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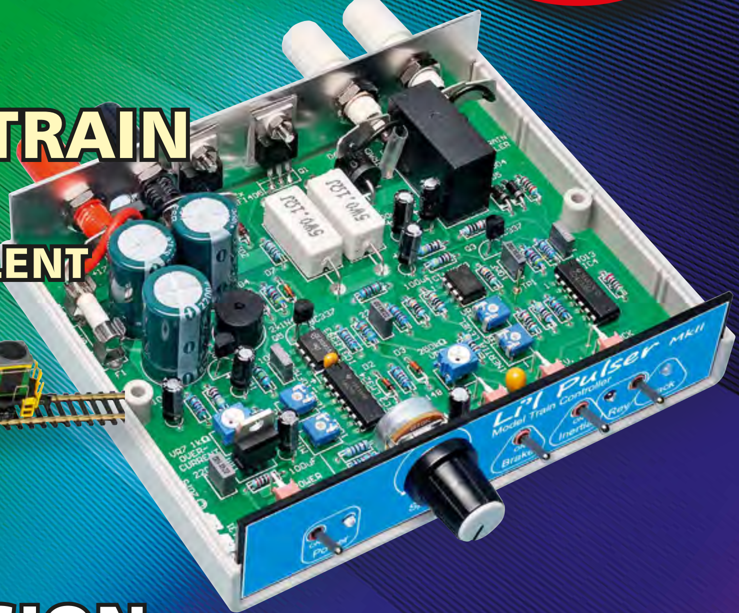

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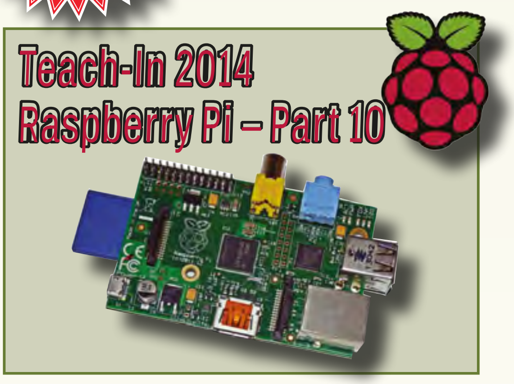

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Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code 660.446UK £11.52

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*Kit Order Code: 8157KT - **£49.95***
*Assembled Order Code: AS8157 - **£54.95***

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***

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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.
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*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.
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*Assembled Order Code: AS3108 - **£89.95***

Infrared RC 12–Channel Relay Board

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*Assembled Order Code: AS3142 - **£74.95***

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*Assembled Order Code: AS3153 - **£49.95***

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Kit Order Code: 8191KT - £29.95
Assembled Order Code: AS8191 - £39.95

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Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

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*Assembled Order Code: AS3190 - **£99.95***

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*Assembled Order Code: AS3188 - **£37.95***

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*Kit Order Code: 3187KT - **£39.95***
*Assembled Order Code: AS3187 - **£49.95***

Video Signal Cleaner

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*Assembled Order Code: VM106 - **£36.53***

Motor Speed Controllers

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DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
*Kit Order Code: 3067KT - **£19.95***
*Assembled Order Code: AS3067 - **£27.95***

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
*Kit Order Code: 3166v2KT - **£23.95***
*Assembled Order Code: AS3166v2 - **£33.95***

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
*Kit Order Code: 3179KT - **£17.95***
*Assembled Order Code: AS3179 - **£24.95***

Computer Controlled Bi-Polar Stepper Motor Driver

Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
*Kit Order Code: 3158KT - **£24.95***
*Assembled Order Code: AS3158 - **£34.95***

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.
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PROJECTS • Electronic Stethoscope • PIC/AVR Programming Adaptor Board – Part 1 • Cheap, High-Current Bench Supply • Ingenuity Unlimited
FEATURES • Jump Start – Signal Injector Probe • Techno Talk • Raspberry Pi • PIC N' Mix • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

JUNE '13

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

JULY '13

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

AUG '13

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

SEPT '13

PROJECTS • Digital Sound Effects Module • USB Stereo Recording & Playback Interface • Vacuum Pump From Junk • Minireg 1.3-22V Adjustable Regulator • Ingenuity Unlimited
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OCT '13

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

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

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

JAN '14

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

FEB '14

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

MAR '14

PROJECTS • Infrasound Detector • Extremely Accurate GPS 1pps Timebase For A Frequency Counter • High-energy Electronic Ignition System – Part 2 • Automatic Points Controller For Your Model Railway Layout
FEATURES • Teach-In 2014 – Part 6 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

APR '14

PROJECTS • Jacobs Ladder • Deluxe GPS 1pps Timebase For Frequency Counters • Capacitor Discharge Unit For Twin-Coil Points Motors
FEATURES • Teach-In 2014 – Part 7 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • PIC N' Mix • Net Work • Beta-Layout's Re-Flow Oven Kit And Controller review

MAY '14

PROJECTS • Rugged Battery Charger • CLASSiC-D ±35V DC-DC Converter • Digital Multimeter Auto Power-Down • Control Relays Over The Internet With Arduino
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PROJECTS • Cranial Electrical Stimulation Unit • Mini Audio Mixer • Adding Voltage And Current Meters To The Bits 'N' Pieces Battery Charger •
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EVERYDAY PRACTICAL ELECTRONICS

Support The National Museum of Computing

Bletchley Park – the once top-secret British home of world-beating WWII German codebreaking that saved countless lives and helped end the war – looks like it's about to be turned into an iPod-Touch-powered tourist theme park sponsored by £5 million of Heritage Lottery funds.

It's great to see that the work of Bletchley Park is being made more attractive and accessible to today's more sophisticated visitors ensuring our proud history can be kept alive. In contrast, the on-camp home of Colossus, arguably the world's first electronic supercomputer, rebuilt and housed at The National Museum of Computing (TNMOC) in one of Bletchley Park's blocks (H) next door, claims it's being starved of through-visitors due to a turf war between them and Bletchley Park's theme park owners.

Thanks to TNMOC, it's possible to track the evolution of electronic computing from that top-secret era of WWII through to the mainframes of the 1950s, then to the dawn of personal computing in the 1980s and beyond. TNMOC is desperate for funding, and previous sponsors have included IBM, HP, Google UK and encryption specialists Pretty Good Privacy. Unbelievably, the Museum also has to pay Bletchley Park for rent and overheads.

In the West, we pretty much owe our freedom to the likes of both Bletchley Park and the world-class codebreakers who used British computing expertise to crack the 'unbreakable' codes of the German Enigma machine. Unsung heroes do much valuable work and it's a scandal that TNMOC should have to rely on handouts and industry funding to keep their charity alive.

Bletchley Park, funded by Heritage Lottery cash (ours) should be doing everything possible to support the fantastic work of TNMOC instead of fencing off Block H, and we understand that Arts Council England was hoping to mediate between the two interests. It is very much to be hoped that these two 'natural allies' find a better way to support each other so that the remarkable wartime story of the Colossus computer will live on in a spirit of mutual co-operation rather than one of bitter rivalry. Readers can help by 'Sponsoring a Valve' (vacuum tube) at: **www.colossusonline.org**

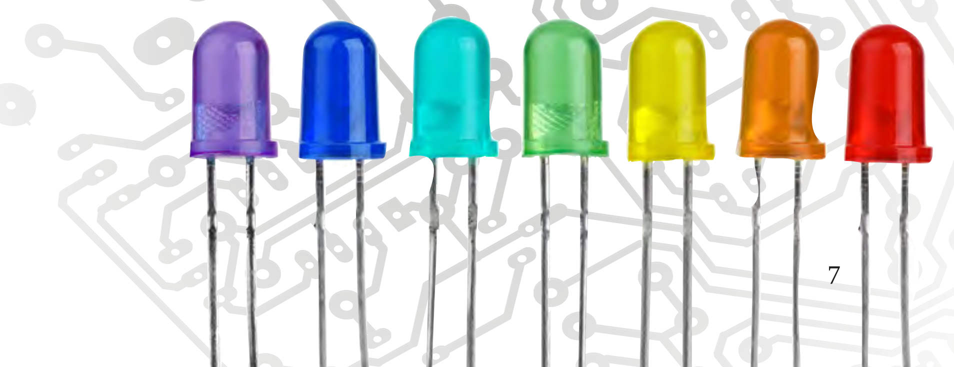
Kickstarter success

I hope readers will join me congratulating Mike Hibbett for his dramatic Kickstarter project success (see last month's *Editorial*). Mike's 'Low Power, Low Cost Microprocessor Development Board' was pitched modestly at £1100 to succeed. At the end of the funding period he achieved a remarkable £4225! More details at: **http://tinyurl.com/n7x2zvh**

New columnist

Last, but not least, I'd like to introduce a new regular writer to *EPE* – Jake Rothman. Jake has produced projects for us before, and now has his own monthly slot. He'll mostly be writing about audio and analogue, but this month kicks off with a great article on working for yourself in electronics – welcome aboard Jake!

Alan Winstanley
EPE On-line editor



NEWS

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

The push to Ultra HDTV – report by Barry Fox

Although 4k Ultra HDTV sets are already on sale, there is no standard for the system. Japanese broadcasters want to push on to 8k, with broadcasts to the home in time for the 2020 Tokyo Olympics.

4k or not 4k?

The SMPTE, Society of Motion Picture & Television Engineers, is trying to set the standards for both 4k and 8k, which are more accurately called UHDTV1 (3840 × 2160 pixels) and UHDTV2 (7680 × 4320), and build on today's (HDTV (1920 × 1080 pixels).

The popular consumer term '4k' is confusing, warns the SMPTE, because 4k actually defines images with 4096 × 2160 pixels, the professional Digital Cinema standard.

Gamut standards

UHDTV is not just about more pixels per picture. It also brings extended colour space to the table; essentially a wider (twice as wide) range or 'gamut' of colours than HDTV. But so far, the existing HDTV colour gamut has had to be used because of camera and display limitations. There are no TVs yet that can support the UHDTV colour gamut. So, conversion techniques to and from HD, SD and UHD will be needed.

This, warns the SMPTE bluntly, is 'NOT trivial'. Simplistic conversion may make UHD colour look worse than original HD material. Content with UHDTV gamut may look worse on HDTV than native HDTV.

Techniques used for HD conversion won't be good for UHD conversions. Colours will look over-saturated or muted. Manual grading, scene by scene, as used for Blu-ray releasing, may be needed.

Frame rate

The existing TV frame rates (50 and 60Hz) are accepted as not good enough for UHD action capture and panning; 100Hz and 120Hz are favoured as the best compromises, with 120Hz proposed as a possible world standard.

The frame rate for NTSC is not exactly 30Hz, it is 23.97Hz (set 50 years ago to avoid interference between analogue colour and sound signals). So, for legacy material, UHD will need to support a slightly-off-120Hz rate (120Hz divided by 1.001).

There will also be a need for time code that runs at speeds higher than 60Hz (to synchronise cameras and recorders), as well as a new standard for digital 'interfaces' to connect UHD equipment running at higher than 60Hz. But there may also be 'mezzanine' compression standards to let new UHD equipment use existing interfaces.

A standard is also needed for 'immersive audio' with up to 22.2 channels (22 main and 2 sub-woofer) for surround with height. And consideration must be given to the fact that most homes will not have 22.2 speaker systems.

When is 4k actually 4k – and will it be quickly superseded by 8k?

UHD also opens the door to high dynamic range pictures, which are brighter, with a wider contrast range between black and pure white.

The latest TVs can now display over 500cdm^{-2} (candela per square metre) – and up to 1000cdm^{-2} – and there is far less noise or snow to degrade the picture. But the number of digital bits which video signals use to code the range of brightness (or grey scale) from black to white (usually 10 bits, maximum 12 bits) is set by industry standards. So there is a need for more efficient coding to make better use of the bits available and improve the 'electro-optical transfer function' (EOTF) or gamma encoding without the need to change the whole ecosystem.

Coding

Current coding systems date back to the days of CRTs and show visible steps in the grey scale – rather than a smooth transition between different shades of grey – even when 12 bits are used.

The SMPTE is looking at ways of making the EOTF more closely match the way the human eye detects brightness. A new PQ 'perceptual quantiser' curve lets 12 bits accurately describe a far wider brightness range – up to 1 million:1 contrast ratio. Often 11, 10 or even 9 bits are able to disguise the steps between shades of grey, with brightness up to 10,000cdm^{-2}.

PQ is based on the brightness levels actually seen on a screen rather than the levels captured by the camera. It relies on test patterns, which concentrate on the most sensitive part of the human eye/brain system, the region near white or grey.

Super-fast-charging batteries

An Israeli start-up called StoreDot has demonstrated a device made of biological structures, which when substituted for a Samsung S4 smartphone battery went from dead to fully charged in just 26s.

StoreDot uses a novel technology, based on its discovery of new generation, self-assembled 'nanodots'. These elementary biological building blocks are at the core of several patented innovations by StoreDot. The nanodots are nano-crystals, uniform in size, 2.1nm in diameter, and consist of bio-organic peptide molecules.

Thanks to their small size, nanodots improve electrode capacitance and electrolyte performance and the end result is batteries that can be fully charged in seconds rather than hours.

StoreDot have effectively developed a new kind of electrode. The electrolyte is modified with nanodots in order to make the multifunction electrode more effective. On one side it acts like a supercapacitor (with very fast charging), and on the other it is like a lithium electrode (with slow discharge).

StoreDot claim that unlike other nanodot and quantum-dot materials that are based on heavy metals – making them toxic – its nanodots are produced from a range of bio-organic materials that are cheap and environmentally-friendly.

StoreDot is currently working on smartphone-sized batteries, but sees no reason why its technology could not be scaled to car batteries, which would revolutionise that sector.

The world's smallest movie

The ability to move single atoms, one of the smallest particles of any element in the universe, is crucial to research in the field of atomic-scale memory. In 2012, IBM scientists announced the creation of the world's smallest magnetic memory bit, made of just 12 atoms. This breakthrough could transform computing by providing the world with devices that have access to unprecedented levels of data storage. But even nanophysicists need to have a little fun. In that spirit, IBM researchers used a scanning tunneling microscope to move thousands of carbon monoxide molecules (two atoms stacked on top of each other), all in pursuit of making a movie so small it can be seen only when you magnify it 100 million times. The resulting atomic movie has been verified by Guinness World Records as the world's smallest stop-motion film. In other words, discrete atoms have been repositioned and then an image taken to create the stop-motion effect, a little like a cartoon. It can be viewed at: **http://youtu.be/oSCX78-8-q0**

USB connector upgrade

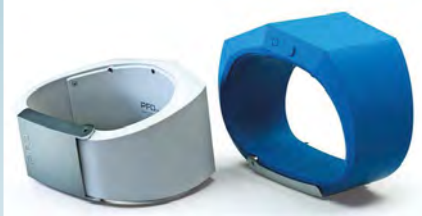
Thanks to low cost and speed upgrades, the USB cable/connector has become the ubiquitous digital interface. Not only for computer equipment and peripherals, but also cameras, MP3 players and a host of other digital devices. That said, one of its main irritants has been the polarised plug – it will only fit in one way. Now, the familiar USB Type-A and Type-B ports are to be upgraded to Type-C. The aim is to make USB similar in operation to Apple's successful Lightning connector, which can be plugged in 'up or down' – there is no wrong way. The target is to have the design finalised by mid-2014.

When all (or most) devices move to Type-C ports, the number and variety of cables users need should fall.

Although there are no definitive illustrations of the new connector yet, it will have to be different enough from existing designs to be incompatible. This is of course unfortunate; however, the new connector is designed to 'scale for future USB bus performance' improvements. So, as USB 3.1 is supplanted by newer and faster versions of the standard, the new Type-C connector shouldn't have to change.

Artist rendering courtesy of Foxconn, the final design is subject to change

GPS tracking bracelet



PFO Tech has launched a GPS tracking bracelet designed for reporters. Journalism can be one of the most dangerous professions today, and in places like Syria it is often called 'an impossible job.' Journalists risk attacks, imprisonment and even death for seeking to tell the truth. The bracelet was launched at the World Press Freedom Day at UNESCO Headquarters aimed in part to address the safety of journalists, adding to a Declaration that highlights the contribution of free expression to development.

PFO's solution includes a GPS bracelet with patented alarm mechanism, a secure monitoring system, a mobile application and hosting service. By triggering the alarm, a journalist can send their live position to pre-chosen recipients such as headquarters, alarm receiving centres, colleagues nearby, and even out on social media platforms to involve the whole world in the event of an attack.

Smartphone 'value'

New research from mobile network Three has found Brits value the content of their smartphone at £1,117 – six times the value of the phone itself (average value £199).

Nearly half (47%) of those polled would rather lose their passport than their smartphone and a third (38%) don't know how to back up their smartphone.

The research found that smartphone users place the most sentimental value on photographs, while their list of contacts came in second. These were followed by banking details, videos, work, music, films and then games.

Regarding photographs, the average Brit values their mobile snaps at £357. Photos and videos can hold a huge amount of sentimental value to owners, who on average store more than 100 of them on their device. Half of all parents (54 per cent) store photos of their children on their phone and do not back them up elsewhere. Ironic, given that one in ten parents have had their smartphones smashed, destroyed or otherwise put out of operation by their children.

Versatile 10-Channel Remote Control Receiver

Works with a universal IR remote, either directly or via a UHF radio link

This 10-channel control system can be used with any universal IR remote control and can even be controlled via a UHF link so you don't have to worry about range or high light levels affecting infrared operation. It can be used to switch relays (and other devices) on and off, making it ideal for controlling motors, lights, solenoids, door catches and even robots.

Most universal remote controls can be used with the unit.

LET'S CLEAR UP some confusion right at the start. Most infrared remote controls are intended to control various functions on just one appliance. For example, your TV remote enables you to control all its functions: channel change, volume, mute, picture and so on. By contrast, this *10-Channel Remote Control Receiver* enables you to use a single infrared remote control to control up to 10 separate devices, turning them on or off. Or you could use it to control more functions on less devices but still using up to 10 buttons on your universal remote.

Each channel in the receiver unit has an open-collector output that can drive an external relay, drive one or more LEDs or even directly switch low-power 12V equipment. Each output is initially set as momentary, meaning that the output is only active while you press the relevant button on the remote control.

Alternatively, one or more of the outputs can be set to change state (toggle) when you press the relevant button on the remote (ie, each output can be set independently). That means that an output that was previously ON turns OFF (and stays OFF) when its channel button is pressed, while an output that was previously OFF turns ON when its button is pressed.

Each individual toggle output can also be set up to be either ON or OFF when power is applied to the unit. For example, you can set the unit to switch on with Channel 1 OFF, Channel 2 ON, Channel 3 ON and so on. By contrast, the momentary outputs are always all off at power up and their initial switch-on state cannot be altered.

An Acknowledge LED indicates whenever a valid remote control signal is received.

Presentation

The *10-Channel Remote Control Receiver* comprises a small box that includes 10 LEDs to indicate the state of each channel. These are labelled from 0-9, corresponding to the 0-9 buttons on the remote control. Each channel has an output that is capable of sinking up to 500mA, so it is suitable for driving a 12V relay or similar load, as indicated above.

Power for the unit comes from a 12V DC plugpack supply. The current requirements depend on what sort of load each channel drives. For 12V relays, you could need up to 75mA for each relay, but the overall current requirements depend on whether the outputs are set for momentary or toggle operation.

If momentary operation for all outputs is selected, there will be only one relay on at one time, and so a minimum of 85mA is required for the supply, ie, 75mA for the relay and about 10mA for the circuitry. For toggle operation on all outputs, all relays could be switched on at the same time and up to 750mA or so would be needed from the 12V plugpack.

The infrared (IR) remote control needs to be a universal type that can be programmed to operate Philips brand or similar appliances. The *10-Channel*

By JOHN CLARKE

Remote Control Receiver can operate using the code for either a TV, a CD player or one or two satellite receivers. Alternative choices are given so that when using the remote to operate the *10-Channel Remote Control Receiver*, it does not affect any other appliances you may have.

For example, you may find that when the *10-Channel Remote Control Receiver* is set to operate using the TV code, your TV also responds. In that case, it's simply a matter of using one of the alternative codes (ie, for a CD player or satellite receiver).

UHF radio link

As well as making provision for IR reception, the *10-Channel Remote Control Receiver* can alternatively use an *IR to 433MHz UHF Transceiver* module. This means that it can be controlled from an IR remote via a UHF radio link – necessary if you don't have line-of-sight for infrared signals.

For this reason, we're also publishing the circuit details for an 'IR To UHF Transceiver' (see the following article). Push a button on your IR remote and the coded IR signal is picked up by this transceiver, converted to a 433MHz radio signal and transmitted to the *10-Channel Remote Control Receiver*. Provided you have line-of-sight between the remote and the transceiver, you're in business – the UHF radio link does the rest.

How it works

Refer now to Fig.1 for the circuit of the *10-Channel Remote Control Receiver*. It's based on either an infrared receiver (IRD1) or a 433MHz receiver module (RX1), a PIC16F88 microcontroller (IC1) and a couple of ULN2003 Darlington arrays (IC2 and IC3). The micro decodes the remote control signal codes and drives the channel outputs accordingly.

The IR receiver module (IRD1) comprises an IR detector, an amplifier and a demodulator. The demodulator removes the 38kHz infrared modulation of the transmitted signal and the output at pin 1 then comprises the on and off levels that constitute the IR encoding. With no signal, the output remains high at about 5V.

The alternative UHF receiver (RX1) receives the UHF signal from the *IR to 433MHz UHF Transceiver* and outputs the encoded signal at its Data terminal. This signal is inverted compared to IRD1's output and so the SET jumper at pin 8 of IC1 is provided to allow either receiver to be selected. When open, the SET input is pulled high (ie, to 5V) via a pull-up resistor inside IC1 and this selects IR signal decoding.

Alternatively, when the SET jumper is installed, pin 8 of IC1 is pulled low (0V) and this instructs IC1 to decode a UHF signal.

Note that for UHF reception, RX1 is installed but IRD1 must be left off the PCB. Alternatively, for IR reception, you would normally just have IRD1 installed. However, in the latter case, you can actually also mount the UHF receiver on the PCB. That's because RX1's output is a high impedance and so would have negligible effect on IRD1's output.

Features and Specifications

Main Features

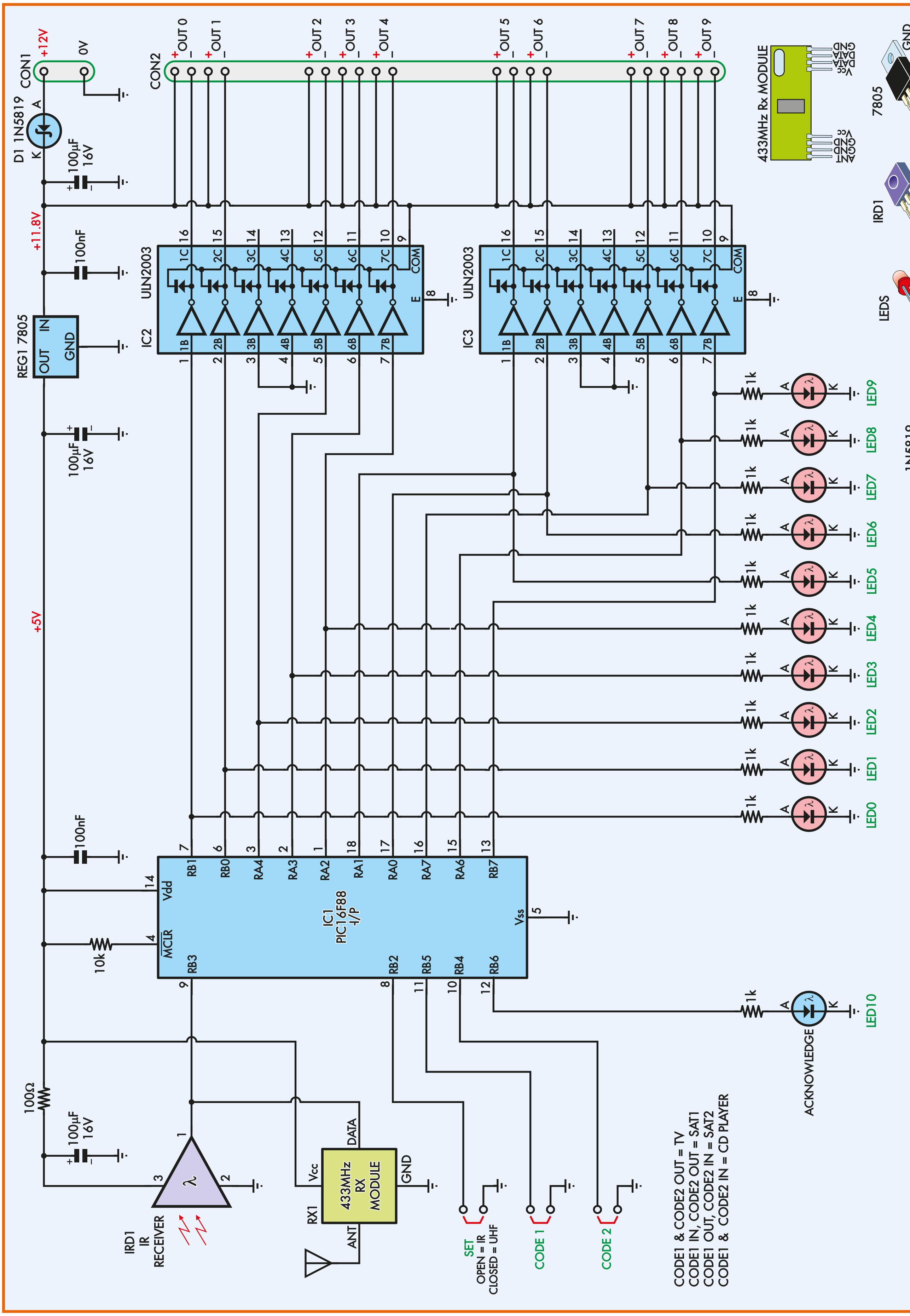
- Uses a commercial infrared hand-held transmitter
- 10 independent channels
- Momentary or toggle operation
- Selectable output state on power up for toggle selection
- 500mA open-collector sinking outputs for each channel
- Outputs suitable to directly drive 12V relays
- Infrared or UHF (433MHz) reception
- Acknowledge LED flashes while receiving transmission

Specifications

Power supply requirements..........12V at up to 50mA plus current drawn by each output; up to 760mA required for 10 relays if all powered at once

Infrared range .... 10m line-of-sight

UHF range ....30m in open space



10-CHANNEL REMOTE CONTROL RECEIVER

Fig.1: the circuit uses either an IR receiver (IRD1) or a 433MHz receiver module (RX1) to pick up the remote control signals. These signals are processed by microcontroller IC1 (PIC16F88-I/P) which then drives two ULN2003 Darlington arrays (IC2 and IC3) plus the Acknowledge and channel indicator LEDs.

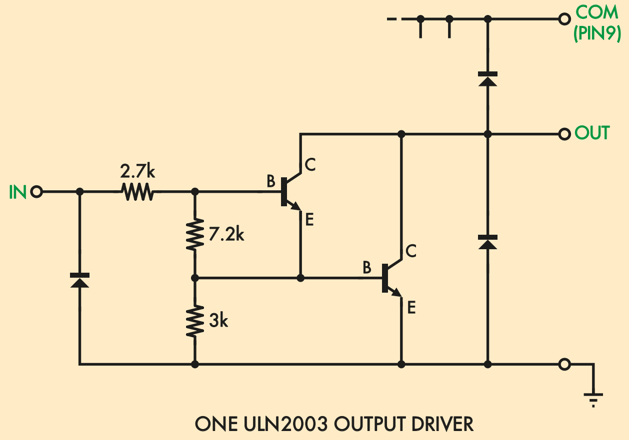


Fig.2: the internal Darlington transistor arrangement for the ULN2003 ICs. There are seven such output driver stages inside each device.

Parts List

- 1 PCB, available from the *EPE PCB Service,* code 15106131, 123 × 61mm
- 1 UB3 box, 130 × 68 × 44mm
- 1 panel label, 102 × 61mm
- 11 2-way PCB-mount screw terminals, 5.04mm pitch
- 1 DIP18 IC socket
- 1 M3 × 10mm screw
- 1 M3 nut
- 3 2-way pin headers with 2.54mm pin spacing
- 3 pin header jumper shunts
- 1 170mm length of hook-up wire (UHF version only)
- 1 2.1mm bulkhead-mount DC socket

Semiconductors

- 1 PIC16F88-I/P microcontroller programmed with 1510613A.hex (IC1)
- 2 ULN2003 Darlington arrays (IC2,IC3)
- 1 infrared receiver (TOSOP4136 or similar) (IRD1) or 1 433MHz receiver (Jaycar ZW-3102, Altronics Z 6905A) (RX1)
- 1 7805 5V regulator (REG1)
- 1 1N5819 1A Schottky diode (D1)
- 10 3mm red high-brightness LEDs (LED0-LED9)
- 1 3mm blue high-brightness LED (LED10)

Capacitors

- 3 100µF 16V PC electrolytic
- 2 100nF MKT polyester

Resistors (0.25W, 1%)

- 1 10kΩ
- 1 100Ω
- 11 1kΩ

Miscellaneous

Cable glands, hook-up wire

Code links

The Code 1 and Code 2 jumpers, on pins 10 and 11 of IC1 respectively, select the encoding mode; ie, either TV, satellite (SAT1 or SAT2) or CD player. Both the circuit and Table 3 towards the end of the article show the jumper linking options to select each code (eg, leave both jumpers out to select TV encoding).

IC1's RB6 output at pin 12 drives the Acknowledge LED (LED 10). This lights whenever a valid remote control signal, either IR or UHF, is being received.

IC1 decodes the remote control signals and provides the 10 channel output signals to drive the Darlington arrays (IC2 and IC3). For example, the channel 0 signal is at RB1 (pin 7) and this drives pin 1 of IC2. Similarly, the channel 1 signal appears at the RB0 output and this drives pin 2 of IC3, and so on for the remaining eight outputs. Note that output channels 0-4 drive IC2, while outputs 5-9 drive IC3.

IC2 and IC3 each include seven separate Darlington transistors, with five Darlingtons used in each package to make up the 10 channels. Fig.2 shows the internal Darlington transistor arrangement for each driver.

As can be seen, the first NPN transistor is driven via a 2.7kΩ resistor, while its emitter drives the second NPN transistor's base. The collectors are commoned to provide an output that can sink up to 500mA when the input is driven by 5V (ie, a Darlington arrangement).

In addition, a diode clamp is connected between each output and the common pin of the IC. This ensures that the transistors are protected from over-voltage when driving an inductive load.

The common pin for the diodes connects to the 11.8V supply. This 11.8V supply is also connected to each of the channel outputs on CON2 (a 20-way screw-terminal block), to provide the positive output terminals. The collector outputs from the Darlington arrays connect to the negative terminals, so that they sink the load current when active.

That way, a relay coil can be directly connected to each pair of output terminals; ie, between the +11.8V supply and the individual collector outputs.

5V regulator

Power for the circuit is derived from an external 12V supply (eg, a plugpack), with Schottky diode D1 providing reverse polarity protection. The resulting 11.8V rail is then filtered using 100µF and 100nF capacitors and fed to 3-terminal regulator REG1. REG1 then provides a 5V supply rail for IC1, IRD1 and RX1 (the 433MHz receiver module).

Note that the supply rail for IRD1 is decoupled via a 100Ω resistor and 100µF capacitor. This minimises supply variations and glitches from being decoded as control signals.

In addition, the 11.8V rail at the output of D1 is fed to the positive terminals of CON2, as described above.

RC5 codes

The Philips RC5 code for infrared transmission is used by many manufacturers, including Philips, Marantz, Mission, Grundig and Loewe. The code comprises two start bits and one toggle bit that alternates between high and low on successive same key presses. A five-bit address is then sent, followed by six command bits.

The bits are sent using bi-phase encoding, whereby a high-to-low transition represents a low bit and a low-to-high transition a high bit. The data is transmitted at a 1.778ms rate, with the whole code taking 24.889ms to send. The next code starts after 113.778ms.

As stated above, the RC5 remote control signal, either from IRD1 or RX1, is decoded by IC1.

Building it

Take a look now at Fig.3 for the assembly details of the *10-Channel Remote Control Receiver*. It's built on a PCB available from the *EPE PCB Service*, coded 15106131 (123 × 61mm) and this clips neatly into a plastic utility case measuring 130 × 68 × 44mm.

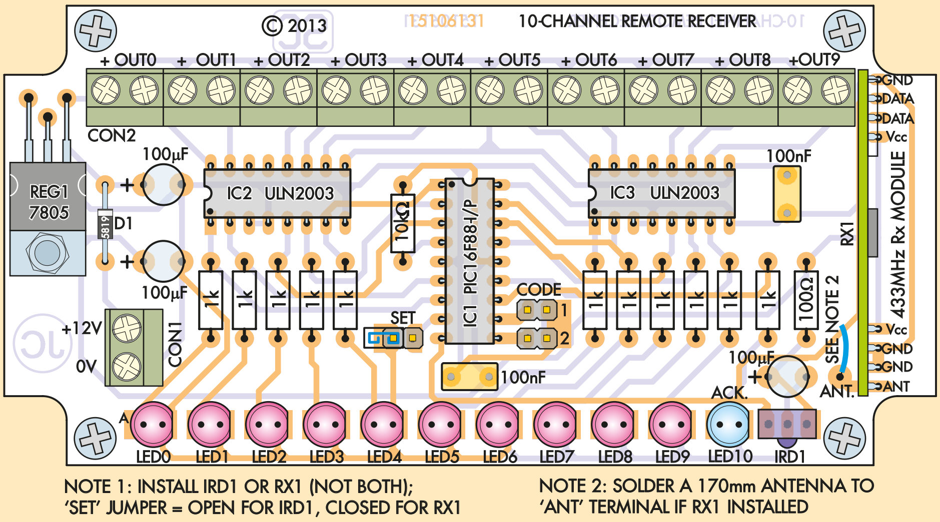
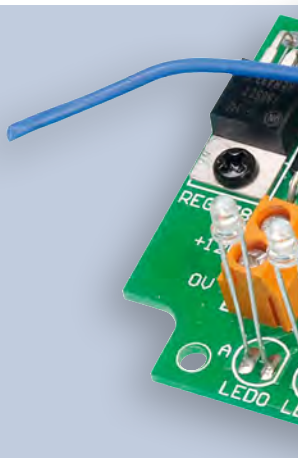


Fig.3: follow this layout diagram to install the parts on the PCB. Note that either IRD1 or RX1 is installed – but not both (see text). You will need to solder a 170mm-long antenna to the 'ANT' terminal if RX1 (the UHF module) is used.



Right: the prototype PCB, ready for installation in the case. Note how the LEDs are all stood off the board (on 25mm lead lengths) so that they later protrude through the holes in the case lid.

Install the resistors and diode D1 first. Table 1 shows the resistor colour codes, but you should also check each one using a digital multimeter before soldering it into place. Make sure the diode is installed with the correct polarity, with the banded end oriented as shown on the layout diagram.

Once these parts are in, REG1 can be fitted. It's mounted horizontally on the PCB, with its leads bent down through 90° so that they go through their respective holes. Secure its metal tab to the PCB using an M3 × 10mm machine screw and nut before soldering its leads (note: don't solder the leads first, otherwise the PCB tracks could fracture as the nut is tightened).

Follow with the three 2-way pin headers for the SET, Code 1 and Code 2 jumpers, then install an 18-pin IC socket for IC1 (be sure to position the notched end as shown). You can also install sockets for IC2 and IC3 if you wish, but these are optional. If you don't wish to use sockets, these two devices can now be directly soldered to the PCB, with their notched ends facing towards REG1.

Do not insert IC1 into its socket yet – that step comes later, after you've checked the 5V supply rail.

The capacitors are next on the list. The two 100nF capacitors can go in either way round, but be sure to install the three 100µF electrolytics with the correct polarity.

The 20-way screw terminal block (CON2) can now be installed. It's made up by dovetailing together 10 2-way blocks, and must be fitted with the wire entry holes facing outwards. Push it all the way down so that it sits flush against the PCB before soldering the terminals. Once it's in, the 2-way terminal block (CON1) can be fitted at lower left.

Installing the LEDs

Now for the LEDs. These must be installed so that the top of each LED is exactly 30mm above the PCB surface, which means mounting them with 25mm lead lengths.

The easiest way to do this is to use a 25mm-wide strip of cardboard as a spacer. It's just a matter of pushing each LED down onto this strip (ie, leads on either side) before soldering it to the PCB. Be sure to orient each LED correctly, with the longer anode leads to the left.

Our prototype used red LEDs for LEDs0-9 and a blue LED for LED10 (Acknowledge) but any colour can be used.

IR/UHF receiver module

The PCB assembly can now be completed by installing either the infrared receiver (IRD1) or the UHF receiver (RX1) and configuring the SET jumper.

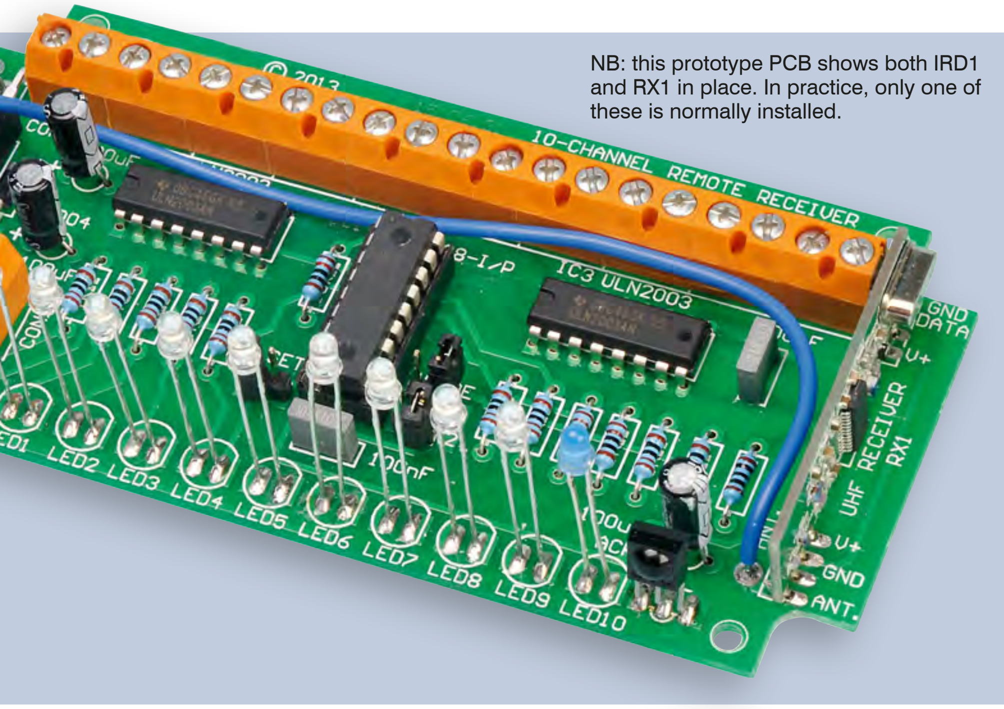
Install IRD1 and leave the SET jumper out if you want to use infrared signals to control the 10-channel receiver. It goes in with its lens facing the adjacent edge of the PCB and is installed with its leads left at full length so it can later be pushed into position to align with its case hole.

Alternatively, install RX1 and fit the SET jumper if you want to control the receiver using a 433MHz UHF radio link. RX1 must be oriented with its component side to the right. **In addition, a 170mm-length of hook-up wire must be soldered to the antenna (ANT) terminal to pick up the 433MHz signal.**

Don't also install IRD1 if you intend using the 433MHz transceiver (RX1), as this would upset the latter's operation. Conversely, you can fit both IRD1 and RX1 if you intend using IRD1 to

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	10kΩ	brown black orange brown	brown black black red brown
❏	11	1kΩ	brown black red brown	brown black black brown brown
❏	1	100Ω	brown black brown brown	brown black black black brown



NB: this prototype PCB shows both IRD1 and RX1 in place. In practice, only one of these is normally installed.

pick up the remote control codes, as explained previously. You might want to do that if you intend swapping over and using RX1 at some later date (in which case you would then have to remove IRD1).

Final assembly

Before installing the PCB in the case, you will need to drill holes in the rear of the base for the DC power socket, plus holes to accept two cable glands. The cable glands route and secure the various leads from the output terminals on CON2.

The DC socket hole should be drilled in one end of the case, ie, near CON1 on the PCB. It should be centred horizontally and positioned about 12mm down from the top of the base. Use a small pilot drill to drill this hole first, then carefully enlarge it to size with a tapered reamer until the socket is a neat fit.

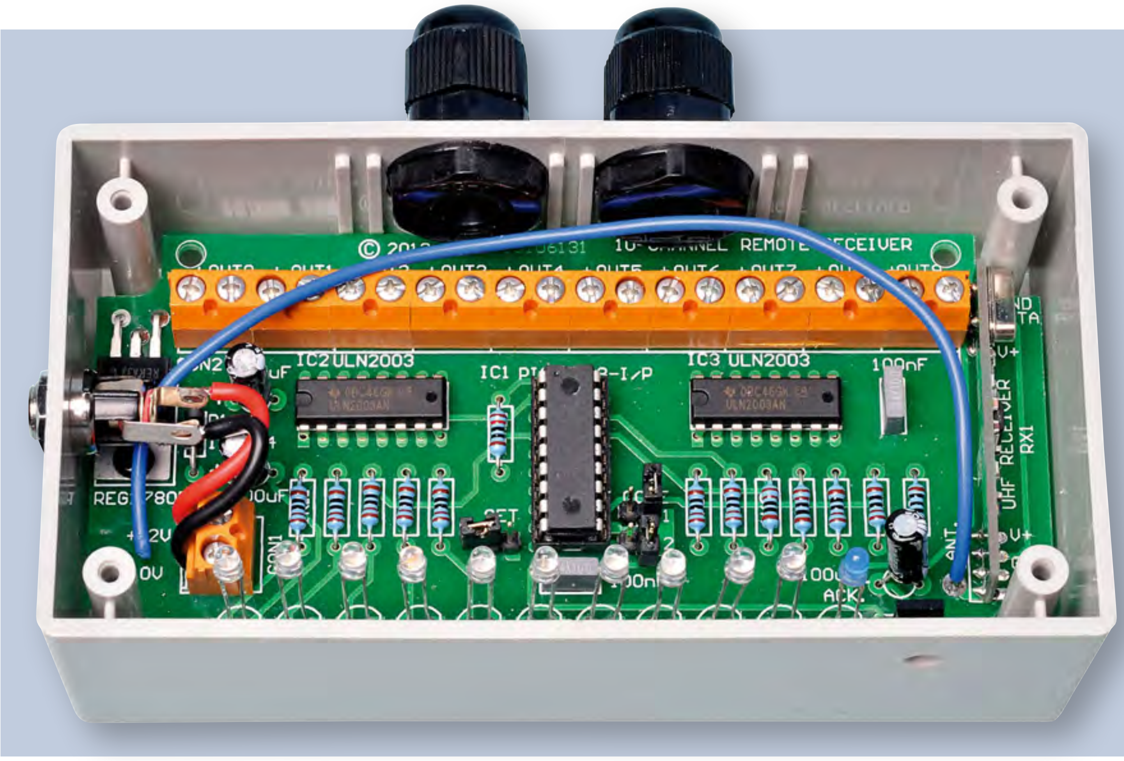
The two cable gland hole centres are exactly 14mm down from the top of the base and must be centred between the two sets of vertical rib pairs. Drill these holes using a pilot drill initially, then enlarge them to 12mm using a tapered reamer.

In addition, a 4mm hole must be drilled in the front of the base in-line with IRD1's lens. This hole is positioned 22mm in from the adjacent side (as measured at the top of the base) and 11mm down.

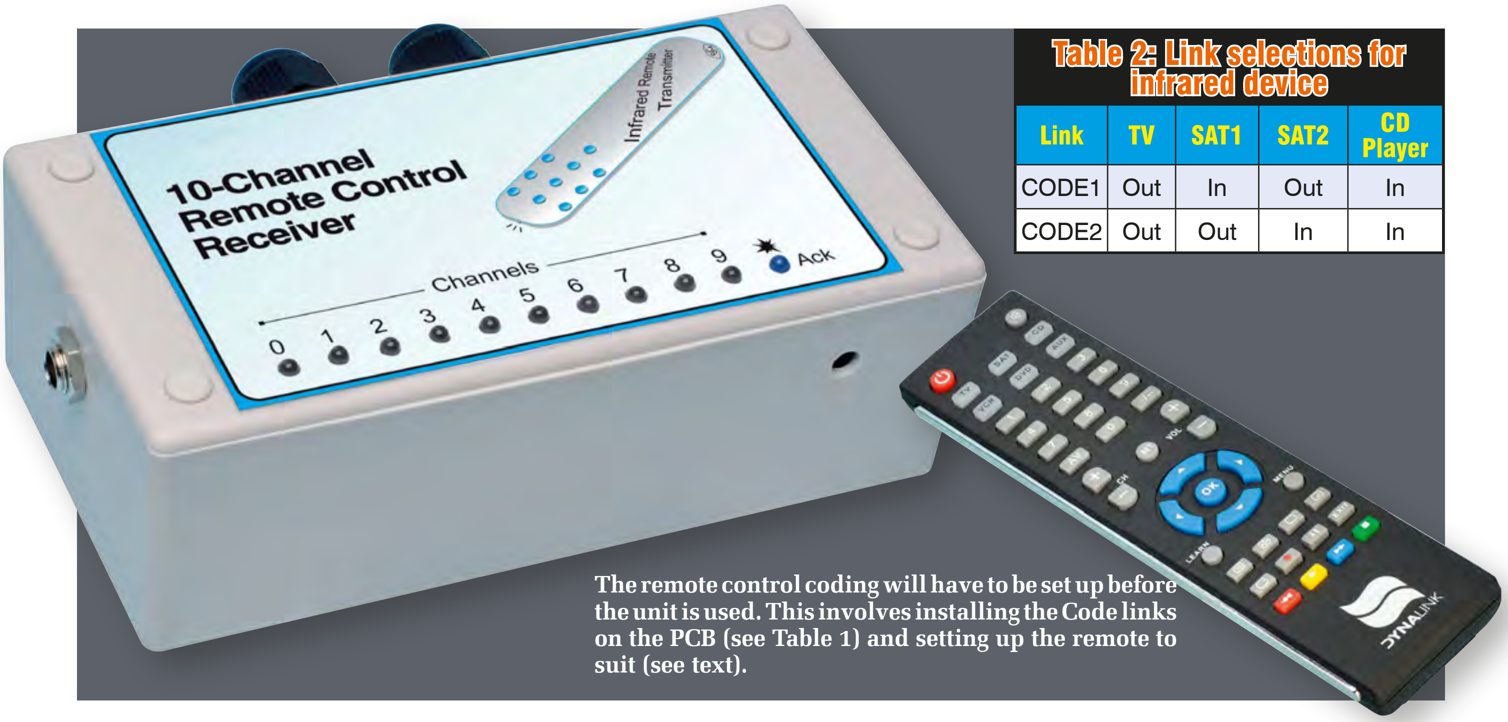
A row of 11 3mm holes is also required along one edge of the lid to accept the LEDs. These holes can be drilled using the front panel artwork as a template. This artwork can be downloaded from the *EPE* website and temporarily attached to the lid using tape.

After drilling, clean up the holes using an oversize drill, then print out another copy of the artwork onto photo paper and attach it to the lid using silicone sealant (or some other suitable adhesive). Once the silicone has cured, the holes for the LEDs can either be punched out or cut out using a sharp hobby knife.

The assembly can now be completed by clipping the PCB into place, fitting the cable glands and the DC socket and running the positive and negative supply leads between the DC socket and CON1. **It's also necessary to bend IRD1's leads so that its lens is aligned with its hole in the side of the case.**



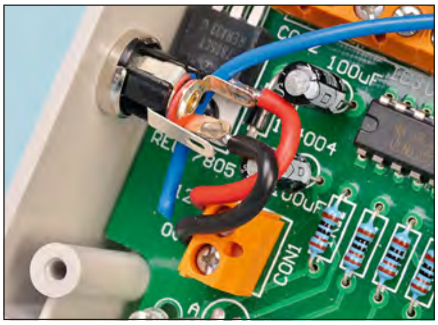
The PCB clips into the integral slots in the sides of the UB3 case. You need to drill holes in the rear edge for two cable glands, a hole in the front edge for the IR receiver (if used) and a hole in the lefthand end for the DC socket. Eleven holes are also required in the lid for the LEDs.



The remote control coding will have to be set up before the unit is used. This involves installing the Code links on the PCB (see Table 1) and setting up the remote to suit (see text).

Table 2: Link selections for infrared device

Link	TV	SAT1	SAT2	CD Player
CODE1	Out	In	Out	In
CODE2	Out	Out	In	In



This close-up shows how the DC socket is wired to screw-terminal block CON1

Initial checks

Now for the smoke test. Check the assembly carefully, then connect a 12V DC plugpack, switch on and measure the voltage between pins 5 and 14 of IC1's socket. You should get a reading of between 4.85V and 5.15V. If this is incorrect, switch off immediately and check the supply polarity, the orientation of diode D1 and the 7805 regulator.

If the reading is correct, switch off and install IC1 in its socket. Make sure that this device is oriented correctly and that all its pins go into the socket. IC2 and IC3 should also now be installed if you are also using sockets for these devices.

Remote control coding

Before testing, you will need to set up the remote control coding. The first step is to decide whether you will be using a TV, satellite or CD player code on the remote, then configuring the jumpers on the *10-Channel Remote Control Receiver* accordingly – see Table 1.

Omitting both the CODE1 and CODE2 jumpers selects the TV code; installing the CODE1 jumper only selects SAT1; installing the CODE2 jumper only selects SAT2; and installing both jumpers selects the CD player code.

That done, the correct code must now be programmed into the remote. This involves selecting TV, SAT1, SAT2 or CD on the remote (to agree with the *10-Channel Receiver*) and then programming in a 3-digit or 4-digit number for a Philips device.

Most universal remote controls can be used.

In the case of other universal remotes, it's just a matter of testing the various codes until you find one that works. There are usually no more than 15 codes (and usually a lot less) listed for each Philips device, so it shouldn't take long to find the correct one.

Note that some remotes may only work in one mode (eg, TV but not SAT). For example, if you have a Digitor 4-in-1 remote, you can use 5005 for TV1 but there's no suitable code for SAT. Similarly, if you have an AIFA RA7, you can use 026 for TV1, but again, there's no suitable code for SAT.

If you are using infrared reception (ie, IRD1 installed), the receiver

Darlington saturation voltage in the ULN2003 devices

According to the ULN2003 data sheet, the output saturation voltage of each Darlington output stage is typically 1.3V @ 350mA (but can be as high as 1.6V). And it's typically 1.1V @ 200mA and 0.9V @ 100mA.

This means that with a supply of exactly 12V and a load drawing 350mA, the load will typically see just 12V – 1.3V – 0.2V (the Schottky diode voltage) = 10.5V. And it could be less than that depending on how much current other channels are drawing, the temperature and so on.

As a result, the Darlington configuration results in a voltage across the load that's substantially below the 12V supply voltage, and while most 12V relays will happily run off 10.5V, other loads such as 12V LEDs may not. In fact, 12V LED lamps and 12V LED strips would probably be quite dim if switched using this unit because of the Darlington saturation voltage.

This can be slightly improved if the positive power supply terminal of each load is connected directly to the 12V supply, ie, bypassing D1. And, in fact, this will be necessary if the load total exceeds 1A, as D1 is only rated as 1A DC.

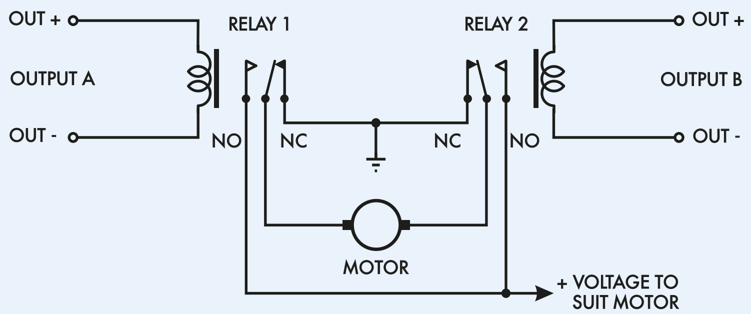


Fig.4(a): using two outputs to drive a motor in forward and reverse:
(1) Both outputs set for momentary operation. In this case, pressing (and holding) the button for Output 'A' activates Relay 1 and causes the motor to rotate one way, while pressing the button for output 'B' activates Relay 2 and causes the motor to rotate the other way.
(2) Both outputs set for toggle operation. If both outputs are off at power-up, the motor will be stopped until one of the outputs is toggled (its direction will depend on which output is turned on). Alternatively, if one output is high and the other low at power-up, then the motor will run as soon as power is applied. The motor can be stopped and reversed by toggling the outputs.
(3) One output momentary and the other toggle. If the toggle output is high at power-up, the motor will immediately run. It can be stopped temporarily by pressing the button for the momentary output, or stopped permanently by pressing the button for the toggle output.

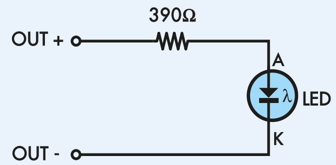


Fig.4(b): driving an LED output

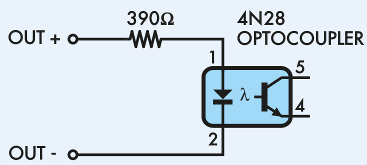


Fig.4(c): driving an optocoupler

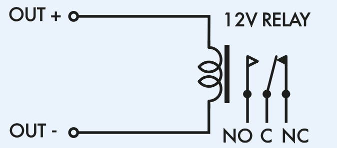


Fig.4(d): driving a 12V relay

Table 3: Setting the outputs for momentary or toggle operation

Step 1	Step 2	Step 3 (toggle operation only)
Press Channel Up, then press channel number to set	Press '0' for momentary operation or '1' for toggle	Press '0' for output off at power up, '1' for output on

should now respond to the channel number buttons on the remote. When you press a button, the Acknowledge (ACK) LED should flash (to indicate that code is being received) and the indicator LED for that channel should light.

As mentioned, the *10-Channel Remote Control Receiver* is initially set so that its outputs are momentary in operation. That means that a channel indicator LED should only light while its corresponding button on the remote is held down and should go out as soon as the button is released.

If it doesn't operate, check that IRD's lens is aligned with its hole in the case. Check also that the code programmed into the universal remote is correct and check that the SET input is open, ie, no jumper installed.

Note that the jumpers on the SET, CODE1 and CODE2 headers are only checked by the microcontroller at power up. So changing these jumpers with the power on will have no effect on the operation until the power is switched off and then on again.

Momentary or toggle

You can easily change one or more outputs to toggle operation to suit your particular application. In this operation mode, an output changes state when its remote button is pressed and remains in that state until the button is pressed again.

The output configuration is done using the hand-held remote. First, press the Channel Up (CH +) button and check that the Acknowledge LED on the receiver stays lit. Then press the number for the channel you wish to program. After that, pressing '1' will select toggle operation for that channel, while pressing '0' will select momentary. If momentary operation is selected, the Acknowledge LED will extinguish and the setting will immediately be stored.

If toggle operation (1) is selected, then you need to enter an additional number – either '0' or '1' – to select the state of the output at power up. A '0' sets the output to off at power up, while '1' will set the output to on. Once you have entered this number, the Acknowledge LED will extinguish and the settings will be stored.

This procedure must then be repeated for any additional channels that require changing. Note that the Channel Down (CH–) button can be pressed before all the numbers are entered to exit the channel programming. There will be no change to the setting if this is done. In addition, the numbers for each setting must be entered within 12 seconds, otherwise the program in the PIC micro will exit without making any changes.

Finally, Figs.4(a)-4(d) show how to use the outputs to drive various devices, including a 12V DC motor in forward or reverse. Note that while Fig.4(b) shows how to drive a single LED, it's also possible to drive series or parallel LEDs – just adjust the value of the current-limiting resistor accordingly.

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Extending the range of the remote control

Want to extend the remote control range or want it to operate without line of sight? You can with the IR To 433MHz UHF Transceiver **described on the following pages.**

IR to 433MHz UHF Transceiver

Mates With 10-Channel Remote Control Receiver

Don't have line-of-sight between your infrared remote and the *10-Channel Remote Control Receiver*? Or do you simply want more range or want it to work outdoors? This *IR To 433MHz UHF Transceiver* will solve the problem.

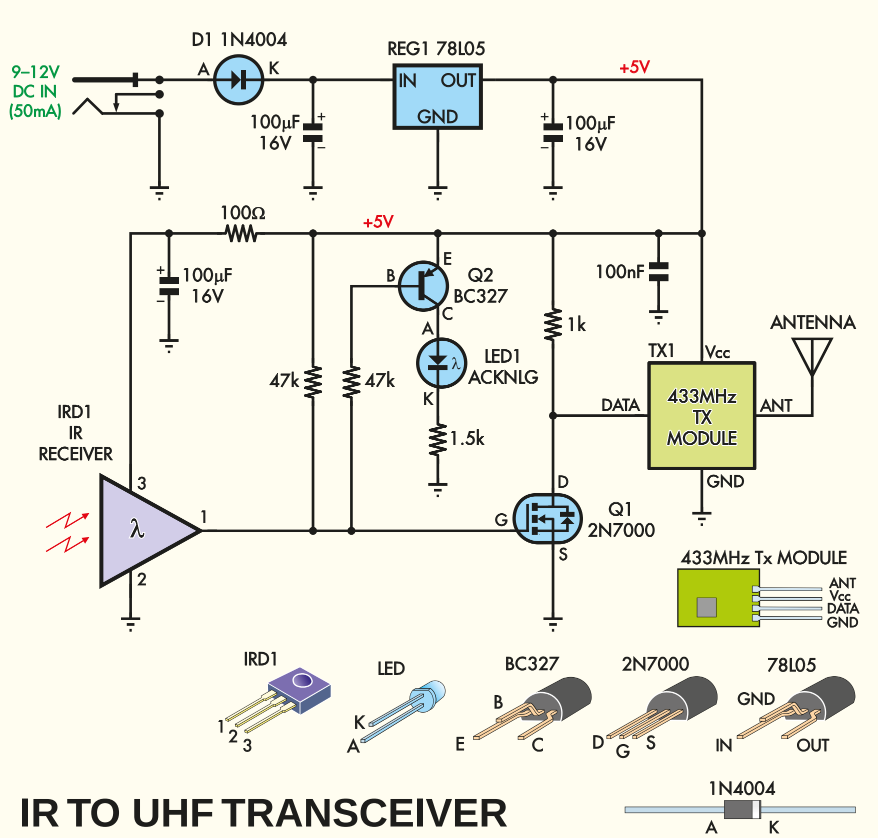


Fig.5: the circuit of the IR To UHF Transceiver. IRD1 picks up the infrared signal and its output drives the Data input of TX1 (the 433MHz transmitter module) via FET Q1. Transistor Q2 drives the Acknowledge LED (LED1).

THE WAY IN which this device works is straightforward: it picks up the coded signal from your IR remote and converts it to a 433MHz UHF radio signal. This is then picked up by the 433MHz receiver in the *10-Channel Remote Control Receiver*, which decodes the signal and switches its outputs accordingly.

In effect, all it does is convert the remote's infrared signals into a radio link, resulting in longer range and no line-of-sight problems. If you want to control the *10-Channel Remote Control Receiver* from another room or outdoors, this is the way to do it.

Specifications

Power supply: 9-12V DC, 50mA

Infrared range: 10m line-of-sight

UHF range: 30m in open space

The transceiver is quite compact and operates from a 9-12V DC supply. In operation, it must be located within range of the infrared remote so that its IR receiver can pick up the remote's signals.

An acknowledge LED on the front panel lights when a valid infrared signal is being received and re-transmitted as a UHF signal.

How it works

Fig.5 shows the circuit details of the *IR To 433MHz UHF Transceiver*. It's based on an infrared receiver (IRD1) and a 433MHz transmitter module (TX1) and not much else.

IRD1's pin 1 output is normally at 5V when no infrared signal is being received. This 5V 'high' is inverted by Q1, an N-channel enhancement-mode FET. It turns on when its gate is high and so the Data input of the UHF transmitter is normally low (ie, at 0V). This low voltage keeps the UHF transmitter off.

When an infrared signal is received from the remote, pin 1 of IRD1 pulses Q1 on and off. Each time FET Q1 turns off, a 1kΩ pull-up resistor at its drain pulls the Data input of TX1 to 5V and the UHF transmitter sends a signal.

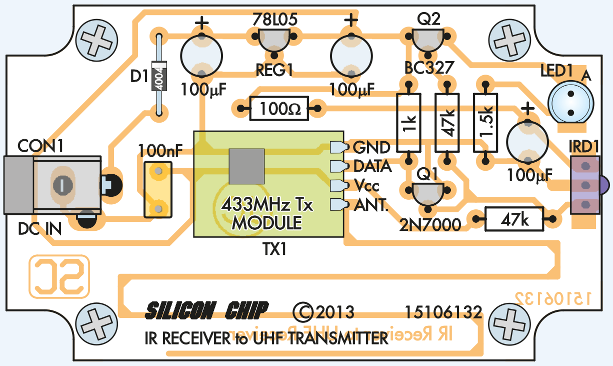
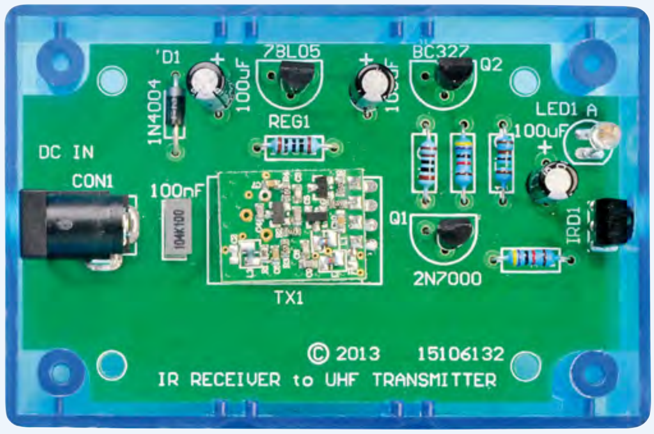


Fig.6: install the parts on the PCB as shown on this layout diagram. LED1 must be mounted with 12mm lead lengths, while the infrared receiver (IRD1) goes in with 4mm lead lengths.



The PCB clips neatly into the UB5 plastic case. Drill holes at each end for the DC socket and IRD1.

At the same time, each time pin 1 of IRD1 goes low, transistor Q2 turns on and drives the Acknowledge LED (LED1) via a 1.5kΩ current-limiting resistor. So this LED flickers upon receipt of infrared transmission.

Power for the circuit is derived from a 12V DC 100mA plugpack supply, with diode D1 providing reverse-polarity protection. The nominal 11.4V supply at D1's cathode is then fed to 3-terminal regulator REG1, which provides a 5V supply for IRD1 and TX1 (the 433MHz transmitter).

Assembly

The *IR To 433MHz UHF Transceiver* is assembled on a PCB coded 15106132 and measuring 79 × 47mm. This is housed in a UB5 plastic utility box (83 × 54 × 31mm).

Fig.6 shows the parts layout on the PCB. Install the resistors and diode D1 first, taking care to ensure that the latter is correctly oriented. REG1, Q1 and Q2 can then be mounted, but be careful not to get these mixed up.

Once these parts are in, install the capacitors but watch the polarity of the 100µF electrolytics. In addition, the tops of the electrolytics must be no more than 15mm above the PCB (so that they will later clear the case lid).

LED1 is mounted with the top of its lens 17mm above the PCB surface. That's done by pushing it down on a 12mm cardboard spacer inserted between its leads before soldering it to the PCB. Make sure the LED is oriented correctly, with its anode (longer) lead going to the pad marked 'A'.

The infrared receiver (RX1) can go in next. It's mounted on 4mm lead lengths so that its top is 10mm above the PCB.

The PCB assembly can now be completed by installing the UHF transmitter (TX1). This module is mounted horizontally and so its four mounting pins will need to be bent down at right angles for insertion into its PCB pads. The antenna for this transmitter is a part of the track pattern on the PCB, so there's no need to fit a separate antenna wire.

Final assembly

The PCB simply clips into the integral ribs of the UB5 case. **Before doing this, you have to drill a hole at each end to give access to the IR receiver and the DC socket.** These holes are both 6mm in diameter and should be centred 7mm down from the top of the base (and centred horizontally).

A 3mm hole must also be drilled in the box lid for the Acknowledge LED. The front panel label can be used as a template to determine the position of this hole. You can download this panel (in PDF format) from the *EPE* website.

Once you have this file, print it out, attach it to the case lid and drill the LED hole to 3mm. A second copy of the artwork can then be printed onto photo paper and affixed to the lid using silicone or some other suitable adhesive. The hole for the LED can either be cut out or punched out with the back end of a 3mm drill bit.

In use, the *IR To 433MHz UHF Transceiver* should be placed no closer than 1m to the *10-Channel Remote Control Receiver* to prevent possible signal overload. In practice of course, the two are likely to be much further away than that and you should get reliable operation at distances up to 30 metres in open space.

What's coming

Finally, we plan to publish a version of this *IR To 433MHz UHF Transceiver* that fits inside an IR remote control. We also plan to publish a companion *UHF To IR Receiver* unit so that the two can be used as an IR range extender with any equipment.

Parts List

- 1 PCB, available from the *EPE PCB Service,* code 15106132, 79 × 47mm
- 1 front panel label, 78 × 49mm
- 1 433MHz transmitter (TX1), (Jaycar ZW-3100, Altronics Z 6900)
- 1 UB5 utility case, 83 x 54 x 31mm
- 1 PCB-mount DC socket

Semiconductors

- 1 infrared receiver, TOSOP4136 or similar (RX1)
- 1 2N7000 N-channel enhancement-mode FET (Q1)
- 1 BC327 PNP transistor (Q2)
- 1 78L05 regulator (REG1)
- 1 1N4004 1A diode (D1)
- 1 3mm blue high-brightness LED (LED1)

Capacitors

- 3 100µF 16V PC electrolytic
- 1 100nF MKT polyester

Resistors (0.25W, 1%)

2 47kΩ	1 1kΩ
1 1.5kΩ	1 100Ω

Into model railways?
Then you'll want to build the . . .

Li'l Pulser Model Train Controller

By JOHN CLARKE

This project started out as a simple revision to earlier train controllers. But this new controller has a lot of extra features and it can deliver considerably more current.

UNLESS YOU ARE already using a previously published model train controller, this little feature-packed controller is likely to be better than any controller you have used. This is particularly true if you are using a commercially-made low-cost rheostat or series transistor train controller.

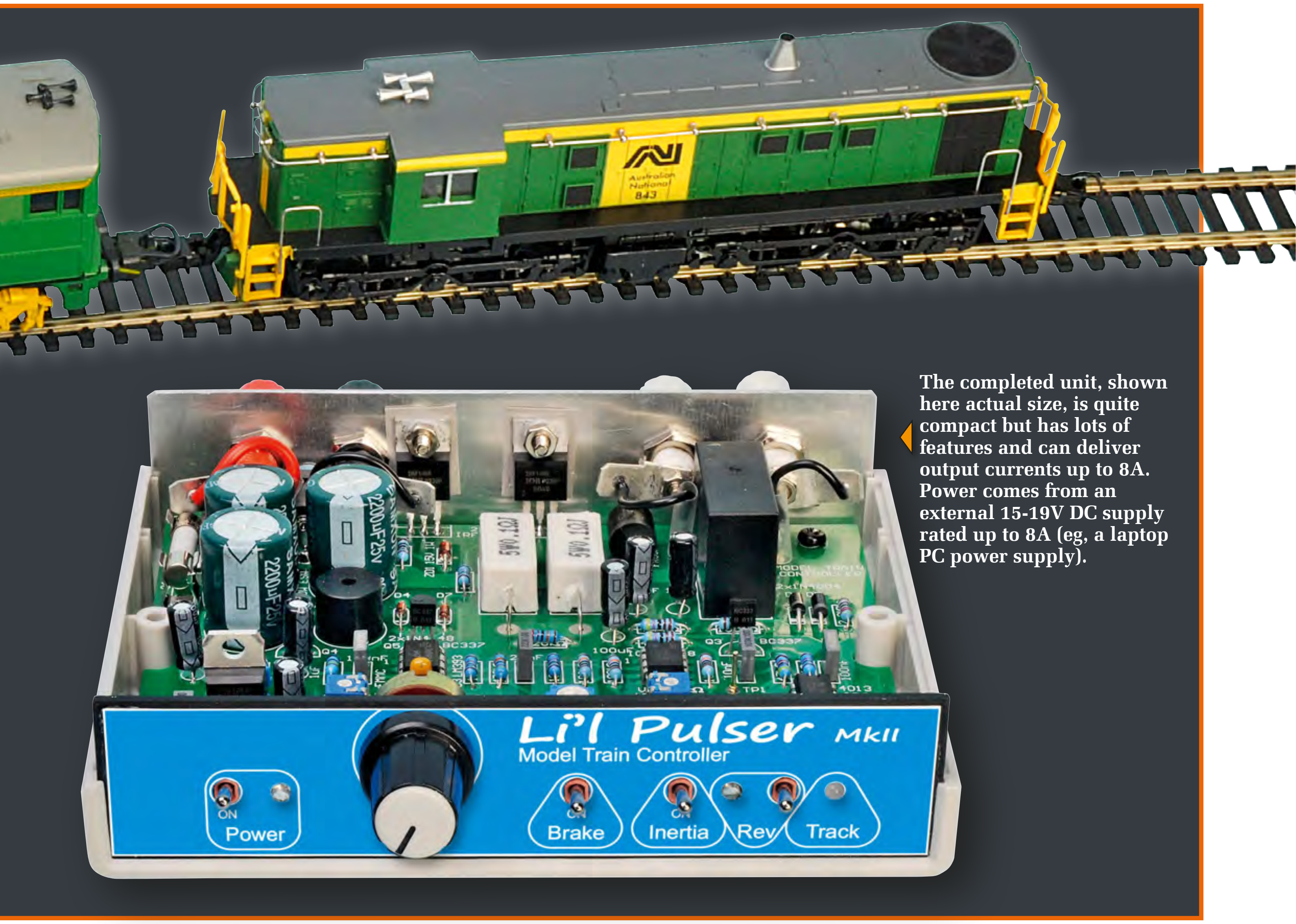
Simple train controllers have plenty of shortcomings. To get the loco started, you have to wind the speed control way past the setting at which you would want it to run. Then the loco suddenly takes off like a startled rabbit. Once running, with reduced throttle setting, the loco then slows down whenever there is the slightest incline.

So what makes *Li'l Pulser* so much better? Well, firstly, it will control the loco at the speed you want, with smooth starts and not too much speed reduction on hills. In model railway jargon, 'pulse power' is what makes this little train controller such a good performer.

Don't let the small case fool you. This little train controller has just about all the operational features of the best designs (such as the *Railpower IV* from *EPE* October and November 2010). And there is no heavy mains transformer or mains wiring involved because you can use an original train controller supply, a 12V lead-acid battery charger or any 15-19V switch-mode laptop PC power supply rated at up to 8A.

Pulse power

As noted earlier, our *Li'l Pulser* applies pulse power to the railway track. This



The completed unit, shown here actual size, is quite compact but has lots of features and can deliver output currents up to 8A. Power comes from an external 15-19V DC supply rated up to 8A (eg, a laptop PC power supply).

involves applying 17V voltage pulses (typically) to the track, even at low throttle settings. These voltage pulses are much more effective at starting and running a loco, particularly at low settings.

The pulses overcome track resistance and motor and gearbox stiction, thus providing a smooth-running loco motor. At low speeds, the 17V pulses are very short, so that the average voltage is low and the motor runs at a slow speed. For faster operation, the pulses are wider, thus applying a higher average voltage to the motor.

But pulse power is not the only feature of this latest *Li'l Pulser* model train controller. It also includes monitoring of the motor back-EMF to provide very good speed regulation. Without this back-EMF control, the model locos would slow down unrealistically with any slight incline.

Naturally, *Li'l Pulser* has reverse polarity and overload protection (essential features for all but the simplest model train controller), together with an audible alarm which beeps briefly for momentary track shorts, but which sounds for longer for more severe overloads.

New features

Previous designs had useful but basic features: a speed control potentiometer, LEDs to indicate power on, reverse and track voltage, and a switch for forward/reverse operation.

By contrast, *Li'l Pulser* has several added features that vastly improve the realism of operation, including inertia (sometimes called 'momentum'), braking and reverse lockout, plus minimum and maximum speed settings.

The most useful added feature is reverse lockout. This makes it impossible

Main Features

- Pulse power for smooth running
- Excellent low-speed control
- Speed regulation
- Speed control pot
- Inertia and braking simulation
- Minimum and maximum speed adjustments
- Adjustable inertia and braking rates
- Inertia on and off selection
- Power on indication
- Track voltage LED indication
- Reverse indicator
- Over-current/short-circuit alarm
- Compact size
- Maximum current: 8A
- Power supply: 15-19V DC

Li'l Pulser Parts List

1 double-sided PCB, available from the *EPE PCB Service,* code 09107134, 129.5 × 100.5mm
1 front panel PCB, available from the *EPE PCB Service,* code 09107132, 132 × 30mm
1 rear panel PCB, available from the *EPE PCB Service,* code 09107133, 132 × 30mm OR
1 aluminium rear panel, 134 × 30 × 1mm (see text)
1 plastic instrument case, 140 × 110 × 35mm
1 piezo buzzer
1 16mm 10kΩ linear PCB-mount potentiometer (VR1)
1 1MΩ miniature horizontal-mount trimpot (VR4)
1 250kΩ miniature horizontal-mount trimpot (VR5)
3 10kΩ miniature horizontal-mount trimpots (VR2,VR3,VR6)
1 1kΩ miniature horizontal-mount trimpot (VR7)
2 nuts and washer for VR1
1 19mm knob to suit potentiometer
1 8A DPDT PCB mount relay (RELAY1)
4 SPDT PCB mount toggle switches (S1-S4)
1 2.5mm PC mount DC socket
1 black binding post
1 red binding post
2 white binding posts
4 6.3mm 45° chassis-mount spade terminals
1 8A M205 fuse (F1)
2 M205 fuse clips
2 TO-220 insulating bushes
2 TO-220 silicone insulating washers
4 M3 × 5mm screws
2 M3 × 10mm screws
2 M3 nuts
7 PC stakes
1 200mm length of 8A hook-up wire

Semiconductors
1 LM358 dual op amp (IC1)
1 LM324 quad op amp (IC2)
1 LM393 dual comparator (IC3)
1 4013 dual D-flipflop (IC4)
2 IRF1405 55V 169A MOSFETs (Q1,Q2)
3 BC337 NPN transistors (Q3,Q5,Q6)
1 BC327 PNP transistor (Q4)
1 7812 3-terminal regulator (REG1)
1 15V 1W Zener diode (ZD1)
1 8.2V 1W Zener diode (ZD2)
1 FR607 6A diode (D6)
2 1N4004 1A diodes (D1,D5)
4 1N4148 diodes (D2-D4, D7)
1 3mm 2-lead bi-colour LED (LED1)
1 3mm red LED (LED2)
1 3mm green LED (LED3)

Capacitors
3 2200µF 25V low-ESR electrolytic (22mm high or less; eg, element14 1800659)
4 100µF 16V PC electrolytic
1 47µF 16V low-leakage PC electrolytic or tantalum
2 1µF 16V PC electrolytic
1 1µF monolithic ceramic (MMC)
1 220nF MKT polyester
2 100nF MKT polyester
1 22nF MKT polyester
2 10nF MKT polyester

Resistors (1%, 0.25W)

1 1MΩ	3 2.2kΩ
1 470kΩ	2 1kΩ
2 220kΩ	2 470Ω
6 100kΩ	1 100Ω
2 47kΩ	1 10Ω
9 10kΩ	2 0.1Ω 5W 5%
5 4.7kΩ	

to throw the loco into reverse while it is moving in the forward direction. This is highly desirable for two reasons. First, it is more realistic and second it prevents derailments. Reverse lockout means that even if you inadvertently switch to change the direction of the train while it is moving, the controller won't do anything until the train has come almost to a full stop.

Inertia and braking add realism to loco operation. While you can simulate the slow increase in speed during starting and the slow decrease in speed during braking by careful adjustment of the speed control, the inertia and braking functions do it automatically and consistently.

It means that the throttle can be preset and the starting and stopping done entirely using the inertia and braking functions. The brake typically slows down the loco at a faster rate than the start-up inertia rate. There are trimpots on the PCB to set these rates.

But while simulated inertia is good most of the time, it can be a problem for shunting operations. So we've added a front panel switch to disable inertia when you don't need it.

Locos don't buzz when stopped

In case you are wondering, the *Li'l Pulser* does not cause locos to buzz when they are stopped. All model locomotives require a few volts DC before they will start moving and before that, pulse power will cause them to buzz. However, the minimum speed setting in the *Li'l Pulser* can be set to switch off the pulses whenever the loco is stopped.

The *Li'l Pulser* can deliver up to 8A DC. This means that it can easily handle trains with double-headed locos, even if they have smoke generators, sound and lighting. This is mainly due to vastly better MOSFETs than those used in earlier designs.

Despite these features, the controller is mounted in a compact plastic case, measuring just 140mm wide, 35mm high and 110m deep. We have packed all the circuit features onto a double-sided PCB with plated-through holes.

On the front panel, there are toggle switches for power, inertia, braking and forward/reverse switching. There is one knob for the throttle control and the three LEDs. The track LED is bi-coloured: green for forward and red for reverse. The reverse LED is red, to give an indication when a train is set to go backwards.

There are four binding post terminals on the rear panel, two for the input power and two for the leads to the track. A DC socket is also included for power, but be aware that these DC sockets are not rated for much above about 4A. So use the binding posts for higher current operation.

Pulse-width modulation

Before having a look at the full circuit of the *Li'l Pulser*, we should describe how the circuit generates the varying width pulses which drive the loco motor. To do that, we have taken the core of the circuit, as shown in Fig.1. It basically consists of a ramp (triangle) wave generator based on IC1a and a comparator based on IC3b. The IC numbers correspond to the same parts on the main circuit shown in Fig.3.

IC1a is one half of an LM358 dual op amp and is configured to work as an oscillator running at about 160Hz. It works by charging and discharging a 22nF capacitor at its inverting input. The result is a triangle (ramp) waveform

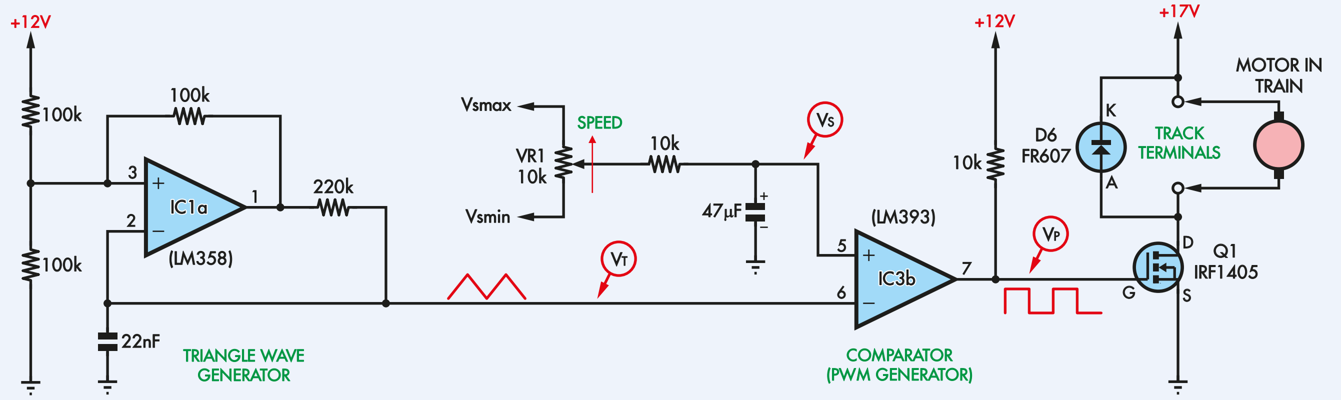


Fig.1: the core of the circuit. IC1a generates a triangle waveform and this is compared with the output voltage from the speed pot (VR1) in comparator IC3b to produce a 160Hz pulse waveform. This then drives MOSFET Q1, which switches the supply voltage to the tracks each time it turns on.

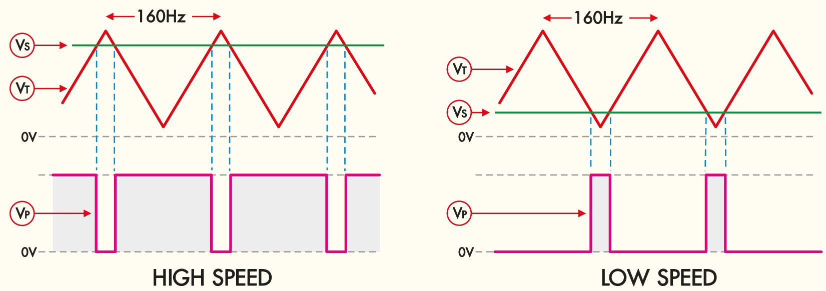


Fig.2: this diagram shows the output waveform (V_P) from comparator IC3b for high-speed and low-speed settings of VR1. The output is high whenever V_S (from the speed control pot) exceeds the triangle wave V_T from IC1a.

at pin 2 and a square wave at its output, pin 1. The triangle waveform is fed to the inverting input (pin 6) of IC1b, one half of an LM393 dual comparator.

The comparator compares the triangle wave at pin 6 with the DC voltage from VR1, the speed control potentiometer. This is depicted in the waveforms shown in Fig.2, with the DC voltage from VR1 shown as the horizontal line V_S. Whenever the triangle voltage V_T is below V_S, the output V_P at IC3b's pin 7 will go high. Similarly, when V_T is above V_S, V_P will go low.

The result is a 160Hz pulse waveform which drives the gate of MOSFET Q1, turning it on each time V_P is high. Fig.2(a) shows the result when the speed pot VR1 is set for a high speed, while Fig.2(b) shows the result for a low-speed setting.

These waveforms are confirmed by the scope shots accompanying this article.

Circuit description

Now let's have a look at the full circuit shown in Fig.3. It uses four low-cost ICs, two power MOSFETs and a relay for forward/reverse switching. IC1a is on the lefthand side of the diagram, while IC3b and MOSFET Q1 are on the righthand side. Most of the rest of the circuitry is there to add the various operating features such as braking, inertia and overload protection.

So let's start at the top lefthand corner of the circuit, which shows the DC input and MOSFET Q2 which has a rather odd configuration. It is actually in series with the negative return lead and we are using it for polarity protection instead of a silicon diode.

It works in two ways. Initially, at switch-on, the MOSFET is off, but its substrate diode (between drain and source) conducts to let current flow. Then, once the supply voltage across the three 2200µF input capacitors builds up, the MOSFET's gate is biased on and so the MOSFET turns hard on and conducts with a very low forward voltage of only a few tens of millivolts; much lower than even a Schottky diode, since its drain source resistance is only 5.3 *milli*ohms!

Note that the MOSFET conducts even though its drain is negative with respect to its source electrode. If this seems a little puzzling, consider that a MOSFET will conduct in either direction, as long as it has the correct gate voltage polarity; in this case, positive. If the supply polarity is reversed, there will be slightly negative gate bias (by virtue of reverse-biased Zener diode, ZD1) and neither the MOSFET nor its substrate diode will conduct.

Because the forward voltage loss across MOSFET Q2 is so low, the amount of power it dissipates at any current up to our rated circuit maximum is very low. In fact, at the rated circuit current of 8A, the power dissipated in Q2 is only around 340mW, which means that, strictly speaking, it doesn't need any heatsinking at all.

The same general comment goes for Q1, which is also an IRF1405 automotive MOSFET. And minimum heat means that we can have a high-power circuit sitting in a small plastic case.

Relay rating

Given that the IRF1405 MOSFET is a high-power device, what actually sets our rated circuit current of 8A maximum? The answer is the reversing relay. Its contacts are rated to switch 8A DC. The other determinants of the maximum current are the two 0.1Ω 5W wirewound resistors at Q1's source, as described later this article.

Going back to the DC input, which can typically be 17V or more, after being fed in via the power switch S4, it then feeds 3-terminal regulator REG1, which provides 12V to all of the circuit except for Q1, which switches the 17V DC rail directly to the tracks.

Speed control

Let's now look at how the basic circuit of Fig.1 has been refined. First, speed control potentiometer VR1 is fed via

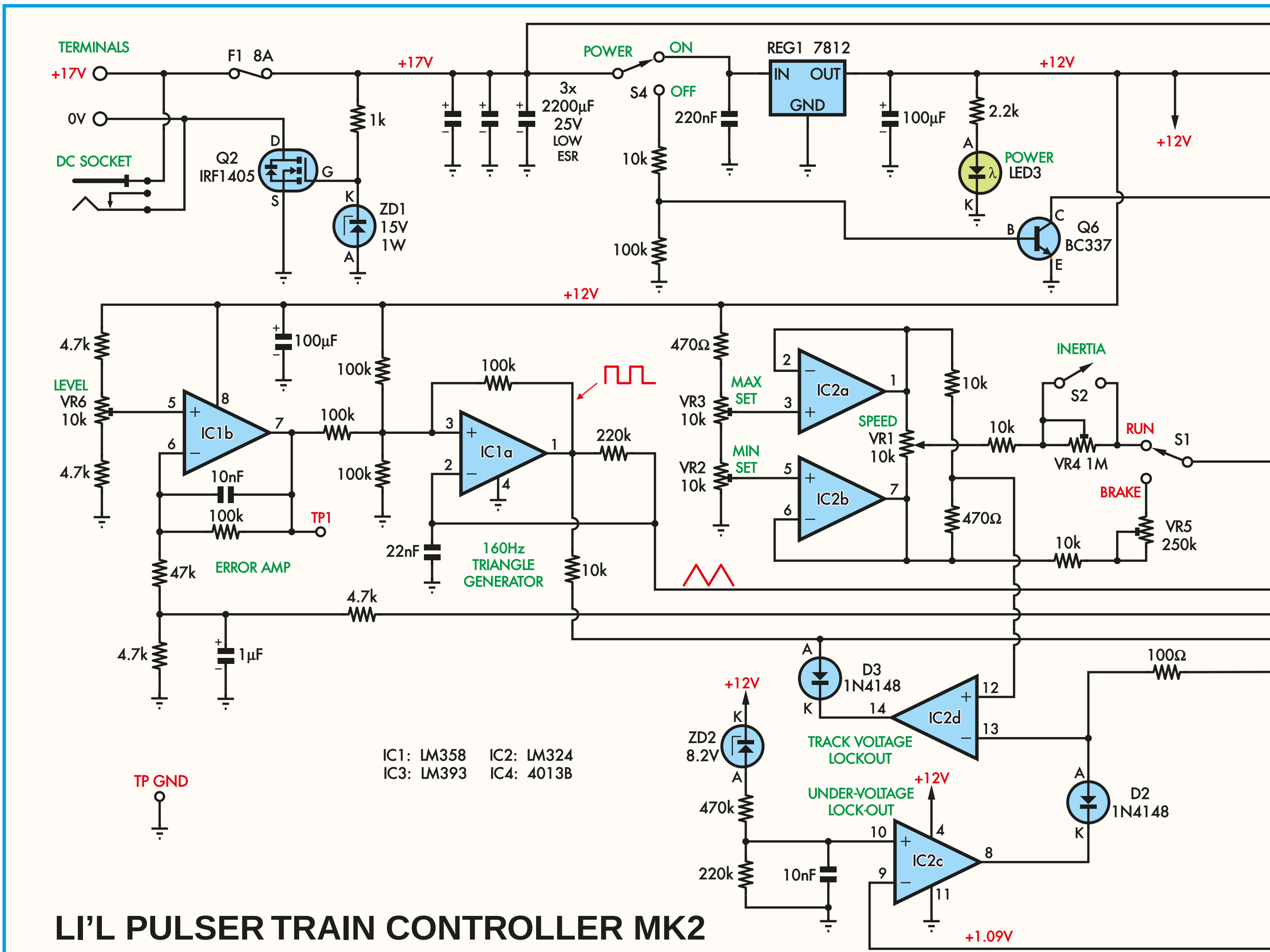
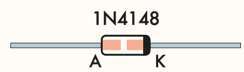


Fig.3: the complete circuit for the *Li'l Pulser* includes back-EMF monitoring based on error amplifier IC1b, to ensure good speed regulation. Also included are a relay (RELAY1) to provide forward and reverse direction, simulated inertia, overload protection (IC3a) and a lock-out feature to prevent a change of direction until the loco has been brought to a stop (IC2d).



two op amps, IC2a and IC2b. These are connected as voltage followers, fed by trimpots VR2 and VR3. So VR2 provides the minimum speed setting (minimising the 'dead spot' at the low setting of speed potentiometer VR1) and VR3 provides the maximum speed setting, so that you cannot apply more than the maximum rated voltage for the locos you are using. Typically, HO-scale locos run with a maximum of 12V DC and N-scale locos typically run with a maximum of 9V.

The voltage from the wiper of speed control pot VR1 is fed via trimpot VR4 and switch S1 to the 47µF capacitor at pin 5 of IC3b. This provides the 'inertia'. What happens is that when you wind up the speed control pot, the actual change in voltage appearing at pin 5 of IC3b is slowed down by the time-constant of VR4 and the 47µF capacitor. Higher settings of VR4 give more inertia, simulating the effect of a heavier train.

For shunting operations, we don't want inertia, so it can BE switched off by S2 which shorts out VR4.

Braking

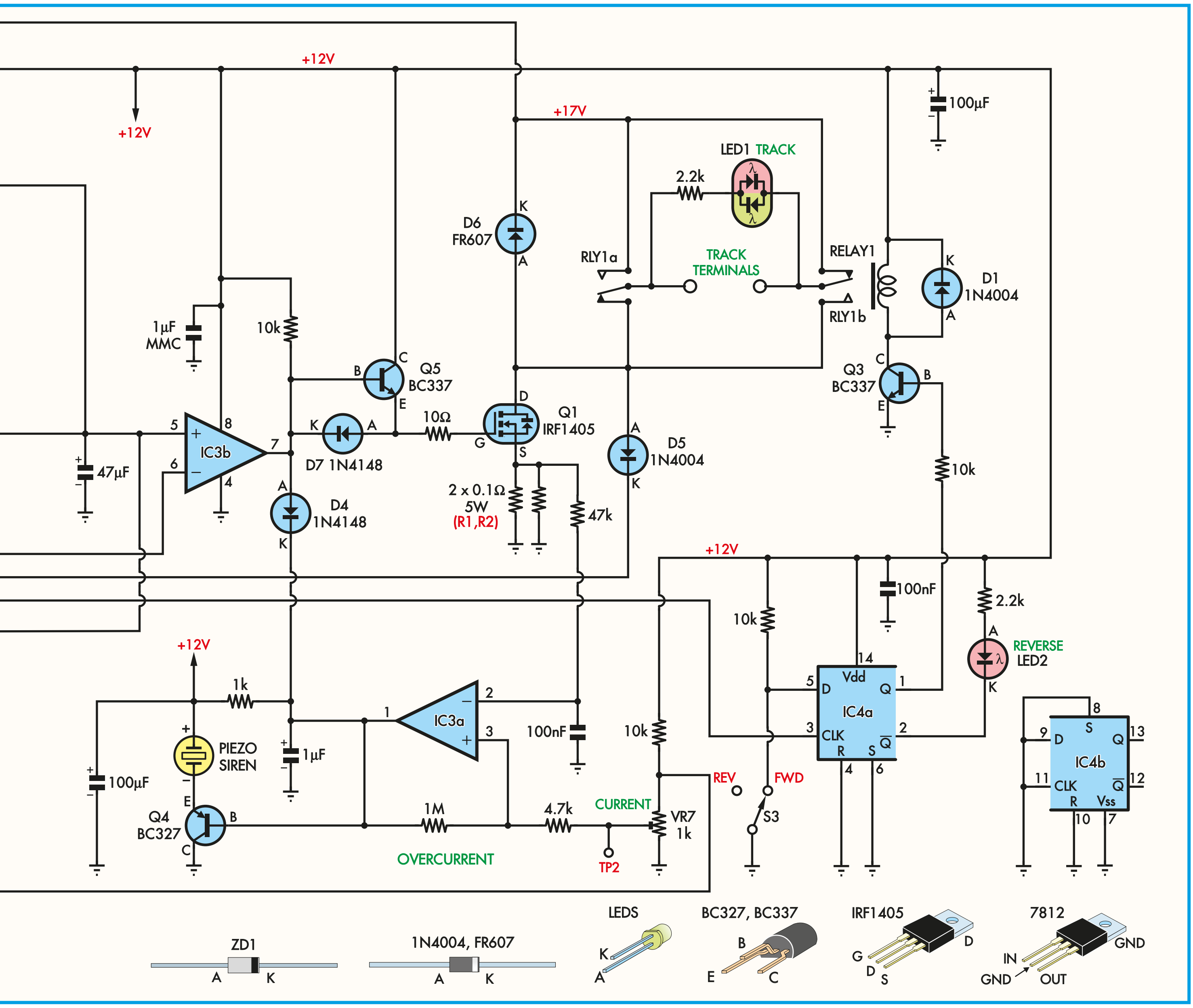
While inertia is for simulating heavy trains, in the scale world of models, we normally want to stop or slow down trains much more quickly than would be possible (or safe) in the full-scale world. So braking switch S1 is included. It is set to RUN when the loco is being driven normally and then to BRAKE when you need to bring it to a quick stop.

In operation, setting S1 to BRAKE connects VR5 to the 47µF inertia capacitor and this has the effect of discharging the capacitor to the output of IC2b, the minimum speed op amp. This means that the 47µF capacitor is only discharged to the point where Q1 is just turned off; any more and there would be more than the necessary delay when the brake was removed.

MOSFET switching

In our simplified circuit of Fig.1, we show the output pulses from 1C3b directly driving the gate of MOSFET Q1. However, that is not the most effective way to drive the MOSFET if we want to minimise its power dissipation.

The problem is that Q1 has quite a high gate capacitance, and if we just turn it on via IC3b's 10kΩ load resistor (this is an 'open-collector' output), Q1 would turn on relatively slowly for each



positive gate pulse. As a result, its dissipation would be higher than we want, as it would spend more time in partial conduction.

For that reason, the gate drive is via transistor Q5 which is connected as an emitter follower. This pulls up Q1's gate much faster, to minimise switch-on time. Conversely, when IC3b's output goes low, Q1's gate is quickly pulled low via diode D7.

Overload protection

Comparator IC3a provides the overload current protection. Two 0.1Ω 5W resistors connected in parallel monitor the load current (ie, through Q1) and the resulting voltage is fed to IC3a's pin 2 via a 47kΩ resistor. The associated 100nF capacitor provides filtering.

The non-inverting input at pin 3 is connected to trimpot VR7, the current setting control. If the voltage at pin 2 exceeds that at pin 3, IC3a's pin 1 output pulls pin 7 of IC3b low via diode D4. This removes gate drive from Q1.

You then get a 'hunt' condition whereby the removal of gate drive to Q1 stops the overload current, so IC3a's output goes high and the MOSFET switches on again. This switching on and off is slowed down using a 1µF capacitor connected to IC3a's output.

IC3a also drives a piezo alarm via transistor Q4 to indicate when an overload is occurring.

Speed regulation

The loco's motor generates a back-EMF that is directly proportional to its speed. In other words, during the period that the motor is not driven by the pulses, it acts as a generator, supplying voltage at its output terminals. We use this back-EMF as a feedback signal to make sure that the controller maintains a relatively constant motor speed for a given throttle setting, regardless of variations in load.

In operation, the motor's back-EMF is monitored by D5, which conducts when MOSFET Q1 is off. Note that D5 monitors the negative terminal of the motor and any back-EMF will be negative with respect to the +17V rail. At low motor speeds, the back-EMF is close to the 17V supply. As the motor speeds up, it will generate more back-EMF and so the voltage we measure will be lower (with respect to +17V).

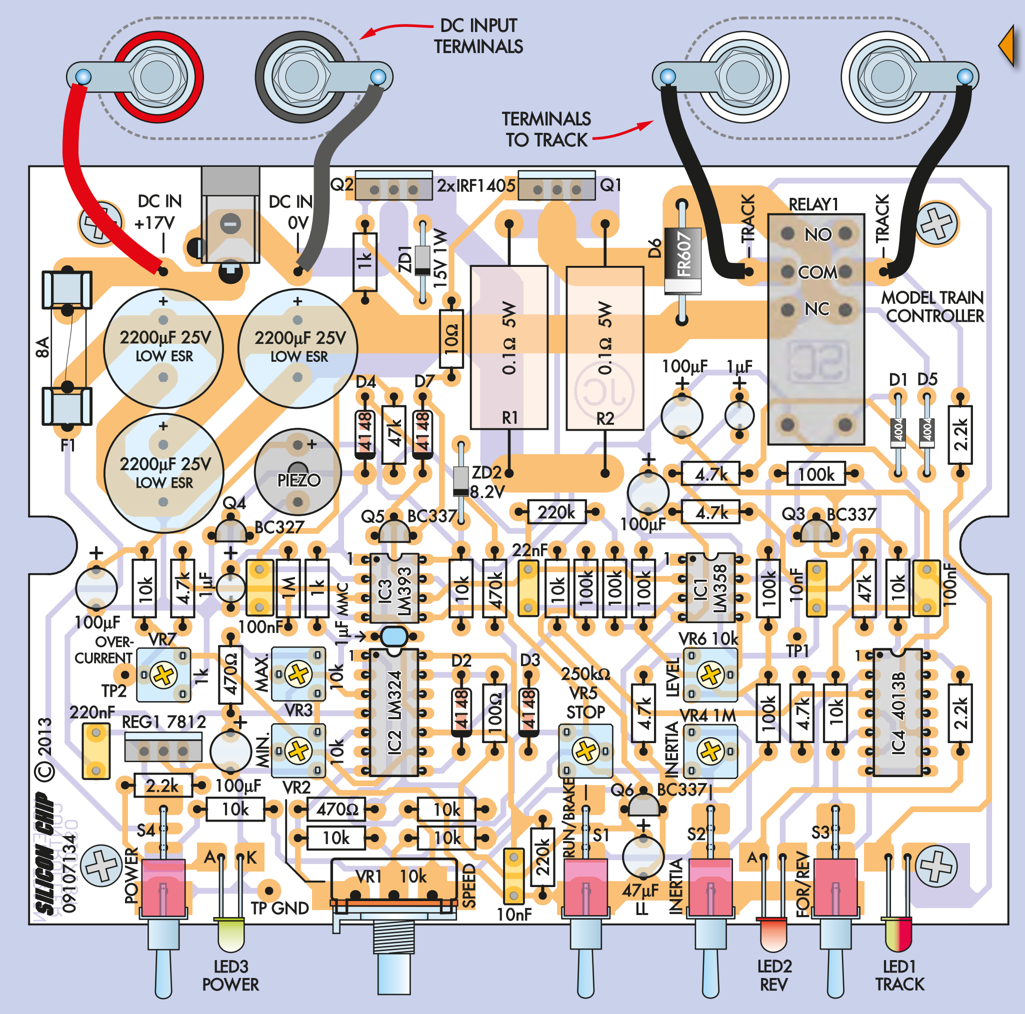
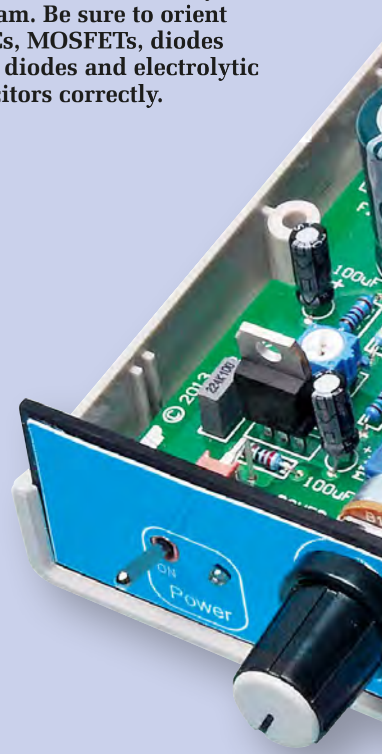


Fig.4: install the parts on the PCB as shown on this layout diagram. Be sure to orient the ICs, MOSFETs, diodes zener diodes and electrolytic capacitors correctly.



Right: the prototype used the plastic front panel supplied with the case, plus a paper label. PCB front panels with pre-drilled holes and screened lettering are available from the *EPE* online shop.

D5 feeds a 1µF capacitor via a voltage divider consisting of two 4.7kΩ resistors and the resulting filtered voltage is fed to the pin 6 inverting input of op amp IC1b (the error amplifier). It amplifies the voltage by a factor of about two and its output is used to control the pin 3 threshold voltage of triangle generator lC1b via a 100kΩ resistor.

So, as the motor speed drops, the back-EMF decreases, and the DC level from pin 7 of lC1b drops. This causes the triangle waveform generated by IC1a to drop with respect to the DC voltage from speed-control potentiometer VR1. This then results in wider positive gate pulses to MOSFET Q1 and more power fed to the motor to maintain the given speed setting.

Trimpot VR6, at pin 5 of IC1b, is included to give some compensation for different motor characteristics; some motors generate more back-EMF than others. VR6 is set so that pin 7 of IC1b is at about mid-supply voltage (ie, 6V) when a motor is connected (more on that in the setting up procedure).

Reverse lockout

Forward and reverse switching is done by RELAY1. This turns on and reverses the loco when the Q output (pin 1) of D-type flipflop IC4a goes high and turns on transistor Q3. IC4a provides the forward/reverse lockout feature whereby the train's direction cannot be changed unless the track voltage is reduced to zero.

This works as follows: IC4a has its data input (pin 5) connected to either +12V via a 10kΩ resistor when the forward/reverse switch (S3) is open, or to 0V when S3 is closed. The Q output at pin 1 changes to the level set at pin 5 when a positive clock pulse is fed to pin 3. So if the setting of the forward/reverse switch is changed, the Q output of IC4a will not change until pin 3 gets a positive clock pulse.

In practice, we prevent a clock pulse from arriving until the gate pulses to MOSFET Q1 are stopped. We do this by monitoring the voltage across the 47µF capacitor at pin 5 of IC3b (ie, the speed-setting voltage) using op amp IC2d, ie, via the 100Ω resistor to its pin 13 input.

IC2d's pin 12 is connected to a voltage divider between pin 1 of IC2a and pin 7 of IC2b. Hence, pin 12 will be very close to the minimum speed voltage from IC2b. So until the voltage across the 47µF capacitor drops below this minimum voltage (when the brake is applied, for example), IC2d's output will be low and this will short out any clock pulse to IC4a (ie, from IC1a) by forward biasing D3.

The 160Hz clock pulses are derived from the output of IC1a, the same op amp that provides the triangle waveform. As soon as the voltage across the 47µF capacitor drops below pin 12 of IC2d, the clock pulses will get through to IC4a. It will then change state and so will the relay.

IC2c is included to ensure that the 160Hz clock signal is applied to IC4a

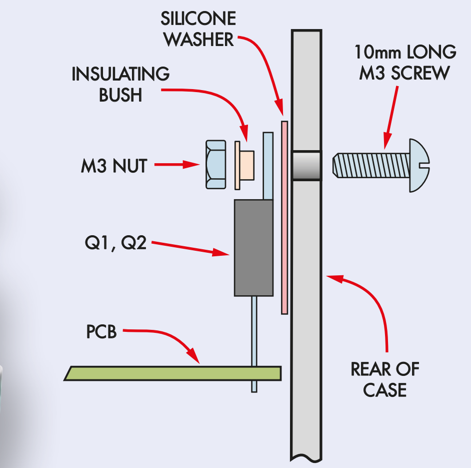


Fig.5: the mounting details for MOSFETs Q1 and Q2. The metal tab of each device must be isolated from the rear panel using an insulating bush and a silicone washer.

to give the correct setting of forward or reverse at switch-on, as set by the forward/reverse switch (S3). When power is first applied, the 10nF capacitor at pin 10 of IC2c is discharged and since this is lower than pin 9 which is biased to 1.09V, IC2c's output is low. As a result, diode D2 pulls pin 13 of IC2d low, so pin 14 of IC2d is high and the clock signal cannot be shunted to 0V by D3.

Zener diode ZD2 plus the voltage divider formed by the 470kΩ and 220kΩ resistors ensure that the supply rail has to rise above about 11V before IC2c's output goes high. When that happens, D2 is reverse biased and the forward/reverse lockout facility based on IC2d operates normally.

IC2c also provides an under-voltage lock-out facility. When the power is switched off, the supply rail quickly drops below 11V and pin 8 of IC2c goes low. As a result, the 47µF filter capacitor at pin 5 of IC3b quickly discharges via the 100Ω resistor in series with D2, and IC3b's output goes low. This forces Q1 to stay off while the supply voltage decays to zero, so that no further output pulses are applied to the track.

As a belt and braces measure, transistor Q6 turns on when S4 is switched to the off position and rapidly discharges the 47µF filter capacitor. This ensures that there's no possibility of an output pulse, regardless of how quickly the under-voltage lock-out circuit kicks in.

Construction

Building the *Li'l Pulser* is easy, with all the parts assembled onto a PCB available from the *EPE PCB* Service, coded 09107134 and measuring 129.5 × 100.5mm. This is housed in a small instrument case measuring 140 × 35 × 110mm (W × H × D).

Our prototype used an adhesive label attached to the plastic panel supplied with the case for the front panel. However, we're making available from the *EPE PCB* Service, a PCB front panel (code 09107132) with blue solder masking, screened lettering and all the holes pre-drilled for a really professional finish. This PCB panel is simply substituted for the supplied plastic panel.

We've also designed a rear-panel PCB (code 09107133) which is also available from the *EPE PCB* Service. This has solder-masked copper on both sides to provide heatsinking for the two MOSFETs (Q1 and Q2). The mounting areas for the MOSFETs are clear of solder masking to improve thermal contact and there are numerous vias between the two sides of this PCB to improve ventilation and heat transfer out of the case.

This PCB rear panel can be used for output currents up to about 5A. This should be more than adequate for the vast majority of layouts, including layouts running double-header (or even triple-header) locos with sound, steam and lighting.

For layouts requiring more than 5A (up to 8A maximum), it's best to use an aluminium rear panel for improved heatsinking (as in the prototype). You will have to cut this aluminium panel to size (134 × 32 × 1mm) and drill the holes yourself (details later). The original plastic panel supplied with the case is discarded.

Fig.4 shows the parts layout on the PCB. Begin by inspecting the board carefully for any defects (rare), then start the assembly by installing the 0.25W resistors. Table 1 shows the resistor colour codes, but you should also check each one using a digital multimeter before soldering it to the PCB.

Fig.6: this scope grab shows the operation of IC1a and IC3b. The green trace is the triangle output from IC1a, while the blue trace is the DC voltage from speed pot VR1. The resultant pulse (yellow trace) from the output of IC3b is fed to the gate of MOSFET Q1. This is a low-speed setting.

Fig.7: this scope grab shows the same signals as in Fig.6, but now the speed voltage from VR1 is higher, leading to wider positive output pulses from the output of IC3b. This corresponds to almost maximum speed. You can compare these scope grabs with the waveforms shown in Fig.2.

The diodes (including ZD1 and ZD2) can go in next. Be sure to use the correct type at each location and make sure they are all oriented correctly. That done, install the capacitors and the two 0.1Ω 5W resistors (the latter can be mounted flush against the PCB, as they run only slightly warm). Take care with the orientation of the electrolytics – they all go in with their positive leads towards the rear of the PCB.

Follow with the trimpots, relay, piezo buzzer (watch its orientation), switches, potentiometer VR1 and the DC socket. Don't get the trimpots mixed up and be sure to trim VR1's shaft to to suit the knob before soldering it to the PCB. The ICs can then be installed. Make sure their notched ends face the rear of the PCB, as shown on Fig.4.

Installing the MOSFETs

Regulator REG1 can now go in, followed by transistors Q3-Q6. Note that Q4 is a BC327 while Q3, Q5 and Q6 are BC337s. Don't get them mixed up.

MOSFETs Q1 and Q2 can now be installed. First, slip the PCB assembly into the case and secure it by installing the two rear mounting screws. That done, slide the rear panel into position, then mount the two MOSFETs on the PCB and temporarily fasten them, along with their insulating bushes, to the rear panel using machine screws and nuts (note: if you are using an aluminium rear panel, you will first have to download the artwork from the *EPE* website and use it as a template to drill the necessary holes).

Check that the rear panel is pushed all the way down into its case slot, then carefully tack solder the two outside leads of each MOSFET to their pads on the top of the PCB. The PCB assembly can then be removed from the case and the MOSFET leads soldered on the underside.

The next step is to fit PC stakes to the four external wiring points and to the three test points (TP1, TP2 and TP GND). Follow with the two fuse clips, making sure that each goes in with its end stop towards the outside (otherwise you will not be able to install the fuse).

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
220nF	0.22µF	220n	224
100nF	0.1µF	100n	104
22nF	0.022µF	22n	223
10nF	0.01µF	10n	103

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	1MΩ	brown black green brown	brown black black yellow brown
❏	1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❏	2	220kΩ	red red yellow brown	red red black orange brown
❏	6	100kΩ	brown black yellow brown	brown black black orange brown
❏	2	47kΩ	yellow violet orange brown	yellow violet black red brown
❏	9	10kΩ	brown black orange brown	brown black black red brown
❏	5	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❏	3	2.2kΩ	red red red brown	red red black brown brown
❏	2	1kΩ	brown black red brown	brown black black brown brown
❏	2	470Ω	yellow violet brown brown	yellow violet black black brown
❏	1	100Ω	brown black brown brown	brown black black black brown
❏	1	10Ω	brown black black brown	brown black black gold brown
❏	2	0.1Ω	not applicable	not applicable

The rear panel carries the four binding posts for the power supply and track connections. An on-board DC socket is also accessible via a hole in the rear panel and can be used instead of the red and black binding posts for currents up to about 4A.

Installing the LEDs

The PCB assembly can now be completed by fitting the three LEDs (LEDs1-3). Use the bi-colour LED for LED1 (Track), the red LED for LED2 (Reverse) and the green LED for LED3 (Power).

To install the LEDs, first orient each one in turn so that its anode lead is on the left (as viewed from the front), then bend its leads down by 90° about 8mm from its body. That done, solder the LEDs in place with their horizontal lead sections 5mm above the surface of the PCB (ie, in line with the switch centres).

The easiest way to achieve this is to cut a 5mm-thick cardboard spacer and simply push the LEDs down onto this before soldering their leads.

Final assembly

Now for the final assembly. The first step is to wind a nut onto VR1's threaded bush. Do this nut all the way up, then fit the front panel to the PCB assembly and secure it by fitting a second nut to VR1 (make sure the switches and LEDs all correctly protrude through the front panel before fitting this nut).

Next, fit the four binding posts to the rear panel – red for the +12-19V terminal, black for 0V and white for the two track posts. Once they're secure, attach a 45° 6.3mm chassis-mount spade terminal to each binding post and secure it using the two small end-nuts (see photo).

Making your own rear panel

An aluminium rear panel will be necessary if you intend using the *Li'l Pulser* to deliver currents above 5A. This panel should be 1mm thick and should be cut to 134 × 30mm.

Once you've cut the panel to size, download the rear-panel artwork (see Fig.10) from the *EPE* website. Print this out onto both plain paper and photo paper.

The paper version is used as the drilling template, while the photo paper version is used as the label. Use a pilot drill to start the holes, then enlarge them to size using larger drills and finish off with a tapered reamer.

Once the holes have been drilled, the label can be affixed to the lid using a suitable glue or silicone and the holes cut out using a sharp hobby knife.

Another alternative is to discard the case altogether and mount the PCB assembly under the layout. You could then mount the speed pot, switches and LEDs on a separate control panel and connect them back to the PCB via flying leads. The two MOSFETs can then either be mounted on an aluminium heatsink or fitted with small finned heatsinks.

The spade terminal ends close to the end-nuts should now all be trimmed so that the don't later interfere with the relay and the DC socket when it's all assembled in the case. This can be done using tin-snips and then filing them down. In addition, you will have to trim the ends of the posts so that they protrude no more than about 1.5mm beyond the end-nuts.

If you can only get double-ended spade terminals, just cut one side off.

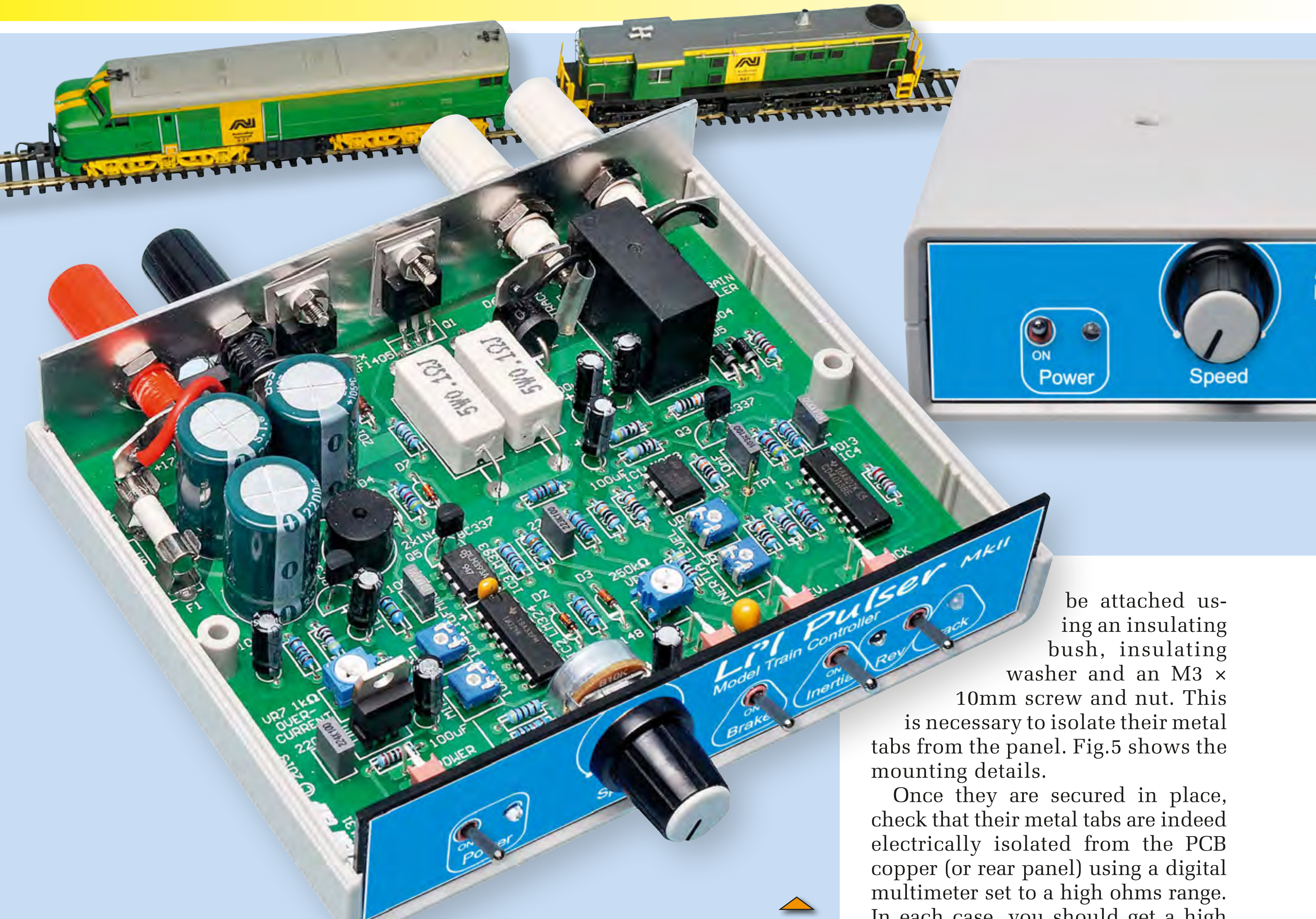
Once the spade terminals are in place, they can be connected to their respective PCB stakes via short lengths of heavy-duty (8A) hook-up wire. Solder these wires to the PCB stakes first, then fit short lengths of heatshrink sleeving over the connections and shrink it down. This will stop the leads from flexing and breaking at the stakes.

The other ends of the wires are then soldered to the spade terminals.

That done, the completed assembly can be installed in the case and the PCB secured to the four corner pillars in the base using four M3 × 5mm screws. Don't worry if the positive binding post terminal touches the adjacent fuse clip, as these are connected together on the PCB anyway, so it doesn't matter.

Securing the MOSFETs

Regardless as to which type of rear panel is used (PCB or aluminium), MOSFETs Q1 and Q2 must both



Another view inside the prototype. MOSFETs Q1 and Q2 must be isolated from the rear panel, regardless as to the type of panel used (aluminium or PCB).

be attached using an insulating bush, insulating washer and an M3 × 10mm screw and nut. This is necessary to isolate their metal tabs from the panel. Fig.5 shows the mounting details.

Once they are secured in place, check that their metal tabs are indeed electrically isolated from the PCB copper (or rear panel) using a digital multimeter set to a high ohms range. In each case, you should get a high megohms (or open circuit) reading. If

Fig.8: these scope waveforms were taken at the gate and drain of MOSFET Q1 to show its switching action. The yellow trace is the gate waveform from IC3b, while the green trace is at the drain and shows the pulses applied to the track, with a resistive load connected. Note that when the gate is positive, the MOSFET switches on and pulls its drain low.

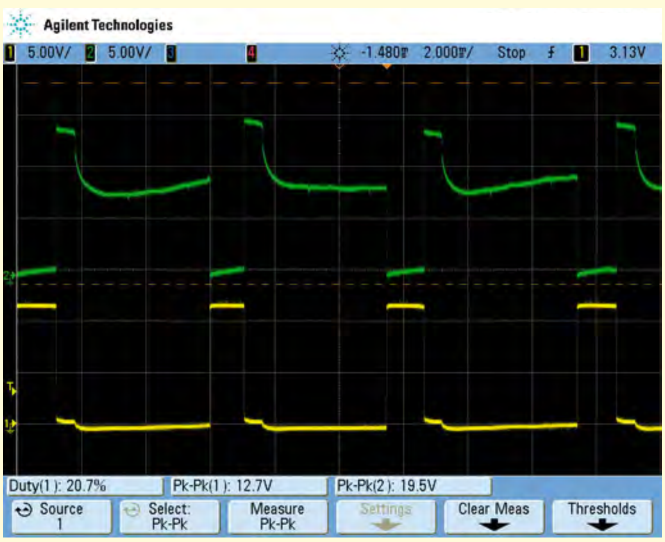


Fig.9: these scope waveforms are again from the gate and drain of MOSFET Q1 but with a 12V permanent magnet motor connected. The green trace shows that when the MOSFET switches off, the voltage at the drain immediately rises to about 17V, but then drops due to the back-EMF generated by the motor. At a higher throttle setting, the back-EMF would be higher, leading to a greater drop at Q1's drain.

A hole can be drilled in the lid of the case, above the piezo buzzer, to let the sound escape. The buzzer provides audible indication of a track short circuit.

not, undo the assembly and locate the source of the problem.

Finally, a 6mm hole can be drilled in the lid of the case directly above the piezo siren, to let the sound out when an overload is detected. Be careful when marking out the position of this hole for drilling – the lid will only fit correctly in one direction.

Testing

As mentioned earlier, the *Li'l Pulser* train controller can be powered from a train power supply, a 12V battery charger or from a 15-19V switchmode laptop PC power supply. The current rating of the supply will depend on your individual requirements, but around 5A will be quite sufficient for most applications. However, you will need a supply with an 8A rating if you want the *Li'l Pulser* to deliver its maximum 8A output capability.

Before connecting the supply, go over your work carefully and check that all parts are in their correct locations and that all polarised parts are the right way around. That done, connect the supply to either the DC socket or to the red and black binding posts.

As stated, the DC socket is only rated up to about 4A. If your supply has a higher current rating, use the binding posts to make the supply connections.

The unit can now be checked out by following this step-by-step procedure:

1) Apply power and check that there is 12V between pins 8 and 4 of IC1.

2) Wind the speed pot (VR1) fully anticlockwise and adjust all trimpots to mid-setting.

3) Check that the brake, inertia and reverse switches are all off, then advance the speed pot and check that the track LED lights green. Check that it gets brighter as you wind up the throttle.

4) Leave the speed pot at a high setting, switch to reverse and check that the reverse LED (LED2) stays off (ie, because of the lockout).

5) Wind the speed pot down and check that the reverse LED lights when the pot is almost fully anticlockwise. Now wind the speed pot up again; track LED1 should now be lit.

If that all checks out, then the *Li'l Pulser* is working correctly and you can proceed to set the current limit. That's done as follows:

1) Connect a multimeter between TP2 and TP GND.

2) Adjust VR7 for a reading of 50mV for each amp of the required current limit. For example, adjust VR7 for a reading of 150mV for a 3A current limit. Similarly, a 400mV reading will give the maximum 8A current limit.

3) Short the output terminals and slowly advance the speed pot. Check that the piezo alarm sounds to indicate a short. Note that the fuse should be changed to a lower rating if the current limit (and/or the supply rating) is lower than 8A. Use a fuse rating that corresponds to the current rating of the supply and set the current limit to be equal to or less than this value.

Final adjustments

The final adjustments involve adjusting the minimum track voltage setting, setting the maximum speed and adjusting the inertia and braking trimpots. The steps are as follows:

1) Set the speed pot (VR1) to minimum and connect the *Li'l Pulser* controller to length of track with a loco.

2) Monitor test point TP1 and adjust trimpot VR6 for a reading of 6V.

3) With the speed pot at minimum, adjust VR2 fully anticlockwise and then slowly clockwise until there is a small amount of track voltage as indicated by noise in the loco motor. Back off the trimpot just a little from that point.

4) Remove the loco from the track, wind the speed pot fully clockwise and measure the DC voltage across the track terminals. Adjust VR3 for the maximum required track voltage. This is usually set for 12V, but you may wish to make this lower to limit the maximum speed of the locos.

5) With the loco back on the track, check that it runs smoothly as the speed control is advanced. Adjust the inertia trimpot (VR4) and the brake trimpot (VR5) to give the required simulated inertia when accelerating and braking.

Note that advancing VR4 past its mid-setting can also have an effect on the minimum speed. That means you may need to readjust the minimum and maximum speed settings (steps 3 and 4 above) after adjusting VR4.

Fig.10: this rear-panel artwork can be copied or downloaded from the *EPE* website and used as a drilling template for an aluminium rear panel. For output currents up to 5A, use the suggested PCB rear panel (see text).

Fraudulent fridges and magic mushrooms

TechnoTalk

Mark Nelson

Is your icebox misbehaving? 'Titter ye not!' Not long ago a 'smart' refrigerator was involved in a massive cyber attack. It may sound ridiculous, but it's proof that the Internet of Things needs to be restrained. Mark Nelson reports.

THOSE OF YOU WITH LONG memories will recall that we discussed the Internet of Things back in the May issue, citing the benefits of integrating a vast plethora of Internet-enabled gizmos and gadgets into a network in order to let them communicate with one another. Now the downside of this arrangement has emerged.

Under the headline, 'More than 750,000 Phishing and SPAM e-Mails Launched From Thingbots', a Californian data security vendor by the name of Proofpoint set out its findings earlier this year. The company revealed that it had uncovered what may be the first proven Internet-of-Things-based cyber attack involving conventional household 'smart' appliances. The global attack campaign involved more than 750,000 malicious email communications coming from more than 100,000 everyday consumer gadgets such as home-networking routers, connected multi-media centres, televisions and at least one refrigerator. All these had been compromised and used as a platform to launch carefully targeted attacks.

Poor protection

According to Proofpoint, cyber criminals have begun to commandeer home routers, smart appliances and other components of the Internet of Things (IoT) and transform them into 'thingbots' to carry out malicious activities. Their task is made all the easier, since these poorly protected Internet-connected devices may be more attractive and easier to infect and control than PCs, laptops, or tablets.

The attack that Proofpoint observed and profiled occurred between 23 December 2013 and 6 January 2014. It featured waves of malicious email, typically sent in bursts of 100,000, three times per day, targeting companies and individuals worldwide. Misconfigured smart gadgets and the use of default passwords left devices completely exposed on public networks, available for takeover and use.

Consumers powerless

According to David Knight, general manager of Proofpoint's Information Security division, 'Consumers have virtually no way to detect or fix infections when they do occur. This is the first time that the industry has reported actual proof of such a cyber attack involving common appliances – but it likely will not be the last example of an IoT attack. IoT includes every device that is connected to the Internet – from home automation products, including smart thermostats, security cameras, refrigerators, microwaves, home entertainment devices like TVs and gaming consoles, to smart retail shelves that know when they need replenishing and industrial machinery. But IoT devices are typically not protected by the anti-spam and anti-virus infrastructures available to organisations and individual consumers, nor are they routinely monitored or sent software patches to address new security issues as they arise.'

It gets worse. Michael Osterman, principal analyst at Osterman Research, comments, 'Consumers have little incentive to make IoT devices more secure, few vendors are taking steps to protect against this threat, and the existing security model simply won't work to solve the problem.' Clearly, industry and consumers need to keep an eye on this growing problem.

Mushrooms and mobiles – a valuable combination

Obsolete and damaged mobile phones are now worth a lot more than they used to be, thanks to a truly 'green' technique invented in Finland's VTT Technical Research Centre. The eco-friendly process, which involves the mycelium of mushrooms (hair-like growths normally found in the soil below the mushrooms), is claimed to recover up to 80 per cent of the gold found in scrap mobile phones and similar devices. This is part of the EU's 'Value From Waste' project, tasked with developing recovery processes on a more sustainable basis; to clean materials of impurities that reduce opportunities for further use; and to increase the amount of recovered materials.

Magic mushrooms

Fungi perform vital roles in ecosystems, probably the most important of which is to decompose organic compounds as they rot. They also have the potential to remove certain pollutants biologically from the soil environment, in a process that occurs entirely naturally. When employed artificially for industrial purposes, 'mats' of fungal mycelium have the potential to act as biological filters, removing chemicals and microorganisms from soil and water.

Unwanted mobile phones contain precious and scarce metals, such as gold and copper. Using the intrinsic ability of mycelium to filter materials, VTT has developed a biological filter made of mushroom mycelium mats, enabling recovery of as much as 80 per cent of the gold in electronic scrap. In addition, extraction of copper from circuit board waste can be enhanced significantly by flotation of the crushed and sieved material.

Pre-treatment helps

VTT researchers have developed both biological and mechanical pre-treatment methods for efficient recovery of precious metals from electronic waste. Other methods developed by researchers included recovery of gold from dissolved materials by biosorption and extraction, using as few harmful chemicals as possible. In particular, the project has developed a method with high extraction capacity for gold recovery, using the newest environmentally friendly extraction reagents. In VTT experiments, it was possible to recover more than 90 per cent of the metal solution dissolved from a circuit board with the help of functional ionic liquid. The method facilitates extraction of target components from impurities. The uniqueness of the method lies in the structure of the biomass, which can be varied using different filament structures of mycelium mats to simplify further industrial processing of precious metals.

Well worthwhile

The potential value of recycling precious metals from e-waste is massive. One estimate considers that 100,000 life-expired cellphones contain 2.4kg of gold, more than 900kg of copper and 25kg of silver. Market prices for scrap vary, but the value could amount to £148,000. Olli Salmi, research professor at VTT, says that their ultimate goal is to make these techniques work on the same industrial scale as current recovery methods used. 'We have been most successful with gold so far, but we'll be working to recover other rare metals too', he comments.

EPE EXCLUSIVE

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Two demonstration circuits for human colour vision

By James Goding

THE HUMAN EYE can see millions of different colours, representing light with a range of wavelengths from about 680nm (deep red) down to about 390nm (deep violet). But we can be fooled into seeing many colours by a TV screen that contains just red, green and blue light emitters (RGB).

Why is that? And why do printers and artists use a different set of colours: cyan, magenta, yellow and black (CMYK)?

These two simple circuits aim to reveal the operation of the human eye and clear up the mysteries through practical demonstrations. Build them into little boxes and you will have a source of delight and amusement for children, and education for young and not-so-young adults.

The human eye contains two types of photo-receptor: around 120 million 'rods', which are concentrated around the edges and 6-7 million 'cones', which are mostly in the centre of the retina (the fovea). The cones allow us to see colour and most people have three types, with broad sensitivity peaks centred towards the red end of the spectrum (560nm), green (530nm) and blue (420nm) – see Fig.1.

The perception of colour by the brain depends on the relative amounts of stimulation of each of these types of photo-receptor. Because the photo-receptors have persistence, rapidly alternating red and green light gives the effect of stimulating the red and green receptors simultaneously. The brain interprets this as yellow. And because the photo-receptor absorption peaks are broad, pure yellow light at 585-590nm also stimulates both red and green receptors.

This is demonstrated by the circuit of Fig.2. IC1 is a 555 timer which generates a quasi-sawtooth waveform with a frequency set using potentiometer VR1. This is buffered by op amp IC2b, half of an LMC6482 rail-to-rail op amp and then fed to the other half of this op amp, which acts as a comparator. VR2 is used to adjust the voltage which the sawtooth waveform is compared against, producing a variable-duty cycle PWM output at pin 1 of IC2a.

This output is used to drive the red element in LED1, which emits light at 625nm. The same signal is also fed to PNP transistor Q1, which acts as an inverter, turning on the green element (568nm) whenever the red one is off, and *vice versa*. So you can use VR2 to adjust the relative on-times of LED1 and LED2 while changing the frequency with VR1.

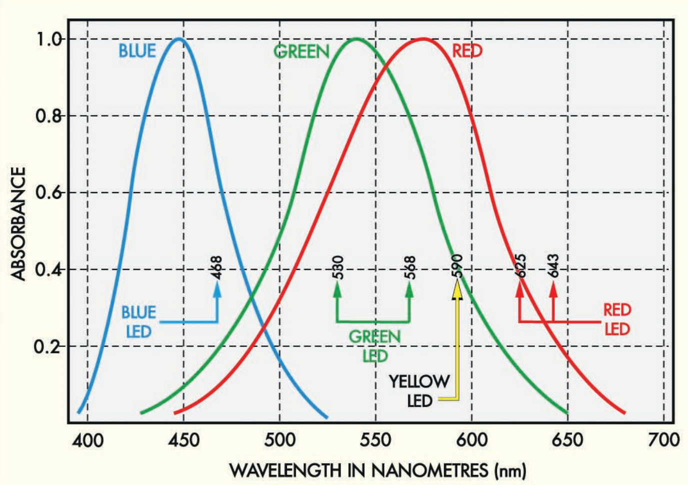

Fig.1: the human eye has three colour sensitivity peaks centred on 560nm (red), 530nm (green) and 420nm (blue).

When the rate of flashing is slow and the duty cycle is set at about 50%, the viewer sees alternating red and green but as the flashing rate is increased, there comes a point where the LED appears yellow. Under conditions of rapid flashing, when the duty cycle knob is rotated, there is a smooth transition from red to orange to yellow and then to green. Slowing the flashing rate provides proof that no trickery is involved.

Note that the red and green cone sensitivity curves shown in Fig.1 overlap much more closely than do the green and blue. Despite this, we are still able to distinguish subtle variations in the shades between green and red because our brains are interpreting the differences in absorption between the two different types of cone cell.

We should point out that some 8% of Caucasian males have red/green colour blindness (dichromacy), mostly due to genetics. Because females have two X chromosomes and the genes to express colour vision are on this chromosome, they effectively have two copies of these genes and so are much less likely to develop colour blindness. While called 'blindness', in most cases the result is a reduction in the ability to distinguish between certain shades of red, yellow and green.

People with one of these conditions will perceive the transitions between red, green and yellow (if visible) at different points than those without. By the way, it is a myth that dogs and cats can't see colour – they have two types of cones, blue and yellow, giving

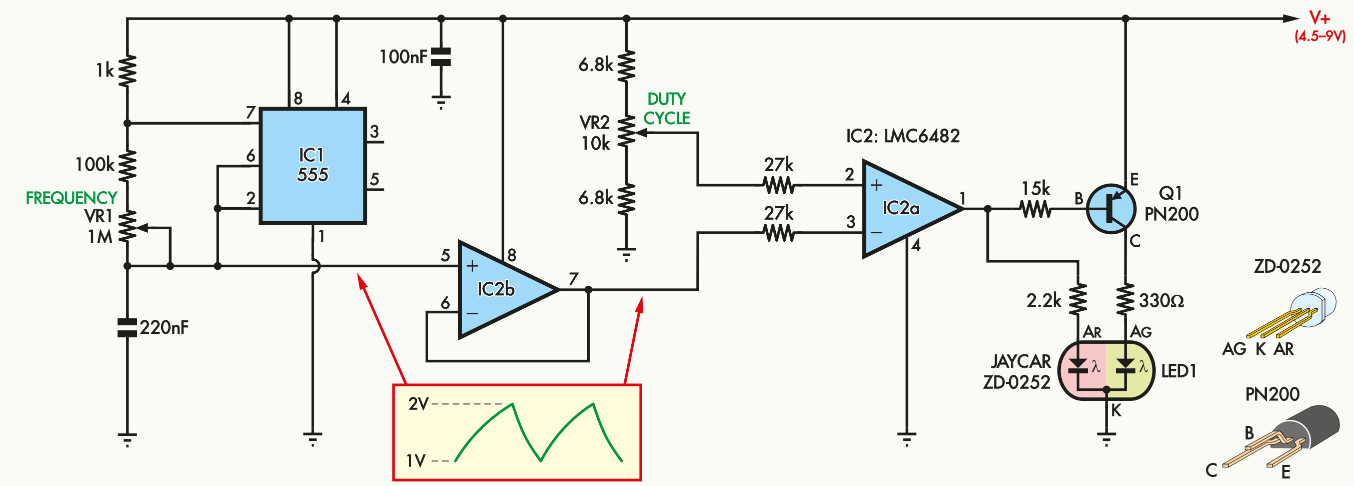

Fig.2: this demonstration circuit uses a 555 timer as a sawtooth oscillator. Its output is buffered by IC2b and compared in comparator IC2a with a voltage set by VR2. IC2a then directly drives the red section in a bi-colour LED (LED1) and the green section in LED1 via transistor Q1. VR2 adjusts the relative on-times of the two colours.

them similar (but not identical) vision to that of a human with dichromatic colour blindness.

Introducing blue

That brings us to the circuit shown in Fig.3, which uses an RGB LED (LED1), allowing you to experiment with any combination of red, green and blue light to see what colour the result appears. The Jaycar ZD0010 RGB LED used is a 'Tri 5 Superflux' with wavelengths of 468nm (blue), 528nm (green) and 643nm (red). The three LED elements are driven by three potentiometer-controlled constant-current sources.

LED2 can be virtually any low-cost red LED and should be positioned so that its lens is hidden. It is used not for its light but for its forward voltage; this is used to bias the bottom ends of the three pots so as to maximise their useful range of rotation. A 2.4V Zener diode would also work, but a red LED is easier to obtain.

If all three knobs are turned fully clockwise, the LED output appears approximately white, since each type of cone in your eye is being stimulated more or less equally. If the blue knob is turned down, the colour changes to yellow. If the red knob is turned down, the colour changes to turquoise (cyan) and if the green knob is turned down the colour changes to purple (magenta).

By manipulating different combinations of the settings of the knobs, any colour can be produced. For example, pink is produced by mixing a small amount of green with a small amount of blue and adding a slight excess of red. This is of course the equivalent of mixing red and white light.

Some limitations should be mentioned. Because the coloured elements of the LEDs are slightly displaced from each other, the colour merging is not quite perfect and the effects are best seen at a slight distance.

Finally, these toys are endlessly fascinating for children, but they forget to turn them off. To conserve battery life, a pushbutton switch could be used for the power.

Further experiments

Now let's look at the question we asked in the first paragraph: why do we use CMYK (cyan, magenta, yellow and black) inks rather than RGB (red, green and blue) like a TV or computer screen? The answer is that video displays create colour additively, just like our second circuit. But ink works by absorbing certain wavelengths of light that would otherwise be reflected from the white paper beneath, and so we combine inks in a subtractive manner.

Cyan ink absorbs red light, allowing green and blue to be reflected from the white paper and the combination of the reflected green and blue light gives it its cyan hue. Similarly, magenta ink absorbs green light but reflects red and blue, while yellow ink absorbs blue light but not red or green.

So if we put a layer of cyan ink down on paper, then yellow, light that would stimulate the red and blue sensitive cones in our eyes is absorbed, leaving just green wavelengths and thus we see it as green. Similarly, red can be made with magenta and yellow inks and blue can be made with cyan and magenta inks.

Black can be made by combining cyan, magenta and yellow inks but black ink is usually used as well as the other three, since black is a common colour in printing and this reduces the total amount of ink used. There are also other benefits that we won't go into here.

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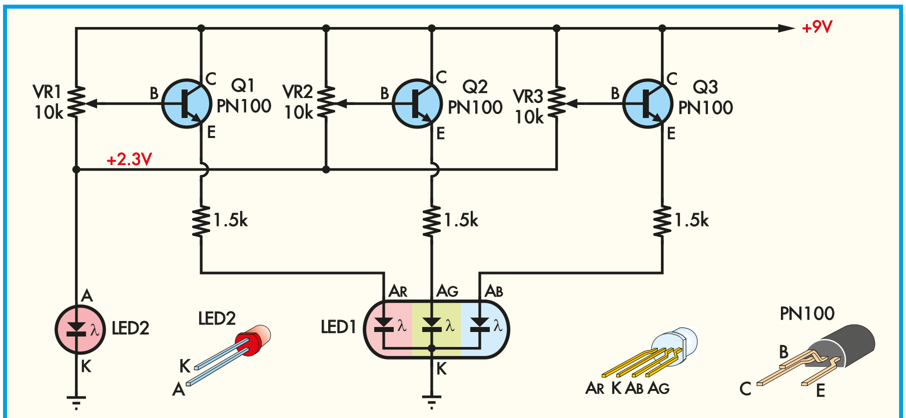
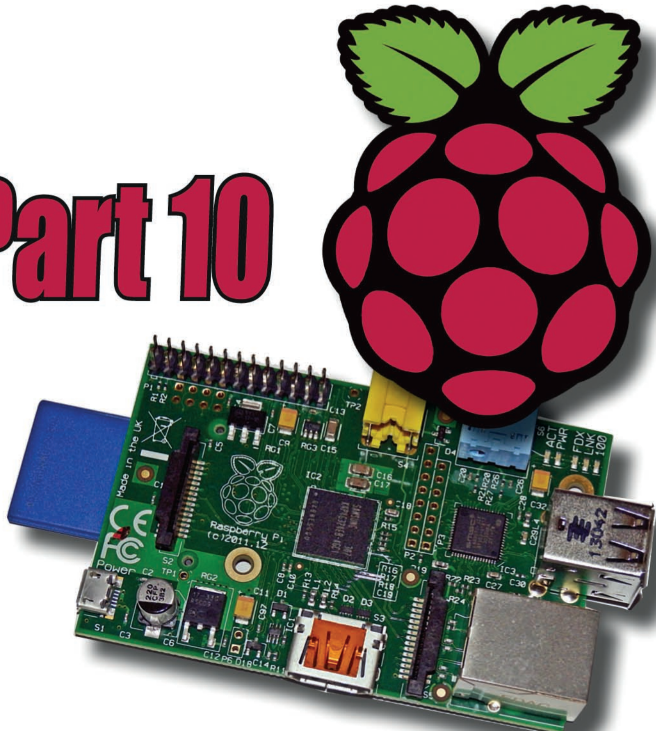


Fig.3: this circuit drives an RGB LED (LED1) via three variable constant-current sources based on transistors Q1-Q3 and potentiometers VR1-VR3.

Teach-In 2014
Raspberry Pi – Part 10

by Mike and Richard Tooley



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

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

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

This series will teach you about:

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

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

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

What will I need?

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

This month

In the final part of *Teach-In 2014*, our *Pi Project* features the construction of a real-time clock interface for the Raspberry Pi. This handy module can be used as an independent time reference for use with your own Python applications. It can also be configured so that it replaces the Pi's 'fake' hardware clock, thus providing you with an accurate, reliable and continuously available system clock. *Python Quickstart* will show you how tkinter can improve the user interface with labels and buttons. We'll also have the answers to our *Home Baking Quiz*. Finally, we will provide you with a comprehensive index of all ten parts of the series.

Python Quickstart

In last month's *Python Quickstart*, we showed you how you can use Python to create an HTML page that can be rendered in an ordinary web browser. This month, we will be looking at ways in which you can produce a more professional looking user interface by incorporating labels and buttons in your Python code. Once again, we will be using tkinter (supplied as standard with Python) as the basis of our GUI interfaces. For more information on tkinter you should refer back to Part 4 of *Teach-In 2014*.

Labels and the label widget

We briefly introduced tkinter's label widget in Part 4 and showed how we can display simple text strings in a window using simple code like this:

```
from tkinter import *
root = Tk()
w = Label(root, text="Teach-In with Raspberry Pi")
w.pack()
root.mainloop()
```

It's worth remembering that this code will remain in the event loop until we close the window (just click on the close button at the top right hand corner of the window). Not only does the event loop handle events from the user (such as the mouse click to close the window) but it also handles redraw messages allowing, for example, the window to be dragged, re-sized, minimised and maximised.

If you don't specify a size, the label window is made just large enough to hold its contents, but if you would prefer to set the size of the window you can use the widget's `height` and `width` options. These options define the size of the label in text units.

Labels can display multiple lines of text by including new line characters. You can also make use of the `wraplength` option to make the label wrap the text by itself. When wrapping text, the anchor and justify options provide greater control of how the text appears. In addition, you can set the foreground (`fg`) and background (`bg`) colour options to allow you to use different colours in the label. You can also select the font (choose from one of Tk's standard font descriptors) to use for the label text. As an example, the following code displays the copyright message shown in Fig.10.1. Note that we have selected Helvetica font with green text on a black background and that the label window has been sized automatically.

```
from tkinter import *
root = Tk()
copyright = """
Copyright (c) 2014 Everyday Electronics
Permission is hereby granted, free of charge,
to any person obtaining a copy of this
software and associated documentation files (the
"Software"), the rights to use, copy, modify,
merge, publish, distribute, sublicense, and/or
sell copies of the Software, and to permit any
person to whom the Software is furnished to do
so, subject to the following condition:
The above copyright notice and this permission
notice shall be included in all copies or
substantial portions of the Software.
"""
w = Label(root, text=copyright, anchor=W,
justify=LEFT, font='Helvetica', fg='green',
bg='black', wraplength=360)
w.pack()
root.mainloop()
```

Updating the text in a label

It is important to be aware that you can easily associate a variable with a label, so that when the text changes, the label will automatically be updated. Here is a fragment of code that defines a variable that is used to hold a formatted time string and then allows its current value to be displayed as a label. Whenever the code is executed it will display current system time in hours, minutes and seconds format, as shown in Fig.10.2.

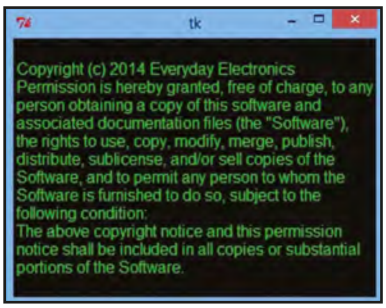


Fig.10.1. The copyright label produced using tkinter

```
from tkinter import *
import time
root = Tk()
v = StringVar()
Label(root, textvariable=v).pack()
time_now = time.strftime('%H:%M:%S')
v.set(time_now)
root.mainloop()
```

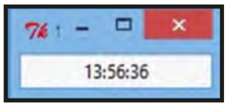


Fig.10.2. Label window displaying current time

Bitmaps and images

The Label widget can also display a bitmap or an image. When displaying images, the widget's height and width options define the label size in pixels. The following example displays a GIF image as a label showing the sequence of a set of traffic lights (see Fig.10.3).

```
from tkinter import *
import time
root = Tk()
imgfile = PhotoImage(file="traffic_lights.gif")
w = Label(root, image=imgfile)
w.photo = imgfile
w.pack()
```

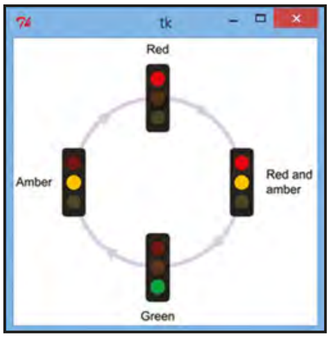


Fig.10.3. Displaying a GIF image in a label

Text and the Text widget

As you've seen, the label widget provides us with a convenient way of displaying text or an image on the screen. The label can only display text in a single font, but the text may span more than one line. The Text widget takes this further and provides us with a much more powerful way of displaying multi-line text, where we can place text in lines and columns and make use of multiple fonts.

The Text widget provides you with an easy way of formatting a text display. It allows you to display and edit text with various styles and attributes. The widget also supports embedded images and windows. The text widget is used to display text documents, containing either plain text or formatted text (using different fonts, embedded images, and other embellishments). It's worth noting that the text widget can also be used as a simple text editor.

By default, you can edit the text widget's contents using the standard keyboard and mouse bindings. To disable editing, set the state option to DISABLED (but if you do that, you'll also disable the insert and delete methods).

Buttons

In previous instalments of *Teach-In 2014* we've used check and radio buttons to provide a way for users to make a selection from one of several options. Conventional buttons provide another method for users to make a choice. Here's an example of how you can display several buttons grouped together in a frame. In a practical application, each button will be given a text string that explains its function. We've also included a function, `quit(self)`, which will allow the user to exit and which will also close the dialogue. Each button has an associated user-defined function (UDF) which is activated when the corresponding button is clicked. In this example program we will just print a message on the console indicating which of the buttons was pressed. If you need to use buttons in your own programs you might find it worth experimenting with

the example code, replacing the user-defined functions, `button1(self)`, `button2(self)` and so on, with your own functions. Fig.10.4 shows how the buttons appear in a Windows environment. Later, we will show you how you can use buttons in a simple Python application for the real-time clock (RTC) module described in *Pi Project.*

```
from tkinter import *

class App:
   def __init__(self, master):
      frame = Frame(master)
      master.wm_title("Select Option")
      frame.pack()
      self.button1 = Button(frame,
text="Button 1", command=self.button1)
      self.button1.pack(side=LEFT)
      self.button2 = Button(frame,
text="Button 2", command=self.button2)
      self.button2.pack(side=LEFT)
      self.button3 = Button(frame,
text="Button 3", command=self.button3)
      self.button3.pack(side=LEFT)
      self.quit = Button(frame, text="  QUIT
", fg="red", command=self.quit)
      self.quit.pack(side=LEFT)

   def button1(self):
      print("Button 1 clicked")

   def button2(self):
      print("Button 2 clicked")

   def button3(self):
      print("Button 3 clicked")

   def quit(self):
      print("QUIT button clicked and window
closed ...")
      root.destroy()


root = Tk()
app = App(root)
root.mainloop()
```

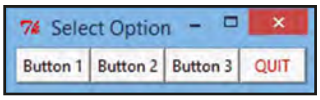


Fig.10.4. Displaying a frame with buttons using Python and tkinter

Pi Project

Last month, we described the construction of an infrared camera/lighting module for use with the Raspberry Pi's NoIR camera. This month, we will be showing you how you can build a real-time clock (RTC) module that can be used as an independent time reference or configured so that it replaces the Raspberry Pi's 'fake' hardware clock. The clock module makes use of a PCF8563 low-cost RTC chip.

PCF8563

The PCF8563 is a CMOS real-time clock (RTC) and calendar chip that is optimised for low-power operation. The chip provides a fully programmable clock which automatically keeps track of the time by storing and updating the year, month, day (and day of the week), hour, minute, and second. The PCF8563chip is interfaced to a host controller using the standard two-line bidirectional I^2C bus (see Part 6 of *Teach-In 2014*). The chip will operate at a maximum bus speed of 400kbps and the internal register address is automatically incremented after each byte that's written to, or read from, the chip. The device incorporates an internal time reference derived from an oscillator and a low-cost external 32.768kHz quartz crystal.

The PCF8563 operates from a supply voltage ranging from 1.0V to 5.5V and demands a current of a mere 0.25µA, or so, when operated from a nominal 3V backup supply derived from a battery or 'super capacitor'. The chip provides a clock output that can be programmed for operation at 32.768kHz, 1.024kHz, 32Hz, and 1Hz. It also offers comprehensive timer and alarm functions.

Register configuration

The PCF8563 contains sixteen 8-bit registers (see Fig.10.5) with an auto-incrementing register address, an on-chip 32.768kHz oscillator with one integrated capacitor, a frequency divider that provides the source clock for the real-time clock (RTC) and calendar, a programmable clock output, a timer, an alarm, a voltage-low detector, and a 400kHz I^2C-bus interface. All 16 registers are addressable 8-bit parallel registers, although not all bits are implemented. The first two registers (memory address 00h and 01h) are used as control and/or status registers. Memory addresses 02h through to 08h are used as counters for the time function (seconds count up to years count). Address locations from 09h to 0Ch contain alarm registers that define the conditions for an alarm. Address 0Dh controls the CLKOUT output frequency. 0Eh and 0Fh are the time control and time registers, respectively.

The Seconds, Minutes, Hours, Days, Months, Years as well as the Minute_alarm, Hour_alarm, and Day_alarm registers all store data in binary-coded decimal (BCD) format. When one of the RTC registers is written or read, the contents of all time counters are frozen. Thus errors generated while writing or reading the chip during a carry condition are avoided.

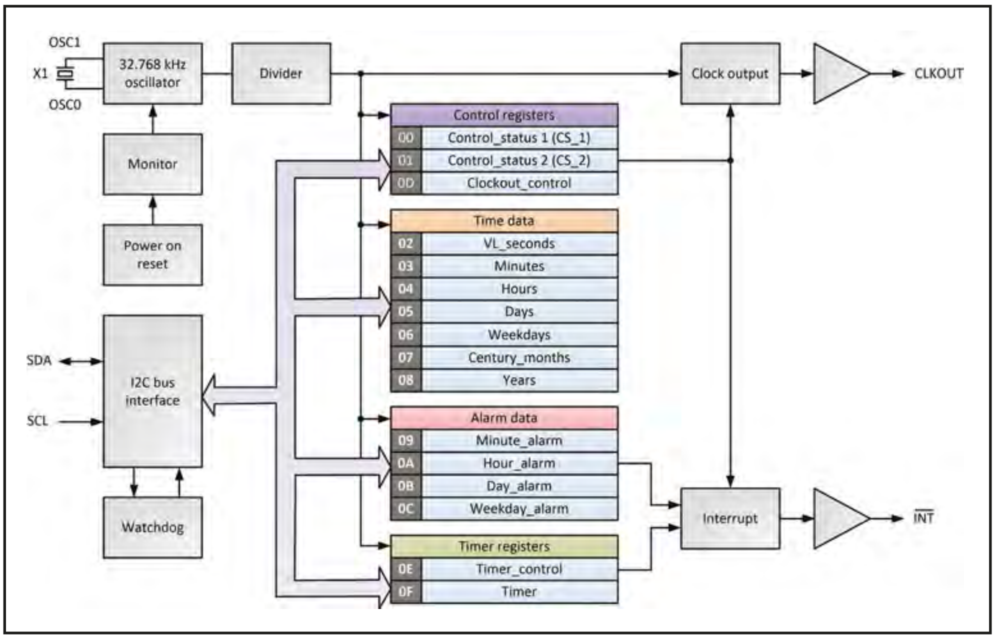


Fig.10.5. Internal architecture of the PCF8563 RTC chip

Clock output

A programmable square wave is available at the CLKOUT pin. Operation is controlled by the register CLKOUT_control at address 0Dh. Frequencies of 32.768kHz (default), 1.024kHz, 32Hz, and 1Hz can be generated for use as a system clock, microcontroller clock, input to a charge pump, or for calibration of the oscillator. CLKOUT is an open-drain output and it is enabled at power-on. When disabled, CLKOUT takes on a high-impedance state. Later, we will show you how you can use a simple Python application to access the PCF8563's clock output.

During read/write operations, the time-counting circuits (memory locations 02h through 08h) are blocked. This prevents possible errors if reading the clock and

Table 10.1 PCF8563 register configuration

Register group	Address offset	Register name	Data bit							
			7	6	5	4	3	2	1	0
Control	00h	CS_1	TEST1	N	STOP	N	TESTC	N	N	N
	01h	CS_2	N	N	N	TI_TP	AF	TF	AIE	TIE
Time	02h	VL_seconds	VL	SECONDS (0 to 59)						
	03h	Minutes	x	MINUTES (0 to 59)						
	04h	Hours	x	x	HOURS (0 to 23)					
	05h	Days	x	x	DAYS (1 to 31)					
	06h	Weekdays	x	x	x	x	x	WEEKDAYS (0 to 6)		
	07h	Century_months	C	x	x	MONTHS (1 to 12)				
	08h	Years	YEARS (0 to 99)							
Alarm	09h	Minute_alarm	AE_M	MINUTE ALARM (0 to 59)						
	0Ah	Hour_alarm	AE_H	x	HOUR ALARM (0 to 23)					
	0Bh	Day_alarm	AE_D	x	DAY ALARM (0 to 31)					
	0Ch	Weekday_alarm	AE_W	x	x	x	x	WEEKDAY ALARM (0 to 6)		
Output	0Dh	CLK_control	FE	x	x	x	x	x	FD[1:0]	
Timer	0Eh	Timer_control	TE	x	x	x	x	x	TD[1:0]	
	0Fh	Timer	TIMER[7:0]							

Table 10.2 Example of HOURS data

Hours register (address offset 04h)	Bit					
	5	4	3	2	1	0
BCD data	1	0	0	0	1	1
Decimal equivalent	2		3			
Hours	23					

calendar. When a read/write register access is completed, the time circuit is released again and any pending request to increment the time counters that occurred during the read access, is then serviced. A maximum of one request can be stored; therefore, all accesses must be completed within one second. As a consequence of this, it is very important to perform a read or write access in one complete cycle, reading or writing the data in a continuous sequence from seconds through to years. Failing to observe this rule could result in the time data becoming corrupted. As an example, if the time (seconds through to hours) is set in one access and then in a second access the date is set, it is possible that the time may increment between the two accesses. A similar problem exists with reading; a roll over may occur between consecutive data reads. For example, when reading the minutes from one access and the hours from the next.

In Table 10.1, bit positions labelled 'x' are not relevant, but bit positions labelled 'N' should always be written with logic 0. If these bits are subsequently read they could be either logic 0 or logic 1, but their values have no particular significance. The VL_SECONDS register (address offset 02h) performs the dual function of providing a low voltage (VL) warning by means of bit-7 and also keeping a record of the SECONDS count using bits 0 to 6.

Data encoding

We mentioned previously that time data is encoded in binary format. For example, if the Hours register (address offset 04h) contains the data shown in Table 10.2, then the stored value is equivalent to a binary-coded decimal (BCD) value of 23 hours. Note that only the six least-significant bits (bit-5 to bit-0) are used to store the HOURS count. Finally, it is important to be aware that had the data been interpreted as natural binary rather than BCD the result would be 35 *not* 23!

Clock module

The complete circuit of the prototype PCF8563 RTC module is shown in Fig.10.6. The PCF8563 (IC1) is interfaced to the Raspberry Pi using the I^2C bus (see *Teach-In 2014* Part 6 for more information). This requires two signal connections to the Pi's GPIO connector, along with ground (0V) and a +3.3V supply (the Pi's +5V supply must *not* be used). The two I^2C single lines are labelled SDA and SCL for the I^2C's serial data and serial clock respectively. The pin connections and signal functions for the 8-pin DIL version of IC1 are shown in Fig.10.7 and Table 10.5 respectively.

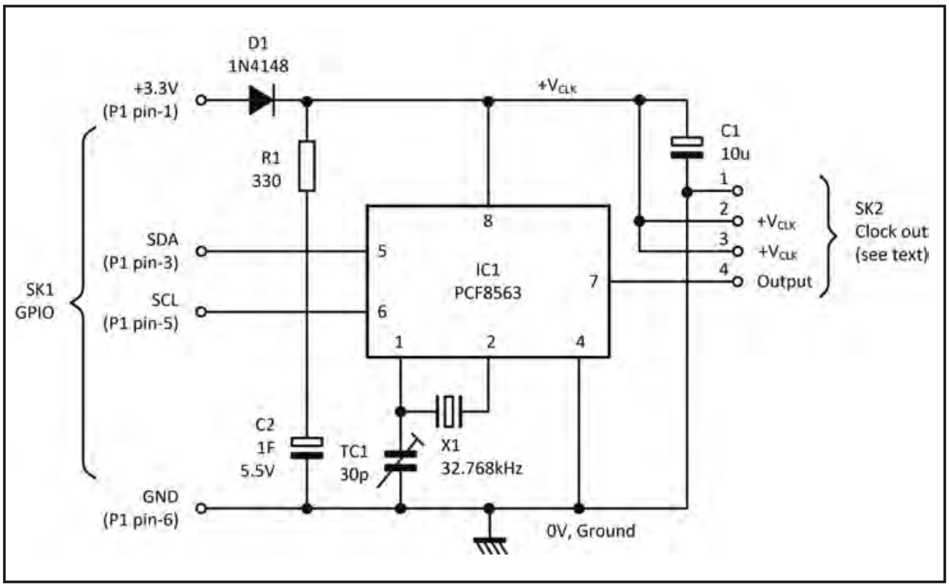


Fig.10.6. Complete circuit of the prototype PCF8563 clock module

Binary-coded decimal

Binary-coded decimal (BCD) provides us with an alternative way of encoding data in a form that can be readily converted from groups of four bits stored in a register. Using BCD, each four-bit group is converted to its corresponding decimal value before the decimal digits are assembled in columns of ascending powers of ten. Tables 10.3 and 10.4 provide you with a comparison of these two coding systems for the decimal numbers 0 to 16. BCD to decimal conversion (and vice versa) is fairly straightforward and can be accomplished with a few lines of Python code, as the following two examples show:

Our first example, `BCD converter – 1`, accepts an 8-bit BCD-encoded binary string and prints its equivalent decimal integer value. The second example, `BCD converter – 2`, accepts a decimal integer and returns its equivalent BCD string. Notice how both of these routines are based on user-defined functions and these may be copied and used in your own Python code whenever the need arises.

Table 10.3 Natural binary code

Decimal value	Natural binary
0	0000 0000
1	0000 0001
2	0000 0010
3	0000 0011
4	0000 0100
5	0000 0101
6	0000 0110
7	0000 0111
8	0000 1000
9	0000 1001
10	0000 1010
11	0000 1011
12	0000 1100
13	0000 1101
14	0000 1110
15	0000 1111
16	0001 0000

Table 10.4 Binary-coded decimal (BCD)

Decimal value	BCD
0	0000 0000
1	0000 0001
2	0000 0010
3	0000 0011
4	0000 0100
5	0000 0101
6	0000 0110
7	0000 0111
8	0000 1000
9	0000 1001
10	0001 0000
11	0001 0001
12	0001 0010
13	0001 0011
14	0001 0100
15	0001 0101
16	0001 0110

```
# BCD converter - 1
# Input: 8-bit BCD encoded binary string
# Output: Equivalent decimal integer
# Python 3.x

def int_to_bcd(x):
    bcdstring = ''
    while x > 0:
        nibble = x % 16
        bcdstring = str(nibble) + bcdstring
        x >>= 4
    return int(bcdstring)

# Get the BCD value from the user
print("BCD Converter")
user = input("Please enter 8-bit BCD: ")
# Convert the user's binary string to an integer
value = int((user), 2)
# Print the result
print("BCD equivalent = " + str(int_to_
bcd(value)))
```

```
# BCD converter - 2
# Input: Decimal integer
# Output: Equivalent BCD encoded string
# Python 3.x

def bcd_to_int(x):
    binstring = ''
    while True:
        q, r = divmod(x, 10)
        nibble = bin(r).replace('0b', "")
        while len(nibble) < 4:
nibble = '0' + nibble
        binstring = nibble + binstring
        if q == 0:
            break
        else:
            x = q
    return int(binstring, 2)

# Get the decimal integer from the user
print("BCD Converter")
user = input("Please enter decimal integer: ")
# Convert the user's decimal string to an integer
value = int(user)
# Print the result and strip the leading 0b
print("BCD equivalent = " + str(bin(bcd_to_
int(value))[2:]))
```

Table 10.5 PCF8563 pin connections (8-pin DIL package)

Pin number	Signal	Function/notes
1	OSCI	Oscillator stage input
2	OSCO	Oscillator stage output
3	/INT	Interrupt output (active low, open drain)
4	VSS	0V ground
5	SDA	Serial data (input and output)
6	SCL	Serial clock input
7	CLKOUT	Clock output (open drain)
8	V_{DD}	Positive supply voltage

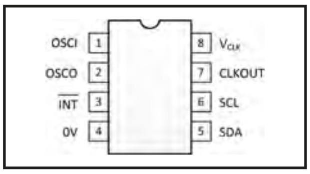


Fig.10.7. Pin connections for the PCF8563 (8-pin DIL package)

Table 10.6 GPIO connections for the PCF8563 clock module

GPIO pin number	PCF8563 signal
1	Ground
3	SDA
5	SCL
6	Ground

Clock reference

The PCF8563 uses an external quartz crystal, X1, to generate its fundamental clock reference signal at 32.768kHz. When divided by 32,768 (2 raised to the power 15) this produces a clock that 'ticks' every second. A low-value trimmer capacitor (TC1) allows precise adjustment of the 32.768kHz clock. If required, this adjustment should be carried out in conjunction with the PCF8563's buffered clock output (see later) and a calibrated digital frequency meter. The connections to the Raspberry Pi's GPIO connector (P1) are shown in Table 10.6.

The Humble Pi prototyping board

As with many of our other *Pi Projects*, we built our prototype clock module using a Humble Pi prototyping board and the wiring layout shown in Fig.10.8. The Humble Pi prototyping board should be fitted with the 26-way connector (SK1) supplied with the Humble Pi. This connector mates with the male connector (P1) on the Raspberry Pi and it ensures that the Humble Pi board neatly sits piggy-back style above the Raspberry Pi. The pin connections for the clock output connector (SK2) are shown in Fig.10.9, while Fig10.10 shows the complete Humble Pi prototype clock module.

As pointed out earlier in this series, there have been some recent changes to the pin labelling convention used on Humble Pi prototyping boards. The latest Version 1.3 boards use pin labelling based on the Broadcom (BCM) chip signals, while earlier versions were based on the earlier Raspberry Pi GPIO pin convention. Go to *Teach-In 2014* Part 7 for a detailed explanation of these changes.

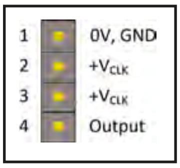


Fig.10.9. Pin connections for the clock output connector, SK2

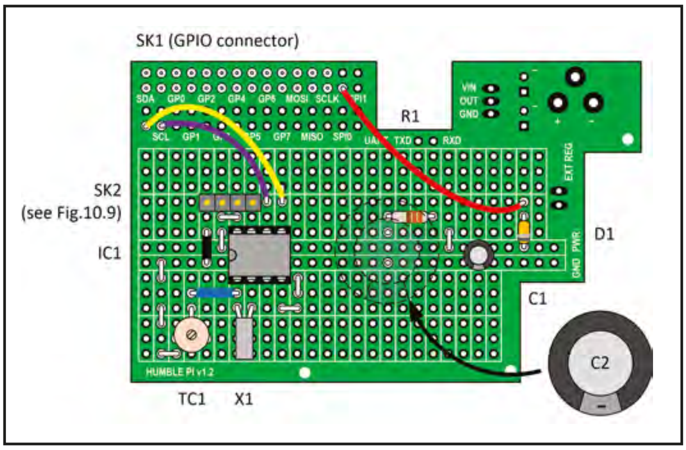


Fig.10.8. Humble Pi prototype board layout

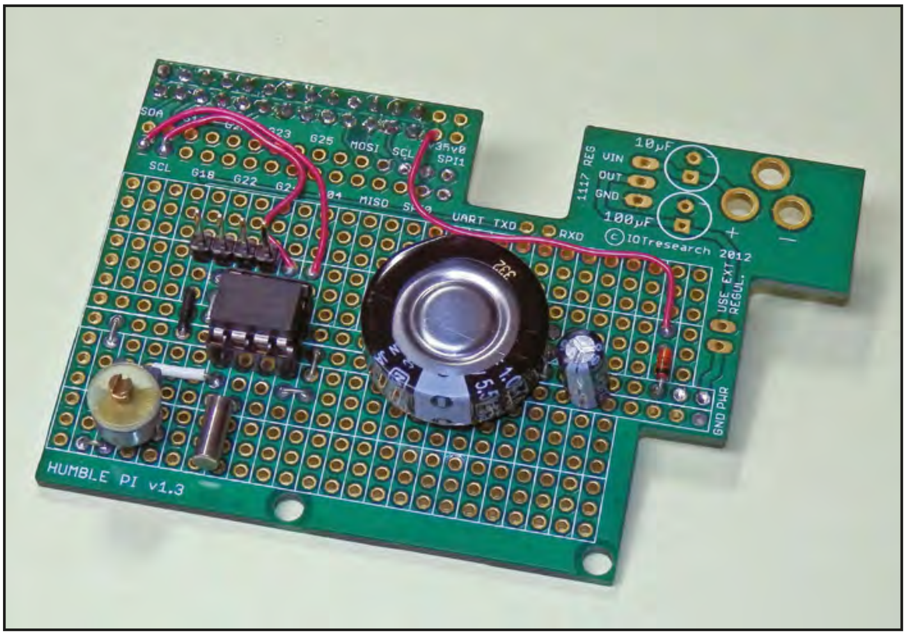


Fig.10.10. The completed Humble Pi prototype board

Configuring the Raspberry Pi for use with the PCF8563 RTC

In order to initialise your Pi for operation with the PCF8563 RTC chip you will first need to register the RTC chip and allocate an I^{2}C address to it. Assuming you've already set up your Raspberry Pi for use with I^{2}C (see *Teach-In 2014* Part 6) you will need to enter the following at the command line interface (e.g. LXTerminal):

```
sudo modprobe i2c-dev
sudo modprobe rtc-pcf8563
```

Next, you should set up root access before configuring the I^{2}C adapter for use with the PCF8563 RTC.

```
sudo su
```

The Pi's usual system prompt should change to:

```
root@raspberrypi: /home/pi #
```

For Revision 1 boards, enter the following from the root prompt:

```
echo pcf8563 0x51 > /sys/class/i2c-adapter/i2c-
0/new_device
```

Alternatively, if you have a Revision 2 board, you need to enter:

```
echo pcf8563 0x51 > /sys/class/i2c-adapter/i2c-
1/new_device
```

If you omit the above commands the PCF8563 RTC module will not be recognised when you next boot the system.

Next, you should check that the RTC has been recognised by the Raspberry Pi. You can do this by entering the command:

```
ls /dev/rtc0
```

If all has gone well the RTC should now be ready for access via the I^{2}C bus. Later, in *Home Baking*, we will show you how to use the PCF8563 RTC module as a replacement for the Pi's 'fake' hardware clock, but before we do that, we will use our new hardware clock as an independent time reference and general purpose clock that can be accessed using some simple Python code.

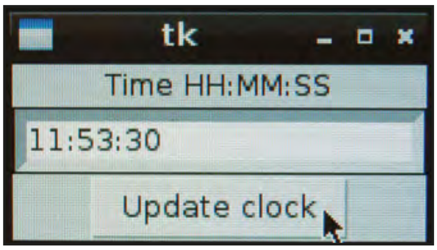


Fig.10.11. The set time dialogue

Using Python to set and read the PCF8563 RTC

Setting the time

The following Python program will allow you to set the current time on the PCF8563 RTC module. The code has been commented so it should be reasonably self-explanatory. Note, as explained earlier, we need to use BCD formatted values when we write to the PCF8563's registers. The time is first entered into a simple dialogue box (see Fig.10.11) using the format HH:MM:SS (note the use of the ':' separator). The 'Update clock' button is then clicked in order to write the data to the respective registers within the PCF8563.

```
# Set PCF8563 clock
# For Python 2.x
from Tkinter import *
import smbus
import time
import subprocess

bus = smbus.SMBus(0)

root = Tk()

label1 = Label( root, text="Time HH:MM:SS")
E1 = Entry(root, bd =5)

mytime = "00:00:00"

# Convert a decimal number to BCD
def dectobcd(n):
    bcdstring = ''
    if n < 10:
        bcdstring = '0000'
    for i in str(n):
        bcdstring += bcddigit(i)
    return int(bcdstring,2)
    return hex(int(bcdstring,2))

# Convert to BCD digit
def bcddigit(q):
    p = int(q)
    r = bin(p)[2:]
    return ('0000' + r)[-4:]

# Set the time
def setTime():
    mytime = E1.get()
    timelist = mytime.split(":")
    hours = (timelist[0])
    hournum = int(hours)
    minutes = (timelist[1])
    minnum = int(minutes)
    seconds = (timelist[2])
    secnum = int(seconds)

# Get new data to write back to the PC8563
    sec_data = str(dectobcd(secnum))
    min_data = str(dectobcd(minnum))
    hrs_data = str(dectobcd(hournum))

# Write data to the PCF8562 registers
    command_string = "i2cset -y 0 0x51 0x02 " +
sec_data
    return_code = subprocess.call([command_string],
shell=True)
    command_string = "i2cset -y 0 0x51 0x03 " +
min_data
    return_code = subprocess.call([command_string],
shell=True)
    command_string = "i2cset -y 0 0x51 0x04 " +
hrs_data
    return_code = subprocess.call([command_string],
shell=True)

submit = Button(root, text ="Update clock", command
= setTime)

label1.pack()
E1.pack()
submit.pack(side =BOTTOM)

root.mainloop()
```

Reading the time

The next Python program will allow you to read and display the current time from the PCF8563 RTC module. Once again, the code has been commented so it should be reasonably self-explanatory. In this example, rather than use sub-process calls we will simply read bytes from the respective registers within the PCF8563. Fig.10.12 shows the time displayed by this program alongside the system time that appears at the bottom right of the screen. Note that, in this example, the RTC time and system time are independent of one another. Later, in *Home Baking*, we will show you how to link the two together so that the system time is taken from the RTC rather than the Pi's 'fake' hardware clock.

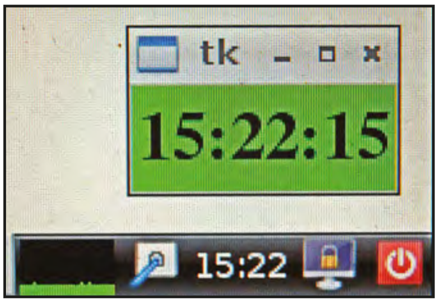


Fig.10.12. The real time display (note the system clock at the bottom)

```
# Digital clock using PCF8563
# For Python 2.x

from Tkinter import *
import smbus
import time

bus = smbus.SMBus(0)

root = Tk()
timenow = ''
clock = Label(root, font=('times', 20,
'bold'), bg='green')
clock.pack(fill=BOTH, expand=1)

def tick():
    global timenow
   # get the current local time from the RTC
    bus.write_byte(0x51, 0x80)
    time.sleep(0.1)
    cs1_data = bus.read_byte(0x51)
    cs2_data = bus.read_byte(0x51)
    sec_data = bus.read_byte(0x51)
    min_data = bus.read_byte(0x51)
    hrs_data = bus.read_byte(0x51)
    sec1 = ((sec_data >> 4) & 0x07)
    sec2 = (sec_data & 0x0f)
    min1 = ((min_data >> 4) & 0x07)
    min2 = (min_data &0x0f)
    hrs1 = ((hrs_data >> 4) & 0x03)
    hrs2 = (hrs_data &0x0f)

    seconds = (str(sec1) + str(sec2))[-2:2]
    minutes = (str(min1) + str(min2))[-2:2]
    hours = (str(hrs1) + str(hrs2))[-2:2]

    timenow = hours + ":" + minutes + ":" +
seconds
    clock.config(text=timenow)
    # update the clock display every 200ms
    clock.after(200, tick)

tick()
root.mainloop()
```

Using the clock output

The PCF8563's clock output (CLKOUT) can provide a useful test signal and may also be used for other purposes where an accurate and stable reference signal is required. The clock output can be programmed so that it provides a signal at 32.768kHz (the default), 1.024kHz, 32Hz, or 1Hz. This signal is available from pin-7 of the PCF8563, but since this pin is an open-drain connection, an external pull-up resistor is required, as shown in Fig.10.13. The

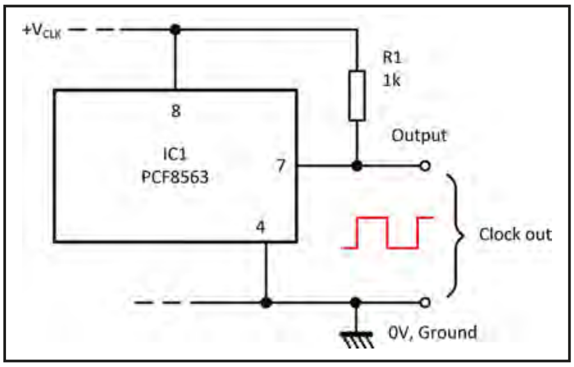


Fig.10.13. Accessing the CLKOUT signal

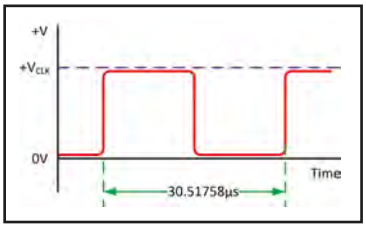


Fig.10.14. The default clock output

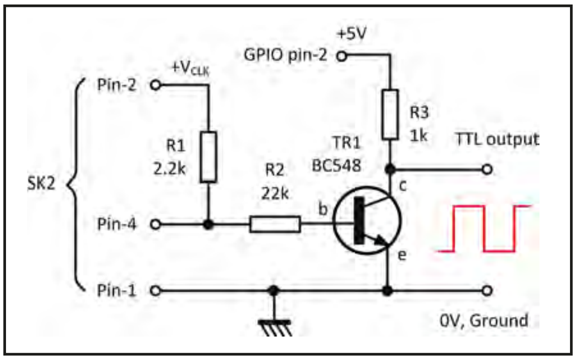


Fig.10.15. Simple TTL-compatible output interface

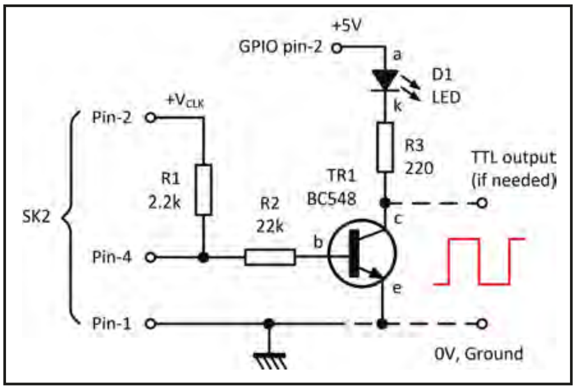


Fig.10.16. Clock-driven flashing LED indicator

CLKOUT takes the form of a square wave with an amplitude equal to the positive supply (+V_{CLK} in Fig.10.6). The output waveform available from pin-7 in Fig.10.13 under the default-programmed condition is shown in Fig.10.14.

In order to produce a TTL-compatible signal suitable for general logic testing (and also for connecting a conventional digital frequency meter) a simple output interface like that shown in Fig.10.15 can be used. Fig.10.16 shows how an LED can be added to the interface in order to produce a clock-driven flashing LED indicator (set the clock output to 1Hz).

Programming the CLKOUT signal

Programming the CLKOUT signal is straightforward and is achieved by sending a data word to the CLK_control register (offset 0Dh).

The clock output can be easily programmed using some simple Python code, as the next example shows. Here we have produced a frame with five buttons (see *Python Quickstart*) and used sub-process calls to write the appropriate bit pattern for each clock frequency to the CLK_control register in the PCF8563. Fig.10.17 shows the user interface for the clock output control program.

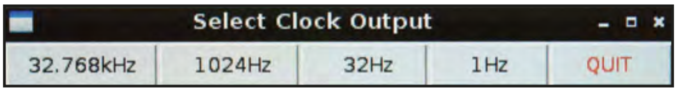


Fig.10.17. User interface for the clock output control program

```
# Set PCF8563 clock output frequency
# For Python 2.x

from Tkinter import *
import smbus
import subprocess

bus = smbus.SMBus(0)

class App:
   def __init__(self, master):
      frame = Frame(master)
      master.wm_title("Select Clock Output")
      frame.pack()
      self.button1 = Button(frame, text="32.768kHz",
command=self.button1)
      self.button1.pack(side=LEFT)
      self.button2 = Button(frame, text="  1024Hz ",
command=self.button2)
      self.button2.pack(side=LEFT)
      self.button3 = Button(frame, text="   32Hz  ",
command=self.button3)
      self.button3.pack(side=LEFT)
      self.button4 = Button(frame, text="   1Hz   ",
command=self.button4)
      self.button4.pack(side=LEFT)

      self.quit = Button(frame, text="  QUIT   ",
fg="red", command=self.quit)
      self.quit.pack(side=LEFT)

   def button1(self):
      return_code = subprocess.call(["i2cset -y 0
0x51 0x0d 0x80"], shell=True)

   def button2(self):
      return_code = subprocess.call(["i2cset -y 0
0x51 0x0d 0x81"], shell=True)

   def button3(self):
      return_code = subprocess.call(["i2cset -y 0
0x51 0x0d 0x82"], shell=True)

   def button4(self):
      return_code = subprocess.call(["i2cset -y 0
0x51 0x0d 0x83"], shell=True)

   def quit(self):
      root.destroy()

root = Tk()
app = App(root)
root.mainloop()
```

Table 10.7 Clock output configuration

CLK_control (address offset 0Dh)	Bit number								Hex equivalent
	7	6	5	4	3	2	1	0	
32768Hz	1	0	0	0	0	0	0	0	0x80
1024Hz	1	0	0	0	0	0	0	1	0x81
32Hz	1	0	0	0	0	0	1	0	0x82
1Hz	1	0	0	0	0	0	1	1	0x83

Home Baking

In our final *Home Baking* feature we will be dealing with the process of setting and reading the real-time clock and also how to configure your Pi so that it acts as a replacement for the Pi's 'fake' hardware clock.

Setting up the PCF8563 RTC as the Pi's 'real' hardware clock

By default, the Raspberry Pi uses a 'fake' hardware clock, but this can be replaced with a 'real' hardware clock based on the PCF8563 RTC module that we described earlier. Note, however, that when the PCF8563 RTC module is dedicated to providing system clock functions it will no longer be available for use with the Python applications that we described earlier in *Pi Project*.

Manually setting the Raspberry Pi's date and time

Before we begin (and if you've already not done so) it's important to know how to manually set the Raspberry Pi's system clock. This is achieved using the Linux `date` command, which requires super user privileges and needs to be following by a date/time string having the following format:

```
MMDDhhmmyyyy
```

where `MM` is the month number (01 to 12), `DD` is the day of the month (01 to 31), `hh` is the hour (00 to 23), `mm` is the minute (01 to 59) and `yyyy` is the year (eg, 2014). As an example, to set the time and date to 10:27 on Monday, 7 April 2014, the required command will be:

```
sudo date 040710272014
```

The system will then echo the date back to you. In the case of our example, this will appear as:

```
Mon Apr 7 10:27:00 BST 2014
```

To read the date from the operating system you can just enter:

```
sudo date
```

This should produce a similar date/time string:

```
Mon Apr 7 10:27:00 BST 2014
```

The hwclock utility

The `hwclock` utility is a program that will allow you to read or set the hardware clock (either the 'fake' clock or from a 'real' hardware clock based on an RTC clock chip like the PCF8563). You can display the current time (using `hwclock –r`), set the hardware clock to the current system time (using `hwclock –w`), or set the system time from the hardware clock. You can also run `hwclock` periodically to add or subtract time from the hardware clock to compensate for systematic drift (where the clock consistently loses or gains time at a certain rate when left to run). Finally, to set the hardware clock to a specific date/time (for example, 16:09 on 7 April 2014), you can use:

```
hwclock --set --date="2014-04-07
16:09:30"
```

The chrony utility

Chrony provides a pair of programs that work together in order to keep your default 'fake' hardware clock accurate; `chronyc` provides the command-line interface to `chronyd`, a background (daemon) program that uses an external time reference source. These sources can be RFC1305 NTP servers, human (via keyboard and `chronyc`), or the computer's real-time clock at boot time. The background program, `chronyd`, can determine the rate at which the computer gains or loses time and compensate for it while no external reference is present. Using the command line interface, `chronyc`, the use of NTP servers by `chronyd` can be switched on and off to provide support for computers with dial-up/intermittent access to the Internet. The software can also act as an RFC1305-compatible NTP server.

The main function of `chronyd` is to obtain measurements of the true (UTC) time from one of several sources, and correct the system clock accordingly. It also determines the rate at which the system clock gains or loses time and uses this information to keep it accurate between measurements from the reference.

To install chrony you need to use:

```
sudo apt-get install chrony
```

The installation process should, by now, be familiar but note that during installation you will be informed that the NTP server is being temporarily stopped. Messages will then appear informing you that the current version of `chrony` is running and on-line. To start the command line interface to `chronyd` you need to enter the following command (once again using super user privileges):

```
sudo chronyc
```

To check your clock against the time from an NTP server (and also determine the current accuracy of your clock and what's needed to compensate for the error) you need to use the tracking option, as shown in the following example:

```
chronyc> tracking
```

```
Reference ID    : 193.227.197.2 (yikes.bl2.tolna.net)
Stratum         : 3
Ref time (UTC)  : Mon Apr  7 09:53:16 2014
System time     : 0.000000235 seconds slow of NTP time
Frequency       : 42.852 ppm fast
Residual freq   : 7.319 ppm
Skew            : 53.437 ppm
Root delay      : 0.133704 seconds
Root dispersion : 0.089000 seconds
```

Further information on using `chrony` is available from: **http://chrony.tuxfamily.org**. A useful source of information on Network Time Protocol (NTP) is available from: **www.eecis.udel.edu/~ntp**

Configuring the system

If you've not already set up the Raspberry Pi so that it recognises the PCF8563 RTC connected via the I^2C bus you will need to use a similar procedure to that which we described earlier in *Pi Project*. You will first need to enter the following super user commands at the command line interface:

```
sudo modprobe i2c-dev
sudo modprobe rtc-pcf8563
```

Next, you should set up root access before configuring the I^2C adapter for use with the PCF8563 RTC.

```
sudo su
```

For Revision 1 boards you should enter:

```
echo pcf8563 0x51 > /sys/class/i2c-adapter/i2c-0/
new_device
```

For Revision 2 boards you should enter:

```
echo pcf8563 0x51 > /sys/class/i2c-adapter/i2c-1/
new_device
```

To set your 'real' hardware clock using the PCF8563 RTC with the current system time you should enter:

```
hwclock --systohc
```

To read the current date and time from the 'real' PCF8563 hardware clock you should use:

```
hwclock -r
```

Finally, to set the Linux/Debian system time to the value in the 'real' hardware clock you can use:

```
hwclock -r
```

Having set up the PCF8563 RTC for use as the system clock (replacing the 'fake' hardware clock with your own 'real' hardware) you will no longer be able to access the PCF8563 using the Python software that we described earlier (or at least until the system is next restarted).

Making the changes permanent

If you are happy with the changes (and don't need to access an independent time reference) you can add the RTC kernel module to the `/etc/modules` list, so that it is loaded whenever the Raspberry Pi boots. Run `sudo nano /etc/modules` and add `rtc-pcf8563` at the end of the list.

Next, create the PCF8563 device at boot time by editing `/etc/rc.local` using:

```
sudo nano /etc/rc.local
```

For a Revision 1 board you will need to add this line to the file:

```
echo pcf8563 0x51 > /sys/class/i2c-adapter/i2c-0/new_device
```

For Revision 2 boards you will need to add this line:

```
echo pcf8563 0x51 > /sys/class/i2c-adapter/i2c-1/new_device
```

Next, add the following line:

```
sudo hwclock –s
```

Note that these lines should appear immediately before the final `exit 0`. Last, it is important to be aware that if you subsequently attempt to access the PCF8563 RTC while it is providing the system clock function you will encounter an I/O error which will inform you that the 'Device or resource is busy'. Because of this you will no longer be able to run the programs that we described earlier in *Pi Project*.

Teach-In 2014 index

Home Baking Quiz – Answers

Finally, here are the answers to last month's Home Baking quiz.

If you have managed to score 15 or more then we reckon that you've become an experienced Raspberry Pi. Home Baker, but, whatever your score, we hope that you've enjoyed the series and that you get many hours of enjoyment from your Raspberry Pi.

1. b
2. b
3. c
4. c
5. a
6. b
7. b
8. a
9. c
10. c
11. c
12. c
13. c
14. b
15. a
16. c
17. c
18. a
19. a
20. a

Max's Cool Beans

By Max The Magnificent

From San Jose...

I was speaking at the EELive! Embedded Systems Conference and Exhibition in San Jose, California, a few weeks ago. My nametag displayed my name as: 'Max the Magnificent.' In fact, the conference organisers even had me billed with this moniker on seven-foot posters associated with what they called 'The Fantastical Theatre of Engineering Innovation.' What can I say? – if you've got it, then you have to flaunt it!

...to Hawaii

I was run off my feet giving two or three presentations a day on different topics (the real trick is to get me to stop talking). One of the great things when you get to be my age is that you no longer have to wear suits and shirts and ties and suchlike. In fact, I no longer even own a suit; all I ever wear these days is Hawaiian shirts (along with jeans or shorts, of course).

Since you've gotten me on this topic, about a year ago I decided to simplify my life. One of the strange things about Hawaiian shirts is the way they shrink over the years. I know this to be true, because some of the little beauties that used to fit quite comfortably had become uncomfortably tight. Strangely, this also appears to be the case with non-Hawaiian shirts, but this is something I no longer have to worry about because I gave all of mine away.

One weekend, I went through my entire wardrobe with extreme prejudice. It's amazing how hard it can be to let go of things, even if you no longer use them. For example, I'd pick up a jacket and say 'That wasn't cheap, I really should keep it.' But then I'd kick myself and say 'But you haven't worn it for 10 years and you have no intention of ever wearing it again.' The end result was that I piled the vast majority of my wardrobe into the back of my truck and donated it to a local charity shop. I noticed last summer that an awful lot of people in the less salubrious parts of town were sporting Hawaiian shirts.

I subsequently replenished my Hawaiian shirt collection with some newer, larger models. Now my clothes occupy just a small portion of our walk-in closet (much like Mother Nature, my wife abhors a vacuum, so she's been more than happy to expand into the empty space). All I now own, in addition to things like socks and handkerchiefs and suchlike, is two pairs of sneakers, a pair of hiking boots, three pairs of jeans, four pairs of shorts, around twenty Hawaiian shirts, and a handful of T-Shirts. Each day commences with choosing the Hawaiian shirt *du jour*, which always puts a smile on my face.

Max in formal attire – poised to start his next presentation

I didn't even know I wanted it...

But that's not what I wanted to tell you about. On the way back from the conference, while I was stooging around the San Jose airport, my attention was captured by some flashing LEDs in one of those mini-stores that sells electronic 'stuff' that you didn't even know existed, but having once seen it you know you can no longer live without it.

The product in question was a Bluetooth-based cylindrical loudspeaker about 9-inches tall whose entire surface acted as a multi-coloured spectrum analyser. 'That's interesting,' I thought, so I ambled over to chat with the lad behind the counter. Once I'd managed to drag his attention away from texting his girlfriend, he grudgingly informed me that the speaker in question cost $199.99. 'Hmmm, it's not that interesting,' I told myself, so I ambled off into the sunset.

...but I did!

But the seed had been planted. Show me a flashing LED, and I'll show you a man drooling. I discovered that I really, really want a multi-coloured spectrogram representation of my music. And not just a piddly little display like that nine-inch loudspeaker. No! I want a man-sized display they requires a truck to transport it from one venue to another. Thus was born the idea for my 'Bodacious Acoustic Diagnostic Astoundingly Superior Spectromatic' (BADASS) display.

Just to give you an idea of where I'm going with this, take a look at some videos on YouTube: **http://youtu.be/LIOUXr9v2RI** and **http://youtu.be/4NJDgvV8RZw** and **http://youtu.be/DUoX9fDibYk**. Come on, you must admit these look interesting.

For my first-pass implementation, I've decided to work with a 16 × 16 = 256 array of tri-colored LEDs. As a starting point, I'll be controlling the display itself using my Arduino Mega (**http://bit.ly/1gEbS2r**), and I'll be implementing the columns of LEDs using NeoPixel Strips from Adafruit (**http://bit.ly/1kDOXnd**).

Prototyping the display

Now, before I start constructing a project like this, I first like to throw a rough prototype together out of things like paper and cardboard, as shown in the accompanying photo. In the real implementation, the cardboard will be replaced by a sheet of plywood stained to look like old wood. Meanwhile, the main display panel and the smaller control panel will be formed out of hardboard painted to look like antique brass.

Each of the LEDs will be presented behind a one-inch diameter countersunk brass washer (these look so tasty). The plywood will be milled down so that the hardboard panels are flush with its surface – also, these panels will be attached to the main plywood panel using brass acorn nuts. I want the final display to have a 'Steampunk' look-and-feel; that is, I want it to look like it wouldn't be out of place in a Victorian setting.

I'm actually moving along rapidly with this. I have the NeoPixel strips and the brass washers and acorn nuts; I've shaped the hardboard panels; and I've routed out the plywood to accommodate these panels. The next step is to drill the 256 holes for the LEDs, along with the holes for the bolts associated with the acorn nuts.

I'll show you what the final result looks like in my next column. Also, we will start considering how we are going to take the audio stream from my iPad and extract its spectrum data in a form that is suitable for presenting on the display. Until next time, have a good one!

Max holding his cardboard prototype in a 'Kilroy was here' pose

Project construction – the big picture

THE articles in this series usually focus on one specific area of electronic project construction, but this month an overview of project building will be provided. This should give complete beginners a good idea of exactly what is involved in building an electronic device, the tools and skills required, and whether it is something they would like to try. I think it is only fair to point out from the start that electronic project construction is not really quite like any other hobby. In addition to the skills associated with building and testing the electronics, it contains elements of other pastimes or crafts.

For example, in the course of building electronic gadgets you might need computing, metalworking, general craft, and woodworking skills. Building electronic projects can involve a wider range of abilities than practically any other hobby. Modern do-it-yourself electronic gadgets cover a wide range of applications, including some quite unusual ones, and sometimes a bit of ingenuity and improvisation can be required.

The right ingredients

Having decided to build a project the next step is to obtain all the components. Unfortunately, this is no longer a matter of going along to your local radio and electronics shop with a list of parts. These days the vast majority of electronic components are purchased via mail, telephone, or usually online ordering. The large electronic component retailers such as Farnell and RS Components are primarily suppliers to commercial and educational customers. However, they will supply to private individuals via their online ordering systems, and they represent important sources of supply for amateur users – eBay can also be a useful source of supply. Without Internet access and online ordering it could be impossible to obtain all the components for most projects.

The range of electronic components currently available is truly massive. In fact, it is so vast that it can be difficult for even experienced users to keep abreast of things, and it certainly makes life difficult for beginners. Before actually buying anything it is essential to study some printed or online component catalogues. These contain photographs of components together with a great deal of useful information about them. Familiarising yourself with the main types of electronic components should greatly reduce the risk of buying the wrong thing.

While some electronic components have been available for many years, and will probably be on sale for many more, some are more ephemeral. Specialised components tend to come and go relatively quickly these days. Some integrated circuits and other semiconductor devices, whether highly specialised in nature or not, are suddenly discontinued. This makes it important to ensure that all the components for a project are still available before you buy any of them.

This is all the more important when building a project from an article that was not published recently. If a project from a few years or more ago requires anything out of the ordinary, it is unlikely that all the components will still be available now. There are specialist suppliers of obsolete parts, and elusive components can sometimes be obtained via auction sites, but the prices tend to be quite high. When ordering the components do not overlook items of hardware such as bolts, battery connectors, control knobs, and the case.

The right one

When selecting your first electronic project it is tempting to opt for something elaborate that will impress your family and friends, but it is more sensible to select something relatively simple and straightforward. It is best to avoid anything that is awkward to build as far as the mechanical side of construction is concerned. With plenty of new things to learn when dealing with the electronics, it is advisable to concentrate your efforts on these and avoid getting sidetracked by the difficult or time-consuming mechanical aspects of construction. Selecting a gadget that has relatively simple electronics minimises the risk of making a mistake and maximises your chances of getting the device to work first time.

Nuts and bolts

Once all the components have been obtained it is time to start building. It does not matter too much whether you start with circuit board or the mechanical side of construction. Here we will consider the 'nuts and bolts' side of things first, and this may consist of little more than drilling some holes in the case. The switches, indicator lights, sockets and the like are fitted in these holes. Further holes to facilitate mounting the circuit board in the case might also be needed. The circuit board is then hard-wired to the controls and sockets in the final stages of construction. With modern projects, and especially the smaller types, an alternative approach is often used. The controls and sockets are

fitted at one edge of the circuit board, and their fixings then provide the mounting for the circuit board as well.

If you have a good selection of do-it-yourself tools such as drills, saws and files, these might be all you need when preparing the case for some projects. However, it is likely that before too long some additional tools will be required. It is probably best to buy any additional tools as and when they are required, rather than splashing out on a selection of tools, some of which you might never need.

Fig.1. Small pliers and wire cutters/strippers should be part of the initial toolkit. The wire cutters on the right here can also act as insulation strippers, and can be adjusted to suit various wire sizes

There are some tools that will certainly be needed right from the start, and these include some small electricians' screwdrivers, wire cutters, small pliers (Fig.1 – left) and insulation strippers. Wire cutters and strippers can be obtained as separate tools, but initially an inexpensive combined wire cutter and stripper tool (Fig.1 – right) should suffice. Use the right tools and do not improvise with scissors, penknives, or whatever, as this is likely to harm the tools, the wires, and yourself! If your fingers are not particularly nimble it is worth obtaining straight and angled tweezers (Fig.2), which can make life much easier when dealing with tiny components.

Holes in metal and plastic cases are made using HSS twist drills, and the woodworking variety is unlikely to be of much use in the current context. Provided they are used carefully, medium or even low-cost drill bits are adequate for use on aluminium and plastic cases, which are relatively soft materials. Good quality drill bits are needed for work on steel panels. A power drill is suitable, but ideally it should be mounted in a good quality drill stand. A small cordless power drill or even a hand drill is often a better choice for what will usually be small scale work. A set of miniature files ranks as one of useful things to have when working on cases. Any holes that are not quite right can be 'fine tuned' using these tools, and they can also be used to make rectangular and other non-circular mounting holes.

In the likely event that no dedicated work room is available, it will be necessary to resort to a garage, kitchen, or anywhere that can provide a reasonably large and well lit area with a table or workbench. When using a part-time work area it will probably be necessary to improvise a temporary work surface from a piece of MDF, plywood or

Fig.2. Angled and straight tweezers can be very useful when dealing with miniature components

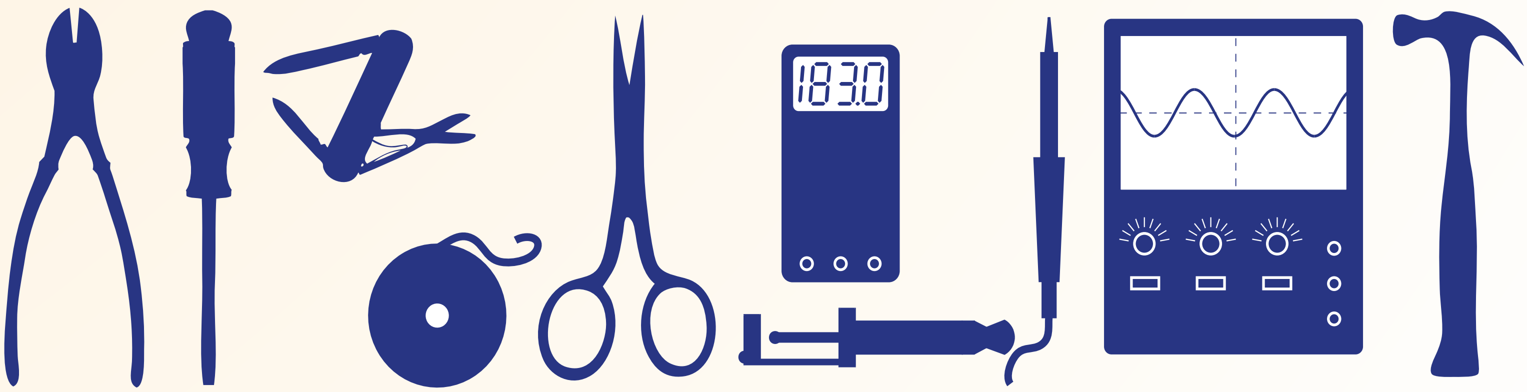
chipboard so that damage to the tabletop is avoided. The work area should always be thoroughly cleaned once the work has been completed. This is particularly important after working on steel cases, since any pieces of swarf produced are likely to have some sharp edges.

Anti-zap

Before starting on the electronic side of project construction it is important to realise that many modern semiconductors are vulnerable to damage from static charges in the environment. We are not necessarily talking in terms of large charges that produces noticeable sparks and 'clicks' as they discharge. Some semiconductors can be damaged by relatively small charges that give no obvious clues to their existence. There is insufficient space available here for a detailed description of anti-static handling precautions and equipment, but a few simple rules should be observed.

If in doubt, always assume that a semiconductor is a type that is easily damaged by static charges. Handle semiconductors as little as possible, and try to avoid touching the leads or pins. Semiconductors are normally supplied in some form of anti-static packaging, and they should be left in this until it is time to fit them on the circuit board. Keep semiconductors away from any likely sources of static electricity, and do not wear clothes that are known to be prone to static generation when constructing circuit boards. Earthed wrist bands are available from electronic component suppliers and from shops that sell computer parts. Any static charge in your body is quickly leaked away to earth when you wear one of these. They are not expensive and it is worth having one of these as part of your initial tool kit. If you build electronic gadgets more than very occasionally it is worth obtaining an earthed mat for the work area.

All or most of the electronic components are fitted on a board that is made from an insulating material such as fibreglass. The board has holes to take the pins and leads of the components, and in its most simple form there are copper pads and tracks on one side of the board. The components are mounted on the opposite surface of the board, which is generally considered to be the top side. The leads are trimmed to length before they are soldered to the copper



pads on the underside of the board. There are no connecting wires as such, but the copper tracks on the underside of the board carry all the required interconnections.

This is the fundamental type of printed circuit construction, and there are some variations on this basic scheme of things such as double-sided boards. These have copper tracks on both sides of the board, but in most cases the components are still fitted on one side. Additional holes carry connections through the board, and the connections weave across the board, crossing over other tracks and avoiding unwanted connections to them. Another type of board lacks holes for the pins and leadout wires, and is used with special surface mounting components that are soldered onto the copper pads (Fig.3). A further variation uses a combination of conventional printed circuit and surface-mount construction. Due to the minute size of the components, any form of surface-mount construction is not a good starting point, and is probably best avoided by beginners.

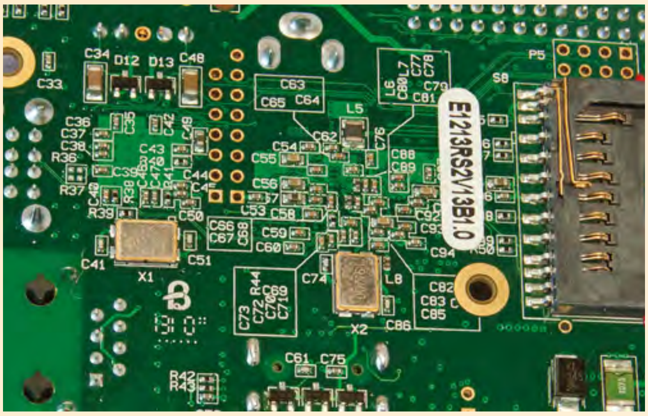


Fig.3. Part of a complex double-sided board that has components and tracks on both surfaces. Projects that use surface mounted components are not a good starting point

A normal printed circuit board is only suitable for one particular circuit, but there are various types of proprietary printed circuit board that are designed to accommodate practically any circuit. Stripboard (Fig.4) is the only one of these that is currently used to any extent for electronic project construction. It is a single-sided board that has numerous small holes on a 2.54mm × 2.54mm matrix. Copper strips on the underside of the board run along the rows of holes for the full length of the board.

Stripboard is used in the same basic fashion as a custom single-sided board, but it is usually necessary to make breaks in some of the copper strips so that they can handle more than one set of interconnections. Link wires are normally needed on the component side of the board to connect various copper strips. In fact, link wires are sometimes needed with custom boards, and they provide a simple alternative to using relatively expensive double-sided boards. Stripboard is less straightforward to use than a custom printed circuit board, giving more scope for making errors. Initially it is probably better to opt for projects where you can use a ready-made custom board.

Hot stuff

Good quality soldered joints are needed to make reliable electrical connections between the various electronic components, and to give the circuit board physical resilience. There is no need to use an expensive thermostatically controlled soldering iron, an inexpensive iron with a rating of about 15W to 20W is sufficient. It should be fitted with a small bit of about 2.0-2.5 millimetres in diameter. For safety reasons the iron should have a proper stand, and this will also act as a heatsink to prevent it from overheating. It should be possible to obtain a soldering kit that includes a small soldering iron, a matching stand, and some solder of the appropriate type for electronic work.

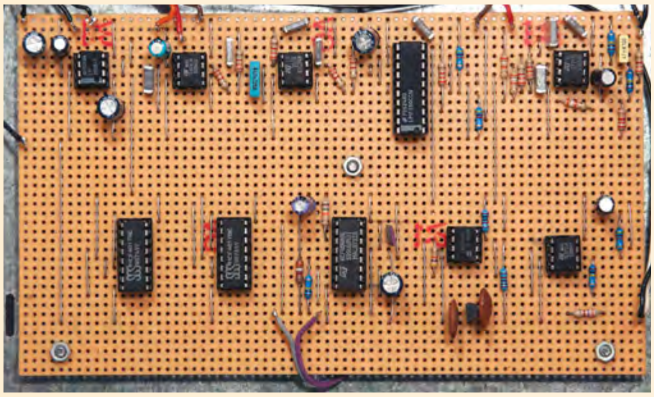


Fig.4. The top side of a circuit board based on a piece of stripboard. The copper strips run horizontally on the other side of the board

A guide to soldering goes beyond the scope of this article, but there is an excellent soldering guide by Alan Winstanley available on the *EPE* website, and any soldering kit will almost certainly come complete with detailed instructions. I would definitely advise against starting construction of a circuit board without gaining some soldering experience first. Obtain some stripboard and a few cheap resistors and practice soldering before moving on to your first project.

Finishing touches

With the completed board fitted in the case, it is just a matter of adding any remaining wiring. This is sometimes termed the 'hard wiring', and it is perhaps less straightforward than building a circuit board. The article should include a wiring diagram that clearly illustrates each connection, and there should be no problems provided this is followed carefully, making sure that no wires are omitted. A thin insulated multi-core wire such as the 7/0.2 type (seven cores of 0.2mm wire) is suitable for most connections. A heavier type, such as 16/0.2 is needed for wiring that carries higher currents, and it is advisable to equip yourself with both types of wire right from the start.

Double check

Avoid the temptation to immediately switch on a newly constructed project. Checks for errors should be made as construction progresses, but it is still a good idea to thoroughly check the finished unit before testing it. Provided you build a project carefully it will probably work first time, but there is bound to be the occasional project that is reluctant to co-operate. The problem is usually caused by a minor mistake somewhere, and some further checking will usually get things sorted out. You are then ready to start looking for your next project!

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Revisiting the kitchen timer

AFTER many months of hardware and software development we approach the original intended destination of these articles – a development board supporting the 'C' programming language, with a decent software development environment. It's still a good environment for writing assembly language programs, but the PIC18F processor family lives in an interesting 'sweet-spot' of low power, low-cost, easy-to-solder devices that can be used effectively with 'C', and that's what we are going to concentrate on for now.

This month, we re-visit the kitchen timer application created last year and re-engineer it in 'C', in part to see what the difference a high level language makes to the code size, and also to see just how much easier the development process is (you may remember us commenting on how laborious it was, coding the user interface in assembler.)

To set the scene, a quick reminder of how the kitchen timer works. The original assembly language template files were extended by adding the file **kitchen.asm**, which holds the logic of the application. **Interrupts.asm** was modified to include the use of a timer decrement routine decTimer.

The **lcd.asm** file was extended to include routines to convert binary values to ASCII, and display them as two digits on the LCD display.

The **main.asm** file has a very small change – placing the processor in sleep mode when the timer is inactive, and otherwise just calling the application's 'handler' routine, which gets called either every two seconds when the timer is inactive, or constantly when it is running:

```
    call     kitchenInit

mainloop:
    call         timerAsleep
    btfsc        STATUS, Z
    sleep
    call         kitchenHandler
    goto         mainloop
```

Creating the application

We start by creating a copy of the template 'C' project files, including the main directory that ends with the characters '**.X**'. The template files were created as part of June's article, and can be found on the magazine's website. Once you have copied the files, rename the **.X** directory to something meaningful, such as **kitchen-C.X**. Always keep the extension '**.X**' the same – it is required by MPLAB-X.

Run MPLAB-X, and once it has started up close any open projects (File->Close All Projects) and open the project that is in your new directory. The project itself will still be called by the old name 'template', and you should change that by right-clicking over the project name in the Projects explorer tab (it has a small IC icon next to it) and then, from the drop-down list, select 'Rename...' Fig. 1 shows what we mean. Give the project the name '**kitchen-C**'.

Next, we add the two new files to the project; **kitchen.c**, and its header file **kitchen.h**. To do this, right-click over the line 'Header Files' within the Project explorer tab, select 'New', and then 'C Header File'. Give the file the name **kitchen**, and select 'Finish'. Next, right-click over the line 'Source Files', select 'New', and then 'C Source File'. Give the file the name **kitchen**, and select 'Finish'.

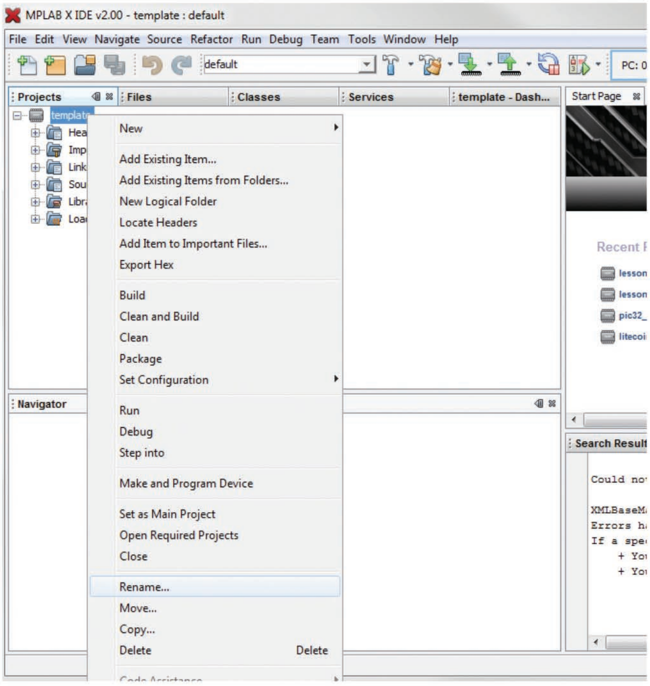


Fig.1. Renaming a project

Now we have our project source files generated, the next thing we do is create the three functions **kitchenInit**, **timerAsleep** and **kitchenHandler**. The kitchenInit and kitchenHandler routines do not take any parameters nor return any, so their function definitions in **kitchen.h** are very simple:

```
void kitchenInit(void);
```

and

```
void kitchenHandler(void);
```

The function `timerAsleep` returns a value indicating whether the timer is running; it only needs to be a yes/no indication, so we will use a single unsigned character type:

```
unsigned char timerAsleep(void);
```

These three functions were added to the new source files, with no code inside them – `timerAsleep` set to return a dummy value of zero, as it must return *something*, or the compiler will complain that you have made an error. We will fill the proper code in shortly.

Back in the file **main.c** we add an `include` directive at the top of the file to make use of the kitchen application functions:

```
#include <stdio.h>
#include <stdlib.h>
#include <pic18.h>
#include 'config.h'
#include 'timers.h'
#include 'interrupts.h'
#include 'hardware.h'
#include 'kitchen.h'
```

and add the calls of the kitchen application handler, mimicking the assembly language version:

```
kitchenInit();

do {
   if (!timerAsleep())
      SLEEP();
   kitchenHandler();
} while (1);
```

That's it for **main.c**. Let's take stock of the resource utilisation so far, looking on the dashboard tab of the project explorer window in MPLAB-X: 33 bytes of RAM used, and 720 bytes of Flash. The assembly version of the complete kitchen timer used 16 bytes of RAM and 1830 bytes of Flash. So we have blown our RAM budget already, and we haven't even started!

The next port of call was **hardware.c**, fleshing out the `HardwareInit` routine. The assembly language version is littered with instructions changing the RAM memory bank, as various SFRs in different banks are configured. It's so nice not having to care about which memory bank an SFR is in with the 'C' language; the compiler handles this for us, and never makes the mistake of forgetting to change the bank registers. That feature alone is a good enough reason to use the 'C' language!

Only a few, minor changes were required to the **interrupts.c** file, leaving just **kitchen.c** and **lcd.c** to be updated.

The original **lcd.asm** had various functions for displaying binary data; we will take a simpler approach, and make use of the 'C' Library's **sprintf** function to convert data into a string. All we need to provide is a raw string print routine. This is a very simple piece of code, that make use of the `LCDWrite` function:

```
void LCDWriteStr(unsigned char *ch)
{
    while (*ch)
        LCDWrite(ch++);
}
```

We also added two functions to turn the cursor on and off.

So now it was time to focus on the main application file, **kitchen.c**.

The keyboard functions were easy to translate directly into 'C', but we now had a decision to make: how to store, increment, decrement and display the timer value. There are three common approaches, each with their positives and negatives:

Store the value as BCD
This is the approach we took in the original implementation, and it works well in assembly language. The code is a bit fiddly to write, but is fast and efficient on code size.

Store the timer as a single decimal value
Here, we store the timer value as the number of seconds in a single, unsigned long variable. This storage method will be the easiest to manipulate, but requires some slightly more complex maths to display the value as three separate values.

Store the timer as three separate values
Here, we store the hours, minutes and seconds in their own unsigned char variables. This is slightly more complicated to store and manipulate (you have to handle the 'carry' from 59 to 00 for example) but it is slightly easier to display.

The second option appears to be the best approach; It's better to *store* data in the most appropriate format. Converting the single value to a display string is not that complicated, and although it wont be very quick, it will certainly be quick enough. Plus, the 'C' programming language has several features and functions to help us with the conversion.

So, we create a variable thus:

```
unsigned long timerVal = 0;
```

The implementation of the `decTimer` function now looks like this:

```
unsigned char decTimer(void)
{
     return (--timerVal);
}
```

That's a single line of code, compared with 80 lines of assembler!

Moving on to the display of the timer, that is just two lines of code now:

```
      sprintf(line1,timeStr,  timerVal/3600,
(timerVal/60)%60, timerVal%60);
        LCDWriteStr(line1);
```

Now, here is the rub – those two lines of code tripled our Flash memory usage to 4860 bytes! The reason for this is the use of the `sprintf` function; we had not used that before, so the compiler added the code for that function into our project. `sprintf` is a 'Swiss army knife' function, it can convert all kinds of data formats to strings, and that flexibil-

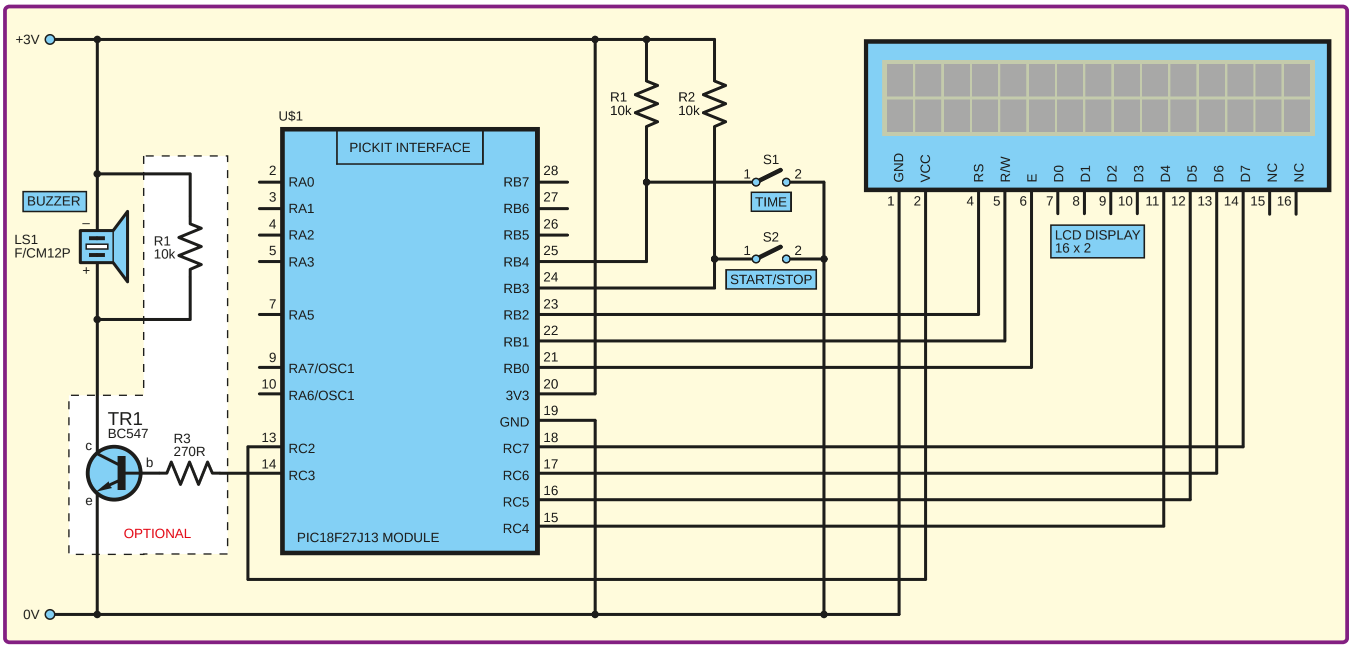


Fig.2. Circuit diagram matching the template files

ity comes at a cost: code size. The good news, however, is that this is a one-off cost; The next time we use `sprintf` the same copy will be used, so the program won't grow in size so much.

Converting the final function, `KitchenHandler`, went reasonably smoothly, taking about 30 minutes to complete. There were several bugs found in the subsequent tests, but these were quickly identified and fixed using the PICKIT3 debugging capabilities.

So in the end, the program took 137 bytes of RAM (compared to 16 bytes for the assembly version) and 6702 bytes of Flash (compared to 1830); over three times the size.

Although a relative size comparison looks bad, one has to remember that this is a small project. For a bigger project, the gap converges a little, as the relatively large C language library functions included in our project get re-used. The main difference, however, is the effort involved. Creating the 'C' version of this project was trivial, and it will be a lot easier to understand than the assembly version (go ahead – compare the two!)

Fig. 2 shows, again, the circuit used for this project – the same as before.

'C' Startup

One of the questions that comes up time and time again is: 'how does the processor know to transfer control to the `main()` function on startup?'

It's a great question, an obvious one to those of us used to programming in assembly language; we know that the processor starts at the reset vector (0×0000 on the PIC) and we are immediately in control of the processor from that point. So who or what is causing the processor to jump to the `main()` function?

With the 'C' programming language, the compiler provides some code to us that performs a little housekeeping following the power-on reset. That code is called 'cstartup' (or 'crt0' by some compilers,) and is responsible for initialising our global variables to a defined state – either zero, or a value we specified in the code. Something has to do it!

Some compilers provide different versions of `cstartup`, enabling you to reduce the language overhead even further if you need to (you can disable bss initialisation and variable loading in MPLAB-X if you wish) but care should be taken when modifying the normal 'C' language features. Things may not work as you expect.

The source code for this project can be downloaded from this month's section of the magazine's website: **www.epemag.com**

Next month

Next month, we introduce some SPI communication routines into our template code, and demonstrate using them to hook the board up to a low-cost colour LCD panel.

Kickstarter

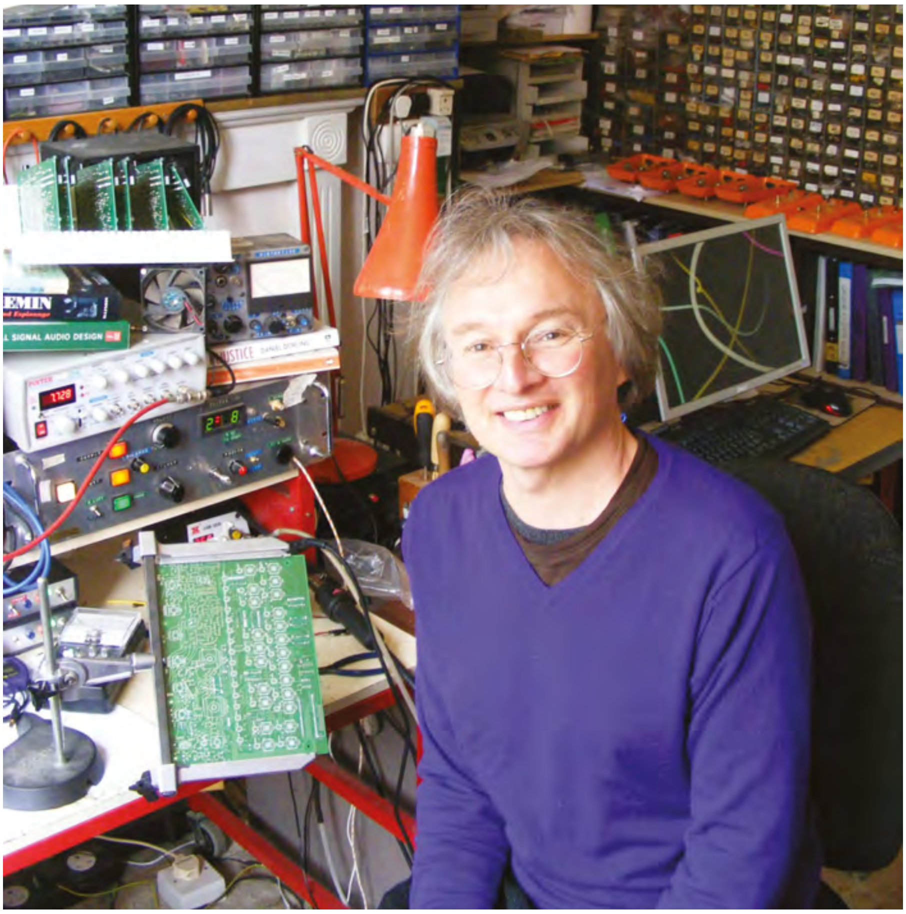
As I write this article, the Kickstarter project is in it's final hours of 'funding.' After launching 45 days ago over 400 boards have been ordered by 186 people – many thanks to everyone who has joined in. Going through the Kickstarter project – developing the idea, creating promotional media, answering questions – has been a fantastic learning experience and I can't wait to do another!

Not all of Mike's technology tinkering and discussion makes it into print. You can follow the rest of it on Twitter at @MikeHibbett, and from his blog at mjhdesigns.com

By Jake Rothman

Working for yourself in electronics

Jake Rothman is an analogue electronic music technology designer, lecturer, science communicator, and manufacturer. He studied and graduated in the 1980s with an HND in Electronics for the Music Industry, and later received a teaching certificate. He has designed valve amplifiers and Theremins, and written numerous articles for *EPE* and *The Modern Electronics Manual*. Here, he describes the trials, tribulations and rewards of running a small electronics business for the last 23 years.



Jake Rothman at home in his office / workshop / general business HQ

Microbusiness

No, I'm not talking microprocessors here, a microbusiness is a very small business, usually consisting of one person or a sole-trader. My company designs and manufactures Colorsound guitar pedals, Theremins and all manner of hand-made boutique 'music tech'. I'm located in a part of Wales where big private-sector employers are rare and microbusinesses form a large part of the economy.

Self-employed, or self-delusional?

I was possibly deluded when I went fully self-employed, like most entrepreneurs I was irrationally over optimistic. I gave up my university lecturing and property in the south of England and left for pastures new. That was the trouble, the endless fields; I fell asleep at the wheel a couple of times coming back from lecturing on The University of Glamorgan's Music Tech BSc, a 140-mile round trip. So I decided to go self-employed full-time.

That was a conscious decision, but of course self-employment can happen at any time if you lose your job. Either way, multinational financial services company Morgan Stanley says 80% of all employment gains in the UK since 2007 have been in self-employment.

Word to the wise

Being self-employed is no picnic, and unless you hit upon a wildly successful product or idea, then it's certainly no route to riches. In fact, you are likely to earn less than working for a good employer. However, it can be very rewarding being your own boss and running your own business. You do get nice little extras – all your purchases for the business are tax-deductible expenses, including your *EPE* subscription! So despite earnings being low, if it's a choice of designing a new guitar effect or selling insurance for £6.30 an hour, I know what I would rather do.

Working in electronics

Electronics is still one of the best areas for self-employment, since it is infinitely scalable – from stuffing PCBs in your bedroom to building another Foxconn in China. It has real advantages over, say bricklaying, because you can leverage your work. For example, if I design a good pre-amp circuit I can put it in several products: an article in *EPE* and then use it in a lecture (put on the net for publicity of course). Finally, I might use it as a demonstration prop on 'Lab in a Lorry' for the Institute of Physics when I work as a STEM (science, technology, engineering and mathematics) ambassador to enthuse school children. Hence, it's possible to get paid at least five times for the same piece of work. Later on, I may be the only person who can fix it, generating more revenue!

On the production side, I prefer doing R&D and testing, so I tend to outsource PCB assembly and the drilling

of cases. However, I still do an hour of tidying and a couple of hours of administration a day. Also, one's home/workplace has to be heated all day – there are many such overlooked tasks and costs when being self-employed.

Intellectual property

Large companies can afford to patent designs, and, more importantly, enforce the patents. I often just have to be content with a few sales and basking in the glory of seeing a successful artist, such as Alison Goldfrapp, use one of my circuits. It can be useful to put a design into a journal, since it can prove you did it first. I have used this to protect myself when some large corporations have accused me of infringing their patents. But publishing a circuit will probably end any hope of a patent; I often wonder how the late Peter Baxandall felt every time he saw an amplifier with bass and treble controls, knowing he had put the circuit in *Wireless World* in November 1952.

Hoarding and advertising

The Internet has greatly reduced the amount of space needed. I used to have hundreds of catalogues and data sheets, now I just use Google. It is the same with components – just a few clicks and a part arrives the next day. Actually, that's a bit of a fib! Since I do retro 1970s analogue electronics and being an ancient 51, I store vast amounts of cellulose-based data and obsolete components. But it doesn't have to be that way for you!

One of the best forms of advertising is via your own website, and if you have the right skills you will get noticed, as one link leads to another. Specialised technologies now have a global reach, so there is room for almost any unique service. Find a stable niche where there is no competition and you can do well. On the other hand, if Yamaha or China do it, forget it.

Discrete hand-made electronics is an artisan craft. Most mass-produced stuff is often just 'clip-art' soldered together. Funding large tooling costs and surface-mount PCB runs is now easier with new business models based on crowdsourcing. There is always somebody to be found doing kits and parts for desirable old products, long out of production. An example would be the Roland TB303 Bass Line by **adafruit.com**

Oh my RoHS!

Along with the liberation of the net, have come increased costs due to regulation, such as RoHS. The requirement to use lead-free solder has been a real disaster for my field, since my products are expected to last 30 years and are priced accordingly. Unleaded solder is fragile and has poor wetting, resulting in shorter life, especially where single-sided PCBs are used with through-hole components. Unlike military electronics, the professional audio industry never did sufficient lobbying to get an exemption. Now, European regulation treats us like we make musical Christmas cards that go straight into the waste stream. There is no such thing as an RoHS-compliant germanium transistor, and old components generally need to be soldered with SnPb solder. All I can do is get the leads treated to get the lead tinning removed at huge cost, convert all the PCBs to plated-through-hole and hand solder in a pure nitrogen atmosphere.

New old stock – NOS – is a great way to bulk buy cheaply

Safety is also paramount when selling to the public, especially when it comes to mains wiring and power supplies. At first, I avoided this issue by buying in approved 'wall-wart' PSUs. The CE emissions side I got round by documenting how I took measures to comply, effectively self-declaration. I finally got a fellow lecturer at a university to put my Theremins through their EMC testing facility.

Inflation

As far as start-up costs go, a home-based electronic business is cheap to set up. Most people already have a computer, printer, Internet connection and domestic hand tools. The basic additional workshop stuff for hardware development, soldering iron, side cutters, multi-meter, power supply, 'scope, signal generator and drawers full of general components, will generally come in at less than £1000. Since analogue electronics is a mature technology, there is plenty of second-hand equipment and NOS (new old stock) components available. Many a time I have set up students with the complete workshop contents of a deceased Radio Ham, often called a 'silent-key' sale at radio rallies.

There is, however, the spectre of rising costs in electronic parts for the first time in 30 years. The deflation in component prices enabled me to hold and even reduce prices for years. Those days are now over, as anyone who has ordered from the big distributors recently will realise. Traditional analogue parts, such as pots, switches, solder, cable and tools, based on my invoices, have gone up 40% in the last few years. Surprisingly, Farnell will negotiate and Rapid also give me end-column prices because I buy every month. I've also sent a few college accounts their way. One new supplier I'm using is Tayda, who are very good value for guitar pedal parts.

Even Chinese electronic costs are now inflating, killing with it the throw-away culture, and allowing repair businesses to become viable again. Analogue music gear is now expensive and desirable – like a good mechanical chronometer – and of course consumers expect it to last, just like well-made furniture.

Tantalising tales

Ironically, I recently bought a boot load of AVX and Kemet tantalum capacitors from the Flight Refueling radio-rally destined for land-fill because they were non-RoHS. I thought surely it is better they be used in some audio gear for 30 years first before they become toxic waste? After all, I was constantly replacing dried-up wet electrolytic capacitors in pro-audio gear and motherboards as part of the repair side of my business. Identifying such failed caps is easy, half the failures are visual and the others can be identified with a Peak ESR meter. The capacitor 'plague' affecting Taiwanese electrolytics, where an industrial spy forgot the corrosion inhibitors in the formula he stole from the Japanese, didn't help either!

Next month, I'll talk about 'how I got the wet electrolytics out of my designs' and knocked the failure rate right down.

Parallel batteries

ATHOUGH most *Circuit Surgery* articles are based on posts in the EPE Chat Zone (**www.chatzones.co.uk**) we are also happy to receive questions or suggestions for topics by email (**editorial@wimborne.co.uk**) and will use them if they are suitable, like the following email from Godfrey Manning.

The question is about power supplies in parallel. I've drawn batteries for simplicity, but it could be regulated DC supplies, transformer secondaries in parallel, etc.

The batteries represent perfect voltage sources and the resistors above them are their internal impedance. I've got both supplies (batteries) in parallel and feeding current into a load resistor (the rightmost resistor). The required nominal supply voltage appears at the measuring point.

Assume the internal impedances are low and similar. Let's start with the off-load voltage from the left battery being very much greater than that of the right battery. To my mind, that's a battery charger. The leftmost battery will charge the right-hand one.

Now alter the batteries until they are closely similar in voltage and assume the small internal impedances are also closely similar. These power sources tend to share the current demanded by the load resistor (Kirchhoff's law applies as always).

It's as if, at some point in the experiment, the rightmost battery's increasing volts now become so similar to the left-hand battery's that current flows out of both and goes into the load. This is a reversal of the current going out of the left battery and into the right-hand one in order to charge it.

How is this calculated? At what point does load-sharing begin, as distinct from the right lower-voltage battery itself loading (drawing charging current from) the left battery?

Paralleling of power sources is a common practice. It provides additional current capacity which is not available from an individual unit, whether that is a small battery cell or a large AC generator. As indicated in Godfrey's question, parallel (voltage) power sources must be matched, balanced and synchronised in order for the combination to be an efficient and effective power source.

Avoiding damage

The point at which the sources are first connected together is important as significant mismatch may result in excessive currents and consequent damage. This is even the case if there is a possibility of eventual self balancing, for example, via battery changing, as described by Godfrey. For DC sources, matching is primarily about the voltages not being too different. For transformers (AC output) the voltage and phase must match. This was discussed recently in *EPE* in the context of the *Rugged Battery Charger* constructional project (pages 10-11, May 2014 issue).

AC sources in parallel

For AC generators, the voltage, phase and frequency must be matched prior to connecting their outputs together. This means their speed of rotation must be matched. If generators are connected in parallel while out of phase they will experience strong mechanical stresses as they are forced to synchronise quickly. This and/or high current flow may cause damage. There are numerous other potential problems, but techniques and procedures are well established in the industries where this is done. A device called a synchroscope can be used to measure the degree to which two generators are synchronised (in phase and frequency).

Basic cell technology

Batteries are often formed by connecting basic electrochemical cells in parallel to increase current capacity. Cells can also be connected in series to increase output voltage and combinations of cells in both series and parallel are often used. Battery packs based on technologies such as lithium-ion typically contain battery management circuitry which helps maintain the required balance between the cells.

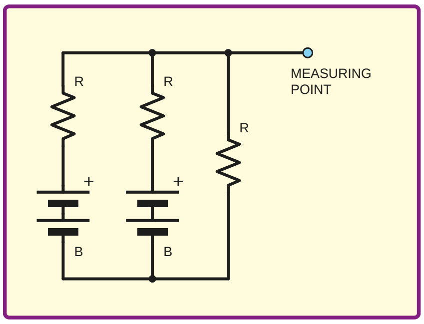


Fig.1. Godfrey's schematic

Circuit theory

Before looking at the specifics of parallel batteries we will discuss some of the circuit theory and simulator usage which might help us calculate what is happening. We need to be sure we can find out which direction the current is flowing to answer Godfrey's question.

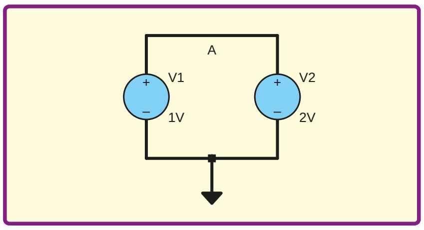


Fig.2. Two ideal voltage sources connected together

Godfrey mentioned perfect voltage sources and it is worth considering what this means. If we connect two ideal voltage sources together, as in Fig.2, what happens? One answer which springs to mind is that we have a voltage drop across zero resistance, so using Ohms law $I = V/R$ with non-zero V and zero R, we get an infinite current. A perhaps more fundamental view is that the schematic itself is meaningless. Ideal voltage sources define the voltage between two points and the schematic in Fig.1 is effectively saying that the voltage between point A and ground is both 1V and 2V. This contravenes the basic concept of what voltage is – you cannot have two different voltages between the same two points.

When we draw a schematic we intuitively understand that the lines between components will become the wiring of a physical circuit, however, this is not what the schematic really represents from a circuit theory perspective. Each connected set of 'wires' on a schematic represents a single point, called a node, which at any point in time has a single voltage (measured to some fixed reference point, usually ground) associated with it. This is illustrated in Fig.3, which shows a version of Godfrey's schematic with its three nodes labelled and highlighted.

In Fig.3 we have used voltage source symbols rather than battery symbols

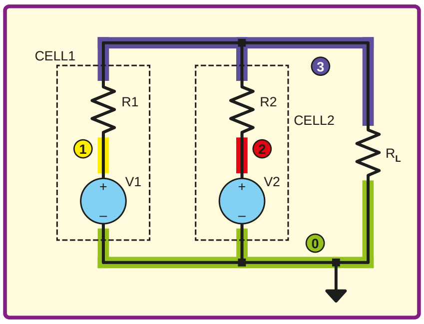


Fig.3. Redrawn with voltage sources and with nodes labelled

because the voltage source and resistor together represent a battery cell. When analysing 'batteries' we should use the term 'cell' for the individual electrochemical cells and battery for a combination of cells wired together. The parts of the schematic representing the two cells are indicated by dashed boxes in Fig.3

From the node-based perspective in Fig.3 we can redraw the schematic in the form shown in Fig.4, which is called a 'circuit graph'. Here, each set of 'wiring' collapses to a dot (the node). The components are represented by branches connecting the nodes. This format for drawing a circuit closely relates to circuit theory and the mathematical models of circuits used by simulators such as SPICE. It better represents that a node is just a point at a specific voltage and, unlike components, does not have other characteristics or parameters. The reference point (ground) from which voltages are measured is always labelled as node 0.

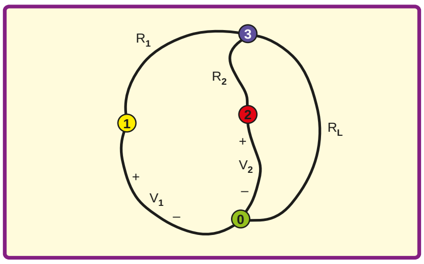


Fig.4. Circuit graph of schematic in Fig.3

Schematics can be used as an instruction on what circuit to physically build and as a mathematical representation of a real circuit. In both cases the information is incomplete. For building, the schematic does not, for example, directly define the placement of components on a board. As a mathematical representation, the schematic only takes account of a certain level of detail about the real physical circuit. If we want to include something in an analysis we have to include it in the schematic as a 'component', or as part of the mathematical model of a component (referred to as its characteristics equation).

Building simulation components

The most basic mathematical model of a resistor is the same as Ohm's law $V=IR$. This does not account for all the behaviour of a real resistor, for example the resistance may change with temperature and applied voltage. We can write a more complex equation to represent this and then any calculation or simulation will be more accurate; that is, assuming we have the right numbers (eg, temperature coefficient) to put into it.

Using a different equation for a basic component is not the only way to obtain a better representation of reality. We can replace a physical component with two or more basic components in what is referred to as an equivalent circuit. This is exactly what Godfrey has done by including the internal resistance of the cells in his schematic. A real cell can be modelled as an ideal voltage source plus a resistor in series. These components are just representations; they not physically separable and we cannot directly measure the voltage at nodes 1 and 2 in Fig.3.

The source plus resistor model of a cell is useful to some degree for the analysis of parallel batteries, but only to a limited extent, as we will see later. Before proceeding with some calculations and simulations we will have a quickly look at Kirchhoff's laws, as Godfrey also mentioned them.

Introducing Kirchoff

Kirchhoff's voltage law (KVL) states that the sum of the voltages, taking direction into account, around any closed loop in a circuit, is zero. KVL allows us to formulate equations relating the voltages within the circuit.

Kirchhoff's current law (KCL) states that the sum of the currents into a node is zero. Currents are taken as positive if they flow in and negative if they flow out. If we designate the wrong direction for a current at a node we will get a negative value if we calculate it when analysing the circuit. KCL allows us to write equations relating currents within the circuit. For example, at node 3 in Fig.4 we can write:

$$I_{R1} + I_{R2} - I_{R3} = 0$$

We note that I_{R3} is subtracted because we have designated it as flowing out. The graph form of the circuit (Fig.4) makes the idea of 'currents into a node' clearer than a schematic, where the connection may be a convoluted path with many joins.

KVL and KCL deal with just voltages and just currents separately. Voltage and current are related by the characteristic equations of the components in the circuit, such as $V = IR$ for a basic resistor.

Simulation

Although we can perform circuit analysis by hand it may be quicker to use an analogue simulator like LTSpice to do the work for us. The situation described by Godfrey can be analysed using an operating point simulation (.op directive) in SPICE. The result is simply a list of the currents and voltages in the circuit. For example, the result for the circuit in Fig.5 is shown above. The values used in Fig.5 are not meant to represent any type of real battery, but just serve to illustrate interaction between two voltage sources in parallel.

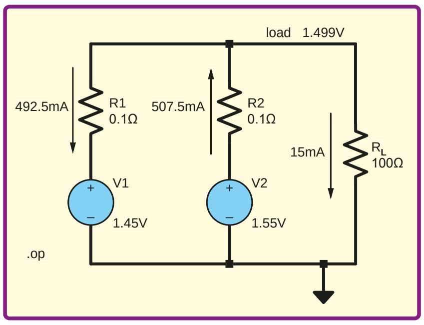


Fig.5. Example cell voltages

```
--- Operating Point ---

V(n001):     1.45     voltage
V(n002):     1.55     voltage
V(load):     1.49925       voltage
I(Rl):       0.0149925     device_current
I(R2):      -0.507496      device_current
I(R1):       0.492504      device_current
I(V2):      -0.507496      device_current
I(V1):       0.492504      device_current
```

In these results, some of the resistor currents are positive and others are negative. This sometimes causes confusion when interpreting SPICE results. There are a couple of key things which help with understanding this. First, remember that SPICE circuits are actually described by a text file called a netlist, not directly by the schematic. Second, in any circuit analysis, as mentioned above, we may choose to designate an arbitrary current direction through any component (which we then assume is the current direction in our analysis). If the actual current is in the opposite direction to our designation the calculation will yield a negative value.

SPICE designates current direction in accordance with the order of the connections in the netlist, however this is not visible on the schematic. If you view the netlist for the circuit in Fig.6 (View > SPICE Netlist on the menu), it will be something like the following:

```
V1 N001 0 1.45
V2 N002 0 1.55
R1 load N001 0.1
R2 load N002 0.1
RL load 0 100
.op
* V
* V
.backanno
.end
```

If you use the schematic editor to rotate R_1 by 180 degrees and view the netlist again, the line for R_2 will change to:

```
R2 N002 load 0.1
```

and the sign of the current will change if you rerun the operating point simulation.

If you are uncertain about the actual direction of the current through a resistor in SPICE look at the voltages on both sides. The current flows from the more positive to the more negative voltage. From a netlist perspective the current is designated from the first connection (node) to the second (for example from node `load` to node `N001` for R_1 in the netlist above) and the result will be negative if the actual flow is opposite to this.

Simulating the battery question

LTSpice is able to print current and voltage values from an operating point analysis on the schematic. To do this, right-click a blank part of the schematic and select View > Place .op Data Label. Place the label, right click it and edit the text in the expression box. For example, to print the current in R_2 use `I(R2)`. You can also print the result of mathematical expressions based on the data values. By default, LTSpice prints many digits, but this can be reduced using rounding expression, for example:

```
round(I(R2)*1k)/1k
```

In Fig.5 there is a 0.1V voltage difference between the internal voltage of the two cells, and each has the same internal resistance of 0.1Ω. Ignoring the load for a moment, we see that the voltage difference is 0.1V and the resistance between the two sources is 0.2Ω, so we would expect the current between the sources to be about 500mA ($I = V/R = 0.1/0.2$). This is confirmed by the simulation results. In general, battery cells will have low internal resistance, so even quite small voltage difference can result in very high currents when they are first connected.

In the situation in Fig.5, the cell represented by V_1 and R_1 (cell 1) would be charged by the cell represented by V_2 and R_2 (cell 2), as described by Godfrey. That is, if the currents were not too high for the cells to cope with and cell 1 was able to accept charge. Cell 2 also provides current to the load.

One question that might arise is, can both cells provide current to the load if their voltages are not equal? The answer is yes if the load resistance is small enough. We can calculate the point from which this occurs by working out the load for which the current in/out of the cell with the lowest voltage is zero. This requires the voltage at the load to be equal to the lower source voltage.

If the current in V_1 and R_1 is zero then we can think of R_2 and R_L as a potential divider which is not loaded/affected by V_1 and R_1. If there is no current in R_1 then there is no voltage drop across it, so the voltage at the load must be equal to V_1. Using the potential divider formula this will be:

$$V_{\text{load}} = \frac{R_L V_2}{R_2 + R_L} = V_1$$

which we can rearrange to give:

$$R_L = \frac{R_2 V_1}{V_2 - V_1}$$

For our example this is (0.1 × 1.45)/(1.55 – 1.45) = 1.45Ω. Simulation results for this situation are shown in Fig.7. More generally, this equation shows that the closer the cell voltages are together the larger the load resistance to which they will both contribute current.

The example we have just looked at is a kind of 'reversal' point, to use Godfrey's term, but this is related to the load not the interaction between the cells. The approach we have used so far models the cells in terms of ideal voltage sources with internal resistance. This approach cannot explain what happens with batteries' cells in detail because an ideal voltage source cannot be charged or discharged like a cell; however, looking at the circuit like this has provided some insights into the behaviour of parallel voltage sources.

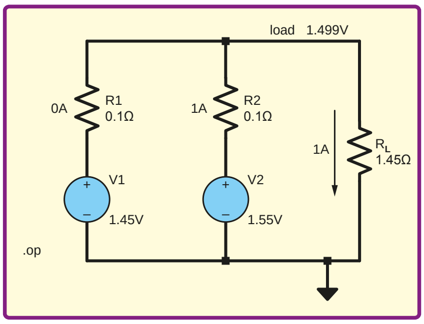


Fig.6. Further example cell voltages

When real rechargeable cells are connected in parallel one will charge the other until a balance point is reached. This process will take a certain amount of time to complete. However, the circuits we have used so far do not model this. If we run a time-based (transient) simulation of the circuits in Fig.5 and Fig.6 nothing will change. The model of the cells used in these circuits does not include the charge/discharge process. The simulations in Fig.5 and Fig.6 show us the situation which would occur for the first instant in time after we simultaneously connected the two cells and the load, but that is all they show.

State of charge

A key cell parameter which we have not mentioned so far is the state of charge (SOC) which is usually defined as the proportion of its total energy capacity that the cell is currently holding. Typically, the cell voltage will decrease as its SOC decreases, but battery designers try to keep the voltage as constant as possible over a wide range of SOC and for many cells the voltage does not decrease significantly until the cell is close to being fully discharged. Despite this, if we have nominally identical cells the one with the higher SOC will have the higher voltage and current will flow from the higher SOC cell to the lower one until the SOCs equalise.

Cell behaviour

If we just consider two cells of the same type connected together (ie, with no load) the voltage at the connection point will immediately go to the average of internal voltage of the cells. For the cells in Fig.3 this is (1.45+1.55)/2 = 1.5V. The movement of charge between the cells will cause their individual internal voltages to move towards the average, but the voltage at the connection point will not change.

The initial current will depend on their voltage difference and internal resistance. For the cells in Fig.3, this is 500mA, as calculated earlier. This current will not be maintained, but will decrease as the SOC of the cells, and hence their voltages, equalise. If we assume the cells' internal resistances do not change much, the change in current is entirely due to change in voltage difference. Decreasing current

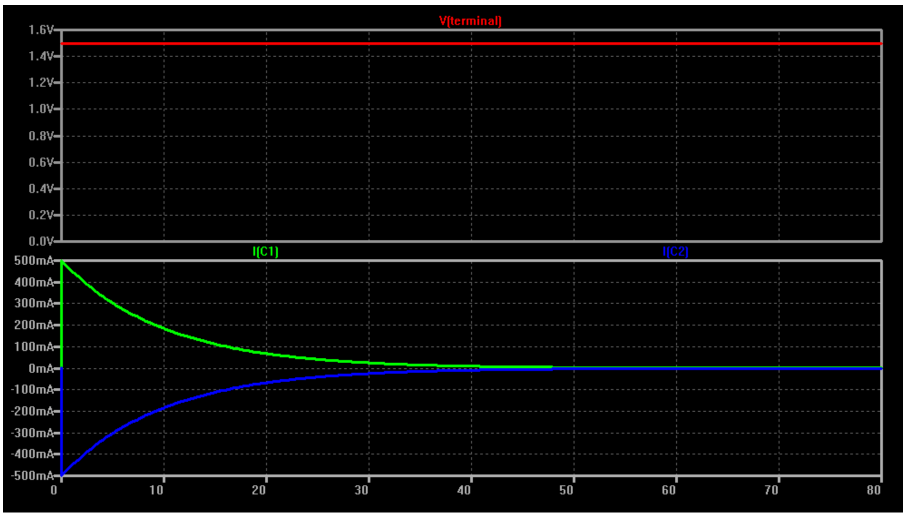


Fig.7. Plot of cell current (cell 1 – C1 and cell 2 – C2) over time for the two cells shown in Fig.3 connected at time=0 (with no load). The voltage at the connection point (V(terminal)) remains constant at the average cell voltage. The graph has arbitrary time units

will mean the rate of change of SOC and hence the rate of change of internal cell voltage will decrease as time progresses. Cells should only be connected when their SOCs are similar to avoid excessive initial current, which might damage them.

Fig.7 is a graph showing what happens over time if the two cells from Fig.3 are connected together with no external load. The voltage at the connection point, *V*(terminal), remains constant at 1.5V and the currents decrease towards zero from 500mA. This plot does not represent any specific real cell, so the time units are arbitrary.

The graph in Fig.7 was obtained in LTSpice by substituting the voltage sources with capacitors and using an initial condition to set the voltage. Actually, capacitors are a poor approximation for cells because their voltage changes steadily with SOC, unlike cells, which more or less maintain their voltage. However, the graph in Fig.7 has about the right shape for the current curves.

The time taken for the cells to balance will depend on a number of factors, particularly: the SOC at which the cells are first connected and the degree to which they are already balanced; the internal resistance of the cells; the SOC-to-voltage relationship of the cells; the temperature; and the point closeness of SOC which is deemed to constitute balance. The exact behaviour will also depend on the cells' age and the number of charge/discharge cycles they have been through. Characteristics such as amount of capacity (energy available at 100% SOC) and internal resistance change with age. It is possible, but not necessarily easy, to model all these details for simulation purposes and discussion of this can be found in academic papers and technical websites.

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

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

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

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC.

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A Broad-Based Introduction to Electronics.

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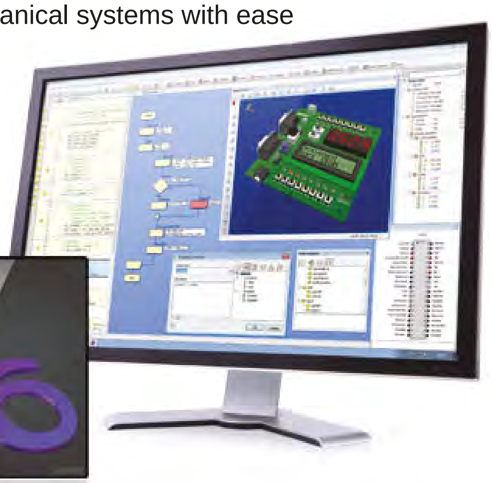

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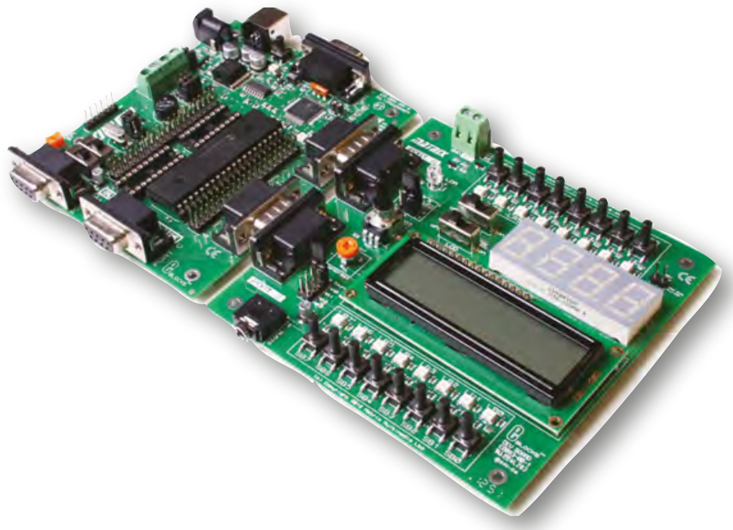

£167 including VAT and postage, supplied with USB cable and free to download programming software

SOFTWARE

ASSEMBLY FOR PICmicro V5

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

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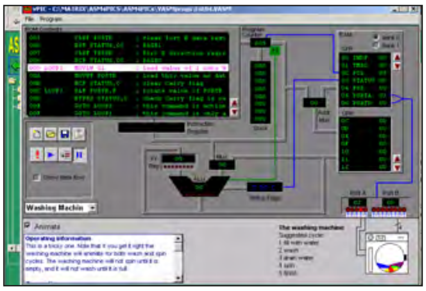

'C' FOR 16 Series PICmicro Version 5

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

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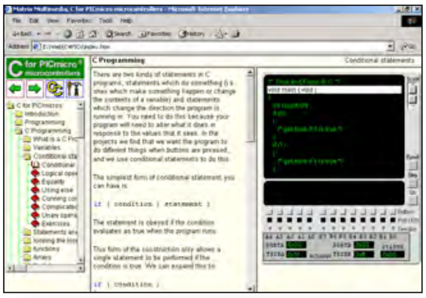


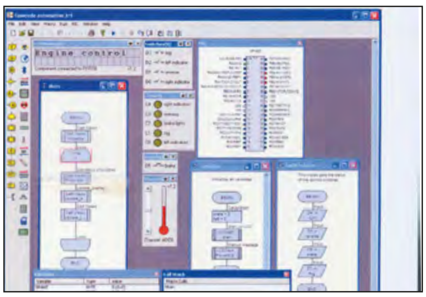
Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V6 (see opposite page)

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

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



PRICES

Prices for each of the CD-ROMs above are:

See previous page for Flowcode Hobbyist/Student prices
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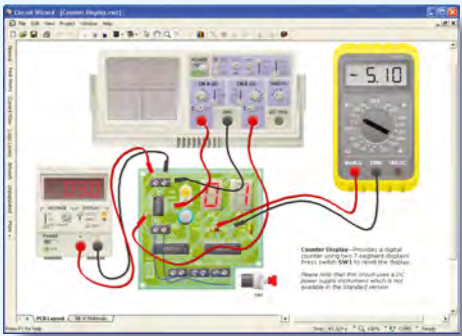

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

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

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

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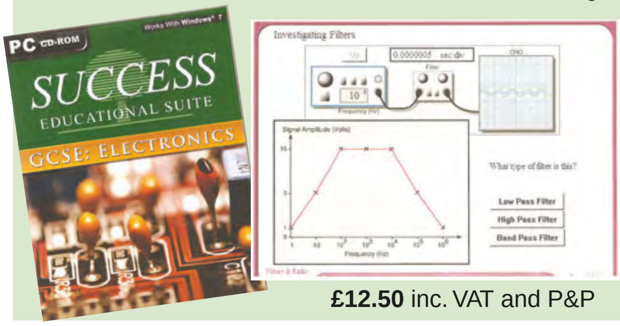

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Note: The software on each version is the same, only the licence for use varies.

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

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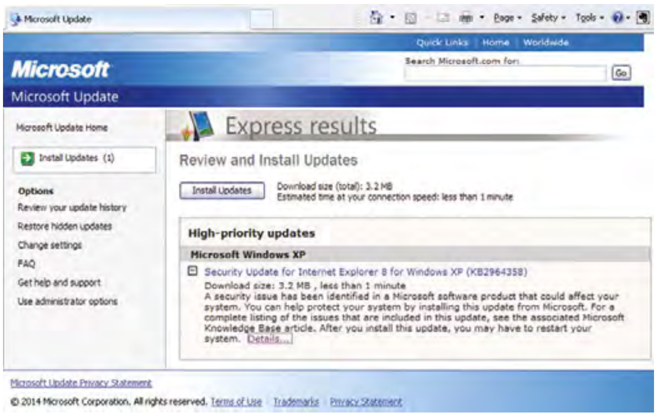
NET WORK

by Alan Winstanley

Feeling vulnerable

I DOUBT if any Windows XP user has avoided the marketing onslaught that reminds them that XP has reached the end of the road, at least as far as downloading security updates and patches is concerned. To quote Microsoft directly, 'PCs running Windows XP after April 8, 2014 should not be considered to be truly protected.' However, it would be fair to say that PCs running XP or any other system before that date were not truly protected, either. Microsoft Internet Explorer is stuck at version 8 in Windows XP, and it gets the blame for harbouring potential security vulnerabilities. An ever-present risk that web surfers face is that suspicious or dodgy websites could cause malicious code to be executed in the browser, which could then allow access to the operating system, personal data or it could wreak havoc over an attached network. To overcome these risks, Microsoft implores users to upgrade to Windows 7 or 8 to 'help protect your computer from malicious attacks'. While these are indeed fine operating systems, an upgrade still does not mean that users will then enjoy 'true protection'. It's just that it is more viable to patch flaws in modern operating systems when new threats come to light.

Microsoft, having finally pulled the plug on the ancient OS, has however relented on the idea that no further updates to XP or IE8 would be supplied after 8 April, at least for one exception anyway. On 1 May, another vulnerability in Internet Explorer was discovered that Microsoft classed as 'critical'. Their Security Bulletin MS14-021 describes how the issue affects all browsers from IE6 up to IE11 and a patch is available via Windows Update – and that *includes* Windows XP. Microsoft decided to include XP because the patch came so soon after the XP cut-off, as explained in the official Microsoft Blog at **http://tinyurl.com/n86y7sp**. Perhaps bolting an XP patch onto the latest Windows Update was trivial, but it seems highly unlikely that any further such patches will be supplied. Visit: **update.microsoft.com** for details. As usual, the website will detect your current OS and genuine Windows licence holders can then download the patch.



Visit **update.microsoft.com** *to fetch the final patch for Windows XP. Later versions access Windows Update via the Start button*

Almost certainly the last ever Microsoft update for Windows XP and IE8

Not just browsers

This type of problem is not restricted to web browsers – it affects other common software tools used by everyday web surfers, notably Adobe Flash and Adobe Reader, which view PDFs. A regular stream of patches helps guard against malicious exploits that can find their way onto a user's system, sometimes without the user's knowledge. It is strongly recommended that readers ensure that both Adobe Reader and Flash are always kept up to date by visiting the Adobe website. These products are often taken for granted, but need regular maintenance. For surfing, users of Windows XP are recommended to switch to Firefox, Google Chrome or Opera (see last month) as these receive constant updates and are likely to be more secure. Firefox is currently at Version 28.0 and runs very well in Windows XP, even on an old machine.

Vulnerabilities in software take many forms and the upkeep of security is a never-ending game of cat and mouse. It is a moot point whether much of the talk is simply alarmist, with little if any practical risk actually being posed to ordinary web users. After all, the chances of a web surfer stumbling upon, say, an obscure Chinese or Brazilian website that hosts a dangerous new exploit that's just been released into the wild are probably slim, but you never know. Of course, it's good practice to be vigilant and to keep browsers and software as up to date as you possibly can, and back up any critical data on disk or online. It is more likely that ordinary email poses a greater danger, especially if a friend's address book is hacked and used to broadcast spam or viruses to everyone else on the list, sent from a recognised email address. Social engineering techniques can also be used to trick people into clicking a link or opening a file.

It is feasible for an attacker to infiltrate via a back door as well, perhaps posing as an email attachment or lurking on a USB stick. Router firewall protection will not help when malware sneaks in from behind, and some exploits can even attack the router (especially if the default admin password is used!). Such attacks can cause a network's DNS settings

to be altered; for instance, a web browser could be tricked into reaching out to a malicious carbon copy of a banking website where some logins can be captured by criminals.

Countdown to Zero

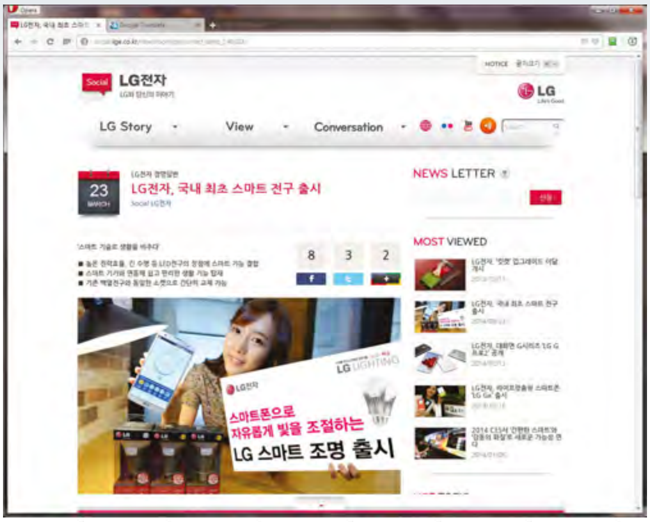
A so-called 'Zero Day' vulnerability is one that exists either in the wild, or in theory, and is presently unpatched. The race is then on for software vendors to release a fix. Vulnerabilities are tabulated through the 'US Government Common Vulnerabilities and Exposures' list. Such is the tidal wave of exploits that are emerging that a new indexing system had to be introduced this year to keep up with demand, allowing more than 10,000 a year to be reported. For example, CVE-2014-1776 covers the Internet Explorer vulnerability described earlier, and it appears on the US National Vulnerability Database (NVD) at **http://nvd.nist.gov**. Its database search engine lists software flaws (CVEs) all the way back to 1997. For Internet Explorer, incidentally, the first reports shown covers IE 3.01 running under Windows 95. A more user-friendly front end is available at **http://cve.mitre.org**

A recent software flaw that has caused widespread alarm goes by the name of CVE-2014-0160, or 'Heartbleed'. It was discovered by staff at Google Security and describes a bug in the encryption program OpenSSL that is found on many Internet servers. Put simply, a hacker could ask a server a simple question that elicits a brief answer, but due to the Heartbleed bug the affected server actually sends back much more information, little by little, including private encryption keys or portions of other data held in memory at the time. At the time of writing, the author is aware of only one confirmed case where Heartbleed caused data to be compromised: at the Canada Revenue Agency some Social Security numbers were stolen (900 stolen over six hours). It was reported that some versions of Android (4.1.1) may also suffer and a number of free Heartbleed Scanner apps can be fetched from Google Play to check this.

Last month, I also mentioned the Synology NAS, an excellent disk-drive unit that attaches to a network to offer RAID-like storage. Following a disk problem I updated the drive to use two Western Digital 'Red' hard disks that are intended for Enterprise or NAS use, being near silent in operation and seemingly running cooler than previous disks. My Synology NAS also updated itself automatically with the latest patch to guard against Heartbleed. There has been worldwide coverage of Heartbleed and surfers have been implored to change all their passwords, just in case. After many years of practical experience I can strongly recommend Roboform password management software and an alternative service from **lastpass.com** is also worth investigating.

Intelligent lighting

Opto-electronics is one of the most exciting branches of electronics technology, and many promising new developments are in the pipeline as the problems of LED heat dissipation and efficiency are gradually overcome with each successive generation. In May's *Net Work*, my item on Philips Hue wireless LED lighting showed what's in store for intelligent and highly efficient lighting that can be controlled by a smartphone or tablet. Hard on its heels comes a new range of white 'smartbulbs' from South Korea's LG (formerly Lucky Goldstar). Again, a tablet or smartphone (iOS or Android) app can control the bulb's intensity, but apart from claiming to offer direct Wi-Fi control the 10W (60W equivalent) smart bulbs also have Bluetooth built in. Security modes, gentle wake-up and sound-to-light disco modes (Android) are offered. Currently available only in Korea, the price is approximately $35-$40 per bulb. Keep an eye out for new LED bulbs from Samsung too, who are expected to offer PAR-style LED bulbs and fluorescent-tube form-factor bulbs – again, with Bluetooth built in to allow direct smartphone control. An intriguing website that monitors technology and media over the border in DPRK (North Korea) is at: **www.northkoreatech.org**, which gives another perspective of life and events in that part of the Korean peninsula.



LG Smart Bulb website pictured – Google Translate can convert Korean dialect into acceptable English

Smart home

In the future smart home, the domestic deep freezer will hook onto the network and will be controllable using a tablet or smartphone app. In years to come it might adjust itself automatically depending on the weather forecast provided by another app, or warn of forthcoming power failures due to scheduled network maintenance. However, the deep freezer cannot directly track the throughput of frozen food as no data is captured about food usage or stocks. That's one step too far, but the next best thing is already on the horizon.

Currently on trial in the US, Amazon Dash is a Wi-Fi scanner that adds food or produce to your shopping list automatically

In my day, a shopping list could be phoned through to the village grocer who delivered the week's groceries in his car: rifling through the box of goodies was a great adventure for a small boy. Fast forward half a century and we have online ordering and deliveries to our door in the time slot of our choice. Amazon is showing the way ahead with the latest device to hook onto the home network: Amazon's Dash is a six-inch wand scanner that works on Wi-Fi and scans the barcodes of fresh produce. Customers can scan an order and add it to their AmazonFresh shopping list ready for home delivery, and if barcode scanning is just too tiresome then voice recognition is built into each wand as well. It's designed to help with stocking up everyday household staples and groceries. Couple it with the promise of Amazon drone aircraft (Prime Air – see: **www.youtube.com/watch?v=98BIu9dpwHU**) currently under trial, then maybe there is the long-term prospect of having regular replenishments of groceries dropping in from the sky. In Britain, a highly-tuned transport network is already very well honed in making doorstep deliveries to consumers, and perhaps Amazon's Dash – or any other supermarket scanner – may eventually become as routine as phoning the grocer was 50 years ago. Amazon Dash is currently on trial in the US for invited customers only.

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

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NEW BOOKS

AN INTRODUCTION TO THE NEXUS 7

This book is intended for the new user of the Nexus 7, although much of it will also apply to the Nexus 10. It is easy to understand being written in plain English and avoiding technical jargon wherever possible.

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Even if you are a complete beginner, this book will help you to easily acquire the skills needed to understand and make the most of the Nexus 7.

118 Pages **Order code BP744** **£8.99**

KINDLE FIRE HDX EXPLAINED

This book is written to help users get to grips, quickly and easily, with the amazing Kindle Fire HDX tablet. You will be guided through the configuration and use of the Kindle Fire HDXs facilities and functions. This book was written using the 7" HDX but it is also applicable to the 8.9" model.

Among the many topics covered are: An overview of the Kindle Fire HDX. Charging and setting up, connecting to a Wi-Fi network, registering the device and connecting to Social Networks; setting up and using the 1-Click Amazon account for buying and downloading books, music and other content that you have searched for. Explaining the use of the Carousel. Starting screen Apps. Web and Device settings and the Mayday facility; browsing the web with Silk Internet explorer, using Bookmarks and History, printing web pages, documents and messages; connecting to a server to send and receive e-mail messages, using and saving attachments. Creating and organising your Contacts and Calendar appointements; using the Kindle Fire camera to take photos and videos. Watching TV, listening to music you bought, imported and from the radio. Using the X-ray feature with books and other media; Using the OfficeSuite to view your documents, upgrading to OfficeSuite Professional 7 to allow both viewing and creation of Word documents. Excel spreadsheets and PowerPoint presentations. And more besides...

This book will help you acquire the skills needed to understand and make the most of your Kindle Fire HDX.

118 Pages **Order code BP743** **£8.99**

WINDOWS 8.1 EXPLAINED

Windows 8.1 is the latest version of Microsoft's operating system. It is installed on all new Windows Desktop. Laptop and X86 tablet computers and is also available as a free upgrade. Whether you choose to use the touch screen Tile interface or the mouse operated Desktop interface, a good working knowledge of the operating system is essential to get the most from your computer and this book will help you to do just that.

The book applies to Windows 8.1, Windows 8.1 Pro and the vast majority of Windows 8.1 Enterprise. Also parts of the book should be applicable to windows RT 8.1 which is built on the same foundation as Windows 8.1 but is a restricted version designed specifically for ARM tablets.

Among the many topic covered are: An overview of the Tile Interface, Desktop, Taskbar, Tray Notification Area, Charms bar and running Apps; managing Windows settings, personalising your PC and creating User Accounts; using the Desktop File Explorer, SkyDive, Internet Explorer and the E-mail App; working with and organising digital photographs, using Media Player to play and store music and to burn CDs and installing Media Center to play DVDs; connecting to wireless networks, setting up a HomeGroup, sharing a printer and networked PCs; using mobility tools to keep your laptop running while away from home; accessibility features should you have dexterity or eyesight problems; keeping your computer healthy and backing up important files; And much more besides…..

180 Pages **Order code BP747** **£10.99**

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

FOR A FULL DESCRIPTION OF THESE BOOKS AND CD-ROMS SEE THE SHOP ON OUR WEBSITE

www.epemag.com

All prices include UK postage

ELECTRONICS TEACH-IN 5

ELECTRONICS TEACH-IN 5

FREE CD-ROM

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FREE CD-ROM – The free CD-ROM is the complete Teach-In 2 book providing a practical introduction to PIC Microprocessors plus MikroElektronika, Microchip and L-Tek PoScope software.

160 Pages **Order code ETI5** **£8.99**

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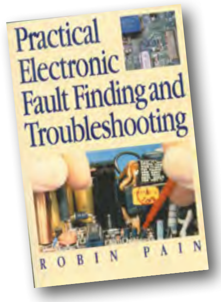

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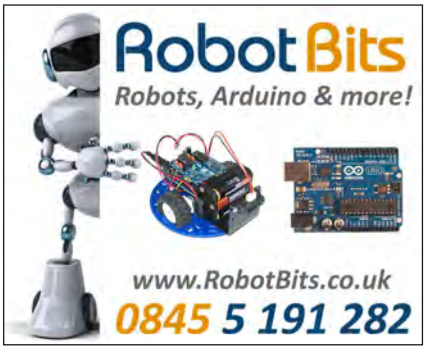

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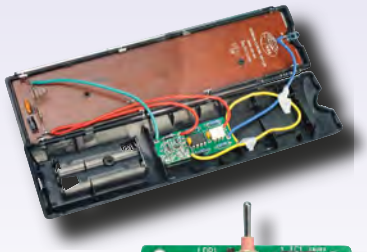

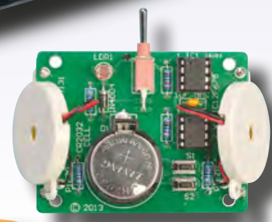

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