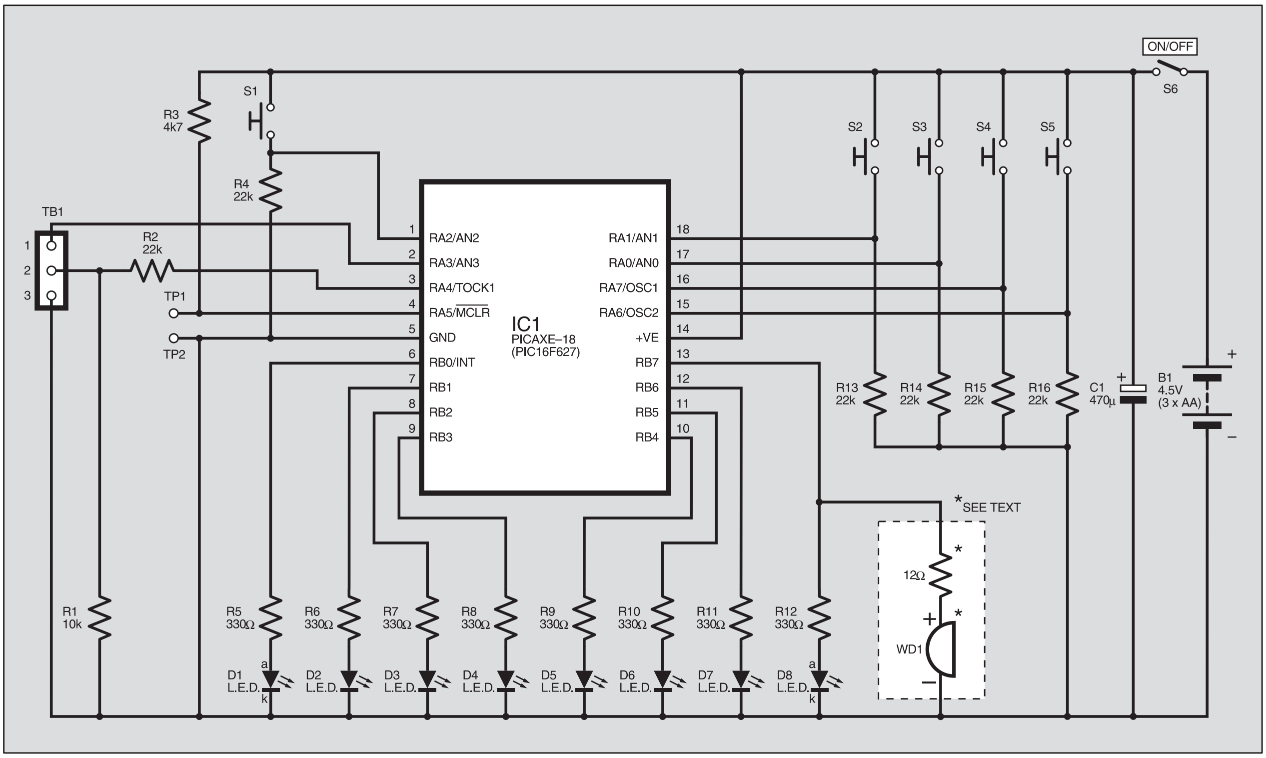


Fig.1. General circuit diagram for all the designs in this PICAXE series of projects.

pin, the number of that input would be substituted for it. For example, to read from RA1/AN1, the command would be **readadc 1,b0**. The variable **b0** is that into which the analogue value is placed.

The PIC16F627 itself (i.e. *not* the PICAXE-18) offers low-resolution analogue readings ranging from 0 to 255 as the voltage at the analogue pin rises from 0V to 5V. However, the PICAXE-18 version of the PIC16F627 can only return values from 0 to 160 in 16 discrete steps. Hence, on a 5V supply, only voltages from 0V to 3·3V can be measured; voltages between 3·3V and 5V will all return a value of 160.

The projects may be powered by batteries (e.g. 3 × AA size cells, although the option to use a 12V battery is described), or by a 5V mains adaptor. Note that the latter *must be a regulated type* since non-regulated adaptors often produce much higher voltages than expected.

Line-up of this month's three demonstration modules: ● Temperature Sensor – Fish Tank Monitor ● VU Indicator – Volume Level Display ● Voltage Sensor – Battery Tester.

TEMPERATURE SENSOR – FISH TANK MONITOR

In the Temperature Sensor – Fish Tank Monitor design, apart from switches S2, S3 and S5 having been omitted, switch S4 now becomes a toggle switch. Its role will be discussed shortly. Resistor R14 is replaced by a negative temperature coefficient (*n.t.c.*) thermistor having a value of about five kilohms (5kΩ) at room temperature, see Fig.2a.

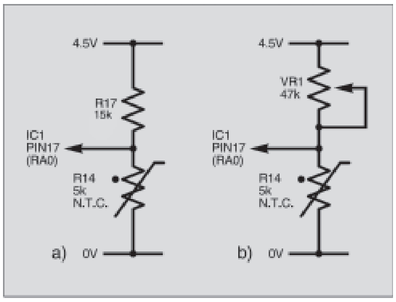


Fig.2. Two possible minor changes to allow temperature sensing.

As the temperature increases, the resistance of the thermistor falls, causing the voltage at pin RA0/AN0 of the PICAXE-18 to fall, and so causing the value of the resulting analogue reading to fall as well.

Switch S3 is replaced by a 12kΩ resistor, R17. The value was chosen so that temperatures from a little below to some way above "normal" room temperature can be indicated. If preferred, R17 could be changed to a potentiometer (VR1) used as a variable resistor. A value of, say, 47kΩ would allow a wider range of temperatures to be accommodated. This change is shown in Fig.2b.

L.E.D. DOT/BAR MODE

In the context of the l.e.d.s (light emitting diodes) used in this series, Dot Mode means that only a single l.e.d. lights at any one time. Bar Mode is when two or more l.e.d.s in a chained sequence light up, forming a bar effect. This is the most common form of display but the program includes both modes of operation, selected by using toggle switch S4 (if used).

If S4 is omitted, the display will always be in Dot Mode (do *not* omit resistor R15, though). If you wish to set the circuit permanently to Bar Mode, fit a wire link in place of S4 so that pin 16 (RA7) is always held at logic 1 (high), in which case R15 can be omitted, although it can be retained if preferred.

As was done in the *Egg Timer* last month, l.e.d. D8 could be replaced by a buzzer (WD1), with the value of resistor R12 being changed to 12Ω. In this case potentiometer VR1 could be set so that the circuit provides an audible warning if the temperature rises above a certain level.

If a small buzzer (low current) is used, it may be driven directly from the designated PICAXE-18 output in addition to the l.e.d. Furthermore, if the circuit is set to Dot Mode, then separate buzzers could be

LISTING 1

```
'temperature sensor 'tem3'
'use 5k thermistor in place of resistor and 12k resistor or 47k variable in place of switch
'for Dot Mode make in7 low, for Bar Mode make in7 high
start:  readadc 0,b0          'put the analogue value at pin0 into b0
        if b0>75 then one     'jump to appropriate display routine
        if b0>64 then two
        if b0>53 then three
        if b0>43 then four
        if b0>32 then five
        if b0>21 then six
        if b0>11 then seven
        let pins=%10000000    'if b0 is less than 12, then make output 7 high (Dot Mode)
        if pin7 = 0 then start 'if input pin 7 is low, goto start
        let pins=%11111111    'if input pin 7 is high, make all outputs high (Bar Mode)
        goto start
one:    let pins=%00000001    'make output 0 high (dot or Bar Mode)
        goto start
two:    let pins = %00000010  'make output 1 high (Dot Mode)
        if pin7 = 0 then start
        let pins=%00000011    'make output 0 & 1 high (Bar Mode)
        goto start
three:  let pins=%00000100
        if pin7 = 0 then start
        let pins=%00000111
        goto start
four:   let pins=%00001000
        if pin7 = 0 then start
        let pins=%00001111
        goto start
five:   let pins=%00010000
        if pin7 = 0 then start
        let pins=%00011111
        goto start
six:    let pins=%00100000
        if pin7 = 0 then start
        let pins=%00111111
        goto start
seven:  let pins=%01000000
        if pin7 = 0 then start
        let pins=%01111111
        goto start
```

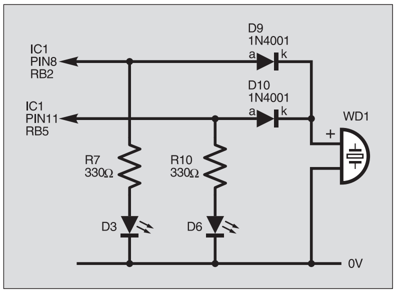


Fig.3. Adding diodes to selected IC1 outputs, such as RB2 and RB5, enables a single buzzer to be driven from several sources.

connected to any two outputs to provide over- and under-temperature warnings. Hence it would be possible to monitor the temperature of a fish tank, for example.

Another approach would be to add diodes to selected outputs so that a single buzzer could be used, but driven from several sources. An example is shown in Fig.3, in which outputs RB2 and RB5 are coupled via diodes D9 and D10 to jointly feed to the buzzer WD1. Resistors R7 and R10, and l.e.d.s D3 and D6 can be retained.

Note that the voltage change caused when a thermistor is employed is not linear. Hence it would be difficult to achieve accurate calibration over a wide range of temperatures. However, it is still possible to set two "safe" points as required for the fish tank monitor either by selecting the appropriate outputs, or by changing the program.

TEMPERATURE PROGRAM

The BASIC source code for the Temperature Sensor program is shown in Listing 1. Comments following an apostrophe are ignored by the compiler. The line at the label **Start:** states **readadc 0,b0**. This command causes the PICAXE-18 to read the voltage at input RA0/AN0 and place the value in variable **b0**.

The next set of lines examine this value and jump to the appropriate command routine to turn on specific l.e.d.s. For example, outputting the command **let pins = %10000000** causes l.e.d. D8 to turn on. A "1" in any position will make the appropriate output go high.

The percentage sign tells the compiler that the number is in binary. The equivalent decimal number is 128 and so you could in fact replace the line with **let pins = 128**. However, the binary representation provides a better indication of which l.e.d.s are affected. Note that in the absence of a percentage sign, the compiler will assume that a decimal number is to be processed. Remember that binary codes are numbered from right to left, in order of bit 0 to bit 7, with bit 0 controlling l.e.d. D1.

The program continually checks whether input RA7 is high or low, to determine whether to display in Bar Mode or Dot Mode. So the command line **if pin7 = 0 then start** causes the compiler to skip the Bar Mode display command, and so display in Dot Mode.

Completed Temperature Sensor module. Note the thermistor mounted in a discarded ballpoint pen barrel.

VOLTAGE SENSOR – BATTERY TESTER

A voltage sensing interface is illustrated in Fig.4. Extra care is required when connecting external voltages to the circuit. It is important, for example, to prevent the voltage at the RA0/AN0 analogue input from rising above 5V d.c., or falling below 0V.

In fact, for the reasons mentioned earlier, the highest voltage which can be measured is 3·3V. So the input voltage is attenuated by resistor R17 and potentiometer VR1. By adjusting VR1, voltages from 0V to 8V can be monitored and displayed on the eight l.e.d.s. A wider range is possible, although 0V to 12V, say, is more difficult to display on eight l.e.d.s! However, you could reduce the range to say 5V to 12V by changing the program.

If accurate voltage detection is required then the circuit should be driven from a reliable voltage supply, such as provided via a 5V regulator. Since only two additional components are required, as shown in Fig.5, i.e. +5V regulator IC2 and capacitor C2, it is worth adding this facility.

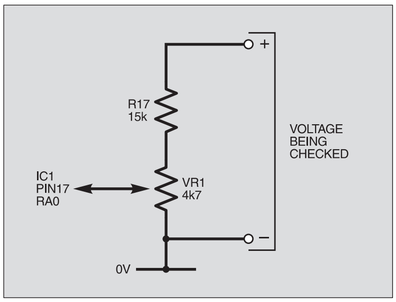


Fig.4. Circuit modification to give a voltage sensing interface. Adjusting VR1 will give a monitoring range of 0V to 8V d.c. on the eight l.e.d.s.

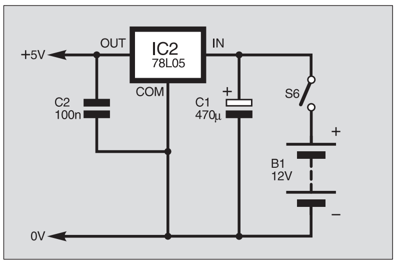


Fig.5. Adding a simple regulator circuit to give more accurate voltage detection.

PROGRAM

The program is similar to the temperature display except that higher analogue values cause more l.e.d.s to be displayed. Provision for Bar Mode or Dot Mode has been included. Note that the commands **high 0**, **high 1**, **high 2** etc. have been used instead of **let pins = x**.

When only a single l.e.d. is required – as in Dot Mode – this method of switching an output high is more economical with memory space – something quite critical with PICAXE devices.

Completed prototype Voltage Sensor (Battery Tester). The l.e.d.s shown here are made up of three red (low), two yellow and three green lights.

VU INDICATOR – VOLUME LEVEL DISPLAY

The circuit diagram in Fig.6 shows the changes needed to produce a VU (Volume Units) Indicator circuit. This is ideally suited to sound level monitoring by connecting the circuit to the speaker or headphone output of an amplifier. The l.e.d.s indicate a relative volume level.

The circuit type is known as a "diode pump". Capacitor C3 a.c. couples the analogue signal to the circuit, preventing any d.c. current flow between the two circuits. Diode D9 only allows positive going aspects of the signal to pass, and diode D10 prevents the output from C3 going below about 0·7V. The effect is that the output from D10 is effectively twice the value of the basic positive-going waveform from the amplifier (less the voltage drops across the diodes).

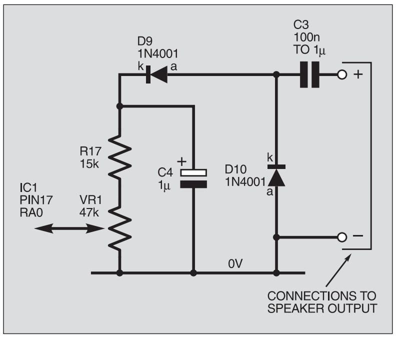


Fig.6. Adding a "diode pump" circuit to produce a simple VU Indicator.

The output from diode D9 causes capacitor C4 to charge up to a level representing the output level from the amplifier. This voltage is then monitored in the same way as before. It is essential that resistor R17 should be retained to minimise the risk of damage to the PICAXE chip in the event of the signal voltage rising too high. Its value may be reduced from the 15kΩ shown, but it is best not to reduce it below about 1kΩ for fear of PICAXE damage.

It is worth noting that you should NOT connect the circuit in Fig.4 direct to the amplifier output since this is likely to contain negative-going waveforms, which if received by the PICAXE chip could cause irreparable damage if the condition is sustained, even though the device has a certain amount of internal voltage and current limiting.

The value of capacitor C3 is not critical, and smaller values will tend to limit bass frequencies – a little experimentation may be helpful.

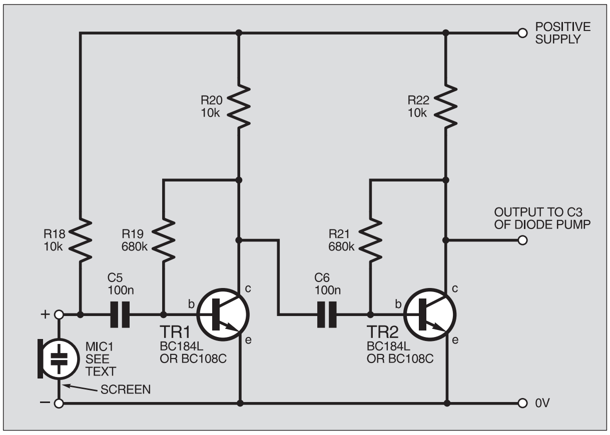


Fig.7. Optional two-transistor microphone amplifier circuit diagram for monitoring microphone outputs.

MICROPHONE INPUT

You may wish to experiment with monitoring the output from a microphone. As the output from a microphone is much lower than required for the circuit to respond adequately, some amplification is necessary. Simple microphone amplifiers can be easily made around op.amps such as the type 741 and various designs have been published.

A very simple but extremely effective amplifier, though, can be made based on two transistors, such as types BC108C or BC184L and a suitable arrangement is shown in Fig.7. In fact, any pair of *npn* transistors with gains of 250 to 400 should work, though you may need to experiment with the resistor values a little for best results.

The capacitor values are not critical and any value between 100nF and 1μF will work well. The capacitors should be non-polarised and electrolytic types are best avoided.

Note that the circuit is intended for use with an electret microphone (MIC1). These inexpensive devices are very small and provide excellent results. Resistor R18 provides power for the microphone. If you wish to try a dynamic microphone instead of an electret, then omit R18. In tests, cheap loudspeakers and headphones also provided good results when used as microphones and with R18 omitted.

COMPONENTS

See SHOP TALK page

Resistors

R1	10k
R2, R4, R13, R15, R16	22k (5 off)
R3	4k7
R5 to R11	330Ω (7 off)
R12	12Ω or 330Ω (see text)
R14	5k n.t.c. thermistor (see text)
R17	15k (see text)
R18, R20, R22	10k (3 off) (see text)
R19, R21	680k (2 off) (see text)

All 0·25W 5% carbon film, except R14.

Potentiometer

VR1	4k7 or 47k rotary carbon, panel mounting, linear (see text)

Capacitor

C1	470μ, radial elect. 16V
C2	100n ceramic or polyester layer (see text)
C3	100n to 1μ ceramic or polyester layer (see text)
C4	1μ radial elect. 16V (see text)
C5, C6	100n ceramic or polyester layer (2 off) (see text)

Semiconductors

D1 to D8	red l.e.d. (or other colours – see text) and mounting clips (8 off)
D9, D10	1N4001 rectifier diode (see text) (2 off)
TR1, TR2	BC184L or BC108C (2 off) (see text)
IC1	PICAXE-18 microcontroller (see text)
IC2	78L05 +5V voltage regulator (see text)

Miscellaneous

B1	4·5V battery (3 x AA) and clip (see text)
S1 to S5	min. s.p. push-to-make switch (not used – see text)
S6	min. s.p.s.t. toggle switch
TB1	3-pin serial connector (shrouded 3-pin header (see text)
TP1, TP2	(see text)
WD1	active buzzer, 5V
MIC1	electret microphone insert (see text)

Printed circuit board, available from the *EPE PCB Service*, code 373 (one for each design – see text); 18-pin i.c. socket (one for each p.c.b.); plastic case 140mm x 80mm x 30mm approx (one per p.c.b.); p.c.b. supports (4 off per p.c.b.); knob for VR1 (see text); stripboard, 18 holes x 10 strips (see text); stripboard, 9 holes x 3 strips (see text); 1mm terminal pins; connecting wires; solder, etc.

Approx. Cost Guidance Only **£20** **excl. case & batts.**

TEMPERATURE SENSOR – FISH TANK MONITOR

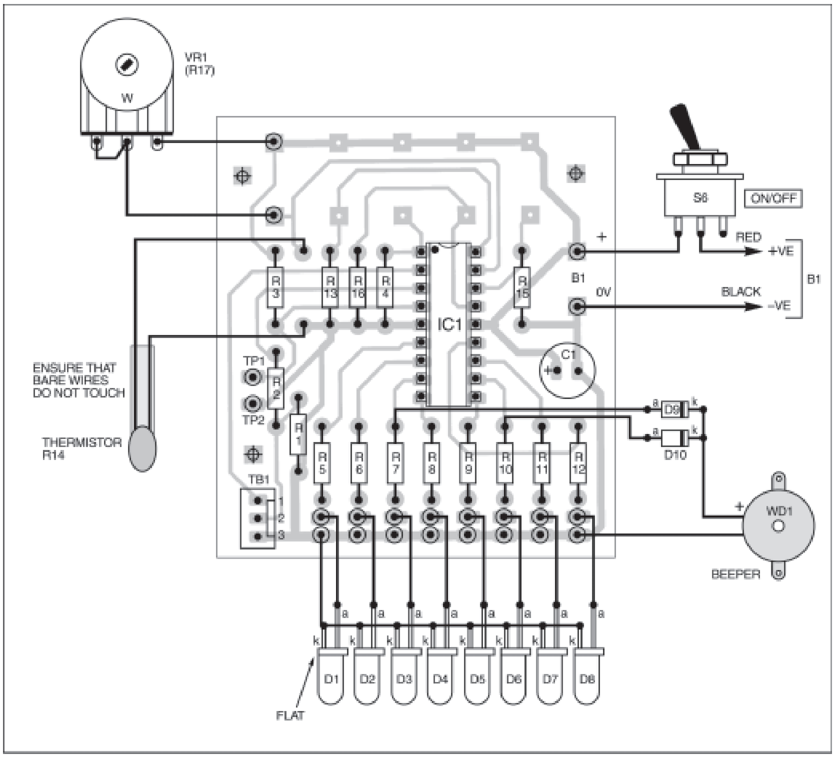


Fig.8. Multiboard component layout and wiring for the Temperature Sensor. As it stands, with switch S4 omitted, this arrangement will give Dot Mode (single l.e.d.) display.

PROGRAM

The program is similar to that for the Voltage Sensor, except that a For-Next loop is used to sample the analogue value 20 times, taking a peak value as it loops.

This provides a more stable display. There is no provision for Dot Mode display, although this could be added to the program if desired.

CONSTRUCTION – GENERAL NOTES

Each project is built on the same printed circuit board (p.c.b.) that was presented in Part 1 of the series last month, shown there as Fig.2. This board is available from the *EPE PCB Service*, code 373. The individual component positioning and wiring details for the projects discussed here in Part 2 are shown separately.

Check the component list for the particular project being constructed, and fit only the required parts. Note that resistors R1 and R2, and connector TB1 are only required if you intend to program the PICAXE in-circuit. Serial connector TB1 must be inserted the correct way round, with the plastic tongue nearer the line of l.e.d.s, as shown in the p.c.b. layouts. Electrolytic capacitor C1 must also be fitted the correct way round.

The l.e.d.s have a common cathode (k) and so only one wire is required for all the cathodes, as shown in their component layout diagrams. The l.e.d.s should be fitted into the drilled case before connecting wires to them.

As discussed in Part 1, solder pins TP1 and TP2 are not essential, but may be useful if the PIC crashes. Shorting the two pins together causes the PICAXE program to restart from the beginning. Switching off the power supply should defeat a crash, but on rare occasions with the PICAXE-18 it is useful to be able to reset the system directly.

When assembly has been completed and *thoroughly checked*, insert the PICAXE-18 chip and program it from the PC using the serial link. Part 1 discussed the programming of PICAXE-18 devices and how PIC16F627 devices could be used instead of them, and readers are referred to that for more information. Pre-programmed PICAXE-18s are available as stated in this month's *Shoptalk*, which also gives information on obtaining the software itself.

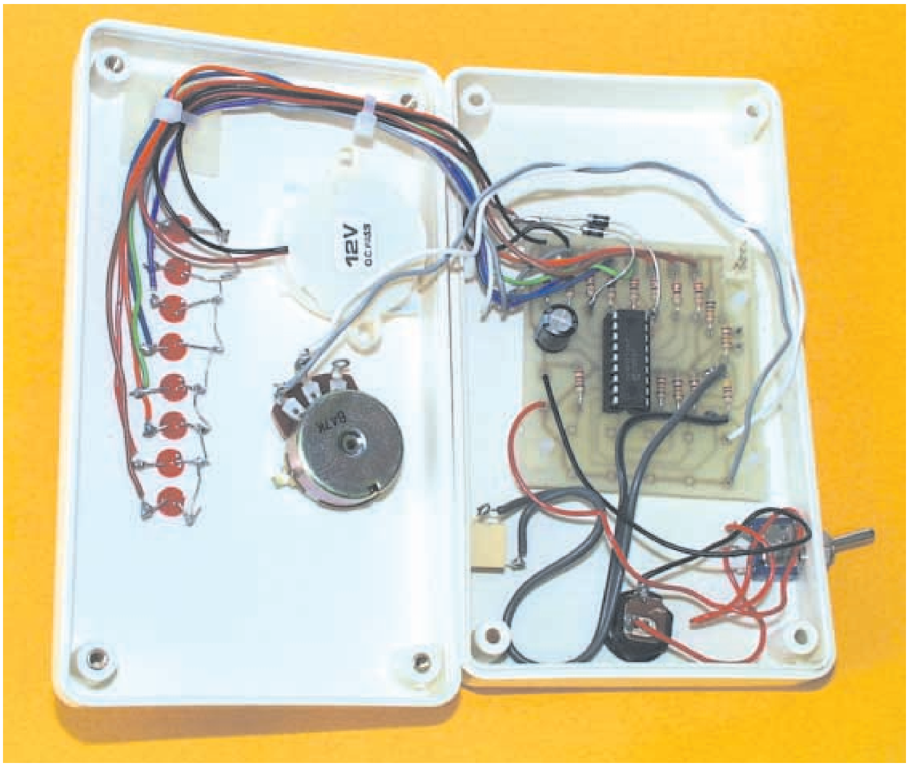
TEMPERATURE SENSOR

The diagram in Fig.8 shows the component layout for the Temperature Sensor based on Fig.2 and Fig.3, for monitoring both high and low temperatures. Since the circuit must always work in Dot Mode, switch S4 is omitted. Potentiometer VR1 has been included, since adjustments are almost certainly required.

Diodes D9 and D10 are connected to the ends of resistors R7 and R10 respectively, either on the component side, or on the copper side of the p.c.b.

If the project is to be used to check air temperature, the thermistor (R14) could be mounted at the end of a pair of leads. Single-core screened cable provides a neat solution.

If the thermistor is to be placed in water then it must be suitably housed to prevent water, as in a fish tank, touching its leads. For example, a glass tube could be employed, or the plastic case of an old ballpoint pen – take care to block any air holes. A suitable filler or glue may be used to retain and seal the thermistor.



General layout of components inside the prototype Temperature Sensor case. A power input socket is mounted on the case bottom and a jack socket for the thermistor on one side panel.

VOLTAGE SENSOR

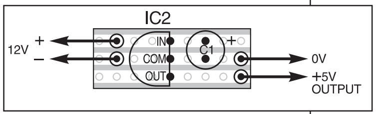
The component layout details for the Voltage Sensor are shown in Fig.9.

As stated earlier, the display will vary with the supply voltage as well as the voltage being sensed, hence for accurate readings a voltage regulator should be employed here.

If a voltage regulator circuit, such as discussed earlier (Fig.5) is to be used, it can be constructed on a small piece of stripboard, as shown in Fig.10.

Capacitor C2 is fitted to the multiboard p.c.b. in the position occupied by C1 in the previous circuits. Ensure that C1 and IC2 are fitted the correct way round.

Fig.10. Stripboard voltage regulator (see text).



Note that the circuit will only function correctly if the battery voltage is above about +7V. If it falls below this level, the output from the regulator will fall below 5V and the l.e.d.s may start flashing randomly!

VU INDICATOR

The VU Indicator component layout details are shown in Fig.11. Diode D10 and resistor R17 are soldered directly onto the potentiometer VR1 tabs as indicated, and C3 is soldered to the junction between the diodes and then connected to the sound source using any technique suited to it, e.g. via a jack socket perhaps.

VOLTAGE SENSOR – BATTERY TESTER

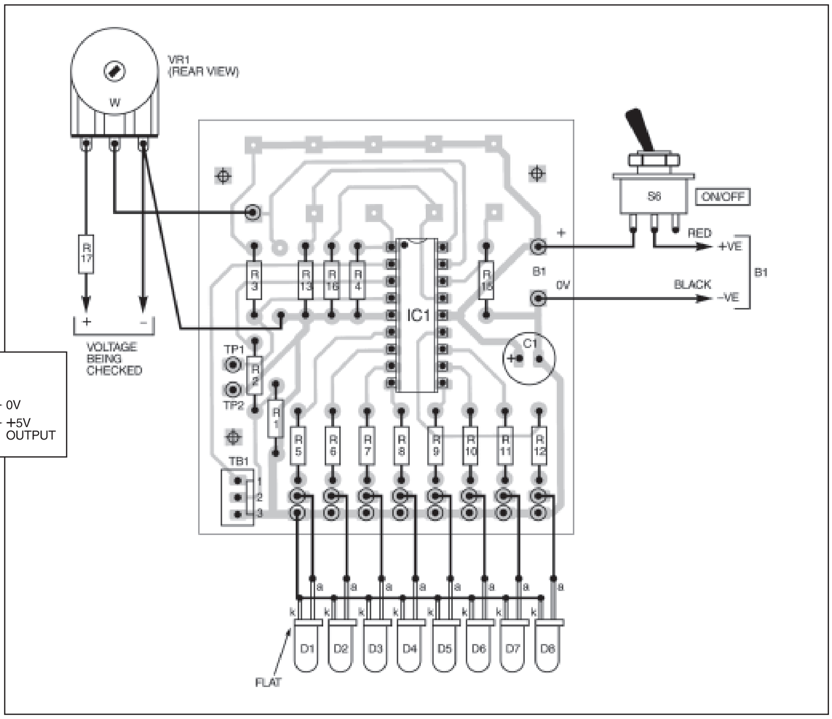


Fig.9. Component layout and wiring for the Voltage Sensor.

Ensure that the diodes are fitted the correct way round.

The potentiometer VR1 provides a firm support since it is fastened to the case. Capacitor C3 should be non-electrolytic (e.g. ceramic disc or polyester layer) and may be fitted either way round.

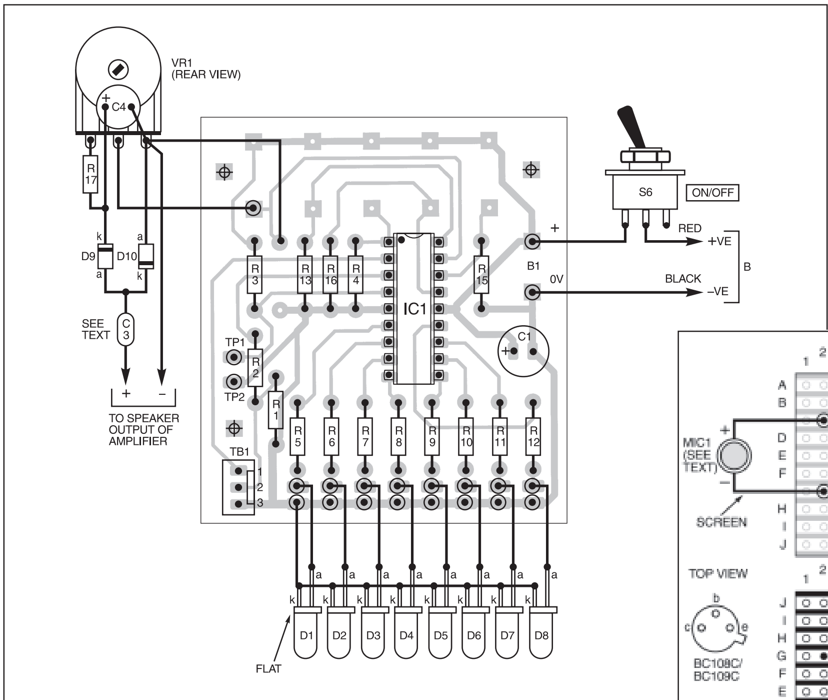
MICROPHONE AMPLIFIER

The two-transistor microphone amplifier circuit is constructed on stripboard as shown in Fig.12. Remember to omit R18 if a dynamic microphone is employed instead of the electret type suggested. Assuming that an electret type is used, you will need to check its polarity when connecting it to the stripboard.

The transistor pin connections shown are for type BC184L, the top view pinouts for a BC108C/BC109C type transistor are shown separately in Fig.12. Ensure that the correct pinouts are used.

The leads of capacitor C6 must be spread out slightly to fit the tracks as shown.

VU INDICATOR – VOLUME LEVEL DISPLAY



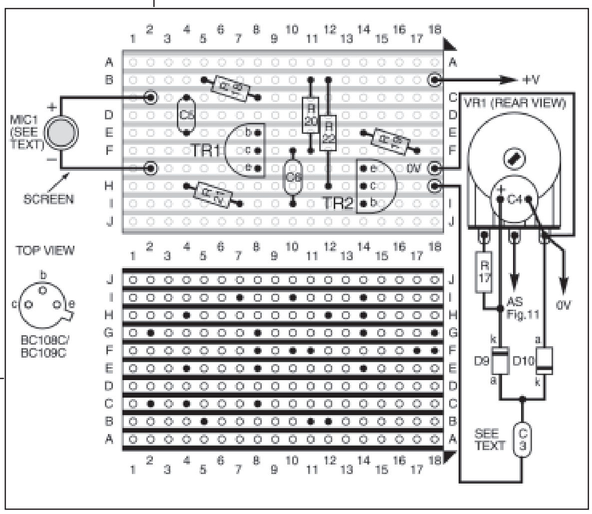
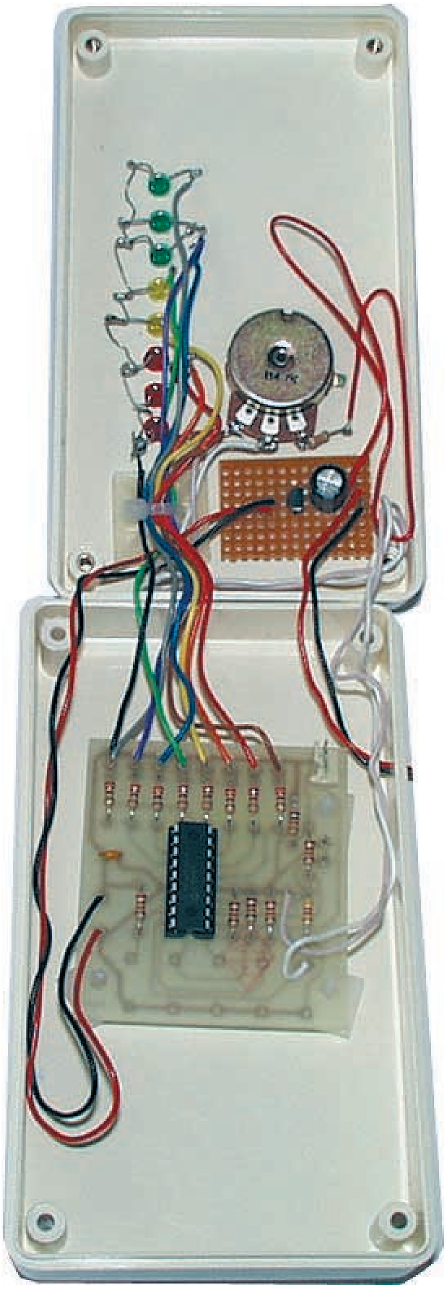
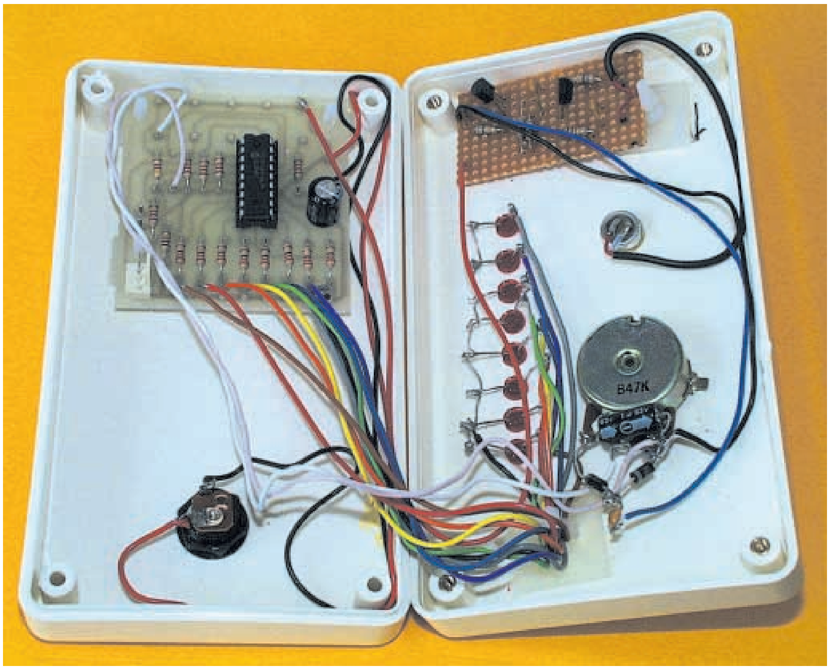


Fig.11 (above). Component layout and interwiring for the VU Indicator.

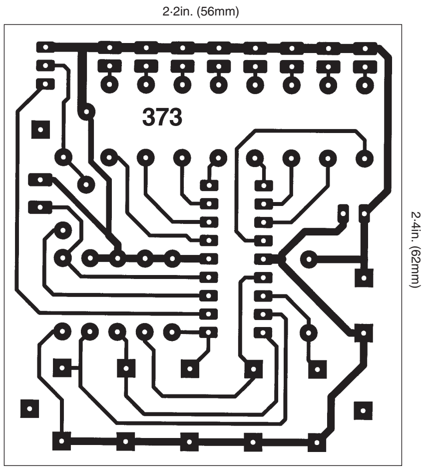
Fig.12 (right). Stripboard component and interwiring details for the two-transistor microphone amplifier circuit (Fig.7).



Component positioning inside the two halves of the Voltage Sensor case.



Completed VU Indicator unit showing the general layout of components inside the case. The miniature electret microphone is mounted just above the control potentiometer.



Multiboard full-size copper foil master pattern. (This board is available from the EPE PCB Service*).*

CASING

As with last month's projects, all three described here were mounted in plastic cases, measuring approximately 140mm × 80mm × 30mm, and drilled as required and shown in the photographs.

Begin by marking and drilling the holes required for the l.e.d.s. Additional holes are required for the thermistor, optional voltage-monitoring and sound inputs, and an external power source, as appropriate.

Each project has an optional potentiometer (VR1), and if this is required a suitable hole must be made for its mounting bush. The p.c.b. should be secured using p.c.b. supports, of which self-adhesive types are suggested.

PROGRAMMING AND TESTING

As discussed last month, there are two ways of obtaining a programmed PICAXE-18 device. The preferred technique is to program it yourself while in-circuit using the PICAXE software, as this allows you to experiment with the BASIC program code and repeatedly reprogram the device with each code version. They can, though, be bought ready-programmed as stated in this month's *Shoptalk*).

Since a PICAXE-18 device is a specially modified version of the PIC16F627 microcontroller, produced by Revolution Education, there is a third programming option. For this you need standard PIC programming facilities to program the PIC16F627 using the hex code that is available for this series of designs.

To test a circuit, switch on the power supply and then, as appropriate, warm the thermistor or apply a voltage or sound signal. Adjust control VR1 until the l.e.d.s. light accordingly, either in Dot Mode or Bar Mode, depending on the circuit's function.

For general information on programming PICAXE devices and checking their in-circuit behaviour, refer to Part 1, last month.

RESOURCES

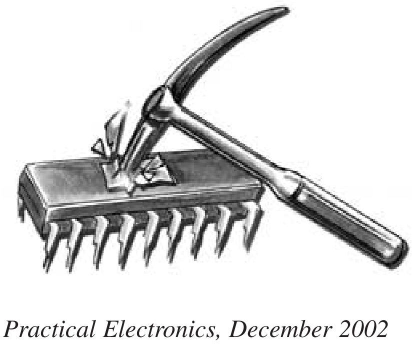
Preprogrammed HEX versions of the PICs for these designs can be obtained (*mail order only*) from: M. P. Horsey, Electronics Dept., Radley College, Abingdon, Oxon. OX14 2HR. The price is £5.90 per PIC, including postage (overseas add £1 p&p). Specify the project for which the PIC is required. Enclose a cheque payable to Radley College.

Software for these three designs and for Parts 1 and 3 of the series, (except the PICAXE programming software) is available on 3.5in disk (*EPE* Disk 5), for which a nominal handling charge applies, from the Editorial office (see the *PCB Service* page). It is also available for free download from the *EPE* ftp site.

PICAXE programming software can be obtained from: Tech-Supplies, Dept. *EPE*, 4 Old Dairy Business Centre, Melcombe Road, Bath, BS2 3LR.

The telephone number of Revolution Education is: 01225 340563, and their web site is at: **www.rev-ed.co.uk**.

Next month: In the third and final part of this series three **Chaser Lights** circuits are presented.



INTERFACE

Robert Penfold

SOME NOTES ON CHOOSING AND USING VISUAL BASIC

PROBABLY the most asked question from readers about Visual BASIC is which version should be used when producing software for PC projects. Sometimes the reader asking the question has an old version of Visual BASIC and doubts its suitability for this application. Other enquiries are from people wishing to buy Visual BASIC, and needing guidance as to the best version.

The Price is Right

There are three normal commercial versions of Visual BASIC, which are the *Standard*, *Professional*, and *Enterprise* varieties. There are additionally the free versions that have been well covered in previous *Interface* articles. The big limitation of these free versions is that it is impossible to compile programs into standalone applications.

There is also an Educational version of Visual BASIC, but this seems to be much the same as the Professional version apart from the license conditions. As one would expect, commercial distribution of programs produced using the Educational version is not permitted.

Visual BASIC Standard is the simplest version, but it lacks some of the extras in the more up-market offerings. In particular, it does not include the MSCOMM ActiveX control that can be used for interfacing via the serial ports. It is fundamentally the same as the Professional version though. However, the license conditions are more restrictive, which could be a problem for anyone intending to commercially distribute their Visual BASIC programs.

The Professional version includes extras such as MSCOMM, plus others that make it easier to produce software for commercial distribution. The license conditions permit virtually unrestricted distribution of programs produced using Visual BASIC Professional.

The Enterprise edition is aimed at groups of programmers who need to produce large programs, and as one would probably expect, it is an extremely expensive piece of software. In fact, it is far too expensive to consider unless you really need its facilities.

Unless you really need the facilities of MSCOMM and more flexible license conditions, the Standard version is the obvious choice. At only about one quarter of the cost of the Visual BASIC Professional it will work quite happily with INPOUT32.DLL, etc. and will give access to the port addresses. If you really do need MSCOMM or a license for full commercial distribution it is necessary to opt for the Professional version.

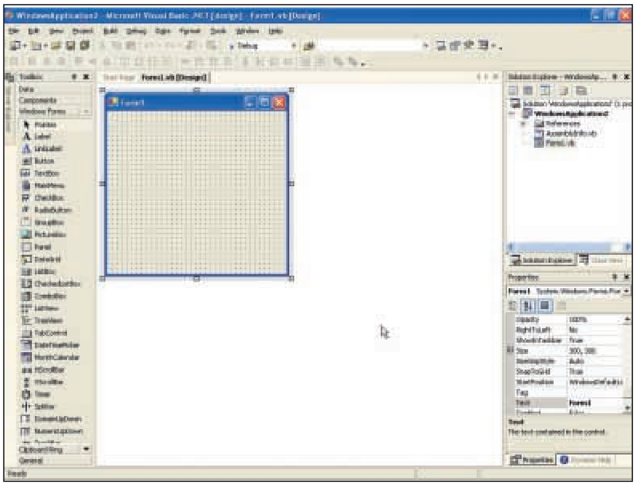


Fig.1. Visual BASIC Net can have the traditional screen layout.

Golden Oldies

If you have access to an old version of Visual BASIC it will probably be perfectly all right for producing software for PC add-ons. The author has only used Visual BASIC 5 and 6 for producing this type software, but one or two readers seem to have had some success using version 4.

Anything prior to Visual BASIC 4 is unlikely to be suitable for the present purpose, but these early versions are now many years old and with the best will in the world have to be regarded as obsolete. Most software for PC hardware projects uses fairly simple components such as labels, timers, and buttons, and does not require the latest high-power features.

Visual BASIC 6 has now been superseded by Visual BASIC NET, and there seems to be some major changes in the new version. It is possible to opt for the same screen layout as Visual BASIC 6, and this gives something like that shown in Fig.1.

There is the usual area for forms in the middle section of the screen with the Project and Properties windows to the right of this. The Toolbox runs down the left-hand section of the screen and this is somewhat different to the simple group of icons in earlier versions. However, the usual components are there, such as labels, scrollbars, and buttons.

Although the menu and toolbars in the top section of the screen do not look radically different to their predecessors, there are some major differences. In particular, the menu system has been completely redesigned and it can take a while to find the required options.

It is still fairly easy to add components on the form, write the code, and test the program. Components that will not appear when the program is run are no longer added to the form. Instead, double clicking on the component in the toolbox results in it appearing in a box at the bottom of the screen.

In the example of Fig.2 a timer component has been added and its icon can be seen in the box. This is a more logical way of doing things, and avoids having to find space on the form for non-displaying components. Double clicking on the component's icon brings up its section of the Code window in the usual way.

Ins and Outs

Writing a program for your PC add-ons is one thing, but getting the program to communicate with the add-ons is quite another. Microsoft's Net programming languages are designed for operation with Windows XP, which slightly complicates matters.

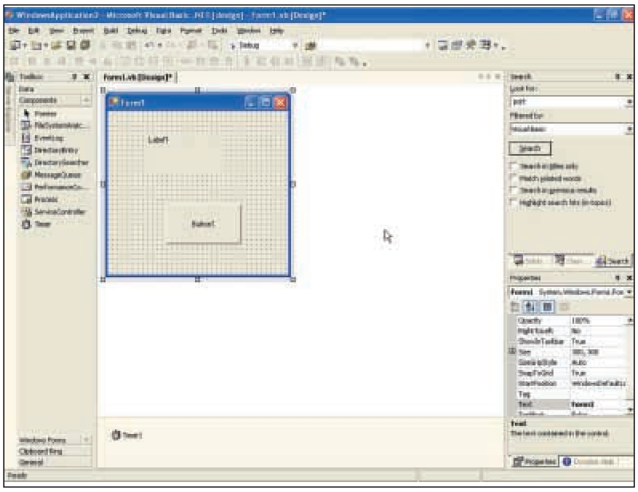


Fig.2. The timer component appears in the box beneath the form rather than on the form.

First, a fairly modern and upmarket PC is needed in order run Windows XP well. Second, Windows XP does not permit direct control of the computer's ports. Ways around this have been covered in *EPE* in the recent past.

With Visual BASIC 6 Professional or Enterprise it is possible to use the MSCOMM ActiveX control to gain access to the serial ports. Some research on the Internet suggests that this component is also included with the Professional and Enterprise versions of Visual BASIC Net.

Unfortunately, it was absent on the borrowed system being used, which was running Visual Studio Net. This is Visual BASIC, Visual C++, and Visual C# bundled together. Trying to add this component to the Toolbox was eventually successful. However, trying to use it in a project produced an error message to the effect that the user did not have a license to use that control, which is not actually correct.

The third-party alternatives to MSCOMM should be more successful, and it should be possible to use any version of Visual BASIC Net to communicate with the PC's ports. If you are only interested in writing programs for PC add-ons there would seem to be little point in upgrading from Visual BASIC 5 or 6.

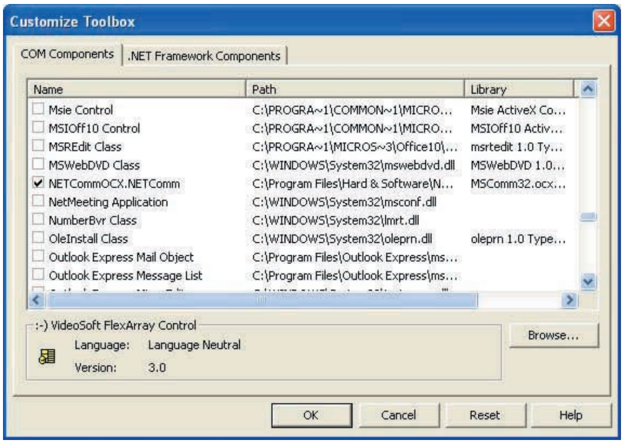


Fig.3 (left). Adding NETCOMM to the Toolbox.

The new features are of no real benefit for this type of programming, and the earlier versions are more straightforward to use than Visual BASIC Net. Visual BASIC 6 is still available, and it might be the better choice for first time users buying Visual BASIC for this type of programming.

MSCOMM Alternatives

As pointed out previously, there are alternatives to Microsoft's own MSCOMM control, and NETCOMM is one that is worth trying if you have a version of Visual BASIC that lacks the real thing. Information about NETCOMM plus the control itself are available from this URL:

http://ourworld.compuserve.com/homepages/richard_grier/NETCommOCX.htm

The download is a ZIP file of about 2·5 megabytes, so you will need WinZip or a similar program to unzip the archive. Installation is very easy because a Setup program is included. Once the setup process has been completed it is necessary to add NETCOMM to the Visual BASIC toolbox.

This process has been covered in previous *Interface* articles, but note that it is slightly different using Visual BASIC Net. Choose the Customise Toolbox option from the Tools menu, which will produce the usual list of available components. This should include NETCOMM, and it must be selected by ticking its checkbox (see Fig.3).

After left-clicking the OK button to return to the main screen, NETCOMM should be included in the list of available components. It can be added to the form in the usual way, and although it is a non-displaying component it will appear on the form rather than in a box beneath it (see Fig.4). The Properties window will show the parameters for the new control and permit them to be changed.

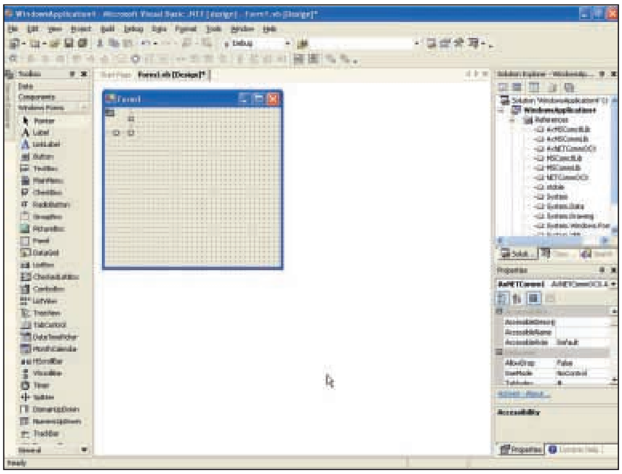


Fig.4 (right). NETCOMM has been added to the form, but it will not be displayed when program is run.

Although NETCOMM is similar in use to MSCOMM, there are inevitable differences. The most obvious one is that it has a different name, although this can be changed via the name parameter.

There are other differences, and the Output parameter becomes **set_Output**. Similarly, the Input parameter becomes **InputData**. There are also a few changes in the syntax, and some parameters can only be changed under program control with no access via the Properties window. Unfortunately, there seem to be more changes than the supplied documentation admits to, so it can take a little experimentation to get things working.

Net Result

On the plus side, NETCOMM is free and it does seem to work quite well. As an initial experiment, a button was added to the form together with the following two lines of code for the form and the button respectively:

AxNETComm1.PortOpen = True

AxNETComm1.set_Output("Hello")

The first line simply opens the default serial port for communications when the form is loaded, and this happens automatically when the program is launched. The second line outputs the text string in parentheses to the default serial port, which will be COM1 unless a different port is specified. Obviously any test string can be used here. The test program loaded and ran correctly using Visual BASIC Net and Windows XP (see Fig.5), so NETCOMM obviously accesses the serial ports via the approved channels.

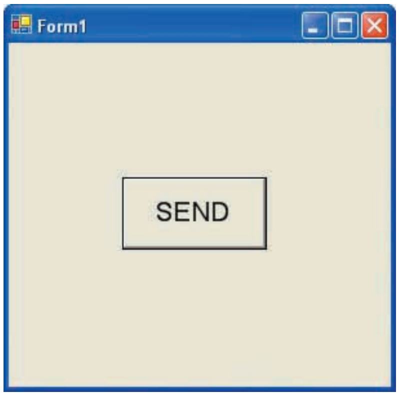


Fig.5. The test program runs successfully under Windows XP.

If you have any version of Visual BASIC that lacks MSCOMM it is certainly worthwhile obtaining and trying this alternative. The Internet is not exactly awash with information about programming the ports of a PC, but there are numerous snippets of information available if you seek them out using a good search engine such as **Google**.

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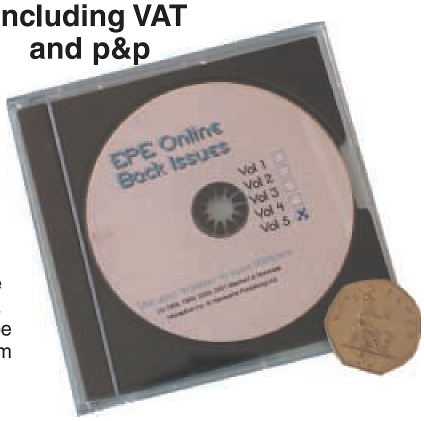

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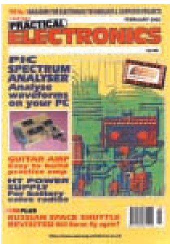

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READOUT

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!

All letters quoted here have previously been replied to directly.

WIN A DIGITAL MULTIMETER

A 3½ 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 ★

DISPLAYING LATERAL THINKING

Dear EPE,

It may interest you to know that I have modified John Becker's *PIC World Clock* (Aug '02) to run from a PIC16F84, and using shift register chips to drive the graphics l.c.d. (GLCD) it uses.

I did it out of interest and to explore GLCDs and thought you would appreciate the lateral thinking. Being relatively new to electronics and PICs it would be so easy to just use other people's hard work (e.g. John's) and not know what was going on. Having built successful motor racing engines for some 12 years, I am used to getting the max from the min and still push for more! Like programming?

As you will appreciate, using shift registers slows things up a tad, some two seconds passing before the l.c.d. shows a picture. This made me look for ways to speed things up and some experimentation took place (flow bench and dyno time).

I was intrigued by the OUTDATA routine and its use – how was its present form arrived at? By applying my interpretation of Toshiba's data sheet (and a couple of accidents!) I found a huge saving in program and processor time/space. For instance, goodbye AUTOWRITE.

I was also using an I^{2}C EEPROM as a table store, the routine to access it was fun to complete, it is only in 8-bit form at present but it works. A lot more pictures/tables could be accessed this way, without using program space or having to be careful using PCLATH commands. Weather pictures, moving maps, that sort of thing.

I have finished the displaying of the "world map", stored on EEPROM. The program is minimal and uses 192 commands total, 88 of which are shift register and EEPROM routines. All 1024 bytes are sent to the l.c.d. without a break. The GLCD works every time, no erroneous displays or characters. Status "checks" are performed but hidden.

Your *PIC Tutorial* said "think default". . . so I did.

Graham Card, via email

Congratulations Graham on what you are achieving – and yes, "max from min" is a pretty good analogy for PIC programming!

I can't offer any more info on how I arrived at my GLCD routines – what is in the text is all that I managed to extract from Toshiba's info, and some of those routines were developed using blood and tears – brilliant of you to find a way to simplify some!

I'll put the source code you sent me in our PIC Tricks *folder (on disk and our ftp site) for other readers to browse.*

PIC A NUMBER

Dear EPE,

I stopped buying electronics magazines (including *EPE*) a couple of years ago, when pressures of work meant that my hobby had to take a back seat. At work (and home) I develop real-time embedded software, with the Microchip PIC being my most common target. I was therefore very interested to see the dedication that *EPE* has been giving to this range of microcontrollers and bought the August 2002 edition. With an almost total lack of UK publications covering embedded programming from a hobbyist's perspective this is a refreshing change.

Having some interest in low power/low cost design, I would like to make a few comments about John Becker's *PIC World Clock*. From a purely hardware perspective, the 78L05 regulator, while cheap, has a very high quiescent current (3mA to 5mA). Micropower 5V regulators are easily available with tiny quiescent currents at reasonable price.

The 7660 used to derive the negative bias voltage for the l.c.d. could be dispensed with. The PIC contains two CCP modules that could be used in PWM mode with a charge pump to generate the required negative voltage. By extending the low power techniques, such as switching the l.c.d. off when not required, using a very low speed clock, and letting the PIC "sleep" as much as possible, the unit could be probably be economically used on batteries only. Perhaps a future article could cover this aspect of PIC programming?

Finally, although John performed an excellent job in exploring the mysteries of code pages, and the use of large lookup tables, the 16F87x range have the ability to read and write their own program memory via a set of special function registers with no paging issues. This, combined with being able to store 14 bits per program word means that RETLW is almost redundant in this type of application.

Keep up the excellent work, I will certainly be buying a copy more regularly.

Mike Rigby-Jones, via email

Thanks for your comments, Mike. I take your point about the regulator but with the l.c.d. drawing about 18mA or so, the 78L05 consumption I felt to be insignificant in comparison, hence the recommendation of the mains adaptor. Using Sleep etc I experimented for some time but even when supposedly "quiescent" this l.c.d. still draws the same current.

Yes, thanks, someone else has also made similar comments about accessing large tables - I live and learn and fresh input is always welcome. And. yes, I know and have used the PICs in negative voltage generation, but the useful voltage I've found to be only about –3·5V.

Glad you've re-found us – and appreciate our PIC emphasis!

AUTOSWITCH

I have recently finished Max Horsey's *Infra-red Autoswitch* (July '02) and it worked like a dream, many thanks for that.

I have a query though: after turning on the power I hear the "click", the bulb stays on for seven seconds because I haven't cut the wire from P1 and P2 yet. After a few hours I decided I wanted the autoswitch to turn off after only one minute or so. When I turned off the power and opened the box I noticed that the transformer was really hot to touch. Is this normal? I have used everything that you said to use and I am using a mains bulb rated at 35W.

Kevin Parr, via email

Kevin's email was forwarded to Max Horsey, who replied:

The lamp used makes no difference and the capacitor is not a problem either. The transformer is a type which is designed to run hot, so providing that the temperature is not excessive, e.g. liable to melt the case, then all is well.

In my prototypes, the outside of the plastic case is warm to the touch and the transformer inside is hot (***do not*** open the case whilst still connected to the mains!). The transformer is self-protected and – according to the supplier – can be short-circuited without permanent damage. Feel the outside of the case – it should be warm, but not uncomfortable.

Max Horsey, via email

PIC TRAINING COURSES

Dear EPE,

We are looking for a course (or courses) for training our engineers in the use and programming of PIC microcontrollers. Microchip (UK) and Bluebird (Nigel Gardener) offer limited courses but we were wondering if you were aware of any held at technical colleges/universities etc. Any help you can give us would be appreciated.

Dave Williams, Taylor Studwelding Systems, Dewsbury, W.Yorks, by email

We don't know of any PIC courses as such Dave, but you might find my PIC Tutorial *of interest – many people have learned PICs through it (and one even got a job through having done so). Originally published in Mar-May '98, it is now available in an upgraded version on CD-ROM as* Assembly for PICmicro V2, *plus its own greatly enhanced development board. Both are advertised in any recent issue of* EPE, *including this one of course.*

PIC ALTIMETER

Dear EPE,

I need the *PIC Altimeter* design by John Becker from your magazine of Sept '98. How can I have the diagram sent by email?

Ghazi Issa, by email

So sorry but we can never send back issues or their diagrams by email, or fax. Back issues can be bought either from our Online shop at ***www.epemag.wimborne.co.uk/shopdoor.htm****, or from the Editorial office, prices as quoted on the site and in current issues. You can also download recent issues from our* EPE Online *site at* ***www.epemag.com****.*

BOUNTY UNSNAGGED

Dear EPE,

Two potential constructional hitches have come to my attention with regard to my *EPE Bounty* (Oct '02). The design as it stands is without problem as far as I am aware, and performs very well, but this note is meant for troubleshooting. Firstly, there might be what appears to be *ground effect* as the detector is swung this way and that over the ground. In fact this is almost sure to be a loose p.c.b. inside the case. Once everything is secured inside the case, the problem is solved. Even very slightly loose parts inside could affect performance.

Secondly, depending on how the circuit was set up, and how the coil was wound and set, tuning might in some cases seem far too "sharp". This would not normally be the case, but to "soften" the tuning if required, wire a 2M2 resistor (or perhaps 4M7, for only slight "softening") between IC1 pins 1 and 5. Further, a 10k resistor may be wired in parallel with potentiometer VR3. Sensitivity is then best with a moderately fast crackle. Happy hunting.

Thomas Scarborough, via email

Thanks Thomas, your simple solutions are now well publicised!

SERIAL PIC TRAINING

Dear EPE,

Have you ever run tutorials regarding RS232 serial communications related to PIC microcontrollers, or indeed just RS232 tutorials as standalone? *EPE* is a good magazine, I always buy a copy for long train journeys. Thanks.

Peter Hale, via email

No we haven't Peter, but the PIC16F87x series offer RS232 serial input/output and I've just recently proved that the MAX232 RS232 chip interfaces well with it. My 8-Chan Data Logger *of Aug/Sep '99 shows how the PIC can output serial data, although it does not use the MAX232. However, my forthcoming* Earth Resistivity Logger *does use RS232 with the PIC and the Windows software. It will be published early next year.*

Back issues for the '99 Logger *are available from our Online shop or Editorial office.*

Thanks for your kind comments – nice to know you are being suitably kept on track!

MAKING P.C.B.S

Dear EPE,

I have followed John Becker's PIC articles for some years and find them a valuable source of ideas. He produces PIC p.c.b.s month after month, would he mind sharing with me how he produces them? I have no problems with the single-sided artwork but getting the image on the copper is another matter.

Jim Fell, via email

Well Jim, back in the late '80s I acquired an early version of EasyPC which I continue to use for the p.c.b. artwork etc, and from it print out to an ink-jet printer onto Overhead Projection film (OHP) which comes from PC World. I then use pre-sensitised copper clad laminate, expose the OHP onto it as a contact print in a UV exposure unit, develop the image in dilute caustic soda and then etch in a heated bubble tank with ferric chloride.

After which I drill the board using an 18,000 r.p.m. drill press using tungsten carbide 0·8mm drill bits for most components, but 1mm for terminal pins for off-board wiring. It all typically takes about half an hour from printout to completion of drilling, depending on board size.

The UV exposure unit, etch tank and drill press are professional items I still have from my business days. There are low cost equivalents around, though, from a variety of sources, although I cannot offer opinions on their quality. Do a web search via ***www.google.com****.*

POSITIONING MATTERS

Dear EPE,

I have just started to make the Guitar Practice Amp as featured in *EPE* Feb '02. I have just got the resistors needed to make it, but they were all put in a bag and I don't know which one has which value. Would I be right in thinking it will affect the whole thing by not putting them in the right hole, or doesn't it matter?

Thom Costall, via email

It very much matters, Thom, which components go where and it is essential *that you get the positioning of the types and their values right. As you appear to be a total novice I recommend that you do not assemble this project without advice from someone who already knows about electronics.*

To learn more about the essential basics of electronics, I recommend that you study my Teach-In 2000 *series of articles – they will give you much of the information you need, starting right at the beginning – how to identify resistors by the colour codes. The 12 articles (a year's worth) are available on CD-ROM as stated in any recent issue of* EPE *– see the Direct Book Service pages. We wish you well in your new-found interest in electronics.*

ENCOURAGING PICS

Dear EPE,

It occurred to me that a lot of your readers or papershop browsers may be put off PIC projects purely from a cost point of view. I retired some time ago and understand this well. It is actually surprising how little you need to spend to get started.

Obviously the first requirement is a PC, preferably with internet connection. Next are the development tools – Microchip's MPLAB is an obvious starting point and it's free, and while there are expensive programmers on sale, there are many inexpensive ones available – one web site worth browsing is at **http://people.man.ac.uk/~mbhstdj/piclinks.html**.

Thanks for your September issue's *PIC Trick* – excellent, my problem is finding the time to fit in the projects between the DIY and the gardening and the shopping and the . . .

Les Clarke, Redditch, Worcestershire, via email

Many thanks Les for your comments and support of PICs! In fact we are not aware of people considering PIC programming to be expensive. They seem to appreciate as you do that costs are pretty minimal.

ANCIENT MORSE

Dear EPE,

I have just come across an old project of John Becker's, *PE* July 1990, the *Analogue Morse Reader*. The p.c.b. has all components fitted except the l.c.d. and the i.c. holders, I even have an EPROM that I programmed.

I think the reason it was never completed was that I was moving house at the time and also seem to remember the cost of the l.c.d. modules were quite expensive. Will I be able to use the same l.c.d. that I now use with your *TK3* programmer? The original l.c.d. needed a negative supply for the contrast, the one I have does not, that seems the only difference.

Colin Manklow, via email

Goodness Colin, that's from a thousand years ago, and a different universe. My memory is far too faded with the years to recall the detail. In general, though, alphanumeric l.c.d.s of any standard type are interchangeable if the contrast adjustment is amended to suit the type, but otherwise no changes should be necessary. To replace an l.c.d. that needs a negative supply by one that does not only requires the contrast pin to be taken via the preset potentiometer to 0V instead of the negative line.

Whilst some years ago it seemed necessary to specify that the l.c.d. should have a certain "compatibility" characteristic (I forget the details), this subject has not raised its head for at least four or five years and so far as I am aware all alphanumeric ("intelligent") l.c.d.s available on the hobbyist market are equally compatible and interchangeable as regards the main controlling chip that's built into them, and thus the code that controls them.

Have said that, though, treat my historical design as just that – history! My recent PIC-based one is far better (Sept '02).

TUTORIALS ON AIR

Dear EPE,

I would be very grateful if you could give me some advice regarding your *EPE PIC Tutorial* as published in the Mar-May '98 editions. I have assembled the kit and p.c.b. from Magenta and after testing all seems fine. My problem is when I try to do the first test on the demonstration disk, e.g. **tasm -1684 -b tuttest.asm**, I get the error message "Bad command or file name". I have followed John's advice to the letter but can't get passed this problem. Any advice would be greatly appreciated.

Ray Jones, via email

I advised Ray to make sure all the files were in the same folder on his hard drive and then make sure he correctly typed the command. Ray then responded:

Thank you for your email and advice, the software is now responding and I'm very grateful. I'm walking on air now the problem is solved!

AERIAL GUITAR?

Dear EPE,

I am entering second year in electronic engineering in Galway, Ireland. This year I get to choose my practical project. I was wondering after looking through *EPE* in college if you would have a schematic for an aerial transmitter-receiver circuit, for use on a guitar. I suppose a frequency range of 80Hz to 20kHz. Any ideas or help would be much appreciated.

Andrew O'Dowd, via email

Sorry Andrew, we've not done such a design, transmitting "sound" generally requires the equipment to have type approval and/or be licenced.

For information on modules that are permitted to be used for data transmission at specific frequencies that are legally and internationally acceptable without licensing, browse ***www.rfsolutions.com****.*

Best wishes for your second year!

BLOOMING WATER!

Dear EPE,

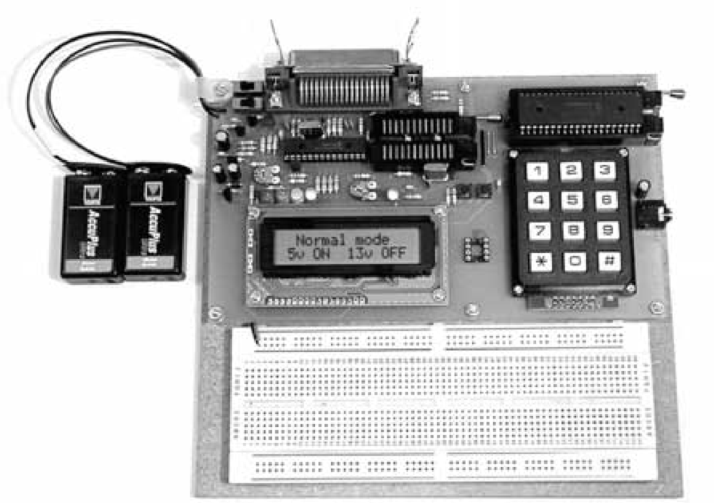
Hi from sunny South Africa. I have an algae problem with my swimming pool and what makes things worse is that I went for a black marble plastered pool. The question I have is what electronic solutions are available and if so where may I obtain a circuit diagram?

There are a couple of gadgets on the market here but are horrendously expensive. Years ago (1974) I came across a device that was used to ionize the water with amazing results. The problem is that I need to keep the chlorine level high and I think it is not healthy. Any ideas I am willing to try.

Dave Liddle, via email

It's not something we know about Dave, but perhaps some Readout *readers might be able to help. Have you tried searching the Web for info? If not, try searching via* ***www.google.com*** *– it's an excellent search engine.*

Learn About Microcontrollers



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Web site:- **www.brunningsoftware.co.uk**

NEW 32 bit PC Assembler

Experimenting with PC Computers with its kit is the easiest way ever to learn assembly language programming. If you have enough intelligence to understand the English language and you can operate a PC computer then you have all the necessary background knowledge. Flashing LEDs, digital to analogue converters, simple oscilloscope, charging curves, temperature graphs and audio digitising.
Kit now supplied with our 32 bit assembler with 84 page supplement detailing the new features and including 7 experiments PC to PIC communication. Flashing LEDs, writing to LCD and two way data using 3 wires from PC's parallel port to PIC16F84.

Book Experimenting with PCs £21.50
Kit 1a 'made up' with software £52.00
Kit 1u 'unmade' with software £45.00

C & C++ for the PC

Experimenting with C & C++ Programmes teaches us to programme by using C to drive the simple hardware circuits built using the materials supplied in the kit. The circuits build up to a storage oscilloscope using relatively simple C techniques to construct a programme that is by no means simple. When approached in this way C is only marginally more difficult than BASIC and infinitely more powerful. C programmers are always in demand. Ideal for absolute beginners and experienced programmers.

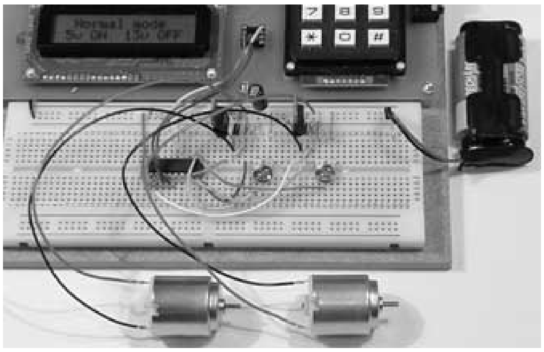
Book Experimenting with C & C++ £24.99
Kit CP2a 'made up' with software £32.51
Kit CP2u 'unmade' with software £26.51
Kit CP2t 'top up' with software £12.99

The Kits

The assembler and C & C++ kits contain the prototyping board, lead assemblies,components and programming software to do all the experiments. The 'made up' kits are supplied ready to start. The 'top up' kit is for readers who have already purchased kit 1a or 1u. The kits do not include the book.

Hardware required

All systems in this advertisement assume you have a PC (386 or better) and a printer lead. The experiments require no soldering.



Experimenting with the PIC16F877

The second PIC book starts with the simplest of experiments to give us a basic understanding of the PIC16F877 family. Then we look at the 16 bit timer, efficient storage and display of text messages, simple frequency counter, use a keypad for numbers, letters and security codes, and examine the 10 bit A/D converter.

The 2nd edition has two new chapters. The PIC16F627 is introduced as a low cost PIC16F84. We use the PIC16F627 as a step up switching regulator, and to control the speed of a DC motor with maximum torque still available. Then we study how to use a PIC to switch mains power using an optoisolated triac driving a high current triac.

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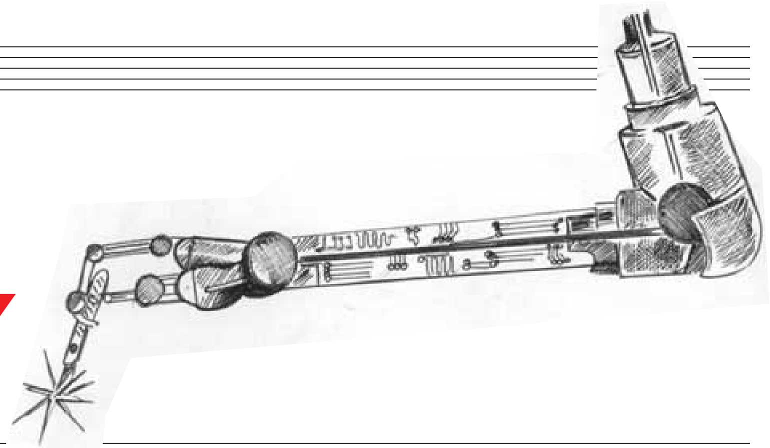
Regular Clinic

CIRCUIT SURGERY



ALAN WINSTANLEY
and IAN BELL

Our team of "surgeons" describe methods for measuring high side and low side currents using op.amps, and we explain the basic differences between some common electric motors.

Current Sensing Techniques

Last month we looked at a question arising from our ten-part educational series *Teach-In 2002* (*EPE* Nov. '01 to Aug. '02) concerning "shift and amplify" circuits working from a single supply. We continue on a similar theme with a question from ***David Ardis*** on the use of differential amplifier circuits for current measurement.

"Teach-In 2002 *Fig.5.16 shows a differential amplifier test circuit. I have built this circuit and used it to measure current. Is it possible to use an op.amp without having a negative 12V rail e.g. from a battery, and if so what modifications have to be made?"*

The circuit to which David refers is an op.amp differential amplifier circuit, as shown in Fig. 1. We can use this circuit to measure current *(I)* by amplifying the voltage dropped across a known (and usually small) sense resistance, R_S, as shown in Fig.2.

The voltage output of the amplifier is proportional to the current in the sense resistor and could be used to drive a suitably calibrated voltmeter, or be connected to an analogue-to-digital converter to make the measurement. In other typical uses it could be connected to a control circuit to regulate the current, or to a comparator to trigger a current limiter.

This arrangement is known as **high side** current measurement because it can be used to measure current without requiring the sense resistor to be connected to ground – i.e. the "low side" of the voltage source producing the current.

The sense resistor must usually be small so that it does not upset the circuitry being monitored, however, the smaller the resistor (and hence voltage drop) the more difficult (error and noise prone) the measurement becomes. For high current measurements, power dissipation in the sense resistor can lead to heating and measurement drift. As usual a suitable compromise must be sought when selecting R_S. Hence, R_S does not have to be a resistor; it could be a piece of wire or even a p.c.b. copper track (trace).

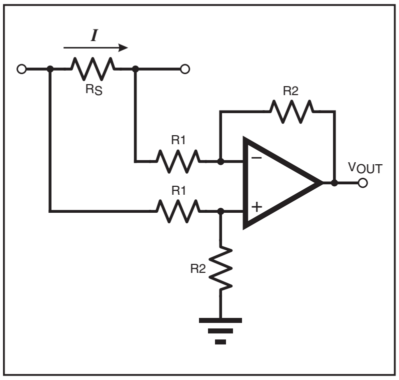


Fig.2. Principles of "high side" current measurement.

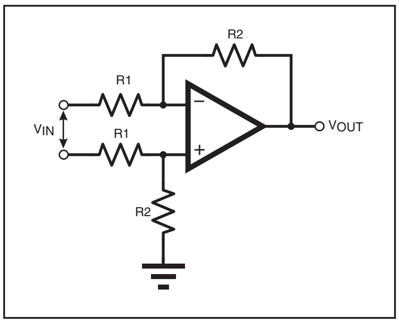


Fig.1. Differential amplifier (split supplies).

On The Low Side

For **low side** current sensing – where one end of the sense resistor is connected to ground – we can use a single-input, rather than differential, amplifier. However, a good differential amplifier will provide a more accurate measurement if, as is often the case on circuit boards, the ground voltage varies. The problem of "ground bounce" was discussed in *Teach-In 2002* and also previously in *Circuit Surgery*. A low side current measurement circuit using a differential amplifier is shown in Fig. 3.

At this point we must also remind you that the common mode rejection ratio (CMRR) of the circuit in Fig. 1 is poor, or, more specifically, it is highly dependent on the sense resistor accuracy. The differential amplifier's output should depend only on the voltage drop *across* the sense resistor, but the voltage *at* the sense resistor appears as a common mode input to the amplifier. If the CMMR is poor this voltage will influence the amplifier's output, distorting the current measurement.

The use of ordinary five per cent or ten per cent carbon film resistors in the differential amplifier circuit will lead to very poor common mode rejection. You need 0·01% resistor accuracy to get just 86dB of CMRR with a prefect op.amp! In an experimental situation you could adjust the resistor values to maximise the CMRR, but you would have to take care to ensure that values did not drift.

Custom Chips

A much better solution is to use a differential amplifier i.c. that has built-in accurate resistors, such as the MAX4198 and MAX4199 from Maxim. Special "high side" current measurement chips are also available, for example the MAX471 and MAX4372. Note that the MAX472 is a current-sense amplifier for battery equipment whose sense range is set by an external resistor. You can view data sheets and some useful application notes for current-sense i.c.s at **www.maxim-ic.com**.

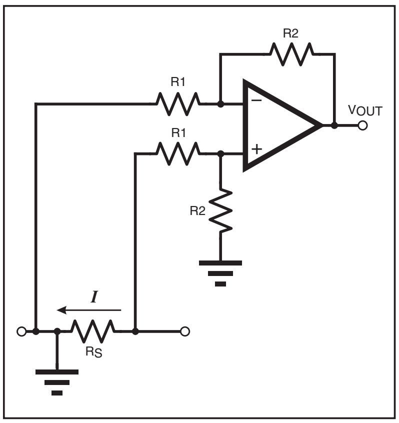


Fig.3. Principle of "low side" current measurement.

The differential amplifier in the circuits shown here may also be replaced by an instrumentation amplifier for better performance, either built using discrete op.amps or better using a dedicated instrumentation amplifier i.c.

In answer to David's question about using a single supply, things are actually easier here than the situation we discussed last month. As we are using a differential input, one side does not have to be referenced to ground.

The circuit shown in Fig.1 can be modified by using the "half-supply rail generator" we showed last month (p.790) to generate an "earth" to connect to the earthy end of resistor R2 (i.e. the point indicated by the earth/ground symbol in Fig.1). See Fig. 4 for an example of the kind of circuit arrangement you might try.

One aspect you have to watch out for is the common mode input range of the op.amp as illustrated in Fig. 4. The high side sense resistor R_s has one terminal connected to the power supply rail, and by virtue of the small voltage drop essential to prevent this resistor interfering with the measurement, the other side of R_S will be at almost the same voltage.

This means that the op.amp's common mode input voltage is about equal to the supply voltage. Not all op.amps work happily under such conditions so this is something you must check when selecting an op.amp for this task.

The manufacture's data sheet will detail the acceptable common mode input range. Special high side current monitoring i.c.s are, of course, designed to cope with large common mode input voltages. *IMB*.

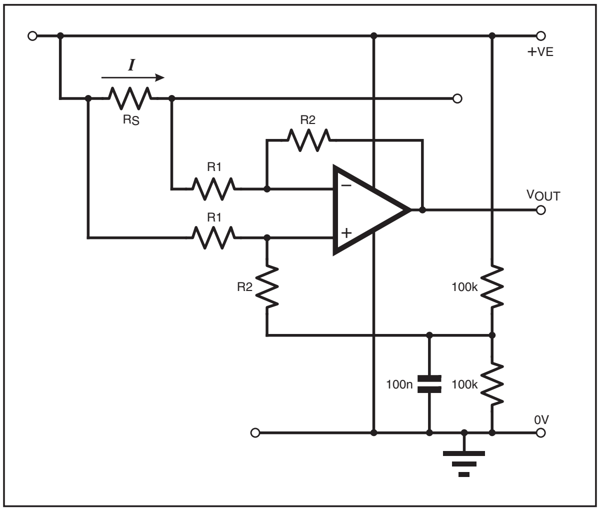


Fig.4. Circuit to illustrate common input voltage when using single supply differential amplifier for high side current measurement.

Motor Mania

What is the purpose of the capacitor usually found clipped to the body of most single-phase a.c. motors? asks **Gerard Galvin** by email.

Whilst the application and repair of electric motors is a topic in itself, and much of it is outside the scope of *EPE*, it's worth summarising some of the different types of electric motor that are in common use.

We all know how transformers work: briefly, they have a primary coil of copper windings which is magnetically coupled to a secondary winding, into which a voltage is *induced*. The *motor effect* relates to the motion of a conductor in the presence of a magnetic field, and is described in Fleming's *Left Hand Motor Rule.*

In the example of an **induction motor**, a series of electric coils is used to create a magnetic field around the motor. These windings are physically static and cannot move, so they are termed *stators*. In the centre of the motor is the shaft, which is part of the *rotor*.

There is no direct electrical connection to the spinning rotor. In order to make the motor spin round, the magnetic fields in the stator cause a field to be induced into the rotor, which is magnetically dragged and pushed around, so the rotor is forced to spin and drive a load. This is why an induction motor can ***only*** operate on alternating current and ***not*** a direct current.

In A Spin

The number of pairs of electromagnetic "poles" in the motor determines the overall speed of operation. If only one pair of poles were present in the motor circuit, then running on a UK supply of 50Hz frequency, one full revolution of the motor would occur every second, implying a fixed speed of 3,000 revolutions per minute (or 3,600 r.p.m. where there is a 60Hz supply). If it were, say, a four-pole motor, then it would travel half a revolution per second, so its speed would be 1,500 r.p.m. and so on.

Hence, it is not the voltage but the *supply frequency* and the *number of poles* that ultimately determines the speed of such motors. This answers a very common query – how to control the speed of an a.c. motor as used in, for example, a bench grinder? The answer is really ***not*** by dropping the voltage but by changing the frequency instead.

However, many items of equipment are not designed for running at less than full speed otherwise they will stall under load and overheat due to excessive induction currents. It is potentially dangerous to overload an induction motor in this way.

Squirrel Cage

Depending on the design, the rotor may be solid steel or it may contain laminations with copper windings, copper bars or permanent magnets. The term "squirrel cage" relates to the use of thick copper loops as a cage of "windings" in a steel or iron rotor.

A heavy current is induced in them by the stator, which creates a magnetic field in the rotor and causes the rotation. The actual design of the rotors and how to control the magnetic fields is a science in itself and will not be discussed further here.

Note that in practice, they are most efficient (i.e. generally producing the least heat with optimal output torque) at 90 to 95 per cent of the applied synchronous frequency. Induction motors inherently run at a speed very slightly less than the stator's a.c. mains frequency or *synchronous speed.*

The term "slip" is used to describe the difference between the speed of the stator frequency and the rotor speed. A squirrel cage motor inherently exhibits some slip when running. If the rotor frequency matched the stator frequency (synchronous mode) then there would be no output torque at all, so some "slip" is essential.

Making A Start

One inherent problem with induction motors, such as the single-phase type used in a domestic garden vac/shredder, is how to *start* the machine to begin with, because at zero revs there is no torque available. Induction motors do not self-start, so something is needed to "kick start" them into operation by giving them a gentle spin, after which they will spin up to full torque.

A common way of starting them is to use a large capacitor in series with a separate auxiliary or *starting* winding fitted within the stator. The capacitor reduces the starter winding's inductive reactance, and as the starter winding current leads the main stator winding current by anything up to 90 degrees, this difference in phase during start-up makes the motor turn over and start, after which the capacitor-start winding is switched out of circuit. Other types of capacitor-started motors are available (capacitor-run or a combination) each with their own characteristics.

If you have ever taken a fan heater or record turntable to bits you will have seen a small squirrel-cage motor that has a number of copper bands spot-welded into the steel lamination body. Strange! These "windings" start the motor by masking, in a crude way, part of the stator field. This creates a primitive permanent starter winding that shades part of the main pole – so it's known as a *shaded-pole motor.*

These are very common as they are cheap to make and quiet in operation but their efficiency is poor. Again, you cannot control their speed by adjusting the applied voltage: it is the number of poles and frequency that matters.

Many types of larger induction motor have a fan running on the rotor to help with cooling. A transmissions engineer once advised me that such motors should never be run at much less than 85% of their designed speed, because the point will be reached where they are generating heat more quickly than the fan's rotation can dissipate it, so the motor will overheat.

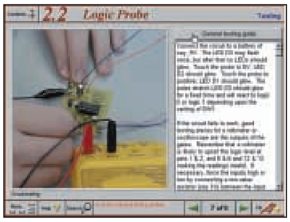
Some extremely sophisticated and expensive motor controllers are available for commercial use but these are well beyond the scope of the average constructional project. The *Synchronous Clock Driver* project (*EPE* Sept. '01) is an example of a PIC microcontroller design which shifts the frequency of very small mains synchronous motors to run at either 50Hz or 60Hz: it was originally designed so that American electric clocks could be operated from the UK 50Hz supply. *ARW*

Next month: The differences in a number of other common motor types will be outlined. You can email the writers at **alan@epemag.demon.co.uk**.

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS

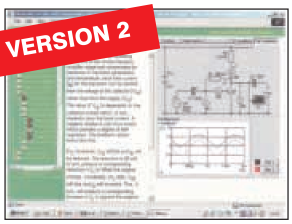


Logic Probe testing

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.

ELECTRONIC CIRCUITS & COMPONENTS V2.0

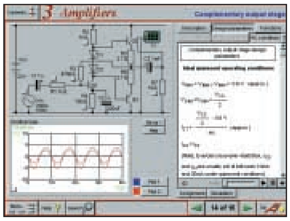
VERSION 2



Circuit simulation screen

Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits. Active Circuits.*** *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.
Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

ANALOGUE ELECTRONICS

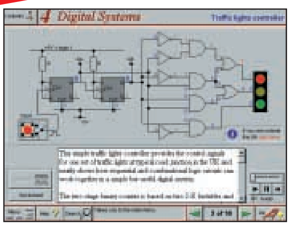


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

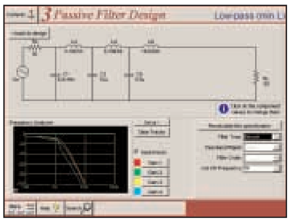
VERSION 2



Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

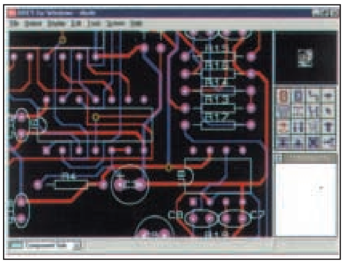
FILTERS



Filter synthesis

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

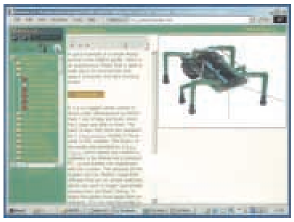
ELECTRONICS CAD PACK



PCB Layout

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

ROBOTICS & MECHATRONICS



Case study of the Milford Instruments Spider

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

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

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

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

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

PICmicro TUTORIALS AND PROGRAMMING

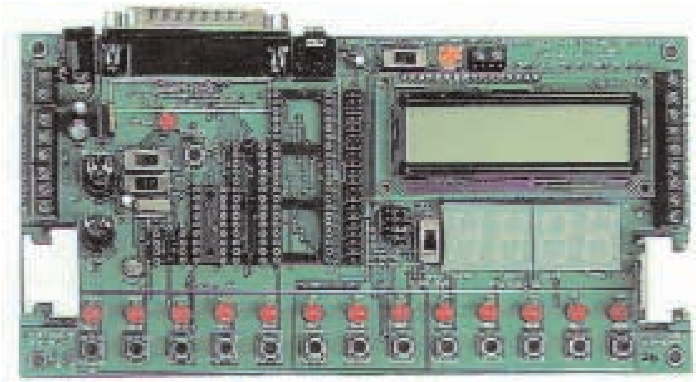
HARDWARE

VERSION 2 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

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

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



£145 including VAT and postage

12V 500mA plug-top PSU (UK plug) £7

25-way 'D' type connecting cable £5

SOFTWARE

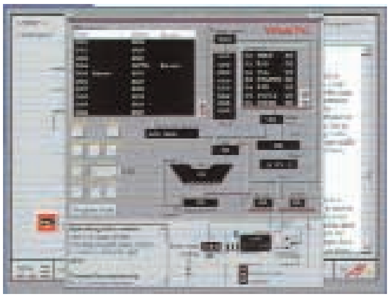
Suitable for use with the Development Board shown above.

ASSEMBLY FOR PICmicro V2

(Formerly PICtutor)

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

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



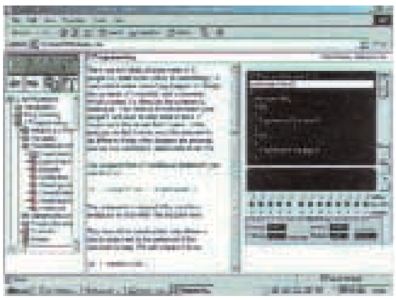
Virtual PICmicro

'C' FOR PICmicro VERSION 2

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

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

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



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

FLOWCODE FOR PICmicro

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

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

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

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

Burglar Alarm Simulation

PRICES

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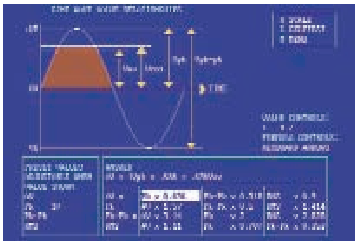

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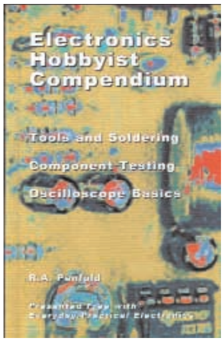

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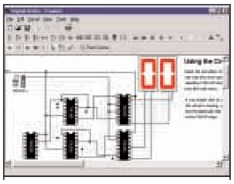

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ELECTRONIC PAPER

IAN GRAHAM

After more than 20 years of research, manufacturers seem to have cracked the problem of making electronic paper.

PAPER'S been around for about 3,000 years, give or take a century or two. We've been writing on it for most of that time and printing on it for over a thousand years. Even now, at a time when everything seems to be going digital, we still read most of our news, articles and fiction in the form of ink on paper.

Scientists have tried for decades to produce an electronic form of paper – a paper-thin, flexible sheet on which electronically generated text or images can be displayed – in effect, the thinnest and most flexible electronic screen ever made. That is quite a tall order, but researchers seem finally to have solved the problems.

Electronic Ink

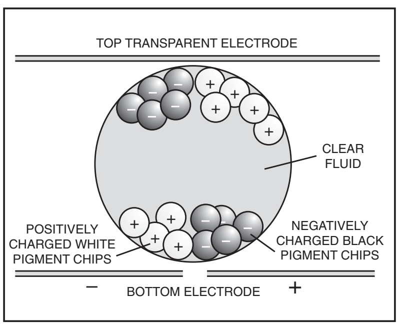
The key development is an electronic ink that can be printed onto thin sheets of material and that changes colour in an electric field. Two companies have come up with slightly different ways of doing it.

One solution being investigated by E-Ink is for an ink made from millions of spherical microcapsules, each no thicker than a human hair. About 155,000 of them could squeeze into a square centimetre. The full-stop at the end of this sentence would contain about 30.

Each capsule contains microscopic particles suspended in a clear liquid. Half of the particles are one colour and half are a different colour – black and white for a monochrome display. Their electrical properties are different too. The white particles are positively charged and the black particles are negatively charged.

The ink is sandwiched between two electrodes, the top one transparent of course. When an electric field is applied to the whole sheet so that the top electrode is negative, the white particles are attracted to the top of the capsules and the black are drawn down to the bottom. The sheet turns white, like a blank sheet of paper.

Reversing the polarity of the field applied to some parts of the sheet brings the black particles up to the top and makes the white particles sink. Those parts of the sheet turn black. It is not hard to imagine that if the capsules are manipulated with sufficiently fine control, the sheet can display text or images, or both. Plus, they are as sharp and bright as if they'd been printed.



Cross-section of the charged E-ink microcapsule.

Colourful Beads

Developed at Xerox and to be marketed by Gyricon Media, the second electronic ink uses millions of tiny beads with a different colour on each side. The two sides carry opposite electric charges. The beads are sandwiched between two electrodes as before. They sit in cavities within the material. Flipping the applied electric field makes the beads rotate to show a different colour.

Unlike conventional displays, it is claimed that images on electronic paper can be viewed clearly over a very wide angle in reflected light, just like a printed image. But what if the batteries run flat? Do the pages go blank?

No. Images created with electronic ink stay put until it's time to change them. They draw current from the batteries only when the image is changed. A programmable electronic ink display will run for up to two years on three AA batteries. And, without power, the image is retained indefinitely.

Go-anywhere Displays

These electronic papers are so thin and flexible that they can be applied to almost any surface – from walls in public places and point-of-sale materials in shops to display panels on all sorts of consumer goods (watches, mobile phones, computers, etc). They could even be built into clothes!

Advertising signs have already been made using electronic paper and inks. Some of them combine programmable graphics and/or text overlaid on a traditionally printed background.

Some of the applications envisaged for electronic paper are pretty neat. Imagine a book of electronic paper pages with the driver electronics built into its spine. Feel like reading the latest best-seller? Just download it from the Web using a wireless link and there it is in black and white, and you can flip through the pages as if it was a normal book.

An electronically charged pencil rotates the bichromal beads in a sheet of Xerox electronic reusable paper.

Electronic Notepads

Xerox and Gyricon Media have also demonstrated how to write and draw on their electronic paper using a charged pencil. Electronically active surfaces aren't new of course. Designers have been using graphics tablets for decades.

However, using a graphics tablet is not the same as jotting something down on paper. Whatever is written on a tablet doesn't appear on the tablet itself, so it is not as natural and intuitive as writing on paper. Writing on electronic paper is much more like the real thing. As the pencil slides across the electronic paper, its charged tip rotates the bichromal (two-colour) beads in the paper and changes their colour.

Looking one step ahead, in theory at least, it may be possible to hook up an electronic notepad like this with character recognition software so that anything written on the pad could be fed straight into a word processor and saved or emailed. □

Constructional Project

EPE HYBRID COMPUTER

PETROS KRONIS

Part 2

Real-time computation of complex system behaviour is greatly simplified by combining analogue and digital processing techniques.

LAST month the circuit technicalities for this design were discussed at length, and the initial constructional aspects were described. In this final part the remaining constructional details are presented (see Fig.18), plus guidance on actually using the design to simulate real-world engineering problems.

TESTING

Before any serious programming is attempted it is good practice to carry out the following simple testing procedures which will help to identify any errors in the construction, or problems in the operation of the computer.

The analogue computer is programmed by connecting the various processing units together via the patch panel. It is necessary that you familiarise yourself with the arrangement of the patch panel.

The panel layout for one amplifier is shown in Fig.19. The layout for the other nine amplifiers is the same except for the reference voltage socket 7, and the four rightmost sockets of the first row of sockets, as indicated in the righthand column.

Functional notations for the sockets are given in Fig.20.

TESTING THE ADDING AMPLIFIERS

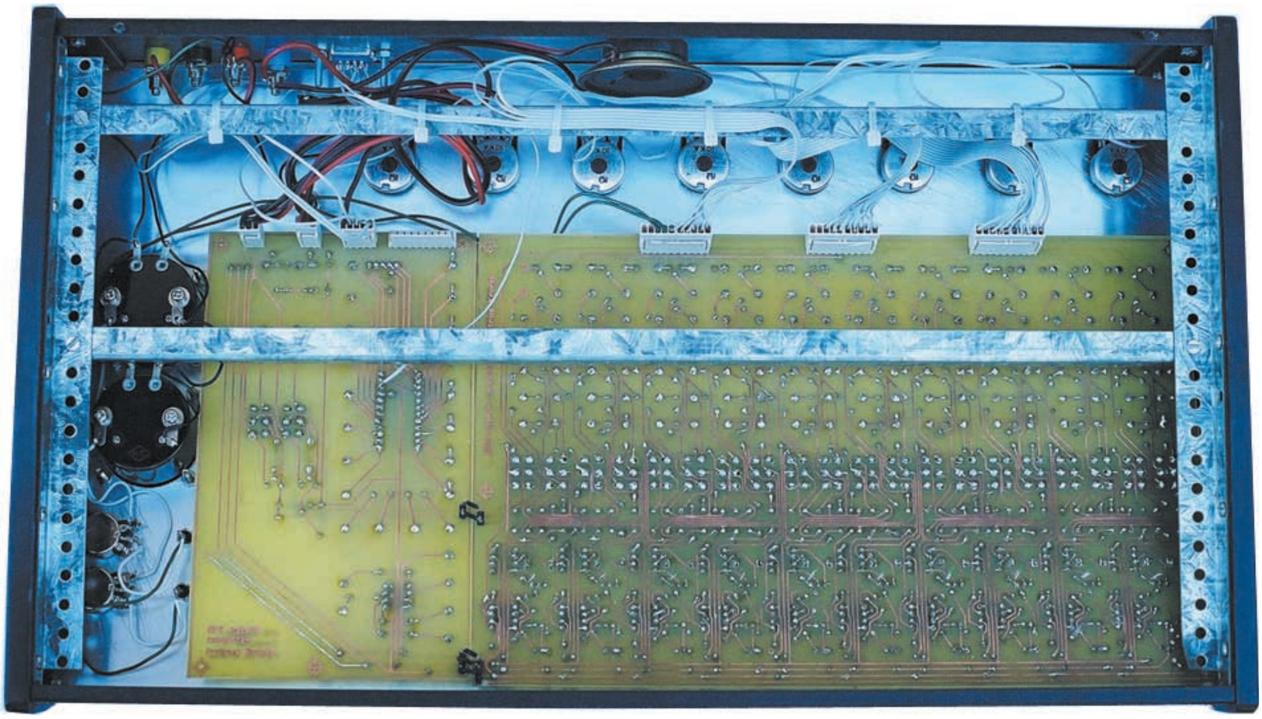
To test the Adding Amplifiers, do it in the following order:

1. Switch all ten amplifiers to **Add** using the amplifier toggle switches, S1 and S2.
2. Switch the power on.
3. Set up a reference voltage of 1V. This can be done by connecting a +15V reference voltage to the input of any of the Coefficient Multiplier potentiometers (VR15) and adjusting the dial until the potentiometer output reads 1V (measured using a multimeter).
4. Apply the 1V reference voltage to the ×1 inputs of the amplifiers. Measure the amplifier output voltage. It should read 1V. Test all 10 amplifiers in turn.
5. Repeat the test, applying the 1V reference voltage to the ×10 amplifier inputs. The amplifier outputs should read 10V.

INTEGRATING AMPLIFIER TESTING

Test the Integrating Amplifiers in the following order:

1. Switch all ten amplifiers to **Integrate** using the amplifier toggle switches, S1 and S2. Switch the mode switches to **Compute/Auto Reset** (S3) and **Compute/Auto Hold** (S4).
2. Make the connection for integration with a nose gain of 1, i.e. connect socket 6 to socket 13 (see Fig.19).
3. Switch the power on.



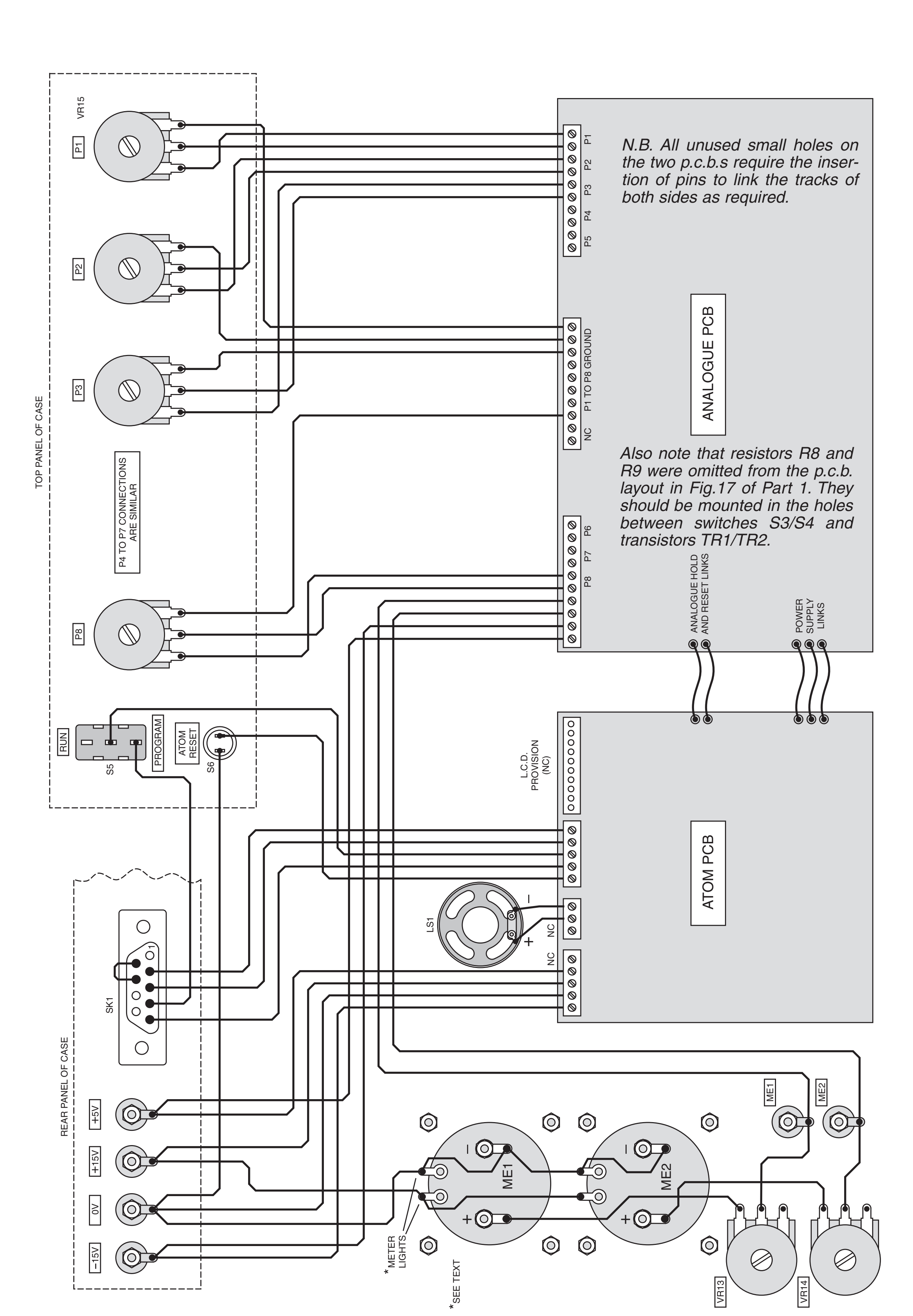


Fig.18. Interconnection wiring diagram.

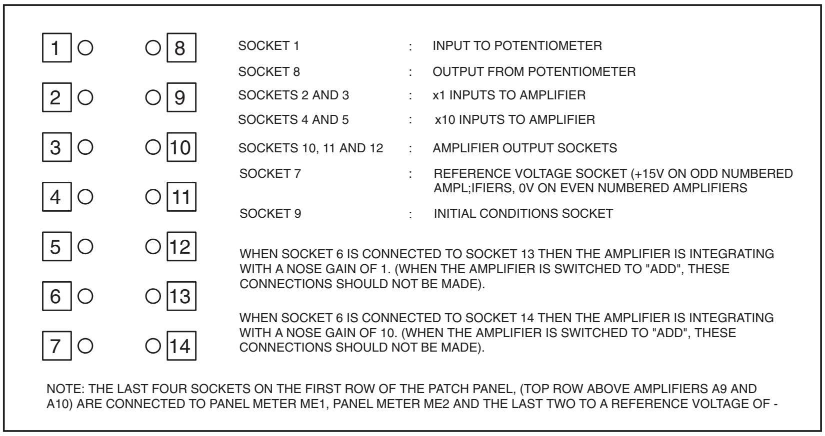


Fig.19. Patch panel socket layout and functions for one amplifier module.

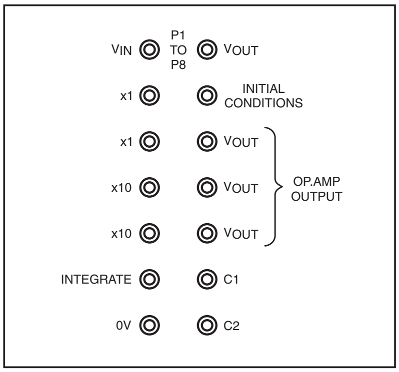


Fig.20. Functional notations for the amplifier module sockets.

4. Using potentiometer VR13 adjust the sensitivity of panel meter ME1 to give maximum deflection at +15V and connect the amplifier output to the panel meter.

5. Apply a 1V reference voltage (as set in the previous tests using VR15) to the ×1 inputs of the amplifier. The output should increase linearly at a rate of 1V per second until the amplifier saturates. The appropriate over-voltage warning l.e.d. (D4) should come on as the amplifier saturates. Bear in mind that the amplifiers invert the input voltage, both when adding and when integrating,

6. If the reference voltage is applied to the ×10 inputs, the output increases at a rate of 10V/s, which is too fast to see unless shown on an oscilloscope. If the integrator is connected with a nose gain of 10, i.e. connection of socket 6 to socket 14, integration is even faster, by a factor of 10.

HOLD MODE TESTING

To test the Hold mode, follow the same procedure described in the first four numbered paragraphs in the previous test, and then:

1. Before the amplifier saturates, switch the Compute/Auto Hold toggle switch (S4) to **Manual Hold**. The processing should freeze and the output should remain constant. (Some drift may be present.)

2. Now switch the Compute/Auto Reset toggle switch (S3) to **Manual Reset**. The output of the integrators should become zero.

PROGRAMMING CONVENTIONS

In the preceding simple examples, the process of connecting the various analogue computer units is described in English. However, this is not very efficient, or universally understandable, and programmers have developed a generally accepted code for the description of an analogue computer program.

The program is represented by a flow diagram, which is a collection of symbols representing the various units of the analogue computer, connected together. The symbols used are those given in Fig.5 (Part 1).

Using this symbolic convention, the analogue computer flow diagram in Fig.21 shows two successive integrations by amplifiers A1 and A2, of a step function of 1V set up by coefficient multiplier P1.

Panel meters ME1 and ME2 are used to monitor the outputs of amplifiers A1 and A2 respectively. If we could plot these outputs on an X-Y plotter we would find that when a step function is integrated the result is a ramp function, and when a ramp function is integrated a square function (x^2) is the result.

These results are shown in the circles of Fig.21. Note that the amplifiers invert the input signals, i.e. a positive step function produces a negative ramp function and a negative ramp function results in a positive square function.

To set up this program on the analogue computer, the patch panel is wired as shown in Fig.22. This diagram is not normally drawn because a programmer with some experience can wire the patch panel by simply looking at the flow diagram. It is given here to help beginners.

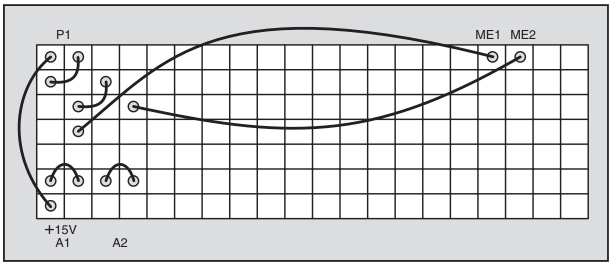


Fig.22. Patch panel connections for the flow diagram of Fig.21.

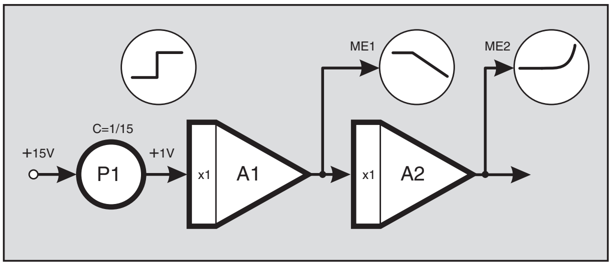


Fig.21. Analogue computer flow diagram example.

To run the program follow these steps:

1. Wire the patch panel.

2. Switch the power on.

3. Calibrate panel meters ME1 and ME2 by applying a reference voltage of +15V and adjusting the sensitivity of the meters to read that value at around maximum deflection, using their potentiometers, VR13 and VR14.

4. Switch amplifiers A1 and A2 to **Integrate**.

5. Set mode switches to **Compute/Auto Hold** (S4), and **Manual Reset** (S3).

6. Switch **Manual Reset** (S3) to **Compute/Auto Reset** to begin the computation function.

7. Observe the panel meters.

OFFSET NULL TRIM

When the input of an ideal op.amp powered by a split power supply (e.g. +15/0V/–15V) is grounded (0V), the output should be zero. However, this is not the case in a real op.amp and a corrective voltage is necessary to eliminate the offset error. The offset voltage of the OPA177 used in the *EPE* Hybrid Computer is very low, 25μV maximum. But even so, the offset null procedure is sometimes needed to reduce errors and unwanted output drift.

Adjust the offset voltage as follows:

1. Set all amplifiers to **Add**.

2. Connect the output of amplifier A1 to meter ME1.

3. Ground one of the ×10 inputs of the amplifier.

4. Turn the sensitivity of the meter as low as possible (VR13).

5. Switch the power on.

6. Increase the sensitivity of the meter gradually to maximum.

7. Adjust the offset null potentiometer (VR1 to VR10, as required) to make the meter read zero.

8. Repeat the procedure for the other amplifiers.

9. Make sure you do not disturb the offset null potentiometers during the programming and execution of the program.

INITIAL CONDITIONS EXAMPLE

In the previous examples we assumed that at the start of the computation, i.e. at time = zero, all variables had zero value. This may not always be the case.

Suppose we wanted to give an initial value to the output of an integrator before the computation begins. We might like to investigate the flight of a rocket, for

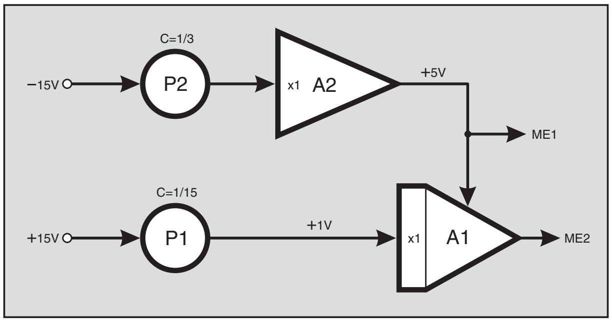


Fig.23. Initial conditions setup.

example, not from the point of launch but from some height above the launching pad, at which the rocket will have some velocity and acceleration. This can be done by connecting wires carrying reference voltages, to the initial conditions sockets of the integrators.

Let us assume that we want to integrate a step function of +1V, but this time we want the integrator to begin integrating from an initial value of +5V.

Set up the program illustrated in Fig.23 on the patch panel (a first test of your understanding of how to implement such programs, as discussed in relation to Fig.21). P1 and P2 are two VR15 potentiometers.

To run this program follow these steps:

1. Switch amplifier A1 to **Integrate** (S3) and A2 to **Add** (S1 and S2).

2. Switch the power on.

3. Adjust P1 to give +1V at the input to A1 and P2 to give +5V at the output of A2.

4. Switch **Compute/Auto Hold** to **Manual Hold** (S4).

5. Switch **Compute/Auto Reset** to **Manual Reset** (S3). Wait a few seconds for the output of A1 to settle to +5V.

6. Switch **Manual Hold** to Compute/Auto Hold (S4).

7. Switch **Manual Reset** to **Compute/Auto Reset** (S3) and observe the results.

You should find that the integration begins from a value of +5V and the output of A1 reduces at a rate of –1V/s until it saturates at –15V.

The initial condition value is invariably formed using an adder and a potentiometer, unless of course the exact value is available as a reference voltage. It is common practice, therefore, not to show these two computing elements in the program diagram but simply to show the value being applied to the initial condition socket as shown in Fig.24.

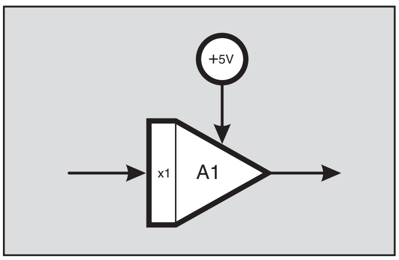


Fig.24. Representation of initial conditions.

SPRING-MASS EXAMPLE

Let's take the spring-mass system and the capacitor-inductor circuit as examples of simulating engineering problems on the analogue computer.

The diagram in Fig.25a shows a mass *m*, suspended by a spring of stiffness *K*. Its electrical equivalent system is shown as a capacitance-inductance series circuit in Fig.25b. Both systems when disturbed will oscillate. We now illustrate how to simulate the systems on the analogue computer and observe their behaviour.

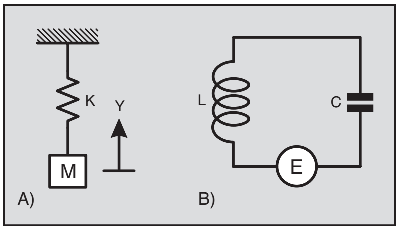


Fig.25. Mechanical and electrical equivalent circuits.

To do this we must first write down the equation of motion, which in the mechanical system involves no more than Newton's Law of Motion:

Force = *mass* × *acceleration*, which we will express as $F = m \times a$.

Imagine that the mass (m) is pulled down a small distance (d) from the equilibrium position and then released. At the moment of release the spring pulls the mass up with a force (F) of Kd. Applying the equation of motion, we get:

$-Kd = ma$

Dividing both sides of the equation by mass m and rearranging so that the highest derivative (a) is on the left hand side of the equation and all other terms on the right hand side, we get:

$a = -Kd/m$

From this equation we draw the flow diagram shown in Fig.26.

Note that there are special textual symbols that can be used to express the graphical symbols, but their discussion and use is beyond the scope of this article.

As the flow diagram shows, by integrating the acceleration (a) using amplifier A1 we obtain the velocity (v) which is shown on panel meter ME1. Amplifier A2 integrates the velocity to give the displacement (d) shown on panel meter ME2.

We use amplifier A3 as an inverter to obtain a displacement of $-d$, and potentiometer P1 to multiply by a constant factor of K/m. The output of the potentiometer is now $-\frac{K}{m}d$ which, looking at our equation, is equal to the acceleration, a. So we connect the output of P1 back to the input of A1 to complete the loop.

The system as it stands will not oscillate unless it is disturbed. Theoretically, once it is disturbed it will continue to vibrate indefinitely, because our equation does not take into account any air resistance (or electrical resistance in the case of the electrical equivalent system) or any energy losses in the system. In practice, however, you will find that the oscillations will reduce and die out due to these effects. The analogue computer should produce results very near to the theoretical predictions.

To run this program follow these steps:

1. Connect the patch panel.

2. Ensure A1 and A2 are Integrating and A3 is Adding.

3. Set mode switches to **Compute/Auto Reset** (S3) and **Compute/Auto Hold** (S4).

4. Switch the power on.

5. Play around with the dial setting of P1. By reducing its value you will see the spring extending (displacement d on ME2), until the amplifiers saturate. Now increase the value of P1 to make the system oscillate at different frequencies, as you vary the value of K/m. Observe the meters ME1 and ME2 to see how the system behaves.

You should find that a high value of K/m (i.e. a high spring stiffness or small mass, or both), gives a high frequency of oscillation and vice versa. The other point to note is that the oscillation is sinusoidal. The output of A1 (the velocity, v), is a cosine function, whereas that of A2 (the displacement, d) is a sine function.

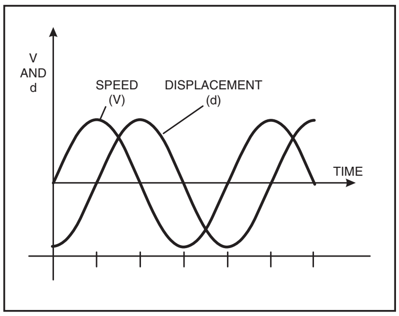


Fig.27. Solution to the problem of the spring-mass system.

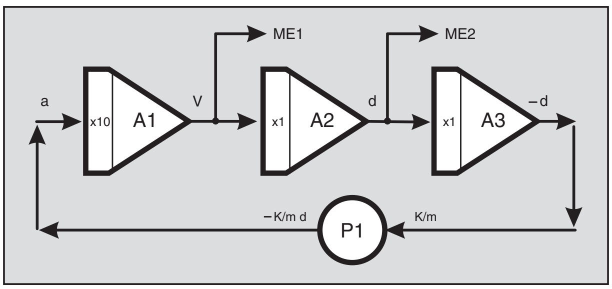


Fig.26. Flow diagram for spring-mass system.

There is a 90 degree phase difference between the two. That is, the mass comes to a momentary stop when the displacement is at its maximum value. This is shown by the diagram in Fig.27.

Notice that we have managed to program the analogue computer to solve the differential equation and produce the solution without having any mathematical knowledge on the solution of differential equations. The only knowledge needed is to be able to apply Newton's Law of Motion. This is one of the great advantages of an analogue computer.

DAMPING EFFECTS

Damping is caused by air resistance or electrical resistance. This form of damping is called *viscous damping* in mechanical systems and is proportional to the velocity.

Viscous resistance is sometimes unwanted. For example, it forces us to burn fuel continuously to drive cars or to propel aeroplanes through the air. Spacecraft travelling in empty space do not have to do this, although they have to burn fuel to decelerate.

In other cases, we find damping very useful. Mechanical vibration is one of these cases, where damping helps to reduce unwanted and dangerous vibrations. Without it, motor cars would provide a very rough ride. Representation of mechanical and electrical damped systems is shown in Fig.28.

In the mechanical system, damping is provided by a dash pot which is full of oil. This system resembles very closely the suspension system of a motor car.

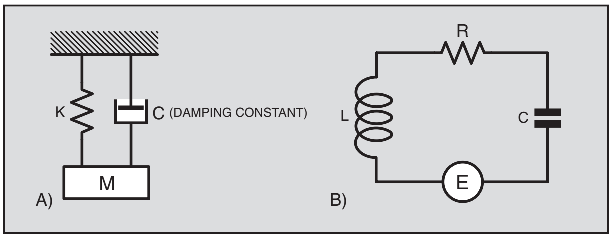


Fig.28. Mechanical and electrical systems with damping.

The following equation applies to the mechanical system:

$$F = ma + Cv + Kd$$

where C is the viscous damping factor.

The equivalent flow diagram is shown in Fig.29.

Connect the program on the patch panel and run it. You can try various forcing functions (F), such as impulse, step, sinusoidal, etc. The impulse function can be achieved by momentarily touching the wire connected to the input of A1 on a reference voltage socket carrying +15V. The diagrams in Fig.30 and Fig.31 show what results to expect when impulse and step forcing functions are applied.

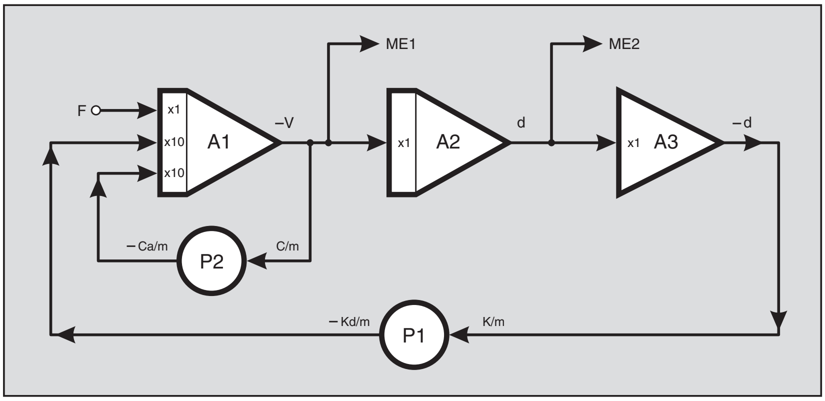


Fig.29. Flow diagram for the damped system.

Turn the dial of potentiometer P1 to select various damping values and observe the results. At a particular value of damping the output reaches the final value with no oscillation and at the shortest possible time. This value is called *Critical Damping*.

One application of the above is in the construction of analogue measuring instruments, like moving coil meters, etc. The input of such instruments is usually a step function and the needle is damped to a value very near the critical damping value so that the meter can be read with the minimum of delay.

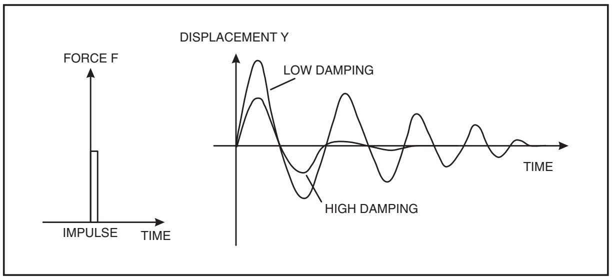


Fig.30. The effect of the impulse function.

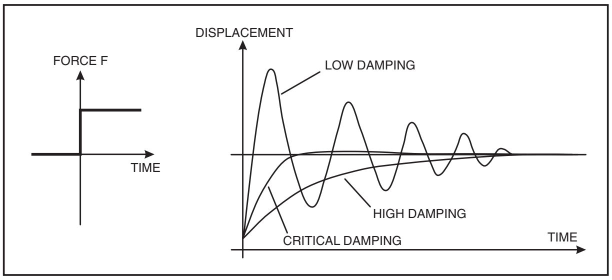


Fig.31. The effect of the step function.

CRACKING THE ATOM

The ATOM is a powerful microcontroller (MCU) which can be programmed in BASIC. It is a customised variant of Microchip's PIC16F876 and offers powerful commands enabling the programmer to carry out operations which would be difficult to achieve in PIC Assembly language, such as floating point mathematical operations. With ATOM BASIC one can perform 32-bit multiplication and division with real numbers up to a maximum value of 4,294,967,295, and this can be done in one line of code.

ATOM BASIC can handle bits, nibbles (4-bit), bytes, words (16-bit), and long values (32-bit), binary, hexadecimal, decimal, integer and floating point mathematical operations. The programmer is offered the usual BASIC facilities such as arithmetic and logical operations, subroutines, arrays, etc. as well as specialised commands which can control servo and stepper motors, produce sound, etc.

The ATOM retains the 384 bytes of RAM and 8K of FLASH program space of the fundamental PIC16F876. It has a built in 5V regulator, a serial port for in-circuit programming and data communication, and an analogue-to-digital converter (ADC).

To program the ATOM, first install the ATOM software which is supplied on a CD-ROM when you buy the chip, or which can be downloaded from the BASIC MICRO manufacturer's internet site at **www.basicmicro.com**. The software enables the programmer to write, compile, load and run programs under an Integrated Development Environment (IDE).

If the software is downloaded, double-click the **.EXE** application and it will automatically unzip. Then double-click the **setup.exe** file, and follow the on-screen prompts.

If the software is installed from the CD-ROM, insert it into your computer. If autorun is enabled the installer menu will appear, select your software and the installation process will begin automatically. Restart your computer after the installation is complete.

Start the software and spend a while reading the *getting started* section of the manual and familiarise yourself with the IDE. Understanding all the features of the IDE will make it easier to use the ATOM more efficiently.

Before you program the microcontroller, connect the Hybrid Computer's RS232 output socket to a vacant serial COM port on your PC, using an appropriate cable. Usually COM2 will be available.

FIRST ATOM PROGRAM

To enter and run your first ATOM program, follow these steps:

1. Run the ATOM software.
2. Click the **Build** button at the bottom of the screen (see Fig.32).

3. Select File, New, Mbasic file, enter file name, and Save.
4. Enter the following program:

```
main
        debug [“Hello”]
        pause 100
        goto main
end
```

5. Save this program with any name of your choosing.
6. Configure the COM port by selecting Tools, System setup, COM2.
7. Switch the Hybrid Computer on and place toggle switch S5 to **Program**.
8. Click on the **Debug** button at the top left corner of screen.
9. Wait until the program is automatically compiled and loaded into the ATOM.
10. Click the **Connect** button, then **Animate** or **Run** to run the program.

You should get the word “Hello” repeatedly displayed in the output window. The command **debug** instructs the ATOM to display the “Hello”, and the **pause 100** instruction to wait 100ms before executing the next instruction, to again repeat “Hello”.

If this program works successfully then it can be assumed that the ATOM is operating correctly and you can proceed to more useful programming.

RS232 SERIAL TESTING

The following program is a test for the Hybrid Computer’s ability to communicate with your PC via the RS232 serial link.

```
Main
      serout s_out,i9600,[“hello”]
      pause 100
      goto main
end
```

This is almost the same program we used before, but this time the **serout** command outputs the data from the Hybrid Computer’s serial port at a baud rate of 9600 bits per second.

This time do not click on the **Debug** button as the debug mode does not work with the **serout** command. Click on **Program** instead, to enter the routine that compiles the program and loads it into the program area of the ATOM.

When the program has been loaded into the ATOM, switch S5 to **Run**, click on **Terminal1** at the bottom of the screen, configure the port to COM2, 9600 bits per second, no parity, no flow control, echo, and click **Connect**. You should see the word “hello” repeated every 100ms.

To make sure that the data arrives correctly and can be read by an independent program, minimise the PC’s Basic Micro software window, and click the Windows Start button, then select programs, accessories, communications, hyperterminal.

This is a program which is available with Windows and can be used to read serial data. Configure the hyperterminal to **Connect using: direct from COM2**. Click Configure and set the port configuration to 9600 bits/s, 8 data bits, no parity, 1 stop bit, and no flow control. Then click on **Advanced** and disable the **Use FIFO buffers** and click **OK**. Then click **Connect** and see if the word “hello” comes through.

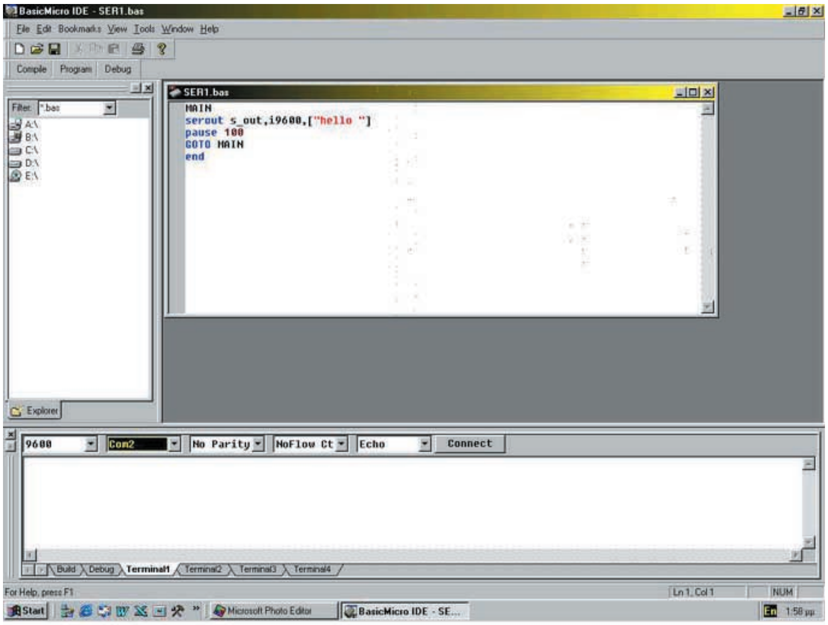


Fig.32. The ATOM software Integrated Development Environment screen.

When finished click disconnect and go into the properties again to return the properties to default. If you fail to do this, you will not be able to reprogram the ATOM because the programming software uses the same COM2 port to send and receive program information.

ADC TESTING

The ATOM has the capability to convert analogue signals to digital values. This is a very useful system to have in a hybrid computer as the two parts of the computer cannot communicate with each other unless the information is converted from one system to the other.

One point to bear in mind here is that the ATOM microcontroller operates on a supply voltage of +5V whereas the analogue computer works with ±15V. The analogue voltage to be converted to digital ***must*** be restricted to values between 0V and +5V. An application of a voltage outside this range on an ADC pin of the ATOM may cause damage to the system.

This may seem very restrictive but there are ways to get round the problem by scaling the input signals, as we shall explain later. For the moment set up the program in Fig.33 on the analogue computer and connect to the ATOM’s ADC pin AX0.

Adjust the dial of the potentiometer P1 to give an output of –5V maximum. Once adjusted do not touch the dial of P1 while the program is running. The –5V signal is inverted by A1 and P8 is used to vary the signal value from 0V to 5V. This way there is no danger of an inadvertent movement of the dial of the potentiometer to present the ADC pin with a voltage outside the range of 0V to +5V.

Enter the following ATOM program.

```
;program to convert analogue value to digital and transmit it to PC
;variable definitions
        value VAR byte
;A/D sampling definition
        clk con 2
;main program
        main
;A/D pin AX0, right justified
        adin AX0,CLK,AD_RON,value
;send value to PC
        serout s_out,i9600,[value]
        pause 100
        goto main
end
```

Do not use **DEBUG** to run the program as this mode does not work with the **adin** command. Click on **Program** to compile and load the program in the ATOM, ensuring than when you do this the toggle switch on the hybrid computer is switched to **Program**. When you run the program switch back to RUN. You can either set up **Terminal 1** to observe the results or use the Hyperterminal program as done before.

While the program is running turn the dial of the potentiometer to vary the analogue value. You will find that as the variable **Value** was declared as a byte the analogue value of 0V to 5V is converted to a digital value between 0 and 255 decimal and displayed as the corresponding character of the ASCII code.

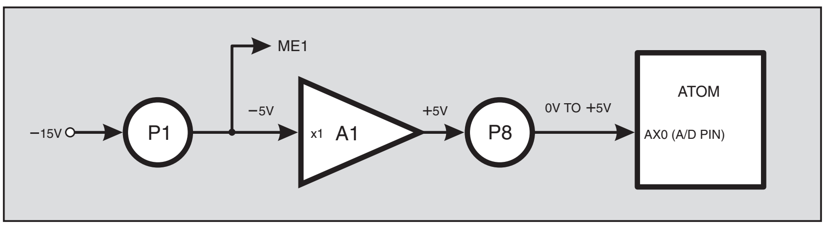


Fig.33. ADC setup program.

ATOM CONTROL

Set up the initial conditions program for the analogue computer, given earlier in Fig.23. There we used **Manual Hold** and **Manual Reset** to freeze the calculation and reset the analogue computer. We are now going to use the ATOM microcontroller to control the operations of **Hold** and **Reset** under program control.

Enter the following ATOM program and use **Program** to compile and load it into the chip.

```
;program to test auto Hold/Reset
        hold var byte
        reset var byte
;initialise variables, 1 ATOM pin P1, 0 is pin P0
        hold=1
        reset=0
        begin:
;place computer in reset and wait 3 seconds
        high hold
        high reset
        pause 3000
;place the computer in compute mode, and execute for 5 seconds
        low reset
        low hold
        pause 5000
;repeat operation
        goto begin
end
```

Before you run the program connect ATOM socket P0 to the **MODE Reset** socket, and socket P1 to the **MODE Hold** socket. When the program is run you should hear the relays click when the computer is placed in the **Reset** and **Hold** modes. When the computer is in the **Hold/Reset** mode the amplifier output will take its initial condition value.

AUDIO CIRCUIT TESTING

ATOM BASIC has commands to produce sounds, and even music. The following is a very simple program to produce some sounds to test the audio circuit.

```
begin:
;play 2 notes out of pins p1 & p2 of duration 1s and 2s
        sound2 p1\p2,[1000\2500\3500,
        2000\4500\6500]
        goto begin
end
```

Before you run this program connect ATOM sockets P1 and P2 to the two audio sockets.

FLIGHT SIMULATION

The flight of an object is described mathematically by differential equations, and these equations can be solved easily and efficiently by the analogue computer. To give an example of how it can be used as a flight simulator, we get the analogue computer to solve the equations, transmit the velocity of the aircraft to the PC and program the PC to produce the graphics and animation.

Note that we select to transmit the speed and not the height of the aircraft as the voltage range of the analogue computer would not be sufficient to represent the range of height of flight envisaged. A Harrier Jump Jet in vertical flight has two forces acting on it, its weight (*mg*) as a downwards force, and the engine thrust (*T*) as an upwards force.

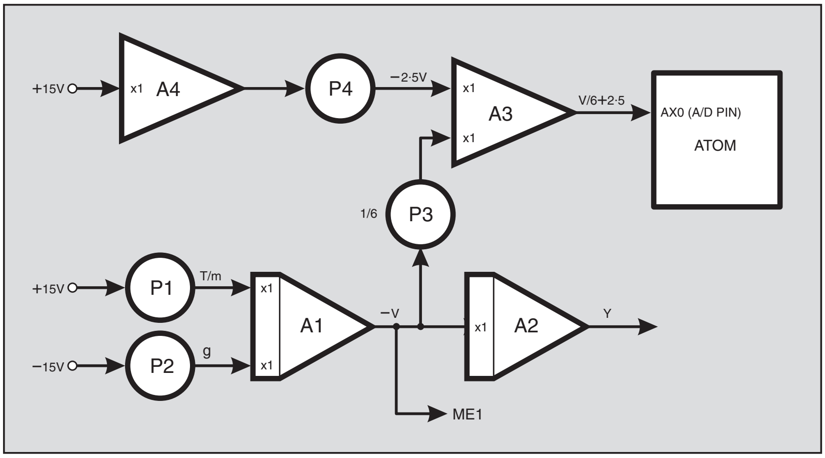


Fig.34. Flow diagram for the Harrier Jump Jet simulator.

The equation of motion according to Newton is:

$T - mg = m \times a$
(force = mass × acceleration)

where:
T = engine thrust
mg = aircraft weight
m = mass
a = acceleration

The analogue computer program in Fig.34 can solve this equation.

Amplifier A1 integrates $T/m - g$, which is the acceleration of the aircraft and outputs $-v$, which is the velocity inverted. Amplifier A2 integrates the inverted velocity to produce the altitude of the aircraft. The other two amplifiers and potentiometers are necessary to scale the velocity and present it to ADC pin AX0 of the ATOM, in the range 0V to +5V.

The output of amplifier A1 can swing between –15V and +15V. Potentiometer P3 divides this output by six (value is now between ±2·5V), and applies this signal to the input of amplifier A3. Amplifier A4 and potentiometer P4 are used to produce a reference voltage of –2·5V which is added to the signal at the other input of A3.

You can see now that as A3 also inverts the signals the output of A3 is in the range that we require, i.e. 0V to 5V. The ATOM now converts the analogue signal to a digital value and transmits it through the serial port to the PC for processing. The PC program can now take this value and scale it back to the original value, by subtracting 2·5 and multiplying by 6.

To run this program, complete the wiring on the patch panel and write the following ATOM program.

```
;program to convert analogue speed to digital and transmit it to PC
;variable definitions
        speed VAR byte
;A/D sampling definition
        clk con 2
;main program
        main
;A/D pin AX0, right justified
        adin AX0,CLK,AD_RON,speed
;send value to PC
        serout s_out,i9600,[speed]
        goto main
end
```

For the graphics and animation now use a Visual Basic program that has been specially written to work as follows:

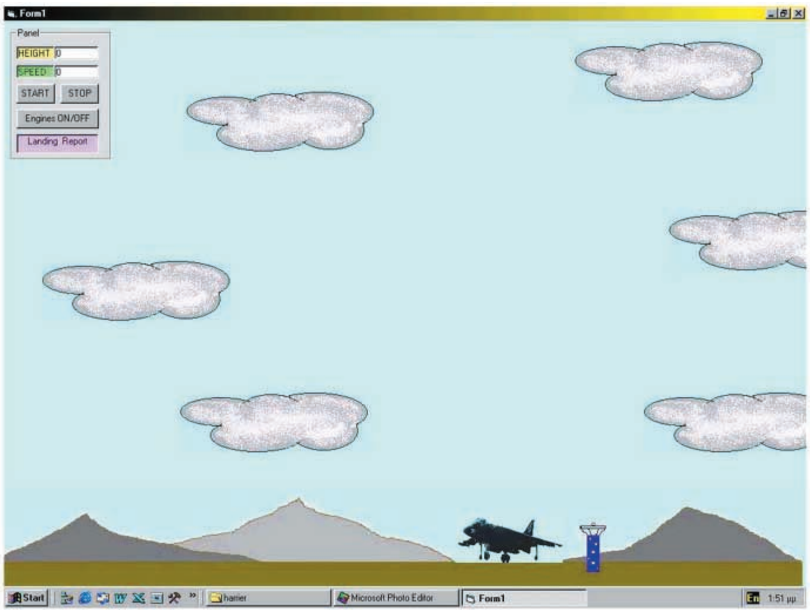


Fig.35. Harrier Jump Jet setup program.

The initial PC screen (Fig.35) shows a landscape with mountains, a cloudy sky and the Harrier on the ground near the control tower. As we apply power to the engines the aircraft takes off vertically and moves up the screen until it reaches a point three quarters of the way up.

At this point and if the aircraft is still gaining altitude, the picture of the aircraft remains stationary and the background picture begins to move down giving the impression of movement of the aircraft. If the thrust of the engines is reduced, the reverse movements occur, with the aircraft moving down until it lands.

The representation of the initial screen picture in Fig.35 also includes an animated instrument panel showing speed, height and other information.

This program is supplied with this project's software. With very little code, a realistic flight simulator has been produced, which communicates with the Hybrid Computer for input information, and which produces graphics with animation.

The program is "standalone" and does not need VB itself to be loaded on the PC. The program's source code is included for those who have a suitable version of VB which can handle serial communications and wish to experiment.

Before running the program, connect the patch panel, connect the serial cable to the PC's COM port, switch the Hybrid Computer on, adjust potentiometer P1 to give a high enough thrust for take off, and click **START** and **ENGINES ON**. After take off, adjust P1 to gain height, hover, and finally to land.

Try to make a smooth landing as you will receive a landing report. At all times the instrument panel will display information about the altitude and speed of the aircraft.

Just for comparison, included with the software is a purely digital version of the same program which does not need the Hybrid Computer to work. All the calculations are done by the PC program. You can download and run this program on your PC before you build your Hybrid Computer, to get a taste of what to expect.

To operate this program after double clicking on the file, click **START** and **ENGINES ON**, and apply thrust by pressing the numeric keys (0 to 9). Keying 9 gives maximum thrust whereas 0 gives no thrust. A value around 4 to 5 achieves hover.

ADDITIONAL CONSIDERATIONS

It was mentioned previously that analogue computers have the disadvantage of a limited voltage range of operation, in our case ±15V. Had we decided, in the Harrier example, to transmit the height to the PC for processing, then we would be limited to a flight from ground to an altitude of 30m if we assume 1V to represent one metre in height.

This problem was avoided by transmitting the speed and letting the PC work out the height. This way +15V represents a speed of 54,000km/hour (more than enough range!), if we assume 1V to be equal to 1m/s.

There is another solution to the problem of limited voltage range which is called Amplitude Scaling. This involves working out additional multiplication factors which are applied to the inputs of amplifiers.

For example, assume for convenience that our voltage range is ±10V, and that we wanted to investigate the flight of the Harrier up to a height of 1000m. We need, therefore, to apply a scale factor of 10:1000 or 1:100, i.e. 0·01. Similar scale factors are worked out for the velocity and acceleration, say 0·2. The equation of motion now becomes:

$$0{\cdot}2 \times a = 0{\cdot}2 \times \left(\frac{T}{m} - g\right)$$

Another consideration which crops up with analogue computers is the need for time scaling, because the solution of differential equations may extend over periods of time ranging from microseconds to many hours. Apart from the fact that it is not convenient to record results that occur within a split second, or results that take many hours to produce, errors occur at high speeds (or frequencies), like phase shifts in computing elements and measuring instruments. Also, at very low speeds, error voltages tend to build up when integrated. Time scaling involves reducing or increasing the gain of Integrators. Time is not involved in the operation of Adders.

SPECIAL TECHNIQUES

Many special circuits and techniques are also used with analogue computers. Some of these involve the use of diode shaping circuits to produce non-linear functions. In physical systems we often find such effects as backlash, Coulomb or dry friction, dead space, etc. Expanding on these topics, though, is beyond the scope of this article.

Another useful unit used with analogue computers is the analogue multiplier which is capable of multiplying two variables. Four quadrant multiplier chips are readily available, but this too is beyond the scope of this article.

The *EPE* Hybrid Computer is a very powerful and versatile tool. As the flight simulator program shows, the programmer can get both aspects of the system, the analogue and the digital, to work together for best results. Moreover, the machine is a great development tool, thanks to the powerful on-board ATOM microcontroller. The ease with which one can write and load programs is a great bonus. We are sure electronics enthusiasts will find many uses for this design.

Petros Kronis is the Engineering Science Teacher at the A' Technical School, Limassol, Cyprus.

RESOURCES

The VB6 software for this project is available for free download from the *EPE* ftp site, or on CD-ROM (for which a charge applies) from the *EPE* Editorial office, see the *EPE PCB Service* page for details. Software for the ATOM can be supplied on CD-ROM when you buy this microcontroller (see this month's *Shoptalk* page for details) or can be downloaded from **www.basicmicro.com**.

SUGGESTED BOOKS

Introduction to Analogue Computers, Technical Education & Management Inc., Foulsham. ISBN 05720027895.

Introduction to Electronic Analogue Computers, C. A. A. Wass, Kenneth Charles Garner, Pergamon Press. ISBN 0080110711.

Design and Use of Electronic Analogue Computers, C. P. Gilbert, Chapman & Hall. ISBN 0412074605.

Analogue and Hybrid Computers, I. V. Borsky, J. Matyas, Iliffe. ISBN 0592017079.

Analogue Computers, Michael Brand, Timothy Eduard Brand, E. Arnold. ISBN 0173122552.

INTERNET LINKS

From the internet and using a search engine such as **www.google.com**, type the words "analogue computer" and search to find a lot of information.

www.science.uva.ul/faculteit/museum/analog computers/ gives details of an analogue computer aircraft simulator at the Royal Aircraft Establishment.

www.dcoward.best.vwh.nct is an analogue computer museum with pictures of various machines.

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270 pages **Order code NE36** **£13.99**

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.

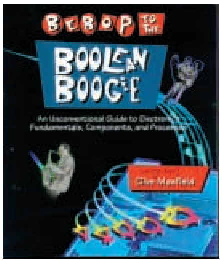
After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors 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.

222 pages **Order code NE31** **£18.99**

Bebop To The Boolean Boogie

By Clive (call me Max) Maxfield
Specially imported by EPE – Excellent value

An Unconventional Guide to Electronics Fundamentals, Components and Processes



This book gives the "big picture" of digital electronics. This indepth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!).

Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day. . . .

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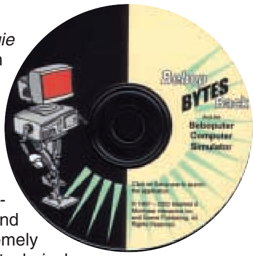
CD-ROM

Clive (Max) Maxfield and Alvin Brown



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 CD-ROM 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 CD-ROM 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!

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DIGITAL ELECTRONICS – A PRACTICAL APPROACH

FREE SOFTWARE

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

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

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

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

250 pages **Order code NE28** **£19.99**

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Ian Hickman

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The contents include a description of the basic oscillscope; Advanced real-time oscilloscope; Accessories; Using oscilloscopes; Sampling oscilloscopes; Digital storage oscilloscopes; Oscilloscopes for special purposes; How oscillocopes work (1): the CRT; How oscilloscopes work (2): circuitry; How oscilloscopes work (3): storage CRTs; plus a listing of Oscilloscope manufacturers and suppliers.

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"Did you ever wonder how the circuit boards and silicon chips inside your personal computer or cell phone were designed? This book walks you through the process of designing a city on an alien planet and compares it to designing an electronic system. The result is a fun, light-hearted and entertaining way to learn about one of the most important – and least understood – industries on this planet."

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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.

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Owen Bishop

Owen Bishop has produced a concise, readable text to introduce a wide range of students, technicians and professionals to an important area of electronics. Control is a highly mathematical subject, but here maths is kept to a minimum, with flow charts to illustrate principles and techniques instead of equations.

Cutting edge topics such as microcontrollers, neural networks and fuzzy control are all here, making this an ideal refresher course for those working in Industry. Basic principles, control algorithms and hardwired control systems are also fully covered so the resulting book is a comprehensive text and well suited to college courses or background reading for university students.

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Robert Goodman

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The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

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Circuits and Design

PRACTICAL ELECTRONIC FILTERS
Owen Bishop
This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.
The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rythm sequencer and a multi-voiced electronic organ.
Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.
88 pages **Order code BP299** **£5.49**

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. Mixers. Volume and balance controls.
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HOW TO USE OP.AMPS
E. A. Parr
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R. A. Penfold
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The circuits covered are mainly concerned with signal generation, power supplies, and digital electronics.
The topics covered in this book include: 555 oscillators; sinewave oscillators; function generators; CMOS oscillators; voltage controlled oscillators; radio frequency oscillators; 555 monostables; CMOS monostables; TTL monostables; precision long timers; power supply and regulator circuits; negative supply generators and voltage boosters; digital dividers; decoders, etc; counters and display drivers; D/A and A/D converters; opto-isolators, flip/flops, noise generators, tone decoders, etc.
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The three volumes of our own *Wireless For the Warrior* by Louis Meulstee are also available. These are a technical history of radio communication equipment in the British Army from pre-war through to the 1960s.
For details see the shop on our UK web site at **www.epemag.wimborne.co.uk** or contact us for a list of *Radio Bygones* books.

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R. A. Penfold
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138 pages **Order code BP371** **£5.45**

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The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.
132 pages **Order code BP374** **£5.45**

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R. A. Penfold
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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.
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EVERYDAY PRACTICAL ELECTRONICS

The No 1 Magazine for Electronics & Computer Projects

VOLUME 31 INDEX

JANUARY 2002 TO DECEMBER 2002

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Back numbers or photostats of articles are available if required – see the *Back Issues* page for details. We do not supply kits or components for our projects.

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