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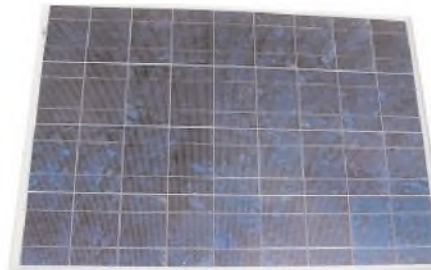
HB7 Stirling Engine

Base measurements: 128 mm x 108 mm x 170 mm, 1 kg
 Base plate: beech - Working rpm: 2000 rpm/min. (the engine has a aluminium good cooling Cylinder)
 Bearing application: 10 high-class ball-bearings
 Material: screw, side parts all stainless steel
 Cylinder brass, Rest aluminium and stainless steel.
 Available as a kit £80.75 or built £84.99
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STEAM ENGINE KIT

Everything in the kit enables you to build a fully functional model steam engine. The main material is brass and the finished machine demonstrates the principle of oscillation. The boiler, uses solid fuel tablets, and is quite safe. All critical parts (boiler, end caps, safety vent etc.) are ready finished to ensure success. The very detailed instruction booklet (25 pages) makes completion of this project possible in a step by step manner. Among the techniques experienced are silver soldering, folding, drilling, fitting and testing. £29.70 ref STEAMKIT Silver solder/flux pack £3.50 ref SSK
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HB9 Stirling engine

Base measurements: 156 mm x 108 mm x 130 mm, 0.6 Kg
 Base plate: beech Working rpm: approx. 2,000 min
 Bearing application: 6 high-class ball-bearings
 Material of the engine: brass, aluminium, stainless steel
 running time: 30-45 min.
 Available as a kit £97.75 or built £101.99
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HB14 Stirling Engine

Base measurements: 156 mm x 108 mm x 150 mm, 1 kg
 Base plate: beech Working rpm: 2000 - 2500 rpm/min, .
 Incl drive-pulley for external drives Bearing application: 10 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel
 Available as a kit £140.25 or built £144.50
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HB10 Stirling Engine

Base measurements: 156 mm x 108 mm x 130 mm, 0.6 Kg
 Base plate: beech Working rpm: approx. 2,000 rpm
 Bearing application: 6 high-class ball-bearings
 Material of the engine: brass, aluminium, stainless steel
 running time: 30-45 min
 Available as a kit £97.75 or built £101.99
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HB15 Stirling Engine

Base measurements: 128 mm x 108 mm x 170 mm, 0.75 kg
 Base plate: beech Working rpm: 2000 rpm/min. (the engine has a aluminium good cooling Cylinder)
 Bearing application: 6 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel
 Available as a kit £97.75 or built £102
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HB11 Stirling Engine

Base measurements: 156 mm x 108 mm x 130 mm, 0.7 Kg
 Base plate: beech
 Working rpm: 2000 - 2500 rpm/min,run
 Bearing application: 4 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel.
 Available as a kit £97.75 or built £101.99
www.mamodspares.co.uk



HB16 Stirling Engine

Base measurements: 128 mm x 108 mm x 170 mm, 1 kg
 Base plate: beech Working rpm: 2000 rpm/min. (the engine has a aluminium good cooling Cylinder)
 Bearing application: 10 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel.
 Available as a kit £140.25 or built £144.50



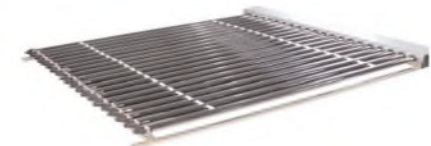
HB12 Stirling Engine

Base measurements: 156 mm x 108 mm x 130 mm, 1 Kg
 Base plate: beech Working rpm: 2000 - 2500 rpm/min,
 Bearing application: 6 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel.
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2kW WIND TURBINE KIT

The 2kW wind turbine is supplied as the following kit: turbine generator 48v three taper/ twisted fibreglass blades & hub 8m tower (four x 2m sections) guylines / anchors / tensioners / clamps foundation steel rectifier 2kW inverter heavy-duty pivot tower. £1,499



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AM/FM Radio This kit enables you to learn about electronics and also put this knowledge into practice so you can see and hear the effects. Includes manual with explanations about the components and the electronic principles. Req's: 3 x AA batts. £13 ref BET1801

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The 75 in 1 electronic kit includes an introduction to electrical and electronic technology. It provides components that can be used to make and test a wide variety of experiments including Water Sensors, Logic Circuits and Oscillators. The kit then progresses to the use of an integrated circuit to produce digital voice and sound recording experiments such as Morning Call and Burglar Alarm. Requires: 3 x AA batteries. £20 ref BET1806
www.slips.co.uk



HB13 Stirling Engine

Base measurements: 156 mm x 108 mm x 150 mm, 0.75 kg
 Base plate: beech Working rpm: 2000 - 2500 rpm/min,
 Bearing application: 6 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel.
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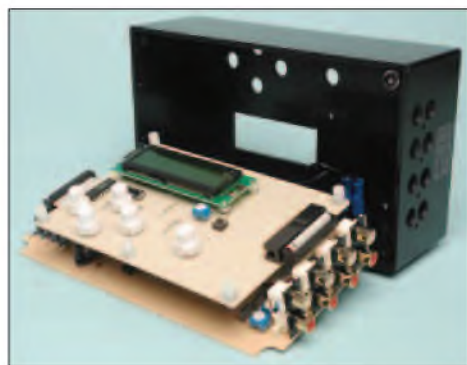
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VOL. 37. No. 1 JANUARY 2008

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Our February 2008 issue will be published on Thursday, 10 January 2008, see page 80 for details.

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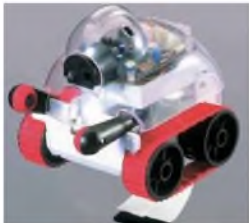
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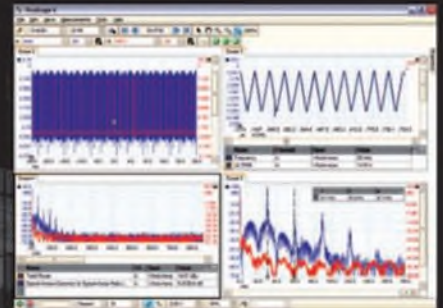
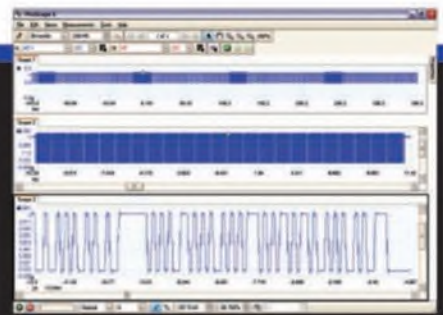
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- Specialized power supply design, particularly low noise power supplies
- Electronic safety interlock designs
- PIC Micro controller firmware development
- PC software development using C++ and visual studio
- PCB design and layout

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PCB Production - Development

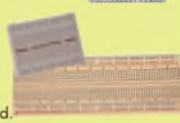
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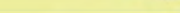
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Capacitance	2000pF - 20μF	(±2.5%)
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Process tanks feature electrically operated pumps and/or heaters with thermostat control, suitable for boards upto 320 x 260mm.	
Universal Tank with heater	
Model 333-007	£169 58
Bubble etch Tank with heater & bubble pump	
Model 333-004	£208 48

PCB Production - Tools

Drill Bits

HSS parallel shank bits available in sizes from 0.3mm to 2.0mm	
0.3-0.95mm in 0.05mm steps	£0 60ea £4 00/10
1.0-2.0mm in 0.1mm steps	£0 40ea £3 60/10

HSS Reduced shank (2.35mm) bit available in sizes from 0.6mm to 1.7mm in 0.1mm steps	£0 84ea £7 60/10
--	------------------

Drilling Machines

Expo Reliant 12V drill, 3.8mm capacity, 8400rpm	£12 78
Expo Zircon 12V drill, 3.8mm capacity, 11900rpm	£14 20

Minicraft MX1 230V, 8000 - 21000rpm with chuck & collet, Model EPE270-390	
Normal price	£48 51



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200ml Aero Duster	£5 13
250ml Cold Clean	£3 14
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400ml Isopropyl alcohol	£3 42



Tubes

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25g Heatsink Compound	£2 60
50g Silicone grease	£3 16

Bench Power Supplies

A range of single output regulated bench power supplies with variable voltage & current limiting. Features: Short circuit and "Foldback" overload protection, Metal case with on/off switch, outputs via Red, Black & Green (Earth) 4mm shrouded sockets.



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Model: 461-554	0-30V 0-10A	£135.00

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High quality analogue panel meters, class 2, zero point correction, mirror scale and prewired for panel illumination. Meter size 46 x 60mm, Cutout size: 38mm Ø

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0-1mA	200Ω	
0-10mA	20Ω	
0-50mA	1Ω2	
0-100mA	0Ω65	
0-1A	60mΩ	
0-3A	20mΩ	
0-5A	12mΩ	
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0-10V	10k	
0-15V	15k	
0-30V	30k	
±50uA	1k9	



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PCB Production - Laminates

Copper clad - paper

Single sided low cost paper composite board	Price
100 x 160mm Board	£0 54
100 x 220mm Board	£0 62
160 x 233mm Board	£1 02
220 x 233mm Board	£1 40
8" x 12" Board	£1 96

Copper clad - glass fibre

Single & Double 1.6mm 305g/m²	Price
100 x 160mm Single	£1 06
100 x 220mm Single	£1 49
160 x 233mm Single	£2 29
220 x 233mm Single	£2 88
8" x 12" Single	£3 99
100 x 160mm Double	£1 09
100 x 220mm Double	£1 25
160 x 233mm Double	£2 30
220 x 233mm Double	£2 90
8" x 12" Double	£4 05

Photoresist Coated 1.6mm 35 micron Pre-coated with a high quality photoresist layer. Available in low cost paper composite or Glass fibre, Single & Double sided. Other sizes also available.

Size	Paper Single	Double	Glass Fibre Single	Double
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6 x 12"	£4 20	£5 04	£5 60	£6 23
9 x 12"	£6 30	£7 70	£8 40	£9 38
10 x 12"	£8 19	£10 01	£10 78	£11 83
12 x 12"	£8 26	£10 08	£10 99	£12 25
100 x 160mm			£2 38	£2 66
203 x 114mm			£3 01	£3 43
220 x 100mm			£3 08	£3 71
233 x 160mm			£4 63	£5 32
233 x 220mm			£6 83	£7 70

PCB Production - Chemicals

100ml Aerosol Photoresist spray, covers 2m²		£4 62
50g Powder developer, makes 1lt		£1 09
500g Powder developer, makes 10lt		£7 08
250g Ferric Chloride Pellets, makes 500ml		£1 68
500g Ferric Chloride Pellets, makes 1lt		£3 04
2.5kg Ferric Chloride Pellets, makes 5lt		£9 84
Clear Fine etch crystals, makes 5lt		£17 58
90g Tin Plating Powder, makes 1lt		£11 58
200ml Aerosol Flux spray		£3 41
110ml Aerosol PCB Laquer spray		£3 54

Tools - Cutters & Strippers

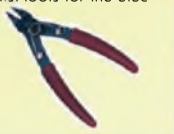
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RJ11 / 12 & 45 Series	£11 83

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Non insulated crimps	£24 38



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7/0 127mm Grey ribbon cable on a 0.05" 1.27mm pitch with a red identifying stripe. Supplied by 305mm (1ft) or on full 30.5m (100ft) reels.

Size	per 305mm	per Reel
10 Way	£0 10	£5 80
14 Way	£0 14	£7 50
16 Way	£0 16	£8 58
20 Way	£0 20	£10 72
26 Way	£0 26	£13 94
34 Way	£0 34	£18 22
40 Way	£0 40	£21 44
50 Way	£0 50	£26 80
60 Way	£0 64	£33 92
IDC Crimp tool		£10 60



CAT5e Networking

UTP Cable conforms to CAT5E 100MHz standard, EIA verified TIA/EIA 568-B.2

305m Box	£45 31
100m Reel	£22 28
exc carriage	

RJ45 Outlet Kit	
Backing Box	
2 Gang Plate	
RJ45 Module	
Blank Module	
Coloured id inserts	
£2.99ea £2.42 (10+)	



Tools	
Plastic punch down tool & cable stripper	£1 40
Professional punch down IDC & trim tool	£7 38



Outlets

CAT5e Outlet Module	£1 70
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2 Gang Plate (4 Mods)	£0 75
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Whiskers and wires

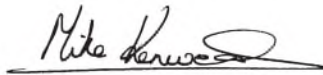
It seems that whiskers and wires could be the break and make of electronics. Mark Nelson reports in *Techno Talk* on problems with whiskers growing on tin-based materials such as solder – a problem that has become more apparent since the lead was taken out of the solder, as instigated by the EU.

The whiskers are causing breakdowns in electronics around the world. A similar problem is also occurring in germanium semiconductors where whiskers grow on the germanium and eventually short out the semiconductor; obviously this is mainly of concern to collectors of old equipment which uses germanium transistors.

At the other end of the scale, similar, but much smaller 'whiskers' in the form of nanowires could signal the next breakthrough in electronic storage. As we rapidly approach the limits of the present technology the race is on to find new ways to speed up computers and to store data, and 'sprintronics' could provide the answer.

Sprintronics is an emerging technology that relies on the detection of weak magnetic fields resulting from the spin of electrons. It may allow an almost infinite number of bits of information to be stored in one particle space. Such technology is being used to build experimental magnetic nanowires standing on end above the surface of a silicon wafer. The nanowire has polarised regions magnetised to point in a certain direction, thus enabling the storage of data. By applying a minute pulse of current to one end of the nanowire the data can be moved along and read off. It will probably take another five years to achieve a working prototype, but the resulting breakthrough in storage capacity could be massive.

The next step would be to develop sprintronics devices that integrate computing power and storage, but this is still a long way off.



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Enhanced Cellphone Options

Barry Fox reports on the developments taking place in cellphone technology

Nokia recently opened the doors of its R&D Centre at Oulu in the Arctic North of Finland for the very first time. Oulu was once the tar-making centre of Europe, but all that remains now of this industry is tar-flavoured schnapps. The town has gone hi-tech, with free WiFi throughout the city. Tero Ojanpera, Nokia Chief Technical Officer, and his engineers revealed developments now in prototype form, ahead of a commercial launch next year.

A cellphone with sensors measures pollution and automatically sends data to a central collection point – if all phones have similar sensors a wide area can be monitored. Another phone tells sky divers when to trigger their parachute. A new camera phone takes a photo when sent a text message; the phone then sends the photo to an Internet site, which is accessed by the remote photographer.

But surely this will be abused by paparazzi, spies and perverts? “It’s use will be subject to privacy concerns, and with permission of course” assures Ojanpera.

‘Shoot to Translate’ is optical character recognition software for a camera phone. Point the camera close to a menu, click to shoot a picture and the viewfinder displays the dish description in a different language. The prototype can cope with 8800 Chinese words and 600 Japanese, with near instant translation into English.

‘Point and Find’, promised for sale next year, is a camera phone which can be pointed at an object in a shop window,

or sales catalogue. The phone then uses optical recognition to steer the user to a website for purchase. Pointing the phone at a movie poster calls up a trailer from the Internet; or pointing at a location on a city guide calls up a list of restaurants in that area, with directions on how to find them. Indoor positioning lets a phone store a pre-loaded or downloaded plan of an indoor location, for instance a shopping mall, concert or festival venue. Any Internet connection, WiFi or cellular, can then be used by members of a family to exchange the map with their current position marked on the map.

A new ‘Home Automation and Remote Control’ system cuts through the chaos of competing and incompatible proprietary systems by using the UPnP (Open Source Universal Plug and Play) standard to let a cellphone work as a single controller.

Nokia is working with Visa on ‘Near Field Communications’ as a way of making a cellphone work as a credit or payment card. The phone has a built-in ‘secure element’ which is a chip, like the chip in a Chip and Pin credit card, with Visa Certification. In future, the secure element will be combined with the cellphone SIM.

Smart Connectivity is a future feature which lets a phone automatically detect and select the ‘most optimal’ way of communicating, WiFi or cellular network and seamlessly switch. “So the owner does not need to think about it”, says Ms Kaisu Laurila-Seluska. What do the cell networks think about this? For instance, because

Oulu has free WiFi, citywide there would be little or no cell revenue from Smart Connect phones. “We are in dialogue all the time. But it’s confidential. The best way to develop products is with end users – not leave them in the lab”, says Ojanpera.

So how come Nokia multimedia phones, designed for easy Internet and email use, do not have a key with a ‘.’; or an ‘@’; or a simple ‘back’ key to undo commands? “They are there if you can find them. Digital ‘natives’ know where to find them” was the best Ojanpera would offer in reply.

Press visitors were loaned the latest Nokia multimedia phones and encouraged to send text messages with questions and comments for real time display on a giant screen during speeches by head man Tero Ojanpera and his team. Before long the audience was using the screen as a communal message board and showing little interest in the speeches being made.

“I slept through the last speech,” wrote one unkind member of the audience. Afterwards, a Nokia minion confided: “We used the system for an internal meeting last week, and all the questions and comments were very sensible. We were surprised at how different it was today.”

There was a big difference though. Nokia’s employees would have been using their own phones, so any seditious comments would have been instantly traceable. The visiting journalists had been loaned phones which made their comments anonymous.

RETURN OF THE COLOSSUS

The world’s first programmable digital computer, developed at Bletchley Park to crack encoded German messages during World War II, recently returned to action to mark the launch of the first part of the emerging National Museum of Computing. It was the first time that *Colossus* has been used since Prime Minister Winston Churchill ordered the destruction of the top-secret machine in 1945, following the Allied victory that it helped achieve. This time the encrypted transmissions were entirely peaceful in content.

The rebuilt Colossus Mark II deciphered a teleprinter message transmitted by radio from colleagues in

Paderborn in Germany, having been encrypted by one of the original Lorenz cipher machines used by the German High Command during World War II. The Paderborn transmissions were intercepted at Bletchley Park by two groups of amateur codebreakers, one using modern equipment and PCs and the other using World War II technology. Other amateur code breakers were also invited to join the challenge to intercept the transmission and to try to beat Colossus in cracking the 1938 Lorenz SZ42 encrypted message.

The recreated Colossus is on public display at The National Museum of

Computing (www.ccht.co.uk/cipher1.htm) at Bletchley Park, Buckinghamshire, following a 14-year rebuilding project led by Tony Sale, a founder of the emerging Museum. Colossus provided the Allies with crucial information on enemy plans. The ten Mark II machines were instrumental in shortening the war by several months and leading to thousands of lives being saved.

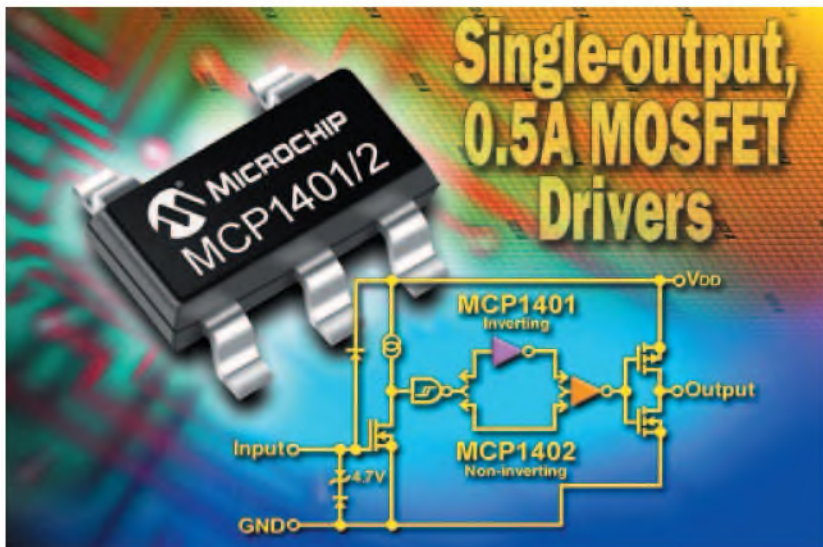
For more information on The National Museum of Computing browse www.tnmoc.org.uk, and for The Cipher Challenge browse: www.tnmoc.org.uk/cipher1.htm.

Microchip's MOSFETs

Microchip has announced the MCP1401 and MCP1402 (MCP140X) single-output MOSFET drivers. The inverting MCP1401 and non-inverting MCP1402 MOSFET drivers are rated for a peak output current of 0.5A, over a wide operating voltage range of 4.5V to 18V. They have excellent latch-up immunity and are available in miniature, 2mm x 3mm DFN and 5-pin SOT-23 packages.

By positioning the tiny gate driver close to the MOSFET's physical gate connection, designers can minimise gate bounce caused by the parasitic PCB layout, gate rise-and-fall times, propagation-delay times and shoot-through current, all of which help to increase system efficiency and reduce power dissipation.

For higher peak output-current applications, Microchip offers the 4.5A MCP 1403/4/5 dual and 6A MCP1406/7 MOSFET drivers. The MCP1403/4/5 devices are available in 8- and 16-pin SOIC and PDIP



packages, as well as a 6mm x 5mm DFN package, while the MCP1406/7 drivers are available in 8-pin SOIC, PDIP and 6mm x 5mm DFN packages, as well as a 5-pin TO220 package.

All of these devices are now available for sampling at sample.microchip.com and purchasing at www.microchipdirect.com. For further information visit www.microchip.com/MCP140X.

32 BIT ARM MICROCONTROLLER

Byvac have released the BV511 32 Bit ARM and operating system. It is an easy-to-use 32-bit microcontroller for education and real applications, with full documentation, easy start and no external tools required. Simply plug into the USB port, install the driver for Windows, Linux or MAC and use, no need for an external power supply.

All communication is via the built-in operating system based on Forth. The 100+ page user manual and tutorial shows how to interface all of the devices. User programs can be saved to Flash to produce a standalone system.

The system can be used as an upgrade path from 8 bits to 32 bits. It is said to be easier to use than most 8-bit microcontrollers, much more powerful, and small enough to be built into user applications. The possibilities are endless, from driving robots, milling machines, making a weather station, controlling heating to experimenting with light and audio.

No tools need to be installed on the PC and so the system can be programmed and used with any PC. It is ideal for students, with no need to be tied to the computer lab.

For more information browse www.bylvac.co.uk.

DAB RECEIVER FOR PC

BlueTinum tell us they are proud to present another world premiere – a USB dongle for a PC that combines DAB/DAB-IP/DVB-T/T-DMB. This combines both digital Radio and TV for your PC, with Teletext function and DVB subtitle support and an external antenna included.

The retail price is expected to be around €54.99 in retail stores around Europe, and is expected to hit the market for Christmas 2007.

For further information contact BlueTinum Denmark, Skudehavnsvej 15, DK-2100 Copenhagen, Denmark. Tel: +45 3325 5625. Fax: +45 3325 1025. Web: www.biuetinum.net.

Thinking Mouse?

A mouse that thinks it's a remote control, or a remote control that works like a PC mouse? Logitech's new MX Air is a cordless laser mouse that works equally well on a desk or in the air.

Looking like a sleek black mouse, the MX Air connects to a PC via a 2.4GHz wireless link, with up to 10 metre range. When moved over a flat firm surface, or mouse pad, it works like an ordinary optical mouse to control the cursor on screen.

When lifted off the surface and held in the air, the MX Air uses its built-in micromechanical gravity sensors and a miniature gyro to detect relative motion. So moving the mouse side to side moves the screen cursor side to side and so on. Pressing and holding a mouse button while moving the mouse sideways or in a circle mimics the rotary touch-sensitive volume and track skip control on an iPod.

Swiping a finger over the mouse controls scrolling; pressing buttons on the mouse controls music or video play, pause and mute. Ideal for use when a PC is being used at home as a TV, music or movie player, or on a plane when there is no room on the seatback tabletop to move a mouse, the MX Air costs £100. We tried the acid test and turned the mouse upside down while waving it in the air. The gravity sensors immediately detected and seamlessly compensated.

Barry Fox

MERG'S AUTUMN JOURNAL

The Model Electronic Railway Group (MERG) has sent its Autumn 2007 Journal. As usual, the Journal reports the activities of the various groups around the southern UK, and features on model railways in general. MERG report that new members are joining at the rate of 15 per month. They believe that this is due to the huge interest in DCC and the large reservoir of resources the Group is able to offer modellers.

To find out more about MERG, contact the Membership Secretary, Brian Martin, 40 Compton Avenue, Poole, Dorset BH14 8PY. Tel: 01202 701930. Email: memsec@merg.info.

EOCS Magazine

The latest quarterly issue of the magazine of the Electronic Organ Constructors Society (EOCS) has arrived, largely reporting this time on the activities on its branches around the UK.

If you are interested in constructing electronic organs and related items, browse www.eocs.org.uk, or contact Ron Coates, Treasurer/Secretary EOCS, 2 Boxhill Way, Seaford, Sussex BN25 3QB. Tel: 01323 894909.

Illuminated Magnifier

A handy new gadget has been launched – a credit card-sized magnifying glass. It magnifies by 250%, making it easier to see the finer details. It is light powered by LED technology, meaning that the light will last for ages.

It costs £4.99 from JML Direct TV (Channel 631) and is available via tel: 0871 2222 631, or via www.jmldirect.com, Boots, WHSmiths, Wilkinsons, Robert Dyas and Woolworths.

Older But Wiser?

A new crisis in the electronics industry? Perhaps not, but it may be only a whisker away. Ever the optimist, Mark Nelson hopes we might just escape the impending doom.

For cynics like me, Noel Coward's parody hit the nail on the head:

*There are bad times just around the corner,
There are dark clouds travelling through the sky
And it's no good whining
About a silver lining
For we know from experience that they won't roll by.*

Of course, if you don't remember these song lyrics, you probably won't remember Flower Power and dendritic growth either. No, we're not talking about hippies, beads or strange plant derivatives with therapeutic effects. The Flower in question was geranium, the dyslectic version of germanium. Back in those swinging sixties germanium, not silicon, was the dominant and all-powerful semiconductor material.

All-powerful but also very vulnerable, as it turned out. Unknown at the time, germanium is susceptible to dendritic disease ('dendritic' means tree-like, from the Greek word *dendron* – rhododendron simply means 'red tree' by the way). You could call this the Dutch Elm disease of the semiconductor world.

Just as most of the UK Dutch Elm trees have been wiped out, most germanium transistors are now either unusable or under threat, which does not please collectors of classic hi-fi equipment one bit. But before we get too deeply bemired in old history, let's see what's eating electronicists today.

Tin whiskers

If you are not careful, history can have a nasty habit of biting you on the bum. Of course, the Spanish-born American George Santayana put this rather more eloquently when he wrote: "Those who cannot remember the past are condemned to repeat it."

Today's problem is tin whiskers that look like errant strands of static-charged hair, erupting in every direction from tin-based materials such as solder. An Associated Press report explains that they measure typically less than a millimetre long and cause havoc with consumer gadgets, heart pacemakers and even a crucial part of a space shuttle. The trouble arises when these whiskers bridge separate parts of increasingly miniaturized circuit boards. They can also flake off and interfere with sensitive optics.

The phase-out of lead in electronic devices has triggered the problem, with many parts using pure tin instead of lead-tin alloys. The problem did not arise previously because the small amounts of lead mixed with the tin were remarkably effective at

preventing whisker eruptions. The lead ban began in Europe and according to Joe Smetana, a principal engineer and tin whisker expert with French telecommunications equipment maker Alcatel-Lucent, "The EU's decision was irresponsible and not based on sound science. We're solving a problem that isn't and creating a bunch of new ones."

EU officials say the regulations banning lead and other hazardous substances are needed to protect people and the environment. There are exemptions from the lead ban for companies in certain industries, such as aerospace, defence and medical equipment.

Space shutoff

Meanwhile, tin whiskers have already left a trail of destruction, chronicled in an extensive database of publicly disclosed failures kept by researchers at NASA's Goddard Space Flight Center in the USA. Last year, NASA engineers testing parts for the space shuttle *Endeavour* discovered that millions of tin whiskers were causing an electronic box to inaccurately point the shuttle's engine, knocking the rocket's trajectory off-kilter, said chief engineer Henning Leidecker, a tin whisker expert.

It turns out NASA had approved the pure-tin-coated clamps used for holding circuit boards in place back when the electronics were made in the 1980s, before the agency adopted its current rule requiring a small amount of lead in its tin coatings. "These whiskers have the potential to destroy missions," Leidecker said.

Problem from the past

Tin whiskers were first noticed in the 1940s. Back in those days, the problem was known as dendritic growth because the tiny hairs looked like small twigs sprouting from the branches or trunks of trees. A similar problem affects germanium devices and pure germanium is known to spontaneously extrude something known as very long 'screw dislocations', normally referred to as germanium whiskers. The growth of these whiskers is one of the primary reasons for the failure of older diodes and transistors made from germanium, as, depending on what they end up touching, they may lead to an electrical short.

This 'disease' commonly afflicts certain early germanium devices. Dead, intermittent or microphonic AF117 germanium transistors are well known among those who repair radios of the 1960s period. These are of the same mechanical construction as types AF114, AF115, AF116, OC170 and OC171, which are found in old televisions. The cause of death or fault mechanism is rather interesting.

Were you to open it up, you would find that the encapsulation surrounding the transistor contains silicon grease and an air space inside the metal can. From the inside wall of the can in the air space grow microscopic hairs (0.008mm across) that are tough, springy and electrically conductive. After some 25 to 30 years these conductive hairs reach the internal lead construction, giving the fault symptoms described. It is not clear if the air space is part of the design intent or is in fact a process error.

Remedies can be effected, of course, and the simplest one is to replace the faulty device with a stock part of the same type. This cure will be short-lived, however, because the conductive hairs will already be growing within this 'new' item, even if it is unused. The only permanent repair may be replacement with another type with similar electrical characteristics, which goes against the grain for anyone who values originality. A near-original repair is to snip the screen lead, thus isolating the can, but this may cause instability and presumably it is only a matter of time before a second internal lead becomes shorted to the can with the same symptoms.

Kill or cure

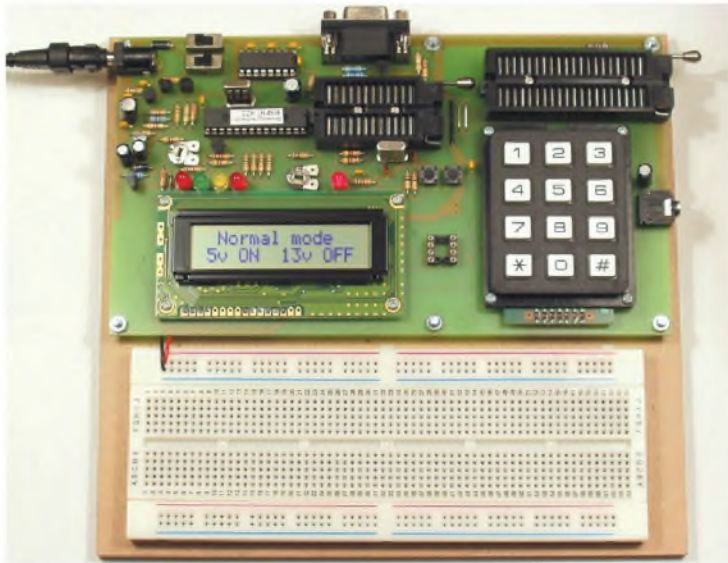
If you're truly adventurous, you may like to take action of an experimental nature. Two courses which have been suggested (I cannot vouch for them, having not evaluated them). One is to blow the short away electrically by discharging a capacitor of 50 μ F charged to, say, 50V connected between the can and the offending lead. The other is to unsolder the can seal, withdraw the offending lead, clean the can interior, refill with silicon grease and reseal. There is a diagram in chapter 13 of the book *Electronic Classics* by Andrew Emmerson.

There's a widely held notion that transistors are reliable, stable devices which, if not mistreated, will last for ever. In the main this is true, but as we've seen there are exceptions to the rule.

Another failure mechanism concerns plastic signal transistors made around 1970. Some of these have become hygroscopic and have absorbed sufficient atmospheric moisture to cause serious problems. The only solution is to replace them with metal-cased devices (which are hermetically sealed).

Plastic devices were never used in products made to military specification; for these metal-cased transistor and ceramic-cased integrated circuits were always specified. However, the plastic transistors were considered good enough for products aimed at the consumer and low-end professional markets.

Learn About Microcontrollers



P927 PIC Training Course £159

The best place to begin learning about microcontrollers is the PIC16F627A. This is very simple to use, costs just £1.30, yet is packed full of features including 16 input/output lines, internal oscillator, comparator, serial port, and with two software changes is a drop in replacement for the PIC16F84.

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- and PIC18F2321 test PICs. £159.00

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Experimenting with PIC Microcontrollers

This book introduces PIC programming by jumping straight in with four easy experiments. The first is explained over ten and a half pages assuming no starting knowledge of PICs. Then having gained some experience we study the basic principles of PIC programming, learn about the 8 bit timer, how to drive the liquid crystal display, create a real time clock, experiment with the watchdog timer, sleep mode, beeps and music, including a rendition of Beethoven's *Fur Elise*. Then there are two projects to work through, using a PIC as a sinewave generator, and monitoring the power taken by domestic appliances. Then we adapt the experiments to use the PIC16F877 family, PIC16F84 and PIC18F2321. In the space of 24 experiments, two projects and 56 exercises we work through from absolute beginner to experienced engineer level using the most up to date PICs.

Experimenting with PIC C

The second book starts with an easy to understand explanation of how to write simple PIC programmes in C. Then we begin with four easy experiments to learn about loops. We use the 8/16 bit timers, write text and variables to the LCD, use the keypad, produce a siren sound, a freezer thaw warning device, measure temperatures, drive white LEDs, control motors, switch mains voltages, and experiment with serial communication.

Web site:- www.brunningssoftware.co.uk

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PIC training and Visual C# training combined into one course. All the features of the P927 course with an extra book and enhanced programmer module.

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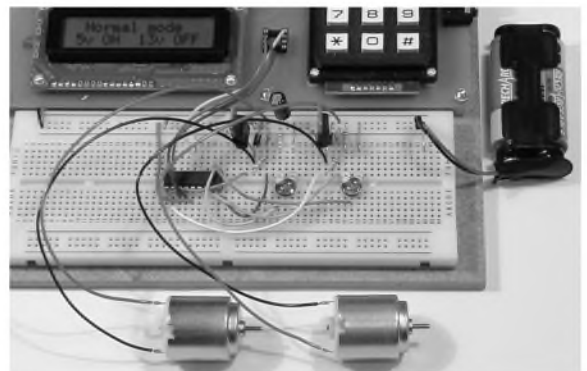
(Postage UK £8, Europe £14, Rest of world £22)

See:- www.brunningssoftware.co.uk/vcreview.htm

Ordering Information

Both training courses need either a free serial port on your PC or a USB to COM adapter (full details on web-site). All software referred to in this advertisement will operate within Windows XP, NT, 2000 or later.

Telephone with Visa, Mastercard or Switch, or send cheque/PO. All prices include VAT if applicable.



White LED and Motors

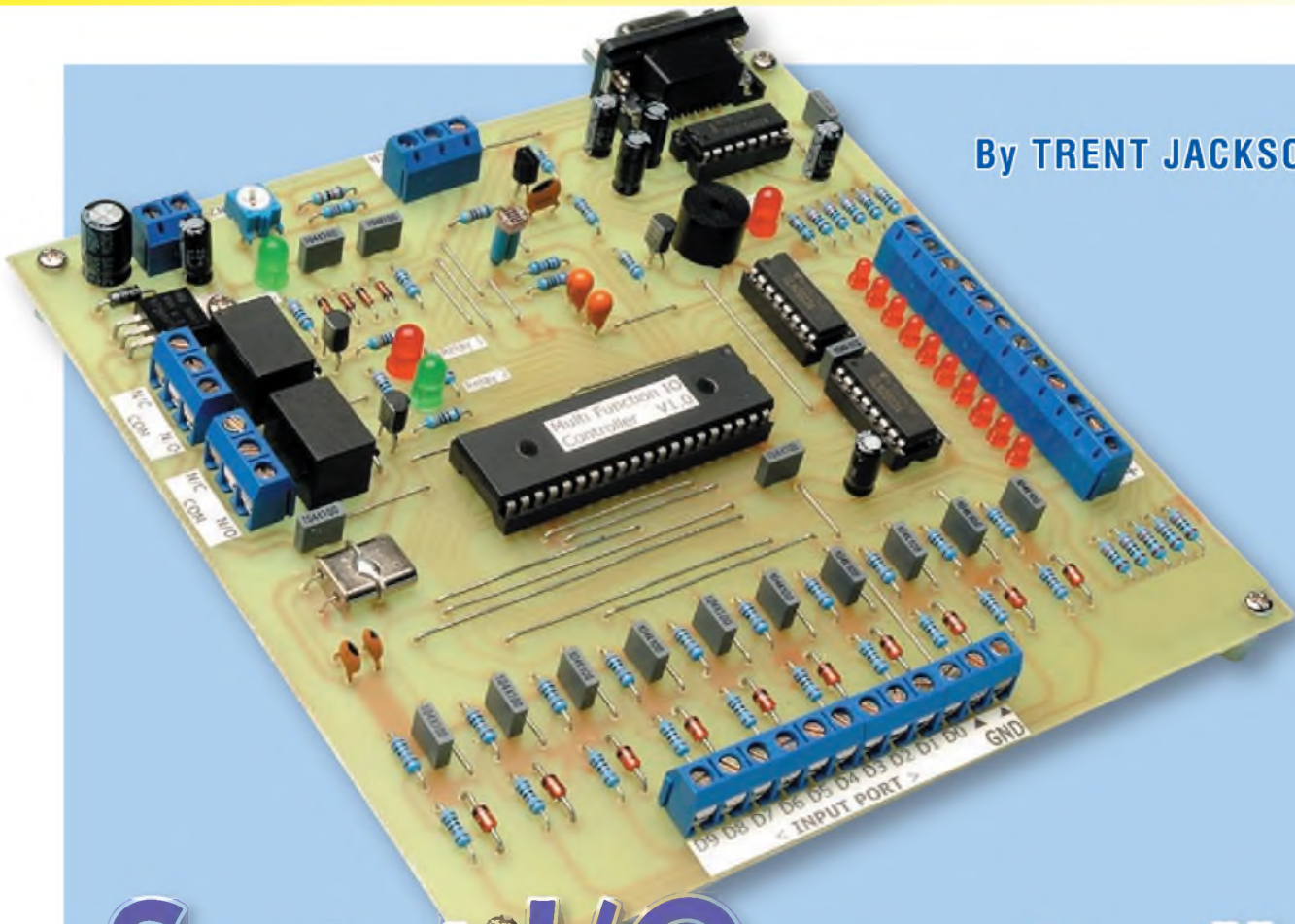
Our PIC training system uses a very practical approach. Towards the end of the second book circuits need to be built on the plugboard. The 5 volt supply which is already wired to the plugboard has a current limit setting which ensures that even the most severe wiring errors will not be a fire hazard and are very unlikely to damage PICs or other ICs.

We use a PIC16F627A as a freezer thaw monitor, as a step up switching regulator to drive 3 ultra bright white LEDs, and to control the speed of a DC motor with maximum torque still available. A kit of parts can be purchased (£30) to build the circuits using the white LEDs and the two motors. See our web site for details.

Mail order address:

Brunning Software 138 The Street, Little Clacton, Clacton-on-sea,
Essex, CO16 9LS. Tel 01255 862308

By TRENT JACKSON



Serial I/O controller & analogue sampler

Looking for an easy-to-drive I/O controller? This unit connects to the serial port of your PC and can be programmed to switch relays, in response to voltage, resistance, temperature and digital inputs. It also includes comprehensive system timers to control the relays and you can set the system up to operate as a PLC-style controller.

PC-based serial I/O controllers and analogue samplers are hardly new. However, this 10-bit unit has some special features that are normally hard to come by in a DIY unit, including closed loop control (as in a thermostat), spreadsheet logging, programmable I/O logic control, and temperature and light

sensing. It also includes real-time system timers that can be used to control two on-board relays.

Speaking of relays, you can also define 'less than' or 'greater than' values in the software to control them. This can be done for any of the input variables – temperature, LDR

resistance, analogue voltage inputs and digital inputs. For example, you could set one of the relays to switch on if the temperature goes above say 20°C and this could then control a fan or some other item of equipment. In short, there are lots of possibilities, especially as the unit can also be directly interfaced to other CMOS circuits.

You can also quite easily create your own software to control the heart of this project, which is (of course) a microcontroller – in this case a PIC! This particular PIC is a 40-pin 16F877A 'power plant', boasting 8K of flash memory, 256 bytes of RAM, eight analogue inputs, 256 bytes of EEPROM memory and lots of other features.

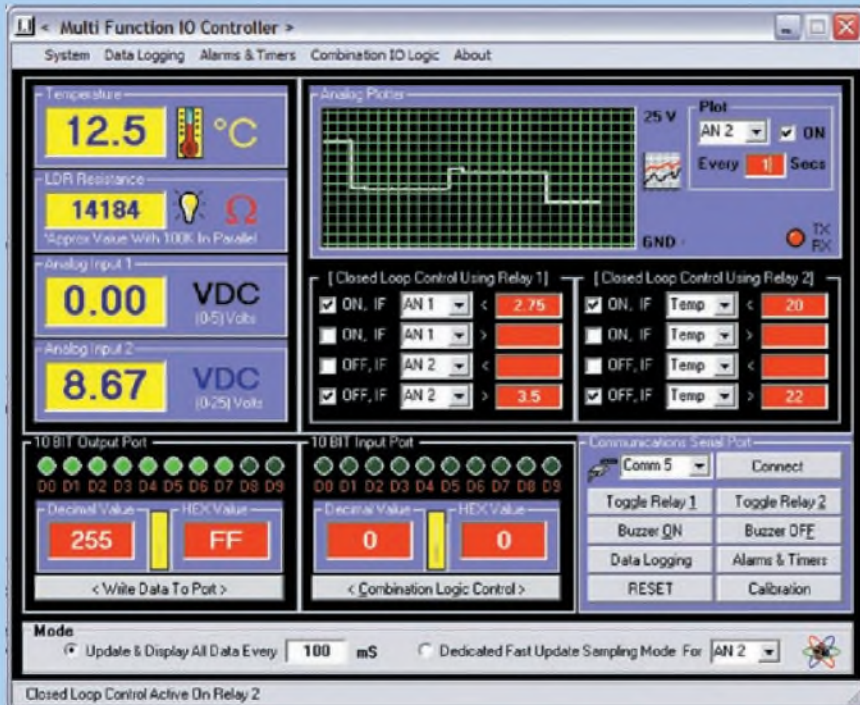


Fig.1: the Serial I/O Controller is controlled by Windows-based software. This is the main GUI (graphical user interface) – check out ‘The PC Software At A Glance’ section for a rundown on all the functions.

Features & Specifications

Rugged 10-Bit Digital Input Port (0-16V)
 0-5V and 0-25V Analogue Voltage Inputs
 Temperature & Light Sensing (LDR) Inputs
 High-Current 10-Bit Digital Output Port
 Closed-Loop Control Using Two Relays
 Serial Interface (2400 bits/s, Inverted)

Temperature Accuracy: $\pm 1^{\circ}\text{C}$
 On-Board System Timers Plus Buzzer
 32-bit Windows-Based Software
 Full Function SpreadSheet Logger
 CRO-Style Analogue Graph Plotter
 Combination I/O ‘AND OR’ Logic

In operation, the PIC communicates with your PC via a serial port. You can connect it to the PC using either a serial cable or a USB-to-serial adaptor.

It’s worth noting that there are not many DIY serial-based 10-bit I/O controllers ‘out there’, most being parallel port-based. The downside to using the serial port is that it is a bit slower. However, given the fact that all data is updated about four times a second, it isn’t all that bad.

Faster speeds can be obtained if you click on the ‘Dedicated Fast Update’ option in the software. In this mode, the variable that you select is updated at a rate of about 20 times a second. Once again, any of the data elements can use this mode, including temperature, analogue inputs, digital inputs

and LDR resistance value. The serial rate is 2400 bits/s, which is fast enough for the job and works reliably.

The system can also be set up to function as a ‘PLC-style’ controller. You can program it via the accompanying Windows software to accept a certain decimal value from the input port and in turn write a pre-defined value to the output port. With 1024 combinations to play with, there’s lots of logic control that can be used for your applications.

The input values, along with temperature and other analogue values, can be assigned to control either of the two on-board relays. A buzzer is also included – eg, to sound a warning when certain preset thresholds are exceeded.

Also included is an analogue plotter. This can be set to plot a graph of

the data element that you select over a preset period ranging from 1-999 seconds. In effect, it’s basically a mini low-speed oscilloscope – see Fig.1.

The output port can be directly written to by clicking the D0-D9 output lines on the software interface (to set the data value) and then clicking the <Write Data To Port> button. Alternatively, the data value can be entered by directly typing it in, in either decimal or hexadecimal format.

It’s the PC software that really makes this project. However, this software would be of little use without the PIC microcontroller – it generates all the analogue and digital ports and converts all the data on these ports into a serial data stream for the PC.

Logging as well

The data logging side of things can handle up to 1000 samples. You can set the sampling time anywhere from 1-999 seconds, which means that this unit is suitable for long-term data acquisition.

All analogue inputs have 10-bit resolution, which equates to a step size of about 5mV (ie, 5/1023). As a result, the temperature readout is capable of displaying 0.5°C changes. The first analogue input has a range of 0-5V and the second 0-25V (with a resolution of 25mV).

Provision has also been made for measuring resistance and there is an on-board LDR that changes resistance according to the light level present. You could replace this LDR with some other resistive device if desired. As stated previously, thresholds for this variable can also be set in the software to control the relays.

Circuit details

Fig.2 shows the block diagram of the I/O Controller, while Fig.3 shows the full circuit details. The circuit is dominated by the PIC16F877A microcontroller, which is clocked at 4MHz using crystal X1 and two 22pF loading capacitors.

This particular microcontroller was chosen mainly for its pin count, rather than for its 8K of program code space. In fact, the code occupies a mere 1K of memory for this project!

All but two pins on the 40-pin PIC micro are used, including four for A/D inputs, 20 for I/O lines, two for serial data transmission, two to control the relays, one for a buzzer and two for the TX/RX lines. Of course, this could all

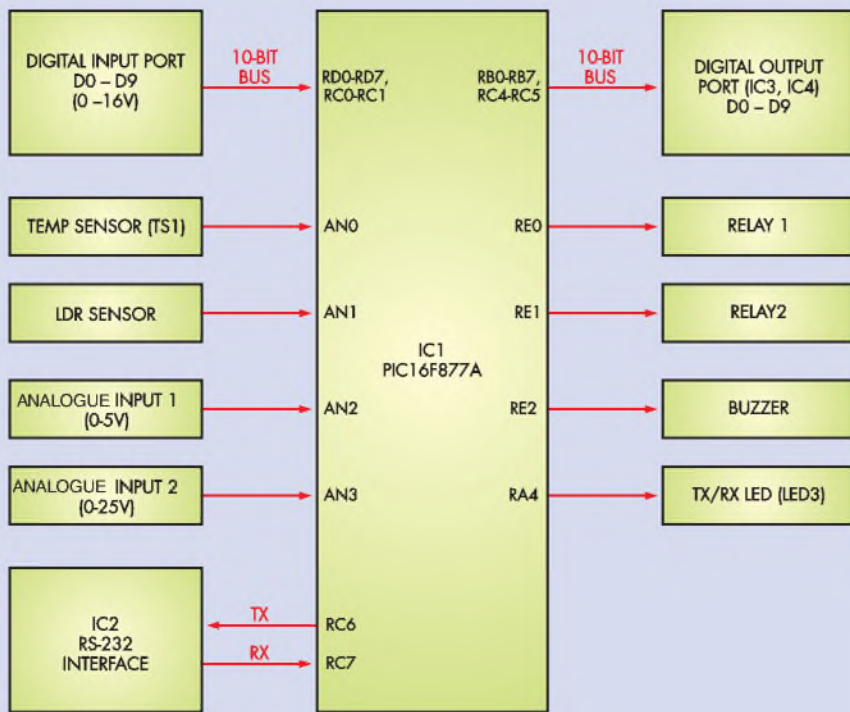


Fig.2: the PIC microcontroller (IC1) dominates the hardware side of the I/O Controller. It generates all the analogue and digital ports and converts all the data on these ports into a serial data stream for the PC.

have been done with (say) an 18-pin PIC16F628 plus a few discrete ICs. However, the 16F877A microcontroller has a price tag of just £4, so why bother?

As shown in Fig.3, the output port consists of two ULN2003 Darlington open-collector driver ICs (IC3 and IC4), along with 10 LEDs (LEDs 5 to 14) and their associated 330Ω current-limiting resistors. The LEDs draw about 10mA each, which is well within the capabilities of the ULN2003 drivers. In fact, these drivers can provide sink currents of up to 500mA per line (although this must be derated when more than one line is active), so there's still plenty of 'headroom' to connect your own 'goodies' to this port.

The LEDs hanging off this port actually have two functions. First, they give an obvious indication as to the status of the data lines (ie, which bits are set). And second, they act as pull-ups for the open collector outputs of IC3 and IC4. As a result, this port can be directly interfaced with other logic circuits (both TTL and CMOS). Note that because of the LEDs, the outputs are no longer open collector.

10-bit input

Want a 10-bit input as well? No problem – that's provided by lines D0-D9 on ports RD0-RD7 and RC0-RC1.

These lines feature Zener diode clamping (ZD1-ZD10), which means that up to 16V DC can be applied. In practice, 3.5 to 16V is the valid range for a logic high, while 0-2V is the valid range for logic lows. Values between these two ranges can be read as either high or low, depending on where the threshold is set.

As shown, a 1kΩ resistor, a 100nF capacitor, a 5.1V Zener diode and a 100kΩ pull-down resistor are connected to each input line. The Zener diodes clamp input voltages that are greater than 5.1V, while the 100nF capacitors and associated 1kΩ resistors act as filters.

The 100kΩ resistors have two functions. First, they act as pull-down resistors when the input lines are floating and second, they discharge the 100nF capacitors when the logic states change, so that the RC time-constants remain valid.

Data communication is achieved via the serial port and an RS232 interface based on IC2, a MAX232 serial data buffer. The external transmit (TX) and receive (RX) signals are on pins 13 and 14 of IC2 respectively, while the PIC micro communicates via ports RC6 and RC7 (pins 25 and 26).

At all times, the software in the PC calls the shots. The PIC micro 'sits

back' and waits for a command on the serial port with the format 'Sync Byte, Function' – see the Control Function Code panel for further details

This makes it very easy for custom software to be developed for this project and in fact, the whole idea was for it to be as universal as possible. A complete list of all the function commands is provided with this article.

Other circuits could easily be adapted to interface to this controller, including PICAXE circuits. The microcontroller software for this project was written using PIC Basic Pro, which is a true compiled high level BASIC language, with similar commands to the PICAXE. The source code is available as a free download from the EPE website at www.epemag.co.uk.

A/D converters

Four out of the eight available 10-bit A/D converters inside the PIC are used in this circuit – one for sensing temperature via an LM335Z precision temperature sensor, one for measuring the resistance of an LDR (or some other variable resistor) and two for measuring the 0-5V and 0-25V analogue voltage inputs.

The relevant inputs are ports AN0 to AN3 on the microcontroller (pins 2-5). The LM335Z temperature sensor is connected to AN0, the LDR to AN1, the 0-5V analogue input to AN2 and the 0-25V analogue input to AN3.

All calibration for these measurements is done via the Windows software provided. For example, temperature measurements are accurate to ±1°C after proper calibration. Considering that the A/D converter is 10-bit and the LM335Z output varies by 10mV/°C, this figure is to be expected.

Calibration for the 0-25V input is achieved using both the software and a 100kΩ trimpot (VR1). This trimpot, and its associated 330kΩ resistor function as an adjustable voltage divider. In practice, VR1 is adjusted to provide a division ratio of 5:1.

The best way to do this is to apply a precise 12.5V to the input, run the PC software and adjust VR1 until you read 12.5V on the screen. Further fine tuning can then be done via software.

Properly calibrated, this input is very stable and quite accurate. In fact, you could use it as a second meter for measuring DC voltages up to 25V.

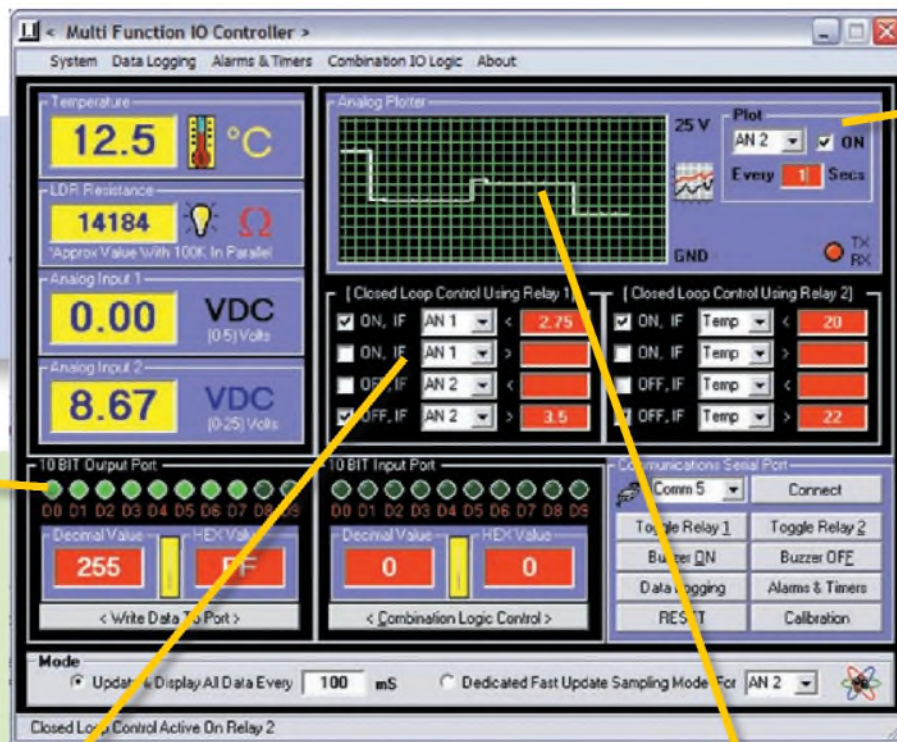
THE PC SOFTWARE AT A GLANCE

THE SOFTWARE for the I/O Controller has been tested with Windows XP and Windows 98SE but should also work with Windows 95, Windows 98 and Windows 2000. It has four main interfaces: (1) the main GUI (designated Multi Function IO Controller); (2) Data Logging; (3) IO Logic Control; and (4) Alarms and Timers. The last three are accessed via the main interface by clicking on the menu items.

Most of the control is retained within the main GUI. This has a host of options which range from displaying the values of all the data elements, a graphical analogue plotter, closed loop control, and input and output data control. In addition, there are a number of command buttons in the bottom righthand corner that perform various tasks (all of which are self-explanatory).

The first step in getting it working is to find an available Comm (serial) port on your PC and click the 'Connect' button. A communications link will then be established.

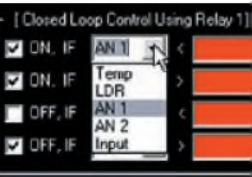
After that, it's simply a matter of setting up the system to perform the required task. The accompanying breakout boxes give further details.



THE INPUT VALUES (ie, Temperature, LDR Resistance and Analog Input 1 & 2 voltages) are clearly displayed here.

THIS SECTION lets you select which input variable to plot.

DATA CAN BE WRITTEN to the 10-bit output port by clicking on the D0-D9 LEDs or by entering in a decimal or hex value and then clicking the <Write Data To Port> button.



Clicking the down arrow lets you choose which input variable to use for closed loop control.

CLOSED LOOP CONTROL: this section lets you control either relay 1 or relay 2 (or both), according to an input variable (voltage, resistance or temperature). Here, for example, relay 1 has been set up to switch on if Analog Input 1 is less than 2.75V and to switch off if Analog Input 2 goes above 3.5V. Similarly, relay 2 switches on if the temperature is less than 20°C and off if the temperature rises above 22°C (ie, it could be used as a thermostat).

However, you have to be careful not to overlap conditions – eg, setting relay 1 to switch on if Analog Input 1 is greater than 3V and off if it goes above 2V would cause erratic operation by toggling the relay on and off continuously. Note that all data is automatically saved when you exit the software.

ANALOG CRO-STYLE GRAPH PLOTTER: this nifty little window shows the history of any input variable that you select by plotting a graph. You can define the update rate anywhere between 1-999 seconds. Alternatively, for faster speeds, you can select the fast update mode option that's located right at the bottom of the window. In this mode, the plotter is updated at about 20 times a second. Make sure you remember to enable this function by placing a tick in the 'ON' box. Plotter scaling is fully automatic for each element.

Variable Data Type	Value	Date	Time
Analog Channel 2	10.00 VDC	07-12-2005	17:03:45
Analog Channel 2	11.06 VDC	07-12-2005	17:03:46
Analog Channel 2	12.98 VDC	07-12-2005	17:03:47
Analog Channel 2	13.96 VDC	07-12-2005	17:03:48
Analog Channel 2	10.73 VDC	07-12-2005	17:03:49
Analog Channel 2	8.58 VDC	07-12-2005	17:03:50
Analog Channel 2	7.69 VDC	07-12-2005	17:03:51
Analog Channel 2	6.76 VDC	07-12-2005	17:03:52
Analog Channel 2	5.81 VDC	07-12-2005	17:03:53
Analog Channel 2	4.90 VDC	07-12-2005	17:03:54
Analog Channel 2	3.97 VDC	07-12-2005	17:03:55
Analog Channel 2	5.44 VDC	07-12-2005	17:03:56
Analog Channel 2	8.77 VDC	07-12-2005	17:03:57
Analog Channel 2	12.45 VDC	07-12-2005	17:03:59
Analog Channel 2	16.15 VDC	07-12-2005	17:04:00
Analog Channel 2	19.43 VDC	07-12-2005	17:04:01
Analog Channel 2	19.43 VDC	07-12-2005	17:04:02
Analog Channel 2	19.43 VDC	07-12-2005	17:04:03
Analog Channel 2	19.40 VDC	07-12-2005	17:04:04
Analog Channel 2	19.43 VDC	07-12-2005	17:04:05
Analog Channel 2	19.40 VDC	07-12-2005	17:04:06
Analog Channel 2	19.40 VDC	07-12-2005	17:04:07
Analog Channel 2	19.40 VDC	07-12-2005	17:04:08
Analog Channel 2	19.40 VDC	07-12-2005	17:04:09
10 BIT Input Data	0 Dec	07-12-2005	17:04:37
10 BIT Input Data	0 Dec	07-12-2005	17:04:38
10 BIT Input Data	0 Dec	07-12-2005	17:04:39
10 BIT Input Data	0 Dec	07-12-2005	17:04:40
10 BIT Input Data	0 Dec	07-12-2005	17:04:41
10 BIT Input Data	1 Dec	07-12-2005	17:04:42

DATA LOGGING: you name it you can log it – Temperature, LDR resistance, Analog Input channel 1 or 2, 10-bit input data . . . the choice is yours! What's more, you can set the logging interval from 1-999 seconds and up to 1000 individual logs can be recorded.

There's also a facility to automatically save logged data at a specified interval, to retain data in the event of power failure. The auto-log file is stored in the program's applications folder and can be opened in any text editor.

Other features include: save, open and print capabilities; logging with or without date or time; the ability to auto-clear the log sheet after 1000 samples have been recorded; and the ability to change the input variable on the fly.

The log sheet scrolls automatically as new data is logged. Once the log is full, a red LED flashes to indicate that you need to save or clear the log so that new data can be recorded – just click on the Clear Log button or select Start New under the logger menu.

THE COMBINATION IO LOGIC CONTROL dialog allows you to set the unit up to function as a PLC-style controller.

To assign values, just type the data in (in decimal or hex format), or click on the data lines. Do this for the input and output values and click on Add To List.

You can save, open and print all logic scripts. And there are a few options that allow you to manipulate the logic – invert, XOR and latch.

With latching, the output remains in its last state until a new input condition has been detected. Without latching enabled, the output port will be cleared once the input value has been removed.

After you create or open a script, be sure to enable it by ticking the Enable Logic Script box. When a script is active, a virtual red LED is turned on. The response time is about 250ms for normal update all data mode and 100ms for dedicated fast update sampling mode.

The screenshot shows the 'Combination IO Logic Control' window. It features a central 'Logic Script' area with 'IF' and 'THEN' sections. The 'IF' section has a '10 BIT Input Port' with a value of 255. The 'THEN' section has a '10 BIT Output Port' with values 341 and 155. Below this is a list of logic conditions and actions, such as 'IF Input Decimal Data = 179 THEN Output Data = 350'. There are buttons for 'Add To List', 'Remove', and 'Clear List'. On the left, there are checkboxes for 'Enable Logic Script', 'Latching Outputs', 'XOR IO', and 'Invert IO'. On the right, there are icons for saving, opening, and printing files.

THE ALARMS & TIMERS INTERFACE has a vast array of timer parameters and buzzer alarm settings, most of them self-explanatory. The main thing to keep in mind is that the time format for the timers is 24-hour mode and must include all digits – ie, trailing zeros.

All settings are automatically saved to a configuration file each time the program closes. These settings are then automatically loaded each time the program executes at start up. Deselecting the Use Date option allows the timers to be cycled on a daily basis (rather than just the programmed dates).

The buzzer alarm conditions are located at the very bottom and you can use any data element you wish. There are three separate conditions – make sure that none of them overlap.

The screenshot shows the 'Alarms & Timers' window. It is divided into two main sections: 'Timers Using Relay 1' and 'Timers Using Relay 2'. Each section contains two timer configurations. Each configuration includes a 'Start Date & Time Event' and a 'Stop Date & Time Event' with fields for Date (DD, MM, YY) and Time (24hr, HR, Min, Sec). There are checkboxes for 'Enable Event 1' and 'Use Date', and radio buttons for 'At Start Time Relay = ON / OFF' and 'At Stop Time Relay = ON / OFF'. At the bottom, there are three 'Sound Buzzer' conditions. Each condition has a 'Condition' dropdown (e.g., 'AN 2', 'Temp'), a 'Sound Buzzer' dropdown (e.g., 'ON', 'OFF'), and a 'Condition' value (e.g., '20', '18').

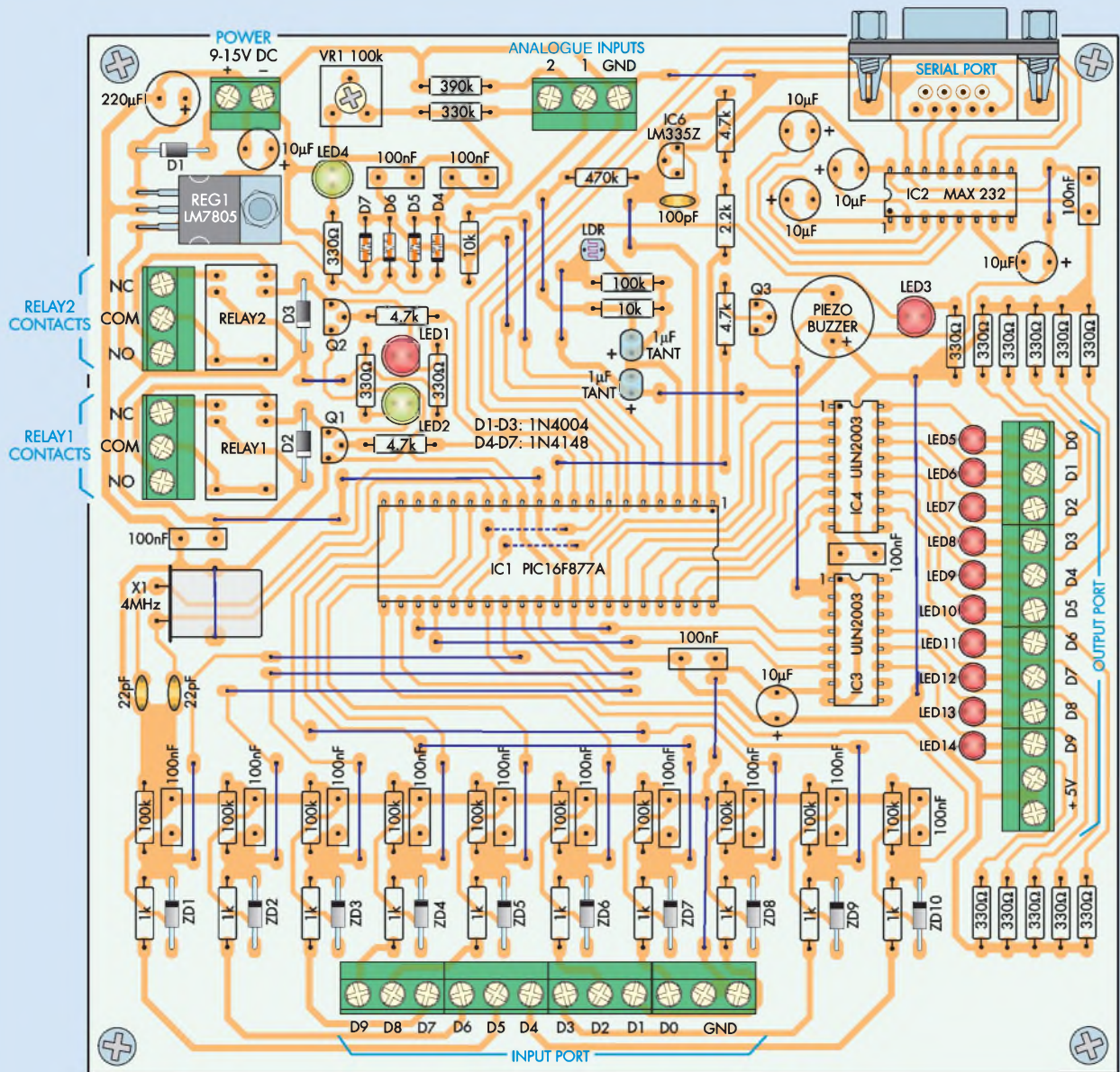


Fig. 4: install the parts on the PC board as shown here but don't install the PIC microcontroller until after the power supply has been tested (see text). Take care to ensure that all polarised parts are correctly oriented and be sure to take the usual precautions against static electricity when handling the ICs. Note that the relays are capable of switching low voltages (up to about 50V DC) only.

Table 1: Resistor Colour Codes

No.	Value	4-Band Code (1%)	5-Band Code (1%)
1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
1	390kΩ	orange white yellow brown	orange white black orange brown
1	330kΩ	orange orange yellow brown	orange orange black orange brown
11	100kΩ	brown black yellow brown	brown black black orange brown
3	10kΩ	brown black orange brown	brown black black red brown
3	4.7kΩ	yellow violet red brown	yellow violet black brown brown
1	2.2kΩ	red red red brown	red red black brown brown
10	1kΩ	brown black red brown	brown black black brown brown
13	330Ω	orange orange brown brown	orange orange black black brown
1	180Ω	brown grey brown brown	brown grey black black brown

Diodes D4 to D7 provide over-voltage protection for each of the four input channels (within reason). They do this by clamping the input voltage to the supply rail if it rises above 5.6V. The 100nF MKT capacitors on the inputs are rated at 100V, while the input impedance is a respectable 390kΩ.

Basically, the two analogue inputs should be able to cope with inputs up to about 50V DC.

Diodes D4 to D7 also eliminate any positive or negative-going spikes due to pulsed DC inputs. ADCs in PIC micros aren't very tolerant when it comes to glitches on the input being measured, so it's necessary to eliminate these.

Ports RE0 and RE1 on IC1 are used to control the on-board relays via buffer transistor stages Q1 and Q2. A 1N4004 diode is included across each relay coil to protect the driver transistors from any back-EMF that may be generated when the relays switch off. LEDs 1 and 2 indicate the status of the relays – ie, LED1 is on when Relay1 is on and LED2 is on when Relay2 is on.

Port RE2 is used to switch the buzzer (PB1) via transistor buffer Q3. This buzzer can be used to warn of certain conditions, as set via the software. For example, it could be set to turn on if the ambient temperature rises above a certain level. Alternatively, it could be programmed to sound if the analogue voltage reading on Ch1 falls below a critical threshold.

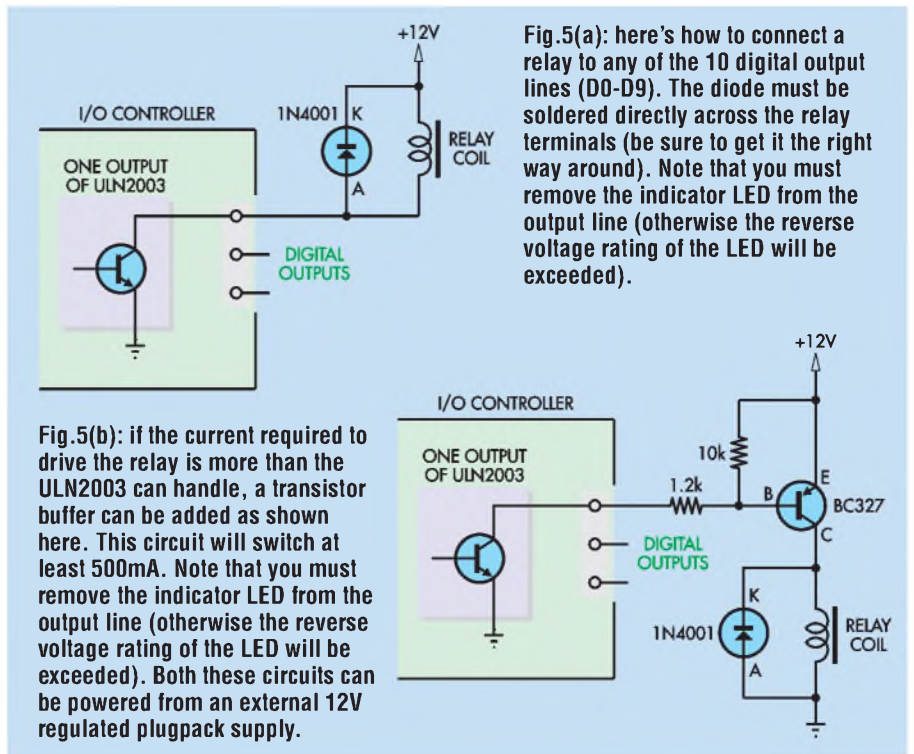
It could even be set up so that it sounds only when a combination of two or more variable conditions are breached.

Port RA4 is used to pulse LED3 to indicate TX/RX activity. This occurs in real-time and if this LED isn't flashing, then it's likely that there's no communications link between the controller board and the PC. It doesn't tell you where the fault is though – it could be on either side (or on both).

Temperature sensing

Let's now see how the LM335Z temperature sensor operates. At 0°C, this device produces 2.73V between its centre pin and ground. This voltage increases by 10mV for each 1°C temperature rise.

As shown, the LM335Z is forward-biased via a 4.7kΩ resistor, which ensures enough current to produce a reasonably accurate measurement. A 100pF capacitor and 470kΩ resistor



filter the output voltage from the sensor, which reduces toggling of the least significant bit that is common to most ADCs – ie, when the voltage level is right on the threshold of a step. This effect is further cancelled out via the software.

The calibration can be tweaked by changing the value of the 470kΩ resistor. A higher value will increase the temperature reading and vice versa. If you play around with the calibration enough, you could probably obtain ±0.5°C accuracy.

Light sensing

LDR1 performs the light sensing operation. It's wired in parallel with a 100kΩ resistor, to bring its low-light level value down to around 90kΩ. The resulting voltage across the series 10kΩ resistor is proportional to the light level and this is applied to port AN1.

In the software, the 10kΩ resistor is treated as part of a voltage divider. Once the voltage across it is known, the LDR's resistance can be calculated to give a value in ohms (the parallel 100kΩ resistor is taken into consideration for this calculation).

The two 1μF tantalum capacitors connected to AN1 ensure stability and provide some hysteresis across the 10kΩ resistor. Note that this input can be calibrated as well and as mentioned

earlier, you can use it to measure other resistive devices as well. Be careful though – there's no input protection.

Power supply

Power for the circuit is derived from a 9-15V DC supply (eg, a plugpack), with diode D1 providing reverse polarity protection. This feeds regulator REG1, which delivers a +5V supply. The associated 220μF capacitor on the input and the 10μF and 100nF capacitors on the +5V rail provide filtering and decoupling.

Construction

Construction is quite straightforward, with all parts mounted on a single PC board coded 652 (161 × 160mm). Fig. 4 shows the assembly details.

Begin by installing the 34 wire links. Some of these are quite long and are close together, so make sure they don't short together. Note also that two of the links go under the microcontroller (IC1).

Once these are in, install the resistors in the locations shown. Table 1 shows the resistor colour codes but you should also check each value on your multimeter before installing it. Follow these with the diodes and LEDs, taking care to ensure these parts are installed with the correct polarity.

The capacitors can go in next, again taking care with the polarity of the

CONTROL FUNCTION CODES

WANT TO WRITE your own control programs? Here's how a basic rundown on how the control codes work, together with a list of all the codes that control the system.

During normal operation, the PIC 'sits back' and waits for a command. When a valid command is received, it's immediately executed and the PIC then goes back to its main internal loop and waits for another command to be issued (Fig.7).

The first byte of data that the PIC expects to receive is an 'a' in the data string. This 'a' is the sync byte and is commonly used to indicate the start of a string. It also greatly reduces errors in the transmission, while also reducing the amount of code required in reading the actual data.

As stated in the article, it's easy to interface other circuits to this controller. Due to its simplicity, you could even use an 8-pin PICAXE micro to control it, in turn giving a huge number of I/O pins to play with.

The first step is to issue the controller with a command string, telling it what function you want processed. Depending on the function, you then issue another command to define the action to be taken. For example, if you want the 'Read Temperature' function, then 50ms after you issue this command, it will read the voltage at the output of the LM335Z temperature sensor. Following A/D conversion, this value will then be output as a serial data string to the serial port.

On the other hand, if you issue the 'Toggle Relays' command, it will then wait for another command to tell it which relay to toggle (Relay1 or Relay2), followed by the state of the relay – ie, ON or OFF. In the case of a data string, it's either a 0 or a 1.

After a command is sent

Now let's see what happens after a command has been sent. We'll take each command in turn.

READ Temperature Command – at least 50ms after this command has been issued, the following string will be sent out: ["a" + #VCC Step Value + "@"]

As previously mentioned, the 'a' is the sync byte and – in the case of the controller talking back – it also sends out an end of string sync byte.

The #VCC Step Value will be a decimal number ranging from 0-1023 which equates to 10-bit binary.

At the receiving end, you will need to convert this value into temperature (as in the PC software provided). The analogue converters are all 10-bit, so the step size is 4.887mV. The decimal value represents the number of steps.

The best way to go about converting these values is to use tables rather than calculations.

Temperature, LDR, Analogue Channel 1 and 2, Input Port Commands – at least 50ms after this command has been issued, the following string will be sent out: ["a" + #Decimal Value + "@"]

Toggle Relays Command – at least 50ms after you have issued the select function command, you must then issue this string to define which relay is to be used and its state (ON or OFF): ["a" + CHR(Relay Number) + CHR(State)]

Note that the 'Relay Number' variable must be in the range of 1-2, while the 'State' variable must be either a 1 or 0 (all in ASCII).

Activate Buzzer Command – at least 50m after you have issued the select function command, you must then issue this string defining the state of the buzzer (ie, ON or OFF, 1 or 0): ["a" + CHR(State)]

Write Port Data Command – at least 50ms after you have issued the select function command, you must then issue this string defining the value of the output port (range 0-1023): ["a" + CHR(Port Value)]

FUNCTION	COMMAND
Read Temperature	"a" + CHR\$(1)
Read LDR	"a" + CHR\$(2)
Read Analog Ch1	"a" + CHR\$(3)
Read Analog Ch2	"a" + CHR\$(4)
Toggle Relays	"a" + CHR\$(5)
Activate Buzzer	"a" + CHR\$(6)
Read 10-Bit Inputs	"a" + CHR\$(7)
Write Port Data	"a" + CHR\$(8)

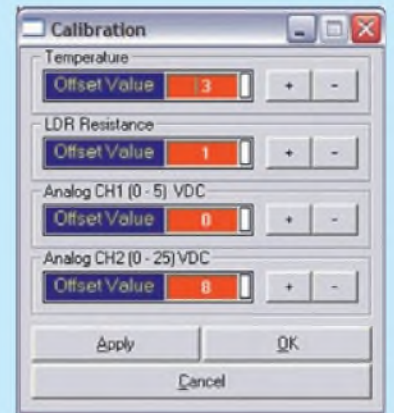


Fig.6: the calibration dialogue lets you enter offset values, to accurately calibrate the four analogue input channels. Once you enter in an offset, the related element is updated instantly. You then click on 'OK' to save these settings to disk, which are automatically restored the next time you run the program.

tantalum and electrolytic types. These can then be followed with the two miniature relays, the buzzer, the screw terminal blocks and the IC sockets.

Now install the three BC548 transistors (Q1-Q3), followed by the LM335Z temperature sensor. This sensor comes in a similar package to the transistors, so don't get them mixed up.

The LM7805 regulator is mounted with its metal tab flat against the PC board. To do this, first bend its leads down through 90° about 4mm from its body, then secure it to the board using an M3 × 6mm machine screw and nut and solder its leads.

The 4MHz crystal is also mounted flat against the PC board – just bend its leads through 90° and push it all the way down onto the board before soldering its leads. It's then secured in place using a wire loop which is soldered at either end to the PC board and also to the top of the metal case (this also connects the case to ground).

Trimpot VR1 and the LDR can now be installed. The latter can be mounted about 10mm proud of the PC board, with its leads sleeved so that they don't short together. That done, you can install the three 16-pin ICs into their sockets, making sure the MAX232 chip is used for IC2. Check that these devices are all oriented correctly and be sure to observe the usual precautions to prevent damage from static electricity.

Parts List

- 1 PC board, code 652, available from the *EPE PCB Service*, size 161 x 160mm
- 11 PC-mount 3-way screw terminal blocks, 5mm spacing
- 1 PC-mount 2-way screw terminal block, 5mm spacing
- 2 SPDT PC-mount 5V DC Mini relays
- 1 mini PC-mount piezo buzzer
- 1 100k Ω horizontal trimpot (VR1)
- 1 light dependent resistor (LDR1)
- 1 4MHz crystal (X1)
- 1 PC-mount DB9F connector
- 1 serial cable
- 1 500mm-length tinned copper wire (for links)
- 3 16-pin IC sockets
- 1 40-pin IC socket
- 5 M3 x 6mm screws
- 1 M3 nut
- 4 M3 x 12mm tapped spacers

Semiconductors

- 1 PIC16F877A microcontroller programmed with IO.hex (IC1)
- 1 MAX232 serial transceiver (IC2)
- 2 ULN2003 Darlington array (IC3, IC4)
- 3 BC548 NPN transistors (Q1-Q3)
- 1 LM335Z temperature sensor (TS1)
- 1 LM7805 voltage regulator (REG1)
- 3 1N4004 diodes (D1-D3)
- 4 1N4148 or 1N914 diodes (D4-D7)
- 10 5.1V 0.5W Zener diodes (ZD1-ZD10)
- 2 5mm red LEDs (LED1, LED3)
- 2 5mm green LEDs (LED2, LED4)
- 10 3mm red LEDs (LED5-LED14)

Capacitors

- 1 220 μ F 25V electrolytic
- 6 10 μ F 16V electrolytic
- 2 1 μ F 16V tantalum
- 16 100nF 100V MKT polyester
- 1 100pF 50V ceramic
- 2 22pF 50V ceramic

Resistors (0.25W, 1%)

- | | |
|------------------|-----------------|
| 1 470k Ω | 4 4.7k Ω |
| 1 390k Ω | 1 2.2k Ω |
| 1 330k Ω | 10 1k Ω |
| 11 100k Ω | 14 330 Ω |
| 2 10k Ω | |

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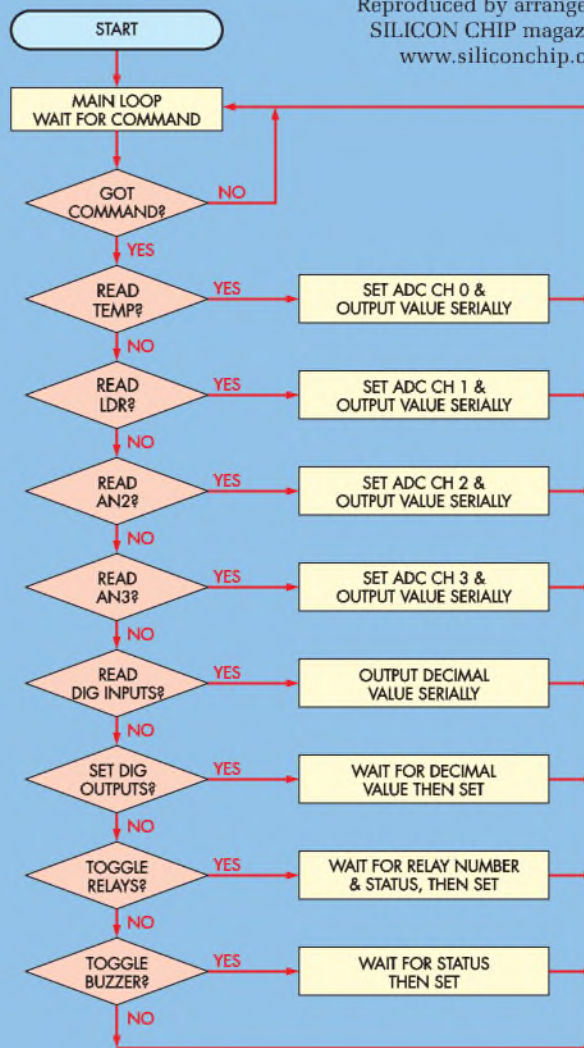


Fig.7: this is the basic flowchart for the PIC software. In operation, the instructions are executed sequentially, after which the microcontroller returns to the 'Main Wait For Command Loop'.

Initial checks

All parts should now be in place except for the PIC microcontroller (IC1) – that's left until the power supply has been checked out.

First, check the assembly carefully to ensure that all parts are in their correct locations and that all polarised parts are correctly oriented. That done, apply power and check the voltage at the output terminal of the 7805 regulator – you should get a reading that's close to +5V with respect to ground. This same voltage should also be present on pins 11 and 32 of IC1's socket.

If all is well, switch off and install IC1 (notched end towards IC3 and IC4). You're now ready to put your new I/O Controller through its paces.

Don't forget to set VR1 as described earlier.

To drive the system, you can either use the Windows-based software or you can write your own control programs. The Windows-based software is easy to drive – just take a look at the accompanying screen grabs and the explanatory notes.

For those who wish to write their own software, the control codes are listed in a separate panel.

Finally, note that the on-board relays are suitable for switching low-voltages only – eg, up to about 50V DC. DO NOT use them to switch mains voltages (ie, 240V AC). The board is not designed to do this and it would be much too dangerous.

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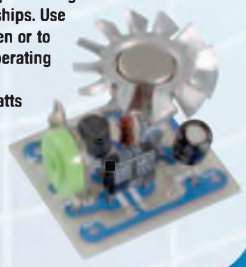
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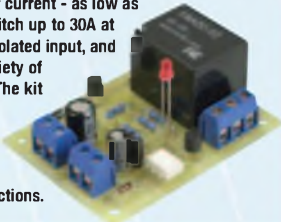
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Using PIC Microcontrollers

Part Three – More PIC Control Concepts

Plus Multiplexing

JOHN BECKER



Last month in *Teach In 2008* Part 2, we showed how PIC software could turn on various LEDs in response to commands within program software. The PIC commands involved in the demo program were discussed. We concluded by discussing the first stages of creating a gaming dice simulation, but with their dots not necessarily in the conventional order.

This month we show how a similar concept can be used to create the example of two normal gaming dice showing the dice dots resulting when they are 'shaken' (activated by a switch). The dice dot order will become as normally expected. Several new concepts and commands are introduced and discussed.

The demo program itself is given in Listing 3.1. (Note: line spaces have been omitted to fit listing on one page.)

First assemble the breadboard with the components required for the demo circuit shown in Fig.3.1. Connect the board to the PIC as indicated, with the PIC programmed with the hex file for Listing 3.1, **Teachincol.hex1**.

Switch on the power, press the breadboard switch S1, and release it. The LED display will then show some LEDs turned on to represent a double-dice throw.

Pressing S1 immediately turns off the the LED display. Releasing it will show a different pair of values. The switch may be pressed as many times as you like, just as you would throw dice in a game.

The program first has its function shown as a comment preceded by a semicolon, as was discussed in Part 2. Now, in Listing 3.1, follow the two statements:

```
#DEFINE BANK0 BCF STATUS,5 ;  
define STATUS register bit 5 clear, as  
BANK0
```

```
#DEFINE BANK1 BSF STATUS,5 ;  
define STATUS register bit 5 set, as  
BANK1
```

We showed last month that the PIC's data direction register (DDR) for PORTB can have its bits set for input and output by changing the BANK controlling them through SFR (special function register) TRISB. The STATUS register associated with various functions, such as BANK changing, is frequently needed in PIC software programs. So too are other common PIC commands which may never need changing.

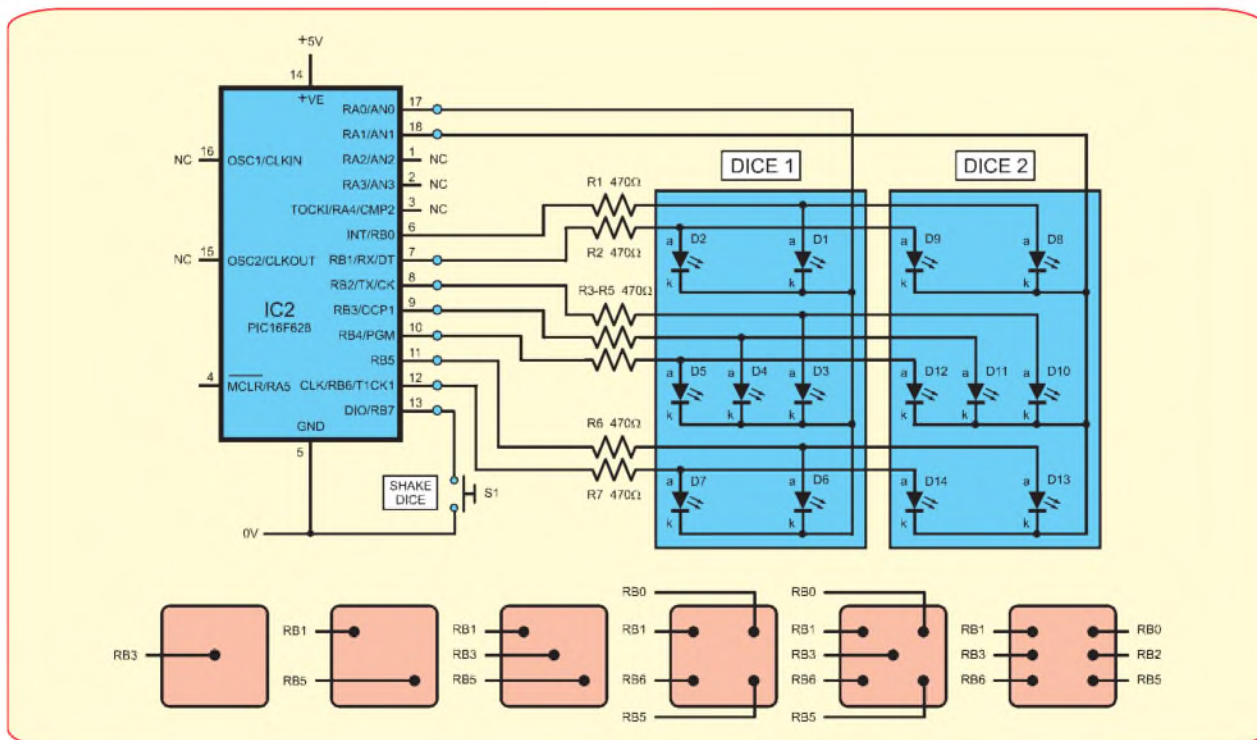


Fig.3.1. Circuit diagram for this month's demonstration is a double dice

Listing 3.1

```

; TEACHINC01.ASM 07JUN07 - TEACH IN 2008 PT3
#DEFINE BANK0 BCF STATUS,5 ; define STATUS register bit 5 clear as BANK0
#DEFINE BANK1 BSF STATUS,5 ; define STATUS register bit 5 set as BANK1

list p=16f628 ; tell MFASM-type programmer to create a list (LST) file
__config $3F30 ; internal 4MHz oscillator
include p16f628.inc ; bring in all standard register values
DICE1 EQU 'h20' ; user register at 'h20' allocated as DICE1
DICE2 EQU 'h21' ; user register at 'h21' allocated as DICE2
ORG 0 ; reset vector
goto STARTIT
ORG 4 ; Interrupt vector address
goto STARTIT
ORG 5 ; PIC program memory location at which to start
goto STARTIT
DICETABLE andlw b'00000111 ; restrict val to first 3 bits (max val below 8)
addwf PCL,F ; add incoming val in W to program counter (PCL)
; (incoming vals are below 8, so jumps beyond 7
; not poss.)
retlw 'b00000000' ; jump 0 (no dice LEDs to be on)
retlw 'b00001000' ; jump 1 (dice LED to be on - bit 3)
retlw 'b00100010' ; jump 2 (dice LEDs to be on - bits 1 and 5)
retlw 'b00101010' ; jump 3 (dice LEDs to be on - bits 1, 3 and 5)
retlw 'b01100011' ; jump 4 (dice LEDs to be on - bits 0, 1, 5 and 6)
retlw 'b01101011' ; jump 5 (dice LEDs to be on - bits 0, 1, 3, 5 and 6)
retlw 'b01110111' ; jump 6 (dice LEDs to be on - bits 0, 1, 2, 4, 5, 6]
retlw 'b00000000' ; jump 7 (no dice LEDs to be on)
STARTIT clrf PORTA ; clear PORTA's output if any
clrf PORTB ; clear PORTB's output if any
movlw $07 ; needed by some PICs, including PIC16F628
movwf CMCON ; so that PORTA is treated as digital port
BANK1
movlw b'00000000' ; all PORTA as output
movwf TRISA ; data direction register for PORTA
movlw b'10000000' ; PORTB 0-6 as output, PORTB,7 as input
movwf TRISB ; data direction register for PORTB
movlw B'00000000' ; pull-ups on (bit 7 = 0) (off if bit 7 = 1)
movwf OPTION_REG
BANK0
DICESTART btfsc PORTB,7 ; is PORTB,7 low (= 0) (switch pressed) ?
goto DICESTART ; no
movlw b'00000011' ; yes, turn off DICE1 and DICE2 displays
movwf PORTA ; via PORTA
clrf DICE1 ; clear DICE1 to zero
clrf DICE2 ; clear DICE2 to zero
DICELOOP clrf PORTB ; clear PORTB to zero to turn off any LEDs
movlw 7 ; add 7 (a prime number) to DICE1
addwf DICE1,F
movlw 3 ; add 3 (a prime number) to DICE2
addwf DICE2,F
btfss PORTB,7 ; is PORTB,7 hi (= 1) yet (switch released)?
goto DICELOOP ; no, continue looping
SHOWDICE movlw B'00000010' ; turn off DICE2, turn on DICE1
movwf PORTA ; via PORTA
movf DICE1,W ; get value in DICE1
call DICETABLE ; call value conversion table
bsf PORTA,0 ; turn off DICE1
movwf PORTB ; put resulting value in W out to PORTB
movlw B'00000001' ; turn on DICE2, turn off DICE1
movwf PORTA ; via PORTA
movf DICE2,W ; get value in DICE2
call DICETABLE ; call value conversion table
bsf PORTA,1 ; turn off DICE2
movwf PORTB ; put resulting value in W out to PORTB
btfsc PORTB,7 ; is switch pressed (PORTB bit 7 clear)?
goto SHOWDICE ; no, so repeat multiplexed dice show
goto DICESTART ; yes, go back to DICESTART, and do another dice throw
END ; end of program code

```

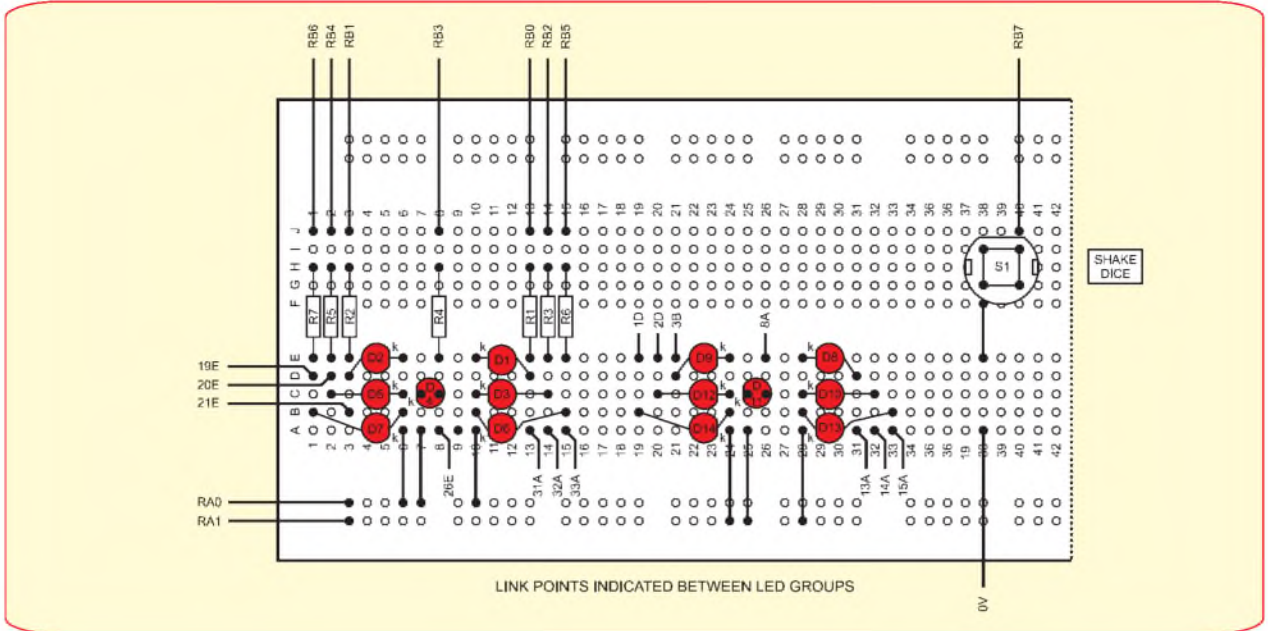


Fig.3.2. Breadboard layout for the 'double-dice' demonstration circuit in Fig.3.1.

As you were told in Part 2, the TRIS registers for most PICs are normally in BANK1, whereas most other SFRs are in BANK0. There is often the need in a program to change between BANKs. It can be useful to be able to use just short commands to cause such actions, without the full command line having to be keyed in. The instruction **#DEFINE** can be used this way, to *define* a single word, which the assembly software will replace with the associated correct command line each time it comes across that word in a program.

Thus, the action to clear STATUS bit 5 can be told to occur each time the word BANK0 is found. Similarly, with the word BANK1 setting STATUS bit 5. The use of BANK statements is also illustrated a little later in the software.

Following the 'definitions' is the instruction:

list p=16f628

On coming across instructions preceded by 'list', assembly programs such as MPASM will produce a List (.LST) file which shows the manner in which the assembly has dealt with the ASM file and its various statements, whether or not they are program commands. Such List files can be useful when developing software and the way in which it has been assembled can be viewed in words.

An example of part of a list file for this demo program is shown in Listing 3.2. The comments have been omitted.

Different assemblers may have slightly different formats for the way the information is displayed, but the essential information should still be obvious. The List file example shown was created through the *TK3* assembly software. Note that this assembler always creates a List file, whether or not a 'list' statement has been found.

Next, follow the 'include' statement explained last month.

The next two lines, show how user-named registers can be specifically allocated instead of using 'Cblock'. The required name is stated in column one followed in column two by the register value required, e.g. DICE 1 EQU 'h20'. The 'Equated' value here is the earliest available for the PIC16F628.

The next six lines are the same as used in Part 2's software. Ignore label DICE-TABLE and its entries for the moment – we'll come back to them shortly.

At label STARTIT are now the commands:

drf PORTA
drf PORTB

The way in which PIC register files contain initial data at switch on or reset was discussed in Part 2. The PIC's datasheet shows their status at such times. Now, in this application, we need to ensure that registers PORTB and PORTA have known values in them whenever the program is run. In this case they are told to hold a value of zero, cleared, using the command **CLRF** (upper or lower case) and the register file that has to be cleared.

Commands CLRF and CLRW

Command CLRF stands for CLear File and is always followed by a single number or name which indicates the file on which the action is to be performed. The command instructs the PIC that all bits within the stated file are to be cleared.

The allied command CLRW (CLear Working register) simply clears the contents of the Working register (W) and is used on its own without a subsequent number or name. In practice, this command may be seldom used, the commands **MOVLW 0** and **RETLW 0** probably finding preference (the latter command is

Parts List Teach-In 2008 – Part 3

- IC2 PIC16F628, (as listed in Part 1) programmed
- R1 to R7 470Ω resistors 0.25W (7 off)
- D1 to D14 red LED (14 off)
- S1 Push-to-make switch, PCB mounting
- Control PCB (as described in Part 1)
- Plug-in breadboard, 64 holes long (6.7in x 2.5in), 0.1in pitch
- Solid, insulated connecting wire

discussed in a future part. Command CLRW has, in fact, been dropped from some PIC families.

There are no direct opposites of CLRF and CLRW, which will set all bits high; other techniques have to be used for this action.

Register CMCON

Many PICs can have their ports used in various ways, as digital inputs and outputs (I/O) for example. Some can also be used for analogue purposes, such as comparison of analogue voltage values or analogue-to-digital conversion (ADC). The PIC16F628 can provide comparison of input pin voltage levels in relation to other values set within the software. That is the mode to which PORTA is automatically set at switch-on. To use PORTA for digital I/O, it needs to be specifically set for that mode, using the two commands:

movlw 7
movwf CMCON

Listing 3.2

C:\PIC\TEACHIN2008\TEACHINC01.ASM LIST FILE 10-25-2007 19:27:50

This file is for information only and is not for editing

A ++ symbol beside column 1 indicates an Include program file (but not headers)

A +M symbol beside column 1 indicates a MACRO

A ## symbol following binary value indicates a source code error in that line.

Some error types not indicated here, but are given in the errors file.

NOTE THAT LIST COUNT OMITTS STATEMENTS FROM 'INCLUDE' FILES THAT HOLD REGISTER EQUATES (e.g. P16F628.INC)

List count deci	Prog count deci	Prog count hex	Code value hex	Code value binary	Input file line count deci	Source code
0001	0	0000	0000		1	#DEFINE BANK0 BCF STATUS,5
0002	0	0000	0000		2	#DEFINE BANK1 BSF STATUS,5
0003	0	0000	0000		3	LIST P=16F628
0004	0	0000	0000		4	
0005	0	0000	0000		5	__CONFIG \$3F30
0006	0	0000	0000		6	INCLUDE P16F628.INC
0172	0	0000	0000			endinclude P16F628.INC
0173	0	0000	0000		7	; DICE1 EQU H'20'
0174	0	0000	0000		8	DICE2 EQU H'21'
0175	0	0000	0000		9	ORG 0
0176	0	0000	2810	00101000 00010000	10	goto STARTIT
0177	0	0000	0000		11	ORG 4
0178	4	0004	2810	00101000 00010000	12	goto STARTIT
0179	0	0000	0000		13	ORG 5
0180	5	0005	2810	00101000 00010000	14	goto STARTIT
0181	0	0000	0000		15	
0182	0	0000	0000		16	DICETABLE:
0183	6	0006	3907	00111001 00000111	17	andlw b'00000111'
0184	7	0007	0782	00000111 10000010	18	addwf PCL,F
0185	0	0000	0000		19	
0186	0	0000	0000		20	
0187	8	0008	3400	00110100 00000000	21	retlw b'00000000'
0188	9	0009	3408	00110100 00001000	22	retlw b'00001000'

There is no need to concern yourself at this time with why the value of 7 needs to be placed into register CMCON, just remember that these two commands are needed for PIC16F628s (and some other PIC devices, including the PIC16F627) in order to use PORTA in digital mode.

But also be aware that other PIC families may have different requirements, or none at all.

Then follows an example of how BANK statements are used in place of keying in the commands for setting and clearing STATUS bit 5:

```
BANK1
movlw b'00000000' ; all PORTA
                    ; as output
movwf TRISA        ; data direc-
                    ; tion register for PORTA
movlw b'10000000' ; PORTB 0-6
                    ; as output, PORTB,7 as input
movwf TRISB       ; data direc-
                    ; tion register for PORTB
movlw B'00000000' ; pull-ups on
                    ; (bit 7 = 0) (off if bit 7 = 1)
movwf OPTION_REG
BANK0
```

PORTA needs to be initialised for all its pins to be used as outputs (although in this program only bits 0 and 1 are actually used) and so is cleared to zero. With PORTB, bits 0 to 6 (right to left) are to be

used as outputs, but bit 7 will be used as an input to monitor the status of the 'dice shake' switch, and so is set to 1.

While still in BANK1 mode, the behaviour of PORTB's pins that are in input mode can be set so that 'light pull-ups' are applied to them (avoiding the need for external biasing via resistors).

Bit 7 (far left) of OPTION_REG is the bit that controls these pull-ups. A value of 0 turns them on, a value of 1 turns them off.

Main start

At label DICESTART begins the real program, everything until now has been preparatory.

First, PORTB bit 7 is read to see if it is low – `btfsc PORTB,7` – which it will *not* be if the switch is not pressed, as the light pull-ups have been turned on earlier.

Since the answer is untrue (false), an immediate jump back to DICESTART is made. This check is then repeated, ad infinitum, until the switch is pressed, when the check will cause the next command to be actioned instead of the jump back.

This next command is `movlw b'00000011'`, and the specified value is then placed into PORTA. The reason for this is connected with multiplexing the two blocks of LEDs, and will be explained presently.

DICE1, DICE2 and PORTB are then cleared. At label DICELOOP, a value of 7 is loaded into W and added to the

contents of DICE1. The subject of adding values will be dealt with more thoroughly later in the series. DICE2 also has a value of 3 added to it.

Both values are prime numbers to ensure that a fair degree of randomness appears to hold true with regard to the resulting dice throws when the switch is released. The DICE registers are 8-bit registers and when a value is added to the existing value and the result is greater than 255, a 'roll-over' back to 0 is made, plus the difference between the total value and 255.

Following the addition, a check of the status of the switch is made, and if it is still pressed, the additive loop is repeated. If the switch has been released, the routine starting at SHOWDICE is entered.

Ignoring the command to write data to PORTA for now, the value held in DICE1 is copied into W, and the command `call DICETABLE` is then actioned, the programming jumping to the earlier, undiscussed, routine commencing at DICETABLE.

Tables

PICs, and other microcontrollers, have the ability to jump to given statements within a table, depending on the value held in W when the table is entered.

In Part 2, the Program Counter was mentioned in passing in relation to bit testing. It is the Program Counter's Low (PCL) aspect

which is now brought into play. (There is a Program Counter High – PCH – but its use is more complex and is not discussed now).

The Program Counter keeps track of which commands are being actioned in various ways, and which command is the next to be actioned. Its existing value can have another value added to it and the command then actioned is the one pointed to following the addition.

With a table, the value in W is added to PCL and the table command pointed to by the new value is actioned. Taking the first five lines in DICETABLE:

```
andlw b'00000111'
addwf PCL,F
retlw 'b00000000' ; jump 0
retlw 'b00001000' ; jump 1
retlw 'b00100010' ; jump 2
```

The first command ANDs the value with binary 00000111 (decimal 7) to restrict it to just eight values max (0 to 7).

The next command is **addwf PCL,F** – add the value in W to the value already in PCL (the program counter value). The value of W has already been placed into it prior to the call to the table.

In the case of the W value being 0, the Program Counter's new value is the same as it would be had 0 not been added to it. Then the next command (at jump 0 – **retlw 'b00000000'**) is performed.

Command **retlw**, means 'return to where the call to the routine was made from, with the specified value held in W'. In this instance, the call was made from the command **call DICETABLE**, and the specified value is (in binary in this case) 'b00000000'. The program thus returns to the command immediately following **call DICETABLE**, which is **bsf PORTA, 0** to turn off DICE1 then the value of 0 is output to PORTB, which means that no LEDs will be turned on.

Had W held a value of 1 in it, then jump1 would have been actioned, with 'b00001000' now held in W. Outputting this value to PORTB would result in PORTB bit 3 being set high, and applied to both LEDs attached to that port pin.

With W originally holding a value of 2, there would be a return with W now holding 'b00100010', and that would be output to PORTB, turning on its bits 1 and 5.

The reason for the **andlw b'00000111'** command at the start of DICETABLE, is to restrict the possible number of jumps that could be called to a maximum of eight (0 to 7). Without this limit, the program could become confused if the value is greater than the number of jumps available!

There are several ways in which the value can be limited, apart from ANDing. Some of them will become apparent as we progress through the series.

The DICETABLE is called twice, once for each of the DICE counters. Each time the resulting value is output to PORTB. The reason for not seeing two images simultaneously is the next topic, but first, the conclusion of the main loop: Following the second output to PORTB, switch S1 is again checked. If S1 remains unpressed, the SHOWDICE routing is repeated. If it is now pressed again, a jump is made to DICESTART, and a new dice value is established and shown.

Multiplexing

In the SHOWDICE routine, both DICE values are output to PORTB. The use of *multiplexing* allows the two values to be shown on different groups of LEDs. The technique simply involves only turning on a particular LED group immediately prior to, or after, a value has been sent to it. In theory, there will be a very brief period when the LEDs still have the wrong value output to them, but the changeover is too fast for the human eye to see.

Multiplexing is achieved here by using PORTA to switch repeatedly between the displays of DICE1 (LEDs D1 to D7) and DICE2 (LEDs D8 to D14). The cathodes (k) of each LED group are commoned, and the connection between a cathode group and the 0V line is only established alternately. Using the LINK A wire on the Control PCB LEDs last month, was a fixed example of this.

PORTA bits 0 and 1 cause the switching, and their setting and clearing depends on which group is needed to be displayed. Take DICE1 for example.

Its cathode group is connected to PORTA,0. Whatever value is applied to PORTB, those LEDs will only be turned on if the 0V connection for them is made by PORTA,0 being low. When that pin is high, that group is turned off. Similarly, for the DICE2 group – their cathodes are commoned to PORTA,1.

To turn on the displays for the DICE1 LEDs, the display value is written to PORTB, and PORTA has a value of b'00000010' written to it. This turns off the DICE2 LEDs, and turns on the DICE1 LEDs. Conversely, for DICE2, its value is written to PORTB, and PORTA has b'00000001' written to it, thus turning off the DICE1 display and turning on DICE2.

Multiplexing is a very powerful tool, as is the use of Tables.

ANDing

Now let's look at two of the commands introduced here, ANDLW and ADDWF. Commands ANDWF and ADDLW will also be examined shortly.

As no doubt most of you are aware, if one binary number is ANDed with another, then only if the same bits of both numbers are set (1) will the answer also have a 1 in that position. Any zeros on either or both sides for any bit will automatically produce a result of 0, eg:

First number :	01110010
Second number :	01011001
ANDed answer :	01010000

This technique is widely used in electronics and computing, the final answer determining the subsequent action to be taken by a circuit or software routine.

There are two ANDing commands available with PICs, ANDLW (AND Literal with W), and ANDWF (AND W with File value). Suppose that the first number in the foregoing examples (01110010) is already contained within W, we then wish to AND it with a fixed number as stated in a program command. Assuming that the fixed number is the second number quoted, the command is:

ANDLW B'01011001'

The PIC ANDs the second (literal) number with that already held in W. The answer (01010000) is retained by W and is available to be further manipulated or copied into any file as specified by the command which follows ANDLW. You could, for example, use the command MOVWF PORTB which will turn on any LEDs associated with that value.

Any of the three numerical formats may be used with ANDLW, eg B'00011111' (binary), H'1F' (hexadecimal), 31 (decimal), are all legitimate and equal.

The command ANDWF is used to AND an existing value within W to a value within a named file, either retaining the answer in W (ANDWF FILENAME,W) or putting it back into the named file (ANDWF FILENAME,F).

It is not possible to directly AND the contents of two files together, the value of one or other file must have already been moved into W before the ANDing can take place. With both commands ANDLW and ANDWF, if the answer is zero, the Zero flag of STATUS is set. If the answer is not zero, the Zero flag is cleared. Zero is the only flag affected by an AND command.

ADDing

There are two ADDing commands available with PICs, ADDLW (ADD Literal to W), and ADDWF (ADD W to a File value). Command ADDLW is used where a fixed number (literal) within a program is to be added to an existing value within W and which has been obtained by a previous operation.

Suppose that W holds the answer produced in the previous ANDing example, 01010000 (decimal 80), and you wish to add a fixed value to it, 53 decimal (00110101), for instance. The command would be:

ADDLW 53 (or ADDLW H'35' hexadecimal), (or ADDLW B'00110101' binary).

The answer in this instance is 10000101 (decimal 133) and is retained in W for further use or copying into a file, e.g. MOVWF PORTB. Command ADDWF adds the contents of W to the value within a stated file. The answer can be held in W (ADDWF PORTB,W) or put back into the named file (ADDWF PORTB,F).

Three flags within STATUS are affected by any ADD command, Carry, Zero and Digit Carry. If the answer to an addition is greater than 255, the Carry flag is set, otherwise it is cleared. If the answer equals zero, the Zero flag is set, otherwise it is cleared. The third flag, Digit Carry (bit DC of STATUS), you have not encountered yet. Although the concept is not illustrated until later, it is appropriate to describe it now.

If you imagine that an 8-bit binary number (eg 10110110) is split into two halves (known as 'nibbles'), 1011 and 0110, the righthand nibble is monitored by the PIC as a separate item and it is served by its own flag, the Digit Carry flag. If an addition takes place which produces a result greater than 15 (binary 1111) for that nibble, the Digit Carry flag is set, otherwise it is cleared.

Command MOVF

Whereas MOVLW means moving a literal value into W, MOVF means MOVE File value. The file (assuming PORTB in this case) is named following the command, but the command itself does not say where the value is to be moved to (unlike MOVLW, where W as the destination is included in the command). The destination is stated by adding a comma after the file name and then adding either W or F, eg:

**MOVF PORTB,W or
MOVF PORTB,F**

Normally, the command would be used with W, so that the contents of the file are brought into W for presumed further use. At first, then, the concept of using F as the destination seems strange. Why move the file value back into the file without the value having undergone some sort of manipulation?

The reason is that many commands automatically affect various flags in the STATUS register, setting or clearing them as appropriate. We have already shown how some STATUS flags are affected by some actions. When command MOVF is performed, irrespective of the W or F destination, the Z flag is affected.

It is set if the file value is zero, cleared if the file value is greater than zero. So if we wish to know whether or not the file value is zero, we can use the MOVF command to affect the zero flag, and do so without changing the file value. It is also significant that the existing contents of the W register are not affected when using the F destination, and can therefore be used elsewhere if needed following the result of the zero check.

Command CALL

Programs can be written as a series of sub-routines which can be reached in one of three ways, directly by default (without being told to go there), via a GOTO command, or by a CALL command. (Routing following automatic detection of an interrupt event is another matter and is discussed later in the series.)

We have shown several examples of the first two. However, a CALL command can be used if one routine needs to make use of another and then, once that has been completed, for the program to jump back to

continue from the command that follows the call. The use of sub-routines allows the same routine to be accessed from many other areas within the overall program, so saving on program space.

A second command always has to be used before the program returns to the calling origin. That command takes one of two forms, RETURN (which is an obvious command – return to where you came from) or RETLW (RETURN to where you came from with a Literal value held in W). There is a third return command, RETFIE, which we shall meet later in connection with interrupts.

A GOTO command can never be used to end a sub-routine call – the PIC will continue to expect a return command and, if repeated calls to a sub-routine are made without a RETURN or RETLW command, it will become confused and unpredictable results could occur. For example, the following is ‘illegal’:

```
PROG1    CALL PROG2
          GOTO PROG1
PROG2    GOTO PROG1
```

This is ‘legal’, though:

```
PROG1    CALL PROG2
          GOTO PROG1
PROG2    RETURN
```

When the program returns from a CALL following a RETURN command, the contents of W are those which were put there by the last command which used W.

Consequently, you can perform a complex sub-routine, end up with an answer in W and, using the RETURN command, return to the main program with that result still retained in W.

Command RETLW, though, returns to the main program with W holding the value which RETLW has acquired as part of that command. A literal value is always specified as part of the RETLW command, eg RETLW 127 or RETLW 0. That value replaces any other value within W and is the one which is held in W on the return to the calling point. The value may be expressed in decimal, hexadecimal, binary or as a ‘named’ value defined during program initialisation.

Stack function

It is important to be aware that PICs have a limit to the number of calls that can be nested (calls being made from within calls). This is due to the PIC’s Stack (the area that monitors the return addresses when calls are completed) being limited to only eight address values. If the Stack receives more than eight addresses it will over-write the earlier ones, causing a program crash.

There is no way to directly read or write to the stack or to determine how full it is (other than through a program simulator). It is, therefore, imperative that if you are using nested calls then you must keep very careful track of how many you are using. In such cases consider whether you could achieve the same result by using GOTO commands for some of the calls, or by returning to the previous calling routine before making the next call.

Another thing to think about

To keep your mind active until Part 4, imagine you are writing a program to control a lift. Just using LEDs to indicate what action is on or off, set up a few switches, like door open or close, motor on or off, floor level reached etc, and allow suitable pauses between an action starting and finishing. Add whatever features you want in the interests of safety.

Having written the program as though the controls are outside the lift, rewrite it from the point of view of an operator inside. You are welcome to add additional LEDs if you wish, and to use binary values rather than decimal in terms of floor display.

Again, there are no definitive questions or answers – it’s just to put your imagination to work again.

Software

The software for Teach In 2008 Parts 1 to 3 is available for free download via the EPE website at www.epemag.co.uk.

Next month

In Part 4 next month, we show how to use alphanumeric liquid crystal displays (LCDs) and illustrate their use through a breadboarded Event Counter.



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Circuit Surgery

Ian Bell



More on SPICE simulation – difficulties

This month we will continue to discuss SPICE simulation, taking an in-depth look at one circuit which presents some simulation difficulties. Again, we will use LTSpice, but most of the discussion will be relevant to all SPICE simulators.

Our ‘difficult’ circuit is shown in Fig.1 – it is an oscillator; or more specifically it is an astable, or free-running multivibrator. Although this is a classic circuit, it is perhaps little known (and used) now as we tend instead to employ a variety of special purpose oscillator or waveform generator ICs (including the well-known 555); or alternatively, provide system timing using the resources available in microcontrollers such as PICs. However, the circuit serves to illustrate problems we might encounter when trying to simulate oscillators or other ‘unstable’ circuits.

It is not unusual to find that oscillators do not oscillate in simulators, unless you know how to overcome the problem. The issue of oscillators failing to ‘work’ in a SPICE simulation was raised some time ago in one of the discussion threads on SPICE on the *EPE Chat Zone* forum (via www.epemag.co.uk). You can install LTSpice (or similar), enter the schematic in Fig.1, run a transient simulation and find that no oscillation occurs, but this does not mean that simulators are useless. It means that you need to know a little more of the subtleties of using this complex tool.

Circuit principles

Before simulating a circuit you should understand the basic principles of its operation and have some idea of the voltages (and currents) likely to occur in the circuit, and the shape of, and frequency of, key waveforms. You should have some approximate idea of major circuit parameters (in this case oscillation frequency) so that you can compare them with the performance measured from the simulation.

We will now look in detail at the operation of the circuit in Fig.1 and derive an equation for its oscillation frequency. Assume that TR1 is fully on and TR2 is off. This means that one side of C1 is effectively connected to ground (0V) via TR1, and the other side will charge towards V_{CC} via resistor R2.

Note that our assumption that TR2 is off implies that the voltage at the base of TR2 is currently somewhat less than 0.5V.

At the same time the voltage across C2 will be at or charging towards something close to V_{CC} . This is because one of C2’s ends is connected to V_{CC} via R4 and the other is held at around TR1’s V_{BE} of about

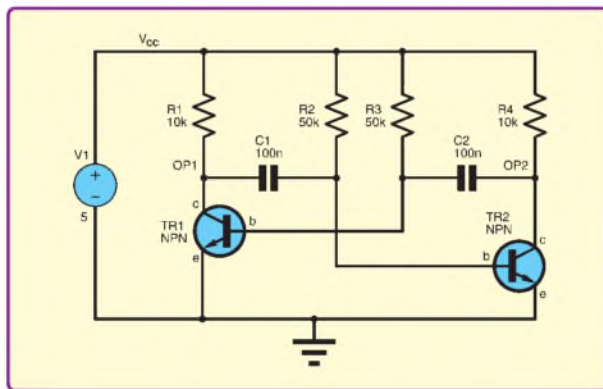


Fig.1. Two-transistor astable multivibrator

0.6V. Note that TR2 does not influence the voltage across C2 at this time because it is fully switched off.

As C1 charges through R2 the voltage at the base of TR2 rises and eventually TR2 will turn on. At this point the voltage at the collector of TR2 falls very rapidly to close to 0V (as TR2 saturates). The voltage across C2 is around V_{CC} with the TR2 collector side of C2 positive. This is because C2 will have held its charge during the brief time TR2 took to switch on, and means the voltage at the base of TR1 will have dropped to around $-V_{CC}$, turning TR1 fully off. At this point the voltage across C1 is quite small (the difference between the V_{CE} saturation voltage of TR1 and the turn of V_{BE} of TR2, so less than 0.6V).

The process described above repeats on opposite sides of the circuit. C2 charges up towards $+V_{CC}$ from $-V_{CC}$ via R3. At this time the voltage across C1 charges from the small voltage it had at the switching point towards V_{CC} . The circuit switches again when C2 charging through R3 brings the V_{BE} of TR1 to around 0.6V, switching it on and TR2 off. We are back to the start of our description and the whole cycle starts again.

Circuit switching speed

The speed at which the circuit switches is determined by how long C1 takes to charge from $-V_{CC}$ via R2 to turn on TR2; and how long C2 takes to charge from $-V_{CC}$ via R3 to turn on TR1. For a charging capacitor the time, t , taken to reach voltage V_t charging from 0V towards an applied voltage of V_a is given by:

$$t = -RC \ln \left(1 - \frac{V_t}{V_a} \right)$$

where $\ln(x)$ is the natural logarithm of x .

In our circuit the capacitors are charging from $-V_{CC}$ towards $+V_{CC}$, which is an effective applied voltage of $V_a = 2V_{CC}$. The time we need is when the capacitor voltage is sufficient to turn on the transistor – that is it has charged from $-V_{CC}$ to $+V_{BE}$. If we ignore the value of V_{BE} for simplicity we can take the voltage of interest as being V_{CC} above the start point, so V_t/V_a is $V_{CC}/2V_{CC} = 1/2$ and the timing equations for the circuit become:

$$t_1 = -R_2 C_1 \ln \left(\frac{1}{2} \right) = 0.69 R_2 C_1$$

$$t_2 = -R_3 C_2 \ln \left(\frac{1}{2} \right) = 0.69 R_3 C_2$$

The period of oscillation is $t_1 + t_2$. If we use equal component values in the two halves of the circuit, so that $R_2 = R_3 = R$ and $C_1 = C_2 = C$, then $t_1 + t_2$ is $1.38RC$ and so the frequency of oscillation is:

$$f = \frac{1}{1.38RC} \text{ Hz}$$

From the values used in the circuit in Fig.1 we would expect a frequency of oscillation of $1 / (1.38 \times 5.0 \times 10^4 \times 1.0 \times 10^{-7}) = 145\text{Hz}$, which is a cycle time of 6.9ms. We would expect the voltage at the collectors of the two transistors to alternately rise from 0V to close to the supply, following a typical capacitor charging curve, and then very rapidly return to 0V once the transistor switches on, where it

will remain for the rest of the cycle. In each cycle we expect the base voltages to suddenly drop to about $-V_{CC}$ and immediately follow a capacitor charging curve back up to about 0.6V, where the voltage will remain more or less static for half of the oscillation cycle.

Ready to simulate

Now we have an understanding of our circuit and an approximate value for a key property, we know what to expect, and are ready to start simulating. We will do a transient simulation, and given that one cycle is around 7ms a total simulation time of 50ms seems reasonable. Using the 'Edit Simulation Command' from the 'Simulation' menu of schematic editor we can set up a transient simulation:

```
.tran 0 50m 0 5m
```

Unfortunately, the expected oscillation does not happen. Both collectors stay at about 70mV and both bases are at about 770mV throughout the simulation. At this point you might be tempted to give up, thinking the simulator is wrong. Actually, the simulator has correctly simulated the extremely unlikely situation that you asked it to do.

Balancing act

The schematic in Fig.1 is perfectly symmetrical – both halves of the circuit are exactly the same. In fact, the circuit will behave in exactly the same way if you removed the capacitors, creating two isolated sub-circuits. The exact symmetry is present in the simulated circuit, but the probability of it happening in a real circuit is so small as to be effectively zero.

What we have is a situation of perfect balance in an unstable system, like balancing a ball on the point of a needle; it might be theoretically possible, but in a real system there is always some asymmetry, or external disturbance, which causes imbalance.

In the real astable, one transistor will switch on slightly faster than the other when power is first applied, the feedback in the circuit will cause the other transistor to tend to switch off and the faster transistor to switch on more. Thus the circuit will quickly tip into one of two possible initial states and will then start to oscillate in the manner already described. We can get the circuit to oscillate in the simulator by forcing an imbalance at the start of the simulation.

One way of doing this is to use the SPICE directive `.IC` (initial condition). To enter a SPICE directive click on the `.op` button in the schematic editor. You can enter the text of the directive and then place it on the schematic. Once a directive is in place it can be edited by right clicking on it on the schematic. There is also a useful feature of switching the text between being a directive and a comment. This allows the directive to 'switched off' without having to delete the text.

We can use the following `.IC` statement to set the initial voltages on the two outputs (collectors) to 0V and 5V ensuring the circuit starts in an asymmetric state. The transient waveform will start from the conditions set by `.IC`:

```
.ic v(op1)=0 v(op2)=5
```

The resulting simulation waveforms (first 20ms) are shown in Fig.2. The shape of the oscillation waveforms fits with our earlier reasoning about the circuit's behaviour, giving us confidence that it is correct.

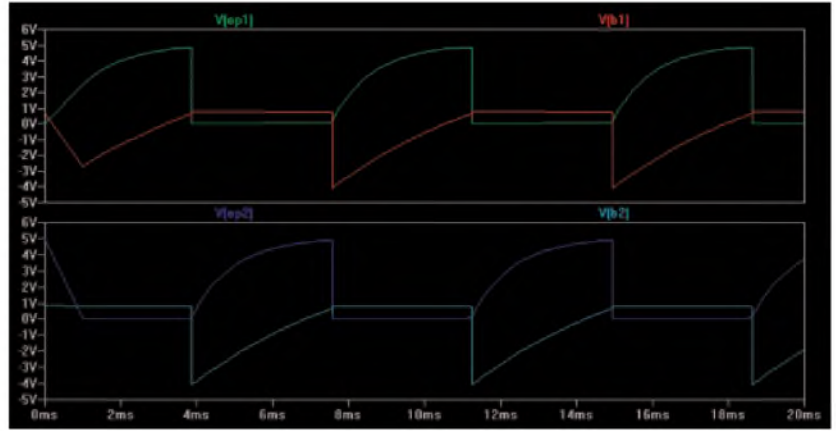


Fig.2. Working simulation of the astable circuit in Fig.1



Fig.3. Setting up cursors on the output waveform

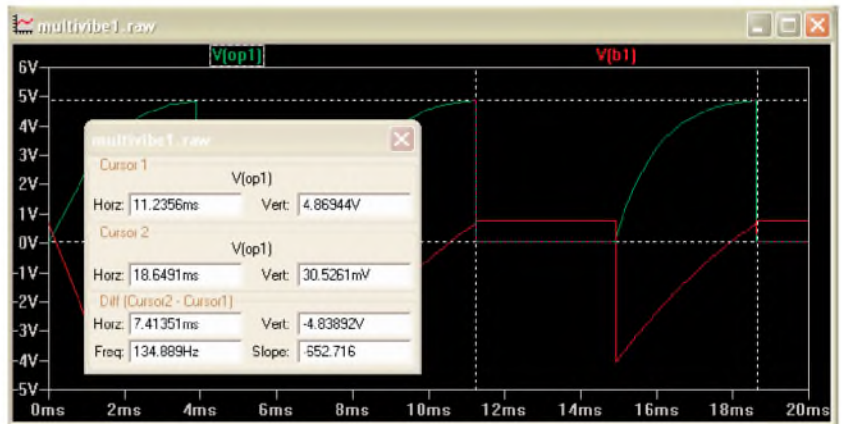


Fig.4. Measuring signal amplitude and frequency

We can measure the frequency of oscillation with the help of the cursors facility in LTspice. Right clicking on the waveform name brings up the 'Expression Editor' window (see Fig.3), which allows us to display one or two cursors. Set the 'Attached Cursors' value to 1st and 2nd and close the window. The cursors can then be dragged to cover one cycle of the waveform in time, and the full voltage range, as shown in Fig.4. The measurement window allows us to directly read the corresponding frequency, which is 135Hz. Given that our earlier calculation was quite approximate this value is reasonable.

Realism

Looking at Fig.2 we might feel that the first millisecond of the simulation is not very realistic. We forced the circuit into asymmetry using the `.IC` directive, without

thinking if the chosen values were meaningful or not. The `.IC` directive forces the initial voltages of a transient simulation, whereas normally the simulator performs a DC analysis to set the starting point of a transient simulation. The DC analysis should ensure that simulation starts correctly in terms of the behaviour of the components. Unfortunately, for this circuit the symmetrical result of the initial DC analysis prevents oscillation from starting.

There is a more subtle approach to getting the initial DC solution right. The `.NODESET` directive is similar in usage to `.IC`, for example we could use:

```
.NODESET v(op1)=0 v(op2)=5
```

However, whereas `.IC` forces initial conditions, `.NODESET` is more like a

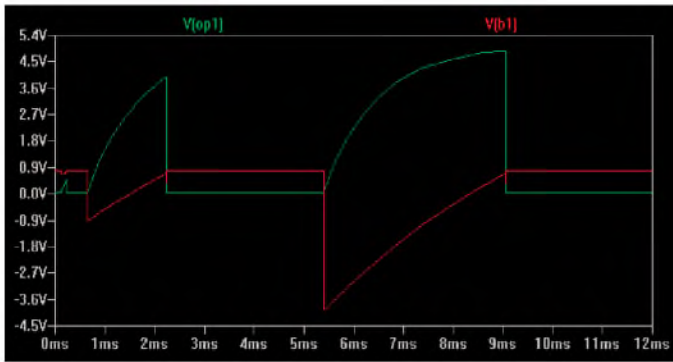
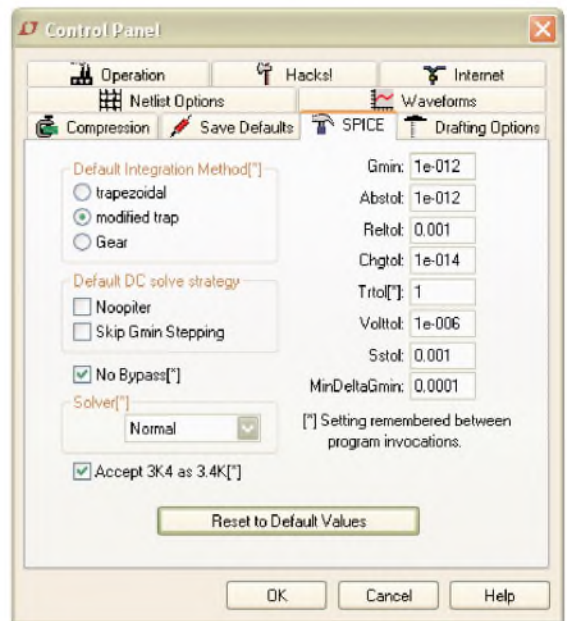


Fig.5. The first few milliseconds using .NODESET instead of .IC to initialise the simulation

suggestion to the simulator; it provides an estimate of the DC solution, which the simulator starts from in the DC analysis.

The .NODESET directive is usually used to overcome convergence problems in the DC analysis. Simulators solve circuit equations approximately and use the result of the current 'guess' to produce a better one, and so on until the solution converges on the correct value (or best estimate). Sometimes this process fails to home in on any solution and the simulator reports a convergence error. The .NODESET can be used to start the estimation closer to the solution so that it is actually found. It is also useful for circuits which have multiple correct DC solutions (such as astables and flipflops), allowing the user to start the circuit in a chosen state.

Fig.6. SPICE settings in the control panel



If we use the .NODESET directive given earlier we get the waveform shown in Fig.5. This shows the oscillation building over a couple of cycles. We have not done a detailed analysis of the circuit's start-up behaviour to really confirm its validity, but it intuitively looks better than Fig.2. If you try this remember to convert the .IC directive into a comment first.

If you try this simulation you may find that it runs very slowly. This can be

overcome by changing a couple of options. Click on the 'Control Panel' button (hammer symbol) and select the SPICE tab in the window that opens (see Fig.6). Using this form set Ttrtol to 7 and Reltol to 0.0001 and you should find the speed is improved.

Next month we will conclude this set of articles on SPICE with a look at some SPICE options, such as these, and how they influence the simulation.

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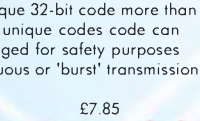
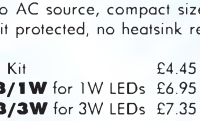
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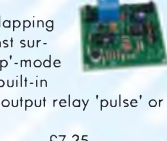
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PIC CARILLON



By John Becker

DING-DONG MERRILY ON HIGH, OR LOWER!

THIS design produces bell-like sounds, using the multiple harmonics of sinewaves to give the tonality expected from bells, complete with the decay of each note played. In its simple standalone form, as described here initially, it is triggered by a 4 × 4 matrix data keypad.

This allows the 12 notes of an octave, including sharps, to be generated. The remaining four keys causes the octave of the note to be changed, providing a complete four-octave range.

This simple unit is basically monophonic, one note at a time, each note being allowed to fade away before the next one is triggered. However, additional channels can be added so that the play rate can be increased, allowing multiple notes and their decays to occur, overlapping each other.

Following the complete description of the basic design and the simple unit, you are then shown how to interface it to the *PIC Polyphonium* (see April-May '07 issues), allowing music scores keyed in or composed through that software to be played through the Carillon unit. Guidance is also given on how it might be

interfaced with the *StyloPIC* of July '02, giving ringing sounds in place of the more 'electronic' sounds normally produced. The latter interface should be treated as experimental and the technique has not been proven by the author.

Bell sounds

Bells and similar have been used by many cultures around the world for centuries, using many different shapes which are struck in some way, ranging from flat metal plates that reverberate, to hollow metal tubes, and on to the more familiar 'bell-shape'.

Historically, such shapes when used on their own are not tuned to any particular 'musical' tones as we accept them now. They simply produced a pleasant or attention-catching sound when struck.

It was not until the 1700s that the bells used in England were combined into groups and roughly tuned to a basic musical scale for use in church towers. In Europe generally, and elsewhere, the idea of ringing a 'peal' of bells has never really taken on the dominance that prevails in the UK up to the present day.

With the introduction of multiple bells, came the need for them to be tuned harmonically and as accurately as the bell foundry could achieve. A bell generates multiple harmonics in addition to the 'strike note' which dominates what we hear.

The relationship of the harmonics depends on the shape of the bell at different positions within its form. It was not until the nature of sound was better appreciated that any degree of control over the shape, and thus the harmonics, became possible.

It was only in the 1920s or so that better attempts at controlling the harmonics and shapes of bells were made. Even now, bell foundries admit to not yet having produced the 'perfect' bell. French bell founder M. Paccard claims, "The perfect profile of the ideal bell has not yet been discovered by any founder. We have twenty profile types". So a search which began many centuries ago still goes on. None-the-less, modern bells have tones that are far better classified and controlled than those of earlier ones still in use. We have, though, 'become used to' the sound of such older bells.

The sound of a bell is also dictated by the material from which it is made. Principally, bronze alloys are used, usually consisting of about 80% copper and 20% tin. Steel is used as well, particularly in American bells of the 19th and early 20th centuries. Cast-iron is used for Chinese bells.

Harmonics

In Alexander Wood's *The Physics of Music*, a brief analysis of a bell is given. It quotes a study by Rayleigh made in 1879 of a ring of bells. He found that the harmonics (partials) principally generated had a relationship of roughly 1, 1.5, 2.0, 2.7 and 3.3 in terms of the frequency (as to how frequency was assessed at that time is unknown). The dominant Strike Note heard was an octave lower than the fifth partial.

Using modern note frequencies, this roughly translates into, for example:

It is this simple ratio that has been used to generate the five frequencies of each strike note in this design.

Partial	Multiplier	Actual Frequency	Nearest True Note
1	1	220Hz	A (220Hz)
2	1.5	330Hz	E (329Hz)
3	2	440Hz	A' (440Hz)
4	2.7	594Hz	D' (587Hz)
5	3.3	726Hz	F'# (739Hz)
Strike Note		363Hz	F# (370Hz)

In reality, bell sounds can be comprised of many other partials. Seven partials are quoted in the book for another bell analysed, consisting of the ratios 1.00, 1.65, 2.10, 3.00, 3.54, 4.97 and 5.33.

Carillons

A true carillon consists of a number of bells played by means of levers, of which any two can be hit at the same time by the human operator's fists. Modern electrical control enables more to be struck simultaneously.

The original home of the carillon is Belgium and Holland, but they are now in quite widespread use elsewhere, including the UK and USA. They are often accompanied by a mechanical display, typically consisting of a rotating platform on which are model figures, sometimes animated, performing at regular intervals around the clock.

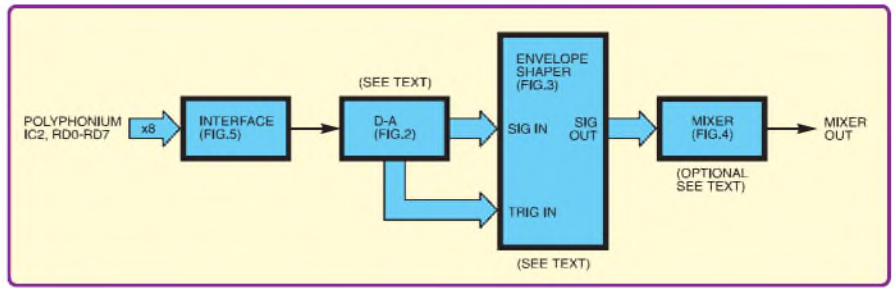


Fig.1. Basic block diagram for the PIC Carillon

(The author has seen and heard the one in Munich, Germany, which inspired Elvis Presley to write his famous *Wooden Heart* in which he used the same theme as the carillon.)

Web searches show that carillons can have different quantities of bells. The one at York Minster (UK) has 11, whereas the Riverside Carillon in New York (USA) has 64, the largest of which weighs 18.25 tons.

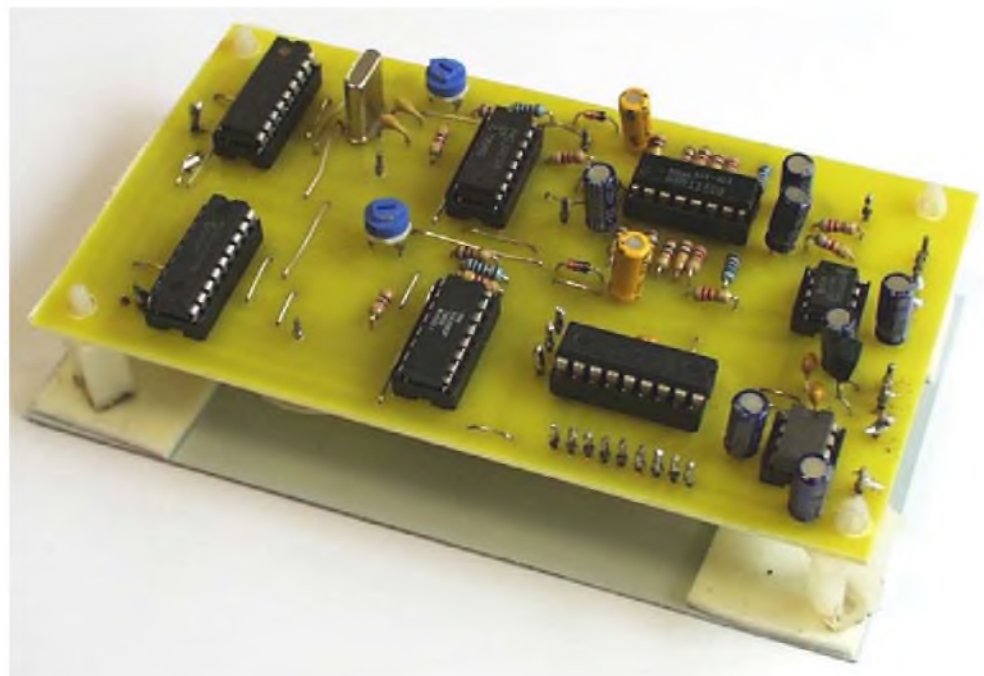
Synthesising bell sounds

When implementing this design, see block diagram shown in Fig.1, the author first created a single sine-wave of a known length within Visual Basic. The data values for this sine-wave were formatted for use in a PIC microcontroller as Data EEPROM statements. The PIC software reads back the values at an incremental rate suited to the frequency required to be heard. By

using several counters, several frequencies can be created simultaneously. As said earlier, five frequencies are used for each bell strike.

The exact rate of access for each note (frequency) was determined in conjunction with a frequency counter and the known modern frequency for each note (internationally standardised by convention in 1939, with *Concert A* set at 440Hz. The value was reaffirmed in 1975 as ISO 16).

The maximum rate at which a typical PIC can run (20MHz is used here) does not allow for the same degree of frequency precision when data has to be read and output to create a sine-wave, compared to creating a simple squarewave output by means of an additive counter, as used in other recent musical designs from the author (including the *Polyphonium*). However, the frequencies are precise enough for the purpose here, especially considering the range of possible frequencies of bells across the ages.



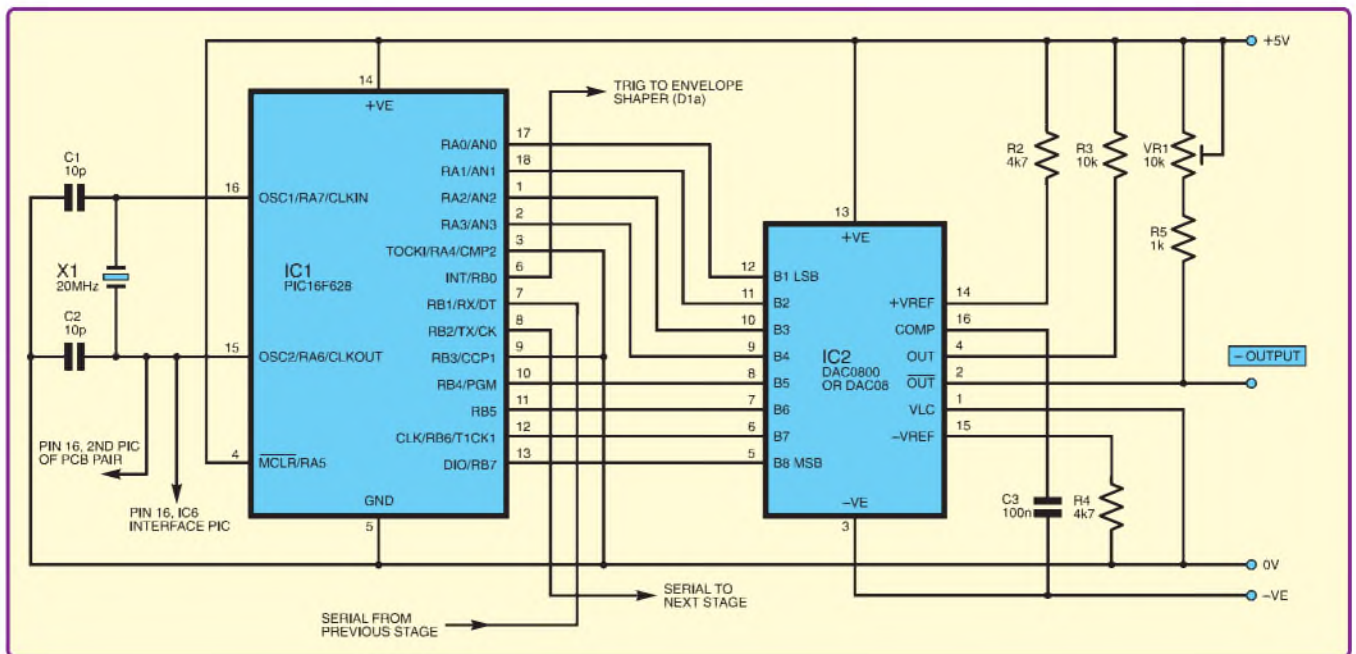


Fig.2. Circuit diagram for the tone control/digital-to-analogue conversion stage of the PIC Carillon. This section is repeated for each 'channel'

Referring to Fig.2, the tone controlling PIC, IC1, serially receives data from an earlier source (more on this later) about each strike note required. That data holds the note required, between 1 and 12, and its octave, between 1 and 7.

From that basic data, the software creates the five frequencies relating to the strike note required, using the partials ratios given earlier, effectively adding them together before outputting a composite 8-bit value via Port A and Port B. This binary value is fed to the digital-to-analogue (DAC) chip IC2. This outputs a varying voltage signal via its pin 2, creating the changing waveform that represents five combined frequencies. The amplitude of the voltage generated by the DAC can be adjusted by preset potentiometer VR1.

Envelope shaper

In principle, this output could be fed direct to the line input of any audio amplifier, and then played through a loudspeaker. Here, though, it is fed to the envelope shaper stage shown in Fig.3.

The envelope shaper is configured around IC4, a transconductance amplifier (TCA). This is used in its voltage controlled amplifier (VCA) mode, in which the signal amplitude that is output is determined by the current flowing into its control pin (via resistor R6), and the value of the resistor (R10) at its intermediate output.

It is a dual-device, the second half being used for another channel. The respective pins are 1, 16 and 5, 7. The device has internal Darlington buffers

and the two outputs are generated across a resistor (R11) at pins 8, 9. It is a very high gain device, and the input signal is attenuated via resistors R7 and R8.

Parts List – PIC Carillon

TWO CHANNELS

- 1 PC board, code 656, available from the *EPE PCB Service*, size 132mm x 76mm
- 1 4 x 4 matrix data keypad – see text
- 1 plastic case, size and type to individual choice
- 1 20MHz crystal (X1)
- 2 10kΩ miniature round carbon preset potentiometers (VR1)
- 2 8-pin DIL sockets
- 4 16-pin DIL sockets
- 2 18-pin DIL sockets
- 4 self-adhesive PCB supports
- Multistrand connecting wire; bare link wire or component off-cuts;
- 30 solder stakes: solder, etc.

Semiconductors

- 2 1N4148 signal diodes (D1)
- 3 PIC16F628 microcontrollers (preprogrammed – see text) (IC1, IC6) (Ready-programmed PICs are available from Magenta Electronics – see their advert)

- 2 DAC08 or DAC0800 digital-to-analogue converters (DAC) (IC2)
- 1 TL071 low-noise op amp (IC3)
- 1 LM13600 or LM13700 dual transconductance amplifier (IC4)
- 1 ICL7660 voltage inverter – see text (IC5)
- 1 78L05 +5V 100mA voltage regulator

Capacitors

- 2 10pF ceramic (C1, C2)
- 5 100nF ceramic disc, 0.2in pitch (C3, C7, C11, C12)
- 2 1μF radial elect. 16V (C5)
- 2 2.2μF radial elect. 16V (C4)
- 5 22μF radial elect. 16V (C6, C8 to C10, C13)

Resistors (0.25W 5% carbon film)

- 6 1kΩ (R5, R8, R9)
- 4 4.7kΩ (R2, R4)
- 12 10kΩ (R3, R11 to R14 – R1 and R15 (one for each))
- 6 100kΩ (R6, R7, R10)

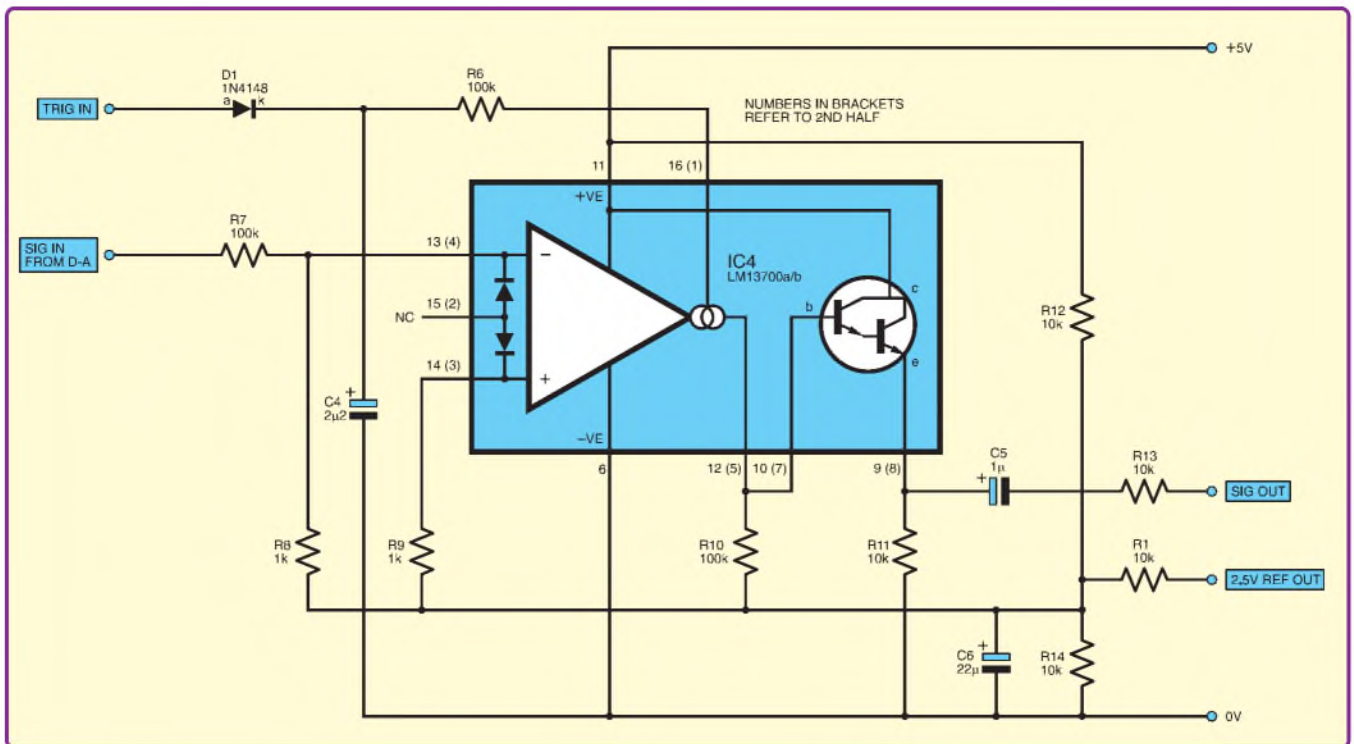


Fig.3. Circuit diagram for the envelope shaper section. This is a dual device IC and the other channels' VCA pins are shown in brackets.

As each note commences, PIC IC1 outputs a brief 5V control voltage pulse from pin RB0. This is fed via diode D1 into capacitor C4 and into the TCA control input, via resistor R6, turning on the VCA. On cessation of the pulse, capacitor C4 discharges via R6 and the reducing current flowing into the control input causes the output signal amplitude to decrease, eventually to cease. The audio effect thus starts with maximum amplitude and gradually fades away, as with a bell.

Because multiple channels can be used for polyphony, the output from the envelope shaper(s) is fed via capacitor C5 and resistor R13 into the simple mixer stage around IC3 in Fig.4. The final signal is capacitively coupled via C13 to the line input of the user's existing audio amplifier.

Keypad interface

As mentioned earlier, the simple version of this design is controlled by a 16-key keypad. The circuit for the interface circuit is shown in Fig.5.

The data keypad has its keys multiplexed internally, outputting an 8-bit code via its connector. This code is fed as two nibbles to PIC IC6, pins RA0-RA3 and RB4-RB7. From the value of the composite byte, the PIC determines which key has been pressed and sends

that information serially to the DAC stage in Fig.2.

The use of the keypad keys in relation to their position can be set by a PIC programming user to be other than those used by the

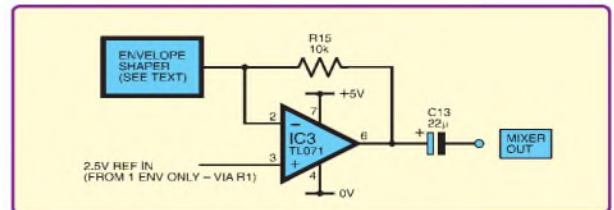


Fig.4. Circuit diagram for a simple mixer

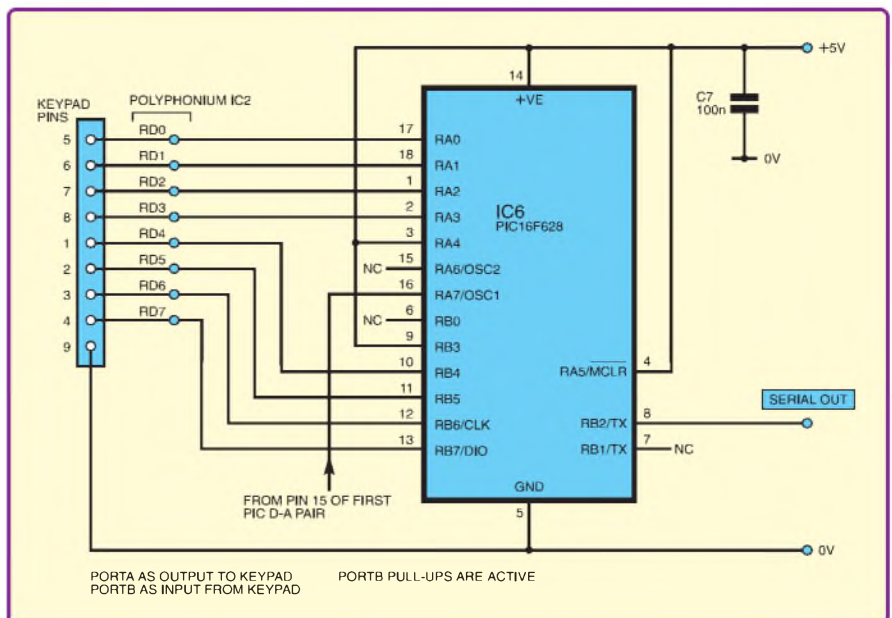


Fig.5. Interface circuit diagram

author. The supplied software, and purchased pre-programmed PICs have the author's suggested use configured, as illustrated in Fig.6a. It will be seen that all 12 notes of a standard octave are available. Note that in modern usage, sharp notes (#) are regarded as the flat (b) of the basic note that follows, thus A sharp is the same as B flat.

The remaining four keys set the octave from which any note is allocated following the pressing of any octave key, causing all subsequent note presses to be related to the same octave until changed. Octave 4 is the one initially used until changed. Octave 3 is lower than Octave 4, and Octave 5 is higher, with Octave 6 higher still.

The serial data transfer rate for all devices in this design is 9600 Baud.

Polyphonium interface

The circuit in Fig.5 is also used for interfacing the *Polyphonium*, without the need to change its hardware or software.

A data output connector was included with the *Polyphonium*, originally used to interface to an LED display. The same connector is used to connect data to the circuit in Fig.5, using the pins that are notated for such use. **The keypad must not be used when the unit is connected to the Polyphonium.**

The Carillon interface only accepts *note frequency* data sent by the *Polyphonium*, ignoring bytes that give *note type* (minims, crochets, etc).

Multiple channels

The software has been written so that each note is acted upon through to its end before the next note is accepted by that channel. Should notes arrive faster than a channel can handle them, they are passed to a re-transmission routine for sending on to the next channel in series, and so on.

It is imagined that if the playing speed of a true 2-key (fist struck) carillon is being simulated at a typical rate of play, then just two channels are needed. The keypad version possibly only needs one channel, unless the keys are pressed really fast. The *Polyphonium* version could need more channels, maybe even more than four if the music sent to it contains multiple notes intended to be heard at the same time.

Readers with PIC programming facilities could amend the note timing routine if wished. The register used

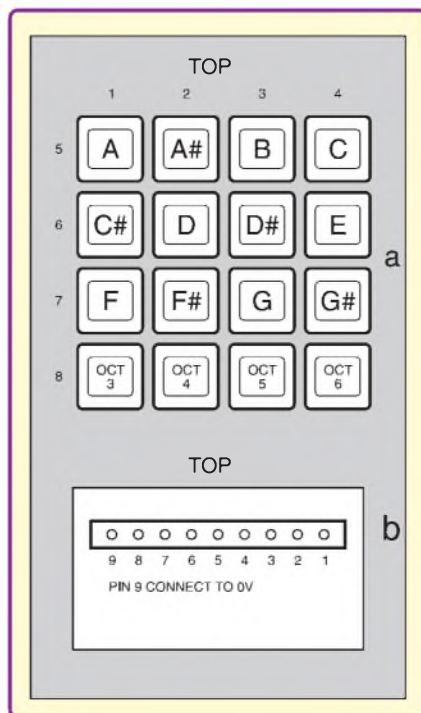


Fig.6. Suggested keypad annotations and pin allocation

is **ENDLENGTH**. Register **NOTELENGTH** sets the pulse length sent to the envelope shaper. The values relate to the number of times that timer TMR0 rolls over since the start of a note.

It is suggested that you build just one channel, or maybe two, until you know the type of music and its play rate you wish to use. In principle there is no upper limit to the number of channels used. Each PCB draws about 85mA.

Software

The PIC software has been written so that identical copies of it are used with all PICs, irrespective of their func-

tion. PIC pins and tracks on the PCB determine the PIC's function, its status being assessed at the initialisation of the program following switch on.

The source code and hex files are available for free download from the *EPE Downloads* site, accessed via www.epemag.co.uk. The supplied hex code is in standard MPASM-type format as usual, and any MPASM-compatible PIC programmer is capable of using it. Preprogrammed PICs are available from **Magenta Electronics** (see their ad in this issue for contact details).

The source code was written using the author's *TK3* software and the author has ensured that its ASM coding format is compatible with MPASM-type assemblers. If you do not wish to change it in any way, you do not need to use it – use the hex file as supplied.

StyloPIC interface

In principle, the Carillon unit can be used with the *StyloPIC*. But, because the author no longer has his *StyloPIC*, he is unable to confirm how to do it. However, as part of the PIC software available, a description of the expected source code changes that need to be made is given, along with the suggested sub-routines. Details of a simple PCB change are also given. See file **CarillonStyloPICmods.asm**.

Information on the alternative course of action that can be taken if the initial technique does not work is provided – it may be necessary to ignore the key connected to PIC pin RC7, which is used for serial data output to the Carillon, C# at the left end of the integral keyboard.

As the link is PIC-to-PIC, an RS232 interface is not required – although it would be if data were to be sent direct from a PC. Previously published PIC

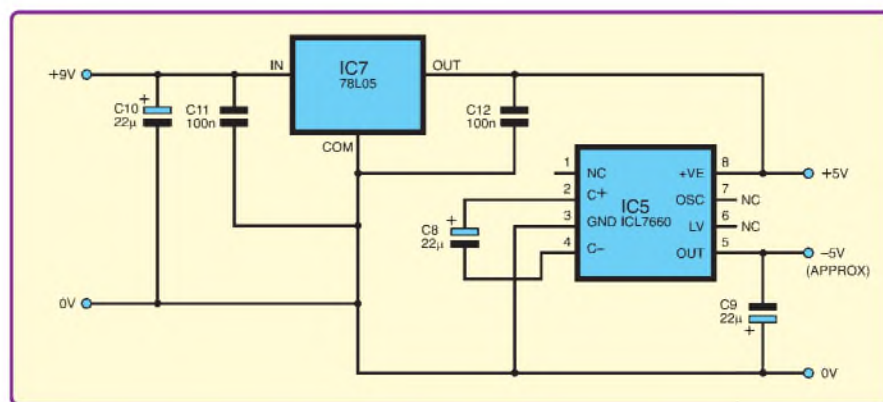


Fig.7. Power supply circuit diagram for the PIC Carillon

ribbon cable and suitable DIL connectors are used to connect them to the PCB.

If using the *Polyphonium* instead of the keypad, use the same PCB pins, connected as shown in Fig.8.

PIC IC6 is not required if the unit is interfaced to the *StyloPIC*. That unit connects to the 'Serial From Previous Stage' point of the first PCB, via a suitable 2-wire lead.

If using multiple PCBs, serial connections between them should be made as shown in Fig.8.

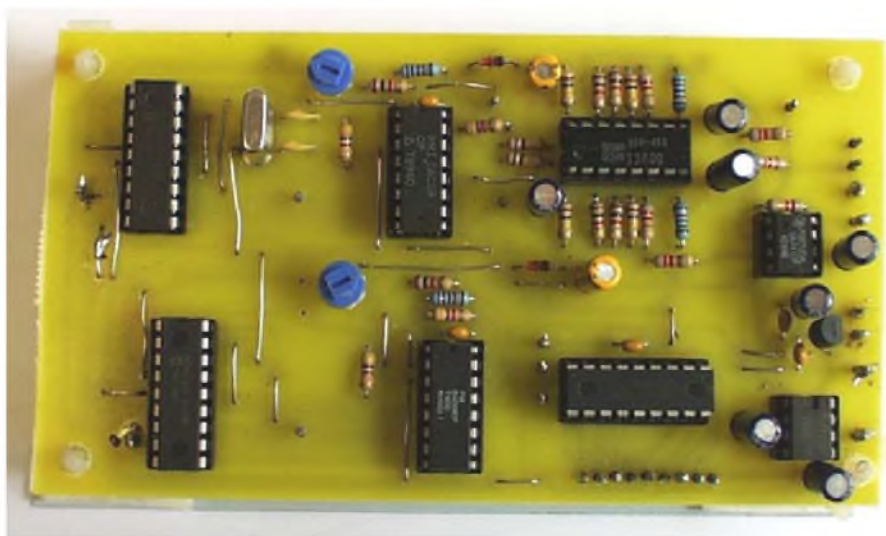
No recommendation is made about casing the design as there are several variants, including the number of channel PCBs used. A plastic case of appropriate size would be suitable.

Setting up

On power up with all ICs in place, including pre-programmed PICs, double-check the +5V and -5V supply lines. Connect the unit to a suitable audio amplifier.

If using the keypad, check that pressing its keys causes notes to be heard from the amplifier. Adjust preset VR1 (on each board) until an undistorted and reasonable amplitude sound is heard. Also, check that the data from the *Polyphonium* or *StyloPIC* is being acted upon.

Let the author know via *EPE* how you like the PIC Carillon. It delights him!



Layout of components on the author's prototype circuit board

References

The Physics of Music, Alexander Wood, ISBN 0-470-95978-9.

There are numerous web links about bells on the Web, accessible via www.google.com for instance. An interesting site is also at www.msu.edu/~carillon/batmbook and includes some historic engravings showing bells in the making.

The UK has at least two bell foundries, Taylor's Foundry at Loughborough, and one at Whitechapel, London. The author has been on a tour of this one. Although safety regulations prohibit the public from seeing the actual casting of bells, other

aspects of it are fascinating. Established in 1570, it cast London's Big Ben bell and the Liberty Bell at Philadelphia. Browse www.whitechapelbellfoundry.co.uk.

Many church towers around the UK offer bell ringing courses, and are looking for new ringers. There are about 40,000 UK ringers. The author's wife is a ringer at a local church, originally training to Ring in the Millennium, as all UK church bell towers did that New Year's Day. She usually rings twice a week. You do not need to be religious in order to join a bell ringing team. You are sure to be welcomed! Also browse www.ringingworld.co.uk. **EPE**

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V2 PC Scope (August 07)

In Fig.6 the two leads marked NC on the left should be marked 'CLK' (upper) and 'Data' (lower). IC15 should be a 79L05, the circuit diagram is correct. In Fig.6 there is a small section of PCB track missing - the right-hand side of C11 needs connecting to the 0V line (the left-hand side of C12).

Readers whose software is not storing new Baud Rate data, for reasons unknown, can change the Baud value in the V2scopeSettings.txt file to the one required.



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Writing to Flash

When we write software for PICs, in the majority of cases we rely on the program being written to Flash memory, and our data (variables) being held in Random Access Memory (RAM). Microchip refer to RAM as registers, but they perform exactly the same function as RAM on other processors. Flash memory is non-volatile – which simply means that its contents are preserved when power is removed – while the contents of RAM are lost.

This separation, where code goes into Flash and data goes into RAM is emphasised by the internal architecture of the PIC processor. The code and data areas of memory occupy physically separate parts of the chip, and you cannot easily move information from one area to another. In fact, on the PIC10, 12 and 16 family devices, the only way to transfer information from Flash memory to RAM is using the `retlw` instruction. This can be used to transfer a single byte of Flash memory to the `W` register, and not very efficiently, since it uses a whole Flash word location to do it.

This kind of CPU architecture is called *Harvard Architecture*, which unlike the larger CPUs from Intel and AMD, are based on *von Neumann Architecture*. The benefit of Harvard Architecture processors is that they can access both Flash and RAM in a single instruction cycle, which speeds up program execution – important for processors running at a low clock speed.

While the PIC16 family of processors provide an additional area of non-volatile EEPROM (Electrical Erasable Programmable Read-Only Memory), this is implemented as a peripheral device attached to the CPU, and so acts like an external EEPROM memory chip, just built into the PIC package.

So why are we discussing this as though there is a problem with the design of PIC microcontrollers? The reason is that there is a wide range of microcontroller system projects that cry out for the ability to transfer information between Flash and RAM, and vice-versa. We will discuss the uses later on in the article, but for now let's see how Microchip solved this 'problem', and how we can make use of it.

Data transfer

Microchip addressed the problem with the introduction of the PIC18 range of processors. At their introduction, for the first time, it was possible to transfer data in both directions – from Flash to RAM, or

from RAM to Flash. And that latter feature opened up a number of very interesting opportunities, as we shall see in a moment. With the PIC18F family of processors, Microchip introduced two new sets of instructions – `TBLRD` and `TBLWT`. These are used to transfer data from Flash and into Flash respectively.

Before we discuss how to use Flash memory, let's take a look at how the memory is organised. Fig.1 shows the memory layout of a typical PIC18 device, the PIC18F2420. (It's worth pointing out that although there are hundreds of PIC variants with different amounts of memory, they do all follow a similar structure.)

Memory layout

The Flash memory contains three distinct blocks of memory: Program Flash, that contains all your code; configuration registers, that define the operation of certain features of your CPU when it powers up; and two bytes called the *device ID* that identify what type of PIC the device is. These last two bytes can only be read, since they are set by Microchip to allow chip programming software to automatically detect the device.

The PIC reserves a few bytes at the beginning of Flash memory for the 'reset address', the first program location that the processor will run at start-up, but otherwise you are free to use the remaining program Flash memory locations as you wish.

The Program Counter register is a special variable used by the processor to remember the address of the current instruction being executed. This register is 21 bits wide, which means, in theory, it can address up to 200000h bytes of memory (the 'h' character means the number is being shown in hexadecimal. 200000h means 2097152 in decimal – rather a lot of memory!)

Although the Program Counter can address this amount of memory, it does not mean your PIC has that much. The PIC18F2420 has only 16384 bytes of Flash, and the remaining possible locations are unused. The config and device ID bytes are shown at addresses much higher than 200000h, so you might wonder how these could be useful to us if the Program

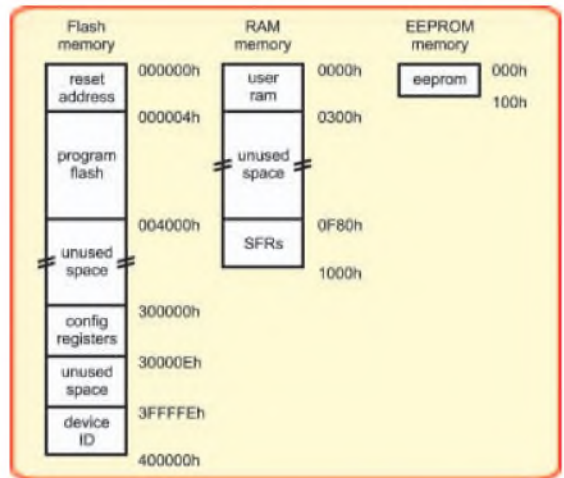


Fig.1. Memory organisation, PIC18F2420. Memory addresses shown in hexadecimal

Counter cannot access them. This is where the `TBLRD` and `TBLWT` instructions come in, as we shall see in a minute.

Accessing the RAM is quite straightforward as most PIC instructions can access them directly, with the Bank Select Register (BSR) determining from which bank of 256 bytes to read.

The EEPROM area is not directly accessible by any PIC instructions, but must be accessed indirectly using a special sequence of program instructions.

While the Device ID bytes are read-only, they can still be used by your program to detect what type of PIC the program is running on, and alter the behaviour of the software accordingly.

Reading Flash

Finally, before getting into the details of accessing Flash memory it's worth taking a quick look at how the Flash memory is arranged. Microchip refers to Flash memory in terms of 'words'. The term 'word' refers to the size of each instruction in memory. The size of this word (in bits) has changed over the years as Microchip introduced processors with greater and lesser capabilities. The PIC10F Flash memory is 12 bits wide, the PIC16F 14 bits wide and the PIC18F uses 16 bits – conveniently, two bytes exactly. This makes reading and writing data in Flash straightforward on the PIC18F.

Reading from Flash requires several steps, and involves a number of Special Function Registers (SFRs), as shown in Fig.2.

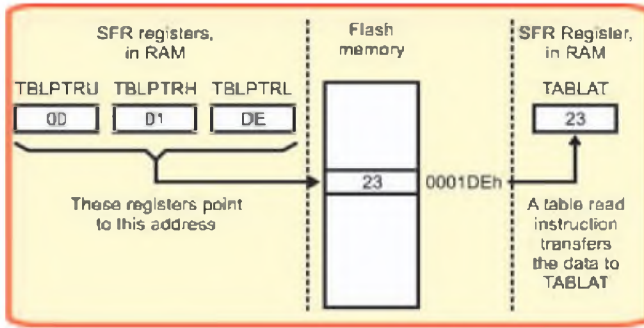


Fig.2. Reading from Flash

To read a byte from Flash you must write the address that you want to read from into the three address SFRs called TBLPTRU, TBLPTRH and TBLPTL. Together these form a 24-bit address register, although the top two address bits in TBLPTRU are unused, and should be loaded with zeros.

Having loaded these three registers, you can execute the TBLRD* instruction to copy the contents of that address into the TABLAT SFR, from where you can then copy it into the W register and use it like any other RAM-based variable.

The code that matches the example in Fig.2 is as follows:

```
movlw 0x00
movwf TBLPTRU
movlw 0x01
movwf TBLPTRH
movlw 0xDE
movwf TBLPTL
TBLRD*
movfw TABLAT
```

Loading up the three registers before each TBLRD* instruction would of course be very inefficient, so it is fortunate that Microchip has provided several versions of the TBLRD* instruction that will automatically update the three registers for us. These variants are:

TBLRD*+ increment the TBLPTR registers by a value of 1 after reading the byte out

TBLRD*+* increment the TBLPTR registers by a value of 1 before reading the byte out

TBLRD*- decrement the TBLPTR registers by a value of 1 after reading the byte out

These are very powerful instructions: they not only read a byte out of memory, they also increment the 22-bit number stored in the three TBLPTR registers, all in a single instruction period.

Writing to Flash

Writing to Flash is more involved than reading, and differs slightly between different processor types. Writing to Flash memory is complicated because the area to be written to must be first erased, just like the old EPROM memories that had to be placed under a UV lamp before being reprogrammed. With Flash, however, the

erase process is somewhat simpler, requiring a few instructions to be executed and a short delay while the erase takes place.

Unfortunately, it is not possible to erase individual byte locations, but instead you must erase a consecutive block of bytes (sometimes referred to as a *row*). On the PIC18F2420 blocks are 64 bytes in size, but this can be smaller for different processors. Always check your datasheet!

The procedure for erasing a block is as follows:

Set the TBLPTR registers to an address anywhere within the 64 byte address range that you want to erase;

Issue the 'flash erase' instruction sequence.

This code sequence is shown in Fig.4.

Something quite unusual happens when you execute the erase instructions: when the final instruction is executed the CPU will halt for around 2ms. No other instructions can run, not even interrupts (which is why global interrupts must be disabled.) This is because the entire Flash memory becomes unavailable until the block erase has completed.

```
; Point TBLPTR to the block we want to erase
movlw 00h
movwf TBLPTRU
movlw 01h
movwf TBLPTRH
movlw 0C0h
movwf TBLPTL

; Prepare for a flash erase request
bsf EECON1, EEPGD
bcf EECON1, CFGS
bsf EECON1, WREN
bsf EECON1, FREE
bcf INTCON, GIE ; disable interrupts

; start the flash erase
movlw 55h
movwf EECON2
movlw 0AAh
movwf EECON2
bsf EECON1, WR ; this takes 2ms

bsf INTCON, GIE ; re-enable interrupts
```

Fig.4. Erasing a Flash block

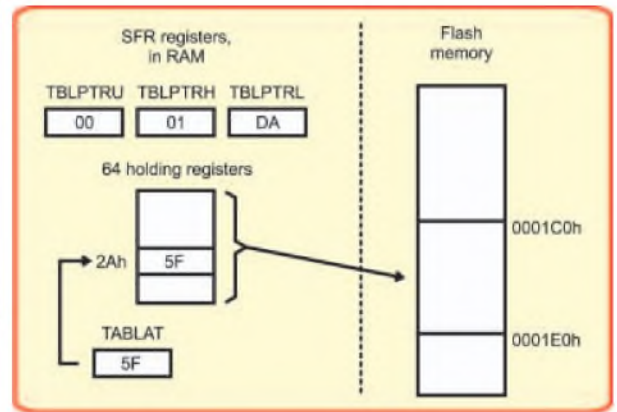


Fig.3. Writing to Flash

Once the erase has completed you are now free to write data into this block of 64 bytes.

Writing to flash is also somewhat complicated by the fact that you have to write 64 bytes at a time (to match the 64 byte area you just erased.) The process to do this appears rather odd and is shown in Fig.3:

Set the TBLPTR registers to the address you want to write to;

Load the byte you want to write to flash into the TABLAT register;

Issue a TBLWT* instruction;

Repeat the above three steps for other bytes you want to change;

When all bytes written, issue the **flash write** instruction sequence.

The reason for the above steps is that when writing bytes with the TBLWT* instruction, your bytes are transferred to a special 64-byte holding buffer. The final flash write instruction sequence transfers all 64 bytes in one go. Once again, the CPU will stall, this time for around 6ms, while the bytes are actually programmed into memory.

The instructions for performing the write operation is shown in Fig.5.

As with the TBLRD* instruction, there are four variants of TBLWT, which provide for automatic increment or decrement of the TBLPTR registers.

As a final point, you should note that when erasing and writing to Flash, your blocks must be aligned on 64-byte boundaries. This means that, for example, the first block in Flash is at locations 0 to 63, and the second block is at locations 64 to 127 and so on. You cannot choose to use an arbitrary start location for a block; it must be a multiple of 64. If you have a block of data

```

; Point TBLPTR to the block we want to write to
movlw 00h
movwf TBLPTRU
movlw 01h
movwf TBLPTRH
movlw 0DAh
movwf TBLPTRL

; Do a write into the write buffer.
; Normally, you would write all 64 bytes
movlw 5Fh
movwf TABLAT
tblwt*

; Now do the actual transfer from the buffer
; to the flash memory
bsf EECON1, EEPGD
bcf EECON1, CFGS
bsf EECON1, WREN
bcf INTCON, GIE ; disable interrupts
movlw 55h
movwf EECON2
movlw 0AAh
movwf EECON2
bsf EECON1, WR ; start program - takes 6ms
bsf INTCON, GIE ; re-enable interrupts
bcf EECON1, WREN

```

Fig.5. Programming a Flash block

that straddles a block boundary you must erase and reprogram both blocks – even if you only want to change the values of two bytes.

There are several control flags being setup in these erase and write instruction sequences, but the details can be ignored as the sequences required are always the same. Other settings of the control bits can be used to read and write to the EEPROM, which we will cover in a later article.

software control. The main use, which has been covered in an earlier *PicN Mix* article, is to implement a bootloader within the application code. A bootloader allows a PIC's program to be updated while the chip is in-circuit or even while in use, and is invaluable for commercial projects.

A somewhat more exotic use would be to implement dynamically loading *Device Drivers*, small pieces of code that are used to control an external peripheral.

Limitations

Flash, unlike RAM, has limitations on the number of times you can write to it. Each time you erase a block, the device experiences stresses that slowly degrade the silicon. The memory is limited to approximately 100,000 erase operations, however, so this should not be a problem in most applications. The other issue to bear in mind is that a block erase and reprogram can take around 8ms, around 10,000 times slower than writing to RAM!

Use of Flash Programming

Despite the limitations there are some very interesting uses for Flash reprogramming under

You could, for example, create a system that can have a series of plug-in modules, with the module-specific device driver software stored in an EEPROM chip in the card. The PIC could read the code from the EEPROM, transfer it to Flash memory and then execute it – all without ever having to switch the system off. When you remove the module and plug in a different one, the new device driver software could be automatically loaded and the system continue operation.

More mundane uses include storing calibration data, or text strings, since, while more involved than using the simple `retlw` instruction, it is a more efficient way of storing data.

Brain teaser

We've mentioned that the use of Flash programming can be used to implement dynamically loadable device drivers – but what kind of uses could that actually be put to in a hobby project? If you have an interesting suggestion for a project that could benefit from such a facility, let us know. We will publish any interesting ideas in a subsequent *PIC N' Mix* article. Submissions by email to mike.hibbett@gmail.com or in writing to *EPE*.

Errata

There was a small error in one of the figures in last month's article. In the main flowchart of Fig.4, the arrow from the bottom of the diagram is shown coming back in at the top, coming into the 'menuState(STARTUP)' box. It should join immediately below this box, not above it.



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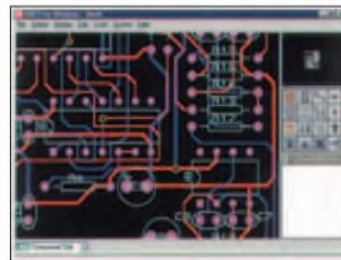


Logic Probe testing

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.

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.

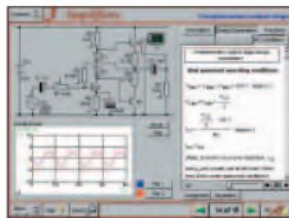
ELECTRONIC CIRCUITS & COMPONENTS V2.0



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

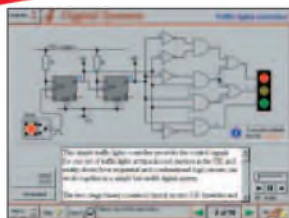


Complimentary output stage

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



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.

ANALOGUE FILTERS



Filter synthesis

Analogue 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.

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

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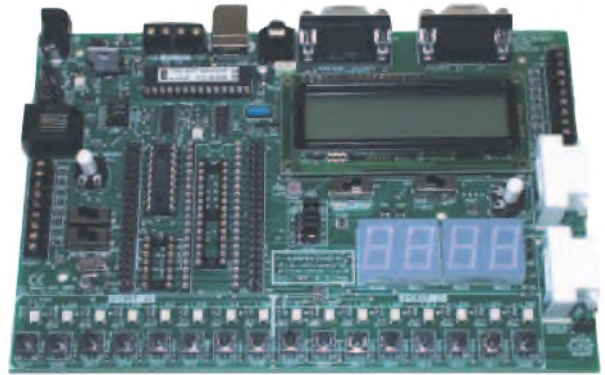
HARDWARE

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SOFTWARE

ASSEMBLY FOR PICmicro V3 (Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (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 45 tutorial sections
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- Includes MPLAB assembler
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- Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.)
- Imports MPASM files.



'C' FOR 16 Series PICmicro VERSION 4

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 V3

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A Powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and I.c.d.'s. The use of macros allows you to control these devices without getting bogged down in understanding the programming.

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
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Flowcode V3 (Hobbyist/Student) – For details on Flowcode, see the previous page.

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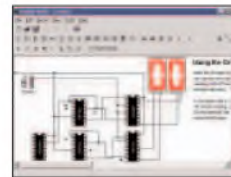
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By JIM ROWE

This device detects an incoming call on your phone or fax and lights an LED and latches on a relay, which you can use to switch on a lamp or horn in another room or your garage.

So what's wrong with listening for the phone ringer or looking at the fax machine's 'out' tray? If you work at home you need to be able to respond to phone calls or faxes as soon as they come in, but you cannot be hovering over the phone all day; there are times when you have to leave your office or home and if you do not physically lift the phone handset and listen (if you have BT Answer 1571) or check the fax as soon as you arrive back, calls or faxes could be without a response for some time.

Or maybe you have an office but spend some time in the workshop. Same problem – or even more so if you are waiting on an important call or fax.

So this is the remedy. Build this device and it will let you know that a phone call has been made or a fax has been received, without you needing to actually check the phone or fax.

What's more, you can use it with a remote light or siren to alert you over the noise of machinery!

The Phone/Fax Missed Call Alert hooks up easily to the fax machine's phone line. It connects in very easily, using a standard low-cost modular cable. The kit of parts should set you back no more than about £15 and you should be able to build it up in a couple of hours at most.

How it works

When someone dials your phone or fax number, the exchange sends out short (200ms) bursts of a 75V 17Hz AC signal – the 'ring signal'. It's this signal that causes your phone to ring or triggers the fax machine into answering and receiving the message.

Our Missed Call Alert is designed to monitor the phone line and respond to the same ring signal, using it to trigger a flipflop and hence latch a relay.

As you can see from the circuit diagram Fig. 1, the Missed Call Alert has two standard RJ12 modular phone sockets, interconnected so that it can easily be connected in 'daisy chain parallel' (ie, it doesn't break the circuit) with your phone or fax machine. It connects across the phone line with a simple 'bridging' circuit, consisting of a 470nF capacitor and 22kΩ resistor connected in series, which passes only AC and limits the current, plus a bridge rectifier formed from diodes D1 to D4 to convert the 17Hz AC signal into pulsating DC.

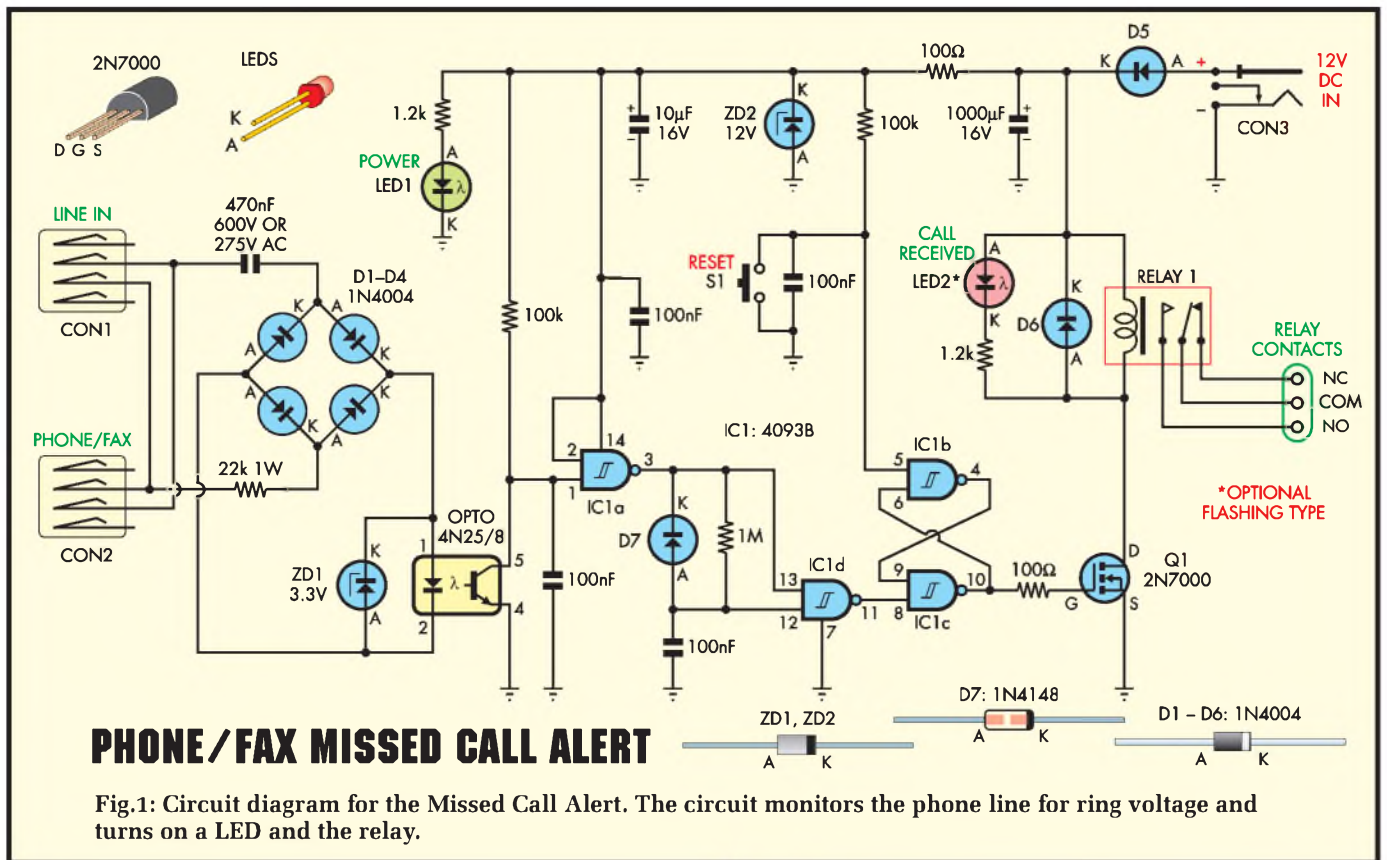
This small pulsing DC current (about 2mA) is passed through the input diode of the 4N25/28 optocoupler. With each pulse the diode emits IR light, which in turn causes the phototransistor inside the opto to conduct.

Zener diode ZD1 is connected across the opto's diode to protect it from damage in the event of noise 'spikes' on the phone line. These can occur, for example, during thunderstorms.

Now until this happens, the phototransistor is not conducting and as a result the input of gate IC1a (pin 1) is pulled up to +12V by the 100kΩ resistor. The 100nF capacitor also charges up to +12V. But when the phototransistor conducts, as a result of the ring signal, the 100nF capacitor is discharged and pin 1 of IC1a is pulled down to ground potential. As a result the output of the gate (pin 3) switches high, pulling input pin 13 of gate IC1d high as well.

At the same time the 100nF capacitor connected between input pin 12 and ground also begins charging, via the 1MΩ resistor.

If the sensing circuit has detected a true ring signal, the output of IC1a will remain high for about 200ms – the length of the first burst of 17Hz AC. This gives more than enough time for the 100nF capacitor to charge up to logic



high level via the 1MΩ resistor and as soon as this happens both inputs of IC1d will be at this level. As a result the output of IC1d (pin 11) will switch low – producing a negative-going pulse to trigger the R-S flipflop formed by interconnected gates IC1b and IC1c.

If the sensing circuit has not detected a true ring signal, the output of IC1a will fall low again before the voltage on pin 12 of IC1d has reached logic high level and when it drops it will remove the charge on the 100nF capacitor via diode D7. As a result both inputs of IC1d will return to ground potential and its output will never switch low. So the purpose of D7, the 1M resistor and 100nF capacitor is to ensure that the flipflop is only triggered by a valid burst of ring signal.

The flipflop based on IC1b and IC1c is normally in its reset state (output pin 4 high, output pin 10 low), because when 12V power is first applied pin 5 of IC1b is held at logic low level for a couple of milliseconds until the 100nF capacitor connected from this pin to ground has time to charge up via the 100kΩ resistor.

With the flipflop in this reset state, the gate of MOSFET transistor Q1 is held down at ground potential via pin 10 of IC1 and the 100Ω suppressor resistor. Q1 is therefore held off. But when pin 11 of IC1d drops low, as a result of the circuit sensing a valid burst of ring signal, the flipflop is triggered into switching into its set state, this results in pin 10 of IC1c switching high. This switches on Q1, allowing it in turn to activate the relay and LED2, to indicate that a call has been received.

It stays this way until you physically reset the Missed Call Alert by pressing pushbutton switch S1 briefly. This discharges the 100nF capacitor, applying a negative-going pulse to pin 5 input of IC1b until the capacitor recharges via the 100kΩ resistor.

NOTE: The Missed Call Alert is not BT Approved

All devices designed to connect directly to the PSTN (public switched telephone network) require official BT Approval before they may be legally connected to the network.

Strictly speaking this requirement also applies to our Phone/Fax Missed Call Alert. However, in designing the unit we have taken great care to ensure that if built up exactly as described, the Missed Call Alert may be connected to a PSTN line with complete safety.

This brief negative-going pulse switches the flipflop back to its reset state, with pin 10 held at ground potential and Q1 turned off again. Thus the relay is de-activated and LED2 also turns off.

Most of the circuit operates from a nominal 12V DC supply, which can come from either a 12V plugpack or a 12V battery. Diode D5 provides protection against reverse polarity damage, while ZD2 ensures that the supply voltage for IC1 can never exceed about 12.5V. LED1 provides power on indication.

By the way, you can use either a standard 5mm red LED for LED2 or alternatively, one of the types featuring its own built-in flasher. The latter cost a few pence more than a standard LED, but the flashing feature makes them better at attracting your attention. Whichever type of LED you use, the relay simply turns on when a call occurs and remains on until you press the reset button.



No electrical connection

Note that because we're using an optocoupler to sense the presence of a ring signal on the phone line and couple this information to the rest of the circuit, there is no ohmic connection between the two – or between the phone line and anything connected to the Missed Call Alert via the plugpack power supply or the relay contacts.

In fact, the optocoupler provides a very high degree of isolation: it can withstand voltages of more than 5,000V peak for over a minute, with an isolation resistance of something like 100G Ω (yes, Gigohms!).

So the Missed Call Alert itself is well protected against damage from 'spikes' on the phone line, and the phone line is also protected against anything nasty which might somehow find its way into the circuit.

Construction

Building the Missed Call Alert is particularly easy, because virtually all of the electronic parts are mounted on a small PC board. This measures 122 × 58mm, carries the code 655 and has rounded cutouts in each corner so that it fits easily inside a standard UB3 plastic box. It actually mounts behind the lid of the box, via four 25mm long M3 tapped spacers.

Wiring up the PC board should be hassle-free if you use the overlay diagram (Fig.2.) and photos as a guide.

Begin by fitting the two RJ12 sockets at the left-hand end. Make sure all six of their fine connection wires are passing down freely through the matching board holes before you push their plastic mounting spigots through the larger holes, as the latter tend to 'snap' into place and this can buckle any of the fine wires that are free to move. Then when both sockets are snapped into position, turn the board over and solder all wire leads to their pads.

Next fit DC connector CON3 to the board, along with the 3-way terminal block. Then fit the resistors, including the larger 22k Ω 1W unit, which fits in the lower left-hand corner.

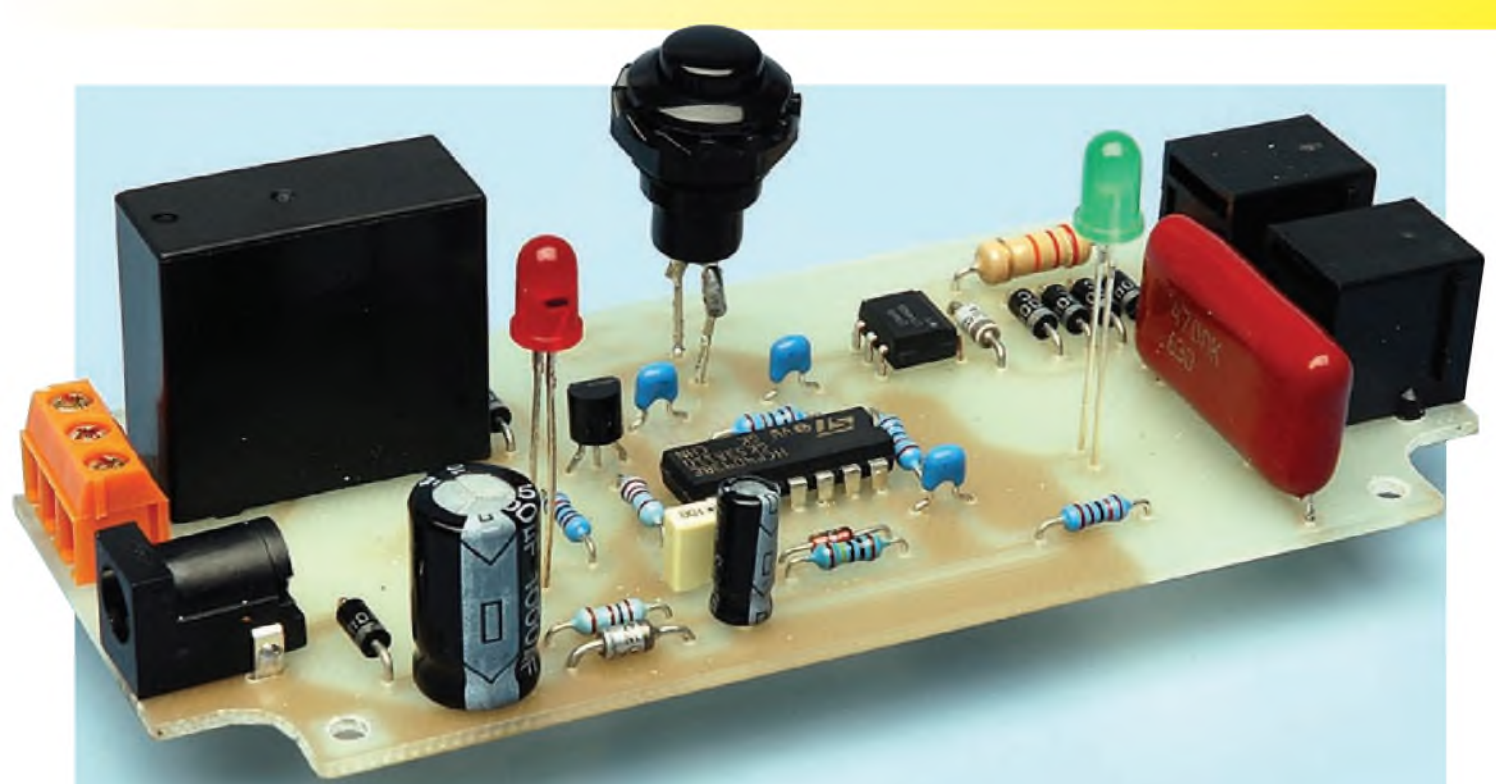
Follow these with the non-polarised capacitors, noting that the 100nF MKT cap goes just above the vertically orientated 100 Ω resistor, while the three smaller 100nF multilayer monolithics go in the other positions. Note also that the board has four holes to fit the 470nF capacitor in the upper left-hand corner, so you should have no trouble fitting either a 630V metallised polyester cap or a 250V AC X2 class metallised polypropylene.

Next fit the two electrolytic caps, taking care to fit both with their positive leads downwards. After these you can fit the 1N4004 power diodes D1 to D6, which are all orientated with their cathode band ends upwards. Then fit Zener diode ZD1, which is orientated the same way, and finally signal diode D7 and ZD2. The last two are both mounted 'east-west', with their cathode bands towards the west (or left).

Now fit the 'active' semiconductor parts, starting with Opto1 and progressing through IC1 and Q1. Take care when you're soldering the last two in place, as they're both CMOS devices and therefore susceptible to static charge damage. Use an earthed soldering iron and ideally, earth yourself as well using a wrist strap.

Don't fit the two LEDs permanently at this stage but just pass the leads of each one through the board holes (longer anode leads uppermost) and just tack-solder the cathode leads to their pads to hold each LED in place.

You can now fit the relay to the board, soldering all five of its connection pins to the pads underneath. This will make your board assembly ready for fitting to the lid of your box.



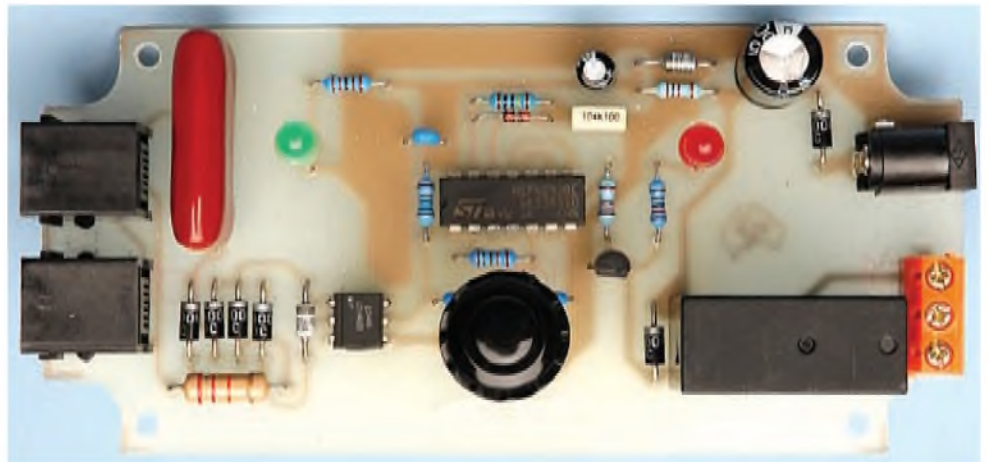
Construction is really simple because everything mounts on the one PC board. Note the 'extensions' to the pushbutton (reset) switch – these are required to bring the switch up to front panel height. The LEDs just poke through the panel.

You'll now need to drill the various holes in the box lid as shown in the cutting diagram, Fig.3. You might also want to cut the holes in the ends of the box itself as well, ready for the final assembly.

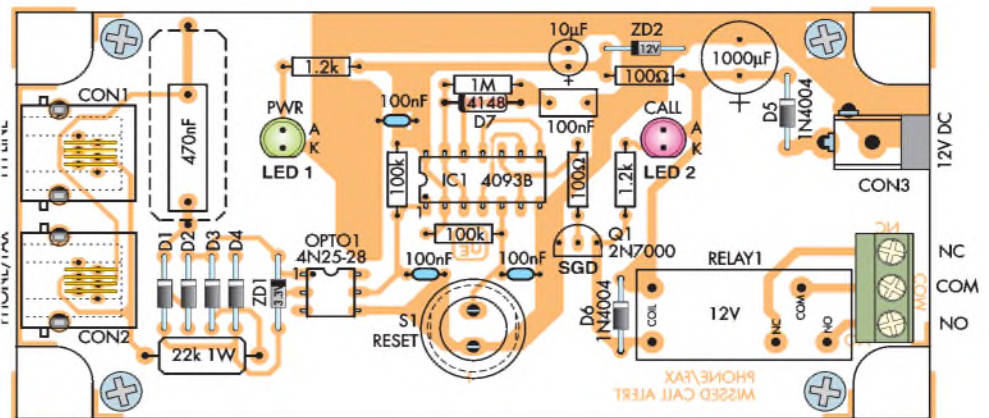
Before you fit the PC board assembly to the lid, first fit pushbutton switch S1 through the 12mm diameter hole in the lower centre and gently tighten its large plastic nut underneath using a spanner. Don't apply too much force, as this will strip the plastic threads.

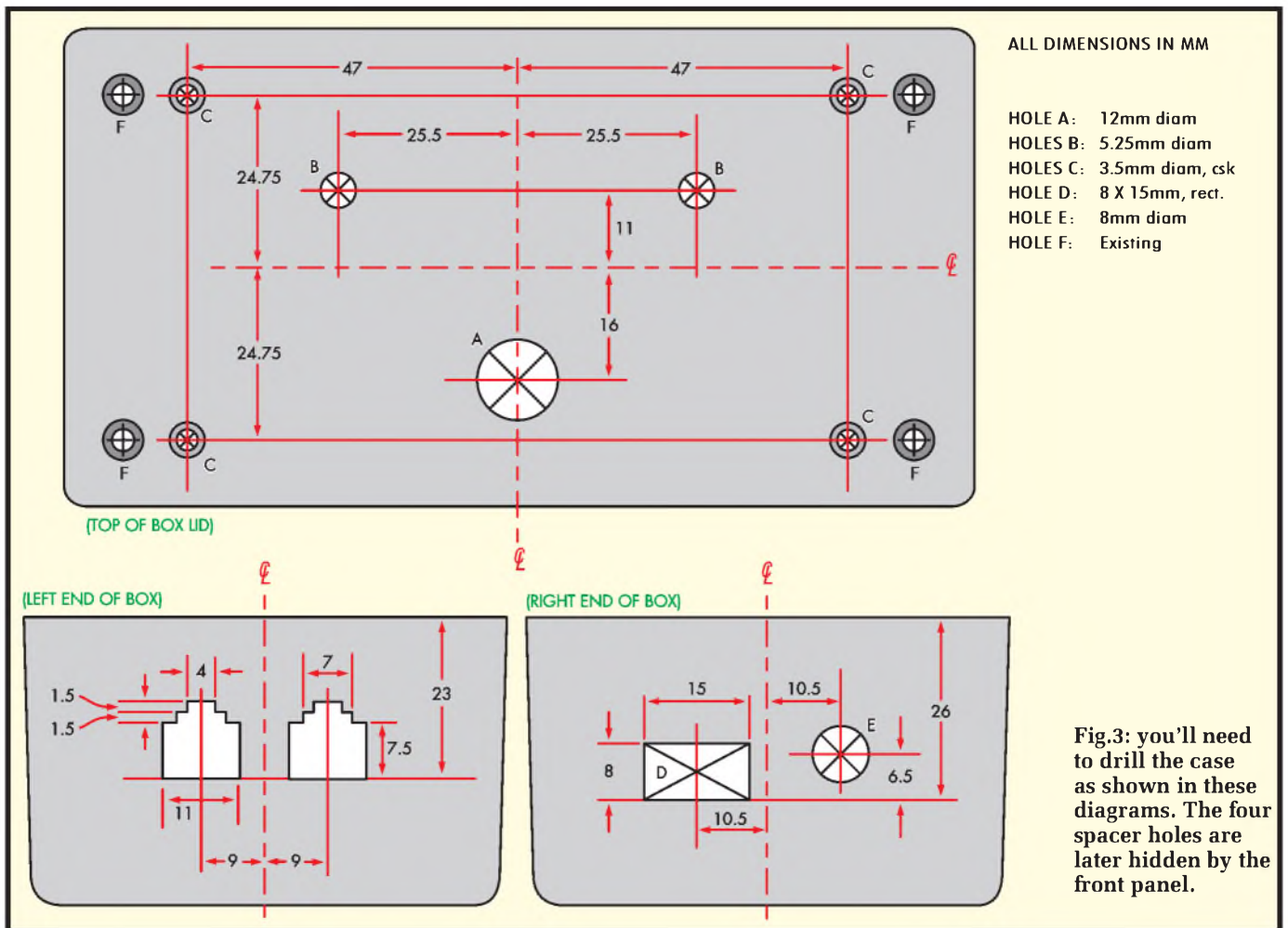
Now turn over the lid, and solder two 20mm lengths of tinned copper wire (or resistor lead offcuts) to the switch connection lugs, to extend them.

Next fit the four 25mm long M3 tapped spacers to the rear of the lid, using four countersink-head M3 screws and with an M3 flat washer between each spacer and the rear of the lid. The washers are used to extend the lid-PC board spacing to about 25mm, because this is necessary to provide clearance for the relay.



Use the photo above in conjunction with the layout (Fig.2) below to assemble the project.





Bring the PC board up to the rear of the lid, lining it up carefully so the wires from the lugs of S1 pass through their matching holes in the board and the bodies of the two LEDs

pass through their matching holes in the lid. Now, with the board resting on the outer ends for the four spacers, fit the four round-head M3 screws to fasten the assembly together.

You should now be able to solder the wires from S1 to their surrounding pads on the board. It will probably also be necessary to untack the temporary LED lead joints, to let you



Fig.4: here's how to connect it to the phone line. At left are shots of the drilled case lid and the completed assembly going into the case.

Parts List

- 1 PC board, code 655, available from the *EPE PCB Service*, size 122 x 58mm
- 1 ABS plastic box, UB3 size (130 x 67 x 44mm)
- 1 2.5mm concentric DC connector, PC board mounting (CON3)
- 2 RJ12 modular phone socket, PC board mounting (CON1,CON2)
- 1 3-way terminal block, PC board mounting
- 1 SPDT 10A PC board mounting relay, 12V/200-285Ω coil
- 1 SPST momentary pushbutton, panel mounting switch
- 4 25mm long M3 tapped spacers
- 4 M3 flat washers
- 4 6mm long M3 machine screws, countersink head
- 4 6mm long M3 machine screws, round head

Semiconductors

- 1 4093B quad CMOS Schmitt NAND (IC1)
- 1 4N25 or 4N28 optocoupler (OPTO1)
- 1 2N7000 N-channel MOSFET (Q1)
- 1 3.3V 1W Zener diode(ZD1)
- 1 12V 1W Zener diode(ZD2)
- 1 5mm green LED (LED1)
- 1 5mm red LED, flashing type if desired (LED2)
- 6 1N4004 power diodes (D1-D6)
- 1 1N4148 signal diode (D7)

Capacitors

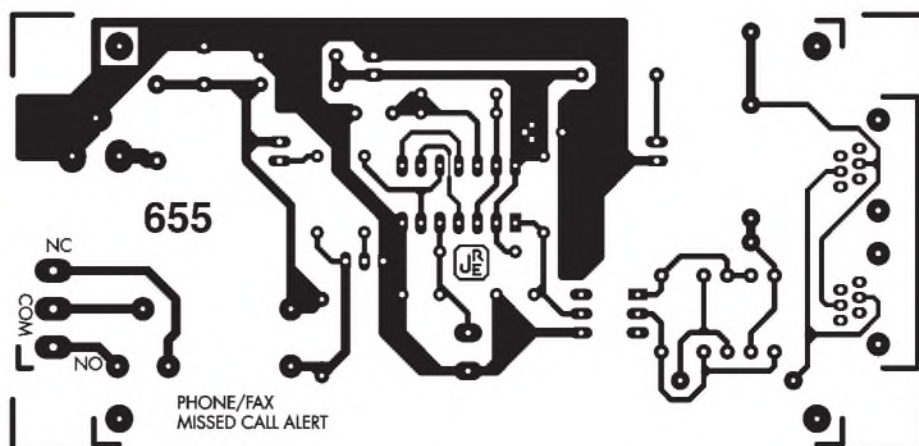
- 1 1000μF 16V RB electrolytic
- 1 10μF 16V RB electrolytic
- 1 470nF 630V metallised polyester (or 250V AC Class X2 metallised polypropylene)
- 3 100nF multilayer monolithic
- 1 100nF MKT metallised polyester

Resistors (0.25W 1% unless specified)

- 1 1MΩ 2 100kΩ
- 1 22kΩ 1W carbon composite
- 2 1.2kΩ 2 100Ω



Fig.5: above is the same-size front panel artwork (also useful as a template!) while the PC board pattern is shown below.



extend the LED bodies through their lid holes as far as they'll go, while leaving enough of the board to allow you to make the final 'permanent' solder joints. Your Missed Call Alert will then be fully wired and assembled, and ready to be fitted into the box. It simply slips down into the box vertically, after which you can fit the four box assembly screws and the plastic sealing bungs.

Putting it to work

There are no setting-up adjustments to be made to the Missed Call Alert, so you should be able to put it to work as soon as it's finished. Just connect it into the phone line of your phone or fax machine using readily available RJ12-RJ12 modular cables, as shown in the hookup diagram (Fig.4), then supply it with 12V DC power from either a plug pack or a

suitable battery. You won't need a heavy-duty plug pack – the Call Alert only draws about 36mA in standby mode, or about 80mA when it has registered a call and activated LED2 and the relay.

That's it. You should find that as soon as a call arrives, the Missed Call Alert will light (or flash) LED2 and activate the relay. So if you use the relay contacts to control a lamp or siren in another room, they'll be activated as well.

To reiterate, to reset the Missed Call Alert all you have to do is press the reset button which turns off LED2 and the relay, resetting the circuitry to wait for the next call. **EPE**

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Please make sure all components are still available before commencing any project from a back-dated issue.

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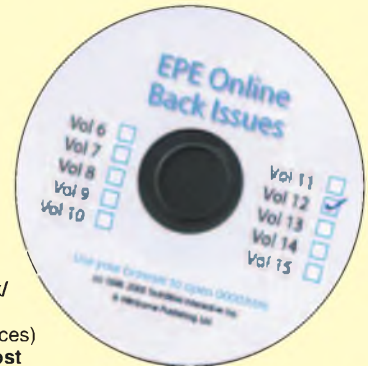
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PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

WHEN you start building electronic projects it soon becomes apparent that it can be quite time consuming to order every component, right down to the last nut and bolt. The time and effort involved is clearly dependent on the size of the project, and life is usually easier in this respect than it was in the past. Many projects are now based on a microcontroller or a specialist integrated circuit (IC).

Taking stock

Although some other components are needed in order to make the chip actually do something, the component count is generally much lower than it was in the days when projects often relied on several semiconductors supported by numerous resistors, capacitors, and other passive components. Quite modest projects often used more than fifty electronic component plus various items of hardware.

Even so, ordering everything required for a typical project can take a while, and there is a risk of delays when you actually start building the project and find that a small but crucial component has been overlooked. There can also be delays if one or two of the components are out of stock, and you have to wait for the retailer to get new stocks.

Before too long, most project builders decide that it is worthwhile having a stock of frequently used and cheaper components so that it is no longer necessary to buy every single component each time a project is constructed. The expensive and more specialist items still have to be purchased in the normal way, but all or most of the more mundane components are taken from a stock of such items.

Choice items

This is fine in theory, but which components should be kept in stock? Unless the components are chosen wisely they could simply be a waste of money. The term 'junk box' has largely fallen from use, but it is what many constructors used to call their stock of components. Care needs to be taken when buying a stock of components, or it could live up to the old 'junk box' name!

It is probably not worthwhile keeping any expensive components in stock, since this would mean committing a significant amount of money with no guarantee that the components would ever be used. Concentrating on the most inexpensive components, and especially those that are used frequently in significant numbers, is a much sounder strategy. The obvious starting point is resistors, which feature prominently in most projects in numbers and cost very little.

Even with resistors, it is necessary to take a 'hard-headed' approach, as there is little point in having a stock of the more exotic resistors such as close tolerance

(one percent) or high wattage types. These tend to be much more expensive than the ordinary types, but are used relatively little in electronic projects. Normal carbon film resistors having a power rating of about 0.25 to 0.5 watts and a 5 percent tolerance rating are a different proposition. These are used in significant numbers in practically every project and are very much in the 'dirt cheap' category.

The problem when buying a stock of small resistors is the huge number of different values available. Matters are complicated by the fact that some values seem to feature prominently in practically every project, while others are hardly ever used. For example, values such as 10k and 100k are used much more often than the nearby values of 8k2, 12k, 82k, and 120k.

The easiest way of obtaining a stock of resistors is to buy one of the resistor development packs that are offered by some suppliers. These typically provide a full range of values from 10 ohms to one megohm, but do not usually weight the quantities to take into account the typical usage of each one. The very high and very low values are little used in practice and are usually absent, so it is helpful if a few of these are purchased separately, together with extra supplies of the most popular values (1k, 4k7, 10k and 100k).

A simple but effective way of building up a stock of resistors is to buy two or three times as many resistors as you actually need. If a project needs (say) four 100k resistors, you would actually order eight or twelve of them. The drawback of this approach is it obviously takes a while to build up a useful stock of resistors. On the other hand, it has the advantage of being relatively painless, since you will hardly notice the increased cost when ordering the components for each project.

Another advantage is the built-in weighting of this method. You automatically obtain larger quantities of the more

popular values, and relatively few of the little-used values. This weighting is based on the quantities used in real-world projects of the type you build, and the quantities you obtain should quite accurately reflect your future need for each value.

The same method can be applied to other components, such as the more common capacitors and the cheaper semiconductors such as diodes, but it should not be used with anything that is expensive or in any way out of the ordinary.

Bargain hunt

Buying the 'bargain' component packs that are offered by some retailers used to be a popular way of stocking up with resistors and some other components. These were available from a number of companies that dealt in surplus stocks of electronic components, but they are less widely available these days. While these packs usually offer very good value for money, in most cases only a limited range of values is included. This does not matter provided the values included in the pack are fairly popular ones, but there is no guarantee that this will be the case.

There can be some rather odd values included in bargain packs. Most projects for the home constructor use resistor values in the E12 series (1, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, 8.2 and their decades). Resistors are also available in the E24 series, which consists of the E12 series plus 12 intermediate values (1.1, 1.3, 1.6, 2.0, 2.4, 3.0, 3.6, 4.3, 5.1, 6.2, 7.5, 9.1 and their decades). It is probably not worthwhile stocking up with resistors having the intermediate E24 values, because these are little used in electronic projects.

For beginners, it is advisable to avoid 'bargain' resistors that are not modern miniature types. Older components are



Fig.1. Potentiometers are available in various styles as well as in a range of different values. They are also relatively expensive

fine for those who undertake the renovation of old radios and other pieces of 'vintage' electronic equipment, but older resistors are far too big to fit into most modern component layouts.

Potentiometers

Potentiometers are much more expensive than small fixed value resistors, and they are available in a number of styles and types (Fig.1). Even given that only a relatively small range of values are available, this makes it expensive to produce a reasonable stock of them. The low cost of preset 'resistors' (Fig.2) are a more practical proposition, and it is probably worthwhile obtaining a small stock of the small horizontal mounting types. This is the most popular type, and they can be obtained at quite low prices.

A complication when trying to produce a stock of ordinary potentiometers is that they are available in log (*logarithmic*) and lin (*linear*) versions. This complication is avoided with preset resistors which are normally only available as linear types. They are not normally described as such in component catalogues, but a preset resistor can be assumed to be a linear type unless it is specifically described as a logarithmic type.

High capacity

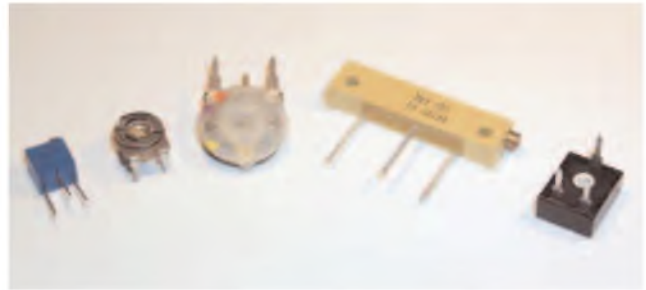
On the face of it, putting together a stock of capacitors should not be much more difficult or expensive than producing a hoard of resistors. The reality, however, is rather different, due to the huge range of types and values involved when dealing with capacitors. If you look in a large component catalogue for a capacitor having a mid-range value of around 10nF (0.01 μ F) to 100nF (0.1 μ F) you will probably find more than a dozen different types to choose from.

This might seem to be excessive, but it is simply a reflection of the difficulty involved in producing a universal capacitor that is well suited to any application. Some capacitors are intended for operation at high voltages, while others are designed to work efficiently at high frequencies, and there are also miniature types, highly stable and accurate components, and so on.

Matters are further complicated by the fact that capacitors of the same general type often exist in more than one physical form. With electrolytic types for instance, there are axial components that have a leadout wire at each end of a tubular body, and printed circuit (PC), or radial, mounting types that have both leads at the same end of the body and are mounted vertically (see Fig.4). These days most types of capacitor are available only in some form of printed circuit mounting guise, but there might be a variety of physical sizes on offer.

The pin spacing of printed circuit mounting components is something that has to be checked carefully. It is usually possible to make a component fit into a layout even if the pin spacing of the component is not quite right. This is unlikely to produce strong or neat results though, and trying to persuade a component to fit into a board that is designed to suit a different pin-spacing can result in damage to the component.

Fig.2. Various types of preset potentiometer. From left to right: sub-miniature multiturn, miniature open-skeleton, adjustable rotary, multiturn, and miniature sealed types



Stocking up

Trying to produce a comprehensive stock of capacitors is not really a worthwhile proposition since the number of components involved would be huge, and many of them would be relatively expensive types. Even the over-buying method is unlikely to work well with capacitors unless it is restricted to the cheapest types. It can be worthwhile producing a stock of the more common capacitors, but it is necessary to buy them very selectively.

Electrolytic capacitors probably represent the best starting point. These are only generally available in the E6 range of values, which is just every other value in the E12 series (1.0, 1.5, 2.2, 3.3, 4.7, 6.8 and their decades). Things can be rationalised a bit further, as it is only every other value in this series that seems to be used to any extent (e.g. 1.0, 2.2, 4.7 and their decades).

A basic but useful stock of electrolytic capacitors could therefore be reduced to something like 10 each of these values/voltages:

1 μ	50 – 100V	10 μ	50V	100 μ	16V
2 μ	50 – 100V	22 μ	25V	220 μ	16V
4 μ	50 – 100V	47 μ	25V	470 μ	16V

Components having higher voltage ratings and (or) values tend to be quite expensive and should only be bought as and when they are

needed. Bear in mind that, provided the component is physically small enough, it is all right to use a capacitor that has a *higher* voltage rating than the one specified in the components list. Never use a capacitor that has a *lower* voltage rating than the one specified by the designer, as this is likely to result in the component breaking down, and it could be dangerous.

Current projects almost invariably use non-electrolytic capacitors of the printed circuit (box-shaped) variety. As pointed out previously, these are available in various types and with differing lead spacings. Most designs use plastic foil capacitors such as the polyester variety, and some of these with 5mm (0.2inch) and (or) 7.5mm (0.3inch) lead spacing should prove to be very worthwhile. Values below 1nF are not used a great deal in general electronics, and it is probably not worthwhile getting a stock of them unless you are into radio construction, or you can obtain them at an attractive price.

As with resistors, buying development packs can save a lot of time and provide components at relatively low prices. With low value capacitors it should be possible to obtain a ceramic or ceramic plate development pack for a modest outlay.

Semiconductors

At one time you could be forgiven for thinking that all electronic projects were



Fig.3. Various non-electrolytic capacitors with values ranging from 1pF to 470nF and voltage ratings from 50V to 250V

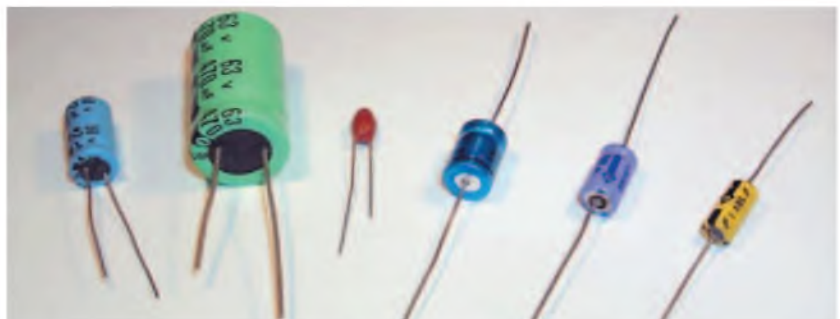


Fig.4. Various electrolytic capacitors with values ranging from 1 μ F to 470 μ F and voltage ratings from 10V to 100V

based on the same few devices. Every project seemed to use a 555 timer, or a 741C operational amplifier, or a CMOS 4001BE, and so on. There were a dozen or so devices that were an essential part of any project builder's stock of components. Things have changed quite radically in recent years, with specialist chips and microcontrollers becoming more popular, and various 'improved' versions of the old favourites appearing.

This makes it difficult to produce a worthwhile stock of semiconductors. It might be worthwhile having a small stock of the old favourites, but it is probably best to limit the stock of semiconductors to a few basics, such as 1N914 or 1N4148 diodes, some 1N4007 rectifiers, and some 5mm LEDs. It is also worth having a selection of DIL integrated circuit holders in the more common sizes, especially the 8-, 14-, and 16-pin varieties.

Nuts and bolts

Hardware is one area where a good stock of parts can still be really useful. Practically every project requires items such as nuts, bolts, spacers, plastic stand-offs and PP3-size battery clips. With nuts, bolts and spacers you will probably have to buy in fairly large quantities anyway, so you will soon end up with a stock of the most-used items.

There is nothing quite like the feeling of running out of solder just as the shops shut, with your latest masterpiece 99 percent completed! Always have plenty of solder in stock, and make it a priority to purchase a 500g reel of 22s.w.g. (0.7mm) solder.

Drawing conclusions

Even if you put together quite a small collection of stock items, storing them



Fig.5. Miniature chests of drawers are ideal for storing small components. This one will be even better when a label is added to each drawer

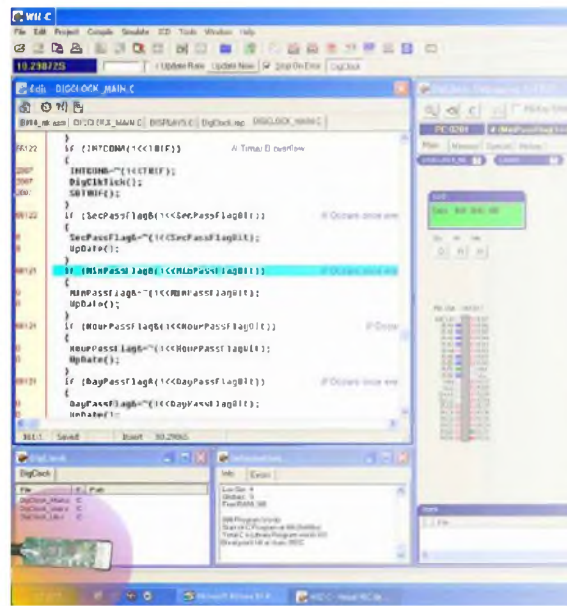
properly is very important, as you will otherwise spend more time trying to find the right components than you will spend constructing projects. It is not difficult to make your own storage system, or to improvise using biscuit tins and any small containers that come to hand. This is not necessarily worthwhile these days, since miniature chests of drawers (Fig.5) can be obtained from your local 'Woolies' or DIY superstore at quite low prices.

The components and items of hardware used in electronic projects are quite light,

so the cheapest plastic drawer units are perfectly adequate for storing them. It is helpful to label each drawer as it will then be possible to rapidly locate any desired component.

Whatever storage system you use, numerous small compartments are better than a few large ones. The diminutive size of electronic components means that they will easily fit into small compartments. Having plenty of small compartments makes it possible to have a narrow range of values in each one, so that it is easy to find the right one.

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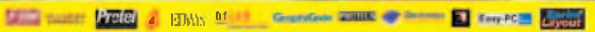
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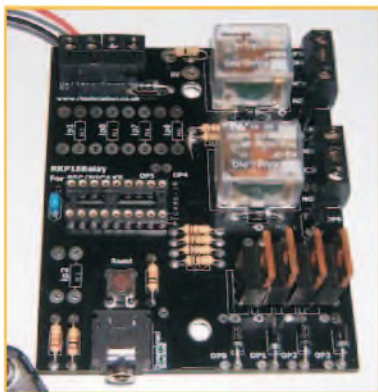


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MIDI DRUM KIT

BY JOHN CLARKE



PART 2: PUTTING IT TOGETHER

Last month we introduced our latest MIDI instrument, the MIDI Drum Kit offering a staggering 546 drum sounds and not a stretched skin in sight! Here's all you need to know to put the control unit together – and it's not that difficult . . .

ARE YOU HOT TO TROT, wanting to start playing with your new MIDI Drum Kit? Let's get started with building it.

Following on from the circuit description of the MIDI Drum Kit in the first article last month, we shall now describe the construction of both the main unit and the different types of sensors.

The unit itself is constructed using two PC boards, the main PC board (coded 653 and measuring 187 × 104mm) and the display PC board (coded 654 and measuring 140 × 100mm).

The assembled PC boards are fitted, one on top of the other, into a plastic box measuring 197 × 113 × 63mm. The

box is actually used upside-down; that is, the normal lid of the box becomes the base and the display board sits in what would normally be the bottom of the box – turned upside down, it becomes the top! Confused? It will all become clearer as we proceed . . .

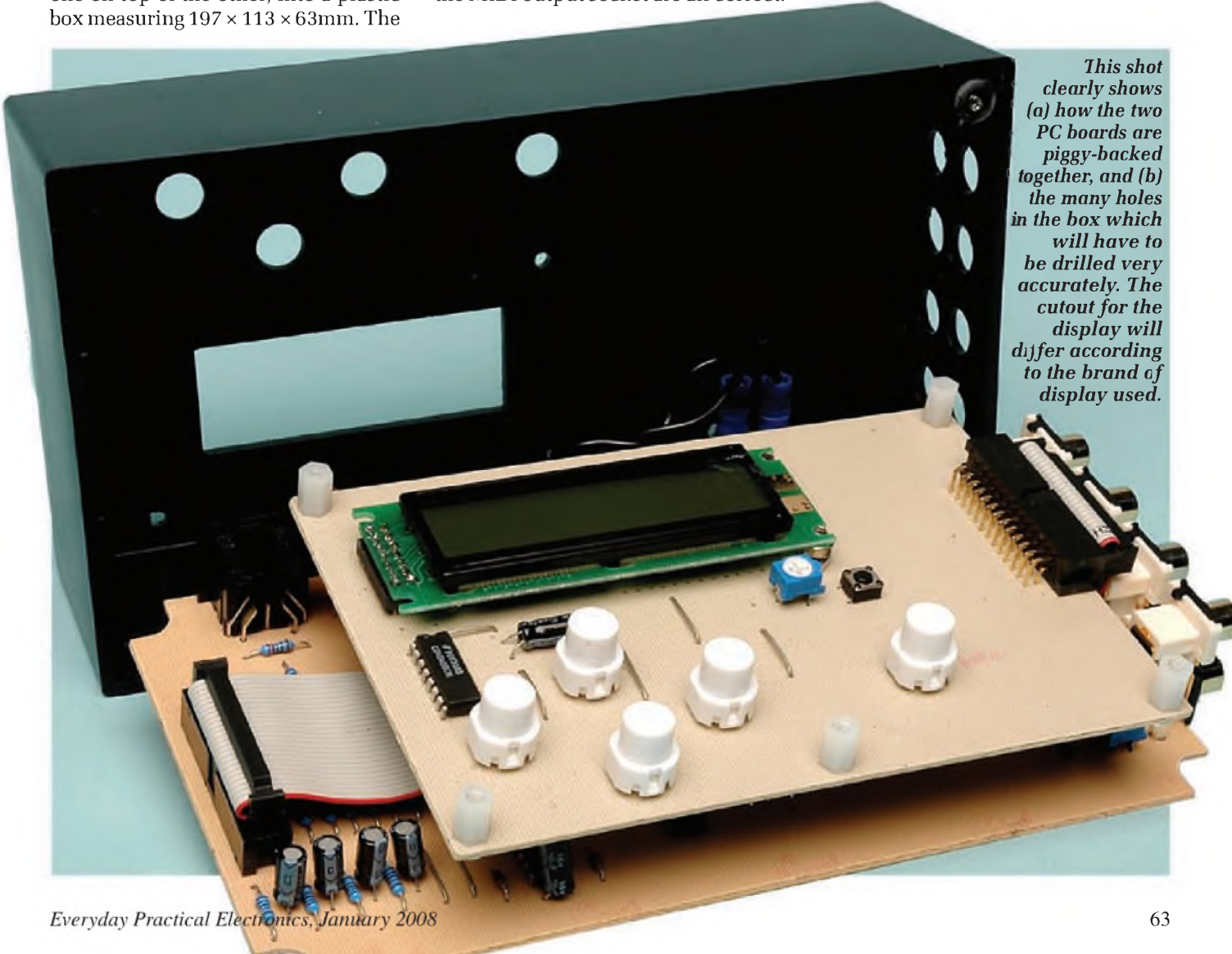
Before starting construction, check the PC boards for correct hole sizes and that there are no breaks in the copper or shorts between tracks or pads. Hole sizes for the corner mounts on the display PC board and for the LCD module should be 3mm diameter.

Check that the mounting holes for the external jack socket, the DC power socket, the DB9F serial connector and the MIDI output socket are all correct.

Finally, the main board has four corner cut-outs, which you can clearly see in our photos, to enable it to fit snugly inside the box mounting pillars. Carefully drill and cut out the various holes in the box, as per the photo below and the front panel artwork – Fig.4.

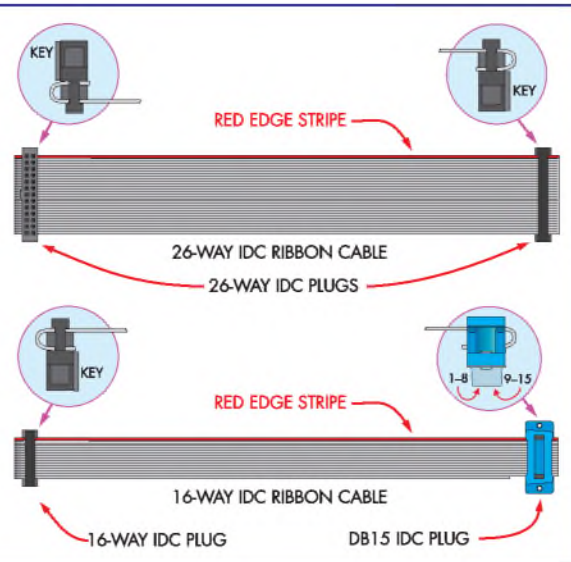
It is vital that the display cutout, switch holes and mounting holes in what will become the front panel (ie, the bottom of the box) are absolutely perfectly placed, otherwise the various components won't fit through.

Similarly, the various connector holes and cutouts along one side and one end are also quite critical, as the connector positions are fixed by their



This shot clearly shows (a) how the two PC boards are piggy-backed together, and (b) the many holes in the box which will have to be drilled very accurately. The cutout for the display will differ according to the brand of display used.

Fig.1: the 26-way IDC cable connects the two PC boards together and the 16-way cable is for a games port connection. Note that each end is different – on the 26-way, one suits a vertical IDC socket and the other a horizontal while the 16-way has a DB15 plug on one end. The easiest way to fasten the IDC sockets onto the cables without the special IDC tool is to squeeze the assembly together in a bench vice.



location on the PC board. The only latitude you have is the cutout for the power switch, as it is on flying leads.

The display board

Start assembly with the display PC board, mainly because there are less components. Insert the links first so you do not forget to do this.

The board has provision for three commonly available LCD modules. If using the Type 1 module, mount it using a dual 7-pin header to connect from the LCD module to the PC board. The Type 2 and 3 modules use a 14-pin SIL header instead.

Solder the pins on the topside of the LCD and on the underside of the display PC board. The two opposite corner mounting holes on the LCD module are held down using two M3 × 10mm screws and M3 nuts, with some Nylon washers placed in between the display PC board and LCD PC board.

Trimpot VR8 and the 10µF capacitor can now be mounted. Note that the 10µF capacitor should lie on its side to provide clearance when the display assembly is secured to the lid. Next is IC4, taking care to orient it correctly. Insert and solder in the 26-way right-angle header plug.

The switches are mounted as shown, with the flat side of the larger switches oriented to the side of the PC board. Switch S5 is mounted with the wider spaced pins mounted in the horizontal plane.

The main board

Begin assembly of the main PC board by installing the links and

resistors. A length of tinned copper wire is useful for links. Otherwise, use the off-cut resistor leads. The resistor colour code table will help you select each resistor but if in any doubt, measure the values using a digital multimeter (some resistor colour bands can be very similar to other colours – brown and red for example – and mistakes are easily made, especially in low light).

Now we move on to installing the semiconductors – the diodes first of all, taking care to orient them as shown. Again, take care with the orientation of the ICs. IC1, IC2, IC5 and IC6 can be soldered directly to the PC board, while IC3 is mounted using a socket.

The capacitors and crystal can be mounted next. Note that the electrolytic capacitors are polarised and must be oriented as shown on the overlay. Neither the crystal nor other capacitors are polarised.

Now mount the PC stakes and trim-pots VR1-VR7. REG1 is mounted horizontally, with a heatsink sandwiched between it and the PC board. Bend its leads by holding them in a pair of fine pliers at the correct position, so they fit into the holes while allowing the tab to be secured to the PC board and heatsink using an M3 × 10mm screw and nut.

Next, insert and solder in the upright 26-way IDC header, taking care to orient it with the locating tab to the outside of the PC board. Then insert and attach the MIDI out socket, the DB9 connector, the right-angle 16-pin header, the DC sockets and the 4-way stereo RCA phono sockets.

LED1 is mounted with the shown orientation, with the longer (anode) lead to the left and as high on its leads as possible. Leave just a millimetre of cathode lead under the PC board for soldering (naturally the anode lead, being longer, will have a bit more poking through). The LED is later bent over to fit into the hole in the side of the box.

Wiring

The photo on the previous page shows the connection between the two boards using a short 26-way IDC cable and the two IDC connectors. The boards are oriented with their connectors at opposite ends – when completed, the two boards and cable make a 'Z' shape.

You will probably have to make the IDC cables yourself as they are non-standard. Follow the diagrams (Fig.1) carefully. Orient the tabs on the side of the connectors as shown and clip in the back of the connector with the cable in place.

The easiest way to press the parts together is to carefully use a vice. Some people use a hammer but this is not recommended for a beginner!

Plug the cable in to both the main PC board and display PC board to make the connections.

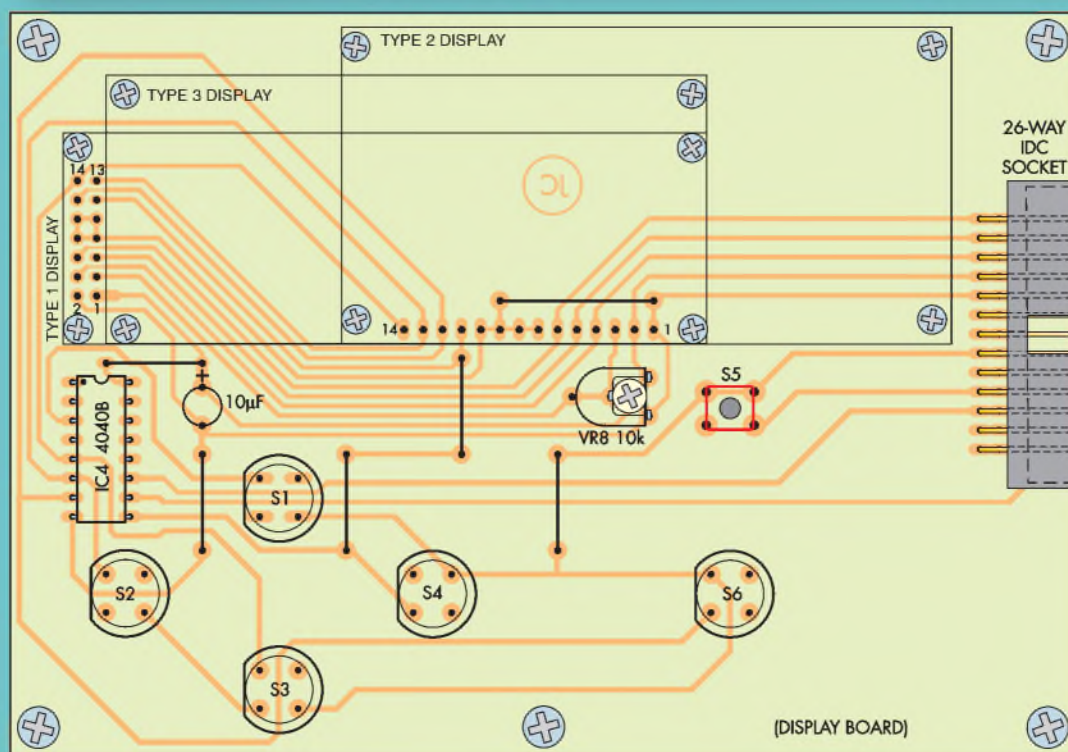
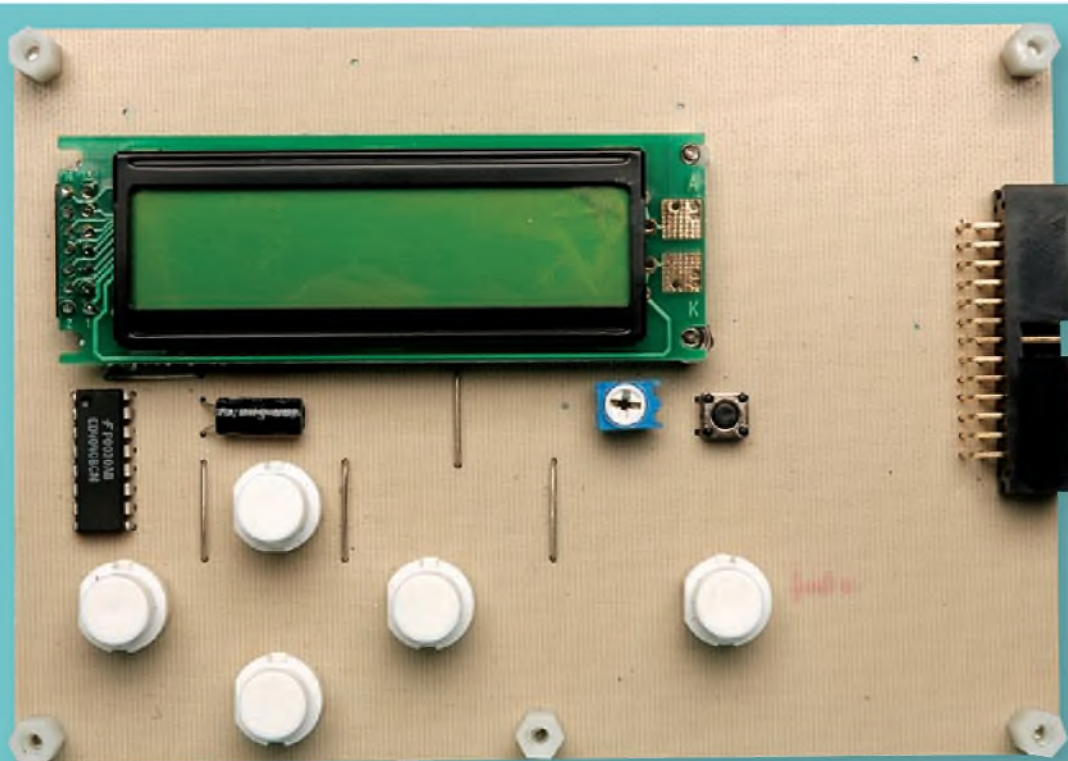
The games port wiring is similar to the 26-way wiring except that we use 16-way cable, of which only 15 wires are used (all 16 wires connect to the 16-way plug but the wire connecting to pin 16 is cut before terminating the cable into the 15-pin DB-15 plug. Both the 16-pin IDC plug and the 15-pin DB-15 plug clamp onto the 16-way cable using a vice, as before.

The wires connecting power switch S7 have crimp connectors for the switch lugs, with the opposite ends soldered to the appropriate stakes on the PC board.

Clip the connectors onto the switch lugs (polarity is unimportant). Your MIDI Drum Kit is now completed and ready for testing. You may have noted that you have one IC (IC3) left over. This is deliberate – do not insert it in its socket just yet! Also, for the moment, remove the IDC cable which connects the two PC boards.

Testing

The Drum Kit is now ready for testing but before you do, give it a careful check-over, looking for dry joints, sol-



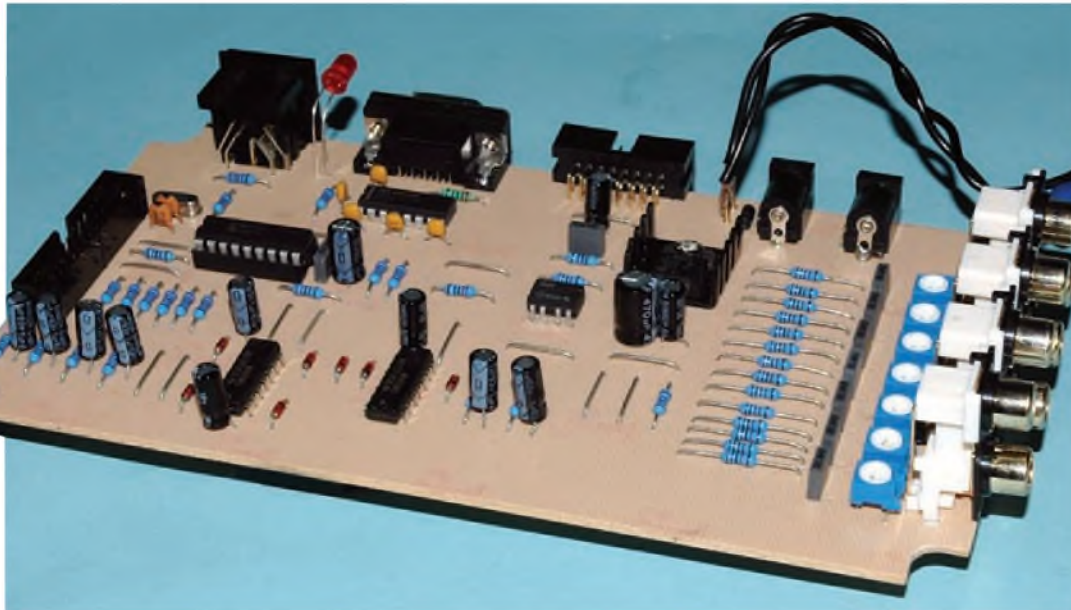
The display board photo (top) and component overlay (Fig.2, above) are reproduced here very close to full-size so you can compare your component placement with the prototype. Note the flat sides on switches S1 to S4 and S6 – they must be inserted this way or they won't work – and also the laid-over 10µF electrolytic capacitor!

der bridges and splashes (especially around IC pins) and of course wrongly placed components. A few minutes now can save hours of frustration (if not damage) later.

If you are satisfied with your construction, plug in the plugpack into the DC socket. Connect your multimeter common (black) lead to pin 11 of IC1 and the positive lead to pin 4.

Switch on the plugpack at the mains and switch on S7.

If you get a reading of about 9V, great. If the reading is zero, check that the DC plug for the plugpack has the right



The main PC board is quite a bit larger than the display board, even though this photo doesn't show it. Note the bent-over LED at the back of the board.

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polarity – it should be +ve to the centre and –ve to the body. If it is wrong, and your plugpack has a polarity reversing plug and socket, separate the two halves and put back in the other way.

If it is now +ve to the centre, plug it back in and check again. If OK, you're on your way. Otherwise, there is some form of major problem with either the plugpack (a broken wire?), REG1 (a solder bridge or unsoldered joint?), or perhaps the diode is soldered in back-to-front.

Measure the output of REG1 by probing the centre and right terminals. The voltage should be about 5V – at least between 4.75 and 5.25V. If this is not correct, check the PC board for a short circuit.

You should also be able to measure the nominal 5V between pins 5 and 14 of IC3's socket and about 9V between pins 4 and 11 of IC2. On IC6, check for 5V at pin 16, –9V at pin 6 and 9V at pin 2. These 9V readings may be anywhere up to 9.6V.

If the voltages are OK, you can now install IC3, after switching off the power. Connect the 26-way IDC

connection cable between the display PC board and the main PC board. The display should be showing characters – it doesn't matter what just yet. If you cannot see anything on the display, adjust trimpot VR8 for best contrast.

Now you can check the operation of all switches by going through the switch usage description, as detailed last month. (Note that we have not yet installed the PC boards in the box).

Setting up

At this stage you can calibrate the unit by pressing the Ports/Cal switch and then pressing the ^ switch to set the calibration sequence.

Changing the port settings can be done now too. Use the < or > switches to select for the serial or MIDI ports. Finally, rotate trimpots VR1-VR7 fully clockwise. These can be adjusted later if a sensor appears to have more sensitivity than the others (you will need to remove the boards from the box to do this).

Mounting the boards

First of all, disconnect the 26-way IDC cable from the main board (but

leave it connected to the display board) and unclip the power switch from the main board. At this point, you can also remove the two capture screws on the DB9 socket – but don't lose them!

Now the display PC board can be mounted within the box. As we mentioned before, the mounting is rather unconventional with the display protruding from the base of the box rather than from the lid. This allows the main PC board to mount close to the opening of the box, making it possible to insert the RCA phono sockets and the DB9 socket into the holes in the sides of the case (even if you have to prise the box edge out a little as you do it).

The display PC board is mounted on 9mm tapped spacers and held in with M3 screws. This is where your precision in drilling and shaping the holes is tested! Once the display board is secured, insert the power switch into its hole in the side of the case. Now comes the main PC board. It is secured in the box only by the screws which hold in the RCA phono sockets and the DB9 sockets – it doesn't have any mounting screws or pillars, unlike the display board.

As you lower the main PC board into the case, reattach both the 26-way IDC cable and the switch wires. Angle the board down so that the RCA sockets go through the holes in the end of the box and then gently prise the side of the box outwards so that the DB9 socket fits into its hole as you locate the board inside the case.

RESISTOR COLOUR CODES

No.	Value	4-Band Code (1%)	5-Band Code (1%)
□ 22	100kΩ	brown black yellow brown	brown black black orange brown
□ 1	22kΩ	red red orange brown	red red black red brown
□ 1	10kΩ	brown black orange brown	brown black black red brown
□ 8	2.2kΩ	red red red brown	red red black brown brown
□ 1	1kΩ	brown black red brown	brown black black brown brown
□ 1	470Ω	yellow violet brown brown	yellow violet black black brown
□ 4	220Ω	red red brown brown	red red black black brown

Parts List – Main Drum Kit

- 1 PC board, code 653, available from the *EPE PCB Service*, size 187 x 104mm
- 1 PC board, code 654, available from the *EPE PCB Service*, size 140 x 100mm
- 1 UB2 box measuring 197 x 113 x 63mm
- 1 DB9 cable (plug to socket lead 1.8m long)
- 1 2-line 16-character LCD module
- 1 250mA 9V DC plugpack
- 1 mini rocker switch (S7)
- 4 stereo PC mount RCA phono sockets
- 2 PC mount DC power sockets
- 1 5-pin PC mount DIN socket
- 1 DB15 IDC male plug
- 1 DB9 PC mount right-angle female connector
- 1 26-pin IDC header
- 1 26-pin right-angle IDC header
- 1 16-pin right-angle IDC header
- 2 26-pin IDC line sockets
- 1 16-pin IDC socket
- 1 7-way DIL header for Type 1 LCD module
- 1 14-way SIL header for Type 2 and 3 LCD module
- 5 SPST PC-mount snap action switches (S1-S4, S6)
- 1 SPST micro tactile switch (S5)
- 1 18-pin IC socket
- 1 heatsink, 19 x 19 x 10mm
- 1 16MHz crystal (X1)
- 5 9mm tapped spacers
- 10 M3 x 10mm screws
- 4 M3 nylon nuts
- 2 M3 x 15mm screws
- 4 No.6 self-taping screws
- 2 crimp spade female connectors for switch (S7)
- 1 serial DB9 cable male-to-female
- 1 30mm length of 0.8mm tinned copper wire
- 1 180mm length of 26-way IDC cable
- 1 2m length of 16-way IDC cable
- 1 100mm length of medium duty hook-up wire
- 1 500mm length of 0.8mm tinned copper wire
- 2 PC stakes

Semiconductors

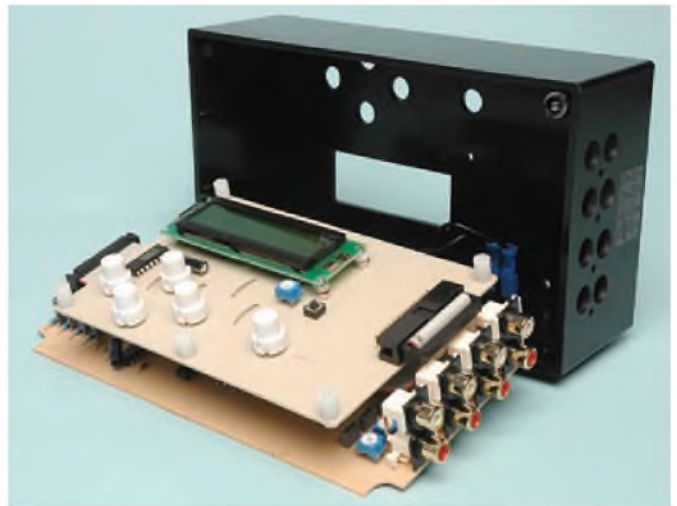
- 2 LM324 quad op amps (IC1, IC2)
- 1 PIC16F88 programmed with DRUMKIT16.hex (IC3)
- 1 4040 counter (IC4)
- 1 6N139 optocoupler (IC5)
- 1 MAX232 RS232 receiver/driver (IC6)
- 1 7805 5V three terminal regulator (REG1)
- 1 1N4004 1A diode (D8)
- 7 1N4148 switching diodes (D1-D7)
- 1 5mm red LED (LED1)

Capacitors

- 1 470µF 16V PC electrolytic
- 1 100µF 16V PC electrolytic
- 5 10µF 16V PC electrolytic
- 7 1µF 16V PC electrolytic
- 5 1µF ceramic
- 9 100nF MKT polyester
- 2 33pF ceramic

Resistors (1/4W 1%)

- 22 100kΩ 1 22kΩ 1 10kΩ 8 2.2kΩ
- 1 1kΩ 1 470Ω 4 220Ω
- 7 20kΩ horizontal trimpots (code 203) (VR1-VR7)
- 1 10kΩ horizontal trimpot (code 103) (VR8)



Viewed from the opposite angle to the earlier shot, the 4 x RCA stereo phono sockets can be seen on the lower (main) board, along with the IDC cable emerging from the top board IDC socket.

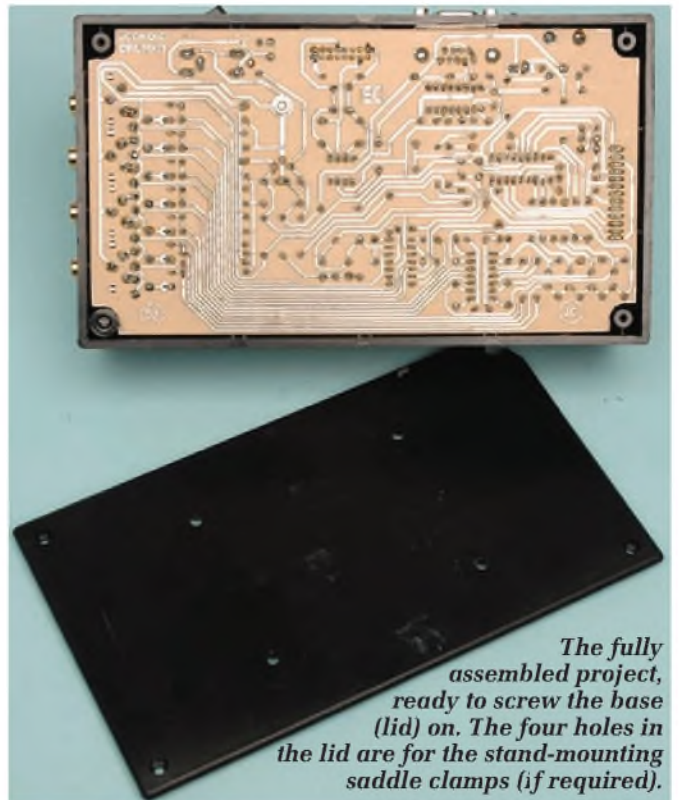
The RCA and DB9 sockets are the only sockets which actually emerge through the box – the rest are flush with the inside of the box.

With the board in place, re-attach the DB9 capture screws from the outside of the box to hold the socket in place. The RCA socket set is held in place using four No.6 self-tapping screws that screw into the holes in the RCA socket mouldings.

(Don't be tempted to rely on the soldered joints to hold the socket set in place – removing and inserting plugs could eventually break the joints).

Mounting on the drum stand?

As you can see from our opening photo, we made up a stand



The fully assembled project, ready to screw the base (lid) on. The four holes in the lid are for the stand-mounting saddle clamps (if required).



Fig.4: the full-size front panel artwork with hole positions for the switches and mounting holes. No display cutout is shown as this will vary with the type of display. An accurate photocopy of this could also be used as a drilling template.



It's almost finished – the PC boards are in, the base is on and the RS232 socket is secured. All that's left now are some labels: one for the front panel and one each for the end (RCA sockets) and side (input/output sockets and power switch).

from 25mm dowel (actually broom handle!) and T-pieces to hold all of the pad sensor plates. This stand can also hold the MIDI Drum Kit control box if you wish.

Do this by attaching two 25mm saddle clamps to the box lid using M4 × 12mm nylon screws and nuts. The screw is inserted from the inside of the case to allow clearance for the PC board.

Nylon screws are required to prevent them shorting anything on the back of the main PC board. The rear panel can now be attached.

Software

The software for this design can be downloaded free from the *EPE* Downloads website (access via www.epemag.co.uk).

Ready-programmed PICs for this project are available from Magenta Electronics (www.magenta2000.co.uk), see their advert.

We had hoped to describe the construction of the two types of pad sensors, foot pedal, footswitch and stand in this issue but space has beaten us – these will be described next month.



The two saddle clamps are held in place with nylon screws and nuts to prevent shorts.

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Automatic PSU Control – For PICs and AVR

THE circuit shown in Fig.1 allows a microcontroller, such as a PIC or AVR, to control a power supply under switch operation. This circuit could form part of your own project to allow a micro to control its own power rails.

This is a proven circuit that I have used it in many projects. A press of the On button, S1, will power-up the micro. Thereafter, the micro can keep its supply enabled by making an output pin go high.

When the micro wants to turn off the supply, it simply makes the output pin go low, and the whole supply is cut off. When the supply is off, there is zero power consumption (barely a microamp of leakage through the capacitor on the battery's supply).

How it works

The circuit operation is pretty straightforward. The main power controlling element is the PNP transistor TR1. The circuit to be controlled (including the 5V regulator IC1) is effectively 'hanging' from TR1's collector (c), this ensures that only a tiny voltage drop (around 150mV) is lost across the transistor when it's on.

Transistor TR1 is normally off, that is until a small current is drawn out of its base through resistor R2. The base current is initially drawn when switch S1 is momentarily pressed, the whole circuit bursts into life and the micro can then take over control.

If the micro wants to keep its own supply alive then it simply has to make an output pin go high (turning on TR2). When the

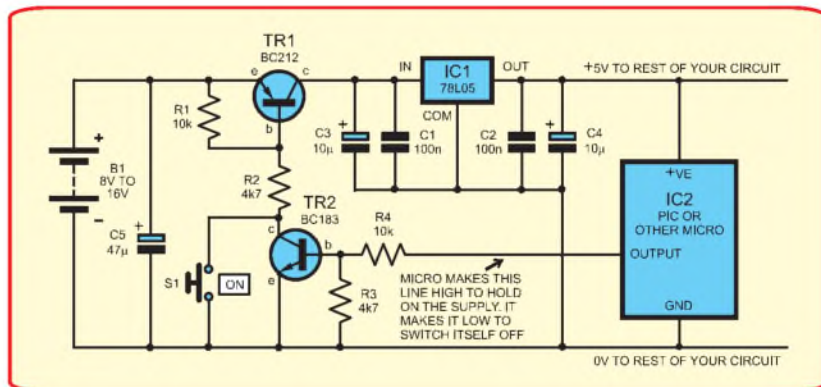


Fig.1. Circuit diagram for the Automatic Power Supply Control

micro wants to turn off its own power, it makes the output pin go low, TR2 turns off and the base current to TR1 is terminated, thus turning off the whole circuit.

Note that the combination of resistors R4 and R3 is particularly important, as they increase TR2's turn-on threshold from around 0.7V to around 2V. The reason that this is important is because a microcontroller's port pins can have a little 'fit' during the collapse of its supply rails (when the supply drops below about 2V). If the micro's port pin does happen to wobble up and down during the supply's collapse, then we don't want it to inadvertently turn itself back on again.

Jez Siddons
Chapel-en-le-Frith

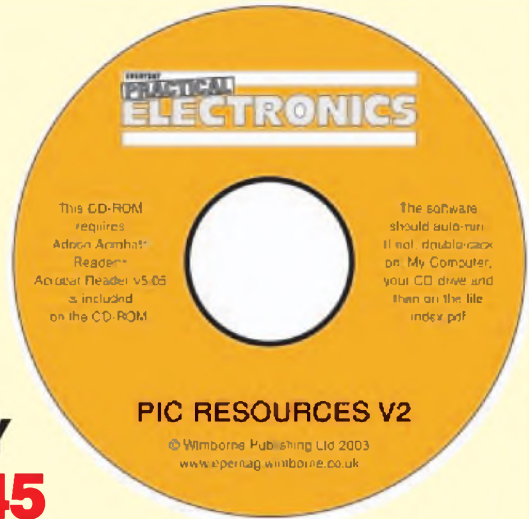
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All letters quoted here have previously been replied to directly.

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★ LETTER OF THE MONTH ★

Banning the Bulb

Dear EPE,

It was most useful to see some light shed on this subject by Dave Geary (*Banning the Bulb* Oct '07) but I feel that some of the manufacturers quote statistics that are, like the way the proverbial drunkard uses a lamp-post (sorry, I mean street lighting column), more for support than illumination. I have to take on trust the amount of energy consumed in the production of compact fluorescents compared to GLS lamps. Of course, the specific energy consumption is less in service (lower wattage), a shining example of reduced CO₂ emissions.

However, CFLs are not yet a mature technology that is ready to replace the standard filament lamp, in fact they do not even occupy the same place in the spectrum of luminous devices. You can guess my age by the impending onset of presbyopia, but I can still solder a surface-mount device aided by a good light and a little magnification. The CFL simply hasn't the right colour temperature for my ageing eyes to read by.

Also, when I walk into a dark room and switch on the light, I expect my passage to be uninterrupted yet made safe by adequate illumination coming on immediately. I'm hardly likely to stand and wait at least 30 seconds while a CFL bothers to 'rise and shine'.

Finally, the idea of high-frequency drivers preventing flicker is horrific to one who also likes to listen to weak signals as part of an amateur radio hobby. The harmonics of the tens-of-kHz lamps have already been the documented cause of interference cases.

There's a prescient misprint in the first paragraph, middle column page 45, '...many manufacturers offering such luminaries (sic)...' Were it only true! As Dave concludes on that same

page, CFLs may be used '...successfully, but only where appropriate'. I'm waiting for an industry luminary to give a red light to the headlong rush to banish all GLS lamps to a previous dark age, to encourage the retrofitting of CFLs only where appropriate, and to recognise that more development is needed before the technology overcomes the above-mentioned hurdles. Also, to put an end to unnecessary 'vanity' lights that burn all night outside many houses and commercial buildings just for appearance's sake but without contributing illumination where it's needed.

**Godfrey Manning G4GLM,
Edgware,
via email.**

Thanks Godfrey. Another reader also queried whether 'pigmy' lamps, such as those used in fridges, are to be banned.

Dave Geary responds:

First, the 'appliance lamps' or 'pygmy lamps' used in fridges and similar will be, it is expected, excluded. They are not energy efficient, but are only on for a short period of time.

Second, Godfrey makes some good points. Like him, I have to trust in the manufacturers' data, but would point out that those that participated in the preparation of the article are subject to rigorous scrutiny by monitoring bodies in the EU and member states. In addition, there is a test to almost every claim they make by pressure groups and, of course, by shareholders.

He is correct in his mention of light spectrum being different to that of a burning filament, but that does not mean that the CFL, or other energy saving light sources, will not provide this in future. Indeed, as I alluded to in the text, there is a frightening pace of

development in both CFL and LED technologies. Different colour temperature CFLs are available, and have been for many years, although the retrofit type has been restricted to something close to that of a GLS (normal!) lamp until now.

The 'warm up' time has been identified by manufacturers as a problem in gaining consumer acceptance and the manufacturers assure me you will see 10 second times in the latest products coming to market. The harmonics issue is one I have not covered, and can only offer the CE marking as a defence. I will ask the manufacturers to comment on this.

Misprints abound, and sadly the trade term 'luminaires' is often changed to 'luminaries' by most spell checkers!

I'll confess to lighting the outside of my house during the night, but for security purposes. The same is true for many commercial buildings. Some may remember the newspaper claims about the cost of lighting Buckingham Palace all night. It is a shame they didn't check the facts first – it's lit by LED technology from Philips, who quote the consumption as similar to an electric kettle – not bad for that much illumination.

It also reminds me of the claims about the HSBC building in Canary Wharf and 'wasted' lighting – it's a 24-hour working building. Nonetheless, there is no point saving energy if there is unnecessary light pollution, and on that, Godfrey and I are completely in agreement.

Osram have since come back to me regarding Godfrey's point on radiated noise. I quote: 'All of our products are within prescribed RFI limits as defined by EN55015, EN55022.' There is also some comment that these standards are not always met by the cheapest of imports!

Dave Geary, via email

Circuit Diagram Software

Dear EPE,

I have been purchasing *EPE* over the years and have always thought that your schematics were very clear and easy to read. Now I am in education and have a need to produce both written material and some schematics for use in teaching. Could you please tell me what software you use to generate your circuit diagrams. I have tried various software and am not having a lot of success in being able to produce anything near as easy to read as your diagrams.

**Steve Liggett,
via email**

We have two artists who do our drawings for us, Richard Hinkley and Matt

Pulzer, who both use the same software. Steve's question was sent on to Matt, who replied:

Thank you Steve for your kind words about the illustrations. I use an application called Corel Draw. My version (3) is absolutely ancient. It is happiest on Win 95, but will work on Win 98. I stick to this because it does exactly what I want, with little fuss.

However – and this is important – it could be done just as well on any vector graphics package. I keep on meaning to migrate to Adobe Illustrator, but never seem to find the time.

The key is not the package, but how it is used:

1. First and foremost, develop from scratch a set of symbols based on consistent line thicknesses. This is a bit tedious, but it is more or less a one-off job. Start with the basic symbols: resistor, capacitor (ordinary and polarised), inductor/transformer, transistor types, battery, op amp etc

2. Stick to one line thickness for interconnections – we use 0.4mm. (Outlines for components are 0.2mm, 0.4mm or 0.8mm). We use a 1mm filled circle where wires connect

3. Stick to one font – Arial, 5pt for most text, 7pt bold for transistor, IC numbers

4. Be consistent about spacing for IC pinouts – usually it's set at two lines of character text for ease of labeling

5. Use snap mode, so that lines 'jump' to mid and end points for neatness

6. Alignment tools are important for keeping relative spacings neat.

Matt Pulzer,
via email

Imperial Success

In a thread on our Chat Zone (via www.epemag.co.uk), I raised another topic, as follows, along with a precis of some of the replies that ensued.

I for one welcome the announcement by the EU that the UK can keep its centuries-old Imperial measurement systems. While for some things I do instinctively think in metric, in others I do not – especially in electronics, where measurements of the components I use (eg ICs) are in tenths of an inch.

Curiously, the other day I tried to buy a normal low cost plastic ruler graduated in millimetres and tenths of an inch, and had difficulty finding one.

terrym: And just as they are starting to make components in metric spacing. Got some caps the other day that are 5mm pitch instead of 5.08 (0.2 inch). Very small difference until you line up quite a few across a board.

zeitghost: Good show. Now I can go back to measuring things in rods, poles and perches.

winston: Well, over here in the Isle of Man we have no metric martyrs – I still get my bananas from the supermarket priced in £/lb, same with meat from the butchers – and we still have £1 notes!

vlf: In Jersey, the Channel Islands, we have a mixed situation...

Produce and goods arrives from UK, France, Poland, Portugal, Kenya and from most other destinations. We can decide what measurement system or language to use, mine is Metric and English, but most days it's a mixture of expletives and frustration!

andrew: This ruling is a complete disaster. Yes, let's keep going with 16 ounces in a pound, 14 pounds in a stone, 1760 yards in a mile etc? You can't be serious? This is all very quaint and historical and familiar, but there's a better way now. But I think age will divide this argument.

kevinbrunt: Of course, part of the reason for the prevalence of imperial quantities in electronics is that bastion of Imperialism (at least in units of quantity) on t'other side of the Atlantic. Mind you, the last justification for retaining imperial units because it made trading with the US easier immediately shot itself in the foot by referring to the pint!

winston: Metric should be the only system used in engineering. However, for 'human' kinds of things, people generally do feel happier with feet, pints and inches, but I was born in the metric age.

atferrari: I was born, live and work (most of the time) in Argentina. Metric is the standard here. It's true also that as a seaman I got used to dealing with both systems (and the frequent conversions to the units at least in my area: ships/cargo operations. Fathoms, yards, miles, knots, long tons (even short tons when loading in USA!) were an every day reality.

The major change for me, I was at sea then, occurred when the British Admiralty decided to start producing 'metric' charts. Now, nobody asks 'How many fathoms do we have under the keel?' (By the way, those charts and the whole system of publications, is, for me, the best in the world.)

Locally, older generations still express the draft of vessels in feet and inches, but young people are more inclined to talk in metres and centimetres.

For electronics, I feel comfortable with inches, mils (thous?) and the easiest for

me is to think of spacing on PCBs (and dimensions in general) in terms of 'hundreds of mils' which are, no surprise, just a tenth of an inch. I always avoided (because I did not need it) the use of non-decimal fractions (1/16, 1/8, and the like).

My question is: what would happen if they decide to change the units of speed for vessels and planes, that is knots to km/hour? What a dangerous mess that would be! Better leave it as is.

One detail: loading chromite once, when about to trim the vessel (adjusting drafts for sailing) the foreman asked me how many 'scoops' I required in the last two holds. My surprise was because I had never heard of that 'imperial' unit before. Finally, I learnt that it was the capacity of a big loader system (clamp) loading some fixed amount of chromite to the rail cars in every drop. He seemed to believe that a 'scoop' was a unit known by all Chief Officers entering that port. Nobody was able to tell me how many metric tons was that 'scoop'.

I measure my age in years, months, days, hours, minutes and seconds. Sumerian origin units?

Cold Heat Soldering Irons

Dear EPE,

I appreciated Alan's article on the cold-heat soldering irons. I did not have a good experience with the one I got here in Arkansas, USA. I am only somewhat experienced in electronics, but am a very experienced metalworker (40 professional years). My soldering iron went ballistic after a few joints. It refused to shut off and I had to take the batteries out of it to get it to shut off at all, it was smoking heavily and almost on fire by the time I accomplished this.

I tried to follow the directions exactly, as it seemed like it would be a handy device. I returned it to the store without completing anything worthwhile. I realized it may have been an odd, faulty model, but it just did not seem like something I wanted to mess with, and the original purchase seemed defective.

I did not have the benefit of doing as many joints as you, so my experience was more limited. I tried mine when they were first advertised on US TV, I am not sure of the exact time, but I believe it was 2005, perhaps before. I was a little appalled that I could not get it to shut down and am glad I am very used to hot things (I am a blacksmith, artist, jeweller).

Bob Patrick, Arkansas,
USA, via email

Alan replied to Bob –

Thanks for the useful feedback, Bob. Your experiences sound pretty alarming, my guess is that some material shorted permanently across the two electrodes in that mysterious 'Athalite' tip so the iron couldn't power off again. They can draw something like four to five amps (which goes through the tip) from the batteries in that mode. I have some deep reservations about using these irons on microelectronics circuit boards.

A few sparse details about the tip are at <http://en.wikipedia.org/wiki/Athalite>

Unfortunately, I haven't had any positive feedback from anyone in the electronics sector concerning these irons. They do have some uses though and work best, in my view, when applied to an isolated existing solder joint, which it will then melt and you can then re-work the joint (reflow soldering). Indeed, I saw an in-store video of these things in the UK doing exactly that – resoldering a broken wire to a PCB.

But I still prefer my old Ungar iron as used in my *Basic Soldering Guide!*

Alan Winstanley,
EPE Online Editor,
via email

C for PICs

Dear EPE,

Thank you for Mike Hibbett's excellent series on *C for PICs*, it has certainly fired my enthusiasm to experiment with C as you suggest. I have been experimenting with debouncing the switches (SW2 and SW3) and noticed the word **BOOL** at the start of the code for the switches. Is this short for Boolean?

I would certainly be interested in a future article covering boot loaders etc.

David Warsop, via email

Mike replied:

Thanks for your comments David, glad you enjoyed it. We did cover serial interface bootloaders in a *PIC n' Mix* article last year, but following reader requests I am planning another article on USB bootloaders. It should appear this year some time.

Regarding the 'BOOL' that you found in the code – yes, this is a boolean data type. The standard C programming language does not provide a boolean type natively, so the author of that piece of code created his own boolean type using the 'typedef' feature of C. You can find it defined in the file `typedef.h`, on the following line:

```
typedef enum _BOOL { FALSE = 0, TRUE } BOOL;
```

Please note that when you create a variable of type **BOOL**, for example **BOOL blsValid**; this variable will take up a whole byte, even though it can only store one of two values. You can add that typedef to your own software if you wish.

Mike Hibbett, via email

1998 PIC Tutorial

Dear EPE,

My college instructor gave me John Becker's original *PIC Tutorial* from 1998, which is based around the PIC16F84. When I tried to get the codes running on a PIC16F84A, it would not work. Would you know why?

Arazy, Malaysia, via email

Arazy, that software was not designed to cope with the 84A, which did not exist in 1998 and which has a different software assembly requirement. I regret it can't be used with the original Tutorial.

There is no difference in writing code for the 84A, it is the same as for the 84. It's the assembly software which has different requirements. That is down to the program used to assemble it. Buy a new programmer, a matter on which I cannot advise – there are too many commercial options. You could ask reader opinion on this via our Chat Zone, access via www.epemag.co.uk.

There is a new PIC Tutorial being covered in Teach In 2008, which started in the Nov issue.

READERS

You are very welcome to air
any point of view through
Readout – drop
us a line!

Net Work



Alan Winstanley

Word's hidden depths

In last month's *Net Work* column I highlighted some options available for users looking for word processing packages as alternatives to Microsoft Word, and I mentioned Sun StarOffice from www.sun.com/staroffice and OpenOffice.org available from www.openoffice.org. Both contain fully featured office applications that are directly downloadable, either for a modest cost or completely free of charge. They include a word processor and spreadsheet, and the freeware OpenOffice.org is supplied with a useful 'Math' equations editor that scientific or technical users may find valuable.

For those using Microsoft Word, a wide variety of online resources are available to help you get more out of this monster-sized word processor. Microsoft's own website at <http://office.microsoft.com> is the first place to start, and although the obvious focus is on the latest versions of their software, versions back to Office 97 are listed. Many patches, third party downloads and critical updates are also provided.

At a time when the British Government's HMRC (Her Majesty's Revenue and Customs) recently lost some insecure compact disks holding the confidential personal data of 25 million British citizens (a likely bonanza for identity thieves – see *The Daily Telegraph* site at <http://tinyurl.com/2cwpdh>), Microsoft Word users may not be aware that Word .doc files also contain hidden data about the document's creation and its originators.

Specifically, it may include details of edits, comments and multiple users who collaborated on it, and if the file is based on earlier files sourced from multiple writers then the hidden data could prove embarrassing or damaging, if you know how to reveal it. For instance, with Word's 'Track Changes' enabled, previous iterations of the file could be seen. For users of Windows XP and Word, Powerpoint or Excel 2002 onwards, Microsoft's Hidden Data Removal Tool is a must. It can be downloaded free at <http://support.microsoft.com/kb/834427>.

Elsewhere on the Internet there are many independent websites and blogs written by users keen to share their knowledge. For example, Allen Wyatt's Word Tips website at <http://wordtips.vitalnews.com> contains a plethora of useful tips, tricks and answers to enable you to build your expertise on a need-to-know basis.

Cracking the IE Defenders

Recently, I had to handle one of the most annoying and pernicious computer infections I have ever come across. A friend's web browser was hijacked and any Google or Yahoo searches made would generate dire warnings that the PC has been 'infected'. Worse, search engine pages included authentic looking links and explicit graphics pointing to adult sites. The machine was also grinding to a halt. Typical symptoms of spyware or a worm.

The artificial popups pointed to a product called 'IE Defender', which has no connection with Microsoft's unloved Windows Defender spyware tool. Every other website link in the spoofed 'results' pointed to www.google.com. It was a sophisticated attack designed to trick people into subscribing to IE Defender malware. As far as infections go, it is the IE Defender popup itself that is the infection, and after many hours of struggling it proved to be extremely difficult to remove – until you know how. IE Defender even has its own authentic looking web site (best avoided) where users who are supposedly infected can purchase IE Defender software. How convenient!

It wasn't as though we could Google for help, because the web browser results were hijacked to show more falsified results

featuring pornographic images and popup alerts for the IE Defender tool. How do you start to deal with such an invasion?

Where possible, try to use a different machine to access the web in search of advice or removal tools; a quick google for 'IE Defender' immediately revealed comments such as: "I was infected with this virus..." or "I'm getting an annoying popup every few minutes..." and "How to remove IE Defender Malware". With so many users saying the same sorry tale, even a non-expert can conclude that IE Defender is not a good thing to have onboard. Security specialists Sophos classifies IE Defender as a 'PUA' or Potentially Unwanted Application, choosing their words rather carefully.

I started by downloading an old favourite – Spybot Search & Destroy from www.safer-networking.org – onto a separate PC initially, transferring it via a USB memory key. Even that was not straightforward, because a Google search for 'Spybot Search & Destroy' threw up misleading sponsored links for unproven or unfamiliar products. In the event, Spybot S&D found several problems, but the IE Defender infection remained firmly in place.

Onto more powerful, paid-for tools then – and sadly my preferred choice of PC Tools' Spyware Doctor (from www.pctools.com) was a massive disappointment. It was very slow to load, it slowed down the machine to a complete crawl, and after a tortuous scan it found just one more worm. Spyware Doctor failed to clear the IE Defender problem, and at a subscription cost of £24.95 + tax, the product's saving grace was the trial period provided to allow for a refund. Note that the annual subscription is automatically renewed unless 20 days' advance notice is given, which busy people will often overlook. Nevertheless, I recommend keeping the product installed and running it periodically.

Test of nerves

The way ahead was to dig deeper and check what others have said online in blogs and forums, and scan through websites in search of other users' solutions. One helpful forum was <http://forums.spywareinfo.com/index.php?showtopic=107621> which alluded to a number of important-looking Windows files that were actually part of the IE Defender infection and need removing. The same troublesome files were mentioned in other sites, so I felt confident that the information was accurate enough.

Very thorough instructions and screenshots were found at the user forum <http://www.bleepingcomputer.com/forums/topic114240.html> noting again that spurious Google adverts for unproven 'Spyware Removal Tools' litter many such sites and in the author's opinion are best avoided. Cross-referring this excellent site with other websites enabled the writer to decide an action plan.

It is a test of nerves to put one's faith in some online instructions and the best you can do is find a consensus of opinion and follow that route. You must take the time to back up any critical data. The Windows Control Panel Uninstall was a failure because IE Defender re-installs itself into a hidden directory. This could be viewed in (Windows XP) Explorer via Tools/ Folder Options/; tick the option 'Show hidden files and folders'. The damaged PC could not boot into Safe Mode as suggested, but various offending DLL files and hidden directories were found and deleted. From Bleeping computer a small Registry fix file (FixIED.reg) was downloaded and executed in a leap of faith.

Happily, after many hours' of time, the laptop then rebooted and sprang into life, with surfing restored and IE Defender banished to where it belongs – in life's Recycle Bin. You can email me at alan@epemag.demon.co.uk

Electronics Teach-In + Free CD-ROM

Mike Tooley

A broad-based introduction to electronics – find out how circuits work and what goes on inside them. Plus 15 easy-to-build projects. The 152 page A4 book comes with a free CD-ROM containing the whole Teach-In 2006 series (originally published in EPE) in PDF form, interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC.

In addition to the Teach-In series, the book includes 15 CMOS-based simple projects from the Back-To-Basics series by Bart Trepak, these are: Fridge/Freezer Alarm, Water Level Detector, Burglar Alarm, Scarecrow, Digital Lock, Doorchime, Electronic Dice, Kitchen Timer, Room Thermometer, Daily Reminder, Whistle Switch, Parking Radar, Telephone Switch, Noughts and Crosses Enigma and a Weather Vane. There is also a MW/LW Radio project in the Teach-In series.

152 pages + CD-ROM **Order code ETI** **£8.50**

THE AMATEUR SCIENTIST 3-0 CD-ROM

The complete collection of The Amateur Scientist articles from *Scientific American* magazine. Over 1,000 classic science projects from a renowned source of winning projects. All projects are rated for cost, difficulty and possible hazards.

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PROJECT CONSTRUCTION

IC 555 PROJECTS

E. A. Parr

Every so often a device appears that is so useful that one wonders how life went on before without it. The 555 timer is such a device. Included in this book are over 70 circuit diagrams and descriptions covering basic and general circuits, motor car and model railway circuits, alarms and noise makers as well as a section on 556, 558 and 559 timers. (Note: No construction details are given.) A reference book of invaluable use to all those who have any interest in electronics, be they professional engineers or designers, students or hobbyists.

167 pages **Order code BP44** **£5.49**

POWER SUPPLY PROJECTS

R. A. Penfold

This book offers a number of power supply designs, including simple unregulated types, and variable voltage stabilised designs, the latter being primarily intended for use as bench power supplies for the electronics workshop. The designs provided are all low voltage types for semiconductor circuits. The information in this book should also help the reader to design his own power supplies. Includes cassette PSU, Ni-Cad charger, voltage step-up circuit and a simple inverter.

91 pages **Order code BP76** **£5.49**

HOW TO USE OSCILLOSCOPES AND OTHER TEST EQUIPMENT

R. A. Penfold

This book explains the basic function of an oscilloscope, gives a detailed explanation of all the standard controls, and provides advice on buying. A separate chapter deals with using an oscilloscope for fault finding on linear and logic circuits, plenty of example waveforms help to illustrate the control functions and the effects of various fault conditions. The function and use of various other pieces of test equipment are also covered, including signal generators, logic probes, logic pulsers and crystal calibrators.

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RADIO

SETTING UP AN AMATEUR RADIO STATION

I. D. Poole

The aim of this book is to give guidance on the decisions which have to be made when setting up any amateur radio or short wave listening station. Often the experience which is needed is learned by one's mistakes, however, this can be expensive. To help overcome this, guidance is given on many aspects of setting up and running an efficient station. It then proceeds to the steps that need to be taken in gaining a full transmitting licence.

Topics covered include: The equipment that is needed, Setting up the shack, Which aerials to use, Methods of construction, Preparing for the licence.

86 pages **Order code BP300** **£4.45**

EXPERIMENTAL ANTENNA TOPICS

H. C. Wright

Although nearly a century has passed since Marconi's first demonstration of radio communication, there is still research and experiment to be carried out in the field of antenna design and behaviour.

The aim of the experimenter will be to make a measurement or confirm a principle, and this can be done with relatively fragile, short-life apparatus. Because of this, devices described in this book make liberal use of cardboard, cooking foil, plastic bottles, cat food tins, etc.

Although primarily a practical book with text closely supported by diagrams, some formulae which can be used by straightforward substitution and some simple graphs have also been included.

72 pages **Order code BP278** **£4.00**

25 SIMPLE INDOOR AND WINDOW AERIALS

E. M. Noll

Many people live in flats and apartments or other types of accommodation where outdoor aerials are prohibited, or a lack of garden space etc prevents aerials from being erected. This does not mean you have to forgo shortwave-listening, for even a 20-foot length of wire stretched out along the skirting board of a room can produce acceptable results. However, with some additional effort and experimentation one may well be able to improve performance further.

This concise book tells the story, and shows the reader how to construct and use 25 indoor and window aerials that the author has proven to be sure performers.

50 pages **Order code BP136** **£2.25**

AN INTRODUCTION TO RADIO WAVE PROPAGATION

J.G. Lee

Radio wave propagation is one of the more important discoveries made in the early 20th century. Although technology lagged behind, early experimenters pursued this newly discovered phenomenon eagerly for, in understanding the physics of propagation, they were discovering more about our Universe and its workings.

Radio wave propagation has its origins in the world of solar physics. The Sun's radiation provides the mechanism for the formation of the ionosphere. How the ionosphere is formed, and how it provides long-distance communication, is carefully explained. Non-ionospheric propagation, including 'moon-bounce' or satellite communications, is covered as well.

This book has been written with the average electronic hobbyist in mind. Technical language and mathematics have been kept to a minimum in order to present a broad, yet clear, picture of the subject. The radio amateur, as well as the short-wave listener, will find explanations of the propagation phenomena which both experience in their pursuit of communications enjoyment.

116 pages **Order code BP293** **£4.45**

ELECTRONIC PROJECT BUILDING FOR BEGINNERS

R. A. Penfold

This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:

Component identification, and buying the right parts, resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job, soldering, making easy work of the hard wiring, construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping, finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages **Order code BP392** **£5.49**

TEST EQUIPMENT CONSTRUCTION

R. A. Penfold

This book describes in detail how to construct some simple and inexpensive but extremely useful, pieces of test equipment. Stripboard layouts are provided for all designs, together with wiring diagrams where appropriate, plus notes on construction and use.

The following designs are included - AF Generator, Capacitance Meter, Test Bench Amplifier, AF Frequency Meter, Audio Multivoltmeter, Analogue Probe, High Resistance Voltmeter, CMOS Probe, Transistor Tester, TTL Probe. The designs are suitable for both newcomers and more experienced hobbyists.

104 pages **Order code BP248** **£4.49**

COMPUTING

COMPUTING FOR THE OLDER GENERATION

Jim Gatenby

Especially written for the over 50s, using plain English and avoiding technical jargon. Large clear type for easy reading.

Among the many practical and useful ideas for using your PC that are covered in this book are: Choosing, setting up and understanding your computer and its main components. Writing letters, leaflets, invitations, etc., and other word processing jobs. Keeping track of your finances using a spreadsheet. Recording details of holidays and other ideas using a database. Using the Internet to find useful information, and email to keep in touch with family and friends. Making 'back-up' copies of your work and checking for viruses. How to use Windows XP to help people with impaired vision, hearing or mobility.

Provides the basic knowledge so you can gain enough confidence to join the local computer class.

308 pages **Order code BP601** **£8.99**

THE INTERNET FOR THE OLDER GENERATION

Jim Gatenby

Especially written for the over 50s. Uses only clear and easy-to-understand language. Larger type size for easy reading. Provides basic knowledge to give you confidence to join the local computer class.

This book explains how to use your PC on the Internet and covers amongst other things: Choosing and setting up your computer for the Internet. Getting connected to the Internet. Sending and receiving emails, photographs, etc., so that you can keep in touch with family and friends all over the world. Searching for and saving information on any subject. On-line shopping and home banking. Setting up your own simple web site.

228 pages **Order code BP600** **£8.99**

THEORY AND REFERENCE

BEBOP TO THE BOOLEAN BOOGIE

Second Edition

Clive (call me Max) Maxfield

This book gives the "big picture" of digital electronics. This in-depth, 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. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate.

Contents: Fundamental concepts, Analog versus digital, Conductors and insulators; Voltage, current, resistance, capacitance and inductance, Semiconductors; Primitive logic functions, Binary arithmetic, Boolean algebra; Karnaugh maps, State diagrams, tables and machines; Analog-to-digital and digital-to-analog, Integrated circuits (ICs), Memory ICs, Programmable ICs, Application-specific integrated circuits (ASICs), Circuit boards (PWBs and DWBs), Hybrids, Multichip modules (MCMs), Alternative and future technologies.

470 pages – large format **Order code BEB1**



circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages

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£5.49

DIGITAL GATES AND FLIP-FLOPS

Ian R. Sinclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic.

200 pages

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OPERATIONAL AMPLIFIER USER'S HANDBOOK

R. A. Penfold

The first part of this book covers standard operational amplifier based "building blocks" (integrator, precision rectifier, function generator, amplifiers, etc), and considers the ways in which modern devices can be used to give superior performance in each one. The second part describes a number of practical circuits that exploit modern operational amplifiers, such as high slew-rate, ultra low noise, and low input offset devices. The projects include: Low noise tape preamplifier, low noise RIAA preamplifier, audio power amplifiers, d.c. power controllers, opto-isolator audio link, audio millivolt meter, temperature monitor, low distortion audio signalgenerator, simple video fader, and many more.

120 pages

Order code BP335

£5.45

PRACTICAL ELECTRONICS HANDBOOK – Fifth Edition. Ian Sinclair

Provides a practical and comprehensive collection of circuits, rules of thumb and design data for professional engineers, students and enthusiasts, and therefore enough background to allow the understanding and development of a range of basic circuits.

Contents: Passive components, Active discrete components, Circuits, Linear I.C.s, Energy conversion components, Digital I.C.s, Microprocessors and microprocessor systems, Transferring digital data, Digital-analogue conversions, Computer aids in electronics, Hardware components and practical work, Micro-controllers and PLCs, Digital broadcasting, Electronic security.

440 pages

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CD-ROM

Clive (Max) Maxfield and Alvin Brown

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TICKLING THE CRYSTAL Domestic British Crystal Sets of the 1920's

Ian L. Sanders

The first book dedicated to the topic of British crystal sets to be published in the last 25 years. For a very brief period during the early 1920's, these simple receivers played a crucial role in the expansion of domestic wireless throughout the United Kingdom. For many families, rich and poor, the crystal set provided an introduction to the new pastime of listening-in to broadcast programmes. Rapidly made obsolete from homes as suddenly as it had arrived, but not without leaving its mark on the history of wireless.

Written by a long-time authority and enthusiast, *Tickling the Crystal* is the most comprehensive work on the subject ever assembled. Containing almost two hundred excellent quality photographs and a wealth of previously unpublished material, it cannot fail to be an invaluable reference for anyone interested in the history of early wireless receivers.

256 pages hardback

Order code TC1

GETTING THE MOST FROM YOUR MULTIMETER

R. A. Penfold

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and

MUSIC, AUDIO AND VIDEO

QUICK GUIDE TO DIGITAL AUDIO RECORDING

Ian Waugh

- Covers
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 - Sound and digital audio essentials
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 - What effects to use
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All modern music recordings use digital audio technology. Now everyone with a computer can produce CD-quality recordings and this book shows you how. Written in a clear and straightforward style, it explains what digital audio recording is, how to use it, the equipment you need, what sort of software is available and how to achieve professional results.

Computer-based recording is the future of music and 208 pages **Order code PC121** £7.95

this book shows how you can join the revolution now.

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Ian Waugh

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All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:

How to play MP3s on your computer, How to use MP3s with handheld MP3 players, Where to find MP3s on the Web, How MP3s work, How to tune into Internet radio stations, How to create your own MP3s, How to record your own CDs from MP3 files, Other digital audio music formats.

60 pages

Order code PC119

£7.45



The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.

109 pages

Order code BP356

£5.45

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR

R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.

Circuits include video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply. **£10.95**

124 pages

Order code PC115

£5.45

ELECTRONIC PROJECTS FOR VIDEO ENTHUSIASTS

R. A. Penfold

This book provides a number of practical designs for video accessories that will help you get the best results from your camcorder and VCR. All the projects use inexpensive components that are readily available, and they are easy to construct. Full construction details are provided, including stripboard layouts and wiring diagrams. Where appropriate, simple setting up procedures are described in detail, no test equipment is needed.

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FAULT FINDING, CIRCUITS AND DESIGN

PIC BASIC PROJECTS – 30 PROJECTS USING PICBASIC AND PICBASIC PRO

BOOK + CDROM

Dogan Ibrahim

Covering the PICBASIC and PICBASIC PRO compilers, this thoroughly revised edition, previously entitled PICBASIC Programming and Projects, provides an easy-to-use toolkit for developing applications with PICBASIC. Numerous simple projects give clear and concrete examples of how PICBASIC can be used to develop electronics applications, while larger and more advanced projects describe program operation in detail and give useful insights into developing more involved microcontroller applications.

Packed with simple and advanced projects which show how to programme a variety of interesting electronic applications using PICBASIC. Covers the new and powerful PIC16F627 and PIC16F73, and the popular PIC16F84 and PIC16F877 models. The CDROM includes program source files, HEX code, data sheets of devices, sensors and schematics of the circuits used in the book.

358 pages **Order code NE44** £21.50

DISCOVERING PICS

BOOK + CDROM + HARDWARE

W.D. Phillips

A good introduction to PIC programming, covering everything you need to know to get you started. No previous knowledge of microcontrollers is required, but some previous experience with electronic circuits is assumed. Covers the basic concept of a microcontroller, fundamentals of a PIC-based circuit and using the MPLAB program. Further chapters introduce binary, PIC architecture, the instruction set, the PIC memory map and special registers plus real world programming. Four simple projects are also fully described, a Wavy Wand, an Electronic Dice, a Games Timer and a Pulse Monitor.

The associated CDROM contains the book in PDF format, MPLAB (plus instruction manuals in PDF format) and all the programs covered in the book as assembler (ASM) files. Those that wish to programme their own PICs will require a PIC programmer.

In addition a p.c.b. based hardware kit is also available that makes up into the Wavy Wand which will spell out a short message via a line of LEDs when waved through the air.

190 pages, A4 spiral bound

Book + CDROM Order code DOC1 £22.00

Book + CDROM + Hardware Order code DOC2 £28.50

PRACTICAL OSCILLATOR CIRCUITS

A. Flind

Extensive coverage is given to circuits using capacitors and resistors to control frequency. Designs using CMOS, timer ICs and op amps are all described in detail, with a special chapter on "waveform generator" ICs. Reliable "white" and "pink" noise generator circuits are also included. Various circuits using inductors and capacitors are covered, with emphasis on stable low

frequency generation. Some of these are amazingly simple, but are still very useful signal sources.

Crystal oscillators have their own chapter. Many of the circuits shown are readily available special ICs for simplicity and reliability, and offer several output frequencies. Finally, complete constructional details are given for an audio sinewave generator.

133 pages **Order code BP393** £5.49

PIC IN PRACTICE (2nd Edition)

David W. Smith

A graded course based around the practical use of the PIC microcontroller through project work. Principles are introduced gradually, through hands-on experience, enabling hobbyists and students to develop their understanding at their own pace. The book can be used at a variety of levels.

Contents: Introduction to the PIC microcontroller, Programming the 16F84 microcontroller, Introductory projects, Headers, porting code – which micro?, Using inputs, Keypad scanning, Program examples, The 16C54 microcontroller, Alphanumeric displays, Analogue to digital conversion, Radio transmitters and receivers, EEPROM data memory, Interrupts, The 12 series 8-pin microcontroller, The 16F87X microcontroller, The 16F62X microcontroller, Projects, Instruction set, files and registers, Appendices, Index.

308 pages **Order code NE39** £19.50

COIL DESIGN AND CONSTRUCTIONAL MANUAL

B. B. Babani

A complete book for the home constructor on "how to make" RF, IF, audio and power coils, chokes and transformers. Practically every possible type is discussed and calculations necessary are given and explained in detail. Although this book is now twenty years old, with the exception of toroids and pulse transformers little has changed in coil design since it was written.

96 pages **Temporarily unavailable** £4.49

PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING

Robin Pain

To be a real fault finder, you must be able to get a feel for what is going on in the circuit you are examining. In this book Robin Pain explains the basic techniques needed to be a fault finder.

Simple circuit examples are used to illustrate principles and concepts fundamental to the process of fault finding. This is not a book of theory, it is a book of practical tips, hints and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialised.

The fundamental principles of analogue and digital fault finding are described (although, of course, there is no such thing as a "digital fault" – all faults are by nature analogue). This book is written entirely for a fault finder using only the basic fault-finding equipment a digital multimeter and an oscilloscope. The treatment is non-mathematical (apart from Ohm's law) and all jargon is strictly avoided.

274 pages **Order code NE22** £28.99

A BEGINNERS GUIDE TO CMOS DIGITAL ICs

R. A. Penfold

Getting started with logic circuits can be difficult, since many of the fundamental concepts of digital design tend to seem rather abstract, and remote from obviously useful applications. This book covers the basic theory of digital electronics and the use of CMOS integrated circuits, but does not lose sight of the fact that digital electronics has numerous "real world" applications.

The topics covered in this book include: the basic concepts of logic circuits, the functions of gates, inverters and other logic "building blocks", CMOS logic IC characteristics, and their advantages in practical circuit design, oscillators and monostables (timers), flip/flops, binary dividers and binary counters, decade counters and display drivers.

119 pages **Order code BP333** £5.45

AUDIO AMPS

BUILDING VALVE AMPLIFIERS

Morgan Jones

The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.

A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.

Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** £22.50



AUDIO AMPLIFIER PROJECTS

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