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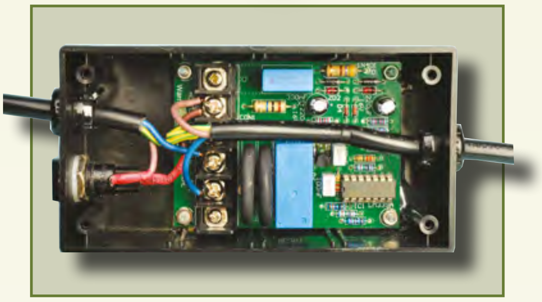

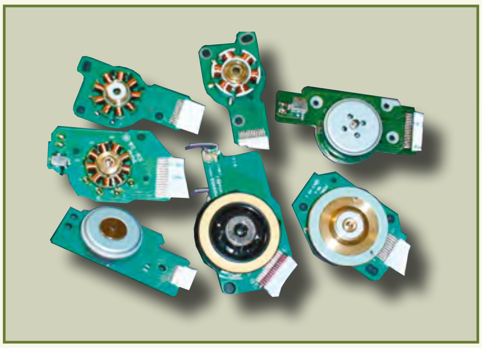

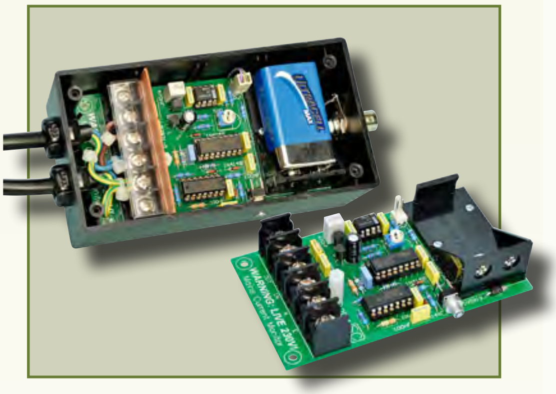

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Our August 2013 issue will be published on Thursday 4 July 2013, see page 72 for details.

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USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£64.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

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USB PIC programmer for a wide range of Flash devices—see website for details. Free Windows Software. ZIF Socket and USB lead not included. Powered via USB port - no external power supply required.
Assembled with ZIF socket Order Code: AS3150ZIF - **£64.95**

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
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Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
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PIC Programmer Board

Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£34.95**

PIC Programmer & Experimenter Board

The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£34.95**
Assembled Order Code: VM111 - **£44.95**

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Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU446 £8.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055NKT - **£29.95**
Assembled Order Code: VM110N - **£43.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two *& Ten Channel versions also available.*
Kit Order Code: 3180KT - **£54.95**
Assembled Order Code: AS3180 - **£64.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£19.95**
Assembled Order Code: AS3145 - **£26.95**
Additional DS1820 Sensors - **£4.95 each**

Remote Control Via GSM Mobile Phone

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£11.95**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£79.95**
Assembled Order Code: AS3140 - **£94.95**

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - **£74.95**
Assembled Order Code: AS3108 - **£89.95**

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£64.95**
Assembled Order Code: AS3142 - **£74.95**

Audio DTMF Decoder and Display

Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU303). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£37.95**
Assembled Order Code: AS3153 - **£49.95**

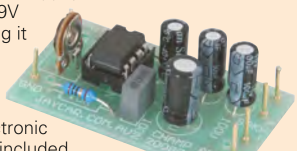
3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone option and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 8191KT - **£29.95**
Assembled Order Code: AS8191 - **£39.95**

Audio Kits for Electronic Enthusiasts

Amplifier Kits

"The Champ" Audio Amplifier Kit
This tiny module uses the LM386 audio IC, and will deliver 0.5W into 8 ohms from a 9V supply making it ideal for all those basic audio projects. It features variable gain, will happily run from 4-12VDC and is smaller than a 9V battery, allowing it to fit into the tightest of spaces.



- PCB and electronic components included
- PCB: 46 x 26 mm

Cat. KC-5152

£3.00*

50W Amplifier Module
Uses a single chip module and provides 50WRMS @ 8 ohms with very low distortion. PC Board and electronic components supplied. Requires heatsink and (+/-) 35V power supply. See website for full specs.

- Kit is supplied in short form version
- PC Board and electronic components supplied.
- PCB: 84 x 58mm

Cat. KC-5150

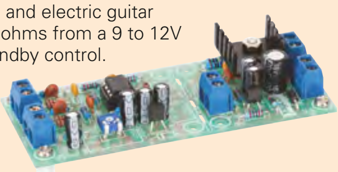
£11.00*

"The Champion" Audio Amplifier Kit with Pre-Amplifier
Suitable for general-purpose audio projects and supports microphone and electric guitar input. It uses the AN7511 audio IC to deliver 2W music power into 8 ohms from a 9 to 12V supply. Features low distortion, two inputs (mixed 1:1), mute and standby control. Power from 4 - 13.5VDC. See website for specifications. Kit supplied with silk-screened PCB, heatsink and PCB mount components.

- PCB: 101 x 41mm

Cat. KC-5519

£7.25*



High Power Class-D Audio Amplifier Kit
High quality amplifier boasting 250WRMS output into 4 ohms, 150W into 8 ohms and can be bridged with a second kit for 450W into 8 ohms. Features include high efficiency (90% @ 4 ohm), low distortion and noise (<0.01%), and over-current, over-temperature, under-voltage, over-voltage and DC offset protection. Kit supplied with double sided, soldermasked and screen-printed silk-screened PCB with SMD IC pre-soldered, heatsink, and electronic circuit board mounted components.

- Power requirements: -57V/0/+57V use KC-5517
- S/N ratio: 103dB
- Freq. response: 10Hz - 10kHz, +/- 1dB
- PCB: 117 x 167mm

Cat. KC-5514

£32.75*

KC-5515

Also available:

Stereo Speaker Protector Kit to suit	**KC-5515 £11.00**
+/- 57V Power Supply Kit to suit	**KC-5517 £11.00**

KC-5517

IR Remote Extender MKII Kit
Operate your DVD player or digital decoder using its remote control from another room. It picks up the signal from the remote control and sends it via a 2-wire cable to an infrared LED located close to the device. Kit supplied with case, screen printed front panel, PCB with overlay and all electronic components.

- Requires 9VDC and 2-wire cable for extending the IR-Tx lead (use WB-1702).
- PCB: 79 x 47mm

Cat. KC-5432

£10.00*

Digital Audio Delay Kit
Corrects sound and picture synchronization ("lip sync") between your modern TV and home theatre system. Features an adjustable delay from 20 to 1500ms in 10ms steps, and handles Dolby Digital AC3, DTS and linear PCM audio with sampling rate of up to 48kHz. Connections include digital S/PDIF and optical Toslink connections, and digital processing means there is no audio degradation. Kit includes PCB with overlay a pre-soldered SMD IC, enclosure with machined panels, and electronic components.

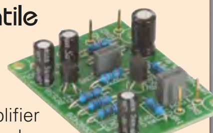
£36.25*

- 9-12VDC power supply required
- Universal IR remote required
- PCB: 103 x 118mm

Cat. KC-5506

Pre-Amplifier Kits

"Pre-Champ" Versatile Preamplifier Kit
This tiny preamp was specifically designed to be used with the 'Champ' amplifier (KC-5152 above). Unless you have a signal of sufficient amplitude the 'Champ' will not produce its maximum power output. The 'Pre-Champ' is the answer with a gain in excess of 40dB, which is more than enough for most applications.

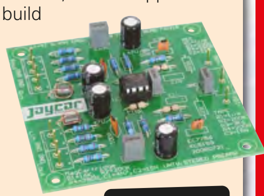


- Power requirement 6-12VDC.
- Kit includes PCB and electroic components
- Can be battery powered.
- PCB: 46 x 36mm

£3.50*

Cat. KC-5166

Universal Stero Preamplifier Kit
Based around the low noise LM833 dual op-amp IC, this preamp is designed for use with a magnetic cartridge, cassette deck or dynamic microphone.The performance of this design is far better than most preamps in many stereo amplifiers, making it a worthy replacement if your current preamp falls short of expectation. It features RIAA/IEC equalisation, and is supplied with all components to build either the phono, tape or microphone version.



- +/- 15VDC
- If power is not available in your equipment use MM-2007 £3.00
- PCB: 80 x 78 mm

Cat. KC-5159

£6.25*

Audio Kits

"minivox" Voice Operated Relay Kit
Voice operated relays are used for 'hands free' radio communications and some PA applications etc. Instead of pushing a button, this device is activated by the sound of a voice. This tiny kit fits in the tightest spaces and has almost no turn-on delay. 12VDC @ 35mA required. Kit is supplied with PCB electret mic, and all specified components.

- PCB: 47 x 44mm

Cat. KC-5172

£6.00*

The "Super Ear" Kit
Assists people who have difficulty hearing high audio frequencies, or use as an interesting education aid in the classroom. By amplifying high audio frequencies, conversations will be made clearer and you will hear sounds not normally heard such as insects or a watch ticking. Kit supplied with case, front label, PCB, 9V battery, and all electronic components. Headphones required.

- PCB: 56 x 26mm

Cat. KA-1809

Note: Not a replacement for a proper hearing aid.

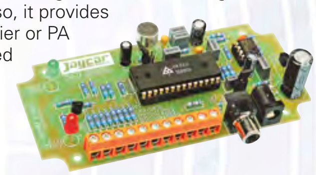
£10.50*

45 Second Voice Recorder Module
This kit has been improved and can now be set up easily to record two, four or eight different messages for random-access playback or a single message for 'tape mode' playback. Also, it provides cleaner and glitch-free line-level audio output suitable for feeding an amplifier or PA system. Powered from any source of 9-14V DC. Supplied with silk screened and solder masked PCB and all electronic components.

- PCB: 120 x 58mm

Cat. KC-5454

£12.75*



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PROJECTS AND CIRCUITS
All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

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We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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EVERYDAY PRACTICAL ELECTRONICS

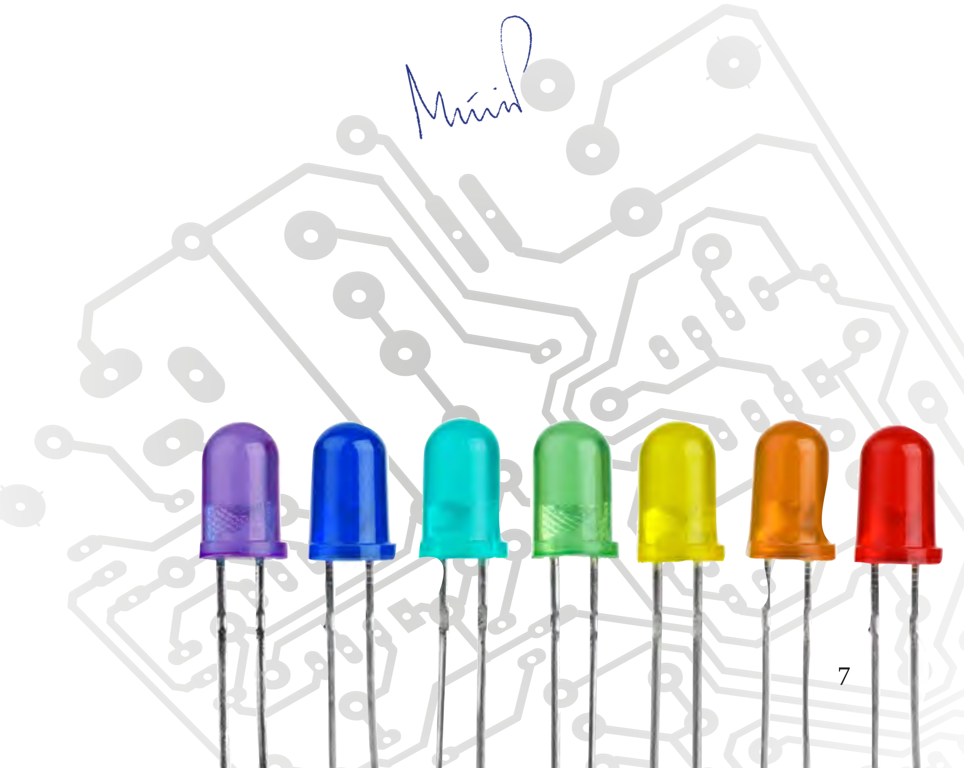
Look after the pennies...

Confession time – I've never really paid much attention to my local pound shops, by which I mean those stores that sell everything for a pound or less. In fact, for the 'every little helps' fans, or those on a really tight budget, there are also 99p shops. However, I recently needed a disposable version of an otherwise pricey item and thought I'd have a look. I didn't find what I was looking for, but I did find a whole host of useful electronic and hobbyist material and gadgets.

Browsing the shelves, there was a surprisingly large selection of tools, and although none of the range was exactly NASA standard, if you need a cheapo hacksaw for a one-off job, 99p is not much of a risk. What really caught my eye though, was the opportunity to buy electronic components at silly prices. There were numerous solar-powered garden lights and other gizmos, most with reasonably sized photovoltaic cells, all just asking to be turned into fun projects. Other cheap-and-cheerful equipment contained LEDs and electric motors, there were 'five packs' of good-quality storage boxes with lids, and a nice choice of corded telephones (think speakers and microphones)… the list goes on. I have no idea how these bargain-basement emporia and their supply chains manage to make and transport their stock, pay import duties, VAT, rent and salaries and still turn a profit, but that's their problem. So, next time you want to have some very cheap electronic fun, why not give these High Street cheap-as-chips stores a look? I think you'll be surprised what can be had for a few quid.

Moving considerably upmarket, we have some fantastic projects for you this month! Those of you who found April's *Resistance Substitution Box* useful now have the perfect accompanying project with its capacitance equivalent. Next, there is a simple, but clever soft-start circuit for power tools – perfect for all you DIYers. Our *High-Current Adaptor* is a sophisticated approach to safely measuring mains currents up to 30A – it will, of course, also measure DC currents. Last, but not least, we have an unusual project for those of you who like to make models and recycle discarded PC components. We show you how to convert the motors in scrapped CD/DVD drives to produce compact high-power drives using neodymium magnets.

Yes, there's plenty to keep you occupied while waiting for the great British summer to make an appearance.



NEWS

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

Making sense of disc burning software – report by Barry Fox

Standing proud from the mess of incompatible audio and video streaming, download and recording standards, and Blu-ray's fussy demands for secure HDMI display and amplifier connections, CD and DVD remain easy-to-use common currencies. Get captured music and movies onto these disc formats and they will play anywhere.

Burning to disc

Unfortunately, it's not that easy to get captured music and movie material onto CD or DVD, as I found out after burning literally dozens of discs while comparatively testing the latest versions of the three main multimedia software suites: Nero 12, Roxio Creator NXT and CyberLink Media Suite 10.

All cost much the same (around £75) and do more or less the same jobs, albeit with different user interfaces and a bewildering range of included or bolt-on modules. When the confusion is stripped away – and with the proviso that in audio and video capture, and playback, there will always be unexpected anomalies and error messages – there are a few basic practical differences between the big three software packages that do matter.

Online video is often in MP4 (an MPEG-4 format based on Quicktime video, with AAC, Advanced Audio Coding audio) and most PCs and media players can play MP4 files 'out of the box'. Easy-to-use video and game capture hardware, such as the Hauppauge and Elgato PVR devices, can be set to capture in MP4. And MP4 is easily edited. So MP4 is good, solid multimedia currency.

DVDs, however, need MPEG-2. So some kind of conversion is needed, along with the file ordering and indexing that is needed to make a burned DVD play on a DVD player. (Just drag-drop copying audio and video files to a blank optical disc will create a disc that only plays on a PC).

Two of the software packages, Roxio Creator NXT, and Nero 12, will reliably burn an MP4 file that has been captured in high definition (eg, 1280 × 720 pixels), direct to a blank DVD in standard definition (576 interlaced) that plays on an ordinary DVD player.

Users of Hauppauge and Elgato capture devices, hooked to Hi Def game or video sources, will immediately see the benefit of this.

Another very useful – but less widely recognised option – offered by Roxio NXT and Nero 12 is to use an ordinary blank DVD to store Hi-Def video in the new AVCHD (Advanced Video Coding High Definition) H/264 format. AVCHD is far more efficient than MPEG-2, so a DVD can store a feature length movie in HD. The finished disc will not play on a DVD player, but it will play in Hi-Def on a Blu-ray player.

The Power Producer module of CyberLink Media Suite 10 gave frustratingly unpredictable results, even with the same source material. Sometimes Power Producer would burn HD source material to an SD DVD; sometimes it just returned an error message (eg, C00C0005) without explaining what it meant.

Out of sync

When I did succeed in burning, I found a major difference in the way the version (Ver. 5.5) of Power Producer that comes with Media Suite, and the latest standalone version, Ver. 6, work. With Ver. 5.5, the audio went hopelessly out of sync with the video, by literally seconds! With Ver. 6, lip sync was preserved. I provided file samples to Cyberlink, but the company has so far been unable to explain these vagaries.

I also failed to burn an AVCHD DVD with either version of Cyberlink Power Producer; the file mysteriously quadrupled in size so became too large to burn.

Both Roxio NXT and Nero 12 did the AVCHD burn job with no hassles.

Incidentally, simple software for burning AVCHD Hi-Def files to standard DVD, from Arcsoft, comes bundled free with Hauppauge capture devices, and does the job well.

The way the three software packages burn audio to CD is also different. For instance, direct capture of DAB radio results in an MPEG-1 Audio Layer 2, or MP2 file with sampling at 48kHz and bit rate ranging from 80kbps mono to 192kbps stereo.

To make a 'Red Book' music CD, the file must be converted to 16 bit/44.1kHz WAV, ordered and burned to CD-R. Only the 'Burning ROM' module in Nero 12 was able to do this on the fly. I could not get either Roxio or Cyberlink to burn a CD direct from MP2.

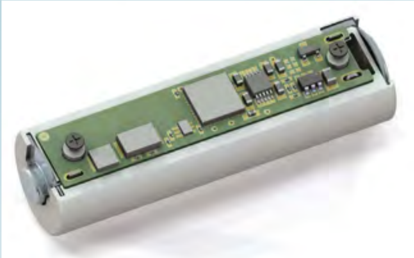
My overall verdict? Nero 12 just beats Roxio. But doubtless there will soon be new versions of all three, which could change the balance.

Tethercell brings intelligence to batteries

Tethercell is a clever adaptor that lets you control any battery-powered devices via Bluetooth, with your smartphone.

Named 'Breakthrough Prototype of The Year' by Bluetooth SIG at Mobile World Congress 2013, Tethercell enables users to connect and control any battery-operated devices from their smartphones or tablets via Bluetooth Smart technology. The adaptor controls the device's power, reads remaining battery power and collects data on usage – turning any existing battery-operated object, from a toy to smoke detector, into a 'smart' device.

A conventional AA battery is replaced with Tethercell's smart battery, which is the same AA size, but which contains an AAA battery plus the Bluetooth, diagnostic and moitoring electronics. No matter how many AA batteries are required to run the



device, you only need one Tethercell. After the Tethercell is snug in the battery compartment, you turn on the device, fire up the Tetherboard app after downloading it free from the App Store and you're ready to connect from any iOS or Android device that is Bluetooth Smart compatible.

The designers report that it performs best with rechargeable cells because of their low internal resistance, especially in high drain devices.

Further details are available at: **www.indiegogo.com/tethercell**

Easy C programming with Parallax

Parallax has launched a new Propeller C Learning System, which consists of a programming tool and a suite of tutorials featuring simple circuits and libraries with code samples for core devices and sensors. The program simplifies learning to program in the C language for new users, but also allows for in-depth exploration of the libraries and background code for those that want to know more.

The program has been launched with new hardware featuring the Propeller multi-core microcontroller. Each core of this on-board chip can be dedicated to process a different task. Each process can run in parallel, providing truly seamless processing for maximum efficiency and multi tasking.

The board features on-board peripherals to complement the program's activities without the need for stacking. Among them, an XBee socket for wireless capabilities, a microSD card socket to allow data logging or audio file playback and a breadboard area to allow easy solder-less connections to servo motors or LCD displays.

The price is listed as $49.95. Visit: **www.parallax.com** for more details.

REDEFINING THE AMP

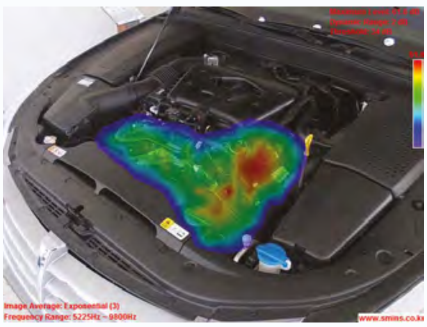
The international system of units (SI) comprises seven base units (the metre, kilogram, second, kelvin, ampere, mole and candela). Ideally, these should be stable over time and universally reproducible. The present definition of the ampere, however, is vulnerable to drift and instability. This is not sufficient to meet the accuracy needs of present and certainly future electrical measurement. The highest global measurement authority, the Conférence Générale des Poids et Mesures, has proposed that the ampere be redefined in terms of the electron charge.

The new front-runner in this race to redefine the ampere is a single-electron pump (SEP) being developed at the UK's National Physical Laboratory (NPL). SEPs create a flow of individual electrons by shuttling them into a quantum dot – a particle holding pen – and emitting them one at a time and at a well-defined rate.

Traditional pumps, thought to be not worth pursuing, have been given a new lease of life by fabricating them out of the world's most famous super-material – graphene.

Previous metallic SEPs made of aluminium are very accurate, but pump electrons too slowly for making a practical current standard. Graphene's unique semi-metallic two-dimensional structure has just the right properties to let electrons on and off the quantum dot very quickly, creating a fast enough electron flow – at near gigahertz frequency – to create a current standard.

Korean sound camera helps solve engine problems



KAIST sound camera imaging of noise

Researchers at the Korea Advanced Institute of Science and Technology (KAIST) have produced a portable 'sound camera'.

Most industrial products, including cars, can produce abnormal noises caused by an error in design or worn-out machinery. However, it is difficult to identify the exact location of the sound with ears alone.

This is where the sound camera comes in. Just as thermal detector cameras show the distribution of temperature, sound cameras use a microphone arrangement to express the distribution of sound and to find the location of the sound. However, existing sound cameras are not only big and heavy, their assembly and installation are complex and must be fixed on a tripod. These limitations make it difficult to measure noises from small areas, such as a car's engine.

The KAIST design is an all-in-one system resolving the inconvenience of assembling the microphone before taking measurements. The handle in the middle is ergonomically designed so users can balance its weight with one hand. The two handles on the sides work as a support and enable the user to hold the camera in various ways.

Front and rear of the KAIST sound camera

Software takes the camera's output and displays a sound map over an image of the target, helping to rapidly troubleshoot problems.

Get thousands of capacitance values with this . . .

6-Decade Capacitance Substitution Box

By NICHOLAS VINEN

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.

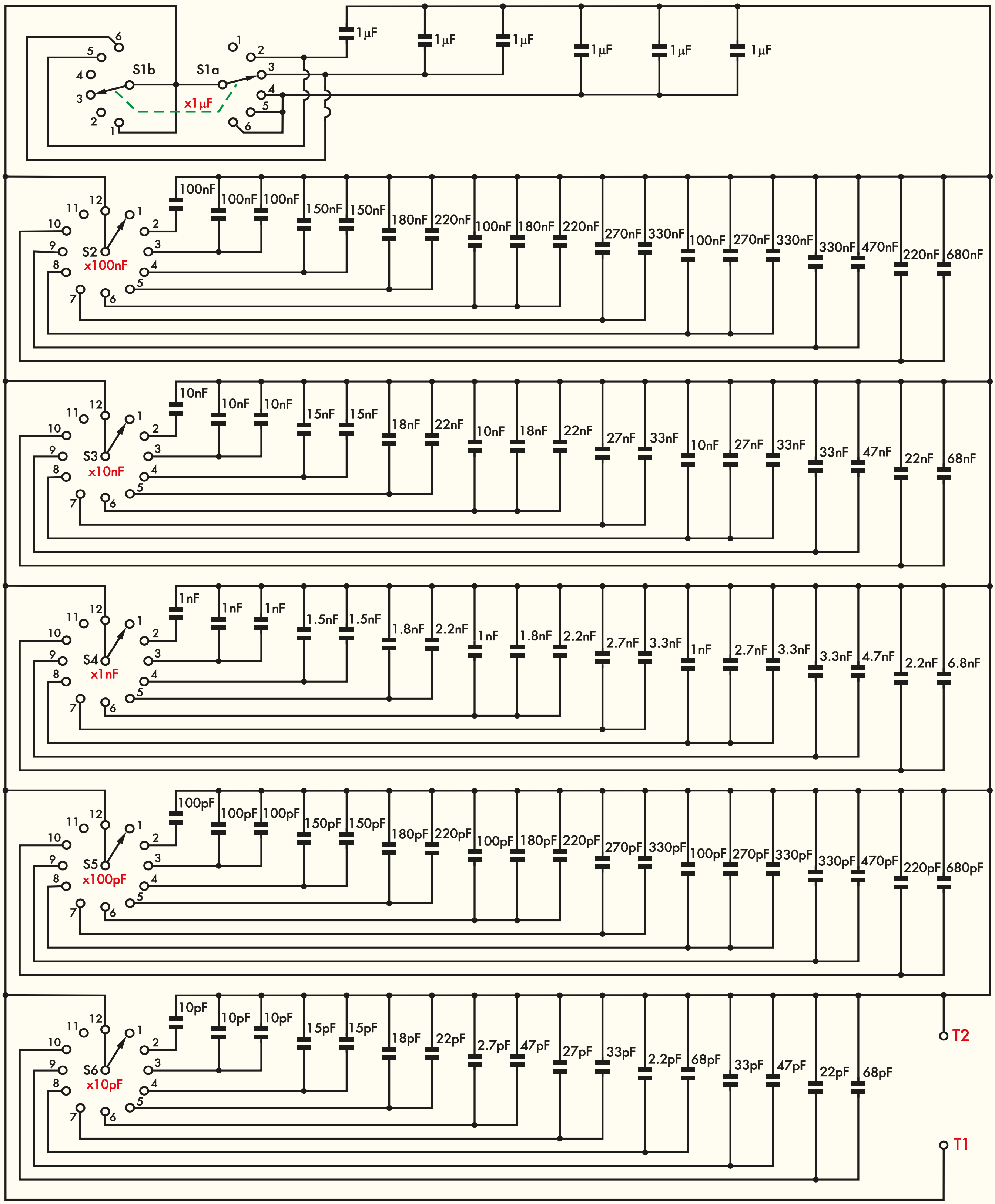
OUR *6-Decade Resistance Substitution Box*, described in April 2013, lets you easily find the right value for a resistor in your circuit. Sometimes though, you also need to vary a capacitance. For example, you may have an RC oscillator where the resistor is integrated in an IC, so you can't change it.

For whatever reason, when you need to tune the value of a capacitor, this new *6-Decade Capacitance Substitution Box* is ideal. It gives you hundreds of thousands of different capacitance values to play with, from about 30pF to 6µF. It can be used to tune oscillators, filters, time delays, compensation networks, rise and fall times, AC-coupling stages, rail-splitters, feedback loops and so on.

Even in situations where you can calculate the required capacitance value, you may still need to tweak it to work in a real circuit.

Design

A capacitance substitution box is slightly trickier to design than a resistance substitution box. Since resistor values sum when connected in series, a rotary switch can be connected to a resistor string, giving you a variable 'tap' point. For example, with 10 ×



CAPACITANCE DECADE BOX

Fig.1: the circuit for the *Capacitance Decade Box* consists of just six rotary switches, two binding posts and a bunch of different non-polarised capacitors. Sets of capacitors are paralleled to give the values required and switches S1 to S6 select one set for each decade. The selected sets are connected in parallel, giving the required capacitance across binding posts T1 and T2.

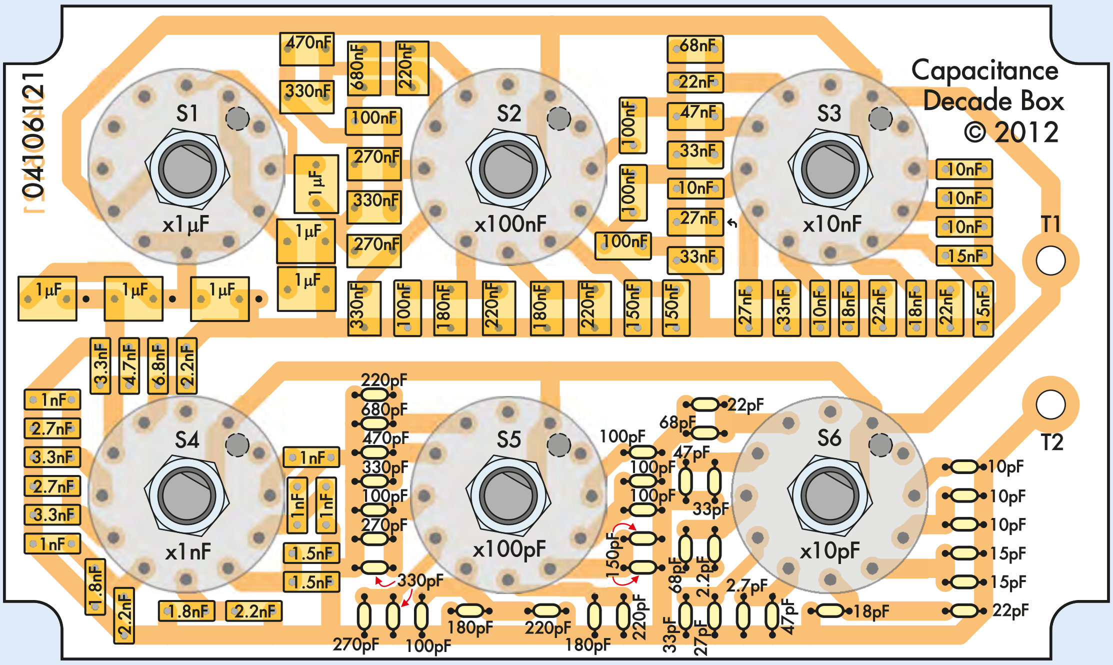


Fig.2: follow this parts layout diagram to build the *6-Decade Capacitance Box*. Note that the switches must be installed with their anti-rotation spigots oriented as shown. The tops of these spigots must also be removed using side cutters.

100Ω resistors and an 11-position rotary switch, you can select a resistance in the range of 0-1000Ω in 100Ω steps.

But connecting capacitors in series gives a different result: two 100pF capacitors in series gives 50pF, three gives 33pF, four 25pF and so on. The resulting values aren't multiples of 10 and even if the values were convenient, there's the additional problem that the more capacitors you put in series, the larger they need to be for the whole string to have even a modest capacitance.

So we need to connect capacitors in parallel to make a substitution box. In practice, this means we need 10 sets of capacitors per decade, with values of (for example) 100pF, 200pF, 300pF, etc. Each switch selects one set for that decade, and the decades are wired in parallel so that the capacitances combine. For example, if you select 300pF with one switch and 2nF with another, that will give you 300pF || 2nF = 2.3nF.

Because capacitor values are assigned logarithmically, to get decimal values, we need one, two or three capacitors in parallel. For example, 300pF can be made using two 150pF capacitors while 400pF can be made with 220pF and 180pF capacitors. We have used values from the E6 series where possible, as these are the most common ones. A few values from the E12 series have also been used, where necessary.

Circuit description

The full circuit is shown in Fig.1. There is one rotary switch per decade, labelled S1-S6. For the 10pF through to 100nF decades they are single-pole, 10-position switches (S2-S6) while S1 has two poles and six positions.

All the capacitors in the circuit are connected together at one end and to binding post T1. Switches S1-S6 connect the other ends of the selected capacitors to T2, while the others remain unconnected and so don't contribute to the total capacitance.

The capacitors around S2, S3, S4 and S5 are arranged identically. The only difference is in their values. The lowest range (S6) is slightly different because we can use two fewer capacitors since we don't worry about sub-picofarad errors. S1 controls the 1µF range and this is arranged a little differently than the others, to reduce the number of large capacitors required.

It works the same way as the other switches to select values up to 3µF. For 4µF, the capacitors used for the 1µF and 3µF positions are connected in parallel, using both switch poles. Similarly, for 5µF, the capacitor sets for 2µF and 3µF are connected in parallel.

The result of all this is that you can basically just 'dial up' a value using the six switches.

Stray capacitance

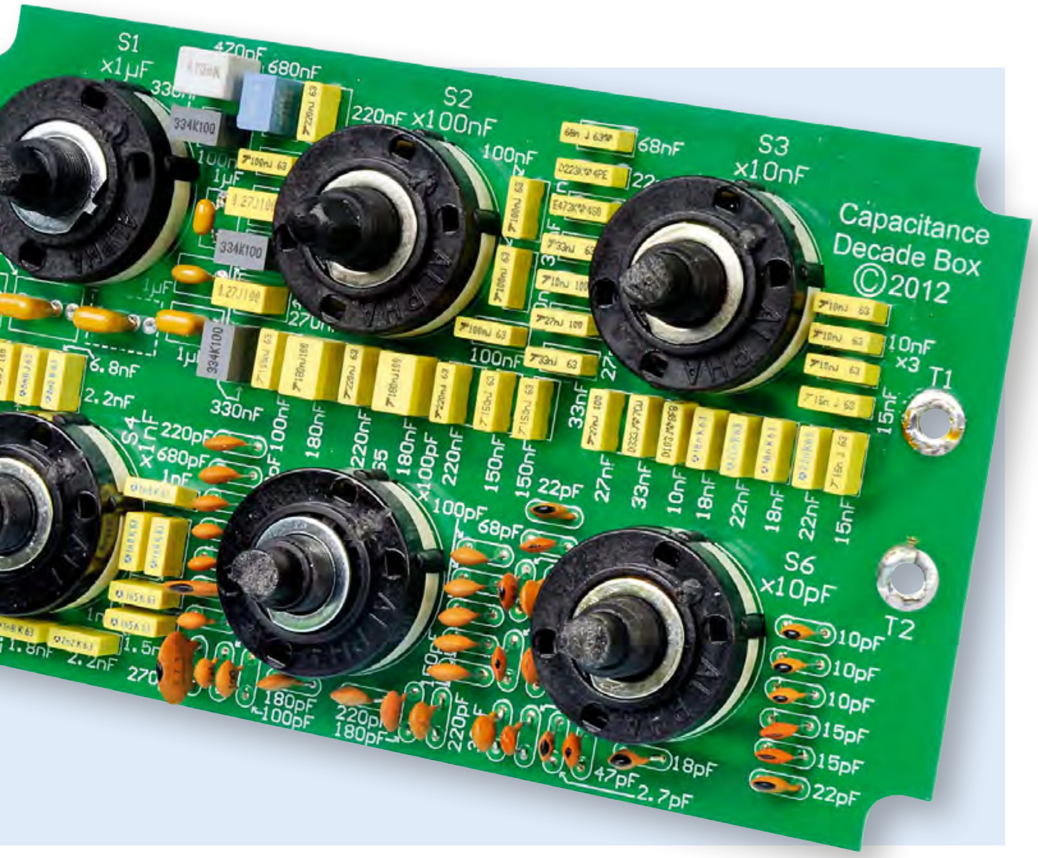
In an ideal world, the capacitance you get would be exactly what you have selected using S1 to S6, but in reality, it will vary slightly, for a couple of reasons.

The first is the stray capacitance of the PCB itself, which is around 30pF. This adds to whatever capacitance you have selected using the rotary switches. It is irrelevant for large values, but could be significant for values below a couple of nanofarads.

The 10pF range is still useful, despite the fact that this stray capacitance is so large in comparison. It means that you can increase the capacitance in small steps (~10pF). You just need to remember to mentally add about 30pF when selecting very small values.

Then there are the tolerances of the capacitors themselves. 1% resistors are commonly available and cheap, but a typical MKT or ceramic capacitor is either ±10% or ±20%. For this project, stick with the 10% types if possible.

Capacitor value variations are somewhat mitigated when paralleling similar values. Say we have two 1nF±10% capacitors connected in parallel and their errors are uncorrelated. Each capacitor will be between 0.9nF and



1.1nF, an error of ±0.1nF. While the worst case values for the combination are 1.8nF and 2.2nF, the average error of any two capacitors is $\sqrt{(0.1nF^2 + 0.1nF^2)}$ = 0.141nF or 7.07%.

If the capacitors are of the same value and from the same batch, we can't assume the errors are uncorrelated. This effect is also less pronounced when the capacitor values paralleled vary significantly. But given the above, when we parallel multiple capacitors of similar values, we can generally expect slightly less variation in the resulting capacitance than the individual tolerances would suggest.

Using 10% capacitors, the result will be accurate enough for most purposes, but if you want better accuracy, use capacitors with a tighter tolerance (eg, 5%) or else buy several of each and pick those closest to their nominal values, using an accurate capacitance meter. To be really tricky, where multiple capacitors are paralleled, you can select them on the basis of the lowest total error for each set.

Capacitor type

We use non-polarised capacitors in this project to make it as versatile as possible. MKT (metallised polyester) types are used for values from 1nF up to 680nF because they have good performance, are commonly available and have a consistently small size. Ceramic capacitors are used for values below 1nF because they are more common at these values. Those with an NP0/C0G dielectric are better; these are common for values of 100pF and below.

You can substitute different types if you prefer, provided they fit.

The 1µF capacitors can be either MKT or monolithic multilayer ceramic (MMC). MKTs have better performance and tend to have tighter tolerances but cost more, and some 1µF MKT capacitors may be too large (they need to have a 5mm or 0.2-inch pin spacing).

Note that through-hole MKT and MMC capacitors generally have a voltage rating of at least 50V and this should generally be sufficient.

Test leads

The most convenient way to use the *Capacitance Decade Box* is to connect it to your circuit with a short pair of banana-plug-to-alligator-clip test leads. But keep in mind that the leads will have some capacitance which will be added to that from the box itself. Longer leads have more capacitance, so keep them short.

The leads also have some inductance (as does the PCB). In practice, this limits the use of the box to circuits operating up to a few megahertz, ie, it may not be suitable for use with some RF circuits, mainly because of stray capacitance.

Parts List

1 PCB, code 04106121, size 146mm × 86mm
1 PCB, code 04106122, size 157.5mm × 95mm (front panel/lid) *OR*
1 front panel label
1 UB1 Jiffy box
1 2-pole 6-position rotary switch (S1)
5 1-pole 12-position rotary switches (S2 to S6)
6 16-20mm knobs to suit S1 to S6
2 captive binding posts

MKT Capacitors

6 1µF MKT or monolithic ceramic (5mm lead spacing)

1 680nF	3 22nF
1 470nF	2 18nF
3 330nF	2 15nF
2 270nF	5 10nF
3 220nF	1 6.8nF
2 180nF	1 4.7nF
2 150nF	3 3.3nF
5 100nF	2 2.7nF
1 68nF	3 2.2nF
1 47nF	2 1.8nF
3 33nF	2 1.5nF
2 27nF	5 1nF

Ceramic Capacitors*

1 680pF	2 47pF
1 470pF	2 33pF
3 330pF	1 27pF
2 270pF	2 22pF
3 220pF	1 18pF
2 180pF	2 15pF
2 150pF	3 10pF
5 100pF	1 2.7pF
2 68pF	1 2.2pF

Note1*: C0G/NP0 ceramic capacitors preferred

Note 2: the PCBs are available from the *EPE PCB Service*

Construction

The *Capacitance Decade Box* is built on a 146mm × 86mm PCB, coded 04106121 which fits into a UB1 jiffy box. This PCB is available from the *EPE PCB Service*. Construction is easy; simply fit the capacitors where shown on the overlay diagram (Fig.2). Start

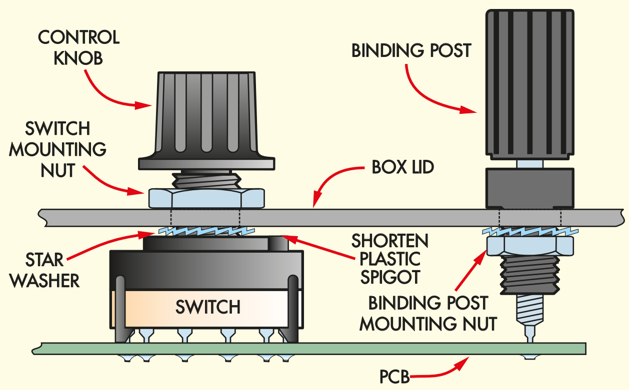


Fig.3: the PCB is secured to the back of the lid by resting it on the tops of the switches and doing up the switch nuts. The binding post spigots are then soldered to their pads.

with the lowest profile MKTs, then mount the ceramic capacitors and the rest of the MKTs.

Before fitting the switches, remove the small plastic spigots that protrude from the base using side-cutters (see Fig.3). Clean up with a file, if necessary, then cut the shafts of all six switches to a length of 10mm. This is easily done by clamping the shaft in a vice and cutting it with a hacksaw. File off any burrs.

The switches can then be soldered to the PCBs. Make sure the 2-pole switch (S1) is fitted with the orientation shown in Fig.2. All the switches must be mounted flush with the PCB; check before soldering more than two pins.

Housing

You can either drill the box lid and attach a front panel label or else purchase a pre-drilled and screen-printed PCB which replaces the plastic lid (157.5mm × 95mm, coded 04106122). This PCB lid gives your *Capacitance Decade Box* a professional appearance. (The front-panel PCB is available from the *EPE PCB Service*.)

Alternatively, you can download the front-panel label (in PDF format) from the *EPE* website, print it out and use it as a drilling template to make the eight holes in the plastic lid. A second copy can then be printed out, laminated and attached to the lid using silicone adhesive.

Next, loosely fit the two binding posts onto the lid, then remove the nuts and washers from the rotary switches. The lower washer has a locking pin, and this is used to select the number of switch positions available.

To do this, place the PCB flat on your workbench, turn all the switches fully anti-clockwise and insert the washers for S2-S6 so that each locking pin goes into the hole marked '10'. By contrast, for switch S1, insert the locking pin of the washer into the hole marked '6', so that it only rotates through six positions.

That done, slip the star-washers over the shafts, then push them through the lid while keeping the PCB horizontal, so you don't knock the washers out of alignment. Guide the binding post shafts through the matching holes on the PCB and then do up the six nuts tight.

You can then tighten up the binding post nuts using a small spanner and after checking that they are correctly aligned, solder them to the PCB pads. Fit the knobs and then drop the lid assembly into the box and attach it using the four provided self-tapping screws. If your box came with rubber plugs that cover the screw holes and you are not using the PCB lid, you can fit them now.

Using it

As stated earlier, the *Capacitance Decade Box* is most convenient in combination with short alligator clip leads, but you can also connect bare wires into the binding posts. You can even use solid-core wire so that the other end can be plugged into a breadboard.

Keep in mind that the rotary switches will have either 'make before break' or 'break before make' operation, depending on the type supplied. This means that if you change the capacitance while the unit is connected to a working circuit, the capacitance will briefly be either very low (~30pF) or higher than usual while switching. In most cases, this won't upset the circuit, but it depends on its exact configuration.

Once you have found the optimal capacitance for your circuit using the decade box, you can disconnect it and measure the capacitance across the output terminals. Alternatively, you can just read out the position of the switches, which should be accurate to within a few percent of the true value for settings above 1nF. ***EPE***

Capacitor Codes

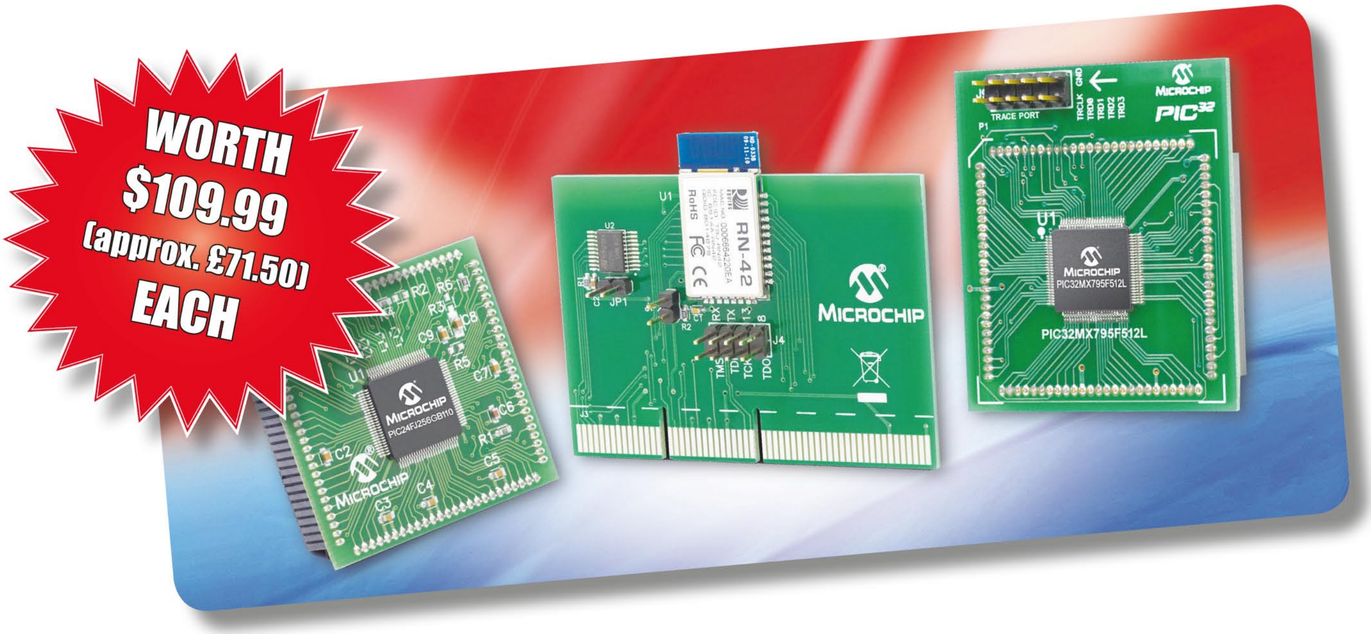
Value	μF Value	IEC Code	EIA Code
1μF	1μF	1u0	105
680nF	0.68μF	680n	684
470nF	0.47μF	470n	474
330nF	0.33μF	330n	334
270nF	0.27μF	270n	274
220nF	0.22μF	220n	224
180nF	0.18μF	180n	184
150nF	0.15μF	150n	154
100nF	0.1μF	100n	104
68nF	.068μF	68n	683
47nF	.047μF	47n	473
33nF	.033μF	33n	333
27nF	.027μF	27n	273
22nF	.022μF	22n	223
18nF	.018μF	18n	183
15nF	.015μF	15n	153
10nF	.01μF	10n	103
6.8nF	.0068μF	6n8	682
4.7nF	.0047μF	4n7	472
3.3nF	.0033μF	3n3	332
2.7nF	.0027μF	2n7	272
2.2nF	.0022μF	2n2	222
1.8nF	.0018μF	1n8	182
1.5nF	.0015μF	1n5	152
1nF	.001μF	1n	102
680pF	NA	680p	681
470pF	NA	470p	471
330pF	NA	330p	331
270pF	NA	270p	271
220pF	NA	220p	221
180pF	NA	180p	181
150pF	NA	150p	151
100pF	NA	100p	101
68pF	NA	68p	68
47pF	NA	47p	47
33pF	NA	33p	33
27pF	NA	27p	27
22pF	NA	22p	22
18pF	NA	18p	18
15pF	NA	15p	15
10pF	NA	10p	10
2.7pF	NA	2p7	2.7
2.2pF	NA	2p2	2.2

Win a Microchip Bluetooth Evaluation Kit

EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win a Microchip Bluetooth Evaluation Kit (DM183036). The kit provides an easy, cost-effective and flexible add-on for embedded evaluation and development using many 16/32-bit PIC microcontrollers or dsPIC digital signal controllers (DSCs), using existing Microchip development tools.

The kit includes the Microchip Bluetooth PICtail, plus daughter-board with the 16-bit USB PIC24FJ256GB110 and 32-bit CAN/USB PIC32MX795F512L microcontroller plug-in modules, both of which are pre-programmed with CandleDragon's dotstack Bluetooth demonstration stack and SPP profile. This kit is designed for use with Microchip's existing Explorer 16 Development Board (DM240001), which is available separately, at $129.99 (approx £85).

Current Bluetooth wireless modules are costly and inflexible because they force developers to use a predetermined baseband radio and microcontroller. The new Microchip and CandleDragon Bluetooth solution enables designers to pair a wide range of radio ICs for Bluetooth connectivity with many of Microchip's 16/32-bit PIC microcontrollers or dsPIC DSCs. Additionally, CandleDragon's dotstack is Bluetooth SIG compliant and supports multiple profiles in a single microcontroller, including SPP, HFP and HID, with more profiles planned for Microchip MCUs in the near future.



HOW TO ENTER

For your chance to win a *Microchip Bluetooth Evaluation Kit,* visit:
www.microchip-comps.com/epe13-bluetooth and enter your details in the online entry form.

CLOSING DATE

The closing date for this offer is 31 July 2013

Stop that dangerous kick-back . . .

Soft Starter for Power Tools

by NICHOLAS VINEN

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 it, it will still kick and that can be enough to throw you off a carefully lined up cut. This can be bad enough when you are trying to start an accurate cut with a circular saw, but it can damage the job if you are using a tool like a large plunge router. But now you can stop that kick with our *Soft Starter for Power Tools*.

OUR *Soft Starter* project from April 2013, which tames switch-on current surges primarily in equipment with switch-mode supplies, has been very popular. But readers started asking 'what about something similar for power tools?'

Many of the smaller mains power tools these days have speed controllers built into the trigger, so they are very controllable when you turn them on.

But larger power tools, such as circular saws, plunge routers, angle grinders and worst of all, large electric drills for concrete core drilling, have a simple trigger or thumb switch which applies full power to the motor. Core drilling is particularly dangerous, as you have to brace the core drill bit hard against the wall or floor and then press the trigger. The resulting torque kick can easily jerk the whole tool out of your hands – and you can be injured in the process.

Why does it kick?

The reason for that enormous initial torque is the very high surge current pulled by a universal (series wound, brush) motor when power is first applied. Because the motor is not rotating, it is not generating any back-EMF to oppose the applied mains voltage, and the resulting surge current can easily be ten times the rated current of the motor with full load.

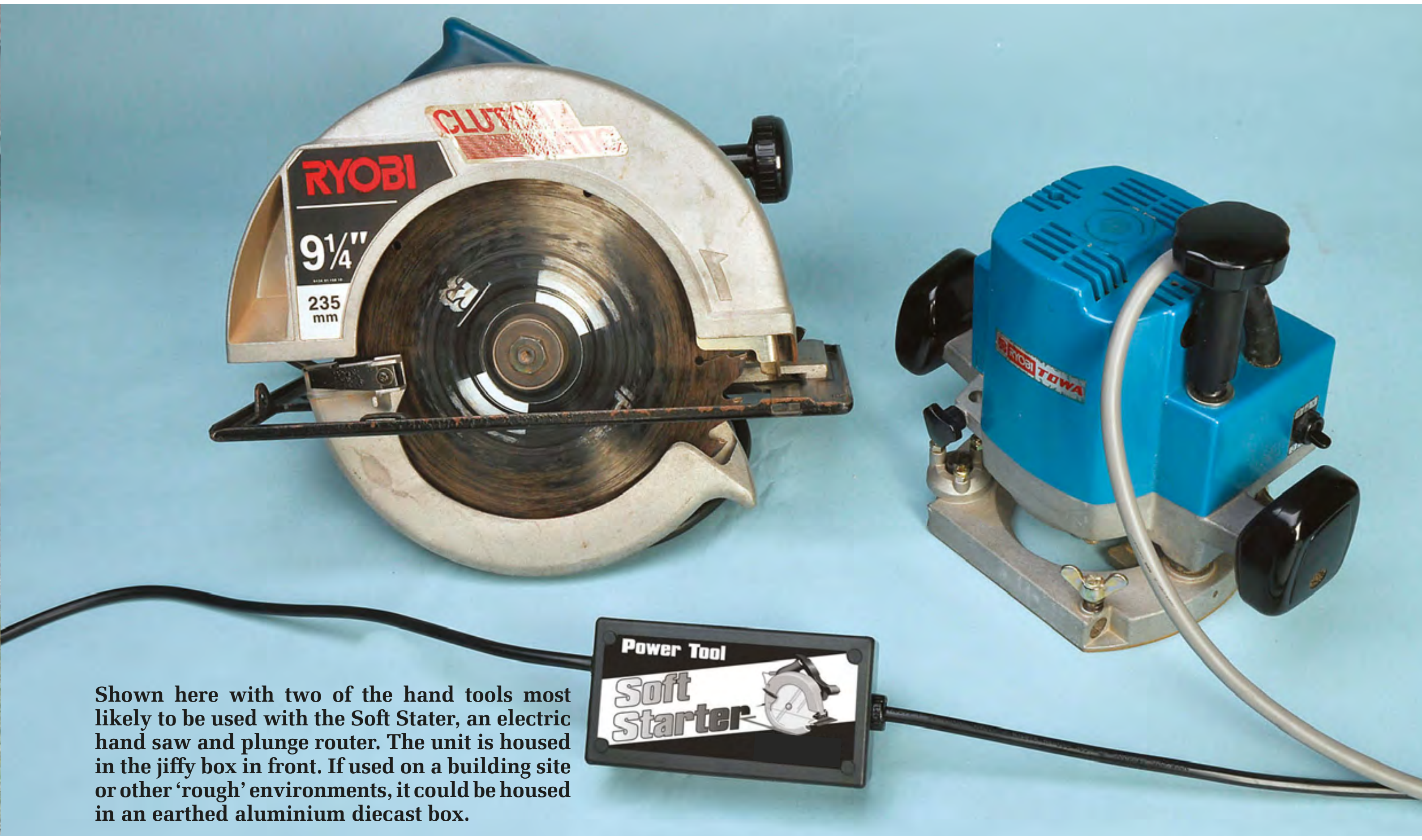
Elsewhere in this article we show some scope grabs depicting these massive currents, which fortunately decay to much lower values within less than half a second. It is those massive currents which cause the lights to flicker when you switch on a big power tool; the mains voltage sags noticeably.

The cure

Our solution is simple: When you squeeze the trigger switch on the power tool, current immediately starts to flow, but is limited to a reasonable value with a big power resistor. Then,

Features and Specifications

Inrush current limiting:	<20A
Minimum load power:	~100W
Maximum load current:	10A
Minimum tool restart interval:	60s recommended



Shown here with two of the hand tools most likely to be used with the Soft Stater, an electric hand saw and plunge router. The unit is housed in the jiffy box in front. If used on a building site or other 'rough' environments, it could be housed in an earthed aluminium diecast box.

after about half a second, we use a relay to short out the resistor and full power is applied to the motor. By that time, the motor is already spinning at high speed so the big peak current is avoided. The basic scheme is shown in the block diagram of Fig.1.

In this case though, we have not used a big power resistor, simply because a suitable value with sufficient rating would be large and expensive. Instead we have used two large negative temperature coefficient (NTC) resistors in series with the neutral side of the load (ie, the power tool). These thermistors have a relatively high initial resistance of about 10Ω each and so they limit the surge current to about 11.5A (230V AC ÷ 20Ω).

Now, while these thermistors are relatively small, they normally become very hot as their resistance drops. However, we don't give them a chance to get really hot because they are switched out of the circuit after a short delay.

So how do we know when to short out the thermistors? Referring to Fig.1, you will see that there is a current-sense resistor in series with the thermistor. This sense resistor has a value of 10 milliohms (0.01Ω) so that the voltage loss across it is quite low. We use this shunt resistor to sense when current starts to flow, immediately after the power tool trigger switch has been pressed.

The sense resistor is connected to a comparator, which works by comparing the instantaneous load current to a reference threshold.

When you turn the power tool on, it draws a lot of current at first, well above this threshold. Once this is detected by the comparator, it begins charging a capacitor and after half a second, it operates the relay. From that point on, the tool is effectively connected directly to the 230V AC mains and operates as if the *Soft Starter* isn't even there.

When the job is finished and you release the trigger switch, the current stops flowing and the circuit resets itself, ready to go again.

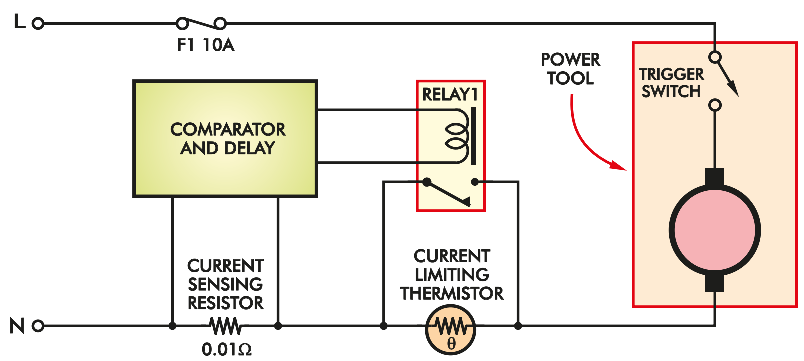


Fig.1: the *Soft Starter* block diagram. Initially, mains current passes through fuse F1, the power tool motor, a current-limiting thermistor and current-sense resistor. A short time after the motor is started, the control circuitry energises Relay1, shorting out the thermistor so the motor gets full power. We actually use two thermistors in series, but the principle is the same.

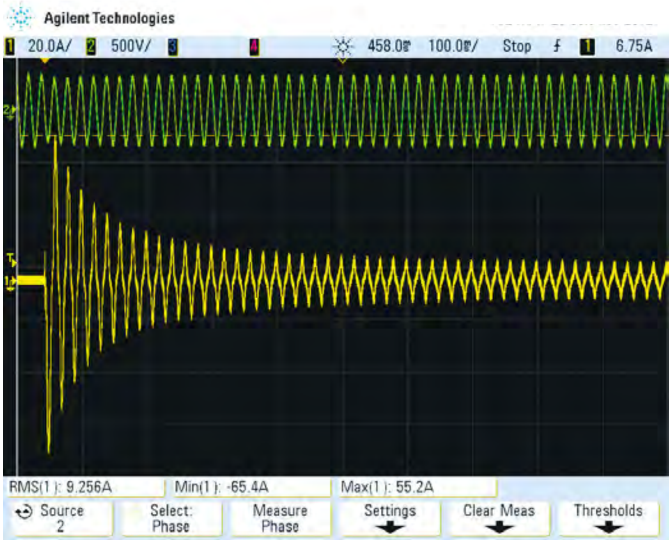


Fig.2: the mains current (yellow) and voltage (green) when starting a 1500W router. The peak current is in excess of 60A, hence the 'kick'. Current drops as the motor comes up to speed and it develops more back-EMF, opposing the mains voltage and thus limiting the current. Note the triangular shape of the current waveform, which is almost in phase with the mains voltage.

Fig.3: with the *Soft Starter* in circuit, the current at start-up is much lower, initially just 10A peak. This increases slowly over the first 200ms or so as the NTC thermistors warm up, then for the next 400ms the current draw drops as the motor comes up to speed. You can see the slight increase in current as the relay kicks in after 600ms and then the current drops further as the motor approaches full speed.

As long as the tool continues to draw at least 100W (and virtually all do), the relay stays closed. When you switch the tool off, the load current drops to zero and the capacitor discharges. After about half a second, the relay opens and the unit is ready to be used again.

Note that if you start and stop the tool multiple times in quick succession, the thermistors won't have time to cool down properly and the starting current on the second and subsequent starts will be higher than the first and so the tool kick-back will be higher. Even though the thermistors only conduct briefly before being shorted out, they still get quite hot in that short time; quick multiple starts means they getter hotter, their resistance is lower and so the surge currents are higher.

So the strategy is clear: to minimise switch-on kick back, don't stop and start the tool repeatedly in a short time. Wait about ten seconds or so between each application of power to the tool.

While this is primarily intended to be used with power tools, there are some other types of load which may be suitable. For example, it may work with some larger power amplifiers, and these could then be switched on using the front panel or remote control rather than having to turn them on and off at the wall, for the *Soft Starter* to be effective.

But there are some caveats. The main restriction is that the load must have a relatively sinusoidal current waveform and draw at least 100W when on.

Some devices with switch-mode supplies or with transformers feeding bridge rectifiers will not be suitable. Switch-mode supplies with active power factor correction (active PFC) should be OK.

The reason is that if the load current is drawn over a narrow part of the mains cycle (ie, near the peaks), the duration of the portion which is above the detection threshold may be too short for the comparator to detect, and so the relay will never activate. Active PFC spreads the current out over the full mains waveform, overcoming this issue.

However, the only sure way of knowing whether a given device can be successfully used with this *Soft Starter* is to try it and check that the relay reliably switches in after the load is turned on. If not, the *Soft Starter* is clearly not suitable for that particular load.

Circuit description

Refer now to Fig.5, the circuit diagram. The mains input and output sockets have their live terminals joined via a 10A fuse, protecting both the *Soft Starter* and the load. The earths are joined, possibly using pin 2 of CON1 as a convenient anchor point. This is vital for safety.

The neutral connection is where the soft start action occurs. Initially, the neutral input (from the mains) and the neutral connection to the PCB are joined via two series NTC thermistors, TH1 and TH2.

Two thermistors provide better in-rush current limiting than one, and also reduce the required cool-down time somewhat.

Also in series with these thermistors is a 10mΩ (0.01Ω) surface-mount resistor, which monitors the load current. Its resistance is so low that it has no effect on the load current and dissipates little power (<1W).

When the contacts of RELAY1 close, they short out both thermistors. This has two advantages; the tool gets full power soon after it's switched on and it allows the thermistors to immediately begin cooling down. The relay is rated at 240V AC/16A, which suits loads up to 4000VA.

13A is the highest continuous current available from standard UK power outlets, so we don't see any problem with the current limitation.

The rest of the circuit monitors the voltage across the 10mΩ resistor and turns on RELAY1 when appropriate. It is based around two active devices, quad precision comparator IC1 and PNP transistor Q1.

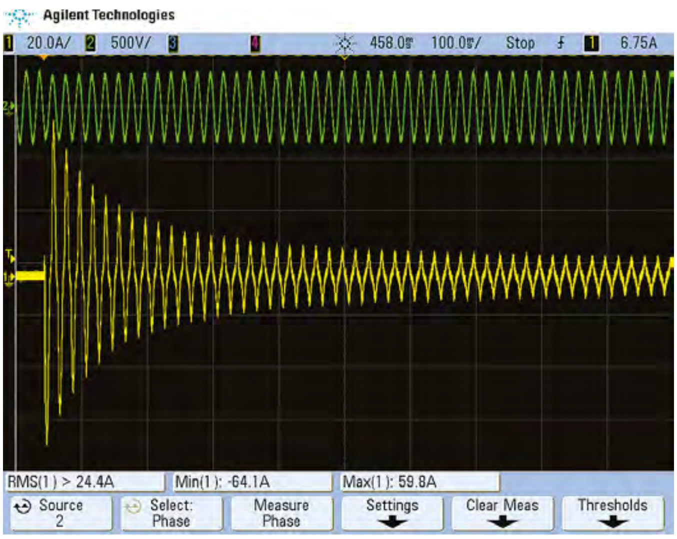


Fig.4: start-up current of a 1750W circular saw without the *Soft Starter*. This is quite similar to the 1500W router waveform opposite, but the peak current is a little higher. Note how the mains voltage (green, top) sags quite markedly for the first few cycles after switch-on due to the huge initial current. With the *Soft Starter*, the result is similar to the router (see Fig.3).

Window comparator

IC1a and IC1b are connected so that if the voltage across the 10mΩ shunt exceeds about 3.3mV (ie, a peak load current of 330mA), their common output at pins 1 and 2 goes low. One end of the 10mΩ shunt is connected to ground and the other to pin 6 of IC1b and, via a 1kΩ series resistor, pin 5 of IC1a.

Since the current waveform is AC, the voltage at these pins can be above or below ground, so IC1b checks to see whether it goes above +3.3mV while IC1a does the same below –3.3mV.

These references voltages are derived from the forward voltage of D3 and D4 (around 0.6V each) using 180kΩ/1kΩ voltage dividers, ie, 0.6V × 1kΩ ÷ (180kΩ + 1kΩ) = 3.3mV.

Diodes D3 and D4 are fed from the +12V and –12V rails respectively via 22kΩ current-limiting resistors. Their forward voltages are reasonably stable over a wide range of supply voltages and the expected operating temperature range. The 22kΩ resistors set the current through each to (12V – 0.6V) ÷ 22kΩ = 0.5mA. A small amount of this current flows through the parallel resistors.

Now consider the operation of comparator IC1b. The shunt is connected directly to its inverting input, while the 3.3mV reference voltage is applied to its pin 7 non-inverting input. The open-collector output pin 1 goes low when the voltage at pin 6 exceeds that at pin 7. This will occur when the voltage across the shunt is above +3.3mV.

Hysteresis

When the shunt voltage is between –3.3mV and +3.3mV, IC1b's output (pin 1) is pulled up to +12V by a 100kΩ resistor. There is a 10MΩ resistor between this output and the non-inverting input (pin 7) which provides some hysteresis, so that the output does not vacillate when the threshold is crossed.

This resistor works as a voltage divider in combination with the resistors connected to pin 7, which provide the +3.3mV reference voltage. When the output is high, the 10MΩ resistor is effectively in parallel with the 22kΩ and 180kΩ resistors at the anode of D3.

This allows an extra 12V ÷ (10MΩ+ 100kΩ) = 1.2µA to flow through the 1kΩ resistor, adding 1.2mV to the reference voltage, ie, it becomes +4.5mV.

But when the output of IC1b is low (–12V), the 10MΩ resistor sinks a similar amount of current from this point, lowering the reference voltage to around 3.3mV – 1.2mV = 2.1mV. It is the 2.4mV difference between the positive-going threshold (4.5mV) and the negative-going threshold (2.1mV) which provides the hysteresis.

In other words, once the shunt voltage goes above 4.5mV and the comparator output goes low, it must drop below 2.1mV before the comparator output will go high again.

The 3.3mV level is just a nominal voltage and does not actually occur in the circuit.

The operation of IC1a is similar, but since its inputs must be swapped to allow it to act as the other half of the 'window', the voltage hysteresis is applied to the feedback from the shunt, rather than the reference voltage.

The 10MΩ and 1kΩ resistors form a divider which has a virtually identical effect on this sense voltage as described above, ie, it raises or lowers it by 1.2mV depending on the output state.

The minimum ±2.1mV thresholds have been selected based on the precision of the LM339A. This has a 2mV maximum input offset voltage with a 5V supply, at 25°C.

Unfortunately, the data sheet is coy about just how this varies with supply voltage and temperature, but under our operating conditions, it should normally be below 2.1mV.

This is why we have chosen the LM339A rather than the more common LM339 variant; if the input offset voltage exceeded the window comparator thresholds, either the relay would switch on with no load or it would never switch off once the load current ceases.

(Remember, power is still applied to the *Soft Starter* even after you've let go the tool's trigger).

Time delay

When the load current is above the stated threshold and the outputs of IC1a and IC1b are low, this charges a 220nF capacitor via the 2.2MΩ resistor, and when the outputs are high, it is discharged in the same manner.

Comparators IC3c and IC3d are wired up in parallel and the capacitor voltage is applied to their non-inverting inputs (pin 9 and pin 11) via a 3.3MΩ resistor.

When the relay is off, the outputs of these comparators (pin 13 and pin 14) are at around +11.4V, since there is little voltage across the relay coil and one diode drop across Q1's base-emitter junction (~0.6V).

The 10MΩ/3.3MΩ feedback voltage divider across the comparators means that when the capacitor is charged beyond 15.8V (ie, its bottom end goes below –3.8V), the voltage at the comparator non-inverting inputs drops below 0V.

We confirm this by performing the calculation for this voltage divider, ie, (–3.8V × 10MΩ + 11.4V × 3.3MΩ) ÷ 13.3MΩ = –0.03V.

The inverting inputs, pins 8 and 10, are connected to ground, so once the capacitor has sufficient charge, the outputs of IC1c and IC1d go low and pull the base of *PNP* transistor Q1 to –12V. Q1 is an emitter follower, and so in this case, it sinks current through the coil of RELAY1, turning it on.

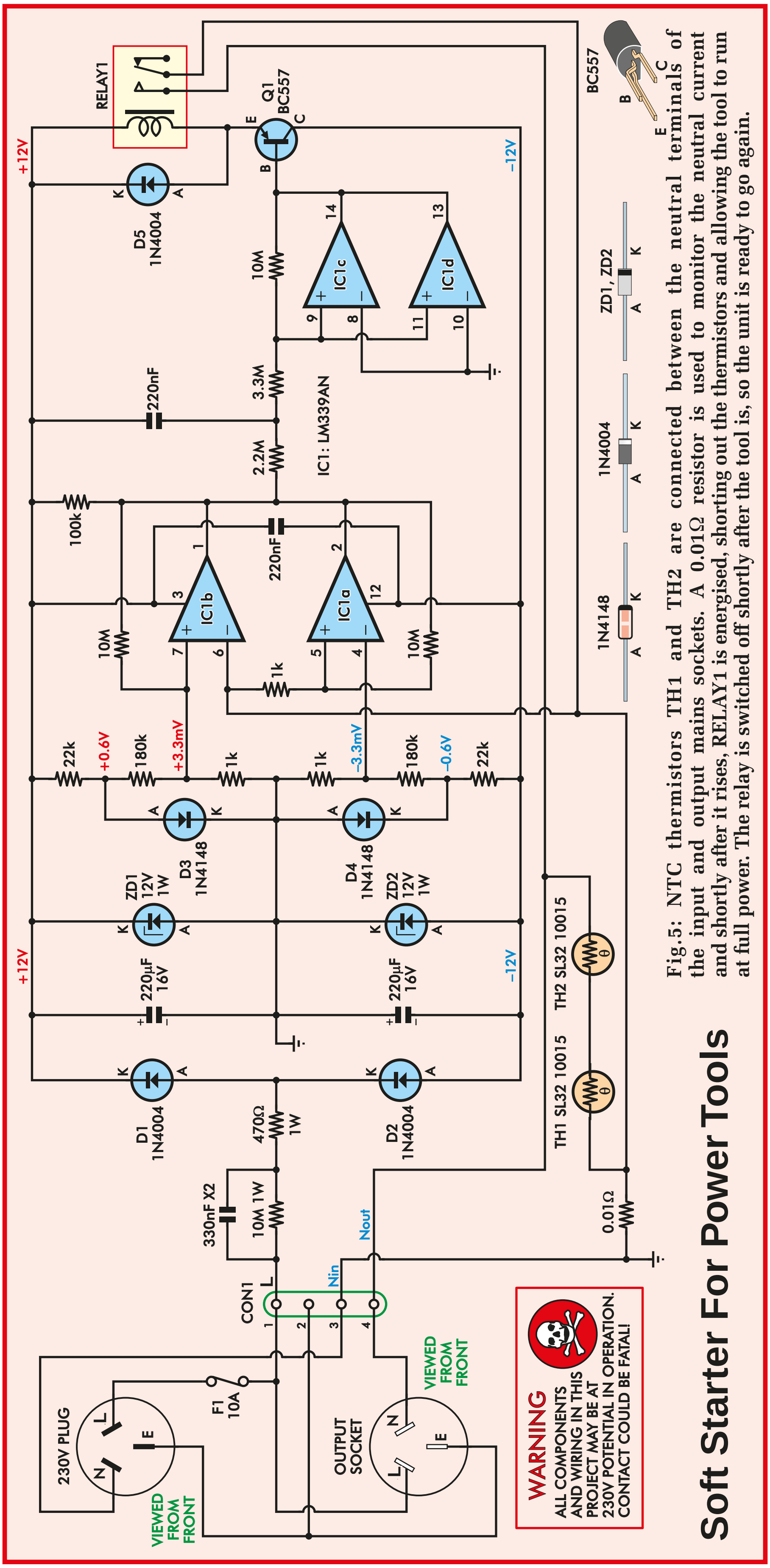


Fig.5: NTC thermistors TH1 and TH2 are connected between the neutral terminals of the input and output mains sockets. A 0.01Ω resistor is used to monitor the neutral current and shortly after it rises, RELAY1 is energised, shorting out the thermistors and allowing the tool to run at full power. The relay is switched off shortly after the tool is, so the unit is ready to go again.

The voltage at the non-inverting inputs then becomes (–3.8V × 10MΩ –12V × 3.3MΩ) ÷ 13.3MΩ = –5.8V. This is the hysteresis for this stage, and the capacitor must discharge by this additional amount before the relay turns off.

This allows the relay to stay on through brief dips in the load current. Diode D5 protects transistor Q1 from any voltage spike created when the relay turns off.

Power supply

The ±12V rails are derived from the mains live line via a 330nF X2 series capacitor, 470Ω current-limiting resistor and dual half-wave rectifier formed by diodes D1 and D2. These diodes charge the 220µF capacitors alternately with each mains half-cycle, to provide the positive and negative rails. 12V Zener diodes ZD1 and ZD2 limit the voltage across these capacitors to about 11.5V. The 330nF capacitor and 470Ω resistor limit the current and thus dissipation in ZD1 and ZD2 to well below their rated 1W.

If you ignore the X2 capacitor and two 1W resistors, this is a traditional AC-to-DC voltage doubler supply. The X2 capacitor has an impedance at 50Hz of around 9.65kΩ, which limits the mains current to about 230V ÷ 9.65kΩ = 24mA. It's a bit more complicated than this calculation implies, but that's a reasonable approximation.

We could have used a wirewound resistor of a similar value, but it would then dissipate $0.024A^2 \times 9.65k\Omega$ = 5.5W. The capacitor dissipates virtually no power.

The parallel 10MΩ resistor discharges the X2 capacitor once power is removed, while the 470Ω series resistor limits the inrush current when power is first applied.

For more details on how this type of supply works, see the description in the original *Soft Starter* article (April 2013).

The specified relay has a nominal coil resistance of 1.1kΩ. This means with a 24V supply it will draw around 22mA. As stated earlier, the X2 capacitor limits the supply current to about 24mA; less due to the series 470Ω resistor and other factors.

When the relay is turned on, the X2 capacitor and 470Ω resistor form a voltage divider with the coil resistance. The supply rails then drop to about ±6V and the two Zener diodes cease conducting, since most of the input current flows through the relay coil.

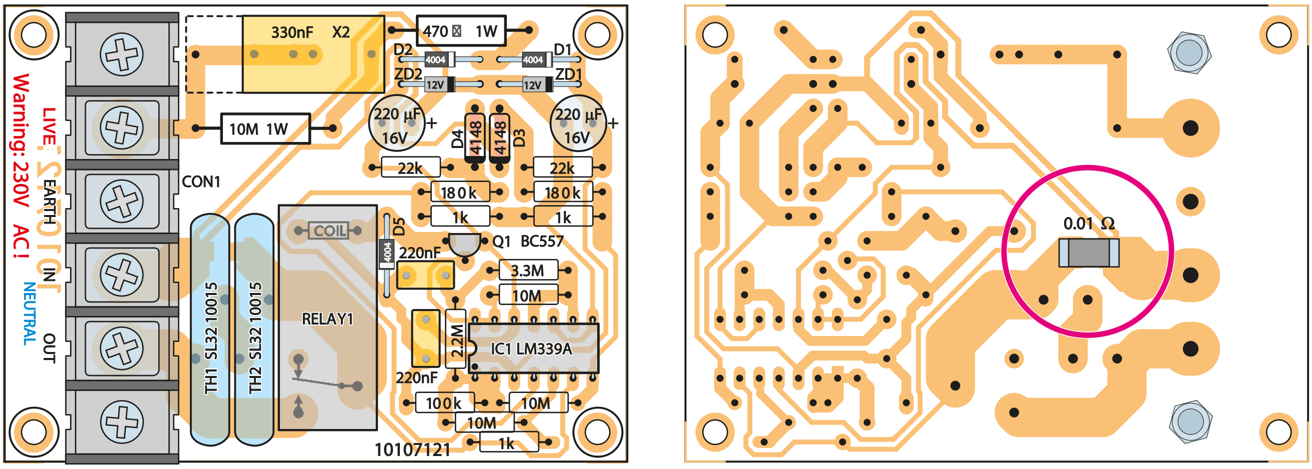


Fig.6: use these overlay diagrams and the photograph below as a guide when building the *Soft Starter*. Just one component, the 0.01Ω SMD resistor, goes on the underside. The diodes, electrolytic capacitors and IC1 must be installed with the orientations shown here. Multiple pads are provided to suit differently sized X2 capacitors. Secure CON1 with a machine screw at each end before soldering its pins.

The relay gets close to the full 24V across its coil initially to turn it on, but the 220µF capacitors then partially discharge. The reduced coil voltage is sufficient to keep it energised and the rest of the circuit will run happily with ±6V or less. When the relay turns off, the 220µF capacitors charge back up to their original level.

PCB layout

While various components in the circuit are shown connected to ground, the main reference point is the 'Nin' (Neutral In) terminal of CON1. This is the potential which the shunt sense voltage is relative to. Because this is very low (just a few mV), it's critical that the ±3.3mV references track this ground potential accurately or the unit won't work properly.

Therefore, the connection between the cathode of D3, the anode of D4 and pin 3 of CON1 is separate from other ground paths.

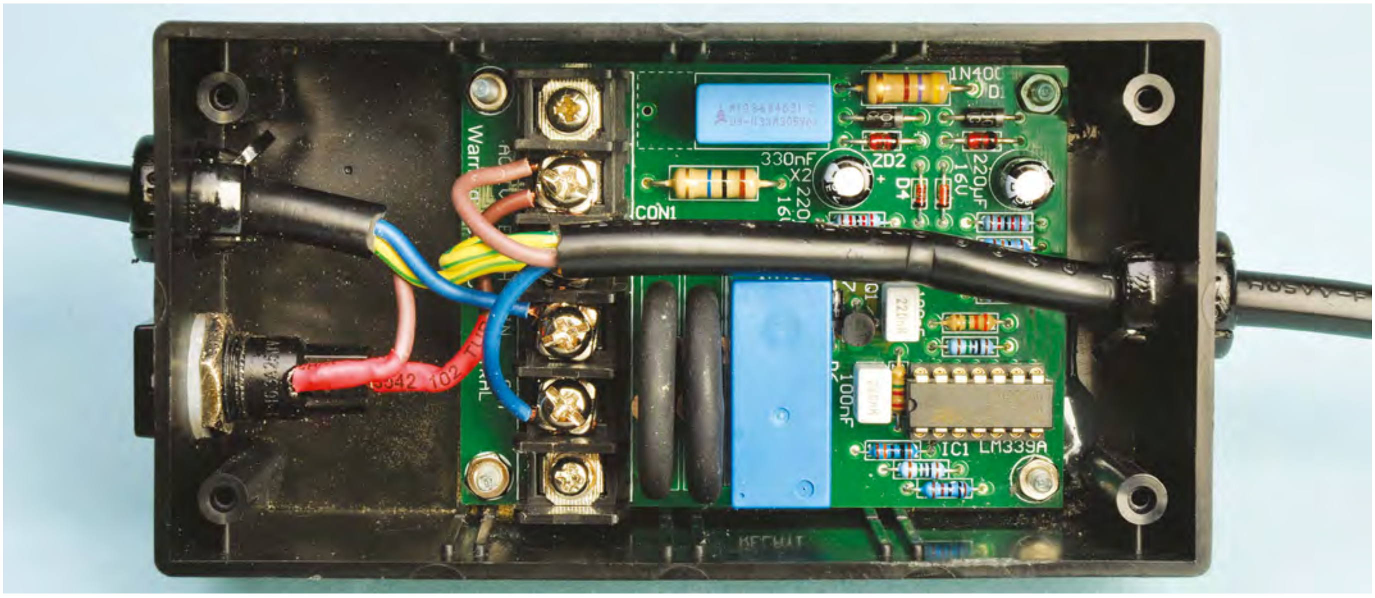
This way, current flowing through ZD1, ZD2, the 220µF capacitors and other components to ground does not interfere with the comparator's operation.

As is typical with a circuit which runs directly from mains, the PCB has a high voltage section at 230V AC and a low voltage section of ±12V (relative to the neutral potential).

Since the only components connected to live are the 10MΩ 1W resistor and 330nF X2 capacitor, all other tracks are clear of those pins. There can also be a fairly high voltage across TH1 and TH2 when they are conducting, so their terminals are kept clear of other tracks.

Construction

The Soft Starter for Power Tools is built on a 59mm × 80.5mm PCB, coded 10107121. This board is available from the *EPE PCB Service*. It is a double-sided PCB with tracks on the top side, paralleling the high-current paths on the bottom to improve its current-handling capability. All components are through-hole types, which mount on the top with the exception of the 10mΩ resistor, which is an SMD.



Here's a view inside the box, fairly close to life-size. You can clearly see the way the wiring is connected to the terminal block on the left end of the PCB – follow this along with the diagram above when wiring it up. If placed inside a metal box, the earth wires must instead be firmly anchored to the box – see text for more details.

Parts list – Power Tool Soft Starter

1 PCB, code 10107121, 59mm × 80.5mm (available from the *EPE PCB Service*)
1 6-position, 4-way PCB-mount terminal barrier (CON1)
2 Ametherm SL32 10015 NTC thermistors (Element14 1653459)
1 250VAC 16A SPST relay, 24V DC coil (Element14 1891740 or similar)
1 UB3 jiffy box or 1 diecast IP65 aluminium case
4 tapped M3 spacers, 5-6mm long (required only for diecast case)
4 M3 × 15mm nylon machine screws
4 M3 nuts
4 M3 shakeproof washers
1 chassis-mount M205 safety fuse holder
1 10A M205 fuse
2 M3 × 15mm machine screws and nuts (to attach terminal block to PCB)
2 cord-grip grommets to suit 7.4-8.2mm cable
1 100mm length brown mains-rated heavy duty (10A) insulated wire
1 50mm length 2.5mm diameter heatshrink tubing
1 short (~1m or so) 10A mains extension cord

Semiconductors
1 LM339A quad precision comparator (IC1) (*do not substitute* LM339) (Element14 9755969)
1 BC557 100mA PNP transistor (Q1)
2 12V 1W Zener diodes (ZD1, ZD2)
3 1N4004 1A diodes (D1, D2, D5)
2 1N4148 small signal diodes (D4, D4)

Capacitors
2 220µF 16V PCB-mount electrolytics
1 330nF X2 capacitor (Element14 1215460)
2 220nF MKT

Resistors (0.25W, 5% unless otherwise stated)

3 10MΩ	1 3.3MΩ	1 2.2MΩ	2 180kΩ
1 100kΩ	2 22kΩ	3 1kΩ	
1 10MΩ 1W	1 470Ω 1W		

1 10mΩ 2W/3W SMD resistor, 6331/2512 package (Element14 1100058) (NB: that is 10 milliohms, not 10 Megohms!)

Refer to the overlay diagram, Fig.6. Start by soldering the chip resistor in place. First, add some solder to one of its two pads using a hot iron. Place the resistor near the pads with its labelled side up, then heat the solder and slide it into place. Remove the iron and check that it is centred over its pads. If not, re-heat the solder and nudge it again.

Once it's in the correct position, solder the other pad. Add a little extra solder to the first one, to re-flow it and ensure a good joint.

You can then fit the smaller through-hole resistors, checking each value with a DMM to ensure they go in the right locations. Follow with the seven diodes, orienting them as shown on the overlay diagram. There are three different types; use the overlay diagram as a guide to which goes where (if you mix them up it won't work!).

Fit the two 1W resistors next, then solder IC1 in place. While we used a socket on our prototype (for development reasons) you shouldn't. Ensure IC1's pin 1 notch or dot goes towards the bottom left, as shown in the overlay diagram. You can then mount Q1, bending its leads with small pliers to suit the pad spacings. Its flat face is oriented as shown.

The two MKT capacitors go in next, followed by the electrolytic capacitors, with their longer (positive) leads through the holes marked '+'.

There are multiple pads to suit different sized X2 capacitors; solder it in place with one pin in the right-most position and the other through the appropriate left-hand hole.

Now you can fit the relay and thermistors (pushed as far down as they will go). Attach the terminal barrier using the 15mm M3 machine screws,

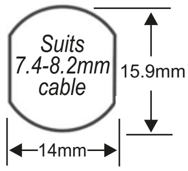


Fig.7: the correct cut-out to make sure cord-grip grommets do grip! Don't be tempted to simply drill a 16mm hole!

with a star washer under each head and nut. Do them up tight, make sure it's straight and then solder the four pins. The PCB assembly is then complete.

Housing

We housed our prototype in a UB3 jiffy box, which the PCB is designed to fit in. It is pushed down to the bottom of the box, so the taller components will clear the lid.

Even though it is a tight fit, to ensure it cannot move around it is fixed to the bottom of the box using nylon screws (the nuts inside can be nylon or metal).

If this unit is to be used on construction sites or in other rough situations where it's likely to be knocked around a bit, it should be housed in a larger, sturdier ABS plastic or (preferably) a diecast aluminium case.

If you want to do this, fit four tapped spacers to the mounting holes on the PCB and then drill four corresponding holes in the box. If the box is plastic, be sure to use nylon spacers and screws (metal is OK on the inside) so that you don't breech the insulation barrier.

If you use a diecast aluminium box, the two mains earth wires must have crimp eyelet connectors fitted (use a ratcheting crimping tool), both terminated on a machine screw through the case which is fitted with star washers and two nuts. This earths the case so that an internal wiring fault can't create a lethal situation.

Whichever housing you use, the first step is to drill three holes; two 14mm holes for the cordgrip grommets which the mains cables pass through and one 11-12mm hole for the chassis-mount fuse holder. The fuse holder can go alongside the entry for the mains supply lead.

Use needle files to expand the grommet holes to the correct profile (see Fig.7). The requirements for fuse holders varies, but they also often require the hole to be profiled; refer to the supplier or manufacturer data for the correct shape.

Solder a short length of brown mains-rated wire to one of the fuse-holder terminals and heatshrink the joint. Fit the fuseholder to the box and position the completed PCB inside it.

You can then cut the extension cord in half and strip a 50mm length of the outer insulation from both free ends. Also strip back 6mm to 8mm of insulation from each of the three inner wires of the two cables.

Feed the cables through cordgrip grommets, squeeze the grommet halves together and push them into place through the holes you made earlier.

If you are lucky enough to have a tool for inserting cordgrip grommets use that, otherwise some sturdy pliers will do. The grommets are hard to take out once they're in, so check that you have fed through an appropriate length of cable so that the individual wires will reach the terminals on the PCB. Keep in mind that the brown (live) wire from the plug end of the cable must reach the fuseholder.

Slip some heatshrink tubing over that live wire (plug end) and solder it to the free tab on the fuseholder. Slip the tubing down and shrink it over the joint. Secure the five remaining wires into the PCB terminal barrier as shown in the photo.

Make sure there are no stray copper strands and that the terminal screws are done up very tightly so nothing can come loose.

As mentioned earlier, if you are using a metal box (eg, diecast aluminium) you will need to make the earth connections to a chassis earth point rather than on the PCB.

Here's the complete project, ready to use. There are no controls on the box... because there are no controls! If used in a rough environment, we'd suggest a diecast box – even if it's a little larger.

Testing

Because the X2 capacitor limits the circuit current, it can be quite safely tested from mains – **but don't put your fingers anywhere near the PCB**.

First, check your wiring. Then put the lid on the box and install a fuse. Use a DMM to check for continuity between the earth terminals of the plug and socket. The resistance must be low (<1Ω).

Do the same check with the two live terminals and the two neutrals. The resistance between the two lives should also be low (<1Ω), while between the two neutrals it should be around 20-30Ω (the cold resistance of the NTC thermistors).

Also measure the resistance between each combination of live, earth and neutral on each plug. You should get >10MΩ resistance between earth/neutral and earth/live at both plug and socket. The resistance between live and neutral should be around 10MΩ at each end (it may read lower initially due to the capacitors charging).

Connect a 100W or greater 230V lamp (eg, a portable floodlight – incandescent, not LED!) to the output socket. While keeping your eye on the lamp, plug the power cord into the wall outlet and switch it on.

Check that the lamp switches on properly – for all intents and purposes, it should appear pretty normal in brightness.

But about one second after this, you should hear the relay click and the lamp will get slightly brighter. Switch the lamp off and check that the relay clicks off after about a second.

If it doesn't work, switch off at the wall, unplug both ends, open the box and remove the PCB. Check for components which are swapped or incorrectly oriented. If you don't see any component problems, check the solder joints and ensure that there are no breaks or short circuits between the tracks or pads.

(Kit suppliers tell us that around 50% of problems with kits are mistakes in component placement. Most other problems are bad solder joints [or components not soldered in!]).

Assuming all is well, you can then do a full test with a power tool to check that it is working as expected.

Remember that if you start the tool multiple times in quick succession, the second and later starts will not have as effective current limiting due to the thermistors heating up. ***EPE***

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Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	4[a]	10MΩ	brown black blue brown	brown black black green brown
❑	1	3.3MΩ	orange orange green brown	orange orange black yellow brown
❑	1	2.2MΩ	red red green brown	red red black yellow brown
❑	2	180kΩ	brown grey yellow brown	brown grey black orange brown
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	2	22kΩ	red red orange brown	red red black red brown
❑	3	1kΩ	brown black red brown	brown black black brown brown
❑	1[b]	470Ω	yellow violet brown brown	yellow violet black black brown

[a] 1 of the 10MΩ is 1W [b]1W

Capacitor Codes

Value	μF Value	IEC Code	EIA Code
330nF*	0.33μF	330n	334
220nF	0.22μF	220n	224

* must be X2 type

Solar max-out?

TechnoTalk

Mark Nelson

We're approaching a solar maximum and already the *Daily Mail* has warned of radio blackouts, interference with GPS navigation and communications satellites in space, as well as damage to power infrastructure on Earth. Is this doom-mongering justified, and will it wipe out everything electronic? Mark Nelson cannot be certain.

IT'S easy to mock the *Daily Mail* and to be fair, the sensational side of the approaching solar maximum has attracted the same doom-laden coverage in many other news media. But surely there must be an element of truth in this panic if so many reports are telling similar stories? In a way there is. Let's take a calm, sane look at what's causing all the fuss, the underlying science, what the worst-case scenario might entail.

The solar cycle

Of course you might be wondering what on earth 'astronomy' has to do with electronics here on Earth, and it's a perfectly reasonable question. The answer is a heck of a lot really, since solar activity powers solar cells (that was pretty obvious!) but also has a profound influence on radio propagation in space, in the stratosphere (upper reaches) and the troposphere (close to earth) and electromagnetic effects on Earth that can affect power lines and telephone cables. Any disturbance to the status quo is potentially problematic.

So what is the solar cycle? It describes how the level of the sun's activity changes over time. This includes changes in the levels of solar radiation and the expulsion of super-hot solar plasma, known as a coronal mass ejection. Billions of tons of solar particles are expelled from the sun and may reach Earth between one and three days later. These changes are periodic and tend to occur in cycles of about eleven years.

Don't do this at home but...

The solar cycle is also known as the sunspot cycle and at peak activity in the solar cycle (known as a 'solar maximum'), there is a discernable increase in the number of sunspots observed on the face of the sun. This phenomenon has been observed in the West since telescopes came into use during the 1600s (Galileo Galilei famously sketched them in 1612), although it was another 250 years before a pattern in the number of sunspots was detected. In those days, people used darkened glass to protect their eyes when observing the sun's surface, but there are safer methods nowadays, so ***always*** check an astronomy website for advice, such as **www.spaceweather.com/sunspots/doityourself.html**.

Negative effects

Communication systems affected by increased solar radiation include military over-the-horizon radar systems (due to increased radio 'clutter') and navigation systems such as GPS and LORAN (disruption to their signal propagation). Satellite communications also suffer as the increased strength of charged particles striking the shell of the 'bird' can lead to electrical discharges that harm, disable or prematurely age components and cause overload damage to solar panels. Scintillation of satellite signals during ionospheric disturbances can have knock-on effects to their telephone, television, radio, and Internet link payloads.

High-voltage power transmission lines, particularly the long-distance ones to be found in China, North America, and Australia, are susceptible to heavy induced currents that can saturate the cores of transformers, an effect that has caused havoc outside Europe when distribution networks have key components knocked out. Finally, it is suggested that the navigational ability of homing pigeons, dolphins and whales could be degraded.

Benign effects

Some of the effects of a solar max are beneficial, at least to hobbyists. Aurora watchers can have a field day, while long-distance radio communication in the upper HF and lower VHF range is enhanced. Auroras can reflect VHF communications, giving audio a peculiar 'ghostly' sound quality, and abnormally long distances can be covered on the six-metre amateur radio band. Enhanced F2 layer multi-hop reception of VHF FM radio means signals can travel 2,000 miles or more. Even greater distances can be spanned when trans-equatorial propagation is enhanced at the peak of sunspot cycles, enabling the reception of television and radio stations between 3,000 and 5,000 miles on frequencies as high as 432MHz. On the other hand, HF communications below 30MHz are subject to disturbance. A website worth viewing for the latest solar news is **www.solarham.net**.

History lesson

The largest scientifically recorded geomagnetic storm occurred in September 1859, known as the '1859 solar superstorm' or the Carrington Event. Studies of ice cores suggest a storm takes place only once in 500 years or so. As well as unusually high numbers of auroras, it was recorded that the solar storm induced abnormal currents in landline telegraph links that used one line wire and an earth return. Excessively strong and spurious currents overpowered the signals being sent.

In an address to the Royal Society of Arts in 1894, Sir William Preece, the Engineer-in-Chief of the General Post Office (which ran the telegraph service), speculated on this theme: 'Strange mysterious sounds are heard on all long telephone lines when the earth is used as a return, especially in the calm stillness of night. Earth-currents are found in telegraph circuits and the aurora borealis lights up our northern sky when the sun's photosphere is disturbed by spots. The sun's surface must at such times be violently disturbed by electrical storms, and if oscillations are set up and radiated through space, in sympathy with those required to affect telephones, it is not a wild dream to say that we may hear on this earth a thunderstorm in the sun. If any of the planets be populated with beings like ourselves, having the gift of language and the knowledge to adapt the great forces of nature to their wants, then, if they could oscillate immense stores of electrical energy to and fro in telegraphic order, it would be possible for us to hold commune by telephone with the people of Mars.'

Worst-case scenario

As we approach solar maximum, are we really doomed then? An article in *Scientific American* suggests that an event of the magnitude of the 1859 solar storm could bring damage to power, communication and satellites system costing billions of dollars, as well as electrical blackouts that might take weeks to eliminate (**www.scientificamerican.com/article.cfm?id=bracing-for-a-solar-superstorm**). We can only pray that this does not happen, although with 500-year intervals between these events, we can hope the next catastrophe is not imminent.

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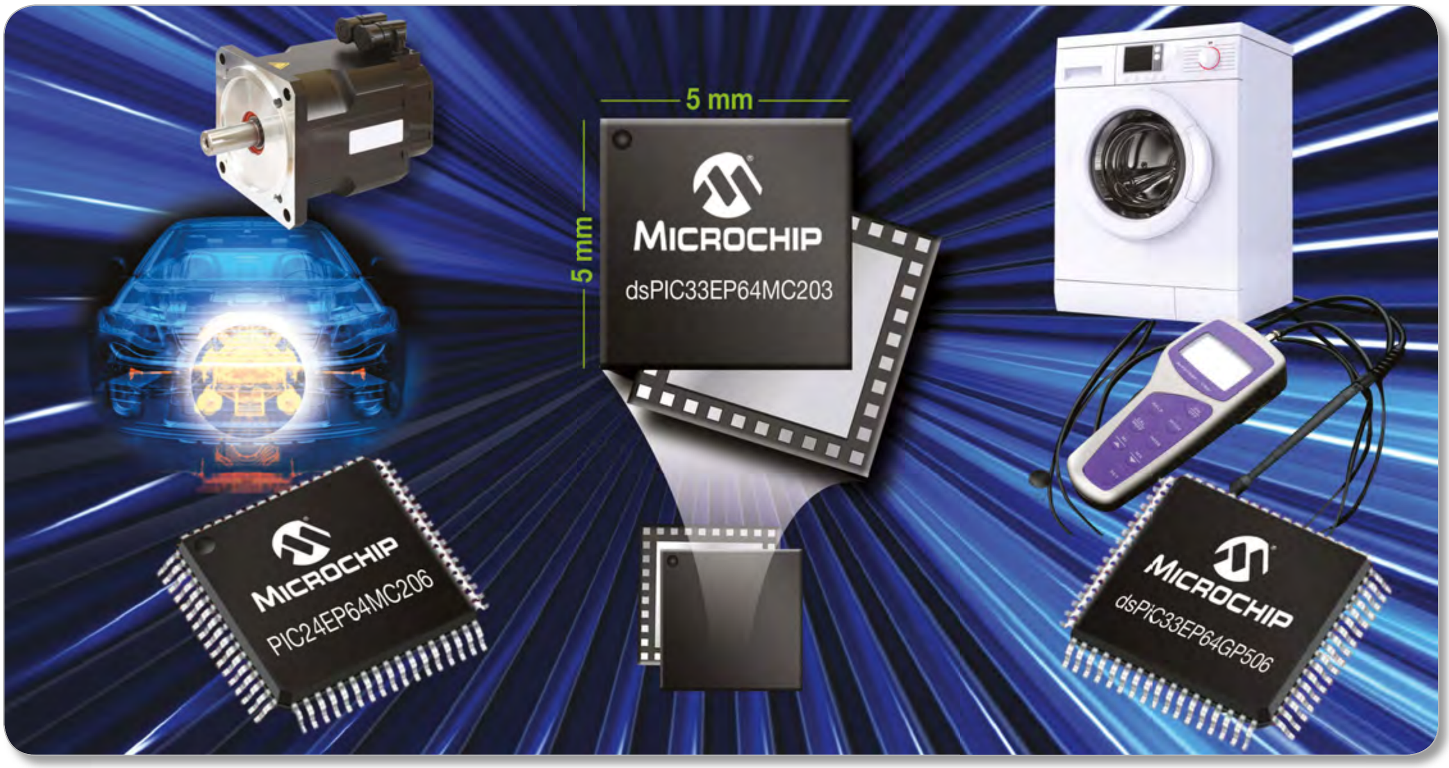

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Want a tiny, HIGH POWER brushless motor?

Start with an old CD/DVD-ROM drive!

Did you know that you can convert flea-power motors from old CD or DVD-ROM drives to high-power operation? You can use them for any model you care to build, and as we show here, even fly an aircraft wth them! While it may seem improbable, it is relatively easy to do; the main change being to fit neodymium 'rare earth' magnets.

I'VE BEEN interested in aero-modelling for many years. When I heard whispers a while ago that I could make my own high-performance brushless model aircraft motors using parts salvaged from an old floppy disk or CD-ROM/DVD drive, at first I was sceptical.

But after doing a little research, I found that it was indeed possible. It seemed that all that was basically required was to place some so-called 'super magnets' inside the motor and to replace the windings to enable higher current flow.

However, as with many projects, when I looked further into it I discovered it wasn't going to be as straightforward as I'd imagined.

I would need to find a good source of old drives, locate the required type of neodymium 'rare earth' magnets, suitable ball-bearings and access to a lathe.

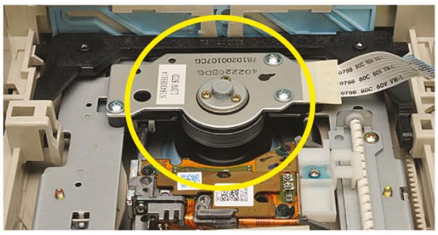
The lathe wouldn't be a problem because my dad recently gave me his old Emco on permanent loan. Finding the right bearings also wasn't much of an issue; the types required are used extensively in the likes of model helicopters and cars and are sold in most model shops (and are also widely available online).

The magnet hurdle also proved easy enough to overcome, since I soon found a source on the web prepared to ship as many as I wanted, and so I promptly sent away for a couple of sets. The next big problem was impatience; the magnets would take a couple of weeks and I wanted be up and running today!

Sourcing parts

Since I own a computer repair company, finding old drives is not a problem; most workshops like ours have a healthy stack of them until periodic clean-outs mean we get to start on a new stack. It is worth ringing around to see what repair shops have available – and avoid those who'll want to charge you for taking away what is essentially rubbish.

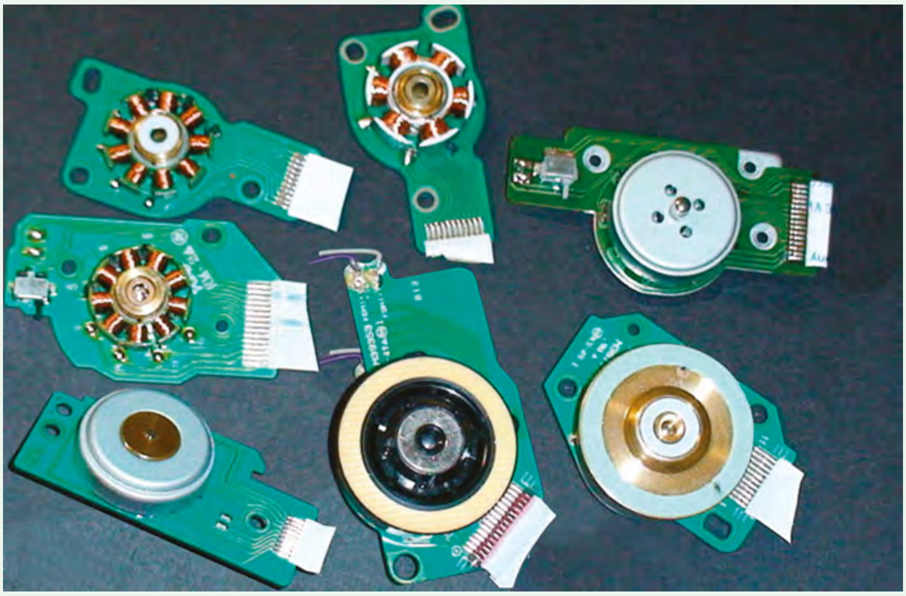
One of the bigger problems you'll face is that many optical drives don't



Here's a typical (if a little ancient) CD-ROM drive, shown in its 'as-removed-from-old-PC' state at left. The centre photo shows the controller board removed, revealing the motor in the centre (circled). Finally, the photo at right shows what we are after: the motor removed from the CD-ROM drive (via those three Phillips screws on the bracket in the centre photo) and held in the hand to show just how small the motor actually is. Despite its tiny size, it's quite a powerful little beast and, just as importantly, is very reliable (when CD-ROM drives fail, it's very rarely the motor that has given up the ghost). But even more important, this motor can be modified to give significantly more power output – enough, in fact, to power an electric model aircraft. And that's what we are doing in this feature.

By
Dave Thompson

At right: an assortment of motors pulled from various surplus drives. Note the variety of styles and sizes; while you can fashion your motor using any sized 'donor' motor, most builders use the 26mm model because the majority of available magnets are designed for this 'standard-sized' body.



use what has become the standard-sized motor; a roughly 25-27mm diameter can/bell with an overall thickness or bell depth of around 6mm. While you can theoretically make your brushless motor from any old drive motor you salvage, many are not particularly suitable for the job, nor are they physically compatible with the standard sizes of available magnets, the majority of which have been designed to fit the 25-27mm motor mentioned above.

I stripped half a dozen old drives to get a couple of decent bells. So get as many old drives as you can while you're on the scrounge.

If you're wondering why I didn't simply work out which make and models of drive contain the right motors and look for them, rather than go through all this rigmarole, it isn't that simple.

You can take two outwardly-indistinguishable models and find they have significantly different mechanisms. The chipset and firmware might be the same, but the cradle, motor and laser assemblies vary greatly from drive to drive, even within supposedly 'identical' models.

Useful bits and pieces

Regarding other parts in your optical drive, there are several parts which could come in useful.

Retain the chromed shafts the laser assembly runs on, as you can use these for prop shafts. They are usually high-quality chromed steel and well worth saving. However, they are often coated with grease, so you'll probably have to clean them before use.

Also take care with the laser. If your donor unit is an 8× or faster DVD drive, the laser diode is a sought-after component for optics experimenters who want them for match-lighting and balloon-popping laser projects, so careful extraction is worth-while.

I suppose you could even sell the laser for a few dollars to cover any costs you may have incurred obtaining the drive, or save it for your own evil-genius laser projects.

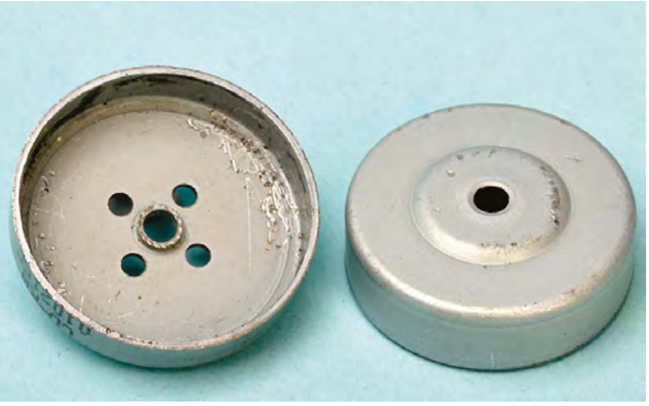
Then again, anyone who wants one of these has probably scrounged it themselves (and possibly discarded the motor!).

If you do decide to salvage it, take great care, as I've found these laser diodes to be extremely static-sensitive and physically easy to damage, and they are usually solidly fastened to the head assembly.

While you are breaking the drive down, there may also be many little gears, switches, bearings, belts and other bits and pieces that always come in handy, so get as much as you can from each drive.

Even if the motor is not a suitable donor, there are plenty of other goodies worth salvaging or passing on to someone who will use them.

A small selection of the thousands of commercial brushless motors available. They're easily distinguishable from standard (ie brushed) motors because invariaby they will have three wires – brushed motors have just two.



Standard sized bells ready for modification. Note the difference in heights. As long as you have enough material to safely glue the magnets to, any sized bell can be used. Also note the lip on the inside of the centre hole – this must be removed as described in the text.

Which motor type?

There are two basic configurations: in-runners and out-runners. An example of an in-runner motor is your typical DC brushed unit, in which the body of the motor remains static and the armature or rotor spins – your car's starter motor is a classic in-runner type. An out-runner motor, on the other hand, has a fixed stator and the outside or motor body rotates instead, typically with a drive shaft connected to the rotating body, to which gears or in my case, propellers are connected.

Out-runners are very efficient, which is why motors like these can deliver a surprising amount of power for their diminutive physical size. Our motor will therefore be an out-runner.

The first thing to do is break down your acquired motor. Sometimes the two halves are only held together by the existing magnet's magnetic field, so pulling this type apart is very easy.

Some will have an 'R' clip, circlip or similar device holding things together. If you strike a clip version, easing the clip free will allow the two motor halves to be parted (if you get the clip off in one piece, save it for optional use later).

If in doubt, a good pull should separate the motor without breaking anything. If you find yourself reaching for a screwdriver in order to lever things apart, be very careful, as it doesn't take much to ruin either component and we need both bits completely intact.

Once the outer bell is removed, you'll see it contains a ceramic magnetic ring. Also note the exposed stator remaining attached to or pressed onto the motor's circuit board (unless you've already stripped that part away).

Put the stator part to one side for the moment and let's look at the bell. Your bell may already have a shaft fixed in place, running down the centre through the stator. If so, count yourself lucky, because very few do these days, however, this pretty much shoehorns you into what style of motor you will be building; more on that later.

When the plastic disc holder, which is typically mounted to the 'top' of the bell assembly is removed (it should pry or break away reasonably easily), you should see a small-lipped hole in the centre. This will later be utilised to house our prop-shaft. Take the bell and, using a small jeweller's screwdriver or similar tool, carefully pry the magnetic ring out.

Take care not to distort the bell doing this; they are reasonably strong but can be easily bent out-of-round if you are too vigorous. It doesn't help that the ring usually doesn't come out easily; though it may seem like it, most are not actually glued in place, relying instead on a very tight interference fit and they sometimes take some removing.

The material the magnetic band is made of is similar in consistency to a ferrite rod, meaning they are very strong but quite brittle.

I usually just break the ring in order to remove it by using an automatic centre-punch; the type you set by turning the end to adjust the spring tension/impact energy and then push down until it 'hammers'.

Start with a lower tension setting before cranking things up to 11. This method seems to shatter the ring easily and a higher setting may end up ruining the bell.

Unless you really want to retain the ring for other experiments, I suggest you do the same; removal without breakage is possible but usually difficult. Once broken, the bits fall out easily.

Check the now-empty bell for any remaining debris and if necessary clean it out with some methylated spirits on a rag; we will soon be gluing to this inner surface, so it needs to be as clean and contaminant-free as possible.

If your bell is one of the rare types that doesn't already have a hole in the centre of it, you'll have to make it. The hole can be drilled by hand with a suitable drill press or hand-held drill, though if you have access to a lathe, this will make the job easier and far more accurate.

If you drill by hand, be very careful to get things perfectly centred. If you don't, even by the tiniest amount, your motor will likely shake itself (and anything attached to it) to bits.

The hole should be the size of the intended prop-shaft and if you have retained the chromed shafts the DVD drive's laser-head assembly was running on then you already have the best item for the job. These are usually 3mm in diameter, so use a suitably-sized drill to make the hole in your bell a tight fit for the chosen shaft.

Once the hole is made, clean it up by using a counter-sink bit or a larger drill to ensure there are is no swarf left behind.

If the bell already has a hole, chances are it has a lip on the inside edge as shown in the picture . This lip will need to be removed. Again, if you have a lathe this is relatively simple, though it can also be done by hand using a larger drill bit, something in the order of 9mm (3/8th inch).

Proceed as if you were counter-sinking the hole and carefully take the lip down until fully removed. The bell material is not hardened, so the drilling should be quite easy. I shouldn't need to stress that going too far will ruin things, so take it slowly.

Motor styles

At this stage you'll have to decide on what style of motor you will build, taking into account how you will ultimately mount it in your model and how you fit the prop shaft to the bell.

One configuration has the bell at the back with the prop shaft running forward through the stator/body assembly. This configuration suits bells with a built-in shaft, as mentioned above.

The second configuration is more common because more donor motors come without embedded shafts and this is the type of motor I built. This version has the bell at the front and the prop

The bearings are tiny – and they are also one of the most important parts of the motor, given the high speed at which it spins. It's always wise to replace any bearings with new ones – they're not particularly expensive and are available at many model shops.

shaft runs forward through the bell to the propeller as well as back through the stator/body assembly and anchors with a circlip at the rear bearing.

In either type of motor, the bell is fixed to the prop shaft via either two nuts or a brazed-on brass fitting and grub-screw assembly – the latter is this type I describe here.

You also have a choice of propeller mounts. You can use two nuts on a threaded portion of the shaft or you can use any of the 'propeller-saver' fittings commonly used on electric model motors (see photo).

Propeller savers have the advantage that they mount using two opposing screws, meaning you don't have to thread the shaft and the prop is held on with an O-ring that loops over the prop and around the mounting screws; should you hit the ground, the prop simply flexes out of the way and hopefully doesn't break.

My advice is to avoid hitting the ground!

Mounting the prop shaft

Methods of mounting the propeller shaft requiring heat (brazing or soldering fittings onto the bell) must be done before the magnets are fitted. Some people might want to braze or solder the prop shaft directly onto the bell and this is fine, as long as it is centred and straight.

However, we have a chicken and egg scenario; fitting the shaft or shaft holder now will make placing the magnets much more difficult, especially if you don't have a jig, whereas heating the bell after the magnets are placed will ruin all your hard work.

I suggest not fixing the shaft to the bell permanently, instead using a removable system such as a brass shaft retainer. This enables you to use the same prop shaft on a variety of bells and motor bodies.

If your shaft is to be cold-fitted, that is, mounted with a couple of nuts either side of the bell, you can proceed with placing the magnets. If you want to braze a shaft-holder to the bell, you can do that now.

Using a lathe, turn up a suitable shaft holder from brass or steel and drill and tap the retaining grub-screw hole(s). Using the prop-shaft as a guide, carefully position and braze the shaft holder in place. Mount the whole bell assembly in a lathe, drill-press or even an electric drill and spin it up, checking to see everything is nicely aligned.

These motors rev like you wouldn't believe and if your alignment is out, the whole thing will vibrate badly and cause problems, so you'll need to either tap it into round or re-do it until you are satisfied everything is perfectly centred and running true.

Once the shaft holder is fitted, you can now remove the prop shaft and proceed to assemble the magnets.

There are many sources on the web for the right-sized rare-earth magnets. Most of these accept Paypal or similar online payments and fire your magnets out in a small envelope as soon as payment clears.

The exact magnet size you'll need will depend on the dimensions of your bell and stator, but 5mm x 5mm x 1mm is a good size to start with.

I began buying my magnets from a US source. I ended up importing magnets made to my own specifications and while this was an expensive exercise, I have since sold many sets to other enthusiasts at about half the price others were charging and this has helped recoup some of the costs.

There are two main types of magnets used in our motors; flat and curved.

Flat magnets tend to be cheaper and can be fitted into a wider variety of bells; curved magnets are usually designed to fit the more standard 1 inch/25-27mm diameter bell and while slightly more expensive (due to the manufacturing process), they are also more efficient.

If you are aiming for maximum performance from your motor, curved magnets provide the best possible efficiency and power output.

Whatever magnets you use, you'll need twelve of them per motor and since they are very small, things can get a bit fiddly.

Refer to the images and note how the twelve magnets are placed; they are equally spaced around the circumference of the bell and their poles are reversed in alternate order, so you have, facing inward (or outwards) a north-south-north-south-north-south configuration.

It is vitally important you observe this same configuration, otherwise your motor will not run properly,

(Left): they're sometimes called 'scary magnets' because they are so powerful (don't get your fingers caught!). In fact, they are 'rare earth' (or neodymium) types and getting them apart can be rather tricky!
(Right): here's the little plastic jig I made up to allow accurate magnet placement inside the motor bell.

These two pics show how the new magnets are glued inside the motor bell. At left, spacers hold the magnets at the correct distance apart, immediately before glueing in place. They do have a tendency to move of their own accord without the spacer. At right, this part of the job is finished, with all the magnets glued in position. Take care not to get any glue on the face of the magnets: clearances are rather tight!

if at all. When you buy a 'set' of 12 curved magnets, you should receive six polarised one way and six the other. Whichever magnets you use, figuring out which way they go is critical.

You don't need to know north from south, just that this side of the magnet is one pole and the opposite side the other pole, meaning the next magnet in the bell must be the reverse of the previous one.

I figure it all out during assembly by putting two magnets together; if they stick, then they are facing the same way; if they try to push apart, that's how they should be placed in the bell.

I originally placed all my magnets by hand, and if you are adept at small, somewhat fiddly tasks this will not present a problem.

However, I have since created a simple plastic jig which has made things easier (see the photo on previous page). If you are serious about making more than a few motors or have fingers of butter and fists of ham, I suggest a jig may be the best way to go, although it is by no means mandatory to use one.

I have also used spacers made from either card or plastic to separate the magnets before and during gluing, however you need to be careful you don't glue the spacer in as well, as these can be difficult to remove without damaging the magnets and bell assembly.

Super glue

At this point, we should have a quick look at the types of glues used in our motors.

Hobbyists would know about so-called 'instant' or 'super' glues, which are thin, fast-setting cyanoacrylate-based adhesives, marketed under a wide variety of names.

However, many people are unaware there are also gel-style cyanoacrylate glues, which are much thicker in consistency and take a few seconds longer to cure then their water-like cousins.

It is this type of instant glue I use to cement my magnets in place. Not only does this give me a little more time to ensure I have things in the right position before the glue sets, I also end up wasting a lot less because it doesn't run everywhere or create problems.

Another very-useful-but-optional addition to my glue tool-kit is cyanoacrylate accelerator, which is used to decrease glue curing time. It usually comes in a pump-type applicator or small spray bottle and can be directed onto the area, instantly curing any cyano-based glue it touches.

A tube of thin instant glue, one of gel-style instant glue and a bottle of accelerator will suffice for all our motor gluing needs.

The magnets stick to the metal side of the bell quite well by themselves (duh) so it is relatively easy to place the first one, hit it with a spot of instant glue and when set, carefully place the next one, spot glue it and so on until all are placed.

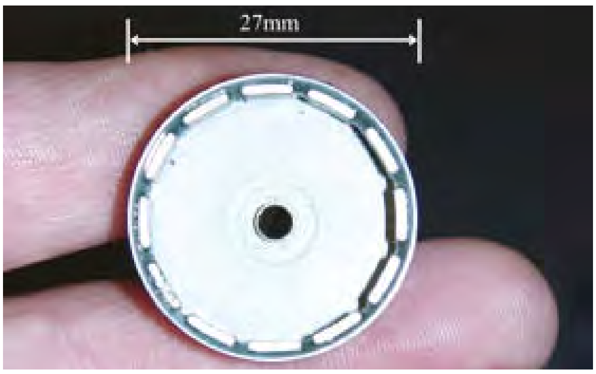
Trying to put all the magnets in and align them before gluing usually ends up like a comedy skit, with your magnets suddenly jumping about before clicking together to form a single column stuck to the bell and all facing the same way.

Keep in mind that these magnets are unbelievably strong for their size and given any chance at all will move just where you don't want them to. If you do happen to end up with a magnet 'stick', pulling them apart is virtually impossible – they need to be 'slid' sideways off each other.

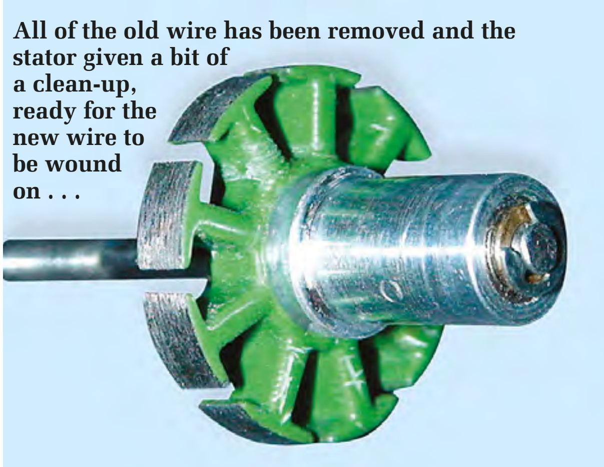
Just be careful that you don't get any flesh between them if they snap together or you might be tempted to say some very naughty words (like 'bother', 'ouch' or even 'oh dear').

I found that carefully placing and securing each magnet before moving on to the next is the best way to proceed, as it keeps everything under control and also allows me to get my magnet positioning right.

Once you've done this a few times, it gets a lot easier, and having a jig to hold things in place as well is a definite advantage. Keep in mind that while magnet spacing is not hyper-critical, (it really doesn't matter if you are off half a millimetre here or there), performance can suffer if the magnets are too far out of line, so try



Another view of the completed motor bell and magnets sitting on the author's fingers . . . giving a good idea of just how small these motors are!



All of the old wire has been removed and the stator given a bit of a clean-up, ready for the new wire to be wound on . . .

And here are the new windings. If you look closely, you can see that the coils are in series with each other, spaced 3 apart (see the wiring diagram below).

to be as accurate as you can. Again, a jig helps here.

When you have all twelve magnets tacked in place, go around, and if necessary add another spot of glue under and between each one to be sure everything is well-anchored in.

Flat magnets will usually have a slight gap under their middle, with only the ends touching the bell, and this gap should be filled with a drop of gel glue as well.

Once done, run the thin glue all around to fill in any gaps and hit the whole thing with your glue accelerator. This should set things nicely and result in a solid mass holding the magnets in place.

Just make sure you put all the glue drops in before giving it a spray, as the accelerator will instantly cure any liquid glue it touches, even that coming out of the tube or on your fingers! (You can also buy cyanoacrylate solvent if the worst comes to the worst).

Also make sure no glue encroaches past the inside-facing surface of the magnets as things run very close and the rotor binding on the stator is one sure way to damage your motor and potentially burn out your speed controller. So, your bell should now have all the magnets glued in place and be ready for the shaft to be assembled.

Mounting the prop-shaft is one of the critical parts of the job because it must be centred and dead straight. If you brazed a shaft holder as described earlier, yours is already done, however if your bell has room and you are taking the locking nuts route, then you've a bit more to do.

Find some appropriate low-profile nuts and thread the back end of the prop shaft you are going to be using to suit.

Mount the bell using one nut on the inside and one (preferably a 'nylock' or similar locking nut) on the outside. Tighten fully and spin up the assembly as described above.

It should be nice and balanced with no wobbling or wandering out of round. If it is out, tap the high side gently with a light (rubber) hammer and try again, repeating the process until it runs true. Once done, put it to one side as you are now ready to wind the stator.

Important note

The prop shaft will be exposed to some very high stresses and possibly temperatures as well. Do not just glue it in place because this can only end in tears – very likely your own – when it flies off and hits you.

As mentioned, these motors are surprisingly fast, so whichever method you use, the prop shaft must be mechanically very well secured to the bell.

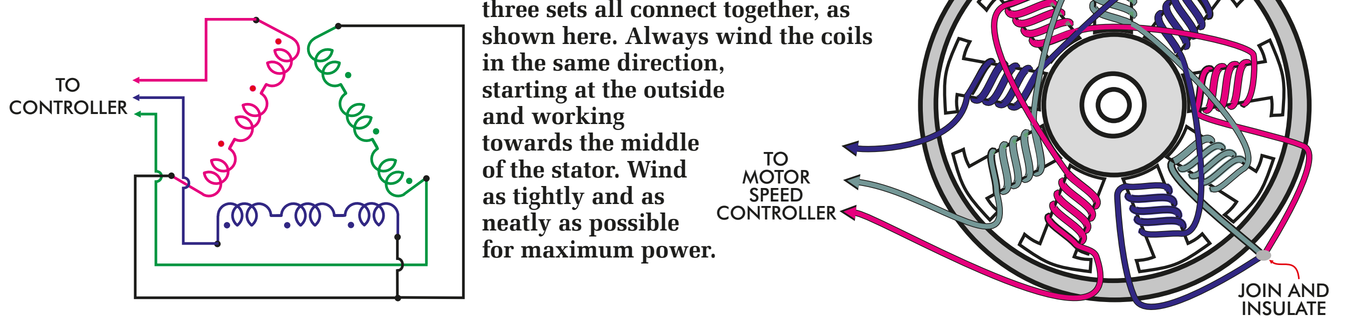
The motor body

Now is the time to decide on the body style and mounting configuration you will use.

Both use the same simple turned aluminium body, though the top hat/bulkhead mounting method requires more lathe work than the other clamp-style mounting system, so it is up to you which one you use.

Both methods require an aluminium cylinder, turned from 10mm or similar aluminium stock, which will become the motor body.

The body must be fabricated so that the stator press-fits into the hole in its centre. Make it about 30mm to 35mm



Here's how to re-wire the motor – there are nine identical coils, each connected as shown here with three in series. The dots indicate the 'start' of the coil while its end connects to the start of the next coil and so on. The 'starts' of each of the three sets of three coils then connect to the motor controller, while the 'ends' of the three sets all connect together, as shown here. Always wind the coils in the same direction, starting at the outside and working towards the middle of the stator. Wind as tightly and as neatly as possible for maximum power.

long and if you use a standard stator, it should be about 8mm in diameter to ensure a perfect tight (interference) fit.

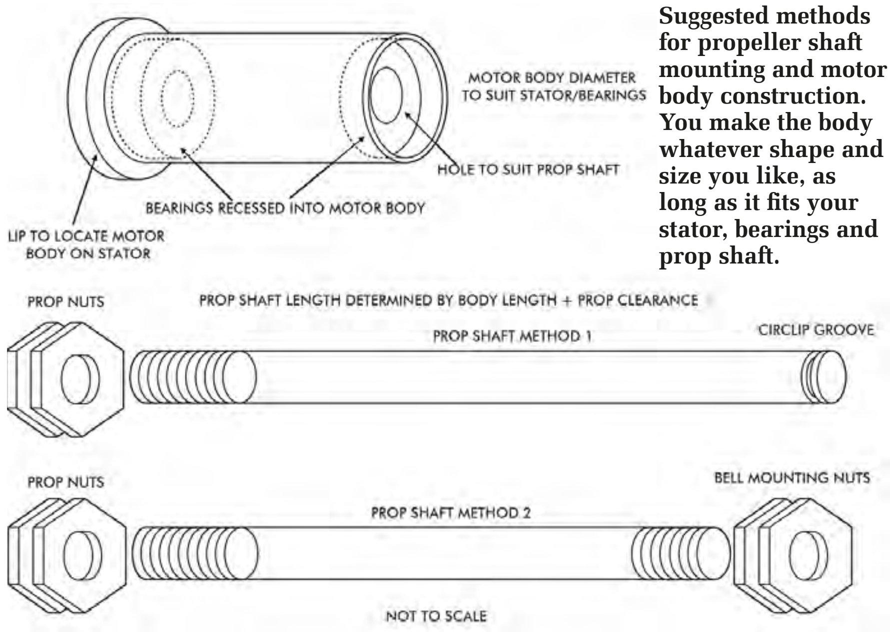
Each end of the shaft then needs to be turned to fit your choice of bearing. If you retained the chromed shaft from your donor CD/DVD drive, the bearings should have a 3mm inside diameter to accommodate the shaft and about a 6mm outside diameter.

As mentioned, these are standard-sized bearings as sold for replacement parts for model cars and helicopters and as such are easily sourced and inexpensive.

If you chose something different for your prop shaft you'll need to source bearings that will suit it.

This is where engineers can have a lot of fun making their motor bodies from whatever material and parts they may have lying around in their bits boxes.

The only considerations are strength and weight – we want to make the motor strong enough while keeping it as light as possible.



Suggested methods for propeller shaft mounting and motor body construction. You make the body whatever shape and size you like, as long as it fits your stator, bearings and prop shaft.

Winding the stator

Now take the stator and push out any centre and strip any PCB or other mounting material from it along with the existing wire until you are left with a naked unit.

It is best to start with known working configurations and if you want to experiment from there, fine.

I recommend starting with 10 to 13 turns of 0.4mm enamelled copper wire, wound as neatly as possible. You can use more turns of a lighter wire or less of a heavier wire (anywhere from 0.25 to 0.5mm or larger).

It is essential you follow the winding directions exactly and wind the same number of turns in the same direction on the correct arms of the stator; any discrepancies here are as potentially damaging as mechanical imbalances.

Once wound, you'll need to connect the stator windings to your speed controller. There should be three free 'ends' that will need connecting and the easiest way to do this is with a strip of Veroboard with the appropriate tracks drilled.

Simply cut a piece wide enough for your motor body to pass through and with a spare track each side and make sure the strips run length-wise. Drill a hole closer to one end big enough to fit your motor's body and break the tracks where required with a 3mm drill bit to create three separate connections near the other end of the board.

Make the hole a reasonably tight fit for your motor body; there are usually no significant stresses or strains on the connector board, so gluing should not be necessary but if you do encounter movement, a spot of instant glue should suffice.

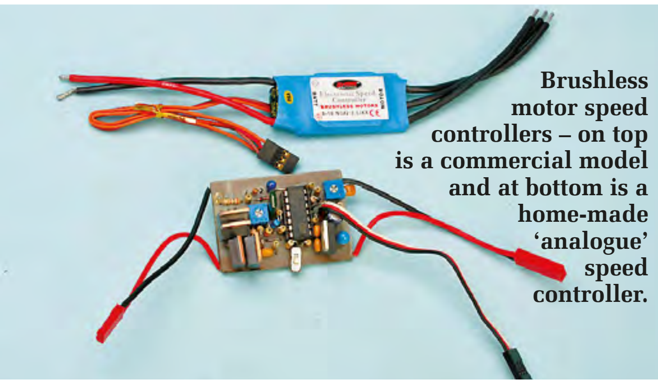
Carefully cut your windings wires to length and scrape the insulation using a hobby knife or similar. Tin the bare leads well before soldering to your connector; high-resistance joints here will cause problems.

Setting it all up

By now your motor body should be complete; the windings wound, connector board fixed and the leads nicely soldered. All that remains is for the magnet/bell/prop shaft assembly to be sized and fitted.

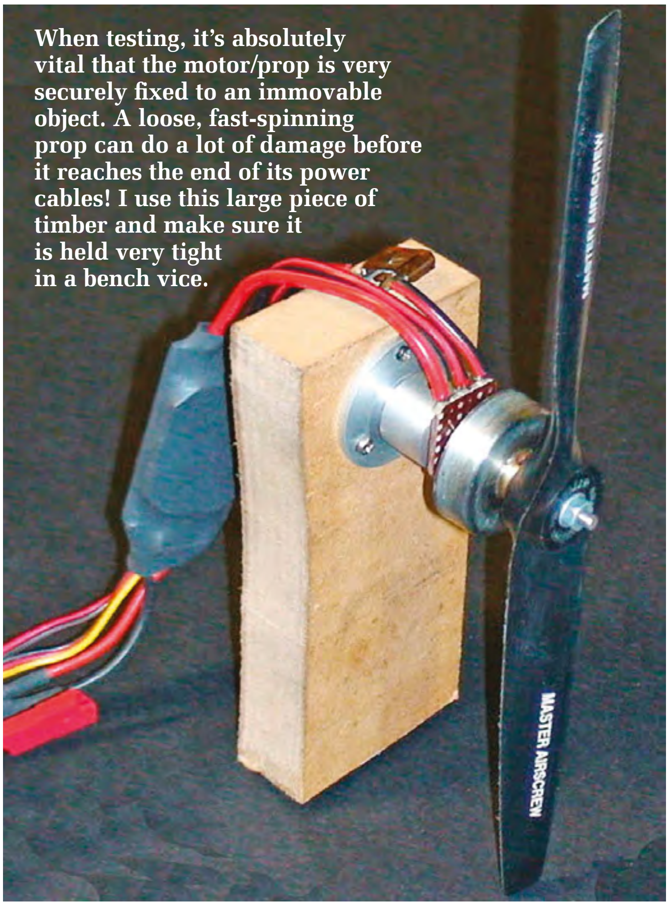
This is how I set mine up:

- I fit the prop shaft loosely through the brass shaft holder and feed enough of the shaft through the bearings in the motor body until it clears the end of the back bearing.
- I have already turned a groove into the end of the prop shaft in order to accept the circlip and I then fit the circlip.
- I push the shaft toward the front of the motor, (the prop end) until the circlip is flush with the back bearing.
- I then push the bell/magnet assembly down the prop shaft until it sits nicely over the stator but doesn't rub against it.



Brushless motor speed controllers – on top is a commercial model and at bottom is a home-made 'analogue' speed controller.

This commercial 'propeller saver' mounts onto the propeller shaft by tightening the two Allen screws. The propeller locates onto on the saver's centre boss and is held in place by a suitable O-ring looped around it and the two Allen screws. In a crash, the O-ring flexes or lets go altogether, releasing the propeller and hopefully saving it from damage.



When testing, it's absolutely vital that the motor/prop is very securely fixed to an immovable object. A loose, fast-spinning prop can do a lot of damage before it reaches the end of its power cables! I use this large piece of timber and make sure it is held very tight in a bench vice.

- I nip up the grub screws holding the prop shaft and give the bell a turn. It should feel totally free but magnetically 'lumpy', the lumpier the better.

  Any rubbing must be investigated and dealt with before applying power. Fine tune the bell position on the shaft if necessary. The bell should definitely NOT rub on the windings.
- I then measure how long I want the prop shaft to be and mark it – you can make it any length to suit your models and mounting methods (within reason of course). I remove the shaft from the motor, cut it to length and then thread it for fitting the prop nuts.

If you are using a propeller saver device, simply cut the shaft to length and then round the end of the shaft using a file or sander.

You can now mount the propeller. Your motor is finished and ready to mount and test.

Testing

If you are using a metal clamp style arrangement to hold your motor, take care you don't squeeze too hard or short the connector board. If you are using a 'top hat' bulkhead mounting system, make sure the grub screws are tight and evenly clamping the motor body.

Over-tightening either mounting system may damage the aluminium motor body so take care not to overdo it.

Wire up your speed controller, R/C receiver (or servo simulator) and LiPo battery as you normally would.

For safety, I always mount a 15A miniature car fuse in one of the speed controller's lines to the motor. LiPo batteries, as used in models like this can pump out some astonishing currents and a cheap fuse can save a lot of grief!

Mount the motor solidly in a vice, test rig or your model and switch on all your R/C gear.

Plug in the motor's LiPo battery, making sure you keep well clear of the propeller.

Most modern speed controllers have a protection feature built-in which won't allow the motor to run at all until the throttle is set to absolute zero, (check your trims as well) but some older speed controllers do not have this facility.

If all looks good, slowly apply some throttle and your brand new motor should leap into life. If you want to get serious about experimentation, a full test rig with a tachometer, voltmeter and ammeter installed is the only way to really fine tune your propeller, wire gauges and number of turns combinations.

Typically, though, you'll just want to get the motor into a plane and go flying and trim it out from there. Whichever way you do it, you have just created a well-performing brushless motor out of junk and that is a satisfying achievement!

Propellers

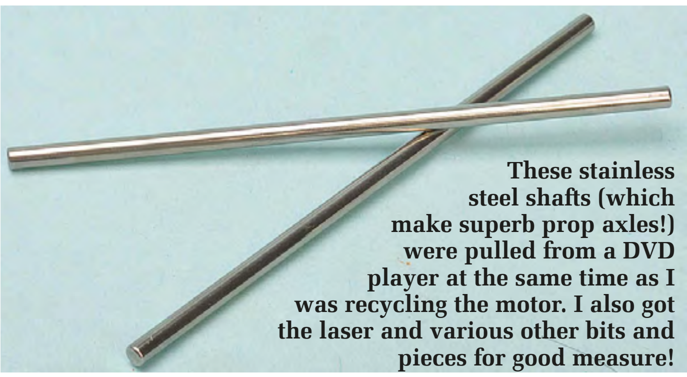
Propeller size depends greatly on the size of the motor you've made, the number of windings and the gauge of the wire used.

If the prop is too small, the motor may rev too high; too big and it might not rev enough and a heavy prop may cause electrical overloading and overheating.

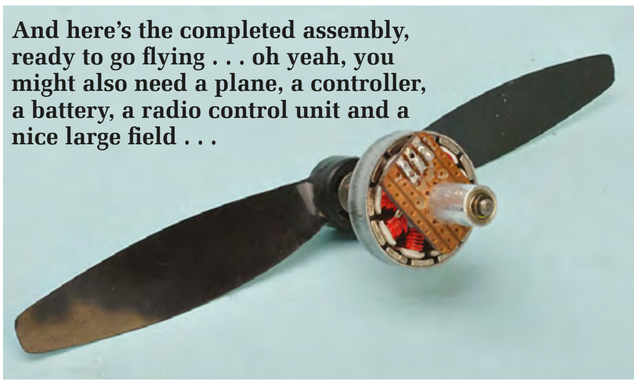
Either condition may damage the motor, especially if you run it at high speed in a test rig without adequate cooling.

Note that the prop blast is *not* usually sufficient to keep things cool when the motor is static at higher revs, so take care when giving it the beans on the bench.

I started with a couple of props, one a 6 × 3 (6 inches diameter and 3-inch pitch) and the other a 7 × 4. On my motors, the smaller prop allowed for very high revs but not a lot of performance in my model. The 7 × 4 suited it much better and the model flew very well with it, while keeping the revs and temperature down. ***EPE***



These stainless steel shafts (which make superb prop axles!) were pulled from a DVD player at the same time as I was recycling the motor. I also got the laser and various other bits and pieces for good measure!



And here's the completed assembly, ready to go flying . . . oh yeah, you might also need a plane, a controller, a battery, a radio control unit and a nice large field . . .

By NICHOLAS VINEN

High-Current Adaptor For Scopes and DMMs

If you want to measure and monitor mains current of up to 30A using your DMM or scope, this is the safe and easy solution. It works just as well with DC and it has significantly better resolution and bandwidth than most clamp meters.

IN OUR LABORATORY, we often need to hook our digital storage oscilloscope (DSO) up to mains-powered equipment to examine the current waveforms. The two most common ways to do this are with a shunt resistor and differential probe or a clamp meter. But both approaches have drawbacks.

A shunt resistor connected in series with one of the mains conductors (eg, neutral) provides the best bandwidth and resolution, but you need a differential probe (which can be expensive), even if you are measuring on the neutral leg, since neutral is usually a few volts above or below earth potential.

The resistor also limits how much current you can measure, depending on its value. For example, a 0.1Ω 10W resistor limits you to measuring around 7A RMS (after de-rating by 50%). This option can also be quite unsafe because the wiring between the shunt and probe is connected directly to mains.

A clamp meter is safer because it doesn't require any exposed mains wiring. But they tend to have a fairly low output voltage, eg, 1mV/A. This gives you lousy resolution and noise performance with scopes, which usually have a maximum sensitivity of 5mV/div. Clamp meters also typically have quite limited bandwidth (eg, 10kHz) which is no good for loads with fast-changing current waveforms – for example, switch-mode supplies.

Also, you need to separate out the mains conductors to use a clamp meter, since if you just clamp it over the cable, the live and neutral currents are of identical magnitude and opposite in direction, so their magnetic fields effectively cancel. Hence you need some kind of special cable or adaptor to measure mains current with a clamp meter.

Our solution

With our adaptor, you get much higher bandwidth and resolution than a clamp meter (80kHz, 100mV/A) with better safety than a shunt resistor, no need for a differential probe and at a fairly low cost.

We use an Allegro ACS712 IC, which, like a clamp meter, operates on the Hall effect principle, but the whole shebang is within a single chip. One side of the IC contains a 1.2mΩ shunt, which can handle a continuous current of at least 30A and pulses up to 100A for 100ms. On the other side is a fully isolated Hall effect sensor and amplification circuitry.

There is no electrical connection between the two halves; sensing is purely based on the magnetic field generated by current passing through the shunt. The chip has an isolation rating of 1500VAC between the two halves, so the output can safely be hooked up to a scope or other device, even if you are measuring mains current at up to 250VAC.

There are three versions of this IC, designed for sensing currents up to ±5A, ±20A and ±30A. They are otherwise identical. For our prototype, we used the 20A version because its output is 100mV/A and this makes it easy to set up our scope to read out directly in amps (by telling it we have a 10:1 current probe). We run it from a 5V supply, giving readings of up to ±25A, although linearity is a little degraded at the extremes.

The 30A version has an output of 66mV/A and can read up to ±38A. You can use this one if you prefer, but then you may need a calculator to interpret the readings.

Power comes from a 9V battery because this is much more convenient than a plugpack when setting up a test. We fitted ours with a mains plug and socket for measuring the current drawn by mains devices. However, it could also have been fitted with DC connectors if that's what we wanted to measure. The output is a BNC socket, making it easy to hook up to a scope. For connection to a DMM, we use a BNC plug to banana socket adaptor.

So that you can't accidentally leave the unit on and drain the battery (easy to do), we incorporated an automatic time-out, which switches the unit off after about 15 minutes. If you want to use it for a longer period, you just have to remember to periodically press the power button to keep it on.

Circuit description

Refer now to the circuit diagram in Fig.1. The power supply is shown at left, while the actual current sense portion of the circuit is at lower right.

IC3 is the ACS712 shunt monitor IC. In addition to a 100nF power supply bypass capacitor, it has a 1nF filter capacitor from pin 6 to ground. This sets its bandwidth to 80kHz and provides a good compromise between bandwidth and residual noise. The shunt side of the IC, at left, is connected to two terminals of a 4-way terminal barrier, which is then wired to the mains plug and socket.

If you increase the value of the filter capacitor at pin 6, the residual noise is reduced, but so is the bandwidth. For example, if you use 10nF instead of 1nF, bandwidth drops to 8kHz and noise to ~20mV (200mA) peak-to-peak. If you use 100nF, the bandwidth drops to 1kHz and noise to ~10mV (100mA) peak-to-peak. If unsure, stick with the recommended value of 1nF.

IC3's output is at pin 7 and sits at half supply (about +2.5V) when there is no current flow. This is buffered by IC4a, half of an LM358 dual low-power op amp. Its is biased into Class-A operation with a 10kΩ resistor from its output pin 1 to ground (The LM358 data sheet explains why this is necessary). A 100Ω series resistor prevents instability that may occur due to output cable capacitance and the signal is available at the '+' output of CON2.

Ideally, we want 0V across CON2 when no current is flowing, rather than 2.5V, so we generate a half-supply rail at around +2.5V and connect that to the negative output terminal of CON2, so there is no voltage across it in the quiescent condition.

This is achieved using a voltage divider consisting of two 10kΩ resistors and 500Ω trimpot VR1. The voltage at VR1's wiper is filtered with a 100nF capacitor and buffered by op amp IC4b, the other half of the LM358. VR1 is adjusted so there is 0V across CON2 with no current through the shunt. CON2 is normally wired to a BNC socket with the negative pin side to its shell.

IC4, the LM358, runs off the +8.7V (nominal) switched rail from the battery so that both outputs have a full 0-5V swing. However, note that once the battery has dropped below 6.5V (when it's quite flat), the full swing may no longer be available. This could result in low readings towards the end of the battery's life.

To improve performance in this respect, an LMC6482 rail-to-rail op amp can be used in place of the LM358, and this will operate normally with a battery voltage down to 5V. However, the LMC6482 draws slightly more supply current; about 1.5mA compared to 0.5mA for the LM358, so the battery life will be slightly less.

Power supply

The ACS712 isolated shunt IC (IC3) runs from a regulated 5V rail, drawing about 10mA. This is controlled using momentary pushbutton S1, which also has an integrated blue LED. This LED lights up when the unit is on. When on, pressing, S1 briefly resets the auto-off timer while holding it down for a second or two turns the unit off.

The power on/off control and auto-off timer functions are provided by IC1, a 4093B quad CMOS Schmitt trigger NAND gate IC, and IC2, a 4060B CMOS oscillator/counter. Both these ICs are permanently powered by the battery, but being static CMOS logic, only draw a tiny amount of current, typically <1μA. This is probably lower than the battery's self-discharge current, so it will last many years with the unit switched off. Schottky diode D1 provides reverse polarity protection.

NAND gates IC1a and IC1b are configured as an RS-flipflop that controls power to IC3 and IC4. When the unit is off, output pin 3 of IC1a is low and output pin 4 of IC1b is high. Therefore, PNP transistor Q1 has no base drive and so no current can flow through its collector-emitter junction and into the rest of the circuit.

The high output from pin 4 in this state also forward biases diode D6, pulling pin 12 of IC2 (MR or master reset) high. This prevents IC2's oscillator from running, minimising its power consumption. Less than 1μA flows through the 10MΩ pull-down resistor.

When pushbutton S1 is pressed, two 47kΩ resistors, a 100nF capacitor and diode D2 provide a delay to debounce the switch. The delay is around 28ms, whether the button is being pressed or released. Because IC1d has Schmitt-trigger inputs (ie, inputs with hysteresis), the resulting slow rise and fall times are not an issue.

When S1 is pressed, input pin 12 of NAND gate IC2d goes high and assuming pin 13 is high (more on this later), its output pin 11 goes low. This sets the RS-flipflop, sending pin 3 high and pin 4 low, turning on Q1 and thus the rest of the circuit.

Pin 13 of IC1d is driven by IC1c. IC1c's inputs (pins 8 and 9) are tied together so that it operates as an inverter.

Specifications

Accuracy: approximately 2% error

Bandwidth: typically 80kHz

Range: ±25A* (linear over ±20A)

Output: 100mV/A*

Noise: ~40mV peak-to-peak (equivalent to ~400mA)

Power supply: 9V battery, approximately 20 hours life

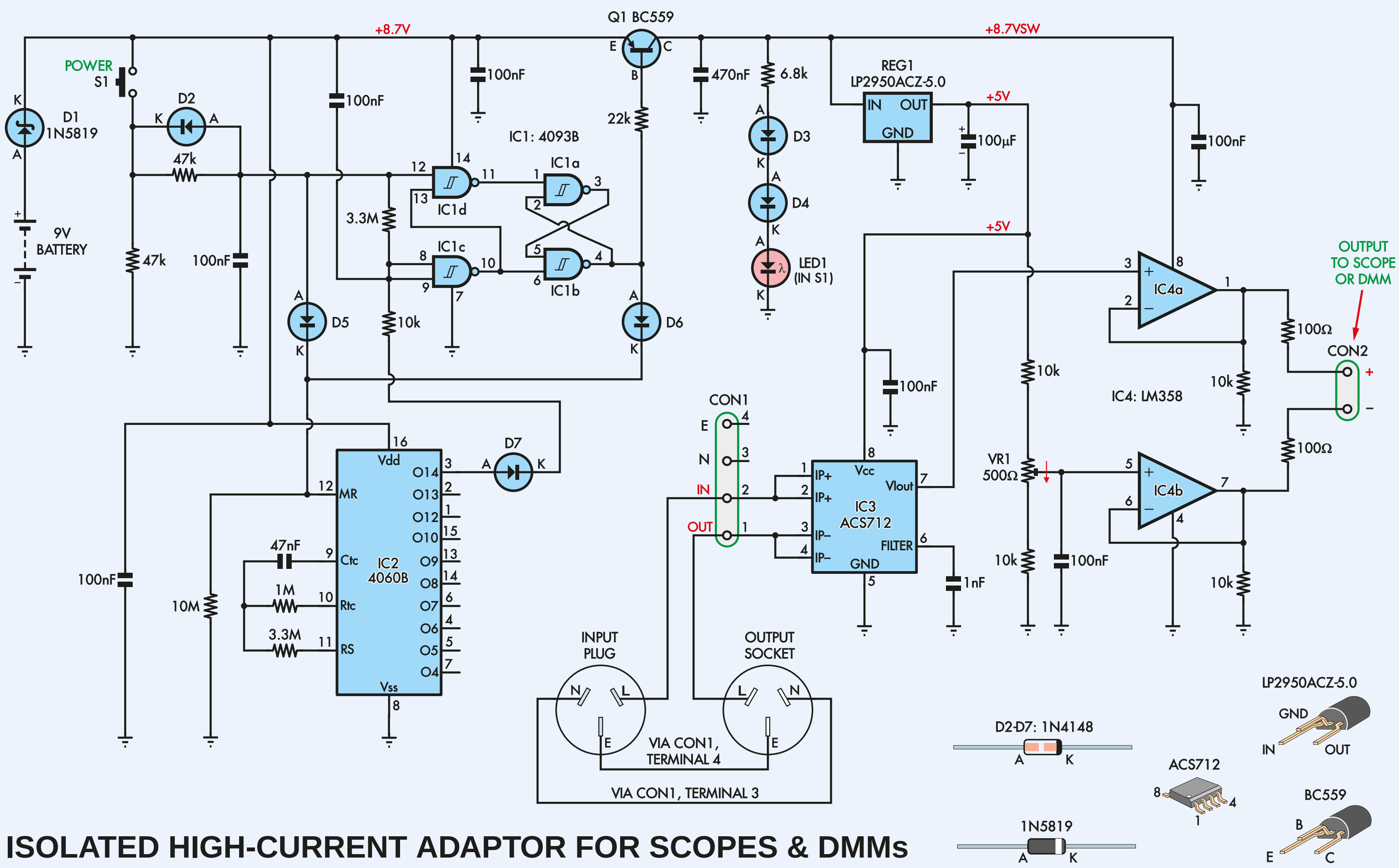
Resistance: ~2mΩ plus cable resistance

Isolation: 2.1kV RMS (suitable for use up to 250V AC)

Withstand current: 100A for 100ms

Other features: power indicator, auto-off to preserve battery life

* With alternative shunt IC, range increases to ±38A (linear over ±33A) with 66mV/A output



ISOLATED HIGH-CURRENT ADAPTOR FOR SCOPES & DMMs

Fig.1: the full circuit of the *Current Adaptor*. Connections are shown for measuring the mains current, but it can also be used to measure low-voltage AC or DC current. Current flows through IC3's internal shunt and a proportional voltage appears at its VI_{out} terminal (pin 7). Op amp IC4 buffers this voltage and a half-supply rail to provide differential output voltages at CON2. IC3's 5V rail is derived from a 9V battery via low-dropout regulator REG1 and switched by transistor Q1, which is controlled by a flipflop formed by IC1a and IC1b. The unit is turned on by a short press from momentary pushbutton S1 and turned off by a long press or after 15 minutes by timer IC2. This prevents the battery from being discharged if the unit is accidentally left on; the timer can be reset with a brief press of S1.

Parts List: Isolated High-Current Adaptor

1 PCB, code 04108121, 60mm × 107mm
1 UB3 jiffy box
1 right-angle PCB-mount tactile pushbutton with blue LED (S1)
1 500Ω mini sealed horizontal trimpot
1 9V battery holder, PCB-mount
1 9V battery (alkaline or lithium recommended)
1 4-way PCB-mount (screw fix) terminal barrier (CON1)
1 2-way polarised header, 2.54mm pitch (CON2)
1 2-way polarised header connector, 2.54mm pitch
1 female BNC panel-mount socket
1 100mm length of light duty figure-8 cable or ribbon cable
3 M2 × 6mm machine screws
2 M3 × 15mm machine screws
4 M3 nuts
2 M3 flat washers
2 M3 star washers
2 M3 × 10mm tapped nylon spacers
1 M3 × 15mm tapped nylon spacer*
3 M3 × 6mm nylon machine screws
1 sheet of Presspahn insulation, 70 × 30mm*
1 mains extension cord with moulded plug and in-line socket*
2 cord-grip grommets to suit 7.4-8.2mm cable*
5 small cable ties*

Semiconductors
1 4093 CMOS quad Schmitt trigger NAND gate (IC1)
1 4060 CMOS oscillator/counter (IC2)
1 ACS712ELCTR-20A-T (Element14 1329624) OR
1 ACS712ELCTR-30A-T (Element14 1651975)
1 LM358 dual op amp (IC4)
1 BC559 PNP transistor (Q1)
1 LP2950CZ-5.0 low dropout, low quiescent current 5V regulator (REG1) (Element14 1262363)
1 1N5819 1A Schottky diode (D1)
6 1N4148 small signal diodes (D2 to D7)

Capacitors
1 100µF 16V electrolytic
1 470nF MKT
7 100nF MKT
1 47nF MKT
1 1nF MKT

Resistors (0.25W, 1%)

1 10MΩ	1 22kΩ
1 3.3MΩ	5 10kΩ
1 1MΩ	1 6.8kΩ
2 47kΩ	2 100Ω

* For measuring mains current, substitute different parts for DC or low-voltage AC current measurement.

Note: the PCB is available from the *EPE PCB Service*

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It is fed from a further delayed version of the pushbutton signal; the 3.3MΩ resistor and 100nF capacitor form an additional low-pass filter, which adds a delay of roughly two seconds. This means that the input to IC1c is still low when pin 12 of IC1d goes high; thus pin 13 of IC1d is also high.

If S1 is held down, after this two second delay, the second 100nF capacitor charges up, bringing input pins 8 and 9 of IC1c high. IC1c's output therefore goes low. Since IC1c also drives an input of IC1d, IC1d's output simultaneously goes high. This condition, with input pin 6 of IC1b low and input pin 1 of IC1a high, resets the RS-flipflop, pulling the base of Q1 high and switching the unit off.

When pushbutton S1 is released, pin 12 of IC1d goes low before pins 8 and 9 of IC1c do, due to the different time constants of the two low-pass RC filters. This is important for ensuring the unit stays off when S1 is released.

Auto-off timer

Alternatively, if pushbutton S1 is only pressed briefly while the unit is on, the 3.3MΩ/100nF RC filter does not have time to charge fully, and so the unit does not switch off. But diode D5 will still become forward-biased and this pulls IC2's MR pin high, resetting the auto-off timer.

Once S1 has been pressed, the timer (IC2) runs for about 15 minutes and then switches the unit off. This time is set by the timing capacitor and resistor (47nF and 1MΩ), which give an oscillator frequency of around 8.5Hz. Output O14 (pin 3) goes high after 2^{13} = 8192 clocks and this gives 8192 ÷ 8.5Hz = 963 seconds or about 15 minutes.

When O14 goes high, this forward-biases diode D7, which charges the 100nF capacitor at pins 8 and 9 of IC1c via a 10kΩ resistor, resetting the RS-flipflop and switching the unit off.

Regulator

When Q1 is on, it supplies the ~8.7V from the battery to REG1, a low-dropout, low quiescent current 5V linear regulator. This draws less power from the battery than a 78L05 would and also allows the unit to continue operating down to a lower battery voltage.

The power LED integrated within S1 is powered from the 8.7V rail via two series 1N4148 diodes and a 6.8kΩ resistor to limit the current. The two diodes cause the LED to dim significantly as the battery voltage drops below about 6V, since the LED has a forward voltage of around 3.3V and the two diodes add another 1.2V to this. This gives a low battery indication before the voltage drops too low for the device to function.

Construction

The unit is built on a PCB coded 04108121 and measuring 60mm × 107mm. This is available from the *EPE PCB Service*. It's designed as a single-sided PCB with one wire link – although we supply a double-sided PCB with that link already present (as a track on the top layer).

IC3, the ACS712, is a surface-mount device (SMD) in an SOIC-8 package and this goes on the underside. There is a slot down the middle of its mounting position, to maximise electrical isolation between the shunt and low-voltage sides. If you have made your own PCB, you should drill a series of 1.2mm holes between the IC pads where shown and file them into a slot.

The first job is to solder this IC in place. It must go in with its pin 1 (indicated with a divot, dot or bevelled edge) towards the bottom of the PCB, as shown in the PCB overlay diagram

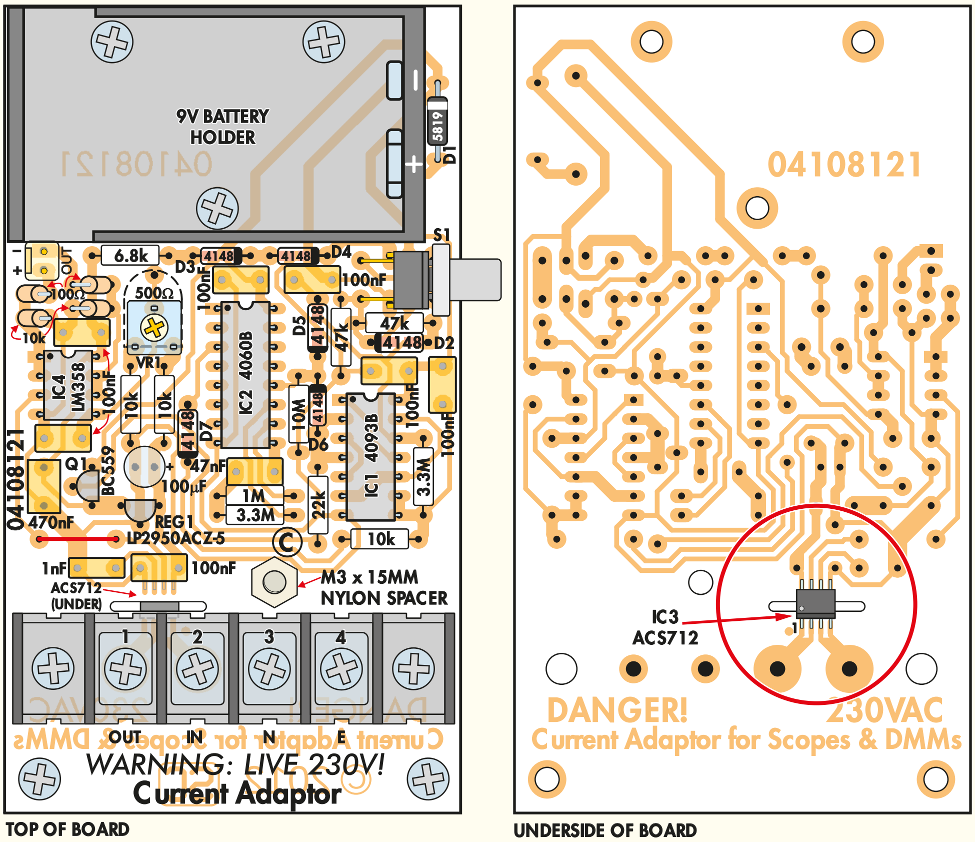


Fig.2: the PCB overlay diagram for the *Current Adaptor*. IC3, the ACS712 Hall effect shunt monitor is soldered to the underside as shown. A slot in the board prevents surface contamination from forming a leakage path between the high and low voltage sides of the IC. The current to be measured flows between the 'IN' and 'OUT' terminals of the terminal barrier at bottom and the output voltage appears across the 2-pin polarised header at upper left, just below the 9V battery holder. Pushbutton switch S1 at upper-right provides on/off control, timer reset and power indication via its in-built blue LED.

(Fig.2). The PCB indicates the correct orientation too.

Put a small amount of solder on one of the pads with the IC resting alongside, heat the solder and slide the IC into place. If it isn't aligned properly on its pads, reheat the solder and nudge it. Repeat until it is correctly aligned, then solder the rest of the pins. Finally, re-solder the initial pin, to ensure the solder has flowed correctly, making a good joint.

Next, fit all the horizontally-mounted resistors, checking their values with a DMM. Follow with the diodes, being careful to orient them as shown on the overlay diagram. Make sure that the larger Schottky diode (D1) goes at upper-right as shown.

Next, solder the DIP ICs in place. In each case, the pin 1 notch or dot goes towards the top of the board. Don't get the 4060 and 4093 mixed up (they have the same number of pins). **We recommend you solder them directly to the PCB so that they can't come loose and float around inside the box (rather than using sockets).**

Fit the MKT capacitors next. There are four different values and they go in the locations shown on the overlay diagram. Then mount transistor Q1 and regulator REG1, which are both in TO-92 plastic packages; check the markings so you don't get them mixed up. You can then install the single electrolytic capacitor (longer lead toward + symbol) and the polarised pin header, followed by the remaining resistors, which go in vertically.

Trimpot VR1 can go in next, followed by pushbutton switch S1. You may need to bend the latter's leads slightly to get them to fit the holes as they are quite delicate and can easily be bent out of shape during transport. That done, use three short M2 machine screws to attach the battery holder to the board, then solder the leads.

That just leaves the terminal barrier, which is mounted using M3 screws with flat washers under the heads and star washers between the nuts and PCB. Do up the screws tight, check that it is parallel with the edge of the board and then solder the pins, using a hot iron and a generous amount of solder.

The PCB assembly can now be completed by attaching three tapped nylon spacers. As shown in one of the photos, the two M3 × 10mm spacers are attached to the two corner holes adjacent to the terminal strip (ie, on the underside of the PCB) using M3 × 6mm nylon screws.

The M3 × 15mm nylon spacer goes on the top of the board as shown in Fig.2 and is also attached using an M3 × 6mm nylon screw. It's used to help retain a Presspahn isolation barrier.

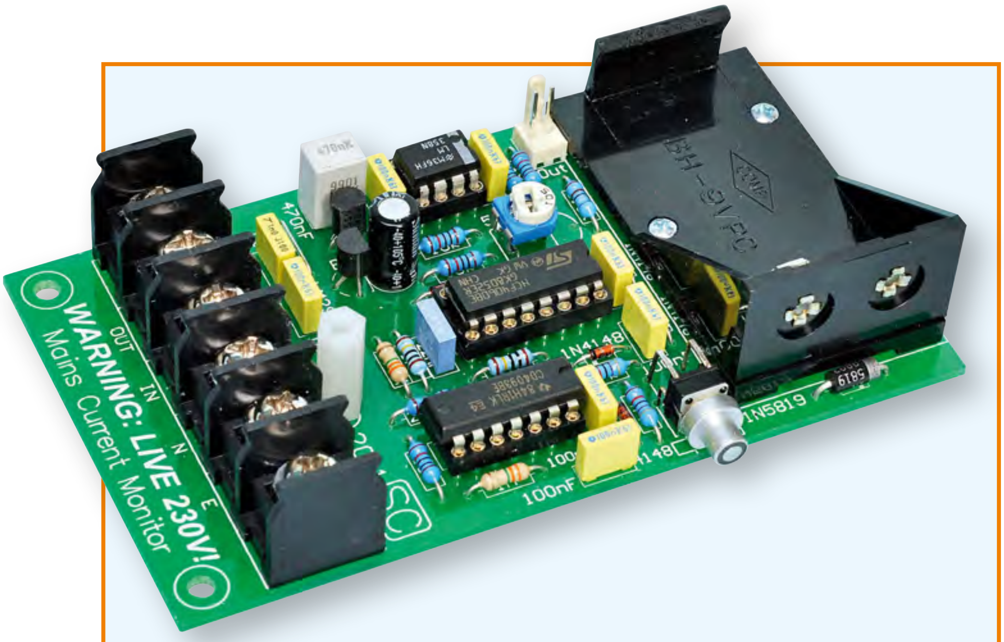
Testing

Check that the power supply works by connecting the battery and pressing the pushbutton. The blue LED should light up. Hold down the pushbutton for a couple of seconds and check that it goes off. Then set the trimpot to its mid-position, turn the unit back on and measure the voltage across the polarised pin header. It should be less than ±250mV. Adjust it as close to zero as you can, using the trimpot, then switch it off again.

Preparing the case

The next step is to drill a 5mm-diameter hole in the side of the case for the on/off pushbutton. This hole is positioned 22mm down from the top lip of the case (ie, not including the lid) and 47.5mm from the output end (again, as measured from the top lip).

You can then drop the PCB into the case at an angle, to check that the hole lines up correctly when the PCB snaps into place. If not, enlarge it slightly.



The completed PCB, without the two corner mounting posts. We used IC sockets for our prototype, but it's better to solder the ICs to the PCB so they can't come loose if the unit is dropped. Once the wires have been connected to the screw terminal block, the clear cover is clipped in place (not shown).

Next, make the holes for the output socket(s). Simply drill a 9mm diameter hole in the middle of the end for the panel-mount BNC socket, or you could use a pair of binding posts if you want. Keep in mind that there is only about 11mm of clearance from the battery to the end of the case, so whatever you use, it can't intrude very far. In fact, before installing the BNC socket, we had to cut off most of the central prong since it stuck out too far (you only need a short section to solder to).

Remove the PCB and fit the BNC socket. Crimp and solder a 70mm length of light-duty figure-8 cable to the two polarised header pins, then push the pins into the moulded plastic housing. Solder the other end of these leads to the rear of the BNC socket, with the lead from pin 1 on the polarised header (normally indicated on the plastic housing) going to the BNC shield, while pin 2 goes to the central pin.

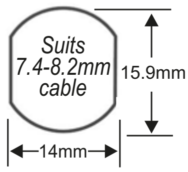
Mains leads

If you are not planning on using the adaptor with mains, you can use binding posts or whatever you prefer to make connections to the terminal barrier. However, this section will describe the procedure for connecting mains cables.

The first step is to cut the extension lead in half. Strip away about 50mm of outer insulation from both ends and then expose 7-8mm of insulation from each live and neutral wire, and 15-20mm for the earth wires.

You will then need to make two holes in the case, at the opposite end to the BNC socket. These are spaced 25mm apart, on either side of the centre of that end and have a diameter of 14mm. Start with a smaller hole (4-5mm say) and then enlarge using a tapered reamer or stepped drill bit. Make sure you don't make the holes too large, since the cordgrip grommets need to be a tight fit. **Then profile the holes to the shape shown in Fig.3, using a file. Again, be careful not to make the opening too large.**

Fig.3: the correct cut-out to make sure the cord-grip grommets do grip. Don't be tempted to simply drill a 16mm hole!

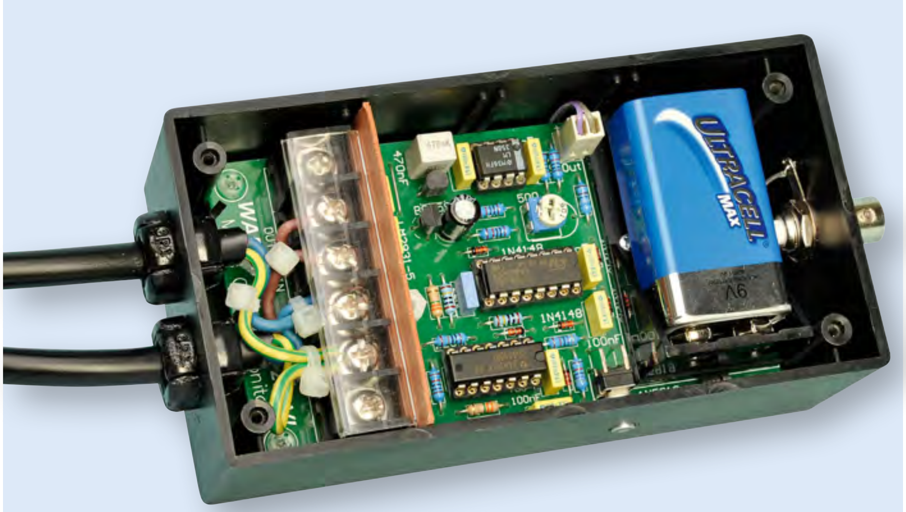


Now place one of the mains leads through one of the cord-grip grommets, with the bare leads towards the narrower end. Squeeze the grommet together hard using large pliers (or if you're lucky enough to have one, a grommet insertion tool), so that only a short length of the cable's outer insulation protrudes from that narrow end.

Push the grommet into one of the holes and it should snap into place. If it won't go, enlarge the hole very slightly and then try again. Be careful, since once it's in, it's very hard to get it out. Do the same with the other cable and grommet in the other hole.

Now check that the two mains cords are securely anchored. You must not be able to pull the cords out of the case, even if you exert considerable force.

That done, connect the two live wires to the terminals marked 'IN' and 'OUT' on the PCB. **For correct output polarity, 'IN' should go to the plug and 'OUT' to the socket (current flowing from IN to OUT will give a positive output voltage).** Do these up tightly, too.



The unit all wired up and ready to go. Note how the 2-wire ribbon cable for the output signal is clamped by the PCB. There isn't a lot of room for the output connector next to the battery, so we had to trim its central solder pin. You can also see how the Presspahn cover is held in place by the plastic case slots, terminal block and tapped spacer.

This close-up view shows how the Presspahn cover is held in place by the plastic case slots, the mains terminal block and the M3 × 15mm tapped spacer.

Twist the two neutral wires together and screw them down tightly to one of the spare terminals on the PCB (see photo). Do the same for the earth wires. Make sure both are secure. You can then use several small cable ties to hold the wiring in place. These must be installed to prevent individual leads from moving and making contact with other wiring if they come loose.

Once these are in place, clip the clear cover on top of the screw terminal block.

Presspahn barrier

The next step is to fit a Presspahn insulation barrier between the mains terminal block and the low-voltage section of the PCB. **This insulation barrier is retained by the adjacent slots in the side of the case and must be trimmed to exactly 63mm × 25mm so that it is a tight fit.**

Two M3 × 10mm tapped nylon spacers are fitted to one end of the PCB as supports.

As shown in the accompanying photo, this barrier is sandwiched between the screw terminal block and the adjacent M3 × 15mm nylon spacer. If necessary, rotate the spacer slightly so that one of its lobes presses the Presspahn insulation firmly against the screw terminal block.

Do not leave the Presspahn barrier out – it makes it impossible for any of the mains wiring to contact the low-voltage section of the PCB and is an important safety measure.

Note that once the lid is in place, the Presspahn barrier is also clamped between the lid and the PCB.

Final assembly

Plug in the polarised header and put the lid on the box. Then use a DMM to make some checks before connecting the device up:

1) Check that the earth terminals on the mains plug and socket have a very low resistance between them (should read zero or very close to it).
2) Do the same check between the neutral terminals and then for live.
3) Check there is no connection between all three pairs of terminals on the mains plug and then on the socket (ie, many megohms; meter should normally read '0L' or similar).
4) Check that there is no connection between both terminals of the BNC socket and all the mains terminals; again, the meter should read '0L'.

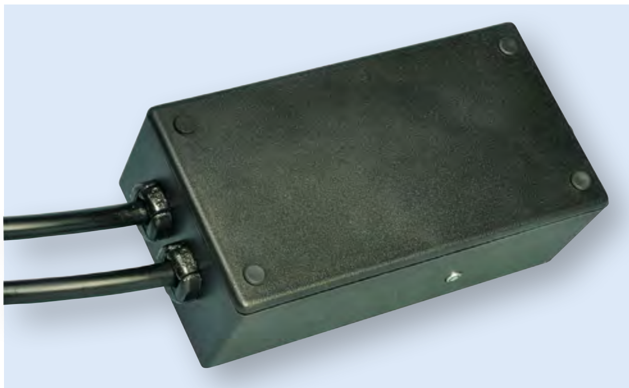
Now plug the unit into mains and, without touching anything, switch on and measure the AC voltage between the BNC shield and earth using a DMM. It should be just a few volts. Do the same check with the BNC centre pin. Only when you have ensured that there is no mains voltage on these two conductors should you connect the BNC output to an oscilloscope.

A BNC plug-to-banana socket adaptor can be fitted to the BNC output socket if you want to connect a DMM.

You can then do a functional test by connecting an appliance with a known current to the output. For example, if you use a 1kW bar radiator, its current should be about 2.4A, depending on the actual value of the mains voltage. You can then monitor the current with a DMM or oscilloscope. Check that you get a sensible reading.

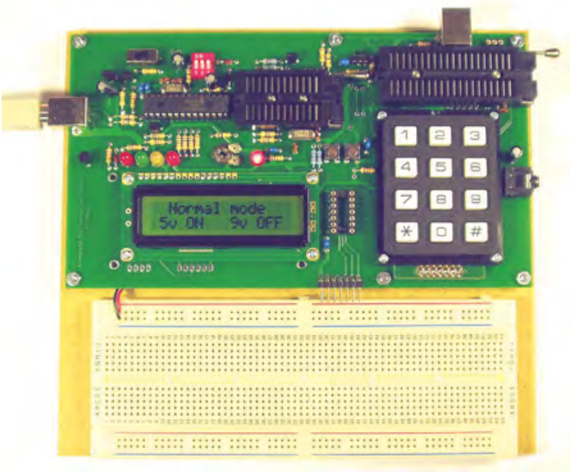
Assuming all is well, disconnect your test load and check the DC output level of the adaptor. It should be close to zero. If not, disconnect all mains cables, open the unit up, make sure it is switched on and adjust the trimpot again. We found that the offset changed slightly the first time we used the unit to measure a high current, so you need to do the final trimming at this stage to guarantee a low offset.

That's it; using the device is simply a matter of plugging it in and switching it on. Don't forget to periodically reset the timer if you are undertaking a long test or measurement session. ***EPE***



The completed unit with the lid in place. Note how the illuminated on/off pushbutton switch protrudes through a hole in one side of the case.

PIC Training Course



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USB powered 16F and 18F PIC programmer module
+ Book Experimenting with PIC Microcontrollers
+ Book Experimenting with PIC C 6th Edition
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This book introduces PIC programming by jumping straight in with four easy experiments. The first is explained over seven pages assuming no starting knowledge of PICs. Then having gained some experience we study the basic principles of PIC programming, learn about the 8 bit timer, how to drive the liquid crystal display, create a real time clock, experiment with the watchdog timer, sleep mode, beeps and music, including a rendition of Beethoven's *Fur Elise*. Then there are two projects to work through, using a PIC as a sinewave generator, and monitoring the power taken by domestic appliances. Then we adapt the experiments to use the PIC18F2321. In the space of 24 experiments, two projects and 56 exercises we work through from absolute beginner to experienced engineer level using the very latest PICs.

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

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This third stage of our PIC training course starts with simple experiments using 18F PICs. We use the PIC to flash LEDs and to write text to the LCD. Then we begin our study of PC programming by using Visual C# to create simple self contained PC programmes. When we have a basic understanding of PC programming we experiment with simple PC to PIC serial communication. We use the PC to control how the PIC lights the LEDs then send text messages both ways. We use Visual C# to experiment with using the PC to display sinewaves from simple mathematics. Then we expand our PC and PIC programmes gradually until a full digital storage oscilloscope is created. For all these experiments we use the programmer as our test bed. When we need the serial link to the PC we flip the red switches to put the control PIC into its USB to USART mode.

In the second part of *Experimenting with Serial Communications* 4th Edition we repeat some of the serial experiments but this time we use a PIC18F2450 with its own USB port which we connect directly to a USB port of your PC. We follow this with essential background study then work through a complete project to use a PIC to measure temperatures, send the raw data to the PC, and use the PC to calculate and display the temperature.

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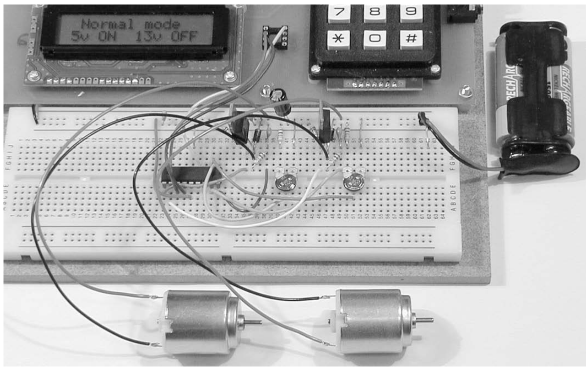

White LED and Motors

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 volt supply which is already wired to the plugboard has a current limit setting which ensures that even the most severe wiring errors will not be a fire hazard and are very unlikely to damage PICs or other ICs.

We use a 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. See our web site for details.

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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, our final Jump Start, *we shall be getting ready for summer with a device that will provide you with a warning that things are getting too hot for comfort and help to cool them when necessary! Our* Temperature Alarm *has a variety of useful applications, from turning on a fan, to opening doors and windows fitted with a suitable mechanism. One obvious application of the* Temperature Alarm *is that of acting as a temperature controller capable of cooling an item of electronic equipment such as an amplifier, computer or power supply. With this in mind, we've kept the PCB small so that it can be easily mounted in an enclosure along with the equipment that's being kept cool. There are, however, many other applications for this circuit, as we will discuss later.*

Under the hood

The simplified block schematic of our *Temperature Alarm* is shown in Fig.1. The circuit uses an operational amplifier as a comparator and a transistor driver to provide sufficient current to operate a small fan, relay

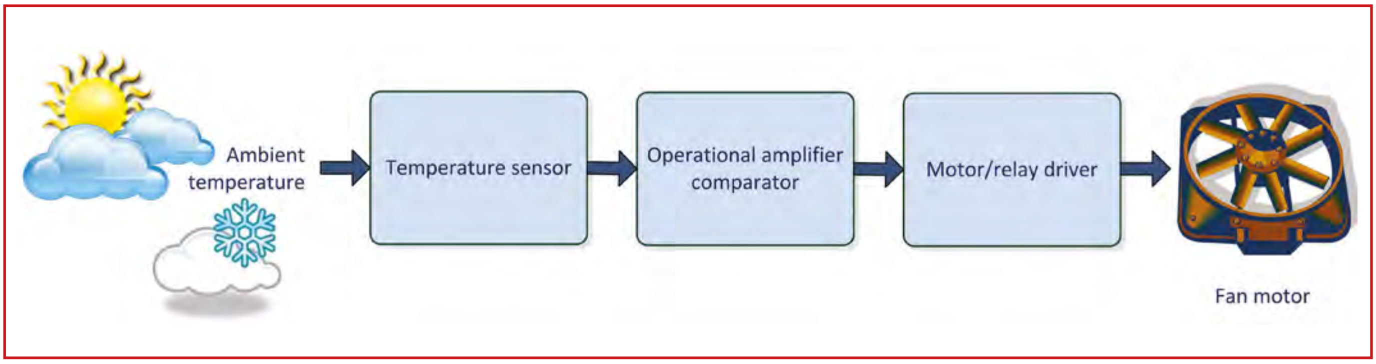


Fig.1. Simplified block schematic of our *Temperature Alarm*

or actuator. As with our earlier Frost Alarm (*EPE* Nov' 12) we shall be using a low-cost miniature thermistor as a temperature-sensing device. Unlike a conventional resistor which maintains its ohmic value reasonably constant over a range of temperature, the resistance of a thermistor changes markedly with temperature. In this particular application we have chosen a thermistor with a negative temperature coefficient (NTC). The resistance of an NTC thermistor falls as the temperature increases, as shown in Fig.2. Further information on thermistors and their characteristics appeared on page 49 of *EPE* Nov' 12.

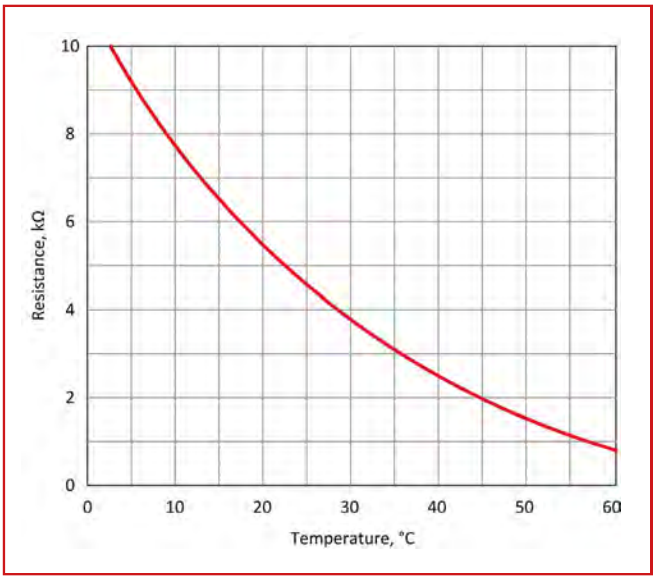


Fig.2. Resistance-temperature characteristic for the NTC thermistor used in the *Temperature Alarm*

The circuit of our initial design for the *Temperature Alarm* developed in Circuit Wizard is shown in Fig.3. The problem of converting the change in resistance produced by our thermistor sensor into a voltage that is either high or low depending on the thermistor's temperature is taken care of by a bridge comparator identical to that used in our earlier *Frost Alarm*, so we will not discuss this particular part of the circuit further.

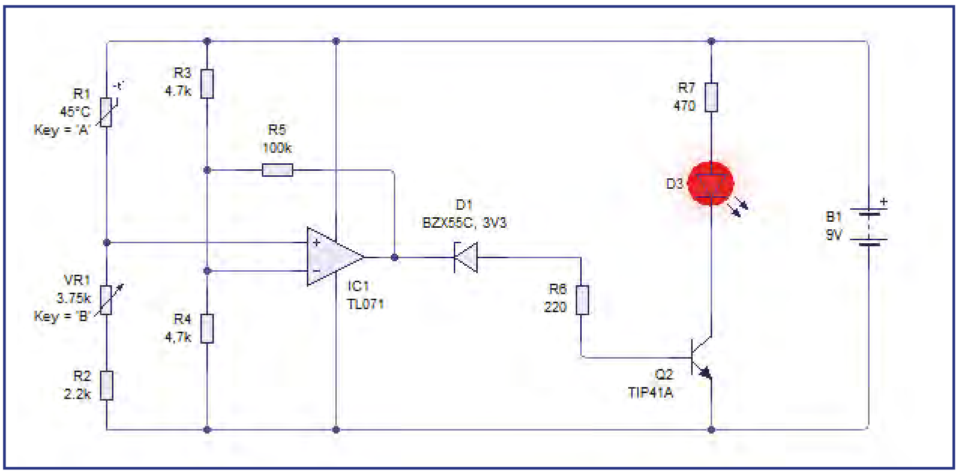
In Fig.3 the output of the bridge comparator is fed to a current amplifier via a Zener diode. This ensures that absolutely no current is fed to Q1 when the temperature is below the threshold set using VR1. If this component is omitted there can be sufficient voltage from the output of IC1 to cause a small (but significant) current into the base of TR1. In effect, D1 corrects for the inability of the output voltage of the operational amplifier to fall close to its negative supply voltage. When the threshold temperature is exceeded the output voltage produced by IC1 will go high, and D1 will then conduct, passing current into the base of TR1. This will effectively drive the transistor into saturation and the collector voltage will then fall to a very low value, causing the LED to become illuminated.

Design notes

One of the essential requirements of our *Temperature Alarm* is that it produces sufficient current to operate a small 12V fan of the type used in computers. These require a current of around 200mA to 250mA when running at rated speed. Not surprisingly, IC1 is unable to deliver a current of this size, so we need to make use of an additional 'driver' stage in order to increase the output current capability. The output driver can be based on a single transistor with sufficient current gain to increase the current available from IC1 when in the 'high' state to the 200mA needed to drive a fan or relay. A current gain of around 100 should be perfectly adequate, and we have chosen a low-cost TIP41 *NPN* power transistor to satisfy this requirement.

In practice, it is desirable for Q1 to be saturated when the *Temperature Alarm* is operating. This simply means that the voltage at the collector of Q1 should fall to a very low value when the transistor is delivering current to the load. Under these (saturated) conditions the voltage appearing

Fig.3. (below) Initial design for the *Temperature Alarm* developed in *Circuit Wizard*



across the load (ie, the fan motor, relay or actuator) will be very close in value to that of the supply, and the dissipation within Q1 will also be minimised under these conditions.

In addition there is a need to protect Q1 from the large back EMF that is generated whenever the current flowing through an inductive load (such as a motor, relay or actuator) is interrupted. This can easily be achieved by connecting a suitably rated diode in parallel with the load, as shown in Fig.4.

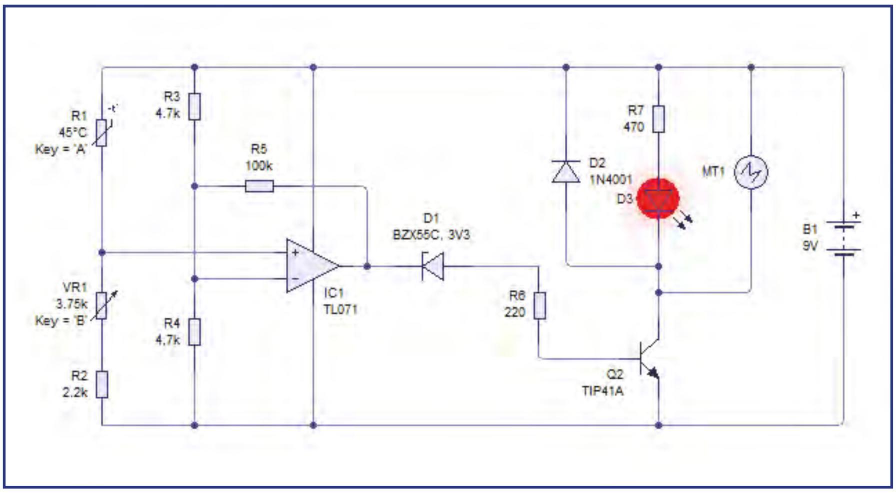


Fig.4. *Temperature Alarm* circuit with diode (D2) protection against the effects of an inductive load

Get real

We have already investigated thermistor characteristics and the operation of a temperature sensing bridge (see *EPE* Nov' 12) so in this issue we will be taking a closer look at the need for diode protection and the operation of the transistor output driver stage. To help bring this into context we will once again be using *Circuit Wizard* to do the modelling for us.

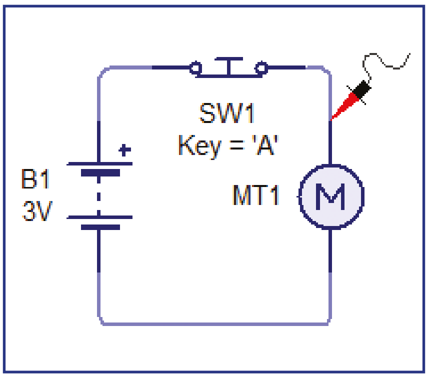


Fig.5. A simple switched-motor control circuit modelled in Circuit Wizard

Fig.5 shows a simple switched motor circuit modelled in *Circuit Wizard*. In this circuit, we've assigned the 'A' key to the normally closed push-button switch, SW1. The supply current to the motor is interrupted whenever the key is operated. When the current is removed from the motor, the magnetic flux set up by the inductance of the motor windings suddenly collapses. As a consequence of this rapid change of flux a very large EMF is generated across the motor terminals, as shown in Fig.6.

There are several important things to notice about the waveform shown in Fig.6. First, the EMF is of the opposite polarity to that of the supply and thus is often referred to as a 'back EMF'. Second, the induced voltage is many times greater than the supply voltage, and third, the induced voltage appears for only a very brief time.

Fig.7 shows a refinement of the motor control circuit. In this circuit we have connected a diode across the motor. This diode is connected with reverse polarity so that it is not normally conducting; but, when the current to the circuit is interrupted and a large reverse voltage appears it is effectively shunted by the diode such that the maximum negative voltage that can appear is limited by the forward conduction voltage of the diode (about 0.7V for a silicon diode) as shown in Fig.8.

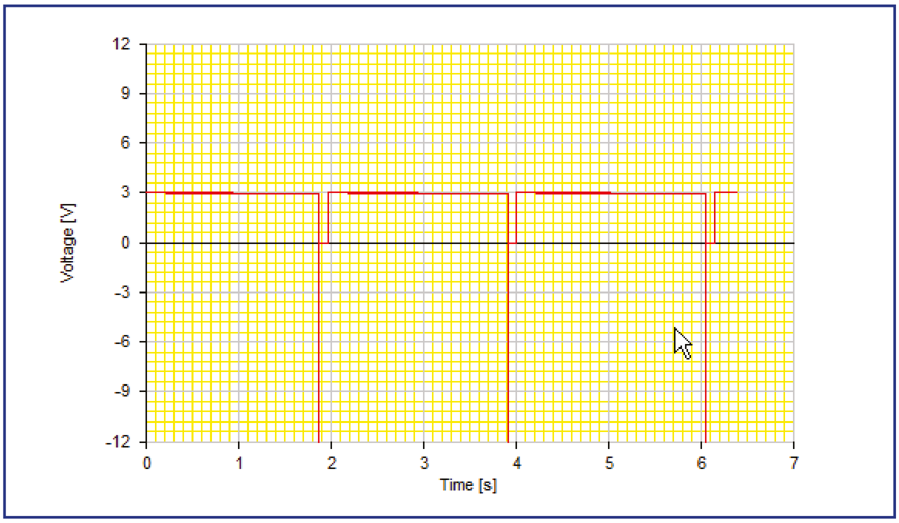


Fig.6. Motor voltage waveform for the circuit shown in Fig.5 (SW1 is operated three times)

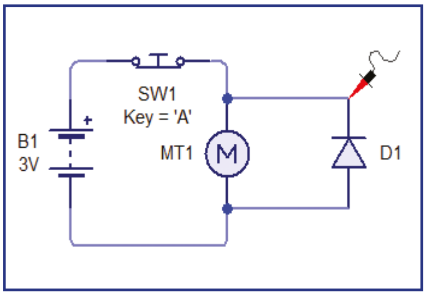


Fig.7. Simple switched motor-control circuit in which a diode is fitted to greatly reduce the back EMF produced when SW1 is operated

Fig.9 shows a motor control circuit in which a transistor switch is used. In this circuit, current flows through the windings of the motor whenever SW1 is operated and ceases when the switch is released. Notice once again the effect of the induced EMF when the flux collapses at the point at which current ceases to flow in the inductive motor windings. In this circuit, the back EMF results in a very high positive voltage appearing at the collector of Q1, as shown in Fig.10. This voltage can easily exceed (even if only for a very small time) the maximum collector-base voltage for Q1. The result is that Q1 will be very quickly destroyed.

Once again, we can employ a commonly available silicon diode to prevent the back EMF from exceeding anything other than a voltage greater than about 1V, as shown in Fig.11.

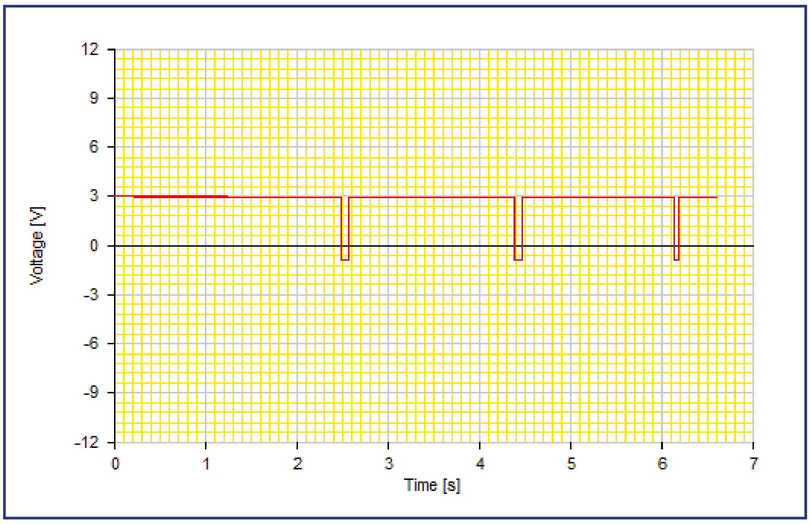


Fig.8. Motor voltage waveform for the circuit shown in Fig.7

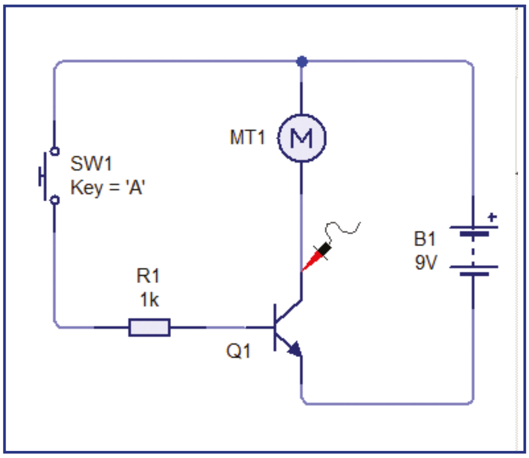


Fig.9. Motor control circuit using a transistor switch

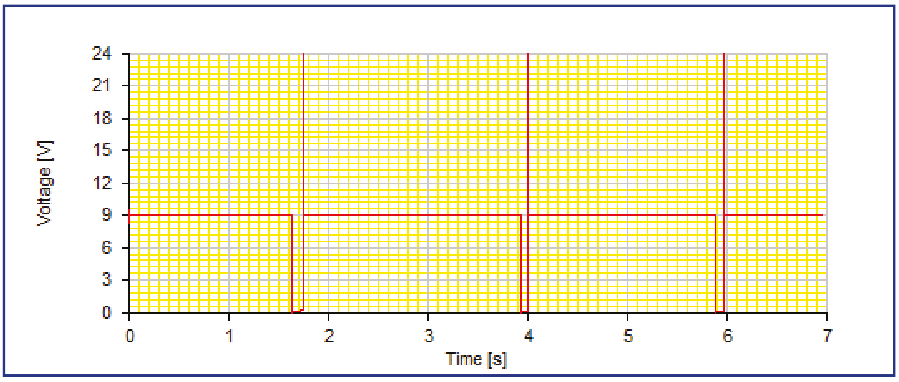


Fig.10. Motor voltage waveform for the circuit shown in Fig.9

The resulting waveform is shown in Fig.12.

Next, we will consider the need to drive the switching transistor, Q1, into saturation. Fig.13 shows a simple test circuit that will allow us to check the relationship between the collector current (output) and base current (input). You might like to check this out for yourself by recording corresponding sets of values in a table (see Fig.14) and then plotting a graph like the one shown in Fig.15. Note that the relationship between collector and base current is linear and that the collector current is approximately 100 times greater than the base current.

Having checked that the relationship between collector and base current is essentially linear, we now need to consider how much current we actually need to feed to the base of a transistor in order to ensure that its collector voltage falls to a very low value (ideally zero). Fig.16 and Fig.17 show a test circuit that will allow us to model this situation. Here we have added a 100Ω resistor to simulate the resistance of the load and two voltmeters; one to indicate the voltage developed across the load and the other to show the voltage appearing between the collector and emitter of Q1.

In an ideal case when the circuit is supplying current to the load we would expect the load voltage to be the same as that of the supply and the collector-emitter voltage to be very low (typically less than 0.5V) providing sufficient base current is supplied. Notice how, in Fig.16, with a base current of less than 1mA applied the collector-emitter voltage takes a value of around 3V, while in Fig.17 it has fallen to less than 0.1V (indicating that the transistor is fully saturated when a base current of around 2mA is available).

The result of all this is that we might conclude that, using a TIP41A transistor and a 100Ω load we need to supply a current of around 2mA, but loads offering different resistances might need more or less base current in order to ensure saturated operation. To put this another way, as the resistance of the load is reduced, more collector current will be needed and consequently more base current drive will be required in order to drive the transistor into saturation.

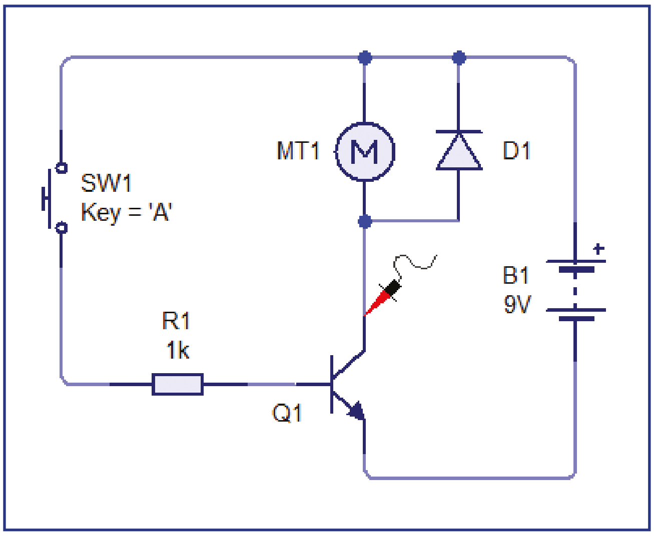


Fig.11. Transistor-switched motor-control circuit in which a diode is fitted to protect Q1

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

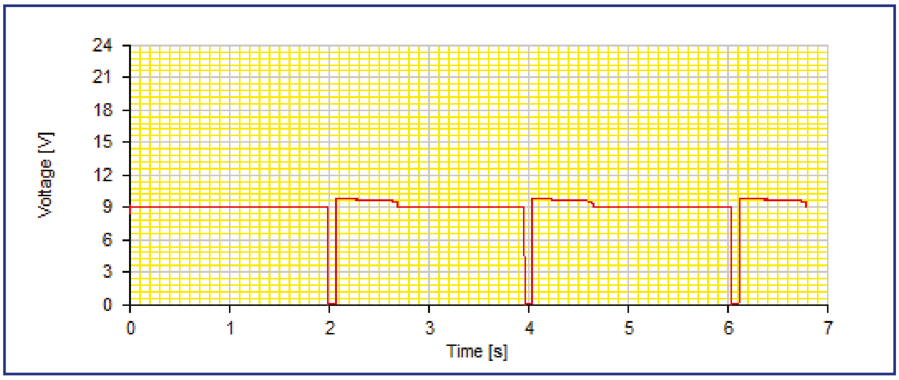


Fig.12. Motor voltage waveform for the circuit shown in Fig.11

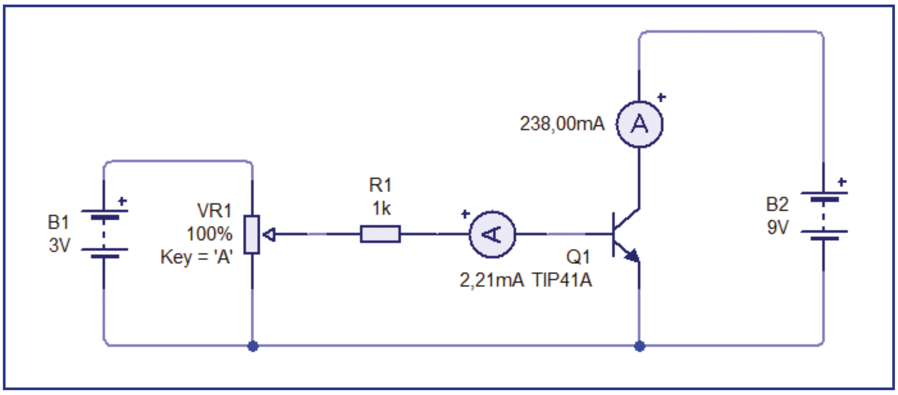


Fig.13. Test circuit for investigating the relationship between the collector current and base current of a transistor

Base current, I_B (mA)	0.32	0.45						
Collector current, I_C (mA)	24.9	39.4						

Fig.14. Typical table of results obtained from the test circuit shown in Fig.13

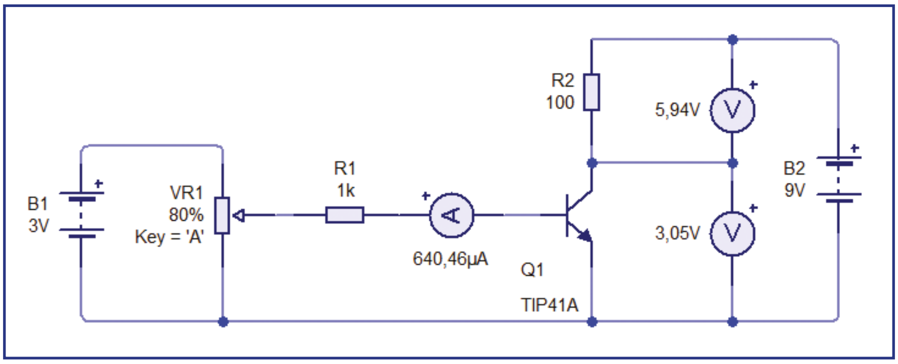


Fig.16. Test circuit for driving a 100Ω load with a base current of less than 1mA

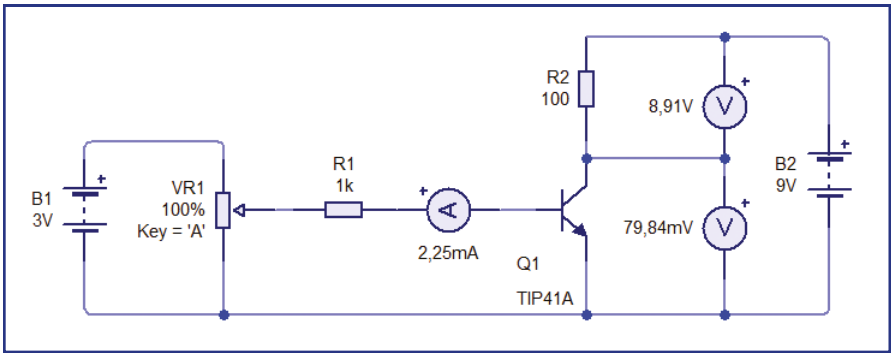


Fig.17. Test circuit for driving a 100Ω load with a base current of more than 2mA

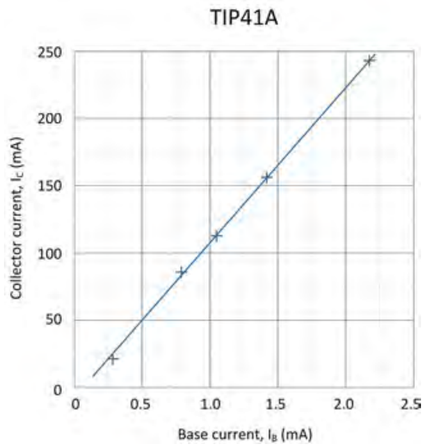


Fig.15. Typical plotted graph, showing the linear relationship between the collector current and base current for a TIP41A transistor

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.

Temperature Alarm – using Circuit Wizard

NOW it's time to put our theory into practice and create our operational unit. Our final circuit is shown in Fig.18. As you can see, we used the same operational amplifier arrangement as we discussed previously, with a TIP41A as our output driver stage. This device can support a collector current of up to 6A; more than adequate to drive a DC fan, buzzer, actuator, lamp or relay output.

to adjust the threshold temperature range. You may also decide to mount your thermistor off-board and/or use a pre-manufactured resistive probe. The table on page 49 outlines some suggested applications; which one will you choose?

For our example design we've gone with the first option; a temperature controlled cooling fan to keep you cool in the hot summer weather… if it ever arrives! Having converted our circuit to a PCB design (Fig.19) we could virtually test our circuit by attaching a PP3 battery and 9V DC motor (Fig.20). Note that we have used a PP3 as our power supply to simulate the circuit. However, this would be an unsuitable power source for the real circuit due to the relatively high current required for the fan and the small capacity of the PP3. Therefore, we would recommend either a multi-cell battery pack, a rechargeable battery, or a suitably rated mains adaptor.

Fig.20 shows our assembled prototype circuit operating a small DC motor. The circuit performs well with a reliable trigger point and a small dead band. The thermistor used (Rapid part number 61-0410) is sensitive

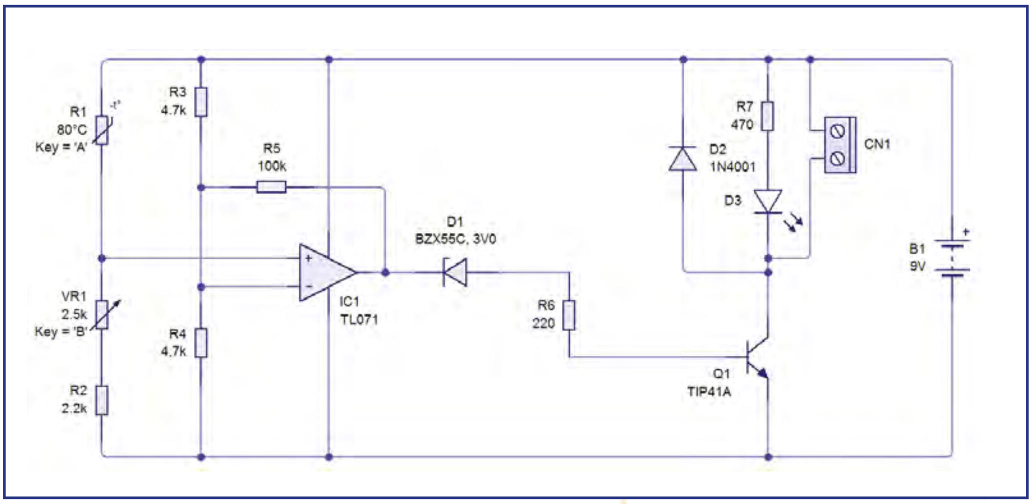


Fig.18. Final practical circuit schematic

The exact nature of your circuit and PCB design will depend on your intended application. As usual with *Jump Start*, we encourage you to experiment, tweak and extend our basic designs to meet your needs and enhance your understanding. Resistors VR1 and R2 may be altered

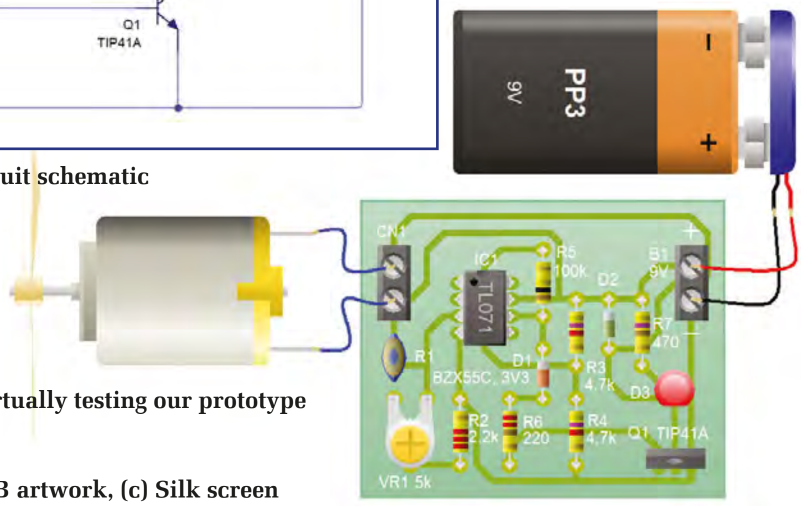
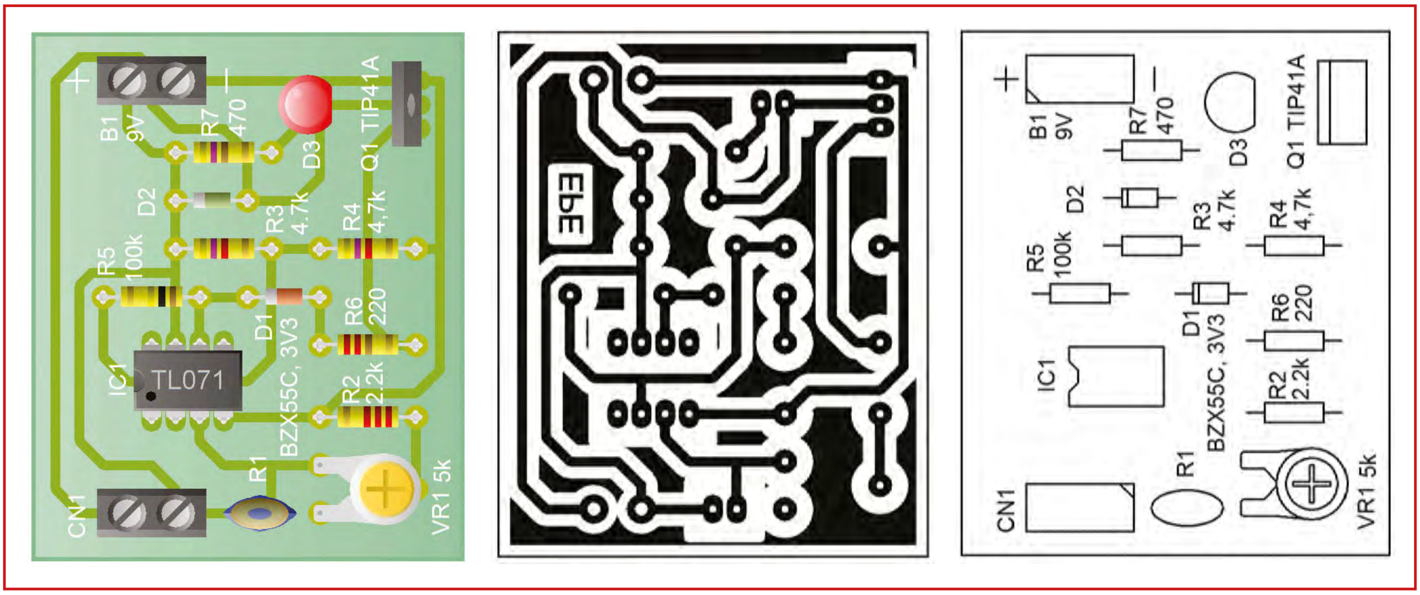


Fig.20. Virtually testing our prototype circuit

Fig.19. Prototype PCB: (a) Real-world view, (b) PCB artwork, (c) Silk screen



You will need...

Temperature Alarm

1 PCB, code 904, available from the *EPE PCB Service*, size 56mm × 46mm
2 Two-way PCB mounting terminal blocks
1 battery clip for a PP3 battery (for test purposes only)
1 PP3 battery (for test purposes only)
1 9V or 12V DC mains power supply rated at 250mA min. (for normal operation)
1 miniature single-pole single-throw (SPST) switch
1 low-profile 8-pin DIL socket
1 NTC thermistor (5kΩ at 25°C) (R1) (eg, Rapid Electronics 61-0410)

Semiconductors
1 BZX55C 3.3V Zener diode (D1)
1 1N4001 silicon diode (D2)
1 Red LED (D3)
1 TL071 operational amplifier (IC1)
1 TIP41A silicon power transistor (Q1)

Resistors
1 2.2kΩ (R2)
2 4.7kΩ (R3 and R4)
1 100kΩ (R5)
1 220Ω (R6)
1 470Ω (R7)
1 5kΩ miniature skeleton preset potentiometer (VR1)

and responds very quickly to changes in temperature. However, it is quite a fragile package with thin legs that can be easily damaged.

There is a range of resistive sensors avail-able that could be used with the circuit. Note that you may need to alter resistor values to achieve the desired operation when using a differently rated thermistor. The data sheet for such devices normally includes a graph to indicate the variation of resistance according to temperature and you should use this to determine the resistance at the required threshold voltage and use this value in your calculations. If you are intending to use an off-board probe you may also like to exchange the thermistor package for a two-pin terminal connector at the PCB conversion stage. If you are intending to control a more powerful or mains AC output you may wish to use a relay or solid state controller (this could either be added at the PCB design stage or wired-off board when using our standard PCB).

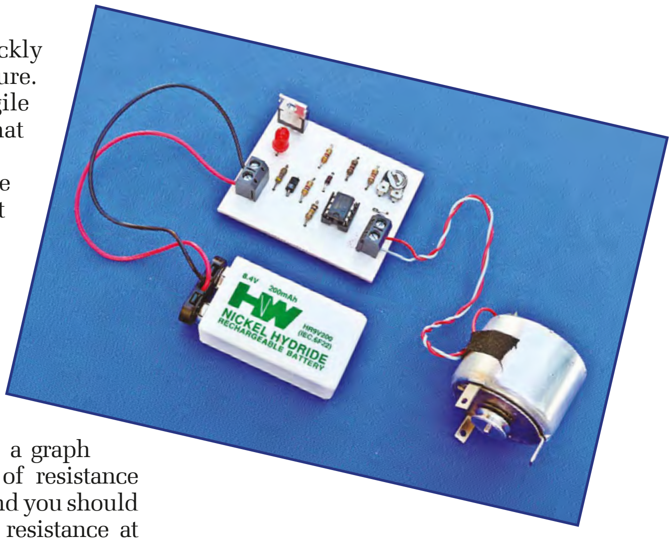


Fig.21. Our assembled prototype ready for testing with a small DC motor

In conclusion

This concludes our *Jump Start* series. We hope that the 15 topics have given you plenty of thought and ideas for use in your own projects. Don't be afraid to adapt our basic designs for your own particular applications. By doing this, you will learn a great deal and will end up with a project that better meets your own requirements. This can be great fun and the satisfaction of realising your own design can be immense. Finally, we plan to be back in September 2013 with a completely new *Teach-In* series devoted to the Raspberry Pi, so watch this space for future developments! ***EPE***

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!

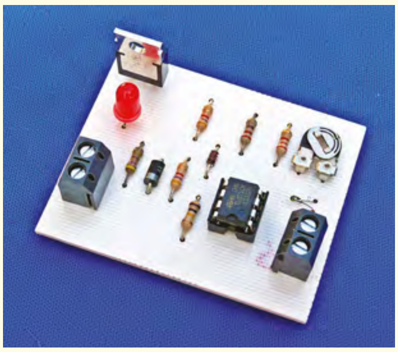


Fig.22. Assembled Temperature Alarm

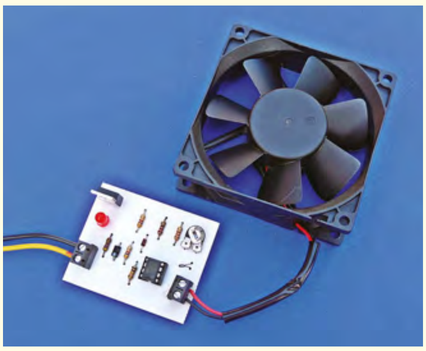


Fig.23. Our Temperature Alarm is ideal for use in cooling applications

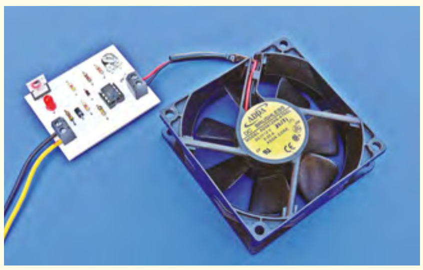


Fig.24. Most large PC fans will operate with a supply of between 9V and 12V and currents of 150-300mA

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

Application	Output device	Typical trigger temperature	Description
Personal cooling fan	Fan	20-25°C	Keeps you cool when it gets too hot! Check out our example using a PC fan in the gallery section.
Fridge/freezer alarm	Buzzer/sounder	Fridge: 5°C Freezer: -18°C	Warns you if the temperature rises above the safe temperature for food storage. Could be used as a battery powered back-up to warn you if the fridge/freezer is accidentally turned off or breaks down and begins to defrost.
Greenhouse environmental control	Window actuator	25°C	Opens windows/vents in hot weather to prevent overheating.
Electronic device cooling system	Fan	35-40°C	Activates a fan when the enclosure temperature rises inside an electronic system. Could also control a water pump on a water cooled system.
Food temperature probe	LED	75°C	Used to check that food is cooked safely. Use an external thermistor probe.
Baby bath water checker	LED/buzzer	37°C	Check that the water temperature is safe for your little ones! Use an external waterproof thermistor sensor.
Fever checker	LED	38°C	Used to test if you have a high body temperature. Use a thermistor probe suitable for internal use.

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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An Atlas LCR Passive Component Analyser, kindly donated by Peak Electronic Design Ltd, will be awarded to the author of the Letter Of The Month. The Atlas LCR automatically measures inductance from 1mH to 10H, capacitance from 1pF to 10,000μF and resistance from 1Ω to 2MΩ with a basic accuracy of 1%. www.peakelec.co.uk

All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

Lightning detector

Dear editor
John Clarke's *Lightning Detector* (Mar 2013) was a very interesting project, and I couldn't help but be drawn to the heart of the radio receiver, the ZN414. This struck a chord with me because the very first *Everyday Electronics* project I built was a matchbox radio, using the ZN414. This was back in the mid-1970s when the magazine was still called *EE*, before it merged with *Practical Electronics* to become *EPE*. In fact, I put 'matchbox radio everyday electronics' into my favourite search engine and immediately found this article, **www.mds975.co.uk/Content/trfradios.html**, which includes a picture of the front cover of the very issue of *Everyday Electronics*, from September 1975!

I was still at school, and I remember how simple the circuit was. I already had some of the components and the others I sourced from my local electronics store, but I had to send off for the ZN414 by mail order.

John's comment that the ZN414Z was originally available in 1984 caught my eye, as it implied 'first available' from that year. To be fair to John, the 'Z' suffix may be an updated model or a manufacturer reference. Nevertheless, I just wanted to remind you that this IC, in some form or other, has been around since at least 1975, and you've been publishing projects that use it for nearly 40 years – keep up the good work!

Mark Stock, by email

Matt Pulzer replies:

I suspect many of us built tiny radios as one of our earliest projects, a tradition Mike and Richard Tooley supported with a recent Jump Start *project.*

Strictly speaking, as editor, I can't condone scanning and posting old EPE *material – it is still under copyright. That said, I don't wish to be a complete wet blanket, and I think after the best part of forty years I can let this one pass.*

I draw many of the circuit diagrams for EPE*, and couldn't help notice that we have managed to maintain much of the clear, clean style developed in the 1970s. Back then it was a case of using transfers (does anyone under 30 even know what they are?!) and pen and ink. Now though, thanks to Adobe Illustrator, it is a much easier job*

Dodgy downloads

Dear editor
I recently followed a link to the *Magnetometer* project in your 2004 volume. This took me to a site, probably Russian, that promised downloads of magazines for free, no subscription needed. Thinking this was a legitimate website, I searched for that issue of *EPE*. The site took me in circles, promising to deliver the download, but never doing it.

I saw a 'Download' button and, thinking I needed software to read the 'free' downloads, I clicked on it. This was a *big* mistake. The site began to download all sorts of software I hadn't asked for (eg, Uniblue and some toolbar), and then attempted to send malware (detected by Norton Internet Security). It deleted my current sessions of Firefox, replaced the traditional interface with the new one and other intrusive actions. Eventually, I was able to return to my previous state, and as far as I know I'm up and running again, although I'll need to run Norton on my downloads and programs before I can be sure of this.

If giving away online issues is not a service you provide, you probably want to end this piracy. I looked at the FAQ on your legitimate site and I didn't see any warnings concerning this problem; so I suggest that you do so, since the site in question is targeting potential customers for abuse.

Mark Harder, by email

Alan Winstanley replies:

Thank you for contacting us about your recent problems with a download. If the link was printed almost a decade ago then of course anything could have happened subsequent to that. Although it's unlikely, it could have been sold, redirected or hijacked since then.

You are quite right to be very cautious about following unrecognised links. Unfortunately, disreputable websites try to attract or intercept traffic that is searching for free copies of software, free downloads or even pirated publications. Often, they also try to make money by charging a few dollars for a faster download.

Some dodgy websites may try to drop files onto your PC that are infected with malware, spyware or viruses. This is a known problem that is impossible to police fully. While I'm not sure that it's our job to warn surfers how to surf the web in safety, it's worth reminding users of the need to be vigilant and use up-to-date anti-virus software to help avoid problems caused by infected files or websites. I also strongly recommend scanning with Malwarebytes, free (only!) from: ***www.malwarebytes.org***

Back issues of EPE *are available via our online Shop and plenty of help is available in our forum at* ***www.chatzones.co.uk****.*

Circuit Surgery success

Dear editor
Please thank Ian Bell for so thoroughly covering my *Chat Zone* query on op amp bandwidth in April's *Circuit Surgery*. I feel quite flattered that he chose this topic. I don't think that I have ever seen my name or *Chat Zone* moniker in national (and international!) print.

I always look forward to his coverage of topics, some I am familiar with, and some I am not, but it is unfailingly informative.

Thanks again for a great column.

Paul Bowden (bowden_p), via email

Matt Pulzer replies:

And thank you Paul for your question, which triggered such an interesting Circuit Surgery *article. We would like to remind readers that* Circuit Surgery *is essentially an opportunity for any of you to ask us questions, however 'basic'. We welcome enquiries and look forward to receiving letters and emails.*

Sourcing old project hex files

Dear editor
Can you kindly send me as an attachment the relevant hex file for the project *Fading Christmas Lights* by Bart Trepak, described in the December 1998 (*Practical Electronics*) issue. I need to reprogram the PIC (16F84) to get the project working again.
I am 74 years old, still kicking, and have been buying and reading your excellent magazine since its first issue – keep it up.

Salvino Vella, Malta

Alan Winstanley replies:

Many thanks for your enquiry. Older source code files for projects up to roughly the 2008 editions will be found on my own website at ***www.epemag.net*** *under the Hobby Electronics section. It should be pointed out that older PIC microcontrollers may not be available any more, so you should check that you can still obtain them before commencing any serious work on an old project. Otherwise, it may be necessary to adapt the source code to run on a current generation microcontroller. (I have sent you the source code by email.)*
It's great to hear from loyal readers and everyone at EPE *much appreciates your continued interest.*

Replacement LCDs

Dear editor
Does anyone connected with the magazine know a source for a replacement small LCD unit about two inches across? I need it to replace a failed display in a pocket calculator.

RB Marshall (Wiltshire)

Alan Winstanley replies

Thank you for your enquiry. I think it would be tremendously difficult to source a replacement LCD as a spare part. There are virtually infinite variations in design and pinouts, and pocket calculators themselves are such a very low price that it becomes non-viable trying to repair them. Sadly, they often end up being thrown away. The LCDs are usually anonymous and have no manufacturers' marks and so I'm afraid I can't highlight any particular source of spares.
If you wished to explore the calculator further, then the best I can suggest is to keep watch for an identical one and rob it for spares, but the chances are that, if faulty, its original owner would have thrown it away! At least by recycling them they don't end up in landfill (we hope).
I'm sorry I could not be of more help, but thank you for your interest.

Thank you!

Dear editor
I was delighted to see my name pop up in a recent *EPE* editorial (March 2013). My association with *EPE* has been one of the happiest of my life. I long had the ambition to transfer my writing to philosophy and theology. With this, *EPE* greatly assisted me by paying me for the *IU* projects submitted. I was able to pursue two postgraduate degrees. Most recently, I had the rare privilege of being published by the Philosophical Society of England.

Rev Thomas Scarborough, Cape Town

Matt Pulzer replies:

Congratulations on your latest publication Thomas, and thank you for your many contributions to EPE.

Economic PSUs

Dear editor
I enjoyed Nicholas Vinen's article on producing a cheap bench supply: useful and cheap. Perhaps Nicholas can surprise us with a further development of a PC power supply unit in the guise of a 13.7V unit suitable for car battery charging, maybe using an SCR/Zener combination? I use a very neat circuit, which charges and floats a battery, requiring an input voltage of between about 14V and 20V.
To increase the 12V to a higher voltage no doubt requires some ingenuity and a deep understanding of switch-mode circuits (which I lack) but I once came across a project where the ferrite output transformer on the 12V line is unsoldered, dismantled and a few turns added to the secondary winding.

Leon van der Merwe, Pretoria, South Africa

Nicholas Vinen replies:

We have considered doing this on a number of occasions, but generally the conclusion seems to be that the cost of the extra circuitry required to turn a PC power supply into a battery charger is higher than simply buying a decent battery charger. A cheaper way would be to modify the power supply to output a higher voltage, but this is both potentially dangerous and requires specific knowledge of the brand and model being modified.

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

editorial@wimborne.co.uk

Max's Cool Beans

By Max The Magnificent

Radiation is one of those topics that just about everyone has heard about, but that the majority of people really don't understand. I asked my wife, Gina, 'What is radiation?' She replied, 'I don't know… I just know that I don't want to be in the same room as it!' As it happens, her response is somewhat unfortunate, because radiation from one source or another is all around us. In addition to cosmic rays raining down on us from above, radioactive elements are found in the ground we walk on, the air we breathe, and the food we eat. Microwave ovens generate (you guessed it) microwaves, old-fashioned cathode ray tube (CRT)-based television sets and computer screens produce low-energy X-rays, smoke detectors contain small amounts of radioactive isotopes, and... the list goes on.

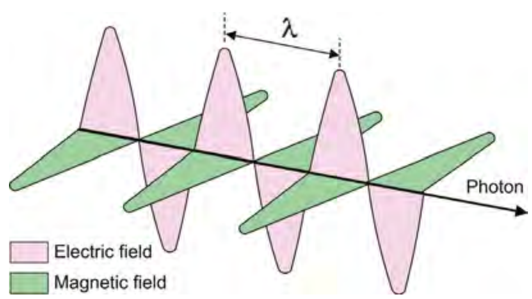
The interesting thing to me is that I've recently been chatting to a lot of embedded design engineers, and I was surprised to discover how little many of them know about radiation in general, and how it affects electronic components and systems in particular. Once again, this is somewhat unfortunate, because as we shrink the size of transistors on our integrated circuits, they become increasingly susceptible to the effects of radiation.

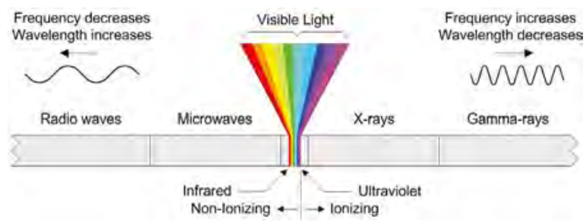
In the not-so-distant past, the only electronic designers and engineers who were concerned about radiation were those whose systems were to be deployed in high-radiation environments, such as nuclear power stations on the ground, or aerospace applications like high-flying aircraft or satellites and deep space probes. But now, with current state-of-the-art digital integrated circuits being fabricated at the 28nm (nanometer) process node, and with 22/20nm and 14nm devices racing towards us, designers are going to have to give this topic much more consideration. It will only take one car to go into uncontrollable acceleration, or one UAV (unmanned air vehicle) to mistakenly fire on a friendly target, and every designer on the planet will find that creating their designs in such a way that they can mitigate against radiation-induced effects is right at the top of their priority list.

Electromagnetic radiation

Radiation comes in different forms. One type is electromagnetic radiation (EM radiation or EMR), which is a form of energy emitted and absorbed by charged particles that exhibits wave-like behaviour as it travels through space. The force carrier for electromagnetic radiation is a massless particle called a photon, which travels at the speed of light.

The electromagnetic spectrum is the range of all possible frequencies of electromagnetic radiation. This spectrum extends from below the low frequencies used for modern radio communication to gamma radiation at the short-wavelength (high-frequency) end, thereby covering wavelengths from thousands of kilometers down to a fraction of the size of an atom. The limit for long wavelengths is the size of the universe itself, while it is thought that the short wavelength limit is in the vicinity of the Planck length. In principle, however, the electromagnetic spectrum is infinite and continuous.





Ionising versus non-ionising

If a photon with a frequency less than that of ultraviolet light interacts with an atom or molecule, then it contains only enough energy to excite an electron into a higher energy level. Sometime later, that electron will return to its original energy level and emit a photon. Since the photon does not strip an electron away from the atom, this is referred to as 'non-ionising radiation.'

By comparison, if the photon has a frequency in the ultraviolet or higher part of the spectrum when it interacts with an atom or molecule, it can impart enough energy to strip away an electron, thereby leaving a positive ion. This is referred to as 'ionising radiation.'

Although it's common to think about ionising radiation as being the real 'problem child,' non-ionising radiation in the case of RF (radio frequency) from things like cell phones can cause a tremendous number of problems. In the past, these problems have predominantly been associated with low-voltage analogue signals, because any RF-induced voltage or current values may be amplified resulting in DC offsets or unwanted modulated signals. Once again, however, as the transistors in digital functions are being created with smaller and smaller geometries, they are becoming increasingly susceptible to RF-induced electromagnetic noise.

Recently, I was talking to an expert in this area, and he was telling me about all sorts of examples, such as an alarm in a nuclear power station that mistakenly triggered at approximately the same time every evening, or an automatic valve in an oil refinery that turned itself on at the same time in the wee hours of the morning. In both cases, the problem was eventually traced to security guards who paused on their rounds to take a break and called in to the security station on their radios to specify their location.

Next month...

In part two of this gripping tale of radiation, we will introduce other forms of radiation and start to consider their effects on digital electronic circuits and the ways in which we can create our designs to mitigate against these effects. Until then – have a good one!

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Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

Loose ends and missing links

THIS month's *Practically Speaking* article is about what could be termed loose ends and missing links. Newcomers to electronic project construction quite rightly become a little concerned when they find that some components in a project have leads, pins or tags that do not connect to anything. Surely there must be some mistake in the construction diagrams when components are left with connection points that are wired to nothing? Surely a finished unit that is built as per these diagrams could not possibly work?

Going nowhere

While it is not a certainty that all is well in these circumstances, in the vast majority of cases the diagrams are correct; there are connection points that quite rightly lead to nowhere, and the project will still work perfectly. One reason for circuits sometimes having components with unused pins or tags is that some components have dummy connection points. This is actually quite common with integrated circuits, and is usually caused by most integrated circuits having encapsulations with two rows of pins, and an even number of pins. If a component only needs (say) seven pins, it would probably have a standard 8-pin encapsulation such as a DIL (dual in-line) type, with one pin being left unused. Unused integrated circuit pins are usually marked 'NC' or 'no connection' on pin-out diagrams.

At one time, it was quite ordinary for manufacturers to offer 14-pin versions of 8-pin chips. By this, I do not mean that they produced something like an 8-pin device and a dual version of the same chip in a 14-pin encapsulation, with the two sections operating independently apart from having common supply pins. Dual chips and the like are still much in evidence today, and do not result in unused pins. I am talking about 14-pin chips that are essential just 8-pin devices with six unused pins added! I am not sure why these 'jumbo' versions were produced, and it is a practice that seems to have gone out of fashion. Consequently, these days you are unlikely to encounter chips where about half of the pins serve no useful function.

Another reason for an unconnected pin of an integrated circuit, and quite a rare one, is that the device has a test or IC (internal connection) pin. In other words, it has a pin that is used in the final test procedure for the device, but it serves no useful purpose thereafter. If an accidental connection is made to an 'NC' pin it will not matter, but it is important in normal use that nothing connects to a test pin. The data sheet for a device that has a test pin will usually contain warnings to this effect.

It is unusual for other types of component to have dummy tags or pins, but it is not unknown. For example, I have encountered transformers equipped with several pins for the secondary windings, but only actually having one secondary winding needing just two tags. This type of thing occurs when a manufacturer rationalises a range of components and uses the same basic structure to accommodate the simple and more complex components in the range. This presumably helps to keep down manufacturing costs, but can be a bit confusing for users of the basic components in the range. With luck, there will be markings on the component to indicate which tags are actually used, and their functions. If not, the manufacturer's or retailer's literature should include a connection diagram that clarifies matters.

Spare capacity

Probably the most common reason for unused connection points on components is simply that their full capabilities are not needed in every circuit. As an example, the popular 555 timer chip has eight pins and they all have functions. If you look at some circuits that use this chip it is likely that most of them will only use seven of the pins, with pin 5 mostly being left unconnected. This pin can be used to modify the internally set threshold levels of the chip, but few applications actually require this facility and pin 5 is therefore mostly left unconnected.

Similarly, many operational amplifiers (op amps) have offset null terminals that can be used to 'fine tune' the output voltage, but this facility is little used in practice. It is quite normal for only five pins of an eight-pin op amp to actually be used. Like test pins, it is important that no accidental connections are made to unused pins which actually have a function. Any solder bridges causing short-circuits to these pins are certain to prevent the circuit from working.

Going spare

Another cause of unused connection points is components with two or more sections that are not fully utilised. This often occurs with logic integrated circuits that contain several elements, such as multiple gates, inverters, or buffers. If a design requires (say) two inverters, a quad or hex device would have to be used because twin versions are not manufactured.

Unused sections may simply be ignored, but remember that with most MOS devices there can be problems if unused inputs are left unconnected. They are vulnerable to damage from static charges and can be operated by stray signals, producing an unnecessary increase in current consumption. The usual solution is to connect the unused *inputs* to one or other of the supply rails. Of course, any unused *outputs* will still be left unconnected. Checking the circuit diagram should show whether the construction diagrams are in error, or the device in question simply has some unused pins.

Switches

The subject of switches has been covered recently in this series of articles, and it will not be considered in detail again here. However, some explanation is in order, since there is nothing unusual about a switch having less than half its tags/pins actually connected to anything. Multi-way rotary switches are probably the worst culprits, and will sometimes have 75 percent of their tags/pins left unused. One reason for this is that with (say) a three-way rotary switch, the manufacturers do not produce them in one, two, three, and four-pole versions. They make only a four pole type, and users simply ignore any extra poles that are not needed.

Fig.1 shows the tag arrangement used for a typical 3-way 4-pole rotary switch. If, for example, you needed a 3-way 2-pole switch, one way of achieving this would be to use tag A with tags 1 to 3 as one pole, and tag C with tags 7 to 9 for the other pole. In fact, any two poles with their associated tags would suffice, and there will be eight tags left unused. Many modern rotary switches have an adjustable end-stop so that you do not have to use the full number of ways, and this makes them much more versatile. For instance, suppose a design requires a 7-way 1-pole switch. It is unlikely that a search of all the current electronic component catalogues would produce a single match for this specification. However, a standard 12-way single-pole rotary switch Fig.1 (left) with the adjustable end-stop set for 7-way operation would give the desired result. The tags from 8 to 12 would be left unused though.

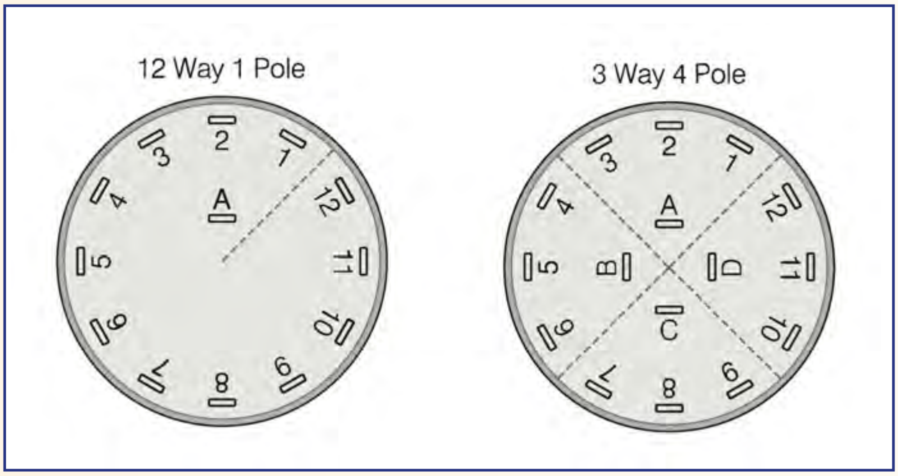

Fig.1. The tag arrangements used for 12-way 1-pole and 3-way 4-pole rotary switches. Both switches are more versatile than their names suggest

There is no real problem when using multi-way rotary switches that fit direct onto a printed circuit board. They will only fit with a suitable orientation, so it is just a matter of making sure that all the pins are correctly aligned before starting to solder them in place. More care is needed when hard-wiring one of these switches to a circuit board, since it is easy to slip ‘out of sync’ by one set of tags. It can be difficult to see the tiny letters and numbers moulded into these components; checks using a continuity tester provide a more reliable means of ensuring that you get it right first time.

Relays are another component that often have a number of unused tags or pins. A relay is a normal mechanical switch, but it is operated via an electromagnet rather than manually. There are relays that provide simple on/off switching, which is all that many applications require, but many of these components have more complex contact arrangements, such as four sets of changeover contacts. These contacts are often underutilised in real-world applications, leaving many tags unused.

Unless you know what you are doing, it is probably best to use the specified relay rather than trying to use a substitute component. Apart from physical considerations that can make it difficult to use an alternative type, the solenoid must have the correct voltage and resistance ratings, the contacts must have suitable voltage and current ratings, and the correct method of connection has to be sorted out.

Bit of a DIN

Connectors often seem to have some left-over connection points, and the ones used in digital/computer projects are perhaps the worst offenders. To some extent, this is due to the use of standard connectors that do not always have the exact number of terminals required. Large numbers of connections are often involved, and using standard connectors will often require compromises.

Also, a digital interface could have something like sixteen input/output lines, but some applications might have more modest requirements, such as a couple of inputs and three

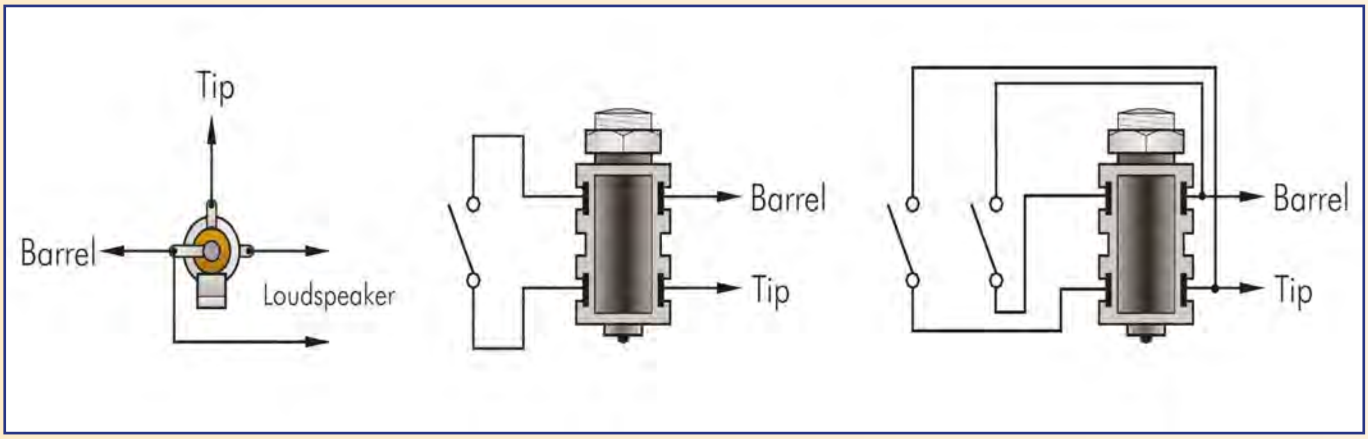

Fig.2. Three types of switched jack socket. With all three types the purpose of the switch or switches is to automatically mute a loudspeaker when a plug is fitted into the socket

or four outputs. You can easily end up with a 25-way connector used with a lead that only has five or six wires. The other pins are either totally unused or are simply not needed in that particular application.

The phenomenon of 'spare' pins/tags is much rarer when dealing with audio connectors, but it is far from unknown. The terminals of DIN plugs and sockets are not always fully utilised. This stems from the practice of using five-way connectors that act as stereo inputs and outputs. Two pins are left unused where only a stereo input or output is required.

I'm alright jack

Jack sockets are probably the most common cause of spare tags. Mono jack sockets are two-way connectors and should have two tags, but the miniature 2.5mm and 3.5mm types often sport three tags. Standard mono jack sockets often go one better and have four tags! The reason for this is that some jack sockets incorporate a switch or switches that necessitates some extra tags.

Miniature jack sockets are often used as headphone or earphone sockets. If there is a built-in switch it will usually be a normally closed type that opens when a plug is inserted into the socket. The switch can be used to automatically switch off an internal loudspeaker when an earphone or headphones are used. This is the age of portable audio devices, most of which do not have an integral loudspeaker, do not require any built-in switch, and have one of the three tags left unused.

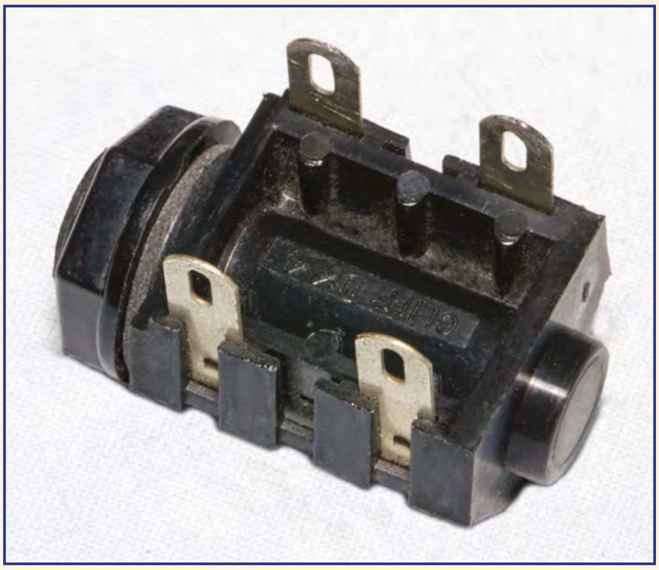

Fig.3.Standard jacks are one of the oldest types of connector, but are still in widespread use today. This is a standard socket that has two built-in switches

On the face of it, a two-way socket and an on/off switch both require two tags, giving a total of four tags. However, with the miniature jack sockets one contact of the switch is combined with the tag that connects to the 'tip' of the plug. Fig.2 (left) shows how this can be used to provide automatic muting of a built-in loudspeaker. The switched standard jack sockets have four tags, as do some miniature types. Sometimes there is a single switch that has its connections kept separate from the socket tags, as in Fig.2 (middle). The more common arrangement is to have two switches that connect internally to the connector's tags, as in Fig.2 (right). With this arrangement, the loudspeaker connects to the two switch tags, and it is completely disconnected when the plug is inserted. Fig.3 shows a standard jack socket of this type.

Matters are confused slightly by stereo jack connectors that have three tags but no built-in switches. The three tags simply carry the earth and two signal connections. There are also jack sockets that have non-standard switch arrangements. Retailers' catalogues sometimes provide internal connection diagrams for the more exotic jack sockets. Due to the numerous variations on this basic type of connector it is probably best to make some checks before wiring one into circuit. The most basic of continuity testers, plus some simple checks will soon show which tags connect to the plug, and the connections between tags when the plug is removed.

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Flip-flop triggering

IN the March issue of *EPE, Circuit Surgery* looked at triggering flip-flops, in particular pulse-catching behaviour (eg, 1s catching). Godfrey Manning emailed us asking for a little more explanation of this topic.

Could you help me better understand the 'Ones Catching' phenomenon to which certain flip-flops are prone? The master-slave flip-flops Fig.9 and Fig.10 (repeated here as Fig.1 and Fig.2, with the latches shown in Fig.3 and Fig.4) only differ in the means by which the data is entered. One is by set/reset and the other by a D input. Ignoring the meaningless state where set and reset are asserted simultaneously, they both look to be postponed, edge-triggered to me. Have I missed the point?

I'll assume that SR or D correctly meet the settling time just prior to the clock edge. Then, latch L1 alters state with every change of input while the clock is high, the latch is also transparent so as to pass the current input to its output – which is ignored by L2 which is in the unchanging state (because its C is low, through an inverter). The clock then changes state, the negative edge renders L1 unchanging and the inverted clock allows L2 to become transparent.

It doesn't seem to matter how the input gets into L1 in the first place, SR or D can change arbitrarily with no effect until the clock edge arrives. I have found a reference to '1s catching' in Horowitz and Hill, but this is confined to JK flip-flops.

To investigate this I worked on a simplified diagram of the internal logic of a 74107 (see Fig.5) (the 7473 is pretty much the same), first assuming that the output Q was high and seeing how a clock pulse affects the response to the K input. This input is one of three going into an AND gate, the others being Q and Clock. To prevent Q from clocking high-to-low, K needs to be low – this in turn forces the AND gate output to low. The AND gate feeds a NOR gate, half of the master flip-flop, the other input of which is low. Now, while Clock is high, if K pulses high then back to low, then the AND gate pulses likewise and the NOR gate receives one high input for a brief instant – this condition resulting in a brief low output. The result is that it flips the state of the master, this altered state is stable even after the 'flip' stimulus is removed (because the other, previously-low, NOR input has flipped high so it's not possible for any further change – that would require 'Two lows give a high').

Well, a keen follower of yours is interested in the explanation! I always read Circuit Surgery *and try to follow every detail (even seeing if I can keep up with the algebra) – not bad for a mere amateur.*

Thanks Godfrey, it is good to hear that you enjoy *Circuit Surgery* and are not put off by the algebra. Apologies for not making the original article clear enough. Much of what you say in your email is correct, but Fig.2 is edge triggered rather than postponed, and we will have another go at explaining and demonstrating this, as well as looking at pulse catching in the context of JK flip-flops (the March article just used the SR flip-flop in Fig.1).

First a quick reminder of the discussion from March: the circuits in Fig.1 and Fig.2 are both master-slave flip-flops, built using two clocked latches. Basic clocked latches such as those in Fig.3 and Fig.4 are transparent, that is the output directly follows the input for one of the clock states. This is undesirable because it is difficult to build well-behaved larger circuits in which all the latches are controlled by the same clock.

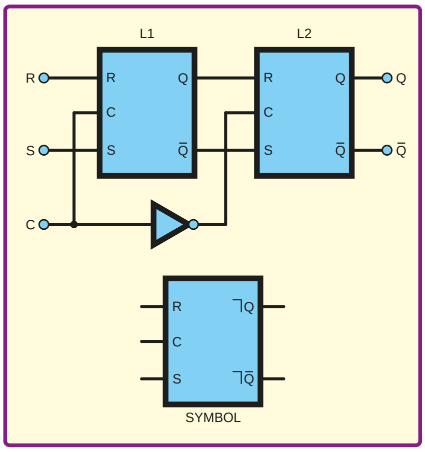

Fig.1. Pulse-triggered master-slave set-reset flip-flop and symbol. Note the postponed output symbols on the flip-flop symbol

When in transparent mode, multiple logic value changes could ripple through series of latches, leading to unpredictable outcomes. Using two latches switched in opposite fashion forms a flip-flop, which is never transparent. The output updates only

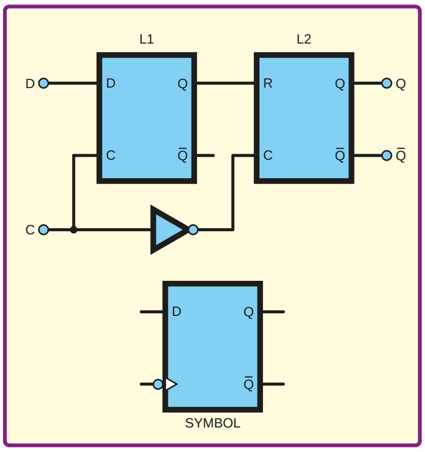

Fig.2. Negative edge-triggered master-slave D-type flip-flop and symbol

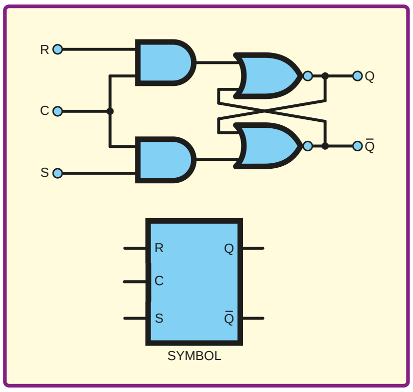

Fig.3. Set-reset latch with control input and symbol

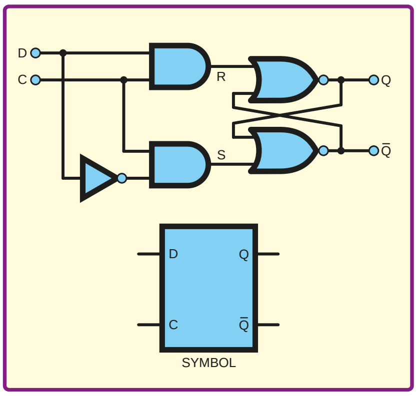

Fig.4. Transparent data latch and symbol

after a clock edge (1 to 0, or 0 to 1 change) and cannot be directly altered by the other (clock-controlled) input(s). Logic level updates in a large circuit can then be more readily coordinated by a system clock.

So the flip-flops in Fig.1 and Fig.2 do indeed both update their outputs on a clock edge, as Godfrey states. The difference is in the *requirements* placed on the inputs for correct operation. This 'correct operation' is based on the idea of a *synchronous* system. As indicated above, in such systems, the current operational state and data values are stored in flip-flops, and these are only updated under the direct control of the clock – that is, all updates are synchronised to the clock. This is not the only way to design a digital system, but it is very well established and widely used because it provides the basis of systematic design strategies which allow efficient and effective design of complex digital circuits.

For both the flip-flops in Fig.1 and Fig.2 (as Godfrey states) we may require adherence to setup and hold time requirements (ie, SR or D respectively do not change too close to the relevant clock edges). The set-up and hold times are basically fixed (for a given technology, temperature, supply voltage...) and, if the flip-flops are clocked at well below their maximum rate, these times represent a small fraction of the total clock cycle. Like Godfrey, we will simply assume that setup and hold times are adhered to in the remaining discussion. They are important, but are not the key issue here.

SR flip-flop

In the case of the SR flip-flop in Fig.1, in addition to setup and hold requirement, we have the condition that R and S must not change while the clock is high. This requirement covers the whole clock-high time, and therefore will typically apply for half the clock period (with a square-wave clock), however fast or slow the clock is. The flip-flop in Fig.1 samples its inputs on the positive clock edge and updates its output to this sampled value on the negative clock edge (ie, it has a postponed output).

It is the sampling by the positive edge that is the really key thing here. If the R or S inputs are activated while the clock is high they may wipe out the value sampled at the time of the positive clock edge. If this happens, updating of the flip-flop can no longer be described as being synchronised by the clock. In the flip-flop in Fig.1, R and S are active high, so by 'activated while the clock is high', we typically mean pulsed to 1 when they should have stayed at 0. This is why this behaviour is called 'pulse catching' in general and '1s catching' in this case.

The circuit in Fig.1 can 'catch' pulses from both inputs during one clock cycle. For example, if we have R=1, S=0 during the positive clock edge, then the master latch (L1) will reset at this point. A pulse to 1 on S while the clock is high will be caught, setting the master latch. A pulse to 1 on R later in the clock-high period can reverse this action, reseting the master latch again. As we will see later, and as noted by Godfrey, this is not the case with JK flip-flops such as the 74107.

D-type

The D flip-flop in Fig.2 both samples its input and updates its output on the negative clock edge (so it is not postponed); unlike the SR flip-flop the positive edge is not involved directly in sampling. The 'master' (first) latch (L1) simply follows the D input while the clock is high; this process starts just after the positive clock edge, but the D value present at this time does not have special significance. The input can change at any time up to the setup time before the negative clock edge without causing a wrong value to be sampled at the negative edge and thus the output.

This difference in behaviour is really by virtue of the fact that the flip-flop in Fig.2 only has one input (other than the clock), rather than because of any fundamental difference in the structure of the two circuits (which, as Godfrey notes, are very similar).

As Godfrey indicates, pulse catching is often discussed in the context of JK flip-flops, because they are commonly implemented as master-slave structures, whereas SR flip-flops are not. The March article used a clocked SR flip-flop as an example to keep the circuits discussed as simple as possible. However, we will now look at the JK flip-flop.

JK flip-flop

The JK flip-flop overcomes the problem with the SR flip-flop of undefined behaviour when both R and S are activated at the same time; otherwise its action is the same (with J being the 'set' and K being the 'reset'). The JK flip-flop toggles its output value when both J and K are 1. Table 1 and Table 2 define the behaviour of both types of flip-flop for comparison purposes. We can also write a Boolean equation for the 'next Q' (Q^+) – after the clock – in terms of the current output (Q) and the inputs J and K:

$$Q^+ = \overline{K}Q + J\overline{Q}.$$

Table 1: SR flip-flop behaviour

S	R	Value of Q after clock (Q^+)	Action performed
0	0	Previous Q	Hold
0	1	0	Reset
1	0	1	Set
1	1	Undefined/ not allowed	Undefined/ not allowed

Table 2: JK flip-flop behaviour

J	K	Value of Q after clock (Q^+)	Action performed
0	0	Previous Q	Hold
0	1	0	Reset
1	0	1	Set
1	1	Previous $\overline{Q}$	Toggle

Godfrey's email mentions the 74107 JK flip-flop. The schematic from the datasheet is shown in Fig.5. This flip-flop has a similar structure to the circuit in Fig.1, but also features a direct/ asynchronous reset (clear) for both latches (the CLR input). The two NOR gates form the master (first) latch and the two NAND gates from the slave (second) latch. There is also some logic to implement the toggle function, which

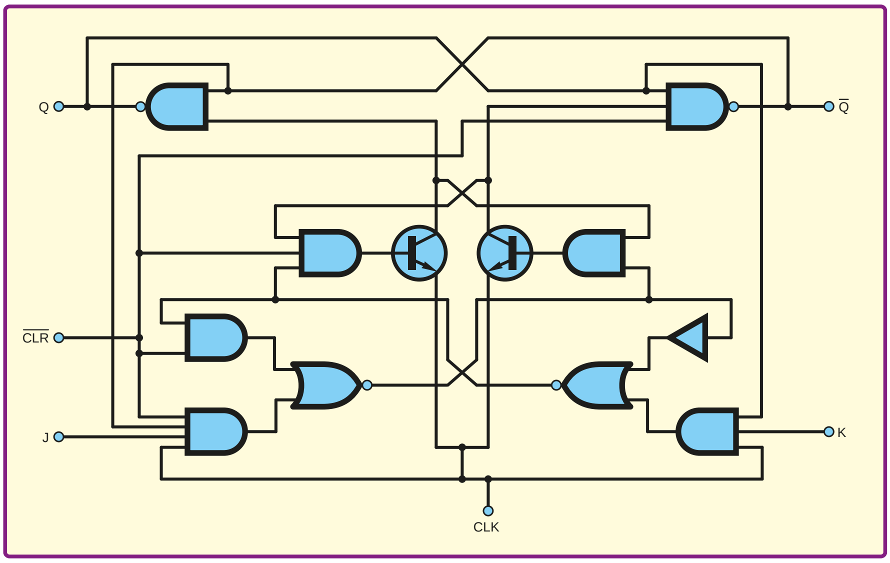

Fig.5. SN74107 JK flip-flop schematic from Texas Instruments datasheet

requires feeding back the flip-flop's outputs to its inputs when J=K=1. The transistors perform the clock inversion.

Pulse catching

Godfrey's description of the 74107's behaviour is correct. This flip-flop is positive-pulse clocked, sampling J and K on the positive clock edge and updating its outputs on the negative clock edge in a very similar way to the circuit in Fig.1. There is a difference though – the JK circuit only catches pulses on one input for any given state of the slave latch.

Once a pulse has been caught, the master latch stays in that state for the rest of the cycle (as Godfrey describes). However, this pulse-catching behaviour can still undo the sampling of the clock; so we have the requirement that the J and K inputs remain stable while the clock is high for correct (synchronous) operation.

Fig.6 shows a simplified version of the 74107 circuit, in which the similarity with Fig.1 is perhaps more obvious than Fig.5. The clear function has been omitted as it is not relevant to our discussion on pulse catching.

Demonstration

We can demonstrate the behaviour of the circuit in Fig.6 by simulating it. In *Circuit Surgery* we often simulate analogue circuits using LTspice. As this is a digital circuit, SPICE may seem like a less obvious choice this month. However, LTspice is able to simulate small digital circuits (and where needed mix these with analogue circuitry). It is not suitable for large digital circuits.

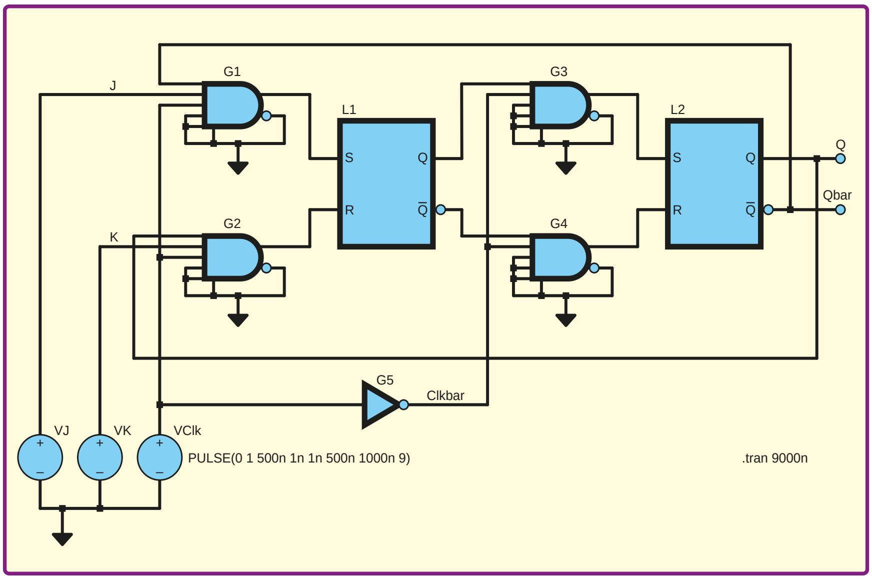

Fig.7. LTspice version of the circuit in Fig.6

An LTspice version of the circuit in Fig.6 is shown in Fig.7. The add component function in LTspice provides a small list of digital gates and flip-flops. These are implemented using behavioural models. At first sight, the logic gate symbols look a little odd. For example, there is a single symbol for both AND and NAND gates – you use the appropriate output for the gate you want. The logic gates have five inputs and can implement gates with two to five inputs. The gate symbols also have a 'common' input on the bottom of the symbol. Unused inputs and outputs must be connected to this common point. The behavioural model code then identifies these as unused and effectively removes them from the simulation.

LTspice logic gates do not require power supply connections and default to using 1V for logic 1, 0V for logic 0, and 0.5V for the threshold between logic 0 and 1. This can be changed via parameter settings, but for a simple pure logic simulation there is no need to do this. The gate delay defaults to zero, but can be set via the td parameter.

For the circuit in Fig.7, the clock is generated using a pulse voltage source and the J and K inputs are created using PWL (PieceWise Linear) sources. The clock has a period of 1µs with 1ns rise and fall times. All gates and flip-flops have td set to 10n to give a 10ns delay.

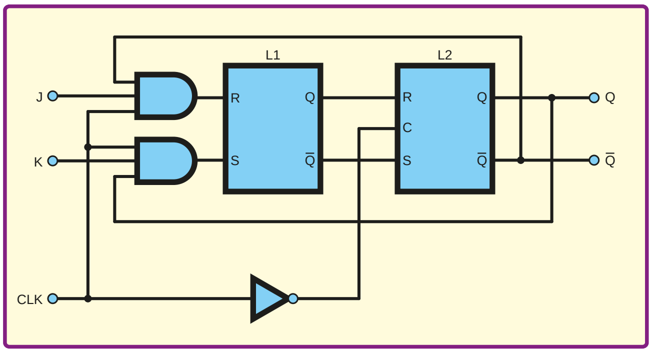

Fig.6. Simplified schematic for the SN74107

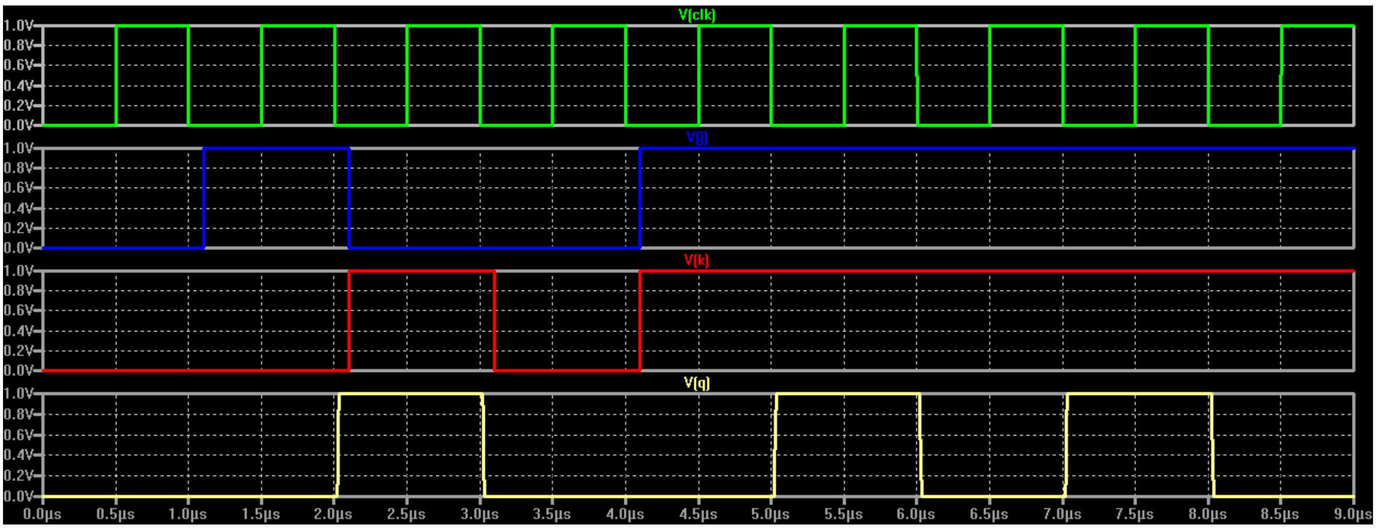

Fig.8. Simulation results for the circuit in Fig.7 with correctly applied inputs

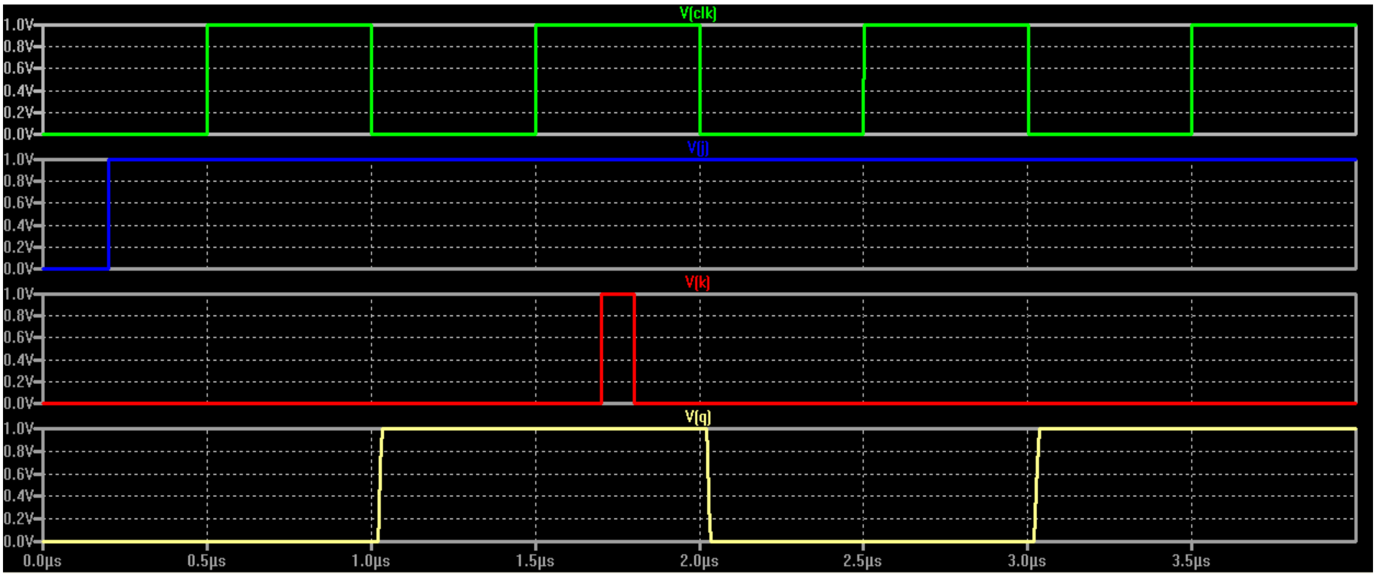

Fig.9. Simulation results for the circuit in Fig.7 showing 1s catching

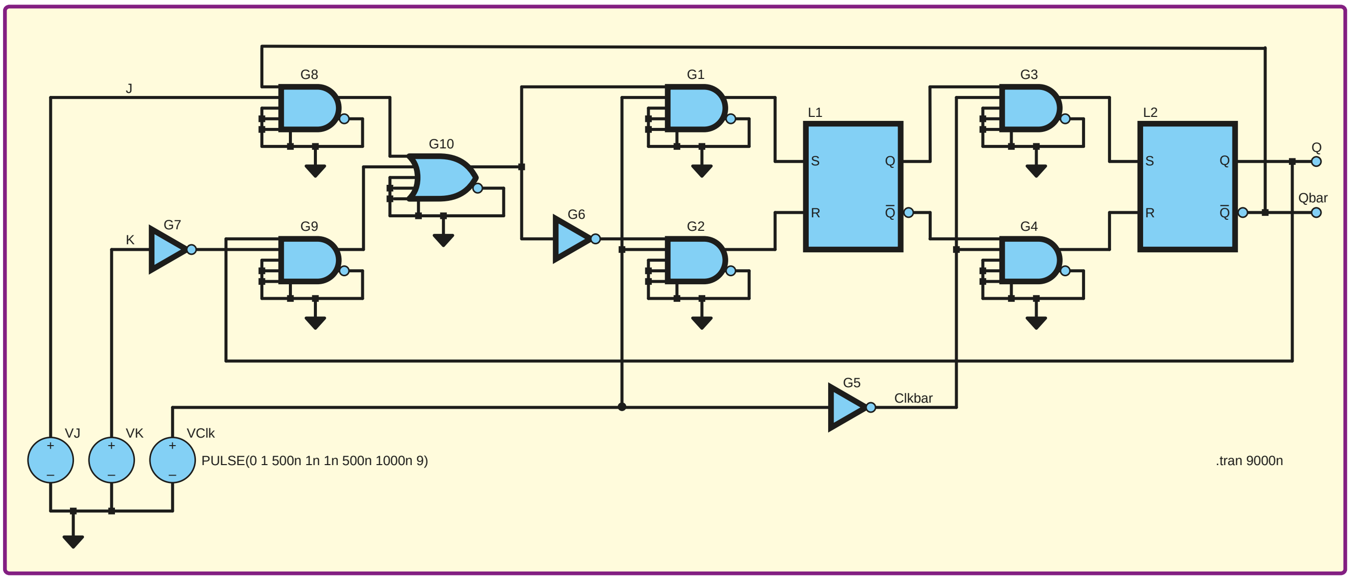

Fig.10. JK flip-flop based on the edge triggered D type in Fig.2

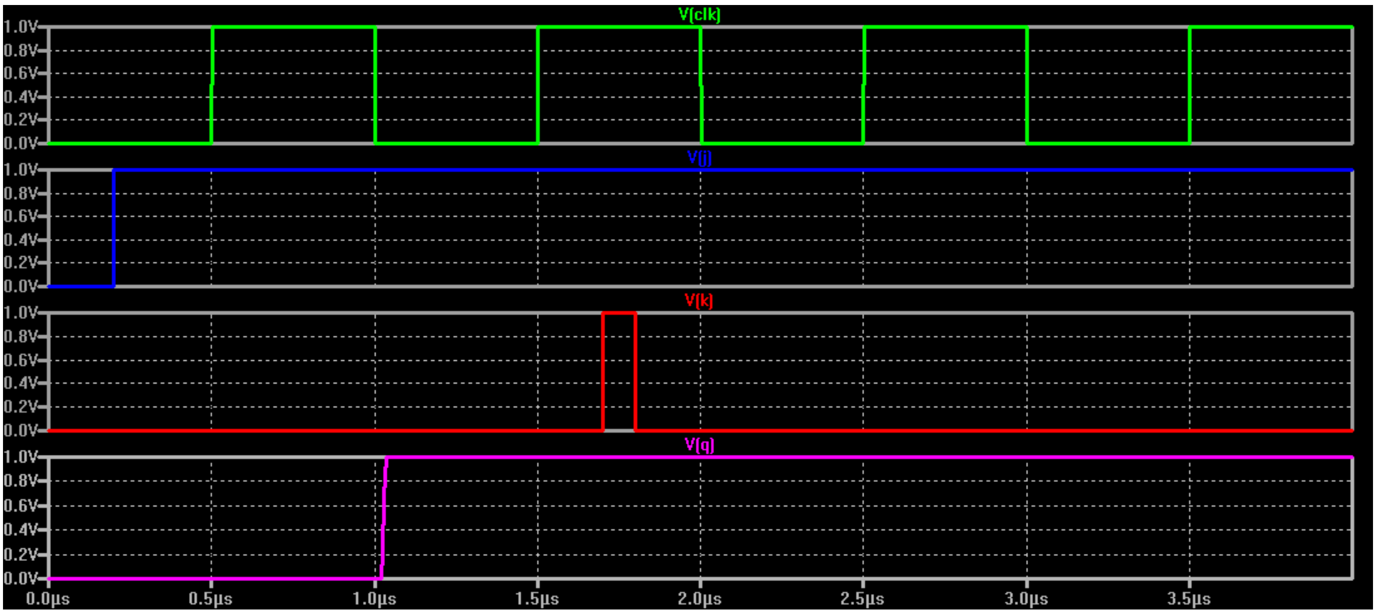

Fig.11. Simulation results for the circuit in Fig.10 showing that 1s catching does not occur

The waveform in Fig.8 shows the circuit operating with inputs conforming to correct usage requirements. Specifically, the J and K inputs change just after the negative clock edge and, most importantly, do not change while the clock is high. The waveform shows the flip-flop being set (J goes high at 1.1µs, is sampled by the positive clock edge at 1.5µs, and the output updates after the negative clock edge at 2.0µs). This is followed by a reset (sampled at 2.5µs, output at 3.0µs). Then both J and K are set high to cause toggling action from the flip-flop.

The simulation results in Fig.9 show the circuit in Fig.7 catching a 1 on the K input. A reset (J=1, K=0) is applied and held from 0.2µs. This is sampled at 0.5µs and output at 1.0µs. The remaining positive edges also sample J=1 and K=0, so the output should ideally remain high for the rest of the simulation. However, between 1.7µs and 1.8µs, while the clock is high, the K input pulses high. This causes the output to reset at 2.0µs. The output is restored to 1 at 3.0µs by the J=1 and K=0 sampled at 2.5µs.

We can use the edge-trigged D flip-flop from Fig.2 to make a JK flip-flop which does not suffer from 1s catching. We take the circuit in Fig.2 and add circuitry to implement the JK Boolean function. The Q^+ value is connected to the D input. Thus, we need a NOT gate for K, a couple of AND gates and an OR gate in addition to the circuit in Fig.2.

Fig.9 shows an LTspice implementation of such a flip-flop. L1, L2, and G1 to G6 form the edge-triggered D-type from Fig.2, and G7 to G10 implement the JK Boolean function. Running a simulation of the circuit in Fig.10 with the same input applied as in Fig.8, produces the same results.

If we apply the inputs from Fig.9 the situation is different. Fig.11 shows the results. This circuit does not suffer from pulse catching. The pulse on K does not cause a reset because the D type is sampling its input (the JK's Q^+ value) on its negative edge. It does not matter what the inputs do while the clock is high as long as they do not change too close to the negative clock edge.

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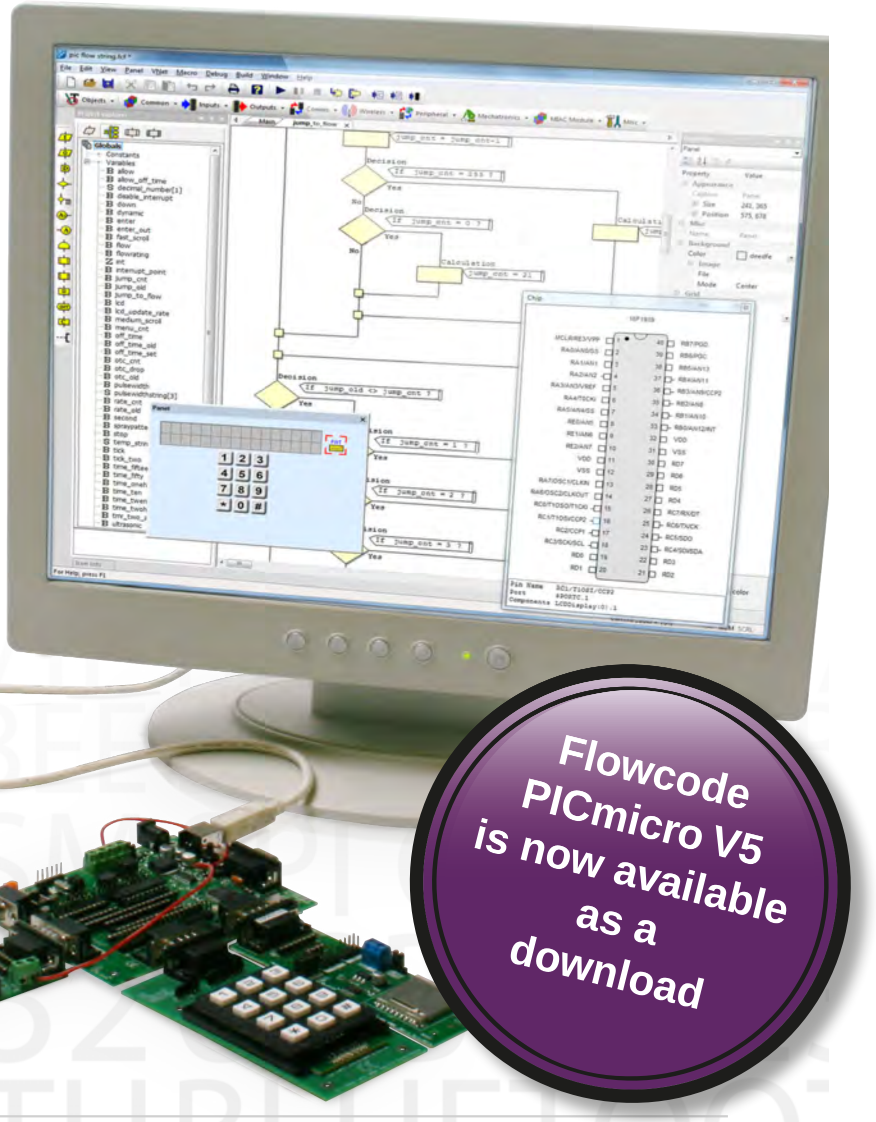

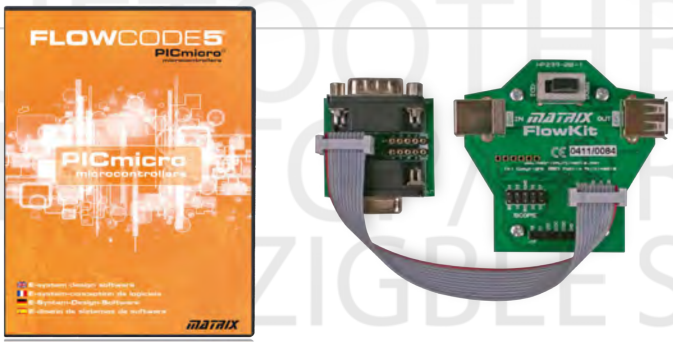

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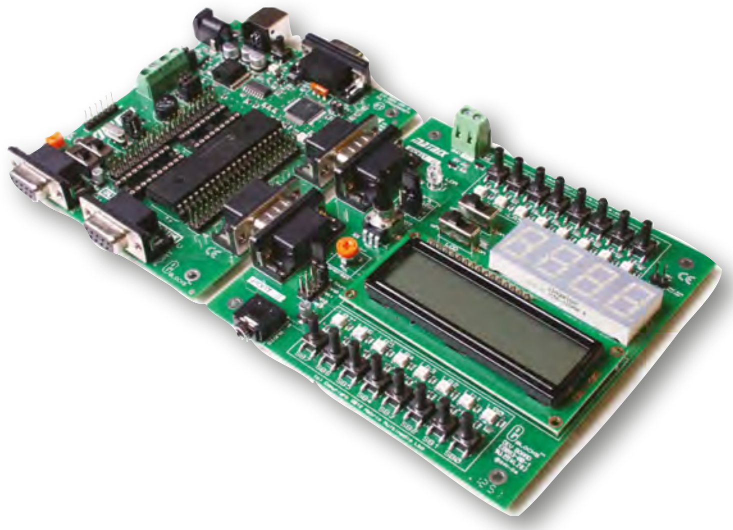

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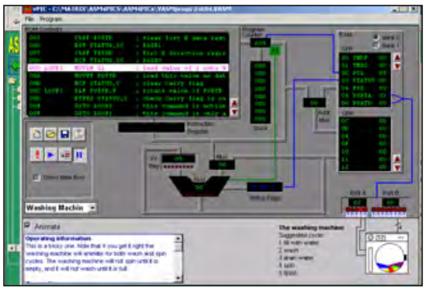

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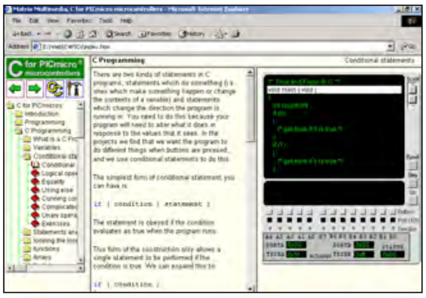

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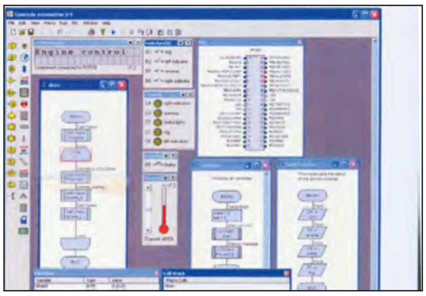

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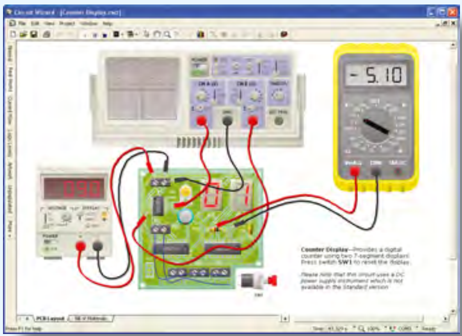

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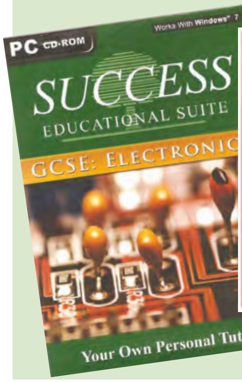

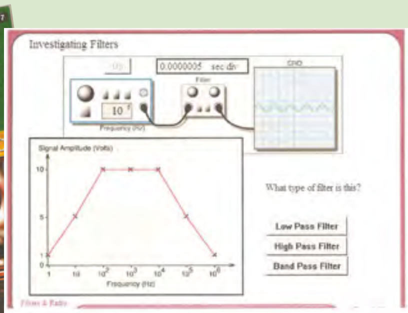

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NET WORK

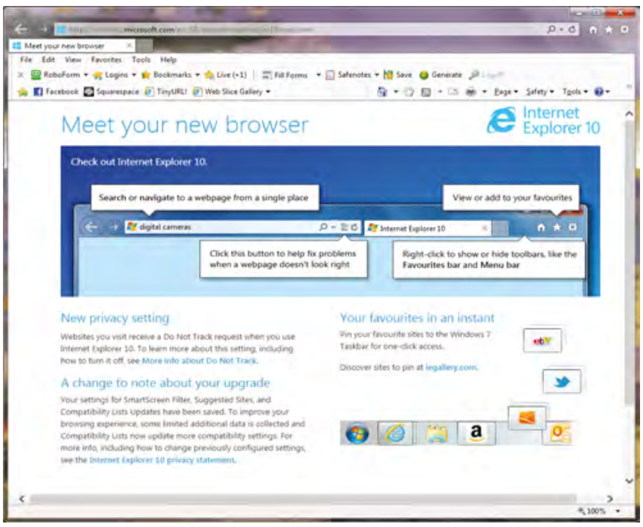
by Alan Winstanley

Total Wipeout

As many computer users will agree, running a home system can have horrendous hidden costs in terms of the personal time spent (or wasted) on maintaining it. I'm sometimes glad that I don't have to call for a hardware engineer to fix home PC or networking problems, otherwise the costs would become insurmountable. Happily, most *EPE* readers can usually handle hardware problems or upgrades for themselves, but for much of the time we depend on software looking after itself, and occasionally a patch becomes available that fixes certain bugs or adds some enhancements.

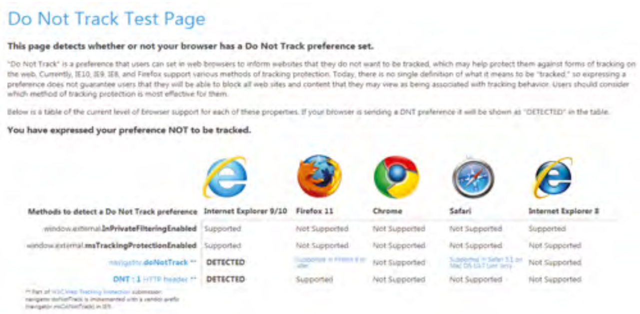
In the 1990s, I recall being horrified at the very thought of Microsoft Windows 98 or Internet Explorer 4 downloading a file and updating itself silently, but these days, fetching an update from the web is an everyday occurrence. Large-scale patches are often released in tranches which are the bane of a computer user's life, especially when several machines are involved. For an overview of Microsoft Windows support and upgrades, visit **http://windows.microsoft.com/en-GB/windows/products/lifecycle**. Note that support for Windows XP expires on 8 April 2014, after which no more updates or security patches will be made available for Microsoft's venerable operating system.

After a blizzard of silent updates on my Windows 7 PC I discovered that my web browser had updated itself and I found myself using Internet Explorer 10. I still hate the way that the Favorites button is over on the right. One of the key points in IE10 is the further implementation of the 'Do Not Track' feature, a way in which users can try to stop websites from scooping up personal data that helps websites follow a user's movements on the web. For example, cookies that are sent to third-party websites enable them to 'pop up' advertisements later on, targeted you based on your recent history of visits. The feeling of being constantly tracked is quite a creepy one,



Microsoft's latest web browser installs on Windows 7 or later. Useful new features include adding instant Favorites on the taskbar

and Microsoft has a useful web page at **http://ie.microsoft.com/testdrive/browser/donottrack/** which scans the Do Not Track settings of popular browsers and reports if DNT is enabled.



Microsoft offers a web page that tests your DNT settings

Still on the subject of software updates, probably the most irksome programs that seem to demand frequent updates are Adobe Reader, Adobe Flash Player and Java. Adobe frequently updates Adobe Reader and Flash Player to fix potential security problems or vulnerabilities. For security reasons it's wise to ensure that you are running current versions on your system: Reader is presently at version XI and Flash Player is V11.7.700, with versions for Windows, Mac and Linux available from **www.adobe.com**.

In a lather over Java

Java is sometimes confused with Javascript by non-techie users. The latter scripting language is in very widespread use and is responsible for many features seen on typical websites today, such as pop-up windows, advertising rotators and many other fancy features on web pages. Java, however, is a self-contained app-like environment that can be embedded into many different platforms, such as mobile phone games or websites. A good example of Java in action is the Wordle website, where you can paste some phrases and Java is used to create a word cloud. I used the previous paragraph of text to create the word cloud shown overleaf. You can have fun at **http://www.wordle.net**, where you can input text and change the colours, fonts and more to create your own design.

Accessing this site in the latest Firefox browser produced an array of pop-up warnings in my case, because a recent Firefox upgrade had caused my legacy Java plug-in to be disabled altogether. The 'Are you sure?' hazard warnings would make many web users think twice before running a Java applet. Even Oracle, the new owner of Java, states that older versions are a security risk. Java is exceptionally prone to vulnerabilities, giving malicious coders an opportunity to compromise a target system or take it over altogether. There are some who refuse to run Java at all, and the best advice is probably that given by Ross Barrett at **www.net-security.org/secworld.php?id=14767**: he suggests that the safest option (other than deleting Java altogether) is to dedicate a separate web browser for using Java only on trusted websites where it's really necessary.

Internet users should think seriously about uninstalling Java, following the instructions at **www.java.com/en/download/faq/remove_olderversions.xml**. For those who can't live without Java, skip over right away to the Java website and fetch the latest iteration of Java Version 7. The Java control options can be accessed via the Windows Control Panel in the Programs section. Launch it to access Java update options and more. To disable Java from running in your browser by default, click the Security tab and untick the box 'Enable Java content in the browser'. This compromise forces you to decide whether or not to run Java when arriving at an unknown website.

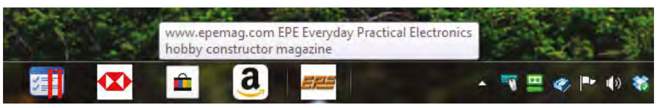
Mac users have not been insulated from Java-related problems. Early this year, Apple's own developers reportedly succumbed to a malicious code attack due to Java vulnerabilities, and Apple belatedly released an update to the Mac OS to plug the gaping hole. As Mac computers are used extensively at Facebook's HQ, this impacted Facebook too and the consequences of a security breach could have been devastating. Get to know your Java setup: it's one more route into your computer system that can be compromised by website hackers, so ensure that it's kept up to date. If you would like to know more about Java vulnerabilities, visit the CERT website, sponsored by the US Dept. of Homeland Security, at: **www.kb.cert.org/vuls/id/688246**.

A word cloud created from Net Work *text with a Java applet, courtesy of* ***wordle.net***

Shortcuts in IE10

After a recent keyboard upgrade, I lost my five Favorites keyboard buttons that opened Amazon, Ebay, the *EPE Chat Zone* and other sites at a keystroke, so I considered using a keyboard macro utility, including the excellent Hot Keyboard Utility. This little program can be a great time saver, as it automates many powerful keyboard macro tasks and is probably the best macro program that I tested. It costs $29.95 from **www.hot-keyboard.com** (30-day trial available). However, for re-implementing web Favorites, Internet Explorer 10 can create website shortcuts directly onto the Windows 7 taskbar, simply drag and drop the URL in the IE10 address bar onto your screen's taskbar, and a shortcut will be created directly. If a website such as Amazon or HSBC has a web icon associated with it, then it will appear on the taskbar and the website's meta data will pop up in a tooltip (see screenshot). That's a great way of quickly accessing your favourite websites.

In Windows 7 you can also right-click on a taskbar shortcut icon and some very useful options will be offered. For instance you can 'pin' favourite websites to the IE button, open a new tab or re-open the last session in a single keystroke. This can be a handy timesaver.



Adding website one-click shortcuts to the Windows 7 toolbar is a great time saver

Incidentally, readers, the new keyboard in question is a splendid USB Illuminated Keyboard from Logitech, which has flat scissor-action laptop style keys instead of clattery buttons. It is near-silent and accurate in operation, and is among the best PC keyboards I have ever used, though it might not suit those with long fingernails. Function buttons provide shortcuts directly to email, your choice of search engine, your web browser home page, plus some multimedia actions. The keyswitches themselves are laser-etched (although I dislike the squared typeface) but the keyboard's main benefit is the variable white led backlighting, great when dusk finally descends over the work area. More technical details are at **www.logitech.com** and the keyboard is available from the usual mainstream web sites. If you are a keen PC user then this keyboard deserves serious consideration.

20 years of surfing

This year is a milestone for Internet users, as we celebrate the 20th birthday of NCSA Mosaic, the first user-friendly web browser designed for a more general audience. Mosaic was a product of the National Center for Supercomputing Applications (NCSA) at the University of Illinois, and its web-browsing prodigy was downloaded at the then-dizzying rate of 5,000 downloads per month. The world-wide web barely existed then, neither did Google, and consequently small paperback books of website addresses were cover-mounted and pored over by avid users of the emerging 'information superhighway'. The developers of Mosaic went on to create Netscape, the first independent mainstream browser which eventually morphed into Mozilla Firefox. The original Mosaic and documentation can be downloaded by FTP from **ftp://ftp.ncsa.uiuc.edu/Mosaic/**

NCSA Mosaic was the first mainstream web browser, released 20 years ago

The true home of the world-wide web itself is CERN, the Swiss-based European Organisation for Nuclear Research, where the 'web' was conceived by Tim Berners-Lee as a way of hosting and disseminating highly complex technical information over CERN's network. He started on the idea in 1989 (see **www.w3.org/History/1989/proposal.html**) and developed the concept on the most advanced computer of its type, a NeXT server, which is now in the process of being restored by CERN.

Tim Berners-Lee's objective was to make complex information easily accessible, and the use of hyperlinks enabled users to click contextual links to access other pages. It is stated that the URL of info.cern.ch was the world's first website. To preserve them for posterity, the earliest set of webpages, known then for the first time as the 'World Wide Web' or W3, has recently been restored by CERN at the original URL of **http://info.cern.ch/hypertext/WWW/TheProject.html**. You can track the progress of this project at **http://first-website.web.cern.ch/**.

The potential uses of the W3 were enormous, and the web would be instrumental in changing everyday society in the 20th century. Thanks to social and mobile networking, the web today is unrecognisable from its earliest roots, all because CERN took the altruistic step of concentrating on particle physics and putting the W3 royalty-free into the public domain for future generations to embrace.

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*, where you could win a valuable prize!

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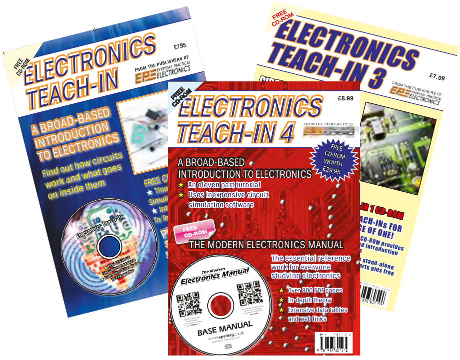

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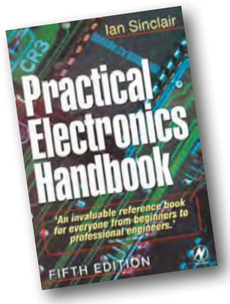

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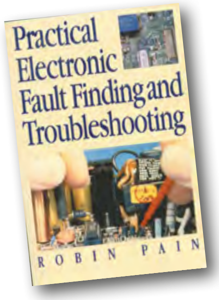

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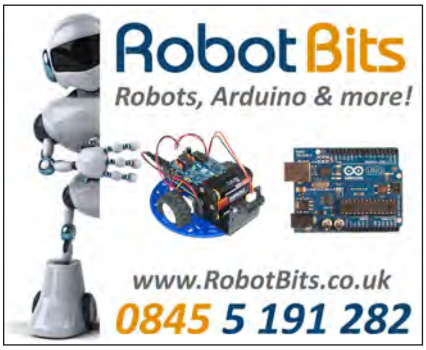

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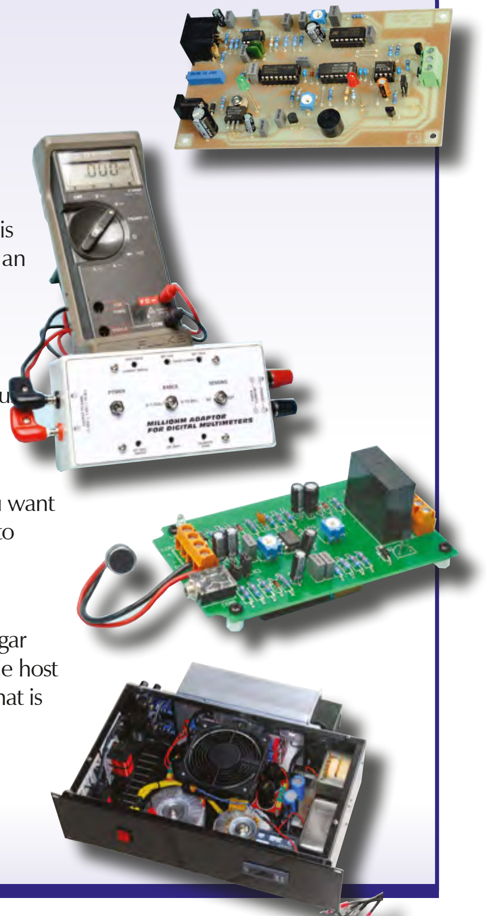
Next Month

Content may be subject to change



Driveway Sentry Mk.2

Here's an impressive and original home improvement project. The Driveway Sentry detects vehicles such as cars or trucks moving along a drive or through a gateway. When movement is detected, it switches on a mains-powered, or battery-powered lighting system, and activates an optional piezo buzzer alarm.

Milliohm Meter Adaptor for DMMs

Do you occasionally need to measure very low resistances accurately, but don't have access to an expensive bench-top milliohm meter or specialist DMM? This low-cost adaptor will let you use almost any standard DMM to make accurate low-resistance measurements.

Build a VOX

A fun project that lets you control devices with sound! VOX circuits can be used anywhere you want to turn something on when a sound occurs, or you speak into a microphone. You could use it to switch on a light, power up an amplifier or even unlock a door.

Build your own amplifier…

This is a different take on our usual amplifier projects. Instead of starting from scratch, Julian Edgar (our recycling guru) has built an amplifier from assorted modules purchased online, and a whole host of salvaged components. The result is a 68W × 4, 0.1% distortion (at full power) power amp that is fun and quick to build.

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