THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

www.epemag.com

INFRASOUND DETECTOR

Measure frequencies down to one hertz or less
Detect sound way below human hearing
Uses an inexpensive electret microphone
Sophisticated software option

EXTREMELY ACCURATE GPS 1PPS TIMEBASE

MAXIMUM ACCURACY FOR YOUR 12-DIGIT FREQUENCY COUNTER

AUTOMATIC POINTS CONTROLLER FOR MODEL TRAINS

RAILWAY FUN WITH INFRARED SENSORS AND AUTOMATIC SWITCHING

Teach-In 2014 Raspberry Pi – Part 6

EPE's comprehensive guide to Raspberry Pi

PLUS: NET WORK, CIRCUIT SURGERY, TECHNO TALK
PIC N' MIX AND PRACTICALLY SPEAKING

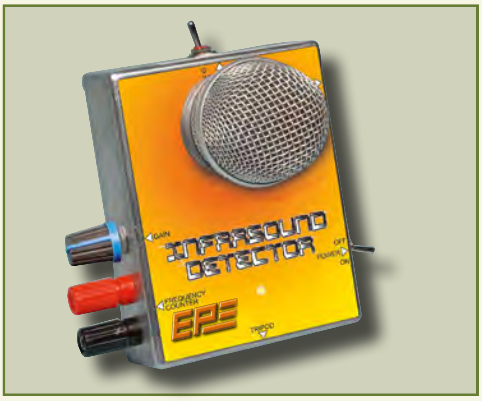
MARCH 2014 £4.40
03
9 770262 361188

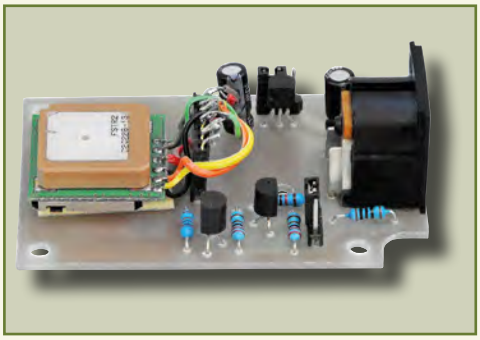
ISSN 0262 3617
• PROJECTS • THEORY •
• NEWS • COMMENT •
• POPULAR FEATURES •
VOL. 43. No 3 March 2014

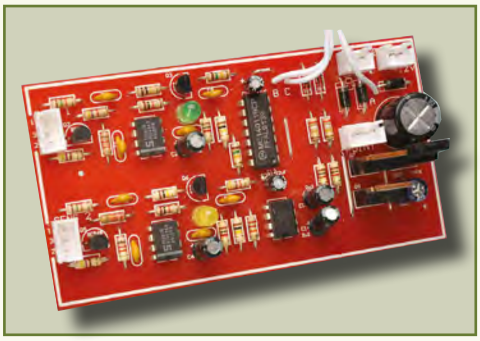
EPE EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

www.epemag.com







Our April 2014 issue will be published on Thursday 06 March 2014, see page 72 for details.

Projects and Circuits

Series and Features

Regulars and Services

EVERYDAY PRACTICAL ELECTRONICS BACK ISSUES

We can supply back issues of *EPE* by post, most issues from the past five years are available. An *EPE* index for the last five years is also available at **www.epemag.com**. Where we are unable to provide a back issue a photocopy of any one article (or one part of a series) can be purchased for the same price. Issues from Jan. 99 are available on CD-ROM or DVD-ROM – and back issues from recent years are also available to download from **www.epemag.com**. Please make sure all components are still available before commencing any project from a back-dated issue.

DID YOU MISS THESE?

BACK ISSUES ONLY £5.00 (each inc. UK p&p.)

Overseas prices £5.80 each surface mail, £6.80 each airmail.

We can also supply issues from years: 2006 (**except** Jan., Feb., Mar., Apr., May, July). 2007 (**except** June, July, Aug), 2008 (**except** Aug, Nov, Dec) 2009 (**except** Jan, Mar, Apr.). 2010 (**except** May, June, July, August, Oct, Nov, Dec) 2011 (**except** Jan).

Where we do not have an issue a photocopy of any ***one article*** or ***one part*** of a series can be provided at the same price.

JAN '13

PROJECTS • 3-Input Stereo Audio Switcher • Stereo Compressor • Low Capacitance Adaptor For DMMs • Universal USB Data Logger – Part 2
FEATURES • Jump Start – iPod Speaker • Techno Talk • PIC N' Mix • Raspberry Pi – Keypad and LCD Interface • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

FEB '13

PROJECTS • Semtest – Part 1 • Crystal DAC • 10W LED Floodlight • Built-In Speakers • Universal USB Data Logger – Part 3
FEATURES • Jump Start – Logic Probe • Techno Talk • PIC N' Mix • Raspberry Pi – Software Investigation • Circuit Surgery • Interface • Max's Cool Beans • Net Work

MAR '13

PROJECTS • Lightning Detector • SemTest – Part 2 • Digital Spirit Level • Interplanetary Voice • Ingenuity Unlimited
FEATURES • Jump Start – DC Motor Controller • Techno Talk • PIC N' Mix • Raspberry Pi – Further Investigation • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

APR '13

PROJECTS • SoftStarter • 6-Decade Resistance Substitution Box • SemTest – Part 3
FEATURES • Jump Start – Egg Timer • Techno Talk • PIC N' Mix • Circuit Surgery • Interface • Max's Cool Beans • Net Work

MAY '13

PROJECTS • Electronic Stethoscope • PIC/AVR Programming Adaptor Board – Part 1 • Cheap, High-Current Bench Supply • Ingenuity Unlimited
FEATURES • Jump Start – Signal Injector Probe • Techno Talk • Raspberry Pi • PIC N' Mix • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

JUNE '13

PROJECTS • Mix-It • PIC/AVR Programming Adaptor Board – Part 2 • A Handy USB Breakout Box • Converter For Neon Lamp Experiments • Ingenuity Unlimited
FEATURES • Jump Start – Simple Radio Receiver • Techno Talk • PIC N' Mix • Circuit Surgery • Interface • Max's Cool Beans • Net Work

JULY '13

PROJECTS • 6-Decade Capacitance Substitution Box • Soft Starter For Power Tools • High Power Brushless Motors From Old CD/DVD Drives • High-Current Adaptor For Scopes And DMMs
FEATURES • Jump Start – Temperature Alarm • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

AUG '13

PROJECTS • Driveway Sentry • Milliohm Meter Adaptor For DMMs • Build A Vox • Superb Four-Channel Amplifier – On The Cheap
FEATURES • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • Computer Error: Reliable Digital Processing – Part 1

SEPT '13

PROJECTS • Digital Sound Effects Module • USB Stereo Recording & Playback Interface • Vacuum Pump From Junk • Minireg 1.3-22V Adjustable Regulator • Ingenuity Unlimited
FEATURES • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • Computer Error: Reliable Digital Processing – Part 2

OCT '13

PROJECTS • LED Musicolour – Part 1 • High-Temperature Thermometer/Thermostat • Ingenuity Unlimited
FEATURES • Teach-In 2014 – Part 1 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • Computer Error: Reliable Digital Processing – Part 3

NOV '13

PROJECTS • CLASSiC-D Amplifier – Part 1 • LED Musicolour – Part 2 • Mains Timer For Fans Or Lights • Ingenuity Unlimited
FEATURES • Teach-In 2014 – Part 2 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

DEC '13

PROJECTS • Six Test Instruments In One Tiny Box • Virtins Technology Multi-Instrument 3.2 • CLASSiC-D Amplifier – Part 2 •
FEATURES • Teach-In 2014 – Part 3 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work

JAN '14

PROJECTS • 2.5GHz 12-Digit Frequency Counter With Add-on GPS Accuracy – Part 1 • The Champion Amplifier • Simple 1.5A Switching Regulator •
FEATURES • Teach-In 2014 – Part 4 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

FEB '14

PROJECTS • High-energy Electronic Ignition System – Part 1 • Mobile Phone Loud Ringer! • 2.5GHz 12-Digit Frequency Counter With Add-on GPS Accuracy – Part 2 •
FEATURES • Teach-In 2014 – Part 5 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

ORDER FORM – BACK ISSUES – PHOTOCOPIES– INDEXES

☐ Send back issues dated . . . .

☐ Send photocopies of (article title and issue date) . . . .

Name . . . .

Address. . . . .

. . . . Tel: . . . .

☐ I enclose cheque/P.O./bank draft to the value of £ . . . .

☐ Please charge my Visa/Mastercard/Maestro £ . . . .

Card No . . . . Maestro Issue No . . . .

Valid From . . . . Card Expiry Date . . . . Card Security Code . . . .
(The last 3 digits on or just under the signature strip)

SEND TO: **Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU.**
Tel: 01202 880299. Fax: 01202 843233.
E-mail: orders@epemag.wimborne.co.uk **On-line Shop**: www.epemag.com

Payments must be in £ sterling – cheque or bank draft drawn on a UK bank. Normally posted within seven days of receipt of order. Send a copy of this form, or order by letter if you do not wish to cut your issue. M03/14

UK readers you can SAVE 81p on every issue of *EPE*

How would you like to pay £3.59 instead of £4.40 for your copy of *EPE*?

Well you can – just take out a one year subscription and save 81p an issue, or £9.80 over the year. You can even save £1.08 an issue if you subscribe for two years – a total saving of £26.10.

Overseas rates also represent exceptional value.

You also:

- **Avoid any cover price increase for the duration of your subscription**
- **Get your magazine delivered to your door each month**
- **Ensure your copy, even if the newsagents sell out**

Order by phone or fax with a credit card or by post with a cheque or postal order, or buy online from www.epemag.com (go to the Online Shop).

EVERYDAY PRACTICAL ELECTRONICS

SUBSCRIPTION PRICES

Subscriptions for delivery direct to any address in the UK: 6 months £23.50, 12 months £43.00, two years £79.50; Europe Airmail: 6 months £27.00, 12 months £50.00, 24 months £95.00; Rest Of The World Airmail: 6 months £37.00, 12 months £70.00, 24 months £135.00.

Cheques or bank drafts (in **£ sterling only**) payable to *Everyday Practical Electronics* and sent to EPE Subs. Dept., Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Tel: 01202 880299. Fax: 01202 843233. **Email:** subs@wimborne.co.uk. Also via the **Web** at: **www.epemag.com**.

Subscriptions start with the next available issue. We accept MasterCard, Maestro or Visa. (For past issues see the Back Issues page.)

ONLINE SUBSCRIPTIONS

Online subscriptions, for reading the magazine via the Internet, £19.99 for one year, visit **www.epemag.com** for more details.

SUBSCRIPTION ORDER FORM

☐ 6 Months: UK £23.50, Europe £27.00 (Airmail), Rest Of The World £37.00 (Airmail)

☐ 1 Year: UK £43.00, Europe £50.00 (Airmail), Rest Of The World £70.00 (Airmail)

☐ 2 Years: UK £79.50, Europe £95.00 (Airmail), Rest Of The World £135.00 (Airmail)

**To: Everyday Practical Electronics,
Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU
Tel: 01202 880299 Fax: 01202 843233
E-mail: subs@epemag.wimborne.co.uk**

I enclose payment of £ .... (cheque/PO in £ sterling only), payable to *Everyday Practical Electronics*

☐ Please charge my Visa/Mastercard/Maestro

My card number is: ....
Please print clearly, and check that you have the number correct

Signature ....

Card Security Code .... Valid From Date.......................
(The last 3 digits on or just under the signature strip)

Card Ex. Date ....Maestro Issue No. ....

Name ....

Address ....

Post code .... Tel. ....

Subscriptions can only start with the next available issue.

VOL. 43 No. 03 MARCH 2014

Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS EDITORIAL Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: (01202) 880299. **Fax:** (01202) 843233.
Email: fay.kearn@wimborne.co.uk
Website: www.epemag.com
See notes on **Readers' Technical Enquiries** below – we regret technical enquiries cannot be answered over the telephone.

Advertisement Offices:
Everyday Practical Electronics Advertisements
113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299 **Fax:** 01202 843233
Email: stewart.kearn@wimborne.co.uk

Editor:	MATT PULZER
Subscriptions:	MARILYN GOLDBERG
General Manager:	FAY KEARN
Graphic Design:	RYAN HAWKINS
Editorial/Admin:	01202 880299
Advertising and Business Manager:	STEWART KEARN 01202 880299
On-line Editor:	ALAN WINSTANLEY
Publisher:	MIKE KENWARD

EPE EVERYDAY PRACTICAL ELECTRONICS

Heists out, hacks in

A couple of interesting BBC reports caught my eye over the Christmas break. It seems that the days of the old-fashioned bank robber are numbered. The British Banker's Association reported that there was a greater than 90% drop in the number of physical robberies from banks between 1992 (847) and 2011 (just 66). A number of reasons were given for this dramatic reduction – the improved design and security of banks, thanks to drop-down barriers, better CCTV and 'DNA spray', which results in robbers being covered with a unique, traceable material that is very difficult to wash off skin and can prove that a suspect was at the scene of a robbery. However, top of the list was the move to various kinds of digital or cyber crime.

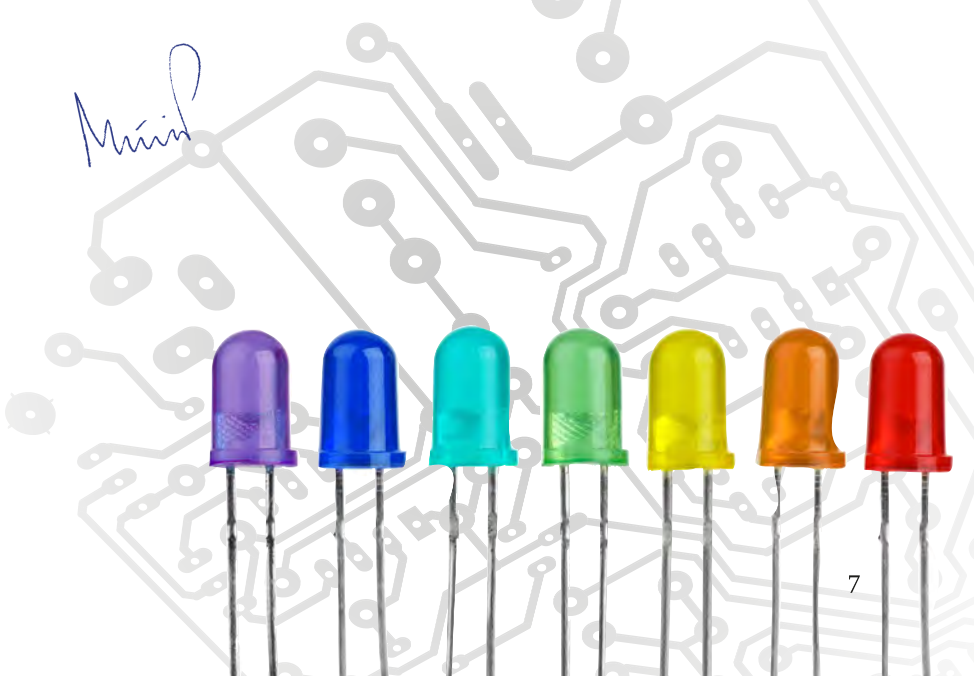
Laptops not shotguns

We are all too familiar with the assorted scams that bombard our email inboxes with offers and invitations to reveal our online bank account details, passwords and PINs. On top of this variation of the old-fashioned 'con' are much more sophisticated cybercrimes that involve hacking large amounts of data about credit card accounts, which are then used to access cash machines. Criminals in New York recently stole $45 million from ATMs using an illegally sourced database of pre-paid credit card information.

ATM attack

Not surprisingly, boxes with large amounts of money (ATMs) sitting on the High Street are popular targets for both crude and technologically aware criminals. While some resort to stealing a JCB digger and literally gouging the ATM out of the wall, others have adopted a much more sophisticated approach. A small hole is drilled in the ATM's housing, giving access to its control system interface. 'Malware' is downloaded from a USB stick and then the hole patched up. The newly installed software allows thieves to activate a special user interface, which gives them control over the machine, delivering its contents. A 'nice' extra touch from the software developers prevents the malware user copying the USB stick and going solo – he or she has to phone the gang leader for a special code each time the system is activated – as the old saying goes, there's no honour among thieves!

So, be careful out there – you may not have a bank or ATM that needs protecting, but cybercriminals seem to be endlessly creative in their search for helping themselves to OPM (other people's money).



Radio switchover: a never-ending story – by Barry Fox

The UK government has abandoned its plan to switch off analogue radio in 2015, and can now only guardedly hope for 2020. The admission was made by Communications Minister Ed Vaizey at the Go Digital conference organised by industry body Digital Radio UK, held at the BBC's Broadcasting House shortly before Christmas.

Vaizey explained the Government's change of position on digital radio switchover: 'We have to bring the listener with us. We can't wave a magic wand and make it happen. We set ourselves a series of benchmarks. Digital listening should be at 50 per cent. Listening via digital (all platforms including DAB radio, digital TV and computer) is currently 35.6 per cent. Coverage needs to match FM coverage for all stations moving from analogue. We are not there yet. So now is not the time to switch over.'

The trouble with cars

'Cars are the intractable problem' Ed Vaizey went on, admitting the blindingly obvious practical problem that a succession of previous government and industry policy makers have failed to recognise.

As Helen Boaden, director of radio at the BBC, reminded, 20 per cent of all radio listening is done in cars and 90 per cent of the 30 million cars already on the road in the UK cannot receive DAB digital radio.

'But 41 per cent of new cars now have DAB' Vaizey noted.

Pushed to give the trade and public some certainty and some idea of a new target date for analogue radio switch-off, Minister Ed Vaizey would say only, 'there is a high possibility it will happen'. He guardedly endorsed the prediction made by other speakers, by saying 'a lot of people say 2020'.

This prompted Steve Holebrook, MD terrestrial broadcast at Arqiva, the UK's transmitter network operator, to warn that this approach creates a Catch 22 situation: FM cover 'equivalence' could be achieved by 2016, but only if the government commits to a firm switch-over date.

'Patronising' – the pro-DAB 'Love' campaign has been damned by BBC Radio 2's DJ, Simon Mayo (the above is a crop of a full advert)

US route to digital

I took the opportunity to ask Minister Ed Vaizey whether he had considered adopting the policy adopted in the US to enable overnight TV switchover – offering coupons to help listeners make the change.

'No work has yet been done on that. We will look at it as we get close,' he replied. 'We first want to provide the opportunity to convert.'

A new scheme, due to be implemented in 2014 and based on the scheme used for digital TVs in the UK, will oblige manufacturers of DAB radios to have them tested by a Government-approved facility, and carry a 'Digital Tick' to signify compliance with the DAB specification and new DAB+ standard already used in Germany.

Minister Vaizey could give no clear reassurance on how the scheme would be policed to stop the sale of untested equipment by fly-by-night manufacturers.

DAB silicon

On a more upbeat note, Sir Hossein Yassaie, CEO of Imagination Technologies, the British company that stole a march on the majors in 2002 and developed the world's first commercially affordable DAB chipset that is now used in 80% of all DAB radios, confirmed that his company has now worked with UK chip-maker Frontier Silicon.

'There is nothing it doesn't do' Yassaie said when asked whether his new chip can really handle all digital radio standards. 'The hardware is ready and it will work in mobiles. It can be in products within 12 months. We are doers not talkers. You will not find a standard that this chip doesn't do'.

Antony Sethill, CEO Frontier Silicon, revealed that converting Imagination's design to silicon had taken two years and cost $10m. Finished samples will go to radio manufacturers in two to three months. The chip provides a unified service list of all broadcasts or all formats, available for reception, he said.

'Power consumption for a DAB chipset ten years ago was 700-800mW' he said. 'Now it is 70mW with the radio full on'.

Although Sethill was cagey over price, he confirmed, '$5 or $6 is the ballpark, depending on volume'.

The conference ended on an unexpected note when guest speaker Simon Mayo, one of the BBC's top radio presenters, could not resist a comment on the industry's TV and radio commercials for digital radio. These feature an animated midget black DJ, with Barry White-style voice, who wants to 'spread the love' for DAB.

'I hate those commercials,' Mayo burst out. 'I absolutely loathe them. They are patronising and I don't know what their message is supposed to be'.

To the obvious surprise of the Digital Radio UK team which had created the commercials, Mayo's outburst brought spontaneous applause from many in the conference audience.

Electrically conductive tape

A new roll of tape distributed by Sparkfun Electronics is one of those 'how on earth do they do that?' products that defies a lot of standard thinking about conductors.

'Z-axis conductive tape (or 3M Electrically Conductive Adhesive Transfer Tape 9703, to give it its full industrial name) is an easy-to-use, pressure-sensitive, double-sided tape designed for connecting, bonding and grounding flex circuits and PCBs. This conductive tape can connect most medium pitch flexible circuits with other flexible circuits, PCBs or LCD screens by simply applying pressure with your finger. That sounds useful, but hardly revolutionary – what's so special about conductive 'Sellotape'? The really clever feature of this tape lies in the Z-axis part of its name. It only conducts through the tape, not along the tape's axis, or in fact in any direction in the plane of the tape (ie, the X and Y-axes).

Z-axis conduction only

This means a user can place a single piece of tape over a fiddly surface-mount array of pads on a PCB and then simply stick an IC on top of the tape above the pads and the device will work normally. Even though you might think all the pads/pins should be shorted to each other, they aren't because of the Z-axis-only rule for conduction. Pad-to-pad connections are all in the plane of the tape and hence they are electrically isolated from each other.

3M explain the 'anisotropic electrical conductivity' behavior as due to the fact that the tape matrix is filled with conductive particles which allow interconnection between substrates through the adhesive thickness (the Z-axis) but are spaced far enough apart for the product to be electrically insulating in the plane of the adhesive.

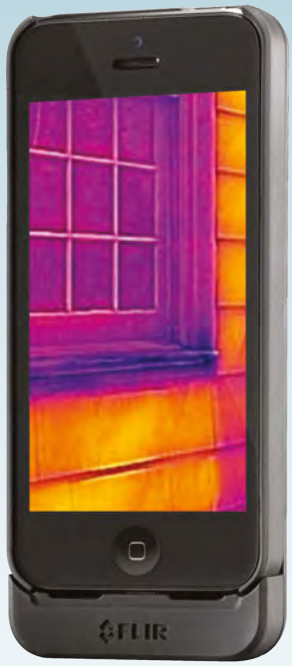
Z-axis tape – a lot cleverer than it looks!

Adhesion and RFI

The tape connects and mechanically bonds medium-pitch flexible circuits with other flexible circuits, rigid printed circuit boards (PCB) or LCD screens. It offers good adhesion to common PCB substrates such as copper, gold, FR-4 epoxy, Kapton polyimide and polyester films. It can also connect and mechanically bond EMI/RFI shield and gaskets to metal frames and enclosures. (The low contact resistance and tape construction results in good EMI performance and it adheres well to common EMI/RFI substrates such as aluminium, stainless steel, and smooth gasket materials.)

Sparkfun Electronics sells a 12.5mm × 2.75m roll for $14.95. Further details, including a brief but impressive demo video are available at: **www.sparkfun.com/products/12042**

iPhone captures thermal images... and stuns!



iPhone accessory manufacturers have come up with a couple of stunning add-ons for the iconic smartphone – in one case, literally.

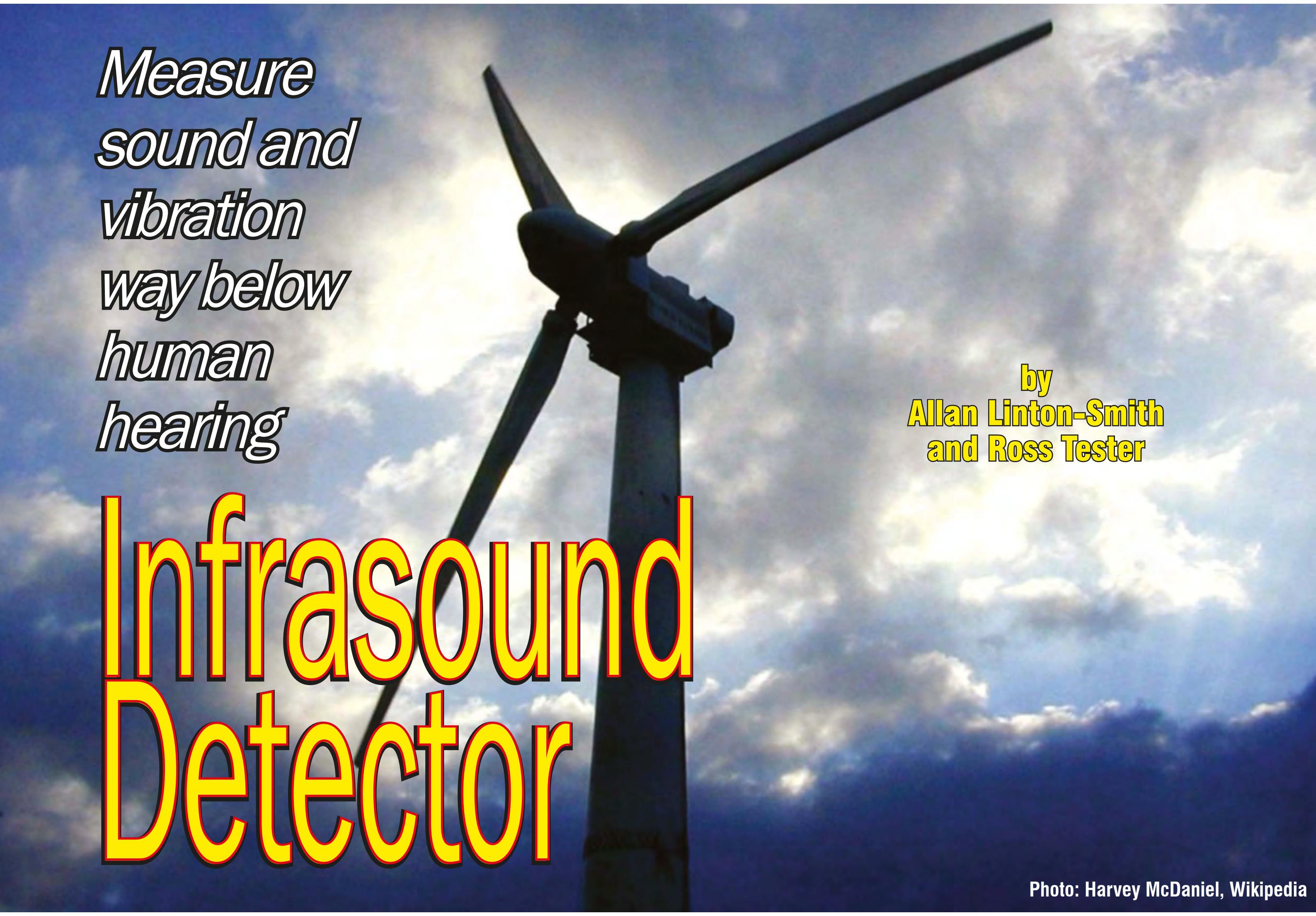
US-based manufacturer Yellow Jacket (the name of a North American predatory wasp), have put a sting in the tail of their iPhone case. Not only does it offer protection to the phone and carry a rechargeable battery that can 'double the life of your phone', but also included is a high-voltage stun gun, delivering 650kV through sharp prongs in the top of the case. The device includes a dual safety switch, and users must flip off the sturdy electrode cover to deliver a shock – simply answering a call will not give you an unexpected jolt! (UK readers are reminded that such accessories are considered to be 'prohibited firearms' under UK law – they are strictly illegal.)

Infra-red camera

Using infra-red sensor technology originally developed for military night vision, FLIR ONE has created a camera accessory that converts heat levels into colour images. These images allow users to observe differences in temperature of just fractions of a degree.

Such a device opens up a new world of possibilities where consumers can see in the dark and detect otherwise invisible heat sources.

True to the spirit of the app-oriented iPhone, in Q1 2014, FLIR will release a software developers kit (SDK) that will give third-party developers all the tools they need to create new apps for specific markets and applications.



Infrasound Detector

by
Allan Linton-Smith
and Ross Tester

Photo: Harvey McDaniel, Wikipedia

Are wind turbines making you sick? Is building vibration making you nauseous? Or do you just want to measure infrasound in your environment? You don't need to spend thousands of dollars to do it properly – just build our low-cost but accurate Infrasound Detector.

There's been a lot of press lately about infrasound, particularly as it applies to wind turbines. But until now, you've needed tens of thousands of pounds of test equipment to detect and measure it.

Our *Infrasound Detector* can be built for less than a hundred pounds, yet will give very accurate results. You can either read the sound pressure directly or store and analyse readings on your computer.

So what exactly is infrasound?

It can be defined as sound below the range of normal human hearing. That's generally reckoned to be below about 20Hz. At these frequencies you can perhaps sense or even 'feel' sound, but you can't actually hear it.

In practice, infrasound involves frequencies from about 20Hz to 0.5Hz, but some natural phenomena can cause infrasound down to the millihertz (0.001Hz) region.

When people complain about ill-effects from infrasound (and there are legions of those reports), many acoustic consultants have taken the attitude that 'if you can't hear it, it can't be doing you harm'.

Reported human reaction to sources of infrasound, such as wind turbines is varied, but some of the reports associate infrasound with a general feeling of malaise, nausea, vertigo, blurred vision, memory problems, tinnitus, anxiety, uneasiness, extreme sorrow, nervous feelings of revulsion or fear, chills down the spine and feelings of pressure on the chest.

Others have reported headaches and migraines, major sleep disorders and even self-harm tendencies.

Some researchers have even given it a label: 'wind turbine syndrome'.

Wind turbines are one example, but you'll also find infrasound caused by traffic noise, heavy surf, engines/motors (especially things like compressors), building vibrations being excited by wind, machinery and so on.

Large animals such as whales, crocodiles, alligators, elephants and emus communicate with infrasound. So, if you want to record amorous crocodiles, our *Infrasound Detector* is a good way to go about it (from a safe location).

Other source of infrasonics are heavy artillery, the calving of icebergs from glaciers and earthquakes.

In fact, there is a theory that the buildup of stresses within the earth's crust before a major earthquake causes infrasound – which could explain why birds and some other animals appear to have some warning of an imminent quake.

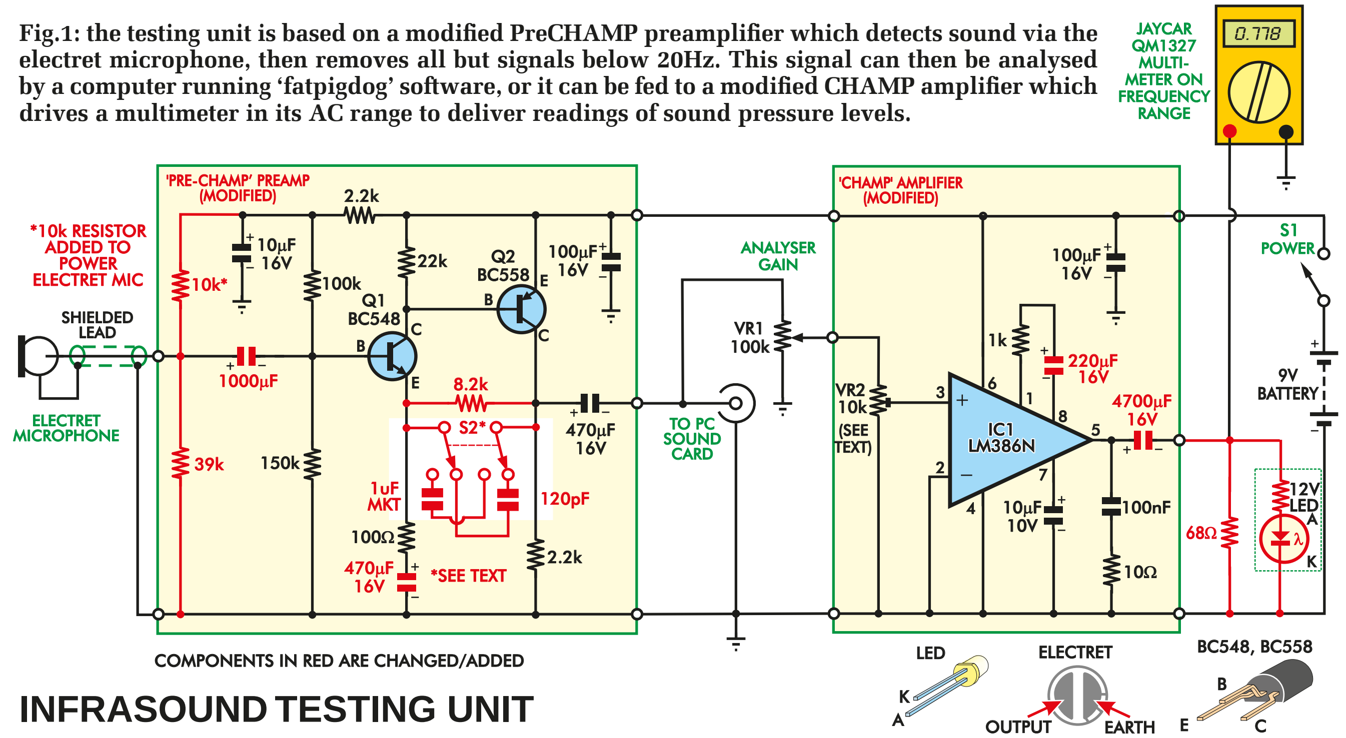
Want another example? The very act of opening or closing a door produces infrasound waves. But that is transitory – you don't normally open and close doors for hours.

Whatever the infrasonic phenomenon you want to investigate, our *Infrasound Detector* is an effective and low-cost way to do it, and it compares more than favourably with commercially available equipment.

While it's economic, it's also accurate and reliable – we believe it can be just as accurate and reliable as commercial gear.

In fact, while our unit should cost well under £100 to build and is easy to put together, it took hundreds of hours

Fig.1: the testing unit is based on a modified PreCHAMP preamplifier which detects sound via the electret microphone, then removes all but signals below 20Hz. This signal can then be analysed by a computer running 'fatpigdog' software, or it can be fed to a modified CHAMP amplifier which drives a multimeter in its AC range to deliver readings of sound pressure levels.



Our *Infrasound Detector* is built into a small diecast box, with an old microphone shield attached to the front. Inside this shield is a low-cost electret mic insert. The terminals at left are the output to a frequency counter (or in our case, a budget multimeter) while a socket is provided on the right side for output to a PC sound card. Suitable analysis software is quite cheap.

Specifications

Microphone frequency response G-weighted:	±2.0dB corrected (0.5Hz-26Hz)
Microphone frequency response C-weighted:	±2.0dB (10Hz-20kHz)
Microphone intermodulation distortion:	0.8% @ 100dB SPL
Preamplifier frequency response:	±0.2dB (0.5Hz-20kHz)
Power amplifier frequency response:	±0.2dB (0.5Hz-20kHz)
Power amplifier output (before clipping):	200mW into 8Ω
Frequency response of virtual instrument:	±0.4dB (0.5Hz-20kHz)
Overall measuring accuracy –	
Without calibration table:	±15dB (20Hz-20kHz)
Using calibration table:	±1.0dB (2Hz-20kHz)
THD+N preamplifier:	0.102% at 1kHz (5Hz-22kHz)
THD+N power amplifier:	0.40% at 1kHz (5Hz-22kHz); 250mW
Preamp input maximum:	50mV
Preamp input minimum:	1.0mV
Power amp input maximum:	500mV
Power amp input minimum:	30mV
Preamp phase distortion:	±6.35° (below 200Hz)
Preamp intermodulation distortion:	0.095% (88mV output 70Hz/7kHz)
Preamp S/N ratio:	–107dBV (10Hz-80kHz ref 630Hz 25mV)

to develop and test. That is because infrasound sweeps can take hours to settle, measure and average – and some very specialised and expensive equipment was required to design and test it.

If you wanted to buy that commercial equipment yourself, you'd have little change from £20,000!

We also had to develop a method for testing and calibrating high levels of infrasound without upsetting the neighbours.

How it works

The output from a wide-range electret microphone is fed to a very-low-frequency bandpass filter. The infrasound signal is amplified and fed to a 'virtual' spectrum analyser which then plots the amplitude of the infrasound signal on the vertical (y) scale versus frequency on the horizontal (x) scale using a principal known as Fast Fourier Transform (FFT).

A computer can then be used to analyse the signal and/or a direct frequency readout can be obtained if used in the field.

CHAMP amp

After constructing many circuits which offered good theoretical performance we discovered that an old (nearly 20 years) preamplifier/amplifier project pair were perfect. The PreCHAMP preamplifier, combined with the CHAMP audio amplifier, can be easily modified to do the job admirably (see box below Parts list).

Yes, we know, we said only two months ago that our new CHAMPION amplifier would kill off older designs, but there's a good reason for resurrecting these here: low quiescent current.

The PreCHAMP and CHAMP draw only about 4mA each on idle, so prolonged operation (which you'll need for field checks) is quite practical using only a 9V battery.

By comparison, the CHAMPION draws up to 60mA, so your 9V battery wouldn't last long.

If you built the CHAMPION project (based on the Panasonic AN7511), you could use it for infrasound with only a few modifications, but you'll probably need to use it with an external supply.

As used here, the modified PreCHAMP now has much improved frequency response; within ±0.2dB over the range 2Hz – 20kHz. The modified CHAMP also gives a flat frequency response at around 0.25-0.5W – so you can feed any oscilloscope or low frequency counter.

Optional CHAMP

The CHAMP is optional – it has been included so that you can take quick measurements in the field.

The PreCHAMP is set up as a band-pass filter and high gain amplifier that is approximately G-weighted, ie, its centre frequency is around 10Hz with –3dB points at 500mHz (0.5Hz) and 26Hz.

A selector switch is provided for switching to 'C' weighting (ie, flat response) so that the unit can easily be calibrated at 1kHz.

The infrasound signal from the PreCHAMP is fed to the CHAMP amplifier, which has been modified to give a flat frequency response from 0.5Hz to 20kHz and is set at high gain so that the signal output to a frequency counter is over 130mV at 1Hz.

Frequency counter?

Whoops! Haven't got one of those? That little problem is solved very cheaply with a multimeter – specifically the Jaycar QM1327 auto-ranging multimeter, which can read read down to 0.1Hz and sells for around £12.

While its specs state it needs a minimum of 3V RMS AC before it will show a frequency reading, we found that it far exceeded its specification and 130mV was sufficient. Few frequency counters go below 10Hz, so the Jaycar meter represents good value in this application.

If you use the CHAMP together with the Jaycar multimeter, then you will be able to determine SPL (the sound pressure level in dB) by switching the DMM to AC volts. This will give an approximate SPL in dB (decibels) as described.

For signals below 0.5Hz this approach will not be accurate, but this will be more than sufficient for the majority of applications.

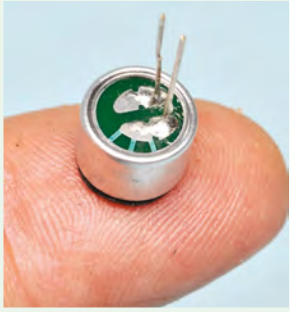
fatpigdog!

The direct readout is very handy in the field, but if you want to do some real analysis, you'll need a computer and suitable software.

We recommend spectrum analyser software from 'fatpigdog' (version 4.04 or later). You can purchase and download the software for around $40 from: **www.fatpigdog.com**

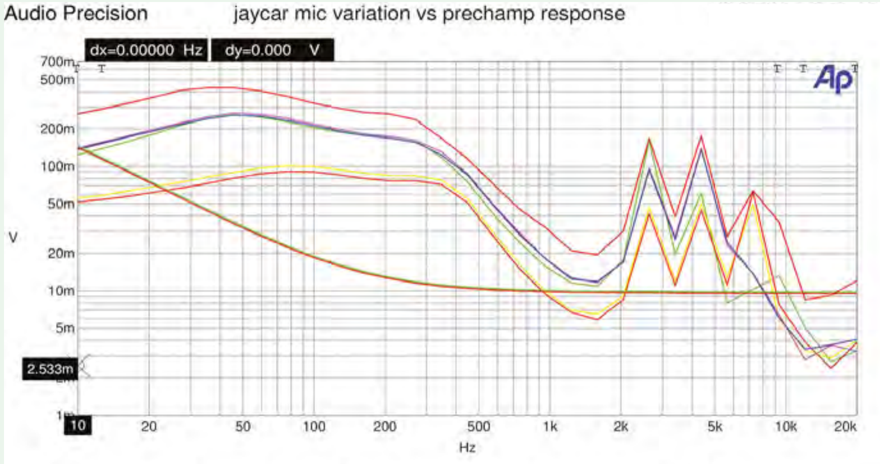
On their website, you will also find various dedicated benchtop spectrum

Electret Microphones



The electret microphone is pretty inefficient at frequencies below 25Hz, hence the very high amplification.

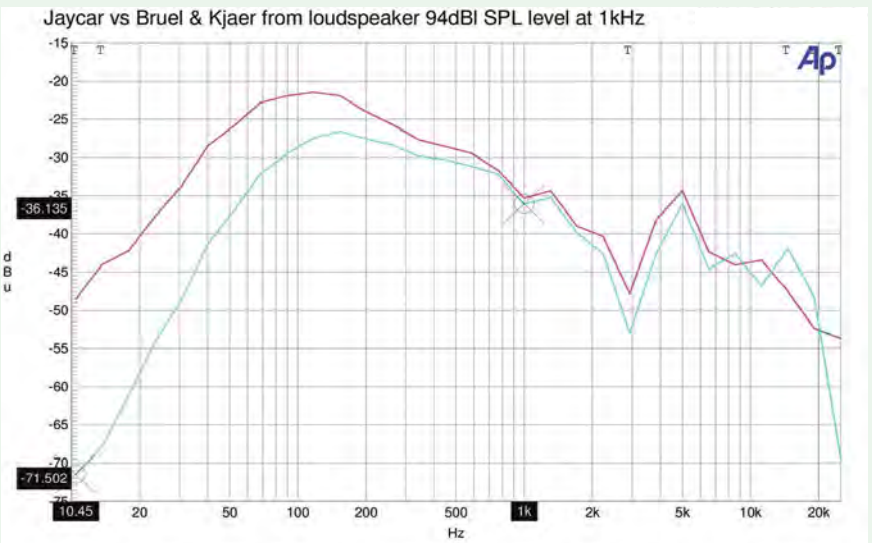
There are lots of electret microphone inserts available, but we are specifying a particular Jaycar model (Cat AM-4011) because we found it to be a very good match for this project. However, you can see from the graphs below that even these specific Jaycar mics are not all the same – some are more sensitive than others due to manufacturing variations – so you may need to buy a few to experiment.



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment	Cursor1	Cursor2
2	1	Green	Solid	7	Anlr.Level A	Left		124.2 mV	124.2 mV
3	1	Yellow	Solid	7	Anlr.Level A	Left		55.61 mV	55.61 mV
4	1	Red	Solid	7	Anlr.Level A	Left		51.84 mV	51.84 mV
5	1	Magenta	Solid	7	Anlr.Level A	Left		140.1 mV	140.1 mV
6	1	Blue	Solid	7	Anlr.Level A	Left		136.9 mV	136.9 mV
8	1	Green	Solid	7	Anlr.Level A	Left		146.1 mV	146.1 mV
9	1	Red	Solid	7	Anlr.Level A	Left		141.6 mV	141.6 mV
10	1	Red	Solid	7	Anlr.Level A	Left		264.9 mV	264.9 mV

Because they have flying pigtails changing them is a pretty easy soldering task. Each electret will need to be calibrated as described below in the 'Calibration' section to enable you to assess sound pressure level (SPL).

By the way, we averaged the frequency response of several of the Jaycar electret microphones combined with the PreCHAMP and compared them with an accurately calibrated Bruel & Kjaer microphone/preamp (expensive!) – and found that the Jaycar electret was actually better at infrasound frequencies!



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment	Cursor1	Cursor2
1	1	Cyan	Solid	10	Anlr.Level B	Left	Bruel&Kjaer	*-36.135 dBu	*-71.502 dBu
2	1	Magenta	Solid	10	Anlr.Level A	Left	Jaycar electret	-35.306 dBu	-48.482 dBu

We used this sweep to show that 1Hz was easily detectable with a resolution of 0.5Hz. By correction, the sound source is 100dB. You need to be patient because the analyser sometimes sets the sweep time to 10 seconds automatically and you have to wait before you can make adjustments.

analysers for sale, but the virtual instrument is about 99% cheaper!

Fatpigdog is fun to use, easy to manage and includes all sorts of extras, such as a waterfall display, spectrum analysis to 22kHz, BMP capture and much more.

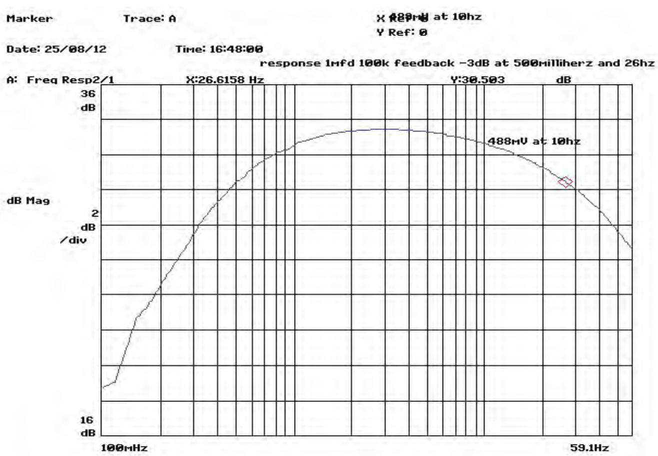
The PreCHAMP output is simply fed to the sound card input of your computer. You could feed the spectrum analyser from the 'CHAMP' output, but we don't recommend this because your computer soundcard is usually set up for microphone-level inputs (ie, millivolts not volts). Any large voltages will usually result in clipping and consequently the spectrum analyser will show multiple peaks from the odd harmonics.

The Jaycar multimeter is an option if you want a handheld detector for quick infrasound detection without having to set up a PC and adjust the software.

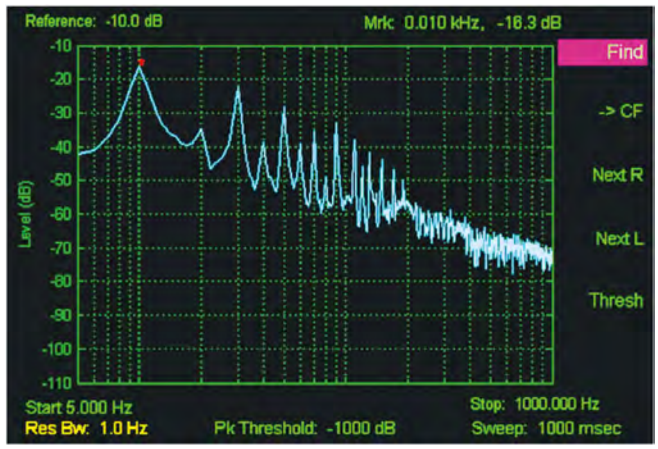
It is fed from the Pre-CHAMP output via the 10k preset pot. You can set the maximum output from the 'CHAMP' by setting the preset fully anti-clockwise.

The only other modification is the addition of a 68Ω 'dummy load' resistor which prevents the output capacitor from building up a DC charge, which would otherwise result in false readings. You *could* attach a loudspeaker instead, but you won't hear much below 25Hz (and it will drain the battery more quickly).

By changing the parameters on the analyser – such as sweep time, start and stop frequencies and resolution bandwidth, you can save and print your spectra for further analysis.



Using the Agilent 35670A, the sweep gives the lower response for the G-weighted PreCHAMP down to 0.1 Hz…that's 1 cycle every 10 seconds! –3dB points are 0.5Hz and 26Hz. Mains hum is not a problem at these frequencies!



fatpigdog spectrum of a 15-inch speaker fed with 200W. The resolution is set at 1Hz and the sweep time is one second. You could actually feel the sound – and it was certainly not nice!

The Jaycar QM1327 Multimeter works fine as a frequency meter and also an AC voltmeter. It's simply held in place on the back of the *Infrasound Detector* with self-adhesive hook'n'loop tape (usually sold under the 'Velcro' brand).

Furthermore, by setting the spectrum analyser to 'max hold' you will be able to observe any infrasound which occurs during an extended period of time.

Using the virtual spectrum analyser requires some practice and patience (just like a real benchtop spectrum analyser) but if you experiment, you will learn to master it all fairly quickly. We'll have much more to say on this later.

Construction

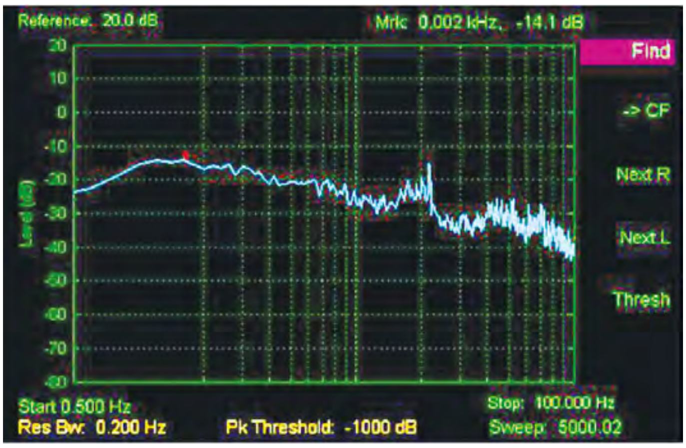
The 'hardware' is built into an aluminium diecast box (to minimise noise) measuring 119 × 93.5 × 34mm. Inside this are the PCBs for the modified PreCHAMP (and CHAMP if you wish to use it) and a 9V battery in suitable holder.

Layout is not particularly critical, but given the very high amplification of the PreCHAMP/CHAMP combination (about 4000 times), outputs should be kept relatively clear of inputs, as is normal practice for an amplifier.

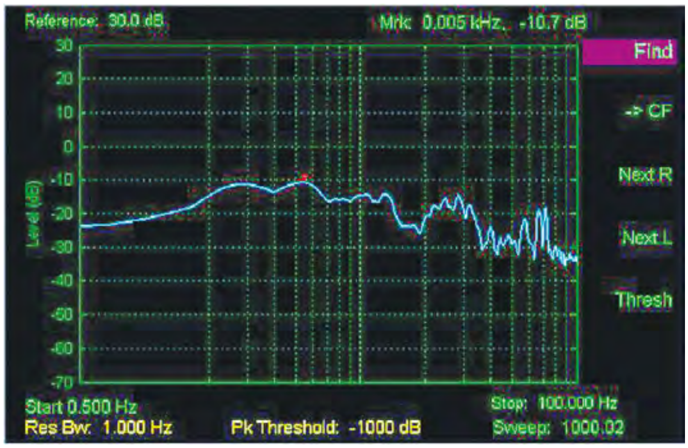
Start by constructing the Pre-CHAMP pre-amplifier as per the instructions given with the kit.

See Figs.1 and 2 for the modifications required – you will only need to change the values of three capacitors and these will easily fit on the PCB.

The 39kΩ resistor should be soldered to the underside of the board input or across the input pins.



This spectrum shows the maximum sound level for suburban traffic. The microphone is a good 5-10 metres away from vehicles and there is significant noise at 2Hz. Note also the peak at around 20Hz – probably from vehicle engines.



You can set up the detector and leave it running for up to an hour. We caught a distant thunder clap at 5Hz and a calculated 84dB. The resolution was set at 1.0Hz and the sweep time was one second. The maximum hold function runs continuously and updates every second.

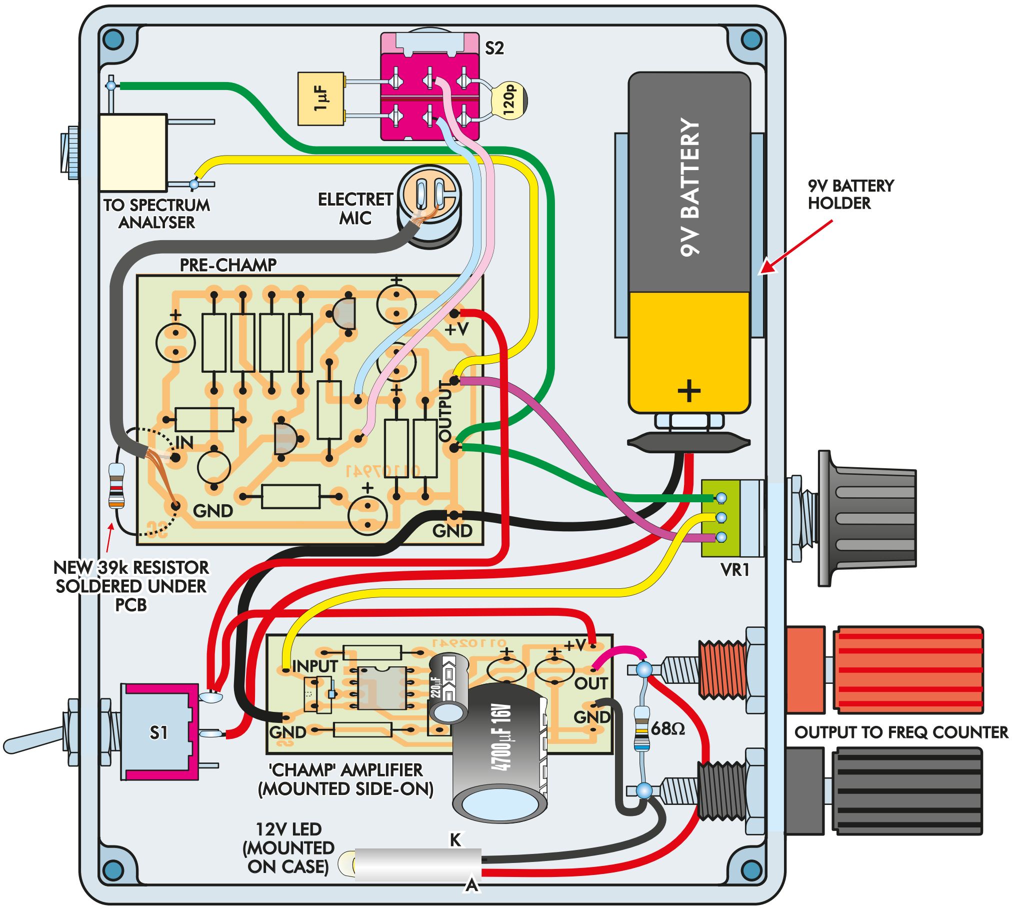


Fig.2 (above): component layout is not critical, but this diagram should give you a guide. Both the PreCHAMP and CHAMP PCBs are held in place with double-sided foam pads. The photo at right shows the same internal view, together with the T-nut tripod adaptor we fitted to the end of the diecast case.

To the two holes on the board marked '1n5' solder two leads and connect these leads to the two central pins of DPDT switch S2.Then solder the 1µF capacitor to one side and the 120pF capacitor to the other (see photo).

Then run leads to CON3 and VR2 as shown in the wiring diagram.

We could have used just a simple SPST switch to switch the larger capacitor in and out of circuit, but the arrangement shown (using a DPDT switch) allows easy mounting of the two external capacitors: they are simply wired across the outside terminals and the wires back to the PCB are wired to the centre terminals.

Assuming you want to include the 'CHAMP' power amplifier, to provide sufficient voltage to the Jaycar Frequency meter (multimeter), construct it as per the kit instructions.

The modifications we have made to give a flatter frequency response involve changing two capacitors. You will find that the 4,700µF capacitor is large but fits neatly on the PCB. However, it is a little too tall and the finished amplifier will have to be put on its side so it can easily fit in the diecast box (see photo below).

Now you can drill and mount all the hardware on the diecast box using the picture as a template and solder all the wires up according to the diagram.

Fitting a tripod adaptor

To enable easy use in the field, we wanted to be able to attach the unit to a camera tripod. We fitted our box with a 1/4-inch threaded bush (Whitworth thread; standard on most tripods/cameras).

In fact, we used a 'T-nut' fitting intended for furniture and shelf hardware (pictured) which has an internal 1/4-inch Whitworth thread. It had four punched points intended to help it grip timber – we simply flattened these out with a hammer, then glued it in place with epoxy inside and out, making sure no epoxy got inside the thread.

T-Nuts are available from most hardware stores and they are really cheap!

As it has a 1/4-inch Whitworth internal thread (same as most tripods) we used a furniture T-nut from a hardware store, flattened out the points, and drilled the box to suit. Then we glued it in place with some two-part epoxy.

However, you need to ensure you do get 1/4 Whitworth – it appears that 5/16 and 3/8 are much more common.

If you must use 3/8-inch, 3/8 to 1/4-inch adaptors are available from better photographic stores.

Finishing off

It will be easier to solder the wires to the boards first, then solder the wires to all the switches and sockets before mounting them inside the box.

Because the circuit boards are tiny and sometimes have no provision for normal screw mounts, you will have to use some good quality, thick double-sided foam pads. Cut it to cover the bottom of the 'pre-CHAMP' board then press it firmly in place, allowing plenty of room for everything to clear.

Next, fit the 'CHAMP' amplifier by putting double-sided tape on the side of the 4,700µF capacitor and the side of the board and then press it all into place as shown.

Check again to see if any wires have come loose, then mount the battery in its holder and switch on. The current drain should be about 8mA. If all is OK, put the lid on and plug in your computer, set up the software and start testing.

The microphone

For the microphone assembly, drill a hole large enough for the electret in the base of the box, solder a short length of shielded cable to the microphone with the shielding to earth (the side connected to the outer case of the electret) and the other end to the the input terminals of the PreCHAMP.

We are looking at frequencies below 30Hz on the G-weighting setting, so hum should not be a problem until you switch to C-weighting

We cut the top off an old dynamic mic and mounted it on the box, then attached the electret to the side with double sided tape as shown.

We maintained the original mic thread to allow us to attach a wind shield and also to calibrate our setup and to make quick changes to test various microphones without having to unscrew the box all the time. But this is not critical and you can just stick the electret to the inside of the box with double-sided tape or even solder it directly to the input pins and just have an appropriate hole in the diecast box.

Whatever you do, you should be able to access the electret to enable quick changes because there is significant variation between electrets, as the graphs will show and having it mounted on shielded cable makes it easier to solder and unsolder.

Checking it out

Once everything is done, connect the output from the pre-CHAMP to your computer mic input, making sure your sound card mixer is set flat; ie, no bass or treble boost.

Check to see if the microphone is working by switching to C-weighting and then talking or whistling. Measure

Here's how we mounted the electret microphone, using an old dynamic mic windshield as the base. The insert is held in place with an adhesive foam tab.

Parts List – Infrasonic Detector

1 PreCHAMP PCB available from the *EPE PCB Service*, coded 01107941 (A Kit is available from Jaycar KC5166*)
1 CHAMP PCB available from the *EPE PCB Service*, coded 01102941 (A Kit is available from from Jaycar KC5152*) [optional – see text]
1 Diecast box
1 frequency-reading multimeter (Jaycar* QM1327) [optional – see text]
1 SPST miniature toggle switch (S1)
1 DPDT minature toggle switch (S2)
1 3.5mm mono socket, panel-mounting
1 banana socket – red
1 banana socket – black
1 short red wire fitted with banana plugs each end
1 short black wire fitted with banana plugs each end
1 electret microphone insert (eg Jaycar* AM-4011) [see text]
1 microphone
1 1/4-in Whitworth T-nut for tripod mount [see text]
1 9V battery
1 U-shaped 9V battery holder
1 3.5mm to 3.5mm shielded audio cable (to connect to sound card)
Short lengths hookup wire and shielded audio cable
Double-sided adhesive foam pads
Self-adhesive hook and loop tape, etc
Epoxy glue (for tripod adaptor)
1 Fatpigdog Virtual Analyzer program (download from www.fatpigdog.com [approx. $40]).

Semiconductors
1 LED, panel mounting 12V type

Capacitors
1 4700µF 16V electrolytic
1 1000µF 25V electroylytic
2 470µF 16V electrolytic
1 1µF MKT
1 120pF ceramic

Resistors
1 39kΩ 1 8.2kΩ 1 68Ω
1 100kΩ (or 50kΩ) log pot
1 knob to suit pot

Items marked '*' are available from: www.jaycarelectronics.co.uk

PreCHAMP and CHAMP
These projects were originally published by Silicon Chip in February 1994, but have stood the test of time well. We recommend buying them in kit form from Jaycar.

Frequency (Hz)	ADD dB to measurement
0.5	41
1	29
2	17
3	11
4	8
5	5
6	4
7	3
8	2
9	1
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	0.5
21	1
22	1
23	1.5
24	1.8
25	2.5
26	3
27	3.2
28	3.3
29	3.4
30	3.5

Table 1: Correction table for a Jaycar AM-4011 electret mic insert.

the output with a DMM set on AC or plug the output into an amplifier or oscilloscope.

Alternatively, you might like to plug the output of the Pre-CHAMP into the mic socket of your computer sound-card and view your 'whistle' on the spectrum analyser. Your whistle should give you a peak at around 1-2kHz, plus harmonics at 2 and 3kHz.

Once all your checks are done, switch it to G-weighting and observe the LED (assuming you have added the CHAMP) It should flash in time with the signal and you can open and shut a door to test it (a car door opening is approx 0.5-2Hz). If all goes well you will finally be ready to fine tune it and try some infrasound testing.

Plug in the Jaycar multimeter, switch it to the Hz range and read off the frequency. On C-weighting you will probably see something in kHz, but on the G-weighting setting you should see frequencies below 20Hz.

The frequencies will probably jump around a bit and you can vary the gain control to stabilise the readings.

During testing indoors, we saw 8Hz coming up consistently on the counter and also on the spectrum analyser.

It disappeared when we switched off our air conditioner but it was a hot day so we put up with the 8Hz (although it was less than 75dB [SPL]).

Calibration

As we mentioned before, calibration is only really needed if you want to establish sound pressure level .

Frequency calibration is already inbuilt in the software and multimeter and is not required for our purposes.

It is fairly straightforward, but it will help if you already have a sound level meter (like the Jaycar QM1591) and an audio oscillator – but if you don't have these items and you don't calibrate, you will still get a pretty good idea from the relative dB levels indicated in the spectrum analyser.

For example, our leaf blower is rated at SPL 70dB at one metre. We set the detector to C-weighting and found that the fatpigdog analyser indicated –15dB at 35Hz at 1 metre, so switching to G-weighting will mean that any infrasound frequency BELOW 26Hz will also be 70dB, if you see –15dB on the analyser.

Sure, it's a rough measurement, but there are many devices which have a dB rating on their label such as mowers or saws, and you can check these out.

For a more accurate calibration, feed a tone (say 1kHz) through an amplifier and loudspeaker and check your C-weighted result against your C-weighted sound level meter. Try various levels, incrementing them by 5dB.

Most sound level meters have absolutely no response below 35Hz, so there is no point checking the G-weighted setting.

If you don't use fatpigdog's software, don't worry, because you can switch the Jaycar multimeter to 'AC volts', making sure the gain control is fully advanced and just take note of the reading at various sound pressure levels. Our setup showed approx 0.9V AC at 94dB.

For frequencies below 7Hz the accuracy falls off somewhat, but if you are looking at 0.5Hz, just switch it to DC volts and watch the rise and fall!

Other unique applications – vibration anaysis

This instrument is very useful in checking out vibration problems, as we found with our 8Hz air conditioning. Sometimes these problems go undetected for years and some have claimed that they may be responsible for nausea, headaches, sleep problems or just a general sense of unpleasantness.

Additionally, traditional methods of sound level monitoring have only focussed on the audible spectrum and have not even considered infrasound effects on the human (or animal) body, and access to infrasound measuring devices has been both difficult and expensive.

Any vibrating device will give off sound, and our setup will detect it and/or datalog it. Not only that, but for a few pounds it could be used in just about any industrial situation where vibrations may be destructive – such as engines, chassis, suspensions even buildings and bridges.

Data logging with waterfall analysis

The software will also enable you to do waterfall analysis, which is really a way of viewing a spectrum analysis as it varies over time.

It can be used as a datalogger for infrasound and audio signals. The vertical scale shows the frequencies of the various harmonics, while the horizontal scale is time – so, the whole chart is a record of a few minutes.

Reproduced by arrangement
with SILICON CHIP
magazine 2014.
www.siliconchip.com.au

SETUP FOR WATERFALL CHARTS

The wiring setup is virtually the same as for testing spectrum analysis microphone 'Pre-champ' output (for voice prints)

The setup for the virtual instrument is:
Click on 'preset'
Then 'display'
Then 'waterfall F2'
Then 'rotate'
Then try different sweep times and resolution bandwidths (Res. Bw…..).
And try different colour schemes by clicking on 'jet'
Press BMP to save image you want.

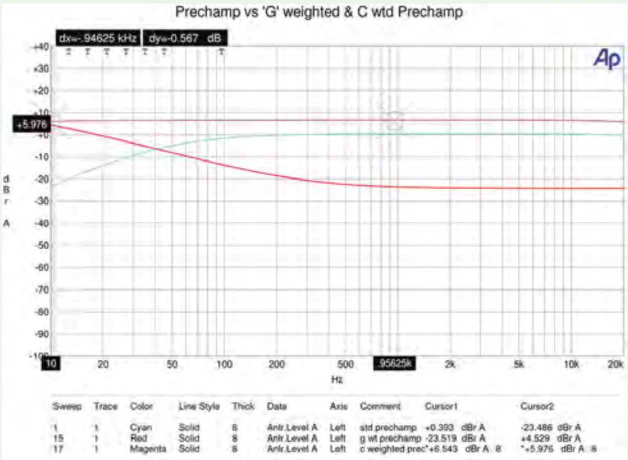
Setting up and operating the Virtual Analyzer

We assume you have downloaded the Spectrum Analyzer software from: www.fatpigdog.com/SpectrumAnalyzer (or updated if you're using an older version).

The originator, Spyro Gumas, is very communicative and can assist if you have any problems.

To start, open and run the program. We used Windows XP but check the website first for compatibility with Vista, Windows 7 or 8.

Initially, you will see the black and white MS-DOS screen appear. You may have to wait (perhaps two minutes or so) and the instrument will appear similar to the trace below:



This sweep shows the frequency response of the modified PreCHAMP: the top line is C weighted and is flat from 10Hz-20kHz. The middle line is an unmodified PreCHAMP (not used) and bottom line (red) is the G-weighted response which joins the top line at 10Hz.Calibration can be carried out at 1kHz on the C setting and then is the same when the unit is switched to G, up to a max of 20Hz.

NOTE: Our Audio Precision analyser cannot go below 10Hz.

Once the virtual instrument pops up, plug the output from the PreCHAMP into your soundcard mic input, switch to G weighting then set up as follows.You can attach the multimeter to the CHAMP output if you wish, but in this case it is redundant.

On the virtual analyser:
Click on 'reset' to clear any previous settings.
Click on frequency
Click on start (F2) and type in '0.5' <enter>.
Click on stop key (F3) and type '100' <enter> (This sets the range to 0.5Hz-100Hz)
Click on Lin/Log key (F4) so you see lin/(log) – now the frequency range is set to a logarithmic scale.
Then:
Click on bandwidth
Click on RBW and type in '0.5' <enter>
Click on sweep and type '10000' <enter>
Click on 'trace' and then 'max hold'

The analyser will then sweep continuously and indicate the number of averages at the top of the page.

The analyser is now ready to do a ten-second sweep of your sound source from 0.5Hz to 100Hz with a resolution of 0.5Hz, and will continuously update itself with the maximum signal. For example, we set it going during a thunderstorm to record the sound over a period of 20 minutes

You can save an image anytime by pressing 'BMP' (bitmap) and you can play around with the RBW (resolution bandwidth) which you can set as low as 0.1Hz.

Refer to the fatpigdog manual provided if you have difficulty because some computers have different delay arrangements with the soundcard and you may need to compensate this with 'tstupid'.

When you are happy with a particular trace, you might like to activate the marker to examine points of interest.

Click on 'marker' then 'ON' and then click 'peak'. The marker will then indicate the dominant frequency.

You will see a red dot appear on the trace, then move the marker to the area you want to measure by clicking on '<' (backward) or '>' (forward) keys.

The marker reading appears at the top of the page eg, 'Mrk 2.558Hz, –86.2dB'.

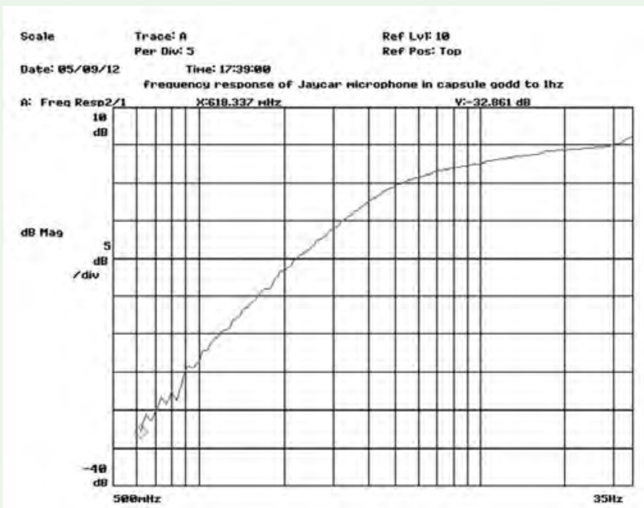
Once you have measurements of the points you are interested in, go to Table 1 and add or subtract the dB value at the frequency of interest. For example, if you measured –10dB at 5Hz from the chart you have to ADD 5dB, ie –10+5=–5

During calibration for our setup we found that –15dB on our spectrum analyser was 74dB SPL, so we have to add 10dB (because –5dB is 10dB louder than –15dB).

So SPL = 74+10 = 84dB

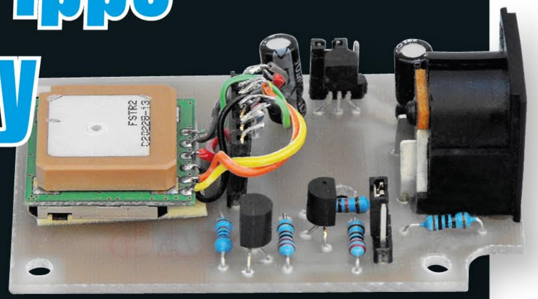
Accuracy

The figures quoted in this article are those achieved on a PC fitted with a generic sound card (nothing special!) so we have every reason to believe that you should achieve similar results.



This shows the actual frequency response of the finished setup using the Jaycar electret and is usable down to 1Hz. You need to allow for fall off by using the table provided. For example, for 1Hz you need to add 29dB to your base figure to obtain the correct SPL.

Extremely accurate GPS 1pps timebase for a frequency counter



Get maximum accuracy from your 12-Digit Frequency Counter using this GPS 1pps Timebase. It connects to the external timebase input of the counter and will let you achieve measurement accuracy close to that of an atomic clock. You can either build it into the frequency counter or use it as a separate module.

By JIM ROWE

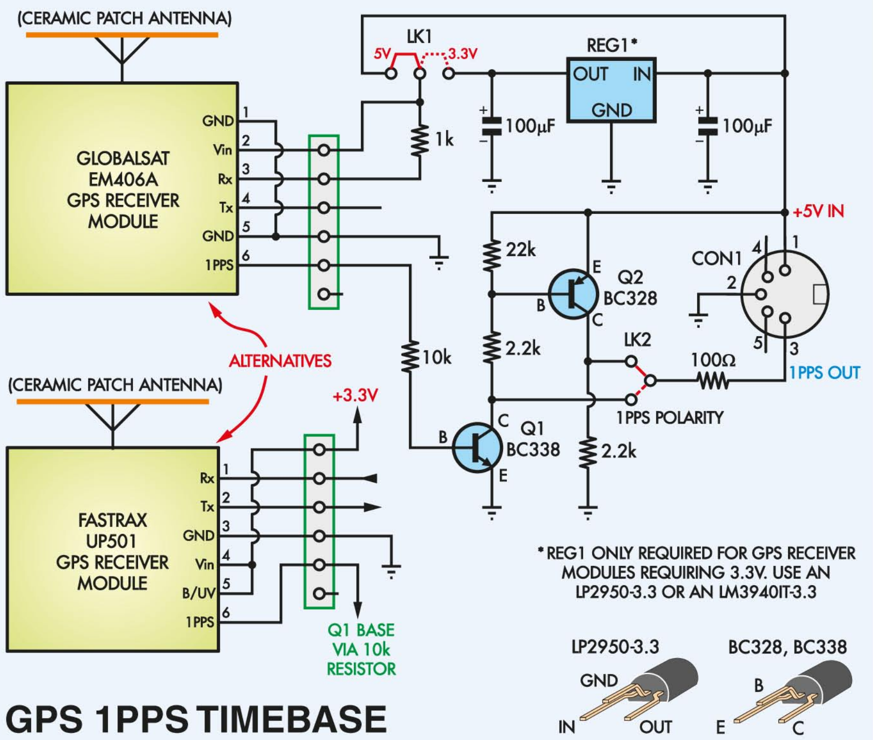


Fig.1: the circuit consists of the GPS receiver module itself plus a couple of transistors (Q1 and Q2) to buffer and level translate the 1Hz (1pps) pulses. Regulator REG1 is required for GPS modules that operate from 3.3V DC.

ARE YOU KEEN to build the new *12-Digit High-Resolution Frequency Counter* described in the January and February 2014 issues of *EPE*? It's a world-first DIY design, but you will also want to get the very best accuracy to go with its 12-digit resolution.

To do this, you don't need our complex GPS-based Frequency Reference (*EPE*, April-May 2009), although this can be used if you have it. If you don't, then there's a much simpler and cheaper approach: purchase a cheap GPS receiver with 1pps output, bung it on a small interface PCB and you get close to atomic-clock precision.

In fact, we promised in our February 2013 issue to publish such a device – and here it is. Build it for your frequency counter and you should be able to achieve a measurement accuracy of around ±1 part in 10^{11}.

Simple circuit

Fig.1 shows the circuit details. It looks simple, but that's because all the complex circuitry needed to receive the signals from the GPS satellites and derive the 1Hz (1pps) pulses is inside the GPS module.

We are specifying either of two GPS modules which are currently available from various suppliers: the GlobalSat EM-406A module, which is available from **amazon.co.uk** for around £40 or the Fastrax UP501 module from **uk.rs-online.com.** This is smaller and also priced at £40, but is becoming harder to buy. The project is also compatible with various other receiver modules, if you find the EM-406A or the UP501 out of stock.

The type of GPS receiver module you'll need is one that incorporates its own ceramic 'patch' antenna for the UHF signals from the GPS satellites, while also providing an output for 1pps (pulse per second) time pulses. It can operate from a DC supply of either 5.0V or 3.3V. A few currently available modules are listed in a panel elsewhere in this article.

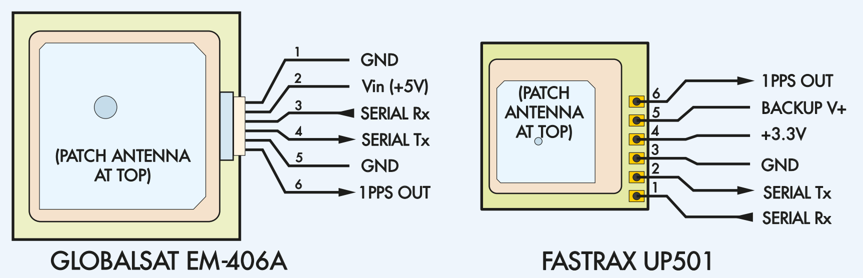


Fig.2: the pin connections for the GlobalSat EM-406A and Fastrax UP501 GPS modules. Check the pin connections if you use a different module.

The EM-406A has its own built-in GPS patch antenna and operates directly from 5V DC. It features the SiRF Star III high-performance GPS chipset, very high sensitivity and an extremely fast time to first fix (ie, from a cold start).

The UP501 and other compatible GPS modules operate from 3.3V DC, so for these we have made provision for fitting a 5V-3.3V LDO (low dropout) regulator (REG1). You can use either an LP2950-3.3 regulator which comes in a TO-92 package or an LM3940IT-3.3 which comes in a TO-220 package.

Apart from the power supply arrangements, there is a simple buffer and level translator for the 1Hz pulses provided by the GPS module. This uses transistors Q1 (BC338) and Q2 (BC328) to ensure that the 1Hz pulses fed out to the counter have a peak-to-peak amplitude of 5V, regardless of the supply voltage used by the GPS module.

Link LK2 allows the 1Hz pulses to be inverted or not by the buffer, so that their 'leading edges' are positive-going regardless of their polarity out of the GPS module (some modules may output them as inverted.)

Why do we need to ensure that the leading edges of the 1Hz pulses fed to the *12-Digit Frequency Counter* are positive-going? Simply because it's the leading edges of the pulses that are locked closely to the 'atomic time' provided by the GPS satellites. The counter uses the positive-going edges of the external timebase pulses to clock its main gate flipflop, so this ensures the highest measurement accuracy.

Assembly

All the parts fit on a PCB coded 04103131, measuring just 66mm × 46mm, which is available from the *EPE PCB Service*. Fig.3 shows the assembly details. Almost half of this tiny PCB is reserved for the GPS module itself, which is usually mounted using double-sided adhesive foam.

To allow for convenient connection back to the counter when it is being used remotely, we have provided space for a 5-pin mini-DIN socket (CON1) at the righthand end of the PCB. This allows you to use a cable fitted with a 5-pin DIN plug to link the GPS timebase back to the counter, at the same time providing the unit with +5V power.

This socket is not needed if the PCB is fitted inside the *12-Digit Frequency*

Parts List

1 PCB, available from the *EPE PCB Service,* code 04103131, 66mm × 46mm
1 GPS receiver module with in-built patch antenna and 1pps output
1 6-way SIL pin strip
2 3-way SIL pin strips
2 jumper shunts
4 M3 × 10mm untapped nylon spacers*
4 M3 × 25mm nylon screws*
8 M3 nuts
Hook-up wire for GPS module
25 × 25mm doubled-sided adhesive foam (to secure GPS module)

Semiconductors
1 BC338 *NPN* transistor (Q1)
1 BC328 *PNP* transistor (Q2)
1 LP2950-3.3 (TO-92) or LM3940IT-3.3 LDO regulator**

Capacitors
1 100µF 16V RB electrolytic (or 2 if a 3.3V supply required)

Resistors (0.25W, 1%)
1 22kΩ 1 1kΩ 1 100Ω
1 10kΩ 2 2.2kΩ

*Only if project is built inside the frequency counter
**Only for a GPS module which requires a 3.3V supply

Extra parts for jiffy box version
1 UB-5 jiffy box, 83 × 54 × 31mm
1 5-pin DIN socket, PCB-mount
1 5-pin DIN socket, panel mount, for frequency counter
2 5-pin DIN plugs
1 2-core shielded cable
4 M3 × 10mm machine screws

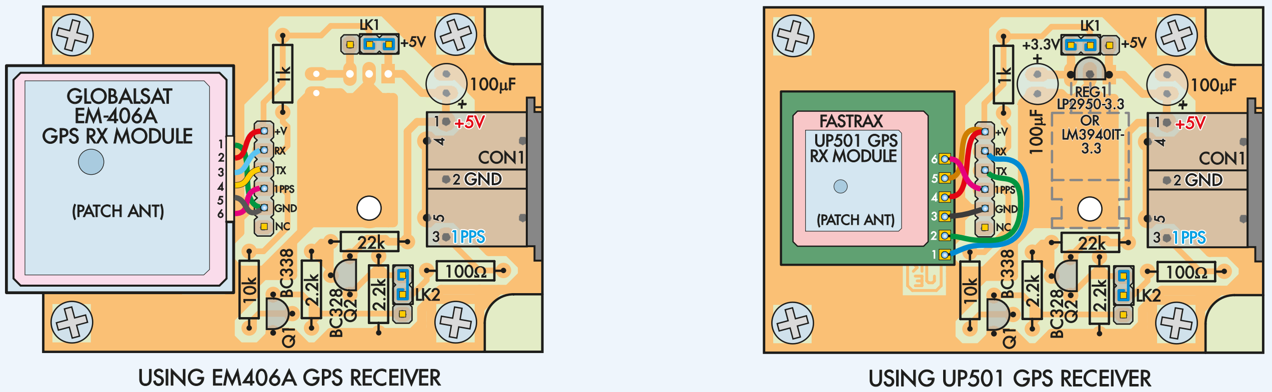


Fig.3: follow these diagrams to build the *GPS 1pps Timebase Module*. Omit CON1 if the unit is to go inside the frequency counter's case and omit REG1 and its 100µF output capacitor if the GPS module uses a 5V supply, eg the GlobalSat EM-406A. Alternatively, fit REG1 and the 100µF capacitor for the Fastrax UP501. Don't forget to set link LK1 accordingly.

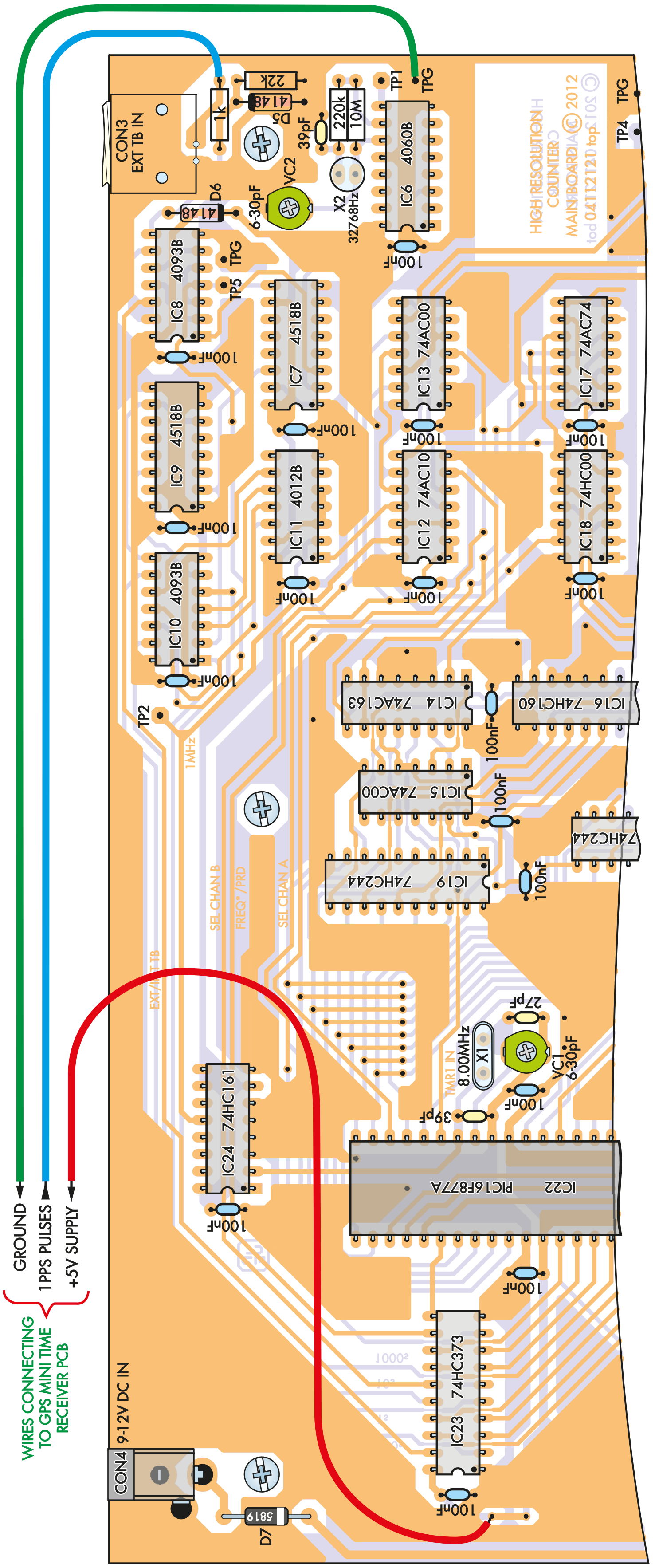


Fig.4: only three leads are required to connect the timebase module to the main PCB in the frequency counter. These leads are connected directly to the GPS timebase board if it is mounted inside the counter case or run to a panel-mount DIN socket (installed on the counter's rear panel) if the GPS timebase is mounted in a separate case (see panel).

Compatible GPS Modules

The following GPS receiver modules should be compatible with this unit:

- GlobalSat EM-406A: 30 × 30 × 10.5mm including patch antenna. Operates from 5V DC with a current drain of 44mA. Provides a 1pps output plus a 'fix' indicator LED. Rated sensitivity –159dBm.
- Digilent PmodGPS: approximately 30 × 55 × 12mm including patch antenna. Operates from 3.3V DC with a current drain of 24/30mA. Provides a 1pps output plus a 'fix' indicator LED. Rated sensitivity –165dBm.
- RF Solutions GPS-622R: 43 × 31 × 6mm including patch antenna. Operates from 3.3V DC with a current drain of 23/50mA. Provides a 1pps output plus a 'fix' indicator LED. Rated sensitivity –148dBm/–165dBm.
- Fastrax UP501: 22 × 22 × 8mm including patch antenna. Operates from 3.3V DC with a current drain of 23mA. Provides a 1pps output. Rated sensitivity –165dBm.

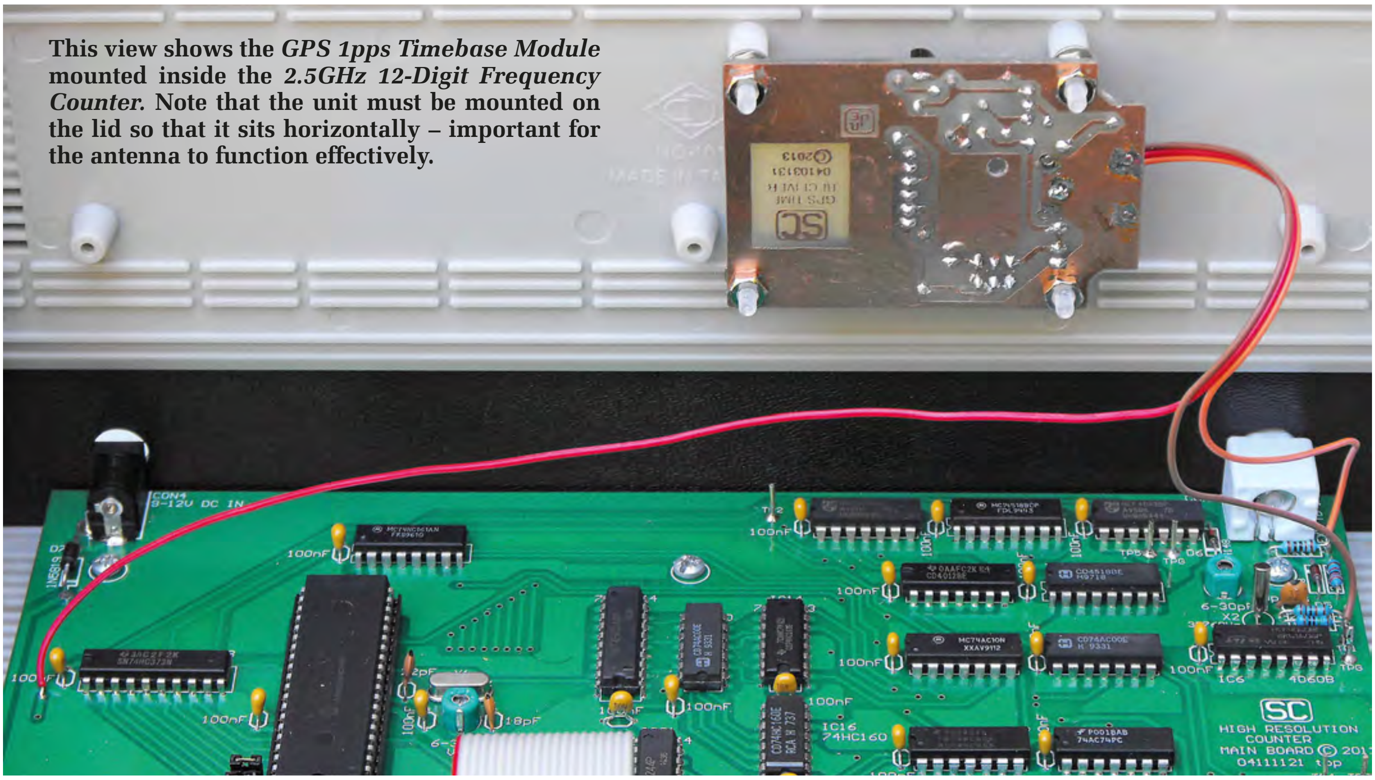
Note that for use in this project, the GPS receiver module should have a built-in ceramic patch antenna and also provide an output for the GPS-derived 1Hz pulses. Not all GPS modules currently available provide both these features.

Counter's case. In this situation, the GPS PCB is linked to the counter's main PCB using three short lengths of insulated hook-up wire.

Two other components shown in Fig.3 are required only if your GPS module needs a 3.3V DC supply, rather than 5V. These are REG1 and the 100µF electrolytic capacitor connected between its output and ground. **If you are using the EM-406A module (which requires 5V) and you are also mounting the receiver inside the counter box, leave out CON1, REG1 and the 100µF capacitor. Conversely, install REG1 and the 100µF capacitor if you are using the UP501 GPS module.**

As previously stated, LK2 must be fitted in the position that provides output pulses with positive-going leading edges (see scope grab – Fig.7).

Most GPS receiver modules, including those specified here, provide 1Hz pulses with this polarity anyway, so the jumper shunt will probably need



This view shows the *GPS 1pps Timebase Module* mounted inside the *2.5GHz 12-Digit Frequency Counter*. Note that the unit must be mounted on the lid so that it sits horizontally – important for the antenna to function effectively.

to be in the upper position; ie, so that the pulses are taken from the non-inverting buffer output (collector of Q2).

Mounting

Fig.5 shows how the timebase PCB is mounted inside the counter box. This is the easiest mounting option and if you're using the EM-406 GPS module (which is quite sensitive), it and others should be perfectly workable even if you are inside a building.

There are just three connections to be run to the main counter board: 1pps signal, +5V and ground (GND). Fig.4 shows the wiring details. As you can see, the ground wire connects to the ground pin just to the right of IC6, while the +5V wire connects to a PCB via to the left of IC23. The wire carrying the 1Hz pulses from the GPS receiver connects to the righthand end of the 1kΩ resistor behind CON3.

On the timebase board, the +5V lead connects to the +5V pad, the ground wire to the GND pad, and the signal lead to the '1PPS' pad. These pads are also labelled '1', '2' and '3' (corresponding to the pin numbers for CON1, which is left out if the timebase is mounted inside the counter case).

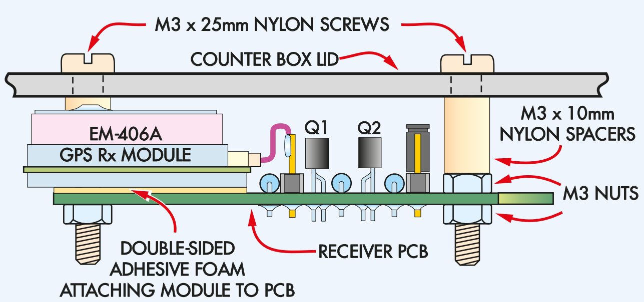


Fig.5: the *Timebase Module* is attached to the lid of the case on M3 × 10mm untapped nylon spacers and secured using four M3 × 25mm nylon screws and eight M3 nuts (four used as spacers).

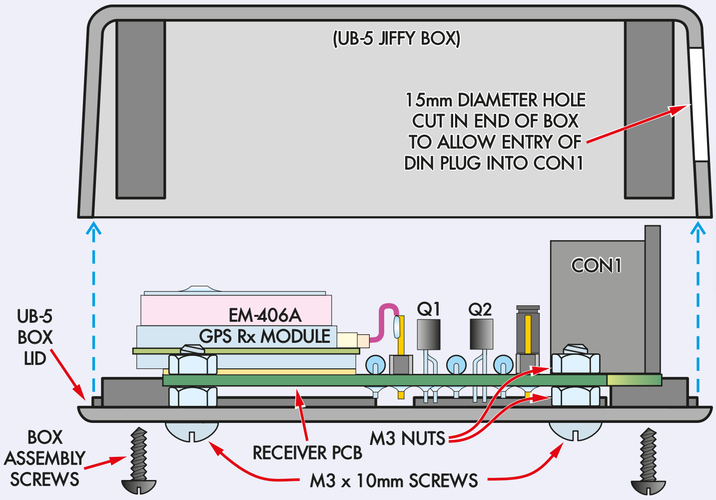
Putting it to use

There are no setting-up adjustments to make before the *GPS 1pps Timebase* is put to use, apart from setting jumper shunts LK1 and LK2 to suit the GPS receiver module you're using. Jumper shunt LK1 is simply placed on the right if the module needs 5V, or on the left if it needs 3.3V.

In most cases, jumper LK2 will need to be placed in the 'upper' position, although there may be some GPS modules which need it in the lower position. If you are in doubt about this and you have access to a scope, use it to check the polarity of the 1Hz output pulses. The 100ms-wide pulses should

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	22kΩ	red red orange brown	red red black red brown
❏	1	10kΩ	brown black orange brown	brown black black red brown
❏	2	2.2kΩ	red red red brown	red red black brown brown
❏	1	1kΩ	brown black red brown	brown black black brown brown
❏	1	100Ω	brown black brown brown	brown black black black brown



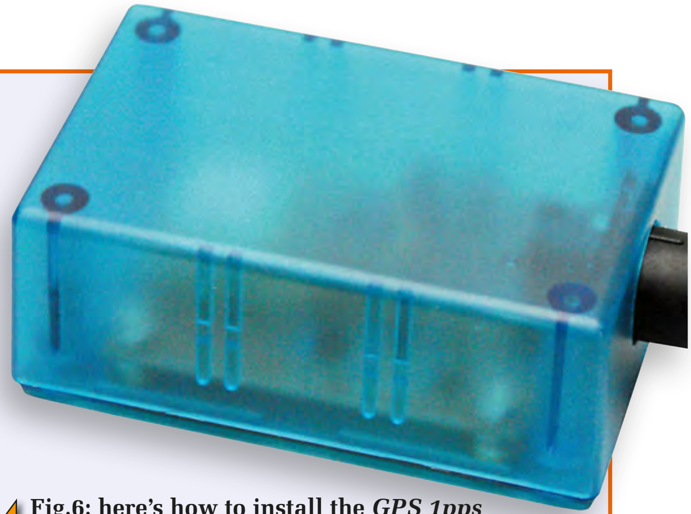


Fig.6: here's how to install the *GPS 1pps Timebase Module* in a UB-5 jiffy box. The module (with CON1 installed) mounts on the case lid.

Building a standalone 1pps Timebase

Some GPS receivers may not have sufficient sensitivity to work indoors. In that case, it will be necessary to install the timebase PCB in a small utility box which can then be positioned on a window sill (or wherever) for better satellite-reception. The unit can then be connected to the counter via a cable fitted with DIN plugs at either end.

Fig.6 shows how the unit is mounted inside a UB-5 jiffy box. You will need to mount DIN socket CON1 on the PCB, then attach the PCB to the case lid using four M3 × 10mm machine screws and eight nuts (four used as spacers).

A 15mm-diameter hole will then have to be drilled and reamed in one end of the box, in line with the DIN socket (ie, to allow plug entry). In addition, a matching 5-pin DIN socket should be mounted on the rear panel of the counter and its terminals run to the corresponding pads on the main counter PCB.

Finally, you will have to make up a suitable cable with DIN plugs to connect the two units together. This can be made up using shielded 2-core audio cable (red lead = +5V, white lead = 1pps signal and shield = GND).

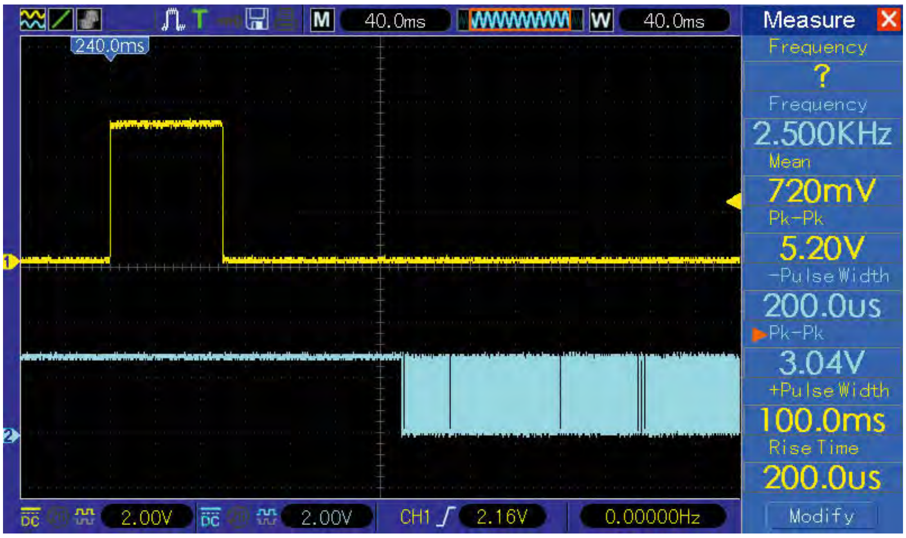


Fig.7: the 1Hz pulses from the timebase must have positive-going leading edges, as shown on the upper trace of this scope grab. In most cases, the GPS module will provide pulses with this polarity, so link LK2 will have to go in the upper (non-inverting) position. If not, then set LK2 to the lower (inverting) position.

be positive-going, as shown in Fig.7. If they're not, the remedy is to fit LK2 to the lower position.

Alternatively, if you don't have a scope you can easily determine the correct position for LK2 by trial and error.

Be aware that most GPS receiver modules will take some time to achieve a 'fix' from the GPS satellites after they are powered up. This start-up period can be as long as 70-80 seconds, depending on the GPS module's sensitivity, your location and the signal strength from the GPS satellites.

This means that until the module does achieve a fix, the 1Hz pulses from it will either be non-existent or 'free running' – ie, not locked to the GPS time reference. So don't expect to be able to make high-accuracy measurements right from switch-on. You'll need to wait a couple of minutes while the GPS receiver locks on to the GPS signals.

While you are waiting and assuming that you have selected the External Timebase option, the 12-digit counter will not usually show any measurement. Instead, it will continue to display 'SILICON CHIP' until pulses are received from the timebase.

If you are impatient and don't want to wait for the GPS 1pps timebase to achieve a fix each time you switch the counter on, there's a remedy for this too: keep it permanently powered from a separate 5V DC plugpack. That way, the GPS-locked 1Hz timebase pulses will be available to the *12-Digit Frequency Counter* whenever you want to use it.

Super stuff from 'Tin Valley'

TechnoTalk

Mark Nelson

The quest for 'superconductivity' and substances with zero resistance at room temperature has met with little success – until now. Mark Nelson reports on the latest supermaterial based on tin. Tired of acquiring an endless collection of laptop PSUs? We've got good news there too!

REMEMBER graphene, the form of carbon that is an excellent conductor of heat and electricity, covered extensively in this column? Well, forget it! Instead, make a note of 'stanene', a special form of metallic tin that theorists predict could surpass graphene, conducting electricity with 100 per cent efficiency at room temperature. A team of theoretical physicists led by researchers from the National Accelerator Laboratory at Stanford University (California) is making this assertion and suggesting that stanene could replace silicon as the basis of semiconductors. The name of the new material – stanene – combines the Latin name for tin (stannum) with the suffix used in graphene, another single-layer material whose novel electrical properties hold promise for a wide range of applications. If so, the name should be 'stannene' but I suspect the fact that it was developed at *Stan*ford University influenced its given name.

The new supermaterial

'Stanene could increase the speed and lower the power needs of future generations of computer chips, if our prediction is confirmed by experiments that are underway in several laboratories around the world,' enthuses team leader Shoucheng Zhang, a physics professor at Stanford. For the past decade, Zhang and colleagues have been investigating the electronic properties of a special class of materials known as 'topological insulators', which conduct electricity only on their outside edges or surfaces, not through their interiors. When topological insulators are just one atom thick, their edges conduct electricity with 100 per cent efficiency.

'The magic of topological insulators is that by their very nature, they force electrons to move in defined lanes without any speed limit, like the German autobahn,' Zhang says. 'As long as they're on the freeway – the edges or surfaces – the electrons will travel without resistance.'

The team's calculations indicate that a single layer of tin would be a topological insulator at and above room temperature, and that adding fluorine atoms to the tin would extend its operating range to at least 100ºC. If this brings superconductors to mind, you're not wrong. States Zhang: 'The effect is not exactly the same but somewhat similar to superconductors – the key difference is that in the field of superconductors, no material was ever predicted and then confirmed; they were all found experimentally. But in topological insulators everything was predicted and then confirmed – so you can appreciate the tremendous power of being able to predict a material theoretically much more quickly that trying to discover it experimentally in a chemistry lab.'

According to Zhang, a likely first application for this stanene-fluorine combination could be in the internal connections between the many sections of a microprocessor, allowing electrons to flow as freely as cars on a highway. Traffic congestion would still occur at on- and off-ramps made of conventional conductors, he said. But stanene wiring should significantly reduce the power consumption and heat production of microprocessors. Manufacturing chips using stanene presents some challenges, such as ensuring that only a single layer of tin is deposited and keeping that single layer intact during high-temperature chip-making processes. But Zhang is not deterred, predicting: 'Eventually, we can imagine stanene being used for many more circuit structures, including replacing silicon in the hearts of transistors. Someday, we might even call this area "Tin Valley" rather than "Silicon Valley".'

Sanity breaks out

Have you ever considered how daft it is that power supplies for laptops and other portable devices are not standardised? With luck, this situation will soon improve, reports *EasyNewsWeb*, with the publication of the first globally-relevant Technical Specification for a single external charger for a wide range of notebook computers and laptops. This is the work of the International Electrotechnical Commission (IEC), which is the international standards and conformity assessment body for all fields of electrical technologies.

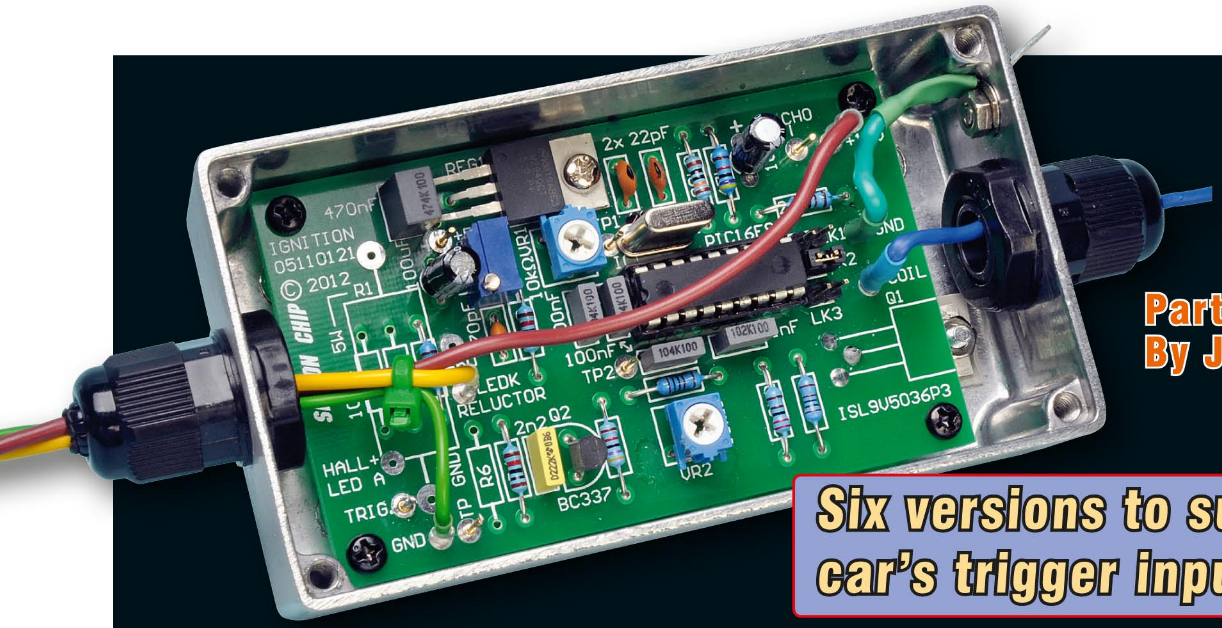
It's good news for consumers, who will be able to use a single external charger with a wide range of notebook computers, making it much easier for external chargers to be reused or replaced when needed. It will also avoid the need to discard computers that may work perfectly well, after their PSUs have failed. Announcing the new standard, IEC General Secretary Frans Vreeswijk stated: "A single power supply covering a wide range of notebook computers is the next step in lowering e-waste and its impact on our planet."

Square pegs in round holes

Something that has not been standardised to any great extent is the variety of line voltages, frequencies and electrical connectors used around the world for electrical supplies and appliances. With the notable exception of Ireland and Britain, Europe has more or less settled on 230V 50Hz, using connectors with two round pins of fixed dimensions for line and neutral (the arrangements for the earth connection are not as well agreed). The flimsy (to British eyes) two flat blades used for North American and Japanese mains connections are also (almost) standardised, but the others details are not (117V 60Hz in the Americas and the alternatives of 100V 50Hz or 60Hz in Japan).

All this means that the harmonisation of PSU connectors mentioned above is a far simpler task than achieving the same for mains voltages and connectors. Just how mammoth a task this is you can discover at: **www.iec.ch/worldplugs**. On this website you can read how the IEC has codified most of the plugs and sockets in use today, also why things are as they are and how they might be improved. It also provides information on the plugs, sockets and voltage used around the world, along with illustrations of the various plugs and sockets available.

It really is a bit of a mess out there in the crazy world of connecting to the grid. For example, the IEC lists 14 official types of plug in use around the world, and despite their attempt to provide standardisation with the design for a universal plug back in the 1970s, so far only Brazil and South Africa have adopted it. Many countries use more than one type of plug, with the Maldives having an astonishing seven varieties. The great British three-pin plug turns up in some surprising places – while I can understand it's use in the Falklands Islands and Kenya, I had no idea it was an official option in Saudi Arabia and Vietnam.



Part 2:
By John Clarke

Six versions to suit your car's trigger input

High-Energy Electronic Ignition System

In Part 1 last month, we introduced our new *High-Energy Electronic Ignition System* and described its operation. In this article, we give the assembly details for six different versions, to suit your car's trigger input, including an ECU/coil tester version.

THE ELECTRONIC IGNITION IS built on a PCB coded 05110121 and measuring 89 × 53mm. This is housed in a 111 × 60 × 30mm diecast aluminium case to give a rugged assembly. Two cable glands, one at either end of the case, provide the cable entry and exit points for the power supply, coil switching and input trigger leads.

The first step is to check the PCB for any defects. You then have to decide which version you are going to build. There are six different versions and it's important to choose the version that suits your car's trigger sensor. For example, if your car has a distributor with a reluctor pick-up, use the layout shown in Fig.5. If it has a Hall Effect or Lumenition trigger, follow the layout of Fig.6.

Similarly, if you are using an existing 5V trigger signal from your car's ECU (electronic control unit), build the layout shown in Fig.10. This is also the version to build if you intend using the unit purely as a coil tester.

Note that the same PCB is used for each version. It's just a matter of installing the relevant input trigger parts to suit your car.

Mounting the parts

Begin the assembly by installing PC stakes at the external wiring points, test points TP1, TP2 and TP GND and at the +5V point (near REG1). The three 2-way pin headers for links LK1-LK3 can then be fitted, followed by the resistors. Table 1 shows the resistor colour codes, but you should also check each one using a digital multimeter before soldering it in place.

Follow with the IC socket, making sure it is oriented correctly, but don't install the PIC micro yet. The capacitors can then go in (orient the two electrolytics as shown), then install crystal X1 and the trimpots. Note that the Reluctor version has an extra trimpot (VR3). This is a multi-turn trimpot and it must be installed with its adjusting screw in the position shown.

Regulator REG1 and transistor Q2 (in the Reluctor version) can then go in. Be sure to fasten REG1's tab to the PCB using an M3 × 10mm machine screw and nut before soldering its leads.

IGBT mounting details

Fig.11 shows the mounting details for IGBT transistor Q1. It's secured to the base of the case, with its leads bent at right angles and passing up through the underside of the PCB.

For the time being, simply bend Q1's leads upwards through 90° and test fit it to the PCB – but don't solder its leads yet. Its tab mounting hole must be clear of the edge of the PCB, as shown in the diagrams.

That done, fit the PCB assembly inside the case and slide it to the left as far it will go, to leave room for Q1. The mounting hole positions for the PCB and Q1's tab can then be marked inside the case, after which the PCB can be removed and the holes drilled to 3mm (hint: use a small pilot drill first).

Deburr these holes using an oversize drill. In particular, Q1's mounting hole must be slightly countersunk inside the case to completely remove any sharp edges. The transistor's mounting area should also be carefully smoothed using fine emery paper. These measures are necessary to prevent the insulating washers which go between Q1's metal tab and the case from being punctured by metal swarf or by a high-voltage arc during operation.

Having drilled the base, the next step is to mark out and drill holes in the case for the two cable glands. These holes are centrally located at either end and should be carefully reamed to size so that the cable glands are an exact fit.

You will also have to drill a 3mm hole for the earth connection in one end of the case. This goes in the end adjacent to the GND connection on the PCB – see photos.

Installing the PCB

Once the case has been drilled, fit 6.3mm tapped nylon stand-offs to the PCB's corner mounting holes using M3 × 5mm machine screws. That done, the next step is to fasten Q1 in place. As shown in Fig.10, its metal tab is insulated from the case using two TO-220 silicone washers and an insulating bush and it's secured using an M3 × 10mm screw and nut.

Do this screw up finger-tight, then install the PCB in the case with Q1's leads passing up through their respective

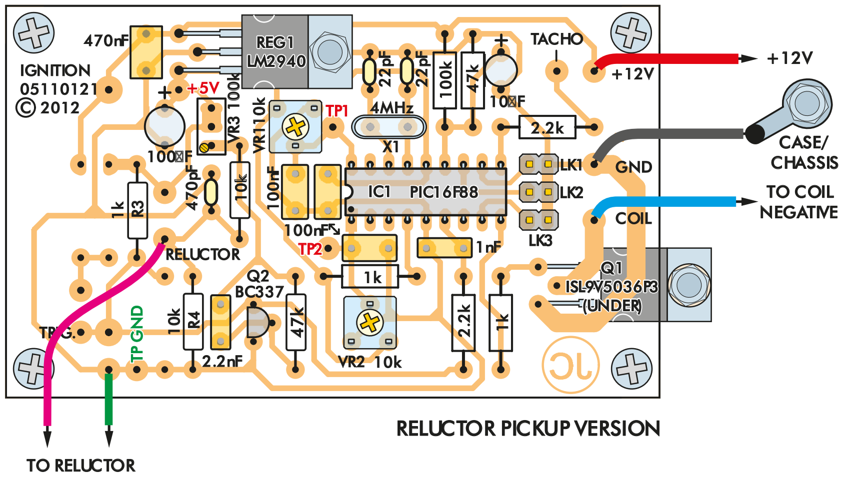


Fig.5: follow this PCB layout diagram if your car's distributor has a reluctor pick-up. Note that Q1 mounts under the PCB and is secured to the bottom of the case using an M3 × 10mm machine screw and nut – see Fig.11.

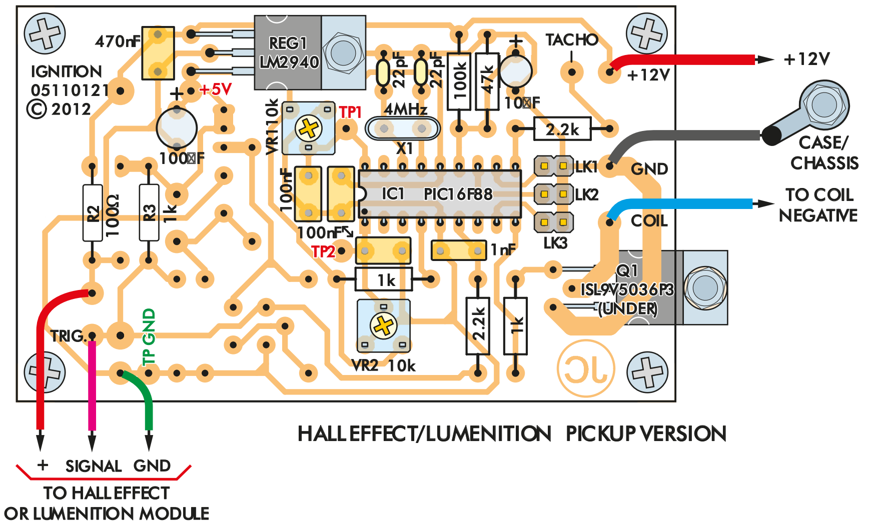


Fig.6: this is the layout to follow if the distributor uses a Hall Effect device or a Lumenition module. Take care with component orientation.

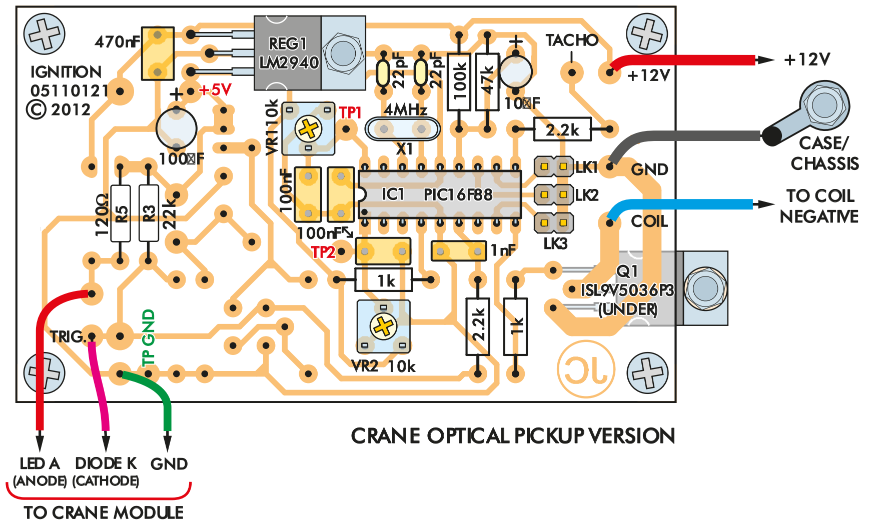


Fig.7: build this version of the ignition if your distributor has been fitted with a Crane optical pick-up.

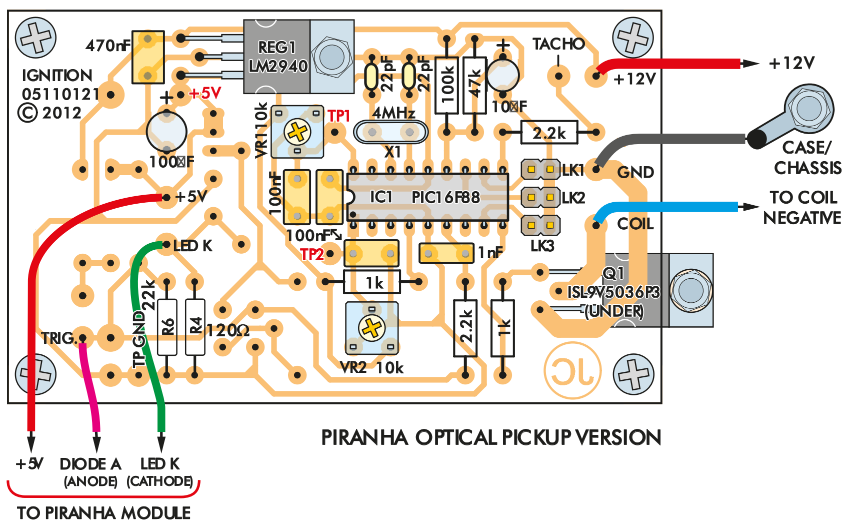


Fig.8: the Piranha optical pickup version is similar to the Crane version but note the different locations for the 22kΩ and 120Ω resistors.

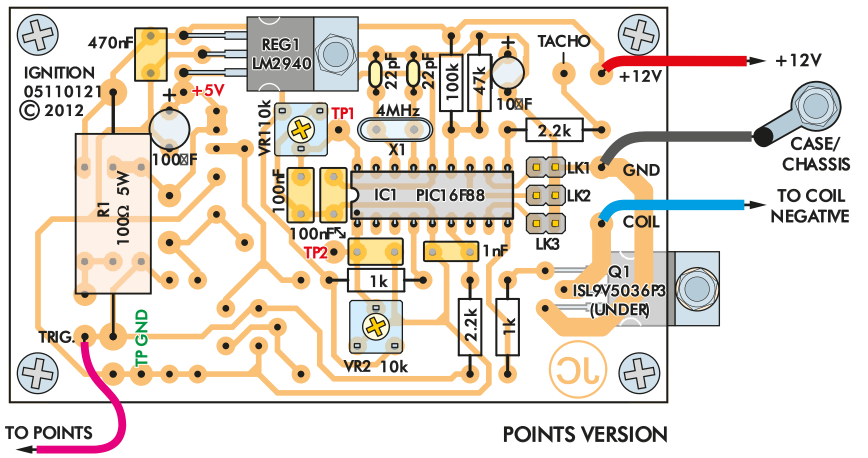


Fig.9: this is the Points version. Secure the 100Ω 5W resistor (R1) to the PCB using neutral-cure silicone, to prevent it from vibrating and fracturing its leads and/or solder joints.

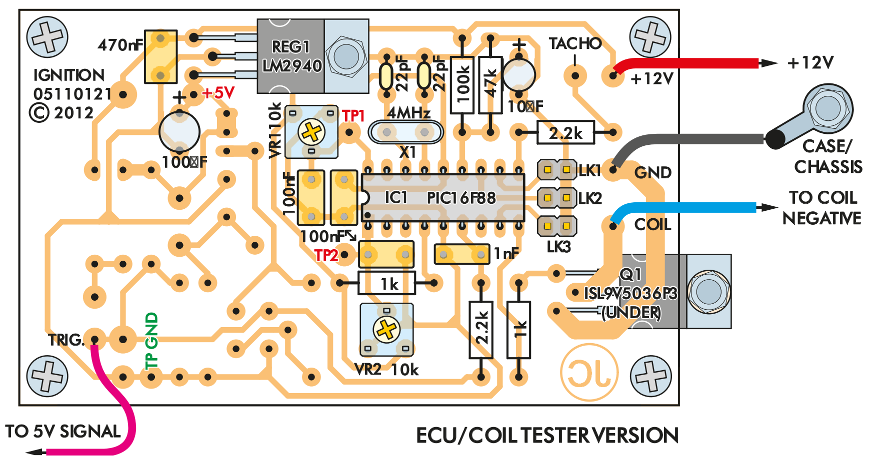


Fig.10: the ECU (engine management) trigger version requires no additional input conditioning circuitry. In this case, the ECU trigger signal goes straight to pin 6 of IC1 via a 2.2kΩ resistor. Build this version also if you only intend using the unit as a coil tester, in which case the 5V trigger input isn't needed.

mounting holes. The PCB can now be secured in place using four more M3 × 5mm machine screws, after which you can firmly tighten Q1's mounting screw (make sure the tab remains centred on the insulating washers).

Finally, use your multimeter to confirm that Q1's tab is indeed isolated from the metal case (you should get an open-circuit reading), then solder its leads to the pads on top of the PCB.

External wiring

All that remains now is to run the external wiring. You will need to run leads through the cable glands and solder them to the relevant PC stakes for the power, coil and input trigger connections. **Note that the coil wire is the only wire that's fed through that righthand cable gland (important to prevent interference due to high-voltage switching glitches; eg, by capacitive coupling into the power and trigger leads).**

The remaining leads (with the exception of the earth lead) must all be run through the other cable gland, at the trigger input end of the case.

As shown in the photos, we fitted heatshrink tubing over the PC stake connections, to prevent the wires from breaking. **So before soldering each lead, fit about 6mm of 3mm-diameter heatshrink tubing over it, then slide it over the PC stake and shrink it down after the lead has been soldered.**

The earth connection from the PCB goes to a solder eyelet lug that's secured to the case using an M3 × 10mm screw, nut and star washer. This same screw also secures a quick connect lug on the outside of the case (see photo).

Initial checks and adjustments

Now for an initial smoke test – apply power to the unit (between +12V and GND) and use your DMM to check the voltage between the +5V PC stake and GND. It should measure between 4.85V and 5.25V. If so, switch off and insert the programmed PIC (IC1) into its socket, making sure it goes in the right way around.

You can now do some more tests by connecting the car's ignition coil between the +12V and COIL leads. The unit should be powered from a 12V car battery (or motorcycle battery), with the case connected to battery negative. The coil's HT (high tension) output should be fitted with a paper clip (or similar) which is then positioned so that it can spark back to the coil's negative terminal over about a 5mm gap.

Before connecting the +12V supply, set the dwell trimpot (VR1) fully anticlockwise and install a jumper on LK2 to enable the spark test mode. That done, apply power and slowly adjust VR1 clockwise. The sparks should start and gradually increase in energy with increased dwell. Stop adjusting VR1 when the spark energy reaches its maximum.

This sets the dwell period to suit your ignition coil. Note that, during the spark test procedure, the spark frequency can be changed using VR2.

Note also that when accelerating, the rapid change in the time between successive firings can cause the dwell to reduce. That's because the micro determines when the coil is to be switched on, based on the previous period between plug firings. During acceleration, this period reduces for each successive firing.

To counteract this reduction in dwell, the software dwell calculation also takes into account the rate of change in the period between firings. This ensures that the initial set dwell period is maintained under normal acceleration. However, you may need to set the dwell to slightly longer than 'optimal' (by adjusting VR1 clockwise) to ensure sufficient dwell during heavy acceleration.

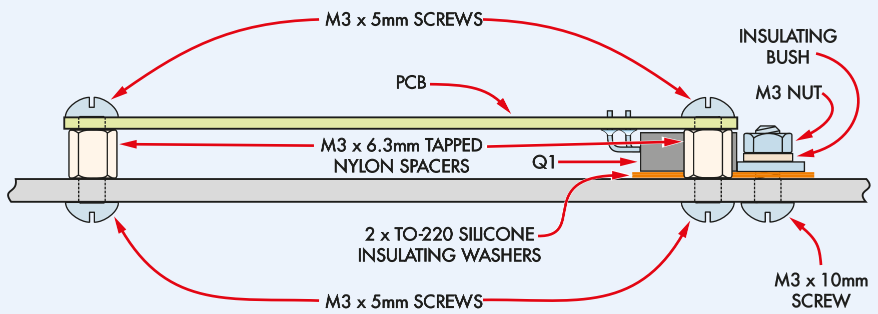


Fig.11: the PCB and IGBT (Q1) mounting details. Note that Q1's metal tab must be insulated from the case using two TO-220 silicone washers and an insulating bush. After mounting, use a multimeter (set to a low-ohms range) to confirm that the tab is properly isolated; it must not be shorted to the case.

That completes the dwell adjustment procedure. **Link LK2 should now be removed, so that all three 2-pin headers (LK1-LK3) are open.**

Installation

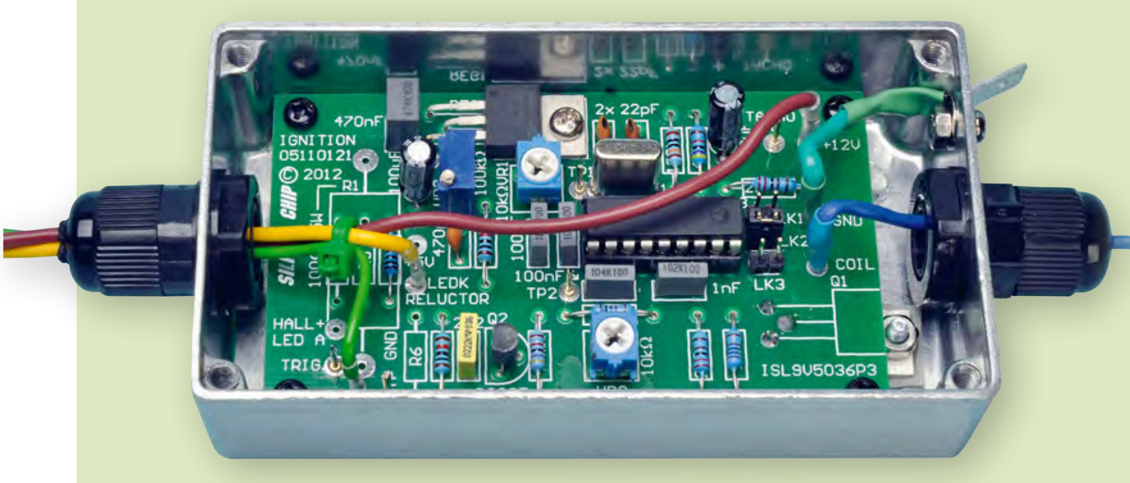
The *Electronic Ignition* box should be installed in the engine bay close to the distributor. Make sure that it's well away from the exhaust manifold and the catalytic converter (if fitted), so that it doesn't overheat.

Use brackets and screws to secure the box to the chassis. That done, wire the positive supply lead to the +12V ignition supply, the negative earth lead to the car chassis (if necessary) and the trigger inputs to the trigger unit in the distributor. The coil lead goes to the coil negative, replacing the existing switched negative lead.

If you are using the Reluctor circuit, connect the Reluctor trigger unit, adjust VR3 fully anti-clockwise and measure the voltage at the trigger test point (TP TRIG). If the voltage is close

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
470nF	0.47µF	470n	474
100nF	0.1µF	100n	104
1nF	0.001µF	1n	102
22pF	NA	22p	22



This is the view inside the completed unit (Reluctor pick-up version shown). Be sure to build it for good reliability by fitting heatshrink over the solder joints on the PC stakes and by fitting a cable tie to the leads as shown. Note that the lead to the coil negative is the only one that exits through the righthand cable gland.

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	100kΩ	brown black yellow brown	brown black black orange brown
❏	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❏	2	2.2kΩ	red red red brown	red red black brown brown
❏	2	1kΩ	brown black red brown	brown black black brown brown

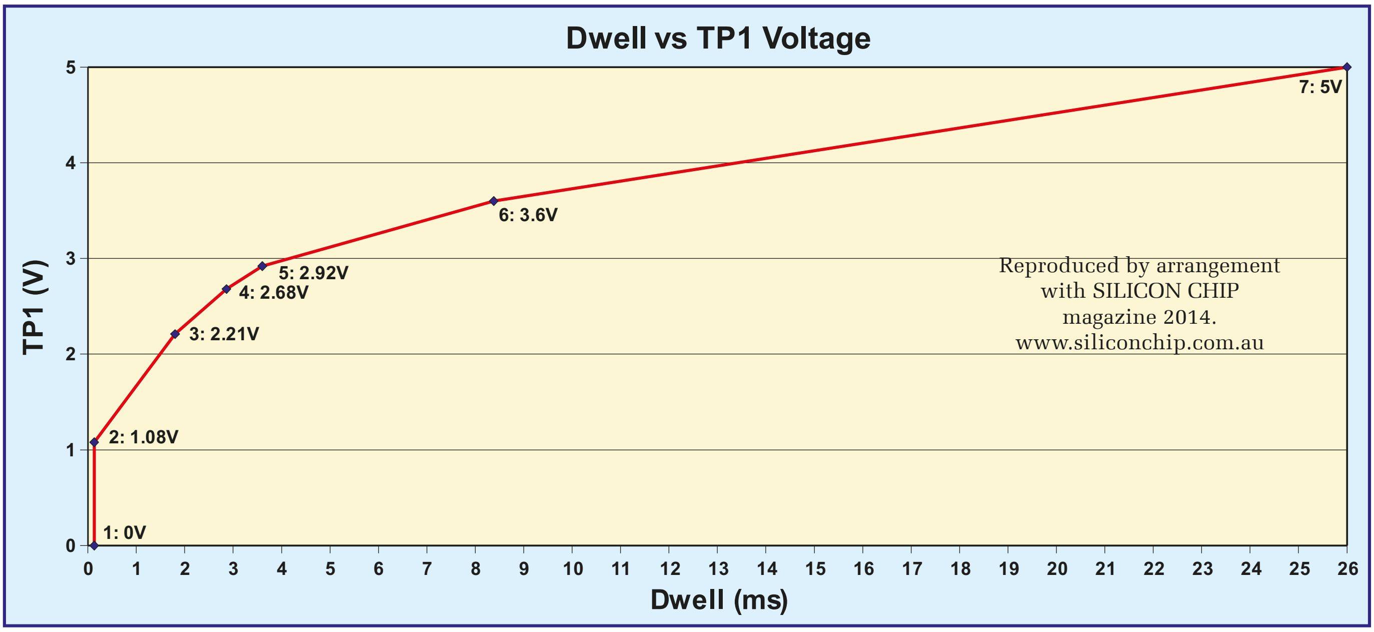


Fig.13: you can check the dwell setting by measuring the voltage at test point TP1 and then reading the dwell period (in milliseconds) off this graph. The dwell is adjusted using trimpot VR1 to give maximum spark energy, as described in the text (see initial checks and adjustments).

to zero, wind VR3 clockwise several turns until the voltage goes to +5V, then wind it another two turns clockwise and leave VR3 at that setting.

Now check that LK1-LK3 are all open (ie, no jumpers installed), then try to start the engine. If it doesn't start, try the invert mode by installing LK3.

If you have a Reluctor pick-up, it's important that the engine fires on the leading edge of the trigger signal. That edge should coincide with the leading edge of each tooth on the Reluctor ring as the distributor shaft rotates, otherwise the timing will usually be so far out that the car won't start. In that case, you can either swap the Reluctor leads or install LK3 as described above.

The quick-connect terminal at the right-hand end of the case provides a convenient connection point for the earth lead.

Once the engine starts, adjust the debounce trimpot (VR2) for best results. This adjustment should be set as low as possible (ie, set VR2 anticlockwise as far as possible). An increased debounce period will be required if the engine runs erratically and it's just a matter of adjusting VR2 clockwise until smooth running is obtained.

If that doesn't do the trick, then the follow mode may be necessary. This is selected using LK1 and will typically be required for badly worn points or worn distributor shaft cam lobes and/or shaft bearings.

Note that, in the absence of trigger signals, the coil switches off after 1s for debounce settings of 2ms and less, or after 10s for debounce periods greater than 2ms. The debounce setting can be measured by connecting a multimeter between TP2 and TP GND. As stated, VR2 sets the debounce period and the calibration is 1ms per 1V.

Ignition coil

For most installations, it's usually best to keep the original ignition coil and ballast resistor (if one is used). If you intend using a different coil, make sure it is suitable, especially if you intend setting the debounce period so that there's a 10s delay before the coil switches off in the absence of trigger signals. In that case, it's important that the coil is able to cope with the continuous current that will flow through it for this period without overheating.

A ballast resistor will prevent excessive current flow through coils that have a low resistance (ie, below 3Ω).

Connecting a tachometer

Finally, the Tacho output (top-right of the PCB) should be suitable for driving most digital tachometers. However, an impulse tachometer will require a signal voltage that's derived from the negative side of the coil. If that doesn't work, try operating the ignition unit in 'follow' mode by installing a jumper across LK1.

EPE EXCLUSIVE

Win an LED Lighting Development Kit

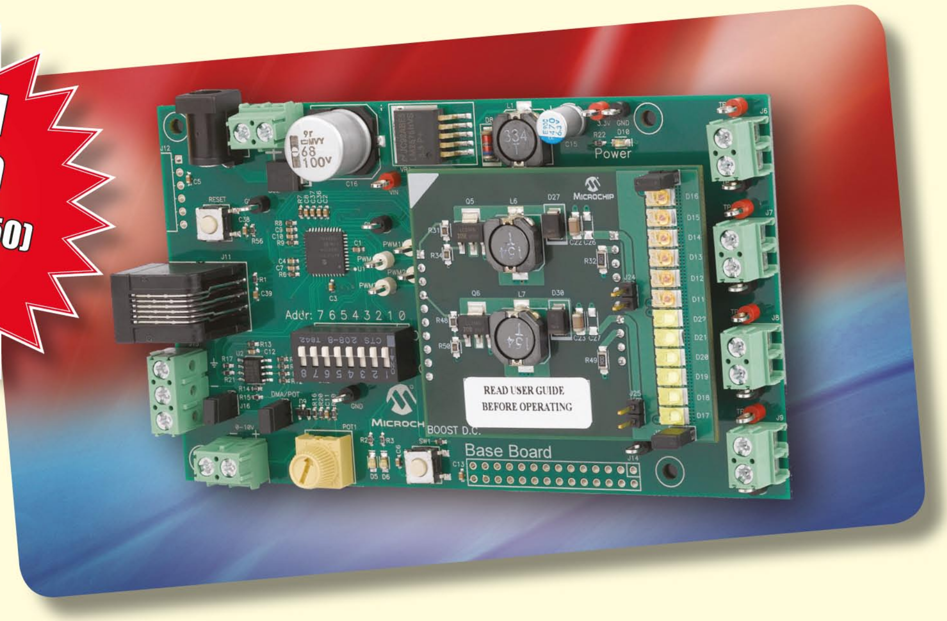
EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win an LED Lighting Development Kit (DM330014). This kit enables designers to quickly leverage the capabilities and performances of the dsPIC33F GS series of digital signal controllers (DSCs) to develop LED-lighting products. The dsPIC33F GS DSC and this development kit allow developers to create a 100% digitally controlled ballast function, while including advanced features such as dimming and colour hue control. The kit includes an LED baseboard with an on-board dsPIc33FJ16GS504, a DC/DC buck daughter board, and a DC/DC boost daughter board.

Benefits offered by the digital power techniques in this reference design and the dsPIC33 'GS' series of DSCs include: • Reduced system cost via higher integration • Higher efficiency using digital-control techniques • Flexible and reusable designs • Advanced features implemented in software

Example applications

LED lighting applications supported by the Development kit include dimmable LCD backlighting, signage, LED replacement of fluorescent tubes and incandescent bulbs, architectural lighting, and automotive lighting applications. Automotive lighting products include exterior applications, such as headlights, daytime running lights and signal lights.

WORTH $249.00 (approx. £151.50) EACH

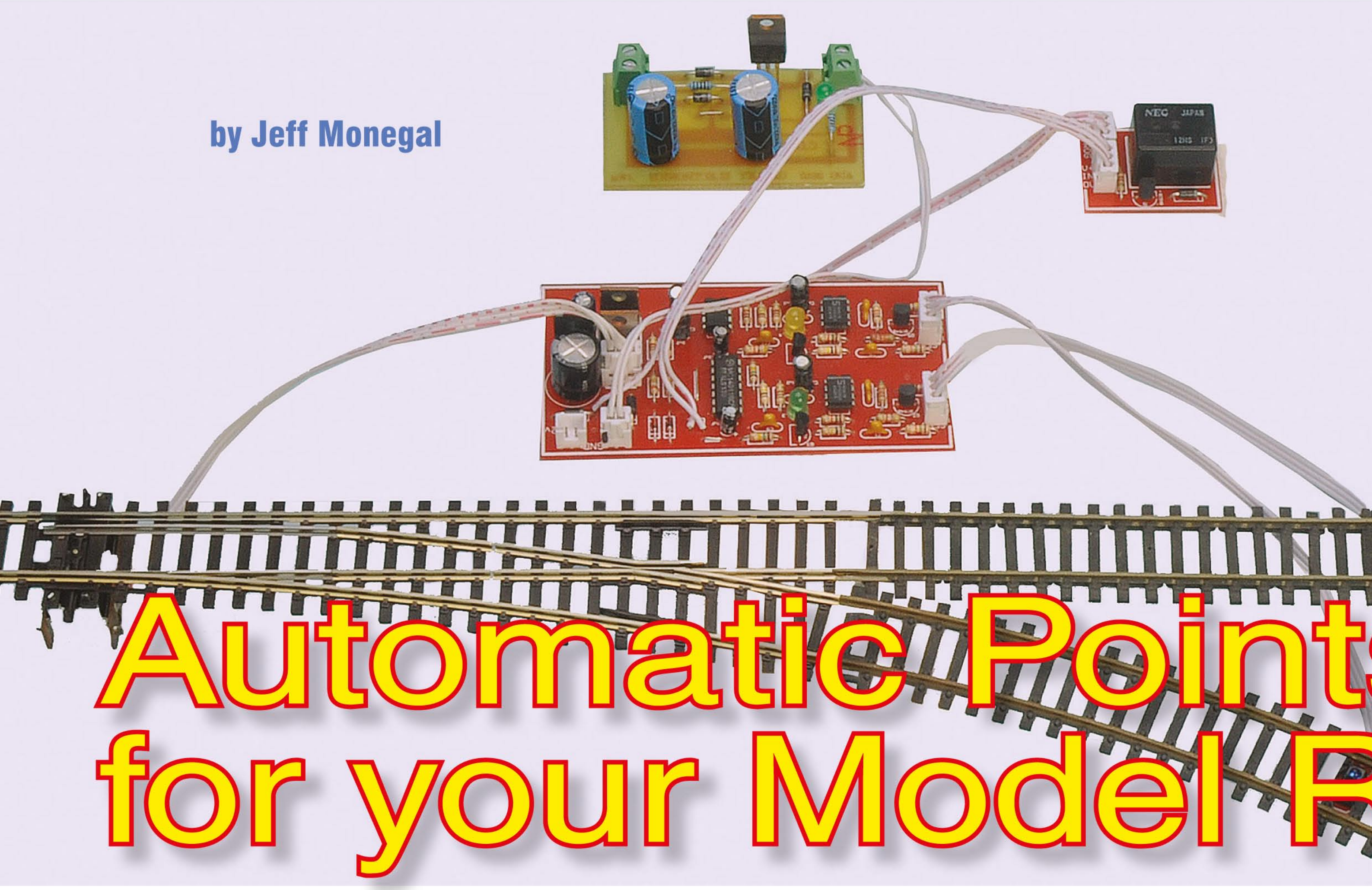


HOW TO ENTER

For your chance to win an LED Lighting Development Kit visit: **www.microchip-comps.com/epe14-led** and enter your details in the entry form.

CLOSING DATE

The closing date for this offer is 31 March 2014



by Jeff Monegal

Automatic Points for your Model R

This Automatic Points Controller can be used by itself on a model railway layout or in conjunction with an automatic reverse loop controller.

Note that this project is only suitable for reverse loops that use a single set of points. It will not work with reversing track systems that use more than one set of points, such as a 'WYE' network.

So as well as automating the points used in a reverse loop, this project can be used wherever points could benefit from automatic control.

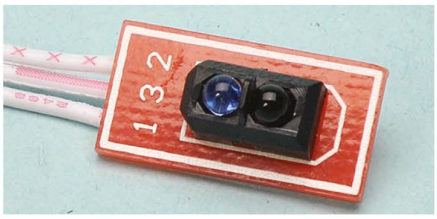
One example is a set of points used on a main line that branches to a siding. During layout operation a train may be shunted into this siding, but the driver has forgotten to switch the points back to allow the fast passenger train that is due soon to pass the points without derailing.

Using this project to control the siding points, the approaching passenger train will automatically align the points to prevent derailments.

Let's now have a look at the circuit in Fig.1 (overleaf).

The IR sensors used to detect the approaching trains are made by Vishay, type TCRT5000. These contain an infrared LED and infrared phototransistor and are designed as a reflective sensor; ie, the LED emits infrared and it needs to be reflected back to the phototransistor for the sensor to work. In use, the sensor is installed between the track sleepers and infrared is continuously emitted from the LED.

An IR signal is constantly transmitted up between the track's sleepers.



The controller relies on these tiny infrared sensors which fit between the track sleepers and detect when a train is passing over them.

As a train covers the IR emitter, a small amount of the IR energy is reflected back to be received by the IR phototransistor, which is physically located near the IR emitter.

The reason for choosing an IR sensor is that they operate just as well in normal ambient lighting conditions as they do in total darkness.

How it works

The two IR sensors operate in the same way. The heart of the circuit is an LM567 tone decoder which is used in an unconventional way.

Normally, the LM567 is used in circuits which sense the presence of a signal within a designated passband. If the signal is present, the output at pin 8 goes low; when it is absent or not within the passband, the signal at pin 8 is high.

The LM567 can be regarded as a specialised phase-locked loop (PLL). A typical PLL has a voltage-controlled oscillator (VCO), a phase detector and loop filter; it is used in a radio receiver

This project uses two IR sensors to detect an approaching train and then automatically switch a set of points to suit the track on which the train is travelling. This avoids the possibility of inadvertent derailments by the operator. It uses four cheap ICs, two MOSFETs and it controls a standard twin-coil snap-action points motor.

s Controller
Railway Layout

to keep the receiver locked to an incoming carrier.

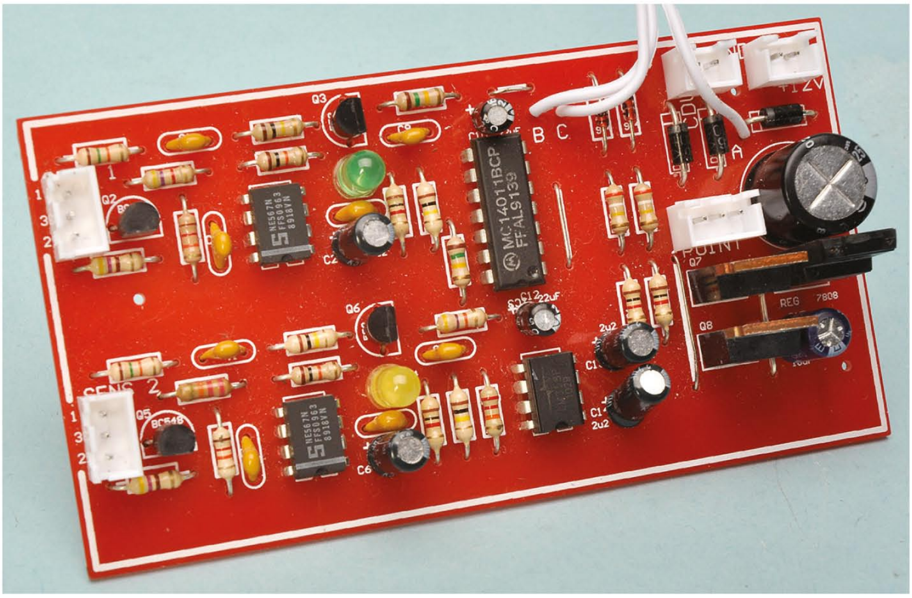
By contrast, the LM567 has a VCO, two phase detectors (I and Q) and a loop filter, but we use it in a different way.

The chip's on board VCO produces the signal which drives the infrared LED and components connected between pins 5, 6 and 0V of IC1, set to its frequency around 1kHz.

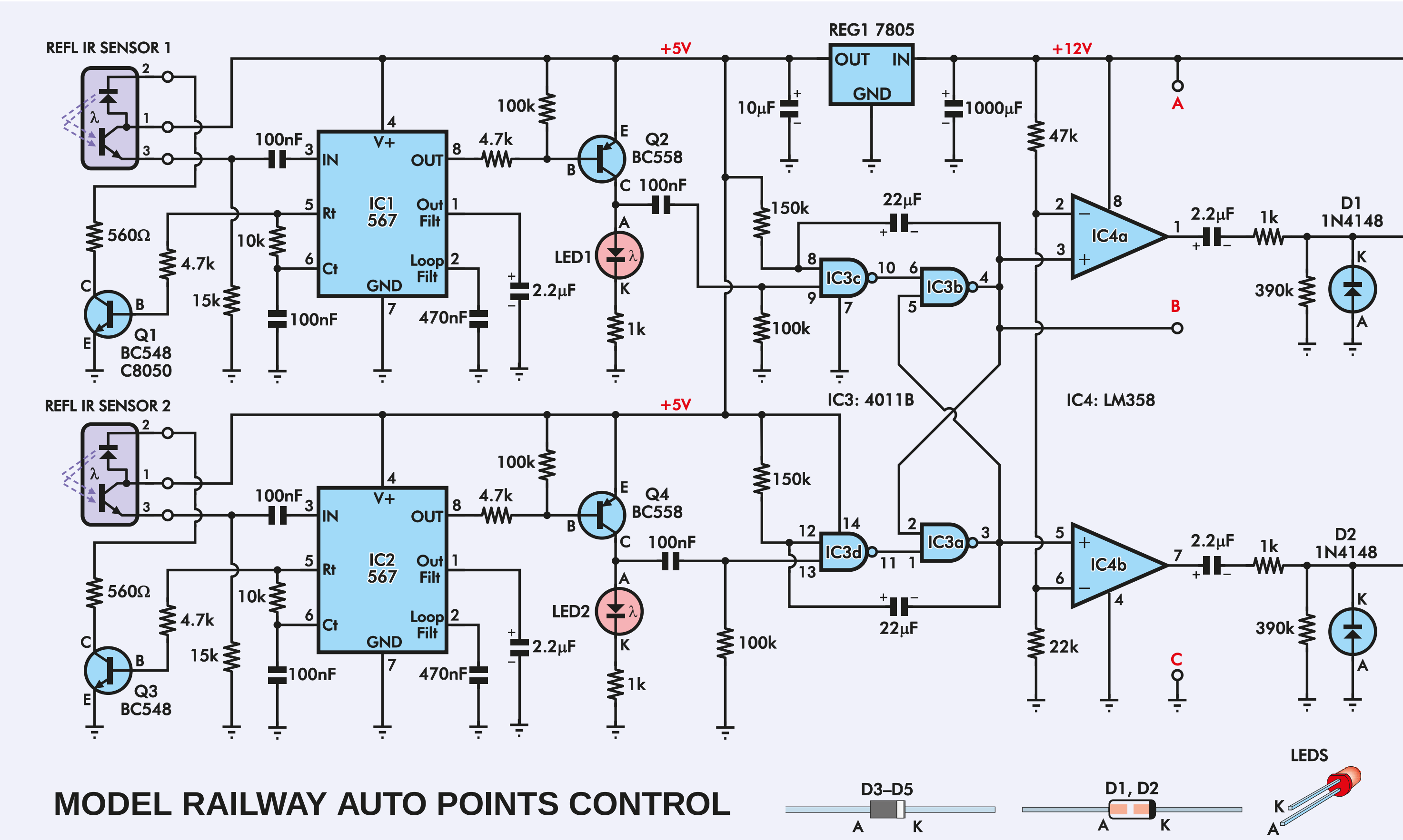
If the emitted IR signal is reflected back to the phototransistor (as when a loco is passing overhead) in the Vishay sensor, the resulting signal is fed from the sensor's pin 3 to pin 3 of IC1 via a 100pF capacitor. The result is that the output pin 8 goes low.

At other times, when no loco is on the track, no IR signal is reflected back to the phototransistor and the signal at pin 8 is high. Hence, when a loco is present above the sensor, pin 8 of IC1 goes low and this turns on PNP transistor Q2 to light LED1.

At the same time, the positive-going signal from the collector of Q2 is coupled to NAND gate IC3c via a 100nF capacitor. Pin 10 of IC3 now goes low and this toggles the RS flipflop comprising gates IC3a and b. Pin 4 now goes high and pin 3 goes low.



(Left): the main PCB for the *Automatic Points Controller* takes the output from the infrared sensors and drives the point motors to set the points according to the track in use.



MODEL RAILWAY AUTO POINTS CONTROL

The low from pin 3 is coupled around to pin 12 via a 22µF capacitor. This capacitor then charges via a 150kΩ resistor, taking around 1.5 seconds to reach a level that will allow IC3d to be triggered by a high coming in on pin 13, from the other sensor circuit.

When a trigger pulse comes in from either sensor, the associated 22µF/150kΩ circuits stop the flipflop from being toggled back again within this 1.5-second period. This ensures that when a sensor toggles the points it cannot be toggled back again by a signal from the other sensor until the capacitor discharge unit (CDU) for the points drive circuit has charged up again.

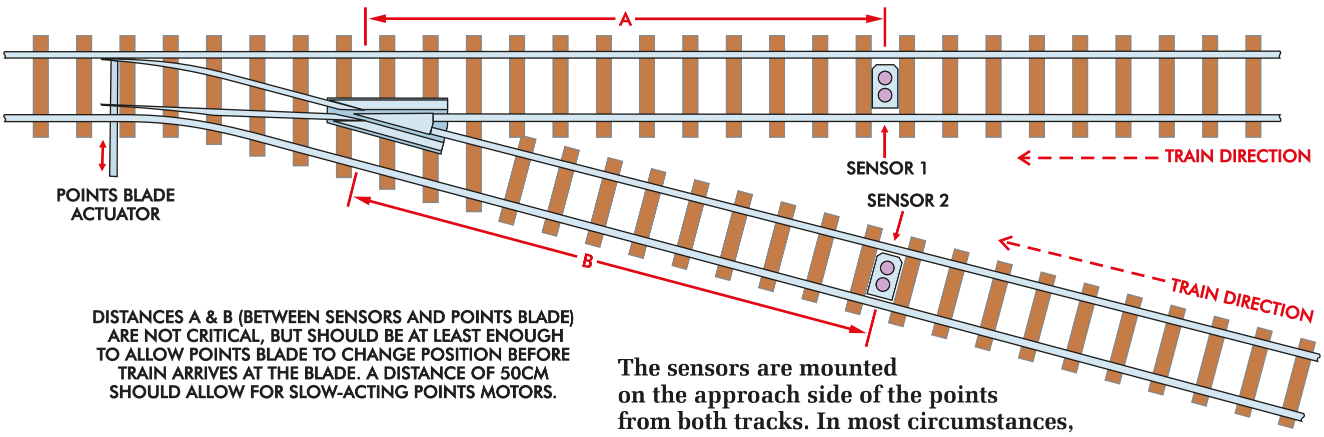
It also prevents the points swapping back and forth in the event that both sensors are detecting trains.

During actual layout operation, the situation where two trains are approaching the same set of points, should not be allowed to occur; a serious crash could result.

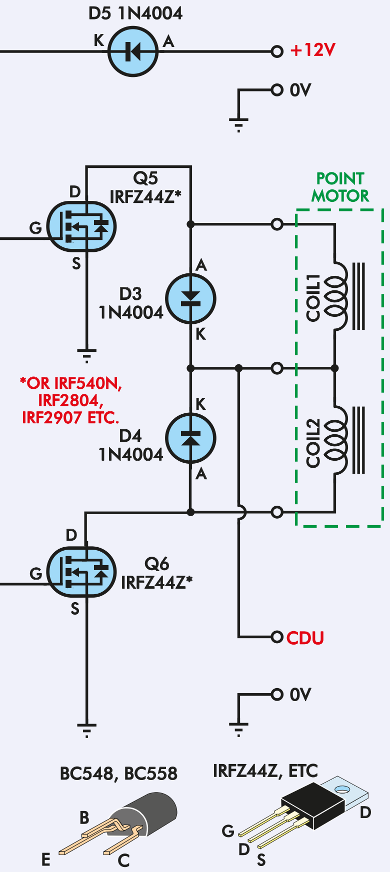
The outputs of the flipflop are fed to the non-inverting (+) inputs of two op amps, IC4a and IC4b. These op amps are there solely to increase the 5V signal from the sensor circuits to a level sufficient to reliably turn on either of the two MOSFETs, Q5 and Q6.

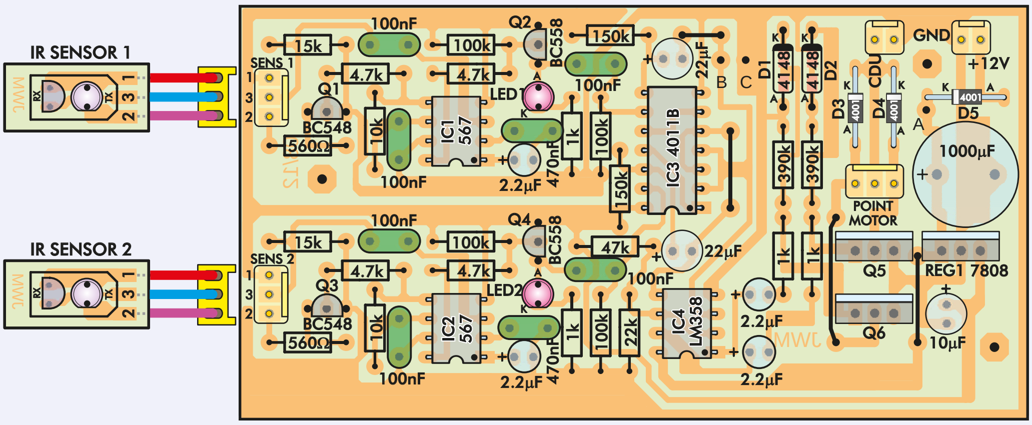
The outputs of each op amp are coupled to the MOSFET gates via 2.2µF capacitors. In conjunction with the 390kΩ resistors, this results in a gate pulse of around two seconds. Once the 2.2µF capacitors have charged, the MOSFETs gate are pulled low via the 390kΩ resistors.

Using series capacitors ensures that the MOSFETs only remain switched



The sensors are mounted on the approach side of the points from both tracks. In most circumstances, the distance from the sensors to the points is not critical.





Figs. 1 and 2: the main circuit diagram and its associated PCB. Full operation is explained in the text. When assembling the PCB, ensure that all polarised components are installed the right way around and check your completed board for missed solder joints, poor solder joints and errors in component placement. Together, they account for almost all problems with assembled projects.

on long enough to ensure the points have changed position.

Next time the flipflop toggles, either one of the op-amp outputs must go low. Because the associated 2.2μF capacitor is charged to the positive rail, the voltage on the capacitor's negative terminal will try to go below the 0V rail. Diodes D1 and D2 prevent this happening, to protect the MOSFET gates.

When either MOSFET turns off, there will be a positive spike voltage generated at the drain electrode and this is quenched by diode D3 or D4.

An add-on relay is provided for installations where polarity of the 'frog' of the points is not automatically switched.

Many modellers use points in which the frog is not switched according to the direction of the points. These points are commonly called 'Electro-frog' and are beneficial when used on layouts operated by DCC. In these conditions the frog polarity must be controlled by external means. See Fig.3.

The frog relay is controlled by an NPN transistor which is supplied base current from pin 4 of the flipflop. Each time pin 4 goes high the transistor switches on the relay. The SPST contacts of the relay are used to control the polarity of the frog.

When this system is used with points of the 'INSULFROG' variety then this relay is unnecessary as the frog is controlled by the switch contacts on the points itself.

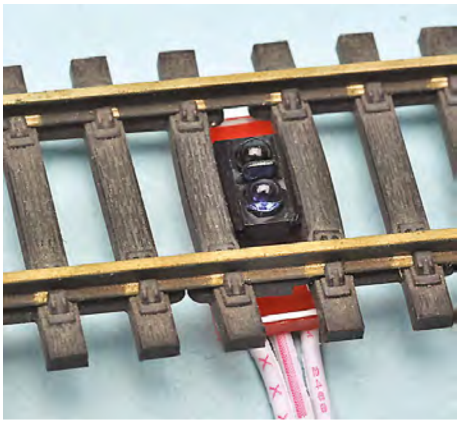
Assembly

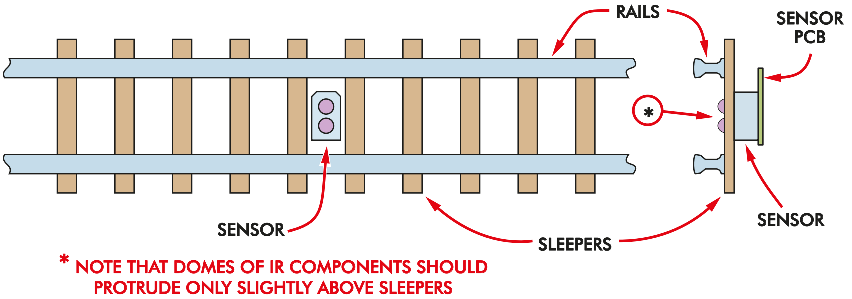
There is nothing special about assembling the points controller. Start by looking at the PCB under a magnifying glass, searching for possible defects in the etched tracks. Once you are satisfied that the board is OK you can insert the resistors and diodes.

Also on the PCB are four wire links. These can be made from the wire off cuts from some resistors. IC sockets are recommended for IC1, IC2, IC3 and IC4. Solder these in next (or the chips themselves if you choose not to use sockets).

Next come the eight electrolytic capacitors and eight ceramic capacitors. The transistors and MOSFETs can now be installed, along with the regulator (in all cases, watch the polarity).

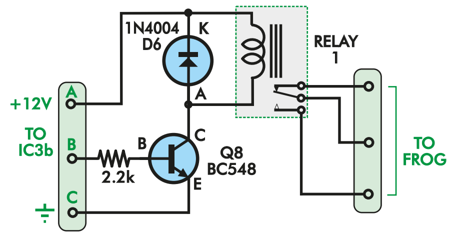
The final components are the 3-pin sockets for each of the two sensor leads and the points motor. The final two sockets are those for power input and the CDU in socket (two pins in both cases).

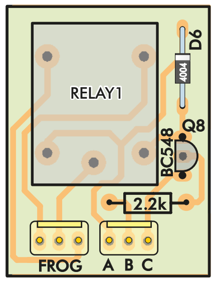




Here's a close-up and diagram of how the sensors are mounted between the rail sleepers. You'll need to prise the sleepers apart a little: the sensor is a tight fit. When completed and tested, a drop of glue will hold it permanently in place.

Fig.3. At left is the Frog Switch Relay, with the simple circuit and PCB component layout show at right. The ponts 'A, B and C' on the circuit diagram and overlay correspond to the same points on the main circuit diagram.





Although it's not mandatory to use plugs and sockets, it does makes things easier if you have to remove the PCB at any time.

Now you can assemble the two IR sensor PCBs. As only one component is used for each PCB assembly it is not difficult, but you must make sure that the components are oriented correctly.

The sensor has a bevelled end and a straight end; the bevelled end should face towards the three terminals on the PCB. The three wires connecting the sensor to the main PCB should be soldered underneath the board (ie, on the copper side) so that they are not seen when the sensor is installed under the track.

At this stage you should have no components left and no unused component holes in the PCBs. Take some time to go over your work. More than 70% of projects that don't work after being assembled can be put down to soldering faults. The next most common fault is polarised components being installed incorrectly.

These days, faulty components are very rare, so if your project does not work then don't straight-away claim you have a faulty component and replace all semiconductors. Chances are that your components will not be the problem.

Time to see if it will work

Start by making sure the sensors are facing straight up on the test bench and are not covered. At this stage do not connect any power supply to the capacitor discharge unit (CDU – see project next month) input terminals.

Use a current-limited power supply of about 12V, set to a current limit of about 500mA (this will ensure that no damage will result if a problem exists). Connect this supply to the power input terminals. The two LEDs will probably come on for a second or two, then the unit should settle down, drawing less then 40mA.

Wave your hand about 50mm above each of the sensors. The LED associated with the sensor you are testing should come on and stay on for about two seconds after you remove your hand. Try this on both sensors. If the LEDs come on then both sensors are working.

Using a multimeter, CRO or logic probe look at the two flip-flop output pins (3 and 4) on IC3. One should be high while the other is low.

Again, cover the sensors one at a time. The flip-flop pins should toggle. Pin 3 of the flip-flop should go high when sensor 2 is triggered and pin 4 should go high when sensor 1 is triggered. If all this is happening then you can be fairly sure that the whole project is working OK.

Connect a power supply, preferably from the companion CDU unit that goes with this system, to the CDU input socket. If the CDU is not available then a DC supply of about 15V at 2A will do. The last step is to connect a twin-coil points motor to the points socket.

When you trigger the sensors the points motor should also swap positions. If all is OK then the system can be installed on your layout. If things have not gone as planned then do not despair just yet.

Fault-finding is simple

There is no microcontroller used in this project, so fault-finding should be simple.

Finding the problem is simply a matter of elimination. If both LEDs are working when they should then at least half the project is OK. In this case, looking at IC3 pin3 and 4 as previously described will tell if IC3 and its components are working or not. Using your multimeter check the following places. IC4 pins 2 and 6 should be at about 2.5V DC. IC4 pins 1 and 7 are the opamp outputs. One should be high (about 10V DC) and the other should be low. They should swap over when the sensors are triggered.

As previously stated, most likely the fault will be soldering related. Other components to check are diodes D1 and D2 in the MOSFET gate circuits. If these have be inserted backwards the drive signal to the MOSFETs will not get through.

If the sensors are not working then you have two of them to compare voltages. It is highly unlikely that both will not work. If that is the case then most likely you have reversed the IR components.

Installation

A look at the diagrams and photos will show how the sensors are installed. The IR components are placed under the track with the domes of the components facing up between the sleepers.

The distance from the points back along the track to the sensor is not critical as long as the points have time to switch before the approaching train reaches it. 100mm would be about the minimum; we generally go for about double this.

A small dob from a hot glue gun will make sure the sensors stay put.

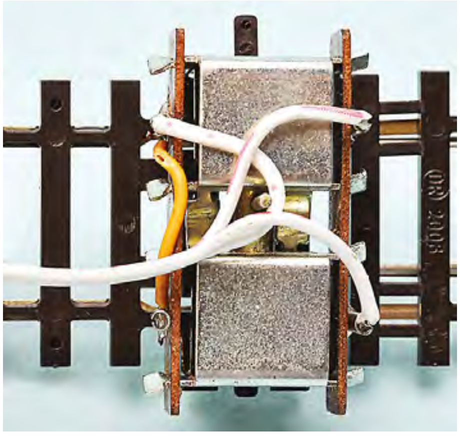
Wave your hand above the sensors at an increasing distance. The sensors should not detect your hand at more than about 100mm.

Slow-motion points

However, at this stage you may want to plan ahead so that this project will work with servo or slow-motion points motors such as the 'tortoise' motor.

If you intend to use these at a later date then you will need a sensor-to-points distance of at least 400 to 500mm. Using a slow motion motor gives a very realistic show of the points being switched.

Once you have the sensors installed, connect them to the main PCB then power it up. Run a loco or carriage over the sensors and make sure the LEDs indicate a successful detection. The sensors should detect all types of carriages and locos.



A close-up view of the under-side of the points motors. Obviously, enough clearance needs to be allowed under the tracks in your layout to accommodate the bulk of these motors.

Once that is done, you can complete the installation, then sit back and enjoy another automated section of your layout.

Off-track sensors

During development of this system a sensor was installed inside a small electrical equipment box model that was then installed next to the track. As a train passed the electrical box the sensor reliably detected the passing of the train every time.

Although the sensors need to be disguised somehow, this is another idea on how to reliably detect the passing of trains and has the advantage of not having to disguise the sensors that are installed under the track.

Next month...

In our April 2014 issue we will present a cheap, simple, but highly effective capacitor discharge unit (CDU) project to safely drive single or multiple points motors.

Parts List – Automatic Points Switching

1 main PCB available from the *EPE PCB Service,* measuring 105 × 55mm, coded 09103132 (includes 2 sensor PCBs, measuring 17 × 8mm)
3 3-pin PCB mount sockets
2 2-pin PCB mount sockets
3 8-pin IC sockets
1 14-pin IC socket

Semiconductors
2 LM567 tone decoders (IC1, IC2)
1 4011B quad Nand gate (IC3)
1 LM358 dual op amp (IC4)
2 Vishay TCRT5000 sensors (Sensor1,2)
2 BC548 NPN transistors (Q1, Q3)
2 BC558 PNP transistor (Q2, Q4)
2 IRFZ44 N-channel MOSFETs [or equivalent] Q5, Q6)
2 1N4148 silicon signal diodes D1, D2)
3 1N4004 silicon power diodes (D3-D5)
2 5mm LEDs (red, green or yellow; LED1,LED2)
1 7805 3 terminal regulator

Capacitors
1 1000µF 25V electrolytic
2 22µF 25V electrolytic
1 10µF 25V electrolytic
4 2.2µF 25V electrolytic
2 470nF MKT (code 470n or 474)
6 100nF MKT (code 100n or 104)

Reproduced by arrangement with SILICON CHIP magazine 2014. www.siliconchip.com.au

Resistors (all 1/4 W carbon)

2 560Ω	4 1kΩ	4 4.7kΩ	2 10kΩ	2 15kΩ
1 22kΩ	1 47kΩ	4 100kΩ	2 150kΩ	2 390kΩ

Extra components required for the Frog Switching relay
1 PCB, available from the *EPE PCB Service,* measuring 37mm × 27mm, coded 09103133
1 SPDT relay
1 IN4004 power diode
1 2.2kΩ resistor
1 BC548 or C8050 NPN transistor [or equivalent]

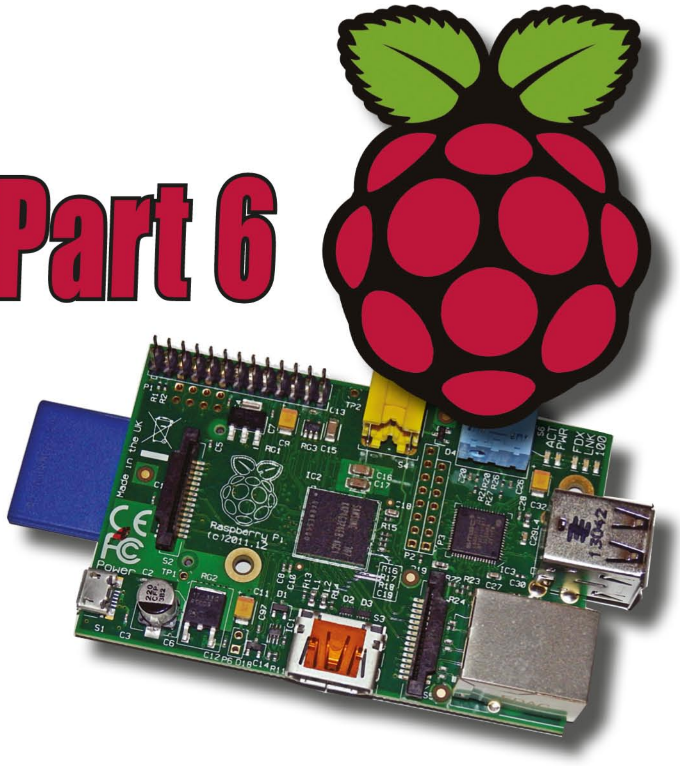
All enquires for this project should be directed to the designer, Jeff Monegal. He can be contacted via email only: jeffmon@optusnet.com.au
All emails will be answered, but please allow up to 48 hours for a reply.

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	2	390kΩ	orange white yellow brown	orange white black orange brown
❏	2	150kΩ	brown green yellow brown	brown green black orange brown
❏	4	100kΩ	brown black yellow brown	brown black black orange brown
❏	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❏	1	22kΩ	red red orange brown	red red black red brown
❏	2	15kΩ	brown green orange brown	brown green black red brown
❏	2	10kΩ	brown black orange brown	brown black black red brown
❏	4	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❏	4	1kΩ	brown black red brown	brown black black brown brown
❏	2	560Ω	green blue brown brown	green blue black black brown

Teach-In 2014
Raspberry Pi – Part 6

by Mike and Richard Tooley



Welcome to *Teach-In 2014* with Raspberry Pi. This exciting series has been designed for electronics enthusiasts wanting to get to grips with the immensely popular Raspberry Pi, as well as computer buffs eager to explore hardware and interfacing. So, whether you are considering what to do with your Pi, or maybe have an idea for a project but don't know how to turn it into reality, our *Teach-In* series will provide you with a one-stop source of ideas and practical information.

The Raspberry Pi offers you a remarkably effective platform for developing a huge variety of projects; from operating a few lights to remotely controlling a robotic vehicle through the Internet. *Teach-In 2014* is based around a series of practical exercises with plenty of information for you to customise each project to meet your own requirements.

The Raspberry Pi is no mean performer; it can offer you very similar performance to that which you might expect from a larger and much more expensive computer system, so don't be fooled by the relatively small price tag. By shopping around you can build a very effective computer system based on a Raspberry Pi for less than £100. However, if you are looking for something more modest and just want to take advantage of the Raspberry Pi as a single-board computer for a particular control application then you can be up and running for a very reasonable outlay.

This series will teach you about:

- **Programming** – introducing you to the powerful Python programming language and allowing you to develop your programming skills
- **Hardware** – learning about the components and circuits that are used to interface microcomputers to the real world
- **Computers** – letting you get to grips with computer hardware and software and helping you understand how they work together
- **Communications** – showing you how to connect your Raspberry Pi to a network and control a remote device using Wi-Fi and the Internet.

So, what's coming up? Regular features of Teach-In 2014 with Raspberry Pi will include:

- **Pi Project** – the main topic for each part will be a project that explores a particular use or application of the Raspberry Pi in the real word. Projects will include shopping for your Pi, set up, environmental monitoring, data logging, automation and remote control.
- **Pi Class** – each of our Pi Projects will be linked to one or more specific learning aims. Examples will include methods of representing and handling data, serial versus parallel data transmission and architecture of a microprocessor system.
- **Python Quickstart** – a short feature devoted to specific programming topics, such as data types and structures, processing user input, creating graphical dialogues and buttons and importing Python modules. We will help you get up and running with Python in the shortest time!
- **Pi World** – this is where we take a look at a wide range of Raspberry Pi accessories, including breadboards, prototype cards, bus extenders and Wi-Fi adapters. We will also help you build your Raspberry Pi bookshelf with a selection of recommended books and other publications.
- **Home baking –** suggested follow-up and extension activities such as 'check this out', a simple quiz, things to try and websites to visit.
- **Special features –** an occasional 'special feature'. For example, how to laser cut your own mounting plate – with additional downloadable resources such as templates and diagrams.

What will I need?

To get the best out of our series you will, of course, need access to a Raspberry Pi. If you don't already have one, don't worry – we will be explaining what you need and why you need it (we will also be showing you how you can emulate a Raspberry Pi using a Windows PC).

This month

In this month's *Teach-In 2014* we will be taking a first look at the Raspberry Pi's I^2C interface. Our *Pi Project* deals with the construction of a simple I^2C-based digital-to-analogue converter (DAC). *Perfect Python* shows how you can easily validate user input, checking that it contains only valid characters and, where appropriate, converting it to the correct numeric format. For good measure, we will show you how a surplus ATX computer power supply can make the basis of an excellent bench power unit for use with a wide range of power-hungry peripherals.

Python Quickstart

Last month, we looked at how you can 'pickle' your data so that it can be saved and later retrieved. We also showed how you can save data in the form of a CSV file that can be subsequently imported by a standard spreadsheet package. This month, we will be taking a look at methods that we can use for validating numeric and alphanumeric input.

Numeric input

A common example of data validation is when we need to make sure that a numeric value entered by a user really is a number. For example, what happens if you use the following simple input routine:

```
num_str = input("Enter a numeric value: ")
value = int(num_str)

# Test input
print(value)
```

Enter '123' as an input and this code fragment works fine, just as you would expect. However, entering '123.0' (ie, a floating point value with decimal point) results in:

```
Enter a numeric value: 123.0
Traceback (most recent call last):
  File "C:/Python33/data_validation_4.py", line 3, in <module>
    value = int(num_str)
ValueError: invalid literal for int() with base 10: '123.0'
```

Now, what happens if a space character is present in the input string? Entering ' 123' (with a leading white space) as our input gives:

```
Enter a numeric value:  123
Traceback (most recent call last):
  File "C:/Python33/data_validation_4.py", line 3, in <module>
    value = int(num_str)
ValueError: invalid literal for int() with base 10: ' 123'
```

Now let's suppose that a non-numeric characters (such as the letter 'a') appears in the user's input. Entering 'a123' for our supposed numeric input results in the following:

```
Enter a numeric value: a123
Traceback (most recent call last):
  File "C:/Python33/data_validation_4.py", line 3, in <module>
    value = int(num_str)
ValueError: invalid literal for int() with base 10: 'a123'
```

These examples show that things are often not quite as simple as they might first appear. In this case, when a user's input should be a number we do need to ensure that it really is a number by checking that there are no stray non-numeric characters in the input string. The characters that we do need to allow are:

- Numbers 0 to 9
- Plus (+) and minus (–) signs
- Stop or period (.) that we might need in floating-point numbers

When the user inputs a whole number (ie, a number with no decimal point) it needs to be interpreted as an *integer*, but when the input contains a decimal point it needs to be interpreted as a *floating-point* value, or '*float*'. So, for example, 123 should be interpreted as an integer while 123.0 and 123.4 should be interpreted as floats.

Fortunately, these requirements can all be satisfied using a user-defined function that waits for an input from the user, rejects any invalid characters in the input string before returning a numeric value of the correct type. Here's an example of a user-defined function, `get_number()`, that does the following:

1. Prompts the user for a numeric value
2. Removes any leading or trailing white space
3. Checks that all of the characters contained in the input string are valid numeric characters (ie: + – . 0 1 2 3 4 5 6 7 8 9)
4. Prints a message if any of the input characters are found to be invalid
5. Returns either an integer or a floating-point number depending on whether a decimal point is present in the input string.

```
def get_number(prompt = "Enter a numeric value: "):
    while True:
        # First remove any leading or trailing whitespace
        num_str = input(prompt).strip()
        # make sure that all char can be in a typical number
        if all(c in '+-.0123456789' for c in num_str):
            break
        else:
            print('Invalid character - try again!')
    # Check whether integer or float has been input
    if '.' in num_str:
        return float(num_str)
    else:
        return int(num_str)

# Test the get_number() function
value = get_number()
print(value)
```

Alphanumeric input

Alphanumeric input is relatively straightforward, but we often need to limit the user's input to a sub-set of acceptable characters and/or limit the number of characters that a user provides. In addition, we might need to ensure that the user's input does not contain any unwanted whitespace characters. Here is an example of a simple input routine that's designed to accept only one of the four cardinal points of the compass (N, E, S and W) from an input supplied by the user. The user-defined function, `get_direction()`, does the following:

1. Prompts user for a required direction
2. Removes leading or trailing white space
3. Checks to ensure that all of the characters contained in the input string are valid characters that represent a direction (ie, upper-case NESW and also their lower-case equivalents, nesw)
4. Checks to ensure that the user has only supplied a single character
5. Prints a message if any of the input characters is invalid or if there is more than one character present in the input string
6. Returns the character as an upper case letter (ie, one of NESW).

Strings and things

In Python, a string is a sequence of ASCII characters. The string's literal value is defined by enclosing it in matching quotation marks (") or apostrophes ('). A basic string might just be "Hello World" or 'Press any key…'

The basic ASCII character set is a 7-bit code and is restricted to a maximum of 128 unique states (0000000 to 1111111 in binary code). By adding an extra leading bit, the basic ASCII character set can be expanded to provide 256 unique codes (not all of these can be used to represent alphanumeric characters, some are reserved for controlling data flow; eg, shift and delete characters).

Most of today's 8-bit codes (eg, ISO 8859-1, the default Linux character set) encompass the standard ASCII characters when the leading bit (bit-7) is not set. The remaining characters (when the leading bit is set) provide additional characters. ISO 8859-1 encodes the 191 basic alphanumeric characters (plus punctuation) in what has become known as 'Latin Alphabet No.1'

Unicode (such as UTF-8) is a more comprehensive, multi-byte encoding scheme. Unicode aims to provide a universal character set that will correctly show any characters from any common language. Every Unicode character requires between 1 and 4 bytes of storage. A special 'escape sequence' can be used to represent Unicode characters that aren't found on your keyboard. Each escape sequence must be preceded by the backslash character (\).

```
def get_direction(prompt = "Enter the required direction: "):
    while True:
        # Remove any leading or trailing whitespace
        direction_str = input(prompt).strip()
       # Make sure that only a single valid character is accepted
        # in either upper or lower case
        if all(c in 'NESWnesw' for c in direction_str):
           if len(direction_str) == 1:
               break
           print('Invalid input - try again!')
     return direction_str.upper() # Return only the upper case
character

# Test the get_direction() function
direction = get_direction()
print(direction)
```

Finally, it's important to note that these examples are provided merely to show you some of the pitfalls and lengths that you might need to go to in order to validate the data supplied by a user. Data validation becomes particularly important when dealing with inputs that represent names, dates, money, email and web addresses. A quick Internet search will often provide you with a ready-made solution or something that you can adapt for your own particular applications.

Pi Project

Last month, we showed how our analogue-to-digital (ADC) interface board could be used in some simple sensing and measurement applications, including light level, resistance and temperature. This month, we shall be looking at digital-to-analogue conversion with a simple interface that will allow you to use your Raspberry Pi to generate a range of analogue output voltages.

MCP4725 DAC

Our digital to analogue converter makes use of a Microchip MCP4725. This is a single-channel, low-power 12-bit DAC, which uses an I^2C interface to a host controller. The MCP4725 incorporates an internal non-volatile EEPROM memory, allowing the chip to retain its digital input when the power is turned off. This feature makes it possible for the analogue output voltage to be retained so that it becomes immediately available without reprogramming each time the power is turned on. The simplified internal arrangement of the MCP4725 is shown in Fig.6.1.

The MCP4725 is supplied in a tiny SOT-23-6 package and it uses the pin connections shown in Fig.6.2. Since the chip is rather small and designed for surface mounting we recommend that you make use of the MCP4725 daughter board supplied by Adafruit Industries (see Fig.6.3). This board can be fitted with a standard 0.1-inch-spaced PCB header, and this will make connection much easier and significantly reduce the chance of a misconnection. The interface circuit and pin connections for the Adafruit board are shown in Figs.6.4 and 6.5 respectively.

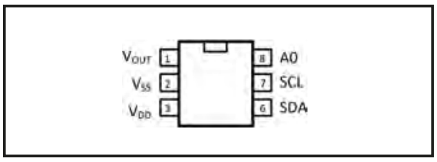


Fig.6.2. Pin connections for the MCP4725

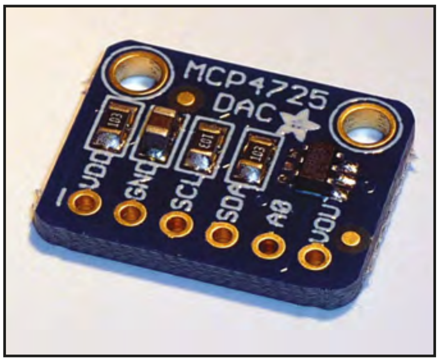


Fig.6.3. Adafruit Industries MCP4725 daughter board

The MCP4725 is designed for operation over the voltage range 2.7V to 5.5V, and thus will be comfortable with the 3.3V supply available from the Raspberry Pi's GPIO connector. Communication with the device is accomplished using the two-wire I^2C protocol (see boxed feature on page 41). The analogue output voltage can vary over the full supply voltage range (0V to +3.3V with the arrangement shown in Fig.6.4). The output current should be limited to a few milliamps, but we will later show how this limitation (as well as the limited voltage range) can be easily overcome with the aid of a simple external amplifier).

Since the MCP4725 is a 12-bit DAC it will operate with digital codes over the range 000000000000 to 111111111111 (corresponding to denary values extending from 0 to 4095). With a 3.3V supply, the smallest code (000000000000) will correspond to an analogue output voltage of 0V, and the largest code (111111111111) will correspond to an analogue output of 3.3V. This yields the following relationship:

V_{out} = Digital code × (4.96/3.3)

From which:

Digital code = V_{out} × (4.96/3.3)

Hence, if we need an analogue output of exactly 1.5V the required digital code would be:

Digital code = 1.5 × (3.3/4096) = 1861

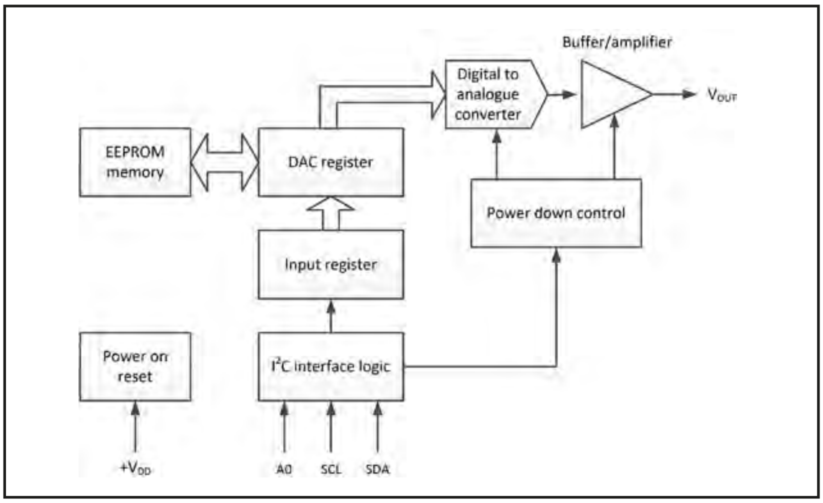


Fig.6.1. Simplified block schematic of the MCP4725 DAC

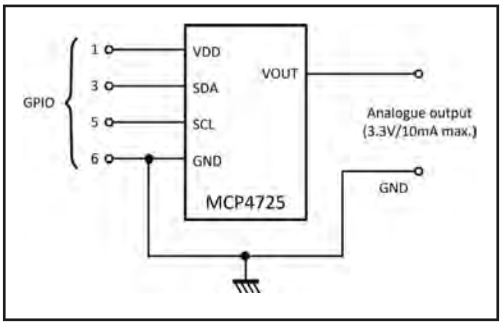


Fig.6.4. Circuit for interfacing the Adafruit MCP4725 daughter board to the Raspberry Pi

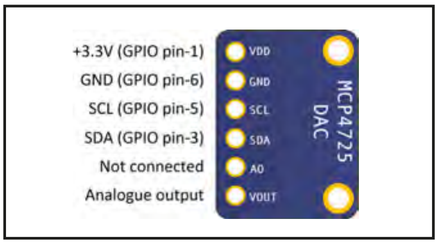


Fig.6.5. Pin connections for the Adafruit MCP4725 daughter board

Note that the '1861' is (for convenience) a denary value. In binary it would appear as '11101000101' and this is the value that would be sent to the DAC register in Fig.6.1.

I^{2}C tools

In order to make use of the I^{2}C interface you will need to have the i2c-tools package installed in your Raspberry Pi. In most current Debian distributions the package will already be installed, but if you do need to install the package you can use `sudo apt-get install i2c-tools` from the system prompt. Then, following installation, you should add a new user to the i2c group using `sudo adduser pi i2c` before rebooting the system using `sudo shutdown –r now`. Note that you will not need to do any of this if you already have i2c-tools installed.

Now, to check for I^{2}C devices connected to your Raspberry Pi you will need to use `i2cdetect` from within LXTerminal (or equivalent) as follows:

```
sudo i2c detect –y 0
```

Note that, as explained in the boxed feature on page 44, for a Rev.2 board you will need to enter this command as:

```
sudo i2c detect –y 1
```

I^{2}C bus

In *Teach-In 2014 Part 4* we introduced you to the serial peripheral interface (SPI) that allows you to connect a wide variety of external chips to your Raspberry Pi. We then went on to use this interface in conjunction with a popular analogue-to-digital converter (ADC) chip. In addition to SPI, the Raspberry Pi provides you with an alternative method of connecting to external devices by means of its 'Inter-Integrated Circuit' interface (abbreviated variously as IIC, I^{2}C, I2C or I-squared-C).

I^{2}C is a very simple bus system where bidirectional data appears on a single line (SDA) and a clock signal is sent on a second bus line (SCL). SPI, on the other hand, offers a point-to-point connection where the data is passed in and out on separate lines (MOSI and MISO). SPI is faster and generally easier to use than I^{2}C, but there can often be situations in which I^{2}C is preferred simply because this is the interface that's built into the chip that you need to use.

I^{2}C was the brainchild of Philips, but several of its competitors (including Motorola/Freescale, NEC, Siemens, STM and Texas Instruments) have developed their own I^{2}C-compatible products. In addition, Intel's SMBus provides a stricter definition of I^{2}C, intended to improve the interoperability of I^{2}C devices from different manufacturers.

Since the data line is shared between multiple devices, I^{2}C uses a system of addressing in order to identify the device that it needs to communicate with. Communication is initiated by means of a unique start sequence. This involves pulling the data line (SDA) low while the clock line (SCL) is high. This can be achieved by using very simple bus interface logic where each of the bus lines are normally pulled high and driven low when activated by a device connected to the bus (see Fig.6.7).

Fig.6.8 shows a simple bus transaction which begins with a start condition, S, and ends with a stop condition, P. Note how the transaction starts and ends with the bus lines in their quiescent high state.

Following the start sequence, transmitted data is only allowed to change when the clock is in its low state. In its basic form, and by virtue of the seven bits available for addressing, the I^{2}C protocol caters for a total of 127 devices. In addition to the seven bits used for addressing, the first byte of an I^{2}C transfer generated by a 'master' includes a bit that indicates the direction of the data transfer. The address is transferred with the most significant bit first (see Fig.6.8).

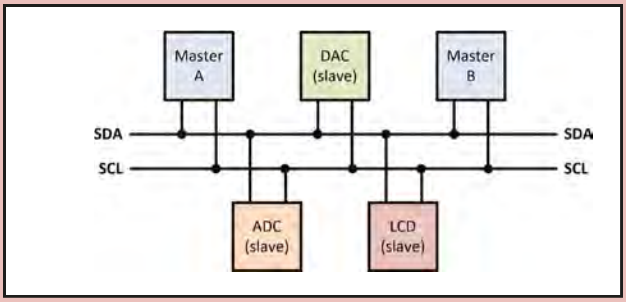


Fig.6.6. I^{2}C bus with two bus masters and three slaves

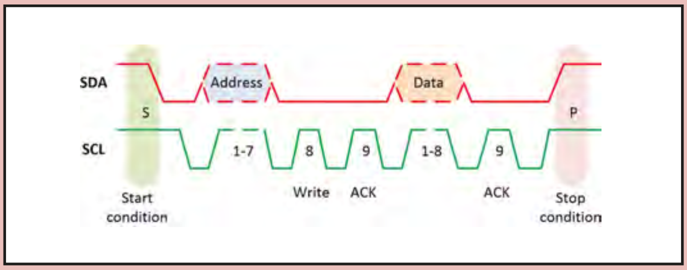


Fig.6.8. I^{2}C bus transaction showing how first address and then data is placed on the bus

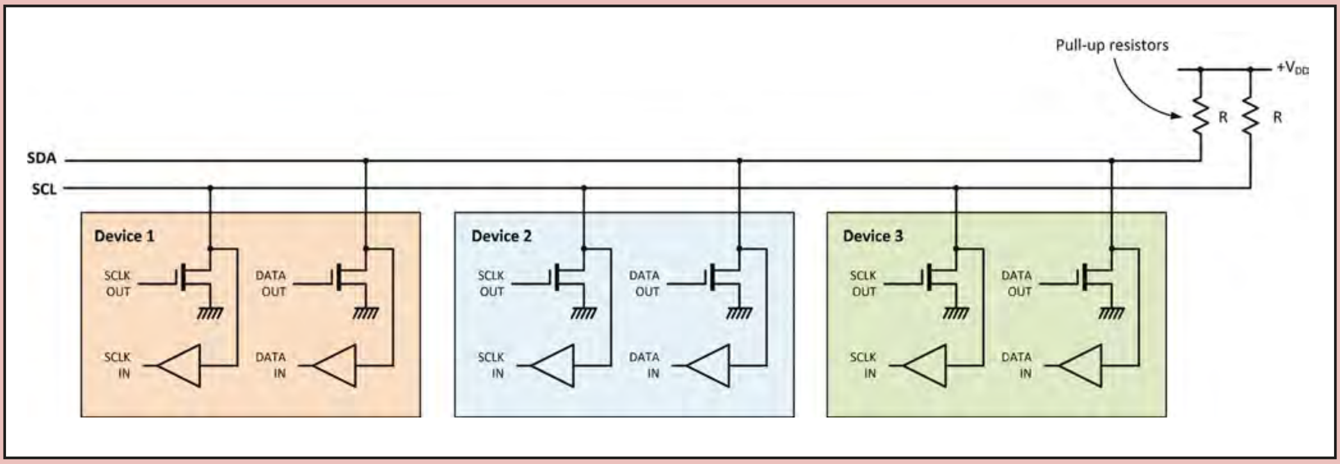


Fig.6.7. I^{2}C bus interface logic

A typical display produced by this command is shown in Fig.6.9. The display shows the mapping of 128 addresses within the I^2C space (but note that a few addresses are reserved for special purposes, so that not all of the 128 possible addresses can be mapped to I^2C devices). If you look carefully at the display you will see that address 62 (hex) has been mapped to the MCP4725 device and so we are now ready to start using it.

I^2C from the command line

The i2c-tools package provides you with a handy command that allows you to send data to an I^2C device. The command is `i2cset` and the command is followed by three bytes of data. The first of these bytes is the address of the I^2C device; the second and third bytes are the data to be sent in conventional order (high-byte followed by low-byte). Here is a brief walkthrough that shows how you can use the `i2cset` command. For the purposes of this exercise we've assumed that you have the MCP4725 DAC connected to your Pi, as shown in Fig.6.4, and that you have a DC voltmeter connected to the two analogue output terminals.

First, it's worth checking that the I^2C device is connected and check its address:

```
i2cdetect -y 0
```

This should show you the address of the MCP4725 within the I^2C address range (see Fig.6.9). In our case, this appeared as 62 hex. (ie, 0x62). If your address is not the same (eg, 0x60) you will need to change the first byte of data in each of the commands that follow. Note also that if you are using a Rev.2 Raspberry Pi the command should be changed to:

```
i2cdetect -y 1
```

Now we will set the DAC output to its maximum value of 3.3V. To do this, we will need to use a digital code of 4095 denary, 111111111111 binary, or 0FFF hexadecimal:

```
i2cset -y 0 0x62 0x0f 0xff
```

Next, we will set the DAC output back to 0V and check that the voltage has returned to zero. To do this we will need a digital code of 0 denary, 000000000000 binary, or 0000 hexadecimal:

```
i2cset -y 0 0x62 0x00 0x00
```

Fig.6.9. Using `i2cdetect` *to show the i2c address map*

> **Processes and sub-processes**
>
> In a Unix-based system, every running program is referred to as a 'process'. Each process runs separately from all of the processes running at the time. This means that each program has its own memory space, instruction stream and system state. A running program is also able to create new processes using selected operating system library functions. These processes are referred to as sub-processes and each can run independently of the calling program with their own system state and execution thread. Because of this independence, a sub-process will execute at the same time as the process that calls it. In the main text we will show how you can make use of sub-process calls to gain access to the I^2C interface from within your Python code.

Finally, let's set the DAC to 1V (or as near as we can get). To do this, we can calculate the value using the relationship that we introduced on page 40. The required code is 1232 denary, 010011010000 binary, or 04D0 hexadecimal:

```
i2cset -y 0 0x62 0x04 0xd0
```

Important note: The use of the `i2cset` command in each of the foregoing fragments of code assumes that you are dealing with the use of a Rev.1 board. If you are using a Rev.2 board the I^2C channel numbers should be changed from 0 to 1 (as mentioned earlier for the `i2cdetect` command).

If you've managed to follow these steps you are well on your way to making good use of the I^2C interface. Next, we will show you how to use Python to do the job in a much more elegant manner!

I^2C from Python 3.x

In order to access the features of the I^2C bus from within Python you can use one of the I^2C libraries, for example, the one available from Adafruit Industries (Adafruit_I2C). These libraries are designed to support the generic framework of an I^2C device, but need to be augmented by supplementary libraries for specific I^2C devices, such as **I2C_DAC.PY** from Adafruit. Another complication is that many of these libraries are designed to run with Python 2.7 and may currently not be compatible with version 3.x. All of this makes life rather difficult, so we've decided to opt for a more simple approach that makes use of operating system sub-process calls directly from our Python code. Later, we will show how the 'System Management Bus' (SMBus or SMB) can be used to access I^2C devices in a more elegant way (see page 44).

Here is a fragment of code (written using Python 3.x) that uses a sub-process call to set the analogue output from the DAC to approximately 1.86V:

```
import subprocess
return_code = subprocess.
call(["i2cset -y 0 0x62 0x09
0x00"], shell = True)
print(return_code)
```

This code is somewhat cryptic and needs an explanation. Before we can make use of the `subprocess.call()` function we need to import the `subprocess` library. The call requires several parameters, the first of which is the `i2cset` command from the i2c-tools library. Note how this command is enclosed in quotation marks (it is a literal string). The `subprocess.call()` generates a return code that can be used to let the Python code know whether the command has executed successfully. If the return code is 1, this tells us that an error has occurred, but if it is 0, the command has been successfully executed. We've used the `print()` function at the end of the code fragment just to check that no errors have occurred, but in a practical application we would need to provide a more meaningful error message.

A stepped voltage generator

Now let's look at a practical example of using the DAC. Let's suppose that we need to generate a voltage that rises in ten steps of 0.3V from 0V to 3V, remaining at each step for two seconds before moving on to the next. Because the digital code is stored in the DAC's internal memory we need to ensure that the output voltage goes back to 0V at the end of the cycle. The required digital codes are as shown in Table 6.5.

One possible solution might be to incorporate the digital codes from Table 6.5 into a list and then use the `subprocess.call()` function in ten separate lines of code, but this would be rather cumbersome. A more elegant solution would be to use a loop in which Python calculates the required digital code for each step and then builds a command string that can be sent via the `subprocess.call()` function. Fortunately, this isn't quite as difficult as it might sound and here's some commented code that shows you how easily it can be done:

```
# Import the required libraries
import time
import subprocess
# Initial voltage = 0V
voltage = 0
step = 0
while step < 10:
    voltage = step * voltage
    # Calculate the digital code
    volts = voltage *  4096 / 3.3
    # Convert the digital code to two bytes
    code = int(volts)
    first = int(code / 255)
    second = code - (first * 256)
    # Format the two hexadecimal values
    value1 = format(first, '#04x')
    value2 = format(second, '#04x')
    # Build the command string
    command_string = "i2cset -y 0 0x62 " + value1 + " " + value2
    # Make the sub-process call
    return_code = subprocess.call([command_string], shell=True)
    # Hold the voltage steady for two seconds
    time.sleep(2)
    # Increment the step counter
    step = step + 1
# After exiting the loop set the output back to 0V
command_string = "i2cset -y 0 0x62 0x00 0x00"
return_code = subprocess.call([command_string], shell=True)
```

See Fig.6.10 for the voltage waveform generated by the Python ramp generator code.

And finally, here's a complete Python 3.x program that will let you produce any desired output voltage from the DAC in the range 0V to 3.3V:

```
# MCP4725 DAC for Python 3.x
import subprocess
voltage = 0
while True:
    value = input("Output voltage: ")
    voltage = float(value)
    while voltage >= 0 and voltage < 3.3:
        volts = voltage *  4096 / 3.3
        code = int(volts)
        first = int(code / 255)
        second = code - (first * 256)
        value1 = format(first, '#04x')
        value2 = format(second, '#04x')
        command_string = "i2cset -y 0 0x62 " + value1 + " " + value2
        return_code = subprocess.call([command_string], shell=True)
        if return_code == 0:
            print("Success - output now set to ", value + " V")
        else:
            print("Error setting DAC - output not changed!")
        voltage = -1
```

Table 6.5 Digital codes (and their hexadecimal equivalents) for the stepped voltage generator

Step number	Voltage	Digital code	Hex. equivalent
0	0	0	0000
1	0.3	372	0175
2	0.6	744	02E8
3	0.9	1117	045D
4	1.2	1489	05D1
5	1.5	1861	0745
6	1.8	2234	08BA
7	2.1	2606	0A2E
8	2.4	2978	0BA2
9	2.7	3356	0D1C
10	3.0	3724	0E8B

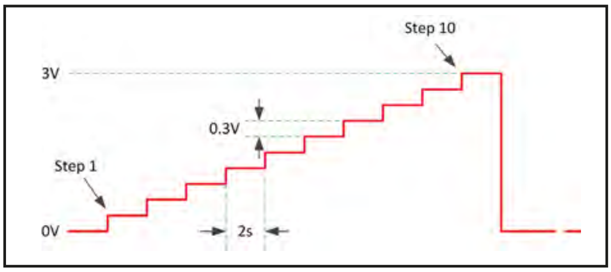


Fig.6.10 Python ramp generator waveform

The main points of the program are as follows:

1. Prompt the user for the required output voltage and convert the input to a floating point number.
2. Check that the user's input is within the acceptable range (0V to +3.3V)
3. Convert the floating-point value into two hexadecimal bytes
4. Insert the two hexadecimal bytes into the `i2cset()` command string
5. Make the `subprocess.call(0)`
6. Check the return code and warn the user if an error is detected.

Note that the code is designed for use with a Rev.1 Raspberry Pi board. If you are using a Rev.2 board you will need to change `command_string` as noted earlier, with the 0 replaced by a 1 (see boxed feature on page 44).

Increasing the voltage and current

The basic ADC will produce a current of up to around 10mA at voltages in the range 0 to 3.3V. Unfortunately, this will be inadequate for many applications but these limitations can be easily overcome with the use of an external power amplifier stage, as shown in Fig.6.11.

L165 power operational amplifier

The L165 is a high-power operational amplifier supplied in a Pentawatt package (see Fig.6.12). The device is able to deliver currents of up to 3A and it operates from a symmetrical voltage supply of typically ±12V (±18V max.).

As with all operational amplifiers, the voltage gain provided by the L165 can be made adjustable by means of negative feedback. In the circuit of Fig.6.9, the voltage gain is variable over the range 2 to 4 by means of RV1. At

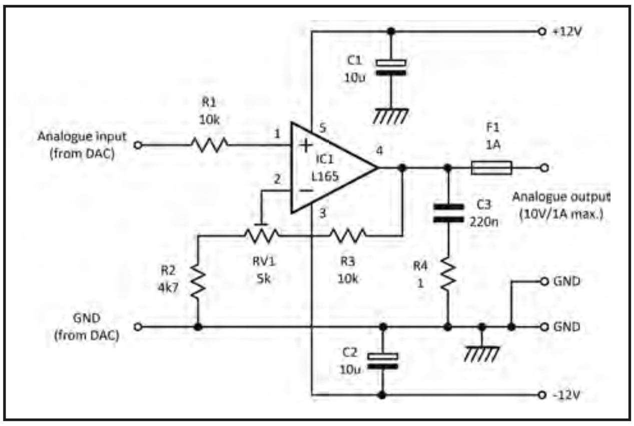


Fig.6.11. Additional amplifier stage for use with the DAC

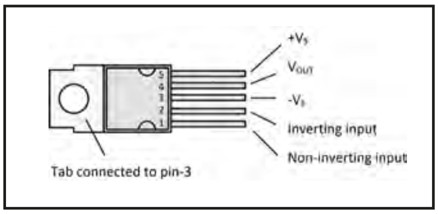


Fig.6.12. L165 pin connections

mid-position of RV1, the voltage gain will be approximately 3 and thus a 3.3V input from the MCP4725 will result in an output of around +10V. In a practical application (see Python code opposite) RV1 is adjusted for the required full-scale value (10V in this case) when an output of 10V is requested.

When the MCP4725 DAC is used with the L165 amplifier, the following Python code will produce any desired output voltage over the increased range 0V to 10V and with an output current of up to 1A:

```
# MCP4725 DAC with amplifier for Python 3.x
import subprocess
voltage = 0
while True:
    value = input("Output voltage: ")
    voltage = float(value)
    while voltage >= 0 and voltage < 10.1:
        volts = voltage *  4096 / 11
        code = int(volts)
        first = int(code / 255)
        second = code - (first * 256)
        value1 = format(first, '#04x')
        value2 = format(second, '#04x')
      command_string = "i2cset -y 0 0x62 " + value1 + " " + value2
     return_code = subprocess.call([command_string], shell=True)
        if return_code == 0:
            print("Success - output now set to ", value + " V")
        else:
            print("Error setting DAC - output not changed!")
        voltage = -1
```

Once again, this code has been written for a Rev.1 Raspberry Pi board. If you are using a Rev.2 board you will need to make changes to the `command_string` so that the 0 becomes a 1 (see boxed feature opposite/below).

Finally, and if you are intending to drive loads that are significantly inductive, such as solenoids, relays and motors, you might find it worthwhile adding some additional protection diodes to the output of the L165 amplifier, as shown in Fig.6.13. These diodes provide an external path for back EMF, augmenting the diodes that the L165 has internally. D1 and D2 should be rated at currents of at least 1A and PIV of at least 50V.

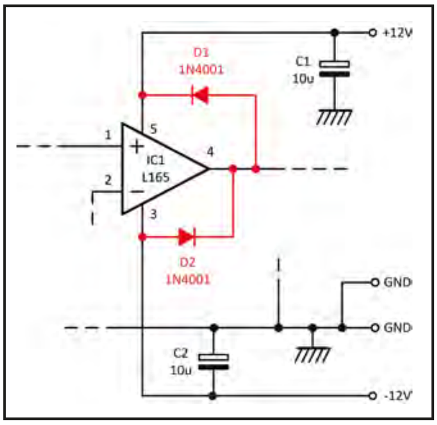


Fig.6.13. External diode protection for inductive loads

I²C and Raspberry Pi board revisions

The Raspberry Pi supports two I²C channels, 0 and 1. However, on the most recent Raspberry Pi revision (Rev.2) the primary and secondary I²C channels have been reversed. On Rev.1 (and earlier) boards the physical connections to the I²C channels are as shown in Table 6.1, but on the Rev.2 boards they are as shown in Table 6.2.

To facilitate the additional I/O present on Rev.2 boards, a new connector, P5, can be fitted. The connecting pads for P5 are located immediately adjacent to the GPIO connector, P1. P5 makes available four additional GPIO signals, together with power. The pin assignment for P5 is shown in Table 6.3.

If you are unsure of which revision you have you can determine a board's revision status by entering the following at the command line: `cat /proc/cpuinfo`. This will show you the hardware revision code for the board in question and this can be used to determine the board's revision number (see Table 6.4).

Table 6.1 I²C channels and physical connections for pre-Rev.2 Raspberry Pi boards

I²C channel	I²C signal	Physical connection	BCM2835 signal
0	SCL0	P1 pin-5	GPIO1
0	SDA0	P1 pin-3	GPIO0
1	SCL1	S5 pin-13	GPIO3
1	SDA1	S5 pin-14	GPIO2

Table 6.3 P5 connections for Rev.2 Raspberry Pi

P5 pin number	Signal connection
1	+5V
2	+3.3V
3	GPIO28
4	GPIO29
5	GPIO30
6	GPIO31
7	GND
8	GND

Table 6.2 I²C channels and physical connections Rev.2 Raspberry Pi boards

I²C channel	I²C signal	Physical connection	BCM2835 signal
0	SCL0	S5 pin-13	GPIO1
0	SDA0	S5 pin-14	GPIO0
1	SCL1	P1 pin-5	GPIO3
1	SDA1	P1 pin-3	GPIO2

Table 6.4 Hardware revision codes and board revision numbers

Hardware code	Board revision
2	Model B Rev.1
3	Model B Rev.1
4	Model B Rev.2
5	Model B Rev.2
6	Model B Rev.2

I²C from Python 2.x

As briefly mentioned earlier, `subprocess.call()` provides us with a way of accessing the I²C bus from Python 3.x, avoiding the use of libraries that are not currently compatible with the latest version of Python. A less cumbersome solution (but one which will only work with earlier versions of Python) is using the SMBus library. In next month's *Teach-In 2014* we will explain how this operates in greater depth, but for the sake of completeness, here are some Python 2.x versions of the code that we met earlier. These programs all make use of the SMBus library rather than sub-process calls.

Stepped ramp generator (see code on page 43)

```
# MCP4725 DAC for Python 2.x

# Import the required libraries
import time
import smbus

# Set the bus to use (for Rev.2 change 0 to 1)
bus = smbus.SMBus(0)

# DAC's I2C bus address
DAC = 0x62

# Initial voltage = 0V
voltage = 0
step = 0
while step < 11:
    voltage = step * 0.3
    # Calculate the digital code
    volts = voltage *  4096 / 3.3
    # Convert the digital code to two bytes
    code = int(volts)
    first = int(code / 255)
    second = code - (first * 256)
    bus.write_word_data(DAC,first,second)
    # Hold the voltage steady for two seconds
    time.sleep(2)
    # Increment the step counter
    step = step + 1
# After exiting the loop set the output back to 0V
bus.write_word_data(DAC,0x00,0x00
```

0 to 3.3V from the MCP4725 DAC (see code on page 43)

```
# MCP4725 DAC for Python 2.x

# Import the required libraries
import time
import smbus

# Set the bus to use (for Rev.2 change 0 to 1)
bus = smbus.SMBus(0)

# DAC's I2C bus address
DAC = 0x62

voltage = 0
while True:
    value = input("Output voltage: ")
    voltage = float(value)
    while voltage >= 0 and voltage < 3.3:
        volts = voltage *  4096 / 3.3
        code = int(volts)
        first = int(code / 255)
        second = code - (first * 256)
        bus.write_word_data(DAC,first,second)
        voltage = -1
```

A low-cost ±12V high-current supply

Our external power amplifier requires a ±12V supply capable of delivering a current of up to about 2A, depending upon the load that it is connected to. A simple solution to this problem makes use of a surplus ATX computer power supply. Such a unit can be removed from a scrapped PC and will only require a few external components in order to operate as a versatile stand-alone power supply, see Fig.6.14.

The standard wiring of a 20-way ATX power connector is shown in Fig.6.15 and the output ratings for a 250W ATX power supply are shown in Table 6.6

Table 6.6 Typical ATX specification

Voltage rail	Colour	ATX 20-way connector pin number(s)	Typical current rating (250W supply)
+12V	Yellow	10	10A
+5V	Red	4, 6, 19, 20	25A
-12V	Blue	12	0.5A
+3.3V	Orange	1, 2, 11	13A
-5V	White	18	0.3A
+5V SB	Dark grey	9	2A
GND	Black	3, 5, 7, 13, 15, 16, 17	n/a

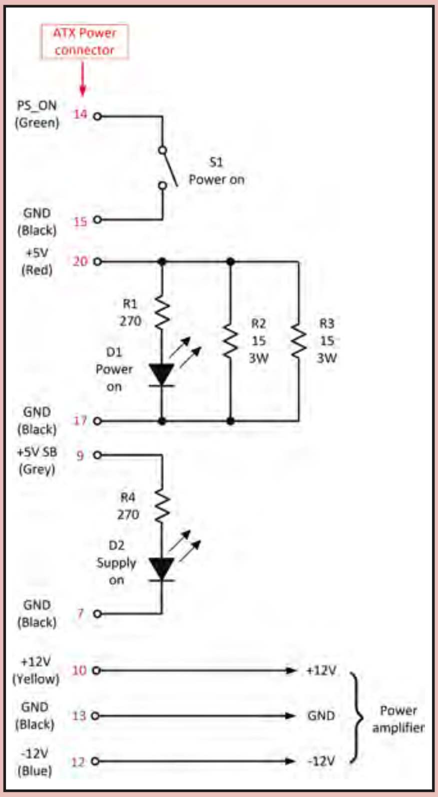


Fig.6.14. Circuit of the ± 12V supply based on an ATX power supply

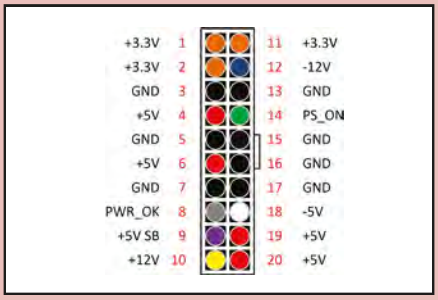


Fig.6.15. The ATX power connector

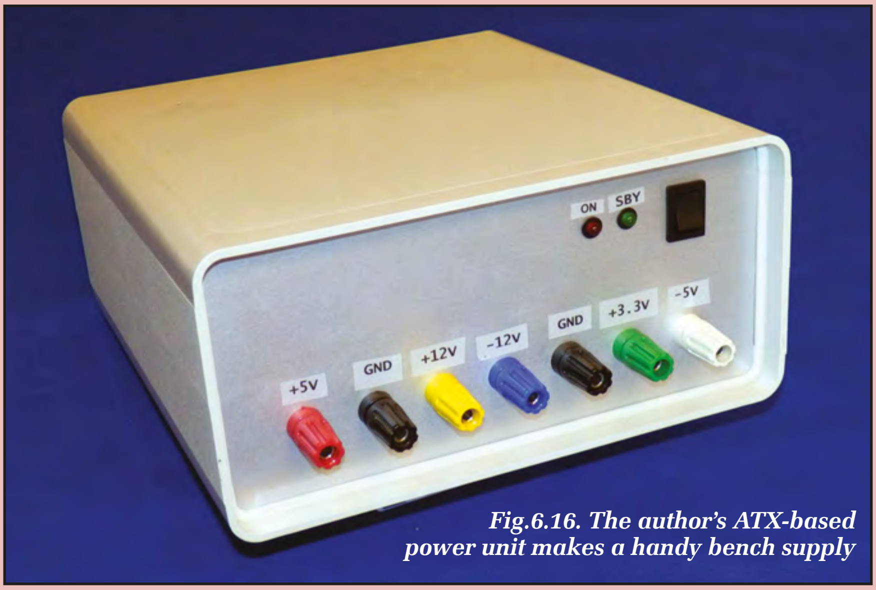


Fig.6.16. The author's ATX-based power unit makes a handy bench supply

0 to 10V from the MCP4725 DAC and L165 amplifier (see code on page 44)

```
# MCP4725 DAC with amplifier for Python 2.x

# Import the required libraries
import time
import smbus

# Set the bus to use (for Rev.2 change 0 to 1)
bus = smbus.SMBus(0)

# DAC's I2C bus address
DAC = 0x62

voltage = 0
while True:
    value = input("Output voltage: ")
    voltage = float(value)
    while voltage >= 0 and voltage < 10.1:
        volts = voltage *  4096 / 11
        code = int(volts)
        first = int(code / 255)
        second = code - (first * 256)
        bus.write_word_data(DAC,first,second)
        voltage = -1
```

In next month's Teach-In with Raspberry Pi

In next month's *Teach-In 2014*, our *Pi Project* features the construction of a 16-channel port expander for the Raspberry Pi. Our *Pi Class* introduces binary, octal and hexadecimal numbers, while *Python Quickstart* deals with methods of handling and manipulating binary, octal and hexadecimal data. We will also be showing you how the System Management Bus (SMBus) can provide you with a simple way of accessing a wide-range of I^2C devices.

STORE YOUR BACK ISSUES ON CD-ROMS

FIVE YEAR DVD/CD-ROMs NOW AVAILABLE

ONLY £16.45
(£29.95 FOR 5 YEAR)
each including VAT and p&p

VOL 1: BACK ISSUES – January 1999 to June 1999
Plus some bonus material from Nov and Dec 1998

VOL 2: BACK ISSUES – July 1999 to December 1999

VOL 3: BACK ISSUES – January 2000 to June 2000

VOL 4: BACK ISSUES – July 2000 to December 2000

VOL 5: BACK ISSUES – January 2001 to June 2001

VOL 6: BACK ISSUES – July 2001 to December 2001

VOL 7: BACK ISSUES – January 2002 to June 2002

VOL 8: BACK ISSUES – July 2002 to December 2002

VOL 9: BACK ISSUES – January 2003 to June 2003

VOL 10: BACK ISSUES – July 2003 to December 2003

VOL 11: BACK ISSUES – January 2004 to June 2004

VOL 12: BACK ISSUES – July 2004 to December 2004

VOL 13: BACK ISSUES – January 2005 to June 2005

VOL 14: BACK ISSUES – July 2005 to December 2005

VOL 15: BACK ISSUES – January 2006 to June 2006

VOL 16: BACK ISSUES – July 2006 to December 2006

VOL 17: BACK ISSUES – January 2007 to June 2007

VOL 18: BACK ISSUES – July 2007 to December 2007

VOL 19: BACK ISSUES – January 2008 to June 2008

VOL 20: BACK ISSUES – July 2008 to December 2008

VOL 21: BACK ISSUES – January 2009 to June 2009

VOL 22: BACK ISSUES – July 2009 to December 2009

VOL 23: BACK ISSUES – January 2010 to June 2010

VOL 24: BACK ISSUES – July 2010 to December 2010

VOL 25: BACK ISSUES – January 2011 to June 2011

VOL 26: BACK ISSUES – July 2011 to December 2011

VOL 27: BACK ISSUES – January 2012 to June 2012

VOL 28: BACK ISSUES – July 2012 to December 2012

VOL 29: BACK ISSUES – January 2013 to June 2013

FIVE YEAR CD/DVD-ROMs

No.1 – Jan '03 to Dec '07
No.2 – Jan '04 to Dec '08
No.3 – Jan '05 to Dec '09
No.4 – Jan '06 to Dec '10
No.5 – Jan '07 to Dec '11
No.6 – Jan '08 to Dec '12

NOTE: These DVD/CD-ROMs are suitable for use on any PC with a DVD/CD-ROM drive. They require Adobe Acrobat Reader (available free from the Internet – **www.adobe.com/acrobat**)

WHAT IS INCLUDED

All volumes include the *EPE Online* content of every listed issue. **Please note that we are unable to answer technical queries or provide data on articles that are more than five years old. Please also ensure that all components are still available before commencing construction of a project from a back issue.**

A great way to buy *EPE* Back Issues – our DVD/CD-ROMs contain back issues from our *EPE* Online website. Note: no free gifts are included.

Order on-line from
www.epemag.com (go to the UK store)
or by phone, fax, email or post

BACK ISSUES DVD/CD-ROM ORDER FORM

Please send me the following Back Issue DVD/CD-ROMs.

Volume Numbers:...

....

Price £16.45 each, £29.95 for Five Year DVD/CD-ROMs – includes postage to anywhere in the world.

Name ....

Address ....

....

....

Post Code..

☐ I enclose cheque/P.O./bank draft to the value of £ ....

☐ please charge my Visa/Mastercard/Maestro £ ....

Card No...

Card Security Code .... (The last 3 digits on or just under the signature strip)

Valid From................ Expiry Date ....

Maestro Issue No...........

SEND TO: **Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU.**

Tel: 01202 880299. Fax: 01202 843233.
E-mail: orders@epemag.wimborne.co.uk

Payments must be by card or in £ Sterling – cheque or bank draft drawn on a UK bank.
Normally posted within seven days of receipt of order.

Max's Cool Beans

By Max The Magnificent

Arduino galore!

As you may recall from my last few columns, I'm really plunging into the world of Arduino microcontrollers. I did recently run into one small 'gotcha' when my main notepad computer asked if I wanted to upgrade from Windows 8 to Windows 8.1. When I did so, the USB COM port I'd been using to program my Arduino disappeared (the `Tools > Serial Port` menu item in the Arduino development environment is greyed out). I've not yet worked out how to solve this little conundrum, but my Windows 7-based notepad continues to work just fine. (FYI: I used the `File > Preferences` command to modify my Sketchbook location to point to my Dropbox folder, which means all of my Arduino programs are backed up in the cloud and are accessible from any of my computers.)

Truth be told, I currently have so many Arduino-based projects 'on the go' that I don't really know where to start. In a previous column I mentioned that I was building a 4×4×4 3D tri-color LED cube powered by an Arduino-compatible controller. Well, I finished that and it looks great – it's sitting on my desk entertaining me with a beguiling light display as I pen these words. This led me to want to build something else that involved LEDs (show me a flashing LED, and I'll show you a man entranced saying, 'Oooh, shiny!').

Infinity mirror

Eventually I decided to make an Infinity Mirror (**http://bit.ly/19Tbg9N**), which involves a thin box frame with a full mirror at the back, a half (one-way) mirror at the front, and a bunch of LEDs mounted around the inside periphery of the frame sandwiched between the two mirrors. When the LEDs are activated, it appears as though you have rows and rows of them receding to infinity. You can find a lot of information about building these on the web, including things like creating your own half-mirror using regular glass coated with a sheet of the same film you use to tint car windows. Unfortunately, these websites tend to be a bit thin-on-the-ground when it comes to specifics, such as the optimal gap between the two mirrors and the type of window-tinting film to use. The end result is that I've spent a happy few weeks experimenting with different setups (I will report further in a future column).

As part of my Infinity Mirror project, I decided to use a strip of NeoPixels from Adafruit.com. The one-metre strip I chose to play with boasts 60 of these incredibly bright, tri-color LEDs (**http://bit.ly/1lPDFgN**). The really cool thing about these LEDs is that you need only use a single digital output pin on your Arduino to control the entire strip, you can daisy-chain multiple strips together, and can essentially control the colour and brightness of each LED individually.

My Steampunk project

But that's not what I wanted to talk to you about. Several years ago, I saw a really funny image of a 'Man *vs* Woman' piece of pseudo-electronic equipment (**http://bit.ly/1hvRvHv**) and I thought to myself 'I'd like to build one of those.' The thing is, I want mine to look really cool and tasty – I'm thinking of a Steampunk look-and-feel – so for the past few years I've been collecting antique knobs and switches and analogue meters and suchlike. All of this is going to be presented in a superb wooden radio cabinet from 1929. (You can read much more about this project in a series of articles I wrote at **http://bit.ly/1eHtHf8**)

This has been an ongoing 'back-burner' project. Every now and then I've played around with one microcontroller or another, experimenting with driving lots of LEDs (there will be about 120 on the front panel) and controlling analogue meters. But each prototype grew to be overcomplicated, at which time my mind would wander off to contemplate something else. So you can only imagine my excitement while I was playing around with my Infinity Mirror project when I thought to myself 'Hang on, if I use Adafruit's NeoPixels, I can control all 120 LEDs on my front panel using a single digital output from my Arduino!' Furthermore, in the case of an Arduino Mega (**http://bit.ly/1gEbS2r**), I can use the 15 PWM (pulse-width modulated) outputs to drive my analogue meters, the 16 analogue inputs to monitor rotary potentiometers, and the remainder of the 54 digital pins to monitor switches and control other 'stuff.'

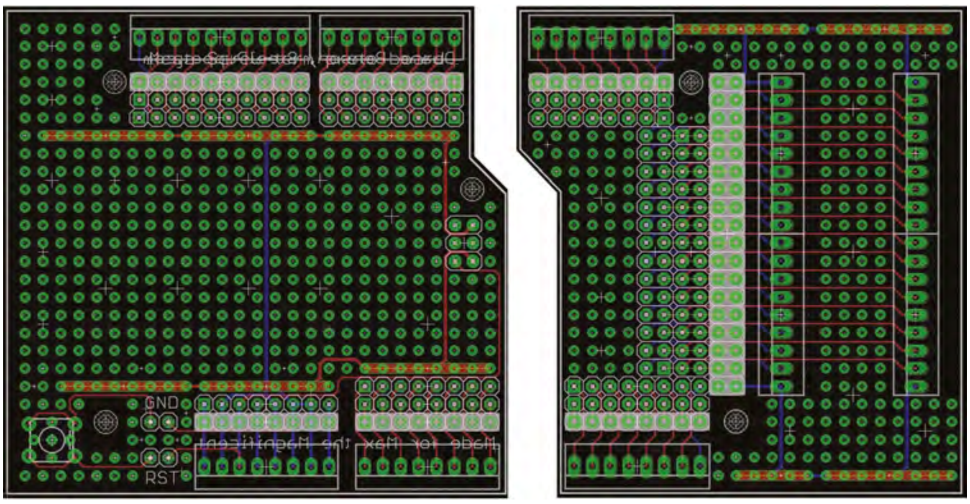


Fig.1. Screw-block prototyping shield

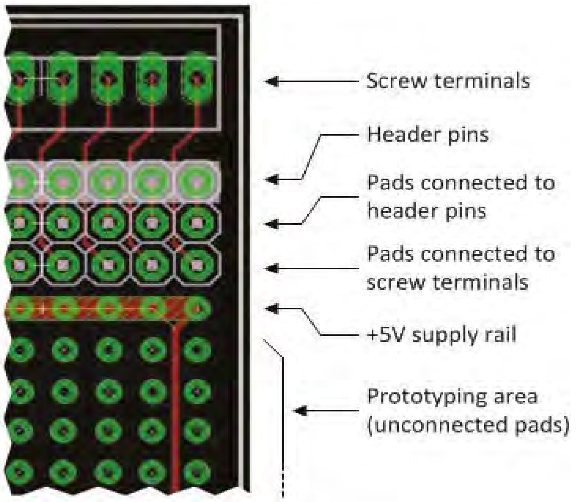
Prototyping shields

Thus it was that my *Pedagogical and Phantasmagorical Inamorata Prognostication Engine* (Mark 1) project returned to the forefront of my attention. This is actually very much progressed – I hope to have the whole thing working in no more than a couple of months – there's just one snag... You can get standard prototyping shields for the Arduino Uno (**http://bit.ly/1cPd1zc**) and the Arduino Mega (**http://bit.ly/1kqVKGA**). You can also get a really cool prototyping shield equipped with screw-block terminals for the Arduino Uno (**http://bit.ly/1bRS72a**). Using these screw-block terminals would make prototyping 'The Beast' a whole lot easier. Sad to relate, however, I've not been able to track down an off-the-shelf equivalent for an Arduino Mega.

But turn that frown upside down into a smile. I called my friend Duane Benson, who is the Marketing Manager at Screaming Circuits (**http://bit.ly/1cZbjj1**). Don't let the 'Marketing Manager' fool you – Duane is a microcontroller expert who creates PCBs for his own hobby projects. Before you could say 'Max truly is magnificent,' Duane had whipped up the most amazing screw-block prototyping shield as shown in Fig.1.

This is really rather clever. The reason the shield is presented in two pieces is that the left-hand board will work on both an Arduino Uno and the left-hand half of an Arduino Mega. Meanwhile, the right-hand board can be applied to the right-hand half of an Arduino Mega.

Now, sometimes I will want a screw-block terminal to be connected directly to its associated header pin. In other cases, however, I will want to have a circuit in the prototyping area with a header pin connected to some component and its associated screw-block terminal connected to other components.



Our solution to this is really rather cunning. Consider the connectors on the upper side of the left-hand board, for example. The green 'jelly-bean' shaped graphics at the very top represent the screw block terminals facing the outside world. Next in we see the whitish area, which corresponds to the header pins that are used to connect this shield to the Arduino Mega below (also you can plug additional shields into these headers from above).

Moving 1/10 of an inch further into the board, the first row of pads are connected to their corresponding header pins, while the next row of pads are connected to the associated screw-block terminals (the next row of pads highlighted in red are connected to +5V; the corresponding row at the bottom of the board is connected to 0V). Thus, if I wish to connect a header pin to its associated screw-block terminal, I need only insert a small jumper connecting the two pads between the header and the power rail. Alternatively, I can use wires to connect these pads to components in the main prototyping area. I have to say that I'm very excited by all of this; I cannot wait for these boards to come back from the shop. Until next time, have a good one!

Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

Hard wiring and cables

IN the days of valve (vacuum tube) circuits it was the norm for the interconnections in electronic equipment to be carried by numerous pieces of wire. This approach did not work very well with semiconductor based circuits, and printed circuit boards gradually took over from the old 'hard wired' approach to building circuits. With modern electronic projects, it is normal for the majority of interconnections to be carried by copper tracks on printed circuit boards. In extreme cases, the hard wiring is totally absent, and once everything has been fitted on the circuit board the electronics are ready to go.

Spoilt for choice

Although hard wiring is much less in evidence than was once the case when building electronic projects, it remains something that is a crucial part of many electronic devices. It is certainly something that every electronic project builder needs to master. The importance of humble pieces of wire becomes apparent if you look through the relevant section of a large online electronic component catalogue. There will probably be thousands of different types, colours, and lengths to choose from, plus countless accessories associated with various kinds of wiring.

Fortunately, many of the wires and cables listed in the large catalogues are of a highly specialised nature, or are intended for general electrical use rather than the internal wiring of an electronic device. A much more limited range of wires and cables is sufficient to cover the majority of general electronic requirements, although there are still quite a few types to contend with. So why are a number of different types of cable needed for the seemingly simple task of carrying an electrical signal over, what in many cases will be very short distances?

There can be purely physical reasons for using one type of cable rather than another, but the diversity of cable types has more to do with the widely differing types of signal encountered in modern electronics. For example, a thin wire that is intended for carrying low currents will, at best, cause unwanted voltage drops if it is used with high currents. At worst it will overheat and could cause a fire. A cable that is capable of carrying very high currents can be used to carry low-level signals, but wire of this type is physically quite thick and a bit 'over the top' for general use. It is also relatively expensive. High frequency signals and low-level audio signals usually require an appropriate variety of screened cable rather than simple connecting wires. There is no universal cable that is ideal for every purpose, or even one that is a passable choice for every application.

Straightforward electrical wires fall into two main categories: the single-strand and multiple-core varieties. The single-core type has the advantage of being easily formed into complex shapes which it will retain. This makes it easy to neatly run a wire from one point to another, following any desired route. It also makes it much easier to neatly run several wires side-by-side to effectively provide a single multi-way cable.

You're nicked

Although single-core wires do have one or two advantages, it is actually the multi-core variety that is used for the hard wiring in most electronic projects. In order to avoid accidental short circuits it is normally essential to use insulated wires and the wire within is easily damaged when the plastic insulation is stripped away. The risk of the wire being nicked slightly can be minimised by using proper wire strippers that are set up correctly, but this does not guarantee absolutely perfect results every time. Unfortunately, even very minor damage tends to seriously weaken the wire at that point, possibly resulting in it breaking with any flexing of the wire.

With multi-strand wire there are typically about six to 16 very fine wires instead of one thick one. I suppose that using multi-core wire does not guarantee that the wire will be impervious to damage and breaking, but it is far less likely to occur. Even if a few strands of wire should be damaged when stripping some of the insulation, there should still be plenty of strands left intact. Ordinary connecting wire, which is also known as 'hook-up' or 'equipment' wire, is usually called something like '12/0.1 equipment wire' in component catalogues. In this example there are 12 strands of 0.1 millimetre diameter wire.

For interconnections that carry low currents it does not really matter whether the wire has six or 16 strands, and any general-purpose multi-strand equipment wire will do. However, bear in mind that these light-duty connecting wires can only handle currents up to about 0.5A (500mA). This is actually much higher than the highest currents found in most projects, but a medium-duty wire such as the popular 7/0.2 variety might be a better choice for general project wiring. Its maximum current rating of about 1.5A makes it suitable for a slightly wider range of projects. The slightly larger diameter of this wire makes it somewhat easier to use.

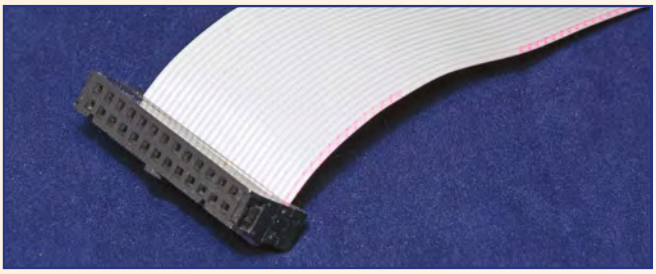


Fig.1. The finer ribbon cables, together with suitable connectors, are suitable for connecting main circuit boards to subassemblies such as display boards. This is a 26-way cable fitted with an IDC connector

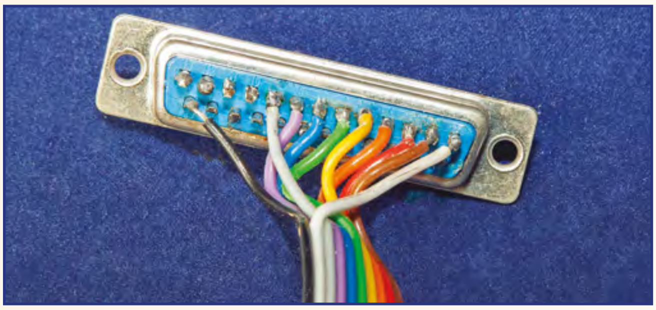


Fig.2. The heavier gauge multi-coloured ribbon cables are suitable for hard wiring where a number of interconnections are required. This is part of a cable used for experimenting with a PC's printer port

There are heavier gauge equipment wires such as the 24/0.2 type, which can safely handle currents up to about 6A. These are only needed for projects that handle high currents, such as power supply units and audio power amplifiers. Heavy-duty connecting wire is a bit unwieldy and relatively difficult to use. It can also be quite expensive. It is only worthwhile using heavy-duty wire when the currents involved are high enough to necessitate its use.

Single stranded

Single-strand equipment wire is available in various thicknesses, such as 1/0.6. In this example the '1' indicates that there is a single core, and the '0.6' gives its diameter as 0.6mm. Most component catalogues list enamelled copper wires in a range of gauges, and this is another form of single-core insulated wire. The insulation is in the form of a very thin layer of varnish or lacquer. This can be carefully scraped away using a penknife or a miniature file, and does not require wire strippers.

Enamelled copper wire has its uses, such as home-made solenoids and inductors. It is far from ideal for hard wiring because of the ease with which the insulation is damaged. The thickness of enamelled copper wire used to be given in the form of a standard or American wire gauge value, but these days it is more likely to be given simply as a diameter in millimetres. Single-strand wire is also available in the form of tinned copper wire, which lacks any insulation. It is useful for link-wires on circuit boards and probably has other uses, but is not suitable for hard wiring.

Ribbon cable

A multi-way cable can be produced by tying or taping together a number of individual insulated wires to make a cable having the required number of leads. Alternatively, a number of separate connecting wires can be used, but this can produce some rather scrappy looking results. Another alternative, and a popular one these days, is to use some form of ready-made multi-way cable. Other types of multi-way cable are available, but ribbon cable is by far the most popular choice for modern circuits. This type of cable has numerous insulated wires laid side by side and joined together to produce a flat cable that usually has upwards of 10 wires. Commercial electronic equipment often uses special ribbon cables that have metal tracks on very thin and flexible strips of plastic. These are not very durable, and do not seem to feature significantly in projects for the home-constructor.

There are two types of ribbon cable that are used in electronic projects, and one of these is specifically designed for use with solderless computer connectors (Fig.1). Mostly, this type of cable is grey in colour apart from some red markings on a lead at one edge, and it has the wires on a 0.05-inch pitch to match the spacing of the terminals on the connectors. The convention is for the red lead to connect to pin 1 on one connector to the corresponding pin of the other connector. This type of ribbon cable can be used for conventional hard wiring, but it is difficult to use and there are better alternatives. It works well when used for something like connecting a main circuit board to a display board, with the two boards and the cable fitted with suitable connectors.

The other type of ribbon cable is basically the same, but its slightly larger size and heavier build makes it easier to use for conventional hard wiring. Also, the wires have the plastic insulation in different colours so that each wire is easily distinguished from its neighbours (Fig.2). It is usually sold in 10- and 20-way varieties, but peeling off a strip having the required number of wires is very easy.

There is a potential problem with ribbon cable, or any other simple form of multi-way cable for that matter. This includes multi-way cables made up from individual wires. Capacitance between the wires can result in signals being coupled from one wire to another, or 'crosstalk' as it is sometimes termed. Although the capacitance values involved are quite small, the unwanted signal coupling can be sufficient to prevent circuits from working properly. It is particularly troublesome with high frequency signals, and logic signals that switch very rapidly from one logic level to the other. There can also be problems with low frequency circuits if the wiring produces small but significant amounts of capacitance between the output and input of the circuit. This produces feedback that can give problems with stability, and can even send the circuit into oscillation.

Where appropriate, the notes on construction should give warnings of potential problems with feedback or crosstalk, together with suitable solutions. A common ploy is to have every other lead connected to the equipment's earth rail. These leads act as screens between the leads that actually carry the signals and greatly reduce any cross coupling.

Screened leads

A screened cable has a normal insulated wire at its core, but this is covered by some form of metal screen. In the case of a 'lapped' screen there are a number of fine wires that are wrapped around the insulation of the inner wire. The lower cable in Fig.3 is a lapped type with a section of the screen un-lapped. Some screened cables are more complex than this, with the wires woven into a braiding, as in the middle cable of Fig.3. The upper cable of Fig.3 shows another variation, with aluminium foil providing the screen. There are some fine copper wires running the length of the cable beneath the foil screen. With all the screened cables an overall plastic sheath protects the screen and holds everything together.

Using a screened cable might seem like a major case of doing things the hard way, but the basic idea is to have the screen carry the earth connection so that it acts as a barrier between the inner wire and the outside world. Electrical noise is prevented from reaching the inner conductor, and the screen will also prevent any signals from being radiated by the inner wire. Screened leads are mainly used for such things as the external wiring in audio systems, televisions aerial leads, video cables, etc. You are therefore more likely to encounter them when making something like a hi-fi connecting cable than when building an electronic project. However, there are some projects that require internal screened cables. For instance, they can be used to prevent problems with feedback, or in order to screen sensitive leads from the mains 'hum' signal produced by an internal power supply.

Audio screened cables are available in single and dual varieties, with the latter being intended for stereo use. There are two types of stereo screened cables, with one having the two inner conductors in a common screen, and the other consisting of two separate screened cables having a common overall plastic sheath. Having separate screens helps to minimise crosstalk between the stereo channels, especially where long cables are involved. For short lengths of internal wiring there is probably no noticeable difference in the performance of the two types.

It is perhaps worth pointing out that some projects, and particularly audio types, often have metal cases that are earthed to one of the supply rails. This is usually done in order to screen sensitive parts of the circuit from 'hum' and other electrical noise in the outside world. Using a plastic or other non-metallic case for this type of project could produce a major reduction in the project's performance.

Special screened cables are also needed for use at high frequencies. In essence, these are much the same as ordinary screened cables, but in general they are much thicker. They are often called 'coaxial' or 'coax' cables in component catalogues, although strictly speaking, practically all screened cables are coaxial types. A radio frequency cable is designed to operate with a certain source and load impedance, which is often 50Ω or 75Ω. The middle cable in Fig.3 is a 75Ω coaxial cable. Using a cable of the wrong impedance is unlikely to give good results. Connectors used with coaxial cables should be of a type specifically designed for use with that type of cable.

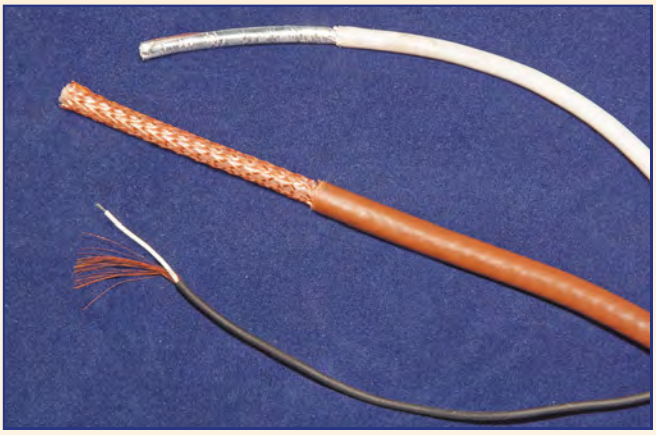


Fig.3. From top to bottom: a coaxial cable having an aluminium foil screen, a coaxial cable with a braided screen, and a lapped audio cable. The cable with the foil screen also has some fine wires running under the screen

Stripped for action

The first task when preparing the end of a screened cable is to remove a piece of the outer sheath. Audio cables are relatively thin and this can usually be achieved using ordinary wire strippers. There are special heavy-duty wire strippers for use with the thicker coaxial cables. A simple alternative is to make cuts on opposite sides of the sheath so that it can be peeled back and trimmed. A sharp modelling knife is required, and due care should be exercised when making the cuts. With any method of removing the outer sheath, try to avoid significantly damaging any of the fine wires in the screen.

With lapped cables, the wires in the screen can be twisted together to form a short lead, which is then tinned with solder to prevent the wires from splaying. To complete the job, wire strippers are used to remove a short piece of insulation from the inner conductor and the end of the wire is then tinned with solder. Fig.4 (top) shows a lapped cable that has been prepared in this way.

It is possible to use essentially the same method with braided cables, where the wires in the braiding can be easily separated and formed into a single wire. This will not always be the case though. The standard approach with awkward screened cables is to remove a generous amount of the outer sheath, and then tease apart the wires in the braiding to produce a gap close to the end of the sheath. The inner conductor and its insulating sleeving are then pulled down and out through the gap in the braiding. The latter can then be squeezed and twisted to form a leads that is then tinned with solder to keep everything in place (Fig.4 bottom).

This method is not practical with some of the thicker coaxial cables, including many of the 50Ω types. The problem is that these cables are very thick and the inner conductor and its sleeving lack the necessary flexibility. Cutting along the exposed screen and peeling it back should provide a solution to the problem. As explained previously, some coaxial cables have an aluminium foil screen plus some fine copper wires. Presumably this is a cheap way of obtaining excellent screening properties, but the aluminium foil lacks durability and cannot be used with ordinary electrical solders. Anyway, with cables of this type any exposed foil is simply torn off so that it cannot produce any accidental short circuits. Connections to the screen are then made via the copper wires.

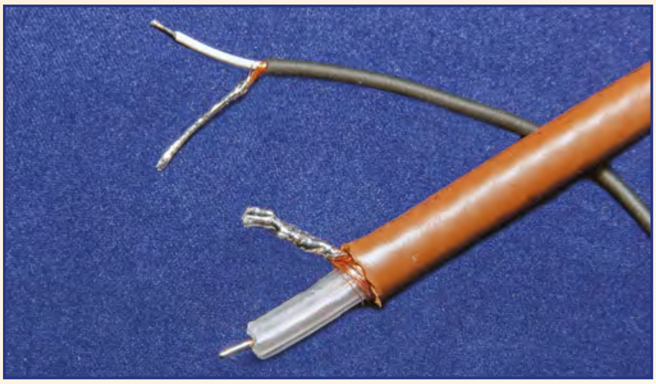


Fig.4. Two screened cables that have been prepared and are ready for connection. The upper one is a lapped audio cable and the lower one is a braided coaxial cable

EPE PIC PROJECTS VOLUME 1 CD-ROM

ONLY £14.75
INCLUDING VAT and P&P

A plethora of 20 'hand-PICked' PIC Projects from selected past issues of *EPE*

Together with the PIC programming software for each project plus bonus articles

The projects are:

PIC-Based Ultrasonic Tape Measure
You've got it taped if you PIC this ultrasonic distance measuring calculator

EPE Mind PICkler
Want seven ways to relax? Try our PIC-controlled mind machine!

PIC MIDI Sustain Pedal
Add sustain and glissando to your MIDI line-up with this inexpensive PIC-controlled effects unit

PIC-based MIDI Handbells
Ring out thy bells with merry tolling – plus a MIDI PIC-up, of course!

EPE Mood PICker
Oh for a good night's sleep! Insomniacs rejoice – your wakeful nights could soon be over with this mini-micro under the pillow!

PIC Micro-Probe
A hardware tool to help debug your PIC software

PIC Video Cleaner
Improving video viewing on poorly maintained TVs and VCRs

PIC Graphics LCD Scope
A PIC and graphics LCD signal monitor for your workshop

PIC to Printer Interface
How to use dot-matrix printers as data loggers with PIC microcontrollers

PIC Polywhatsit
A novel compendium of musical effects to delight the creative musician

PIC Magick Musick
Conjure music from thin air at the mere untouching gesture of a fingertip

PIC Mini-Enigma
Share encrypted messages with your friends — true spymaster entertainment

PIC Virus Zapper
Can disease be cured electronically? Investigate this controversial subject for yourself

PIC Controlled Intruder Alarm
A sophisticated multi-zone intruder detection system that offers a variety of monitoring facilities

PIC Big-Digit Display
Control the giant ex-British Rail platform clock 7-segment digits that are now available on the surplus market

PIC Freezer Alarm
How to prevent your food from defrosting unexpectedly

PIC World Clock
Graphically displays world map, calendar, clock and global time-zone data

PICAXE Projects
A 3-part series using PICAXE devices – PIC microcontrollers that do not need specialist knowledge or programming equipment

PIC-based Tuning Fork and Metronome
Thrill everyone by at long last getting your instrument properly tuned!

Versatile PIC Flasher
An attractive display to enhance your Christmas decorations or your child's ceiling

NOTE: The PDF files on this CD-ROM are suitable to use on any PC with a CD-ROM drive. They require Adobe Acrobat Reader – included on the CD-ROM

EPE PIC PROJECTS CD-ROM ORDER FORM

Please send me .... (quantity)

***EPE* PIC PROJECTS VOL 1 CD-ROM**

Price £14.75 each – includes postage to anywhere in the world.

Name ....

Address ....

....

....

.... Post Code ....

☐ I enclose cheque/P.O./bank draft to the value of £ ....

☐ please charge my Visa/Mastercard/Maestro £ ....

Card No. ....

Card Security Code ....
(The last 3 digits on or just under the signature strip)

Valid From .... Expiry Date ....

Maestro Issue No. ....

SEND TO:
Everyday Practical Electronics,
Wimborne Publishing Ltd.,
113 Lynwood Drive, Merley, Wimborne,
Dorset BH21 1UU.
Tel: 01202 880299. Fax: 01202 843233.
Email: orders@epemag.wimborne.co.uk

Payments must be by card or in £ Sterling – cheque or bank draft drawn on a UK bank.

Normally posted within seven days of receipt of order. Send a copy of this form, or order by letter if you do not wish to cut your issue.

Order on-line from
www.epemag.com
or by Phone, Fax, Email or Post.

BECOME A PIC PROJECT BUILDER WITH THE HELP OF *EPE!*

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Kitchen timer software design

WE continue this month with the software design for a kitchen timer, based on the PIC18 prototyping board that we have been developing over the last few articles. Although a kitchen timer is not a particularly exciting design, it does show how the board can be used to quickly create projects with a minimum of fuss and stress.

To recap, the kitchen timer will have a 2 × 16 character LCD display and two push buttons for the user interface, a piezo buzzer to signal the timer expiry and an LED (on the development board itself) to flash while the timer is running. The circuit is shown in Fig.1.

First task

Start by copying the template project files (available on the *EPE* website: **www.epemag.com**) to a new directory, say c:\kitchen1. Now open the project by double clicking on the **PIC18F27J13-Template.mcw** file in the new directory. In the project dialog window (as shown in Fig.2.) right-click on the project name, **PIC18F27J13-Template.mcp**, and select 'Save-As'. Give it a name such as **kitchen.mcp** and save it, making sure that the destination directory is your chosen one – the save dialog may default to your original directory.

This will rename both the project *and* the workspace itself, so you can now delete the files **PIC18F27J13-Template.mcw**, **PIC18F27J13-Template.mcs** and **PIC18F27J13-Template.mcp** from your new directory.

To confirm that we have not accidentally deleted a file during this copy and rename process, we do a clean build of the project by clicking on 'Project' on the main menu, followed by 'Build All'. If this is the first time you have built the code after downloading it from the magazine website you will probably be presented with a warning message at this point, indicating that there is a 'Tool-Location Discrepancy'. The project workspace file 'remembers' the directory in which the assembler and linker programs are located. Naturally, your PC is probably configured slightly differently to ours, and so you must tell MPLAB where the programs are located. Simply click the button beside the 'MPLAB IDE' entry, and the build will carry on. After a few seconds you will see the message 'BUILD SUCCEEDED' in the output dialog window.

You can quickly download this onto the development board, as shown in Fig.3, to verify that the on-board LED flashes. Note that you do not need to power the development board separately as the PICKIT has enough spare power output.

Programming in MPLAB

To program the processor within MPLAB, connect the development board directly to your Microchip programming interface and then select 'Programmer' from the main menu, 'Select Programmer' and then click on the device you are using (we are using a PICKIT3).

Now click on 'Programmer' again, followed by 'Settings'. On the Power tab, set the Voltage to 3.5V and tick the 'Power Target circuit from ...' box. On clicking OK, the Output dialog window in MPLAB should indicate that the processor has been found. You can now go back and select

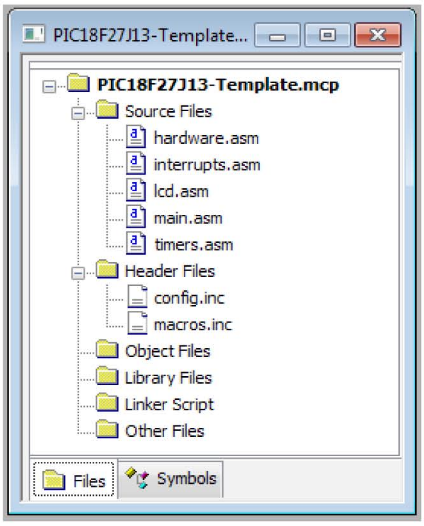


Fig.2. MPLAB project dialog window

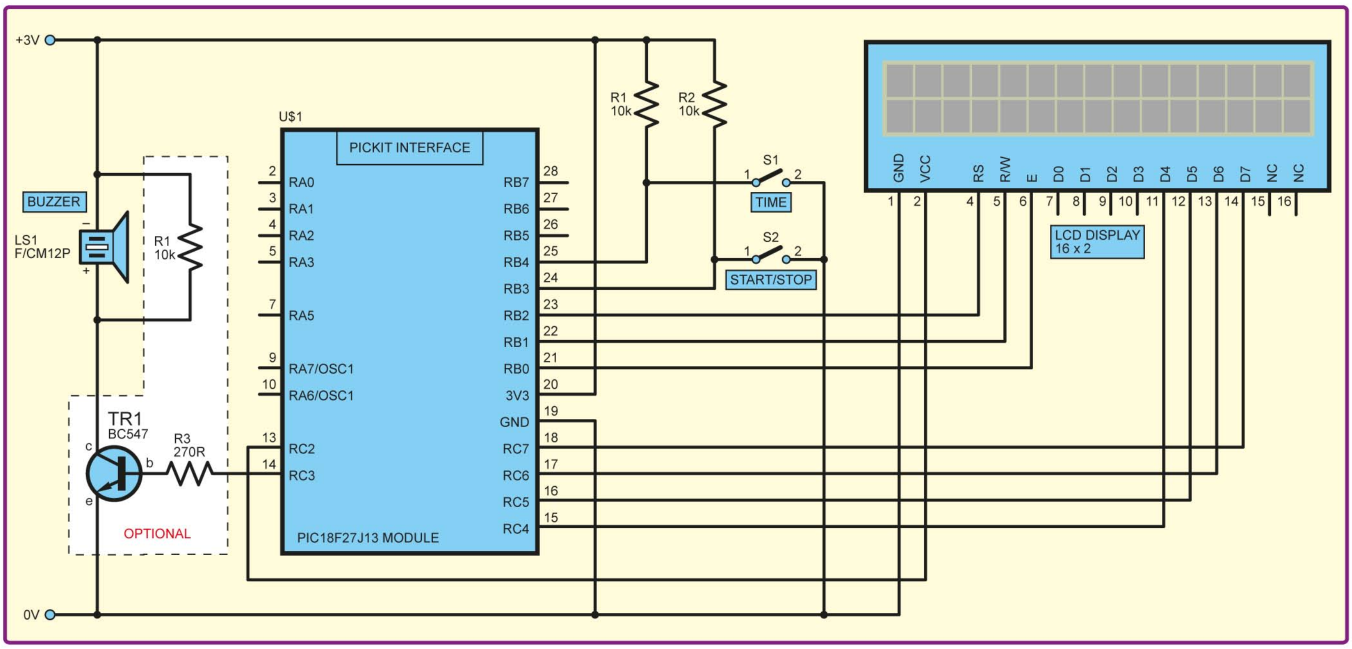


Fig. 1. Kitchen timer circuit (very similar to Fig.3. from February 2014 *article – I made just one change, the VCC pin on the LCD)*

‘Programmer’ followed by ‘Program’. The program will be downloaded, and then the RESET pin will be de-asserted, and the board should start running your code. Even in this minimalist configuration with no additional components connected to our board you can still debug your code too if you wish, although there isn’t much point. When you tire of watching the LED flash you can disconnect the development board from the programming interface by simply separating the two.

Fig.3. Running the board from the PICKIT3 – no wires required!

Bringing it together

The next step is to wire up the circuit on a prototyping PCB (as shown in Fig.4.) so we can start adding components for the buttons and the buzzer. As we don’t know at this stage whether we need a transistor driver for our buzzer, the prototyping board simplifies the ‘experimentation’ phase of the circuit design. We prefer to leave the soldering iron switched off until we are happy that the design is reasonably sound.

You may have noticed that in the template source code we have the LCD connected to pins PORTA0,A1,A2 and the lower four bits of PORTB.

The wiring for the kitchen timer circuit shown in Fig.1. is different, in part so that we have the LCD and keys all lined up on one side of the board, but also to demonstrate how simple it is to move peripherals from one set of pins to another.

With the prototype board wired to match our circuit, it’s time to write some code. Or rather, time to start modifying the code we already have. We start by changing the definition of the pins that the LCD connects to. The changes are minimal: six EQU statements change, indicating which pins are now used, and because the four data signals are now driven by the *upper* 4 bits of an I/O port rather than the *lower* four bits, there are minor changes to the writeNibble function and LCDInit. You can see the changes, all confined to **lcd.asm**, in the source code available from the magazine website. It takes a few minutes to make the changes, download the application and verify that the LCD still works. The circuit can still run from the PICKIT3 power, as the LCD does not draw much current. On a more power-hungry circuit you should have the board’s normal power supply connected.

You may want to take some time to compare the differences between the kitchen timer application and the template source files, all of which are available for download on the *EPE* website. An excellent (and free) tool for comparing files is ‘Winmerge’, found at the website **winmerge.org**. An excellent tool to keep in your software toolbox!

Making a sound

There are two remaining bits of functionality that we must add before we can tie everything together with a nice user interface: making the buzzer sound, and detecting button presses.

We are using a piezo buzzer in this design. Piezo buzzers require an alternating signal to be applied to them (typically a square wave driven from a digital output pin) and will have a distinct peak sound output at a particular frequency, called its resonant frequency. The part we used has a resonant frequency of 4kHz, which corresponds to a toggle rate of 125µs.

We have several options for generating this signal on an I/O pin: bit-bashing (where the timing of the signal is based on the number of instructions executed), using a timer coupled to an interrupt service routine or by using the pulse-width modulation feature of the capture/compare peripheral.

Bit-bashing is very processor intensive and is only really used as a last resort; it would make the rest of the software design difficult and unwealdly. Using a timer is not a *bad* idea in this case, but will end up consuming about 1% of the available processor power. The pulse-width modulation (PWM) feature is the *perfect* solution, as once set up it runs with no CPU involvement at all, only requiring the RC oscillator to be running.

Setting up the PWM is a little tricky. There are three steps involved, and the datasheet is not completely clear on how it is done. First, the PWM output signal must be connected to a pin – the output is one of the processor’s re-mappable signals. We put it onto the PORTC.3 pin. Next, we have to configure Timer2 to have a period (determined by use of the PR2 period register and the divide-by-16 prescaler) of 250µs. Finally, we have to configure the capture/compare module to toggle at 125µs (ie, half of 4kHz). It took several attempts to get right and half an hour puzzling over the datasheet.

The final code has been placed in the **hardware.asm** module. Once set up in the hardwareInit function we turn the buzzer on and off by setting and clearing the PWM module enable bit. We will leave this code in the template, not because it is going to be frequently used, but because it was so difficult to set up in the first place!

Buttons

In some respects, handling button presses is harder than driving LCD displays. LCDs are generally well-behaved electronic devices, while buttons are nasty mechanical devices that get pressed in peculiar ways. A button does not go cleanly from one state to another, but progresses through a noisy period that can last for several tens of milliseconds. There isn’t much you can do about it; low value pull-up resistors, around the 470Ω mark, will reduce the duration of the noise but will not eliminate it. You have no choice other than to *debounce* the signal, which means delaying for a *debounce period*,

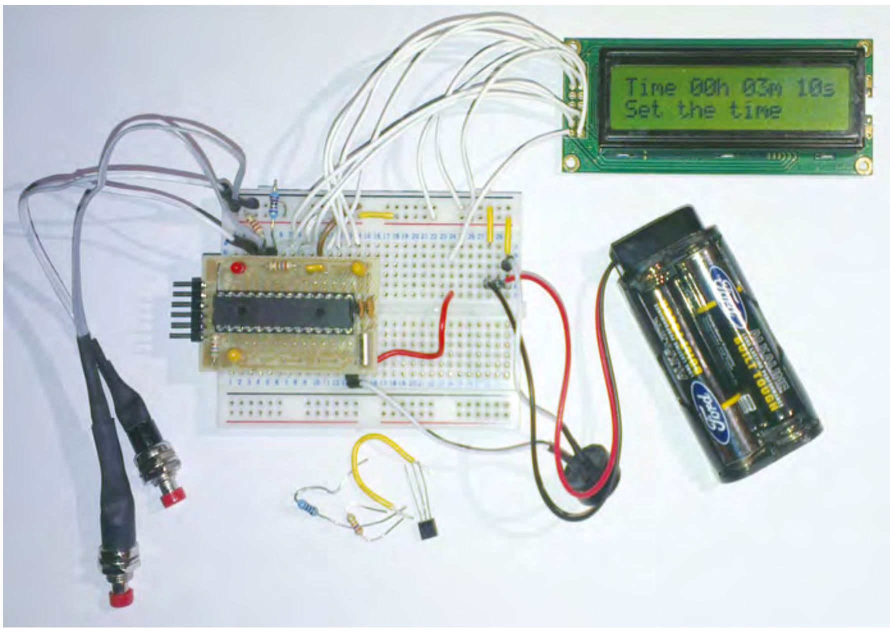


Fig.4. Prototype board setup

typically 20ms to 50ms, and checking the signal again. If the state is the same as it was previously, you accept that value. If it is different, you repeat the test again after another debounce period has elapsed, and repeat until the level is stable.

There are two ways to achieve this effect – in a tight code loop or via an interrupt routine called by a timer. There is an obvious danger with doing it in a tight loop, in that the code may never exit (unlikely, but it could potentially take several seconds if someone is messing with the buttons) and so this technique *might* mess up other parts of the software. Interrupt routine polling is better – you set a flag visible to the main code when a key press is detected – but is, obviously, a bit harder to get working initially.

Sometimes, a simple tight loop implementation is fine, and the potentially long delays caused by polling the keys is not a problem. This little project is one such example, as the timing critical stuff (flashing the LED, counting down the time, buzzing the sounder) are all handled elsewhere away from the main code loop. We have implemented two functions for each button; one to wait for the key to be released, and the other to return the current state of the button. It's important to detect both the press and the release, as otherwise you will find the software reading multiple key presses.

Key processing is simple, and project specific, so we have not included the code we have written back into the template.

Connecting the buttons to the external interrupt pins (which in our application are free, as we are not using them) would add a considerable benefit – it would enable us to switch the oscillator off and place the processor into a deep power down state. This would eliminate the need for a physical on/off switch, as the current consumption would be negligible. We will return to this idea next month when we recreate the application in the 'C' programming language.

User interface

With the lower level code having been created or modified from the template, the completion of the project becomes a straightforward programming activity, gluing the lower level code together. Although it is good practice to split an applications functionality into several files, this project is small enough and simple enough that we could keep it all within the main application file **kitchen.asm**.

The user interface is simple: a key press will start the program, then the TIME button can be used to increment the timer, and the START button will move from seconds, to minutes, to hours and then on the next press start the timer.

At this point, the timer will display the countdown of the time in hours, minutes and seconds. Either button will stop the alarm, and turn it off. When the timer reaches zero, the buzzer will sound, until a button is pressed.

The LED will flash every two seconds while the timer is running.

The periodic decrementing of the time is done in the interrupt routine, as the code to do this is minimal. It would be perfectly acceptable to simply set a flag to indicate 'decrement the timer' and let the foreground task handle the work. Which is exactly what we do for updating the display – writing to the LCD takes a lot of time, relatively, and so it is better to do this in the main code loop.

Writing the timer handling code – the increment and decrement code – was painfully boring. There is no value in creating tight, small, fast code for this part of the design and so the effort involved in writing this in assembly language was not really rewarding. This is where programming in a higher level language can be a joy.

Wrapping it all up

Creating the kitchen timer took a few evenings effort; creating the template code, non-functional though it is, took four times as long – much of it procrastinating over nuances of the processor, trying ideas out and puzzling over why things did not work. This was a fairly clear validation of the whole template code idea in the first place.

It's also important to evaluate any newly written piece of software and decide whether it is generic enough and useful enough to go into the template code. The only thing worse than writing boring code, is writing the same boring code again!

Some things did not work out as expected; the transistor driver to the buzzer was found to be unnecessary, but then that is the point of using prototyping boards before committing to PCB design (or gluing the components in place, as we did).

Next month

Next month, we will start our move away from assembly language programming and into the higher level programming language, C, creating a new template project file set. We will take a look at some other useful template features, such as serial interfaces, and look at how serial-to-Bluetooth adaptors may change the way we control and exchange data with our embedded projects.

MOSFET basics – Part 1

RECENTLY there has been a thread on *EPE Chat Zone* discussing power MOSFETS. This was prompted by ***dave_g*** pointing out the usefulness of International Rectifier's Application Note AN-937 'Gate Drive Characteristics and Requirements for HEXFET Power MOSFETs'. It was pointed out that power MOSFET gate driving has also been discussed in *Circuit Surgery* (Jan 2007). Later, ***basementboy*** made an appeal for a basic guide to FETs.

'Is there a quick and dirty FET guide? For example, *NPN* transistors are readily turned on with a small +ve current WRT E and conduct C to E. For a small transistor up to say 24V, a 1k is fine to turn it on. Connect the base to the supply and you no longer own a transistor. What would be the equivalent for a FET, and what must be avoided?'

Power MOSFET drive is a relatively advanced topic and although the aforementioned application note starts with a quick overview, it is really aimed at designers who are already familiar with the basics. So this month we will look at the basic theory of MOSFET operation, for MOSFETs in general, rather than specifically for power devices. The following may not be 'quick and dirty', but hopefully it will provide some insight into the basics of MOSFETs.

MOSFET layout

The MOSFET is a semiconductor device which has three main connections – the gate (G), source (S) and drain (D). For those familiar with bipolar transistors, these correspond roughly with base, emitter and collector. Strictly speaking, the MOSFET actually has four terminals – the fourth is the substrate or bulk (B) semiconductor in which the device is formed. In many cases (particularly discrete devices) the bulk and source are shorted within the fabricated structure of the device, so there are only three external connections. Like the two types of bipolar transistor (*NPN* and *PNP*) there are two types of MOSFET – *N*-channel and *P*-channel, often referred to as NMOS and PMOS transistors, or simply *N* and *P* transistors.

Enhancement and depletion modes

The term 'channel' refers to the conducting channel between source and drain, which as we will see is a key feature of MOSFET operation. This channel is most commonly created by the action of the applied voltages, in which case the MOSFET is called an enhancement-mode device. It is also possible to build the channel in which the MOSFET is fabricated, so applying appropriate voltages can remove it. This is called a depletion-mode MOSFET.

Holes and electrons

The, *N* and *P* in NMOS and PMOS (and *NPN* and *PNP*) refer to the type of chemical used to 'dope' pure silicon to create interesting semiconductor behaviour. N-type silicon has more electrons free to take place in electrical conduction than in pure silicon. P-type has fewer electrons than pure silicon, but these gaps can he regarded as mobile 'holes' which act as positive charge carriers and allow electrical conduction. Placing an *N* region next to a *P* region creates a *PN* junction, also known as a diode junction, through which current will usually flow in only one direction.

If a sufficiently positive voltage is applied to a diode junctions' *P* side (called the anode) with respect to the *N* side (cathode) a current will flow. This is indicated by the arrow direction in the diode's schematic symbol (*P* to *N*). Holes can flow from the *P* to *N* side and electrons from the *N* to *P* side. Electrons move in the opposite direction to that which we designate as current flow, despite the fact that most electrical circuits are connected using metal conductors, in which conduction takes place due to electron movement. This is known as conventional current. Historically, the convention of current being defined as flowing from positive to negative was agreed before the discovery of conduction by electrons.

When a *PN* junction is formed, electrons from the *N* side move into the *P* side and holes from the *P* side move into the *N* side. They combine (effectively cancel on another out) to create a region close to the junction without any free mobile charge carriers. This is known as a depletion region. A diode conducts in forward bias when sufficient voltage has been applied to remove the depletion region. Reverse bias makes the depletion region larger. Depletion regions are important in MOSFET operation too, as we will see later.

Symbols

A number of versions of the MOSFET schematic symbol are in use (see Fig.1 and Fig.2). The full symbol shows the bulk as a separate connection, however, as mentioned, the bulk is often connected to the

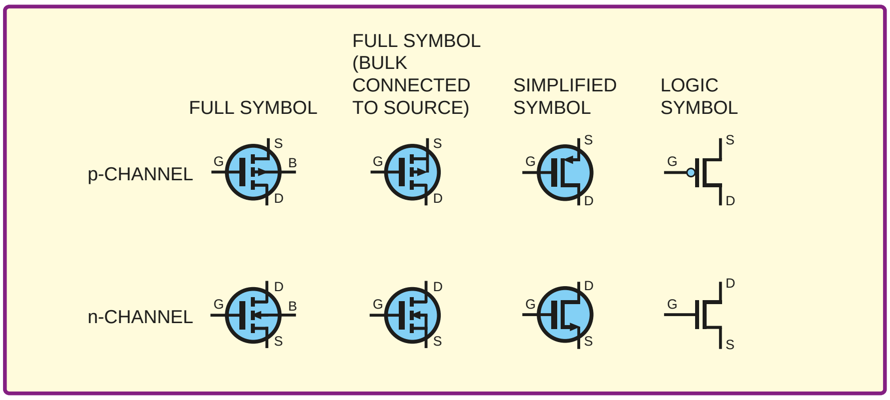


Fig.1. Enhancement-mode MOSFET symbols

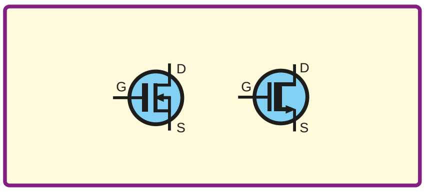


Fig.2. Example depletion-mode N-channel MOSFET symbols. Continuous or thicker 'channel' lines are used to indicate depletion mode (compare with Fig.1)

source, which may be shown in the symbol, or implied in the simplified symbol in which the bulk connection is not shown. For logic schematics (eg, internal schematics of logic gate circuits), a logic version of the MOSFET symbol is often used in which the PMOS transistor is indicated by an 'inversion bubble' to represent the fact that its switching behaviour is logically opposite to that of the *N* device.

MOSFET structure

MOSFET is an acronym for Metal Oxide Semiconductor Field Effect Transistor. MOS refers to the basic structure of the device, which comprises three layers: a conducting gate (Metal), a thin insulating layer (Oxide – specifically silicon dioxide) and a conducting channel (Semiconductor). The voltage on the gate controls current flow through the channel, whose ends are connected to the device's source and drain terminals. The gate insulation means that it is the electric field produced by the gate voltage, rather than gate current, which controls the channel current – hence the name Field-Effect Transistor. Despite the name, the 'metal' layer does not have to be made of metal; it can also be a semiconductor, which is common for MOSFETs in integrated circuits.

The MOS, structure which is of the form conductor/insulator/conductor is like that of a capacitor. Therefore the gate of a MOSFET behaves like a capacitor. Changing the gate voltage requires current flow to charge or discharge the capacitance. For large power MOSFETS this current can be very significant and was one of the aspects of the *Chat Zone* thread and earlier *EPE* article. If the gate voltage is constant there is (ideally) no gate current.

The MOSFET can be operated in a number of ways depending on the relative voltages on its terminals. The most basic modes are listed below and will then be explained in more detail in terms of the device structure and physics.

MOSFET switching

As an on/off switch. The gate voltage is used to switch the channel (and hence the connection between source and drain) between highly conducting and non-conducting states. This is used in digital circuits, high power MOSFET switches (as mentioned above), and for switching/routing both analogue and digital signals.

Current source

As a voltage-controlled current source, the gate voltage sets the source to drain current irrespective of the drain source voltage. This is used in most linear circuit applications, such as amplifiers.

Voltage-controlled resistor

As a voltage-controlled resistor. The resistance between the source and drain is controlled by the gate voltage. A MOSFET can be used as a fixed or voltage controlled resistor in some circuits.

MOSFET switching operation

Fig.3 shows a simplified cross-section of an enhancement-mode *N*-channel MOSFET in which we can see the four terminals: source, drain, gate and bulk. As can be seen, the structure is symmetrical. In the usual approach to MOSFET theory, designation of which terminal is source and which is drain depends on the applied voltages (which means they can swap round in some circuits). For an *N*-channel device, current flows from drain to source, with the drain more positive than the source. Understanding that conduction actually occurs due to electrons moving from source to drain (opposite to conventional current) makes the terminal names make more sense. In comparison, for a *P*-channel device, conduction is by holes flowing from source to drain, so current is also from source to drain. The source is more positive than the drain for a *P*-channel MOSFET. In both cases the charge carriers flow from source to drain. Note that a discrete MOSFET with source and bulk connected internally is not full symmetrical externally.

Referring again to Fig.3, if we apply zero, low or negative gate-source voltage the device is off because the source-bulk-drain *N-P-N* regions act a bit like two back-to-back diodes – which will not conduct in either direction. Thus the conducting channel does not exist and no current flow occurs between source and drain if a voltage is applied across them. This situation is referred to as the cut-off region of operation of a MOSFET. We can have a large voltage applied between drain and source but no current flow between them, although in practice there will be some leakage current. The maximum drain-source voltage will depend on the point at which it undergoes some form of electrical breakdown.

If we apply a positive gate-source voltage to the *N*-channel MOSFET, this will attract (negatively charged) electrons from the nearby silicon to the *P*-type region just under the gate. The higher the voltage the greater the density of electrons just under the gate. If the voltage is high enough, and hence the electron density is sufficient, the region will behave as if it is *N*-type silicon instead of its native *P*-type. At this point, we will have created an *N*-type channel connecting the *N*-type drain and source regions, thus we have an *N-N-N* path from source to drain (see Fig.4). Conduction can now take place from source to drain. The transistor is on and the gate-source voltage at which this occurs is called the **threshold voltage**, V_T.

In the scenario in Fig.4 we assume that the source-drain voltage is very small – this is consistent with an on switch – we would expect and hope the voltage drop across a switch to be zero. In practice, the source-channel-drain path has some electrical resistance (referred to as $R_{DS,ON}$) so some voltage drop occurs and power is dissipated by the device. The maximum current which can flow between drain and source is limited by the power handling capacity of the device. For operation as a switch, we may have a gate voltage well above

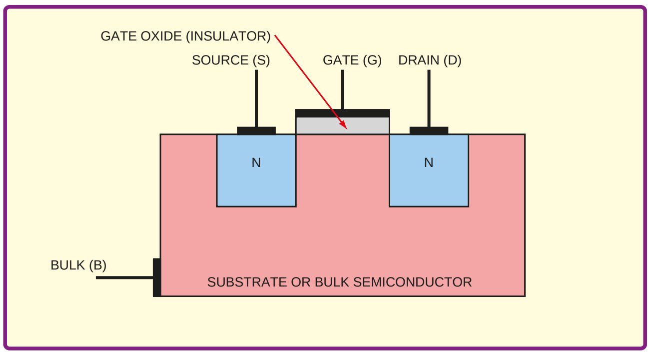


Fig.3. Cross section of N-Channel MOSFET with device off. The MOSFET acts as off switch between source and drain. The voltage on the gate is small or negative with respect to the source and bulk. The drain source voltage may be large

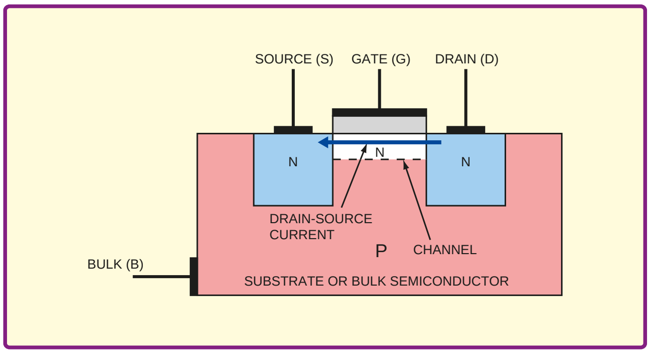


Fig.4. Cross section of N-Channel MOSFET with the device on. A positive voltage, greater than the threshold voltage, has been applied to the gate. The MOSFET acts as on switch between source and drain. We assume the drain-source voltage is small

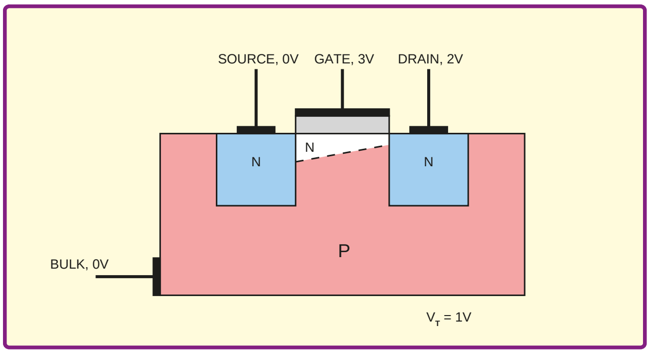


Fig.5. Cross-section of N-Channel MOSFET with significant V_{DS} but with V_{DS} less than (V_{GS}–V_T). This is the linear region of operation

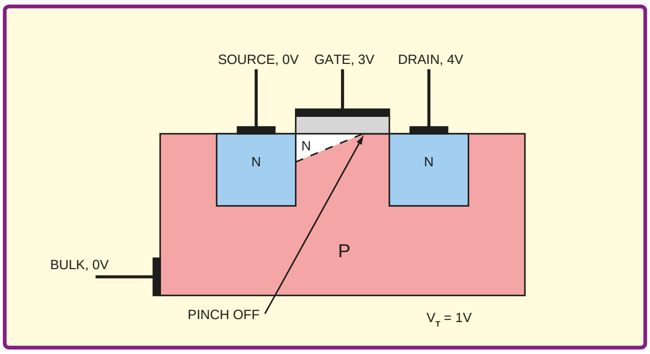


Fig.6. Cross-section of N-Channel MOSFET with V_{DS} greater than (V_{GS}–V_T). This is the saturation region of operation

the threshold voltage to make sure the device is fully on. The maximum voltage between the gate and channel is determined by the electrical field strength at which the gate oxide breaks down.

Linear operation

This preceding description may be sufficient if all we need is a digital gate or on/off power control – we can select conducting or non-conducting by switching the gate between two appropriate voltages. For linear circuits we need to know a little more detail.

The creation of the conducting channel requires the gate-to-channel voltage to be larger than the threshold voltage. Assuming the bulk is at 0V, if both the source and drain are at 0V the situation is simple – the gate voltage creates a uniform channel between source and drain, but this of little use since there will be no current through the device. If a voltage (V_{DS}) is also applied between source and drain (the usual situation in a linear circuit) then the voltage difference between the gate and channel varies as we move along the channel from source to drain.

Imagine that we have applied sufficient gate voltage to create the conducting channel ($V_{GS} > V_T$) and that bulk, source and drain voltages are all 0V. For example, assume that V_T is 1V and that we have 3V on the gate. We now increase the drain voltage, keeping the other voltage the same. If the drain voltage is 1V (see Fig.5) then the gate-to-channel voltage will be 3V at the source end, but only 2V at the drain end, varying linearly along the channel. The conductivity of the channel at any point depends on how far above the threshold voltage the gate-to-substrate voltage is at that location (ie, the value of $V_{Gate\text{-}Substrate} - V_T$). In this example the gate-to-channel voltage is greater than V_T along the whole channel, with $V_{Gate\text{-}Substrate} - V_T$ being 2V at the source end and 1V at the drain. This is depicted in Fig.5 by showing the channel diminishing along its length.

A detailed analysis of the MOSFET will determine conductivity of the channel in terms of device dimensions, charge distribution and properties of the semiconductor (particularly carrier mobility), employing calculus to integrate the appropriate equation along the channel.

For a very rough analysis, we can simply use the fact that channel conductivity is proportional to $V_{Gate\text{-}Substrate} - V_T$ and note that it varies from V_{GS}–V_T at the gate end to V_{GD}–V_T at the drain end. We would like all voltages referred to the source; we can use $V_{GD} = V_{GS}$–V_{DS} so that the channel voltage at the drain end can be expressed as V_{GS}–V_{DS}–V_T. We then simply assume that the conductivity of the channel is proportional to the average at the two ends, that is:

$$\frac{(V_{GS}-V_T)+(V_{GS}-V_{DS}-V_T)}{2}$$

which can be tidied up to give:

$$(V_{GS}-V_T)-\frac{V_{DS}}{2}$$

The drain-source current (I_{DS}) is proportional to the channel conductivity and the applied voltage (V_{DS}), so we multiply the above by V_{DS} to get a value proportional to I_{DS}. The constant of proportionality is a referred to as the gain factor of the transistor and often given the symbol β. Thus, for a situation like that shown in Fig.5, the drain current is given by:

$$I_{DS}=\beta\left[(V_{GS}-V_T)V_{DS}-\frac{V_{DS}^2}{2}\right]$$

In this region of operation the MOSFET behaves like a non-linear resistor (note the V_{DS} squared in the equation). For very small values of V_{DS} the squared term in the equation has little influence and the resistance of the MOSFET is more or less inversely proportional to ($V_{GS} - V_T$); so the device acts as resistor whose value is set by the gate voltage. This region of operation of the MOSFET has several names: **linear**, **ohmic** and **triode**.

Saturation operation

When V_{DS} is increased beyond the point at which it is equal to ($V_{GS} - V_T$) the gate-to-channel voltage at the drain end will be less than the threshold voltage. The channel will not extend the full length from source to drain and is said to be pinched off (see Fig.6). This does not stop drain-source conduction, but causes saturation of the drain current – further increases in V_{DS} above ($V_{GS} - V_T$) do not increase I_{DS}. This is referred to as the **saturation** region of MOSFET operation.

In Fig.6, the drain is at 4V so gate-to-substrate voltage varies from 3V at the source end to –1V at the drain end. The pinch off point occurs where the difference between the gate and channel voltage is V_T. V_T is 1V in this case, so the channel voltage is 2V (with respect to the grounded source) at the pinch off point.

An obvious question is why does conduction occur when the channel does not reach the drain? The answer is that the zone between the end of the channel and the drain is a depletion region. This does not contain any free charge carriers, but conduction can occur with charge carriers from elsewhere. This is what happens; the electrons from the channel move through the depletion region and are swept towards the drain under the influence of the electric field from the drain

The conductivity of the channel (and hence drain source current) can be argued using the same very rough approach as before. $V_{Gate\text{-}Substrate} - V_T$ is still V_{GS}–V_T at the source end, but is zero at the point where pinch off occurs, so average conductivity of the channel is:

$$\frac{(V_{GS}-V_T)+0}{2}=\frac{(V_{GS}-V_T)}{2}$$

The current in the channel is proportional to the conductivity times the voltage across the channel (from pinch-off point to source). This voltage is V_{GS}–V_T because by definition the $V_{Gate\text{-}Substrate}$ voltage is equal to V_T at the pinch-off point, so the end of the channel is at V_T below the gate voltage. The constant of proportionality is β again, so the drain current is:

$$I_{DS,SAT}=\frac{\beta}{2}(V_{GS}-V_T)^2$$

This equation does not contain V_{DS}, so as stated above, the drain current does depend on V_{DS} when V_{DS} is greater than ($V_{GS} - V_T$). This is only an approximation and in fact V_{DS} does increase with increasing V_{DS} in the saturation region.

This article has described MOSFET operation and shown the most basic MOSFET equations. The reality is more complex, particularly for the very small devices used in modern digital ICs. The structure of power MOSFETS is different from that shown here to provide the low on resistance, but the basic principles are still the same.

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

NEW OUT NOW

FLOWCODE 6

Now you can develop complex electronic and electromechanical systems with ease

Flowcode is one of the world's most advanced environments for electronic and electromechanical system development. Engineers use Flowcode to develop systems for control and measurement based on microcontrollers, on rugged industrial interfaces or on Windows compable personal computers

FREE VERSION
The free edition of Flowcode allows users to sample the fully featured product for 30days, after which it will revert to a more limited form and will lose its ability to compile to microcontrollers. It will continue to provide most of its functionality with Matrix hardware devices like the Matrix Forumula Flowcode robot, MIAC and ECIO.

CHIP PACK ONLY - £79.00
Purchasing a Chip Pack only will provide the ability to compile to hardware. Chip Pack versions are suitable for users who only require the basic Flowcode components. The Chip Pack version is equivalent to the Flowcode v5 Student/Home version. Multiple chip packs can be purchased to allow Flowcode to compile to more hardware targets.

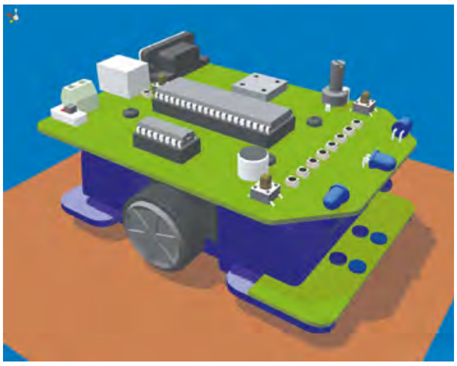
PROFESSIONAL UPGRADE PACK - £220.00
Adding the Professional bolt-on pack to the Flowcode licence will unlock all the functions and components available in Flowcode. It will also be licensed for commercial use.

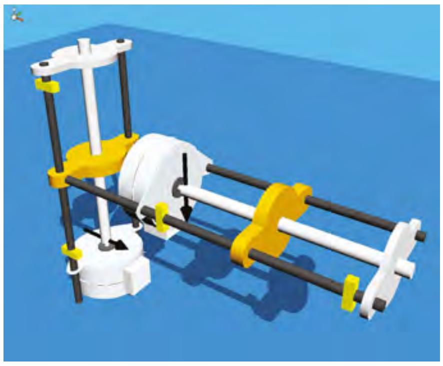
ACADEMIC VERSIONS
Special arrangements can be made for Academic versions of Flowcode. Academic multi-user versions (10 user, 50 user) are also available. Only educational schools, colleges and universities are able to apply to purchase an Academic version of Flowcode. Please contact us for more information.

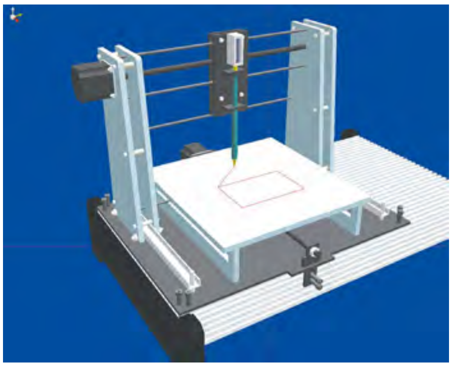
FLOWCODE 5 TO FLOWCODE 6 UPGRADE
Upgrades from Flowcode 5 to Flowcode 6 will be given a discount of 50% to the appropriate licence prices in Flowcode v6.

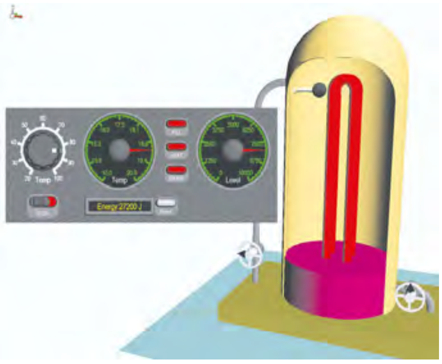
FLOWCODE 4 TO FLOWCODE 6 UPGRADE
Upgrades from Flowcode 4 to Flowcode 6 will given a discount of 30% to the appropriate licence prices in Flowcode v6 (pay 70% of the price).

New simulation, 3D and test features allow you to design a greater range of systems including:


...robotic systems design...


...electromechanical system design...


...machine building...


...pumping and heating systems

PRICES Prices for each of the items above are:

(Order form on third page)

(UK and EU customers add VAT to 'plus VAT' prices)

Flowcode 6

PICMICRO/AVR/DSPIC/PIC24 & ARM Download only

Chip Pack (Hobbyist/Student)	**£94.80 inc. VAT**
Pro-pack (Schools/HE/FE/Industry)	**£299.00 plus VAT**
Flowkit	**£64.90 plus VAT**

Please note: Due to popular demand, Flowcode PICmicro, AVR, DSPIC, PIC24 & ARM V6 are now available as a download. Please include your email address and a username (of your choice) on your order. A unique download code will then be emailed to you. If you require the CDROM as a back-up then please add an extra £14 to the above price.

PICmicro TUTORIALS AND PROGRAMMING

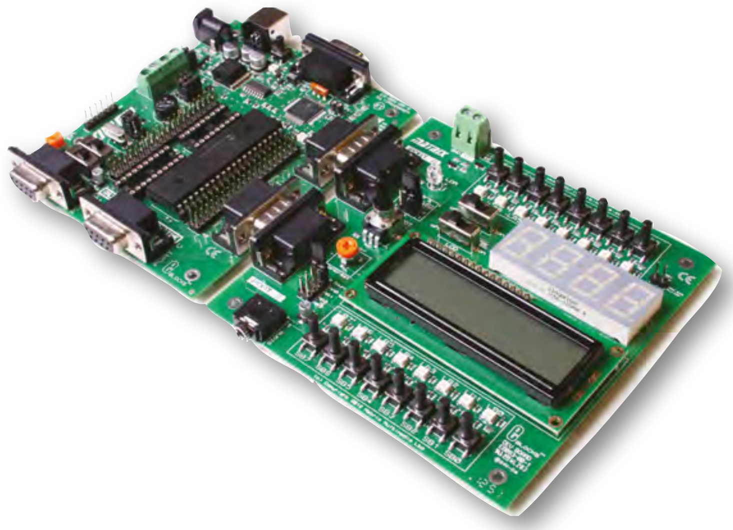
HARDWARE

PICmicro Multiprogrammer Board and Development Board

Suitable for use with the three software packages listed below

This flexible PICmicro microcontroller programmer board and combination board allows students and professional engineers to learn how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40 pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the multiprogrammer board. For those who want to learn, choose one or all of the packages below to use with the hardware.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual LEDs, quad 7-segment display and alphanumeric LCD display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Compatible with the E-blocks range of accessories



£167 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

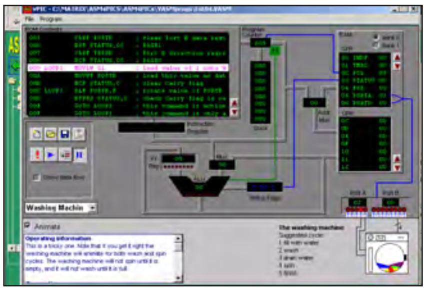
ASSEMBLY FOR PICmicro V4

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

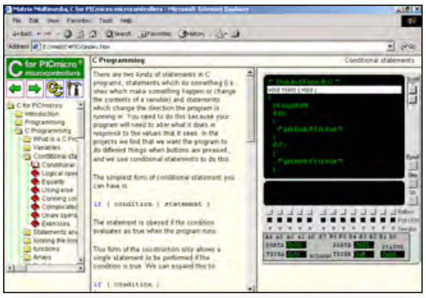


‘C’ FOR 16 Series PICmicro Version 4

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-ROM 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.



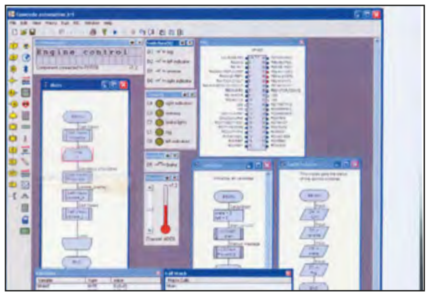
Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V6 (see opposite page)

Flowcode is a very high level language programming system 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 LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. 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
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

Features include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



PRICES

Prices for each of the CD-ROMs above are:

See previous page for Flowcode Hobbyist/Student prices
(Order form on next page)

(UK and EU customers add VAT to ‘plus VAT’ prices)

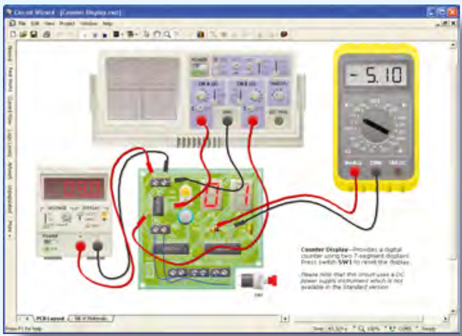
Hobbyist/Student	£58.80	inc VAT
Professional (Schools/HE/FE/Industry)	£150	plus VAT
Professional 10 user (Network Licence)	£499	plus VAT
Site Licence	£999	plus VAT
Flowcode 10 user (Network Licence)	POA	plus VAT
Flowcode Site Licence	POA	plus VAT

CIRCUIT WIZARD

Circuit Wizard is a revolutionary software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.
Two versions are available, Standard or Professional.

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

✱ Circuit diagram design with component library (500 components Standard, 1500 components Professional) ✱ Virtual instruments (4 Standard, 7 professional) ✱ On-screen animation ✱ Interactive circuit diagram simulation ✱ True analogue/digital simulation ✱ Simulation of component destruction ✱ PCB Layout ✱ Interactive PCB layout simulation ✱ Automatic PCB routing ✱ Gerber export ✱ Multi-level zoom (25% to 1000%) ✱ Multiple undo and redo ✱ Copy and paste to other software ✱ Multiple document support



This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT Professional **£91.90** inc. VAT

GCSE ELECTRONICS

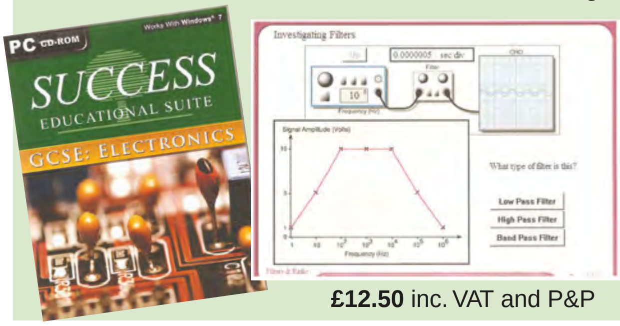
Suitable for any student who is serious about studying and who wants to achieve the best grade possible. Each program's clear, patient and structured delivery will aid understanding of electronics and assist in developing a confident approach to answering GCSE questions. The CD-ROM will be invaluable to anyone studying electronics, not just GCSE students.

✱ Contains comprehensive teaching material to cover the National Curriculum syllabus ✱ Regular exercises reinforce the teaching points ✱ Retains student interest with high quality animation and graphics ✱ Stimulates learning through interactive exercises ✱ Provides sample examination ques-tions with model solutions ✱ Authored by practising teachers ✱ Covers all UK examination board syllabuses ✱ Caters for all levels of ability ✱ Useful for self-tuition and revision

SUBJECTS COVERED

Electric Circuits – Logic Gates – Capacitors & Inductors – Relays – Transistors – Electric Transducers – Operational Amplifiers – Radio Circuits – Test Instruments

Over 100 different sections under the above headings



£12.50 inc. VAT and P&P

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

Please send me: CD-ROM ORDER FORM

- ☐ **Assembly for PICmicro V4**
- ☐ **'C' for 16 Series PICmicro V4**

Version required:
- ☐ **Hobbyist/Student**
- ☐ **Professional**
- ☐ **Professional 10 user**
- ☐ **Site licence**

- ☐ **Flowcode for PICmicro V6 (DOWNLOAD ONLY)**
- ☐ **Flowcode for AVR V6 (DOWNLOAD ONLY)**
- ☐ **Flowcode for ARM V6 (DOWNLOAD ONLY)**
- ☐ **Flowcode for dsPIC V6 (DOWNLOAD ONLY)**
- ☐ **Flowcode for PIC24 V6 (DOWNLOAD ONLY)**
- ☐ **Flowkit**

Version required:
- ☐ **Chip pack** (**Hobbyist/Student)**
- ☐ **Pro pack (Schools/HE/FE/Ind.)**

Email: . . . .

Username: . . . .

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

- ☐ **PICmicro Multiprogrammer Board and Development Board V4 (hardware)**

- ☐ **Circuit Wizard – Standard**
- ☐ **Circuit Wizard – Professional**
- ☐ **GCSE Electronics**

Full name: . . . .

Address: . . . .

. . . . Post code: . . . . Tel. No: . . . .

Signature: . . . .

☐ I enclose cheque/PO in £ sterling payable to WIMBORNE PUBLISHING LTD for £ . . . .

☐ Please charge my Visa/Mastercard/Maestro: £ . . . .

Valid From: . . . . Card expiry date: . . . .

Card No: . . . . Maestro Issue No. . . . .

Card Security Code . . . . (The last 3 digits on or just under the signature strip)

ORDERING
ALL PRICES INCLUDE UK POSTAGE

Student/Single User/Standard/Hobbyist Version price includes postage to most countries in the world
EU residents outside the UK add £5 for airmail postage per order

Professional, Multiple User and Site License Versions – overseas readers add £5 to the basic price of each order for airmail postage (**do not add VAT** unless you live in an EU (European Union) country, then add VAT at 20% or provide your official VAT registration number).

Send your order to:
Direct Book Service
Wimborne Publishing Ltd
113 Lynwood Drive, Merley,
Wimborne, Dorset BH21 1UU

To order by phone ring

01202 880299. Fax: 01202 843233

Goods are normally sent within seven days

E-mail: orders@wimborne.co.uk

Online shop:

www.epemag.com

NET WORK

by Alan Winstanley

Quite TecTile

LAST month, I explained how Near-Field Communications (NFC) can work in conjunction with an NFC-equipped smartphone to automate some tasks such as turning on the phone's built-in flashlight, launching a website or configuring the phone for in-car or cycle use. NFC is a short-distance RF system with a working range of a few centimetres and it's found in many modern smartphones. NFC labels or tags are sold online by RapidNFC.com, Amazon, eBay and Maplin and a range of apps for Android and Windows is available from the usual sources.

NFC technology seems to have flown under the radar of most smartphone users, not helped by the total omission from Apple's iPhone lineup. However, Apple's arch-rival Samsung has its own take on NFC labels in the shape of Samsung TecTiles, a programmable 25mm square adhesive NFC tag with an 888-byte memory. You can set alarms, send a text message, open a website, use the phonebook or launch a choice of apps. by tapping your NFC-enabled phone onto a TecTile. NFC tags and TecTiles lend themselves to some imaginative uses that might appeal to social networkers for example: a hotel or sports club could have a tag on its reception desk that allows visitors to tap and update their Facebook status automatically. Attending a theatre or conference? Visitors could be asked to tap their NFC-enabled phone onto a tag to switch it to silent mode.

Samsung TecTiles are programmable NFC tags for use with a compatible app and NFC device.

For iPhone users, perhaps in the future, iBeacon technology (see last month) might set an iPhone to silent mode wirelessly with no intervention from the user being needed. Looking even further ahead, as an alternative to GPS-driven services, maybe smartphone owners will be able to opt into a third-party site that allows their MAC code to be detected automatically by a location's wireless network; social network sites could be updated without the user doing anything with their phone. (See last month's item on Euclid Analytics, which uses a mobile phone's MAC code to track a shopper's physical movements in-store.)

There now appears to be a UK-compatible app for Samsung TecTiles or you can try downloading your own choice of NFC app from Google Play Store. TecTiles reportedly work on any brand of NFC-equipped Android phone, but this has not been proven by the author, and you should test the compatibility of hardware and software using the Samsung TecTile app with your own phone. There is also the option to 'lock' a TecTile, which sets the tag to read-only mode for ever, which may be a wasteful expense. Software apps, especially from small or solo developers, seem to be constantly updated and some niggles might limit the usefulness of NFC tags until they are ironed out, but they are an interesting development and worth bearing in mind. More details of Samsung TecTiles are at: **http://tinyurl.com/pybphkh** and TecTile labels can be sourced from Amazon and eBay.

There is plenty of potential to automate tasks using mobile and wireless technology. Samsung, for example, also markets a small range of laser printers and multi-function devices that are NFC-enabled, including the M2022W. Simply 'Tap & Print' and a file on your mobile NFC device will be printed wirelessly. Perhaps it's more hassle-free than pairing a Bluetooth device.

Size matters

Here in Britain, it's reported that in the past decade an average home has shrunk by two square metres as hard-pressed families struggle to cram more stuff (and kids) into smaller homes that are blighted by inadequate storage. If more evidence is needed, householders often use the garage to contain their overspill while parking their expensive cars outside (which may also be used for more storage). Entire streets are dotted with junk-filled garages, while cars are parked on the drive.

This brings me to the 2014 Consumer Electronics Show in Las Vegas where a new range of Samsung Ultra HD TVs and Smart TVs was launched, including a 105-inch monster-size Samsung TV set that most households would struggle to find a space for. Apart from giant curved-screen UHD TVs, and a bendable one that converts from flat to curved at the touch of a button, another buzz hailing from Samsung was 'Smart Home', their vision for the future and how they think everything will gradually become connected together. Sadly, my ability to watch Samsung's hour-long PR movie from CES 2014 was hampered by the typically mediocre ADSL bandwidth in my rural English locality, but Samsung's objectives and aspirations for the future made interesting viewing none the less.

Samsung Electronics' President and CEO BK Yoon reckoned that it's the consumer, not technology, that is driving the way forward. He cited a number of trends that will determine the way technology shapes itself in the future, starting with the facts that there are now almost as many mobile phone subscribers as there are people on planet Earth, and 70% of US subscribers own smartphones. As consumers, we're also heading (not always voluntarily) away from rural areas into townships and consequently the level of urbanisation will rise from 50% to 60% by 2030, he claimed. The implication is that the demand for connectivity will rise in urban and cosmopolitan areas, and rural regions risk being starved of amenities and resources (eg, healthcare). Consequently, more services will need to be networked together, especially if they are to be accessible to rural consumers.

Two more factors influencing the future demand for technology are: first, the world's ageing population, with 1 billion people expected to reach 60 within the next decade. Second, extreme weather events such as flooding, polar vortices, heatwaves and hurricanes re-inforce a basic human instinct, namely that one's home is the most important place to be. Mindful of these converging factors Samsung offered us a glimpse of tomorrow's technology that it thinks consumers will be utilising.

With 2014 being dubbed the Year of the Internet of Things, Samsung is embracing this under its 'Smart Home' banner. Samsung expects that we'll seek the re-assurance of a 'protective home' that shelters us from pollution, crime and disease. This implies advances in safety and security (eg, network cameras, doorlocks, and access controls) and maybe networked health care. Next was the rising trend toward flexible homeworking as employees commute less and work from home more (using their own devices) under more flexible hours. It's foreseen that we will create and consume more content at home as well; last year 52% of US TV content was streamed rather than being watched per the schedules.

Samsung's Smart Home is cloud-driven and promises to allow users to control networked devices and monitor their property remotely

Smart home

The last part of the jigsaw was the need for technology to respond to our needs, by showing information and putting us in control. In their fully networked future, Samsung's Smart Home offers the prospect of using mobile devices to control our environment. Forthcoming Smart Home mobile devices and apps will therefore focus on 'Device Control' (controlling networked domestic appliances, turning freezers up or down, switching indoor and outside electric lighting), while 'Home View' would allow a Smart Home device's built-in IP camera to be viewed over the network. Last, 'Customer Service' would offer online help and updates.

Samsung's Smart Home will also make use of voice commands to give homeowners more control of their networked devices. Say 'Going out' and a Smart Home could turn off the air conditioning and activate certain doorlocks. Say 'Movie Mode' and the lighting could dim, the curtains could be closed electrically and the sound system could be turned up. What use is a networked freezer or refrigerator to anyone? Easy; you could be alerted to faults, maybe the door has been left open, or you could set the temperature from your phone or tablet. My Bosch dishwasher displayed an enigmatic error code that a long Google session eventually translated into 'blocked filter'. Such problems may diminish when networked appliances relay useful information to the customer's tablet screen (but doubtless the need to 'call engineer for an expensive service' will remain).

Perhaps datalogging will record temperature trends or a weather app could check ambient temperatures and control the fridge temperature. More food could also be ordered for delivery to your door, using a fridge's built-in LCD tablet, and its IP camera could be accessed using Home View. Virtually all of this is do-able.

Fuzzy logic

Samsung envisions a networked home of appliances that can be controlled by mobile devices such as smartphones, tablets and smartwatches. Large Ultra High Definition screens and immersive sound will become the norm and will be utilised to the max by video games developers. With UHD content sorely lacking, the emphasis will be on up-scaling to get a 'near UHD experience'. (The fact that many of us have imperfect vision anyway and wear glasses to view fuzzy images seems to have been lost.)

Large UHD screens could help with multitasking and home control, watching TV while interrogating devices on the home network, tiling different screens on a UHD screen. As the 'Internet of Things' expands, gradually a whole range of network-compatible gadgets and devices will become available; everything from door locks to security systems, air-con, curtain closers or baby monitors, all the way up to giant deep freezers, could become controllable over the home network. Health professionals will be able to check a patient's heart monitors or blood pressure over a network, which is beneficial for those who live in rural areas. I expect that cars too will hook onto the home network so that its navigation system can be updated online. In the future a 'smart' car could transmit error codes and service reminders direct to its owner or the garage service department. (This kind of thing already happens in aerospace: every current Rolls-Royce aero engine in use worldwide transmits data back to Rolls-Royce here in the UK, where each engine's performance is constantly monitored by the manufacturer.)

As you start to think how ordinary everyday appliances could become network-enabled, the possibilities of home networking are immense, and this year a new wave of network-ready appliances will start to arrive as a precursor to building a fully-networked home.

All of this is very exciting stuff. To date, though, in the writer's case a year of smart TV ownership has tinged any sense of euphoria with a healthy dose of scepticism. If my experiences are anything to go by then we have some way to go before a dependable plug-and-play home network becomes reality. Samsung's Smart Home will use a cloud (theirs) to manage the home network, but how reliable will it be? My smart TV occasionally locks up, it spends a tiresome amount of time updating itself, and the Youtube app, slavishly configured on my Android phone to queue up on the smart TV will lose my list of movies in the blink of an eye. Expensive Homeplug devices were needed because 802.11n Wi-Fi was so troublesome. At one time, smart TV Internet access went down without warning for a day, eventually pinned down to updates and outages on Samsung's own network. The quality and content of many downloaded TV apps is variable and their worth is questionable.

Once again, a tantalising picture of the future is being held up, but whether home networking is being over-sold and fails to deliver in practice remains very much to be seen. You can email the author at **alan@epemag.demon.co.uk**

DIRECT BOOK SERVICE

ELECTRONICS TEACH-IN BUNDLE – SPECIAL BUNDLE PRICE £14 FOR PARTS 1, 2 & 3

ELECTRONICS TEACH-IN 2 CD-ROM
USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

CD-ROM **Order code ETI2 CD-ROM** **£9.50**

ELECTRONICS TEACH-IN 3 CD-ROM

The three sections of this CD-ROM cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on circuit design problems – from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by the readers of *EPE*.

The CD-ROM also contains the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial).

The Teach-In 1 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.

CD-ROM **Order code ETI3 CD-ROM** **£8.50**

CD-ROMs **Order code ETIBUNDLE** Bundle Price **£14.00**

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

FOR A FULL DESCRIPTION OF THESE BOOKS AND CD-ROMS SEE THE SHOP ON OUR WEBSITE www.epemag.com

All prices include UK postage

1

ELECTRONICS TEACH-IN 4

ELECTRONICS TEACH-IN 4 CD-ROM

A Broad-Based Introduction to Electronics.

The Teach-In 4 CD-ROM covers three of the most important electronics units that are currently studied in many schools and colleges. These include, Edexcel BTEC level 2 awards and the electronics units of the new Diploma in Engineering, Level 2.

The CD-ROM also contains the full Modern Electronics Manual, worth £29.95. The Manual contains over 800 pages of electronics theory, projects, data, assembly instructions and web links.

A package of exceptional value that will appeal to all those interested in learning about electronics or brushing up on their theory, be they hobbyists, students or professionals.

CD-ROM **Order code ETI4 CD-ROM** **£8.99**

ELECTRONICS TEACH-IN 5

FREE CD-ROM

ELECTRONICS TEACH-IN 5

Jump Start – 15 design and build circuit projects dedicated to newcomers or those following courses in school and colleges. The projects are: Moisture Detector, Quiz Machine, Battery Voltage Checker, Solar-Powered Charger, Versatile Theft Alarm, Spooky Circuits, Frost Alarm, Mini Christmas Lights, iPod Speaker, Logic Probe, DC Motor Controller, Egg Timer, Signal Injector Probe, Simple Radio Receiver, Temperature Alarm.

PLUS:

PIC' N MIX – starting out with PIC Microcontrollers and PRACTICALLY SPEAKING – the techniques of project construction.

FREE CD-ROM – The free CD-ROM is the complete Teach-In 2 book providing a practical introduction to PIC Microprocessors plus MikroElektronika, Microchip and L-Tek PoScope software.

160 Pages **Order code ETI5** **£8.99**

RASPBERRY PI

RASPBERRY Pi MANUAL: A practical guide to the revolutionary small computer
176 pages **Order code H001** **£17.99**

RASPBERRY Pi USER-GUIDE
262 pages **Order code JW001** **£12.99**

PROGRAMMING THE RASPBERRY Pi
192 pages **Order code MGH4** **£10.99**

GETTING STARTED WITH RASPBERRY Pi
164 pages **Order code OR01** **£11.50**

MICROPROCESSORS

INTERFACING PIC MICROCONTROLLERS
Martin Bates
298 pages **Order code NE48** **£30.99**

PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C – LEARNING TO FLY THE PIC24 Lucio Di Jasio (Application Segments Manager, Microchip, USA)
496 pages +CD-ROM **Order code NE45** **£38.00**

INTRODUCTION TO MICROPROCESSORS AND MICROCONTROLLERS – SECOND EDITION
John Crisp
222 pages **Order code NE31** **£29.99**

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – THIRD EDITION. John Morton
270 pages **Order code NE36** **£25.00**

PIC IN PRACTICE (2nd Edition)
David W. Smith
308 pages **Order code NE39** **£24.99**

MICROCONTROLLER COOKBOOK
Mike James
240 pages **Order code NE26** **£36.99**

PROJECT CONSTRUCTION

IC 555 PROJECTS
E. A. Parr
167 pages **Order code BP44** **£5.49**

ELECTRONIC PROJECT BUILDING FOR BEGINNERS R. A. Penfold
135 pages **Order code BP392** **£5.99**

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
132 pages **Order code BP374** **£5.45**

THEORY AND REFERENCE

PRACTICAL ELECTRONICS HANDBOOK – Fifth Edition. Ian Sinclair
440 pages **Order code NE21** **£32.50**

STARTING ELECTRONICS – 4th Edition
Keith Brindley
296 pages **Order code NE100** **£18.99**

ELECTRONIC CIRCUITS – FUNDAMENTALS & APPLICATIONS – Third Edition Mike Tooley
400 pages **Order code TF43** **£25.99**

FUNDAMENTAL ELECTRICAL AND ELECTRONIC PRINCIPLES – Third Edition C.R. Robertson
368 pages **Order code TF47** **£21.99**

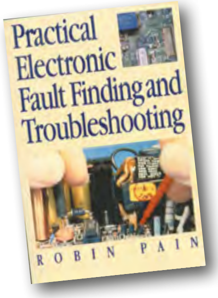
A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R.A. Penfold
142 pages **Order code BP332** **£5.45**

UNDERSTANDING ELECTRONIC CONTROL SYSTEMS
Owen Bishop
228 pages **Order code NE35** **£36.99**

FAULT FINDING AND TEST EQUIPMENT

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
96 pages Order code BP239 £5.49

PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
Robin Pain
274 pages Order code NE22 £41.99



HOW ELECTRONIC THINGS WORK – AND WHAT TO DO WHEN THEY DON'T
Robert Goodman
394 pages Order code MGH3 £21.99

OSCILLOSCOPES – FIFTH EDITION
Ian Hickman
288 pages Order code NE37 £36.99

HOW TO USE OSCILLOSCOPES AND OTHER TEST EQUIPMENT
R.A. Penfold
104 pages Order code BP267 £5.49

AUDIO & VIDEO

VALVE AMPLIFIERS – Second Edition
Morgan Jones
288 pages Order code NE33 £40.99

BUILDING VALVE AMPLIFIERS
Morgan Jones
368 pages Order code NE40 £29.00

DIGITAL AUDIO RECORDING
Ian Waugh
60 pages Order code PC121 £7.95

QUICK GUIDE TO MP3 AND DIGITAL MUSIC
Ian Waugh
60 pages Order code PC119 £7.45

MAKING MUSIC WITH YOUR COMPUTER
Stephen Bennett
92 pages Order code PC120 £10.95

QUICK GUIDE TO DIGITAL AUDIO RECORDING
Ian Waugh
208 pages Order code PC121 £7.95

ELECTRONIC PROJECTS FOR VIDEO ENTHUSIASTS
R.A. Penfold
109 pages Order code BP356 £5.45

COMPUTING AND ROBOTICS

NEWNES INTERFACING COMPANION
Tony Fischer-Cripps
295 pages Order code NE38 £41.00

HOW TO BUILD A COMPUTER MADE EASY
R.A. Penfold
120 pages Order code BP707 £8.49

EASY PC CASE MODDING
R.A. Penfold
192 pages + CDROM Order code BP542 £8.99

FREE DOWNLOADS TO PEP-UP AND PROTECT YOUR PC
R.A. Penfold
128 pages Order code BP722 £7.99

WINDOWS XP EXPLAINED
N. Kantaris and P.R.M. Oliver
264 pages Order code BP514 £7.99

THE INTERNET – TWEAKS, TIPS AND TRICKS
R. A. Penfold
128 pages Order code BP721 £7.99

eBAY – TWEAKS, TIPS AND TRICKS
R. A. Penfold
128 pages Order code BP716 £7.50

AN INTRODUCTION TO eBAY FOR THE OLDER GENERATION
Cherry Nixon
120 pages Order code BP709 £8.49

COMPUTING FOR THE OLDER GENERATION
Jim Gatenby
308 pages Order code BP601 £8.99

ANDROIDS, ROBOTS AND ANIMATRONS
Second Edition – John Iovine
224 pages Order code MGH1 £16.99

ROBOT BUILDERS COOKBOOK
Owen Bishop
366 pages Order code NE46 £26.00

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold
288 pages + Order code BP901 £14.99

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold
298 pages Order code BP902 £14.99

HOW TO FIX YOUR PC PROBLEMS
R. A. Penfold
128 pages Order code BP705 £8.49

WINDOWS 7 – TWEAKS, TIPS AND TRICKS
Andrew Edney
120 pages Order code BP708 £8.49

GETTING STARTED IN COMPUTING FOR THE OLDER GENERATION
Jim Gatenby
120 pages Order code BP704 £8.49

BOOK ORDERING DETAILS

All prices include UK postage. For postage to Europe (air) and the rest of the world (surface) please add £3 per book. Surface mail can take up to 10 weeks to some countries. For the rest of the world airmail add £4 per book. CD-ROM prices include VAT and/or postage to anywhere in the world. Send a PO, cheque, international money order (£ sterling only) made payable to **Direct Book Service** or card details, Visa, Mastercard or Maestro to: **DIRECT BOOK SERVICE, WIMBORNE PUBLISHING LIMITED, 113 LYNWOOD DRIVE, MERLEY, WIMBORNE, DORSET BH21 1UU**.

Books are normally sent within seven days of receipt of order, but please allow 28 days for delivery – more for overseas orders. *Please check price and availability (see latest issue of* Everyday Practical Electronics*) before ordering from old lists.*

For a full description of these books please see the shop on our website.
Tel 01202 880299 Fax 01202 843233. E-mail: dbs@wimborne.co.uk

Order from our online shop at: www.epemag.com

BOOK ORDER FORM

Full name: ....

Address: ....

....

....

.... Post code: .... Telephone No: ....

Signature: ....

☐ I enclose cheque/PO payable to DIRECT BOOK SERVICE for £ ....

☐ Please charge my card £ .... Card expiry date..

Card Number .... Maestro Issue No............................

Valid From Date .... Card Security Code .... (The last three digits on or just below the signature strip)

Please send book order codes: ....

....

Please continue on separate sheet of paper if necessary

PCB SERVICE

CHECK US OUT ON THE WEB

Basic printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are drilled and roller tinned, but all holes are a standard size. They are not silk-screened, nor do they have solder resist. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. * **NOTE: PCBs from the July 2013 issue with eight digit codes** have silk screen overlays and, where applicable, are double-sided, plated through-hole, with solder masks, they are similar to the photos in the relevent project articles.

All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

PROJECT TITLE	ORDER CODE	COST
FEBRUARY '13		
10W LED Floodlight	885	£6.75
★ Crystal DAC (double-sided)	886	£18.46
Jump Start – Logic Probe	887	£6.42
MARCH '13		
Lightning Detector	888	£8.75
★ Digital Spirit Level	889	£8.75
★ SemTest – Part 2		
– Main/Lower Board	890	£16.52
– Display/Upper Board	891	£15.55
Interplanetary Voice	892	£8.75
Jump Start – DC Motor Controller	893	£8.55
APRIL '13		
Six-Decade Resistance Substitution Box	894	£10.10
SoftStarter (single-sided)	895	£8.36
Jump Start – Egg Timer	896	£8.36
SemTest HV DC Crowbar	897	£13.61
MAY '13		
Electronic Stethoscope	898	£9.72
PIC/AVR Programming Adaptor Board (d'ble-sided)	899	£23.33
Jump Start – Signal Injector Probe	900	£8.16
JUNE '13		
USB Breakout Box	901	£7.97
Jump Start – Simple Radio Receiver	902	£8.94
Mix-It	903	£11.28
JULY '13		
6-Decade Capacitance Substitution Box	04106121	£18.00
6-Decade Capacitance Substitution Box Panel/Lid	04106122	£18.00
SoftStarter For Power Tools	10107121	£9.00
High-Current Adaptor For Scopes And DMMs	04108121	£18.00
Jump Start – Temperature Alarm	904	£7.97
AUGUST '13		
Driveway Sentry	03107121	£18.00
Build A Vox	01207111	£22.00
Milliohm Meter Adaptor For DMMs	04102101	£18.00
SEPTEMBER '13		
MiniReg Adjustable Regulator	18112111	£6.00
USB Stereo Recording Interface	07106111	£18.00
Digital Sound Effects Module	09109121	£9.00
OCTOBER '13		
High-Temperature Thermometer/Thermostat	21105121	£22.00
LED Musicolour	16110121	£22.00
NOVEMBER '13		
Mains Timer For Fans Or Lights	10108121	£9.10
CLASSiC-D Amplifier (inc. 3 Rockby Capacitors)	01108121	£26.50
– Speaker Protector	01108122	£9.10

PROJECT TITLE	ORDER CODE	COST
DECEMBER '13		
CLASSiC-D Amplifier – Power Supply	01109111	£16.66
USB Instrument Interface	24109121	£26.38
– Front Panel	24109122	£28.54
JANUARY '14		
Champion	1109121/2	£8.88
Simple 1.5A Switching Regulator	18102121	£5.53
FEBRUARY '14		
2.5GHz 12-Digit Frequency Counter – Display PCB	04111122	£12.88
– Main PCB	04111121	£27.13
– Front Panel	04111123	£22.38
High-Energy Electronic Ignition System	05110121	£9.10
Mobile Phone LOUD Ringer!	12110121	£9.10
MARCH '14		
Extremely accurate GPS 1pps Timebase For A Frequency Counter	04103131	£8.88
Infrasound Detector – Pre CHAMP PCB	01107941	£5.54
– CHAMP PCB	01102941	£5.54
Automatic Points Controller (inc. 2 sensor PCBs)	09103132	£13.42
Automatic Points Controller – Frog Relay	09103133	£5.54

*** See NOTE above left regarding PCBs with eight digit codes ***

Please check price and availability in the latest issue.
A large number of older boards are listed on, and can be ordered from, our website.
Boards can only be supplied on a payment with order basis.

EPE SOFTWARE

★ All software programs for *EPE* Projects marked with a star, and others previously published can be downloaded free from the Library on our website, accessible via our home page at: **www.epemag.com**

PCB MASTERS

PCB masters for boards published from the March '06 issue onwards can also be downloaded from our website (**www.epemag.com**); **go to the 'Library' section.**

EPE PRINTED CIRCUIT BOARD SERVICE

Order Code | **Project** | **Quantity** | **Price**

. . . .

Name . . . .

Address . . . .

. . . .

Tel. No. . . . .

I enclose payment of £ . . . . (cheque/PO in **£ sterling only**) to:

Everyday Practical Electronics

MasterCard VISA Maestro

Card No. . . . .

Valid From . . . . Expiry Date . . . .

Card Security No. . . . . Maestro Issue No. . . . . . .

Signature . . . .

Note: You can also order PCBs by phone, Fax or Email or via the Shop on our website on a secure server:

http://www.epemag.com

CLASSIFIED
ADVERTISEMENTS

If you want your advertisements to be seen by the largest readership at the most economical price our classified page offers excellent value. The rate for semi-display space is £10 (+VAT) per centimetre high, with a minimum height of 2·5cm. All semi-display adverts have a width of 5.5cm. The prepaid rate for classified adverts is 40p (+VAT) per word (minimum 12 words).

All cheques, postal orders, etc., to be made payable to Everyday Practical Electronics. **VAT must be added**. Advertisements, together with remittance, should be sent to Everyday Practical Electronics Advertisements, 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Phone: 01202 880299. Fax: 01202 843233. Email: stewart.kearn@wimborne.co.uk. For rates and information on display and classified advertising please contact our Advertisement Manager, Stewart Kearn as above.

ADVERTISERS INDEX

ADVERTISEMENT OFFICES:
113 LYNWOOD DRIVE, MERLEY, WIMBORNE,
DORSET BH21 1UU
PHONE: 01202 880299
FAX: 01202 843233
EMAIL: stewart.kearn@wimborne.co.uk
WEB: www.epemag.com

For editorial address and phone numbers see page 7

Next Month

APRIL '14 ISSUE ON SALE 6 MARCH 2014

Jacob's Ladder

Remember those amazing spark generators in the original Frankenstein films? They are called 'Jacob's Ladders'. Our version looks and sounds spectacular and is quite easy to build. As the high voltage sparks climb up the vertical wires they snap and snarl, almost as a warning for you to keep your distance! It even smells convincing, as the purplish discharge generates ozone.

Deluxe GPS 1pps Timebase

Did you enjoy the precision GPS timebase featured in this issue? That was the 'no frills' version. Nest month, we present a *Deluxe GPS 1pps Timebase*, which also suits our recently described *12-Digit Frequency Counter*. It not only provides the same near-atomic-clock-accuracy 1pps pulses for the counter's timebase, but also extracts the NMEA 0183 data stream from the GPS satellites for processing on your PC.

Rugged Battery Charger from Bits'n'Pieces

Need a big, powerful, simple and cheap battery charger? Then look no further, we have just the design you've been looking for!

Capacitor Discharge Unit for twin-coil points motors

Got a model railway? If it's not just a simple loop of track it's bound to have one, two or maybe dozens of sets of points. That means you need at least one Capacitor Discharge Unit (CDU) to power them.

Teach-In 2014: Raspberry Pi – Part 7

Next month, in *Teach-In 2014*, we'll feature the construction of a 15-channel port expander for the Raspberry Pi. We look at methods of handling and manipulating binary, octal and hexadecimal data. Plus, we'll show how the System Management Bus (SMBus) can provide access to a wide-range of I²C devices.

Content may be subject to change

Published on approximately the first Thursday of each month by Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Printed in England by Acorn Web Offset Ltd., Normanton, WF6 1TW. Distributed by Seymour, 86 Newman St., London W1T 3EX. Subscriptions INLAND: £23.50 (6 months); £43.00 (12 months); £79.50 (2 years). EUROPE: airmail service, £27.00 (6 months); £50.00 (12 months); £95.00 (2 years). REST OF THE WORLD: airmail service, £37.00 (6 months); £70.00 (12 months); £135.00 (2 years). Payments payable to "Everyday Practical Electronics'', Subs Dept, Wimborne Publishing Ltd. Email: subs@epemag.wimborne.co.uk. EVERYDAY PRACTICAL ELECTRONICS is sold subject to the following conditions, namely that it shall not, without the written consent of the Publishers first having been given, be lent, resold, hired out or otherwise disposed of by way of Trade at more than the recommended selling price shown on the cover, and that it shall not be lent, resold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.

Looking to speed your analog development time?

PIC® MCUs with Intelligent Analog make designs easier

With a powerful combination of rich analog integration and low power consumption, the PIC24FJ128GC010 family enables a significant cost reduction over a multi-chip design as well as enabling lower noise, faster throughput, smaller PCB size and a faster time to market.

In addition to Microchip's first 16-bit ADC and a 10 Msps 12-bit ADC, the PIC24FJ128GC010 integrates a DAC and dual op amps to simplify precision analog design. The on-chip LCD driver provides the ability to drive displays with up to 472 segments for information-rich user displays; whilst mTouch™ capacitive touch sensing adds advanced touch capabilities.

The PIC24FJ128GC010 family helps to reduce noise to deliver more consistent analog performance in a very small form factor. Simply add sensors to the low-cost starter kit for easy prototyping.

GET STARTED IN 3 EASY STEPS:

1. Begin with the low-cost PIC24F Starter Kit for Intelligent Analog (DM240015)
2. Add custom sensors to the clean analog header to create a prototype
3. Re-use and modify the demo code to speed development

PIC24F Starter Kit for Intelligent Analog (DM240015)

For more information, go to: www.microchip.com/get/euGC010

MICROCHIP

Microcontrollers • Digital Signal Controllers • Analog • Memory • Wireless