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VOL. 42. No 6 June 2013

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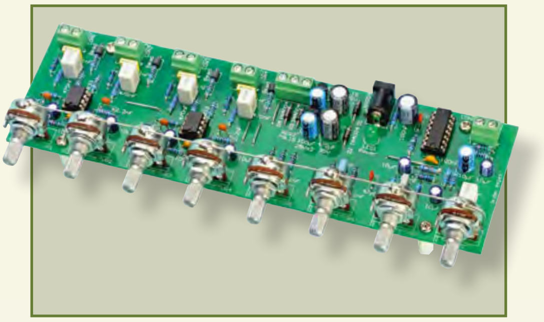

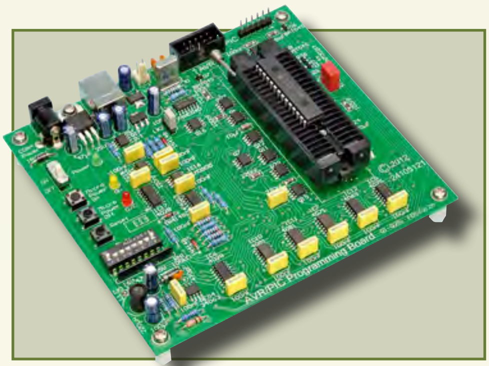

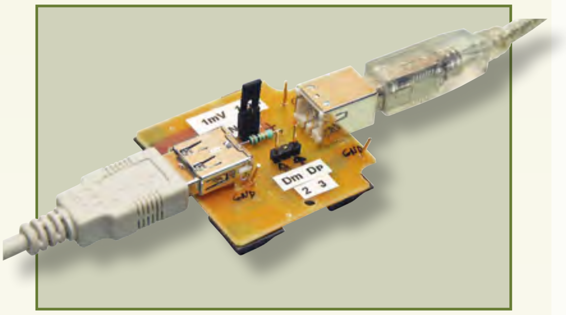

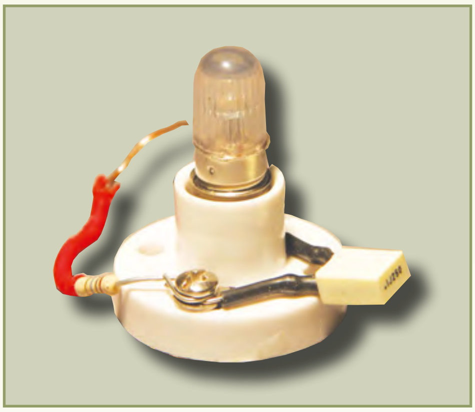

Our July 2013 issue will be published on Thursday 6 June 2013, see page 72 for details.

Projects and Circuits

Series and Features

Regulars and Services

Arduino - Compatible Products

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs (includes Jaycar stepper motors). Arduino projects can be stand-alone, or they can be communicated with software running on your computer. These Arduino development kits are 100% Arduino compatible. Designed in Australia and supported with tutorials, guides, a forum and more. A very active worldwide community and resources are available with many projects, ideas and programs available to freely use. Learn more at www.jaycar.co.uk/arduino

Arduino Experimenters Kit

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£32.75*

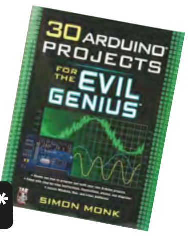
HOT SELLER

- Comprehensive instructions included
- Size: 340(W) x 165(H) x 36(D)mm

Cat. XC-4262

30 Arduino Projects for the Evil Genius

This is a practical project oriented book describing lots of projects based around the Arduino microcontroller. Be warned, there is nothing intrinsically evil about this book. The title is a catchy marketing department trick. It does have, however, 30 practical projects which specify components all most of which are available from Jaycar. Hours & hours of evil fun.



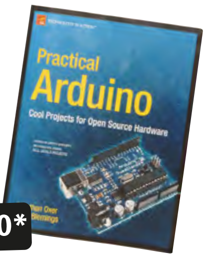
- Soft cover, 191 pages. 220 x 275mm

Cat. BM-7134

£14.00*

Practical Arduino

A much larger and detailed book. It takes you beyond basics quite quickly and shows you how to make up a typical application/design.



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Arduino Compatible Boards - Pre Built

"Eleven" Arduino-compatible Development Board

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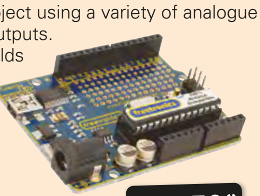
Accepts expansion shields and can be interfaced with our wide range of sensor, actuator, light, and sound modules.



- 8 analogue inputs

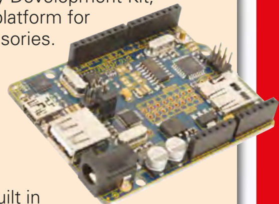
Cat. XC-4210

£14.50*

Also available:
ProtoShield Basic (XC-4214 £1.75*)

USBDroid, Arduino-compatible with USB-host Support

This special Arduino-compatible board supports the Android™ Open Accessory Development Kit, which is Google's official platform for designing Android™ accessories. Plugs straight into your Android™ device and communicates with it via USB. Includes a built-in phone charger.



- USB host controller chip
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- microSD memory card slot

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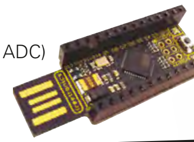
LeoStick (Arduino Compatible)

A tiny Arduino-compatible board that's so small you can plug it straight into your USB port without requiring a cable! Features a full range of analogue and digital I/O, a user-controllable RGB LED on the board and an on-board Piezo/sound generator.

- ATmega32u4 MCU with 2.5K RAM and 32K Flash
- 6 analogue inputs (10-bit ADC) with digital I/O, 14 extra digital I/O pins



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Also available: **LeoStick Prototyping Shield (XC-4268 £3.00*)**

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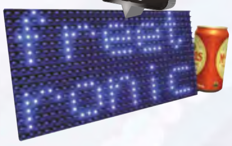
Large Dot Matrix Display Panel

A huge dot matrix LED panel to connect to your Freetronics Eleven, EtherTen and more! This large, bright 512 LED matrix panel has onboard controller circuitry designed to make it easy to use straight from your board.

- 5V operation
- 32 x 16 high brightness Blue LEDs (512 LEDs total) on a 10mm pitch
- Viewable over 12 metres away
- Controller IC's on board, simple clocked data interface
- Arduino-compatible library, graphics functions and example support
- Size: 320(W) x 160(H) x 30(D)mm

£32.75*

NEW 2013



Cat. XC-4251

USB Li-Po Charger

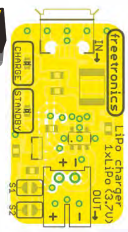
NEW 2013

Charge Li-Po cells from any USB source, USB plugpack, laptop or PC.

- 3.7V output for a single Li-Po cell
- Micro-USB jack
- "Charge" and "Standby" LEDs
- Size: 27(W) x 16(H) x 10(D)mm

Cat. XC-4243

£4.75*



NEW Arduino Compatible Boards & Modules

StepDuino Arduino Compatible

A self-contained board with onboard stepper motor drivers, servo interface, microSD card slot, and 20x4 character LCD. Perfect for building robots or other mechatronics projects: just connect up stepper motors and go!

NEW 2013

- 2 x 4-wire stepper motor controllers
- 1 x servo interface
- Serial communications header
- Compatible with the Arduino IDE
- Size: 113(W) x 74(H) x 25(D)mm

£54.25*

Cat. XC-4249

USB-Boost

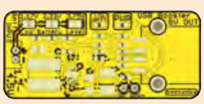
Takes a power input of 1.2 to 4.5V, and boosts it to a regulated 5V output up to 500mA. Perfect for powering Arduino projects from batteries, such as a single 3.7V Li-Po cell. Can even be used to charge USB devices such as mobile phones from a low-voltage source. Includes status outputs so your microcontroller can actively monitor the status of the power supply.

- USB output jack
- Low-input automatic cut-off to protect battery
- Configurable low-input level of 1.17V, 2.33V, or 3.75V
- Size: 46(W) x 21(H) x 10(D)mm

Cat. XC-4239

£4.75*

NEW 2013



Temperature Modules

Humidity & Temperature Sensor Module for Arduino

Measure temperature and relative humidity using a simple interface that requires just three wires to the sensor: GND, power, and data. Supported by an Arduino library that makes it very easy to read values into your project, so with a single I/O line from your microcontroller you can read both temperature and humidity.

- -4°C to +125°C temperature range with +/-0.5°C accuracy
- 0-100% relative humidity with 2-5% accuracy
- 3 to 5V operation
- Blue power LED
- Size: 31(W) x 23(H) x 4(D)mm

Cat. XC-4246

£7.25*

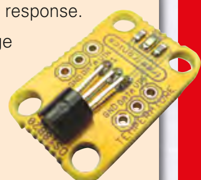
Temperature Sensor Module for Arduino

Sprinkle these around your house to collect temperature data using your Arduino. This 1-wire bus temperature sensor module is easy to connect and use. You can even daisy-chain several together on the same wire. 0.5°C accuracy and fast response.

- -55 to +125°C temperature range
- +/-0.5°C accuracy
- Selectable 9 or 12 bit precision
- Size: 23(W) x 16(H) x 6(D)mm

Cat. XC-4230

£6.25*



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Standard counter, 0 to 99 from input pulses or external signal. With reset input, 13.5mm Displays,
Power: 12Vdc 90mA.
CD-9 Cebek Module £12.99
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Red 7 Segment display in attractive enclosure, automatic time base selection, battery back-up, 12 or 24Hr modes.
Power: 9Vac or dc
MK151 Velleman kit £15.09
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Gas filled nixie tubes with their distinctive orange glow. HH:MM display, automatic power sync 50/60Hz
Power: 9-12Vac 300mA
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Compact mono 1.8W RMS 4Ω power stage, short circuit & reverse polarity protection. 30-18kHz, Power: 4-14Vdc 150mA
E-1 Cebek Module £5.87
Proximity Card Reader Kit
A simple security kit with many applications. RFID technology activates a relay, either on/off or timed. Supplied with 2 cards, can be used with up to 25 cards. Power: 9Vac or dc
MK179 Velleman kit £14.25
Mini USB Interface Board
New from Velleman this little interface module with 15 inputs/outputs inc digital & analogue in, PWM outputs. USB Powered 50mA, Software supplied
VM167 Module £26.80
20W 2 Channel Amplifier
Mono amplifier with 2 channels (Low & High frequecy), 20W RMS 4Ω per channel, adjustable high level. 22-22kHz, short circuit & reverse polarity protection.
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E-14 Cebek Module £22.11
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MK127 Velleman kit £9.02
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General purpose low cost thermostat kit. +5 to +30°C Easily modified temperature range/min/max/hysteresis
3A Relay
Power: 12Vdc 100mA
MK138 Velleman Kit £4.55
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Stereo power stage with 5W RMS 4Ω, 30-18kHz, short circuit & reverse polarity protection.
Power: 6-15Vdc 500mA
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200W Power Amplifier
A high quality audio power amp, 200w music power @ 4Ω 3-200kHz Available as a kit without heatsink or module including heatsink.
K8060 Velleman kit £12.85
Heatsink for kit £9.95
VM100 Module £38.54
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PC Based USB controlled function generator. 0.01Hz to 2Mhz Pre-defined & waveform editor. Software supplied. See web site for full feature list.
PCGU1000 Velleman £118.38
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Single rail regulated power supply complete with transformer. 130mA max, low ripple, 12Vdc with adjustment.
FE-103 Cebek Module £13.16
MP3 Player Kit
Plays MP3 files from an SD card, supports ID3 tag which can be displayed on optional LCD. Line & headphone output. Remote control add-on. Power: 12Vdc 100mA
K8095 Velleman kit £39.99
Velleman PC Scope
PC Based USB controlled 2 channel 60Mhz oscilloscope with spectrum analyser & Transient recorder. 2 Scope probes & software included. See web site for full feature list.
PCSU1000 Velleman £249.00
1-180 Second Timer
Universal timer with relay output. Time start upon power up or push button. LED indication. 5A Relay
Power: 12Vdc 60mA
I-1 Cebek Module £12.92
DC to Pulse width Modulator
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Power: 8-35Vdc
K8004 Velleman kit £9.95
Velleman PC Scope/Generator
PC Based USB controlled 2 channel oscilloscope AND Function generator. Software included. See web site for full feature list.
PCSGU250 Velleman £113.67
Cyclic Timer
Universal timer with relay output. Time start upon power up or push button. On & Off times 0.3-60 Seconds, LED indication. 5A Relay
Power: 12Vdc 80mA
I-10 Cebek Module £14.12
Audio Analyser Kit
A small spectrum analyser with LCD. Suitable for use on 2, 4 or 8Ω systems. 300mW to 1200W(2Ω) 20-20kHz Panel mounting, back-lit display. Power: 12Vdc 75mA
K8098 Velleman kit £31.65
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Single channel RF keyfob transmitter with over 13,122 combinations. Certified radio frequency 433.92MHz.
Power: 12Vdc 2mA (inc) For use with TL-1,2,3,4 receivers.
TL-5 Cebek Module £14.64
Light Detector
Adjustable light sensor operating a relay. Remote sensor & terminals for remote adjustment pot.
5A Relay
Power: 12Vdc 60mA
I-4 Cebek Module £13.98
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512 DMX Channels controlled by PC via USB. Software & case included. Available as a kit or ready assembled module.
K8062 Velleman kit £47.90
VM116 Module £67.15
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Single channel RF receiver with relay output. Auto or manual code setup. Momentary output, 3A relay
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Power: 12Vdc 60mA
I-6 Cebek Module £13.08
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Featuring 5 in, 8 digital outputs, 2 in & 2 analogue outputs. Supplied with software. Available as a kit or ready assembled module.
K8055 Velleman kit £24.80
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An electronic lock with up to ten 4 digit codes. Momentary or timed (1-60ec/1-60min) output. Relay 5A
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DA-03 Cebek Module £54.26
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A temerature controlled relay. Adjustable between -10 to 60°C Sensor on remote PCB. Connector for external adjustment pot. 5A Relay
Power: 12Vdc 60mA
I-8 Cebek Module £12.80
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PC Controlled 16A relays with toggle, momentary or timed action. Test buttons included, available in a kit or assembled.
K8090 Velleman kit £39.95
VM8090 Module £58.40
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A 230Vac 375W motor speed control unit giving 33 to 98% of full power.
Power: 230Vac
R-8 Cebek Module £12.14
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Simple push button control of a relay. Either 1 or 2 button operation 5A Relay
Power: 12Vdc 60mA
I-9 Cebek Module £12.83
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EVERYDAY PRACTICAL ELECTRONICS

Stalwart retires

After very long service to the electronics fraternity, Dave Barrington has finally retired. Straight out of school aged 15, Dave started his career in publishing with George Newnes – the original publisher of the *Practical* magazines. He first worked as a copy boy on *Practical Motorist*, *Practical Householder* and *Practical Wireless*; transferring to *Practical Electronics* on its launch in November 1964. He continued to work on *PE*/*EE*, and then for *EPE* when the magazines were merged.

Dave officially took retirement as a full-time staff member some years ago, but continued to work for the magazine on a freelance basis until March of this year – nearly 50 years dedicated to the electronics hobbyist.

For many years, Dave has been responsible for maintaining the accuracy of your magazine with his unerring eye for detail and his fastidious and patient checking of diagrams, component lists, page layouts and all the other important sections of a magazine devoted to building and understanding complicated electronic circuits.

Thank you Dave, for your dedication and commitment over so many years. We wish you well for a long, happy and well-earned retirement.

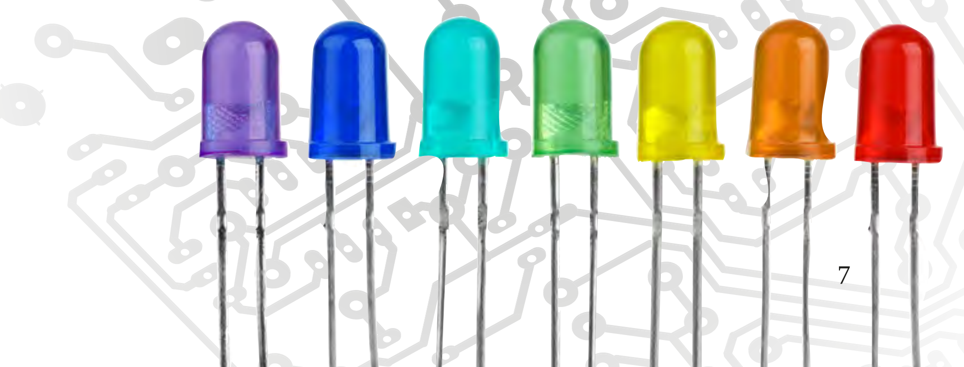
Mike Kenward
Publisher, *EPE*

In this issue

We have some useful and elegant projects for you this month. Top of the list is a superb *Four-Channel Audio Mixer*. It's not difficult to build and can be easily adapted for extra inputs. Next, we conclude our highly capable, two-part programmer project for 8/16-bit PICs and 8-bit Atmel AVR microcontrollers. Plus, we have a very handy *USB Breakout Box* that will let you monitor your computer's port activity.

Last, but not least, we have an article looking at that fascinating, but often-ignored optical component – the neon lamp. 'Neons' may be golden oldies, harking back to the time of valves, wiring looms and Bakelite radios, but they have some unusual properties that present opportunities for experimentation and fun, a phrase that pretty much sums up *EPE*.

I couldn't sign off this month without adding to Mike Kenward's appreciation of Dave Barrington. Dave's great experience, helpful suggestions and good humour were invaluable when I first became editor, and he has continued to be a source of great support ever since. I too wish him all the best for a relaxing and rewarding retirement.



NEWS

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

Audio file upgrade call for action... eventually – report by Barry Fox

The record companies are belatedly waking up to the need for something better than MP3 – which they adopted after failing to agree a secure high-quality system.

There is already an audio-only version of Blu-ray, but it has not been adopted or promoted by the record companies; there are several high-quality download systems, like lossless FLAC, but these are mainly promoted by specialist independent sites such as HDTracks: **www.hdtracks.com**

Evangelical campaign

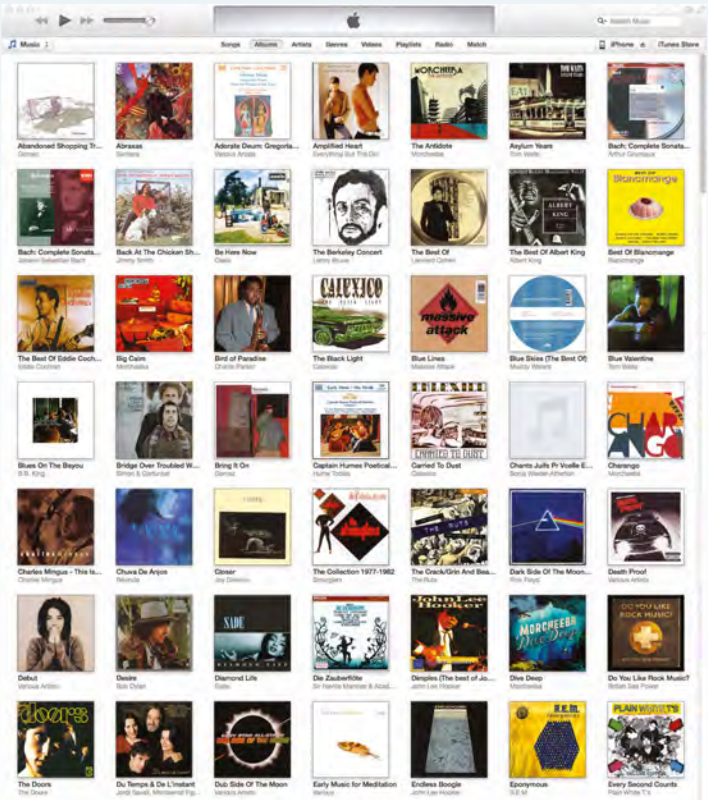
The Universal Music Group (UMG) recently hosted an open day at Abbey Road studios, at which a panel, including Mercury president of music, Mike Smith, Abbey Road engineer Jonathan Allen, record producer Ben Hillier and Dolby Labs 'evangelist' Jonathan Jowitt, called on the music industry to 'use and promote a higher-than-MP3-quality audio file called something like HD Audio'.

Dolby evangelist Jowitt suggested 'a big education campaign to show hi-fi quality is out there'.

UMG has no concrete suggestions, either on a higher-quality format, or format name, a UMG spokesman explained later.

'We are not working on anything specific' he said. 'We just wanted to inspire debate. We have not issued a press release but are posting a blog on our website': **www.umusic.co.uk**

But this will only be seen by someone browsing record company websites. Reporting on the event, UK music industry trade paper, *Music Week*, said the panel agreed 'it's time for labels and services to be brave and market a new format', and warned that the record companies 'could be missing out on a big payday by failing to invest in marketing a new high-quality, consumer-friendly digital format'.



Music is largely consumed as computer files, but is the quality good enough?

Poll

Music Week is now polling the music industry on the questions: 'Could the music industry have missed its Blu-ray moment? Do you think it's time the music industry invested in a new high-quality, consumer-friendly digital format? Should the music industry invest... Or has the moment passed?', see the poll at: **http://tinyurl.com/bm2to8f**

Waiting for Dolby

Dolby Labs' long-term work on administering patents and trademarks puts the company in pole position to know what formats are on offer and have some concrete proposals. But Dolby also did not issue any press release.

'Invites for the audio press to attend had to be very limited. We relied mainly on Dolby Labs to suggest names,' UMG's spokesman explained.

Working on the principle that a technology company which employs an evangelist who calls for 'a big education campaign' would be anxious to educate, I asked Dolby Labs for some factual flesh to add to the bare bones generalities.

'JJ's comments should be understood as a call to action to the industry at this stage' said Dolby's spokeswoman. Asked what kind of action, by whom and based on what technology and nomenclature, she replied: 'We have nothing more to add at this stage.'

EPE EVERYDAY PRACTICAL ELECTRONICS

If you have some breaking news you would like to share with our readers, then please email:

editorial@wimborne.co.uk

Pocket pico projector

Rollei's projector works with smartphones

Gone are the days when projectors were expensive, power-hungry, chunky and not very portable. Rollei, in collaboration with SK telecom, has launched the Innocube IC200T/IC200C pico projector. The cube-shaped, portable pico projector is just 45 × 45 × 46mm in size, has a lithium-polymer battery (2300mAh/120 minutes running time) and makes a nice companion for iPhones, iPads, smartphones or tablets.

Its 35 ANSI lumens of brightness means this little gadget projects an image up to 150cm across (from a distance of two metres – 4:3 aspect ratio) onto any living room or office wall. The VGA resolution is 640 × 480 pixels; the contrast ratio is 800:1.

Thanks to the latest LED technology the projector has a lifespan of 10,000 hours. Weighing in at just 129g, this is a projector that can be taken pretty much anywhere, making it handy for presentations when out and about, or as a mobile home cinema at a friend's place. The minimal heat generation needs very little cooling – there is no annoying fan noise.

As well as phone/tablet devices, the Innocube connects easily to a laptop or a general device meeting the HDMI standard. Focus adjustment is manual and the device includes internal speakers.

The recommended retail price is 299.95 euros.

Cave radio opportunity for electronics enthusiasts

Communicating between a cave and the surface is a formidable challenge, yet it's a common requirement for underground explorers and it plays a vital role in coordinating cave rescues. With the growth of interest in low frequency radio in recent years, radio amateurs and electronic enthusiasts are well placed to make a contribution in this area. Indeed, the cave radio currently used by many of the UK's rescue teams was developed by radio amateurs.

If you'd like to get involved in this unusual yet fascinating realm of radio, and perhaps make a contribution to the state-of-the-art, the journal of the Cave Radio and Electronics Group (*CREG Journal*), published by the British Cave Research Association (BCRA), is essential reading. And with the recent introduction of online access, costing just £4.00, it's never been cheaper to learn about sub-surface communication.

If you want to get a better feel for the sort of articles published in the *CREG Journal*, just head to **http://bcra.org.uk/pub/cregj** where you can see a contents list for the current and previous issues. You can also sign up there for a year's subscription (normally four issues) for either the new online access or to receive the paper edition in the post.

CREG Journal is produced on a non-profit basis, the motivation behind it is purely the dissemination of useful information.

HP comes clean

Some of the most stylish and up-to-date electronic devices use materials that are sourced from gruesome, decades-old conflicts, such as in the Democratic Republic of Congo. Minerals are traded by ruthless combatants to fund war, and some of the largest companies in the electronics industry have come in for heavy criticism for ignoring the human cost of their products.

Now, Hewlett-Packard has announced that it is making public a list of the 195 ore smelters across the world that supply minerals for the company's products. By revealing the source of their minerals, HP are hoping that a combination of their purchasing clout and trading transparency will result in conflict-free sources for its raw materials.

Next wonder material?

Graphene could soon face competition as the next great wonder material, according to a report from website *Gizmag*. Associate Professor Darren Sun and a team of researchers at Singapore's Nanyang Technological University have developed applications for a material known as 'Multi-use Titanium Dioxide' (MUTD).

The researchers used MUTD to produce hydrogen and clean water from wastewater, double the lifespan of batteries, create antibacterial wound dressings ... and more.

The material is made by converting cheap titanium dioxide crystals into nanofibres, which are then incorporated into flexible filter membranes. Depending on the application, the membranes can also include mixtures of carbon, copper, zinc and/or tin.

Sun's team have also created a black version of the material, in which the titanium dioxide is in crystalline form. This was used in a functioning flexible solar cell.

Phone-charging camping stove

US company BioLite has developed a camping stove that lets you cook with simple, easy-to-find fuels, while also providing electricity to charge mobile phones and LED lights off-grid.

The stove cooks food and drink with nothing more than natural found fuel (wood, leaves, twigs), eliminating the need for heavy, expensive, polluting petroleum or bottles of gas. It's quick to light, fast to boil and clean to use.

The clever bit is the incorporation of a power module that houses a patented thermoelectric generator, converting heat to electricity. It also contains a small microprocessor, which manages the flow of power both to the in-built fan that regulates air (oxygen) to the fire and the electrical output.

The stove provides electrical power through a USB port, delivering up to 2W of power at 5V for charging USB-compatible devices.

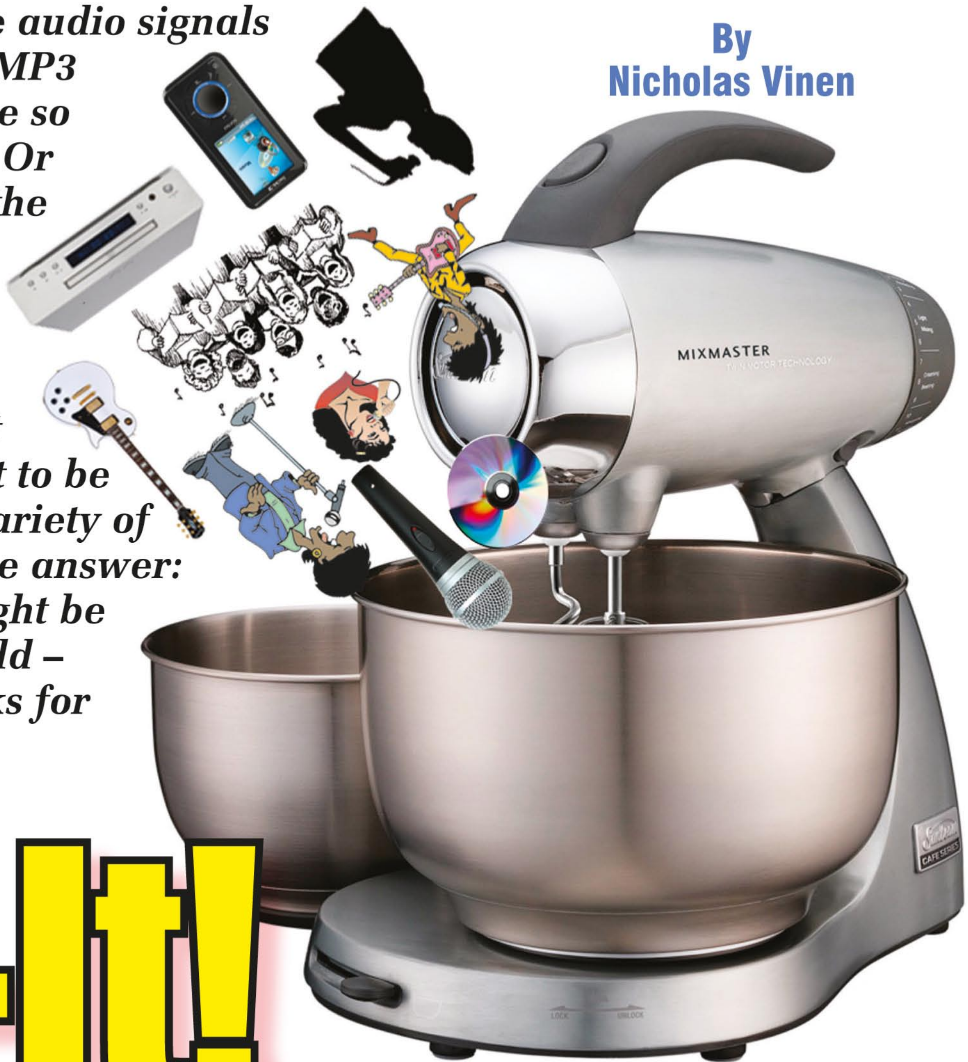
The stove costs $129.95, plus p&p, more information at the Biolite website: **www.biolitestove.com**

Charge your phone in the great outdoors

Anyone can build this high performance four-channel audio mixer...

Want to mix two or more audio signals together? Maybe it's an MP3 player and a microphone so you can 'play' Karaoke. Or perhaps you've formed the next earth-shattering band and need to mix a couple of guitars and a mic or two together. Or you've built a PA amplifier and want to be able to drive it from a variety of signal sources. Here's the answer: this 4-channel mixer might be simple and cheap to build – but its performance lacks for nothing!

By
Nicholas Vinen



Mix-It!

THIS mixer is something of a reprise of a very popular 4-Channel Mixer from April 2009.

While this one has several similar features, (it is an audio mixer, after all!) it also has a number of improvements – for example, performance, cost, ease of build – and as a bonus, the PCB is smaller, so you can fit it into a more compact case.

It features four inputs, which can be configured for a wide variety of signal sources; from very low level (eg, microphone or guitar) right through to quite high (eg iPODs/MP3 players, CD/cassette decks [remember them?!]).

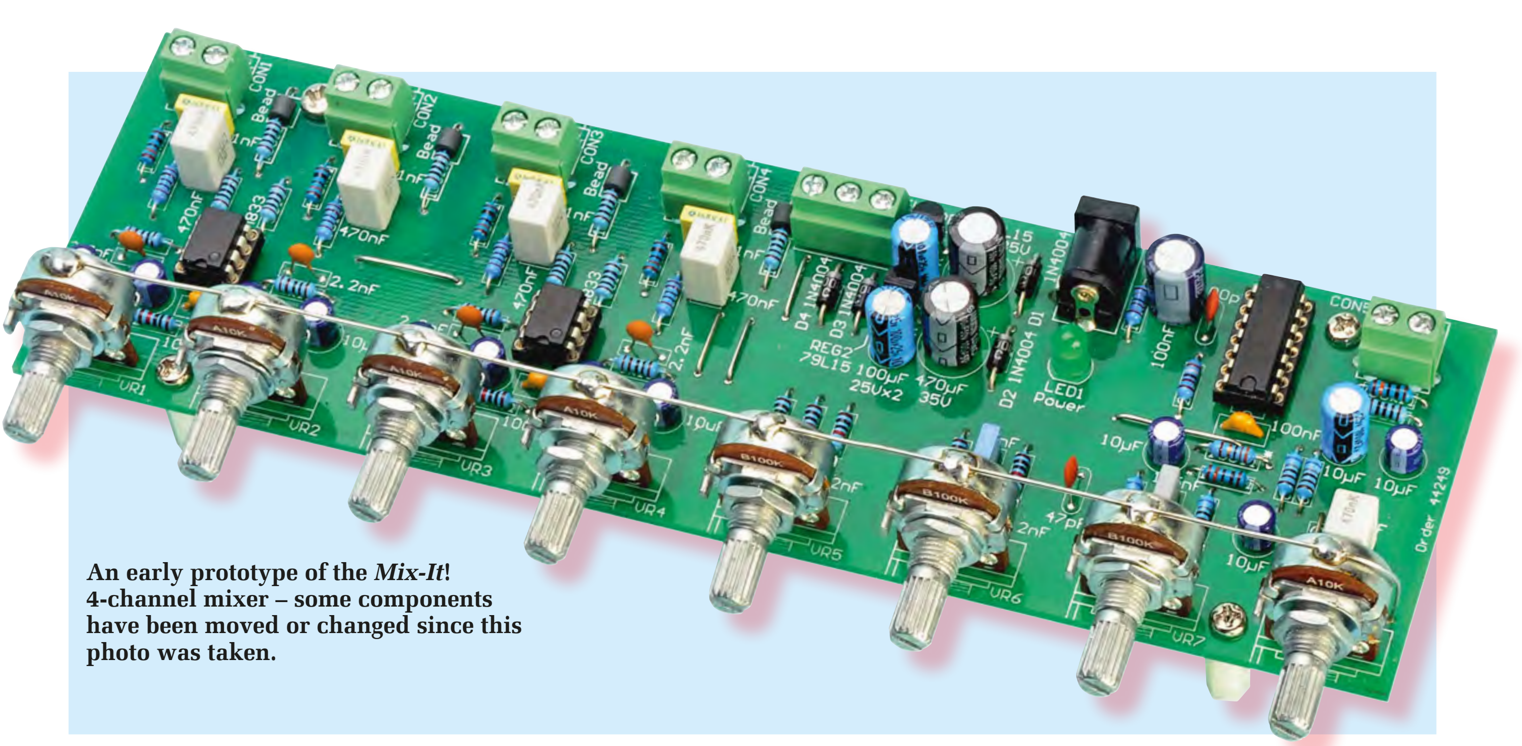
It has bass, midrange and treble controls, individual channel level controls, along with a master volume control and an on-board power supply. You can build it as a stand-alone unit, or it can be incorporated into a PA or guitar amplifier. In fact, it doesn't even need to be a PA/guitar amplifier: with almost 800mV output, this mixer could be used with virtually any amplifier with a 'line in' or similar input.

Other features include a variety of power supplies – it could use a low voltage AC supply – say around 15V – or it could use a split DC supply, such as that commonly found in amplifiers (eg, ±15V).

We'll have more to say on the audio mixer's supply options shortly.

Features

- Four unbalanced inputs with 1MΩ || 100pF input impedance (see text)
- Gain of 0-36dB per channel (depending on feedback components)
- Bass, mid and treble controls (±10dB)
- Master volume control
- Input radio signal filtering
- Flat frequency response
- Low distortion and noise
- Four supply options: 15V AC, 12-30V DC, ±15V or unregulated split supply



An early prototype of the *Mix-It*! 4-channel mixer – some components have been moved or changed since this photo was taken.

How it works

Each of the four identical inputs, CON1-CON4, can be fitted with either a terminal block or preferably, a PCB-mounting shorting-type RCA socket. We say preferably, because unconnected inputs are then shorted to ground and therefore don't introduce any noise or hum into the circuit.

Each input has an RF filter, consisting of a ferrite bead and 100Ω resistor in series with the signal, and a 100pF capacitor to ground. These act as low-pass filters with a cut-off frequency of 16MHz, while the ferrite beads greatly improve the rejection of signals above a couple of hundred kilohertz.

We mentioned 'ground' a moment ago. In this circuit, it's important to note that there are two different 'grounds'. The first is the 'power' ground and uses the conventional ground symbol (⏚). The second is the 'signal' ground and it uses a different symbol (⏚). We'll explain these a bit more when we look at power supplies shortly.

The audio signals are then AC-coupled to op amps IC1b, IC1a, IC2b and IC2a via 470nF capacitors with 1MΩ biasing resistors. This high value is necessary if the mixer is used with electric guitars, as their frequency response changes when driving lower impedances due to loading effects on the inductive pick-up(s). The relatively low value RF filtering capacitors (100pF) were chosen for the same reason.

While most of the coupling capacitors in the circuit have been increased compared to the original design, here we have used a lower value since the input coupling capacitors need to be non-polarised. This is because the signal source could potentially have a high DC bias, or the input might be accidentally shorted to a power rail.

We also wanted to use an 'MKT' (polyester) capacitor, because they are more reliable and linear than non-polarised electrolytics, which also vary greatly in size.

Before each op amp is a 100Ω resistor, which acts as an additional RF stopper.

IC1a-IC2b are TL072 low-noise JFET- input op amps. Due to the high value bias resistors, the LM833s used in the original design are not suitable. They would have an excessive output DC offset due to their relatively high input bias currents. JFET-input op amps have a much lower input bias current with only a small increase in noise.

The gain for these op amps is set by the two resistors at their outputs. In the circuit we have used 'middle of the road' values of 1.8kΩ and 220Ω, resulting in a gain of about 9.2 (18dB). Gain is calculated using the formula:

$$\frac{1.8k\Omega + 220\Omega}{220\Omega}$$

This is about half that of the original design, which could not handle line-level input signals without clipping. This one can – up to 900mV RMS, or more with reduced gain.

These values can be changed to suit various input devices, as we shall see shortly.

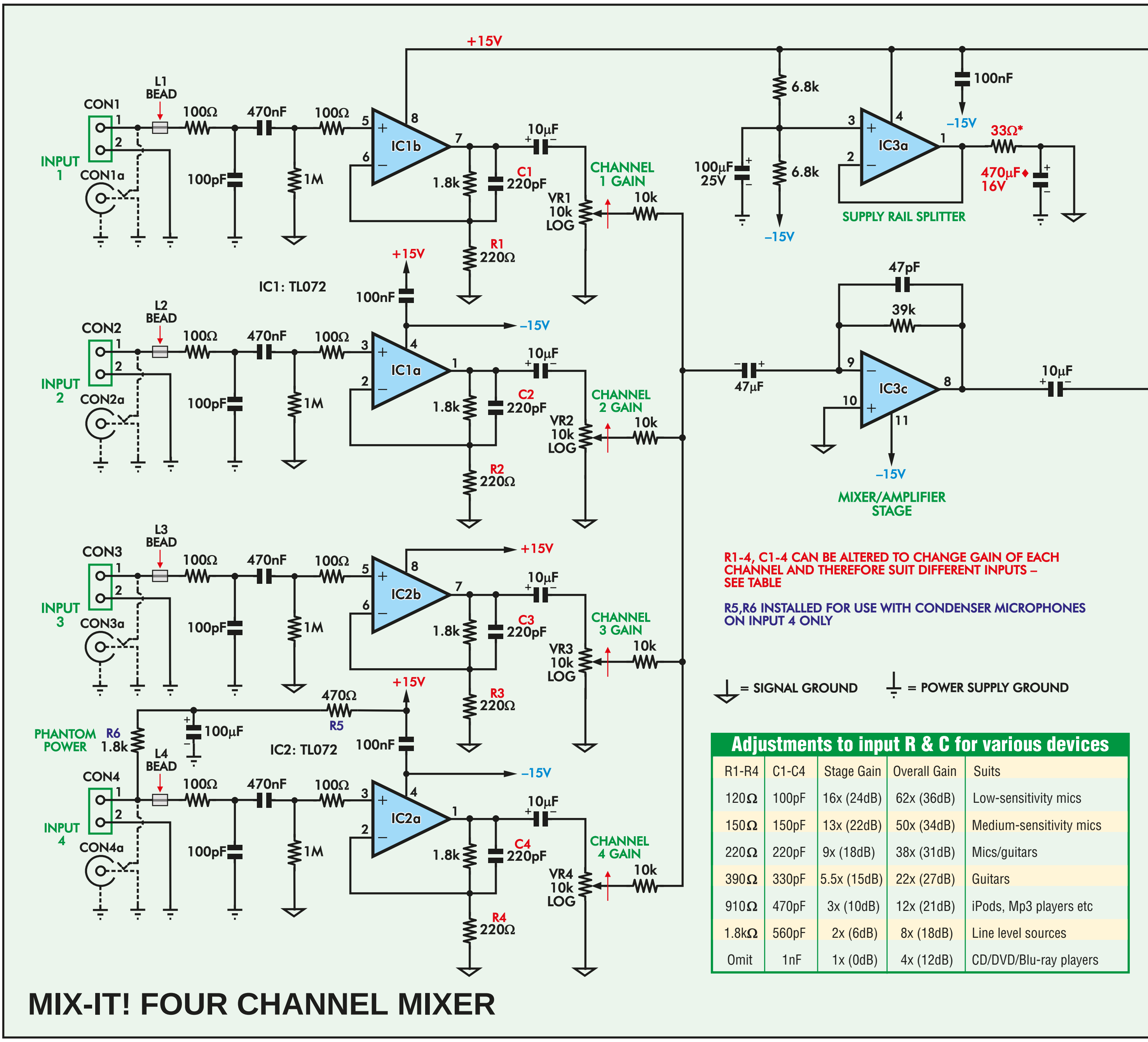
The feedback capacitors (nominated as 220pF) roll off the op amp closed-loop gain at high frequencies to improve stability, reduce noise and provide a further degree of RF rejection.

The op amp outputs are AC-coupled via 10µF electrolytic capacitors to 10kΩ log volume pots (VR1-VR4). These capacitors are polarised, to minimise size and cost. We can get away with this because the op amp input bias currents (small though they may be with JFET inputs) cause the op amp outputs to have a slightly positive DC bias.

The pot wipers then connect to four 10kΩ mixing resistors, which are joined

Specifications

• Input range for line-level output: 18-900mV	
• Frequency response:	20Hz-20kHz, +0,-1.2dB (see Fig.3)
• Signal-to-noise ratio:	–75dB @ 32dB gain; –92dB @ 0dB gain
• THD+N (for 20Hz-20kHz bandwidth):	0.015% @ 32dB gain 0.003% @ 18dB gain 0.002% @ 0dB gain



Adjustments to input R & C for various devices

R1-R4	C1-C4	Stage Gain	Overall Gain	Suits
120Ω	100pF	16x (24dB)	62x (36dB)	Low-sensitivity mics
150Ω	150pF	13x (22dB)	50x (34dB)	Medium-sensitivity mics
220Ω	220pF	9x (18dB)	38x (31dB)	Mics/guitars
390Ω	330pF	5.5x (15dB)	22x (27dB)	Guitars
910Ω	470pF	3x (10dB)	12x (21dB)	iPods, Mp3 players etc
1.8kΩ	560pF	2x (6dB)	8x (18dB)	Line level sources
Omit	1nF	1x (0dB)	4x (12dB)	CD/DVD/Blu-ray players

Fig.1: the circuit diagram consists of four near-identical input stages, the outputs of which are mixed and amplified before being fed into a tone control stage and output buffer. Any of the four inputs may be altered from that shown to account for different audio devices – anything from a microphone to a Blu-ray player can be accommodated (see table above).

together at the other end. This is the 'virtual earth' point and is held at signal ground potential by op amp IC3c.

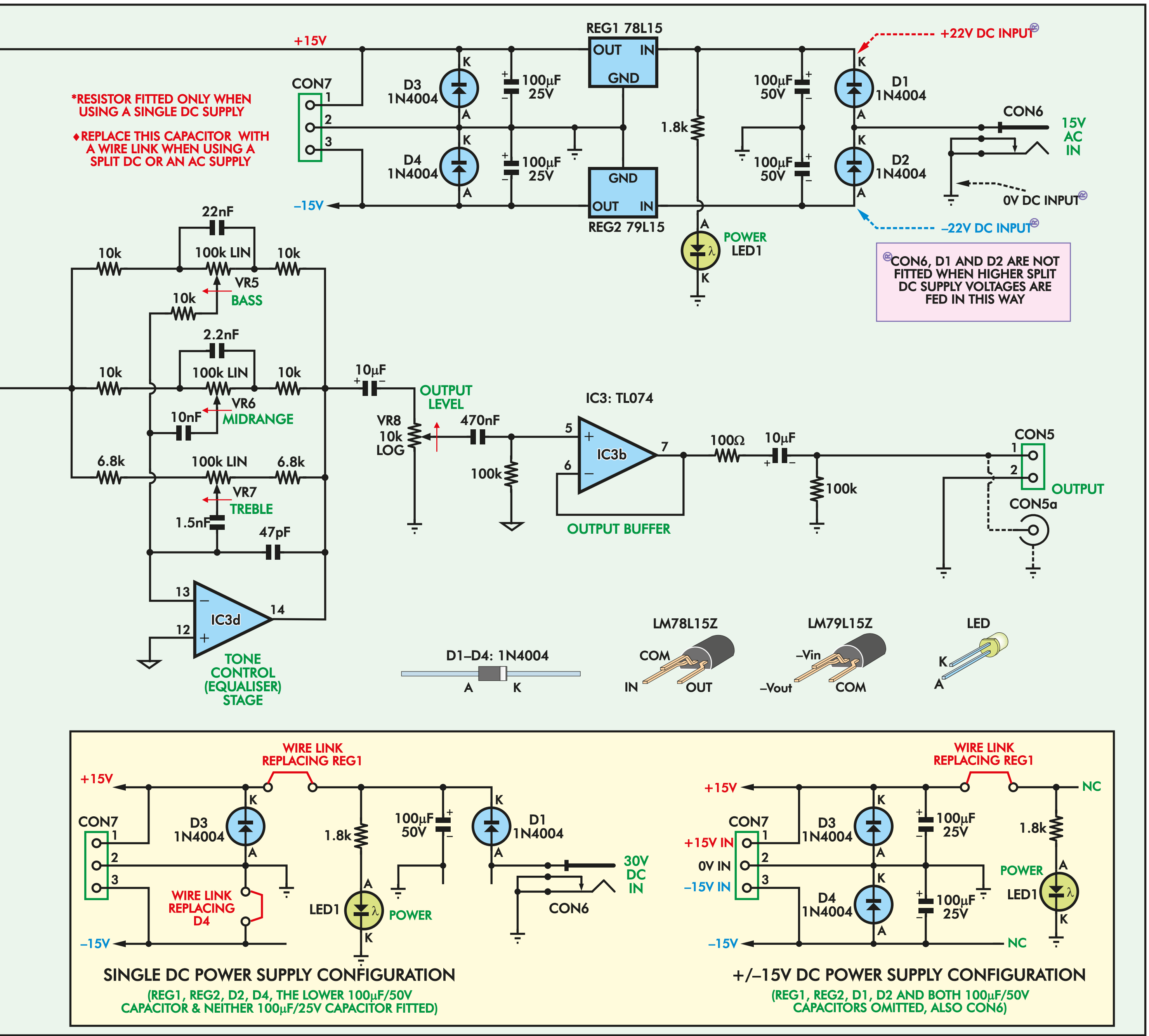
Its non-inverting input (pin 10) is at signal ground potential and it is configured as an inverting amplifier with a gain of –3.9, as set by the ratio of the 39kΩ feedback resistor to the 10kΩ mixer resistors. The overall maximum gain of the unit is therefore 3.9 × 9.2 = 36 (or 31dB).

The resulting output signal is the sum of the four input signals (from the wipers of the pots).

A 47pF feedback capacitor limits the bandwidth again, and the output is AC-coupled to the active tone control stage with a 10µF capacitor, oriented so that it will have the correct DC bias.

The tone control stage is a traditional Baxandall-style arrangement (named after Peter Baxandall, the man who first described this circuit) with three bands – bass, mid and treble. We have copied this unchanged from the original design as there is nothing wrong with it. Three 100kΩ linear potentiometers, VR5-VR7, adjust the feedback around op amp IC3d, which is in an inverting configuration.

The combination of capacitors across VR5 and VR6 with the capacitors at the wipers of VR6 and VR7 means that each pot controls the feedback over a different audio 'band'. Thus, they each boost or cut a different range of frequencies. Refer to Fig.6 to see the effect of these pots; this shows the frequency response of



Inset at the bottom of the main circuit are two variations for powering the mixer – two are shown on the main circuit diagram above (15V AC and ±22V DC). Each of these is further illustrated on the component overlay. R5, R6 and the 100µF capacitor on the main circuit are only needed if your microphone requires phantom power (see text).

the mixer with the controls set at their maximum extents, as well as centred (blue trace).

Having been inverted twice, once by the mixer and once by the tone controls, the signal at output pin 14 of IC3d is in phase with the inputs. This is coupled to the master volume control pot, VR8. The output is taken from the wiper and then coupled with a 470nF MKT capacitor to the non-inverting input of op amp IC3b, with a 100kΩ DC bias resistor. This op amp simply buffers the signal to provide a low-impedance output.

The 100Ω resistor at the output of this op amp isolates it from any cable capacitance which could otherwise cause oscillation. As with the inputs, output connector CON5 is either a terminal block or RCA socket. A final 10µF AC-coupling capacitor is used so that the output DC level is at 0V, regardless of the signal ground potential, with a 100kΩ DC bias resistor setting this DC level.

Power supply

Like the original design, this unit can be powered from a ±15V regulated DC supply, via CON7. If the mixer is installed in a case with a preamplifier, there is a good chance that such rails will already be present.

But if not, or in cases where the mixer is used as a stand-alone unit, the mixer can be run off low-voltage AC or DC. An unregulated split supply can also drive the unit in some cases, as will be explained later.

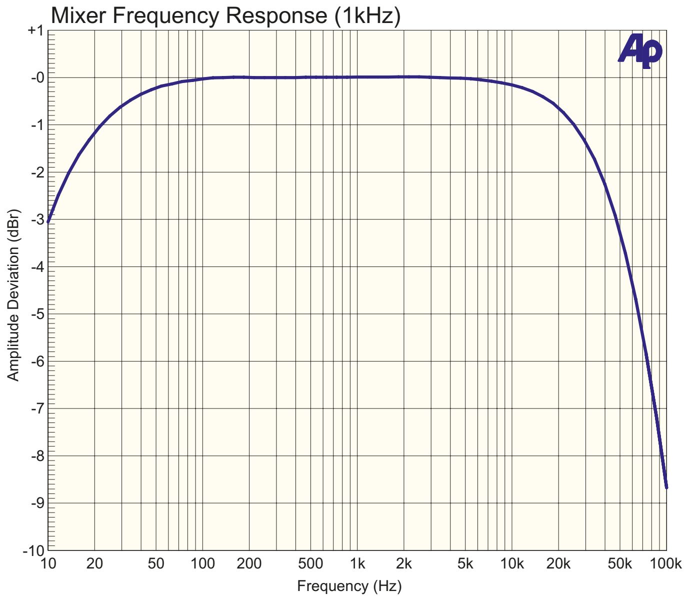


Fig.2: frequency response of the mixer with the tone controls set to their mid positions and gain at maximum. Roll-off is only 1.2dB at 20Hz and –0.75dB at 20kHz, while the –3dB points are at 10Hz and 45kHz.

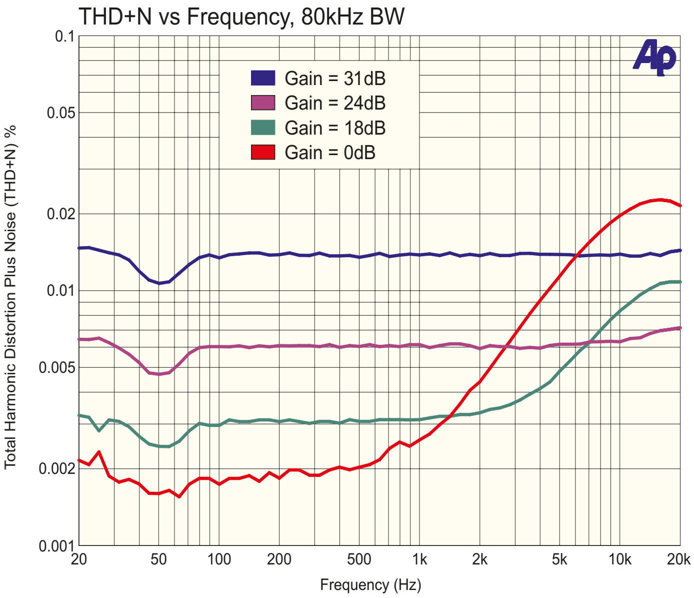


Fig.3: performance with a 15VAC supply. At high gain settings, noise and 50Hz hum field pick-up dominate the distortion graph; the dip at 50Hz is when the test signal cancels some of the mains hum.

For low-voltage AC, 15-16V RMS is supplied to CON6. Diodes D1 and D2 act as two half-wave rectifiers, charging the 100µF 50V capacitors alternately as the AC signal swings positive and negative to provide unregulated rails of approximately ±22V DC. ((16 x$\sqrt{2}$) – 0.6V).

This is then regulated to ±15V by REG1 (78L15, +15V) and REG2 (79L15, –15V). The output voltages are filtered with 100µF capacitors. Diodes D3 and D4 prevent them from being reverse-biased during operation, which could cause REG1 or REG2 to 'latch up' when power is first applied. This can happen because one rail starts to charge up before the other due to the half-wave rectification.

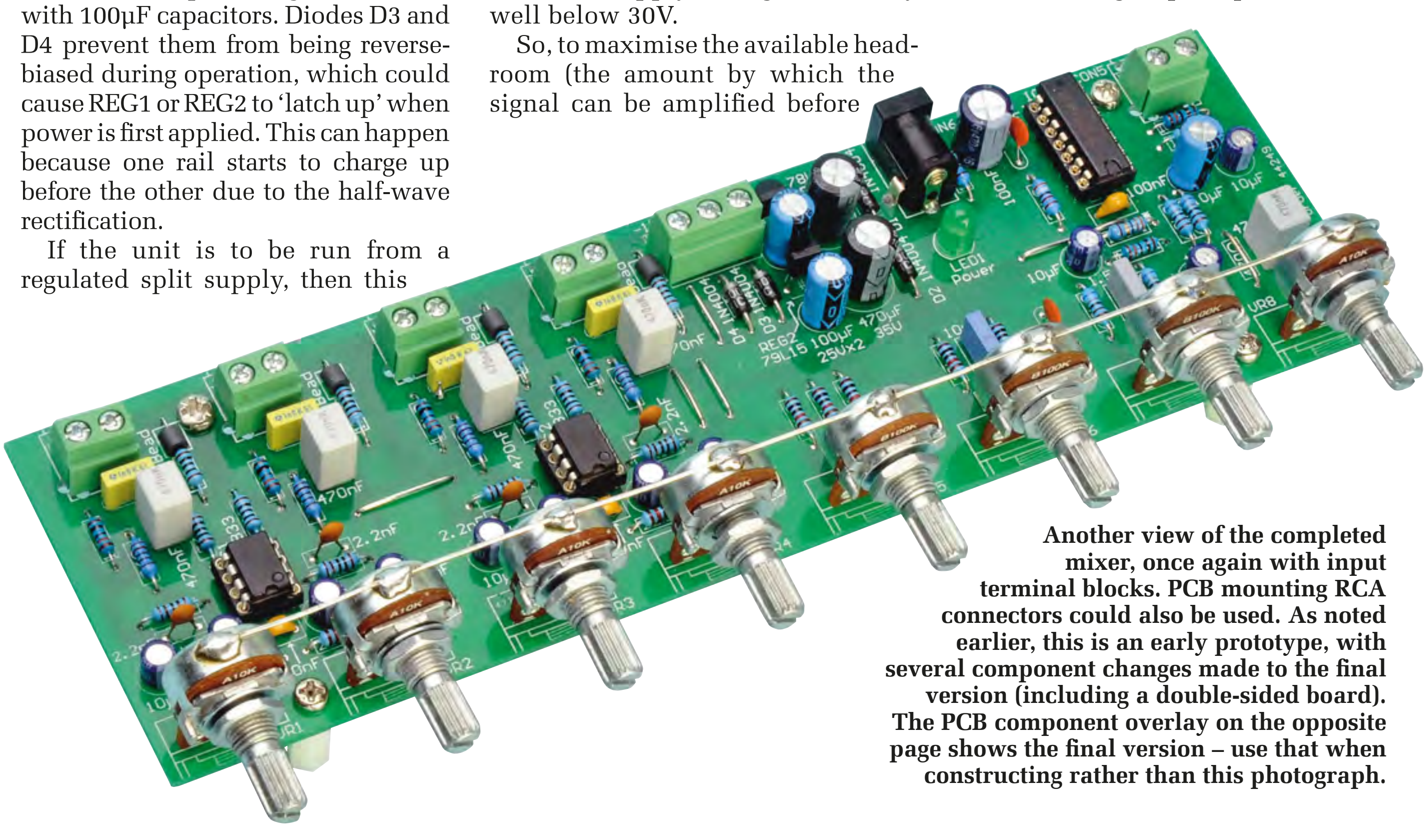
If the unit is to be run from a regulated split supply, then this is connected to CON7, bypassing the regulators and powering the circuit directly.

If an unregulated split supply is to be used, then it can be connected via the pads for D1 and D2, bypassing the rectifier and feeding the regulators directly.

The situation for a single DC supply is a little more complicated. In this case, the supply voltage is usually well below 30V.

So, to maximise the available headroom (the amount by which the signal can be amplified before clipping), the regulators are bypassed (linked out) so that the full voltage, less D1's forward voltage, is available to the op amps. D2 is also linked out and power is applied via CON7.

In this case, since there is no negative supply, the signal ground potential must be positive. This bias is generated by op amp IC3a. The two resistors connected to its non-inverting input (pin 3) form



Another view of the completed mixer, once again with input terminal blocks. PCB mounting RCA connectors could also be used. As noted earlier, this is an early prototype, with several component changes made to the final version (including a double-sided board). The PCB component overlay on the opposite page shows the final version – use that when constructing rather than this photograph.

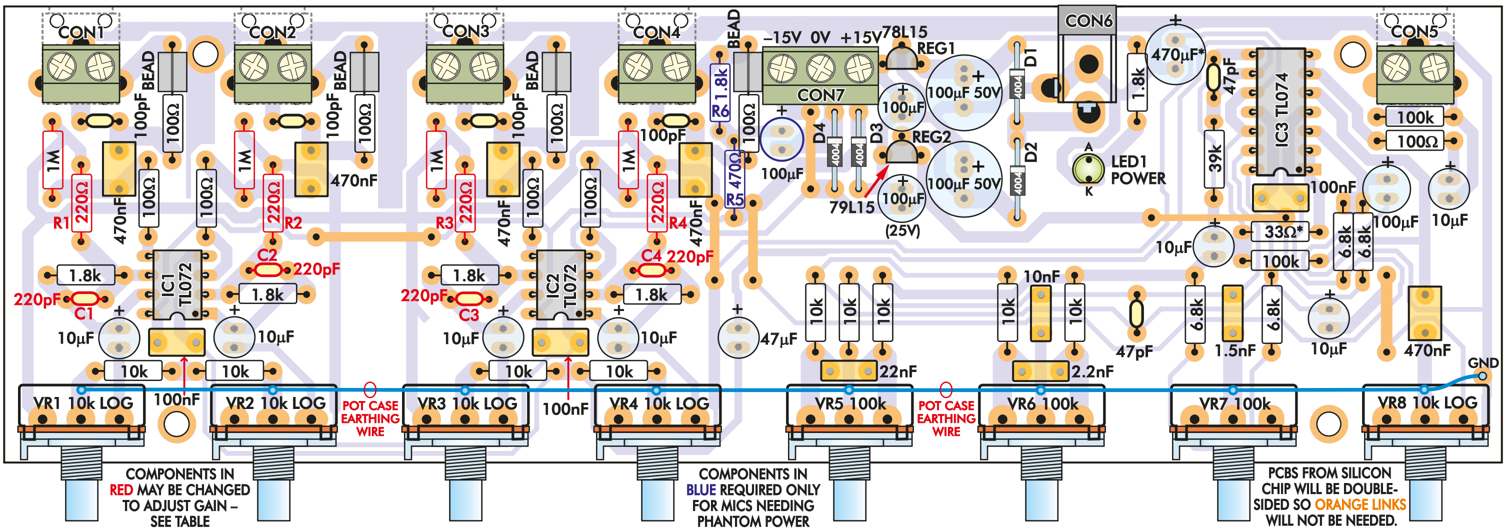


Fig.4: the complete component overlay for the *Mix-It! mixer*. In this case, we have shown 220Ω resistors and 220pF capacitors in the R1/C1...R4/C4 positions, which would make it suitable for guitars and many microphones. However, you can change these resistors to suit other input devices (see the table on the circuit diagram) or even add switching to one or more channels to allow the input(s) to be switched at will (see Fig.8). R5, R6 and the associated 100µF capacitor on input 4 are provided for microphones requiring 'phantom power'. If you don't need this, you can leave these components out.

a divider across the supply rails, producing a voltage of roughly half the DC supply. For example, if the DC supply is 12V, this point is at about 6V. It is filtered using a 100µF capacitor, to remove supply noise.

IC3a buffers this voltage, providing a low output impedance, and this is filtered further using a 33Ω resistor and 470µF capacitor. The 33Ω resistor prevents op amp instability due to the large capacitive load. The RC low-pass filter formed by the 33Ω resistor and 470µF capacitor is important to achieve good performance, as even a tiny amount of supply ripple coupling into the signal earth will be greatly amplified and coupled into the output, dramatically reducing the signal-to-noise ratio and increasing the distortion.

We would normally use a 100Ω resistor at the op amp output, to isolate it from a capacitive load, but experimentation shows that 33Ω provides better hum rejection, presumably due to the fact that higher values increase the output impedance of the buffer stage too much.

To quantify the loss of headroom when running from a single supply, 12V DC can be considered equivalent to a ±6V split supply. Considering the limited op amp voltage swing, this gives a maximum signal handling of about $(6V - 1V) / \sqrt{2} = 3.5V$ RMS. With a fixed gain of 10 at each input, the maximum input level is then 350mV RMS.

That's plenty for most microphones and musical instruments, but line level sources are generally at least 500mV and so they will clip unless they are attenuated somehow (or the input stage gain is reduced; more on that later).

The foregoing explains why separate signal grounds and power supply grounds are required when a single rail DC supply is used. But when an AC or split supply is used, the signal ground is connected directly to power supply ground to ensure the polarised coupling capacitors are correctly biased. This is achieved by omitting the 33Ω resistor and replacing the 470µF capacitor with a wire link.

All these options may seem confusing, but we have provided diagrams showing which components to install in each case.

Construction

The mixer is built on a PCB coded 903, 198mm × 60mm. Refer to the overlay diagram (Fig.4). If you are not using an AC supply, refer also to one of Figs. 5, 6, 7 or 8 to see the changes required to suit your particular situation.

The PCB can be double-sided with plated-through holes, so there will be no need for links. However, the PCBs supplied by our *PCB Service* are not double sided.

Because it is also unlikely students (and some readers) will make a double-sided board, six tinned copper wire links will be needed for single-sided boards (they're shown on the PCB overlay).

Now insert the resistors. It's best to check the value of each with a digital multimeter before fitting it.

The 1N4004 diodes go in next, with the striped (cathode) ends towards the top of the PCB. If you're using IC sockets, mount them now, with the notches oriented towards the bottom of the PCB, as shown. Otherwise, just solder the ICs into place, taking care that they are oriented with pin 1 towards the bottom of the board. IC sockets do make it easy to place and remove ICs, but we prefer to solder them in permanently, as long as there is no mistake!

If installing the regulator(s), bend the leads to fit the pad spacings on the board and solder them in place. Don't get them mixed up and ensure that the flat side faces as shown on the overlay diagram. The LED can be installed next, flat side also facing down, followed by the ceramic and MKT capacitors, from smallest to largest.

Solder 3-way terminal block CON7 in place, with the wire entry holes facing the top edge of the PCB. If you are using terminal blocks for the inputs and outputs, fit them now too. Follow with the DC socket and then the electrolytic capacitors, all of which have the longer positive leads inserted in the hole closest to the top edge of the PCB (stripes towards the bottom edge).

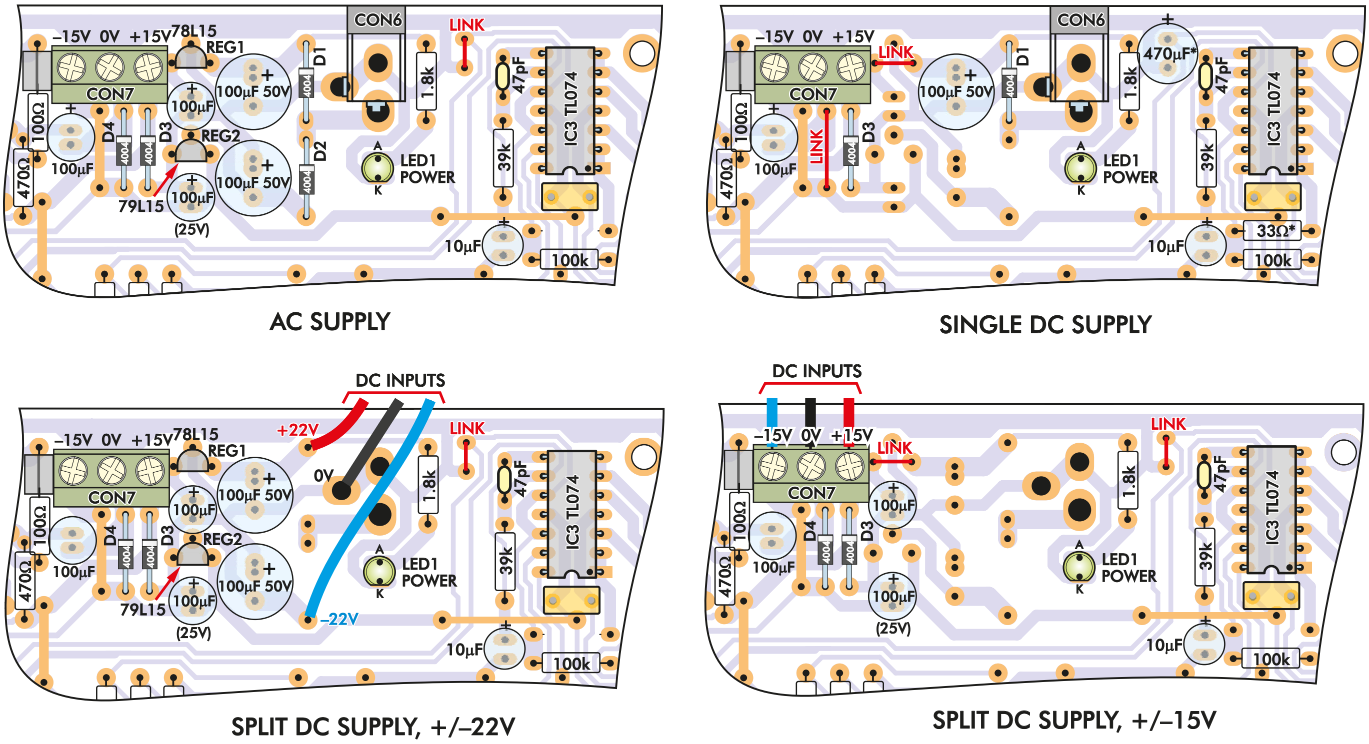


Fig.5: four variations on a theme . . . the mixer is quite versatile as far as power supply goes – simply wire yours according to the power supply you are going to use.

Ensure the correct type of capacitor, as shown on the overlay diagrams, is placed in each location.

If you are using RCA sockets for the inputs and outputs, mount them now, checking that they are pushed down all the way onto the PCB, and that the sockets are parallel to the board and perpendicular to the edge.

To minimise noise, all of the pot bodies are connected together and then to the PCB with a 250mm length of tinned copper wire. To prepare them for soldering, hold gently in a vice and file away a patch of the passivation layer on the top of each pot (otherwise the solder won't take). If your pots have long shafts, now is also a good time to cut them to the length you require (don't forget to take into account any case or cabinet width).

Solder the pots in place, ensuring that you note the difference between the three 100kΩ linear types and the 10kΩ log types. While you have the soldering iron in your hand, run a thin layer of solder over the surface of the pot where you just removed the passivation.

Now solder one end of the tinned copper wire to the pad marked 'GND' to the right of VR8, bend it over the top of VR8 and then solder it to the top of VR1, so that the wire passes across the top of each pot. Once it is held tightly in place, solder it to the top of the remaining pots and trim the excess.

If you are using them, fit the nylon spacers to the four mounting holes and then, if you are using sockets, insert the ICs. They must be oriented with their pin 1 dots at the same end as the notches on the sockets, ie, towards the bottom of the board. If not using sockets, carefully solder in the ICs, again noting orientation.

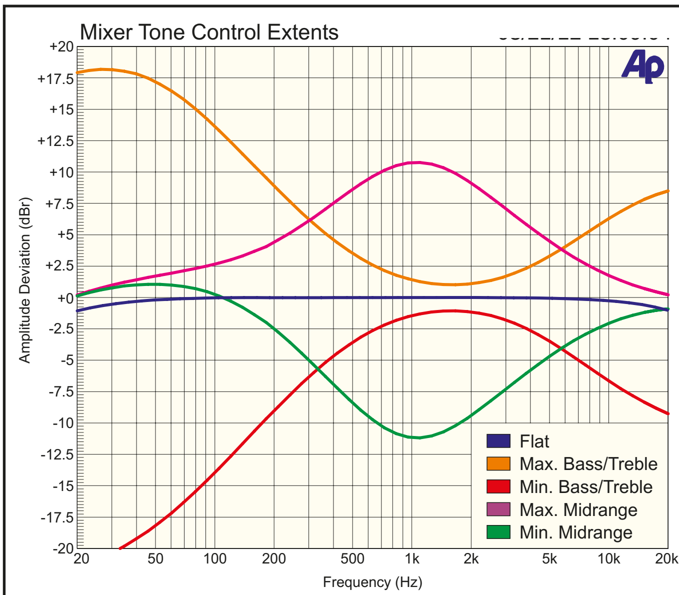


Fig.6: the operation of the tone controls. The blue trace is the same as Fig.2, but with a different scale. The tone controls allow a boost or cut of around 10dB for each band, with the centre frequencies around 30Hz for bass, 1kHz for mid-range and above 20kHz for treble.

Housing it

The mixer should ideally be housed in an earthed steel case, although it can be used inside an amplifier or guitar amplifier/speaker case.

If you are using a case, the pots are all 25.4mm (1 inch) apart, so you will need to drill a horizontal row of eight 8mm-diameter holes in the front panel. The board can then be 'hung' behind the front panel via the potentiometers.

You may need to snap off the small locating spigots on each pot with small pliers (or, preferably, drill small pilot holes to accommodate them. The spigots stop heavy-handed users trying to twist the pots on the panel).

While not really necessary, you can also attach the PCB to the bottom of the case using the tapped spacers – although this method of mounting might be preferable if poking the pot shafts through a thick (eg, guitar speaker box) panel.

The most common input connectors for guitars, microphones and so on will usually be 6.35mm jack sockets and/or XLR sockets. The PCB is designed to accommodate RCA sockets 'on board', but this may not be the most convenient to use.

The altenative is to mount the sockets on a case panel – often they are mounted on the front panel or adjacent vertical panel next to their respective controls. If so, you will need to run shielded cable from the sockets to the input connectors (CON1-CON4).

The output can then go to an RCA socket on the rear panel, or to an internal power amplifier. Either way, use shielded cable for this connection too.

When using chassis-mount jack sockets, use switched sockets and wire them to short out the input signal when nothing is plugged in, to minimise noise and hum. See Fig.7 for details on how to do this.

The power supply wiring can then be run. Wire split supplies (+15V, 0V, –15V) up to CON7. Single DC supplies or low voltage AC go to CON6. The overlay diagrams show how the wires are connected.

If you want a front-panel power indicator, it is possible to mount LED1 off-board and connect it up with flying leads and optionally, a pin header.

Parts list – Mix-It! Four Channel Mixer

1 PCB, code 903, size 198mm × 60mm available from the *EPE PCB Service*
5 2-way mini terminal blocks (CON1a-CON5a) OR
5 PCB-mount switched RCA sockets (CON1-CON5)
1 PCB-mount DC socket (CON6)
1 3-way mini terminal block (CON7)
8 small knobs, to suit VR1-VR8
4 small ferrite beads
1 plugpack or other power supply
1 250mm length tinned copper wire (or 400mm if wire links are used)
4 M3 nylon tapped spacers
4 M3 × 6mm machine screws
2 8-pin DIL sockets (optional)
1 14-pin DIL socket (optional)

Semiconductors
2 TL072 dual low-noise JFET-input op amps (IC1, IC2)
1 TL074 quad low-noise JFET-input op amp (IC3)
1 78L15 +15V 100mA linear regulator (REG1)
1 79L15 –15V 100mA linear regulator (REG2)
1 green 5mm LED (LED1)
4 1N4004 diodes (D1-D4)

Capacitors
1 470µF 16V electrolytic
2 100µF 50V electrolytic
4 100µF 25V electrolytic
1 47µF 50V electrolytic
7 10µF 50V electrolytic
5 470nF MKT
3 100nF MKT
1 22nF MKT
1 2.2nF MKT
1 1.5nF MKT
4 220pF ceramic
4 100pF ceramic
2 47pF ceramic

Resistors (all 1%, 0.25W)

4 1MΩ	2 100kΩ	1 39kΩ	9 10kΩ	4 6.8kΩ
6 1.8kΩ	4 220Ω	9 100Ω	1 33Ω	

5 10kΩ logarithmic 16mm potentiometers (VR1-VR4, VR8)
3 100kΩ linear 16mm potentiometers (VR5-VR7)

Testing

Turn all the volume knobs, including master volume to their minimum (ie, fully anti-clockwise) and set the tone controls to their centre positions. Switch on the power supply and check that LED1 lights.

Plug the output of the mixer into a suitable amplifier and turn that on – with level controls at a minimum you should hear nothing! It's then just a matter of applying a signal to one input, then slowly turning up the corresponding input and master volume controls to check that the output sound is undistorted.

Note that since there is a fair bit of gain available, if you use a line level source, you won't have to turn the volume knobs up very far.

Check each of the four inputs in turn and also check that the tone controls have the appropriate effect on the signal.

If you hear a lot of hum or noise, it's probable that it's being induced into the sensitive input stages from whatever amplifier you've teamed the mixer with – in which case, you might need to house the unit in an earthed metal box inside the amplifier case.

Alternately, hum may be caused by a hum loop, either from the power supply or the input cabling. You might need to experiment a little with earthing arrangements for best results.

Changes for MP3 players

Some constructors may wish to experiment with some component values. By doing so, you can adapt tthe mixer to your particular requirements.

For example, the feedback resistors for IC1 and IC2 can be changed to give different maximum gain settings for each input. You could, for example, reduce the gain of inputs 1 and 2 so that they can accept signals up to 1-2V RMS, suitable for use with a CD or DVD player, while leaving inputs 3 and 4 with a high gain to suit microphones

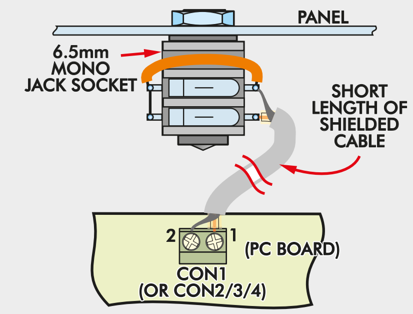


Fig.7: how to wire a standard switched phono jack as a shorting jack and connect it to the PCB. This is highly recommended, otherwise, unconnected inputs may contribute noise and hum to the output of the mixer.

or a guitar. Or you could increase the gain of one channel above the nominal 31dB to suit a microphone with a very small output signal.

The easiest way to change the gain of each input is to change the values of R1 and C1 for channel 1, R2 and C2 for channel 2 and so on. Smaller values for these resistors increase the gain and larger values decrease them. The associated capacitor is changed at the same time, to keep the frequency response constant. The table on the circuit diagram shows various options for these components, but other combinations are possible.

You can also alter the gain for all inputs by changing the 39kΩ resistor between pins 8 and 9 of IC3c. A higher value resistor will give you more overall gain, but will also increase the noise and distortion. So, for example, if you change the 39kΩ resistor to 82kΩ you will double the overall gain, while changing it to 22kΩ will halve it.

It may be possible to gain a slight improvement in performance by replacing the TL072 and TL074 op amps with OPA2132/2134 or similar. However, the benefits will be marginal, as other factors already limit the performance.

It is possible that some devices such as iPods and MP3 players may not work with the mixer as published because there is no DC path for the input signals to flow to ground. This can easily be solved with the addition of a resistor (eg, 100Ω) connected across the input for that channel. Probably the easiest way to do this is between the terminals of CON1a, CON2a, etc – even if there other cables going in there.

However, an input modified in this manner will no longer work with some microphones, guitars and other devices with a high output impedance (normal 600Ω 'dynamic' microphones will not be too badly affected).

Phantom power for condensor microphones

It would arguably be fairly unusual for condensor microphones to be used with a mixer such as this, but it is possible.

The difficulty is that condensor microphones require a DC supply on their output (known as 'phantom' power), normally around 16-48V at 1-2mA and use the microphone cable to power the microphone.

Because the inputs to the op amps are AC-coupled, feeding DC 'up the line' will have no effect on the mixer. Phantom power can, therefore, easily be achieved by connecting a bypassed DC supply between the positive supply and the 'hot' side of the microphone input.

We have made provision for this on one channel only, channel 4, with R5, R6 and a 100µF bypass capacitor. If you do not require phantom power, you can simply leave out these three components.

In fact, you should not connect phantom power to a microphone that doesn't need it. Putting a DC bias on a dynamic microphone's voice coil, for example, will usually result in a lower (or no) output and may even permanently damage the microphone.

Making inputs truly versatile

We designed this mixer to be as simple as possible to build, with everything 'on board'. This assumed that constructors would nominate the input device required for each channel and fit appropriate resistors and capacitors for R1, C1, and so on (as per the table on the circuit).

But what if you need to regularly swap inputs with devices that have different signal levels? It happens often in, for example, a band – or where various microphones are required to suit vocals or instruments.

It would be quite simple to fit a multi-pole switch to any or all of the input op amps and so switch various values of R and C.

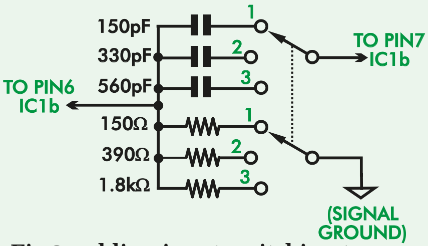


Fig.8: adding input switching to one or more channels is really easy and makes the mixer much more versatile (but does complicate construction a little). Here we've shown a 2-pole, 3-position switch capable of selecting a microphone (1), guitar (2) or line-level (3) source. 2-pole rotary switches with up to six positions are also available if you want more switchable inputs.

For most applications, the input bias resistors will be satisfactory. However, you could bring these all down to 100kΩ if you really want to.

Small double-pole (or 'changeover') slider switches are available with up to four positions, so you could, in theory, fit four different values of R and C on the switch (again, as per the table on the circuit) and then be able to select the input level required according to the device being connected and, of course, its signal level. (See Fig.8).

Alternatively, small rotary switches can be configured to have two poles and six positions, so most of the variations shown on the circuit diagram could be accommodated.

The resistors and capacitors could be wired directly to the switch and three wires (eg, rainbow cable) run to the appropriate positions on the PCB (ie, the positions which would have been occupied by R1, C1...).

Want more than four channels?

Getting greedy, aren't we! Seriously, adding additional channels to a design of this type is easy – you simply build additional input circuits – up to and including the 10kΩ resistor after the individual channel 'gain' pots (VR1-4).

The 'mixed' output of the four new channels is simply connected to the negative side of the 47µF capacitor before the existing IC3c, just as happens now.

Power (ie ±15VDC), can be taken from a suitable point on the existing mixer – the supply will handle it – and signal and supply grounds are also connected to suitable points. ***EPE***

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From intra-body experiences

TechnoTalk

Mark Nelson

Many people 'have had an out-of-body experience', a feeling of extra-corporeal floating. The sensation may arise from psychological factors, intoxication or even electrical stimulation of the brain. Now researchers are finding applications for electronics *within* the human body. There's no Frankensteinian involvement, but Mark cannot help feeling a slight queasiness.

IN-BODY electronics are not new. Experiments with artificial pacemakers date back to 1899, although all the early trials used external devices. The first clinical implant was in 1958 in Sweden. Although the device failed after three hours, the patient, Arne Larsson, went on to receive 26 different pacemakers during his lifetime, dying at the age of 86 and outliving the inventor as well as the surgeon. Excellent as these devices are, they require electrical power and patients face regular operations (at five to seven-year intervals) to replace worn-out batteries. For this reason, a longer-lasting power source for pacemakers would be welcome news.

Perpetual motion machine?

A development under examination in the US is to use power generated by the heart itself to recharge batteries using piezoelectricity – an electrical charge generated mechanically. This is a particularly benign use of energy harvesting, a technology we have discussed many times in this column. This application, in which human heartbeats generate electricity to recharge the battery of the electronic pacemaker, might appear to be perpetual motion, but of course this is not the case. Pacemakers require only small amounts of power to generate the electrical impulses that help the heart maintain a normal heartbeat, and the energy harvester actually generates more than ten times the power required by modern pacemakers.

The research at the University of Michigan is led by Dr Amin Karami, who said his team's findings suggest this kind of patient-power could eliminate the need for replacements when batteries are spent. 'Many of the patients are children who live with pacemakers for many years. You can imagine how many operations they are spared if this new technology is implemented,' he stated. He added that piezoelectricity might power other implantable cardiac devices such as defibrillators, which also have minimal energy needs.

However, piezoelectricity is not the only solution under examination, especially for body devices that need greater power. For these, the best solution seems to be miniaturised biofuel cells consuming substances naturally occurring in the human body or in its direct environment.

Bio-batteries are here

Or rather not here, but in Poland. Researchers from the Institute of Physical Chemistry in Warsaw have created an organic bio-battery that has direct in-body potential. What's more, it promises comparatively high voltage and long useful life (relative to other biofuel cells at least). It uses oxygen from the air, plus a cathode composed of an enzyme, carbon nanotubes and silicate. It's by no means a competitor for the batteries that you and I use for cellphones or torches, but for powering internal body implants such as heart pacemakers it offers considerable promise.

Of course, organic bio-batteries are not new, as the Institute's Dr Martin Jönsson-Niedziółka, reminds us. 'One of the most popular experiments in electrochemistry is to make a battery by sticking appropriately selected electrodes into a potato. We are doing something similar; the difference is that we are focusing on biofuel cells and the improvement of the cathode. And, of course, to have the whole project working, we'd rather replace the potato with a human being'.

Nothing noxious

Body-function applications are becoming more ambitious. Today, they include cardiac pacemakers or hearing aids; tomorrow it will be contact lenses that change focal length automatically or computer-controlled displays generating images directly in the eye. These devices will only work if coupled to an efficient and long-lasting power supply.

Standard types of battery are unsuitable for powering implants inside the human body, as they use harmfully strong alkalis or acids, unless the battery housing is absolutely impervious. Their size and weight are generally too great too. Biofuel cells offer an essential advantage in that to generate power, it is enough to insert the electrodes into the body. So far, the Polish team has successfully powered a lamp composed of two LEDs, using a stack of four batteries connected in series. There is still a long way to go, and researchers must solve the problem of relatively low electric power that is common to all biofuel cells.

Spoof story?

You could be forgiven for assuming last month's news story about using the human body as a comms channel was an April Fool's joke, but in fact this announcement was made in February. That was when Arizona-based Microchip Technology revealed its BodyCom technology – the first in the world to employ the human body as a secure, low-power communication channel. The company describes it as providing short-range, low data-rate communication for connecting securely to a wide range of wireless applications. According to Microchip, when compared to other wireless technologies, BodyCom offers lower active and standby energy usage, increased security through bidirectional authentication, and simpler circuit-level designs.

The press release is as clear as mud, but fortunately the product video (**https://www.youtube.com/watch?v=dTuXAGUjnQA**) translates better into plain English. The gist of the demonstration is that in situations where you need to prove you are authorised to do something (open a locked doorway, start a piece of machinery or anything similar), you can do this just by putting your finger on a touch pad. The enabling device is a keyfob that remains in your pocket; it sends and receives data through your body, using capacitive coupling. It's a lot easier to understand if you watch the video!

According to the manufacturer, its implementation is simpler than comparable products, plus, it has a lower overall bill of materials and power consumption measured against existing technologies. The system complies with (American) FCC Part 15-B regulations on radiated emissions. Because a wireless transceiver is not used, a significant cost component is eliminated and no radio antenna design work is necessary. At the same time, battery life is extended and there are no high-power inductive fields that might endanger health.

As well as the keyfob security devices used for BodyCom, Microchip provides a development board that can be used to build prototypes and a Windows-friendly software development environment. More about BodyCom at: **www.microchip.com/pagehandler/en_us/technology/embeddedsecurity**.

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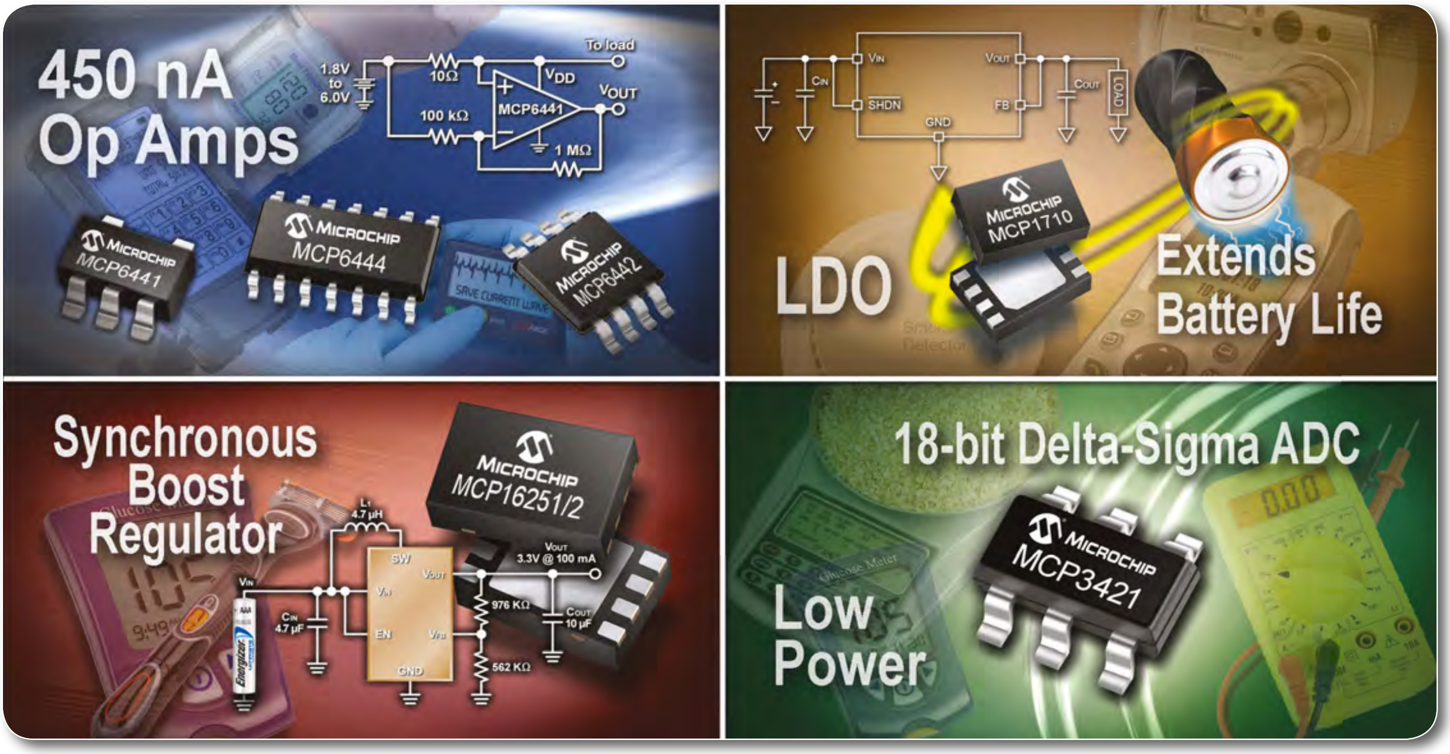

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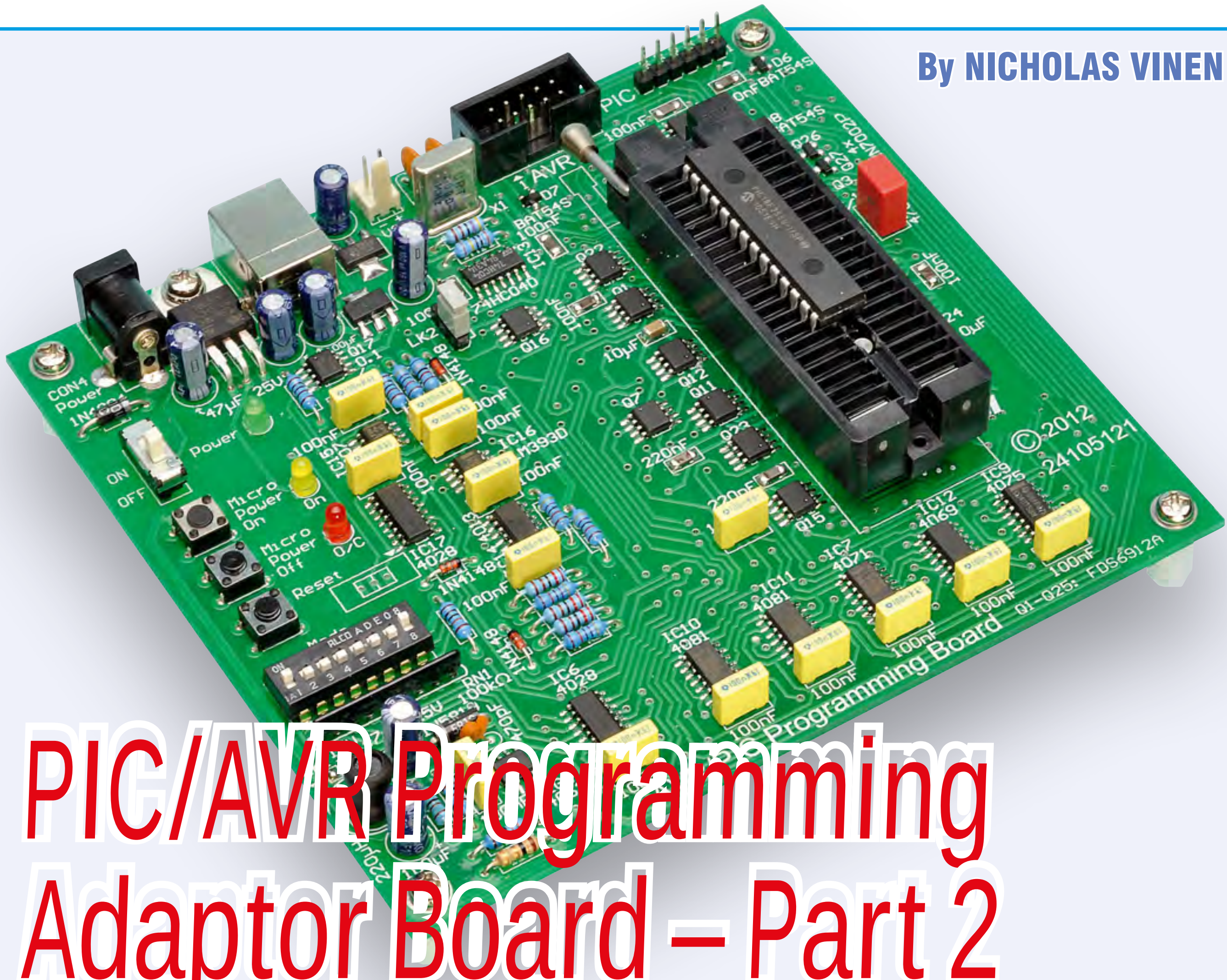
By NICHOLAS VINEN



PIC/AVR Programming Adaptor Board – Part 2

Last month, we described our new programming adaptor board which works in conjunction with an In-Circuit Serial Programmer (ICSP) to program most 8-bit and 16-bit PIC and 8-bit Atmel AVR microcontrollers. Here, we give the details of how to build it and how to use it.

AS NOTED last month, virtually all the semiconductor devices in the *PIC/AVR Programming Adaptor* are surface-mount, apart from the diodes and LEDs. This approach has been taken because otherwise the PCB would have been impractically large.

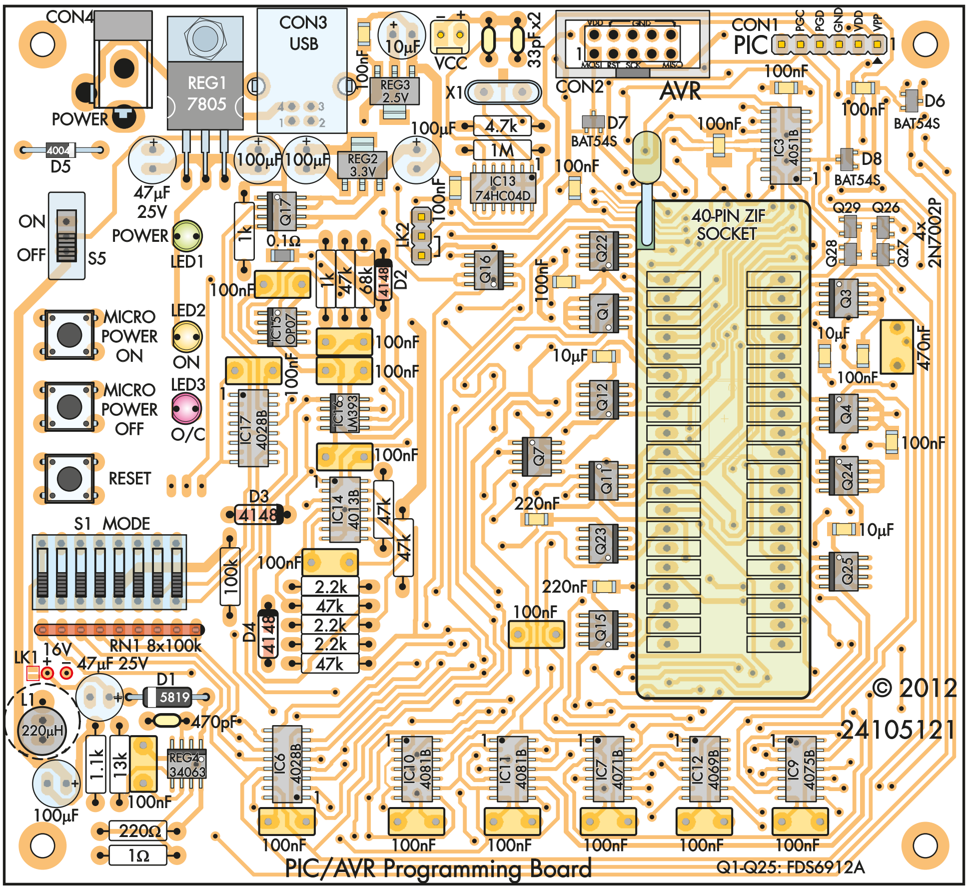
Even so, the double-sided PCB is fairly densely populated on the top-side and has quite a few SMDs underneath as well. However, we have specified SMDs with a 'reasonable' pin spacing, so they should not be too challenging to solder.

The double-sided PCB supplied by the *EPE PCB Service* is not through-hole plated and will require all vias to be wired and soldered through before any components are fitted – there are numerous vias. It will also be necessary to solder a number of components, including a number of pins on the 40-pin production DIL socket, on both sides of the board. This is not an easy task and some readers may prefer to purchase a PCB from *Silicon Chip* in Australia which is through-hole plated, with solder mask and with component overlay; the cost is approximately £30 per board including postage to the UK – order from the *Silicon Chip* website at **www.siliconchip.com.au**.

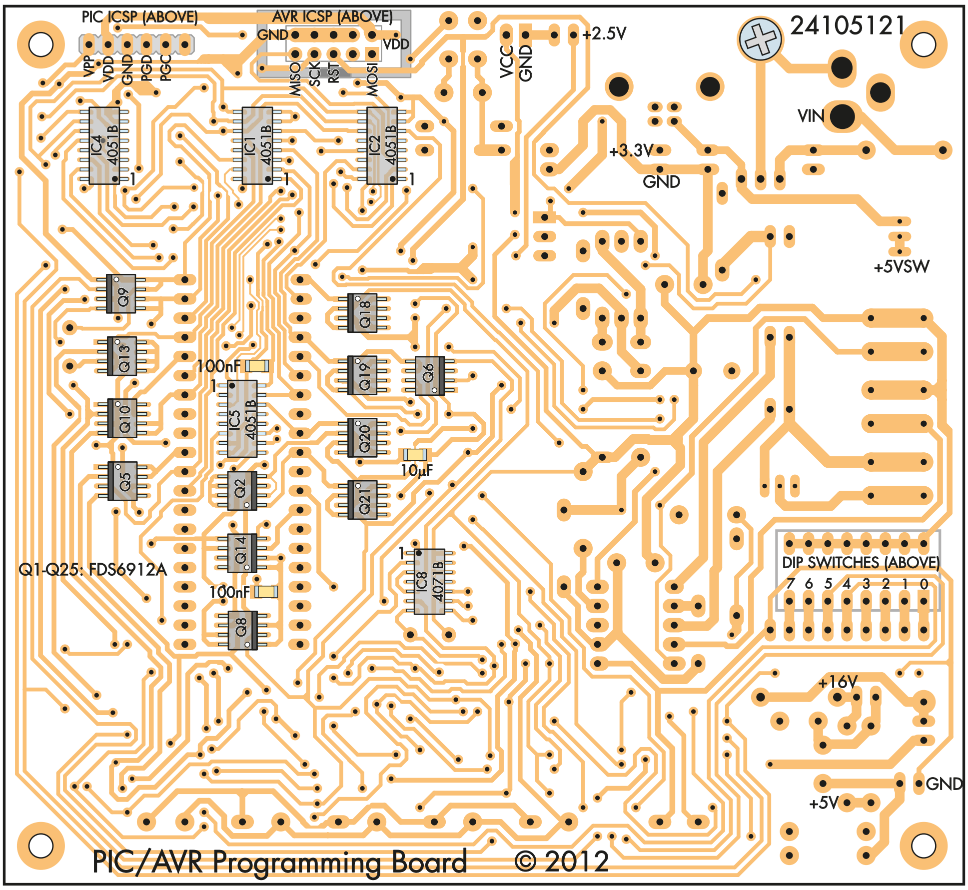
Fig.4(a) and Fig.4(b) show the component overlays for both sides of the PCB. Install the surface-mount parts on the top first. You can refer to the panel later in this article for a step-by-step procedure on hand-soldering SMDs.

Note that most of the SMD components are static-sensitive, and so you should ideally build it on an anti-static

Fig.4: the overlay diagrams for both sides of the PCB. Install the parts as shown here, paying close attention to the orientation of the ICs, MOSFETs and electrolytic capacitors. Pin 1 is shown with a dot in one corner of the IC, but in some cases there may be no dot and instead, a bevelled edge on the IC package indicates the side with pin 1.



(TOP OF BOARD)



(UNDER SIDE OF BOARD)

mat or using some other method to prevent damage to the MOSFETs and ICs.

Starting assembly

Start with the three small dual diodes (D6-D8) and then fit the four 2N7002P MOSFETs. These diodes and MOSFETs look virtually identical, so be careful not to get them mixed up.

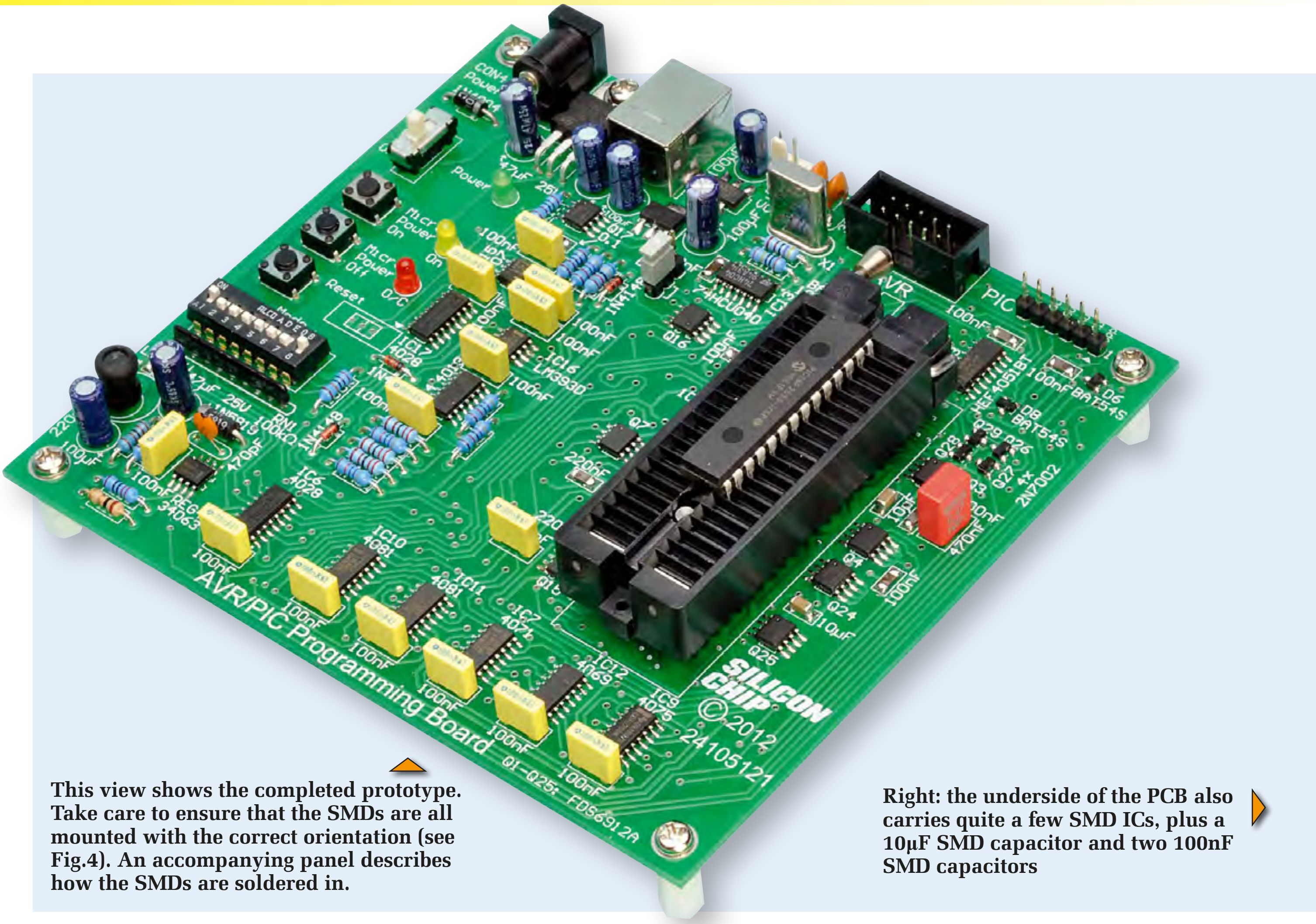
Follow with the 13 FDS6912A dual MOSFETs that go on the top of the board. They are in 8-pin SOIC packages and are not all oriented in the same manner, so check carefully that each one is the right way around before soldering it in place. These MOSFETs usually have both a bevelled edge on one side of the package and a dimple to indicate pin 1 – the position of both is shown on the overlay diagram.

There are also 13 ICs (including REG4) on the top of the PCB and they go in next. Again, their orientations vary, so you should check each one carefully. Some of the ICs may have a dot or dimple indicating pin 1, but some will only have a bevelled edge, and that is the most reliable way to tell which way they go in. Many of the ICs are in identical packages, so take care that each type goes in its designated location.

Regulators REG2 and REG3 can now be fitted. Solder the three pins and then the tab. Don't get the two mixed up. Then you can fit the passive SMD components, which consist of eight 100nF ceramic 'chip' capacitors, two 220nF ceramic capacitors, three 10µF ceramic capacitors and one 0.1Ω SMD resistor/shunt.

It's now time to fit components to the other side. First fit the four tapped spacers at each corner on the top side of the board, using M3 × 6mm screws. That done, flip it over and it will rest flat and level on the spacers rather than the components you have just finished soldering.

Refer now to Fig.4(b). There are a further 12 FDS6912A dual MOSFETs,



This view shows the completed prototype. Take care to ensure that the SMDs are all mounted with the correct orientation (see Fig.4). An accompanying panel describes how the SMDs are soldered in.

Right: the underside of the PCB also carries quite a few SMD ICs, plus a 10µF SMD capacitor and two 100nF SMD capacitors

so fit them now. Again, be careful with orientation as it varies. Follow with the five remaining ICs and then the three passive SMD components: one 10µF and two 100nF ceramic capacitors. You can then remove the tapped spacers and refit them on the reverse side of the board, in preparation for the next step.

Through-hole components

Now we come to the resistors. Check each value with a DMM before soldering them into place. Follow with the five diodes, oriented as shown on the overlay diagram. There are three different types, so be sure to put them in the correct locations.

Mount the 40-pin production (or dual-wipe) IC socket next, with the notch at the top. Check carefully that its edges are parallel to the edges of the PCB before soldering more than a couple of pins, otherwise the ZIF socket will be crooked when it is inserted

Bend the leads of REG1 down 90° 6mm from the plastic body and then mount the tab onto the PCB using the remaining M3 × 6mm machine screw, a shakeproof washer and a nut. Do it up tight, then solder and trim the leads.

Fit the 9-pin resistor network next, with its pin 1 (usually indicated by a dot) towards the righthand end of the PCB. The 8-way DIP switch can then go in, with the text right-side up, as shown in the photos. That done, solder the three LEDs in place with their anodes to the right (flat sides to the left), followed by the MKT and ceramic capacitors.

Bobbin inductor L1 is next. There is an extra pad on the PCB so that you can fit different-sized chokes. If you're using the smaller type, make sure it is soldered across the bottom two holes. You can then fit slide switch S5, which can go in either way, although you may wish to mount it with the stamped 'ON' text at the top.

Now solder in the 2-way, 3-way and 6-way pin headers (CON5, LK2 and CON1 respectively). Follow with the IDC socket (CON2) and then crystal X1. You can then fit all the electrolytic capacitors with the longer lead though the hole marked with a '+' symbol in each case.

The DC and USB sockets go in now. In each case, ensure they are aligned with the edge of the PCB before soldering their pins. Attach the USB socket's tabs to the mounting pads before soldering the smaller pins.

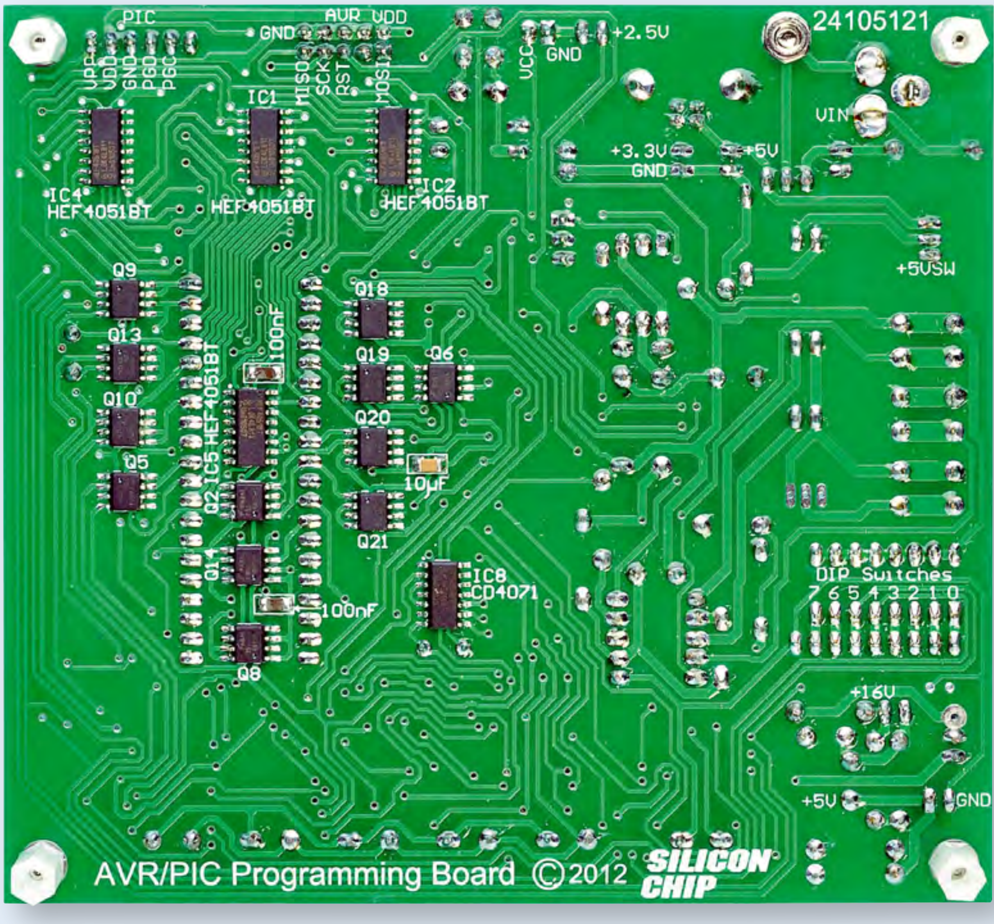
You can now mount the tactile pushbuttons after pushing them down firmly onto the top of the board. Orientate them so that the pins are on the left and right sides.

Testing

First, check that the power supply is operating properly. Move all the DIP switches to their lower (off) positions. The two pads for LK1 (below the DIP switches) must not be shorted together.

If you have a current-limited bench supply, set it for 9V and 100mA and connect it between a convenient ground point and the anode of D5. Otherwise, you can use a 9-12V DC plugpack. Leave S5 in the 'off' position – and then switch on the power supply.

Check the output of REG1 at its right-most pin. You can use the tab or mounting screw to connect the ground probe. You should get a reading very



close to 5V. Assuming that's OK, switch on S5 and check that the green power LED lights up.

There are two small round pads to the right of LK1, below the DIP switch bank, labelled '+' and '–'. These allow you to check the output of REG4, which should be close to +16V. However, since they are quite close together, you may find it easier to measure between TP1 (the positive test point) and the same ground point you used earlier, eg, REG1's tab.

Confirm that REG4 is providing around 16V. If not, then switch off and check it and the surrounding circuitry for faults such as incorrectly oriented components or bad solder joints. Assuming that it's OK, measure the output of REG2 at its tab, relative to the same ground point you used earlier. You should get 3.3V.

You can now disconnect the power supply and short LK1's pads together using a small blob of solder. Set up the DIP switches for the PIC18F2xJ5x series of microcontrollers, as shown in Fig.5. Apply power, turn power switch S5 on and then press the 'Micro Power On' pushbutton. The yellow LED should light up. If the red LED lights up, switch off and check for faults in the power supply circuitry.

Check the voltage at pin 32 of the ZIF socket (adjacent to pin 9), relative to a convenient ground point, eg, the tab of REG1. You should get a reading of around 3.3V. Check that pins 8 and 31 read very close to 0V. They should not be floating, which normally gives a reading somewhat above 0V.

Now set your DMM to continuity mode and check that there is a good connection between pin 1 of the ZIF socket and the V_{PP} pin of CON1 (right-most). Check this in both directions, ie, swap the multimeter probes around and ensure that there is a connection either way. You can then perform the same test to check that ZIF socket pin 40 (upper-right) is connected to PGD (CON1, third-from left) and that socket pin 39 connects to PGC, the second-from-left pin of CON1.

Now use the DMM to check that the five right-most pins of CON1 are not connected to each other. You may get a brief beep out of the multimeter with the probes between V_{DD} and GND due to power supply bypass capacitance. There should not be continuity between PGD, PGC and V_{PP}.

Assuming that your DMM also has a capacitance mode, measure the capacitance between pins 6 and 8 of the ZIF socket. This should be around 10µF. Much less than that indicates a fault.

If that all checks out OK, chances are good that your programming adaptor board is working properly. You could test other modes in a similar manner, referring to the relevant microcontroller data sheets, but it would take a while to check all the various modes.

It's now time to install the ZIF socket, with the lever towards the top of the board. Support the PCB underneath the socket and press it down hard. Its large pins are a tight fit, but they should go in with some effort and it won't easily come off again unless you really need to remove it. The unit is now ready for use.

Using it

Fig.5 and Fig.6 provide the instructions you need to operate the unit. These can be copied and laminated to keep with the unit. Note that it's generally not a good idea to change the positions of the DIP switches while the unit is switched on as the design assumes that all the logic is static. This also avoids the possibility that you might accidentally change to the wrong mode while a microcontroller is in the ZIF socket and powered up.

Note that some PICs require 5V for programming even though they can run at 3.3V (eg, PIC12F675). For this reason, it's generally best to program with a 5V supply if the micro is rated to operate at 5V, which may require different DIP switch settings than those shown in Fig.5. If in doubt, check the data sheet.

Generally, LK2 can be left in its default position, with the jumper shunt across the bottom two positions. That way, the in-circuit programmer receives power at the same time as the micro, and so it won't try to 'probe' it when it is unpowered.

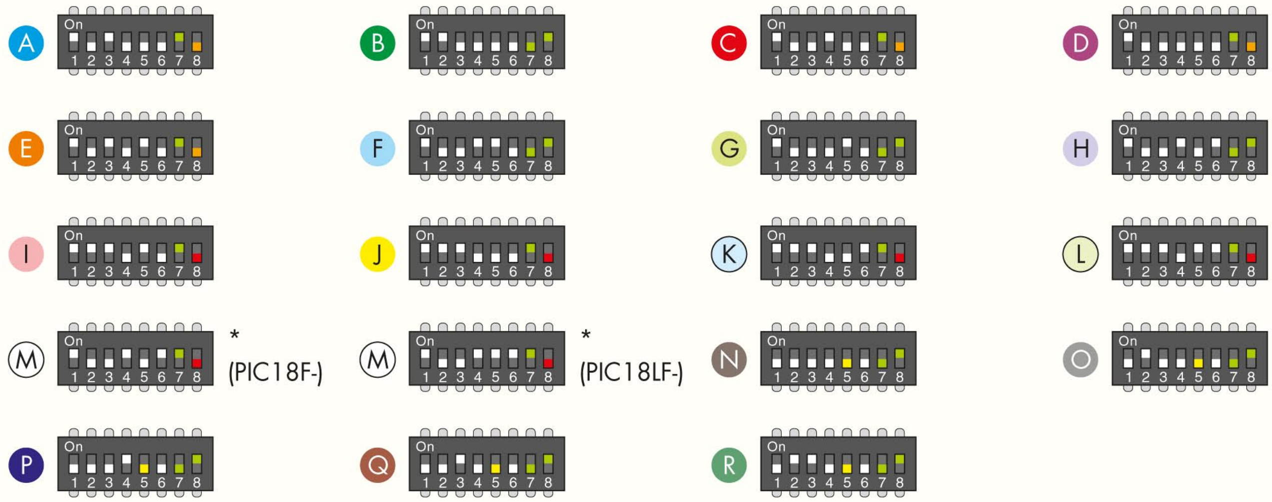
But, if the programmer is to provide power for the micro and you want to be able to switch it using the on-board power on/off buttons, you can move the shorting block to the other position. In this case, the programmer's V_{DD} pin

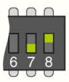
Setting The DIP Switches and Programming The Device

PIC/AVR Programming Adaptor Board Device Selection

PIC12F-, PIC12HV-	(A) All
PIC16F-, PIC16LF-	(A) 50x, 51x, 526, 63x, 67x, 68x, 690, 720, 721, 785, 145x, 150x, 1823-1825, 1828, 1829 (B) 54, 7x, 8x(A), 540, 61x, 62x(A), 648(A), 716, 1826, 1827, 1847 (C) 722-726(A), 737, 767, 882, 883, 886, 913, 916, 151x, 17xx, 1906, 193x (D) 707, 747, 777, 87x(A), 884, 887, 914, 917, 1904, 1907
PIC18F-, PIC18LF-	(A) 1xK2x (D) 4x1x, 4x2x, 4x3x, 4x8x, 4xK2x, 4xK8x (B) 1220, 1230, 1320, 1330 (E) 1xK5x (G) 4x5x (M)* 2xJ5x (C) 2x1x, 2x2x, 2x8x, 2xK2x, 2xK8x (F) 2x5x (H) 2xJ1x, 4xJ1x, 4xJ5x
PIC24E-	(I) All
PIC24F-	(I) J16MC102 (J) 0xKA102, 0xKLx01, 0xKLx02 (K) JxxGAx0x (L) JxxGB00x
PIC24H-	(I) J16GP102, J16MC102, J32MC202, J32MC204, J16GP304, J32GPx0x, J64GPx0x, J120GPx0x
dsPIC33E-	(I) All
dsPIC33F-	(I) J12GP202, J12MC202, J32GP30x, J32MC30x, J64GPx0x, J64MCx0x, J128GPx0x, J128MCx0x
ATtiny-	(N) 13(A)(V), 15L, 25/45/85(V) (O) 26(L), 261/461/861(A)(V) (P) 2313(A)(V), 4313 (Q) 48/88
ATmega-	(Q) 48/88/168/328(P)(A)(V), 8(A)(L) (R) 16/32(A)(L), 164/324/644/1284(P)(A)(V), 8535(L)

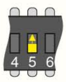
x = any digit 0-9 (P), (A), (V), (L) = optional letter suffix




Setting shown for 5V programming; 3.3V also suitable.

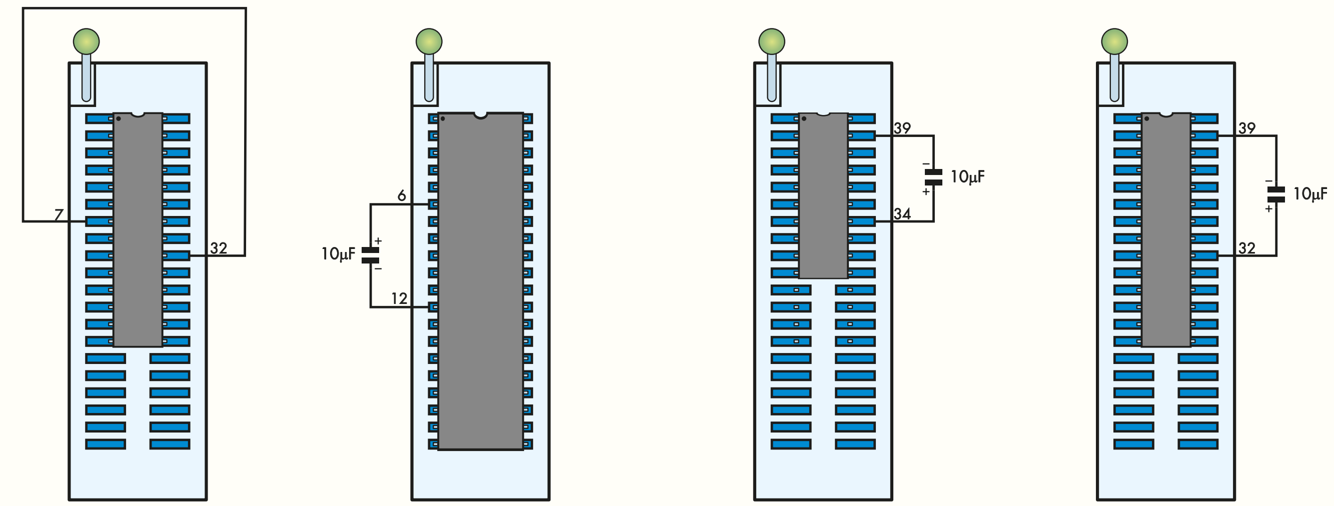

Setting shown for 3.3V programming; some micros may need 5V for programming.


Setting shown for 3.3V programming; 5V not recommended and may be disabled.


(AVR only) External clock may be enabled. Use only if necessary.

PIC/AVR Programming Adaptor Board Step-by-Step Guide

1. Set power switch in "off" position
2. Look up device to be programmed in Device Selection sheet and set DIP switches as shown.
3. Lift ZIF socket level and insert microcontroller with pin 1 at upper-left.
   Hold microcontroller steady and push lever down until it locks.
4. Launch PC software, select correct target device and connect programmer to CON1 or CON2.
   Do not connect both PIC and AVR programmers at the same time.
5. Switch on power to programming adaptor board. Check that green LED is lit.
6. Press "Micro Power On" pushbutton. The yellow LED should light up. If red LED lights instead, press "Micro Power Off" button and re-check DIP switch positions.
7. If providing external microcontroller power (eg, from PICkit3), enable it now.
8. Check device signature using PC software. This is automatic with Microchip MPLab. Assuming it is correct, you can then proceed to program, read and/or verify the flash memory in the target microcontroller as required.
9. If providing external microcontroller power (eg, from PICkit3), switch it off now.
10. Press "Micro Power Off" pushbutton and switch board power off.
11. Lift ZIF socket lever. The microcontroller can be safely removed.



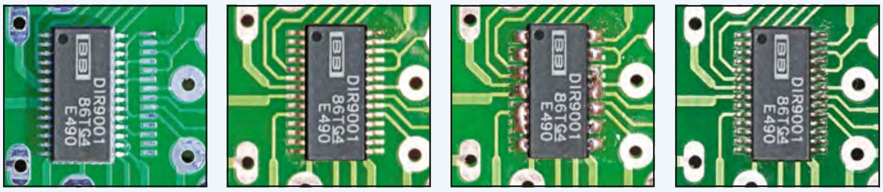
Insert a wire link in the ZIF socket as shown here to program PIC18F2331 or PIC18F2431 micros in mode C.	An extra 10µF tantalum or ceramic capacitor is required to program PIC18F44J10 or PIC18F45J10 micros in mode D.	An extra 10µF tantalum or ceramic capacitor is required to program PIC24FVxxKA301 but not PIC24FxxKA301 micros in mode K.	An extra 10µF tantalum or ceramic capacitor is required to program PIC24FVxxKA302 but not PIC24FxxKA302 micros in mode K.

Fig.6: here are the instructions for using the unit, along with the special case devices which can be programmed with an extra wire link or 10µF capacitor inserted in the ZIF socket. Ensure that this extra component is well clamped at both ends before applying power, and take care with tantalum capacitor orientation.

Fig.5: this diagram shows the supported devices along with the relevant DIP switch configuration. Look up the part series in the table at the top, then find the letter code for the particular suffix and set the DIP switches to the corresponding configuration. There may be some parts not listed here that can be programmed in one of the modes.

is the source of voltage for the micro power supply circuitry, including the electronic fuse (although in-circuit programmers normally provide some form of current limiting too).

Soldering the surface-mount devices (SMDs)



Installing an SMD IC: (A) place a small amount of solder on the top-right pad; (B) re-melt the solder and slide the IC, then solder the diagonally opposite pad; (C) solder the remaining pads (ignore solder bridges); (D) remove the excess solder using solder wick and clean up using isopropanol.

If you don't have a solder reflow oven, you can solder the SMDs one at a time, by hand. With a little practice, this isn't too difficult, especially since the parts used in this project have a relatively large spacing between pins.

You will need a temperature-controlled soldering iron with a medium-size or smaller conical tip, a magnifying glass (preferably a magnifying lamp), angle-tip tweezers, some desoldering braid (or solder wick) and a syringe of no-clean flux paste. **Don't try to attempt the job without these basic tools, otherwise you could wreck both the ICs and the board**.

You don't need to use a very thin tip on the soldering iron. In fact, using a thin tip can make the process more difficult when it comes to applying enough heat to the solder wick and getting the solder to reflow properly. The standard tip supplied with most good irons should be sufficient and a medium-to-fine conical tip works well.

Be sure also to use fine, good quality solder (0.71mm diameter solder is ideal).

Step-by-step procedure

The step-by-step procedure for soldering each SMD is as follows:

(1) Remove one part from the tube or tape packaging. With tape, peel back the clear layer using tweezers to expose one device at a time. Take care not to drop the smaller devices because they can be impossible to find if they land on the floor.

(2) Find the component's location on the PCB. Place the board flat on the workbench with the right side up and oriented so that pin 1 will be at upper-left.

(3) Apply a tiny amount of solder to the top-right pad for the device (or top left if you are left-handed). To do this, briefly touch the pad with the soldering iron and add a dab of solder – just enough so that you can see smoke from the flux – then quickly remove the iron.

You should now be able to see a small solder bulge on that pad (check with a magnifying glass if unsure).

(4) Clean the tip of the iron with a damp sponge to remove any excess solder.

(5) Place the component next to (but not on) the pads. If you are right-handed, place it slightly to the left of the pads and vice versa.

(6) For leaded components (ICs, MOSFETs and diodes), check that the leads are resting on the PCB surface. Capacitors and resistors should lie flat on the board. For resistors, keep the label side up.

(7) Check that the component orientation is correct. For ICs, ensure that the corner dot/dimple or bevelled edge is on the lefthand side. Note that SOT-23 FETs and dual diodes have a triangular pin layout, so the necessary orientation should be clear. Other components (resistors, capacitors) are not polarised and orientation is not important.

(8) Grab the part by its sides using a pair of angled tweezers.

(9) Use the soldering iron to melt the solder on the top right pad, then gently slide the part along the board and into place. Remove the soldering iron immediately it is in place.

This process should only take a couple of seconds, to avoid overheating the pad and the component.

Don't worry about getting it in exactly the right place the first time. Just try to avoid getting any solder on the other pins. As long as you do that, repositioning the part is easy.

(10) If the part is not exactly lined up with the pads, simply re-melt the solder and nudge it until it is. Wait a few seconds between each attempt. When the part is correctly lined up, all its pins will be centred on their pads.

(11) Once you are happy with the alignment, re-check that the component orientation is correct, then rotate the board 180° and solder the pin at the opposite corner. It shouldn't move much during this step but if it does, reheat the joint and adjust it as necessary.

(12) Now solder the rest of the pins. The components used here can be successfully soldered one pin at a time without forming bridges.Don't worry if you do get bridges, as they are easily removed later. It's more important to make sure that solder has flowed onto all the pins and pads.

(13) Even if you have no bridges, it's recommended that you apply a thin layer of flux paste along both rows of pins, towards the outside. A thin layer should be enough (you can always add more later if necessary). You can now remove any excess solder.

That's done by placing a length of solder wick immediately alongside (but not on top of) some of the pads. Now place the soldering iron on top of the solder wick, pressing it down onto the board, while gently sliding the wick towards the solder on the pads.

As the wick heats, it will start to melt the flux and the excess solder, creating visible smoke. At that point you can slide it right up against the pins. Most of the excess solder should then be sucked into the braid. Finally, slide the wick along the board away from the pads and lift it and the soldering iron off the board.

At all times, you should be pressing down onto the PCB only while sliding the wick along it. The whole process should take no more than about 5-6s.

Don't worry if some solder bridges are left behind – rather than applying the heat for too long, it's better to remove what's left with a second pass. When you are finished, the pins should be left with a near-perfect amount of solder and no bridges.

The reason we recommend that you do this, even if there are no visible bridges, is that it virtually guarantees good solder joints by reflowing the solder with the additional flux. Otherwise, it's possible to get a joint that a cursory check suggests is OK, but on closer inspection the solder has adhered to the component pin but has not flowed down onto the pad below it.

(14) Repeat the above process for the other side of the component.

(15) Inspect the part using a magnifying glass to check for any solder bridges or bad joints. If there are solder bridges, apply a little flux and then use the solder wick to clean it up.

(16) If you are using no-clean (non-corrosive) flux (ie, the recommended type) then you theoretically don't need to clean off the flux residue. However, since this board won't necessarily be installed in a housing, it's a good idea to clean the sticky flux off it using pure alcohol (eg, isopropanol).

Finally, if you do get flux on your hands, be sure to wash them as it can be toxic.

Current-Limit Adjustment

Once you have finished programming a chip, by default, it will immediately begin executing the new program code. However, while the electronic fuse current limit has been chosen to supply sufficient current for programming the micro, in some cases it may not be enough once it starts operation, especially with high-speed parts such as dsPIC33s. In this case, the micro power will trip off immediately after programming is complete and you will lose the ability to perform further operations, even if you reset the micro power supply.

There are two solutions to this. The first is to set the in-circuit programmer to hold the micro in reset once programming is complete. This can be done in Microchip MPLAB via the Programmer menu using the 'Hold In Reset' option. However, this option is only available when the programmer is operating normally, so you have to do this first.

The other option is to increase the current limit to allow the micro to operate once it is programmed. This can be done by reducing the value of the 68kΩ feedback resistor across IC15 (adjacent to D2 on the PCB). For example, substituting a 47kΩ resistor increases the current limit to around 130mA. Avoid increasing it much more than this; if the current limit is high enough, you risk damage to the micro under fault conditions.

Programming dsPIC30s

We last published a PIC programmer in the May 2010 issue. This was called a *Low-cost Programmer for dsPICs and PICs* and it connected to the PC via a serial port. That project required the now-defunct WinPIC software, which is still available but is not being updated to suit newer micros or the latest Windows operating systems.

Most constructors would be better off with the new design described here because it can handle a larger portion of the PIC range, works with up-to-date software and is easier to use. The one thing the previous unit can do that this one can't is to program dsPIC30F micros. While a small range of dsPIC30s is still available, they have essentially been made obsolete by the dsPIC33F and dsPIC33E/PIC24E series.

As a result, we don't expect many people still use them. If you need to program one, you could use the May 2010 programmer, or alternatively, build a programming jig on stripboard.

USB power

If you are going to run the board from USB power, it generally draws less than 100mA. However, depending on the exact configuration and the micro being programmed, it could draw more, so it's best to run it from a computer host port or a powered hub, especially since it has no circuitry to negotiate power allocation from the host computer. ***EPE***

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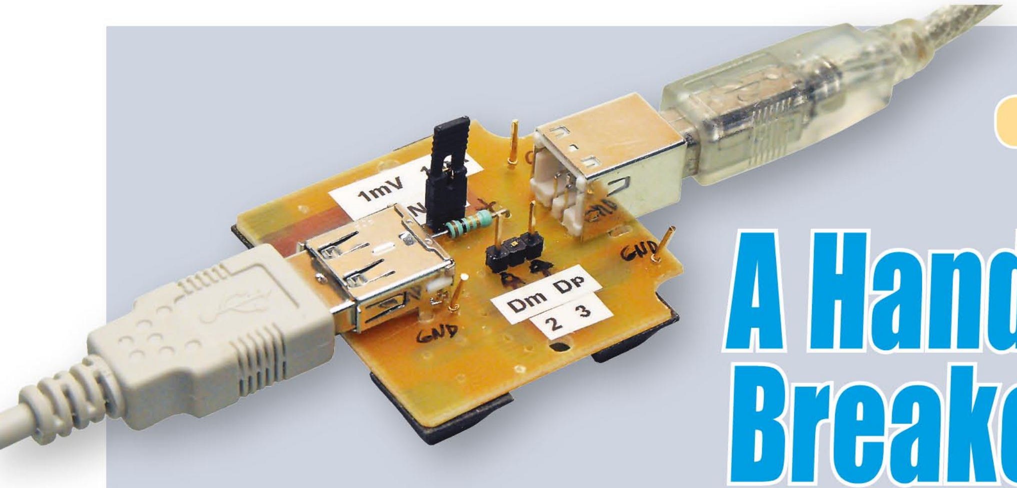

By JIM ROWE

A Handy USB Breakout Box

You can build it in 10 minutes and for less than a tenner

USB is a great interface, but it is isn't foolproof. The good thing is that you can troubleshoot it with this simple USB 'breakout box'. It connects into virtually any USB 1.1 or USB 2.0 cable and lets you examine D+ and D– signal line activity with your scope – as well as letting you check the USB power line voltage (Vbus) and even the current being drawn from the bus.

RECENTLY, I've been working on the development of a USB device, ie, a device designed to hook up to a PC via a USB cable and become a 'bus powered peripheral'. Along the way, I realised that I was going to have to measure the current drawn by the device, to make sure it conformed to the USB specification. Since I also struck trouble getting the device to 'enumerate' properly when it was first hooked up to a PC, it was also going to be handy to be able to check the voltage levels on the two USB signal lines with my scope, to see if the voltage levels were within specification.

Now, since the device's USB connector was mounted directly on its PCB, the only way to measure the current drawn from the host via the USB bus would be to cut the pin 1 track on the board, so I could connect in a milliammeter. But I didn't want to cut a track on the board just for this test, because it would need to be bridged again with a short length of wire afterwards.

It also turned out to be a bit tricky connecting my scope's probes to the two USB signal lines, because my board was fairly small, with a high component density near the USB socket. In fact, this is always the way with USB interfaces – they're hard to get at.

What I really needed was a small 'breakout box' which could be connected in series with the USB cable between the PC and the device. This would make any of the bus lines available for testing. So I knocked one up using a small piece of PCB cut from an old prototype board. The latter already had a USB type-A socket mounted on it, so all I had to do was add a type-B socket and a handful of other parts. It looked a bit untidy (as you can see from the above photo) but it worked well and let me do the testing in short order.

This proved to be such a handy circuit that I decided to design a PCB pattern for it. So when you build one, it will look better than my prototype. What's more, it will take take just 10 minutes or less to put together.

Circuit details

Fig.1 shows the circuit and there really is very little to it. All four USB lines basically pass 'straight through' between the type B input socket and the type A output socket, so normal operation can continue.

The Vbus line has a 1Ω 1% resistor connected in series with it, but this is normally shorted out by a jumper shunt (JP1). When you want to measure the current being drawn from the host PC by the USB device, you simply remove the jumper shunt and connect a DMM between the two ends of the resistor. The resistor then acts as a current shunt, converting milliamps into millivolts.

So, by switching your DMM to its lowest DC voltage range (say 0-2V), you'll be able to measure the device current in milliamps very easily.

If you want to measure the bus voltage as well, this is easily done by connecting your DMM (set to the next higher DC voltage range) to the two pins of the other SIL pin strip (Vbus) on the top left of the circuit. In most cases, you should get a reading of +5V, unless there's a problem.

The two SIL pin strips near the bottom of the circuit are provided so you can easily monitor the D+ and

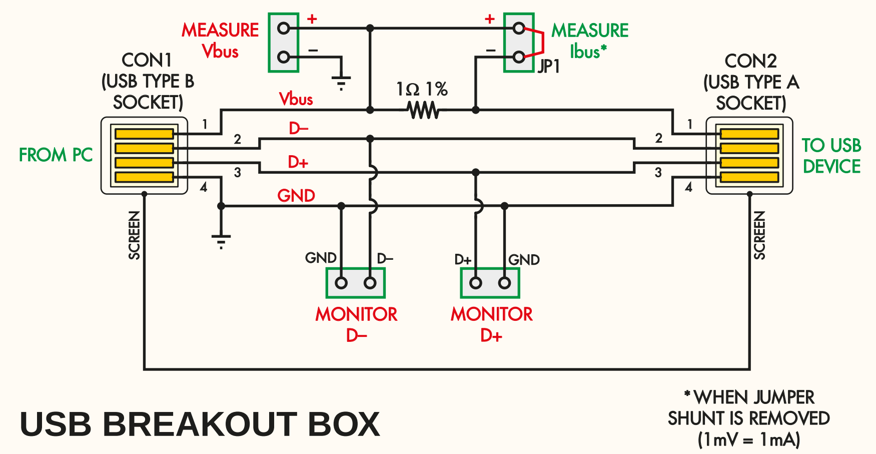

Fig.1: with jumper JP1 in place, all four USB lines basically connect straight through. The current is measured by removing JP1 and monitoring the voltage across the 1Ω resistor (1mV = 1mA).

D– signal line waveforms with an oscilloscope. As you can see from the scope grabs (Fig.3, Fig.4 and Fig.5), these signals take the form of bursts or 'packets' of data at 1ms intervals. The data is encoded using a differential NZRI (non-return-to-zero inverted) format, with the D+ and D– lines pulsing in synchronism, but with reversed polarity. To conform to the USB specification, both data line signals should have a peak-to-peak amplitude of between 3.0V and 3.7V.

Note that while the outer screens of CON1 and CON2 are connected together, to preserve the continuity of the USB cable screen, they are not connected to the USB cable ground (ie, pin 4) inside the breakout box. This is necessary to make sure that the box doesn't disturb the operation of the screen in USB 2.0 cables.

I should note here that the main information you'll be able to get from the D+ and D– waveforms is their peak-to-peak amplitude, whether they are switching in the correct differential fashion and whether they're both fairly constant in amplitude, rather than varying sporadically or cyclically – either of which are indications of problems. It's not easy to get much more information than this because of the differential NZRI encoding.

Fig.2 shows the assembly details. It's just a matter of installing the parts as shown, not forgetting the wire link. The four 2-way pin headers are snapped off an 8-way header.

The corners of the board can be fitted with rubber feet or it can be mounted in the base of a standard UB-5 zippy box.

In use, jumper shunt JP1 is removed if you want to measure the voltage across the 1Ω resistor, to determine the current drawn by the attached USB device.

Protocol analyser

Like most tools, the breakout box is handy for what it does, but inevitably has its limitations. For examining USB bus operation in more detail once you've checked the basics, you really need a USB protocol analyser, which can look at all of the control and data packets flying back and forth along the bus, identify those coming from the host and those returning from the device. This will let you see what's happening (or not happening, when it's supposed to).

There are a few software USB protocol analysers currently available, which can be very handy for this 'deeper' level of troubleshooting. As the name suggests, these are basically software programs which run on the PC and 'keep an eye' on the activity at any designated USB port, so that they can either display it in 'real time' or save all of the information in a log file, which you can open later and examine in detail.

One of these software USB protocol analysers I can recommend is *USB-Trace*, developed and marketed by a firm called SysNucleus. A free 15-day evaluation copy of *USBTrace* can be downloaded from their website at **www.sysnucleus.com** and although it's a bit restricted in terms of the data it can save during a single session, it's still quite handy.

If you want the full version, this can be purchased online for US$195.00. Also available for free downloading are software decoders for the various USB device classes, so *USBTrace* can be more informative about their operation.

There's also a Microsoft 'USB Device Viewer' software tool called *UVCview.exe* which can be quite handy when you're troubleshooting USB device operation. It's part of Microsoft's Windows Driver Kit (WDK), which can be downloaded for free from **www.microsoft.com/downloads/**

The latest version at the time of writing is V7.1.0, which comes as a 618MB ISO file. This must be burnt to a CD-R before *UVCview* can be installed. ***EPE***

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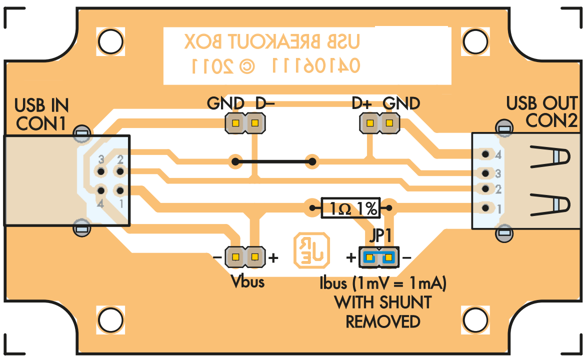


Fig.2: the PCB will only take about 10 minutes to assemble. Don't forget to solder the earth lugs on the sides of the USB sockets. The board can be fitted with rubber feet at the corners, or you can cut out the corners and fit the board into the base of a UB-5 zippy box.

Parts List

- 1 PCB, code 901, size 76mm x 45mm, available fron the *EPE PCB Service*
- 1 PC-mount USB type B socket (CON1)
- 1 PC-mount USB type A socket (CON2)
- 1 1Ω 1% 0.25W resistor
- 1 SIL 8-way pin header strip
- 1 jumper shunt
- 4 self-adhesive rubber feet

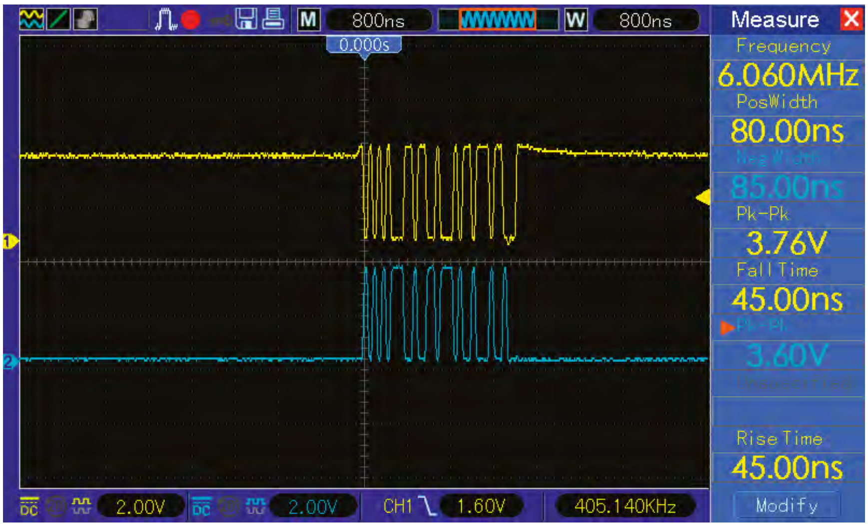


Fig.3: a single USB control packet showing the differential NZRI encoding (D+ in yellow and the D– in blue). The frequency reading is not relevant, but note how the two waveforms have approximately equal P-P amplitudes.

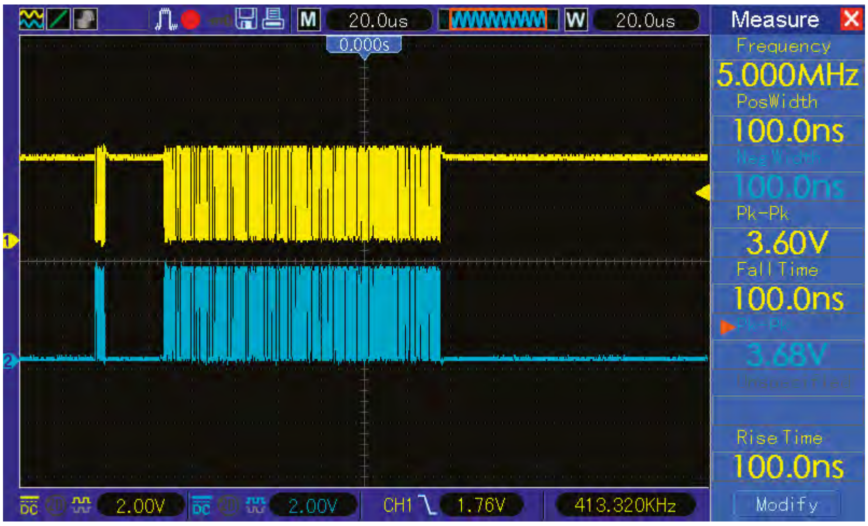


Fig.4: another capture of the D+ and D– signal waveforms, at a slower timebase rate. Here we see a control packet, followed by a much longer data packet. Again, the frequency reading is not relevant.

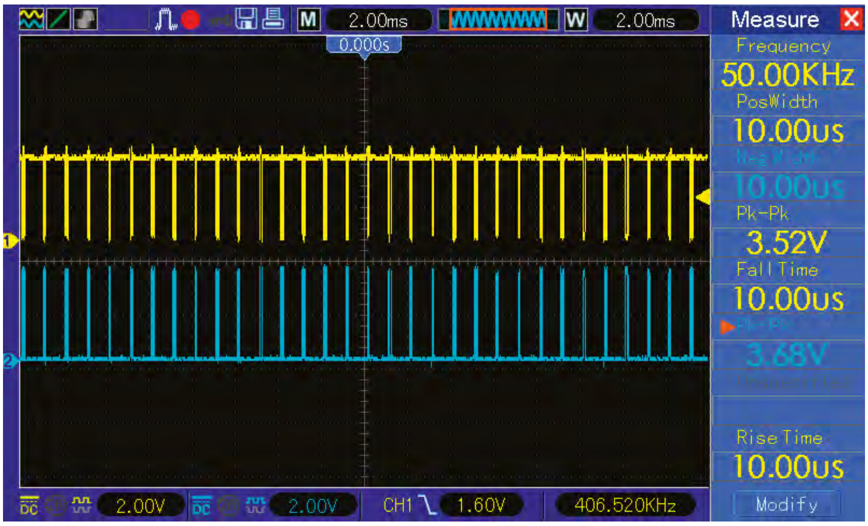


Fig.5: this third capture of USB signal waveforms is at a much slower rate again, and shows the way the D+/D– data packets are sent at intervals of 1ms. Again, the frequency reading is not relevant.

Converter For Neon Lamp Experiments

By John Ellis

Readers, who are generally more familiar with LEDs, may be interested in experimenting with neon lamps because of their unusual negative-resistance properties. Circuits to make flashing neon lamps were once quite common, from a basic relaxation oscillator, with three components, to the intriguing neon lamp multivibrator which uses a total of just five components.

AT ONE time, manufacturers such as GE and Osram/GEC provided a number of neon bulbs with different levels of brightness. The classic 'beehive' lamp is now rare, and an unused one can fetch £60 on eBay. Today, only the wire-ended neon lamp is widely available; such as the one stocked by RS components (part no. 105-017). Most other styles of neon lamp, if available, tend to use a wire-ended type hidden inside a glass envelope of some kind. Neon lamps are still used in electrical equipment as indicator lights, and while the standard low brightness lamp offers 25,000 hours of life, many higher brightness types have shorter lifetimes.

The reason a neon lamp can be used in a relaxation oscillator is that it requires a higher voltage to strike, or turn on, than is needed to sustain an electrical discharge once lit. Typical values for standard neon lamps are 60V striking and 55V operating voltage; and when running, they typically consume 0.6mA. Circuits using these lamps can be operated from 90V. The high brightness types are unsuitable for experimentation because they generally have higher striking voltages, around 130V.

In the past, 90V batteries were available for portable valve radios, if such a thing can be imagined today. Today, a DC-DC step-up converter can readily provide a suitable power supply, which can operate from 6V batteries, and if this article has any real novelty, it is in the new converter design, as neon oscillators are almost as old as neon lamps!

Neon oscillator

The basic neon lamp oscillator circuit is shown in Fig.1. In this circuit, high value resistor R1 and capacitor C1, typically 10MΩ and 0.1µF respectively, provide a low-frequency time constant. Initially, C1 is uncharged, but when power is applied it will charge through R1. When the striking voltage is reached, the neon lamp will light. However, once lit, the impedance of the ionised neon gas is much lower than the more-or-less open circuit that it was before striking. This allows the capacitor to discharge quickly, giving a short current pulse.

As the capacitor voltage falls, the neon lamp current becomes too low to sustain the discharge, and the neon extinguishes. Once extinguished, the capacitor charges up again until the striking voltage is reached, and so on. The waveform on the neon lamp is an exponentially rising 'sawtooth'. Typical flash rates for this circuit can be from less than one per second up to about 10kHz. Above this frequency, the neon gas does not de-ionise quickly enough for reliable oscillatory action.

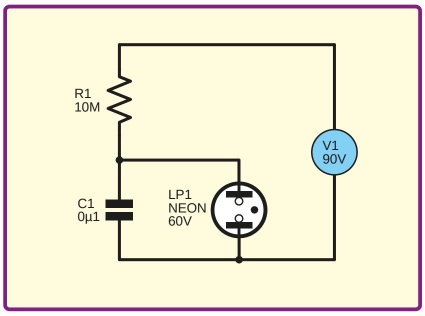


Fig.1. Neon lamp relaxation oscillator

If an output voltage is required, a low-value resistor, such as 1kΩ, can be wired between the earthy side of the neon and the ground (negative) lead, and used as a pulse take-off.

Neon multivibrator

The circuit shown in Fig.2 is a fascinating type of multivibrator. It uses just five components: two neon lamps, two resistors and one capacitor (plus the power supply).

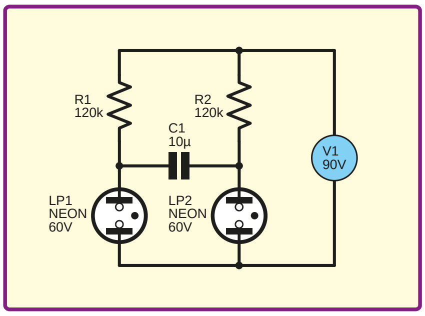


Fig.2. Neon lamp multivibrator

In this circuit, the capacitor is initially uncharged. On applying power, the voltage across the neon lamps increases. No two neon lamps are identical, so one will strike before the other. (This is a relatively safe assumption, there is often a spread of a volt or two between their striking voltages – even if closely matched – and random ionisation events, including cosmic rays, might trigger one rather than the other.) So, the voltage across one neon lamp, say LP1, will drop to its sustaining voltage. At this point, the voltage on the other side of the capacitor drops too, causing the voltage on the other neon lamp (LP2) to fall to a lower value.

The capacitor then charges through R2, and LP1 conducts current from both R1 and R2. When the voltage on LP2 reaches the striking voltage of that neon, it will turn on, causing the capacitor voltage to fall, and thus forcing LP1 below its sustaining voltage, so turning it off. Now the capacitor charges in the opposite direction with LP2 conducting, until LP1 strikes again, and so on. The waveforms across the neon lamps are half sawtooth in profile, possibly best described as 'Z-tooth'

Waveforms

The graphs in Fig.3 show the waveforms, as simulated using voltage-dependent switches (with 1GΩ off-resistance, 1kΩ on-resistance and 5V hysteresis) to represent the neon lamps.

The capacitor only has to operate on a voltage difference between the striking and extinguishing voltages of the neon lamps, and thus a 63V rating is adequate. The capacitor should, however, be a non-polarised, metallised plastic film type for low leakage – not an electrolytic one. The capacitor voltage is close to a triangular wave, but has a slight curvature due to the exponential nature of the charging voltage. A linear triangular wave could be generated if the resistors were replaced by current sources, such as a high voltage PNP transistor, eg, the MPSA92.

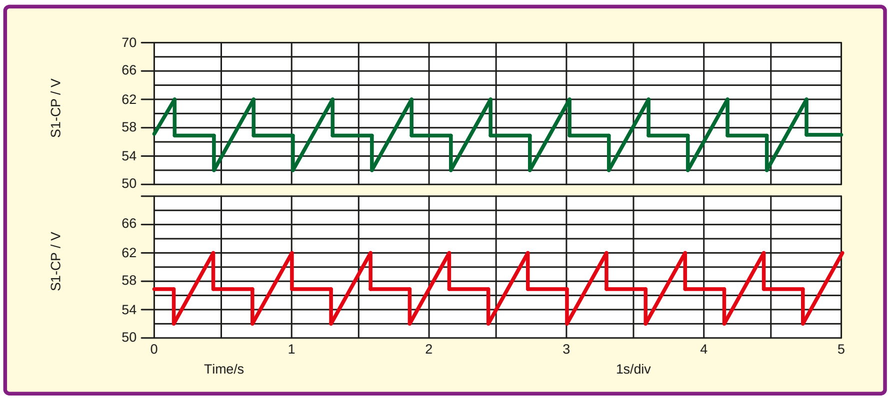


Fig.3 (above). Waveforms across the two neon lamps in a multivibrator – see Fig.2

Fig.4 (right). Neon lamp 90V converter

90V converter

To operate neon lamp circuits, a 90V supply at a few mA is needed. A simple flyback converter running from a low voltage supply can provide this. The simplest type of flyback circuit would use a ferrite-core transformer with three windings: one for the primary; a secondary for the 90V output and a feedback winding to generate a free-running oscillation.

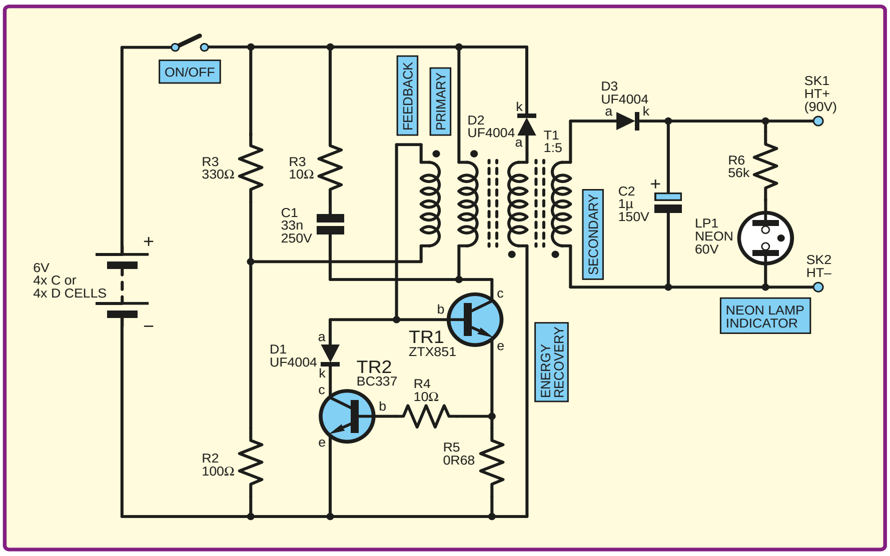
There are some considerations regarding such a simple circuit. The first is that some means of stopping the positive feedback is needed in order to allow the flyback, or magnetic discharge, to occur. One approach is to allow the ferrite core to saturate, which was a widely used technique once, but this is grossly inefficient because the effective or differential permeability, controlling the inductance, falls to zero, allowing the current to spike to a high value immediately before switching off – although, if the transistor gains were falling with increasing current, as they do, perhaps the spikes were not so great because the transistors would not conduct enough!

Another approach requires the base current to be limited by using a suitable resistor in series with the feedback winding, and, in this case, the collector current stops increasing when the feedback winding can no longer provide enough base current to support it. While this approach can work well, it generally requires an adjustable potentiometer to suit a particular transistor, to allow for different gains between individual devices, and so is not very convenient.

Consider the circuit shown in Fig.4, Here a second transistor is used as a simple current monitor. By connecting the second transistor to a resistor wired in series with the emitter of the main converter device, it will begin to conduct once the voltage reaches about 0.6V or so. Once this sense transistor conducts, it progressively shunts base current away from the switching transistor, and therefore has the effect of stopping the feedback signal at a level primarily set by the base voltage of the sensing device and value of the resistor. In this way, a non-saturating core can be designed, and no adjustment is needed for individual transistor gains.

A fourth winding is added to the transformer to provide voltage regulation and efficiency savings when the output is lightly loaded.

The winding details of the ferrite core are shown below.



Transformer design and construction

1. Use an RM8 core with power bobbin. (This is larger than strictly necessary, but is easier to wind than the smaller RM6 core.)

2. Use N27, N41, N47, N87 or equivalent material; eg, EPCOS B65811-JR047 or Ferroxcube equivalent (3C90).

3. Primary: 20 turns of 0.46mm-diameter (26 SWG) insulated copper wire, in just over one layer (16 turns per inch)

4. Energy recovery: 8 turns of 0.46mm-diameter insulated copper wire wound in the remaining second layer. Insulate the primary using electrical tape (polyester) so that the flying leads can be taken down and back across the primary winding without risk of shorting, and use another layer of insulation tape after completing the energy recovery winding.

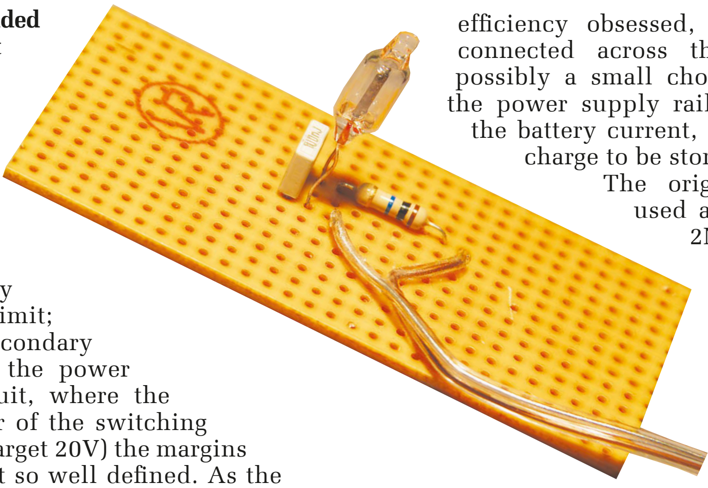
5. Feedback winding: 5 turns of 0.19mm-diameter (38 SWG) insulated copper wire, bringing the leads out at opposite ends of the bobbin so as not to fold back as before. Insulate this winding with another layer of tape.

6. Secondary: 100 turns of 0.19mm-diameter (38 SWG) insulated copper wire for the output, followed by two layers of insulating tape to hold and protect the coils.

7. Important – the primary and feedback windings must be wound in the same direction. The secondary and energy recover windings are both wound in the opposite direction to the primary (as indicted by the dot symbols on the diagram).

For each coil, note the start and end connections because the polarity is important for correct operation of the circuit. Assemble the core halves with a 60µm spacer, which can be made from standard polyester electrical insulating tape (not the thick PVC type) to provide a 0.12mm air gap.

Relaxation oscillator with wire-ended neon built on Veroboard. A circuit like this *must* be mounted in an insulating box before running



Component selection

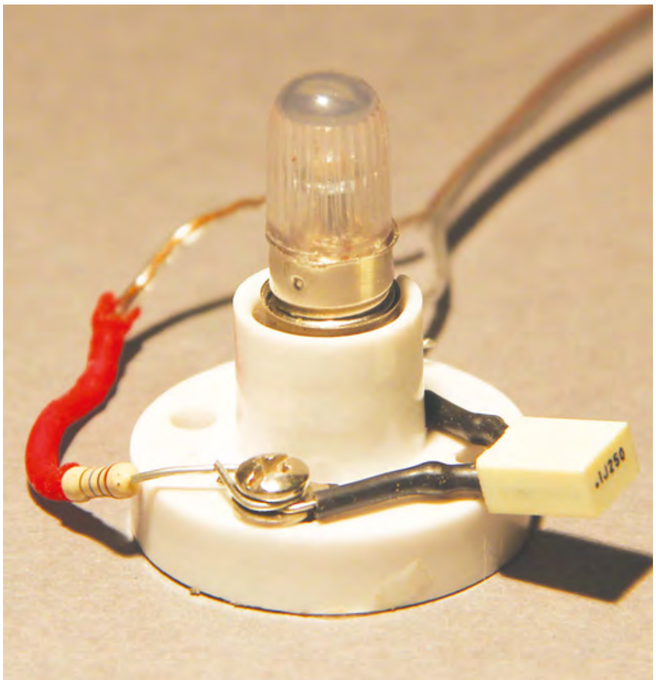
Capacitor C1 and resistor R3 damp oscillations due to leakage inductance in the transformer. The energy recovery winding acts as an overvoltage limit; excess output not taken by the secondary should be diverted back into the power supply. However, in this circuit, where the flyback voltage on the collector of the switching transistor is quite high (design target 20V) the margins between the secondaries are not so well defined. As the theoretical energy recovery winding should be 7.5 turns, using 8 to account for the voltage drop needed by D1 means that it is possible that the output voltage falls short of 90V.

The unit was designed to deliver up to 1W output, corresponding to a total load resistance of about 10kΩ. If the voltage is lower than 90V on full load, the number of turns on the secondary could be increased to compensate. If higher, then some turns can be taken off.

Although the energy recovery winding can return power to the power supply, batteries are not efficient at converting this back into chemical energy. For the efficiency obsessed, a capacitor should be connected across the power supply, and possibly a small choke fitted in series with the power supply rail. This will smooth out the battery current, and enable the returned charge to be stored efficiently.

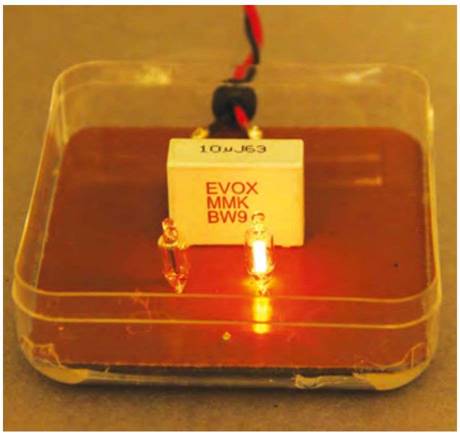
The original transistor line-up used a 2N3054 for TR1 and a 2N3053 for TR2. Neither of these transistors is very common these days, but NTE sell a 2N3054 – available from Farnell – which seems to work well using a 100Ω resistor for R1. The original 2N3053 specifies a saturation voltage of 1.4V at 150mA, which may restrict the ability in this circuit where the collector voltage needs to run below 0.6V to bypass the base current of TR1. However, the majority of devices sold today seem to be built using collector epitaxial layers offering a saturation voltage of around 200mV, so these old workhorse transistors could be used – with care.

The improved 2N3053A transistor could be specified to reduce the risk of finding a genuine (poor) 2N3053 from new old stock. Otherwise, it may be better to use the newer types of transistor specified in the diagram. ***EPE***



Left – Neon relaxation oscillator using an MES neon lamp and components wired directly to the MES lamp holder. (Note: the lampholder is normally rated at 50V maximum, but the neon works between 50-60V. Be aware that voltages above 50V are not considered safe and any exposed metal should be insulated. The units shown should be assembled into a suitable box. Although, in this case, the high voltage side of the resistor is sleeved and any current flow from the resistor is limited to a safe value, there might still be a possibility of a high current pulse from the capacitor.)

Below – Views of a neon lamp multivibrator built into a small plastic container. These photos with the neon lamps illuminated are with the lid removed



EPE EXCLUSIVE

Win one of THREE Microchip MPLAB Starter Kit For PIC24H MCUs

EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win an MPLAB Starter Kit for PIC24H MCUs. This is a complete hardware and software kit for exploring the power of the PIC24H family of MCUs for multi-tasking needs. With a built-in debugger on the board, simply install the software and connect the USB cable to the PC. Start up MPLAB IDE and gain full control. Run the accelerometer-based sample programs and check out the interaction of the accelerometer and the switches with the MCU on the visual display and listen to the speech playback. Connect your own analogue sensor for sensor signal processing. Download and test your own applications.

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Jump Start

By Mike and Richard Tooley

Design and build circuit projects dedicated to newcomers, or those following courses taught in schools and colleges.

WELCOME to *Jump Start* – our series of seasonal 'design and build' projects for newcomers. *Jump Start* is designed to provide you with a practical introduction to the design and realisation of a variety of simple, but useful, electronic circuits. The series has a seasonal flavour, and is based on simple, easy-build projects that will appeal to newcomers to electronics, as well as those following formal courses taught in schools and colleges.

Each part uses the popular and powerful 'Circuit Wizard' software package as a design, simulation and printed circuit board layout tool. For a full introduction to Circuit Wizard, readers should look at our previous *Teach-In series*, which is now available in book form from Wimborne Publishing (see *Direct Book Service* pages in this issue).

Each of our Jump Start *circuits include the following features:*

- ***Under the hood*** **–** provides a little gentle theory to support the general principle/theory behind the circuit involved
- ***Design notes*** **–** has a brief explanation of the circuit, how it works and reasons for the choice of components
- ***Circuit Wizard*** **–** used for circuit diagrams and other artwork. To maximise compatibility, we have provided two different versions of the Circuit Wizard files; one for the education version and one for the standard version (as supplied by *EPE*). In addition, some parts will have additional files for download (for example, templates for laser cutting)
- ***Get real*** **–** introduces you to some interesting and often quirky snippets of information that might just help you avoid some pitfalls
- ***Take it further*** **–** provides you with suggestions for building the circuit and manufacturing a prototype. As well as basic construction information, we will provide you with ideas for realising your design and making it into a complete project
- ***Photo Gallery*** **–** shows how we developed and built each of the projects.

Coming attractions

Issue	Topic	Notes
May 2012 ✓	Moisture alarm	Get ready for a British summer!
June 2012 ✓	Quiz machine	Revision stop!
July 2012 ✓	Battery voltage checker	For all your portable gear
August 2012 ✓	Solar mobile phone charger	Away from home/school
September 2012 ✓	Theft alarm	Protect your property!
October 2012 ✓	Wailing siren, flashing lights	Halloween "spooky circuits"
November 2012 ✓	Frost alarm	Beginning of winter
December 2012 ✓	Mini Christmas lights	Christmas
January 2013 ✓	iPod speaker	Portable Hi-Fi
February 2013 ✓	Logic probe	Going digital!
March 2013 ✓	DC motor controller	Ideal for all model makers
April 2013 ✓	Egg Timer	Boil the perfect egg!
May 2013 ✓	Signal injector	Where did that signal go?
June 2013 ✓	Simple radio	Ideal for camping and hiking
July 2013	Temperature alarm	It ain't half hot ...

In this month's Jump Start *we shall be preparing for the summer months with a project that is ideal for use away from home in the shape of a simple radio suitable for receiving local stations on the medium waveband. The radio operates from a 9V PP3 battery and is ideal for camping and hiking and can also be used with the* iPod speaker *that we featured in the Jan'13 instalment of* Jump Start.

Under the hood

The simplified block schematic of our *Simple Radio* is shown in Fig.1. The circuit comprises just four stages; a radio frequency (RF) tuned circuit, an RF amplifier, a demodulator and an AF amplifier. The RF tuned circuit provides tuning and selectivity, and incorporates a ferrite rod for reception of strong local stations without the need for an external wire antenna. For more distant reception, an external wire antenna (just 4m to 5m of insulated wire) will help to bring in signals from further afield.

The RF tuned circuit is followed by a single-stage RF amplifier. This increases the signal from the tuned circuit from a few tens of microvolts to several

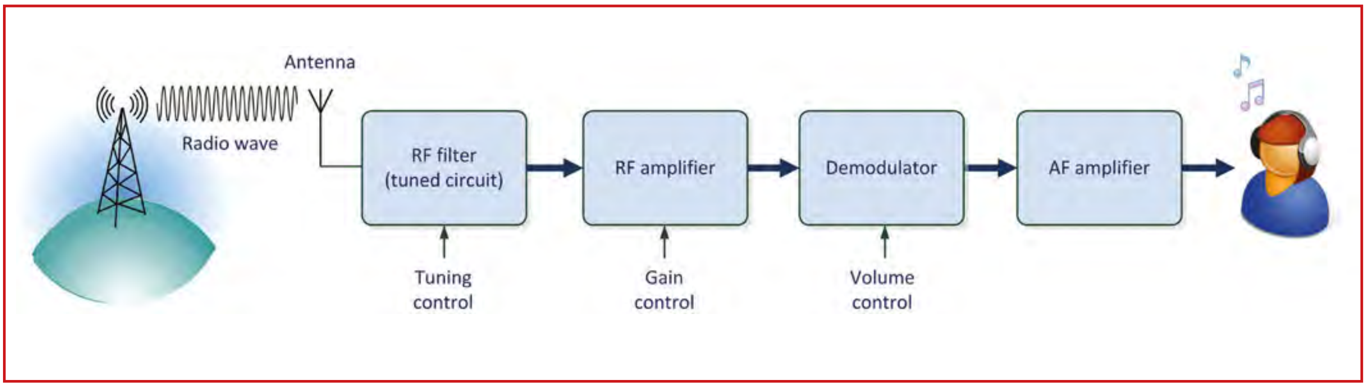


Fig.1. Simplified block schematic of our *Simple Radio Receiver*

hundred millivolts. The output of the RF amplifier is then fed to a demodulator stage. This stage recovers the modulation (ie, the audio signal) from the amplitude modulated RF output produced by the RF amplifier and presents a filtered audio frequency (AF) signal to the volume control and AF amplifier. Finally, the AF amplifier provides more voltage gain and an output impedance suitable for feeding to headphones or an external audio amplifier.

Design notes

We've not met tuned circuits before in our *Jump Start* series, so it's worth taking a little time to explain their properties. Tuned circuits are essential in radio circuits as they provide us with a means of selecting a signal that is transmitted on a particular frequency. If you take a look at the two forms of tuned circuit shown in Fig.2 you will see that they both comprise of a combination of inductance, *L*, and capacitance, *C*. In such circuits, there will be one particular resonant frequency at which the inductive and capacitive reactances will be equal and opposite and, as a consequence, will effectively cancel each other out. In order to select a particular radio signal we simply need to ensure that the resonant frequency of the tuned circuit is the same as that of the wanted signal. The tuned circuit will then accept the signal that we want and reject those on other frequencies.

The two forms of tuned (resonant) circuit shown in Fig.2 are classified according to whether the two reactive components are arranged in series or in parallel. Fig.2(a) shows a series tuned circuit while Fig.2(b) shows a parallel tuned circuit. In the former case, the circuit will have minimum impedance at resonance and, as a consequence, it will pass the greatest current at the resonant frequency. Because of this, the series circuit shown in Fig.2(a) is often referred to as an 'acceptor circuit'. In the latter case, the circuit will exhibit maximum impedance at resonance and, as a consequence, will pass least current at the resonant frequency. As a result, the parallel circuit shown in Fig.2(b) is often referred to as a 'rejector circuit'.

The resonant frequency, f_0, of the two tuned circuits shown in Fig.2(a) and Fig.2(b) is given by the relationship:

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \qquad \text{(Hz)}$$

where *L* is the inductance (in henry), *C* is the capacitance (in farad) and f_0 is measured in hertz.

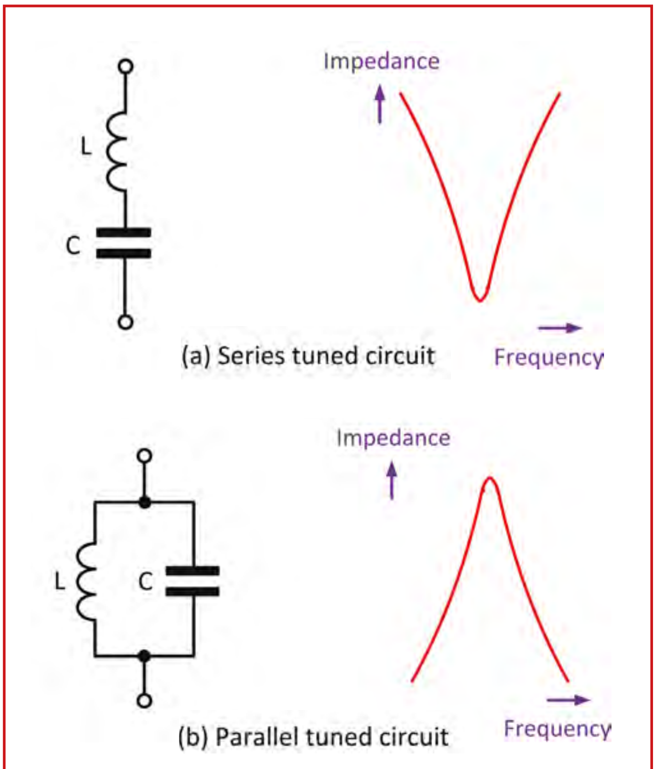


Fig.2. Series and parallel tuned circuits

Q-factor and bandwidth

In practice, there is always some loss resistance present in any tuned circuit. This resistance is usually attributable to the resistance of the coil winding used in the inductor, which we have shown this in Fig.3. The *Q*-factor (or quality factor) of a tuned circuit provides us with a measure of the 'goodness' of a tuned circuit. The effect of the additional series loss resistance is that it reduces the *Q*-factor of the circuit. In other words, the lower the series loss resistance the greater the *Q*-factor.

As the *Q*-factor of a tuned circuit increases, the frequency response curve becomes sharper. As a consequence, the

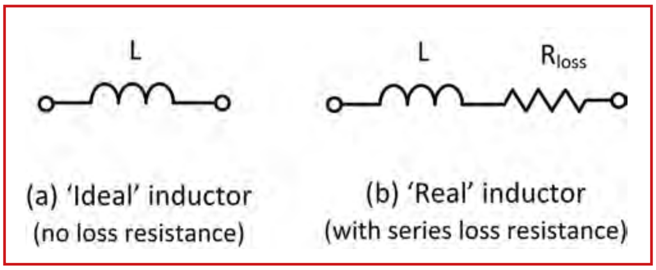


Fig.3. Series loss resistance

bandwidth of the tuned circuit is reduced and the circuit becomes more selective and therefore the receiver in which it is used will become less susceptible to signals that are close in frequency to the ones that we want to listen to. We have illustrated the relationship between *Q*-factor and bandwidth in Fig.4.

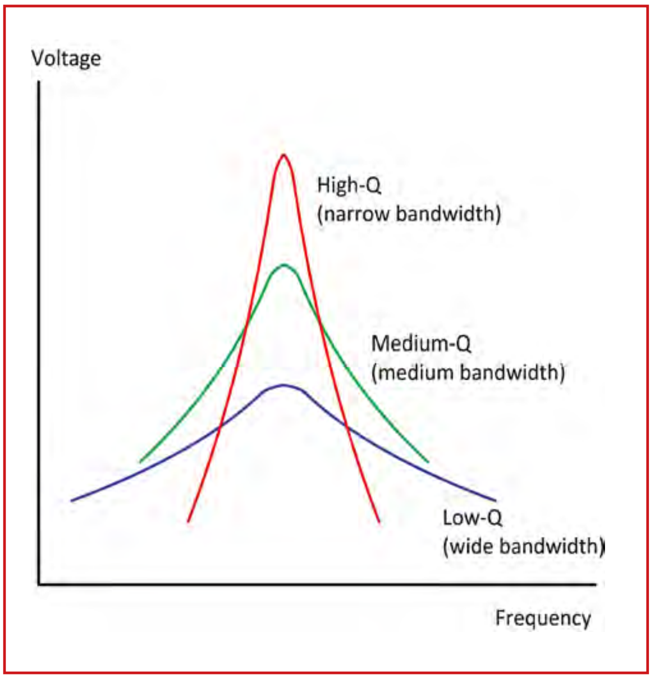


Fig.4. Relationship between *Q*-factor and bandwidth

Tuning

To be able to cover a range of frequencies we need to be able to vary the value of either (or both) of the two components. In practice, it is easier to make the capacitor variable and keep the inductor fixed. Using common types of variable capacitor it is usually possible to cover a frequency range of about 3 to 1. In the case of our *Simple Radio* we have chosen values that will enable a frequency coverage that extends from about 550kHz to around 1.6MHz (ie, covering most of the medium wave AM band).

In order to receive strong local signals without the need for an external antenna we have used an inductor wound on a ferrite rod. This arrangement is shown in Fig.5(a), together with its corresponding frequency response in Fig.5(b). Note that maximum RF voltage is developed across the parallel tuned circuit at resonance (f_0) and that the resonant frequency can be varied by changing the value of variable capacitor VC1. The bandwidth of the tuned circuit arrangement is defined as the range of frequencies that extend either side of the resonant frequency to the points at which the RF output voltage has fallen to 70.7% of its maximum value (if you are wondering why this value is used it corresponds to a reduction in RF power by a factor of two, ie, the 'half power points' on the frequency response characteristic).

The relationships between frequency response, *Q*-factor and bandwidth are given by the following relationships:

$$Q\text{-factor:}\ \ Q = \frac{2\pi f_0 L}{R}$$

$$\text{Bandwidth:}\ \ f_w = f_2 - f_1 = \frac{f_0}{Q}$$

As an example, let's find the resonant frequency, *Q*-factor and bandwidth of a 400μH inductor with a series loss resistance of 100Ω when tuned by a variable capacitor set to a value of 100pF (these values are similar to those used in our *Simple Radio*):

The resonant frequency will be:

$$f_0 = \frac{1}{2\pi\sqrt{400\times10^{-6}\times100\times10^{-12}}} = \frac{1}{2\pi\times2\times10^{-7}}$$

$$= \frac{0.159}{2\times10^{-7}} = 0.795\times10^{6} = 795\,\text{kHz}$$

The *Q*-factor will be:

$$Q = \frac{2\pi f_0 L}{R} = \frac{2\pi\times795\times10^{3}\times400\times10^{-6}}{100}$$

$$= 199.7\times10^{-1} = 19.97$$

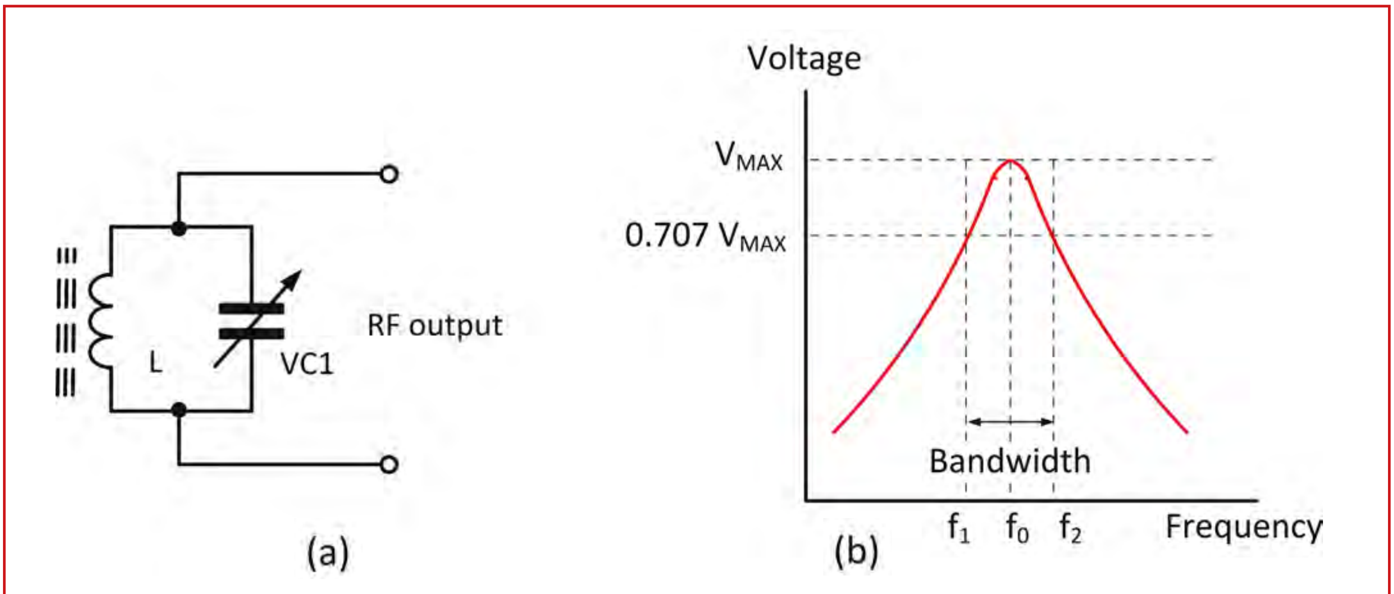


Fig.5. Variable tuned circuit and characteristic frequency response

The bandwidth will be:

$$f_w = \frac{f_0}{Q} = \frac{795\times10^3}{19.97} = 39.8\times10^3$$

$$= 39.8\times10^3 = 39.8\text{kHz}$$

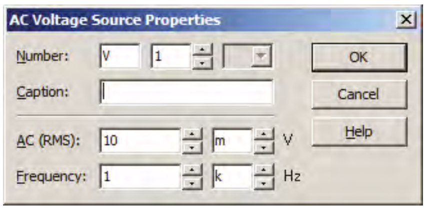
Get real

It can be difficult to simulate RF circuits using *Circuit Wizard* so, this month we will simply concentrate on the operation of the AF amplifier of our *Simple Radio*, showing how this circuit can be quickly and easily tested.

Fig.7. (right) Setting the AC voltage source properties in *Circuit Wizard*

Fig.6 (below). AF amplifier section modelled in *Circuit Wizard*

Fig.6 shows the AF amplifier section of the *Simple Radio* modelled in Circuit Wizard. When checking the operation of this circuit you will need to set the signal source to an appropriate voltage level and frequency. We have chosen a typical signal of 10mV RMS and a frequency of 1kHz as typical values that we might expect as an output from the demodulator circuit. If you right click on the AC voltage source you will be able to enter these values as shown in Fig.7.



Next, you will need to set the graph properties that Circuit Wizard will use when it displays the waveform at the test probe connected to the output of the AF amplifier. To do this you simply need to right click on the graph itself and then select Properties from the Graph Properties menu, as shown in Fig.8. The values that we have chosen allow us to view a voltage range extending from –2V to +2V, and a time scale of 1ms.

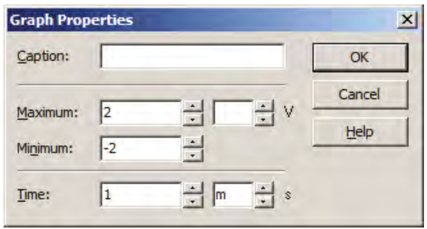
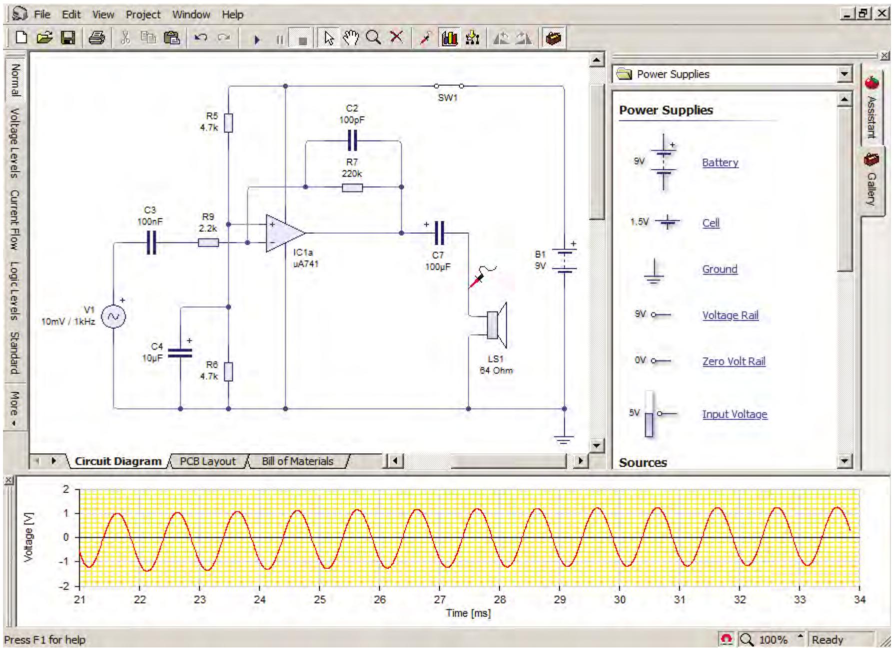


Fig.8. Setting the Graph Properties



A note regarding Circuit Wizard versions:

Circuit Wizard is available in several variants; Standard, Professional and Education (available to educational institutions only). Please note that the component library, virtual instruments and features available do differ for each variant, as do the licensing limitations. Therefore, you should check which is relevant to you before purchase. During the Jump Start series we aim to use circuits/features of the software that are compatible with the latest versions of all variants of the software. However, we cannot guarantee that all items will be operational with every variant/version.

Simple Radio Receiver – using Circuit Wizard

FIG.9 shows our complete radio circuit ready for PCB conversion. Note that we have used three-pin terminal blocks in place of potentiometers VR1 and VR2 as *Circuit Wizard* does not offer an off-board option during the PCB conversion wizard process and we intend these to be case mounted. Note that the 'tuned circuit' is also to be mounted off-board (refer to Fig.11).

Our example PCB design is shown in Fig.10. If you're creating your own PCB design, take some time to lay the components out neatly, allowing the most efficient routing. You may also wish to use smaller track widths and/or spacing, as this is a more complex

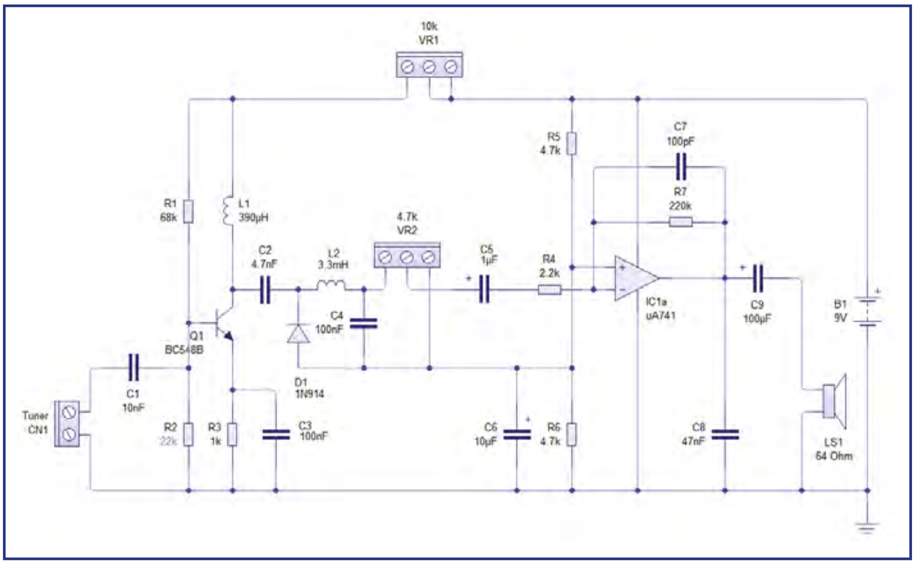


Fig.9. Circuit schematic ready for PCB design

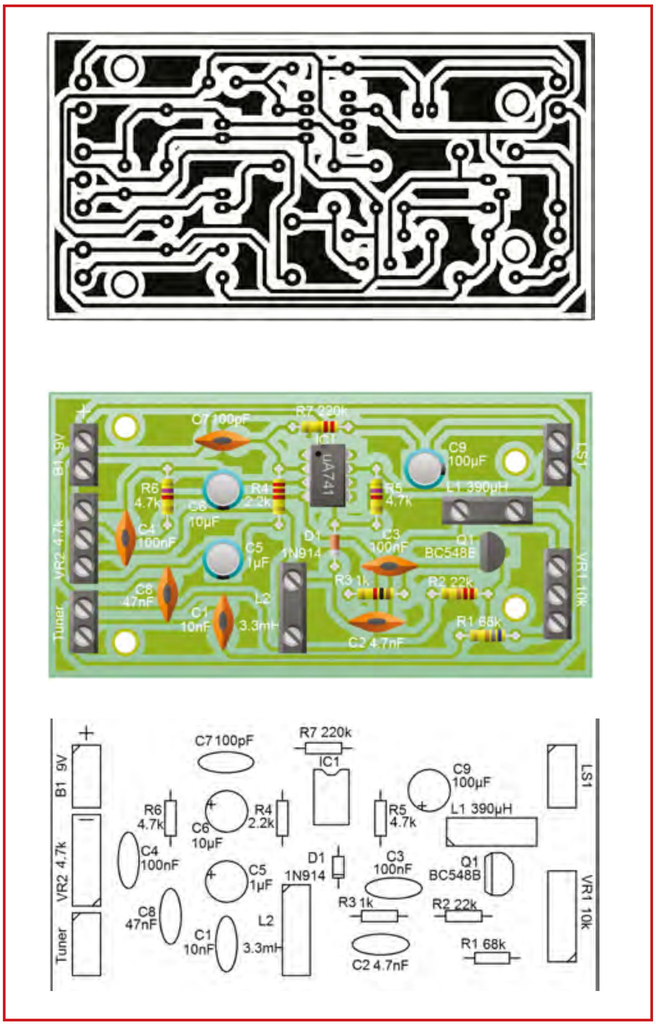


Fig.10. PCB design example (from top to bottom); PCB artwork; PCB real-world view; PCB silk screen

circuit. Alternatively, you can purchase a PCB from the *EPE PCB Service* (order code 902) and spend your time creating a really cool case/enclosure!

As with all of our *Jump Start* projects, we encourage you to design your own projects and enclosure to meet your own ideas and needs. For this month's example we have decided to pay homage to the era of the beautiful early valve radios. Back in the days before television, families would have gathered around their wireless set glued to the latest music, news and entertainment. Valve radios were invariably large and were often built into ornate wooden cases. Just as everyone now wants the latest flat screen TV home cinema system, in those days people wanted the smartest radio set to grace their living room. Our enclosure design is based on a 1930s Pye Model-Q radio with its 'sunrise' speaker grille (see Fig.16). This was a very early battery-operated radio that used four vales and was intended for portable use (although it's very far from what we would consider portable these days).

We used CAD software (TechSoft 2D Design) to re-draw the grille shape and design a simple interlocking case that could be laser cut from 3.6mm plywood. The two slots on the base locate with the two feet on the front grille supporting the main controls. We used a dark wood exterior ply in this case, as it gave us the hard-wood veneered look to match the original 1931 radio. This could also be stained, varnished or lacquered to gain your desired finish. Alternatively, MDF or acrylic could also be used. There are some wonderful early radio designs; why not do some research and create your own retro radio case design?

Our CAD design for the radio enclosure can be found in the Jump Start folder at **www.epemag.com**.

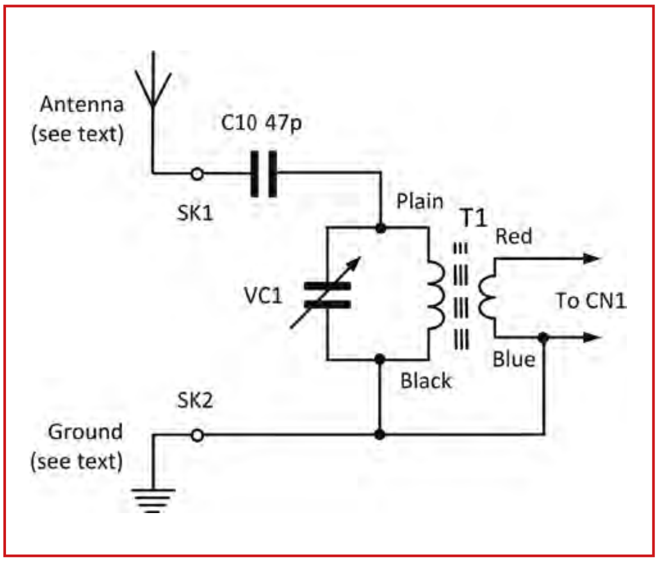


Fig.11. Tuned circuit 'off-board' components

Controls

We incorporated three controls on to the front panel of the *Simple Radio*; power/gain, tuning and volume. The first of these is a dual switch/potentiometer device with the switch interrupting the power supply connection and the potentiometer connected as VR1. A miniature variable capacitor (Rapid part 12-0255) was used as part of the tuned circuit arrangement connected to CN1 (see Fig.11). This is a dual component, designed for use in 'superhet' radios that have both antenna and local oscillator tuned circuits. In the *Simple Radio* we only need to use the larger component, which has a maximum value of 141.6pF, but for a wider frequency coverage the two capacitors can be connected in parallel to provide a maximum value of 200pF.

Fig.12. The finished 'retro' radio!

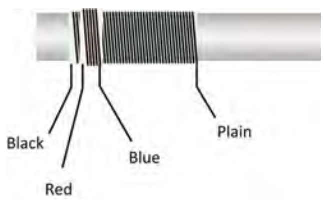


Fig.13 (left). Connections to the Rapid ferrite rod antenna

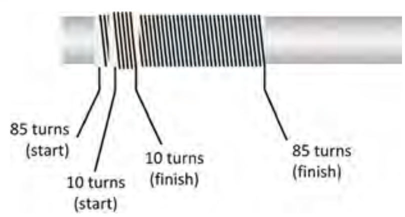


Fig.14 (right). Coil winding details for winding your own ferrite rod antenna. Wind both coils the same way

The ferrite rod antenna that forms the inductive part of the tuned circuit was mounted using two spring clips and grommets to the base plate. This component can be supplied as a ready wound transformer (Rapid part 88-3099 – see Fig.13) or can be wound on a small ferrite rod recovered from an old radio. When winding your own ferrite rod antenna it is advisable to wind the coil assembly (T1) on a tube so that it can slide along the rod in order to locate the optimum position for the required frequency coverage. You will need at least 85 turns of insulated wire for the main (tuned) winding and 10 turns over-wound for the secondary winding, as shown in Fig.14. You must wind both coils with the same sense.

We have specified the 1N914 diode for use in the *Circuit Wizard* model, but better results can be obtained with a BAT443 silicon Schottky diode (eg, Rapid part 47-2904). This diode is not available within *Circuit Wizard*, but it has a much smaller forward voltage drop and 'in turn' this will result in a significant increase in the receiver's sensitivity. If a BAT443 device is unavailable, a 1N914 will give acceptable results but with reduced sensitivity.

In order to provide the external connections (aerial, ground and head-phones) we mounted a small bracket with two 2mm female connectors. This permits the attachment of a ground (black) and external antenna (yellow) as well as a 3.5mm headphone jack socket. An aerial can be easily made from a piece of insulated stranded wire and a length of about 4m to 5m should be sufficient to give good results. In testing (from the West Sussex area) we were able to pick up several local/national radio stations at good strength, including Radio 5 Live, Talk Sport and Virgin AM. Table 1 (shown on our website – **www.epemag.com**) shows a list of stations in the UK that can be heard in your area.

Using the Simple Radio

The *Simple Radio* will give reasonably loud and good quality sound on a pair of headphones. At maximum gain setting (corresponding to minimum resistance of the gain control, VR1) the RF stage can be prone to oscillation and the optimum setting of the gain control is the point just before oscillation starts. This will provide maximum gain and greatest selectivity (ie, the ability to reject signals on frequencies close to the wanted signal). Oscillation usually manifests itself as a loud whistle when the gain control is advanced too far. However, in practice, the gain control can usually be set to the minimum level needed to produce a good quality signal, well before the onset of oscillation. Note that less gain will usually be required when an external antenna is connected, and consequently gain adjustment is less critical in such circumstances.

Once the correct value of gain has been found, the volume control can be adjusted for a comfortable listening level. Note that the gain control will need re-adjustment for different stations and it can be useful to experiment with the optimum position of the windings on the ferrite rod antenna. This can be accomplished by simply sliding the coil until a satisfactory tuning range and sensitivity is obtained (see Fig.13 for the position that we used).

A great extension of this project would be to connect the output of the radio to the amplifier circuit that we featured in the Jan'13 edition of *Jump Start* and attach a loudspeaker. Note that our sunrise grille is therefore only for aesthetic reasons on our prototype project and we simply glued a piece of dark card behind it to give the illusion of a classic speaker grille!

The rear view of our radio design is shown in Fig.19. Note that radio circuits can be rather sensitive and it is worth experimenting with the best position of the off-board components (in particular the ferrite rod and tuner components) to achieve the best results without unwanted feedback or instability. Short leads should be used wherever possible and inputs should be kept well separated from outputs. Radio enthusiasts quite rightly consider receiver design an art!

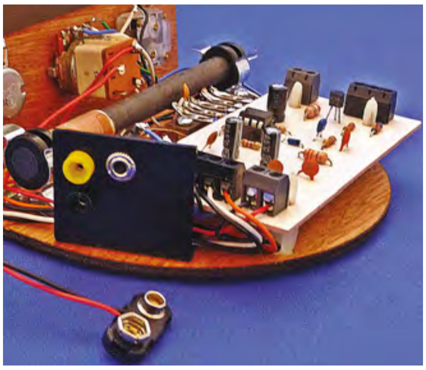


Fig.15. Rear bracket with antenna, ground and headphone connectors

For more info:
www.tooley.co.uk/epe

You will need...

Simple Radio Receiver

1 PCB, code 902, available from the *EPE PCB Service*, size 52mm × 99mm
1 8-pin low-profile DIL socket
3 2-way PCB-mounting terminal blocks
2 3-way PCB-mounting terminal blocks
1 5-way miniature tag strip
1 yellow 2mm socket (SK1) (see Fig.15)
1 black 2mm socket (SK2) (see Fig.15)
1 3.5 mm jack socket

Semiconductors
1 BC548 NPN transistor (Q1)
1 BAT443 Schottky diode (D1) (e.g. Rapid 47-2904, see text)
1 741 operational amplifier (IC1)

Resistors
1 68kΩ (R1)
1 22kΩ (R2)
1 1kΩ (R3)
1 2.2kΩ (R4)
2 4.7kΩ (R5, R6)
1 220kΩ (R7)

1 10kΩ variable potentiometer with double-pole switch (VR1)
1 4.7kΩ variable potentiometer (VR2)

Inductors
1 ferrite rod radio aerial (e.g. Rapid 88-3099) (T1) (see text and Fig.13)
1 390μH min. axial lead inductor (e.g. Rapid 88-2836)
1 3.3mH min. axial lead inductor (e.g. Rapid 88-2843)

Capacitors
1 142pF AM variable capacitor (e.g. Rapid 12-0255) (VC1)
1 10nF min. polyester (C1)
1 4.7nF min. ceramic (C2)
2 100nF min. polyester (C3, C4)
1 1μF 50V radial electrolytic (C5)
1 10μF 35V radial electrolytic (C6)
1 100pF min. ceramic (C7)
1 47nF min. ceramic (C8)
1 100μF 25V radial electrolytic (C9)
1 47pF ceramic capacitor (C10) (see Fig.11)

Photo gallery...

The Gallery is intended to show readers some of the techniques that they can put to use in the practical realisation of a design, such as PCB fabrication and laser cutting. This is very important in an educational context, where students are required to realise their own designs, ending up with a finished project that demonstrates their competence, skills and understanding.

The techniques that we have used are available in nearly every secondary school and college in the country, and we believe that our series will provide teachers with a tremendously useful resource!

Fig.16. Pye Model Q radio at the Washford Radio Museum in Somerset (www.wirelessmuseum.org.uk/)

Fig.17. Laser cutting the retro-design radio enclosure

Fig.18. Assembled case parts awaiting the electronics fit

Fig.19. Rear view of radio showing our component layout

Next month

In our final *Jump Start* after a long cold winter and ever hopeful of some warmer weather this summer we shall be getting ready for hot days with a *Temperature Alarm* that will provide you with an audible and visual warning that things are getting too hot for comfort!

Special thanks to Chichester College *for the use of their facilities when preparing the featured circuits.*

PIC Training Course

PIC Controlled Propagator

The use of LED lighting for plant propagation is relatively new. This extension to our PIC training course is an opportunity for you to further your knowledge of PICs while experimenting with this fascinating subject. The book starts with an introduction from first principles of which wavelength of light is best for growing plants and how an adequate brightness can be achieved at reasonable cost.

The P206 grow light control system uses a 28 pin PIC with real time clock and temperature measuring routines. An alphanumeric LCD displays the real time, soil and air temperatures, and soil moisture, and four high current MOSFETs are used for light control, flowerpot heater control, automatic watering and to drive a cooling fan. These are low cost circuits so two or more can be used if more controls are needed.

Looking at the picture you may be tempted to think the tomato plant will not survive as the grow light is too small. But the tomato plant in the picture has spent its entire life under that very light. Yes it is true that now a bigger light is needed but this light was particularly designed to raise strong healthy seedlings. The light from 144 LEDs is concentrated into a 50mm circle. It is as bright as sunlight.

If you DO NOT already have a Brunning Software programmer you will need the following.....

P206 USB powered 16F & 18F programmer module
+ P206-28 experimental module with PIC18F2321
+ P206-IO input/output module
+ 16 char 2 line plug in LCD
+ Plug in keypad
+ Book experimenting with PICs & Plant Propagation
+ PIC assembler and C compiler software on CD
+ USB cable..................................£ 93.00

If you DO already have a Brunning Software 16F & 18F programmer you will need the following.....

P206 to P928/P931/P942 adaptor
+ P206-28 experimental module with PIC18F2321
+ P206-IO input/output module
+ 16 char 2 line plug in LCD
+ Book experimenting with PICs & Plant Propagation
+ BSPWAv9.82 software on CD......£ 59.00

Experimenting with PICs & Plant Propagation

This book is not intended for absolute beginners but we do start with a chapter of revision to make sure you understand how a PIC is used to control external circuits. Then we jump in and load the library code to drive the LCD and for the real time clock. We learn how to create a 3 watt heating element for a flowerpot, study the requirements for making a grow light, consider the problems of automatic watering, and think about how to improve the simple grow light. (90 pages 240mm by 170mm with wiro binding to open flat.)

Web site:- www.brunningsoftware.co.uk

Grow Light Kit £45

The LEDs are soldered together in groups of 3 LEDs and one resistor, and assembled together like spokes of a wheel. There are full instructions in the book but you will need good soldering skills.

150 off 5mm LEDs
+ 50 off 5% resistors
+ tinned copper wire & leads
+ 12 volt 2 amp PSU........ £45.00

Heater & Moisture Kit £6.80

The 12 volt 3 watt flower pot heater is made by soldering 15 resistors together then insulating the assembly using heat shrink sleeving. Thermistors are used to monitor soil and air temperatures. The thermistors need to be soldered to leads and waterproofed with araldite. The soil moisture probe is made using 1.2mm tinned copper wire and heat shrink sleeving. Full instructions are in the book.

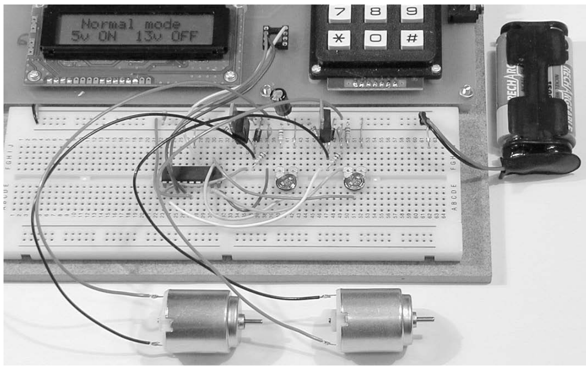
15 off 5% resistors
+ heat shrink sleeving & leads
+ 2 off thermistors & leads
+ Tinned copper wire & sleeving
+ connecting leads........ £6.80

P206 PIC Training Course

Our P206 PIC training course offers the same training as our P931 course. The P206 hardware is modular. For example the P206-28 module is the plug in test bed for 28 pin PICs. When detached it is a self contained project circuit which can drive LCD/keypad/P206-IO (4 × power MOSFETs and i/o). See website for details.

Ordering Information

Our P206/P931/P942 programmers connect directly to any USB port on your PC. All software referred to operates correctly within Windows XP, NT, 2000, Vista, 7, 8 etc. Telephone for a chat to help make your choice then go to our website to place your order (Google Checkout or PayPal), or send cheque/PO, or request bank details for direct transfer. All prices include VAT if applicable.



White LEDs and Motors

Our PIC training system uses a very practical approach. Towards the end of the PIC C book circuits need to be built on the plugboard. The 5 volts is supplied from the programmer with a current limit which ensures that even severe wiring errors will not be a fire hazard or damage PICs.

We use a PIC16F1827 as a freezer thaw monitor, as a step up switching regulator to drive 3 ultra bright white LEDs, and to control the speed of a DC motor with maximum torque still available. A kit of parts can be purchased (£31) to build the circuits using the white LEDs and the two motors. The P206 kit (£38) includes a plugboard and connecting lead. See web site for details.

Mail order address:

Brunning Software

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

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Real-time clock and calendar

WE complete (well, almost) our exploration of low-power modes this month by making use of the real-time clock peripheral built into the PIC processor. Simple as it is, this peripheral provides a very useful purpose – significantly reducing the power consumption required to maintain a real-time clock. This module is called the 'Real-time clock and calendar' or RTCC, as it maintains not only the time of day, but also a full calendar, valid up until the end of 2099. The peripheral will fail after that date, but I don't think this is something for us to worry about too much!

It's not unusual in a low-power embedded microcontroller system (that has been properly designed, that is) to find that maintaining a real-time clock is the main activity consuming power from the processor. Unlike input signals that might occur infrequently, the clock needs to be updated every second (or possibly every millisecond, if an accurate clock is required) and that will consume energy as the processor wakes up and updates a few variables before going back to sleep. So, off-loading this work to a dedicated peripheral makes sense, and gives the processor designers the chance to add a few bells and whistles to the peripheral.

Fig.1 shows the 'programmers model' of the PIC's real-time clock peripheral. It's input clock can be selected between the external watch crystal oscillator (the one we have been using up to now with a timer) or the internal 'RC' oscillator. It's unlikely that you would want to use the internal oscillator; based on an on-chip resistor and capacitor it will not be very accurate, and the whole point of a real-time clock is, as it says on the tin, to maintain the 'real' time. Not a very poor approximation to it.

We have the external 32kHz crystal fitted in our circuit, so the choice of input clock is easy.

Within the peripheral, a series of prescalers drops the input clock down to 2Hz (one tick every 0.5s) and this is the timebase for the rest of the peripheral. Running with a very low clock frequency is another technique that helps reduce current consumption on-chip, which is of course an important requirement for this module.

The RTCC not only maintains the time and date, but also has a flexible alarm feature, which can trigger an interrupt or pulse an output pin – a feature that can be used for purposes other than the obvious wake-up signal; it can be used to generate accurate but *very* long period pulses, perhaps to wake some other hardware device periodically (once a day, once a week or even once a year for example).

The 'calendar' aspect of the module maintains the day, month and year values in a convenient BCD (binary coded decimal) format that makes translating the data for display very easy. And yes, the module automatically handles leap years – but not daylight saving changes.

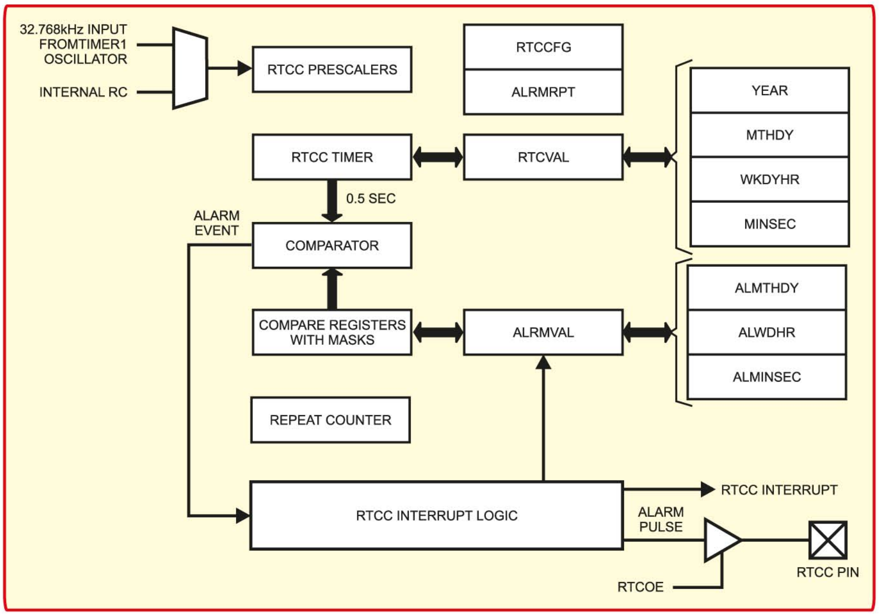


Fig.1. RTCC peripheral

Completing the user interface

We add a few buttons to provide a 'user interface' and help us demonstrate a couple of new microcontroller features.

As the processor is going to be spending most of its time in sleep mode with the LCD off, we rely on an initial keypress to 'wake' the processor up and turn the LCD on. How do we detect that the key has been pressed if the processor is asleep? If we were to wake the processor up periodically and poll the input ports (say, twice a second to give a reasonable response) we would significantly increase the current consumption of the circuit, negating all our hard work. There must be a better way to handle this requirement.

External interrupt

This is the kind of problem that external interrupt inputs were made for. Instead of having the processor wake up and look for a key being pressed, we connect one of the buttons to a pin with an interrupt input capability, and let the keypress wake the processor. Combined with the use of the real-time clock module, this means the processor will remain asleep indefinitely, waiting for a key press or the batteries to go flat many, many months later.

There are two sources of external interrupts on our particular processor; 'interrupt on change', associated with the upper four bits of PORTB pins, and an interrupt input on PORTB.0. The problem is, we have already allocated those pins for other uses (remembering that we want to keep the top two bits of PORTB free for the debugger interface). So, what do we do? Must we change our circuit and software to move some of the LCD control signals around? Fortunately we do not.

Another feature of the newer PIC microcontroller devices comes to our aid – re-mappable peripheral functions. These are internal peripheral features that include serial interfaces, PWM outputs, timer inputs and interrupt inputs that can be connected to a pin of your choice rather than being tied to a fixed pin. This is a very useful feature for simplifying PCB layouts and in our case helps solve a (deliberate, honest!) blunder in our earlier pinout choices – we can map the INT1 interrupt input to the pin RC2 where one of our keys is connected.

Re-mappable peripherals

With over twenty peripheral output signals, eighteen peripheral inputs and nineteen pins that can be used, it's easy to be confused at first viewing as how to make sense of this all. There are over thirty control registers provided to control them all. Fortunately, these break down into two simple groups, **RPINRxx** and **RPORxx**. Each peripheral input feature has an RPINRxx register; you write into it the pin number that you wish to connect it to. For peripheral **output** signals, each physical pin has an RPORxx register. You write into the register, which corresponds to the pin you are interested in, the output peripheral number that you want to assign to it.

As we want to connect pin RP13 (which is the same as pin RC2) to the INT1 input signal, we simply issue the instructions:

```
movlw .13 ; Pin number. Pin RC2 is also re-mappable pin RP13

movwf  RPINR1 ; RPINR1 is the control register for INT1
```

To 'turn off' this mapping and return the port pin to an ordinary I/O port pin, we write a value of 31 decimal into the register:

```
movlw .31 ; Pin number. 31 is 'no pin'

movwf  RPINR1 ; disable peripheral function on pin RC2
```

We will use both of these sequences in our code, as the input pin will need to operate differently depending on what state the microcontroller is in – with the display off and the processor in low-power mode, the pin will function as an interrupt. When the key has been pressed and the interrupt wakes the processor, it will be turned into a normal input pin to allow for the user interface control.

Pull-ups

The final point of the hardware design worth discussing is that of pull-up resistors on the input pins connected to the buttons. Any pin configured as a digital input must be driven either high or low by the circuit at all times, otherwise the pin will 'float' around the mid point, causing potentially large currents to be drawn. The pin will also be more succeptable to static damage if a stray finger should touch it. The value of the pull-up is not critical, with values in the range of 1k to 10k being typical.

A lower value will reduce the amount of 'key bounce' that occurs as the button is pressed, which may improve the responsiveness of the application by a few tens of milliseconds, though it is debatable whether it is possible to notice such a change. A lower value will, however, result in a slight increase in current consumption due to leakage through the input pin, but not by much. Nonetheless, in our circuit we have gone with 10k pull-up resistors to keep the power consumption as low as possible (Fig.2).

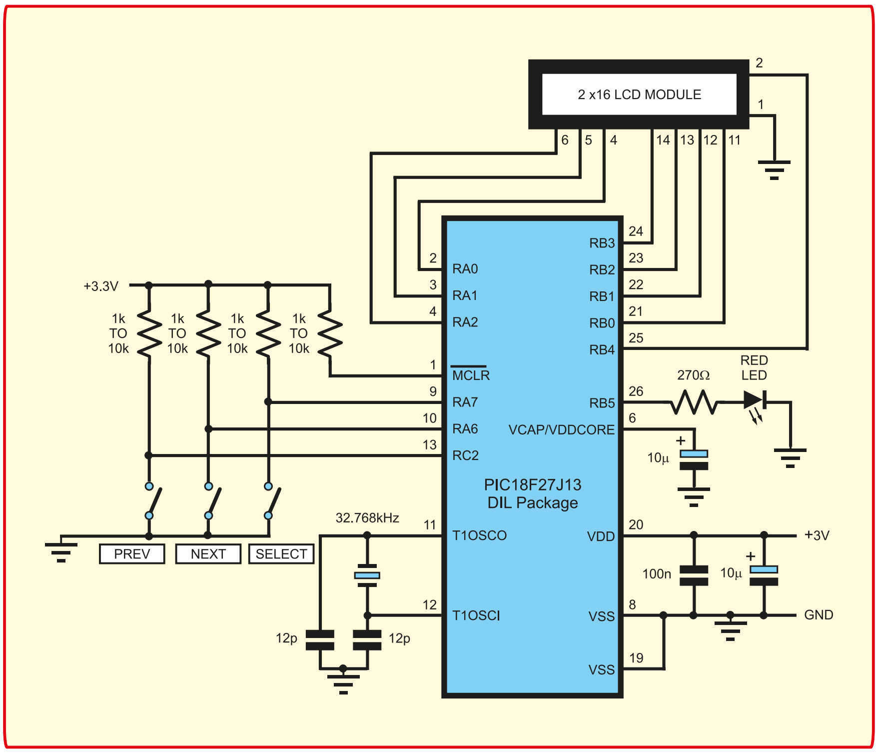


Fig. 2. Updated Schematic

Next month, we look at the software in some detail, and move from assembly language to the (slightly) higher level language 'C', demonstrating how higher level languages make writing and maintaining the software easier.

Commercial development board

In this series of articles we are working towards a simple development board that can be put to many different uses. While this will result in a cheap and easy-to-use board, it won't suit everybody. There are some occasions where a pre-built general purpose development board is necessary, and we thought it might be interesting to take a break from our own development efforts to look at one of the many boards available on the market.

There are literally dozens of different companies offering general purpose PIC development boards, but we take a look at one with a bit of history – the EasyPIC board from MikroElektronika, based in Serbia. The EasyPIC board has been in production for over ten years now and is currently at revision 7. The board is available directly from MikroElectronika or from distributors including Farnell in the UK, who sell it for £99 plus VAT.

Ours came direct from the manufacturer and on opening the box the initial impressions were good. MikroElektronika seem to enjoy creating neat, strong, durable packaging for their hardware, and the box for the EasyPIC is no different. The board is supplied in a strong anti-static bag and two manuals, a DVD (full of software tools and examples) and a high quality USB cable complete the contents.

It's unusual to see a printed user guide and here we get two – a beautifully detailed user guide, with full colour images of the various components described clearly for the complete novice (but still a joy to read for the more experienced hobbyist) and a full schematic with explanations of each section of the board.

Reading and understanding the user guide is essential. The versatility of this board means it is quite complicated, and with dozens of headers and dozens of jumpers it can take a while to get the board configured correctly for your required processor and application. Fortunately, the manuals explain this clearly. The complexity of the board is a natural consequence of its flexibility, supporting over 250 different PIC processors on a single board.

The board is quite large, measuring 10.5 × 8.5 inches, as shown in Fig.3. It can run from an external power supply (DC or AC, 9V to 30V) or through a USB cable. The board itself can be configured to operate at 3V or 5V, as required by whatever processor you fit.

As might be expected for a board that supports over 250 different processors, there are eight dual-in-line sockets to take your processor of choice. To get you started, the board is supplied with a PIC18F45K22, a very capable part that runs at 16 MIPS, and with 64KB FLASH and almost 4KB RAM it provides ample resources for many projects. The chip is a dual-in-line part, fitted in a socket, so you simply remove it and fit your own processor choice, which must also be a DIL packaged part.

Fig. 3 EasyPIC V7 board.

Did we mention it supports over 250 PIC processors? These are devices from the PIC10, PIC12, PIC16 and PIC18 families. There are some more recent parts that are not supported, so if you have a specific part in mind, it's worth checking that it is supported.

This is by far the most flexible board that we have seen, and you can do a lot with this without needing to solder a single wire; driving an LCD, EEPROM, LEDs, 7 segment LEDs, buzzer, serial comms, USB comms, they are all either supplied on board (in the case of LEDs, buzzer, 7-segment LED display) or simple plug-in parts.

The board might be a little too complex for the complete beginner, who may find the much more limited though well supported Microchip PICKit 2 + PICDem demonstration board easier, although you will need to resort to the soldering iron much sooner than with the EasyPIC board. You would, however, quickly outgrow a PICDem board, but you are unlikely to outgrow something as flexible as the EasyPIC board.

Compilers

Demo versions of the company's Basic, Pascal and C Compilers are supplied, limited to creating programs up to 2K words in size. The programming hardware is built into the board, and a simple USB cable (supplied) connects the board to your PC. To create and debug larger programs, you must purchase a compiler, which cost in the region of £160. Alternatively, you can disable and bypass the on-board programming hardware and connect a Microchip programmer/debugger unit such as the PICKit or ICD, and develop and debug software using the free (and less limited) Microchip tools.

Development software aside – we will be taking a close look at MikroElektronika's compilers in a later article – the board comes with a full compliment of LEDs, buttons, variable resistors and headers for all the processor ports, making access to the hardware simple, and without the need to resort to a soldering iron. Small add on boards, ranging from graphics LCD panels, Wi-Fi, GPS, Bluetooth down to simple real-time clock modules extend this 'plug & play' and soldering-iron free approach. They do increase the cost, of course, but if you need to develop an application quickly and the cost is not a concern, this is definitely a tool for you.

Many projects incorporate a serial UART interface, so it's nice to see that the board includes a dedicated USB-to-RS232 interface, meaning you can build UART-based projects, but connect the interface to a PC using just a USB cable. For projects making use of a processor's on-board USB peripheral, a dedicated USB connector is provided too.

The lack of a 32kHz watch crystal on-board is a shame, but they had to stop at some point, and the real-time clock function can be supplied by one of the add-in modules.

Overall, the EasyPIC board would be ideal for a student studying embedded systems development, who needs the flexibility over time for several different processors and is prepared to put in a little up-front study to understand the boards complexities.

The EasyPIC V7 board can be purchased from Farnell, part number 2281646. A PIC32 variant is also available. The board can be ordered directly from *MikroElektronika* at **www.mikroe.com**.

PLEASE TAKE NOTE

The PCBs available from the *EPE PCB Service* for the *SoftStarter* project in the April '13 issue are single sided and are only suitable for switching loads up to 10A, if you require 20A, (the maximum the relay is rated for) then two pieces of 22swg (0.711mm) tinned copper wire should be soldered to the large PCB lands running from the relay contacts to the Live In and Live Out terminals, thus ensuring the PCB can carry the load.

We apologise for the incorrect information regarding the PCB in the article.

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Slew rate and amplifiers

FOR the last couple of months, we discussed a question about op amp bandwidth posted on *EPE Chat Zone* by **bowden_p**.

I wish to put a 200kHz sawtooth waveform through several stages of op amp processing with reasonable fidelity. The incoming amplitude is up to about 0.5V p-p at about 3:1 rise/fall ratio, and the op amps then apply up to ×3 gain. What op amp gain-bandwidth product (GBP) would be needed for this task?

I believe a sawtooth waveform has both even and odd harmonics, so if say the 6th harmonic is to be passed without much loss, then 200kHz × 6 × 3 is the signal bandwidth = 3.6MHz. The op amp open-loop gain required to pass this without much loss would then be, say a minimum of 10, so the overall GBP comes to 36MHz!

(The op amps would have feedback applied to limit gain to the required ×3 or less.)

1. Is this a good estimate of the GBP required?

2. How does this relate to the unity-gain frequency quoted in data sheets?

Is this true, or have I lost the plot somewhere?

All comments welcome; my forte is not in analogue electronics, but I am trying to understand this area more.

Quick recap

This is the third and final article in response to this question. In the first article, we looked at the relationship between feedback and frequency response, the meaning of the term gain-bandwidth product (GBP), and found that **bowden_p**'s implied GBP specification is 3.6MHz (assuming that six harmonics is sufficient, so the required bandwidth is 1.2MHz with a gain of 3).

In the second article, we concentrated on using the LTspice simulator to investigate the frequency response (and hence GBP) of a couple of different op amps (a 'slow' one and a 'fast' one) in order to determine their suitability for handling signals such as those defined by **bowden_p**. The circuit shown in Fig.1 was used in these simulations and will be used again this month.

The *Chat Zone* discussion following from **bowden_p**'s question included posts related to LTspice simulation, and **bowden_p** mentioned being new to this. Therefore, last month's article provided quite a lot of detail on how to use LTspice – for the benefit of readers, like **bowden-p**, who are new to analogue circuit simulation. Another topic mentioned in the *Chat Zone* thread was slew rate, which along with small signal bandwidth, may be significant in amplifier design issues such as that faced by **bowden_p**.

Last month, we started to address slew rate by performing a transient simulation of the circuit in Fig.1, with the input source (V1) configured to produce a 500mV peak to peak sinewave. The input signal and the response of the two op amps is shown again in Fig.2. This demonstrates that the slower amplifier (the LT1001) is unable to reproduce the correct output waveform shape. However, last month we saw that the LT1001 could output an undistorted sinewave at much lower amplitudes. The distortion in the LT1001's output in Fig.2 is due to slew rate limiting.

This month, we will look at slew rate in more detail and will again perform LTspice simulations to compare the two op amps. After discussing slew rate in general, we will simulate the amplifiers using **bowden_p**'s required triangular waveform and assess the two amplifiers' capabilities in performing this task.

Slew rate

The voltage (or current) at the output of any circuit can only change at a certain maximum rate. This is determined by factors such as the current available to drive internal capacitive nodes. The maximum rate of change of the output voltage, V_o, is called the slew rate, *s*.

Mathematically we write:

where *dy/dx* is the notation used in

$$s = \left.\frac{dV_o}{dt}\right|_{max},$$

calculus for the 'differential', or rate of change of a quantity *y* (voltage, *V*, in this case) in response to a change in *x* (time, *t*, in this case). The change *dx* (or *dt*) is very small (tending to zero) so that we have the instantaneous rate of change at any give point.

We can write this formula in a less precise and more 'wordy' way as

If the demand (ie, input to the circuit)

$$\text{slew rate} = \text{maximum value of} \left(\frac{\text{output voltage change}}{\text{time taken for that change}}\right)$$

requires the output to change faster than the slew rate, then the circuit will fail to 'keep up' with what the demand is requiring it to do. This may be

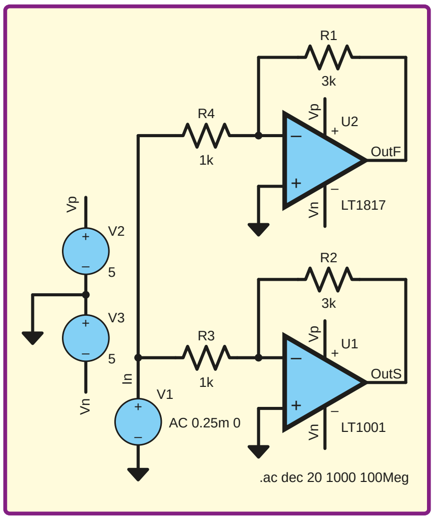


Fig.1. Circuit for LTspice simulation comparing a fast (LT1817) and slow (LT1001) op amp

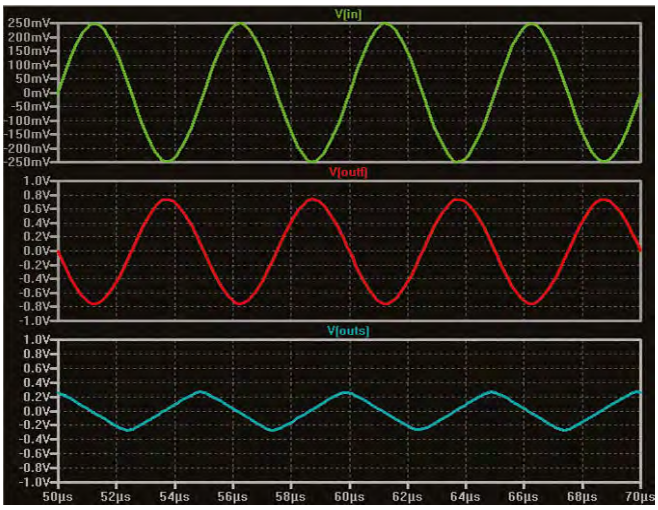


Fig.2. Transient simulation of the circuit in Fig.1. with a 0.5V ptp 200kHz sinewave input

beneficial or detrimental depending on the situation in which it occurs.

Slew rate is often a performance-limiting factor; that is, the more slew rate you have the better, because the demand is faithfully responded to, implying an undistorted output. Unwanted slew rate limiting is probably most well known in the context of amplifiers, including operational amplifiers, as we have seen in Fig.2.

There are occasions when it is necessary to specifically limit slew rate. Deliberate slew rate limiting is used (for example) to reduce electromagnetic interference (EMI) by reducing the high frequency energy in a signal, reducing voltage spikes induced by stray inductance, and keeping mechanical parts moving within safe acceleration limits when driven by electronic controllers.

For amplifiers, including operational amplifiers, slew rate limits the maximum available output swing at high frequencies due to the distortion that occurs if the output cannot move fast enough to follow the required waveform shape. When an amplifier is slew rate limited, it behaves in a non-linear manner. In extreme cases, very high levels of distortion occur. For example, an input sinewave will result in an output triangular wave. This is exactly what we observed in the final simulation we discussed last month, and which is shown again in Fig.2.

Full-power bandwidth

For an amplifier with a maximum output voltage, V_m, the frequency at which it can output an undistorted sinewave of magnitude V_m is called the full-power bandwidth *(FPBW)*. This is a very different 'bandwidth' characteristic from gain-bandwith product, but may be more significant in some applications.

If you know calculus, you will recall that the differential of a sine function is a cosine and realise we can use the slew rate definition above to work out the relationship between required slew rate, amplitude and frequency. If you have not studied calculus, don't worry about it, just skip the next paragraph to the full-power bandwidth defining equation below.

For a sinewave output signal V_o with peak amplitude V_m and frequency ω (in radians), we can write $V_o = V_m \sin\omega t$ so $dV_o/dt = \omega V_m \cos\omega t$. Thus a slew rate of:

$$s = \left.\frac{dV_o}{dt}\right|_{\max} = \omega V_m$$

is required to 'keep pace' with the fastest part of the sinusoid and distortion will occur if $\omega V_m > s$.

This gives a full power bandwidth of:

$$FPBW = \frac{s}{2\pi V_m}$$

where f is the (sinewave) signal frequency in hertz, s is the slew rate in volts per second and V_m is the peak signal amplitude. Many operational amplifiers can produce output voltages close to the supply rail voltages, so V_m is typically similar to the supply voltage (for a split supply around ground), or half the supply voltage for a single supply configuration.

At low frequencies, the maximum peak undistorted output swing of an amplifier is limited by the power supply voltage. At high frequencies it is limited by the slew rate.

The slew rate of the LT1001 is typically 0.25V/µs. The formula for full-power bandwidth gives us *FPBW* = 250000/(2×π×14) = 2.8kHz at its maximum output swing of ±14V (14V peak sinewave). Below this frequency the LT1001 is supply limited and can output a sinewave with peak amplitude at the device's maximum swing.

Above the *FPBW* frequency the available maximum undistorted output amplitude drops. For the LT1001 to achieve a 200kHz undistorted sine output signal, the amplitude must be less than 200mV peak (= $s/2\pi f$). The 750mV peak sinewave ideal output from the LT1001 ($V_{(outs)}$) in the simulation shown in Fig.2 (ie, three times the 250mV peak input sinewave, $V_{(in)}$) is clearly beyond this and accounts for the distortion seen in Fig.2.

The slew rate of the LT1817 is comparatively huge at 1500V/µs – in fact, this is a key capability of this device and is a headline figure on its datasheet. Its maximum output swing is around ±3.8V, which gives a FPBW of 63MHz. As this is significantly higher than 200kHz we do not observe any slew rate limiting in output of the LT1817 in Fig.2.

Bandwidth limitations

Full-power bandwidth limitations sometimes confound inexperienced circuit designers. The LT1001's datasheet states that its GWP is around 800kHz, implying a bandwidth of 270kHz at a gain of 3 (which we confirmed in simulation last month). So, if one is unaware of slew rate limitations, it is an easy mistake to assume that an amplifier built using the LT1001 can output a 14V sinewave at 200kHz. The *FPBW* of 2.8kHz and the results in Fig.1 show us that this is not the case.

Bandwidth, as opposed to *FPBW*, is defined for arbitrarily small-signal amplitudes. *FPBW* is not always quoted on operational amplifier datasheets because it is dependent on the supply voltage used (the LT1817 datasheet quotes 80MHz at 3V peak signal, rather than 63MHz at 3.6V). However, using the formula given you can always work it out from the slew rate, which will be stated.

So far, we have looked at the performance of these op amps with respect to sinewave inputs, however, **bowden_p** requires a triangular wave.

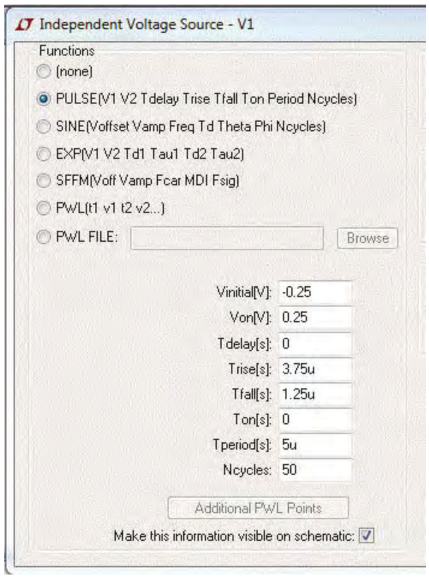


Fig.3. Independent Voltage Source window with settings for creating a triangular waveform

Taking up our LTspice tutorial theme again, this immediately raises the issue of how we obtain a triangular wave in LTspice. We need the voltage source V1 in the simulation schematic shown in Fig.1 to produce this waveform.

In LTspice, right clicking the V1 voltage source (and clicking the advanced button if necessary) opens the Independent Voltage Source window (see Fig.3). This provides a number of methods for defining a waveform (such as sine and pulse). At first, things do not look very promising as there is no 'triangle' option. However, a pulse waveform can be configured to produce the required triangular signal.

Bowden_p's requirement is for 0.5V peak-to-peak amplitude and we will assume this is centred on 0V. This means our 'pulse' starts at –0.25V (the pulse 'off' or initial voltage) and switches to +0.25V (the pulse 'on' voltage). These are values used for the Vinitial[V]: and Von[V] parameters of the pulse waveform.

The required frequency is 200kHz, which means each cycle of the waveform lasts 1/200,000s = 5µs. Thus the Tperiod[s]: parameter in should be '5u'. The pulse waveform settings include the rise time and fall time of the pulse edges. If we make these add up to be exactly equal to the period, the pulses will not have any flat bottom or top sections – we will get a triangular waveform.

The requirement for a 3:1 rise/fall ratio, corresponds to ¾ of the period spent rising and ¼ of the period spent falling. A quarter of the period is 5/4 = 1.25µs, so the rise time is 3.75µs and the fall time is 1.25µs. These are set via the Trise[s]: and Tfall[s]: parameters in the pulse waveform setup.

The waveform definition can be displayed on the schematic, if desired, as here:

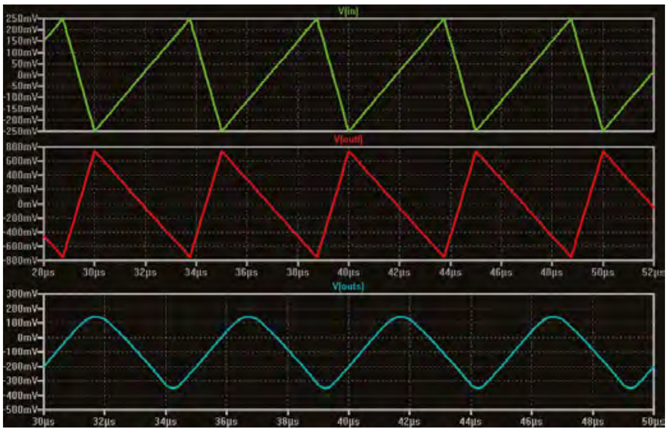


Fig.4. Transient simulation of the circuit in figure 1 with a triangular wave input. The LT1817 produces the correct output, but the LT1001 is significantly slew rate limited and fails to reproduce the correct waveform shape

PULSE (–0.25 0.25 0 3.75u 1.25u 0 5u)

While discussing the parameters of the triangle waveform, it is useful to consider the slew rate requirement it presents. We require a gain of 3, giving an output of 1.5V peak-to-peak. The fastest part of the waveform is the falling input edge, which takes 1.25µs. Thus, the amplifier output must change 1.5V in 1.25µs, which is a slew rate of 1.2V/µs.

The slew rate of the LT1001 is 0.25V/µs, so we would expect it to struggle with this signal. The output can only change by about 310mV in 1.25µs. The slew rate of the LT1817 is 1500V/µs; and at this speed a change of 1.5V would take just one nanosecond, so the LT1817 is well within its slew rate limits here.

We can now run a transient simulation similar to the one in Fig.2, but with the triangular input. The results are shown in Fig.4. The first trace is the input signal, V_{in}, defined as just described.

The second trace is the output from the fast LT1817 op amp, V_{outf}. Right clicking the trace title to activate a double cursor (as described last month) we can measure the amplitude. The value is 1.5V peak-to-peak as required. The triangle waveform appears reversed because the amplifier is inverting. The LT1817 is doing a good job amplifying the sharp triangle waveform, as might be expected from our earlier discussions on its gain-bandwidth product specification with respect to the requirements for this job.

The situation is not so good for the LT1001 op amp. This is a high-precision amplifier aimed at high accuracy, but low frequency applications. The third trace, V[outs], clearly shows that the LT1001 is unable to reproduce the output signal and the result is very similar to that produced by the sinewave input (as shown in Fig.2). The overall shape of the LT1001 output waveform in Fig.4 is due to slew rate limiting, but the rounded corners of the triangle are due to bandwidth limiting attenuating the higher harmonics of the input signal.

We can see what happens to the triangle wave if it is just bandwidth limited rather than slew rate limited by reducing the amplitude of the signal, but keeping the same basic shape. The result is shown in Fig.5, in which the input amplitude is 1000 times smaller than for Fig.4. Here we see that the LT1001's output is a rounded version of the required shape, while the LT1817 produces a sharp waveform, as before. However, as we saw with the low amplitude sinewave the LT1817 suffers from a significant DC offset in comparison with the LT1001.

In this article, and the one last month, we have compared the performance of the LT1001 and LT1817 with respect to **bowden_p**'s application, with the purpose of demonstrating some of the concepts, calculations and simulations which might be applied when selecting a suitable op amp. These two devices were chosen somewhat randomly in order to provide examples with very different characteristics. We do not have full details of the target application, so we cannot conclude that the LT1817 is the most appropriate device in this case – it is one of many potentially suitable high speed amplifiers on the market.

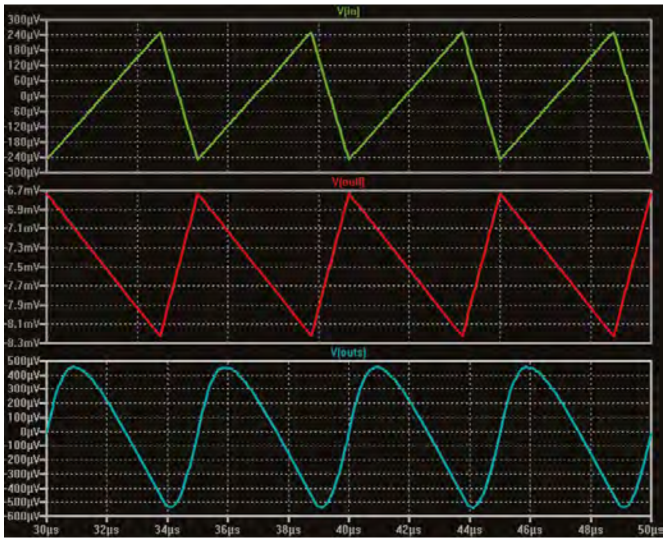


Fig.5. Repeat of the simulation shown in figure 4 with the input amplitude reduced by a factor of 1000. The V[outs] signal is now just bandwidth limited, as the op amp slew rate has not been exceeded

INTERFACE

By Robert Penfold

VB Express lives on

As those who have followed this series over the years will be all too aware, improvements in PC hardware and programming languages have, in many cases, not actually been improvements for those using simple methods of interfacing their own add-ons to a PC. In fact, they have made simple interfacing progressively more difficult. Easy-to-use-and-access ports, such as the serial and parallel printer types have become obsolete, and computing languages seem to become ever-more complex. Modern PCs are more secure than those of a few years ago, but shortcuts that used to work are not acceptable with modern versions of Windows. Everything has to be done 'by the book' or your program grinds to a halt, assuming that you managed to get it to compile properly in the first place!

Express results

There is no longer a genuinely simple and straightforward way of interfacing your own gadgets to an up-to-date PC. The main choices available to the PC add-on enthusiast are to use an old PC and computing language, use a microcontroller instead of a PC, or use a virtual serial port on a USB port. It is the latter that has been pursued in this series of articles over the past few years, and it works quite well in conjunction with Microsoft's Visual BASIC, or even the free Visual BASIC Express. In the current context it is unlikely that the free version is any less suitable than the normal commercial versions. Since the commercial versions are quite expensive, the availability of a suitable free version is no doubt essential to many who use this method of interfacing.

Microsoft periodically updates its programming languages, including the free Express versions. In the past these changes have often been unhelpful for PC add-on enthusiasts, and at best have been largely irrelevant. Towards the end of last year there was a complete revamp of this range of software. The bad news is that the standalone version of Visual BASIC Express is no longer available as a download. The good news is that it is possible to download a new version of Visual Studio Express, and this includes Visual BASIC Express.

As far as I have been able to ascertain, it is no longer possible to download the older versions of Visual BASIC Express. All is not lost if you are using a PC that is incompatible with the latest version, since some of the earlier versions of Visual Studio Express are still available as free downloads. At the time of writing this piece, it was possible to download versions back to Visual Studio Express 2005, but the older downloads might be withdrawn before too long. Anyway, whether you need a new version or an older one, it seems that you have to download and install Visual Studio Express.

Spoilt for choice

The revamp of Microsoft's programming languages has produced several different versions to choose from. These versions are aimed at different areas of interest, and are as follows:

- Express for Web
- Express for Windows 8
- Express for Windows Desktop
- Express for Windows Phone
- Team Foundation Server Express

The general Windows 8 version and the one for Windows desktop applications seem like good choices in the current context. Since it is desktop applications that are needed for operation with user add-ons I eventually opted to download Express for Windows Desktop.

One downside of having to download Visual Studio Express, rather than just the Visual BASIC Express component, is that the download is relatively large. In addition to Visual BASIC Express, the download includes the companion C# and C++ programming languages. At over 600MB, the download is over four-times larger than the last standalone version of Visual BASIC Express. This is probably not a practical proposition with a dial-up connection, but should not take too long with any form of broadband link.

The Microsoft servers are normally very fast, and the download speed is usually close to the maximum that your Internet connection can handle. It downloaded in a few minutes on my mobile broadband link, but used well over ten percent of my monthly data allowance in the process!

This version will run under Windows 7 with Service Pack 1 installed, or with Windows 8. An earlier version of the program is needed for operation under Windows XP or Vista. The hardware requirements are not too stringent for a standard installation. The main requirements are a 1.6GHz or faster processor, 1GB of RAM, 5GB of hard disc space, a 5400 RPM or faster hard drive, and a DirectX-9-capable video card running at a resolution of at least 1024 by 768 pixels.

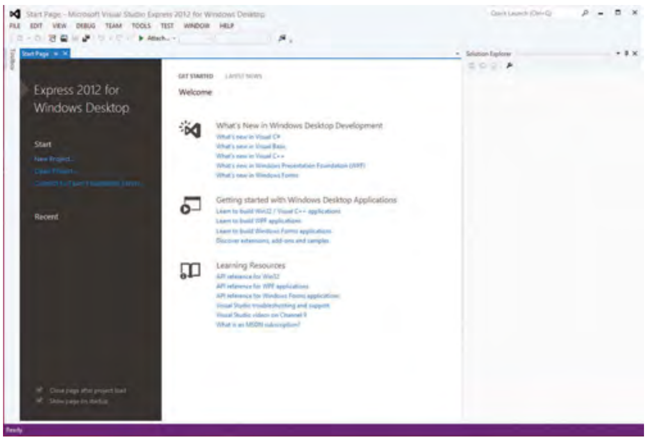


Fig.1. It can take a while to get the program installed and registered, but this is the initial window once it is 'up and running'

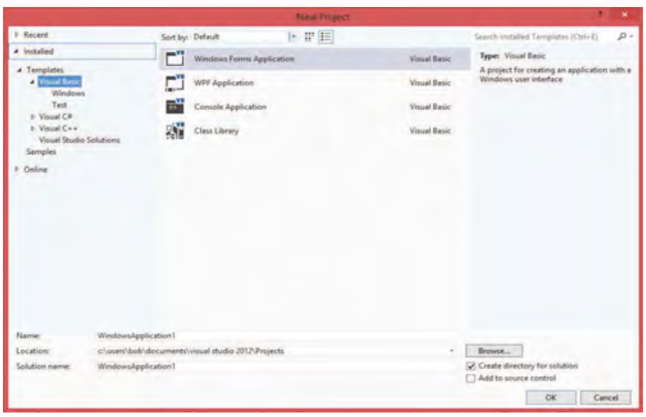


Fig.2. Three programming languages are available via the left-hand column of this screen, including Visual BASIC. Windows Form Application is selected from the main panel

Burning issues

The downloaded file is an ISO image type, and the idea is for this to be burned to a CD-ROM. The finished CD-ROM contains a program file and a folder that holds all the source files needed for installation. If the CD-ROM is not set up to auto-run, it is just a matter of running the program file in order to get installation under way. Things then follow along the normal lines for installing a Windows program.

However, things did not go according to plan with my installation, which came to a halt with an error message about half way through. This was possibly due to an error in the writing process when burning the CD-ROM, although the program did not report any issues. Anyway, extracting the files from the ISO image to the hard disc and then running the program file resulted in the broken installation being repaired and completed successfully.

This would suggest that there is no need to use the CD-ROM route unless you would like to have an installation disc. Simply extracting the installation files and then running the installation from hard disc is quicker and easier. There is an alternative installation method, which is to download and run a small program which will then perform an online installation. This is potentially the more convenient way, but it does not leave you with the files needed for reinstallation, or for installation on a second computer.

Registration

As with the previous versions of Express software, registration of the program is effectively compulsory. The program is only a 30-day evaluation copy until the registration process is completed. Registration can be completed online, and it involves going through the usual questionnaire-type form. The process should be quicker and easier if you are already registered as a Microsoft customer.

While registration is not popular with everyone and unpopular with many, bear in mind that until a few years ago, Microsoft sold roughly equivalent versions of this software for a few hundred pounds. Although it is an evaluation copy prior to registration, once registered you have to observe a few legal niceties, but are licensed to distribute the software produced using any of the three Express programming languages in the package.

Business as usual

Installing a major piece of Windows software never seems to be particularly quick, and in this case it could take an hour or more to install the program, register it, and complete the final setting up and installation. Eventually, the program produces an initial screen like the one in Fig.1. There are numerous options here, but to create a new Visual BASIC program it is the New Project link in the Start section on the left that is selected. At the next window (Fig.2) you select Visual BASIC in the left-hand column, Windows Forms Applications in the main panel, and choose a name and folder for the project in the bottom section of the window.

Operating the OK button then launches Visual BASIC Express, which looks much like the previous version. There are the usual menu and toolbars at the top of the screen, a space for the form in the main section, the Solution Explorer and Properties windows on the right, and a tab to expand the Toolbox on the left. The latter provides the usual range of visual components, such as buttons, labels, textboxes, and scrollbars (Fig.3), plus non-visual ones such as the Timer and the all-important SerialPort component.

Power Packs

One welcome change in the new version is that it is no longer necessary to download and install the latest Power Pack in order to obtain basic drawing components. These used to be a standard part of Visual BASIC, but were omitted when VB.Net was introduced. They could be reinstated by installing a semi-official download called the Visual Basic Power Packs. However, these components are now included as part of a standard Visual BASIC Express installation, and are at the bottom of the list of Toolbox components. Of course, it is still possible to draw on the screen using traditional programming rather than the visual approach, but designing things such as virtual meters and controls is usually very much quicker if the required elements are dragged onto the form and then 'fine tuned' in the Properties window.

The basic drawing elements are lines, rectangles, and ovals, although the latter are actually ellipses rather than ovals. The rectangles and ovals have separately defined outlines and fills, and various fancy fills including gradient types can be used (Fig.4). It is possible to simply use the drawing elements for decoration, but they are normal components that can be used in an active fashion if required. For instance, the colour of a circle can be altered so that it can be used as a virtual LED indicator light, and clicking on a drawing element can be used to trigger an action of some kind. This makes it easy to use them in things like virtual rotary switches and panel meters.

End class

Everything seems to operate much as before, and I had no difficulty in loading and running some simple programs written using the previous version of Visual BASIC Express. This did not require the conversion process that in the past always seemed to be required when loading a program written using an earlier version. It is still early days, and I have not used Visual Studio Express for Windows Desktop very much, but it still seems to be a good choice if you need a free programming language for controlling add-ons via a virtual serial port. From the simple interfacing point of view it appears to be fully compatible with the previous version. However, it seems a shame that you have to download and install several hundred megabytes of additional software, even if you have no use for it.

Details of Visual Studio Express for Windows Desktop can be found at this web page, which also includes a link to the download page: **www.microsoft.com/visualstudio/eng/products/visual-studio-express-for-windows-desktop**

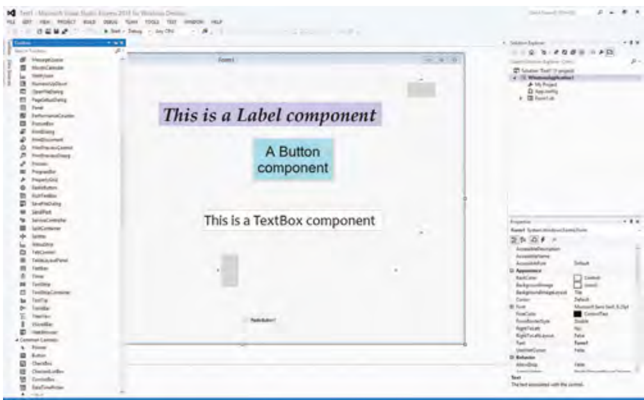


Fig.3. Once into the program, it appears to be much the same as the previous version. The usual range of components is available from the Toolbox, including the all-important SerialPort type

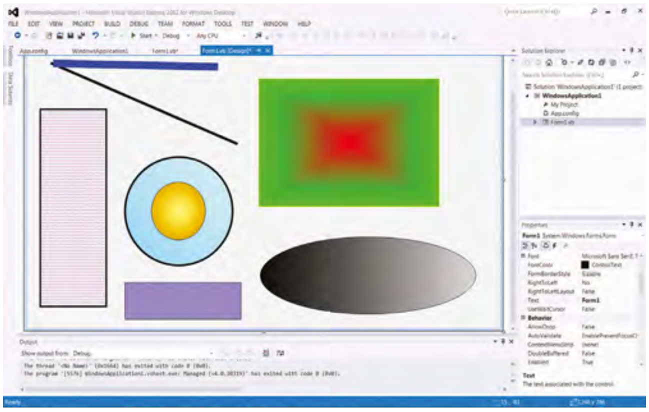


Fig.4. The Visual BASIC Power Packs are now included as part of a standard installation. These provide an easy way of adding lines, rectangles and ovals (ellipses) to a program

Ingenuity Unlimited

Our regular round-up of readers' own circuits

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Watch the birdie! – Electronically

SOME time ago, I built a system to enable me and my wife to watch activity inside a garden nest box. A small colour CCTV camera module (Genie GC400) was placed inside a die cast box (Fig.1 and Fig.2), which was in turn, mounted inside the nest box.

The nest box was mounted on the outside of the garden shed, as shown in Fig.3. You can see in Fig 4 that the garden shed is some distance (about 15m) from the house, so it was not practical to run cables to the shed, which meant that battery power and radio-based communication with the camera became important design considerations.

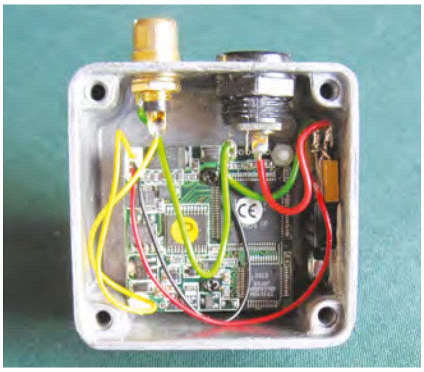


Fig.1. The diecast box open showing the CCTV circuit and wiring

Fig.2. The diecast box sealed ready to be put in position

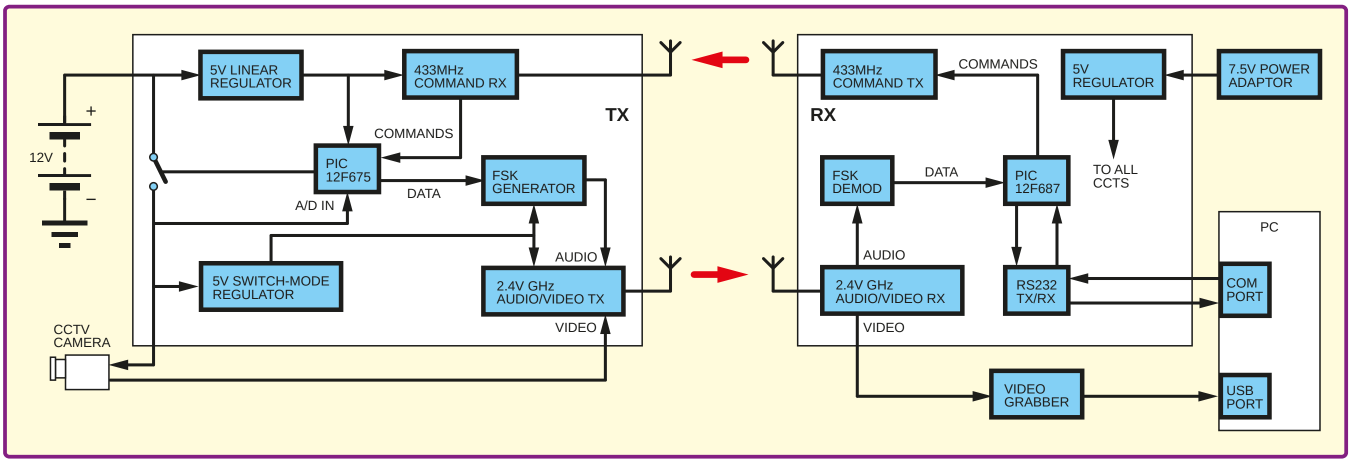


Fig.5. Circuit diagram

Fig.3 (left).The nest box in position, on the garden shed

Fig.4 (below).The shed is some distance from the house, which is why a radio-based system was used

Brief description of system

There are two parts to the system, the video transmitter (marked 'TX') and, the video receiver ('RX').

The system shown in Fig.5 was used to enable the camera video output to be viewed and the camera to be controlled remotely.

The camera's datasheet specifies that the power supply must be 12V ±10% (10.8V to 13.2V). The system needed to be battery powered, so a low-dropout voltage regulator was included in the system. This regulator used was an LM2937, which can handle a maximum input voltage of 26V and has reverse polarity protection, so it can protect the camera module against power supply mishaps. However, to ensure stability, it requires a low-ESR (less than 3Ω) capacitor at the output of at least 10µF. These can be rather expensive (for a capacitor) but I decided it was worth spending £6 or so for a good regulator and capacitor to protect a £45 camera module. The video transmitter circuit mounted in a diecast box is shown in Fig.6.

TX, the video transmitter

This is battery powered, and to keep the consumption as low as possible when the camera is switched off, a low-power 5V regulator only feeds a 433MHz 'command receiver' and a PIC12F675, see Fig.8.

When the 433MHz receiver (IC4) gets a data byte, it passes it to the PIC, which decodes it and checks it for errors. If it is a command to turn the camera on, the PIC closes a switch (the PVN012), which connects the battery to a switch-mode power regulator, which in turn, supplies 5V to the 2.4GHz audio/video transmitter module (IC2) and to a phase-locked loop (PLL) (IC6).

The switched 12V supply is also taken via a potential divider to an A/D input of the PIC to measure the battery voltage; and, if this falls below 10.5V, the 12V switch is opened to prevent deep discharge of the battery.

If the push button (SW2) is pressed and held while the TX is switched on (by operating SW1), the PIC will turn everything on so that the camera and video link can be tested without using a remote command.

To send data (at present only battery voltage) and command responses back to the RX, the PIC feeds a logic-level signal to the PLL, where it is used to control the frequency generated by the PLL's VCO (voltage controlled oscillator) to generate a frequency-shift signal. This was done so that the (otherwise unused) audio channel of the A/V module could be used to transmit the information.

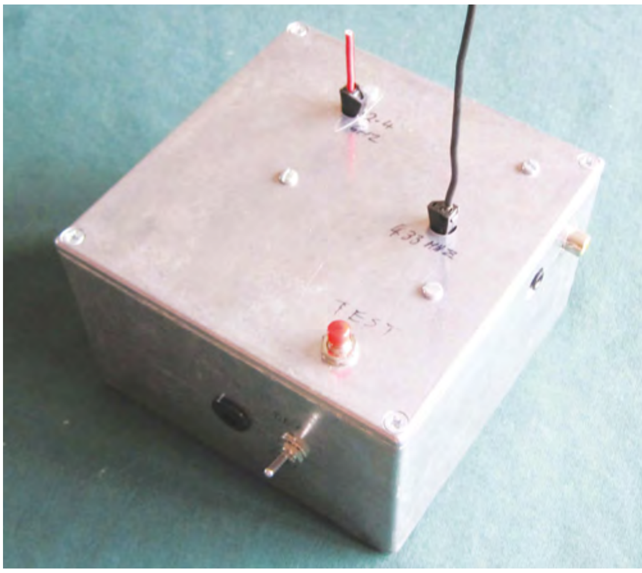
Fig.6 shows that the TX PCB is mounted in the lid of a die cast box. This gives ease of access to the PCB, and as shown in Fig.7, allows the antennae to be plugged in through the top of the box.

Fig.6. The battery-powered transmitter

RX, the video receiver

This is powered from a mains adapter. To allow control of the camera or request data by a PC, IC6 (Fig.9.) provides an RS232-to-5V-logic-level conversion. The resulting signals are

Fig.7 (below). External view of the transmitter



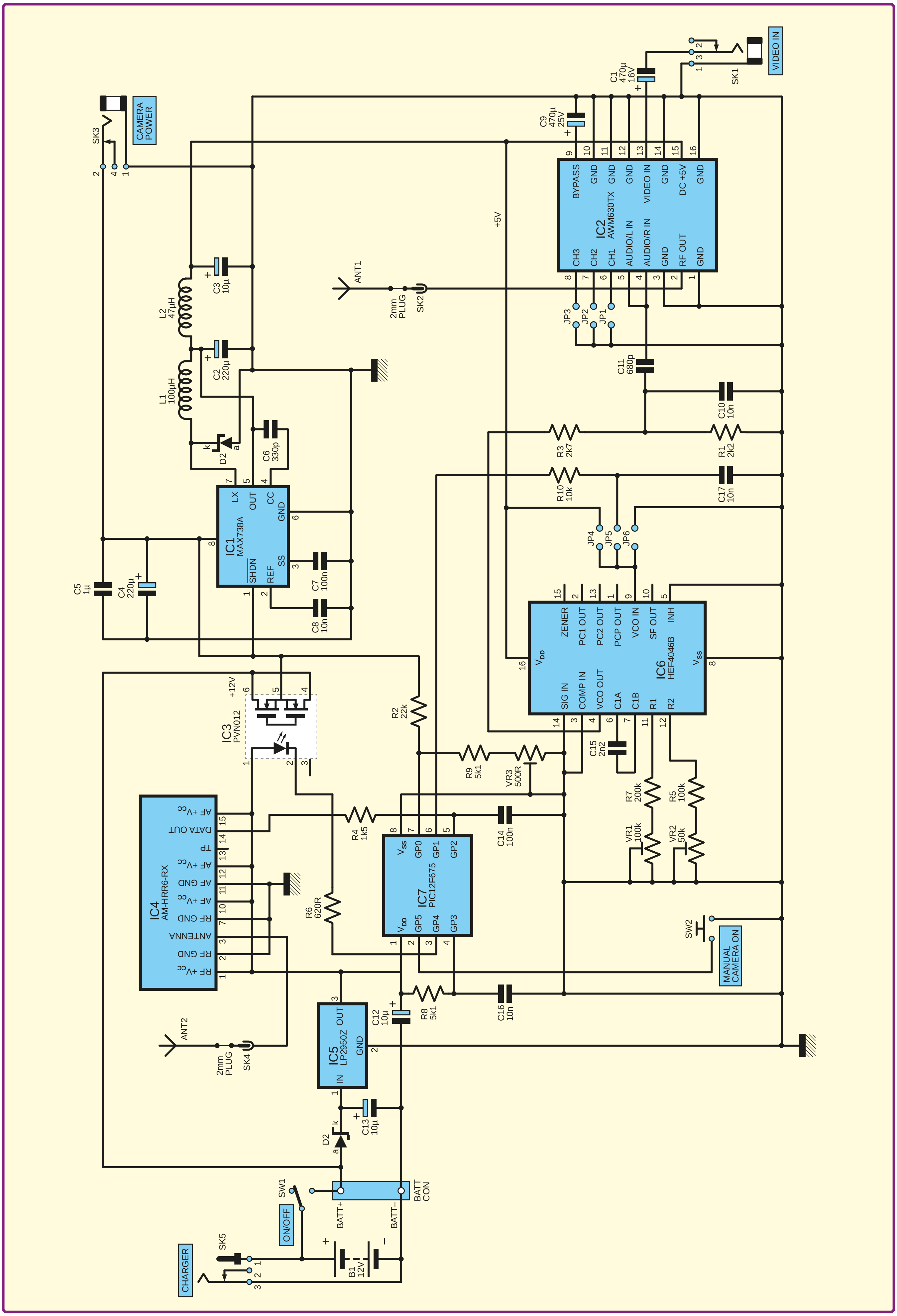


Fig.8. The video transmitter circuit

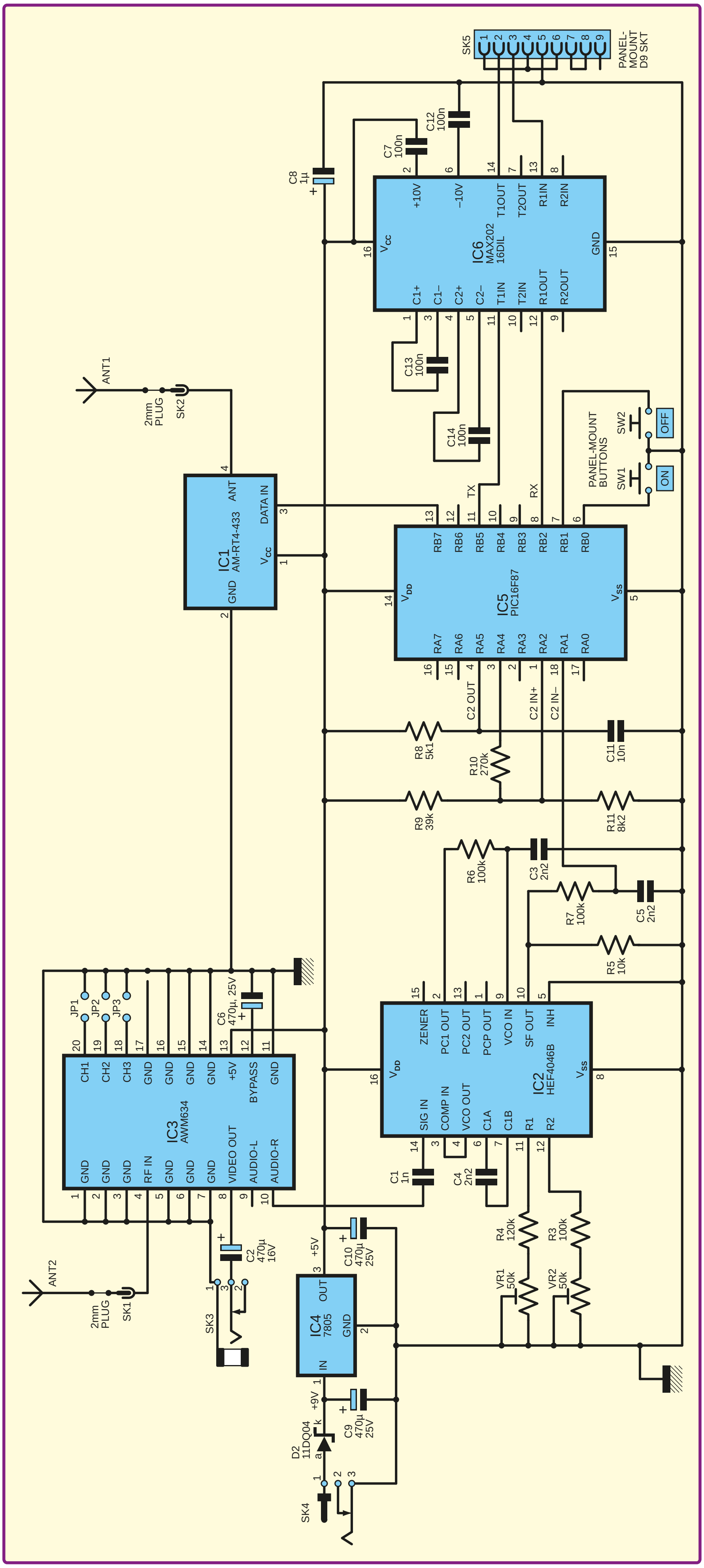


Fig.9. The video receiver circuit

fed to the UART interface of the PIC, which feeds the command bytes to the 433MHz transmitter (IC1). There are also two buttons fed to PIC input lines to provide manual camera on/off control.

The video signal from the TX and the command responses are received by the 2.4GHz A/V module (IC3), which is designed for use with the 2.4GHz TX module.

The audio output from IC3 is fed to a PLL (of the exact same type as the one on the TX system), where it is demodulated, filtered (to remove some ripple) and fed to an input of the PIC, which has been configured as an analogue comparator, with some positive feedback to give a little hysteresis. The resulting data can be the battery voltage or a response to a data request or a command (to confirm that the TX system has received and understood the command).

The block diagram (Fig.5.) shows the system linked to a PC – which can issue commands and receive data – so that pictures can be recorded. However, the composite video can also be taken to a TV monitor and the on/off buttons used for control so that a PC need not be used. The same PCB mounting scheme used for the TX was also used for the receiver.

The camera on/off control works fairly reliably, but the data communications link, which uses a very simple serial data system, appears to suffer from interference, and is not as good as it could be. There is also interference on the 2.4GHz band (which causes patterning on the video signal), so in the near future I intend to redo the system using a better communication system operating with 5.8GHz audio/video modules, which are becoming available at reasonable cost.

I don't claim copyright for the hardware design or the firmware used in the PICs, so readers who do not want to build the whole system are welcome to use any of the ideas in their own projects. The software for the PC was written in C# using 'MS Visual Studio Express'. The software used in this project, and a video can be downloaded from the *EPE* website (**www.epemag.com**)

Alan Pugh, via email

Screen grab of Blue Tits feeding in the nesting box

READOUT

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

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All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

✩ LETTER OF THE MONTH ✩

SMD soldering

Dear editor
I thought that the *Digital Spirit Level* (March 2013) design from Andrew Levido was excellent and I was tempted to build one since the hardware looked to be fairly simple. Using the *EPE* PCB produced an insurmountable problem with mounting the 3mm square sensor. I am quite able to solder SMDs (surface-mount devices), given a good PCB with a solder-resist layer and an appropriate soldering iron. However, with the specified chip, I found it impossible to mount without more sophisticated equipment.

Fortunately, all was not lost. I have obtained a mounted device of the same generic type, the MMA8452. This has a 12-bit ADC instead of the 14-bit device in the 8451; also it doesn't have a FIFO, but this isn't used in the design so that is not a significant issue. I have constructed the design substituting this device and have found it works fine. The chip comes on a small PCB so it can be mounted separately from the main board. There is obviously some loss of resolution with this device, but I believe it is still adequate to maintain the 0.1-degree resolution of the display.

The substitute MMA 8452 I used is sold as a Sparkfun SEN-1095, available from SK Pang and various sources on eBay.

Ken Naylor, by email

Matt Pulzer replies:

I'm sorry to hear the SMD presented problems, but relieved to hear you found a workaround – thank you for taking the time to pass on your solution.

Remembering *EE*

Dear editor
I grew up in Hull, NE Yorkshire and started to buy *Everyday Electronics* in 1977 when I was 12. The recent talk of mains switching issues reminded of Alan Winstanley's *Mains Delay Switch* project in *Everyday Electronics* (April 1978). It had a weird unijunction transistor and I just couldn't get it to work. I remember my mother spending a lot of money on me to get the parts.

Despite my frustration with the unijunction device, a year later I passed the radio amateurs exam and started to become more interested in electronics. Moving on a few years I became an avionics technician at British Aerospace, Brough, where I worked in a lab and built aerospace simulators.

I have worked as an engineer, a technician, and now as an industrial electrician around the world, so it has not been a bad career.

I am now programming Ardunio microcomputers to start my own business, although I still work full time at Campbell's Soup in Texas. I recently graduated from Texas A&M university with a bachelors degree (I already had an HNC from Hull, 1986) and now I am in an MBA program and have applied to a PhD program next autumn.

I liked *Everyday Electronics*, its sister magazine *Practical Electronics* seemed to run its projects over too many issues and, at the time, I had very little money. Back then, most of my parts came from a surplus shop in Hull or Watford Electronics by mail.

Darren Cunningham, by email

Alan Winstanley replies:

It's great to hear your feedback and I'm really pleased that EE magazine is remembered with affection.

I suspect the problem was the 2N2646 unijunction transistor, a flakey device that formed a simple oscillator – I'm glad it didn't put you off electronics!

I wish you every success in your endeavours over in Texas and would like to thank you for dropping me a line. Our forum at **www.chatzones.co.uk** *is one way of keeping in touch or exchanging views.*

EPE online updates

Dear editor
I've been a subscriber for several years and had no difficulty in getting downloads from the site. I've started to make the *Interplanetary Voice* project and the *Digital Spirit Level*. I can't find either the 'front panel' for the *Interplanetary Voice* project, or the files for the *Digital Spirit Level*. This month's issue doesn't appear on the website. Where are the files?

Also, can we have the site updated with back issues. It appears to have been dormant for some time.
Very disappointing.

Ray Drury, via email

Alan Winstanley replies:

Thank you for your comments and I am sorry to learn of your disappointment with the website. The update schedule rotates around the date the hard copy is published, but this will vary slightly depending on pressure of work; also, assembling files from multiple sources is a complex task.

You will be pleased to learn that back issues from 2012, 2011 and 2010 have now been uploaded. The rest will follow as a matter of course. Thank you for your continued interest.

Code for old projects

Dear editor
I am looking for the source code for your (May 2000) *Multichannel Transmission System*. If possible, I would like to purchase a set of the programmed PICs.

Peter Lock, via email

Alan Winstanley replies:

This is a very old PIC-based project and the legacy source code is therefore hosted on the separate website EPEMag.Net: **www.epemag.net/microcontroller-code.htm**

Unfortunately, we cannot supply pre-programmed MCUs, and you should check that all parts are readily available before commencing construction of old projects. Further help from PIC users may be available in our forum: **www.chatzones.co.uk**.

Soldering iron questions

Dear editor
I bought a soldering station for electronics as a means of rehabilitation following an injury. I searched and searched for useful information and then I found your (Alan Winstanley's)

soldering guide. I thought I would take a chance and write, hoping that you may be able to answer a couple of questions for me.

What I want to know is what the numbers and letters mean when shopping for a tip – eg, 900M-T-2C. I have just bought a Toolcraft ST80-D 80W digital soldering station from a company named Conrad Electrical Ltd, but I've had so much trouble with them (it took 11 emails to get help) that I really can't deal with them any more. I also don't know what tips are suitable or safe for my 80W iron.

Graham Beland, via email

Alan Winstanley replies

*I was sorry to learn of the problems you are experiencing with obtaining data for your soldering station. I believe the Toolcraft iron is an own-brand model marketed by Conrad in Germany (***www.conrad-uk.com***). I looked at the Conrad website, and the part codes have no real meaning, so I wouldn't attach any significance to the numbering sequence.*

A number of soldering iron tips are marketed for this soldering station, and their website gives details and drawings under the 'Accessories' tab of the product's web page. They are available in both chisel and bevelled shapes of various diameters, and my advice is to settle on the one that suits you best. A chisel has a wedge-shaped 'screwdriver style' end, while a bevelled one is chopped at an angle to produce an elliptical working face instead. I don't enjoy using a pointed tip because they lack a decent working surface.

For general hobby electronics use you usually don't need to change tips all the time, but I find it handy to have a small, medium (general use) and large tip to cover most eventualities. You will have plenty of spare capacity in your 80W station to handle larger solder joints. As I explain in my online Basic Soldering Guide *(***www.epemag.wimborne.co.uk/solderfaq.htm***), the higher rating doesn't mean that the iron gets hotter than, say a 25W one, but it simply has more power in reserve to make it more 'unstoppable' when soldering larger work pieces that would otherwise cool down the tip too much (because larger volumes of metal tend to suck all the heat out of the tip).*

The accessories listed by Conrad for this iron are as follows, and they are all said to be suited for this 80W iron.

Chisel / Conrad Part No.
0.8mm 588189-89
1.2mm 588203-89
2.4mm 588216-89
3.2mm 588228-89

Pencil-point (supplied with iron)
0.2mm 588240-89

Bevelled (slanted tip)
1.0mm 588252-89
2.0mm 588264-89

I hope the above is of use in helping you choose a suitable tip for your new iron, and wish you best of luck with your soldering and rehabilitation

IF YOU HAVE A SUBJECT YOU WISH TO DISCUSS IN READOUT PLEASE EMAIL US AT:

editorial@wimborne.co.uk

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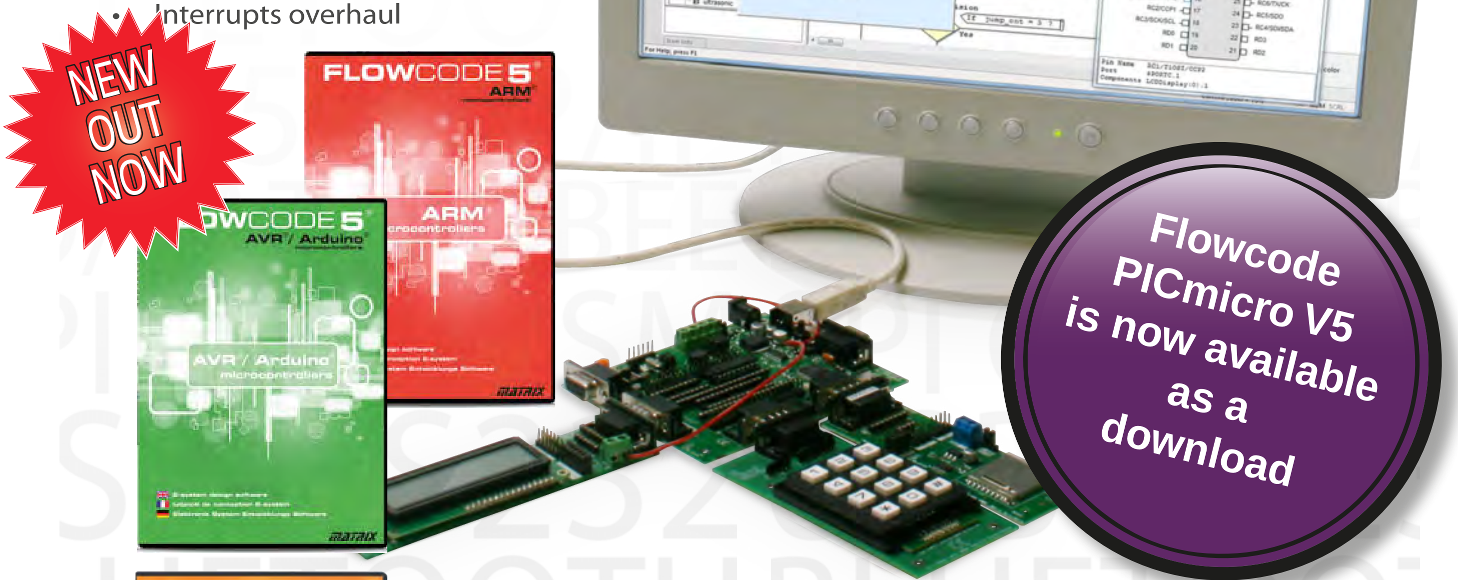

The FlowKit can be connected to hardware systems to provide a real time debug facility where it is possible to step through the Flowcode program on the PC and step through the program in the hardware at the same time. The FlowKit can be connected to your own hardware to provide In-Circuit Debug to your finished designs.

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Please note: Due to popular demand, Flowcode PICmicro, AVR, DSPIC, PIC24 & ARM V5 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.

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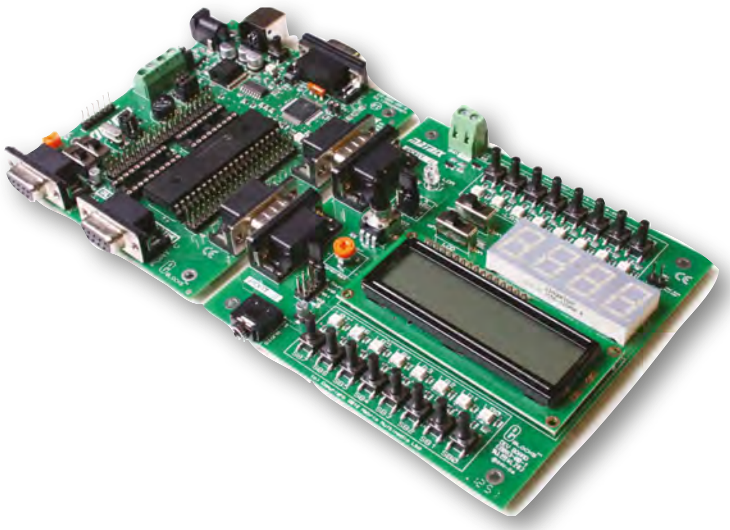
- Fully protected expansion bus for project work
- USB programmable
- Compatible with the E-blocks range of accessories



£161 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

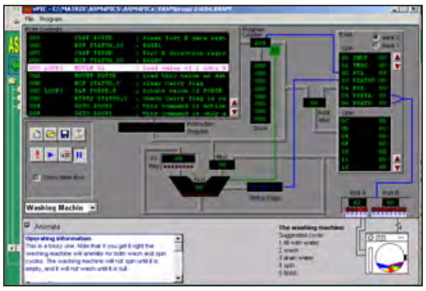
ASSEMBLY FOR PICmicro V4

(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.

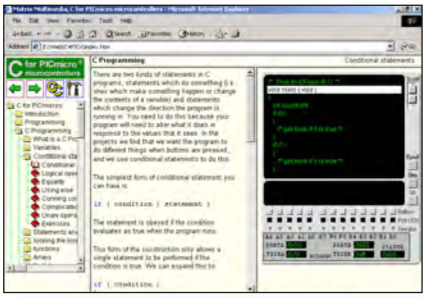


'C' FOR 16 Series PICmicro Version 4

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 V5 (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
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- 16-bit arithmetic strings and string manipulation
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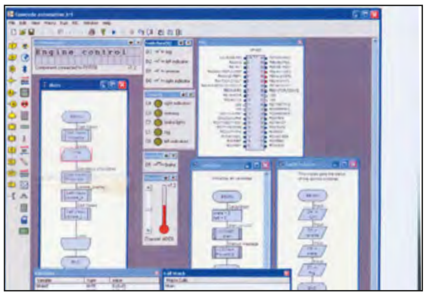
- I2C.

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)



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Flowcode 10 user (Network Licence)	**£599**	**plus VAT**
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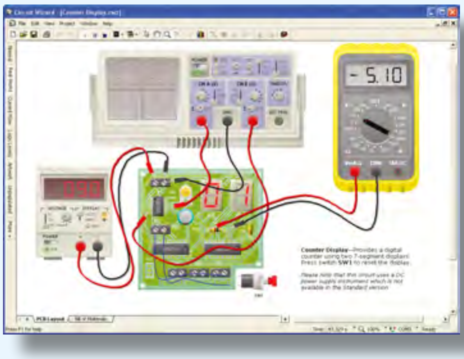

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

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

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.

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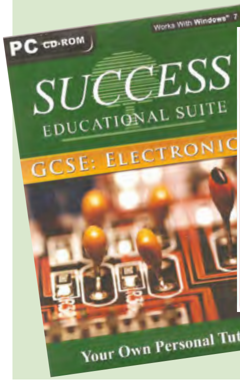

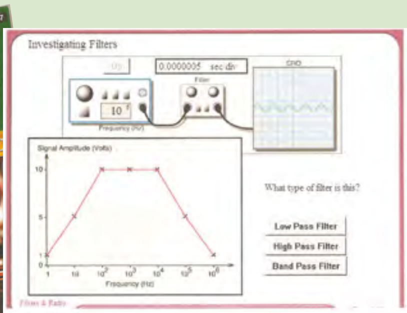

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Max's Cool Beans

By Max The Magnificent

In my previous column, I talked about the fact that I'm going to be presenting a paper at an embedded systems conference. The topic of this paper is how radiation (both ionising and non-ionising) can affect electronic components and systems. As part of this talk, I've created a 'stage prop' that looks a bit like a Steampunk suitcase equipped with antique-looking lights and switches and so forth. This really is rather tasty. It's sitting on my desk in front of me as we speak.

Mock electronics

The point is that I required some rather eclectic components – the sort of things that are hard to find in a modern electronics parts store. What I wanted was the sort of store we had in my youth, jam-packed with boxes and shelves containing all sorts of esoteric delights from yesteryear. Amazingly enough, after moaning and groaning about the lack of such a store for the past 23 years since I moved from England to Huntsville, Alabama, USA, it turns out that there is just such a store here in town. Called Mock Electronics (**www.mockeletronics.samsbiz.com**), this emporium is located (hidden might be a better word) in the farthermost back corner of a run-down strip mall in downtown Huntsville. The outside of the store has a strange chameleon-type ability to fade into the background. It's almost as if it were equipped with a Doctor Who-style perception filter, because – even though I now know where it is – it's easy to drive by without it registering on the conscious mind. But I digress...

Mock Electronics is deceptive on so many levels. From the battered and faded appearance of the outside of the store you really don't expect to find much of interest inside. Also, for some reason, the front facade leads you to believe that the interior of the store will be somewhat on the small side. Well, appearances can be deceiving, as they say, because when you open the front door you are presented with aisles and shelves that fade away Matrix-like into the distance, laden with all manner of tempting treats.

And that's just the half of it, because when you eventually make your weary way to the massive L-shaped service counter at the far end of the store, you realise that there's a magical world of mystery behind the counter in the form of narrow, dimly-lit walkways between numerous shelves, jam-packed with myriad little drawers and boxes containing a veritably treasure trove of antique and modern components.

Goodness only knows what delights are hidden back there. I do know that when I showed them my Steampunk suitcase featuring the three antique faceted light covers, the lady who owns the store disappeared into the gloom, ferreted around for a while, and reappeared triumphantly brandishing the compatible base sockets. These would have made my life so much easier had I known that such a thing existed, but unfortunately I'd already glued my light covers into the case (bummer).

Vacuum tubes

As an aside, if you are ever constructing electronic-looking artifacts whose sole purpose is to look 'cool,' then lighting old vacuum tubes (valves) from underneath using tri-colored LEDs whose color values you dynamically vary using a microcontroller can look outstanding. Sad to relate, old tubes can be hard to find these days. Fortunately for me, the folks at Mock Electronics don't throw anything away, and they sold me a huge bag of failed vacuum tubes for just a few dollars.

Now, I don't know about you, but I LOVE old electronics things like vacuum tubes. The reason I mention this is that, while rooting around in the nether regions of the store, I discovered the most amazing vacuum tube, spring-mounted in a metal transportation rack. I don't know what this tube was originally intended for, but I'm guessing something like a very high-power amplifier. Just to provide you with a sense of scale, I stood a 12inch wooden ruler against the front-left part of the transportation rack, as shown in the photo.

The four-way spring assemblies holding the bottom and top of the tube to the metal frame allowed it to be transported without being jerked or vibrated to pieces. I simply couldn't help myself. I had to have this for my collection, and it now has pride of place in my office.

Jetson TV

But wait, there's more… do you remember the American animated television sitcom called *The Jetsons* that was first produced in the early 1960s? Well, hidden away in an 'odds and sods' corner of the store, my eyes fell on a little portable television set which I am guessing is circa the mid-1970s. This little retro beauty looks just like something you might have seen on *The Jetsons*.

The amazing thing is that this little rascal still works. Of course the VHF signals it requires are no longer transmitted, but (with the help of my friends) I've come up with a workaround. It starts with a little Wi-Fi TV box that allows me to stream programs from the Internet and/or from a USB memory stick. I take the composite video output from this box and feed it into an old games controller, and then take the VHF output from the games controller and feed it into my 'Jetson's TV.' It works like a charm and it looks über- cool sitting on a shelf in my office presenting old science programs from the 1960s.

NET WORK

by Alan Winstanley

Retiring a TV and Dave

IN recent months, I described the use of Wi-Fi 'range extenders', devices that are marketed as simple plug and play solutions for wireless deadspots around the home – but are they 'simple'? Regular readers will recall my early efforts were thwarted before I opted for a Billion 3100SN Wireless Access Point (AP). This Wireless-N wall-plug Ethernet AP (access point) is somewhat brittle (see *Net Work*, December 2012), but apart from one PC that stubbornly refuses to connect to the AP, there have been no further network problems.

After the digital TV switchover in the UK, I covered some popular personal video recorders (PVRs) which have Ethernet connectivity that enables TV channels and 'On-demand TV' to be received via broadband. Homeplug-type adaptors can provide Ethernet via the ring mains (provided everything is on the same phase), or use 802.11n wireless networking, or as a last resort use a direct cable connection to the router. Some devices, such as the Pure Avalon PVR mentioned last month, have Wi-Fi built in. Other models are very fussy about the choice of wireless adaptor and a dedicated Wi-Fi dongle can be an expensive hidden cost.

An ongoing issue is the fact that some PVRs only offer limited extras, perhaps YouTube and BBC iPlayer at most. Users are tantalised by promises of updates and improvements that have yet to appear. The new YouView broadband TV service (see *Net Work*, April 2013) offers on-demand TV using a YouView decoder which leaves owners of current generation PVRs feeling even more short-changed. With this in mind, I decided to look at other ways of accessing these services and my attention turned to the TV set itself – a 10-year old boulder of a Sony Trinitron with analogue tuner that had become increasingly annoying to use.

Smart TV for ever

The Internet has reshaped our shopping experiences for ever, making it easier to review products, compare prices and drive the best deal. When it comes to buying a new TV, I would prefer to use a bricks and mortar outlet and it is interesting to see how retailers are adopting the Internet, with websites such as catalogue-based Argos (**www.argos.co.uk**) offering a likely-looking TV online at a best price, with free delivery. I added one to my shopping cart only to find that delivery was being charged extra. Checking the local store prices by phone, there was also a £20 price hike that made Amazon cheaper with free delivery too. Online orders aren't confirmed until goods are despatched: that gives the store breathing space to cancel any pricing errors. Read the terms carefully: Argos famously listed a £300 TV for £2.99 online, and more legal details are on: **www.out-law.com/page-6079**.

There comes a point where you can lose faith in a website, but before ordering from Amazon instead, I visited my local Argos store. Happily the price matched the website's and of course I could take one away in the car.

I had settled for a Samsung Smart TV sporting a misnomer of an 'LED screen', which has an Ethernet port next to its aerial socket. The next question was how to connect it to my broadband. As a Samsung Wi-Fi dongle (not included) adds a hefty 10% to the retail price, I connected the TV to the ethernet port of the Billion 3100 Wireless Access Point nearby, sat back and waited.

The Samsung Smart TV found my network straight away and proceeded to update itself rapidly, adding a range of apps in a completely troublefree and seamless setup that was a joy to behold. On-demand TV, Netflix and many other apps were soon accessible and the superb Samsung Smart TV is proving a delight to use, with iPlayer and YouTube loading very rapidly. A spare USB keyboard works with it as well.

Anyone for tennis? A young Dave B discovers early Smart TV in June 1977's *Practical Electronics* – well, playing the *PE TV Sportcentre* anyway! A secretary helped with the photoshoot

Three cheers for Dave!

I'd like to close with a personal tribute to *EPE*'s retiring assistant editor, David Barrington. It was Dave who coined the '*Net Work*' title for this Internet column back in August 1996, but over the years Dave has also honed into shape many of my constructional articles and former columns such as *Ingenuity Unlimited*, *Build Your Own Projects*, *Circuit Surgery* and *Teach-In*, ensuring they 'scanned' properly when read and often making me look better in print than I maybe deserved. Being a magazine for hobbyists does not detract from the need to be professional, and Dave's expertise surely ranks among the very best in the business, having evolved in the British hobby publishing scene and playing a substantial role in giving *Everyday Practical Electronics* a quality edge over the decades.

Dave's editing and production skills, relentless cross-checking and unswerving attention to every detail ensured that *EPE* readers enjoyed a consistently high standard of presentation from cover to cover. It has been a great privilege and pleasure working with Dave and his incisive red pen and witty side-headings in *Net Work* will be greatly missed. Dave enters his well-earned retirement with flying colours, and on behalf of all appreciative readers and myself, I wish David a very peaceful and relaxing life in the years ahead.

I hope you enjoyed this month's *Net Work*. Readers can email me at: **alan@epemag.demon.co.uk** or write to the Editor at: **editorial@wimborne.co.uk** for possible submission in *Readout*, which could win you a valuable prize!

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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.

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MAY '12

PROJECTS • Compact High-Performance 12V Stereo Amplifier • High-Quality Digital Audio Signal Generator – Part 3 • Low-Power Car/Bike USB Charger • Solar-Powered Lighting Controller – Part 1

FEATURES • Techno Talk • Jump Start – Moisture Detector • Circuit Surgery • Practically Speaking • PIC N' Mix • Net Work.

JUNE '12

PROJECTS • Digital Insulation Meter • Dual Tracking ± 0V To 19V Power Supply – Part 1 • Low-Power Car/Bike USB Charger • Solar-Powered Lighting Controller – Part 2

FEATURES • Jump Start – Quiz Machine • Techno Talk • Pico 2205 MSO PC oscilloscope • PIC N' Mix • Circuit Surgery • Interface • Net Work.

JULY '12

PROJECTS • Lab-Standard 16-Bit Digital Potentiometer • Intelligent 12V Fan Controller • Dual Tracking ±0V To 19V Power Supply – Part 2

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AUG '12

PROJECTS • Ultrasonic Cleaner • Electrolytic Capacitor Reformer and Tester – Part 1 • High-Performance Microphone Preamplifier • High-Power Reversible DC Motor Speed Controller

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SEPT '12

PROJECTS • Designing And Installing A Hearing Loop For The Deaf • Hearing Loop Receiver • Ultrasonic Anti-Fouling For Boats – Part 1 • Electrolytic Capacitor Reformer and Tester – Part 2

FEATURES • Jump Start – Versatile Theft Alarm • Raspberry Pi – Real-Time Clock • PIC N' Mix • Circuit Surgery • Practically Speaking • Net Work.

OCT '12

PROJECTS • Two TOSLINK-S/PDIF Audio Converters • Digital Lighting Controller – Part 1 • Ultrasonic Anti-Fouling For Boats – Part 2 • Designing And Installing A Hearing Loop For The Deaf – Part 2 • Ingenuity Unlimited

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PROJECTS • Hearing Loop Level Meter – Part 1 • Digital Lighting Controller – Part 2 • RFID Security System • Easy USB *plus* Telescope Driver Control • Ingenuity Unlimited

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DEC '12

PROJECTS • Universal USB Data Logger – Part 1 • Hot-Wire Cutter • Digital Lighting Controller – Part 3 • Hearing Loop Level Meter – Part 2 • Ingenuity Unlimited

FEATURES • Jump Start – Mini Christmas Lights • Techno Talk • PIC N' Mix • Circuit Surgery • Interface • Max's Cool Beans • Net Work

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

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APR '13

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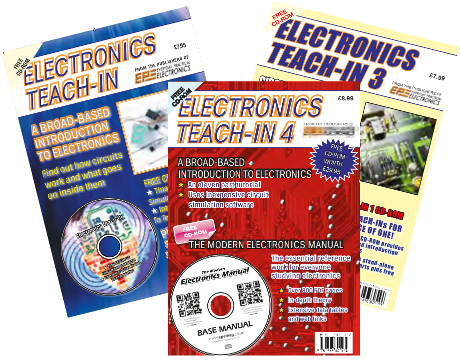

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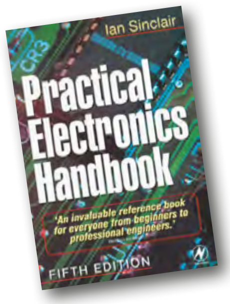

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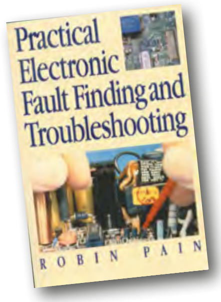

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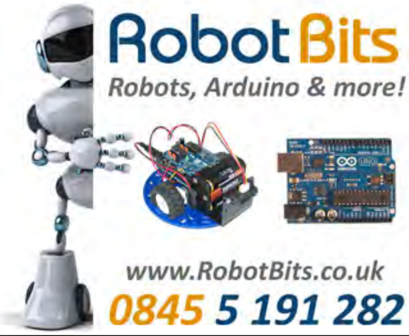

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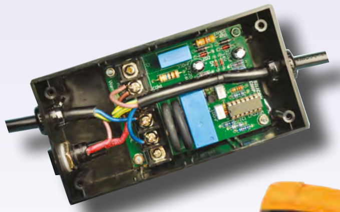
Next Month

Content may be subject to change



Soft Starter for Power Tools

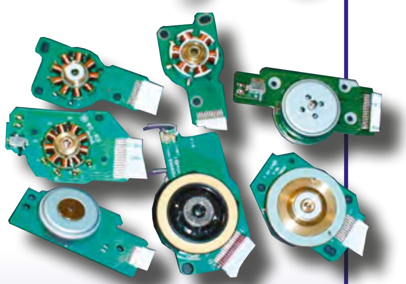
Does your electric saw, router or other large mains-powered hand tool kick like the proverbial mule when you squeeze the trigger? No matter how firmly you hold the grip, it will still jump, and that can be enough to throw you off a carefully lined up cut. Now you can stop that kick with our *Soft Starter for Power Tools*.

6-Decade Capacitance Substitution Box

When breadboarding or prototyping, sometimes you need to experiment with a capacitor value. Substituting a range of different capacitors can be a bit tedious. What you need is a capacitance decade box, which makes it easy to find the right value for your circuit. What's more, it's the perfect partner for April's *6-Decade Resistance Substitution Box*.

High-power brushless motors

Stand by for one of our best-ever recycling projects! Did you know that you can convert the flea-power motors from old CD or DVD-ROM drives to high-power operation – eg, for model aircraft or other demanding uses? While it may seem improbable, it is relatively easy to do, the main change being to fit neodymium 'rare earth' magnets. The result is a high-torque, low-cost, compact motor.



Jump Start – Temperature Alarm

Sadly, all good things must come to an end, and next month's *Temperature Alarm* will be the final project in Mike and Richard Tooley's series, Jump Start. Like the 13 previous circuits, it will be fun and easy to build, aimed at all levels of experience, but is especially dedicated to newcomers, or those following courses taught in schools and colleges.

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